Bus Maintenance Enhancement Training (MET)

Maintenance Enhancement Training (MET)

Objective:

MET is designed to prepare the participant for application to the UTA "Transit Bus Repairer" apprenticeship program.

Task 1:

The participant will complete a self-study module for sections 1 through 6.

Safety .... Section 1
Tools .... Section 2
Fasteners .... Section 3
Preventive Maintenance .... Section 4
Basic Electricity .... Section 5
Hydraulics, Pneumatics .... Section 6

Additional Information

Welding ....Appendix A
Engine ....Appendix B
Transmission ....Appendix C

Task 2:

The participant will complete a test provided by Maintenance Training.

Standard:

The MET testing procedure has been designed to evaluate the understanding and knowledge of the participant.

For any further information, testing, or study materials please contact Maintenance Training.

Randy Welsh ....Ext. 2526
Rick Garcia ....Ext. 2804
Aaron Evans ....Ext. 2803
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SAFETY

Learning Objective: The student will have an understanding of safety, and how it applies to UTA shops.

Task: The Student should become familiar with all safety terms, equipment and procedures utilized at UTA.

Standard: The student will complete a written examination in which he/she will attain a minimum score of 80% to pass the written test.

Safety Equipment	Safety Procedure
Safety Glasses	Clean work area and equipment
Hearing Protection	Read all instructions and precautions
Exhaust fumes	Follow instructions and service procedures
Face shield	Store and handle flammable material.
Proper use of tools and equipment	Illuminate work area. (Proper lighting)
Respirators	Battery safety,(charging and testing)
Reflective vest, foot wear, hand protection, hard hat	Shop equipment (Lifts, jacks, lifting ,chains etc)
Fire extinguisher	Fluid Disposal procedures (what goes where)
First aid kit	Welding safety, goggles, helmet protective clothing, etc.
	Welding safety
	Fire prevention

November 2, 1999

SHOP SAFETY

First we will discuss general shop safety.

Be Prepared for Emergencies

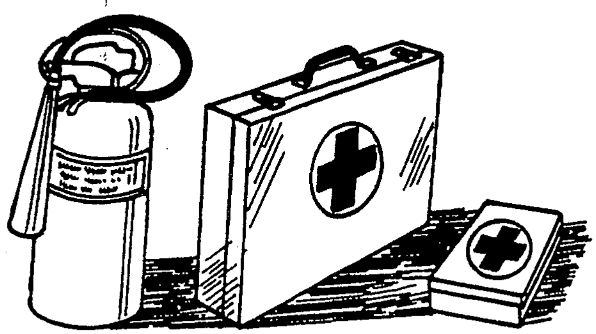

Fig. 96 — Be Prepared

Be prepared if a fire starts.

Keep a first aid kit and fire extinguisher handy.

Keep emergency numbers for doctors, ambulance service, hospital, and fire epartment near your telephone.

Wear Protective Clothing

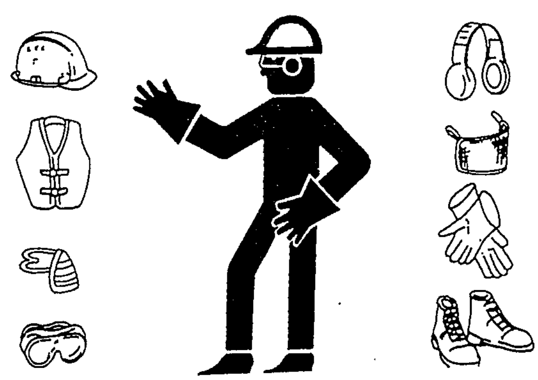

Fig. 97 — Wear Protective Clothing

Wear close fitting clothing and safety equipment appropriate to the job.

Prolonger exposure to loud noise can cause impairment or loss of hearing.

Wear a suitable hearing protective device such as earmuffs or earplugs to protect against objectionable or uncomfortable loud noises.

Use Equipment Safely

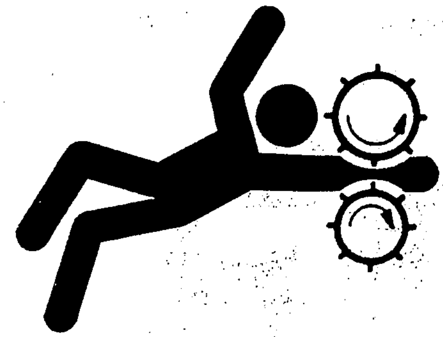

Fig. 98 — Use Equipment Safely

Tie long hair behind your head. Do not wear a necktie, scarf, loose clothing, or necklace when you work near machine tools or moving parts. If these items were to get caught, severe injury could result.

Remove rings and other jewelry to prevent electrical shorts and entanglement in moving parts.

Work in Clean, Ventilated Area

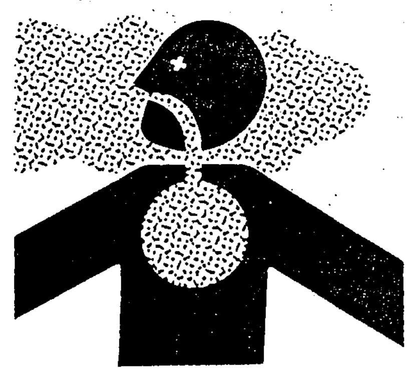

Fig. 99 — Work in Clean, Ventilated Area

Before starting a job:

- Clean work area and machine.
- Make sure you have all necessary tools to do your job.
- Have the right parts on hand.
- Read all instructions thoroughly; do not attempt shortcuts.

Engine exhaust fumes can cause sickness or death. If it is necessary to run an engine in an enclosed area, remove the exhaust fumes from the area with an exhaust pipe extension.

If you do not have an exhaust pipe extension, open the doors and get outside air into the area.

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Illuminate Work Area Safely

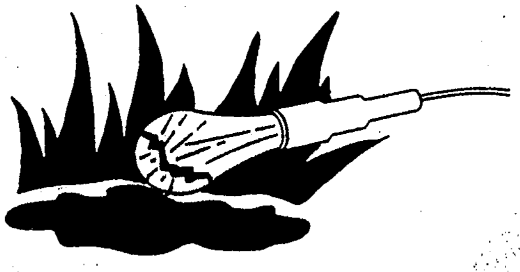

Fig. 100 — Illuminate Work Area Safely

Illuminate your work area adequately but safely. Use a portable safety light for working inside or under a machine. Make sure the bulb is enclosed by a wire cage. The hot filament of an accidentally broken bulb can ignite spilled fuel or oil.

Practice Safe Maintenance

Understand service procedure before doing work. Keep area clean and dry.

Keep hands, feet, and clothing from power-driven parts. Disconnect all power and operate controls to relieve any pressure. Lower equipment to the ground. Stop the engine. Remove the key. Allow machine to cool.

Securely support any machine elements that must be raised for service work.

Keep all parts in good condition and properly installed. Fix damage immediately. Replace worn or broken parts. Remove any buildup of grease, oil, or debris.

Disconnect battery ground cable (-) or power supply before making adjustments on electrical systems or welding on machine.

Use Proper Tools

Use tools appropriate to the work. Makeshift tools and procedures can create safety hazards.

Use power tools only to loosen threaded parts and fasteners.

For loosening and tightening hardware, use the correct size tools. DO NOT use U.S. measurement tools on metric fasteners. Avoid bodily injury caused by slipping wrenches.

Use Only Recommended Service Replacement Parts.

Fig. 101 — Use Proper Tools

Support Equipment Properly

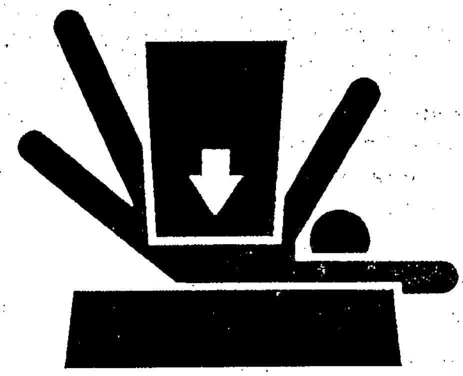

Fig. 102 — Support Equipment Properly

Before working on the machine:
- Lower all equipment to the ground.
- Stop the engine and remove the key if equipped.
- Disconnect the battery ground strap or power supply.
- Hang a "DO NOT OPERATE" tag at operator station.

Always lower the machine or attachment to the ground before you work on the machine. If you must work on a lifted machine or attachment, securely support the machine or attachment with properly rated floor stands.

Do not support the machine on cinder blocks, hollow tiles, or props that may crumble under continuous load. Do not work under a machine that is supported solely by a jack. Follow recommended procedures in technical manual.

Lifting heavy components incorrectly can cause severe injury or machine damage.

Follow recommended procedure for removal and installation of components in the manual.

Handle Fluids Safely

Fig. 103 — Handle Fluids Safely

When you work around fuel, do not smoke or work near heaters or other fire hazards.

Store flammable fluids away from fire hazards. Do not incinerate or puncture pressurized containers.

Make sure machine is clean of trash, grease, and debris.

Do not store oily rags; they can ignite and burn spontaneously.

Avoid High Pressure Fluids

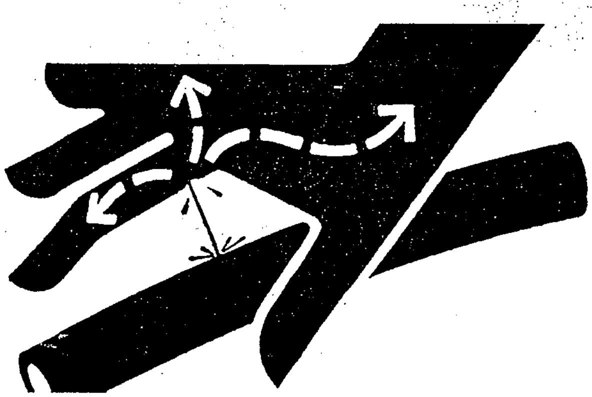

Fig. 104 — Avoid High Pressure Fluids

Escaping fluid under pressure can penetrate the skin causing serious injury.

Avoid the hazard by relieving pressure before disconnenting hydraulic or other lines. Tighten all connections before applying pressure.

Search for leaks with a piece of cardboard. Protect hands and body from high pressure fluids.

If an accident occurs, see a doctor immediately. Any fluid injected into the skin must be surgically removed within a few hours or gangrene may result. Doctors unfamiliar with this type of injury should reference a knowledgeable medical source.

Remove Paint Before Welding or Heating

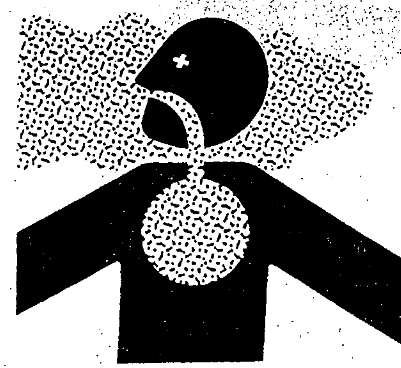

Fig. 105 — Remove Paint Before Welding or Heating

Avoid potentially toxic fumes and dust.

Hazardous fumes can be generated when paint is heated by welding, soldering, or using a torch.

Do all work outside or in a well ventilated area. Dispose of paint and solvent properly.

Remove paint before welding or heating:

- If you sand or grind paint, avoid breathing the dust. Wear an approved respirator.
- If you use solvent or paint stripper, remove stripper with soap and water before welding. Remove solvent or paint stripper containers and other flammable material from area. Allow fumes to disperse at least 15 minutes before welding or heating.

Avoid Heating Near Pressurized Fluid Lines

Flammable spray can be generated by heating near pressurized fluid lines, resulting in severe burns to yourself and bystanders. Do not heat by welding, soldering, or using a torch near pressurized fluid lines or other flammable materials.

Pressurized lines can be accidentally cut when heat goes beyond the immediate flame area. Install fire resisting guards to protect hoses or other materials.

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Fig. 106 — Avoid Heating Near Pressurized Lines

Service Air Pressurized Equipment Safely

Explosive separation of a tire and rim parts can cause serious injury or death.

Do not attempt to mount a tire unless you have the proper equipment and experience to perform the job.

Always maintain the correct tire pressure. Do not inflate the tires above the recommended pressure. Never weld or heat a wheel and tire assembly. The heat can cause an increase in air pressure resulting in a tire explosion. Welding can structurally weaken or deform the wheel.

When inflating tires, use a clip-on chuck and extension hose long enough to allow you to stand to one side and NOT in front of or over the tire assembly. Use a safety cage if available.

Check wheels for low pressure, cuts, bubbles, damaged rims or missing lug bolts and nuts.

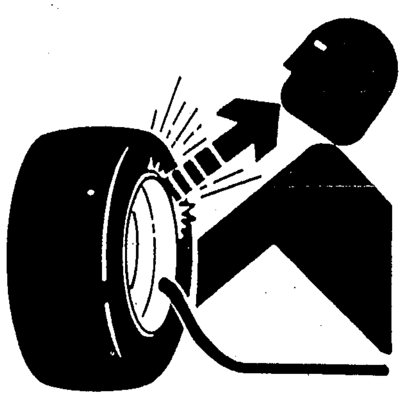

Fig. 107 — Service Air Pressurized Equipment Safely

Prevent Battery Explosions

Fig. 108 — Prevent Battery Explosions

Keep sparks, lighted matches, and open flame away from the top of battery. Battery gas can explode.

Never check battery charge by placing a metal object across the posts. Use a volt-meter or hydrometer.

Do not charge a frozen battery; it may explode. Warm battery to 16°C (60°F) first.

Prevent Acid Burns

Sulfuric acid in battery electrolyte is poisonous. It is strong enough to burn skin, eat holes in clothing, and cause blindness if splashed into eyes.

Avoid the hazard by:
1. Filling batteries in a well-ventilated area.
2. Wearing eye protection and rubber gloves.
3. Avoiding breathing fumes when electrolyte is added.
4. Avoiding spilling or dripping electrolyte.
5. Use proper jump start procedure.

If you spill acid on yourself:
1. Flush your skin with water.
2. Apply baking soda or lime to help neutralize the acid.
3. Flush your eyes with water for 10-15 minutes. Get medical attention immediately.

If acid is swallowed:
1. Drink large amounts of water or milk.
2. Then drink milk of manesia, beaten eggs, or vegetable oil.
3. Get medical attention immediately.

Avoid Harmful Asbestos Dust

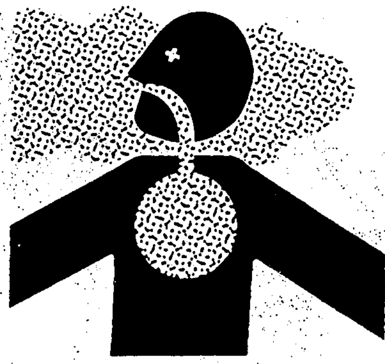

Fig. 109 — Avoid Harmful Asbestos Dust

Avoid breathing dust that may be generated when handling components containing asbestos fibers. Inhaled asbestos fibers may cause lung cancer.

Components in products that may contain asbestos fibers are brake pads, brake band and lining assemblies, clutch plates, and some gaskets. The asbestos used in these components is usually found in a resin or sealed in some way. Normal handling is not hazardous as long as airborne dust containing asbestos is not generated.

Avoid creating dust. Never use compresed air for cleaning. Avoid brushing or grinding of asbestos containing materials. When servicing, wear an approved respirator. A special vacuum cleaner is recommended to clean asbestos. If not available, wet the asbestos containing materials with a mist of oil or water.

Keep bystanders away from the area.

Dispose of Fluids Properly

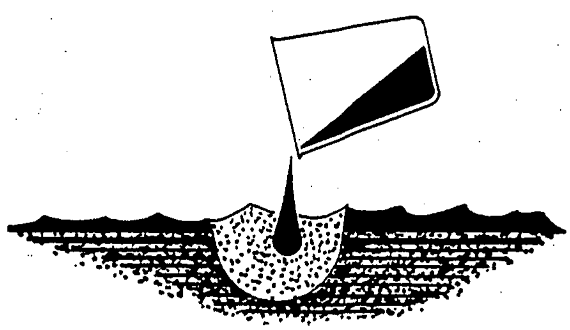

Fig. 110 — Dispose of Fluids Properly

Improperly disposing of fluids can harm the environment and ecology. Before draining any fluids, find out the proper way to dispose of waste from your local environmental agency.

Use proper containers when draining fluids. Do not use food or beverage containers that may mislead someone into drinking from them.

DO NOT pour oil into the ground, down a drain, or into a stream, pond, or lake. Observe relevant environmental protection regulations when disposing of oil, fuel, coolant, brake fluid, filters, batteries, and other harmful waste.

Live With Safety

Fig. 111 — Live With Safety

Before returning machine to service or customer, make sure machine is functioning properly, especially the safety systems. Install all guards and shields.

TOOL SAFETY

Strict adherence to tool safety makes the difference between a job well done or a serious injury. Not only using the right tool for the job, but using it correctly with the proper safety apparel is very important.

The following is a list of safety guidelines:

- Always wear safety goggles or glasses when using punches, chisels, hammers, power tools and cutting tools. A full face shield should be used during grinding or cutting operations.
- Wear ear protection whenever noise levels are excessive; usually caused by power tool operation, machine noise or hammer blows.
- Wear a dust and/or vapor mask when appropriate; such as when grinding, welding, or when working around harmful vapors like cleaning solvents and spray paints.
- Wear appropriate apparel, loose clothing can get caught in moving parts.
- Use the right tool for the job.
- Keep tools sharp and in good shape. Keep them clean and well-adjusted. Make sure handles are securely fastened. Replace any cracked or broken tools.
- Screwdriver handles and ordinary plastic dipped handles are not designed to act as insulation; don't use on live electrical circuits.
- Never use any tool as a hammer unless manufactured for that purpose.
- Never use a pipe extension or other form of "cheater" bar to increase the leverage of any wrench.
- Never use a hammer on any wrench, except one that's designed to be struck.
- Hold a chisel or punch with a tool holder if possible.
- Keep all guards in place and in good working order when operating power equipment.
- Don't pull on a tool cabinet to move it; push it in front of you.
- Before moving tool cabinet, close the lids, lock drawers and doors.
- Do not open more than one loaded drawer of a tool cabinet at a time. Close each drawer before opening another. Too many drawers opened at one time could cause the tool cabinet to tip over.
- Set the brakes on the locking casters after cabinet is positioned at your work place.
- Keep work area clean. Store tools not in use. Disconnect all power tools when not in use.
- Keep children or spectators a safe distance from the work area.
- Remember, horseplay in the shop can cause accidents.

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ELECTRICAL SAFETY / CHAPTER 4

SAFETY

Safety is too expensive to learn by accident. Hospital bills, doctor bills, medical supplies, and rehabilitation costs can be a big financial burden on both individuals and companies.

Because of recent dramatic increases in these costs, both company-provided and private insurance plans have begun to shift more of this burden onto the insured parties.

Accidents also result in lost time from work and more importantly, may cause a permanent handicap or a loss of health that affects the injured party's family and earning ability. Unsafe practices also result in property damage.

Accidents are reduced by incorporating safe work practices into shop management programs. Safety must be thought of as a normal part of the management process just as supplies, personnel and overhead costs are.

Electricity has brought advanced technology into our homes and workplaces. From light bulbs to microcomputers, it plays a significant role in our everyday lives.

It is easy to take this unseen and somewhat mystical convenience for granted and to forget that, as wonderful as its gifts, it is a powerful and dangerous force capable of causing property damage, serious bodily injury and even death.

Fig. 1—Safety Precautions Prevent Battery Explosions

Electricity and batteries can cause fires and explosions (Fig. 1). And, of course, the hazard of electrocution is always present.

People become especially complacent when working around low voltages.

However, keep in mind that a current of only one milliampere (one thousandth of an ampere) can be felt, a current of 25 milliamperes can kill and a current of 100 milliamperes probably will kill.

If certain conditions exist, a current of only 0.006 ampere can electrocute a healthy person in less than a second.

A typical battery may have two to five amperes of current flowing across its terminals (Fig. 2). Remember that this amount of current is enough to kill. Therefore, safety must be your first and most important consideration when working around and with electrical equipment.

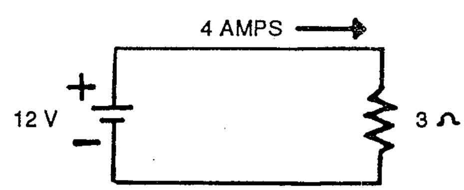

Fig. 2—A Basic Series Circuit of a Battery

Body resistance varies from person to person. It ranges from approximately 1000 to 500,000 ohms. The reasons for such variance depend on many factors: weight, height, body chemistry, etc.

An individual's own resistance may be lowered by perspiration, weather, wet ground conditions, and other variables.

When you learn to measure resistance, you will be able to measure your own body resistance by holding the end of a probe in each hand and taking an ohmmeter reading.

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Electrical current follows the path of least resistance. Accidents happen when the human body becomes such a path.

ELECTRICAL SYSTEM

Avoid these hazards when servicing an electrical system:

- **Fires**
- **Short-Circuit Start**
- **Bypass Start Hazard**
- **Battery Explosions**
- **Acid Burns**
- **Electric Shock**

Fires

Electrical systems can cause fires if not properly maintained. One of the purposes of the energy stored in the battery is to start the engine. But if a bare wire of the start system touches a metal part of the machine it will become extremely hot or may even spark and could cause a fire in dust, chaff, leaves, or oil-covered wires. Most machinery fires do not result in personal injury, but every fire is a potential source of injury. Inspect electrical systems regularly. Make sure wires are properly insulated and clean dust, chaff, leaves, and oil off wires.

Every self-propelled machine should have an all-purpose ABC dry chemical fire extinguisher on board to cover all type of fires. Everyone involved with the machine should know how to use it and its charge should be checked annually.

Short-Circuit Start

If insulation on electrical wires is cracked or worn, a short circuit can occur. Electricity could flow to the cranking motor and start the engine when no one is around.

If the positive and negative terminals of a cranking motor are accidentally contacted by another metal object, the current will flow between the two terminals, and accidentally start the engine.

Bypass Start Hazard

Bypass starting of tractors and other farm equipment is a very serious safety concern.

Never short across the starter terminals with a screwdriver or other devices to start a tractor. You bypass the neutral start switch by doing so and if the tractor is in gear when the engine starts, it could suddenly lurch forward and crush you (Fig. 3). Many people have died doing it. DON'T TRY IT!

Never bypass start any tractor or other self-propelled machines and never start it while standing on the ground. Start tractors and self-propelled machines only from the operator's station and with the transmission in neutral or park.

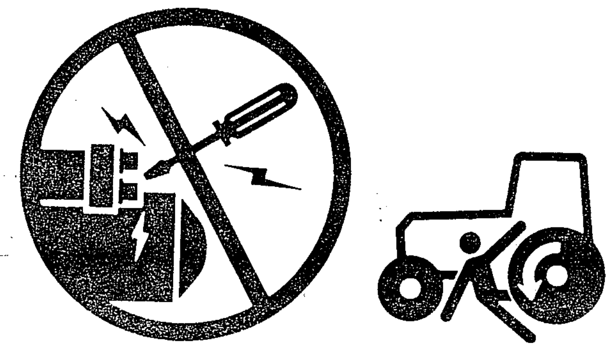

Fig. 3—Avoid the Short-circuit Starting Hazard

Neutral-start switches keep the engine from starting when the transmission is engaged or when the clutch is engaged. Check them periodically to make sure they are working properly. Neutral-start switches can be located so that starting is only possible when:

A. The clutch or inching pedal is depressed.

B. The shift lever is in neutral or park position.

C. Any combination of the above.

These switches should prevent engine cranking when the rear wheels are engaged with the engine. If they don't, they must be adjusted or replaced.

Battery Explosions

Batteries contain sulfuric acid and explosive mixtures of hydrogen and oxygen gases.

When charging and discharging, a lead-acid storage battery generates hydrogen and oxygen gas. Hydrogen will burn, and is very explosive in the presence of oxygen.

A spark or flame near the battery could ignite these gases, rupturing the battery case and splattering acid on property, clothing, skin and eyes.

Special care must always be used around batteries:

Wear eye protection. Also wear rubber gloves and a rubber apron when working around electrolyte.

Keep sparks and flames away from the battery.

Never smoke around a battery.

Always work on batteries in places which are well-ventilated.

If the battery has been on charge or is being charged during a test procedure, blow away gases before continuing testing.

Do not break electrical circuits near the battery top as a spark could start an explosion.

To prevent battery explosions:

1. Maintain the electrolyte at the recommended level(Fig. 4). Check this level frequently.

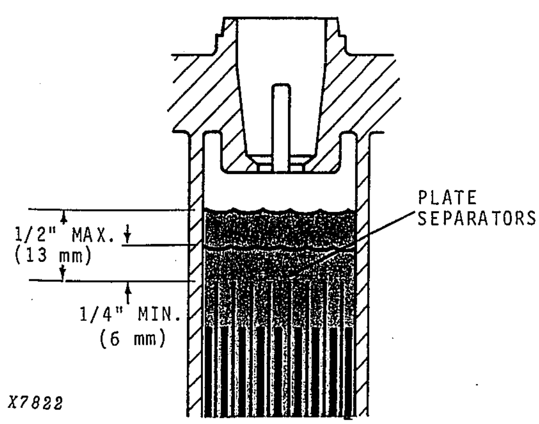

Fig. 4—Keep Electrolyte at the Proper Level to Prevent Explosions

When the level is properly maintained, less space will be available in the battery for gases to accumulate.

2. Put only distilled water in the battery.

3. Use a flashlight to check the electrolyte level. Never use a match or lighter. These could set off an explosion.

4. Do not short across the battery terminals by placing a metal object between them.

5. Do not charge a frozen battery. Warm the battery to 16 °C (60 °F).

6. Remove and replace battery clamps in the right order. This is very important.

   If your wrench touches the ungrounded (usually positive) battery post and the machine chassis at the same time, the heavy flow of current will arc across the terminals producing a dangerous spark.

   To prevent this from happening, follow these rules:

   a) When removing the battery, disconnect the grounded battery clamp first (Fig. 5).

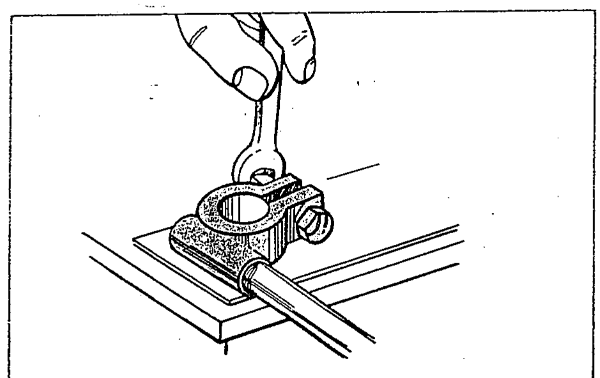

Fig. 5—Connect and Disconnect Battery Cables in the Proper Sequence

   The ground post lead will be connected to the engine block, frame or other metallic surface. The positive post lead will be connected to the starter relay.

   Some systems may have a positive ground. Although this is not common, always make sure you know which post is grounded.

   b) When installing the battery, connect the grounded battery clamp last.

7. Prevent sparks from battery charger leads.

   Turn the battery charge off or pull the power cord before connecting or disconnecting charger leads to battery posts (Fig. 6).

If you don't, the current flowing in the leads will spark at the battery posts. These sparks could ignite the explosive hydrogen gas which is always present when a battery is being charged.

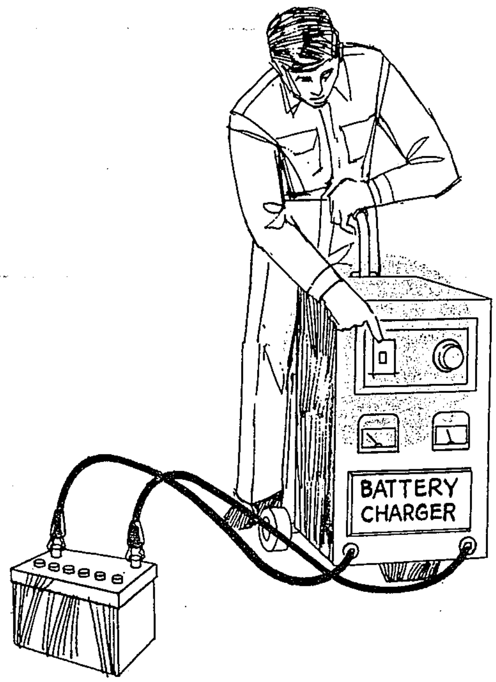

Fig. 6—Turn Off Charger Before Connecting or Disconnecting the Charger Leads

Connecting a Booster Battery

Improper connecting of a booster battery from one machine to the dead battery of another machine can be dangerous and can cause a battery explosion. Follow these procedures when connecting a booster battery from one machine to the dead battery of another machine.

1. Remove all cell caps of the dead battery (if so equipped).

2. Check to make sure the dead battery is not frozen. Never attempt to boost a battery with ice in its cells.

3. Be sure that booster battery and dead battery are of the same voltage.

4. Turn off all accessories and ignition of both machines.

5. Place gearshift of both vehicles in neutral or park and set the parking brake. Make sure vehicles do not touch each other.

6. Check the electrolyte level of the dead battery cells. Add distilled water to cells if low. Cover the vent holes with a damp cloth, or if caps are safety vent type, replace the caps before attaching jumper cables to the batteries.

7. Attach one end of one jumper cable to the booster battery positive terminal. Attach other end of the same cable to the positive terminal of the dead battery. Make sure of good, metal-to-metal contact between cable ends and terminals.

8. Attach one end of the other cable to the booster battery negative terminal. Make sure of good, metal-to-metal contact between the cable end and the battery terminal.

Caution: To prevent sparks and possible battery explosion, never allow ends of the two cables to touch while attached to the booster battery.

9. Connect other end of second cable to engine block or frame of the disabled vehicle as far away from the dead battery as possible. This is to insure that if a spark should occur at this connection, it would not ignite hydrogen gas that may be present above the dead battery.

10. Try to start the disabled vehicle. Do not engage the starter for more than 30 seconds or starter may overheat and booster battery will be drained of power. If the disabled vehicle will not start, start the vehicle with the booster battery and let it run for a few minutes with the cables attached. Try to start the disabled vehicle again.

11. Remove cables in exactly the reverse order from installation. Remove damp cloth and replace vent caps.

Acid Burns

Battery electrolyte is approximately 36 percent full-strength sulfuric acid and 64 percent water.

Even though it is diluted, it is strong enough to burn skin, eat holes in clothing and cause blindness if splashed into eyes.

Fill new batteries with electrolyte in a well-ventilated area, wear eye protection and rubber gloves, and avoid breathing any fumes from the battery when the electrolyte is added.

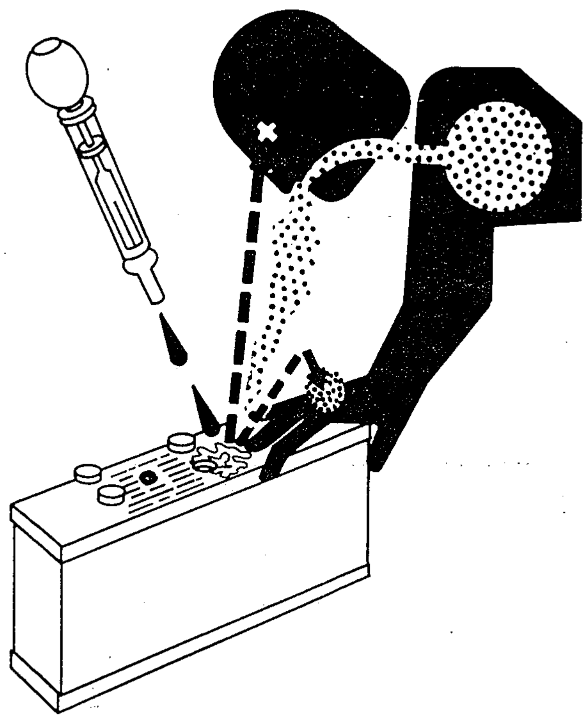

Fig. 7—Avoid Electrolyte Hazards When Using a Hydrometer

Avoid spilling or dripping electrolyte when using a hydrometer to check specific gravity readings (Fig. 7).

If you spill acid on yourself, flush your skin immediately with water for several minutes.

Apply baking soda or lime to help neutralize the acid.

If acid gets into your eyes, force the lids open and flood the eyes with running water for 15 to 30 minutes. Get medical attention immediately.

If the acid is swallowed, drink large amounts of water or milk, but do not exceed 2 quarts (2L). Get medical attention immediately.

Electric Shock

Injury from electric shock depends on the number of vital organs through which current passes.

Electricity travels at the speed of light which is 186,000 miles per second, leaving no reaction time.

Further, the hand muscles contract causing a firmer grip on a current-carrying wire or component.

To prevent a current path from flowing through your heart, always keep one hand away from the voltage source when working on a circuit. *Don't become part of the current path.*

The voltage in the secondary circuit of an ignition system may exceed 25,000 volts. For this reason, don't touch spark plug terminals, spark plug cables or the coil-to-distributor high-tension cable when the ignition switch is turned on or the engine is running (Fig. 8). The cable insulation should protect you, but it could be defective.

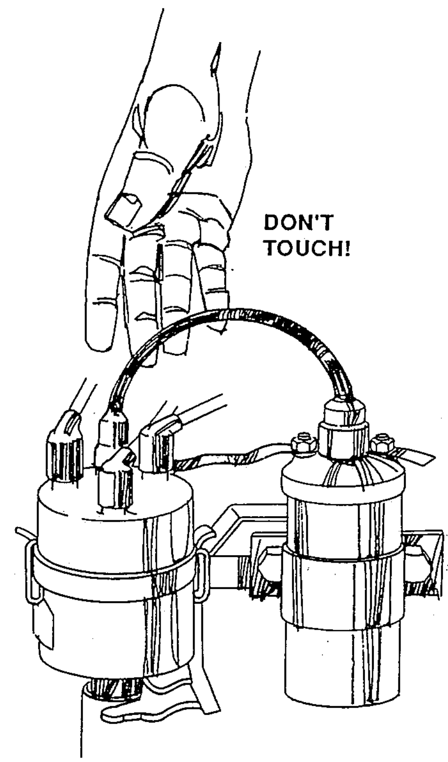

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Fig. 8—Turn Off Ignition Switch Before Performing Repairs

Never run an engine when the wire connected to the output terminal of an alternator or generator is disconnected (Fig. 9).

If you do, and if you touch the terminal, you could receive a severe shock. When the battery wire is disconnected, the voltage can go dangerously high, and it may also damage the generator, alternator, regulator or wiring harness. Don't short across the battery terminals by placing a metal object between them.

Electric shock may cause unconsiousness and burns on the skin at the area of contact.

Use a dry rope or stick to move the victim to safety.

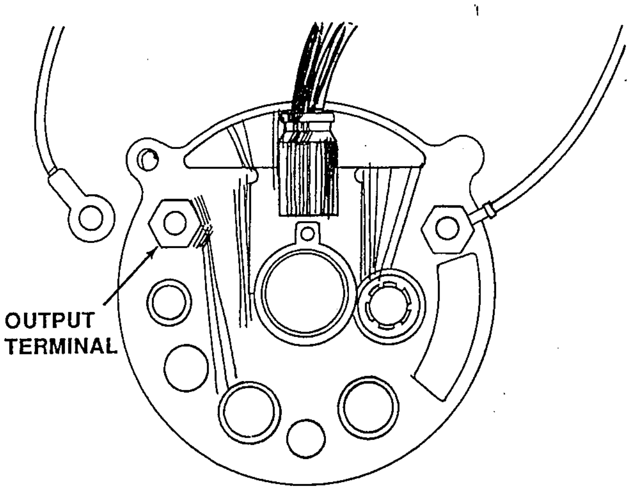

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Fig. 9—Connect the Alternator or Generator Output Terminal Lead Before Running an Engine

De-energize the power source: open the switch or cut the cable or wire using an ax with a wooden handle.

Keep the victim lying down and still with clothing loosened around the neck, chest and abdomen.

If the victim is not breathing, apply cardiopulmonary resuscitation (CPR). Seek medical attention immediately.

SHOP PRACTICES AND WORK HABITS

The best way to minimize hazards associated with electricity and electrical equipment is to follow proven shop practices and employ good work habits:

- Wear eye protection. Plastic goggles protect eyes from impact from the front and sides. Unvented or chemical splash goggles also offer protection against chemical vapors and liquids (Fig. 10).
- Rest regularly to avoid the effects of fatigue. Never use drugs, alcohol or tobacco when working on equipment.

~~ing on equipment~~nt.

- Avoid horseplay.
- Never work on dangerous equipment when you are ill, angry or anxious.

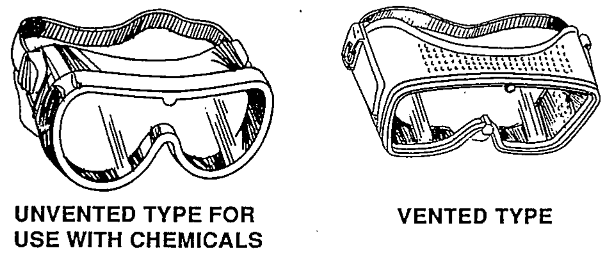


Fig. 10—Wear Unvented Safety Goggles Around Acids

- Be alert.
- Work only in adequately ventilated areas.
- Make sure the work area has sufficient light.
- Be aware of common machine hazards. Don't take shortcuts. Shortcuts shorten lives, and because of the problems that they cause, cost more in time and money than they save.
- Lock out or disconnect the electrical power source from the electrical system before you begin your service procedure.
- Know your limitations: age, weight and height all have a bearing on the jobs you are capable of doing.

Fig. 11—Keep a First Aid Kit Readily Available

- Learn the basic rules of first aid and keep a first aid kit readily available (Fig. 11).
- Apply immediate first aid to all injuries. If an injury appears severe, don't move the victim. Call a doctor and follow his instructions.

- Wear rubber gloves and a rubber apron when working around electrolyte.
- Know who to call for help. Keep emergency numbers for doctors, ambulance services, hospitals, and fire departments near the telephone.
- Never use water on electrical fires.

Keep a dry chemical fire extinguisher suitable for Class C fires close to but not in the fire hazard area.

Both Class B (burning liquids) and Class C (electrical equipment) fires require a pressurized dry chemical fire extinguisher of 20-pound capacity.

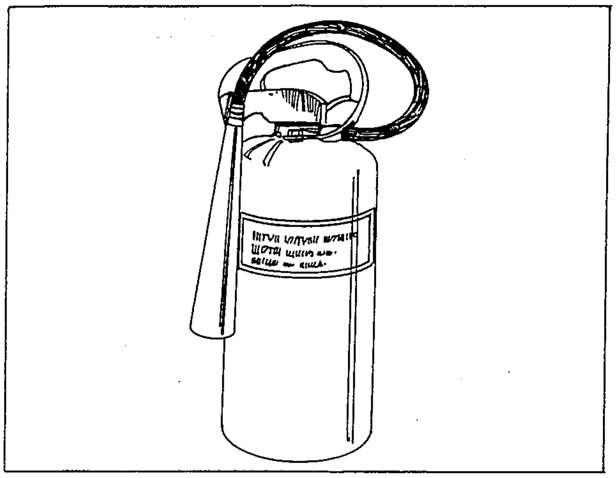


Fig. 12—Keep an ABC Dry Chemical Fire Extinguisher Handy

Shops should be equipped with at least one all-purpose ABC dry chemical fire extinguisher (Fig. 12). This extinguisher will put out Class A (combustibles like paper and wood), Class B, and Class C fires.

- Make sure that wires are properly insulated and clean and that electrical components are free of dust, chaff, leaves and oil.
- Always read, understand and follow the instructions and manuals provided with equipment (Fig. 13). Don't guess. Keep manuals in a clean, dry, readily available place.
- Read and understand labeling on the equipment. Replace labels that are damaged or worn. Heed the safety-alert symbols on the labels and in other instructional materials (Fig. 14).
- Pay attention to signal words:

Signal words like *Danger, Warning* and *Caution* draw attention to potentially unsafe areas. Learn these signal words and let them become your "think trigger."

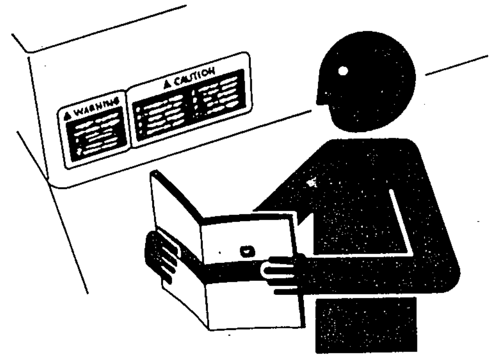


Fig. 13—Read and Follow Manufacturer's Instructions

Fig. 14—This Safety-alert Symbol Could Save Your Life

DANGER means that one of the most serious potential hazards is present. Exposure to these hazards would result in a high probability of death or a severe injury if proper precautions are not taken.

WARNING means the hazard presents a lesser degree of risk of injury or death than that associated with Danger.

CAUTION is used to remind of safety instructions that must be followed and to identify property damage hazards and hazards involving minor injuries.

Safety messages utilize colors as an aid to communication. Red and white are the colors used with the word Danger. Black and yellow are found on signs carrying the words Caution or Warning.

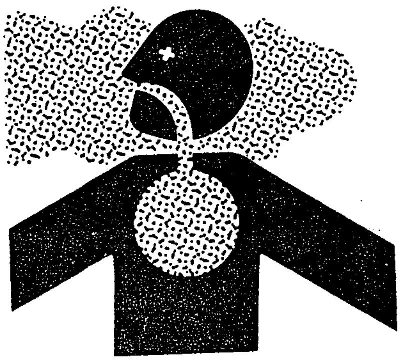


Fig. 15—Pictorial = Danger of Hazrdous Fumes or Dust

Pay attention to pictorial representations of safety hazards. A good pictorial should identify the hazard and portray the potential consequences of failure to follow instructions (Fig. 15).

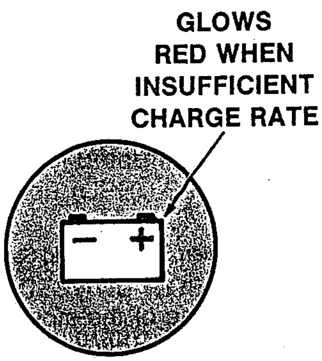


Fig. 16—Use of Color with Universal Ammeter or Generator Light

- Be able to identify universal symbols used to help identify controls. Color is often used with these symbols to indicate operating conditions (Fig. 16).
- Never work alone. Make sure someone knows you are working in the shop and will check on you and render aid if you are injured.
- Do not wear jewelry or other metallic objects when working on equipment. Keep metal parts of clothing, such as zippers and buttons, covered.
- Keep clothing, hands, feet and flooring dry. Make sure floor surfaces are clean.
- Use insulated tools whenever possible.

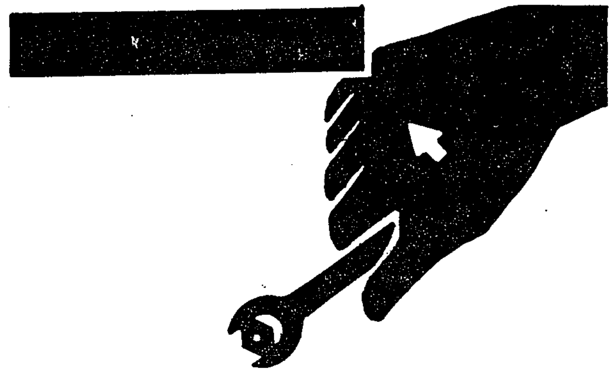


Fig. 17—Proper Use of Tools Prevents Injury and Property Damage and Extends Tool Life

Always select the right tool for the job and use it in the right way (Fig. 17).

Keep tools in good condition and store them safely when not in use.

Guard against eye injuries when cutting with pliers or cutters. Short and long ends of wire often fly or whip through the air when cut. Wear eye protection when cutting wire. Select a cutter big enough for the job. Keep the blades at right angles to the stock and don't rock the cutter to get a faster cut. Adjust the cutters to maintain a small clearance between the blades to prevent them from stiking each other when the handles are closed.

- Use non-metallic receptacles and funnels when working with electrolyte. Do not store electrolyte in a warm or sunny location.

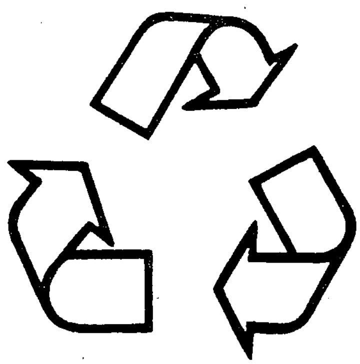


Fig. 18—Dispose of Fluids Properly

- Properly store and dispose of hazardous materials such as battery acid (Fig. 18). Do not pour battery acid down a drain or into a stream, pond or lake.

Improper disposal of fluids can harm the environment and ecology. Check with state environmental agencies for information concerning the proper disposal of battery acid.

Used batteries must be recycled. Battery retailers are required to take one old battery for each one you buy. Manufacturers recycle batteries to produce new ones.

- Remember that you and your coworkers contribute to each other's safety. Would you want to work around someone with unsafe working habits? Would you take your machinery to a repair shop known for unsafe working conditions and practices?

Fig. 19—Safety: Your Life Depends On It

When it comes to safety, be a leader, not a follower. Safety is everybody's business (Fig. 19).

SUMMARY: ELECTRICAL SAFETY

In summary:

- **Follow safe shop practices and work habits.**
- **Pay attention to signal words, like DANGER, WARNING, and CAUTION.**
- **Be aware of hazards that could occur while working on an electrical system.**
- **Even though battery acid is diluted, it can still cause severe burns. Always wear gloves and eye protection when servicing batteries.**
- **Always keep one hand away from the voltage source when working on a circuit.**

SHOP TOOLS AND EQUIPMENT

Learning Objective: The student will have a working knowledge of basic shop tools and equipment used in UTA shops.

Task: The student should identify and explain the purpose of the following pieces of equipment.

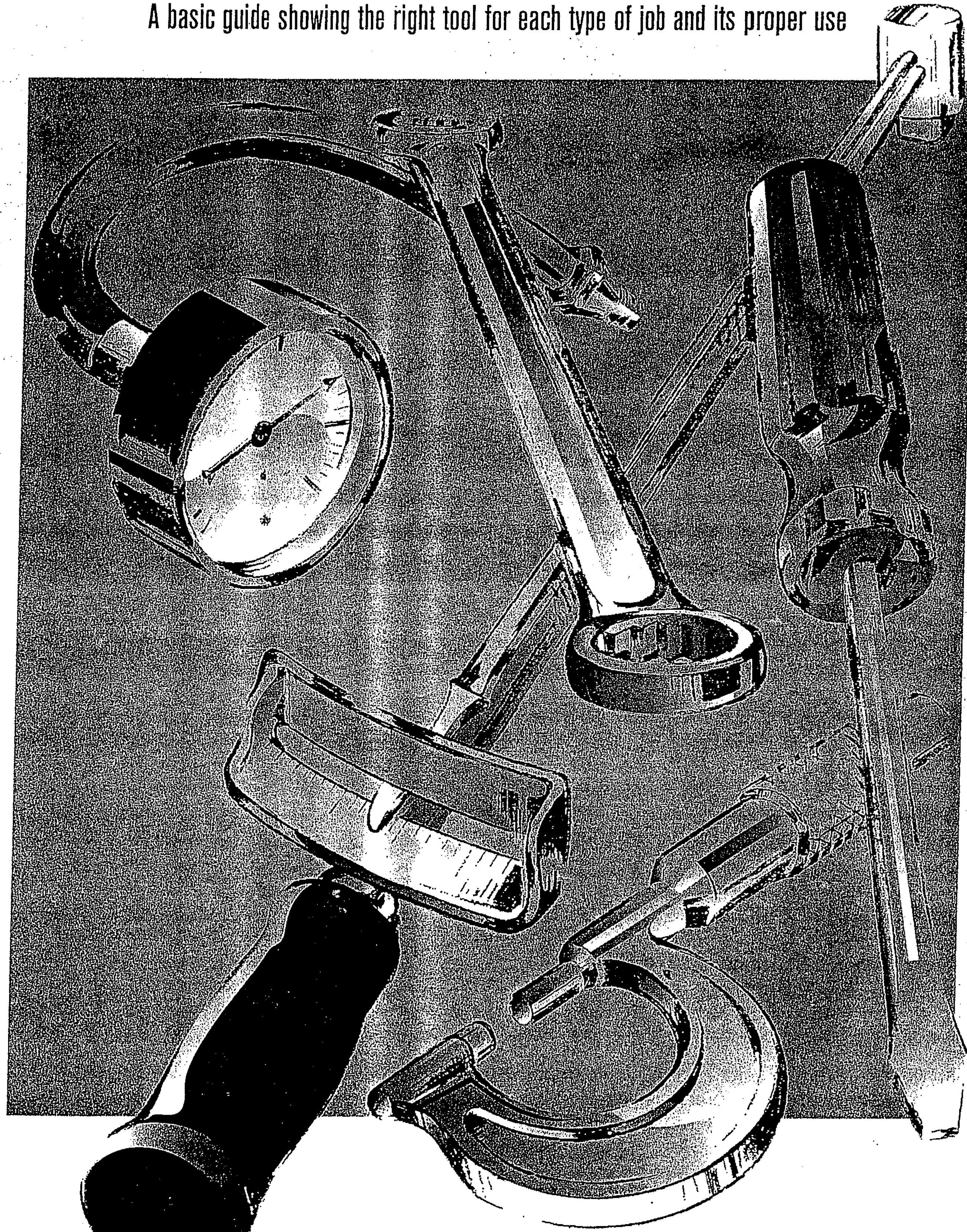
Standard: The student will complete a written examination in which he/she will attain a minimum score of 80% to pass the written test.

Tool	Tool
Allen Wrench or Set Screw Wrench	Socket
Breaker Bar/Flex Handle	Socket Universal Joint
Cold Chisel	Tap
Dial Caliper	Torque Wrench
Die	Vernier Caliper
Flaring Tool	Vise Grips
Feeler Gauge	Wire Strippers/Crimping Tool
Flare Nut Wrench	Impact Wrench ½" 3/8" Etc.
Micrometer	Grinder's
Multi-Meter	Drill press
Offset Screwdriver	Frame and Axle hoists
Ratchet	Jacks and Jack stands
Screw Extractor	Bead Blaster
Arbor press	Lock and Tag out procedure

November 2, 1999

SHOP TOOLS

A basic guide showing the right tool for each type of job and its proper use



FUNDAMENTALS OF SERVICE

PUBLISHER

Fundamentals of Service (FOS) is a series of manuals created by Deere & Company. Each book in the series is conceived, researched, outlined, edited, and published by Deere & Company. Authors are selected to provide a basic technical manuscript which is edited and rewritten by editors.

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TO THE READER

PURPOSE OF THIS MANUAL

The main purpose of this manual is to train the reader in the use of shop tools. For the novice, it is a training guide; for the experienced technician, a reference. The story is written in simple form using many illustrations so that it can be easily understood.

WHAT IS "FUNDAMENTALS OF SERVICE"?

This manual is part of a series of texts and visuals called "Fundamentals of Service", or "FOS". These materials are basic information in power mechanics for use by teachers as well as shop service equipment are covered – both automotive and off-the-road. Emphasis is on theory or operation, diagnosis, and repair.

Manuals in the Fundamentals of Service (FOS) series:

- **Engines**
- **Hydraulics**
- **Power Trains**
- **Electronic and Electrical Systems**
- **Shop Tools**
- **Weldings**
- **Hoses, Tubing and Connectors**
- **Identification of Parts Failures**
- **Air Conditioning**
- **Bearings and Seals**
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- **Fuels, Lubricants, and Coolants**
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- **Plastics Repair**
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- **Fasteners**
- **Glossary of Technical Terms**

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We have a long-range interest in good service

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SHOP TOOLS

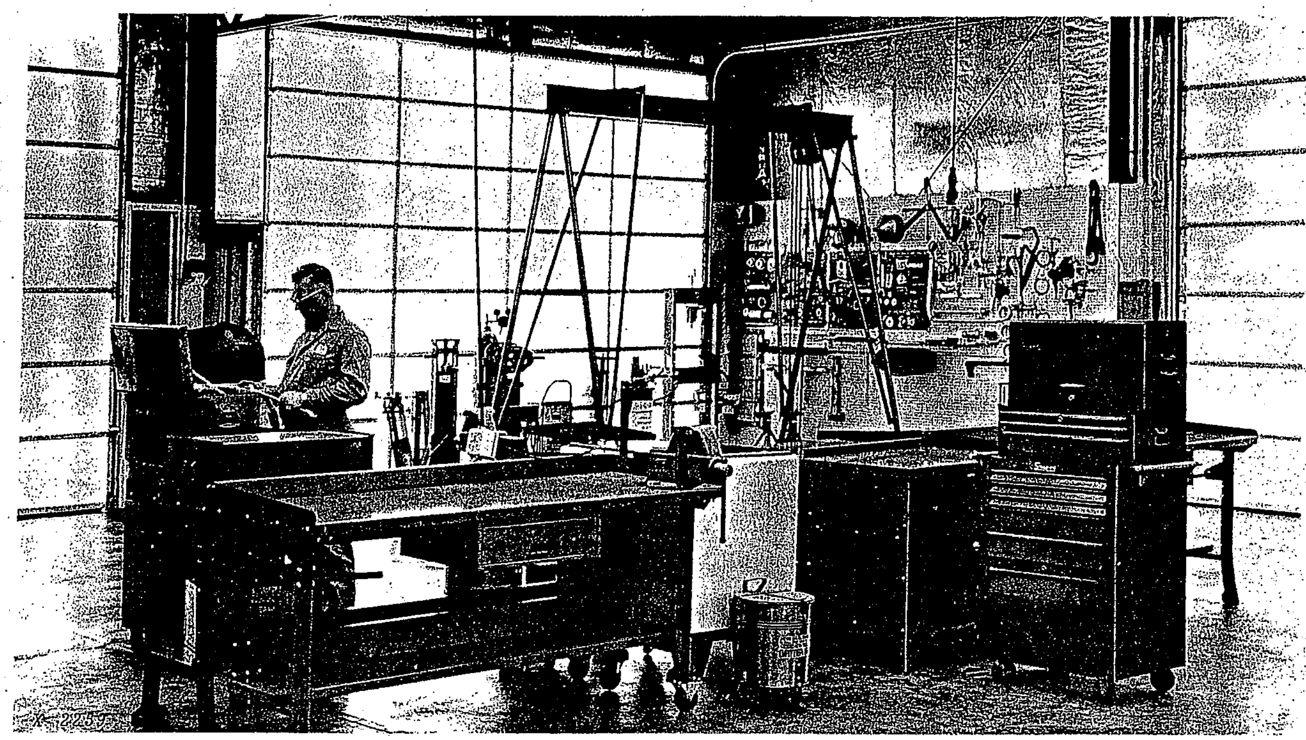

Fig. 1 — Tools Don't Make The Service Technician — But They Help

INTRODUCTION

Tools don't make the service technician — but they help. Knowing how to use and care for them will put you a step ahead of the crowd.

To get the best out of your tools, remember these three rules:

1. **Purchase only quality tools**
2. **Keep tools in safe condition**
3. **Use the right tool for the job**

Service technicians are known by the tools they use, so buy the best, keep them in good shape, and use them right.

In this book, we'll cover the tools shown in the box at right.

Screwdrivers	*Screw Extractors*
Hammers	*Pullers*
Pliers	*Pick-Up Tools*
Wrenches	*Inspection Mirrors*
Chisels	*Tubing Cutters*
Punches	*Soldering Equipment*
Files	*Feeler Gauges*
Hacksaws	*Micrometers*
Vises	*Dial Indicators*
Clamps	*Spring Testers*
Twist Drills	*Pressure Gauges*
Taps and Dies	*Speed-Measuring Tools*

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SCREWDRIVERS

Screwdrivers are the tools most easily misused. Regardless of other abilities, screwdrivers should only be used to install and remove threaded fasteners.

Screwdrivers discussed here are divided into eight designs:

- **Common**
- **Phillips®**
- **Clutch-head**
- **Offset**
- **Starting**
- **Pozidrive® or Supadrive®**
- **Torx®**
- **Scrulox® (Square Tip)**

Each one allows you to produce a twisting motion to tighten or loosen screws — but for different jobs.

Keep screwdrivers organized to make selection easy. Keep handles clean and free of grease and oil that could cause slippage. Discard screwdrivers with broken or damaged handles.

COMMON SCREWDRIVER

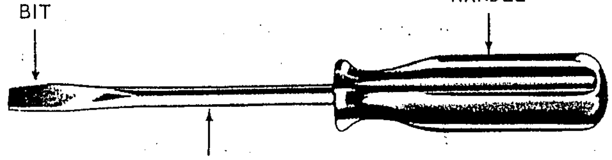

Fig. 2 — Common Screwdriver

Never use a screwdriver as a cold chisel, a punch, or a prying bar. If you must tap on the screwdriver, use one made for tapping.

Don't twist the shank of a standard screwdriver with a pliers or wrench. If necessary, use a heavy-duty screwdriver with a square shank.

Never use a screwdriver to check an electrical circuit.

Don't hold work in the hand while using a screwdriver — the point may slip and hurt you. A good rule is never to get any part of your body in front of the screwdriver bit.

Be sure the screwdriver bit is wide enough and fills the slot in the screw head (Fig. 3). Two small a bit will twist and "chew up" the screw.

Always hold the screwdriver shank vertical to the screw head as you twist it.

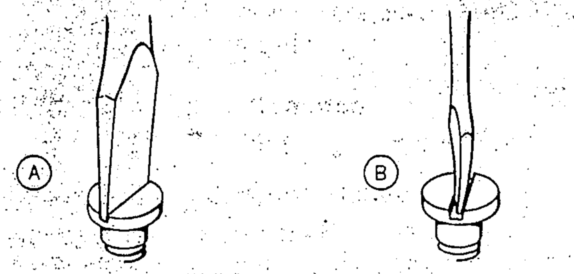

Fig. 3 — Be Sure The Screwdriver Fits The Screw Slot

If the screwdriver bit becomes rounded or broken, it can be reground as follows:

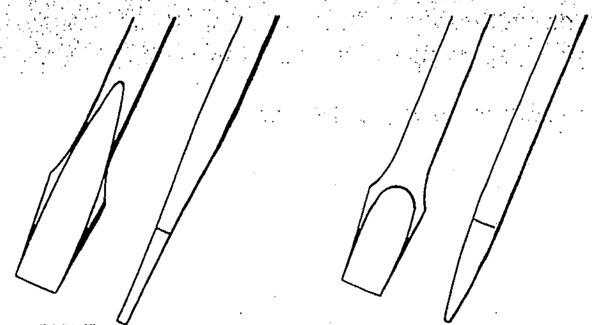

Fig. 4 — Grinding The Screwdriver Blade

1. Grind the tip until it is straight and at right angles to the shank (Fig. 4). The sides should have very little taper and should never come to a sharp point at the tip.

2. **IMPORTANT: Never hold the screwdriver against the grinding wheel for a long time.** Dip the bit in water to keep it cool. This will prevent loss of tempering and softening of the bit.

3. If the bit is correctly ground, it will stay down in the screw slot regardless of the twisting force. If ground with too much taper, the bit will rise out of the slot as it is turned.

NOTE: Only the end of the screwdriver bit is hardened, so there is a limit to how many times it can be successfully reground.

PHILLIPS SCREWDRIVER

This screwdriver (Fig. 5) has a cross-shaped, pointed tip. It will not slip sideways out of the cross slots of a cross-recessed head screw, but more force must be exerted in keeping it in the slots.

If the bit gets broken, it is not practical to repair it.

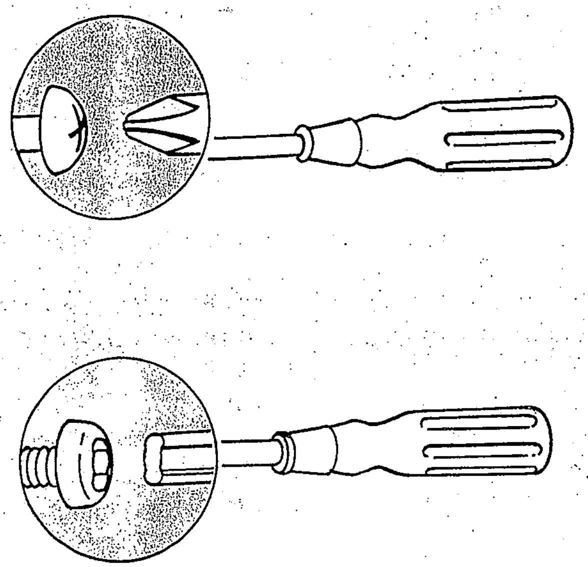

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Fig. 5 — Phillips and Clutch-Head Screwdrivers

CLUTCH-HEAD SCREWDRIVER

This screwdriver (Fig. 5) is used with screws for sheet metal and trim where a neat appearance is vital. This type of screw is sometimes called figure-eight or butterfly screw. The tip of the screwdriver is very strong and stays in the screw opening with only moderate pressure.

OFFSET SCREWDRIVER

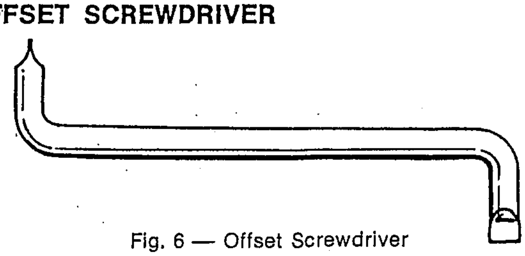


Fig. 6 — Offset Screwdriver

Offset screwdrivers (Fig. 6) are used where space is limited and the screw is hard to reach. Bits are usually at right angles to each other, allowing the screw to be turned a quarter turn at a time by using opposite ends alternately.

Use the offset screwdriver cautiously as the bit has a tendency to ride out of the slot and damage the screw head.

STARTING SCREWDRIVER

Starting screwdrivers (Fig. 7) are used for removing and installing screws in places difficult to reach with the hand. Once a screw is started, a common screwdriver can often be used to finish the job.

Other starting screwdrivers have twisting centers or are magnetized to hold the screws.

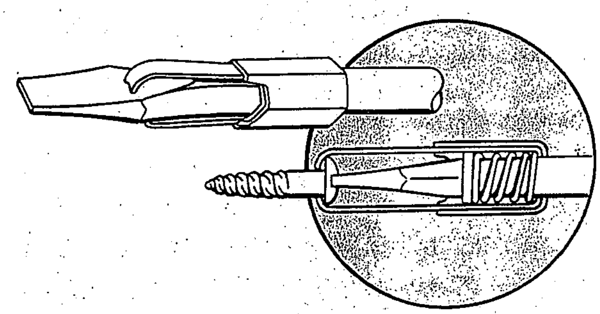


Fig. 7 — Starting Screwdriver (Shown Holding Screw)

POZIDRIVE OR SUPADRIV SCREWDRIVER

This screwdriver (Fig. 8) is similar to the Phillips screwdriver, but the screwdrivers should never be interchantged with each other. Misuse can cause tool and fastener damage.

The driving surface in the Pozidriv fastener is flat, a Phillips fastener driving surface is angled. This makes for a tighter, more positive fit between tip and fastener.

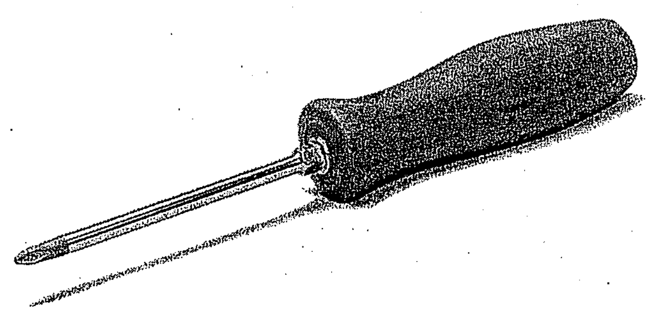


Fig. 8 — Pozidriv or Supadriv Screwdriver

TORX SCREWDRIVER

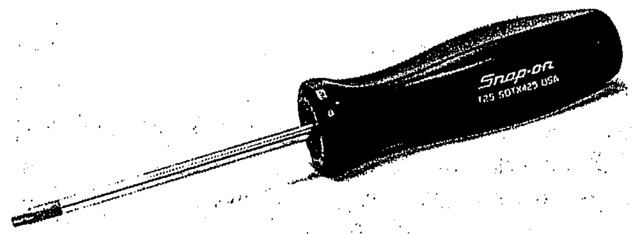


Fig. 9 — Torx Screwdriver

Torx screwdrivers (Fig. 9) have a six-point, star-shaped, flat tip. The tip fits into the fastener with a large contact surface engagement. This allows for higher torques to be applied to the fastener without damaging the fastener. Tip sizes are designated by a number preceeded by the letter T.

SCRULOX (SQUARE TIP) SCREWDRIVER

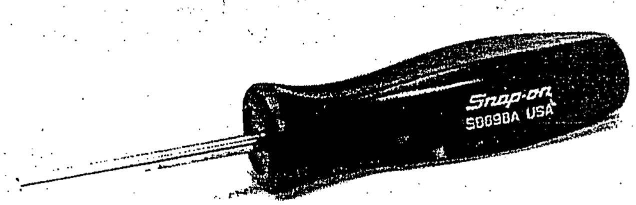


Fig. 10 — Scrulox (Square Tip) Screwdriver

The square tip screwdriver is used to install and remove scrulox fasteners. These types of fasteners are used primarily in recreational vehicles and truck body panels.

HAMMERS

After screwdrivers, hammers can be the next most abused tool. There is a right way and a wrong way to use a hammer, regardless of the type.

Always grip the hammer close to the end of the handle to increase leverage for a harder blow (Fig. 11). Whenever possible, strike the object squarely with the full face of the head to prevent damage to the hammer face and to the object.

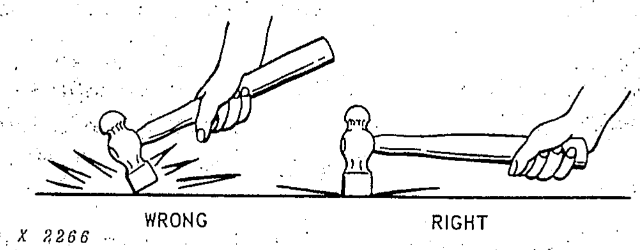


Fig. 11 — Correct Use Of A Hammer

The handle of a steel hammer extends through the head and is held tightly in the head by a wedge (Fig. 12) or an epoxy bond. If the wedge starts to come out, drive it in again to tighten the handle. If the wedge is lost, replace it before using the hammer. If the epoxy bond is loose or broke, replace the hammer.

Never use a hammer with a loose head.

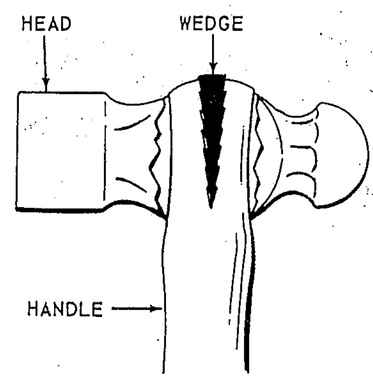


Fig. 12 — Correct Installation of Hammer Head On Handle

The hammer handle should never be used for prying or pounding.

Never strike a steel hammer on a machined surface or another hammer.

⚠ CAUTION: Wear eye protection. Always wear goggles when striking hardened tools and hardened metal surfaces. This will protect your eyes from flying chips. Whenever possible, use soft-faced hammers (plastic, wood, or rawhide) when striking hardened surfaces.

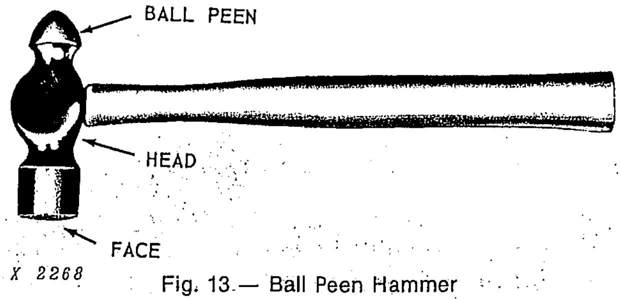


Fig. 13 — Ball Peen Hammer

Ball peen hammers (Fig. 13) are most commonly used by shop service technicians. The flat face is for hammering and the ball part is for founding off rivets and similar jobs.

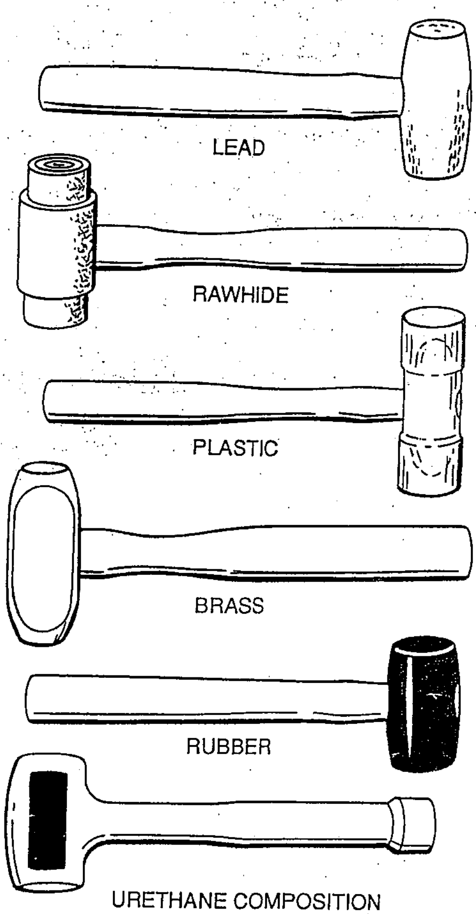


Fig. 14 — Soft Hammers

Soft hammers (Fig. 14) are used in place of steel hammers to protect machined surfaces or fragile parts. These hammers are commonly made of lead, rawhide, plastic, brass, rubber, or urethane material. Urethane hammers are sometimes filled with lead shot to produce a "dead blow."

PLIERS

COMBINATION PLIERS

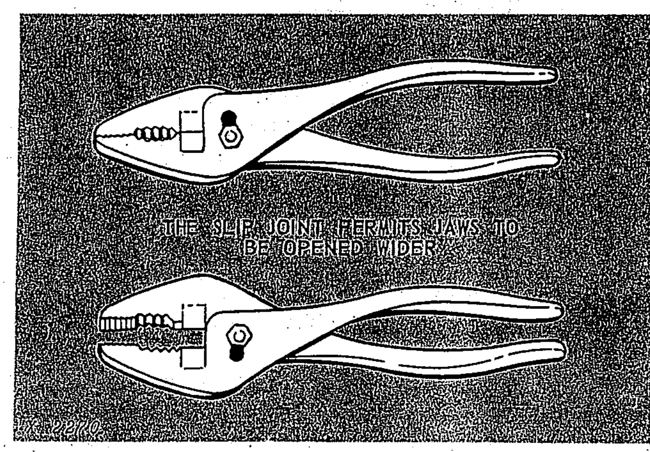


Fig. 15 — Combination Pliers

Combination pliers (Fig. 15) are often misused. They are made for *holding* work — not for tightening or loosening nuts.

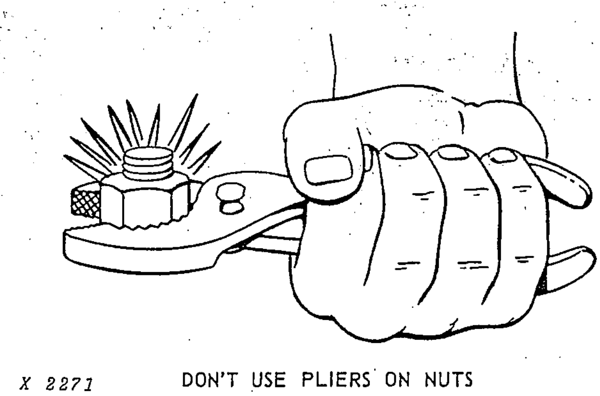


Fig. 16 — Wrong Use Of Pliers

A slip joint permits the jaws to be opened wider. For extra-wide objects, rib-joint pliers are used.

Avoid using pliers on hardened surfaces as this dulls the teeth of the pliers and they lose their grip.

DIAGONAL CUTTER PLIERS

Diagonal cutter pliers (Fig. 17) are ideal for pulling cotter pins, especially from slotted nuts. They may also be used for spreading the ends of cotter pins. *Never use diagonal pliers for cutting large-gauge wire.*

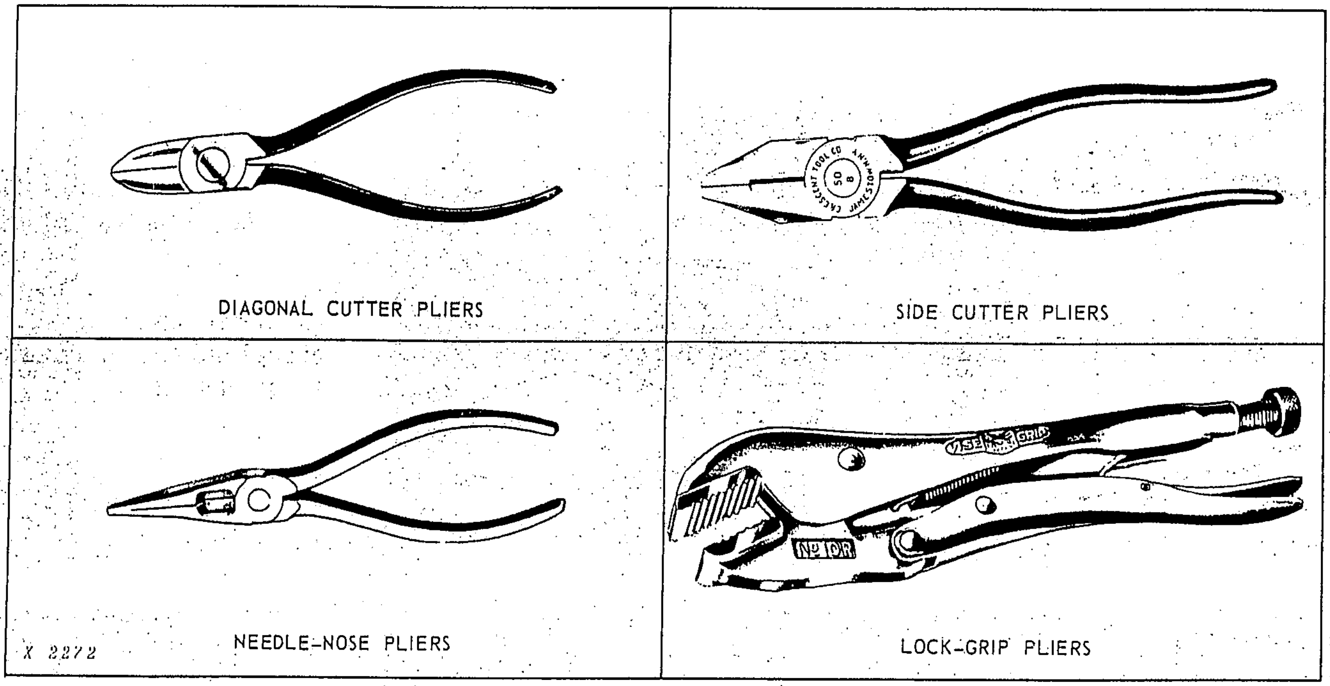


Fig. 17 — Pliers

SIDE CUTTER PLIERS

Side cutter pliers (Fig. 17) are for the service technician who cuts a lot of large-gauge wire.

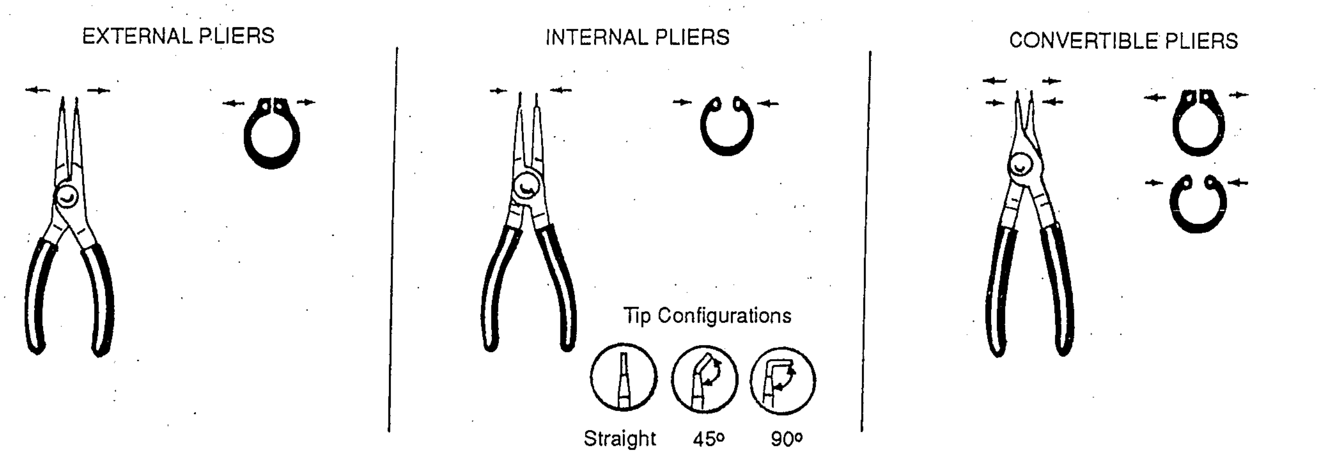
NEEDLE-NOSE PLIERS

Needle-nose pliers (Fig. 17) are used primarily for handling small objects and for reaching into restricted areas. Never force them beyond their gripping capacity.

LOCK-GRIP PLIERS

Lock-grip pliers (Fig. 17) are specially designed to clamp and hold a round object. One jaw is adjustable to fit different sizes or nuts, bolt heads, pipes, or rods.

Never use these pliers on material where marring the finish is a problem.



SNAP RING PLIERS

Snap ring pliers (Fig. 18) are used to spread snap rings just the right amount as they are removed or installed.

Angled tips are available for those hard to get snap rings. This is a handy tool and also helps prevent overexpanding of snap rings.

OTHER TYPES OF PLIERS

Special types of pliers are also available for certain jobs: Battery (terminal nut) pliers, water-pump nut pliers, ignition pliers, hose clamp pliers, brake spring pliers, retaining ring pliers, groove-grip snap ring pliers, horseshoe lock ring pliers, and slip-joint (channel) pliers.

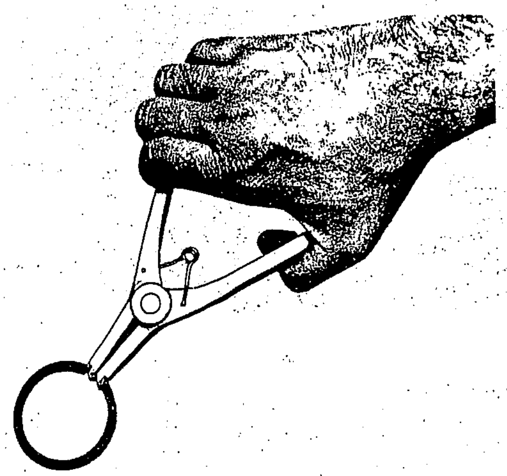


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Fig. 19 — Use Of Retaining Ring Pliers

CARE OF PLIERS

Keep pliers clean and occasionally put a drop of oil on the joint pin. This will prevent rusting, the enemy of all tools.

WRENCHES

There are many types of wrenches available, each intended for a specific use. In this book, we will discuss the following most common wrenches:

- **Open-end**
- **Adjustable Open-end**
- **Box**
- **Tubing**
- **Socket**
- **Set Screw**
- **Spanner**
- **Torque**

Never hammer on a standard wrench. Use a heavy-duty striking wrench designed for use with a hammer (Fig. 20).

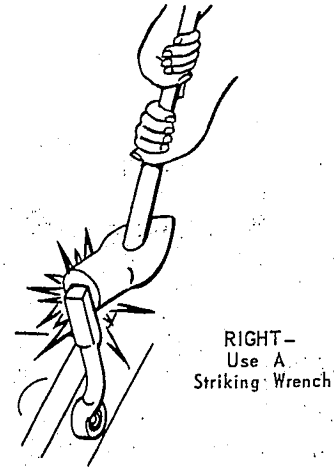

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Fig. 20 — Never Hammer On A Standard Wrench

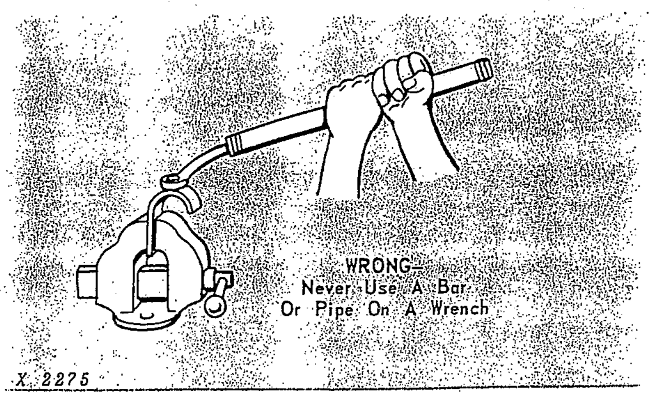

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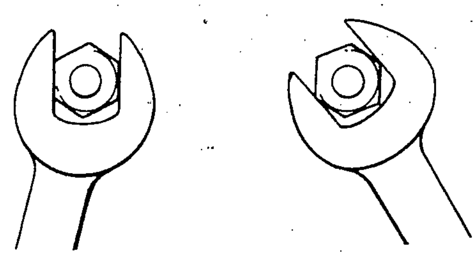
Fig. 21 — Never Use A Bar Or Pipe On A Wrench

Never use a bar or pipe to increase leverage on a wrench (Fig. 21). The only exception is when the work is hard to reach and you must use an extension, as with a socket wrench (Fig. 31).



X 2276 GOOD FIT BAD FIT

Fig. 22 — Correct Fit Of Wrench On Nut Is Important

Be sure the wrench correctly fits the nut or bolt head (Fig. 22).

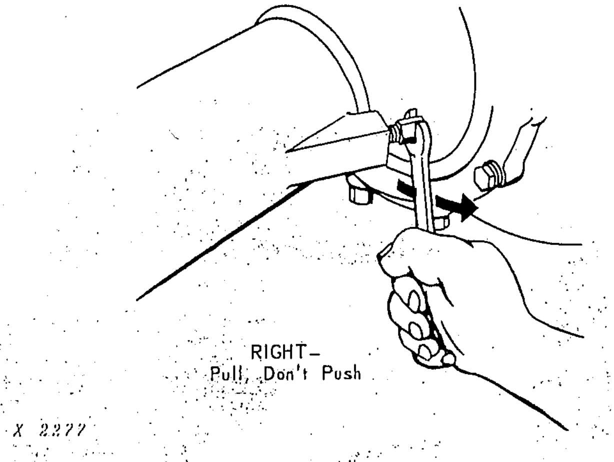


Fig. 23 — Always Pull On A Wrench — Don't Push

Always PULL on a wrench — don't PUSH. Save your knuckles (Fig. 23). If you must push, use the base of your palm and keep your hand open.

OPEN-END WRENCHES

Open-end wrenches have an opening at each end. The openings designate the size of wrench in inches (or millimeters) and are often combined, as 5/16 by 3/8 (metric wrenches — 16 mm by 18 mm). These figures refer to the distance across the flats of the nut or bolt and not the bolt diameter.

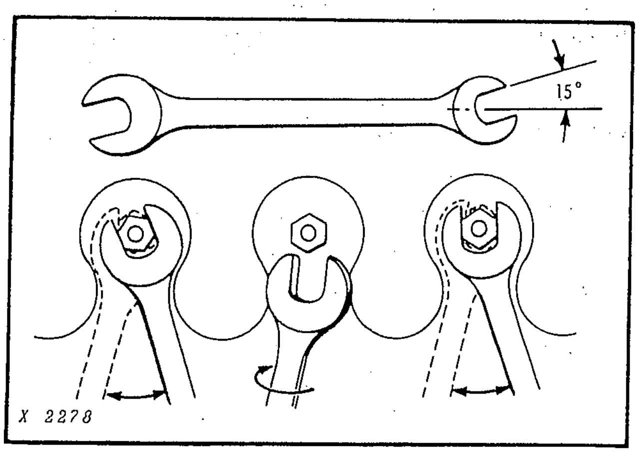


Fig. 24 — Loosen Nuts In Crowded Places By "Flopping" The Wrench

The head and opening of an open-end wrench is normally at an angle of 15 or 22-1/2 degrees to the body (Fig. 24).

The offset angle allows you more swing space in crowded places by "flopping" the wrench as shown.

ADJUSTABLE OPEN-END WRENCHES

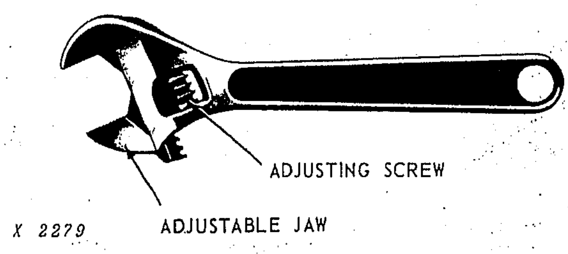


Fig. 25 — Adjustable Open-End Wrench

The adjustable open-end wrench (Fig. 25) has a sliding jaw moved by an adjusting screw. This wrench is not meant to take the place of an open-end wrench, except when an add-sized nut or bolt is encountered. This does help to cut down the number of open-end wrenches you need to carry.

Adjustable wrenches aren't intended for hard service — treat them gently.

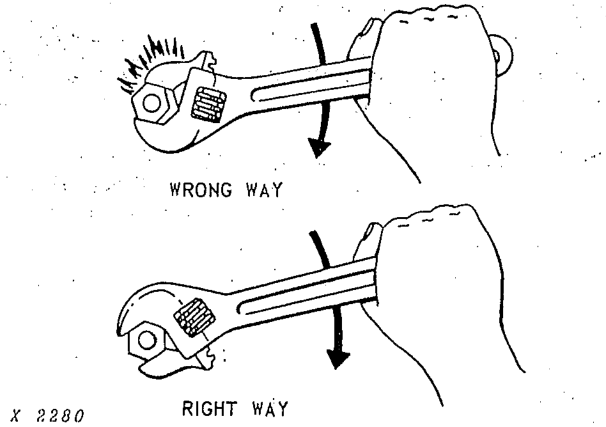


Fig. 26 — Correct Use Of Adjustable Open-End Wrench (Tightening Shown)

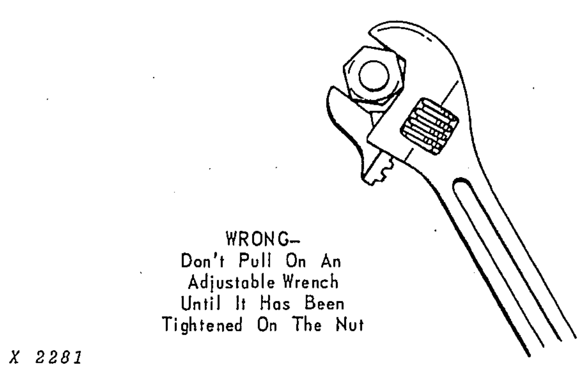


Fig. 27 — Tighten The Adjustable Wrench On The Nut

Remember these three points:

1. Always place the adjustable wrench on the nut so that the pulling force is applied to the stationary jaw side of the wrench (Fig. 26). This side can withstand much greater force.

2. After placing the wrench on the nut, tighten the adjusting screw so that the wrench fits the nut snugly (Fig. 27). Otherwise the nuts will be rounded off.

3. Keep the wrench clean. Wash it occasionally in cleaning solvent and apply a light oil to the adjusting screw and slide.

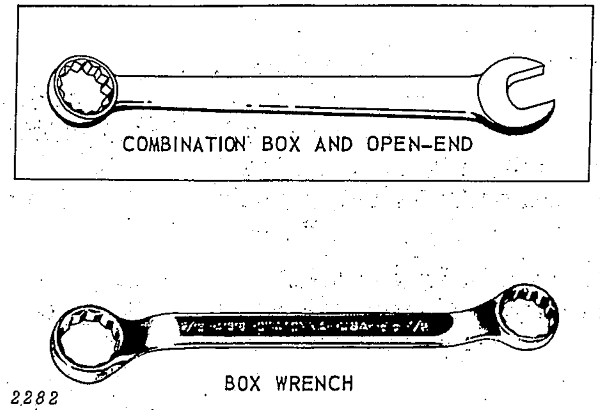


Fig. 29 — Box Wrenches

BOX WRENCHES

Box wrenches completely surround the nut to avoid slipping and are handy for working in close quarters.

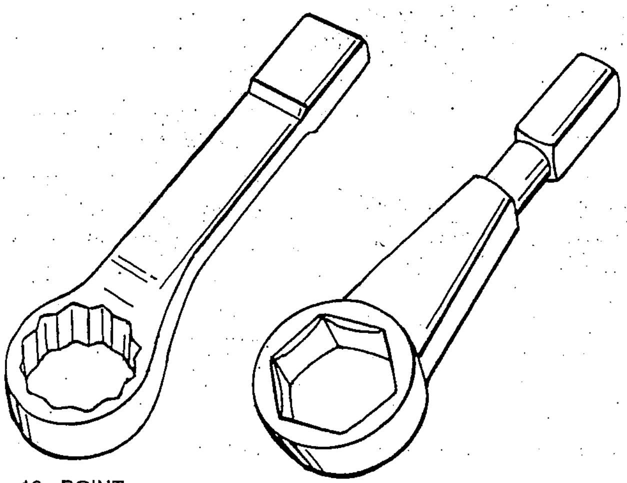


Fig. 28 — Striking Box Wrenches

In place of the hexagonal or six-sided opening, most box wrenches have 12 notches arranged in a circle and are called 12-point wrenches. A 12-point wrench can be used to continuously loosen or tighten a nut with a minimum swing of the handle of only 15 degrees, compared to a 30 or 60 degree swing of the open-end wrench. Larger box wrenches are also available in six-point styles. Six-point wrenches should be used on higher torqued hardware to provide greater contact, reducing possible damage to hardware or tool.

Some box wrenches are made with an offset at one or both ends (Fig. 29). This provides clearance for your hands and saves knuckles.

Combination box and open-end wrenches (Fig. 29) can speed up nut-and-bolt installations. The box end is used to break loose or snug down the nut, while the open-end is used for greater speed the rest of the time.

TUBING WRENCHES

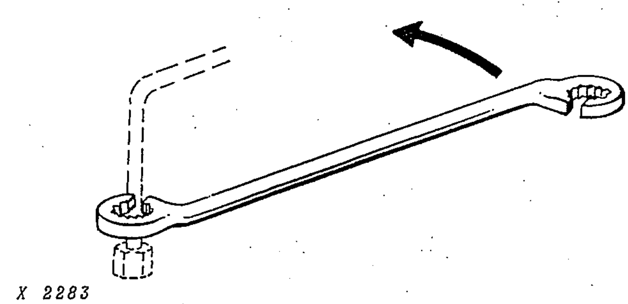


Fig. 30 — Tubing Wrench

A tubing wrench (Fig. 30) is similar to a box wrench but has a cut-out large enough to slip over hydraulic tubing. When using the wrench, pull only in the direction of the arrow in Fig. 30 to avoid spreading the wrench opening.

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SOCKET WRENCHES

Socket wrenches have done the most to make service work faster and easier. Fig. 31 shows a modern twelve-point socket wrench, a sliding T-handle, a speed handle, a universal joint, and a ratchet handle. In addition, several extensions and L-handles are available. Combined in various ways, these socket sets can do many nut-and-bolt jobs. Larger sockets are also available in six-point styles.

To use the socket wrench with a ratchet, you select the size of socket that fits the nut, engage it on the rathet handle and place the socket on the nut.

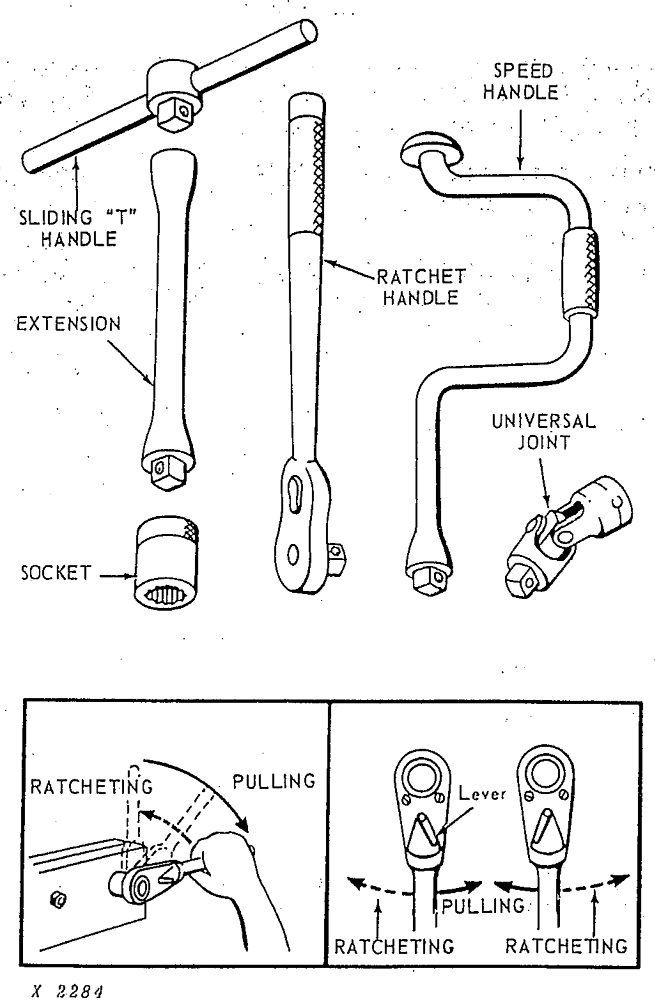

Fig. 31 — Socket Wrenches And Handles

Inside the head of the ratchet handle is a pawl or dog which engages or fits into one or more of the ratchet teeth. Pulling on the handle in one direction, the dog holds in the ratchet teeth and turns the socket. Moving the handle in the other direction, the dog ratchets over the teeth, permitting the handle to be backed up without moving the socket (see insert in Fig. 31). That's why the ratchet handle can be worked so rapidly — the socket does not have to raised off the nut to get another "bite." The handle ratchets in one direction when tightening a nut and in the other direction when loosening a nut.

A means usually is provided on the handle for changing the direction of ratcheting (see insert in Fig. 31). On some makes there is a little lever which is flipped to the right to make the head ratchet when the handle is moved in a counter-clockwise direction. This is the way you want it to work when tightening a nut. When unscrewing a nut the lever is flipped to the lfet and the handle then ratchets in a clockwise direction.

The reason that a modern socket wrench set is so adaptable for repair work is that in addition to the set of sockets and the ratchet handle, it contains numerous other accessories.

A hinged offset handle accessory is very convenient. To loosen a tight nut the handle can be swung so as to be at a right agle to the socket and thus provide the greatest possible leverage. Then, after the nut is loosened to the point where it turns easily, the handle can be hinged into the vertical position and twisted by the fingers to quickly remove the nut from the bolt or the stud.

Another part of the socket set is the sliding offset handle. The head can be positioned at the end or at the center of the handle. The sliding offset and an extension bar can be made up as a "T" handle.

Speed handles sometimes called "speeders" or "spinners" are convenient for many jobs such as removing or tightening oil pan screws. The speed handle is worked like a brace which the woodworker uses with a bit to bore holes. A speed wrench will help you get cylinder head nuts off in a hurry after they are first broken loose with the sliding offset or the ratchet handle.

A universal joint frequently comes in very handy when working on nuts in those places where a straight wrench cannot be used. The universal joint enables you to work the wrench handle at an angle with the socket. Often this is a big help when working close places.

Large socket wrench sets also contain extra deep sockets for use on spark plugs and on nuts which are a long way down on the bolts, such as on U-bolts.

Another accessory to the socket wrench set is a handle which measures the amount of pull you put on the wrench. This is called a "torque wrench." We will discuss torque wrenches later.

Keep all parts of the socket set free of dirt and grit. Wash them occasionally in cleaning solvent and apply a light oil to all universal joints and ratchets.

Never use hand sockets or adapters on electric or air powered tools; use only impact sockets and adapters for power tools. Most sockets can be distinguished by finish; hand sockets are chrome plated and impact sockets are black oxide finish.

SET SCREW WRENCHES

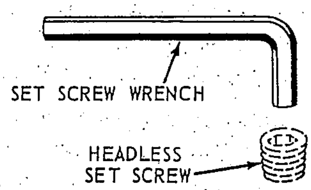

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Fig. 32 — Set Screw Wrench

These wrenches (Fig. 32) are for headless set screws and other countersunk hardware. Most are L-shaped bars of tool steel, usually hexagonal.

SPANNER WRENCHES

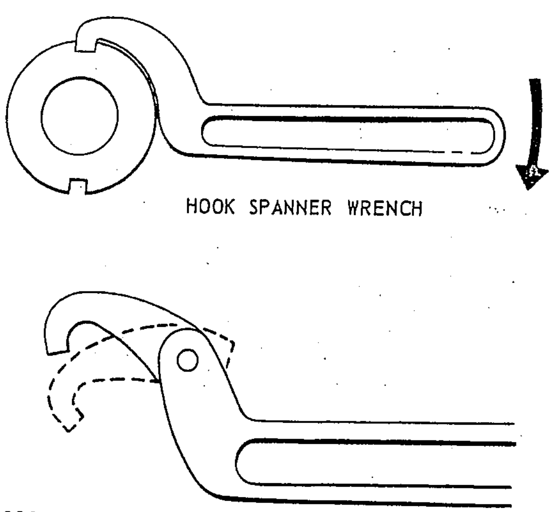

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Fig. 33 — Spanner Wrenches

Spanner wrenches (Fig. 33) are usually special tools supplied with a machine. There are a number of types: The hook type (shown), U-shaped hook type, end spanner, pin spanner, and face pin spanner.

WHICH WRENCH TO USE?

Now that we have talked about all of the ordinary wrenches used by service technicians, you may wonder how you are to find out which is the best type of wrench to use for the particular work you are doing. Should it be an open-end wrench, an adjustable wrench, a socket wrench, a box wrench or a combination box and open-end wrench? This is something that is best learned by actual experience, but there are a few simple rules which will be helpful.

First, determine if the fastener is unified inch or metric size. Unified inch fasteners use dashes or marks on the head or nut. Metric fasteners have the property class number on the head or nut. Refer to the torque tables at the back of this manual for the proper identification.

The type of job to be done, and the location and number of nuts or cap screws are the next things to consider when selecting the wrench.

Usually, if there are a number of nuts to be taken off or put on, the socket wrench set is what you should use. In removing the cylinder head from an engine, for example, you would first break the nuts loose by using a socket on a hinged offset handle with the handle bent over at an angle of practically 90 degrees to provide the necessary leverage. Then after the nuts were broken loose, the hinged handle would be held in the vertical position and twisted with the fingers to run them off.

If the engine is installed in a machine and there is plenty of room to operate a speed handle, then after breaking the nuts loose with the offset handle, transfer the socket to a speed handle and use this combination to spin the nuts off.

In replacing and tightening the nuts, the wrenches would be used in the reverse order.

For such jobs as removing and installing engine oil pans, timing gear covers, and transmission case covers, the right size of socket on a speed handle would be the best wrench to use. It can be used to loosen or tighten these cap screws because no great amount of force is required.

There are many nuts, particularly those on some intake and exhaust manifolds, where box, socket, or combination box socket and open-end wrenches can be used to good advantage.

For the nuts on fuel and oil lines, hydraulic brake lines, and clutch and transmission control rods, open-end wrenches or tubing wrenches are the only wrenches that can be used.

With a little actual experience in the shop, and after using each type of wrench in the tool kit a few times, you will find that with a little THINKING it is not at all difficult to select the type best suited for the job and to pick the right-size wrench. A good serviceman is the man who can use his head as well as his hands — who can coordinate his brain and muscles.

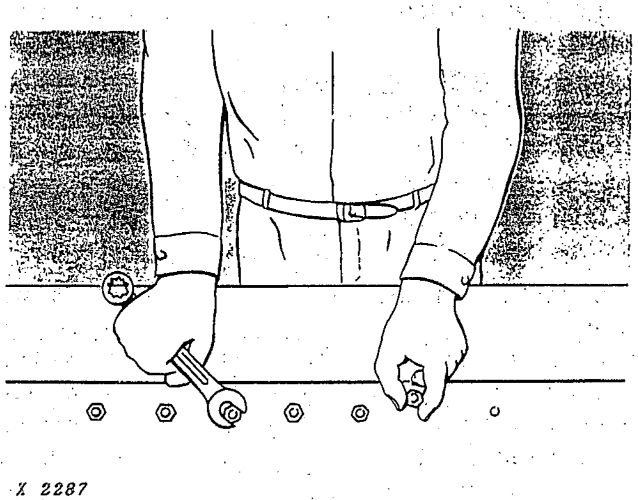

Fig. 34 — Using Both Hands To Get The Job Done In Half The Time

For instance, in replacing cylinder head nuts you will find you can get the job done in about half the time if you use both hands simultaneously instead of just one (Fig. 34). It is something like learning to use a typewriter — the beginner starts with two fingers but the experienced typist uses all ten. It is just a matter of practice.

TORQUE WRENCHES

A torque wrench (Fig. 35) measures resistance to turning — called **torque.**

Torque and tension are not the same thing. **Torque** is **twist**, measured in *pounds-foot (Newton-meters).* **Tension** is a straight **pull,** measured in *pounds (Newtons).* Wrenches designed to measure the tightness of a nut are **torque** wrenches, not tension wrenches.

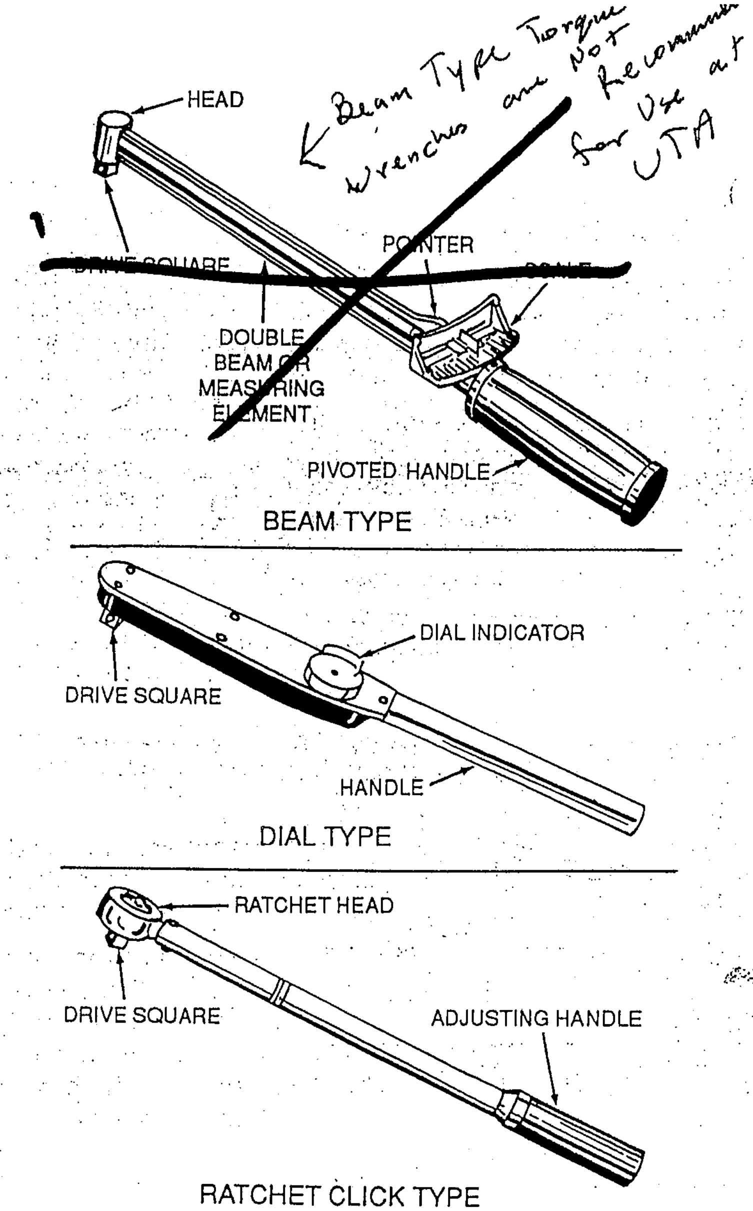

Fig. 35 — Torque Wrenches

TORQUE is based on the fundamental law of the lever — FORCE X DISTANCE = TORQUE. This is shown in Fig. 36.

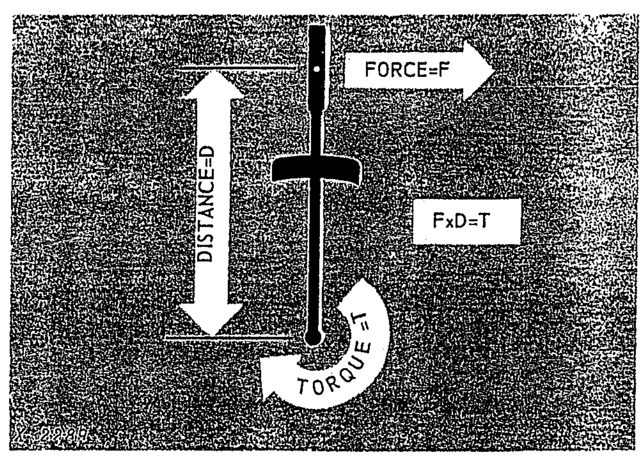

Fig. 36 — Formula For Torque

Lever length is the distance from the center of the drive square (Fig. 35) to the axis of the handle pivot where the force is concentrated.

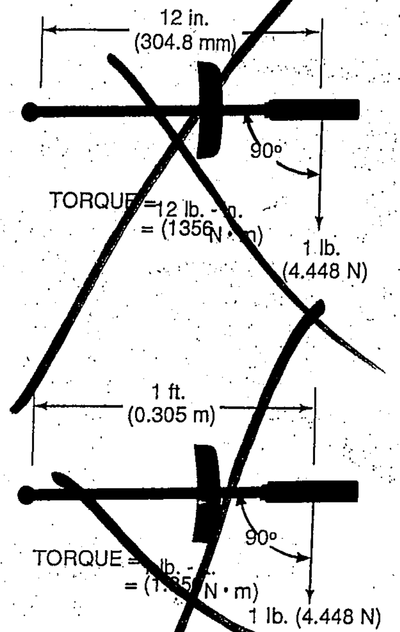

Fig. 37 — Units for Measuring Torque

If the lever length is measured in inches (millimeters) and the force in pounds (Newtons), then the torque developed is measured in **pound-inch (Newton-millimeters).** If the lever length is measured in feet (meters), then the result is termed **pound-foot (Newton-meters)** (Fig. 37).

Pound-foot multiplied by 12 = pound-inch.
(Newton-meters multiplied by 1000 = Newton-millimeters)

Pound-inch divided by 12 = pound-foot.
(Newton-millimeters divided by 1000 = Newton-meters)

Most torque wrenches have a signaling device which can be preset for the torque desired. When you reach that torque on the wrench, you are signaled by the wrench.

Formula For Torque Of Adapter Or Extension

Adapters and attachments can be used with torque wrenches to aid in reaching inaccessible places.

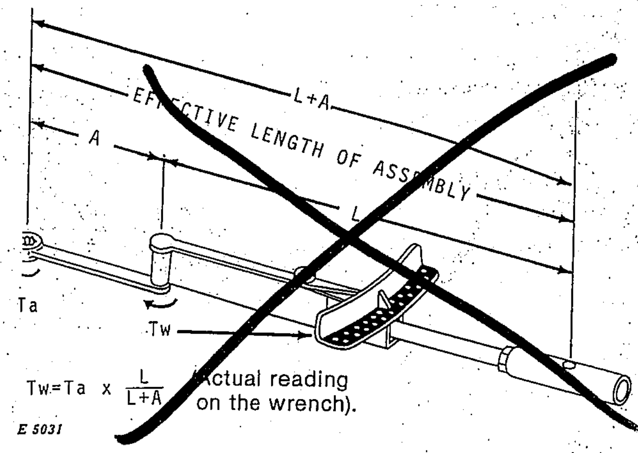

Fig. 38 — Calculating Torque With An Adapter

When an adapter is used with the torque wrench, the total effective length of the assembly is the sum of the lever length (L) plus the adapter length (A) as shown in Fig. 38. To get the actual torque reading, use the following formula:

Ta = torque at end of adapter
Tw = torque wrench reading
L = lever length of torque wrench
A = length of adapter

The formula is:

$$Ta = Tw \times \frac{L + A}{L}$$

Selecting A Torque Wrench

Selecting the proper size and range of torque wrench is important in getting accurate results. A good rule of thumb is to select a torque wrench having enough capacity so that your working range is within the middle two quarters of the scale.

For example, if you choose a 600 pound-foot (814 N-m) capacity torque wrench, any job within 150 to 450 pound-foot (203 to 610 N-m) is the best working range. Under normal conditions, this will give you the most accuracy.

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Using A Torque Wrench

Torque wrenches can be pulled or pushed. Apply force steadily.

If a seizure occurs while tightening, back off the nut and retighten it with a steady sweep of the handle. Take the torque reading while the wrench is moving.

For click-type torque wrenches, an audible click is heard when tension is released at the pre-set torque.

When tightening a nut or bolt with damaged or blocked threads, note what torque is required to move through the damaged area. Then add this extra torue to the recommended reading.

Handle torque wrenches very carefully, it is a delicate measurement instrument. If the wrench is dropped, check it for accuracy before using it again. Store wrench in a case when not in use.

Checking Torque Wrench For Accuracy

To check the accuracy of a rigid torque wrench, do the following:

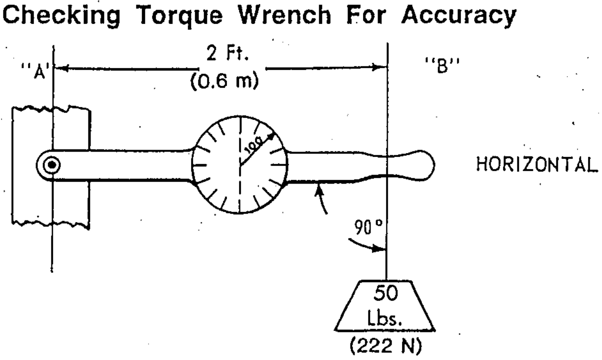
1. Hang the torque wrench on a fixed nut as shown in Fig. 39.

2. Set the indicator to "O". (This will compensate for the weight of the wrench.)

3. Hang a known weight from the wrench handle at any known distance from the center of the nut as shown.

4. Weight in pounds multiplied by the distance from A to B in feet will give you the lb-ft (N-m) of torque. This figure should agree with the indicator reading.

Checking Torque Wrench For Accuracy



A = Center Line of Nut B = Point of Suspension

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Fig. 39 — Checking Torque Wrench For Accuracy

Example shown: 50 lbs. x 2 ft. = 100 lb-ft
(22.7 kg x 9.81 = 222 N;
222 N x 0.6 m = 133 N-m)
Note: 9.81 is a factor for gravitational pull.

Remember that any weight or distance can be substituted in the formula, Weight x Distance = Torque.

NOTE: To check the accuracy of flexible torque wrenches, hang the weight from the pivot point of the handle. Weight x Distance will then give you the Torque.

Always check wrenches within the range where they are normally used.

Why Proper Torque Is All-Important

Bolt torque is based on this concept: For a bolt to stay tightened, it must be tightened enough so that the load *in the bolt* is greater than the loads which the bolt must *absorb* during operation.

Overtightened bolts are "stretched" until their threads are damaged or assembly parts are warped or misaligned.

Undertightened bolts allow a "shearing" force to develop between the mating parts as they try to move. If the parts impose a greater stress than the stress or load in the bolt, they will eventually fatigue and break the bolt or work it loose. Shear bolts are designed to fail under predetermined loads. Always replace shear bolts with identical grade bolts.

Up to 90 percent of applied torque is used for overcoming friction, but the percent varies with different types of bolts and nuts. Other variables include the material in the parts to be held together, location of the assembly, forces exerted on it, and lubrication of the bolt threads. In short, every torquing job varies, and that is why a specific torque is given in the machine technical manual for each location.

A general guide for torquing various types of bolts and nuts is given in the tables at the back of this manual.

CHISELS

Cold chisels are used for cutting metal in jobs such as breaking rivets and splitting nuts.

CORRECT USAGE

Ordinarily the chisel should be held between the thumb and first finger about an inch from the head of the chisel. Hold it with a steady but rather loose grip to lessen the blow on the hand in case of a miss.

Torque Wrench Testing

In the course of performing mechanical maintenance and repairs it is critical to adhere to proper procedures – including proper torque of fasteners. Each of UTA's maintenance facilities is equipped with a Norbar Professional Torque Tester. This instrument is accurate to ±0.5% of reading. It is critical that torque wrenches be tested on a regular basis to ensure proper torque values are achieved.

Three essential operating modes allow the pro-Test to be used with all torque wrench types: **'Track'** displays the live value, **'Peak Memory'** records the highest value and **'First Peak Memory'** records the first peak of torque (for click type torque wrenches). Both memory modes can be used with manual or automatic reset.

All common units of torque measurement are included and selectable from the front panel.

CAUTION: Always wear safety glasses when using a chisel.

A chisel will cut any metal softer than itself. Always use a chisel that is big enough for the job and a hammer that is heavy enough for size of chisel; the larger the chisel, the heavier the hammer.

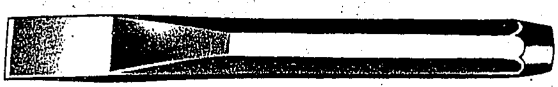

Fig. 40 — Flat Cold Chisel

FLAT COLD CHISEL

The flat cold chisel (Fig. 40) is the one most commonly used. The cutting edge is slightly convex (curved outward) as shown in Fig. 41. This causes the center portion to receive the greatest shock, thus protecting the weaker corners. Cutting edge angle should be 60 to 70 degrees for general use.

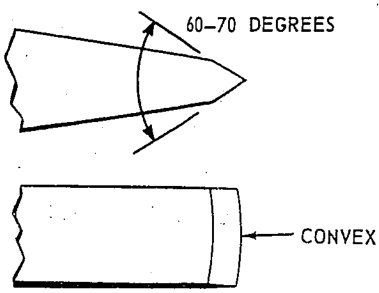

Fig. 41 — Correct Shape Of Flat Cold Chisel Edge

SPECIAL COLD CHISELS

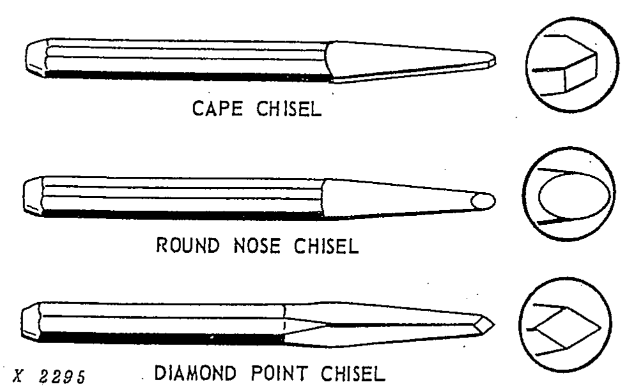

Fig. 42 — Special Chisels

Cape chisels (Fig. 42) are used for cutting keyways, narrow grooves, and square corners.

Round nose chisels are used for cutting semicircular grooves and chipping inside corners which have a fillet or radius.

Diamond point chisels are used for cutting V-grooves and square corners.

PROPER CARE OF CHISELS

IMPORTANT: When grinding a chisel, never hold it against the grinding wheel for any great length of time. Dip it frequently in water or coolant to keep it cool. Unless this is done, heat caused by friction with the grinding wheel will draw the temper and cause the cutting edge to become soft and almost useless.

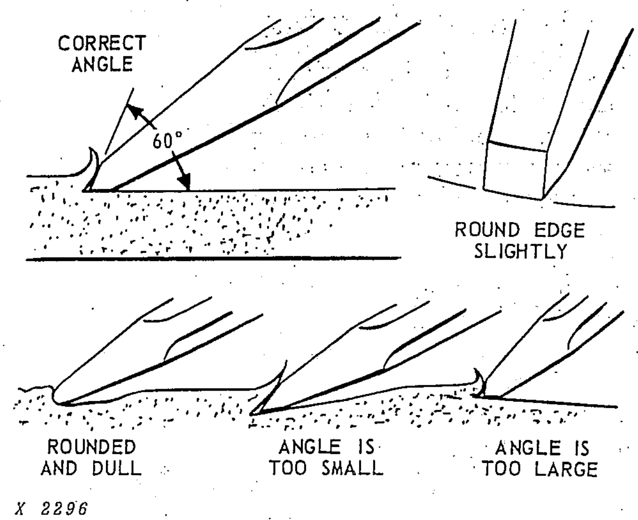

Fig. 43 — Results Of Correct and Incorret Chisel Grinding

Fig. 43 shows the results of correct and incorrect chisel grinding.

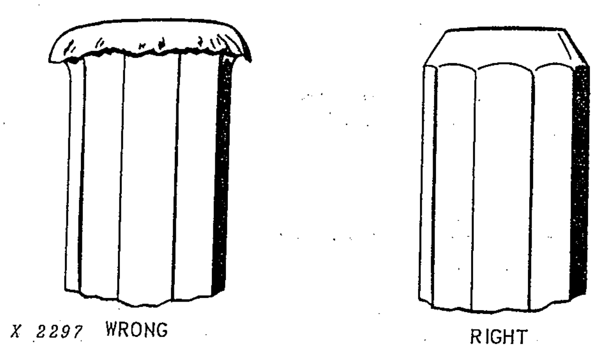

Fig. 44 — Chisel Heads

The head of a chisel will spread or mushroom out after being used a great deal as shown in Fig. 44. This spreading is rough, and will injure the inside of the hand if the chisel should slip. Also, pieces may break away from the overhang with enough force to cause injury. For safety, keep the chisel head ground down as shown in Fig. 44.

PUNCHES

CORRECT USAGE

When using a punch, hold it with a steady, but rather loose grip to lessen the blow on the hand in case of a miss. Always use a hammer proportionately large enough for the punch.

CAUTION: Always wear safety glasses when using a punch or drift.

Use the proper size punch for the job, and a proper size hammer for the size of the punch. The larger the punch, the heavier the hammer.

PROPER CARE OF PUNCHES

The head of a punch will, in time, spread or "mushroom" like chisels, and should be ground down to prevent injury. Refer to Fig. 44.

The tip of a starting punch, pin punch and brass drift can also "mushroom" or become chewed and gouged, resulting in a rounded or uneven tip that could be potentially dangerous. Any "mushroom" should be ground off and the tip end ground flat and perpendicular to the centerline of the punch.

As with chisels, care should be taken when grinding the tip of a punch. Never overheat the tip; dip it frequently in water or coolant to keep it cool.

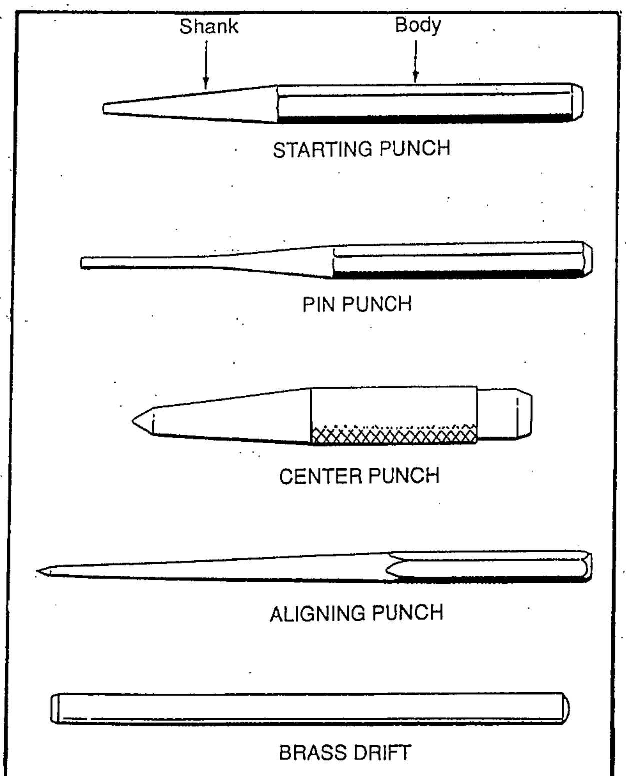

Fig. 45 — Punches

STARTING PUNCHES

A starting punch has a long gentle taper which extends from the tip to the body of the punch. This type of punch is used to knock out rivets and to start driving out straight or tapered pins.

PIN PUNCH

A pin or drift punch (Fig. 45) is used for driving out pins after the starting punch can no longer be used.

CAUTION: Never use a pin punch to start a pin. Since it has a slim shank, a hard blow may cause it to break or bend.

CENTER PUNCH

A center punch (Fig. 45) is used to mark the location of a hole that is to be drilled and to eliminate drill "wandering."

Frequently, a center punch is used for marking the relationship between mating parts.

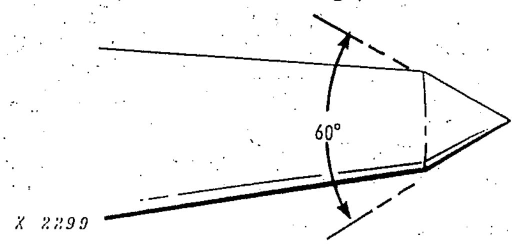

Fig. 46 — Correct Angle For Point Of Center Punch

The point on a center punch is accurately ground and is concentric with the punch body. Included angle is usually 60 degrees as shown in Fig. 46. Do not use a center punch on metal that is so hard it may dull the point.

ALIGNING PUNCH

An aligning punch (Fig. 45) is useful in shifting parts so corresponding holes "line up."

CAUTION: An aligning punch should never be used as a center punch.

BRASS DRIFT

A brass drift is used as a pin punch where delicate work is required. It is used in place of a steel punch so as to protect fragile parts and machined surfaces.

FILES

Files (Fig. 47) are made in numerous sizes and shapes, each one having a specific use. They are further designated by the coarseness or fineness of teeth, shape of teeth, and whether they have singe- or double-cut teeth.

Fig. 47 shows what the parts of a file are called. The size is figured from the heel to end of tip.

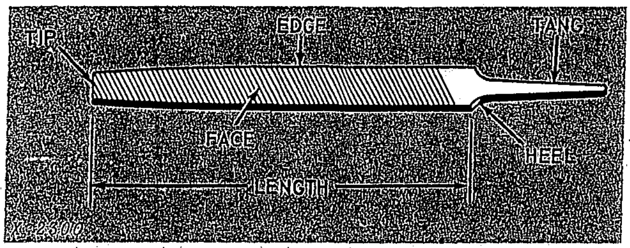

Fig. 47 — File

There are many kinds of files, but here we will cover only those a service technician will normally use.

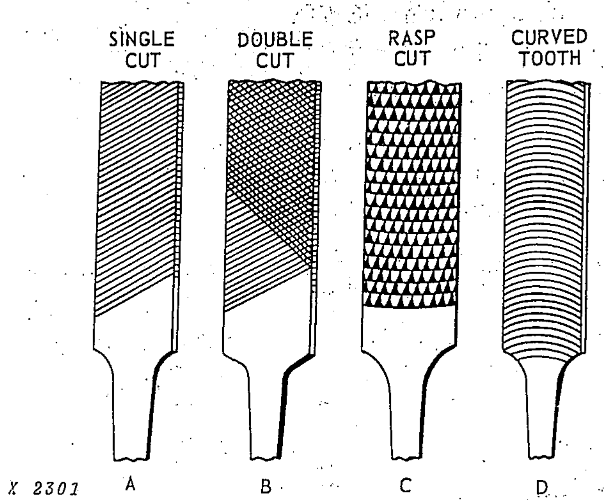

Fig. 48 — Four Types Of File Teeth

Shown in Fig. 48 are four representative files generally used in shops.

"A" shows a **mill file,** which received its name by having been used to sharpen saws. Mill files are always single-cut, meaning only one row of teeth appear on the blade.

"B" illustrates a **machinist's file,** which has double-cut teeth.

"C" is a **rasp cut file** on which all teeth have been individually cut and disconnected from each other for independent teeth in cutting.

"D" is a **curved tooth file** which has a single row of teeth cut on the blade in a curve to aid in self-cleaning.

Mill and machinist's files are further classified with reference to coarseness of teeth into Bastard, Second-cut, and Smooth-cut.

Mill files are generally used for tool sharpening. Machinist's files are used for filing and finishing machine parts. Rasp files are used for cutting wood and very soft metals. The curved tooth file is used on aluminum and steel sheets.

CORRECT USE OF FILES

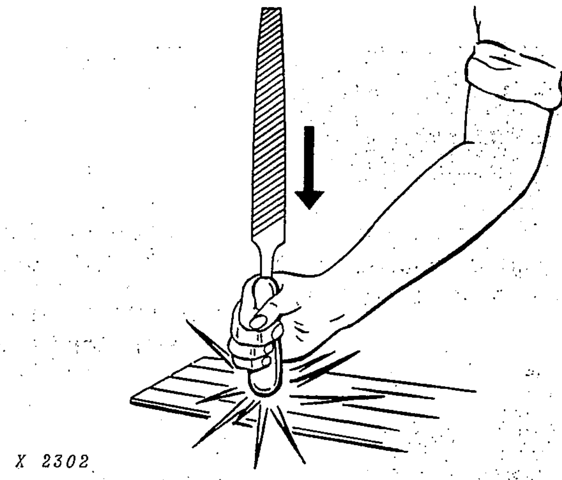

Fig. 49 — Tightening File Handle

Before attempting to use any file, equip it with a tight-fitting handle similar to that shown in Fig. 49. This eliminates the danger of injuring your hand.

Normally *PUSH the file across the work, cutting only on the forward stroke.* To prevent damage to teeth, raise the file from the work on the return stroke.

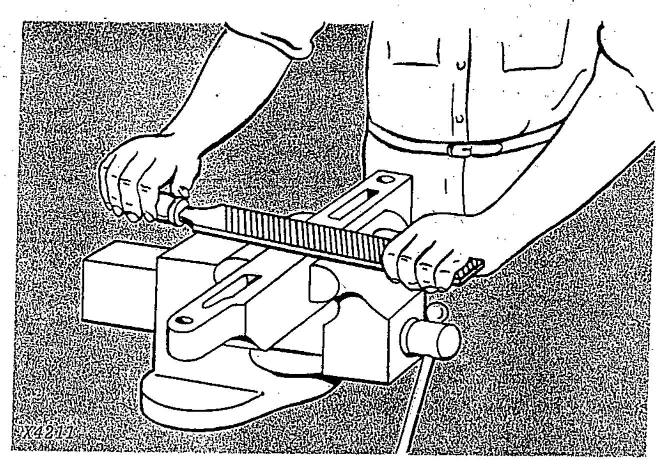

Fig. 50 — Correct Method Of Draw-Filling

When it becomes necessary to finish a flat surface, for example a gasket surface, it should be draw-filed. This is done by using a machinist's file and drawing the file crosswise over the work with a light pressure (Fig. 50). Holding the file in this manner allows it to cut when moving in both directions.

When using a file, *apply only enough pressure to keep the file cutting.*

Never hammer on a file, or use it for prying. Do not use the file after the teeth have become clogged until it has been properly cleaned. Learn to tap the file at the end of the stroke to clear the teeth of chips.

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PROPER CARE OF FILES

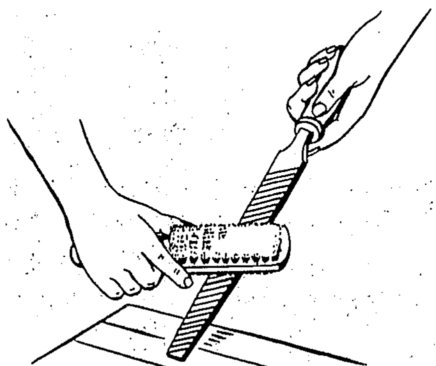
X 2304

Fig. 51 — File Card

Clean a file by using a file card (Fig. 51). This is a brush with short, stiff wire bristles. If chips are left after using the file card, they should be lifted out with a pointed or flattened cleaning wire called a "scorer" which is included as a part of most file cards.

To keep files sharp, see that their surfaces are protected when not in use. Do not throw files around on the bench or into a drawer. Keep files away from water to prevent rusting and keep them from getting oily, as this prevents fast, clean cutting.

HACKSAWS

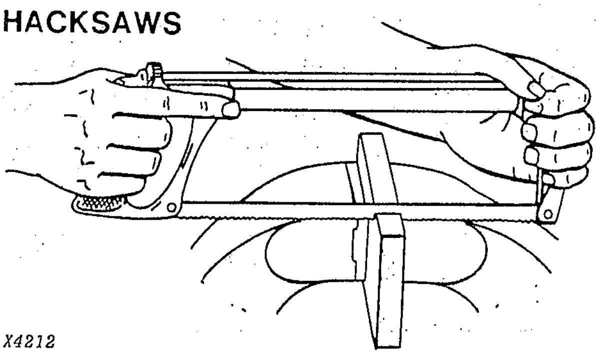
X4212

Fig. 52 — Correct Way To Use A Hacksaw

Hacksaw frames are designed to take blades of various lengths. The blade can be positioned at various angles along its axis.

CORRECT USE OF HACKSAW

When placing blade in frame, be sure the frame is correctly adjusted for length of blade with sufficient adjustment remaining to permit the blade to be *tightly stretched.* A properly stretched blade will vibrate with a clear humming sound when plucked.

Place blade in frame so teeth point AWAY from handle.

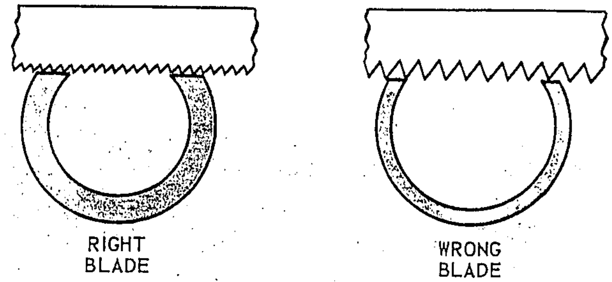

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Fig. 53 — Selecting the Correct Hacksaw Blade

Always use a blade suitable for the thickness of the material to be sawed. Blades are made with 14, 18, 24 and 32 teeth per inch (5.5, 7, 9.5, and 12.5 teeth per cm).

The most simple method of selecting the proper blade is to remember that *two saw teeth should always be contacting the material when sawing.*

Fig. 53, left diagram shows the correct blade being used to saw thin material. The diagram at right shows how a blade with teeth to large will cause the work to fall between two teeth, making it almost impossible to saw and damaging the saw blade.

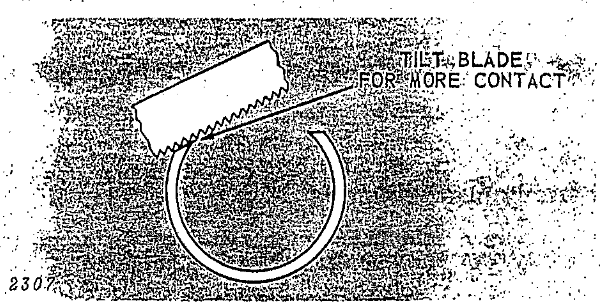

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Fig. 54 — Sawing Thin Tubing

When cutting very thin material, such as tubing, shift the angle of the saw blade as cutting progresses to increase the area of contact between blade and material, allowing as many teeth as possible to contact the work at one time (Fig. 54).

Use sufficient pressure on the forward or cutting stroke so that the teeth actually bite into metal. It is not necessary to lift blade from work on back stroke, but pressure should be relieved. Always use sufficient pressure to keep blade from getting pinched or jammed in the work as this often breaks teeth or blade.

Except when starting, use the full length of the blade on every stroke.

For efficient cutting of average metal, work the blade at 40 to 50 strokes a minute. Reduce this rate for harder metals. There is a limit to the hardness of metal that can be sawed.

PROPER CARE OF HACKSAWS

Wipe the blade occasionally with an oily cloth to keep it from rusting. Also, keep the blade away from other tools to eliminate the possibility of teeth being broken or dulled.

Normally, metal hacksaw blades are never sharpened due to the fine teeth and the hardness of the metal. For these reasons, replace them when worn.

VISES

A vise is a heavy-duty holding tool. Several types are generally used in the shop.

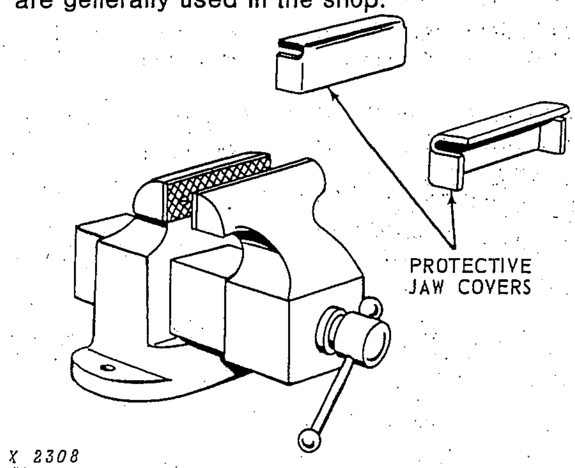

Fig. 55 — Machinist's Bench Vise

Fig. 55 shows the most commonly used machinist's **bench vise.** Also illustrated are jaw covers of soft metal used to hold machined parts to prevent marring the surfaces. A similar type is the **anvil vise.** Light hammering may be done on the stationary jaw of this vise.

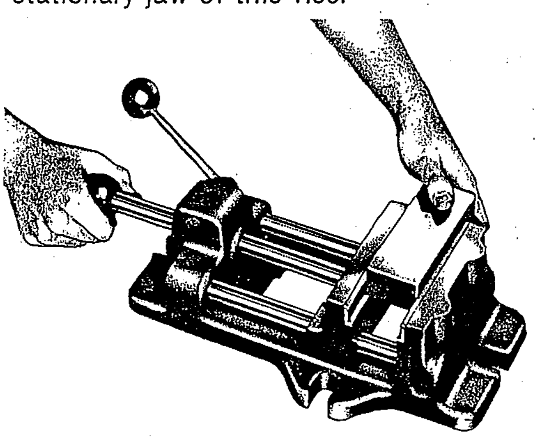

Fig. 56 — Drill Press Vise

Fig. 56 shows a **drill press vise,** which should always be used when drilling small parts. It is dangerous to attempt drilling small pieces when holding them with pliers or hands.

CORRECT USE OF VISES

Never use a hammer to tighten or loosen a vise, the weight of the body is sufficient.

Always use a vise big enough for the parts or type of work to be held.

When round parts must be held, soft metal or hard wood jaws can be used to prevent slipping or damage to parts. Whenever finished surfaces must be held, be sure to use soft metal jaw covers as shown in Fig. 55 to prevent marring the finish.

CLAMPS

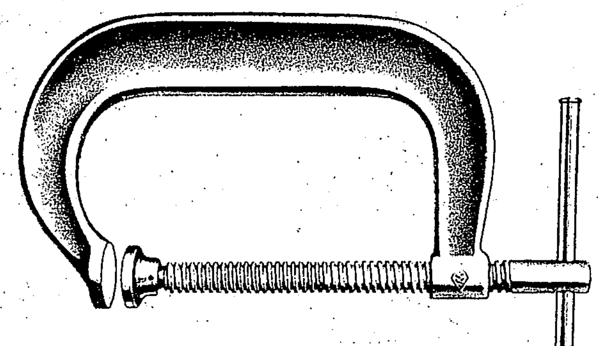

Fig 57 — C-Clamp

C-clamps (Fig. 57) are more portable and versatile than vises, but do not hold the complete work stationary. However, they are handy for fastening materials together, as while welding.

TWIST DRILLS

Twist drills (Fig. 58) are made of either carbon tool steel or high-speed tool steel. Carbon steel will lose its temper if excessively heated and allowed to cool. High-speed steel drills can become "red hot", then cool, but still not lose their temper.

Fig.58 shows the parts of a twist drill. Drills with three or four flutes are used only for enlarging drilled holes or drilling out cored holes. Two-fluted drills must be used for drilling into solid metal stock.

The three principal parts of a drill are the shank, body, and point. The flutes of a drill afford channels for chips to pass out, carry any lubricant to the point, and provide correct rake to the lips, thereby causing chips to curl tightly to occupy less space.

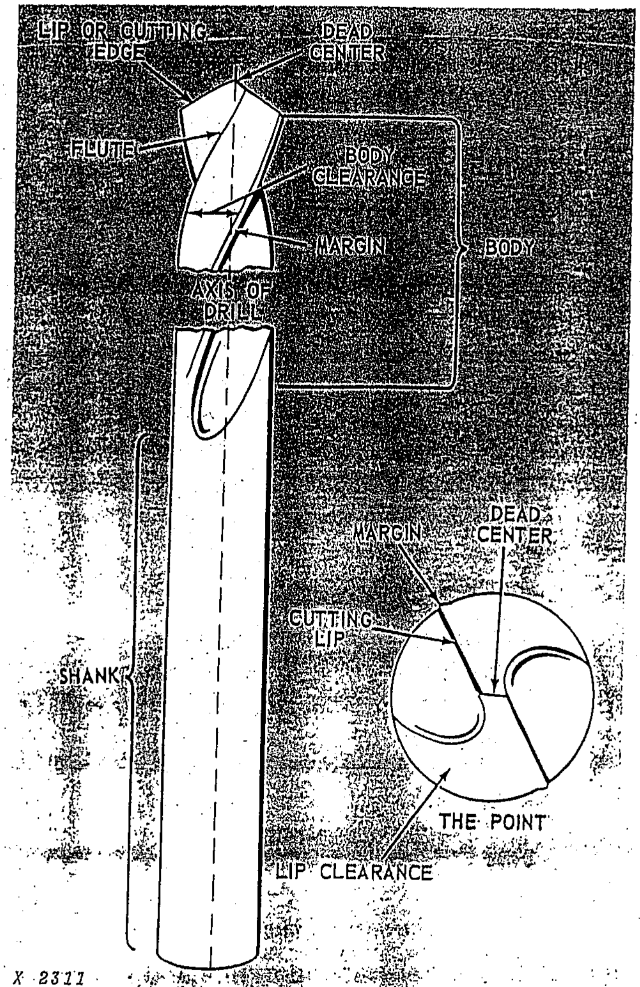

Fig. 58 — Twist Drill

CORRECT USE OF DRILLS

When using a low-speed, slow-feed method of drilling, carbon tool steel drills can be used.

When high-speed or fast-feed of the drill is necessary, use drills of high-speed tool steel.

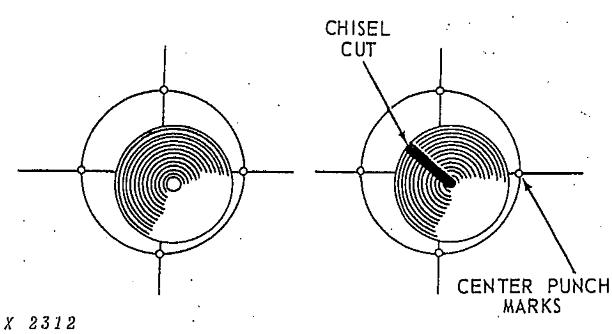

Fig. 59 — How To Draw The Drill Back To Correct Center

Always center punch the exact spot to drill holes accurately.

After the drill has enlarged the center punch mark slightly and before the whole point has entered the material, check to see that the hole is correctly centered. If the drill is not entering the right spot, it can be drawn over by making a chisel cut on the side to which the drill should be drawn (Fig. 59).

Whenever possible, use a lubricant to cool the drill.

GRINDING OR SHARPENING DRILLS

Before using a drill, be sure it is sharp and ground according to the material to be drilled.

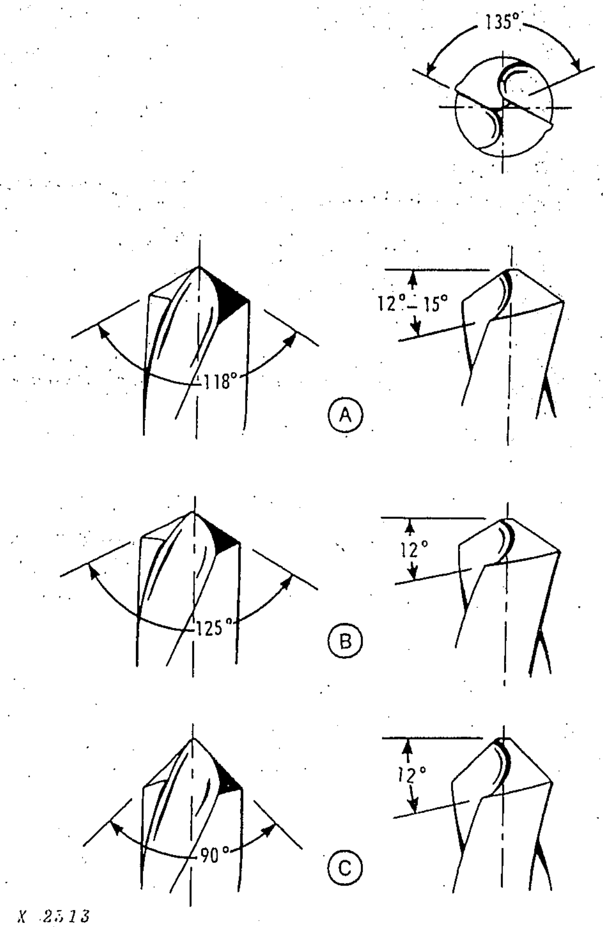

Fig. 60 — Common Shape Of Drills

Fig. 60 illustrates the most commonly used shapes. The *lips* do the cutting and therefore must be ground to a sharp edge. These lips or cutting edges must be of uniform length.

The portion behind lips is ground down on an angle to provide lip clearance (see Fig. 60, right column).

For steel and cast iron, these lips are ground on a 59° angle to the drill axis or 118° included angle as shown in Fig. 60. Note that lip clearance angle on "A" is 12° to 15°.

"B" illustrates a drill ground to drill heat-treated steels and drop forgings. Note that included angle is greater and lip clearance angle is 12°.

When drilling softer material such as wood, hard rubber, fiber, or soft cast iron, a much smaller included angle can be used as shown at "C".

When any unusual material such as spring steel must be drilled, consult a machinist's handbook to obtain the correct angles and shapes.

Several attachments for grinders are available for grinding drills accurately.

NOTE: Always be sure to keep drills cool while grinding by dipping occasionally in suitable coolant — water or oil.

TAPS AND DIES

Taps are used for cutting internal threads. There are many styles of taps, but for general shop use, a set of taper, plug, bottom and machine screw taps should be provided (Fig. 61).

Each type of tap will have to be provided in both National Fine (NF) and National Coarse (NC) threads, as well as in the various sizes, 1/4, 5/16, etc.

Metric taps are provided in various sizes with the dimension for pitch (distance between threads) also listed. The metric pitch is listed in place of NC or NF.

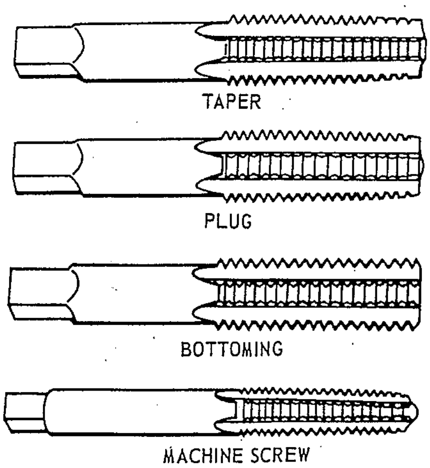

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Fig. 61 — Four Kinds Of Taps

The *taper tap* is used to tap completely through the hole. Notice that it has a long gradual taper that allows the tap to start easily.

The *plug tap* is used to tap threads partway through. The *bottoming tap* is used to cut threads all the way to the bottom of a blind hole. The plug tap should be used in the blind hole before the bottoming tap, as the bottoming tap will not start well.

The plug tap is the most widely used and, except when running threads completely to the bottom of a blind hole, will work satisfactorily.

The *machine screw tap* handles the small diameter, fine thread jobs.

TAP DRILL SIZES

Recommended for
AMERICAN NATIONAL SCREW THREAD PITCHES

COARSE STANDARD THREAD (N. C.)
Formerly U. S. Standard Thread

Sizes	Threads Per Inch	Outside Diameter at Screw	Tap Drill Sizes	Decimal Equivalent of Drill
1	64	.073	53	0.0595
2	56	.086	50	0.0700
3	48	.099	47	0.0785
4	40	.112	43	0.0890
5	40	.125	38	0.1015
6	32	.138	36	0.1065
8	32	.164	29	0.1360
10	24	.190	25	0.1495
12	24	.216	16	0.1770
1/4	20	.250	7	0.2010
5/16	18	.3125	F	0.2570
3/8	16	.375	5/16	0.3125
7/16	14	.4375	U	0.3680
1/2	13	.500	27/64	0.4219
9/16	12	.5625	31/64	0.4843
5/8	11	.625	17/32	0.5312
3/4	10	.750	21/32	0.6562
7/8	9	.875	49/64	0.7656
1	8	1.000	7/8	0.875
1 1/8	7	1.125	63/64	0.9843
1 1/4	7	1.250	1 7/64	1.1093

FINE STANDARD THREAD (N. F.)
Formerly S.A.E. Thread

Sizes	Threads Per Inch	Outside Diameter at Screw	Tap Drill Sizes	Decimal Equivalent of Drill
0	80	.060	3/64	0.0469
1	72	.073	53	0.0595
2	64	.086	50	0.0700
3	56	.099	45	0.0820
4	48	.112	42	0.0935
5	44	.125	37	0.1040
6	40	.138	33	0.1130
8	36	.164	29	0.1360
10	32	.190	21	0.1590
12	28	.216	14	0.1820
1/4	28	.250	3	0.2130
5/16	24	.3125	I	0.2720
3/8	24	.375	Q	0.3320
7/16	20	.4375	25/64	0.3906
1/2	20	.500	29/64	0.4531
9/16	18	.5625	0.5062	0.5062
5/8	18	.625	0.5687	0.5687
3/4	16	.750	11/16	0.6875
7/8	14	.875	0.8020	0.8020
1	14	1.000	0.9274	0.9274
1 1/8	12	1.125	1 3/64	1.0468
1 1/4	12	1.250	1 11/64	1.1718

SPECIAL THREAD (N. S.)

Sizes	Threads Per Inch	Outside Diameter at Screw	Tap Drill Sizes	Decimal Equivalent of Drill
1	56	.0730	54	0.0550
4	32	.1120	45	0.0820
4	36	.1120	44	0.0860
6	36	.1380	34	0.1110
8	40	.1640	28	0.1405
10	30	.1900	22	0.1570
12	32	.2160	13	0.1850
14	20	.2420	10	0.1935
14	24	.2420	7	0.2010
1/16	64	.0625	3/64	0.0469
3/32	48	.0938	49	0.0730
1/8	40	.1250	38	0.1015
5/32	32	.1563	1/8	0.1250
5/32	36	.1563	30	0.1285
3/16	24	.1875	26	0.1470
3/16	32	.1875	22	0.1570
7/32	24	.2188	16	0.1770
7/32	32	.2188	12	0.1890
1/4	24	.250	4	0.2090
1/4	27	.250	3	0.2130
1/4	32	.250	7/32	0.2187
5/16	20	.3125	17/64	0.2656
5/16	27	.3125	J	0.2770
5/16	32	.3125	9/32	0.2812
3/8	20	.375	21/64	0.3281
3/8	27	.375	R	0.3390
7/16	24	.4375	X	0.3970
7/16	27	.4375	Y	0.4040
1/2	12	.500	27/64	0.4219
1/2	24	.500	29/64	0.4531
1/2	27	.500	15/32	0.4687
9/16	27	.5625	17/32	0.5312
5/8	12	.625	35/64	0.5469
5/8	27	.625	19/32	0.5937
11/16	11	.6875	19/32	0.5937
11/16	16	.6875	5/8	0.6250
3/4	12	.750	43/64	0.6719
3/4	27	.750	23/32	0.7187
7/8	12	.875	51/64	0.7969
7/8	18	.875	53/64	0.8281
7/8	27	.875	27/32	0.8437
1	12	1.000	59/64	0.9219
1	27	1.000	31/32	0.9687

TAP DRILL SIZES (METRIC)

Bolt Diameter (In mm)	Distance Between Threads (In mm)	Diameter of Drill (In mm)	Bolt Diameter (In mm)	Distance Between Threads (In mm)	Diameter of Drill (In mm)
M 2	0.4	1.6	M 22	2.5	19.5
M 2.2	0.45	1.75	M 24	3	21
M 2.5	0.45	2.05	M 27	3	24
			M 30	3.5	26.5
M 3	0.5	2.5			
M 3.5	0.6	2.9	M 33	3.5	29.5
M 4	0.7	3.3	M 36	4	32
M 4.5	0.75	3.7	M 39	4	35
			M 42	4.5	37.5
M 5	0.8	4.2			
M 6	1	5	M 45	4.5	40.5
M 8	1.25	6.8	M 48	5	43
M 10	1.5	8.5	M 52	5	47
M 12	1.75	10.2	M 56	5.5	50.5
M 14	2	12	M 60	5.5	55
M 16	2	14	M 64	6	58
M 18	2.5	15.5	M 68	6	62
M 20	2.5	17.5			

Fig. 62 — Tap Drill Size Charts

USING THE TAP

After determining the diameter, and number of threads per inch (pitch for metric) of the screw or stud that will enter the tapped hole, use a tap drill size chart to find what size hole to drill. See Fig. 62 as a sample chart.

For example, suppose you find that you want a threaded hole for a 3/8 stud with coarse (National Coarse) threads. Referring to the top chart in Fig. 62, you will find the 3/8 N.C. will have 16 threads per inch. Looking directly across from the 3/8 size, you will find that the tap drill size is listed as 5/16. This means that for a 3/8 N.C. stud, you must first drill a hole 5/16 in diameter.

For an example of using a metric tap, suppose you want a threaded hole for an M 5 stud. Referring to the bottom chart in Fig. 62, you will find the M 5 size will have a pitch of 0.8 mm. Looking directly across from the M 5 size, you will find that the tap drill size is listed as 4.2. This means that for an M 5 stud with a pitch of 0.8 mm, you must first drill a hole 4.2 mm in diameter.

If the hole is to be tapped partway through, use the proper size plug tap. Place the tap in a tap handle, and carefully start the tap in the hole (Fig. 63). Place some tap lubricant on the tap. After threading the tap in one or two turns, back the tap up about a quarter to one-half turn to break the chip. Repeat this process as your tapping continues.

Be careful the hole does not clog with chips. It may be necessary to withdraw the tap and remove the chips. Taps are quite brittle. Use them with care, and make certain you use the proper size tap drill.

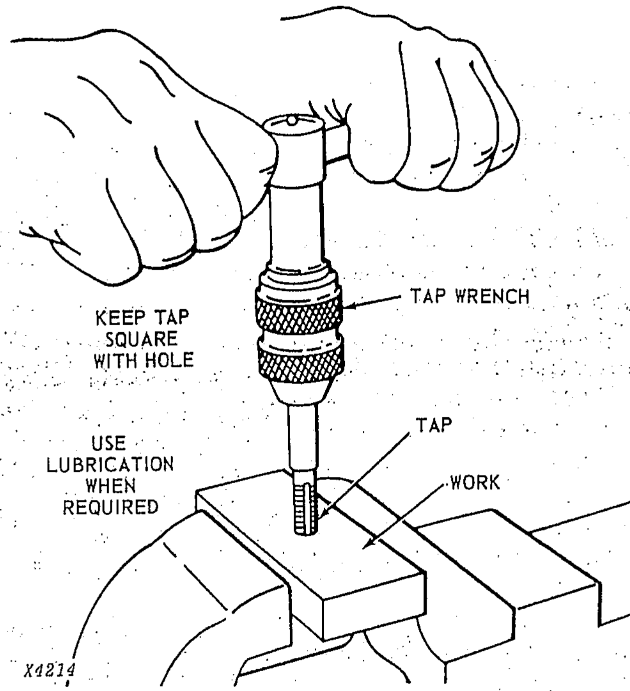


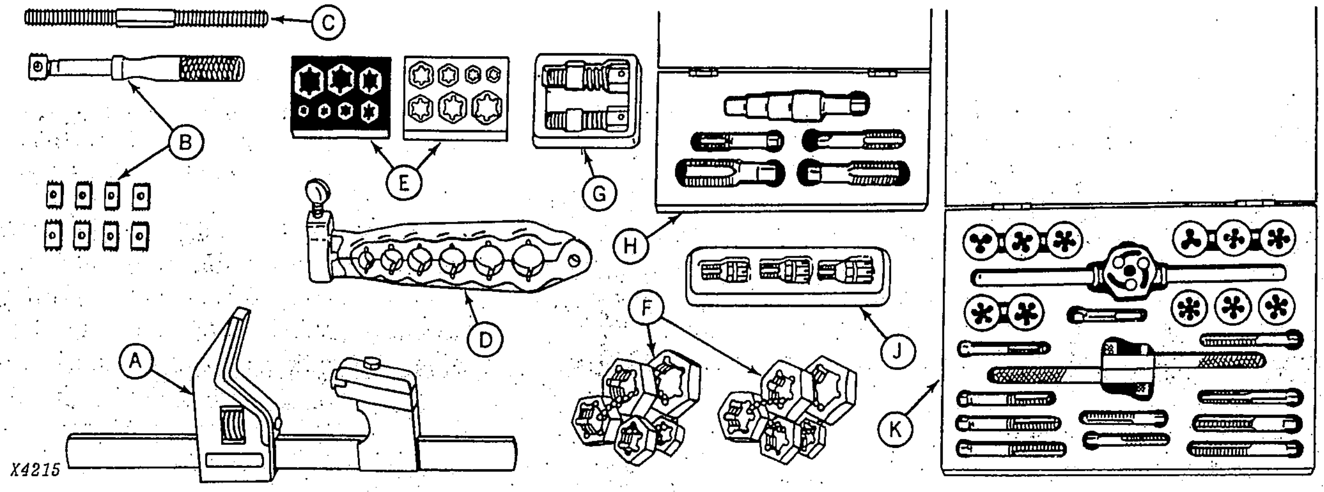
Fig. 63 — Using The Tap To Thread A Drilled Hole

DIES

Dies are used to cut external threads. A die of the correct size is placed in a diestock (handle) and it is turned. Use lubricant, back up every one or two turns, and keep free of chips.

Dies are often adjustable in size so you can enlarge or reduce (slightly) the outside diameter of a threaded area.

Both taps and dies should be cleaned, slightly oiled, and placed in a protective box for storage.



A — Rethreading Tool
B — Internal Thread Chaser
C — Thread Restorer
D — Axle Rethreader
E-F — Rethreading Dies
G-H — Spark Plug Hole Taps
J — Tap and Die Set for Tube Flare Fittings
K — Combination Tap and Die Set

Fig. 64 — Taps and Dies

SPECIAL TAPS AND DIES

The service technician will also find use for a few special taps and dies as illustrated in Fig. 64.

One form of rethreading tool is shown in "A". It is placed on the thread and turned.

"B" shows an internal thread chaser used to clean up dirty or damaged internal threads.

The thread restorer, "C", is handy for quickly reconditioning external threads.

The axle rethreader, "D", is placed around the good thread area, clamped shut, and is then turned back over the damaged area.

Nut or rethreading dies, "E" and "F", can be turned on a damaged thread. An ordinary box wrench can be used to turn them.

"G" and "H" show spark plug hole taps. These are very handy to clean up damaged or carboned plug hole threads.

A combination tap and die set for tube flare fittings is illustrated in "J".

A combination tap and die set is pictured in "K".

SCREW EXTRACTORS

To remove *broken* screws or studs, use a screw extractor (Fig. 65). It resembles a reverse-threaded drill bit or a punch with sharp flutes. The twist type are not tapered so they do not expand or distort sidewall of hole. Do not heat extractors, or they may lose their temper and ability to grab the sidewalls.

SCREW EXTRACTORS

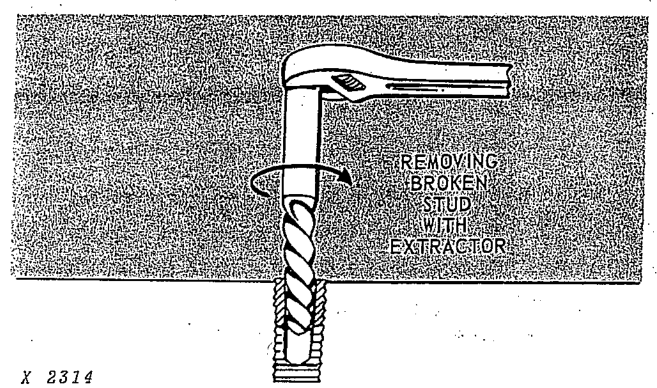


Fig. 65 — Removing Broken Stud With Screw Extractor

To use: Drill into the exact center of the broken stud. Be sure the hole is smaller than the inside of the stud threads to avoid damage to threads in the tapped hole. Drill a small pilot hole first for greater accuracy. Turn the extractor into the hole as shown and back out the stud carefully. Extractors are available for most screw sizes.

In an emergency, a diamond-point chisel can be used to remove a broken stud (Fig. 65). Simply drive the chisel into the stud after drilling a small hole into the center of the stud. Then turn the chisel carefully with a wrench.

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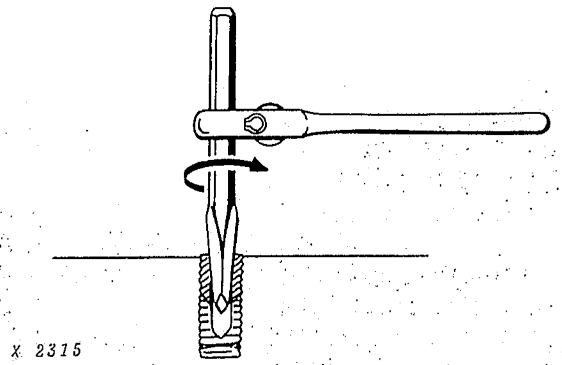

Fig. 66 — Using Chisel As Emergency Stud Remover

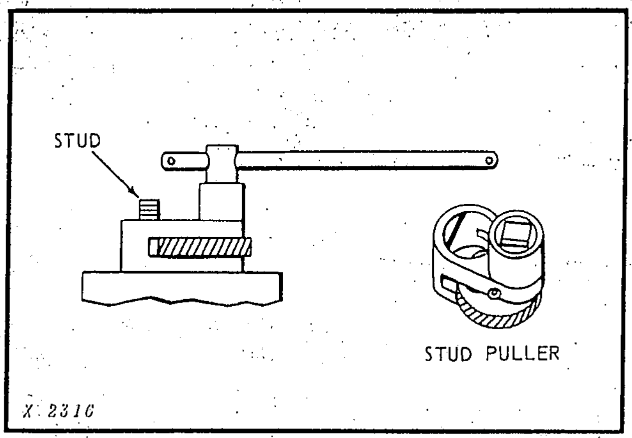

Fig. 67 — Stud Puller For Unbroken Studs

To remove *unbroken* studs, use a stud puller.

To use: Drop the stud puller over the stud to be removed (Fig. 67). Use a tee or flex handle to turn the stud out. The puller automatically grips the stud with a knurled eccentric as pressure is applied. One size fits almost all studs. In all stud removals, *use a generous amount of penetrating oil.*

PULLERS

Fitted parts can be damaged during removal and installation unless care is taken. Using hammers, pry bars, and chains may only cause more problems. However, special pullers which fit the parts and apply force evenly and smoothly are often the answer (Fig. 68).

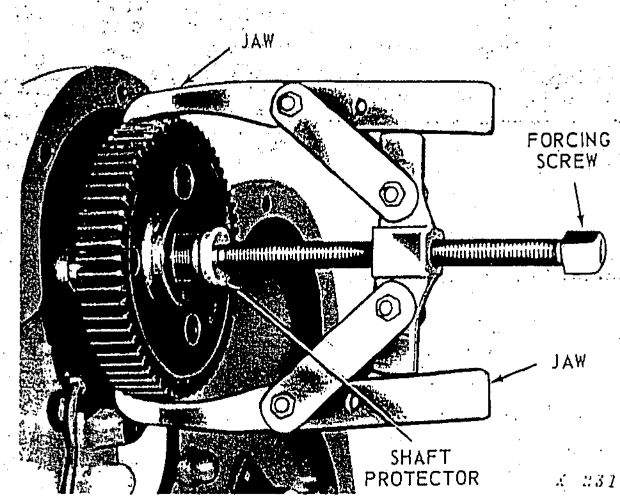

Fig. 68 — Gear Puller

There are three types of pullers (Fig. 69):

- **External puller**
- **Press-puller**
- **Internal puller**

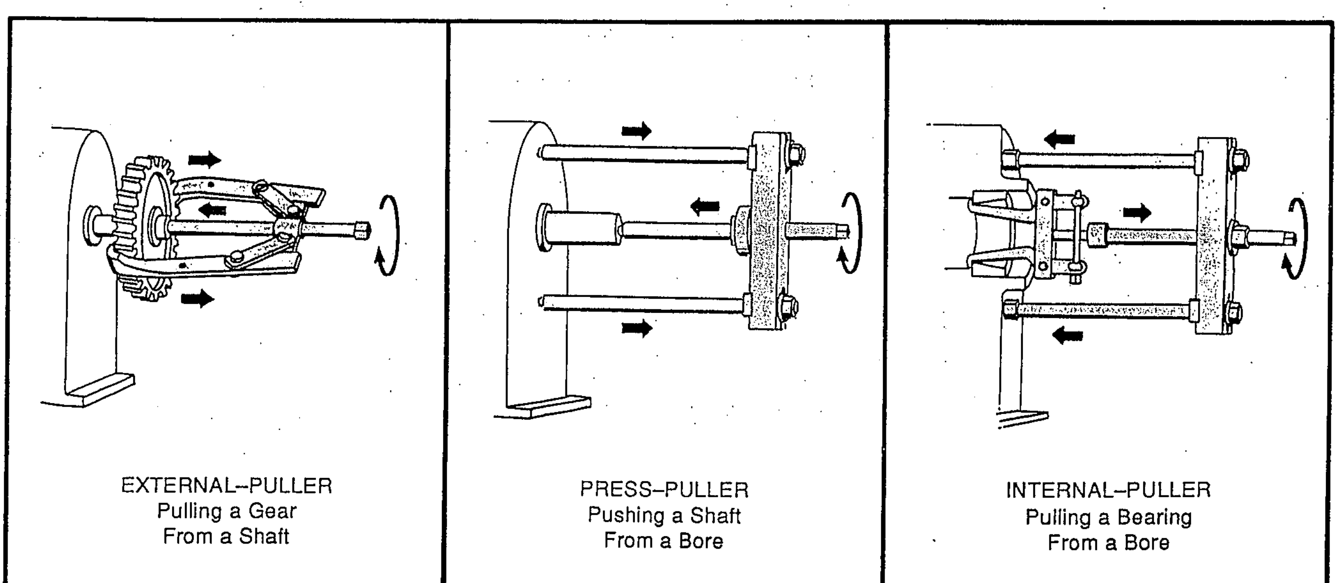

Fig. 69 — Pullers — Three Basic Types

EXTERNAL pullers grip the back of the object with their jaws as shown while the forcing screw pushes against the stationary part, such as a shaft. When the forcing screw is turned, the jaws pull the object.

PRESS-pullers have legs which mount on the stationary part while the object is pushed or pressed. As the forcing screw is turned into the object, the object is removed.

INTERNAL pullers also have legs which mount on the stationary part while the forcing screw pulls the object. However, the jaws go *inside* the object and reach *out* to grip it. This puller is commonly used to pull a bearing from a bearing bore as shown.

RULES FOR USE OF PULLERS.

1. Don't use a hammer — use a puller. Machined parts and precision bearings which are pressed on can be ruined by forcing them.

2. Don't use a pry bar — use a puller. A puller gives a smooth, even pull and prevents "cocking" the part you are pulling.

3. Choose the right type and size of puller for each job. The main questions are: Can you reach it? Can you grip it? Do you have enough power? This leads you automatically to the type of puller you should use.

4. For special pulling jobs, use a combination puller; for bigger jobs, use a hydraulic puller.

5. Don't overload a puller. A general rule is to use a puller with a forcing screw which is at least one-half the diameter of the shaft.

6. Place a shaft protector over the end of shafts before installing a puller against shaft (see Fig. 68).

7. When installing parts which must be forced into place, normally use a shop press rather than trying to use a puller.

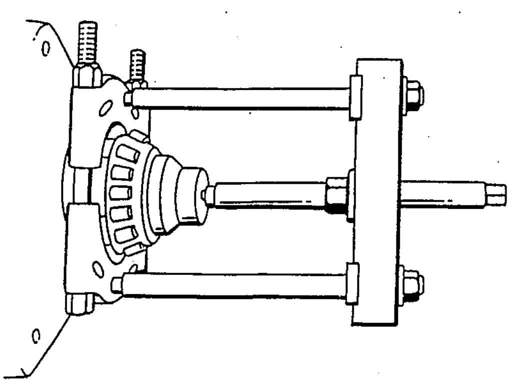

Fig. 70 — Using Knife-Edge Pulling Attachment

When a bearing must be pulled from a shaft, but the bearing is against a flat housing, use a **knife-edge pulling attachment** (Fig. 70). This prevents pulling only on the outer race of the bearing and ruining it.

PICK-UP TOOLS

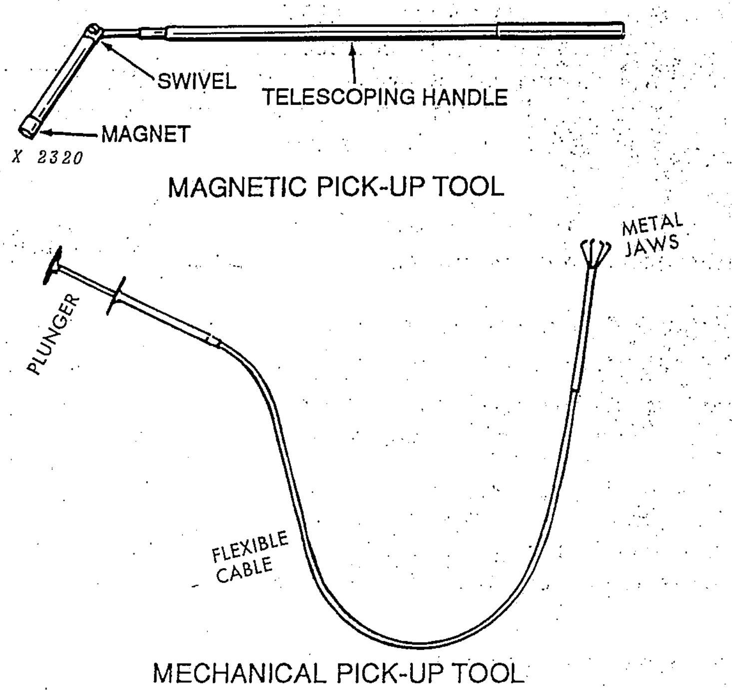

Fig. 71 — Pick-Up Tools

These tools (Fig. 71) have a small magnet on the tip or metal fingers. They are handy for retrieving small parts which have fallen into hard-to-reach places such as transmission cases. This may prevent having to disassemble a complete unit to recover "stray" parts.

INSPECTION MIRRORS

Inspection mirrors are handy for reaching in and viewing the "blind" side of components, as in closed gear cases. A pin flashlight or a "trouble light" is an extra aid in viewing with the mirror.

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TUBING CUTTERS

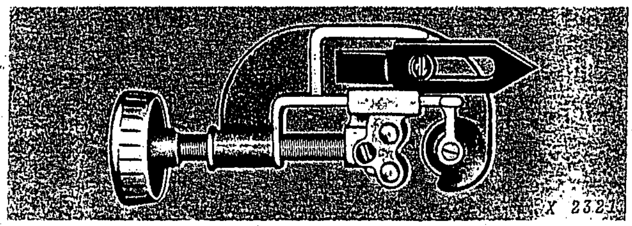

Fig. 72 — Tubing Cutter

These tools (Fig. 72) are used to cut tubing made of copper, aluminum, or steel. As the tool is turned, a sharp wheel cuts into the tubing. Pressure is slowly increased until the tube is cut off cleanly.

The tubing cutter is sometimes sold in a kit which includes a cutter, a tube flaring tool, and a tube bending tool.

SOLDERING EQUIPMENT

Soldering is the process of joining two pieces of metal by using a third metal as an adhesive. Unlike welding, soldering does not involve melting the two metals being joined, only the joining metal is melted. Standard solder melts at 800°F (426°C), far below the melting point of most metals.

NOTE: Welding is covered in a separate FOS manual, FOS-52B, on "Welding."

Most metals can be soldered. The only exceptions are chromium, beryllium, manganese-bronze, and titanium.

There are three methods of soldering:

1. **Soldering iron**
2. **Torch**
3. **Resistance**

In the SOLDERING IRON method, the iron is heated either electrically or in a flame periodically.

Soldering with a TORCH (Fig. 73) is faster because it produces more heat. Torches are used for soldering heavy sheet metal, pipes, and heavy tubing which require more heat than soldering irons can produce.

RESISTANCE soldering is similar to resistance (spot) welding except that the metals are not melted. Heat created by an electrical current is applied across the joint until the metals are hot enough to melt solder. The solder flows into the joints and the heat is then removed.

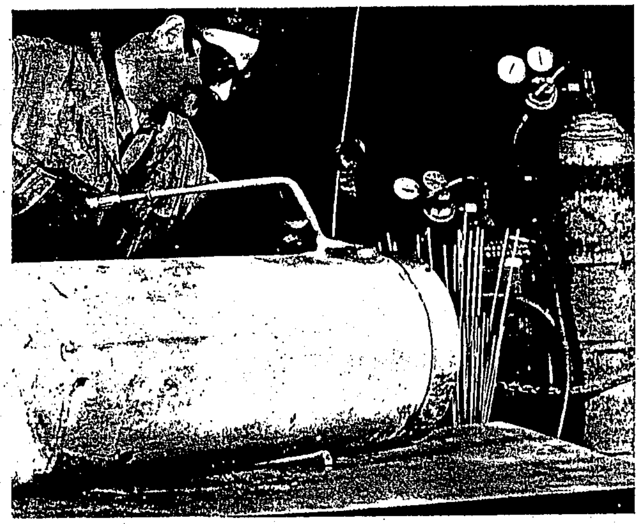

Fig. 73 — Soldering With A Torch

SOLDERING MATERIAL

Solder is a mixture of tin and lead — usually equal parts of each. "Hard solder" which melts at a higher temperature, may contain twice as much tin as lead.

Solder is available in stick and in wire rolls. Some types contain their own flux, while others must be dipped in flux or have flux applied to the joint areas. (Flux is a substance such as borax or rosin which helps to fuse the two metals together.)

HOW TO SOLDER

1. Clean the joint thoroughly.

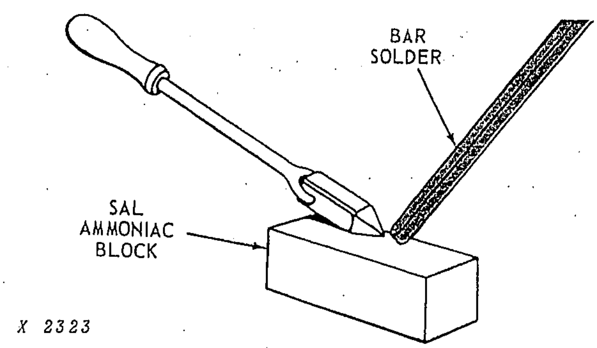

Fig. 74 — Tinning The Soldering Iron

2. Tin the soldering iron by rubbing it on a sal ammoniac block, then touching solder to it (Fig. 74). Or simply heat the soldering iron and touch the solder to it.

3. Heat both pieces to be soldered and apply flux (if flux is not included in the solder).

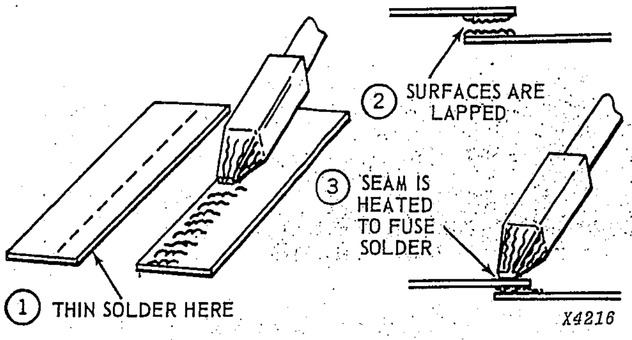

Fig. 75 — Soldering Copper Wires

4. Apply solder to the joints — not to the iron (1, Fig. 75).

5. Lap the two pieces (2) and hold the heated iron over the seam (3) to fuse the solder. Remove heat after the solder has thoroughly penetrated the joint.

6. Hold the two lapped pieces rigid until the solder cools and sets.

FEELER GAUGES

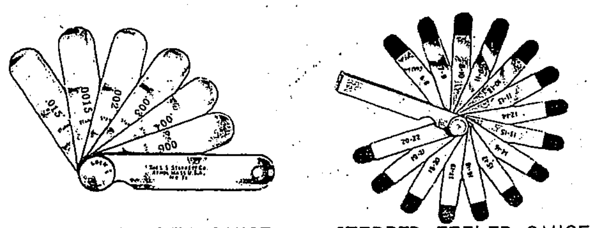

Fig. 76 — Feeler Gauge Sets

Feeler gauges (Fig. 76) are precision measuring tools for checking small clearances.

Standard feeler gauges have several blades arranged around a common pivot. Thickness of each blade is marked in thousandths of an inch or millimeters.

For example, an "0.006" indicates six-thousandths of an inch. A blade marked "6" indicates the same thing. On metric feeler gauges, an 0.15 indicates fifteen-hundredths of a millimeter.

Stepped feeler gauges have blades which have two thicknesses (Fig. 76). The tip of the blade is one thickness, while the rest of the blade is two-thousandths of an inch thicker. These feeler gauges are convenient for making quick, approximate measurements.

For thicknesses more than about 25 thousandths of an inch (1 mm), **wire** feeler gauges are often used. An example is a spark plug gap gauge.

USE OF FEELER GAUGES

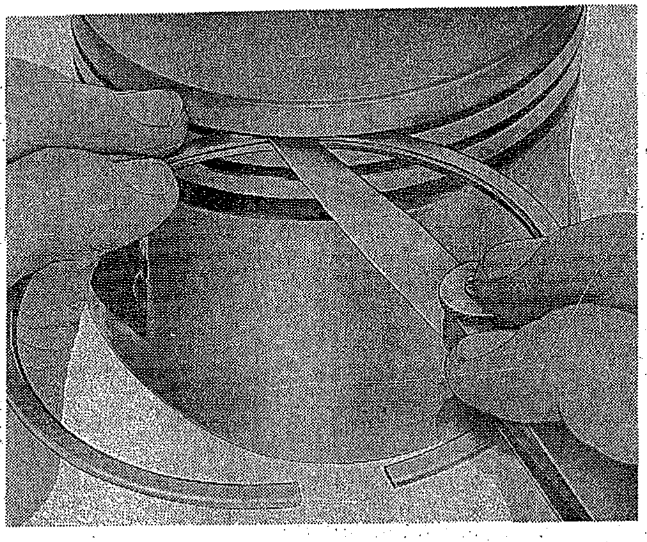

Fig. 77 — Use Of Feeler Gauge

Never get the blades of the gauge wedged in the clearance space. If the blade being tried cannot enter the space without forcing, use a thinner blade, or adjust clearance to conform.

Never bend or twist the blades. Always move the feeler gauge body in the same plane as the blade being used. Fig. 77 shows a feeler gauge being used correctly.

CARE OF FEELER GAUGES

When in doubt about the thickness of a blade, measure it with a micrometer.

Occasionally wipe the blades clean with an oily cloth to remove dirt and prevent rusting.

MICROMETERS

Micrometers or "mikes" are precision tools which measure in thousandths of an inch.

We will cover four types of micrometers:

- **Outside micrometers**
- **Inside micrometers**
- **Telescope gauges**
- **Depth micrometers**

Let's look at each one in detail.

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OUTSIDE MICROMETERS

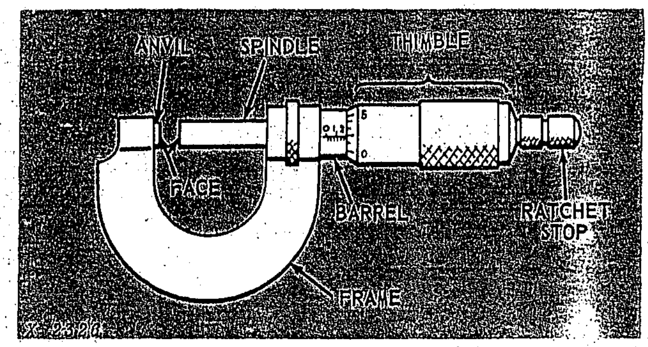

Fig. 78 — Outside Micrometer

An outside micrometer (Fig. 78) is used to measure the size of parts (diameter, thickness, etc.) accurately to within a very minute part of an inch.

How To Use: Before measuring a part, determine the size of micrometer needed. Micrometer sizes are determined by the distance between faces of anvil and spindle when the thimble is screwed to both zero extremes of barrel. An accurate 1- to 2-inch (25 to 50 mm) micrometer will always have a minimum of one inch (25 mm) between faces and a maximum of two inches (50 mm). It cannot be used for measuring a part less than one inch (25 mm) thick.

After selecting the correct micrometer, open it up to a distance a little *greater* than the thickness of the part to be measured. With the micrometer held in one hand, bring it over object to be measured.

NOTE: One or both hands can be used to operate the micrometer.

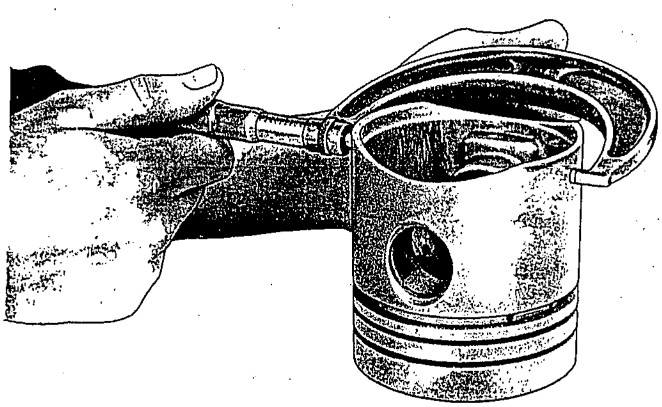

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Fig. 79 — Correct Use Of Outside Micrometer

Turn thimble lightly between the thumb and first finger until faces of anvil and spindle contact the work (Fig. 79). If the micrometer is equipped with a ratchet stop, turn it until at least two clicks can be heard.

Some micrometers do not have a ratchet stop; in this case a "feel" has to be developed to know when the correct contact pressure is being made by the spindle.

IMPORTANT: Never tighten spindle so tight that work cannot be drawn from between anvil and spindle.

Do not slide the micrometer back and forth excessively across the work because this will wear away the face of both the anvil and spindle.

If possible, take the reading before removing the micrometer from the work, to obtain a more accurate reading. If the reading cannot be taken before removing the micrometer, remove it very carefully to prevent disturbing the position of the spindle.

In hard-to-reach places, use outside calipers to take a more accurate measure; then transfer to an inside micrometer for the reading.

The graduations on a micrometer will be easier to understand when its construction is known. Micrometers use the principle of accurately cut screw-threads to determine measurement. Fig. 80 shows the barrel and thimble of a micrometer used to measure thousandths of an inch. This micrometer has 40 threads to an inch cut on the barrel and thimble. For construction and use of metric micrometers, see discussion beginning on next page.

Movement of the thimble on the barrel is limited to one inch. One complete revolution of the thimble is 1/40 part of an inch or 0.025 inch. The position of the thimble in relation to barrel is used to read measurements.

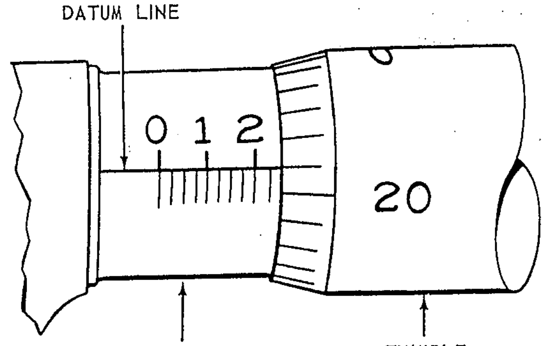

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Fig. 80 — Micrometer Graduations

The line marked lengthwise on the barrel is known as the revolution or datum line (Fig. 80).

Cross markings on this line show the distance the thimble travels in one revolution, or .025 inch between two lines. Every fourth line is numbered 1, 2, 3, etc., designating 0.100, 0.200, 0.300 etc. inch. The thimble is marked and divided into 25 equal parts. Each time the space between two lines on the thimble passes the datum line, the spindle moves 1 thousandth inch (0.001 inch). Every fifth line on the thimble is numbered 0, 5, 10, 15, and 20.

Following is an example of a reading taken from Fig. 80:

Highest figure whose reference line is visible on barrel — 2, this equals . . . . 0.200 inch

Number of lines visible on barrel beyond highest figure — 1. This equals . . . . 0.025 inch

Line on thimble aligning with revolution of datum line — 21, this equals . . . . 0.021 inch

Total . . . . 0.246 inch

If the line on the thimble does not align with the datum line, use the value which comes closest to it, or estimate the fraction of a thousandth over the line on the thimble below the datum line.

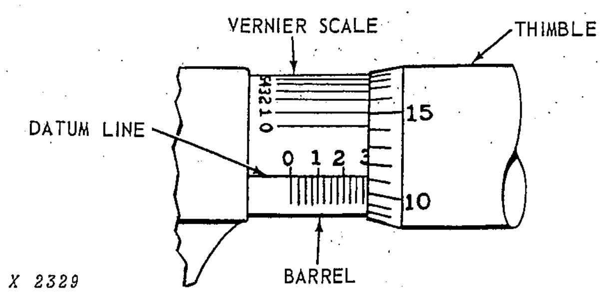

Fig. 81 — Micrometer With Vernier Scale

If more accurate readings are desired, use a **vernier** micrometer (Fig. 81). This micrometer has a vernier scale on the barrel which divides thousandths on the thimble into tenths making it possible to make a measurement to one *ten*-thousandth inch (0.0001 inch).

Take the value of the line on the thimble which falls below the datum line and add to this the value of the vernier scale reading. To determine the vernier scale reading, look along the edge of the thimble and find any vernier line and thimble line which coincide. For example, if the vernier line number 2 is found to coincide with a line on the thimble, then the vernier value is 0.0002 in.

Following is an example of a reading taken from Fig. 81:

Highest figure whose reference line is visible in the barrel — 2. This equals . . . . 0.200 inch

Number of lines visible beyond highest figure — 3. This equals . . . . 0.075 inch

Line on the thimble below the datum line — 11. This equals . . . . 0.011 inch

Vernier line coinciding with line on thimble — 2. This equals . . . . 0.0002 inch

Total . . . . 0.2862 inch

METRIC MICROMETERS

Fig. 82 shows the barrel and thimble of a metric micrometer used to measure hundredths of a millimeter. This micrometer contains threads every 0.5 mm.

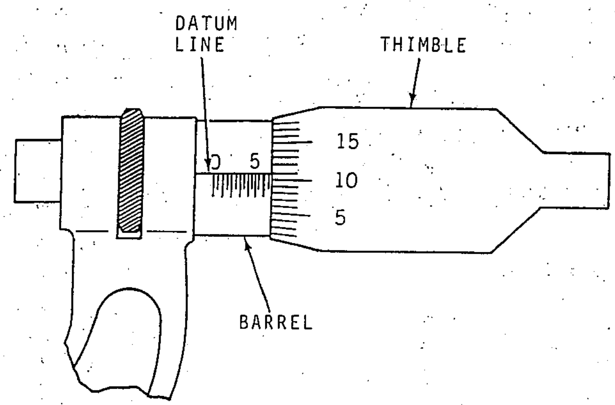

Fig. 82 — Barrel and Thimble of Metric Micrometer

Movement of the thimble on the barrel is limited to 25 mm. One complete revolution of the thimble is 0.5 mm. The position of the thimble in relation to barrel is used to read measurements.

Scales on metric micrometers are the same as on conventional micrometers except that measurements are in millimeters instead of inches.

Cross markings appear below the datum line in Fig. 82 and show the distance the thimble travels in one revolution, or 0.5 mm between lines. Every tenth line is numbered 5, 10, 15, etc. designating 5, 10, 15 mm, etc. The thimble is marked and divided into 50 equal parts. Each time the space betwen two lines on the thimble passes the datum line, the spindle moves one hundredth of a millimeter (0.01 mm). Every fifth line on the thimble is numbered 5, 10, 15, 20, etc.

Following is a reading taken from Fig. 82:.

Highest figure whose reference line is visible on barrel — 5. This equals .... *5.00 mm*

Number of lines visible on barrel beyond highest figure — 3. This equals .... *1.50 mm*

Line on thimble aligning with revolution of datum line — 11. This equals .... *0.11 mm*

Total .... *6.61 mm*

If the line on the thimble does not align with the datum line, use the value which comes closest to it, or estimate the fraction of a hundredth over the line on the thimble below the datum line.

If more accurate readings are desired, use a **vernier micrometer** (Fig. 83). The vernier scale divides hundredths on the thimble into tenths, making it possible to measure to one thousandth millimeter.

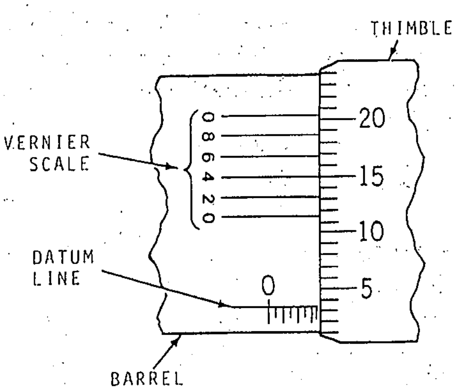

Fig. 83 — Vernier Micrometer

Take the value of the line on the thimble which falls below the datum line and add to this value of the vernier scale reading. To determine the vernier scale reading, look along the edge of the thimble and find any vernier line and thimble line which coincide. For example, if the vernier line number 2 is found to coincide with a line on the thimble, then the vernier value is 0.0002.

Following is an example of a reading taken from Fig. 78:

Highest figure whose reference line is visible in the barrel — 0. This equals .... *0 mm*

Number of lines visible beyond the highest figure — 7. This equals .... *3.5 mm*

Line on thimble below the datum line — 3. This equals .... *0.03 mm*

Vernier line coinciding with line on thimble — 4. This equals .... *0.004 mm*

Total .... *3.534 mm*

INSIDE MICROMETERS

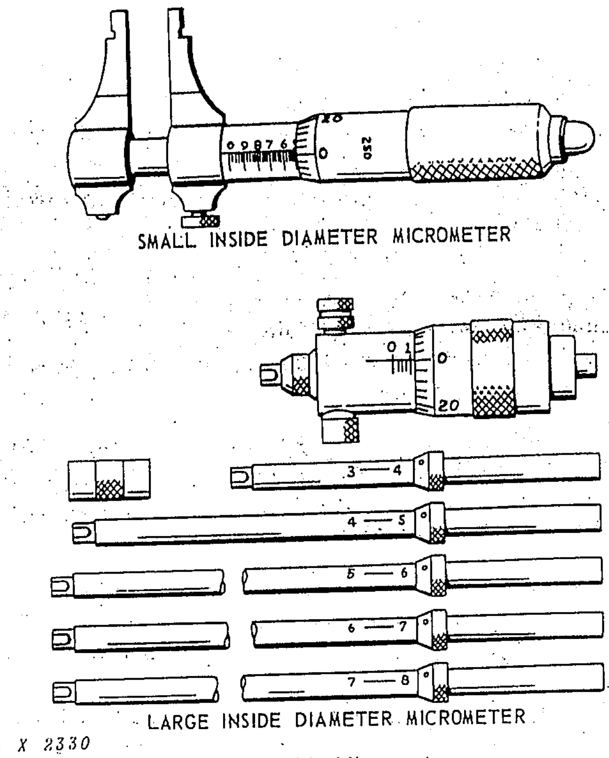

Fig. 84 — Inside Micrometers

There are two types of inside micrometers: One for measuring small diameters and one for large diameters (Fig. 84).

Each type is read exactly like the outside micrometer and must receive the same care.

IMPORTANT: Never adjust an inside micrometer so tight that it cannot be withdrawn from the work.

In hard-to-reach places, use an inside caliper to take the measure; then transfer to an outside micrometer for the reading.

TELESCOPE GAUGE

The telescope gauge (Fig. 85) is used to measure bores or openings. Place gauge in opening, expand to proper setting, lock by turning stem. This gauge has no scale markings. Measure the setting with an outside micrometer.

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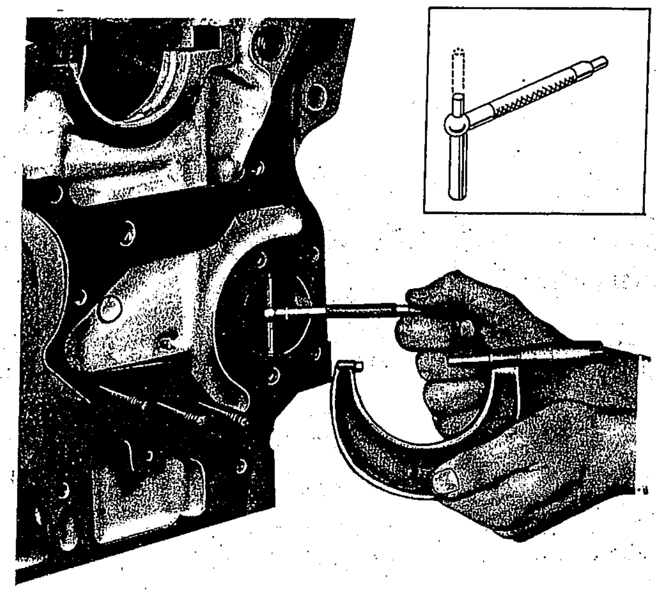

Fig. 85 — Telescope Gauge

DEPTH MICROMETER

Depth micrometers (Fig. 86) are used to measure the depth of openings.

Place the base of the micrometer firmly on the flat surface and turn down the thimble until the pin just touches the bottom of opening. Take the reading in the same way as with an outside micrometer.

When using micrometers, you must convert fractions to their decimal equivalents. (Refer to the decimal chart in weights and measures at the back of this book.

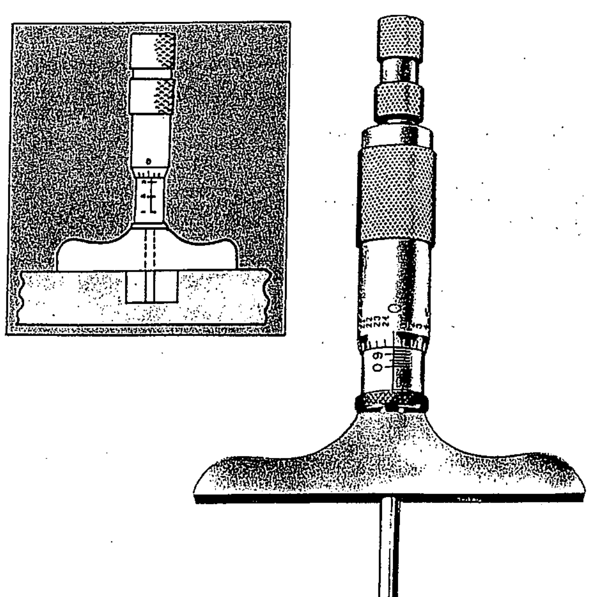

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Fig. 86 — Using Depth Micrometer

CARING FOR MICROMETERS

1. Avoid placing micrometers where they will become heated. This will affect their accuracy.

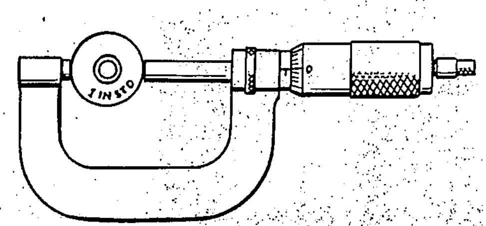

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Fig. 87 — Checking Micrometer With Standard

2. Check micrometers periodically with a master gauge or standard, to assure accuracy (Fig. 87).

3. Keep micrometers in a case or box when not in use. This will protect them from grit and dirt.

4. Never allow a micrometer to become rusty or dirty. Wipe with a clean cloth oiled with a few drops of fine machine oil.

5. Always be sure micrometer faces which contact the work are clean before measuring. Never use anything abrasive for wiping faces clean.

IMPORTANT: If a micrometer is accidently dropped, never use it again until it has been checked on a master gauge or standard.

DIAL INDICATORS

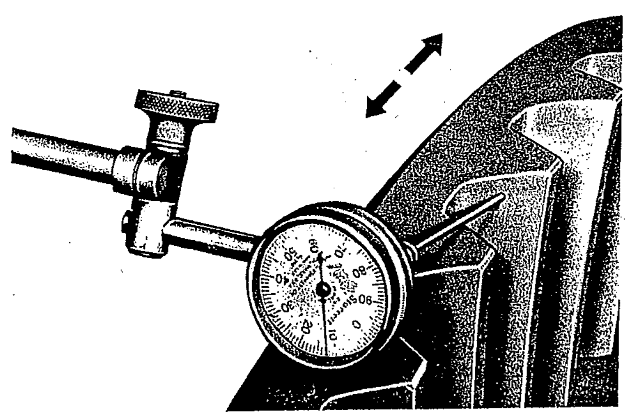

Fig. 88 — Dial Indicator Measuring Backlash On A Gear

Dial indicators measure the movement in shafts or gears which have adjustable endplay or backlash (Fig. 88).

Some indicators have C-clamps for mounting them, while other have a magnetic mount.

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Be sure to mount the indicator securely and at right angles to the moving part. This will assure that the full movement is registered on the dial.

To record the full movement also be sure to pry the parts in *both* directions, noting the full range of movement on the indicator dial.

SPRING TESTERS

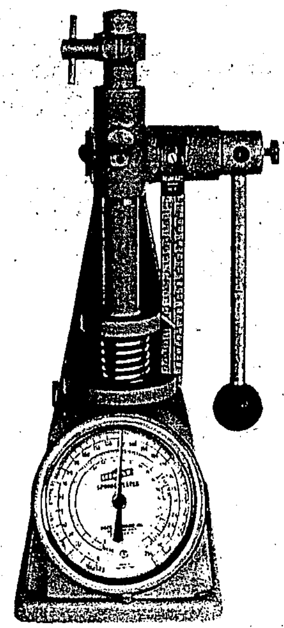

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Fig. 89 — Using A Spring Tester

Spring testers check springs for resiliency to see if they match the specifications. Engine valve springs, for example, should all be of uniform strength to allow the valves to work smoothly.

To use the tester (Fig. 89), insert the spring, pull on the lever to compress the spring to the specified compressed length, and read on the dial the pounds of pressure exerted.

Never use the stop on the tester to fix the length to which the spring is to be compressed. The stop should only be used when comparing one spring with another.

CARING FOR SPRING TESTERS

Zero is adjustable on most spring testers by moving a small lever or other device on the dial.

Normally, the pointer can also be tapped into position if it does not match the zero mark after the adjustment above.

Check the scale pointer occasionally to make sure it is correct.

PRESSURE GAUGES

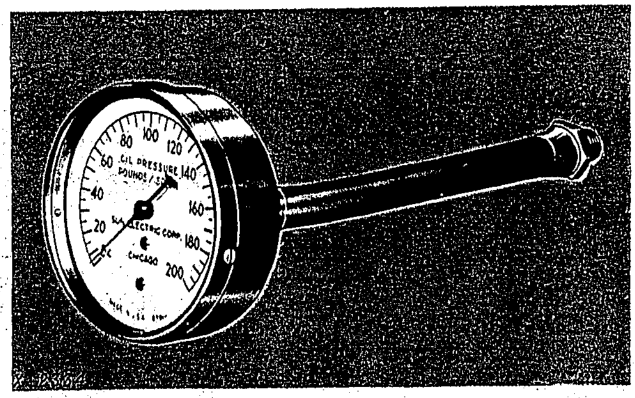

Fig. 90 — Pressure Gauge (Oil Pressure Type Shown)

Pressure gauges (Fig. 90) measure the force exerted on a container by the liquid or gas within it. This is usually called "pounds per square inch" or "psi" (kilopascal or kPa in metric).

Pressure gauges include those to check oil pressure (shown), tire air pressure, compression pressure, cooling system pressure, and fuel pressure.

Gauges may be permanent or hand-held (as shown). Some gauges show only immediate pressure, while others indicate the last-checked pressure until reset.

Pressure gauges should never be oiled. However, keep out all dirt and corrosion to assure an accurate reading.

SPEED-MEASURING TOOLS

Shop tools used for measuring speed are available in many shapes and forms. The following are discussed here:

- **Revolution Counters**
- **Tachometers**
- **Vibration Tachometers**
- **Stroboscopes (Timing Lights)**
- **Photo Tachometers**
- **Oscilloscopes**
- **Electronic Tachometers**

The simplest tool for measuring speeds is the **mechanical revolution counter** (Fig. 91). When taking a reading, the rubber-tipped shaft is pressed against the end of the revolving shaft for a set period of time. The number of revolutions is noted on the dial and figured as revolutions per minute (rpm).

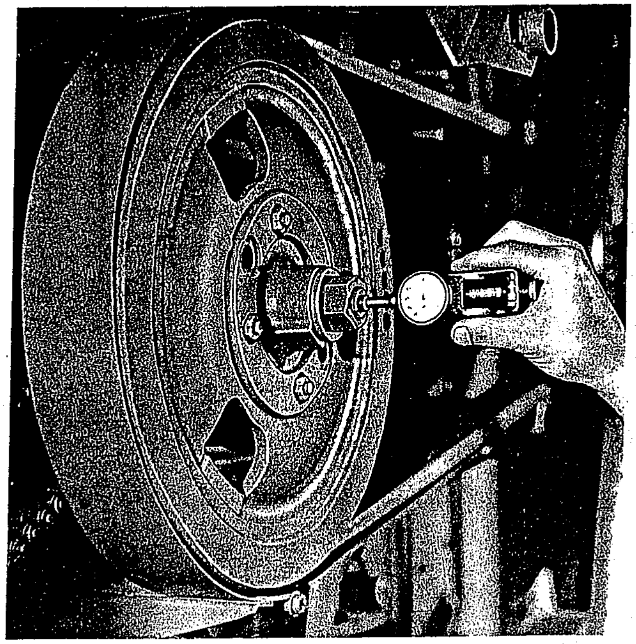

Fig. 91 — Mechanical Revolution Counter

Tachometers (Fig. 92) do the same job as counters; they show the revolutions compared to a time increment (as rpm). Another example of this is the common speedometer, which indicates wheel revolutions per hour, computed in miles per hour (mph). Tachometers on most machines, however, give engine speed in revolutions per minute (rpm).

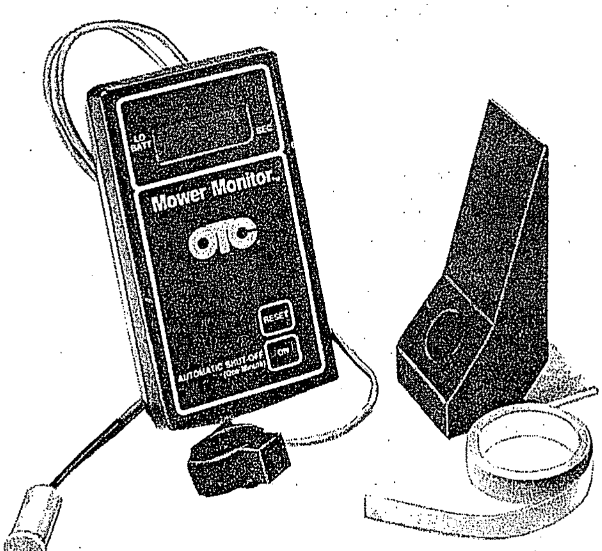

Fig. 92 — Electronic Photo Tachometer

The **vibration tachometer** (Fig. 93) (sirometer) will indicate the revolutions per minute (rpm) of revolving equipment by matching rpm to vibration frequency. Place the vibration tachometer on a level

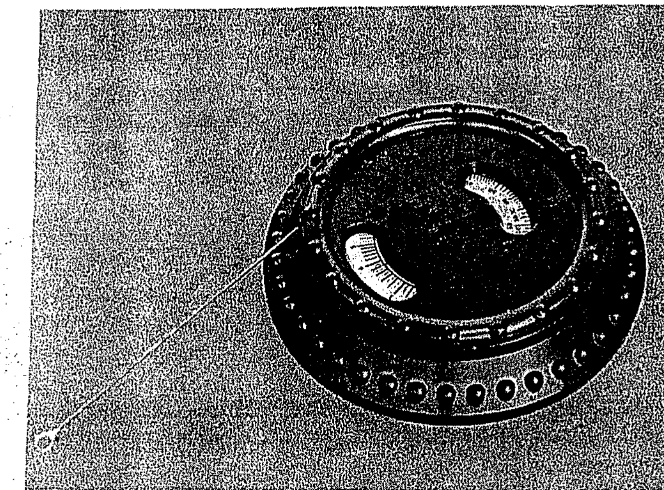

Fig. 93 — Vibration Tachometer

surface of the operating equipment. When the adjustable length of wire resonates consistently with the equipment, the rpm is read on the tachometer scale.

The **stroboscope** gives speed of rotation or vibration. It does not touch the device it is checking, but uses a rapidly flashing light. To determine the rotating speed of a shaft, for example, the speed of the flashing light is adjusted until the shaft appears to stand still. In other words, the speed of the shaft is synchronized to the flashing light. The speed of the shaft can then be read on the dial of the stroboscope.

A **timing light** operates the same as a stroboscope except that it receives its power and timing impulses from the machine being tested. Timing lights are commonly used to test and adjust the ignition timing of engines.

A **photo tachometer** (Fig. 92) is a highly accurate instrument used to check rpm and stopping time. The equipment uses a photo (light) probe and reflective tape. The meter measures the time between each pass of the tape.

An **oscilloscope** measures speeds from slow heart beats to high ratio frequencies. It is widely used in testing the vibrations in various parts of a test engine or other components. A common time signal (such as a 60-cycle current) is used for comparison against the unknown time cycle. This comparison is displayed on a cathode ray tube.

Electronic tachometers measure speed in a variety of ways. One type has an inductive pick-up sensor clamped to the fuel injection pump line. The sensor "reads" the fuel pulsation in the line and sends a signal to the digital meter. Another type requires no hook-up. A sensor is located in the meter. When the meter is held near the spark plug wire, the sensor picks up the electrical pulses in the wire. The meter times the pulses and then displays the rpm.

SPECIAL TOOLS

There is one category of shop tools that we have not covered — the **special tools** recommended for specific jobs in the shop. This includes both test equipment and specialized repair tools.

In this chapter we have covered only the *basic* shop tools which are widely used in the shop. For more complex tools, refer to the FOS manuals on such subjects as "Electrical Systems" and "Engines." And for special repair tools, refer to the machine technical manual to perform the job properly.

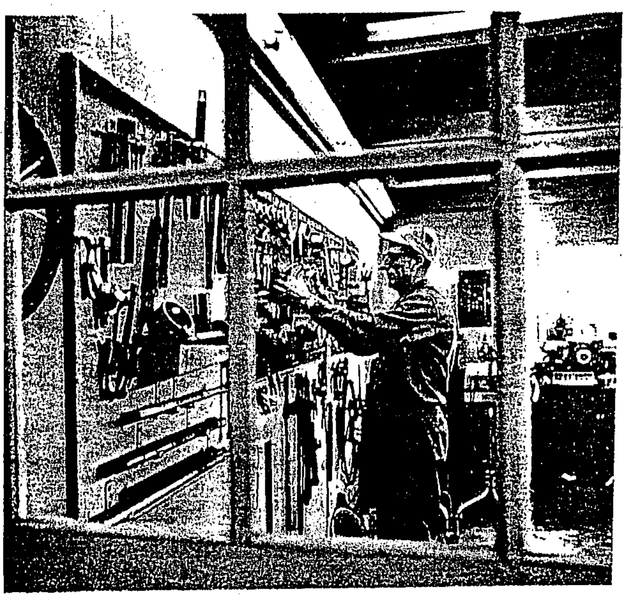

Fig. 94 — Special Tools Are Also Needed To Completely Equip The Shop

TOOL CARE

As stated in the beginning of this book, tools don't make the service technician but they help. Worn or damaged tools are of no help. In many cases they are a hinderance. Did you ever try to remove a nut with a cracked or rounded socket? The nut usually remains tight but the corners get rounded off. Now the problem is worse!

Proper care is an important part of every technician's career. Keep tools in usable, safe condition. In a shop environment, tools can be used by many other people. Keep the respect of fellow service people by using tools properly and return them in good condition to their respective shelf or area.

Let's quickly review proper use and care of shop tools:

SCREWDRIVERS

- Don't use screwdrivers for prying, punching, chiseling, scoring, or scraping.
- Use the correct tipped screwdriver for the fastener to be turned.
- Keep handles clean.
- Keep screwdrivers organized to find the proper screwdriver quickly.

HAMMERS

- Never strike a hammer on a hardened part or another hammer.
- Grasp handle near the end and strike object with full face of hammer.
- Discard hammer when face is chipped or mushroomed.

PLIERS

- Avoid using pliers on hardened surfaces, teeth become dull and lose gripping power.
- Keep clean and oil pivot pin occasionally.

WRENCHES

- Never use a "cheater bar" on a wrench handle.
- Never cock a wrench, be sure it is positioned squarely on fastener.
- Never hammer on a wrench, use a striking wrench.
- Install adjustable wrench so greater force is on the fixed jaw.
- Replace any spread, worn or damaged sockets and wrenches.
- Do not use hand (chrome) sockets on power or impact tools.
- Select proper wrench or socket for the fastener to be turned, especially for metric hardware.
- Keep wrenches, sockets, and ratchets clean and dry. Lubricate ratchets occasionally.
- Be sure ratcher pawl is engaged properly before appllying much force.
- Treat torque wrenches as a delicate measurement instrument.

Store click-type torque wrenches at the lowest setting.

PUNCHES AND CHISELS

- Never use a punch or chisel with a chipped or mushroomed end. Grind tool end down.
- Keep working end of punches and chisels ground to the proper angle or flat.
- Replace bent or broken punches.

FILES

- Never hammer on or pry with a file.
- Keep file teeth clean and handle tight.
- Keep files neatly stored, away from moisture and oil.

HACKSAWS

- Keep blade tightly stretched.
- Wipe blade with oily cloth to prevent rust.
- Store hacksaw carefully to prevent injury or damaged teeth.

VISES AND CLAMPS

- Do not hammer on handle to tighten or loosen.
- Use large enough vise or clamp for the particular job.
- Use wood or soft jaws if object to be held may be marred.

TWIST DRILLS

- Use proper feeding speed for the type of drill used.
- Use lubricant to cool drill when possible.
- Replace or sharpen damaged or dull drill bits.

TAPS AND DIES

- Use proper size tap drill.
- Lubricate tap and die during use.
- Use proper style tap for the job to be done.

SCREW EXTRATORS

- Drill proper size hole.
- Do not heat extractor.

PULLERS

- Choose right type and size of puller.
- Be sure puller is secure before applying force.
- Don't overload puller.

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PICK-UP TOOLS

- Keep stored in an accessible area and in clean condition.

MIRRORS

- Protect mirror from damage.

TUBING CUTTERS

- Use slow, even pressure to cut tubing.
- Replace cutter wheel when dull or damaged.

FEELER GAUGES

- Never bend or twist blades. Do not force a blade into an opening.
- Wipe blades occasionally to remove dirt and prevent rusting.

MICROMETERS AND DIAL INDICATORS

- Do not put micrometers and dial indicators where they will become heated.
- Never drop micrometer. Check a dropped micrometer before using it again.
- Wipe micormeter with clean cloth and light machine oil.
- Store precision measuring instruments in a case.

SPRING TESTER

- Treat as any other precision measurement instrument.
- Use stop only when making spring comparisons.

PRESSURE GAUGES

Store in protected case to prevent damage to gauge case and glass.

- Keep parts plugged to prevent contamination or damage.

SPEED-MEASURING TOOLS

- Store tools safely in cases.
- Protect from dirt, oil, or moisture.
- Turn electronic devices off to preserve battery life.

TOOL CABINETS AND STORAGE AREAS

- Keep tools in proper areas and in an organized manner.
- Keep floor clean and oil-free.
- Advise supervisor of any damaged or missing tools immediately.
- Request any additional tools necessary to complete a job as soon as possible.

SAFETY

Safety in the shop is a must! Safe practices and common sense must be exercised at all times.

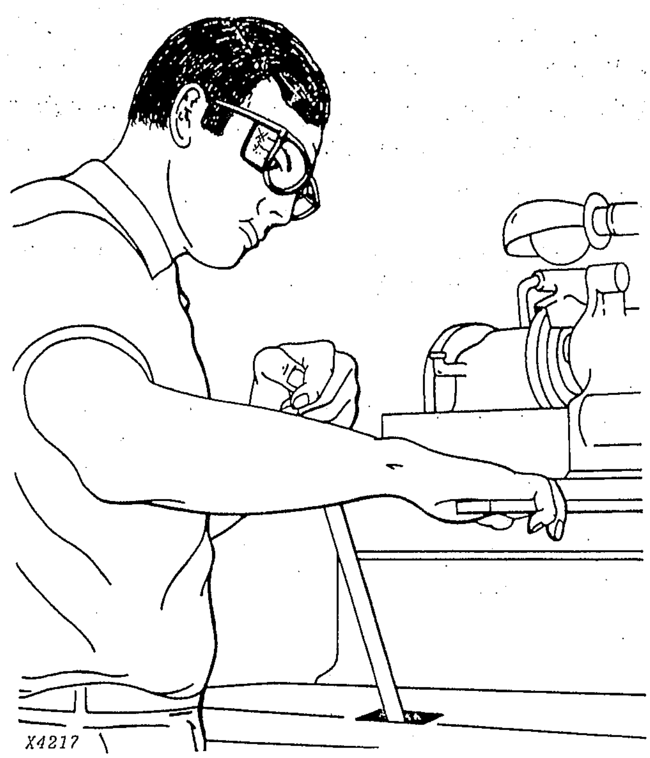

Fig. 95 — Use Safety Glasses and Shields When Grinding

WEIGHTS AND MEASURES

Here are most of the equivalent and conversion charts you will need in everyday shop work.

FRACTIONS, DECIMALS AND MILLIMETERS CHART

Inches		mm	Inches		mm
1/64	.016	0,40	33/64	.516	13,10
1/32	.031	0,79	17/32	.531	13,49
3/64	.047	1,19	35/64	.547	13,89
1/16	.062	1,59	9/16	.562	14,29
5/64	.078	1,98	37/64	.578	14,68
3/32	.094	2,38	19/32	.594	15,08
	.100	2,54		.600	15,24
7/64	.109	2,78	39/64	.609	15,48
1/8	.125	3,18	5/8	.625	15,88
9/64	.141	3,57	41/64	.641	16,27
5/32	.156	3,97	21/32	.656	16,67
11/64	.172	4,37	43/64	.672	17,07
3/16	.188	4,76	11/16	.688	17,46
13/64	.203	5,16	45/64	.703	17,86
7/32	.219	5,56	23/32	.719	18,26
15/64	.234	5,95	47/64	.734	18,65
1/4	.250	6,35	3/4	.750	19,05
17/64	.266	6,75	49/64	.766	19,45
9/32	.281	7,14	25/32	.781	19,84
19/64	.297	7,54	51/64	.797	20,24
5/16	.312	7,94	13/16	.812	20,64
21/64	.328	8,33	53/64	.828	21,03
11/32	.344	8,73	27/32	.844	21,43
23/64	.359	9,13	55/64	.859	21,83
3/8	.375	9,53	7/8	.875	22,23
25/64	.391	9,92	57/64	.891	22,62
	.400	10,16		.900	22,86
13/32	.406	10,32	29/32	.906	23,02
27/64	.422	10,72	59/64	.922	23,42
7/16	.438	11,11	15/16	.938	23,81
29/64	.453	11,51	61/64	.953	24,21
15/32	.469	11,91	31/32	.969	24,61
31/64	.484	12,30	63/64	.984	25,00
1/2	.500	12,70	1	1.000	25,40

WEIGHT MEASURE

1 Gross or Long Ton = 2,240 Lbs.
1 Net or Short Ton = 2,000 Lbs.
1 Cubic Foot of Water = 62.5 Lbs.
1 Gallon of Water = 8.33 Lbs.

SQUARE MEASURE

1 Township = 36 Square Miles
1 Square Mile = 640 Acres
1 Acre = 4,840 Square Yards
1 Acre = 43,560 Square Feet
1 Square Yard = 9 Square Feet
1 Square Foot = 144 Square Inches
1 Hectare = 2.471 Acres

SURVEYOR'S MEASURE

1 Link = 7.92 Inches
1 Rod = 25 Links
1 Chain = 4 Rods
1 Acre = 10 Square Chains
1 Acre = 160 Square Rods
1 Township = 36 Square Miles (6 Miles Square)

LENGTH MEASURE

1 Mile = 8 Furlongs
1 Mile = 80 Chains
1 Mile = 320 Rods
1 Mile = 1,760 Yards
1 Furlong = 10 Chains
1 Furlong = 220 Yards
1 Station = 6.06 Rods
1 Station = 33.3 Yards
1 Station = 100 Feet
1 Chain = 4 Rods
1 Chain = 22 Yards
1 Chain = 66 Feet
1 Chain = 100 Links
1 Rod = 5.5 Yards
1 Rod = 16.5 Feet
1 Yard = 3 Feet
1 Yard = 36 Inches
1 Foot = 12 Inches

CUBIC MEASURE

1 Cubic Foot = 1,728 Cubic Inches
1 Cubic Yard = 27 Cubic Feet

DRY MEASURE

2 Pints = 1 Quart
8 Quarts = 1 Peck
4 Pecks = 1 Bushel
1 Bushel = 2,150.42 Cubic Inches

FLUID MEASURE

1 Teaspoon = 1/3 Tablespoon
1 Tablespoon = 1/2 Ounce
2 Cups = 1 Pint
16 Ounces = 1 Pint
2 Pints = 1 Quart
4 Quarts = 1 Gallon
1 Gallon = 231 Cubic Inches
1 Gallon = .1337 Cubic Foot
1 Cubic Foot = 7.5 Gallons

METRIC WEIGHTS AND MEASURES

Weight Measure

10 milligrams.................................1 centigram (cg)

10 centigrams.................................1 decigram (dg) — 100 milligrams

10 decigrams..........1 gram (g) — 1000 milligrams

10 grams.....................................1 dekagram (dkg)

10 dekagrams......1 hectogram (hg) — 100 grams

10 hectograms.......1 kilogram (kg) — 1000 grams

1000 kilograms.................................1 metric ton (t)

Area Measure

100 square millimeters (mm^2)..................1 square centimeter (cm^2)

10 000 square centimeters.....1 square meter (m^2) — 1 000 000 square millimeters

100 square meters.....................................1 are (a)

100 ares.....hectare (ha) — 10 000 square meters

100 hectares....................1 square kilometer (km^2) — 1 000 000 square meters

Linear Measure

10 millimeters (mm)...................1 centimeter (cm)

10 centimeters.............................1 decimeter (dm) — 100 millimeters

10 decimeters......1 meter (m) — 1000 millimeters

10 meters...................................1 dekameter (dkm)

10 hectometers.............................1 kilometer (km) — 1000 meters

Cubic Measure

1000 cubic millimeters (mm^3).....cubic centimeter (cm^3)

1000 cubic centimeters...1 cubic decimeter (dm^3) — 1 000 000 cubic millimeters

1000 cubic decimeters.............1 cubic meter (m^3) 1 stere — 1 000 000 cubic centimeters — 1 000 000 000 cubic millimeters

Volume Measure

10 milliliters (ml).............................1 centiliter (cL)

10 centileters...................................1 deciliter (dL) — 100 milliliters

10 deciliters................1 liter (L) — 1000 milliliters

10 dekaliters............1 hectoliter (hL) — 100 liters

10 hectoliters............1 kiloliter (kL) — 1000 liters

METRIC/ENGLISH CONVERSION TABLES

1 meter = 39.37 inches
= 3.2808 feet
= 1.0936 yards

1 centimeter = 0.3937 inch

1 millimeter = 0.03937 inch

1 yard = 0.9144 meter

1 foot = 0.3048 meter

1 foot = 304.8 millimeters

1 inch = 2.54 centimeters

1 inch = 25.4 millimeters

1 pound = 0.4536 kilograms

1 pound (force) = 4.448 Newtons

1 cubic inch = 16.387 cubic centimeter

1 cubic inch = 0.163 870 liter

1 pound-inch = 0.113 Newton•meter

1 pound-foot = 1.356 Newton•meter

1 pound/square inch = 6.895 kilopascal

1 gallon/minute = 3.785 412 liter/minute

TEMPERATURE CONVERSION CHART

Temperatures are given in **Centigrade (C)** or **Fahrenheit (F).** Use the chart below for quickly converting from one to the other.

Degrees C.	Degrees F.
0	32
30	86
100	212

Temperature Conversion Formulas
To convert Centigrade to Fahrenheit, multiply by 9/5 and add 32.

To convert Fahrenheit to Centigrade, subtract 32 and multiply by 5/9.

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UTA

Bus Maintenance Tool List

Applies to: Central Business Unit, Meadowbrook Business Unit, Mt. Ogden Business Unit, Special Services Business Unit, Support Maintenance, Timpanogos Business Unit

The following tools are required for: Transit Vehicle Technicians, Mechanic Apprentices, Master Technicians, A-Level Mechanics, Journeyist Mechanics

1 each	Roll-Around Tool Box
1 set	Wrenches, Combination End, ¼″ to 1 ¼″ in 16th's″ 1 5/16″, 1 1/2″, 1 3/4″, 2
1 set	Wrenches, Combination End, 6 mm to 24 mm
1 set	Sockets, ¼″ Drive, Complete ¼″ to ½″
1 set	Sockets, ¼″ Drive, Complete 4 mm to 13 mm
1 set	Sockets, ⅜″ Drive, Complete ⅜″ to 1″
1 set	Sockets, ⅜″ Drive, Complete 6 mm to 19 mm
1 set	Sockets, ½″ Drive, Complete ½″ to 1 ½″
1 set	Sockets, ½″ Drive, Complete 12 mm to 26 mm
1 each	Drive, ¼″ Ratchet
1 each	Drive, ¼″ Nut Driver Handle
1 each	Drive, ⅜″ Ratchet
1 each	Drive, ½″ Ratchet
1 each	Drive, ½″ Breaker Bar
1 each	Extensions, ¼″ Drive, 3″, 6″
1 each	Extensions, ⅜″ Drive, 3″, 9″, 12″
1 each	Extensions, ½″ Drive, 3″, 9″, 12″
1 each	Plug Removers (Square) ¼″ – ⅜″ – ½″
1 set	Wrenches, Allen Standard
1 set	Wrenches, Allen Metric
1 each	Torque Wrench, ¼″ Drive, Inch Pound, 5 – 50 inch lb. (No Spring Bar Type) (Optional)
1 each	Torque Wrench, ⅜″ Inch Pound, 20 – 200 inch lb. (No Spring Bar Type)
1 each	Torque Wrench, ½″ Drive to 250 lb./ft. Max. (No Spring Bar Type)
1 each	Knife
1 each	Air Nozzle, OSHA Approved 30 lbs.
1 set	Extractors, ¼″ to ½″ (Easy Outs)
1 each	Gasket Scraper
1 each	Flashlight
1 each	Hacksaw, Adjustable 10″ to 12″
1 each	Tape Measure, 12′
1 each	Ladies Foot Type Pry Bar, 6″ to 12″, or Closest Size Available
1 set	Torx Driver and Bits T8-30, Security Type
1 set	Screw Drivers, Common, Numbers 1 – 4
1 set	Screw Drivers, Phillips, Numbers 1 – 4
1 each	Screw Drivers, Stubby, 1 Common – 1 Phillips
1 each	File, Flat 10″
1 each	File, Round (10″ Suggested)
1 each	File, Triangle Small (8″ Suggested)
1 each	File, Half Round (10″ Suggested)

Revised: 04-07-2010

1 each	Hammer, Ball Peen, 8 oz.	
1 each	Hammer, Ball Peen, 32 oz.	
1 each	Hammer, Compothane, (1 ½ lbs. Suggested)	
1 each	Pliers, Cutting, Diagonal	
1 each	Pliers, Water Pump, Channel Lock Medium Size (10" Suggested)	
1 each	Pliers, Vise Grip, 10"	
1 each	Pliers, Snap Ring Combination Internal and External	
1 each	Pliers, Needle Nose, (Medium 6" Suggested)	
1 each	Grip Pliers	
2 pair	Pliers, Hose Crimp	
1 each	Tin Snip Straight Cut	
1 each	Wire Strippers and Crimpers	
1 each	Wrench, 10" to 15" Adjustable (Only One Required)	
1 each	Pipe Wrench, 12" to 14" Adjustable	
1 set	Chisel Set, ¼" thru ¾"	
1 each	Punch, Drift 8"	
1 each	Punch, Center	
1 each	Punches, Straight and Tapered (Small, Medium, Large)	
1 each	Brass Drift ½"	
1 each	Volt Meter	
1 each	Vernier Caliper 5", – 16th's and 32nds	(Optional)
1 each	Air Ratchet	(Optional)
1 each	Wrench, Impact, ½"Drive	
1 set	Sockets, Impact, ½" Drive, ½" to 1 ¼"	

The following tools are required in addition to the above list for: Mechanic Apprentices, Master Technicians, A-Level Mechanics, Journeyist Mechanics

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1 each	Impact Gun, ⅜" Drive	
1 set	Sockets, ⅜" Drive, Impact, ⅜" to ¾"	
1 set	Sockets, ⅜" Drive, Deep, ⅜" to ¾"	
1 set	Sockets, ⅜" Drive, Weather Head Set	
1 set	Sockets, ½" Drive, Deep Impact, ½" to 1 ½"	
1 set	Sockets, Crows Foot, ⅜" to 1", 1 ½", 2"	(Optional)
1 set	Sockets, Crows Foot, 10 mm to 24 mm	(Optional)
1 each	Stud Installer/Remover	
1 set	Wrenches, Flare-Nut, 7/16" to ¾"	(Optional)
1 set	Wrenches, Flare-Nut, 10 mm to 17 mm	(Optional)
1 each	Slide Hammer, or Seal Remover	
1 each	Hand Impact Driver	
1 each	Extension or Flex Magnet	
1 each	Extension Mirror	
1 each	Pliers, Large Channel Lock	
1 each	Thread chasers, Standard, Fine, Metric	(Optional)
1 set	Cummins Tune-Up Tools	(Optional)
1 each	Air Hammer, Punch, and chisel Attachments	
1 each	Hand Pop Rivet Tool with Tips	(Optional)

FASTENERS

Learning objective: The student will have a basic understanding of fasteners and how they are identified and used.

Task: The student should be able to identify and explain the purpose of the following fasteners.

Standard: The student will complete a written examination in which he/she will attain a minimum score of 80% to pass the written test.

Fastener	Fastener
Cap screw	Hex head bolt
Cotter pin	Woodruff keys
Adhesives	Toothed lock washers
Keys	Set screw
Rivets	Lock washers
Tapping screws	Clevis pins
Machine screws	Studs
Castle nuts	Socket head screw
Washers	Locking nuts
Quick lock pins	Round head square neck bolts
Spring lock pins	

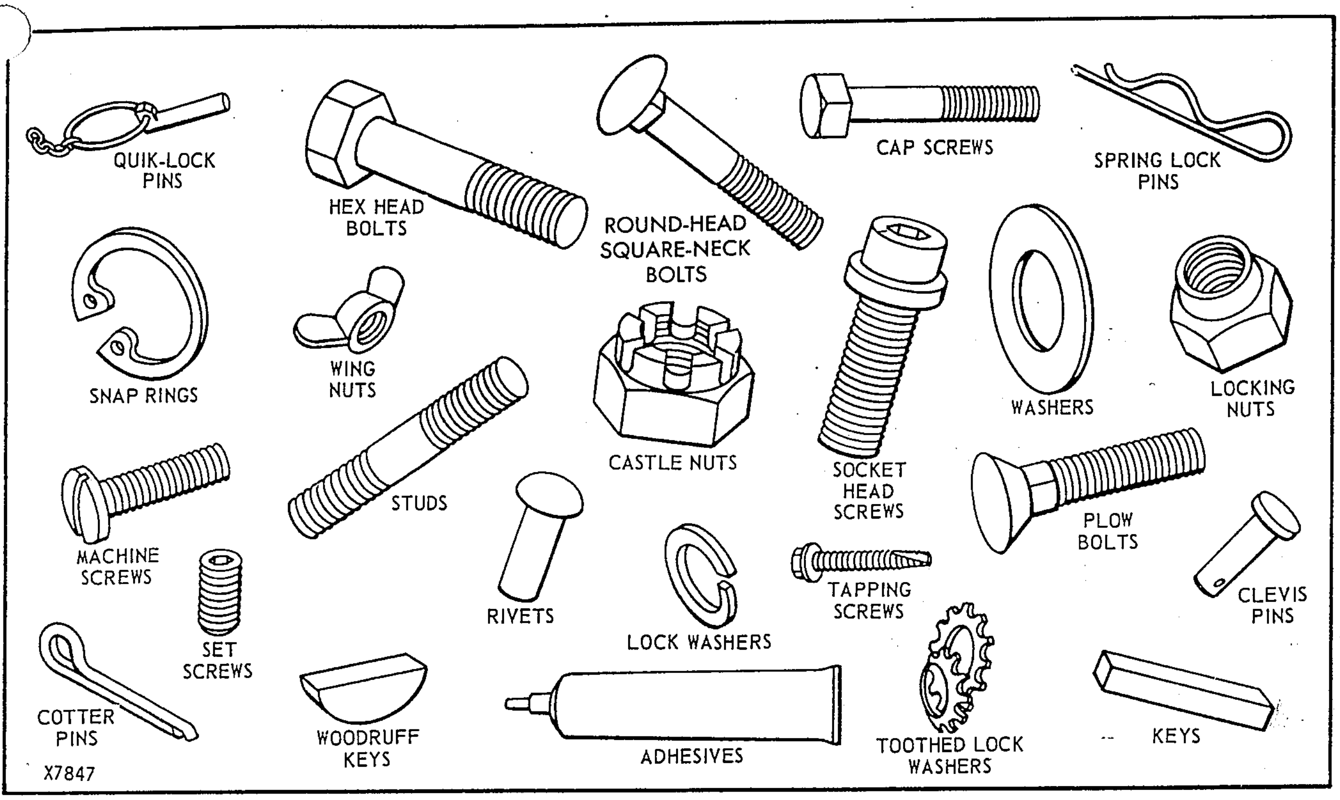

Fig. 1 — Typical Fasteners Discussed in This Manual

Almost since the dawn of civilization, man has used fasteners to hold together the things he makes. Probably first came rope-like vines or reeds, leather thongs (Fig. 2) and simple wooden pegs. Gradually, as the need arose, he developed other more sophisticated fasteners until now there is a host of them — some simple like buttons, safety pins, zippers, paper clips, nails (Fig. 3); others more complicated or developed for a special need such as high-strength bolts, lock nuts, keys. Industry has even found numerous applications for VELCRO® as a fastener.

Today few products could be made without fasteners. They are an important part of our everyday living and are encountered in almost everything we make or repair.

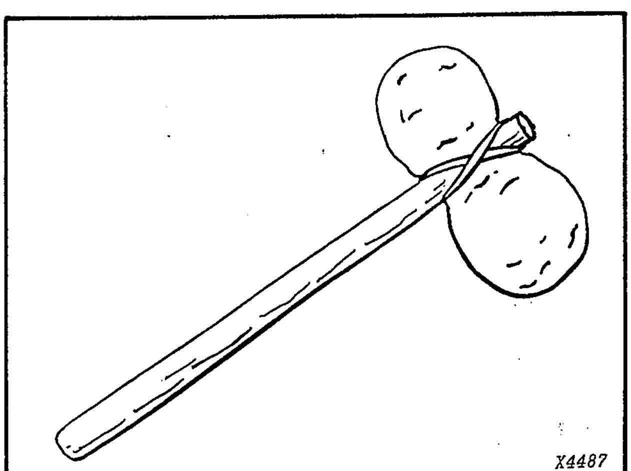

Fig. 2 — A Primitive Stone Ax. A Leather Thong Fastens the Head to the Handle.

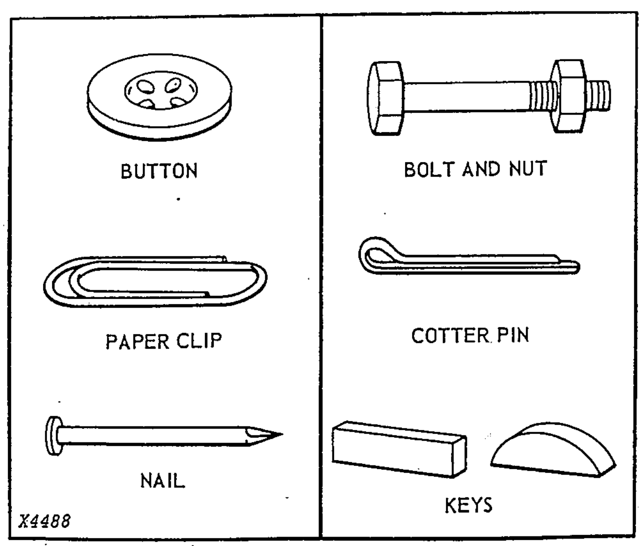

Fig. 3 — Common Modern Fasteners

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WHY FASTENERS?

Fasteners are used today in manufactured products for a number of very important reasons:

They simplify manufacture. Because of their complexity, many components and assemblies cannot be made in one piece; they must be made of two or more parts (Fig. 4), held together by fasteners. Thus fasteners greatly simplify manufacture.

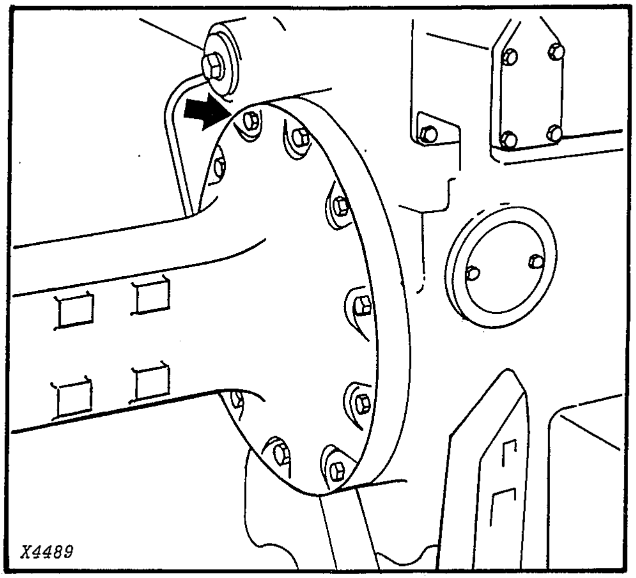

Fig. 4 — Tractor Rear Axle Housing Fastened to Differential Housing with Cap Screws

They simplify repairs. Fasteners also simplify the jobs of maintenance and repair; by removing the fasteners (Fig. 5), an assembly can be separated into the individual parts for inspection, repair or replacement.

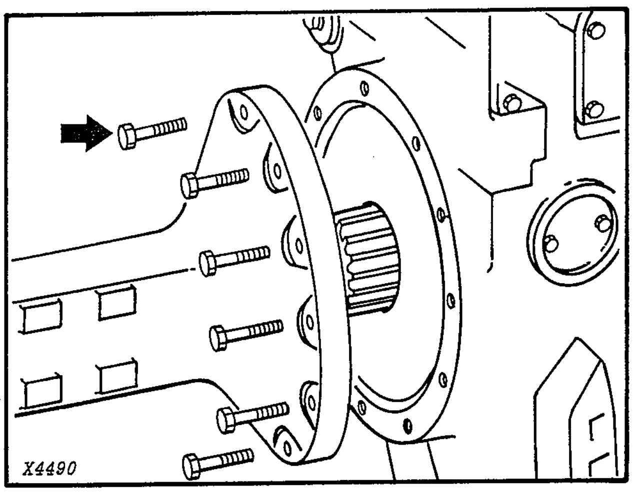

Fig. 5 — When Fasteners are Removed, the Assemblies Can Be Separated into Individual Components

They provide safety. Many fasteners also serve as safety devices. Such items as lock washers, cotter pins, lock wire, jam nuts assure that an assembly, once put together, will stay that way with little possibility of its coming apart.

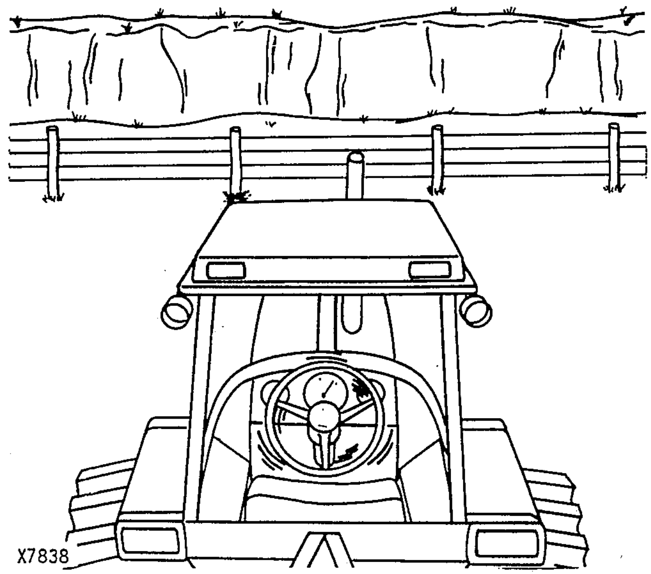

Fig. 6 — Fasteners Are Safety Devices

Think what would happen if someone forgot to install a small, cheap cotter pin in the steering mechanism of your car or tractor, permitting a nut to come loose and fall off! Certainly your safety would be in extreme jeopardy (Fig. 6).

FASTENERS MUST HAVE MANY QUALITIES

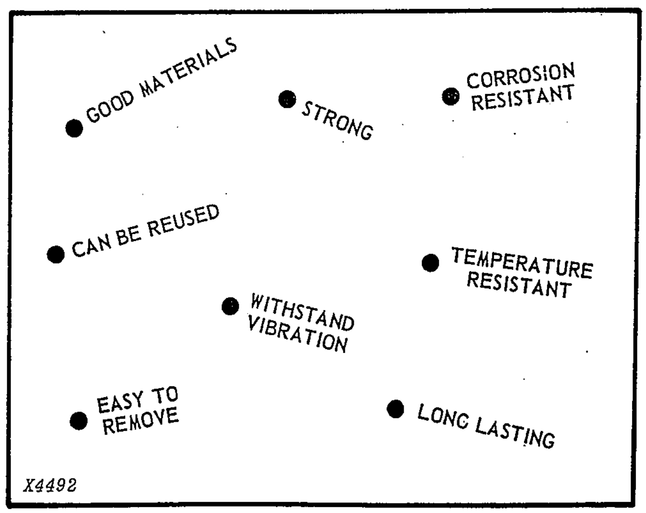

Fig. 7 — Some Requirements for Satisfactory Fasteners

To do their job in modern products, fasteners must be carefully made out of high-quality materials. They must be strong enough to hold the components together, yet quick and easy to remove or install, and capable of being used over and over (Fig. 7).

Many fasteners must stand vibration without loosening, must be unaffected by extremes in temperature, must be corrosion resistant, and must last as long as the parts they join.

Because the right fastener is so important, a good mechanic will make sure that the ones he uses are of the right type, size and quality — and he will remove and install them in the correct manner, using proper tools. He'll read and follow all available service information, such as may be provided by the manufacturer in shop and technical manuals (Fig. 8).

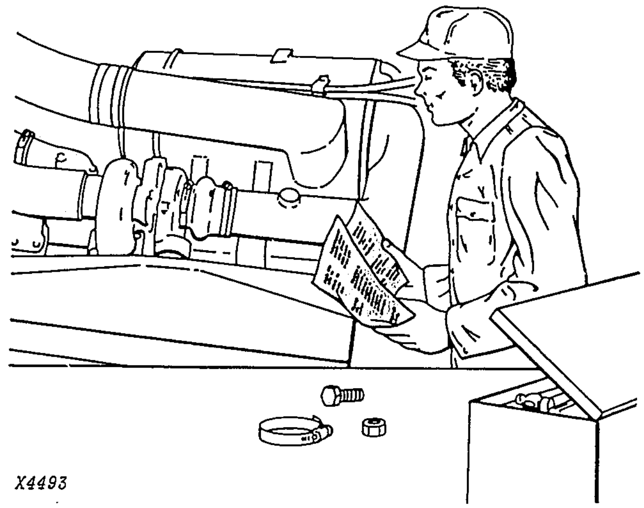

Fig. 8 — Read and Follow Instructions

BOLTS, CAP SCREWS, NUTS, WASHERS, AND LOCKING DEVICES/PART 2

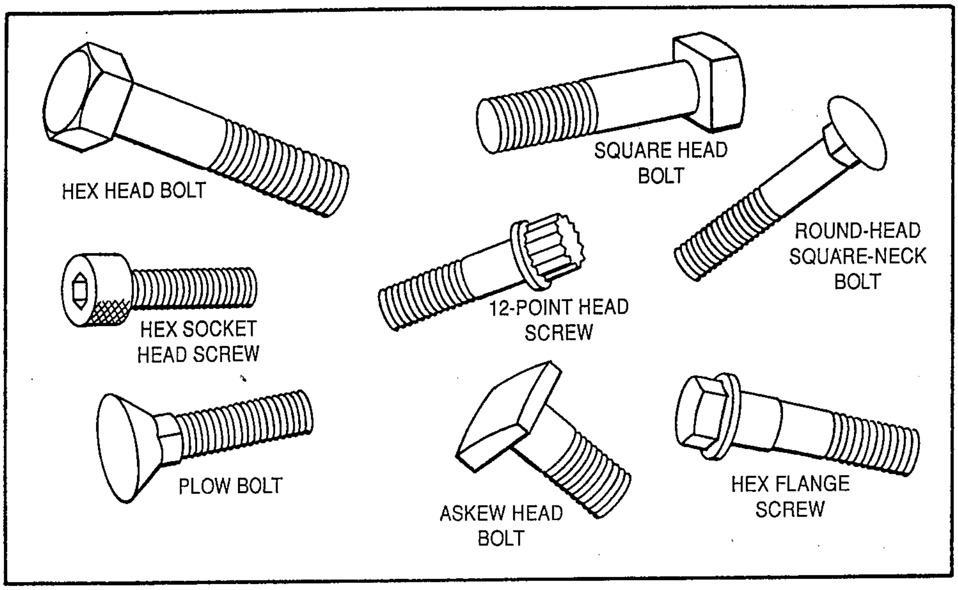

Fig. 9 — Typical Bolts and Cap Screws

Bolts, cap screws, and nuts are used as fasteners for a great number of mechanical devices. There follows a rather complete description of these versatile fasteners. Some of this information may seem rather rudimentary to you. But since this is a manual of "Fundamentals," such information must be included for those who may not be as familiar with fasteners as you are. It is hoped that what follows will be interesting and, perhaps, increase your fund of general knowledge. Also, many of the terms introduced apply equally to other types of fasteners and will not be repeated.

COMMON BOLTS AND CAP SCREWS

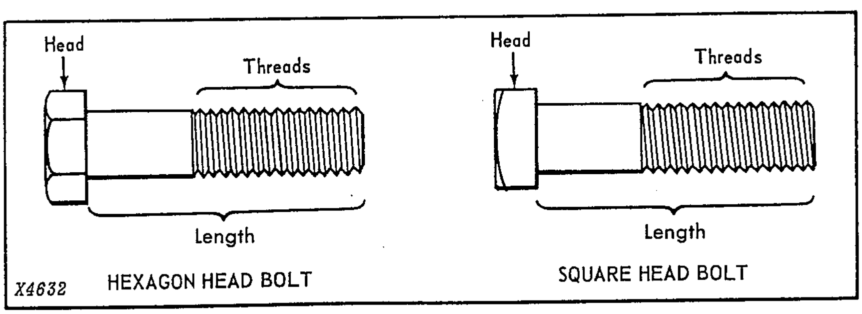

Fig. 10 — Bolt Parts

Bolts are usually used in plain holes drilled through the parts being fastened. The bolt is held in place with a mating nut. In contrast, cap screws are normally used in threaded holes, without a nut.

A **bolt** (or cap screw) is a length of metal rod with a head and a body (Fig. 10). The head is usually square or hexagonal (six-sided). In modern use most bolts have hex heads. The shank of a bolt has external

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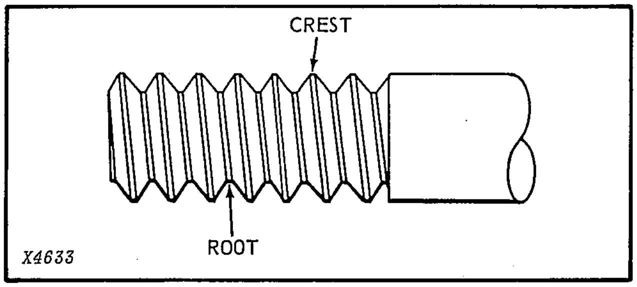

Fig. 11 — Names of Thread Parts

helical ribs, called *threads*, at the end opposite the head. The top of the rib is called the *crest,* or thread tip (Fig. 11). The bottom of the groove is called the thread *root*. Threads are made by cutting or by forming with a die (Fig. 12). Die-formed (or "rolled") threads are stronger than cut threads.

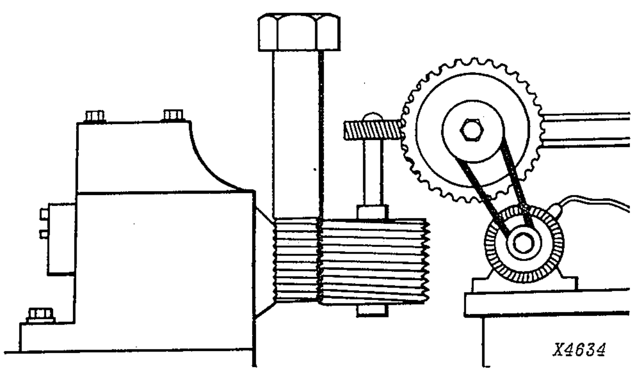

Fig. 12 — Die-Formed (Rolled) Threads are Best

Usually a bolt "mates" with internal threads of a *nut* (Fig. 13) which screws onto the threads of the bolt.

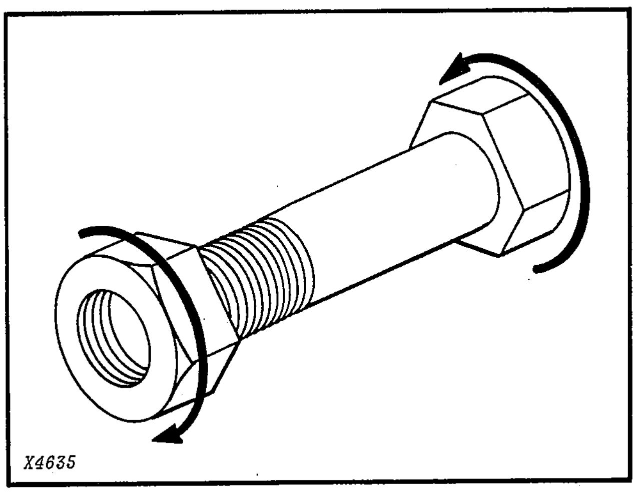

Fig. 13 — Bolt and Nut Combination

HOW TO MEASURE BOLTS

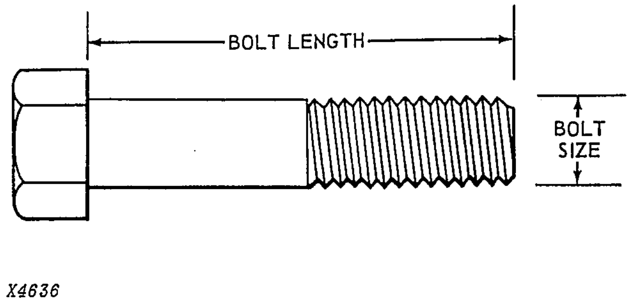

Fig. 14 — Where Bolts are Measured

The **size** of a bolt is determined by the diameter of the crest of the threads (Fig. 14).
The **length** of a common bolt is determined by measuring from the bottom of the head to the end of the threads.

NOTE: Some bolts (like flat countersunk head bolts, for instance) are measured slightly differently.

The unthreaded part of the bolt is called the *body.*

The flattened point end of a bolt is normally pointed by rolling the first threads undersize at an approximate 45-degree angle.

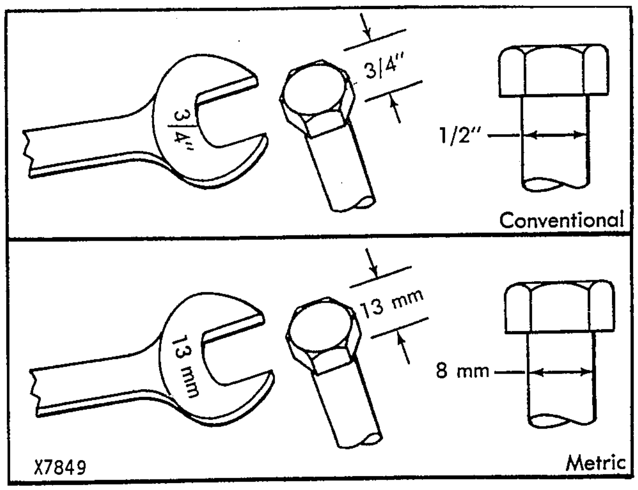

Fig. 15 — Selecting the Proper Wrench

A bolt head is measured across **flats.** Head size determines what size wrench or socket must be used to turn or hold the bolt. For example, a ¾-inch wrench (Fig. 15) is needed to turn a ½-inch bolt (a 13-mm wrench is needed to turn an 8-mm hex bolt or nut).

THREADS

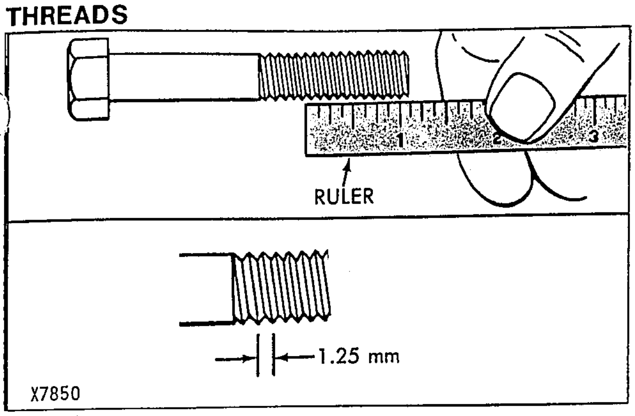

Fig. 16 — Measuring Threads Per Inch (Top) and Pitch (Bottom)

Threads are measured by counting the number per inch (Fig. 16). Threads on metric threaded fasteners are measured by the distance between threads (pitch) in millimeters (Fig. 16). Also, screw gauges are available that match the bolt threads against those on the gauge (Fig. 17); there is a separate gauge for each thread size.

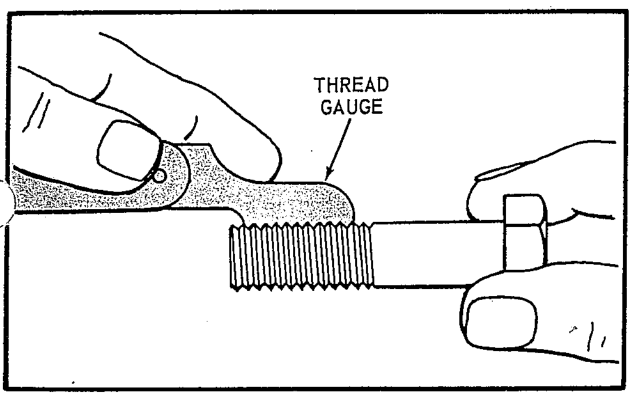

Fig. 17 — Using a Thread Gauge to Determine Threads Per Inch or Pitch

Some threads are coarse (Fig. 18) with deep grooves and are used for most applications. Other threads are finer, with shallower grooves. Bolts with fine threads are used only under special conditions where coarse-threaded bolts are not suitable. For example, when the parts being fastened have thin walls.

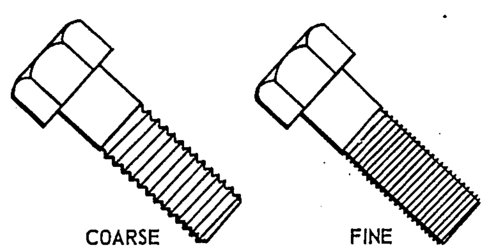

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Fig. 18 — Examples of Coarse and Fine Threads

There are carefully controlled standards for threading bolts and nuts. These are approved by the American National Standards Institute (ANSI). They establish such things as the pitch (angle) of threads, the depth of the root, and manufacturing tolerances, or fit, designated by a thread class symbol, such as 1A and 2A. The ANSI specifications are referred to as "Unified Screw Thread Standards." See Metric Thread Description below.

Have you ever seen a bolt or screw described like this?

½ — 13 UNC — 2A x 3

Perhaps you have wondered what the figures and letters mean. The simple chart below (Fig. 19) will help you understand them.

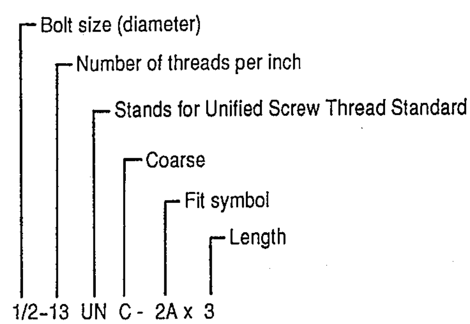

Fig. 19 — What Bolt Descriptive Symbols Stand For

In the above chart, if the bolt has *fine* threads, "UNC" would be replaced by "UNF."
In older publications you might find the phrase "½ — 13 NC (or NF) —" instead of UNC (or UNF). The NC and NF in these phrases stand for "American National Coarse" or "American National Fine" which was an earlier way of designating threads. However, since its adoption in 1948, the ANSI designation has replaced the earlier American National designation. Another earlier designation of coarse threads was U.S. Standard; fine threads were designated as S.A.E. Threads.

METRIC THREAD DESCRIPTION

The following chart shows how to describe metric threaded fasteners and what each letter and number represents.

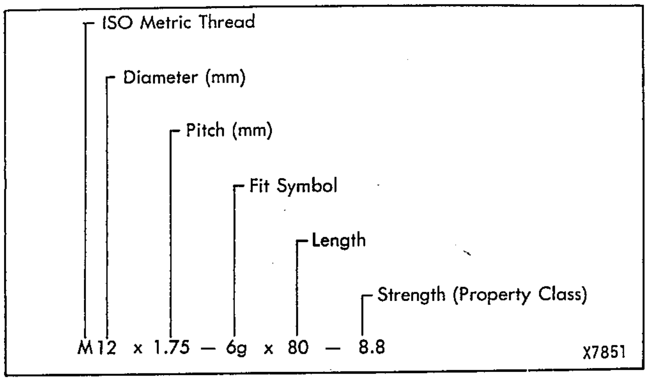

Fig. 20 — Metric Bolt Descriptive Symbols

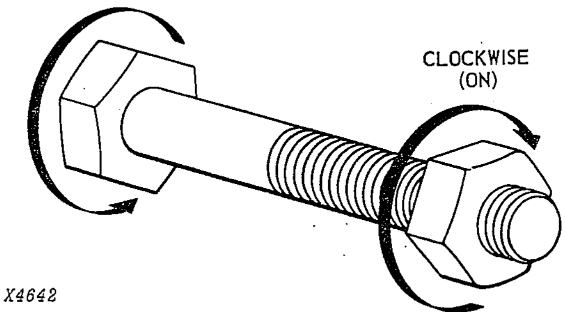

Fig. 21 — A Bolt and Nut with Right-Hand Threads (The Nut is Turned in a Clockwise Direction)

Bolts and screws normally have right-hand threads; that is, they are turned to the right in a clockwise manner when they are threaded into a nut or part (Fig. 21).

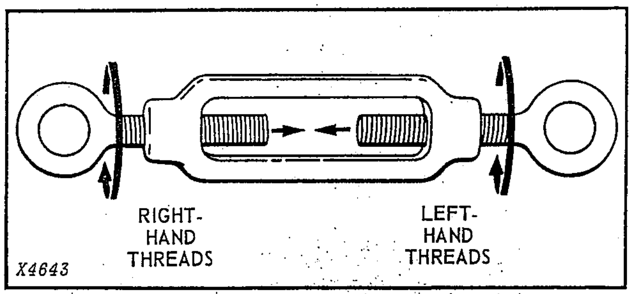

Fig. 22 — A Turnbuckle Has Both Right- and Left-Hand Threads

In a few rare cases, bolts, screws and nuts with left-hand threads are needed. A turnbuckle (Fig. 22) is one example of right- and left-hand threads in use.

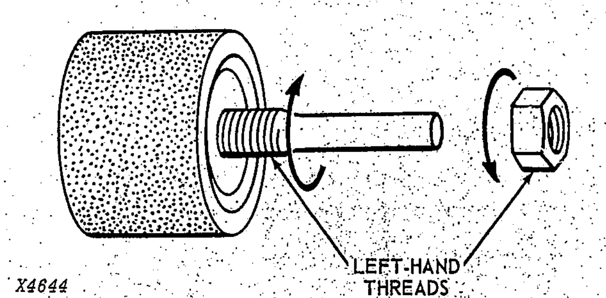

Fig. 23 — The Spindle and Nut on This Sanding Wheel Have Left-Hand Threads

Left-hand bolts and nuts are also used when rotary motion may tend to spin them loose. The spindle and nut of a sanding attachment (Fig. 23) for an electric drill is one example.

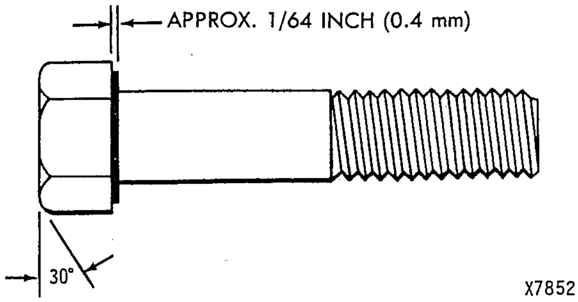

Fig. 24 — Washer Face Under Head of Bolt

Some cap screws have a circular bearing surface or washer face (Fig. 24) under the head. On other bolts a similar circular bearing surface is sometimes obtained by chamfering (bevelling) the corners on the undersurface of the head.

Many modern high-quality bolts and other fasteners are plated with a coat of zinc or cadmium for resistance to corrosion, and are sometimes dipped in chromate as further resistance to rust.

GRADES (OR PROPERTY CLASSES) AND HEAD MARKINGS

The kind of steel bolts and screws are made of and the treatment they receive during manufacture determine their strength and so their ability to do their job.

The Society of Automotive Engineers (SAE) has established certain standards for classifying unified (inch-series) bolts and screws into grades, based on their material and treatment and on their *tensile* strength and yield strength. (Tensile strength is how much pull they can stand without breaking.)

For metric standards and property classes see discussion beginning on page 9.

The SAE has also designated markings to be put on bolt and screw heads to indicate the grade. The markings consist of radial *"slashes"*, and all high-quality inch-series bolts and screws ¼ inch and larger of recent manufacture have them.

The chart below identifies the various grades, the head markings (slashes), composition, heat treatment, and tensile strength.

Most modern manufacturers are using Grade 5 or better hardware in their products. Even if grades lower than 5 are used in manufacture, Grade 5 or higher is usually specified for replacement.

GRADE (OR PROPERTY CLASS) MARKINGS FOR STEEL BOLTS & SCREWS

UNIFIED (INCH) STEEL BOLTS & SCREWS				
HEAD MARKING	SAE GRADE	DIAMETER inches	TENSILE STRENGTH psi (MPa)	
no mark	Grade 1	1/4 to 1-1/2	60,000 (414)	Approx. Equiv.
no mark	Grade 2	1/4 to 3/4 (Length up to 6 in)	74,000 (510)	Approx. Equiv.
	Grade 5.1	(.138) No. 6 to 5/8	120,000 (827)	Approx. Equiv.
	Grade 5.2	1/4 to 1		
	Grade 5	1/4 to 1		
		over 1 to 1-1/2	105,000 (724)	
	Grade 7	1/4 to 1-1/2	133,000 (917)	Approx. Equiv.
	Grade 8.2	1/4 to 1	150,000 (1034)	Approx. Equiv.
	Grade 8	1/4 to 1-1/2		
Socket Head	(none)	up to 1/2	180,000 (1241)	Approx. Equiv.
		5/8 and larger	170,000 (1172)	

Fig. 25 — SAE Grade Markings and Strength Specifications

METRIC STEEL BOLTS & SCREWS			
TENSILE STRENGTH (MPa)	DIAMETER mm	SAE PROPERTY CLASS	HEAD MARKING
400	5 to 36	Class 4.6	4.6
420	up to 16	Class 4.8	4.8
520	5 to 24	Class 5.8	5.8
800	up to 16	Class 8.8	8.8
830	over 16 to 36		
900	up to 16	Class 9.8	9.8
1040	up to 36	Class 10.9	10.9
1220	up to 36	Class 12.9	12.9

Fig. 26 — Metric Steel Bolts and Screws

METRIC GRADES (PROPERTY CLASS) AND HEAD MARKINGS

The International Organization for Standardization (ISO) has established standards for classifying metric bolts and screws into property classes. These classes are based on strength (tensile and yield). Markings (numbers) on the head indicate property class. All high quality metric bolts and screws larger than 4 mm have these markings.

The above chart (Fig. 26) identifies various grades, head markings (numbers), and tensile strength.

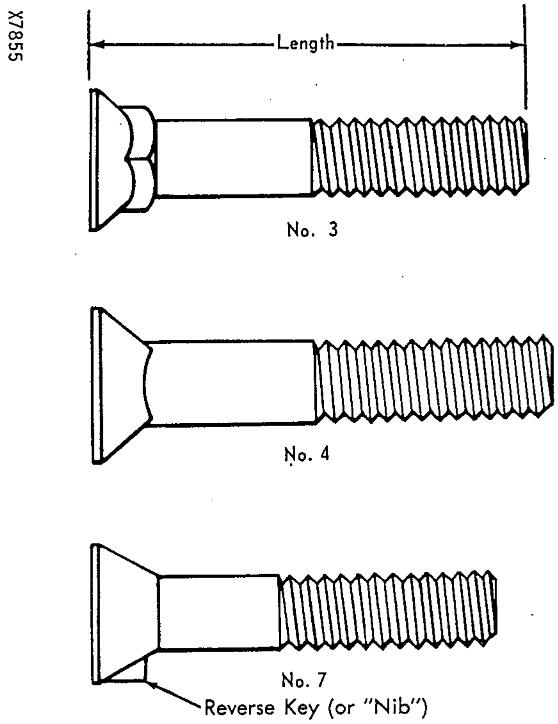

Fig. 32 — Typical Plow Bolt Head Styles

HEX SOCKET CAP SCREWS

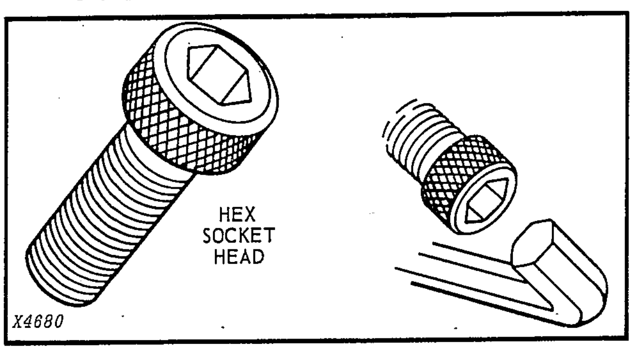

Fig. 33 — Hex Socket Head Cap Screw

Hex socket cap screws (Fig. 33) are sometimes used in recessed (sunken) holes (Fig. 34) or in confined spaces where the small head size is an advantage.

The head of a hex socket head cap screw is approximately the same diameter as the width across flats (and washer face) of a hex cap screw (both inch and metric) with the same thread size.

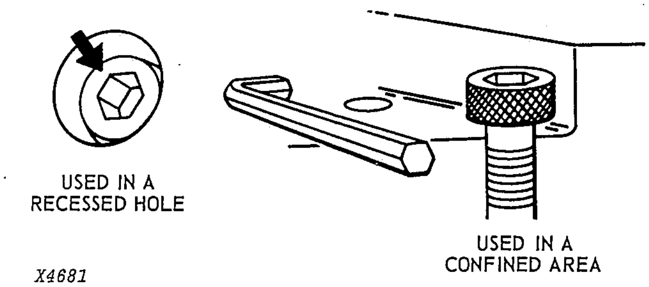

Fig. 34 — Hex Socket Head Cap Screws are Handy in Recessed Holes or Confined Spaces

12-POINT FLANGE HEAD SCREWS

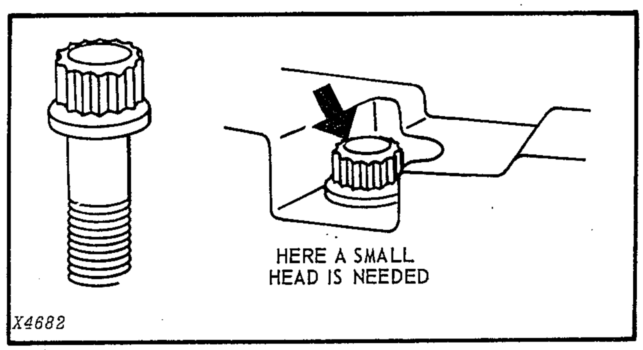

Fig. 35 — 12-Point Head Screw

These high-strength screws (Fig. 33) are turned by gripping external teeth around their heads. They are used where high-strength screws with small heads are required (Fig. 35).

12-point head screws are identified by diameter, screw length and body length in the same manner as standard hex head screws (Fig. 36). They can be turned by means of a small double hex socket (page 24) or a 12-point box-end wrench. Special sets of 12-point head screw sockets are also available.

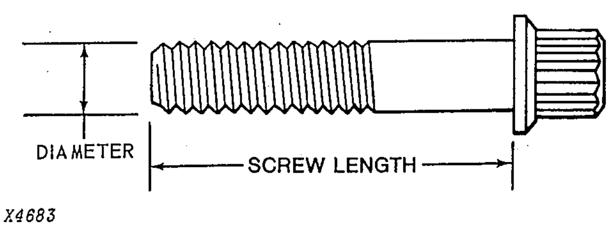

Fig. 36 — 12-Point Head Screw Dimensions

NOTE: Broken bolts and cap screws can be removed by tools usually called "stud drivers."

NUTS

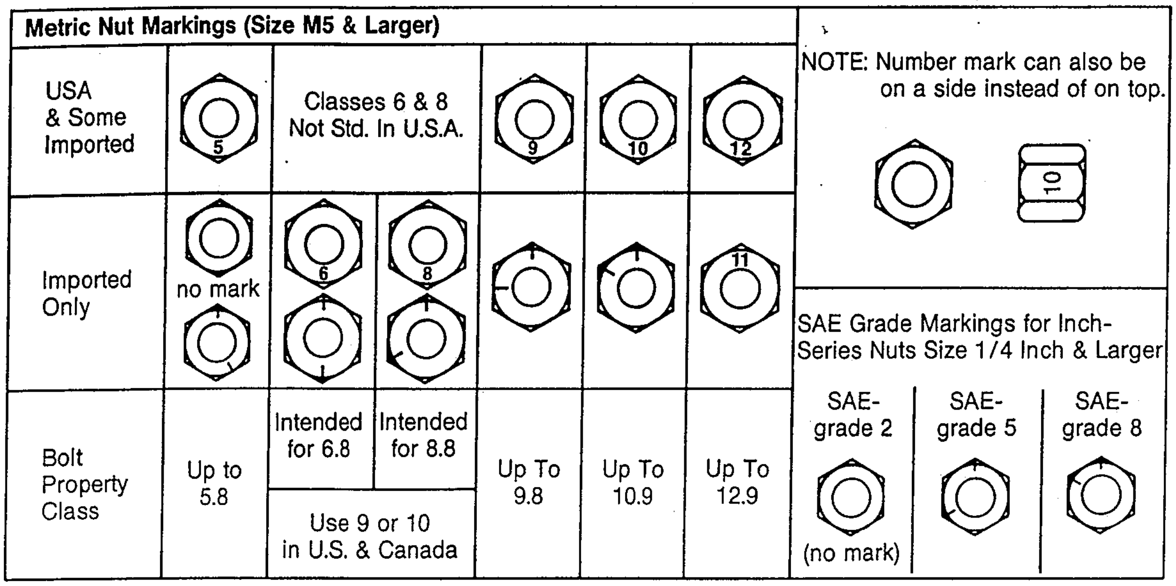

Fig. 37 — The Grade Of The Nut Indicates The Highest Grade Bolts Or Cap Screws On Which They Should Be Used To Avoid Stripping.

Most everyone is familiar with the nuts that screw onto a bolt.

There are literally hundreds of nuts of all shapes and sizes for special applications. To cover them all is far beyond the scope of this book. Those discussed are the ones you are most likely to encounter.

HEX AND SQUARE NUTS

The most common nuts are made of steel and are hexagon or square. They have coarse or fine internal threads that correspond to those of the bolt. Threads per inch can be determined with a screw gauge (Fig. 38) just like bolt threads are measured.

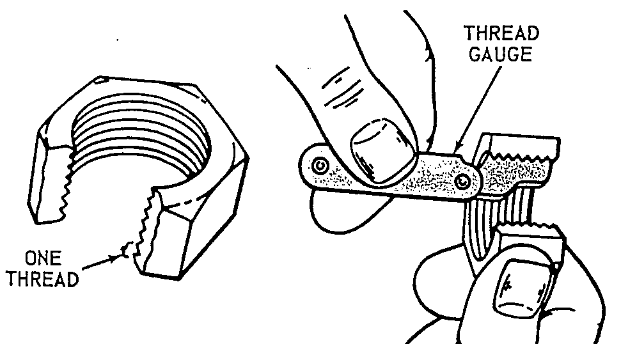

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Fig. 38 — Determining Threads Per Inch with a Thread Gauge

The corners of some nuts are chamfered (beveled) on one side. Other nuts have chamfered corners on both sides so they can be installed with either side down.

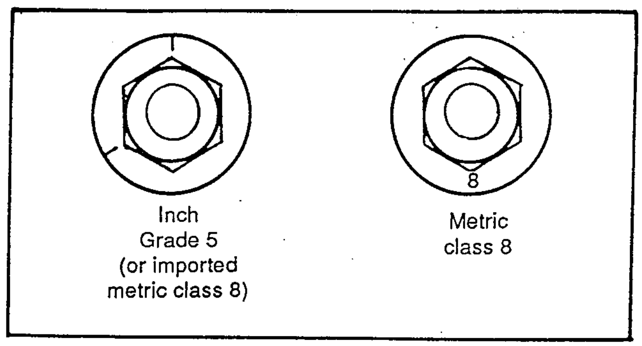

Fig. 39 — Flange Nuts Can Be Marked On Top Of The Flange Instead Of On Top Of The Nut.

The American Society for Testing and Materials (ASTM) and SAE are responsible for material and strength standards for unified (inch) nuts. ISO and ASTM establish standards for property classes for metric nuts. Normal metric nuts, used in the U.S.A., are classed as 5, 9, and 10. These numbers indicate the highest tensile strength of screw or bolt on which they should be used to avoid stripping.

Nuts have three important dimensions: (1) thickness, (2) distance across flats, and (3) thread size which is the same as that of the bolt with which it is to be used.

JAM NUTS (INCH SERIES) "THIN" NUTS (METRIC)

One way to lock a threaded part in place is with a jam nut. Usually a jam nut is thinner than a "full" nut, but otherwise it is much the same as a full nut.

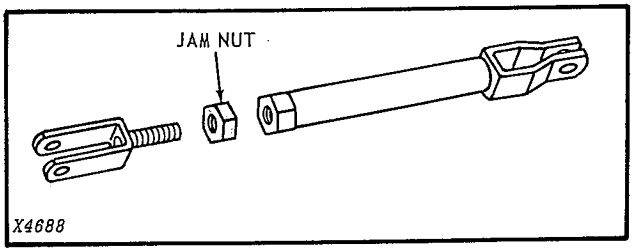

Fig. 40 — Location of a Jam Nut

A common application of jam nuts is on control linkage, such as the steering tie rods on a car or tractor, or the lift linkage (Fig. 40) on a modern chisel plow, which has to be adjusted for length. Once the adjustment is made, the jam nut is tightened against the rod end to lock the adjustment.

Metric property classes for thin nuts are 04 and 05. The 05 class is heat threated.

CASTELLATED AND SLOTTED NUTS

There are many applications where it is necessary to secure a nut in place so it can't possibly come loose. For this purpose castellated and *slotted* nuts are available.

The name for castellated nuts (commonly called *castle* nuts) comes from the fact that they resemble the battlements on an old feudal castle.

Slotted nuts are commonly used to adjust the position of or tension of a machine part. The nut is not tightened to a solid joint. A pin is used to hold the adjustment in place.

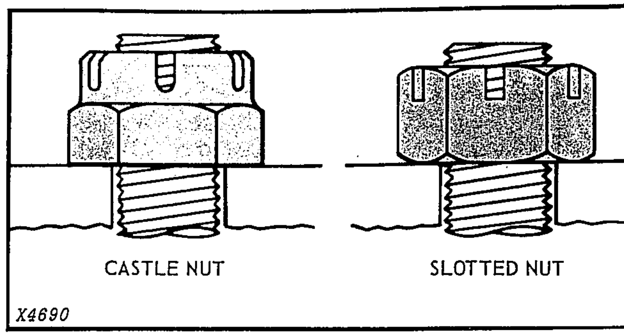

Fig. 41, Fig. 42 — Castle And Slotted Nuts

As you can see from the above illustrations (Figs. 41 and 42), the top part of a castle nut is smaller in diameter than the body of the nut. **(It should be noted that castle nuts are no longer standard in the U.S.A.)** A slotted nut is simply a hex nut with slots.

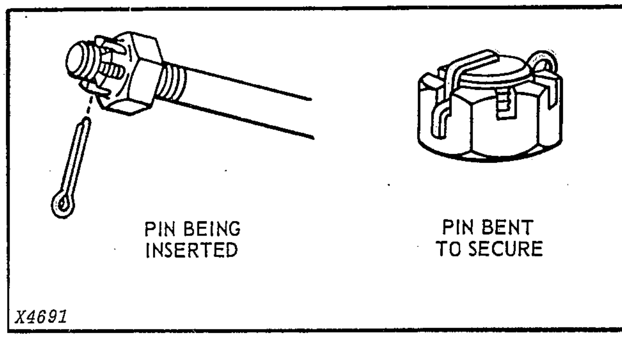

Fig. 43 — How a Cotter Pin is Used to Secure a Castle or Slotted Nut

Both nuts are used with bolts having a hole drilled through the end. When the nut is tightened onto the bolt, a cotter pin (Fig. 43) is inserted through the slots and hole to hold the nut firmly in place. (For more about cotter pins and installation, see page 19.)

Castle and slotted nuts are identified by thickness and width across flats as well as by thread diameter and thread count (pitch).

SELF-LOCKING NUTS

Some nuts, once tightened, stay firmly in place because of the way they're made.

There are many types of these lock nuts, utilizing many ingenious means of staying tight. The ones that are most commonly used are called *prevailing-torque* and *plastic-insert* nuts. (Often referred to by their trade name "elastic" nuts.)

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Prevailing-Torque Nuts

An all metal *prevailing-torque* nut is, by definition, one that is "**frictionally resistant to rotation due to a self-contained prevailing-torque feature.**" This simply means that they grip the mating threads. There are many ways of doing this.

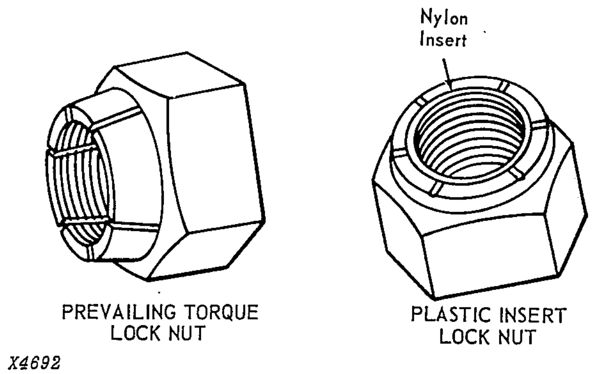

Fig. 44 — Prevailing-Torque and Insert-Type Self-Locking Nuts

One popular prevailing-torque nut (Fig. 44) resembles a castle nut, but the top is split into sectors bent inward. When the nut is threaded onto a bolt, the sectors are forced outward and grip the bolt tightly.

Prevailing-torque nuts can be reused approximately 4 or 5 times depending on the applications. If specified by manufacturer, be sure to lubricate nut when tightening or loosening.

Plastic Insert Nuts

These nuts (Fig. 44), which are actually a special type of prevailing-torque nut, contain a relatively soft collar of unthreaded material built into the head. The collar may consist of suitable fibrous material or a plastic such as nylon.

When the nut is threaded onto a bolt the threads are impressed into the collar. Being elastic, the collar has a tendency to return to its original shape when removed so this nut can be reused 4 or 5 times.

Another feature of self-locking nuts is their ability to seal out moisture.

OTHER NUTS

As mentioned before, there are many other types of nuts available for special uses. You're probably familiar with *wing* nuts, *crown* nuts (also called cap or acorn nuts), single-thread nuts, and a host of others that you probably will seldom see. Fig. 45 shows just a few of these, many of which have self-locking features.

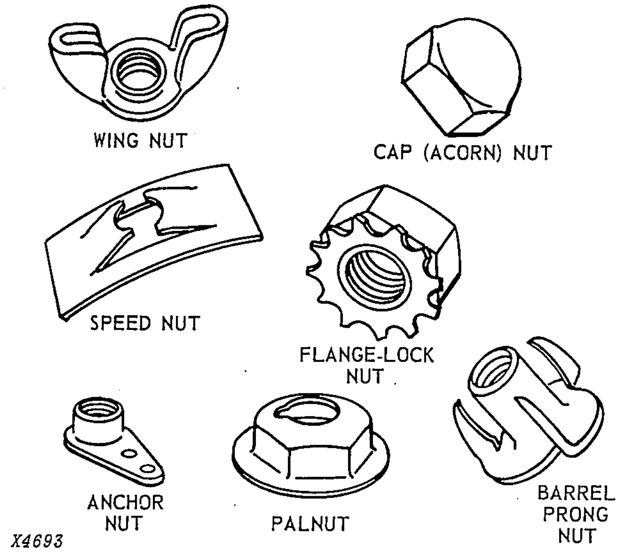

Fig. 45 — A Few Special-Purpose Nuts

CHEMICAL NUT LOCKS

Regular nuts can be locked in place with a liquid lock (Loctite®, for instance) to prevent loosening, especially from vibration. Most chemical locks (Fig. 46) are free-flowing plastic material. When applied to threads, the lock will fill the spaces between them and hardens, raising the "break loose" torque.

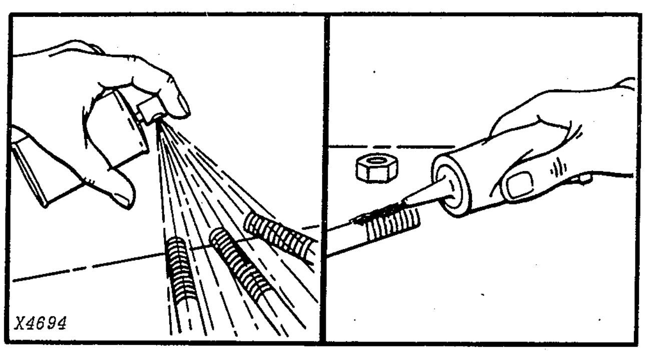

Fig. 46 — Sealants and Primers for Nuts and bolts

A primer should always be sprayed on the threads to clean them and speed up the drying time of the chemical lock.

Although chemical locks are excellent for keeping nuts and bolts tight, the bond can be broken, if necessary, for nut or bolt removal.

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RESTORING THREADS

Even though you try to be careful, sometimes threads may be damaged when work is done. If no replacement is readily available, threads may be touched up and small nicks or burrs removed.

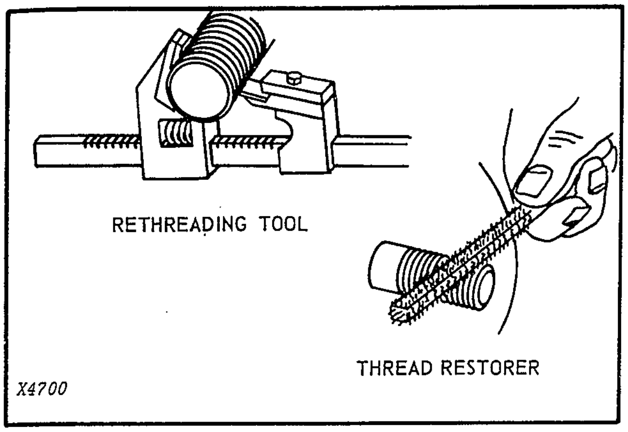

Fig. 52 — Using a Rethreading Tool and Thread Restorer

This can be done with a *rethreading tool* (Fig. 52). A file-like *thread-restorer* can also be used.

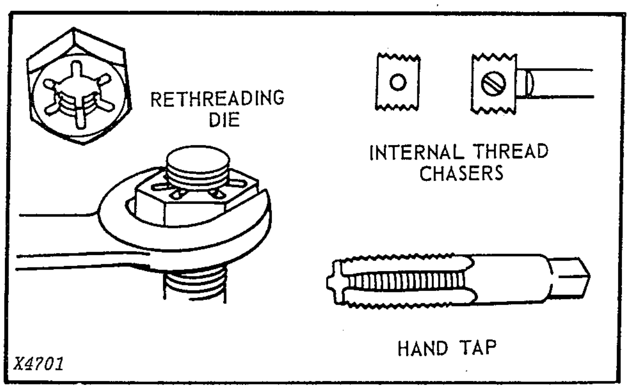

Fig. 53 — Other Thread-Restoring Tools

Another means of cleaning or restoring bolt and stud threads is a rethreading die of the proper size (Fig. 53). Internal holes can be recut with an internal thread chaser (Fig. 53) or hand tap.

NOTE: More information on proper techniques for installing, removing, and tightening nuts is given beginning on page 23 of this manual.

WASHERS

PLAIN WASHERS

A plain washer (Fig. 54) is simply a steel disk with a hole through the center. Though simple parts, washers are very important in many applications.

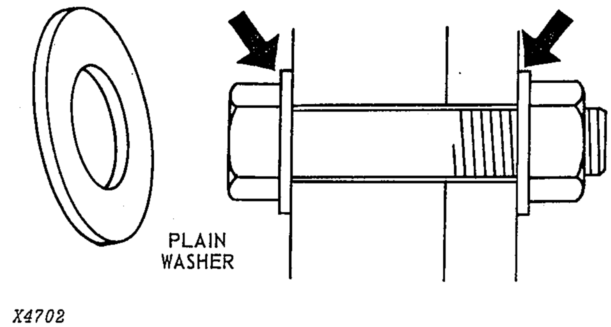

Fig. 54 — A Flat Steel Washer

When used under the head of a bolt, or under a nut (Fig. 54), a plain washer distributes the load over an area larger than the head of the bolt or nut, thus reducing the stresses that would otherwise exist. Washers also protect the surfaces of fastened parts from damage which might occur without them when a bolt is tightened.

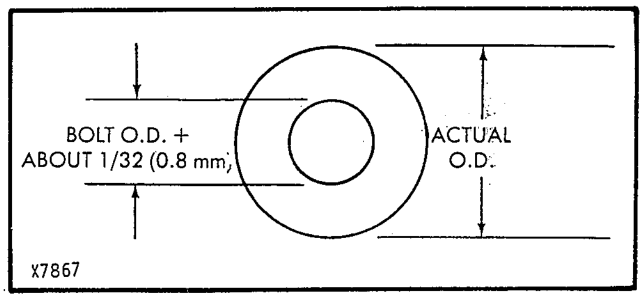

Fig. 55 — How Flat Washers are Measured

A plain washer is also used to span large clearance holes or slots. Some plain washers are hardened to resist bending or to resist friction during tightening.

Plain washers are identified by their outside diameter and diameter of the hole which is the *bolt* size rather than the actual diameter of the hole. The hole is a little oversize [1/32 inch (0.8 mm)] (Fig. 55) so the washer will slide easily over the body of the bolt.

Usually washer thickness is given in decimal portions of an inch or in millimeters (i.e., .060 inch, 1.6 mm). Sometimes inch-size washer thickness is specified by the *gauge* of the steel from which it is stamped. The larger the gauge number, the thinner the washer. For instance, washers stamped from 16-gauge steel are 0.0598″ thick; 10-gauge washers are 0.1345″ thick. Some typical metric washer thicknesses in mm are 0.5, 1, 1.2, 1.6, 2, 2.5, 3, 4, and 5.

LOCK WASHERS

Helical Spring Washers

The helical spring lock washer is used as a spring take-up device to compensate for wear and looseness between two fastened parts. They also are used to distribute the load of a fastener over a larger area of the fastener head by acting like a plain washer.

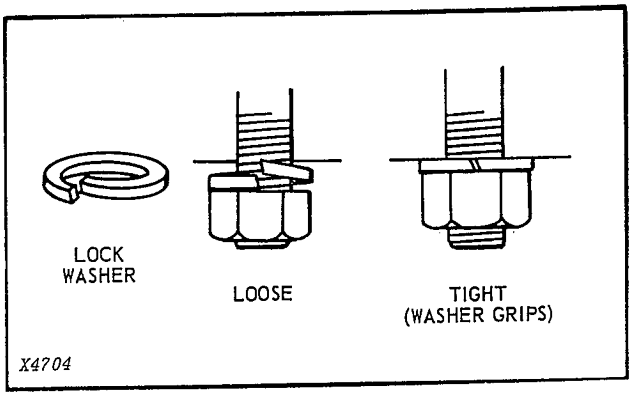

Fig. 56 — A Helical Spring Washer and How it Works

Toothed Lock Washers

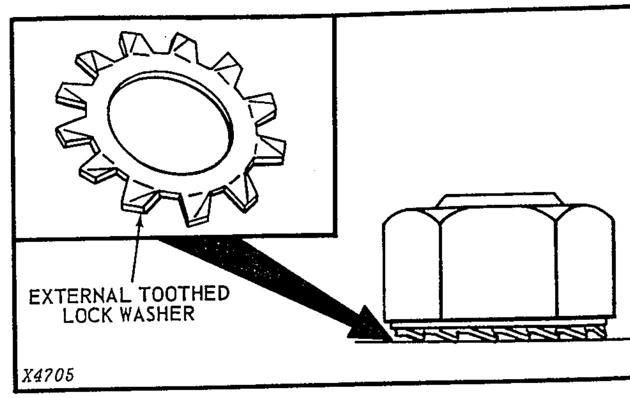

Fig. 57 — How a Toothed Lock Washer Grips

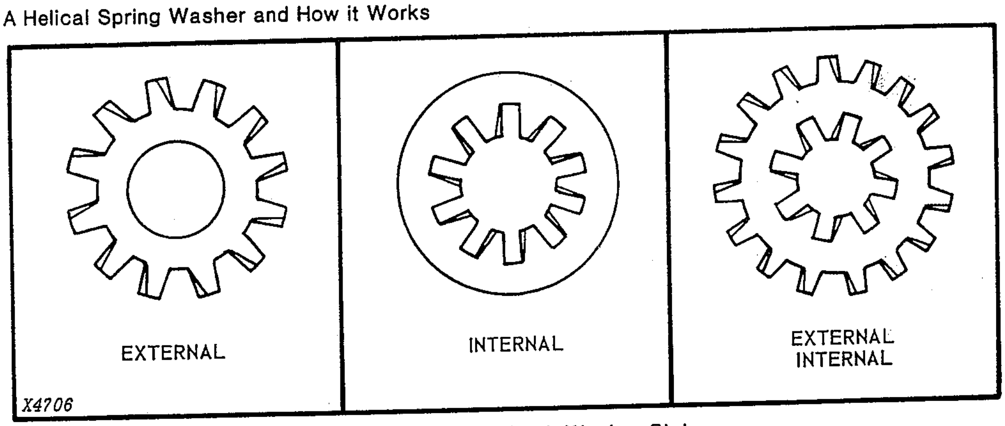

Fig. 58 — Toothed Lock Washer Styles

Helical spring lock washers provide a hardened bearing surface that helps protect joint material from damage caused by rotation during tightening. In this way, they are used like plain washers (Fig. 56).

Conical shaped spring washers have also been developed. They are applied to the same types of situations as the helical spring washer. They also are applied to the same situations as the plain hardened washer.

Toothed lock washers are used to increase the friction between the screw or nut and the assembly. Toothed lock washers also can be used to improve electrical contact at a battery post connection. As the toothed washer is tightened, it digs through paint and corrosion and into the metal contact (Fig. 57).

Internal toothed washers are used when a smoot surface is needed to help prevent snagging of hanc and clothing at a fastener (Fig. 58).

Another common external tooth washer cone-shaped for use with countersunk, flat-hea screws (Fig. 59).

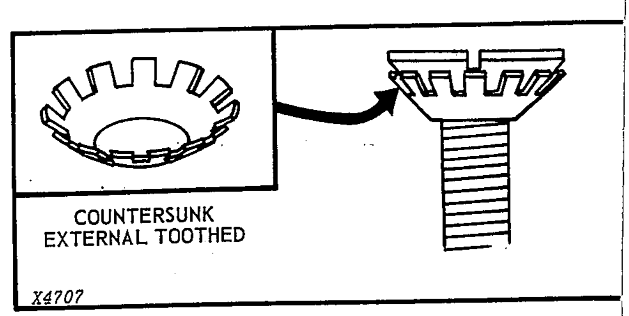

Fig. 59 — A Cone-Shaped External-Tooth Lock Washer

Toothed washers are identified by bolt size. Like helical spring washers and machine screws, those under ¼-inch are designated by number. Metric toothed washers are designated by nominal screw (thread) diameter in millimeters.

There are many other toothed lock washers, developed for special applications, but they all work on the same principle.

COTTER PINS

Back on page 14 where castle and slotted nuts were discussed, cotter pins were mentioned. These simple pins are used to hold a nut and bolt tightly together and to keep the nut from coming off.

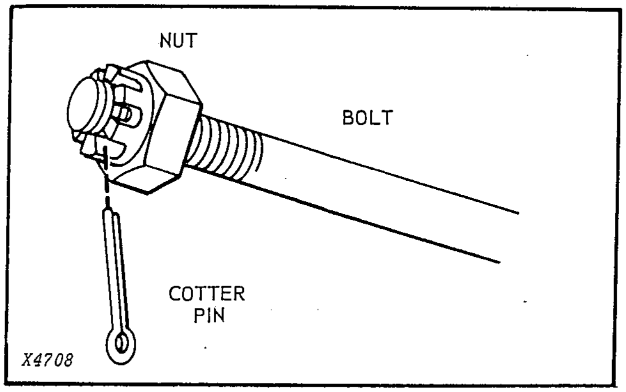

Fig. 60 — Relation Between a Cotter Pin, Nut, and Bolt

The cotter pin is slipped between the nut slots and through a hole in the end of the bolt (Fig. 60).

Cotter pins are made of soft metal so the prongs can be bent around the nut.

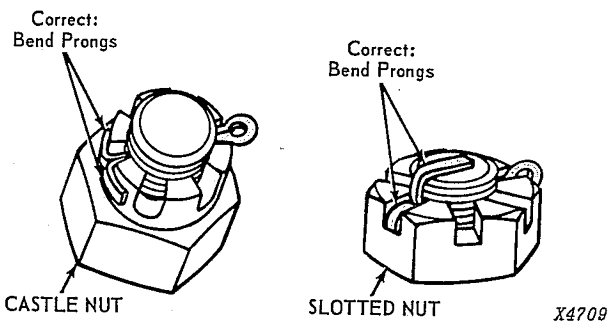

Fig. 61 — Cotter Pin Prongs Properly Bent Around a Castle Nut and a Slotted Nut

When used with a castle nut the prongs are usually bent back against the rounded nut top (Fig. 61).

When a cotter pin is used with a slotted nut (on an engine connecting rod, for instance), one prong is usually bent up and over the end of the bolt (Fig. 61).

If the hole in the bolt does not line up with the nut slots when the nut is tightened, the nut must be tightened just enough more so the pin can be inserted.

NOTE: Some bolts used with castle nuts may have two holes for more precise adjustment.

IMPORTANT: Never LOOSEN a nut to align the cotter slot, unless the instructions of the machine manufacturer say to do so.

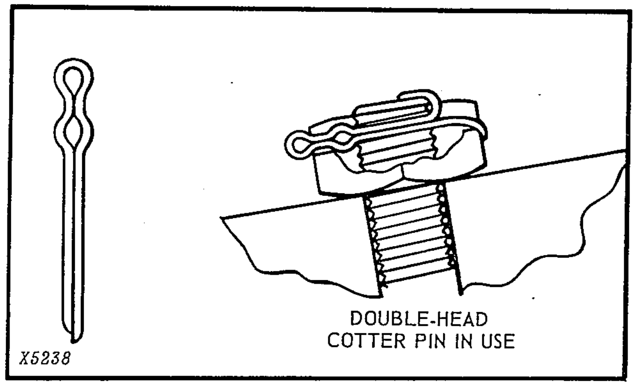

Fig. 62 — How a Double-Head Cotter Pin is Used

When installed, the eye of the cotter pin head is inside the nut slot. To make removal easier, a double-head cotter pin (Fig. 62) is sometimes used.

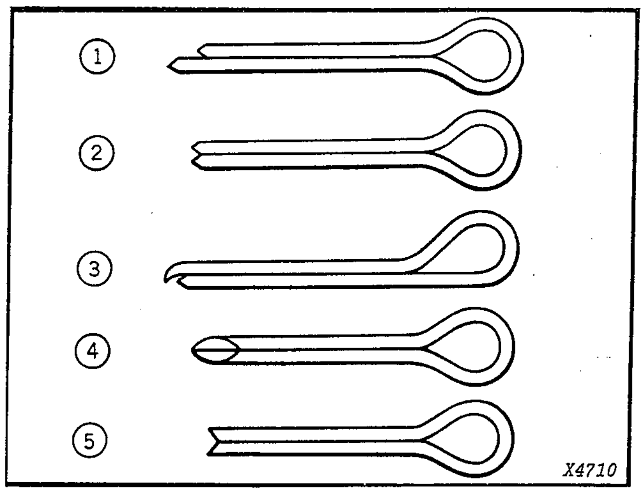

Fig. 63 — Common Styles of Cotter Pin Ends

A number of different point styles are available. Those which are considered standard are shown in Fig. 63:

1 — Chisel point with extended prong for general use
2 — Chisel point with even ends
3 — Hammerlock type for castle nuts
4 — Taper pointed to align parts for quick insertion
5 — Internal V-cut type

FAILURES DURING ASSEMBLY

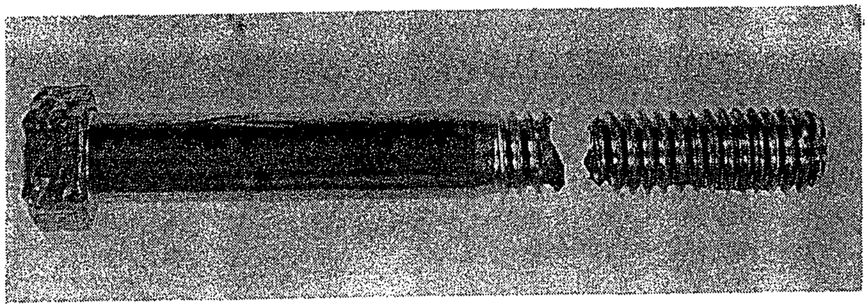

Fig. 118 — Bolt Twist Off

Bolt Twist Off

This cap screw failure was from poor thread quality or a large friction factor between components.

Recommendation: Replace.

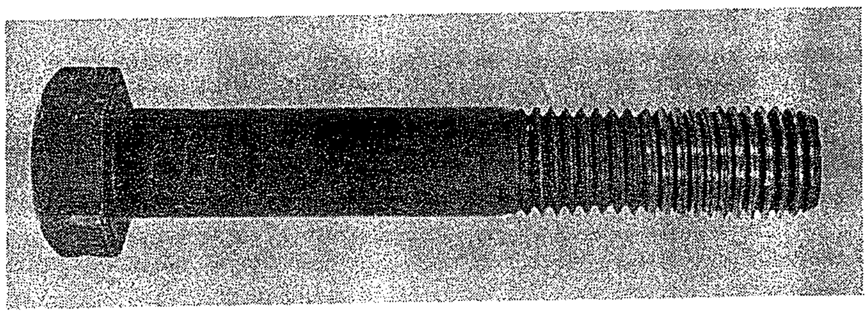

Fig. 119 — Galling of Thread

Galling

The deformed thread (galling) is due to poor thread contact with the nut.

Recommendation: Replace

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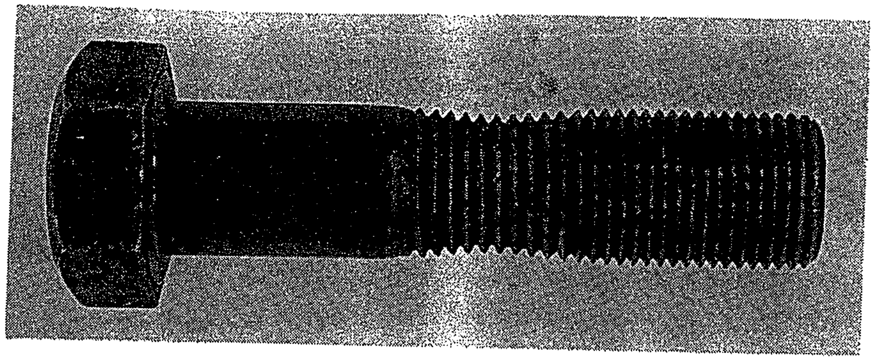

Fig. 120 — Excessive Torque

Bolt Yield And Tensile Failure

Excessive torque caused this cap screw to stretch and reduce the thickness of threads.

Recommendation: Replace and reduce assembly torque.

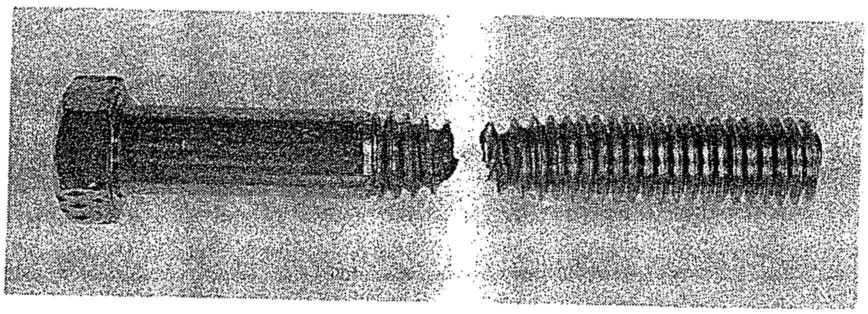

Fig. 121 — Low Friction

When friction is low, the recommended torque will produce too much tension on the cap screw and cause this failure.

Recommendation: Replace and reduce torque.

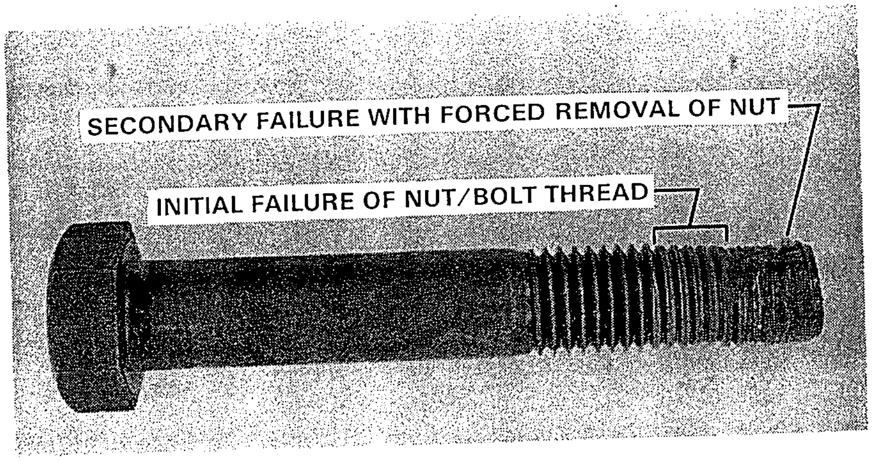

Fig. 122 — Thread Failure

Nut/Cap Screw Thread Failure

A cap screw can be "stripped" by using a nut with a short thread length or the incorrect hardness.

Recommendation: Replace with a higher grade nut, or increase nut height.

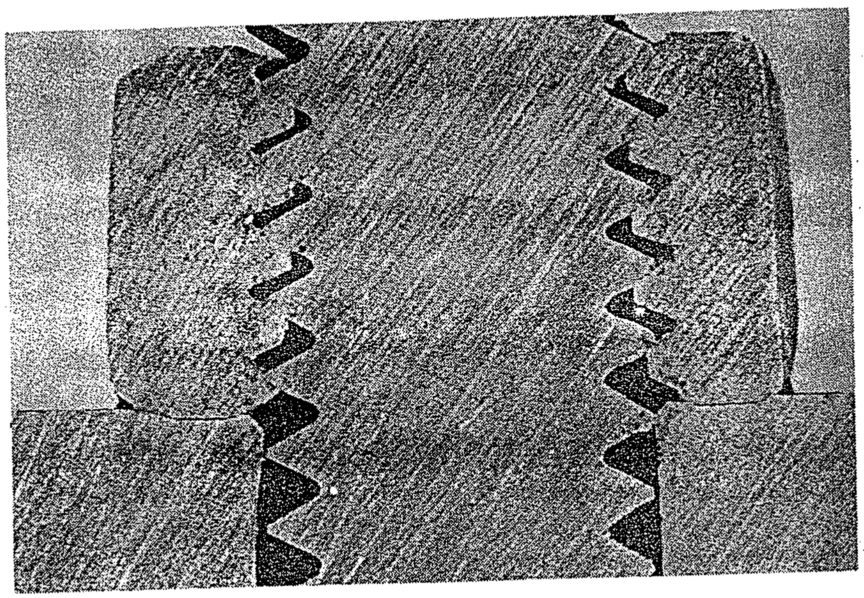

Fig. 123 — Low Grade Nut

Nut Dilation

When a low grade nut is used in assembly, the washer face (A) of the nut expands in diameter.

Recommendation: Replace with higher strength nut, add hard washer in joint or use a flanged nut.

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FAILURES DURING USE OR AFTER ASSEMBLY

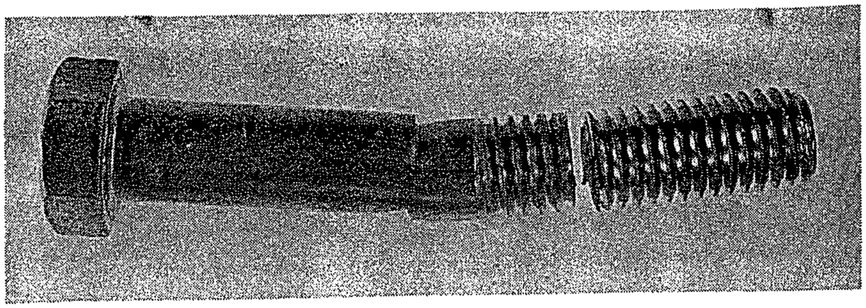

Fig. 126 — Crosswise Load

Shear Failure

This cap screw indicates a large crosswise load was placed on the joint components.

Recommendation: Replace and increase cap screw torque. Use bushings to carry shear loads. Replace with larger cap screw.

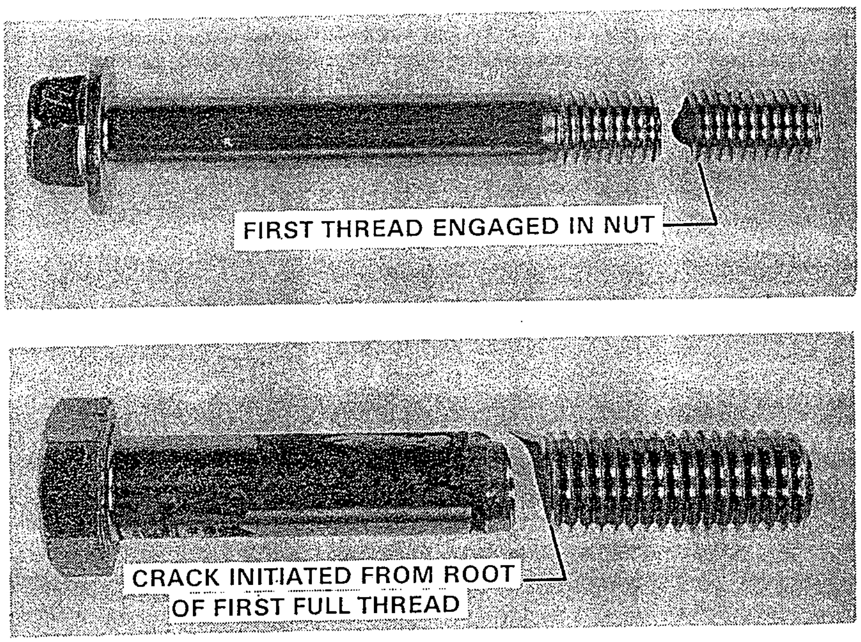

Fig. 127 — Low Torque

Fatigue Failure

These fasteners failed from a low cap screw torque, or a combination of low cap screw torque and high cyclis stress. The service loads may have been higher than expected, or compounded by bending loads.

Recommendation: Replace and use higher cap screw torque. Replace with larger cap screws. Reduce stress concentrations on cap screws.

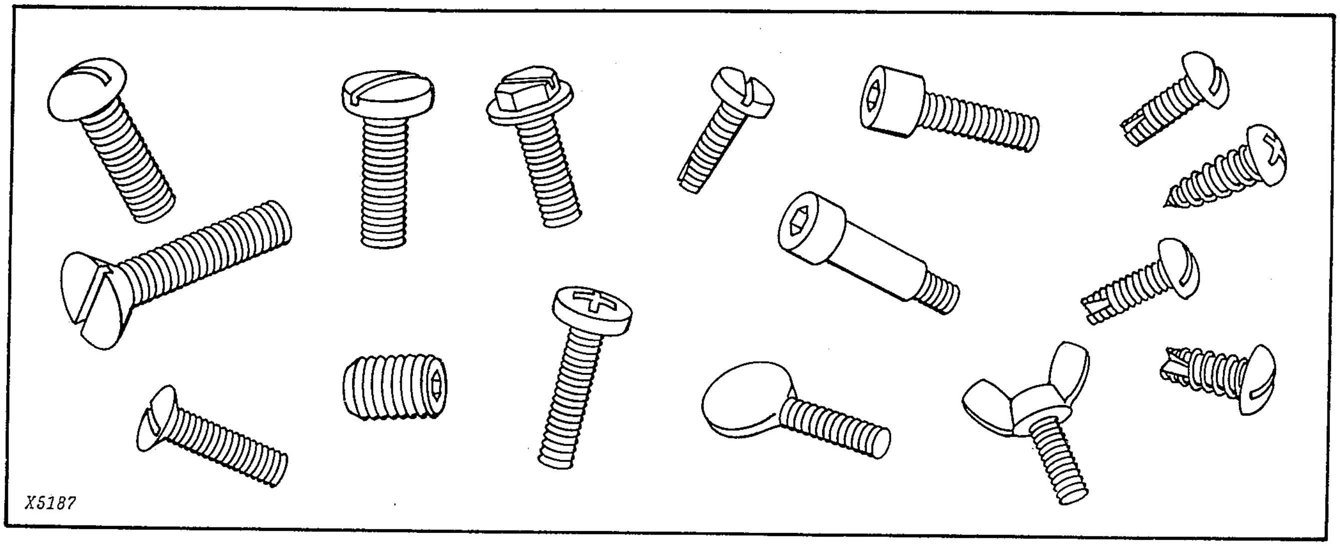

Fig. 129 — There Are Screws of Many Shapes and Sizes for Many Purposes. A Few Representative Ones Are Illustrated Here.

SCREWS

Screws constitute a large and important family of fasteners. They come in many and varied styles and sizes (Fig. 129). Only those you are most likely to encounter will be discussed here.

All screws are threaded lengths of steel rod with a head on one end. There are a large number of head styles. One of the most commonly used is the "Machine Screw".

MACHINE SCREWS

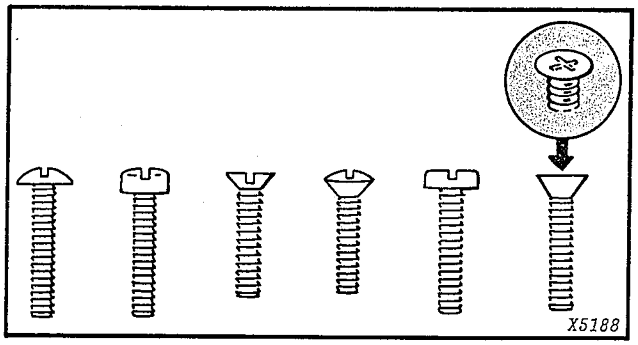

Fig. 130 — Typical Machine Screws

Typical examples of machine screws are shown in Fig. 130. In most applications machine screws are turned into threaded holes, although they may be used with nuts.

At one time or another most everyone concerned with mechanical things has bought machine screws at his local hardware store or other source. When you do so, if the diameter of the screw is less than ¼-inch, you'll notice that the package or box identifies the size of the screws it contains by a small number and a figure in inches. For example, No. 4 X 1½". In the example the No. 4 refers to the diameter of the screw, and the 1½" to its length.

Have you ever wondered just what size, in familiar measurements, the numbers stand for? The chart below tells you.

MACHINE SCREW SIZES

Screw Number*	Size in Decimals	Approximate Size in Fractions
No. 2	0.086"	a little over 5/64"
No. 3	0.099"	a little over 3/32"
No. 4	0.112"	a little over 7/64"
No. 5	0.125"	exactly 1/8"
No. 6	0.138"	a little under 9/64"
No. 8	0.164"	a little over 5/32"
No. 10	0.190"	a little over 3/16"
No. 12	0.216"	a little under 7/32"

These numbers apply also to lock washers.

The diameter of screws ¼ inch and larger is expressed in fractions of an inch. These screws are usually made of SAE grade 60M (equivalent to SAE Grade 1) hardware. (See page 9.)

Metric machine screws are identified by the nominal diameter in millimeters (such as M3.5 or M4). The designation may appear as M4 x 0.8 with 0.8 being the distance between threads (pitch) in millimeters. Metric machine screws are usually of the property class 4.8.

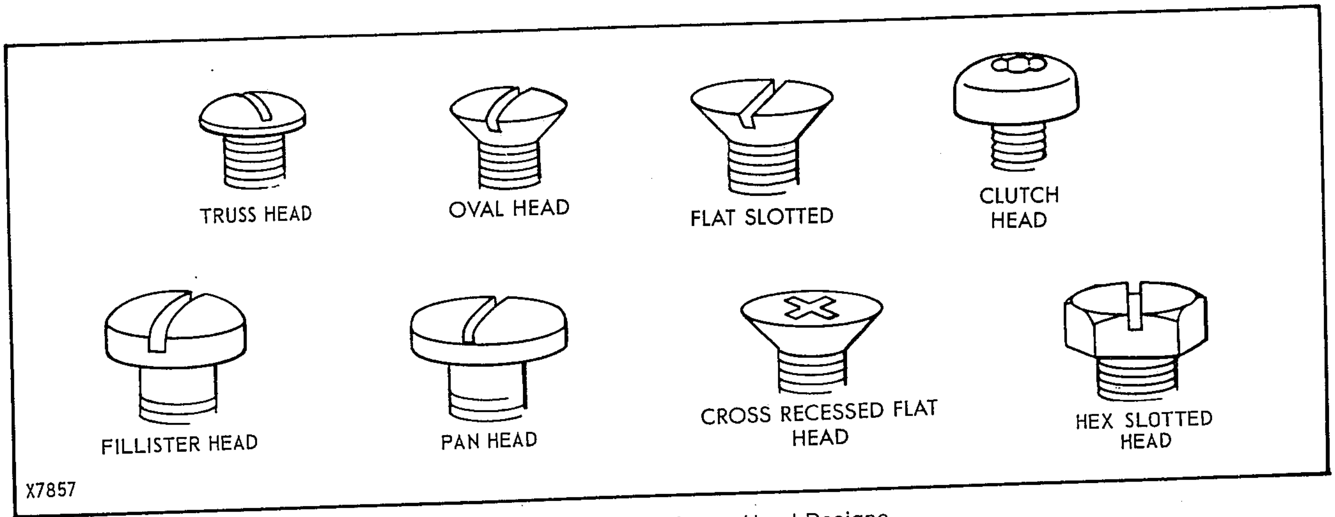

Fig. 131 — Machine Screw Head Designs

Inch-size machine screw threads are counted by the number to the inch, just like bolt threads. A 6-32 screw has a No. 6 body diameter and 32 threads per inch. Most machine screws are fully threaded.

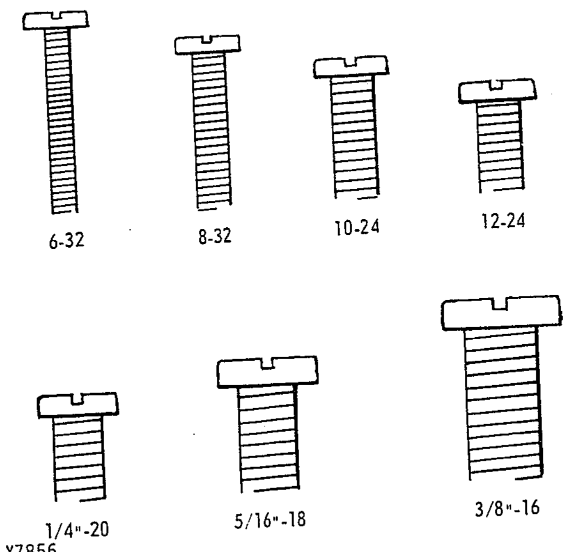

Fig. 132 — Inch-size Machine Screw Sizes and Threads Per Inch — Actual Size

Fig. 132 shows common body sizes and thread count, actual size.

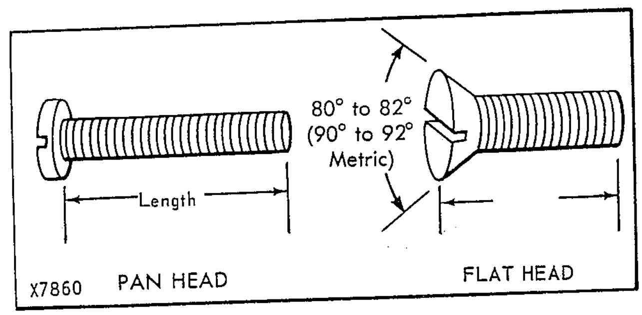

Fig. 133 — Where the Length of Machine Screws is Measured

The length of most machine screws is measured from just under the head to the end of the thread (Fig. 133). However, in the case of flat head countersunk screws, the overall length is measured.

There are many head designs for machine screws. Those most commonly used are shown in Fig. 131.

The *pan head** machine screw is the most commonly used. Variations of this design are *truss head,* which is wider and rounded, and *oval head* which requires a countersunk hole.

Another widely used machine screw is the *flat head** which also requires a countersunk hole.

The *fillister head* is cylindrical and has a round top. A similar screw design with a flat top that blends into the sides is called a large *pan head* screw.

*Stove bolts are identical to round head and flat head machine screws.

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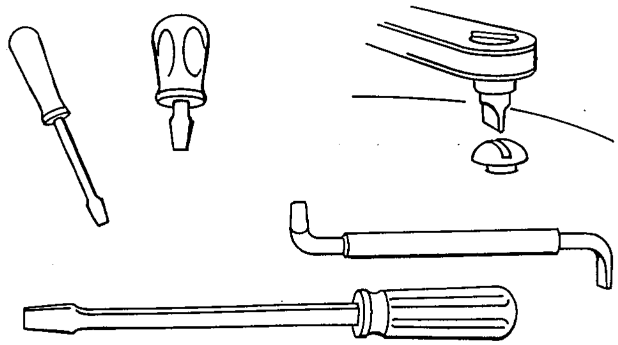
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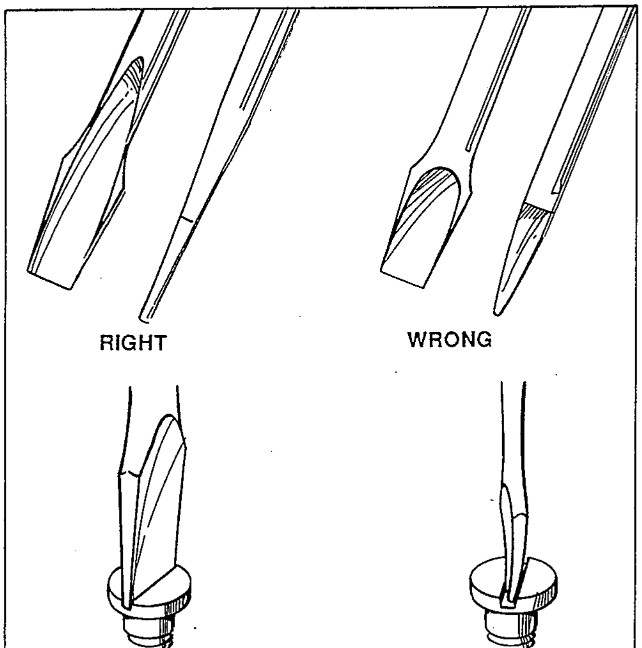
Fig. 134 — Commonly Used Screwdrivers

All of these screws are installed or removed with a screwdriver. There are a number of sizes and shapes of screwdrivers. A few of these are illustrated above.



X4547

Fig. 135 — Check Tip of Screwdriver

To avoid slipping, do not use a screwdriver with a worn or damaged tip. Use a screwdriver with a square-edged tip that is the correct size to fit the screw slot.

NOTE: Though screwdrivers are simple tools, they may need reconditioning occasionally. There is a right way and a wrong way to do this. For instructions, see "Fundamentals of Service, Shop Tools".

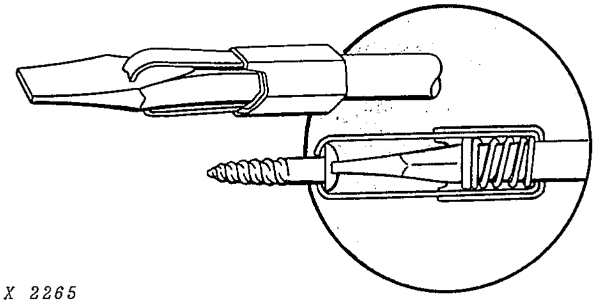

X 2265

Fig. 136 — Starting Screwdriver (Shown Holding a Screw)

When a screw must be installed in close quarters or other places difficult to reach by hand, a starting screwdriver can be used. One type is shown in Fig. 136.

Other starting screwdrivers have twisting centers or are magnetized to hold the screws.

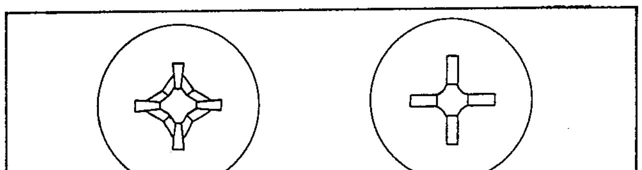

X7858

Fig. 137 — Cross-recessed Head Designs

Another variation of machine screw has a cross-recessed head. Two types of cross-recessed heads are shown in Fig. 137. Most metric cross-recessed screws will be of the type on the right. The screwdriver for these has a cross-shaped, pointed tip. Because of the extra bearing surface between screw and screwdriver, turning force can be quite high, but more force must be exerted to keep the screwdriver point in the slots. Various sizes of cross-shaped, pointed tip screwdrivers are made to fit different screw sizes.

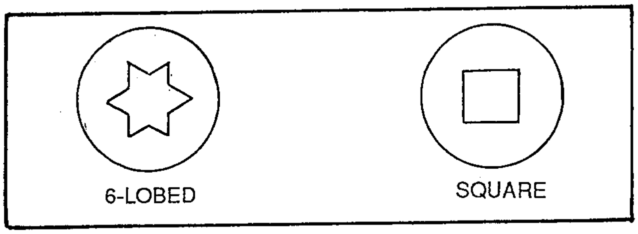


Fig. 138 — Other Recessed Head Screws

There are other recessed head screws that provide extra bearing surface between the screw head and screwdriver. The correct screwdriver must always be used to avoid damaging the head of the screw.

Screws with hex slotted heads (Fig. 131) are a popular variation of machine screws. These can be installed or removed by means of a screwdriver, a wrench, or a handy, readily available tool with a hex socket, called a nut driver. A nut driver must be procured for each screw head size.

When a neat appearance is vital *clutch-head* screws (Fig. 131) may be used to fasten sheet metal and trim. A special screwdriver is used to install these screws. The tip stays well in the screw opening and requires only moderate pressure.

TAPPING SCREWS

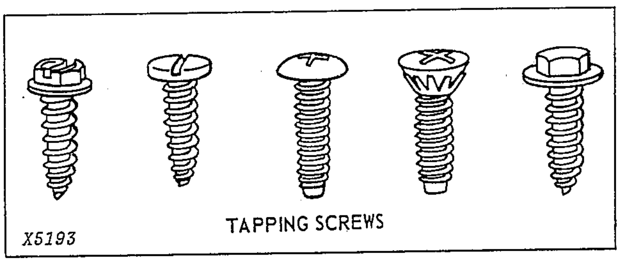


Fig. 139 — Typical Tapping Screws

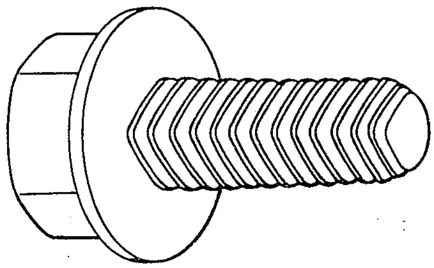
Another family of screws has been used widely in recent years to attach covers, panels and other light parts. Such parts may be made of sheet metal, soft metal castings (like aluminum, bronze, brass), plywood, fiber glass, plastics, etc. The members of this family are called *tapping* screws (Fig. 139). Another name for them is *thread-forming* screws because they form their own threads in the parts that they are screwed into. A third popular name is *sheet metal* screws.

Most of these screws come with cross-recessed heads in pan, flat, or hex design. There are others with special heads or threads that carry a variety of trade names or numbers. They are too numerous to be listed in detail.

The mating threads produced by a tapping screw closely fit the threads on the screw. This close fit usually keeps the screw tight, even under vibrating conditions.

Tapping screw diameters are designated by numbers similar to those used to identify machine screws (page 45). They come with coarse or fine threads and are almost always case hardened to cut satisfactory threads and stand hard twisting force.

Metric tapping screws (sheet metal screws) are designated by nominal diameter in millimeters.



X5194

Fig. 140 — A High Performance, Thread Rolling Screw

Fig. 140 shows a "high-performance" thread rolling screw for use in heavier materials that require deep thread engagement. This screw has a three- or four-lobed cross-section to provide three or four thread-forming edges. Body size corresponds to that used for machine screws.

When using most tapping screws, holes of the proper size must be drilled in the parts being fastened.

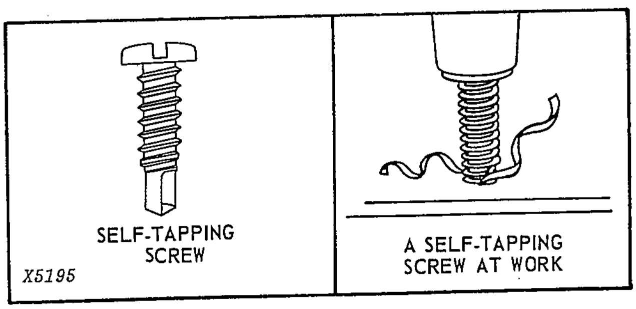


Fig. 141 — Self-Drilling Tapping Screws

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Self-Drilling Tapping Screws. An interesting variation of tapping screws is one that has a specal point to *drill* its own hole, thus eliminating drilling or punching (Fig. 141). Since these screws must usually be installed with a power tool, you may not encounter them very often.

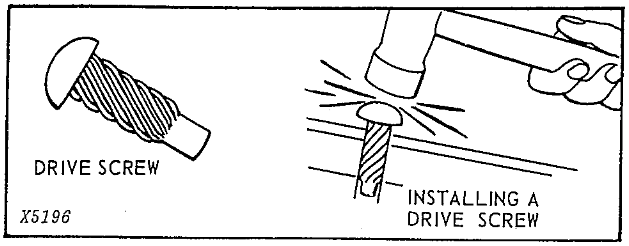


Fig. 142 — A Typical Drive Screw.

Drive Screws.

Another variation is the *metallic drive* screw (Fig. 142) that is hammered or pressed into the hole for fast installation. These screws have no slots in the head and, once installed, cannot be removed.

SET SCREWS

A set screw is frequently used to hold a collar, pulley, gear or the like to a rotating shaft to prevent relative movement between the two parts. They achieve this by pressing against a flat or by fitting into a small hole in the shaft.

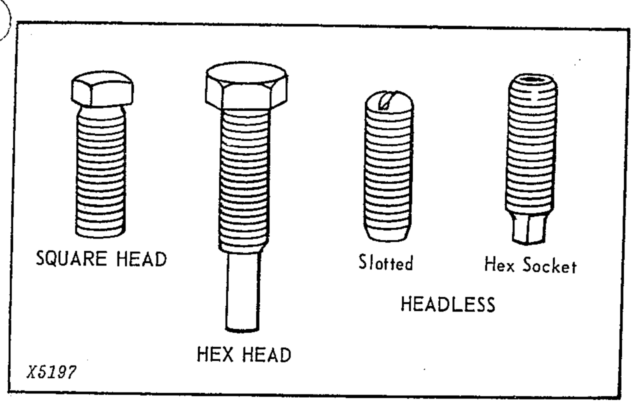


Fig. 143 — Types of Heads on Commonly Used Set Screws

Set screws may have square or hexagon heads (Fig. 143) or may be headless with a screwdriver slot or hex Allen wrench socket.

There are a variety of point styles, each best suited for its job. The more common ones are illustrated

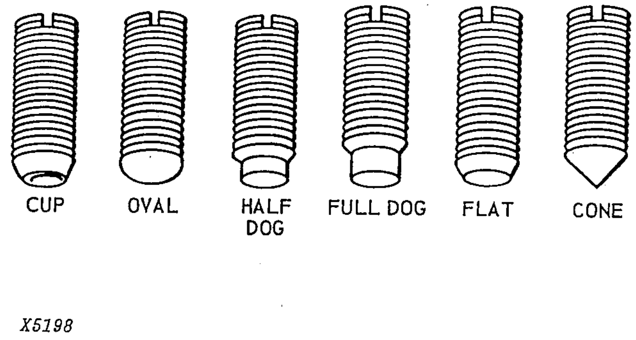


Fig. 144 — Set Screw Point Styles

in Fig. 144. The cup point and dog point are by far the most commonly used.

The cup point screw has applications where the installation is more or less permanent and cutting action of the point on the shaft is not objectionable. Dog point screws are used for the same purpose, but their holding power is more permanent because the point projects into a drilled hole in the shaft.

Set screws with flat or oval points are used when frequent adjustments must be made between the two parts held together.

Set screws are made of high-strength material and are heat treated. Threads may be either coarse or fine. Diameters are expressed by numbers or inch fractions (or millimeters for metric screws), the same as machine screws (page 45).

While set screws have many applications, they are not an especially strong type of fastening because they depend upon friction and a slight amount of "shear" to hold parts together. Furthermore, the cup or cone types usually raise a burr on the shaft which makes the part held to it difficult to remove.

STUDS

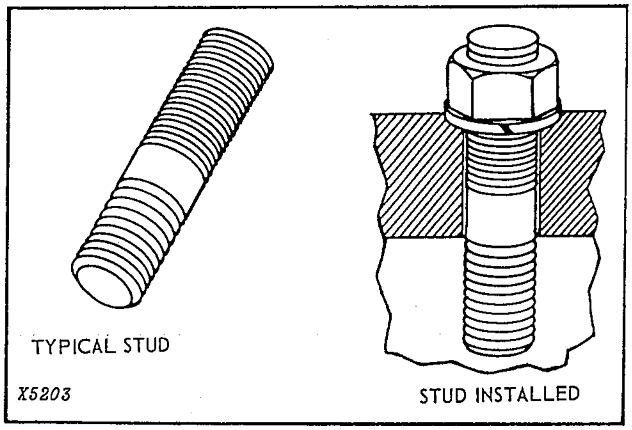


Fig. 150 — A Typical Stud

Another type of fastener is the stud (Fig. 150) which is merely a steel rod with threads on both ends.

One end is screwed into a part, other parts are assembled over the studs and screwed in place with a nut. Sometimes a lock washer is also used.

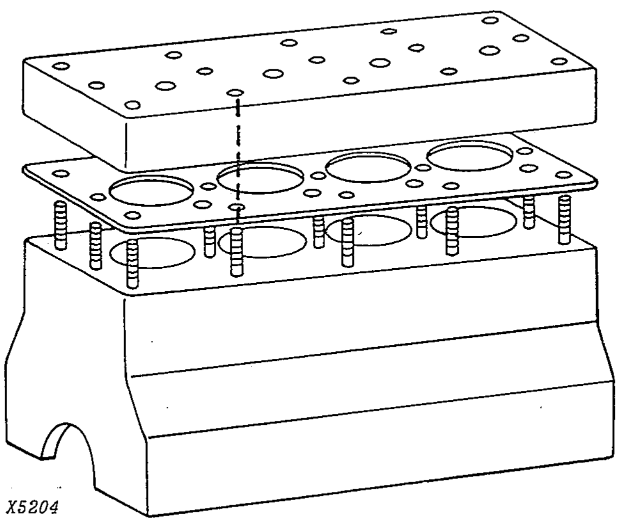


Fig. 151 — How Studs Simplify the Assembly of Several Parts

The advantages of studs over bolts and nuts or cap screws is primarily in manufacturing processes. During assembly of an engine, for instance, they act as *pilots*. You can see how much easier it is to slip a gasket and cylinder head onto studs screwed into the cylinder block (Fig. 151) rather than to line up many holes through the head and gasket for cap screws.

Some studs have coarse threads on one end and fine threads on the other. One type has coarse interference threads on the "tap" end that are larger than the threads in the tapped hole. When the stud is screwed into place the stud threads compress, creating a locking action.

Most studs should not be installed so far that they "bottom" in the tapped hole. To do so may cause the stud to fail, may damage the threads in the tapped hole, or if oil is used, develop a hydraulic lock (page 36).

TAPER-LOCK STUDS

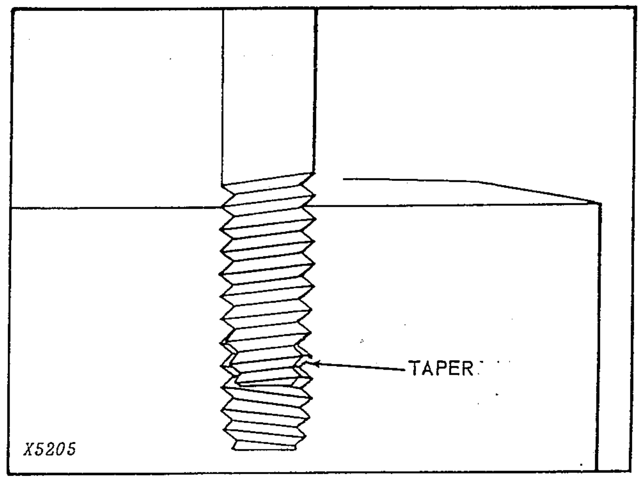


Fig. 152 — A Taper Lock Stud

Another type of stud is called the *taper-lock* (Fig. 152). The tap end is tapered and the mating hole is tapered in the same manner.

A taper-lock stud screws in easily and, unlike other studs, hits the bottom of the hole where the taper or *chamfer* wedges it tightly in place.

Taper lock studs can be unscrewed quite readily and may require tightening or sealing with a sealant if they loosen.

The most common extractor, which has become known as an "Ezy-Out" is a hardened, tapered rod with coarse, sharp, left-handed spirals, resembling threads (Fig. 157). A "flat" on top is provided so the tool can be turned with a wrench.

To use the extractor a hole is drilled in the exact center of the stud. This must be done carefully; most studs are hard and difficult to drill. Extractor kits are available with guides (Fig. 157) that center the drill in the hole and keep it straight.

The extractor is inserted into the hole where it securely bites into the stud and allows it to be unscrewed. Extreme care must be taken to avoid breaking the extractor off in the stud. Very difficult removals should probably be made by a good machinist.

Extractor sets contain extractors in several sizes, guides in several sizes to center the drill, and other useful items.

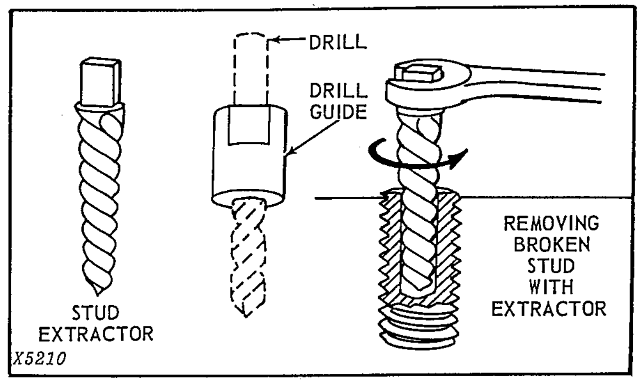


Fig. 157 — Extractor for Removing Broken Studs

NOTE: Although these tools are commonly called stud removers, they can also be used to remove broken bolts and cap screws.

PINS

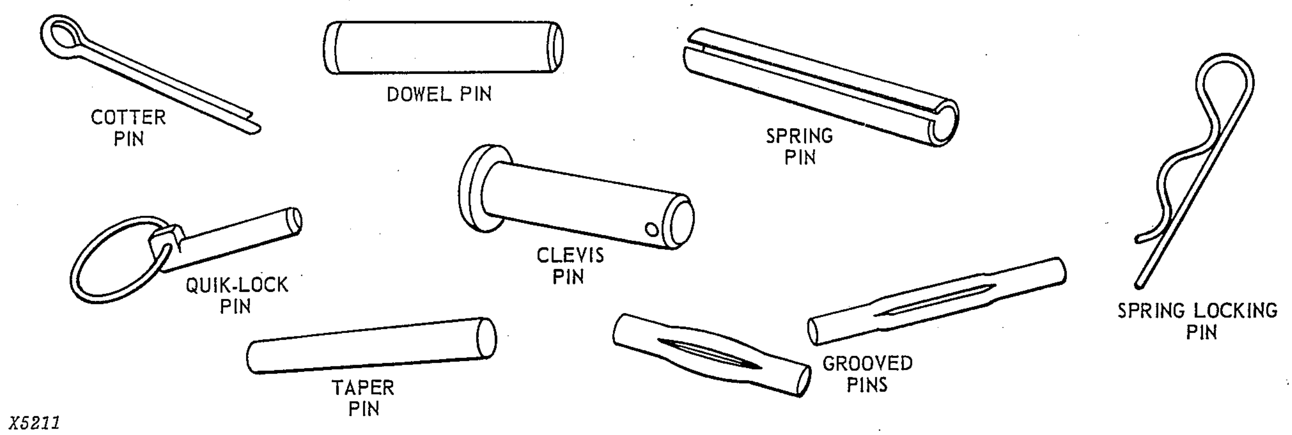


Fig. 158 — Some Frequently Used Pins

Few manufacturers of machines and similar products could get along without pins (Fig. 158) of one kind or another. In their many forms, pins are convenient fasteners, utilized in many ways.

CLEVIS OR HEADED PINS

The simplest pin, perhaps, is a headed pin, sometimes called a *clevis* pin because it is used to attach a part to a U-shaped yoke known as a *clevis* (Fig. 159).

Headed pins are usually drilled on the end opposite the head for insertion of a cotter pin or one of several types of special "convenience" pins.

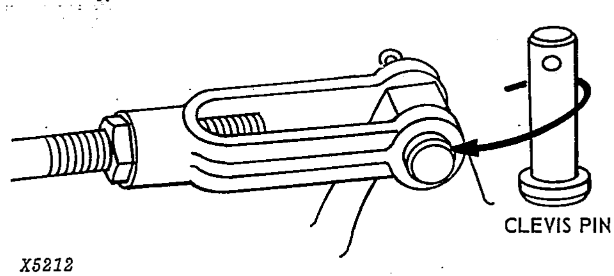


Fig. 159 — A Clevis Pin Used to Attach a Yoke

SNAP RINGS

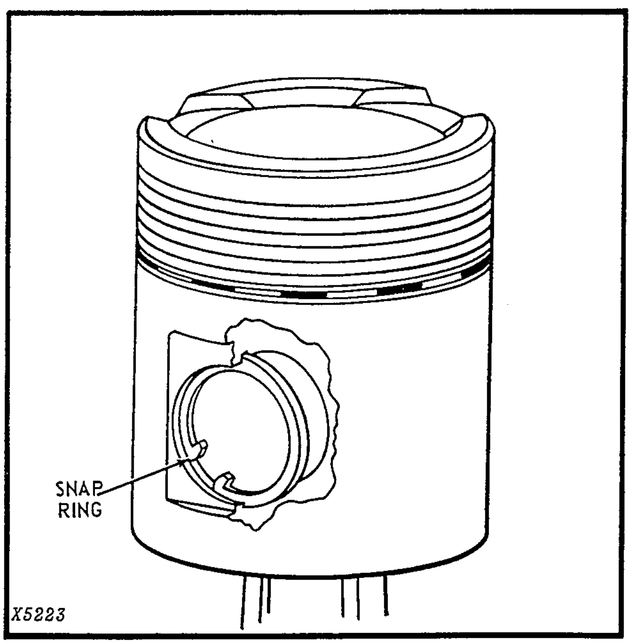


Fig. 170 — A Snap Ring Secures the Wrist Pin in a Piston

There are many applications where there's a need for a removable *shoulder* to accurately locate, retain, or lock components on shafts and in bores and housings. A good example is the wrist pin that connects the connecting rod to the piston in an internal combustion engine (Fig. 170).

The wrist pin is kept from slipping out of its bore by a spring steel *snap ring* at each end. The snap ring fits into a circular groove in the wrist pin hole in the piston wall near the end of the pin.

Because these rings keep parts in place, they are often called *retaining rings* or *lock rings.*
There are two basic styles of snap rings: internal and external.

INTERNAL SNAP RINGS

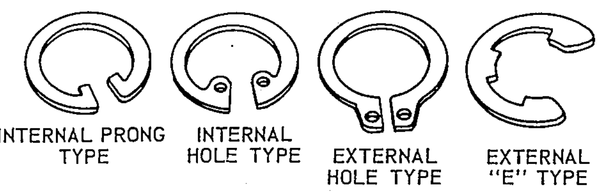


Fig. 171 — Typical Snap Rings

Internal snap rings (Fig. 171), like the wrist pin retainer described above, fit *inside* a hole and so are called "internal."

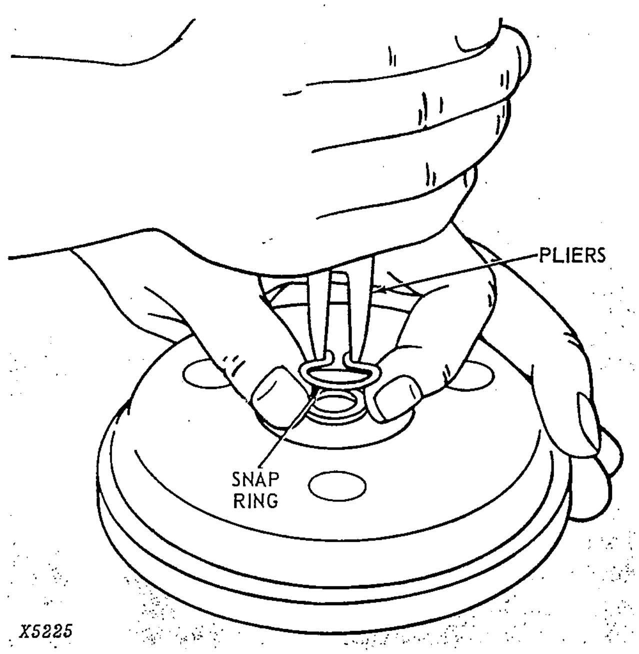


Fig. 172 — Removing an Internal Snap Ring

The prong-type ring is removed or installed by grasping the two prongs with pliers and compressing the ring until it slips from its groove. Fig. 172 shows an internal snap ring being removed from the drive plate of the compressor for a modern tractor or combine air conditioner. To install the ring, it is compressed and inserted into its groove. When released, it will spring outward and firmly seat itself in the groove.

Another type of internal snap ring has two holes that can be engaged by the tips of a special snap ring plier (Fig. 172, previous page).

EXTERNAL SNAP RINGS

External snap rings are installed around a shaft, rather than in a groove around a hole. Many bearings are located on and locked to their shafts this way.

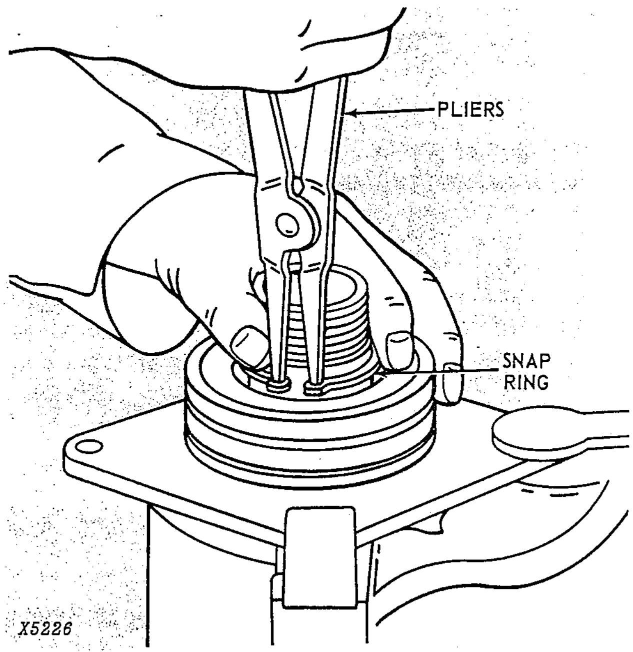


Fig. 173 — Removing an External Snap Ring

Most external rings are removed and installed by means of a special plier. The jaws on this plier *open up* (Fig. 173) when the handles are squeezed, instead of closing as do the jaws on regular pliers.

Small shafts are often locked in place with an external "E" snap ring (Fig. 171, previous page), usually removed or installed with ordinary pliers.

Snap rings can be formed out of wire or can be punched from flat material. They are generally reusable unless they are damaged or broken.

In addition to the snap rings described and illustrated, there's a wide variety of shapes and sizes, too numerous to be discussed in this manual.

There are so many that if a replacement is needed, it must be accurately identified.

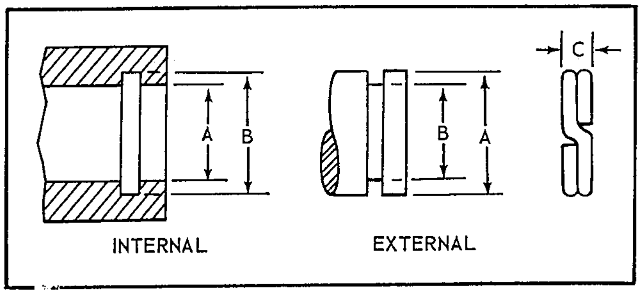


Fig. 174 — How Snap Rings Are Measured

Typical measurements are bore diameter (A, Fig. 174), groove diameter (B), and ring width (C). Note that "A" is the *inside* diameter and "B" the *outside* diameter of internal snap rings. In the case of external rings, "A" is the *outside* diameter and "B" the *inside* diameter.

In addition to measurements, snap rings are identified by appearance and prong design.

RIVETS

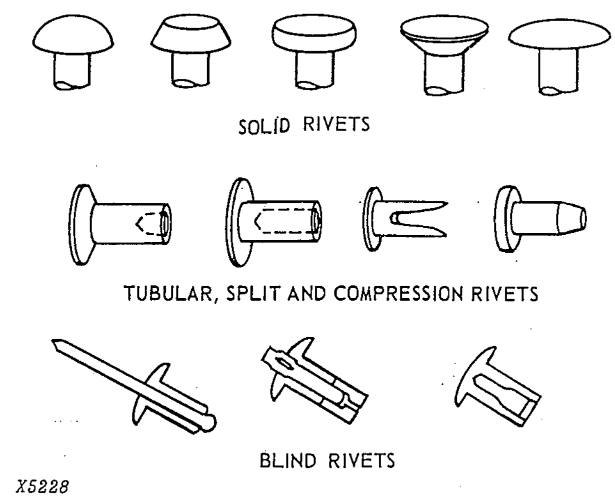


Fig. 175 — Some Frequently Used Rivets

A very useful family of fasteners consists of rivets — soft metal pins with a head on one end (Fig. 175). They are low in cost, installed at high-speed, permanent, and versatile.

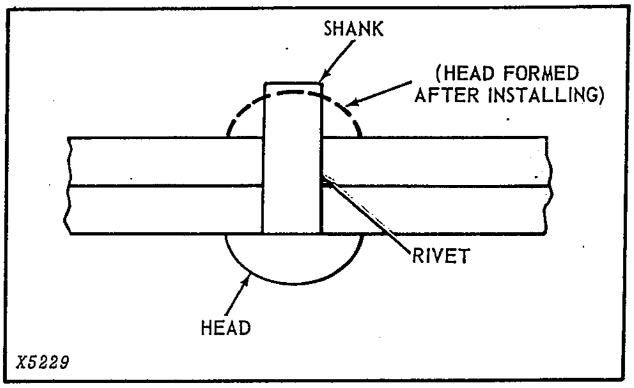


Fig. 176 — How Rivets Are Installed

Common solid rivets are used primarily to hold two or more flat, parallel parts together. The parts are drilled or punched, a rivet inserted into the matching holes (Fig. 176), and a second head formed on the other end of the rivet, called the *shank*.

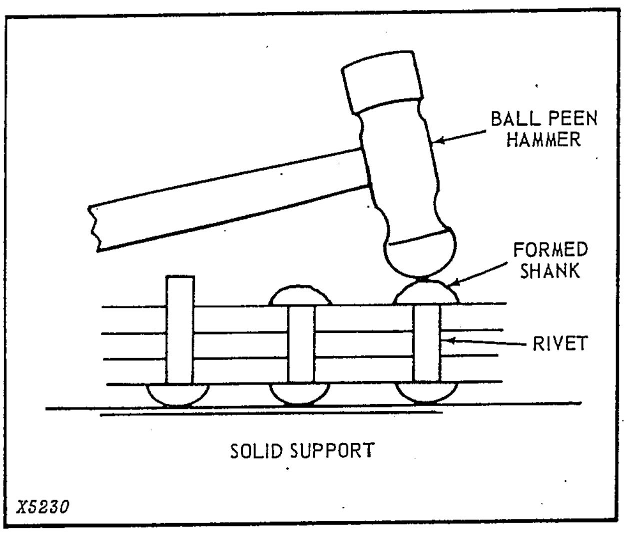


Fig. 177 — Peening the Second Head of a Rivet

A large shop may have a riveting machine to form the second head. More commonly, the second head is peened or formed by a mechanic using a *ball peen* hammer (Fig. 177). While doing this, the rivet head must be "bucked" or pressed against something solid as the second head is formed; otherwise, it will not grip securely.

Like other fasteners, rivets come in many sizes with a variety of head shapes. Some of the most common are illustrated in Fig. 178.

The size of rivets in common use ranges from 3/32 inch to 1½ inches (1 to 36 mm) in diameter and most any practical length. A ⅞-inch (or 22 mm) diameter rivet is about the largest that can be peened by hand.

BLIND RIVETS

These useful fasteners, intended only for light duty usage, can be installed in a joint which is accessible from one side only. This construction is often said to have a "blind hole." There are several types of blind rivets.

One type in common use requires a special tool to install it. After the rivet is inserted, the tool pulls a stem up through the hollow center and forms the second head (Fig. 179); the stem is then broken off.

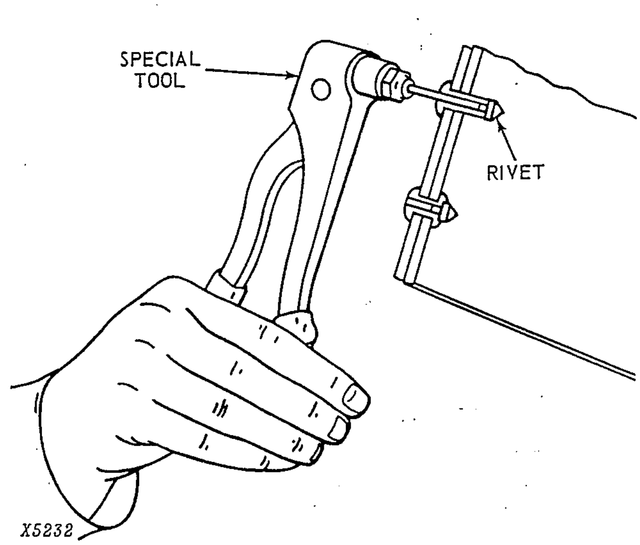


Fig. 179 — Installing a Special Rivet in a "Blind" Hole

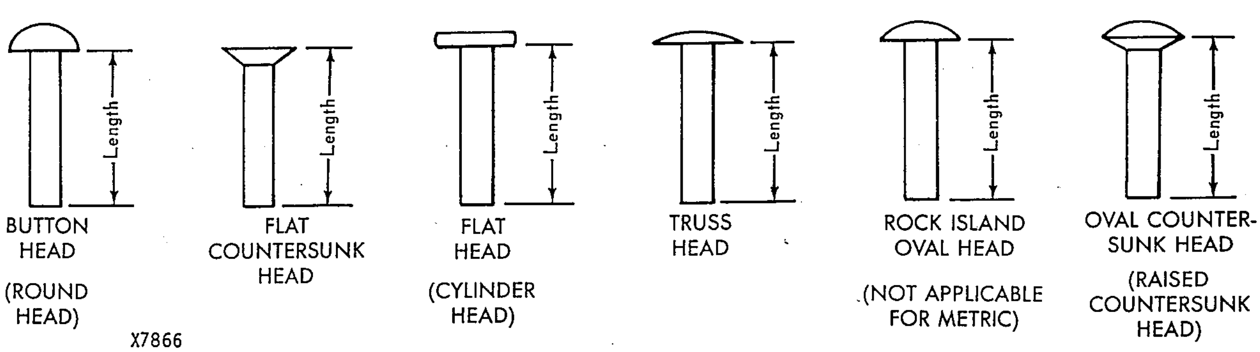
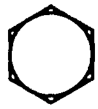
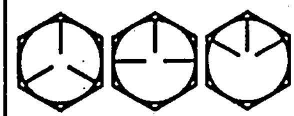
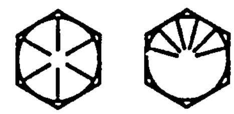
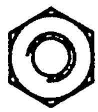
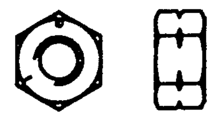
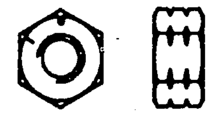


Fig. 178 — Typical Rivet Head Styles (Metric Nomenclature in Parentheses)

Litho in U.S.A.

UNIFIED INCH BOLT AND CAP SCREW TORQUE VALUES

SAE Grade and Head Markings	NO MARK	1 or 2[b] 	5 5.1 5.2 	8 8.2 
SAE Grade and Nut Markings	NO MARK	2 	5 	8 

Size	Grade 1				Grade 2[b]				Grade 5, 5.1, or 5.2				Grade 8 or 8.2			
	Lubricated[a]		Dry[a]		Lubricated[a]		Dry[a]		Lubricated[a]		Dry[a]		Lubricated[a]		Dry[a]	
	N·m	lb-ft	N·m	lb-ft	N·m	lb-ft	N·m	lb-ft	N·m	lb-ft	N·m	lb-ft	N·m	lb-ft	N·m	lb-ft
1/4	3.7	2.8	4.7	3.5	6	4.5	7.5	5.5	9.5	7	12	9	13.5	10	17	12.5
5/16	7.7	5.5	10	7	12	9	15	11	20	15	25	18	28	21	35	26
3/8	14	10	17	13	22	16	27	20	35	26	44	33	50	36	63	46
7/16	22	16	28	20	35	26	44	32	55	41	70	52	80	58	100	75
1/2	33	25	42	31	53	39	67	50	85	63	110	80	120	90	150	115
9/16	48	36	60	45	75	56	95	70	125	90	155	115	175	130	225	160
5/8	67	50	85	62	105	78	135	100	170	125	215	160	215	160	300	225
3/4	120	87	150	110	190	140	240	175	300	225	375	280	425	310	550	400
7/8	190	140	240	175	190	140	240	175	490	360	625	450	700	500	875	650
1	290	210	360	270	290	210	360	270	725	540	925	675	1050	750	1300	975
1-1/8	470	300	510	375	470	300	510	375	900	675	1150	850	1450	1075	1850	1350
1-1/4	570	425	725	530	570	425	725	530	1300	950	1650	1200	2050	1500	2600	1950
1-3/8	750	550	950	700	750	550	950	700	1700	1250	2150	1550	2700	2000	3400	2550
1-1/2	1000	725	1250	925	990	725	1250	930	2250	1650	2850	2100	3600	2650	4550	3350

DO NOT use these values if a different torque value or tightening procedure is given for a specific application. Torque values listed are for general use only. Check tightness of fasteners periodically.

Shear bolts are designed to fail under predetermined loads. Always replace shear bolts with identical grade.

Fasteners should be replaced with the same or higher grade. If higher grade fasteners are used, these should only be tightened to the strength of the original.

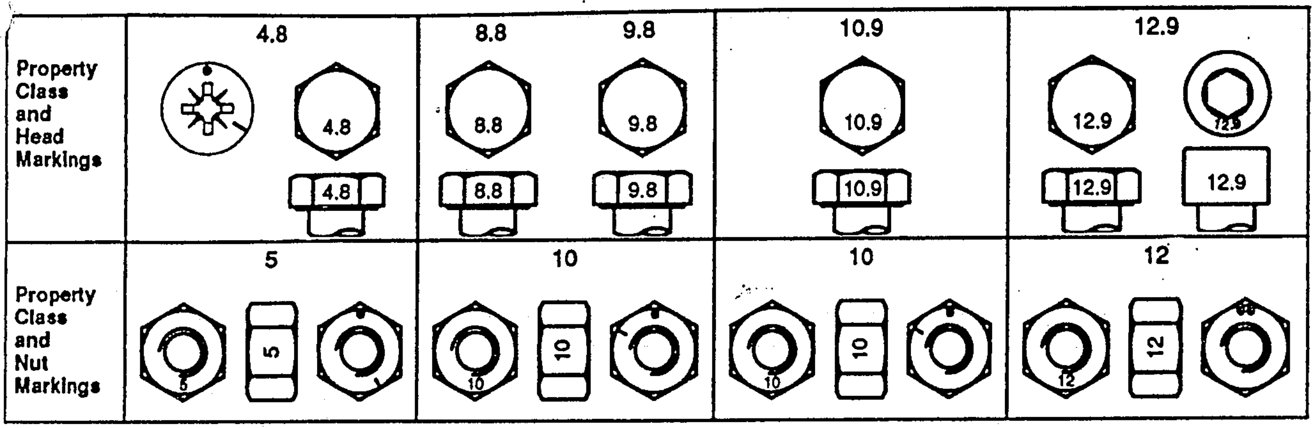
Make sure fasteners threads are clean and that you properly start thread engagement. This will prevent them from failing when tightening.

Tighten plastic insert or crimped steel-type lock nuts to approximately 50 percent of the dry torque shown in the chart, applied to the nut, not to the bolt head. Tighten toothed or serrated-type lock nuts to the full torque value.

[a] *"Lubricated" means coated with a lubricant such as engine oil, or fasteners with phosphate and oil coatings. "Dry" means plain or zinc plated without any lubrication.*

[b] *Grade 2 applies for hex cap screws (not hex bolts) up to 152 mm (6-in.) long. Grade 1 applies for hex cap screws over 152 mm (6-in.) long, and for all other types of bolts and screws of any length.*

METRIC BOLT AND CAP SCREW TORQUE VALUES ←



Size	Class 4.8				Class 8.8 or 9.8				Class 10.9				Class 12.9			
	Lubricated[a]		Dry[a]		Lubricated[a]		Dry[a]		Lubricated[a]		Dry[a]		Lubricated[a]		Dry[a]	
	N·m	lb-ft	N·m	lb-ft	N·m	lb-ft	N·m	lb-ft	N·m	lb-ft	N·m	lb-ft	N·m	lb-ft	N·m	lb-ft
M6	4.8	3.5	6	4.5	9	6.5	11	8.5	13	9.5	17	12	15	11.5	19	14.5
M8	12	8.5	15	11	22	16	28	20	32	24	40	30	37	28	47	35
M10	23	17	29	21	43	32	55	40	63	47	80	60	75	55	95	70
M12	40	29	50	37	75	55	95	70	110	80	140	105	130	95	165	120
M14	63	47	80	60	120	88	150	110	175	130	225	165	205	150	260	190
M16	100	73	125	92	190	140	240	175	275	200	350	225	320	240	400	300
M18	135	100	175	125	260	195	330	250	375	275	475	350	440	325	560	410
M20	190	140	240	180	375	275	475	350	530	400	675	500	625	460	800	580
M22	260	190	330	250	510	375	650	475	725	540	925	675	850	625	1075	800
M24	330	250	425	310	650	475	825	600	925	675	1150	850	1075	800	1350	1000
M27	490	360	625	450	950	700	1200	875	1350	1000	1700	1250	1600	1150	2000	1500
M30	675	490	850	625	1300	950	1650	1200	1850	1350	2300	1700	2150	1600	2700	2000
M33	900	675	1150	850	1750	1300	2200	1650	2500	1850	3150	2350	2900	2150	3700	2750
M36	1150	850	1450	1075	2250	1650	2850	2100	3200	2350	4050	3000	3750	2750	4750	3500

DO NOT use these values if a different torque value or tightening procedure is given for a specific application. Torque values listed are for general use only. Check tightness of fasteners periodically.

Shear bolts are designed to fail under predetermined loads. Always replace shear bolts with identical property class.

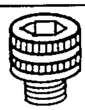
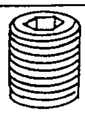
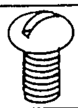
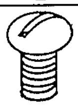
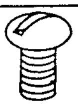
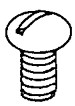
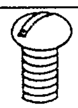
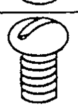
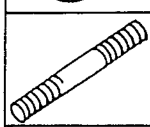
Fasteners should be replaced with the same or higher property class. If higher property class fasteners are used, these should only be tightened to the strength of the original.

Make sure fasteners threads are clean and that you properly start thread engagement. This will prevent them from failing when tightening.

Tighten plastic insert or crimped steel-type lock nuts to approximately 50 percent of the dry torque shown in the chart, applied to the nut, not to the bolt head. Tighten toothed or serrated-type lock nuts to the full torque value.

[a] "Lubricated means coated with a lubricant such as engine oil, or ...teners with phosphate and oil coatings. "Dry means plain or zinc ...ted without any lubrication.

Miscellaneous Fasteners Torque Values

Fastener	Type	Minimum Tensile Strength	Material	Body Size or Outside Diameter									
				2	3	4	5	6	8	10	1/4	5/16	3/8
	SOCKET HEAD CAP SCREW	160,000 PSI	HIGH CARBON QUENCHED TEMPERED								16 (22)	33 (45)	54 (73)
	SOCKET SET SCREW	212,000 PSI	HIGH CARBON QUENCHED TEMPERED					9*	16*	30*	70*	140*	18 (24)
	MACHINE SCREW STAINLESS		18-8	2.6* (294)	4* (452)	5.5* (622)	8* (904)	10* (1130)	20* (2260)	23* (2599)	75* (8475)	132* (14916)	20 (27)
	MACHINE SCREW STAINLESS		316	2.7* (305)	4* (452)	5.7* (644)	8* (904)	10* (1130)	22* (2486)	25* (2825)	80* (9040)	140* (15820)	22 (30)
	MACHINE SCREW YELLOW BRASS	60,000 PSI	CU 63 ZN 37	2* (226)	3.3* (3729)	4.4* (497)	6.4* (723)	8* (904)	16* (1808)	20* (2260)	65* (7345)	110* (12430)	17 (23)
	SILICONE BRONZE TYPE "B"	70,000 PSI	CU 96 ZNI - 5 MIN	2.3* (260)	3.7* (418)	4.9* (554)	7.2* (814)	10* (1130)	19* (2147)	22* (2486)	70* (7910)	125* (14125)	20 (27)
	MACHINE SCREW ALUMINUM	55,000 PSI	CU 3.8 - 4.9 1.2 - 1.8 MN .3 - .9	1.4* (158)	2.1* (237)	2.9* (328)	4.3* (486)	5.4* (610)	12* (1356)	15* (1695)	46* (5198)	82* (9266)	13 (18)
	MACHINE SCREW MONEL	82,000 PSI	NI 67 CU 30 FE 1.4	2.5* (283)	4* (452)	5.5* (622)	8* (904)	11* (1243)	21* (2373)	27* (3051)	87* (9831)	155* (17515)	23 (31)
	SEM 5 HEAT TREATED STEEL	120,000 PSI	1018 1022	4* (452)	5* (565)	7* (791)	11* (1243)	15* (1695)	27* (3051)	37* (4181)	90* (10170)	200* (22600)	330* (37290)
	STUDS	Use SAE 2, 5 and 8 values when grade is known, with nut of sufficient strength.											
	TAPPING SCREW	Set up joint as it will be in production. Use 70% of overtorque failure as production specifications.											

PREVENTIVE MAINTENANCE

Learning Objective: The student will have an understanding of PM intervals and the importance of PM to UTA.

Task: The student should be able to identify and explain the following terms.

Standard: The student will complete a written examination in which he/she will attain a minimum score of 80% to pass the written test.

Road-call mileage
PM interval
Cost savings
Oil samples
Oil change interval
Inspection sheets

Inspection sheets: Please familiarize yourself with the PM Inspection sheets that are in this section.

November 2, 1999

The Importance of Preventive Maintenance to U.T.A.

Recent years have seen a dramatic increase in the demand for service provided by UTA. This increase, in part, is due to significant increases in the cost and shortages (real or unreal) of energy. But mostly due to the rising population causing over crowding of the major traffic arteries. If UTA is to maintain the growth pattern of the past years, it will be necessary to provide expanded, convenient, inexpensive, and above all reliable service. This is where **YOU** come in. This places a lot of pressure on the maintenance department. Reliability and ensuring there are buses available for service without breakdowns, is one of the most important factors to the public.

Improved operator skills and training can do a lot to improve reliability, but good bus preventive maintenance is the most important factor in improving and maintaining good and reliable transit service. The following outlines the necessity of a good PM inspection program.

- In addition to improving our public image and providing our customers with the best transportation value possible. Breakdowns cost UTA an enormous amount of money every year. An effective Preventive Maintenance program can significantly reduce these costs.

- Along with saving money, we have extended our road call mileage from 700 miles between road calls in 1979, to around 8,000 miles today.

Rebuilding engines or transmissions, and doing tune-ups are usually considered the more glamorous or desired jobs, but PM is where we can make the greatest impact on the fleet. In fact, if the PM inspectors are trained right and do their job correctly, they can eliminate a lot of breakdowns that are occurring, and the need for other repairs like engine overhauls.

Therefore, the Maintenance Department values the importance of Preventive Maintenance.

Inspection Intervals

- We found that in the Transit industry, oil change intervals ranged from 3,000 to 20,000 miles plus. It was decided that the short 3,000 mile intervals would not be economically feasible unless there was a continued problem with things like fuel dilution, etc. Today's oils are capable of much more than 3,000 miles and it is our goal to develop a condition based monitoring system that will dictate oil change intervals.

- Transit coaches at UTA are inspected and serviced every 3,000 miles. The inspection schedule for all coaches is as follows:

MILEAGE	INSPECTION	INTERVAL
3000	E	3000
6000	D	6000
9000	E	3000
12000	C	12000
15000	E	3000
18000	D	6000
21000	E	3000
24000	B	24000

MILEAGE	INSPECTION	INTERVAL
27000	E	3000
30000	D	6000
33000	E	3000
36000	C	12000
39000	E	3000
42000	D	6000
45000	E	3000
48000	A	48000

- E Inspection 3000 miles
- D Inspection 6000 miles
- C Inspection 12000 miles
- B Inspection 24000 miles
- A Inspection 48000 miles

Preventive Maintenance is a very important program to UTA. Its success is a key factor in making efficient use of the dollars spent for transit in this state. The future of transit in Utah demands that we make every effort to provide the safest, most reliable, cost-effective transportation possible, to the public.

Oil Analysis

UTA has implemented an extensive oil analysis program to complement its ambitious Preventive Maintenance System. UTA is forward looking and intends to improve its maintenance programs by moving toward proactive maintenance - effective oil sampling and analysis is an important first step in this evolutionary process.

Recently, the question was posed "Why oil sample?" it costs so much!" After some debate about the advantages of what can be achieved by oil analysis, it was determined that a few dollars spent towards maintenance and condition monitoring is much better than a downtime problem that could cost thousands.

That's not really all that uncommon in today's safeguarding environments, however the challenge is getting timely oil analysis implemented... and adopted by everyone on the maintenance team.

There are many types of oil analysis tests that can be run to help determine "Root Cause Failure" of your equipment. It all depends on what type of "maintenance concept" you are trying to achieve for your organization. Basically, there are four types of maintenance concepts that most of us use:

1. **Unplanned Maintenance:**
   a. Very high maintenance cost
   b. Short component life
   c. No time for failure analysis
2. **Preventive Maintenance:**
   a. Moderately high maintenance cost
   b. Over and under maintained equipment
   c. Short component life
3. **Predictive Maintenance:**
   a. Reduced maintenance cost
   b. Increase production
   c. Increased component life
4. **Proactive Maintenance:**
   a. Root cause analysis guides your maintenance action.
   b. Reduces the number of breakdowns
   c. Tending to develop unique component history

The main reason for performing oil analysis testing is to improve the quality of equipment and machinery maintenance decisions. Without this data, we run in the "Unplanned Maintenance" zone and spend more money repairing machinery and equipment that usually could have been detected by oil sampling.

There are basically three categories of oil analysis testing:

1. **Wear Metal Debris Analysis**
2. **Fluid Properties (Oil condition)**
3. **Contamination**

To run a company to a "Proactive" level of maintenance, usually involves doing all three tests as a necessity. But most of all, the Fluid Properties and Contamination categories are the most commonly used tests. This way one can determine if the oil is safe for continued use and what environmental elements are entering into the equipment's vital components.

Here are a few of the tests that can be used to establish a condition based monitoring system and reduce maintenance costs.

1. **TAN = Total Acid Number**
2. **TBN = Total Base Number**
3. **Particle Count**
4. **Viscosity**
5. **FTIR = Fourier Transform Infrared Spectroscopy**
6. **Analytical Ferrography**
7. **Ferrous Density**

Fleet Engineering
MEMORANDUM

To: GEORGE BRYANT, Salt Lake Business Unit Maintenance Manager
REED SNYDER, Transportation Team Manager of Timpanogos
BRUCE CARDON, Transportation Team Manager of Mount Ogden
ROD STAPLES, Division Maintenance Manager of Meadowbrook
MIKE SHAFFER, Division Maintenance Manager of Central
FELIX MONTANEZ, Assistant Manager Paratransit Maintenance

From: Kurt Burningham, Fleet Engineering
Date: **Revised** September 9, 2005
Subject: OIL SAMPLING AND ANALYSIS PROCESS – VMRS 4000

UTA uses *LubeTrak* to handle our oil analysis and oil analysis data. This document outlines the oil analysis process from beginning to end. Please discard any previous oil sampling information.

Why Oil Analysis?
When simply put, oil analysis is using complex tests to determine the level of impurities in a given sample of oil. Laboratories test for things like Viscosity, Particles, TAN, TBN, Soot, Additives etc. These tests help determine if proactive steps should be taken to prevent damage to a piece of machinery. By analyzing the oil, a lot can be learned about a machine's internal condition.

How Often Do We Take A Sample?
While each division has responsibility to make decisions for their fleet, and can take samples more often, below are recommended sample intervals:
Engines: at every other oil change (6,000 miles for small engines like 7.3 liter Fords, or 12,000 miles for all large engines).
Transmissions: every 24,000 miles.
Differentials: as needed (to assist in problem solving).
Hydraulics (steering etc.): as needed (to assist in problem solving).

When And Where Should The Sample Be Taken?
Ideally, scheduled engine and transmission oil samples should be taken a few days before the oil is going to be drained. That way, if a problem is found with the component, corrective steps can be taken before the oil is drained – this potentially saves wasted oil and filters.

At UTA, taking the sample before the oil is drained means that as soon as the division is notified that an oil change inspection is due, the samples should be pulled from the bus. Where possible, take the sample on the fuel island, as the bus is being fueled.

Samples for troubleshooting purposes can be taken anytime and anywhere they are deemed necessary. Just make sure the sample's label states what is being tested and why.

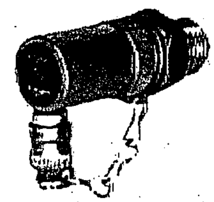
How To Take The Sample?
While there are different methods of obtaining the sample, a few things pertain to each:

- The equipment (engine or transmission) should be at operating temperature.
- A great amount of care must be used to ensure that the sample does not get contaminated. This means flushing sample valves whenever possible, not reusing sample bottles, needles or tubes, and keeping all items used to collect the sample clean (not allowing anything to come in contact these items). What seems like a minor contamination can, in fact, greatly compromise the integrity of the sample. Even putting the sample bottle cap in your pocket can cause this contamination (sweat, lint, copper, nickel, dirt).

Warning: Be very careful when working around the engine compartment. Some surfaces are HOT! Never allow hands or loose clothing to come near turning belts or pulleys. Use appropriate protective equipment to protect yourself from oil, heat, etc.

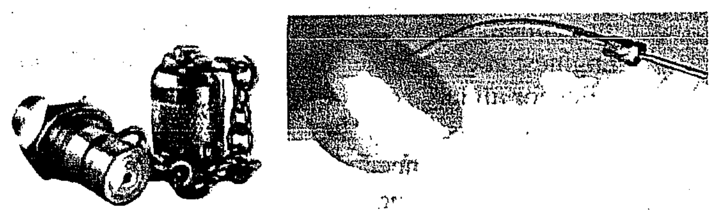
The sample methods listed below are from best to worst.

1. **Pushbutton sample valve (P/N KP18NV):**
   - Use a new sample bottle.
   - Run engine to warm component being tested up to operating temperature.
   - Remove valve cap and wipe spout area clean.
   - With engine running, push the end of the valve to flush a small amount of oil into a separate container before collecting sample into sample bottle.
   - Fill sample bottle about 80% full.
   - Replace valve cap.



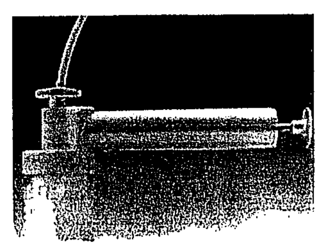
Pushbutton Valve

2. **Probalizer sample valve (P/N OD1014):**
   - Use a new sample bottle, needle and tube.
   - Run engine to warm component being tested up to operating temperature.
   - Remove valve cap and wipe spout area clean.
   - With engine running, insert the new needle into the valve and flush a small amount of oil into a separate container before collecting sample into sample bottle.
   - Fill sample bottle about 80% full.
   - Replace valve cap.



Probalizer Sample Valve

3. **Vampire suction pump from reservoir:**
   - Make sure the pump is clean and attach a new sample bottle to it.



Vampire Sample Valve

- Run engine to warm component being tested up to operating temperature.
- Remove dipstick.
- Wipe as much dirt from dipstick and tube area as possible.
- Cut a length of new, clean tubing to match length of dipstick.
- Immediately after running engine, run tubing down dipstick tube while trying to limit the amount of contamination it picks up form dipstick tube. Try to make sure tubing takes a mid-pan sample – never from bottom of pan.
- Use pump to draw oil into sample bottle until it is about 80% full.
- Replace dipstick.

4. **Midstream sample from reservoir/pan:**
This sampling method is ONLY used for differentials or when other methods are unavailable, (i.e. engine will not run).
   - Use a new sample bottle.
   - Where possible, warm engine to operating temperature.
   - Remove reservoir/pan drain plug.
   - Allow oil to drain for 10-15 seconds so a mid-stream sample can be taken.
   - Fill sample bottle about 80% full.

What To Do With The Sample After Obtaining it.

- Attach the LubeTrak label that came with the sample bottle to the bottle containing the oil.
  - Write the unit number and description on this label. The description line is used to give CTC additional instructions on why a sample is being tested.
- Print out a UTA oil sample label for the bus and place the UTA label in the black shipping bottle with the bottle containing the oil. Do not attach the UTA label to either bottle.
  - The information on the LubeTrak label identifies to CTC that this test is being done for one of LubeTrak's customers.
    - Test package (color) – this tells CTC what level of analysis to perform.
    - Customer Number – this tells LubeTrak where to send and post the test results.
  - The UTA label has the rest of the information needed by CTC and LubeTrak.

Note: If for any reason you are unable to use the UTA label, fill out the LubeTrak label by hand with information obtained from JD Edwards and/or Fuel & Oil.

- Make sure the sample bottle cap is tight.
- Place the bottle into the black shipping bottle. Make sure the shipping bottle cap is tight.
- Do not discard the boxes the shipping bottles come in. Send them to the warehouse for use in shipping samples to CTC.
- The sooner the samples are sent off, the sooner you can see and interpret the data. Therefore, as soon as possible, collect all samples and give them to the courier for delivery to the warehouse. After the samples have been taken, do not allow them to sit around.
- As soon as the warehouse has at least 15 samples, all samples are placed into boxes and delivered by UTA courier to Greyhound Bus Lines in downtown SLC. (Samples are shipped from UTA every weekday at approximately 7:30 a.m.)
- Greyhound will then transport the samples to CTC Analytical Services in Sparks, Nevada for analysis.
- LubeTrak works with CTC to collect and post the data for use by UTA. All samples received will be available for viewing within 24 hours of delivery to CTC.

How To See And Interpret The Data.

- Log on to www.lubetrak.com.
- Click on My LubeTrak Login near the top of the screen.
- Enter the Username and Password for your division.
- The screen that appears shows the new samples that LubeTrak has posted for your division.
- From here you can view results and run reports on individual samples, groups of samples or on your fleet.
- LubeTrak will notify your shop – via E-mail and Fax – of all "Critical" conditions found in any equipment in your fleet.
- **Remember, in addition to being warned of "Critical" and "Abnormal" situations, one of the greatest values of oil analysis is in "Trend Analysis".** That means viewing samples over time (by charts and graphs) to see how wear metals vary. If tracked over time, trends can show a problem developing even when there is no Critical warning.
- When in LubeTrak's main web site, before logging in, you can go to the Newsletter Archives to see important information concerning oil analysis.
- After logging on to LubeTrak's Web site under your division's name, clicking on Services and then Knowledge Library will give you another menu of items about oil analysis. Here you can find information on limit levels of the different contaminants. Of particular interest are:
  - **Transit Alarm Limits – Diesel Engines**
  - **Transit Automatic Transmission Alarm Limits**
    - **Both of the above library items are going to change soon. Changes are being done to make the charts more closely reflect UTA's needs.**

Contacts:

Questions with procedures – Kurt Burningham @ 3040 or Allen Bryant @ 2546.
Questions with contract, bus locations etc. – Bruce Hone @ 3217.
Questions with LubeTrak – Brett Winberg @ (801) 501-7746.

c.c. Doug Woodbury, Randy Welsh, Shawn DeWitt, Mary Kay Bonica, Jesse Stone, Jeff Allen, Jay Moser, John Knight, Felix Montanez, Don Stanger

What is Proactive Maintenance?

According to major industries throughout the world, it's time to throw out your old ideas on machine maintenance. The cost-saving trend is toward a maintenance program that targets the root causes of machine wear and failure. Predictive and preventive methods are out: proactive maintenance methods are in. Why? Because proactive maintenance methods are currently saving industries of all sizes thousands, even millions, of dollars on machine maintenance every year. This concept of saving large amounts of maintenance, however, may be tough for some to grasp. According to DuPont, "maintenance is the largest single controllable expenditure in a plant." In many companies it often exceeds annual net profit. The problem of costly maintenance has truly reached a serious level, but as some companies have found out, and more come to realize every day, their maintenance costs can be cut drastically by establishing a "proactive" line of defense.

Getting to the Root of the Problem

When it comes to the life of any machine, whether it's a lawn mower or a 1,000 h.p. bulldozer, cleanliness counts. Laboratory and field tests show that more than any other factor, fluid contamination is the number one culprit of equipment failure - even the most microscopic particles can eventually grind a machine to a halt. Yet, the accepted methods currently being used to combat machine damage are based on either detecting the warning signs of failure once they've already begun (predictive) or regular maintenance according to a schedule rather than the machine's true condition (preventive). No discipline has previously taken a micro view on machine damage - concentrating on the causes instead of the symptoms of wear. Proactive maintenance is that discipline, and it is quickly being recognized worldwide as the single most important means of achieving savings unsurpassed by conventional maintenance techniques.

Proactive vs. Preventive/Predictive

Imagine being able to pinpoint and eliminate a disease long before any symptoms occur in your body. It would save you money in doctor bills and keep you out of the hospital in the long run. This is the advantage of proactive maintenance over predictive maintenance. Proactive maintenance commissions corrective actions aimed at he sources of failure. It is designed to extend the life of mechanical machinery as opposed to 1) making repairs when often nothing is broken, 2) accommodating failure as routine and normal, and 3) preempting crisis failure maintenance - all of which are characteristics of the predictive/preventive disciplines. While effective to a degree, neither preventive nor predictive maintenance is geared to detect the most common and serious failure culprit: contamination. Therefore, the first logical step to proactive maintenance is the implementation of a strict contamination control program for lubrication fluids, hydraulic fluids, gear oils, and transmission fluids.

The Steps to Contamination Control

Heat, moisture, air and particles literally rob fluids and lubricants of life. But with rigid contamination control practices, these fluids and lubricants can last indefinitely which, in turn, prolongs the life of the machine's components and keeps the machine running at the highest level of efficiency. Plus, the costs to begin a proactive contamination control program are quickly absorbed in maintenance cost savings. A basic contamination control program can be implemented in three steps:

1. Establish the target fluid cleanliness levels for each machine fluid system.
2. Select and install filtration equipment (or upgrade current filter rating) and contaminant exclusion techniques to achieve target cleanliness levels.
3. Monitor fluid cleanliness at regular intervals to achieve target cleanliness levels.

Contaminant Monitoring: The Cornerstone of Contamination Control

For the same reason you wouldn't drive a car cross country without a fuel gage, you shouldn't attempt proactive maintenance without a routine monitoring program. Monitoring will give you the information you need to ensure your machinery is operating below harmful contamination levels.

SAMPLE INSPECTION SHEETS

7/00kb

3,000 MILE "E" INSPECTION
9500, 9600, 9700 & **9900** GILLIG
MCI 9000
ORION 9100, 9200 & 9300
ELDORADO NATIONAL 9400 & 9600
TROLLEY 1,000 MILE "A" INSPECTION

BUS NUMBER	WORK ORDER NUMBER	DATE	HUBODOMETER MILES AT INSPECTION

STEAMED CLEANED	YES	NO
UNDERSTRUCTURE	___	___
ENG. COMPARTMENT	___	___
BATTERIES	___	___
FUEL TANK CAP	___	___
RADIATOR	___	___

DIVISION	
CENTRAL	___
MEADOWBROOK	___
MT. OGDEN	___
TIMPANOGOS	___

FIRST SPACE - Inspector(s) number to be used as a check off identification for work completed.
SECOND SPACE - Use this space to indicate whether an item was okay, adjusted, or repairs needed.
" 3 " = Okay - Item checked is ready for service.
" X " = Adjusted - Item checked has been replaced and is ready for service
" O " = Repairs Needed - Any item requiring repair.

Numbers in ( ) indicate P/M manual page number.

INTERIOR
__ __ Run Luminator destination sign test pattern
__ __ Mirrors
__ __ Passenger chime – next stop – aid passenger chime
__ __ Stanchion and grabrails
__ __ Seats and frames
__ __ Lights
__ __ Exit doors, touch bars, and sensitive edges

DRIVER CONTROL AREA
__ __ Horns
__ __ Windshield wipers and washer
__ __ Turn signal switches and tell-tale lights
__ __ Four way flashers/auxiliary flasher
__ __ Headlights (high & low)
__ __ Front door operation
__ __ Driver's seat and belt
__ __ All instruments and switches

EXTERIOR
__ __ Mirrors
__ __ Lights
__ __ Tires, tire air pressure, & tread depth

ENGINE COMPARTMENT
__ __ Fluid leaks
__ __ Line routing
__ __ Drain water from fuel filter water separator (when equipped)

UNDER STRUCTURE
__ __ Differential leaks and breather
__ __ Air lines and wires - leaks, cracks, and routing
__ __ Engine oil, transmission fluid and coolant leaks
__ __ All under floor equipment

LUBRICATION
__ __ Drain air box canister (6V-92 engine)
__ __ Check differential fluid level, fill if needed
__ __ Wipe off all grease fittings before greasing
__ __ King pins (#2 grease)
__ __ Steering components (not gears)(#2 grease)
__ __ Brake components (#2 grease)
__ __ Drive shaft (#2 grease)
__ __ Fan drive shaft (9000) (Ultra Duty [red])
__ __ Mirror brackets (#1 grease if fittings, MPS on ball)
__ __ Door bearings (#1 grease if fittings)
__ __ Windshield wiper pivot points (MPS)
__ __ Bike rack pivot points (MPS)
__ __ Change engine oil & filter (ElDorado National ONLY)

MISC.
__ __ 3,000 mile Lift-U inspection (if equipped)
__ __ 3,000 mile evaporative AC inspection (if equipped)
__ __ Run A/C system 15 to 20 minutes (winter if equipped)
__ __ Run Webasto 5 to 10 minutes (if equipped)

EMPLOYEE SIGNATURE	EMPLOYEE NUMBER
1	
2	
FOREMAN SIGNATURE	DATE

BUS NUMBER	WORK ORDER NUMBER	DATE	HUBODOMETER MILES AT INSPECTION

STEAMED CLEANED YES NO

UNDERSTRUCTURE ___ ___
ENG. COMPARTMENT ___ ___
BATTERIES ___ ___
FUEL TANK CAP ___ ___
RADIATOR ___ ___
Numbers in ( ) indicate P/M manual page number.

DIVISION

CENTRAL ____
MEADOWBROOK ____
MT. OGDEN ____
TIMPANOGOS ____

FIRST SPACE - Inspector(s) number to be used as a check off identification for work completed.
SECOND SPACE - Use this space to indicate whether an item was okay, adjusted, or repairs needed.
" 3 " = Okay - Item checked is ready for service.
" X " = Adjusted - Item checked has been replaced and is ready for service
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INTERIOR
___ ___ Destination signs, route boxes (2-1)
___ ___ Fare card holder and schedule boxes (2-4)
___ ___ Window visors (2-3)
___ ___ Mirrors (2-3)
___ ___ Fire extinguisher (2-3)
___ ___ Emergency reflectors and/or road flares (2-3)
___ ___ Modesty panels & driver's partition (2-3)
___ ___ Lights (4-1)
___ ___ Passenger chime and Stop Requested lights (2-1)
___ ___ Aid passenger (stop requested light) (2-1)
___ ___ Stanchions and grab rails (2-1)
___ ___ Seats and frames (2-3)
___ ___ Emergency exit hatches (2-1)
___ ___ Flooring and step wells (2-5)
___ ___ Windows and latches (2-2)
___ ___ Emergency escape windows and latches (2-2)
___ ___ Climate control (19-2)
___ ___ Passenger floor heaters (19-2)
___ ___ Front & rear step heaters (19-3)
___ ___ Rear door sensitive edges and alarm (1-9)
___ ___ Rear door brake/throttle interlock adjustment (7-3)

DRIVER CONTROL AREA
___ ___ Fuel filter heater (winter) (95/96/97) (9-4)
___ ___ Indicator light test (1-1)
___ ___ Low oil warning light (1-5)
___ ___ No Charge warning light (1-5)
___ ___ Master control switch (1-5)
___ ___ Starter cut-out (1-3)
___ ___ Transmission shift selector and indicator lights (1-11)
___ ___ Low air circuit (1-5)
___ ___ Headlights, dimmer switch and tell tale light (1-3)
___ ___ Fog lights (96/97 ski & 9900) (1-3)
___ ___ Turn signals and tell-tale lights (1-3)
___ ___ Four-way flashers (1-9)
___ ___ Auxiliary flasher circuit (1-9)
___ ___ Dash night lights and panel dimmer (1-3)
___ ___ Horns (1-1)
___ ___ Wiring (in DCP) (4-1)
___ ___ Vanner EM-70 (1-5)
___ ___ Steering free play (13-1)
___ ___ Steering column shaft & mounting (95/96/97) (13-3)
___ ___ Tilt & telescopic steering (95/96/97) (13-3)
___ ___ Voltmeter (1-3)
___ ___ Oil gauge (1-5)
___ ___ Fast idle (1-1)
___ ___ Driver's heater, defroster and mechanical temperature controls (19-1)
___ ___ Driver's vent (95/96/97) (19-3)
___ ___ Dash fans (19-3)
___ ___ Driver's overhead light (1-3)
___ ___ Windshield wiper and washer controls (1-12)
___ ___ Brake and throttle pedals (1-1, 1-2)
___ ___ Park brake control valve (1-4)
___ ___ Door air power (1-7)
___ ___ Emergency door exits (9900) (1-6)
___ ___ Doors and door control (1-7)
___ ___ Exit door tell-tale light (1-7)

DRIVER CONTROL AREA (continued)
___ ___ Brake/throttle interlock (1-8)
___ ___ Kneeling system (1-4)
___ ___ Driver's seat and seat belt (2-4)
___ ___ Radio and farebox mounting (2-3)
___ ___ Public address system (1-2)

EXTERIOR
___ ___ Passenger door linkage and bearings (1-8)
___ ___ Windshield wiper blades (1-15)
___ ___ Mirrors (2-2)
___ ___ Bike rack (2-5)
___ ___ Lights, lenses and reflectors (1-3) (4-1)
___ ___ Access doors and hinges (2-5)
___ ___ Ski Racks (winter) (2-5)
___ ___ Body damage (major or unsafe) (2-2)
___ ___ Windows, hinges and weather stripping (2-2)
___ ___ Wheel seals (17-2)
___ ___ Front axle hub vent (14-1)
___ ___ Fuel tank filler cap, gasket and O-ring (9-3)
___ ___ Back up lights & alarm (4-2)

DRIVE TEST
___ ___ Brakes and brake application valve (21-2)
___ ___ Steering operation (21-2)
___ ___ Retarder operation (21-1)
___ ___ Jake brake operation (96/97 ski) (21-1)
___ ___ Rattles (21-2)
___ ___ Gauges (21-1)
___ ___ Engine or transmission noise (21-2)

ENGINE COMPARTMENT
___ ___ Wiring (4-1)
___ ___ Engine compartment lights and sockets (4-1)
___ ___ Oil pressure (record) Idle ________ Full throttle _________ (8-1)
___ ___ Rear start (4-1)
___ ___ Low coolant circuit (95/96/97 M11) (1-13)
___ ___ High temperature circuit (95/96/97 M11) (1-13)
___ ___ Engine protection module (EPM) (95/96/97 M11) (1-13)
___ ___ EPM override switch (95/96/97 M11) (1-14)
___ ___ Fire detection system (8-8)
___ ___ Pressurize cooling and heating systems (5-3)
___ ___ Cooling and heating systems leaks (5-3)
___ ___ Filler cap, seal and manual pressure relief valve (5-4)
___ ___ Pressure relief valve (5-3)
___ ___ Water pump weephole (5-5)
___ ___ Air, oil and fuel leaks (5-3, 8-1, 9-1 & 12-2)
___ ___ Hose routing (5-4, 8-1, 9-1, 12-2)
___ ___ Air intake system (10-1)
___ ___ Intake restriction (10-1)
___ ___ Filter minder/restriction gauge (10-2)
___ ___ Starting fluid bottle (not on ISC engine) (winter) (8-7 or 8-8)
___ ___ Hydraulic system (13-2)
___ ___ Radiator (5-4)
___ ___ Fan shroud (5-4)
___ ___ Drive belt guard (8-4)
___ ___ Drive belt pulley alignment (8-5)
___ ___ Drive belt condition & tension (8-5)

ENGINE COMPARTMENT (continued)

___ ___ Vibration damper (8-1)
___ ___ Exhaust system (11-1)
___ ___ Dipstick & dipstick guide tube (8-2)
___ ___ Oil filler tube, cap and seal (8-1)
___ ___ Crankcase breather tube (8-4)
___ ___ Fuel pump drain hole (S-50) (9-3)
___ ___ Coolant additive package (5-2)
___ ___ Low coolant level sensor (DDC engines only) (5-2)
___ ___ Transmission dipstick and filler tube (12-1)
___ ___ Davco fuel filter (35ft) (9-2)
___ ___ Change fuel filter(s) (9-1 or 9-2)
___ ___ Engine block heater (8-9)
___ ___ Clean and spray exposed electrical terminals (4-1)
___ ___ Radiator fan motor (5-5)
___ ___ Cooling system fan operation (5-6)

REAR SEAT ENGINE ACCESS

___ ___ Rear seat engine access (8-4)
___ ___ Exhaust system (8-4)
___ ___ Any leaks or problems (8-4)
___ ___ Door seal and fasteners (8-4)
___ ___ Clean and spray exposed electrical terminals (4-1)

MISC.

___ ___ Batteries and tray (4-2)
___ ___ Battery internal hydrometers (if equipped) (4-2)
___ ___ Charging voltage (4-7)
___ ___ Load test all batteries (record) (4-2)
________v ________v ________v ________v
___ ___ Corrosion spray battery terminals (4-2)
___ ___ Starting and charging system voltage drop (4-7) Starting system; positive loss ___________+ negative loss _________ = Total loss_________
Charging system; positive loss ___________+ negative loss _________ = Total loss_________
___ ___ Tire air pressure - record on tire card (3-1)
___ ___ Tires and tire tread depth (3-1)
___ ___ Wheels & lug nuts (3-1)
___ ___ Heater filters (19-1)
___ ___ Passenger floor heater filters (19-3)
___ ___ Defrost filter (winter) (9900 & 9700 ski) (19-3)
___ ___ Test fuel tank & filler (9-3)
___ ___ Webasto auxiliary heater (19-4)
___ ___ 24,000 mile Lift-U inspection (95/96/97)
___ ___ 6,000 mile ramp inspection (9900)
___ ___ Thermo King "Yearly" inspection (19-4)

UNDERSTRUCTURE

___ ___ King pin wear (14-1)
___ ___ Front axle (14-1)
___ ___ Front suspension (air springs, shock absorbers, radius rods, sway bar, & fasteners) (15-1)
___ ___ Front air spring debris (95/96/97) (15-2)
___ ___ Front ride height (15-2)
___ ___ Tie rod ends (13-1)
___ ___ Drag link ball joints and anti-rock bushing (13-1)
___ ___ Fuel tank mounting and leaks (9-3)
___ ___ Wiring & Brake hoses (4-1) (7-1)
___ ___ Brake block wear (5/16" minimum) (7-1)
___ ___ Wheel seals (17-2) (14-1)
___ ___ Splash guards (20-1)
___ ___ Automatic slack adjusters (7-3)
___ ___ Frame cracks (20-1)
___ ___ Differential (17-1)
___ ___ Rear axle breather – remove and clean (17-1)
___ ___ Rear suspension (air springs, shock absorbers, panhard rod & fasteners) 16-1)
___ ___ Rear ride height (16-2 or 3)
___ ___ Tire chains (96/97 ski) (20-1)
___ ___ Drive shaft (18-1)
___ ___ Drive shaft attaching fasteners (18-2)
___ ___ Transmission breather (12-1)
___ ___ Transmission mounting brackets and fasteners (12-2)

UNDERSTRUCTURE (continued)

___ ___ Transmission oil cooler (12-2)
___ ___ Engine oil, transmission fluid and coolant leaks (5-3, 8-1, 9-1 & 12-2)
___ ___ Flywheel housing inspection hole - oil leaks (8-2)
___ ___ All other understructure equipment (20-1)
___ ___ Clean and spray all exposed electrical terminals (4-1)

AIR & BRAKE SYSTEM CHECKS

___ ___ SR-1 spring brake valve operation (7-3)
___ ___ Drain air tanks (6-5)
___ ___ Air dryer (6-8)
___ ___ Air dryer purge valve (6-8)
___ ___ Supply tank check valve (6-8)
___ ___ Air compressor performance (record) (6-6) Sec.________
___ ___ Governor cut-in and cut-out psi (6-9)
___ ___ Air leaks, brakes released _______psi. drop (6-5)
___ ___ Apply brakes - 20 psi drop maximum ________psi drop (6-5)
___ ___ Air leaks, brakes applied _______psi. drop (6-6)
___ ___ Air safety valves (6-7)
___ ___ Primary and secondary tank check valves (6-5)
___ ___ Dash air pressure gauges (6-5)
___ ___ Rear service brake pressure (7-1)
___ ___ Brake interlock pressure (7-2)
___ ___ Air leaks with Son-Tector and soap (6-4)

LUBRICATION

___ ___ Change engine full flow oil filter (8-3)
___ ___ Change engine oil (8-3)
___ ___ Torque engine oil pan plug (8-3)
___ ___ Spinner II oil filter (95/96/97) (8-10)
___ ___ Service FiltaKleen filter (9900) (8-4)
___ ___ Change transmission fluid (12-3)
___ ___ Torque transmission pan plug (12-3)
___ ___ Change transmission filters (12-2)
___ ___ Change differential oil (17-1)
___ ___ Wipe off grease fittings before greasing
___ ___ King pins (#2 grease) (14-1)
___ ___ Steering linkage (#2 grease) (13-2)
___ ___ Front stabilizer bar isolator bushing (95/96/97) #2 grease) (15-2)
___ ___ Brake components (#2 grease) (7-1)
___ ___ Drive shaft (#2 grease) (18-1)
___ ___ Tire chains (96/97 ski) (#2 grease) (20-1)
___ ___ Steering gear seal (#1 grease) (13-3)
___ ___ Upper steering shaft (#1 grease) (13-3)
___ ___ Steering miter gear (9900) (gear lube) (13-1)
___ ___ Front axle oil level (gear lube) (14-1)
___ ___ Change rear axle oil (9900 35ft bus only) (gear lube) (17-2)
___ ___ Passenger door linkage and bearings (JT-6) (1-8)
___ ___ Driver's seat sliders (silicone spray) (2-4)
___ ___ Window channels (silicone spray) (2-2)
___ ___ Brake pedal (multi purpose spray lube) (1-2)
___ ___ Throttle pedal (multi purpose spray lube) (1-1)
___ ___ Driver's vent (95/96/97) (multi purpose spray lube) (19-3)
___ ___ Dash heater and defroster temperature cables (MPS) (19-1)
___ ___ Battery tray rollers and latches (multi purpose spray lube) (4-2)
___ ___ Access door hinges (multi purpose spray lube) (2-5)
___ ___ Bike rack pins and latch (multi purpose spray lube) (2-5)
___ ___ Windshield wiper pivot points (multi purpose spray lube) (1-15)
___ ___ Exterior mirrors (multi purpose spray lube) (2-2)
___ ___ Run engine and check fluid levels and leaks (8-3 & 12-3)

EMPLOYEE SIGNATURE	EMPLOYEE NUMBER
1	
2	
FOREMAN SIGNATURE	DATE

24,000 MILE "B" INSPECTION – 9500, 9600, 9700 & **9900** GILLIG

7/00kb

BUS NUMBER ______ WORK ORDER NUMBER ______ DATE ______ HUBODOMETER MILES AT INSPECTION ______

STEAMED CLEANED	YES	NO
UNDERSTRUCTURE	___	___
ENG. COMPARTMENT	___	___
BATTERIES	___	___
FUEL TANK CAP	___	___
RADIATOR	___	___

DIVISION	
CENTRAL	___
MEADOWBROOK	___
MT. OGDEN	___
TIMPANOGOS	___

FIRST SPACE - Inspector(s) number to be used as a check off identification for work completed.

SECOND SPACE - Use this space to indicate whether an item was okay, adjusted, or repairs needed.

" 3 " = Okay - Item checked is ready for service.

" X " = Adjusted - Item checked has been replaced and is ready for service

" O " = Repairs Needed - Any item requiring repair.

Numbers in ( ) indicate P/M manual page number.

INTERIOR
___ ___ Destination signs, route boxes (2-1)
___ ___ Fare card holder and schedule boxes (2-4)
___ ___ Window visors (2-3)
___ ___ Mirrors (2-3)
___ ___ Fire extinguisher (2-3)
___ ___ Emergency reflectors and/or road flares (2-3)
___ ___ Modesty panels & driver's partition (2-3)
___ ___ Lights (4-1)
___ ___ Passenger chime and Stop Requested lights (2-1)
___ ___ Aid passenger (stop requested light) (2-1)
___ ___ Stanchions and grab rails (2-1)
___ ___ Seats and frames (2-3)
___ ___ Emergency exit hatches (2-1)
___ ___ Flooring and step wells (2-5)
___ ___ Windows and latches (2-2)
___ ___ Emergency escape windows and latches (2-2)
___ ___ Climate control (19-2)
___ ___ Passenger floor heaters (19-2)
___ ___ Front & rear step heaters (19-3)
___ ___ Rear door sensitive edges and alarm (1-9)
___ ___ Rear door brake/throttle interlock adjustment (7-3)

DRIVER CONTROL AREA
___ ___ Fuel filter heater (winter) (95/96/97) (9-4)
___ ___ Indicator light test (1-1)
___ ___ Low oil warning light (1-5)
___ ___ No Charge warning light (1-5)
___ ___ Master control switch (1-5)
___ ___ Starter cut-out (1-3)
___ ___ Transmission shift selector and indicator lights (1-11)
___ ___ Low air circuit (1-5)
___ ___ Headlights, dimmer switch and tell tale light (1-3)
___ ___ Fog lights (96/97 ski & 9900) (1-3)
___ ___ Turn signals and tell-tale lights (1-3)
___ ___ Four-way flashers (1-9)
___ ___ Auxiliary flasher circuit (1-9)
___ ___ Dash night lights and panel dimmer (1-3)
___ ___ Horns (1-1)
___ ___ Wiring (in DCP) (4-1)
___ ___ Vanner EM-70 (1-5)
___ ___ Steering free play (13-1)
___ ___ Steering column shaft & mounting (95/96/97) (13-3)
___ ___ Tilt & telescopic steering (95/96/97) (13-3)
___ ___ Voltmeter (1-3)
___ ___ Oil gauge (1-5)
___ ___ Fast idle (1-1)
___ ___ Driver's heater, defroster and mechanical temperature controls (19-1)
___ ___ Driver's vent (95/96/97) (19-3)
___ ___ Dash fans (19-3)
___ ___ Driver's overhead light (1-3)
___ ___ Windshield wiper and washer controls (1-12)
___ ___ Brake and throttle pedals (1-1, 1-2)
___ ___ Park brake control valve (1-4)
___ ___ Door air power (1-7)
___ ___ Emergency door exits (9900) (1-6)
___ ___ Doors and door control (1-7)

DRIVER CONTROL AREA (continued)
___ ___ Exit door tell-tale light (1-7)
___ ___ Brake/throttle interlock (1-8)
___ ___ Kneeling system (1-4)
___ ___ Driver's seat and seat belt (2-4)
___ ___ Radio and farebox mounting (2-3)
___ ___ Public address system (1-2)

EXTERIOR
___ ___ Passenger door linkage and bearings (1-8)
___ ___ Windshield wiper blades (1-15)
___ ___ Mirrors (2-2)
___ ___ Bike rack (2-5)
___ ___ Lights, lenses and reflectors (1-3) (4-1)
___ ___ Access doors and hinges (2-5)
___ ___ Ski Racks (winter) (2-5)
___ ___ Body damage (major or unsafe) (2-2)
___ ___ Windows, hinges and weather stripping (2-2)
___ ___ Wheel seals (17-2)
___ ___ Front axle hub vent (14-1)
___ ___ Fuel tank filler cap, gasket and O-ring (9-3)
___ ___ Back up lights & alarm (4-2)

DRIVE TEST
___ ___ Brakes and brake application valve (21-2)
___ ___ Steering operation (21-2)
___ ___ Retarder operation (21-1)
___ ___ Jake brake operation (96/97 ski) (21-1)
___ ___ Rattles (21-2)
___ ___ Gauges (21-1)
___ ___ Engine or transmission noise (21-2)

ENGINE COMPARTMENT
___ ___ Wiring (4-1)
___ ___ Engine compartment lights and sockets (4-1)
___ ___ Oil pressure (record) Idle ________ Full throttle ________ (8-1)
___ ___ Rear start (4-1)
___ ___ Low coolant circuit (95/96/97 M11) (1-13)
___ ___ High temperature circuit (95/96/97 M11) (1-13)
___ ___ Engine protection module (EPM) (95/96/97 M11) (1-13)
___ ___ EPM override switch (95/96/97 M11) (1-14)
___ ___ Fire detection system (8-8)
___ ___ Pressurize cooling and heating systems (5-3)
___ ___ Cooling and heating systems leaks (5-3)
___ ___ Filler cap, seal and manual pressure relief valve (5-4)
___ ___ Pressure relief valve (5-3)
___ ___ Water pump weephole (5-5)
___ ___ Air, oil and fuel leaks (5-3, 8-1, 9-1 & 12-2)
___ ___ Hose routing (5-4, 8-1, 9-1, 12-2)
___ ___ Air intake system (10-1)
___ ___ Intake restriction (10-1)
___ ___ Filter minder/restriction gauge (10-2)
___ ___ Starting fluid bottle (not on ISC engine) (winter) (8-7 or 8-8)
___ ___ Hydraulic system (13-2)
___ ___ Radiator (5-4)
___ ___ Fan shroud (5-4)
___ ___ Drive belt guard (8-4)

ENGINE COMPARTMENT (continued)
__ __ Drive belt pulley alignment (8-5)
__ __ Drive belt condition & tension (8-5)
__ __ Vibration damper (8-1)
__ __ Exhaust system (11-1)
__ __ Dipstick & dipstick guide tube (8-2)
__ __ Oil filler tube, cap and seal (8-1)
__ __ Crankcase breather tube (8-4)
__ __ Fuel pump drain hole (S-50) (9-3)
__ __ Coolant additive package (5-2)
__ __ Transmission dipstick and filler tube (12-1)
__ __ Davco fuel filter (35ft) (9-2)
__ __ Change fuel filter(s) (9-1 or 9-2)
__ __ Engine block heater (8-9)
__ __ Clean and spray exposed electrical terminals (4-1)
__ __ Radiator fan motor (5-5)
__ __ Cooling system fan operation (5-6)

REAR SEAT ENGINE ACCESS
__ __ Rear seat engine access (8-4)
__ __ Exhaust system (8-4)
__ __ Any leaks or problems (8-4)
__ __ Door seal and fasteners (8-4)
__ __ Clean and spray exposed electrical terminals (4-1)

MISC.
__ __ Batteries and tray (4-2)
__ __ Battery internal hydrometers (if equipped) (4-2)
__ __ Charging voltage (4-7)
__ __ Load test all batteries (record) (4-2)
________v ________v ________v ________v
__ __ Corrosion spray battery terminals (4-2)
__ __ Tire air pressure - record on tire card (3-1)
__ __ Tires and tire tread depth (3-1)
__ __ Wheels & lug nuts (3-1)
__ __ Heater filters (19-1)
__ __ Passenger floor heater filters (19-3)
__ __ Defrost filter (winter) (9900 & 9700 ski) (19-3)
__ __ Webasto auxiliary heater (19-4)
__ __ 24,000 mile Lift-U inspection (95/96/97)
__ __ 6,000 mile ramp inspection (9900)
__ __ Thermo King "Semi Yearly" inspection (19-4)

UNDERSTRUCTURE
__ __ King pin wear (14-1)
__ __ Front axle (14-1)
__ __ Front suspension (air springs, shock absorbers, radius rods, sway bar, & fasteners) (15-1)
__ __ Front air spring debris (95/96/97) (15-2)
__ __ Front ride height (15-2)
__ __ Tie rod ends (13-1)
__ __ Drag link ball joints and anti-rock bushing (13-1)
__ __ Fuel tank mounting and leaks (9-3)
__ __ Wiring & Brake hoses (4-1) (7-1)
__ __ Brake block wear (5/16" minimum) (7-1)
__ __ Wheel seals (17-2) (14-1)
__ __ Splash guards (20-1)
__ __ Automatic slack adjusters (7-3)
__ __ Frame cracks (20-1)
__ __ Differential (17-1)
__ __ Rear axle breather – remove and clean (17-1)
__ __ Rear suspension (air springs, shock absorbers, panhard rod & fasteners) 16-1)
__ __ Rear ride height (16-2 or 3)
__ __ Tire chains (96/97 ski) (20-1)
__ __ Drive shaft (18-1)
__ __ Drive shaft attaching fasteners (18-2)
__ __ Transmission breather (12-1)
__ __ Transmission mounting brackets and fasteners (12-2)

UNDERSTRUCTURE (continued)
__ __ Transmission oil cooler (12-2)
__ __ Engine oil, transmission fluid and coolant leaks (5-3, 8-1, 9-1 & 12-2)
__ __ Flywheel housing inspection hole - oil leaks (8-2)
__ __ All other understructure equipment (20-1)
__ __ Clean and spray all exposed electrical terminals (4-1)

AIR & BRAKE SYSTEM CHECKS
__ __ SR-1 spring brake valve operation (7-3)
__ __ Drain air tanks (6-5)
__ __ Air dryer (6-8)
__ __ Air dryer purge valve (6-8)
__ __ Supply tank check valve (6-8)
__ __ Air compressor performance (record) (6-6) Sec.________
__ __ Governor cut-in and cut-out psi (6-9)
__ __ Air leaks, brakes released ______psi. drop (6-5)
__ __ Apply brakes - 20 psi drop maximum ______psi drop (6-5)
__ __ Air leaks, brakes applied ______psi. drop (6-6)
__ __ Air safety valves (6-7)
__ __ Primary and secondary tank check valves (6-5)
__ __ Dash air pressure gauges (6-5)
__ __ Rear service brake pressure (7-1)
__ __ Brake interlock pressure (7-2)
__ __ Air leaks with Son-Tector and soap (6-4)

LUBRICATION
__ __ Change engine full flow oil filter (8-3)
__ __ Change engine oil (8-3)
__ __ Torque engine oil pan plug (8-3)
__ __ Service FiltaKleen filter (9900) (8-4)
__ __ Change transmission fluid (12-3)
__ __ Torque transmission pan plug (12-3)
__ __ Change transmission filters (12-2)
__ __ Check differential oil level (17-1)
__ __ Wipe off grease fittings before greasing
__ __ King pins (#2 grease) (14-1)
__ __ Steering linkage (#2 grease) (13-2)
__ __ Front stabilizer bar isolator bushing (95/96/97) #2 grease) (15-2)
__ __ Brake components (#2 grease) (7-1)
__ __ Drive shaft (#2 grease) (18-1)
__ __ Tire chains (96/97 ski) (#2 grease) (20-1)
__ __ Steering gear seal (#1 grease) (13-3)
__ __ Upper steering shaft (#1 grease) (13-3)
__ __ Steering miter gear (9900) (gear lube) (13-1)
__ __ Front axle oil level (gear lube) (14-1)
__ __ Change rear axle oil (9900 35ft bus only) (gear lube) (17-2)
__ __ Passenger door linkage and bearings (JT-6) (1-8)
__ __ Driver's seat sliders (silicone spray) (2-4)
__ __ Window channels (silicone spray) (2-2)
__ __ Brake pedal (multi purpose spray lube) (1-2)
__ __ Throttle pedal (multi purpose spray lube) (1-1)
__ __ Driver's vent (95/96/97) (multi purpose spray lube) (19-3)
__ __ Dash heater and defroster temperature cables (MPS) (19-1)
__ __ Battery tray rollers and latches (multi purpose spray lube) (4-2)
__ __ Access door hinges (multi purpose spray lube) (2-5)
__ __ Bike rack pins and latch (multi purpose spray lube) (2-5)
__ __ Windshield wiper pivot points (multi purpose spray lube) (1-15)
__ __ Exterior mirrors (multi purpose spray lube) (2-2)
__ __ Run engine and check fluid levels and leaks (8-3 & 12-3)

EMPLOYEE SIGNATURE	EMPLOYEE NUMBER
1	
2	
FOREMAN SIGNATURE	DATE

12,000 MILE "C" INSPECTION – 9500, 9600, 9700 & **9900** GILLIG

BUS NUMBER	WORK ORDER NUMBER	DATE	HUBODOMETER MILES AT INSPECTION

STEAMED CLEANED	YES	NO
UNDERSTRUCTURE	___	___
ENG. COMPARTMENT	___	___
BATTERIES	___	___
FUEL TANK CAP	___	___
RADIATOR	___	___

DIVISION	
CENTRAL	___
MEADOWBROOK	___
MT. OGDEN	___
TIMPANOGOS	___

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" O " = Repairs Needed - Any item requiring repair.

Numbers in ( ) indicate P/M manual page number.

INTERIOR

___ ___ Destination signs, route boxes (2-1)
___ ___ Fare card holder and schedule boxes (2-4)
___ ___ Window visors (2-3)
___ ___ Mirrors (2-3)
___ ___ Fire extinguisher (2-3)
___ ___ Emergency reflectors and/or road flares (2-3)
___ ___ Modesty panels & driver's partition (2-3)
___ ___ Lights (4-1)
___ ___ Passenger chime and Stop Requested lights (2-1)
___ ___ Aid passenger (stop requested light) (2-1)
___ ___ Stanchions and grab rails (2-1)
___ ___ Seats and frames (2-3)
___ ___ Emergency exit hatches (2-1)
___ ___ Flooring and step wells (2-5)
___ ___ Windows and latches (2-2)
___ ___ Emergency escape windows and latches (2-2)
___ ___ Climate control (19-2)
___ ___ Passenger floor heaters (19-2)
___ ___ Front & rear step heaters (19-3)
___ ___ Rear door sensitive edges and alarm (1-9)
___ ___ Rear door brake/throttle interlock adjustment (7-3)

DRIVER CONTROL AREA

___ ___ Fuel filter heater (winter) (95/96/97) (9-4)
___ ___ Indicator light test (1-1)
___ ___ Low oil warning light (1-5)
___ ___ No Charge warning light (1-5)
___ ___ Master control switch (1-5)
___ ___ Starter cut-out (1-3)
___ ___ Transmission shift selector and indicator lights (1-11)
___ ___ Low air circuit (1-5)
___ ___ Headlights, dimmer switch and tell tale light (1-3)
___ ___ Fog lights (96/97 ski & 9900) (1-3)
___ ___ Turn signals and tell-tale lights (1-3)
___ ___ Four-way flashers (1-9)
___ ___ Auxiliary flasher circuit (1-9)
___ ___ Dash night lights and panel dimmer (1-3)
___ ___ Horns (1-1)
___ ___ Wiring (in DCP) (4-1)
___ ___ Vanner EM-70 (1-5)
___ ___ Steering free play (13-1)
___ ___ Steering column shaft & mounting (95/96/97) (13-3)
___ ___ Tilt & telescopic steering (95/96/97) (13-3)
___ ___ Voltmeter (1-3)
___ ___ Oil gauge (1-5)
___ ___ Fast idle (1-1)
___ ___ Driver's heater, defroster and mechanical temperature controls (19-1)
___ ___ Driver's vent (95/96/97) (19-3)
___ ___ Dash fans (19-3)
___ ___ Driver's overhead light (1-3)
___ ___ Windshield wiper and washer controls (1-12)
___ ___ Brake and throttle pedals (1-1, 1-2)
___ ___ Park brake control valve (1-4)
___ ___ Door air power (1-7)
___ ___ Emergency door exits (9900) (1-6)
___ ___ Doors and door control (1-7)

DRIVER CONTROL AREA (continued)

___ ___ Exit door tell-tale light (1-7)
___ ___ Brake/throttle interlock (1-8)
___ ___ Kneeling system (1-4)
___ ___ Driver's seat and seat belt (2-4)
___ ___ Radio and farebox mounting (2-3)
___ ___ Public address system (1-2)

EXTERIOR

___ ___ Passenger door linkage and bearings (1-8)
___ ___ Windshield wiper blades (1-15)
___ ___ Mirrors (2-2)
___ ___ Bike rack (2-5)
___ ___ Lights, lenses and reflectors (1-3) (4-1)
___ ___ Access doors and hinges (2-5)
___ ___ Ski Racks (winter) (2-5)
___ ___ Body damage (major or unsafe) (2-2)
___ ___ Windows, hinges and weather stripping (2-2)
___ ___ Wheel seals (17-2)
___ ___ Front axle hub vent (14-1)
___ ___ Fuel tank filler cap, gasket and O-ring (9-3)
___ ___ Back up lights & alarm (4-2)

DRIVE TEST

___ ___ Brakes and brake application valve (21-2)
___ ___ Steering operation (21-2)
___ ___ Retarder operation (21-1)
___ ___ Jake brake operation (96/97 ski) (21-1)
___ ___ Rattles (21-2)
___ ___ Gauges (21-1)
___ ___ Engine or transmission noise (21-2)

ENGINE COMPARTMENT

___ ___ Wiring (4-1)
___ ___ Engine compartment lights and sockets (4-1)
___ ___ Oil pressure (record) Idle ________ Full throttle ________ (8-1)
___ ___ Rear start (4-1)
___ ___ Low coolant circuit (95/96/97 M11) (1-13)
___ ___ High temperature circuit (95/96/97 M11) (1-13)
___ ___ Engine protection module (EPM) (95/96/97 M11) (1-13)
___ ___ EPM override switch (95/96/97 M11) (1-14)
___ ___ Fire detection system (8-8)
___ ___ Pressurize cooling and heating systems (5-3)
___ ___ Cooling and heating systems leaks (5-3)
___ ___ Filler cap, seal and manual pressure relief valve (5-4)
___ ___ Pressure relief valve (5-3)
___ ___ Water pump weephole (5-5)
___ ___ Air, oil and fuel leaks (5-3, 8-1, 9-1 & 12-2)
___ ___ Hose routing (5-4, 8-1, 9-1, 12-2)
___ ___ Air intake system (10-1)
___ ___ Intake restriction (10-1)
___ ___ Starting fluid bottle (not on ISC engine) (winter) (8-7 or 8-8)
___ ___ Hydraulic system (13-2)
___ ___ Radiator (5-4)
___ ___ Fan shroud (5-4)
___ ___ Drive belt guard (8-4)
___ ___ Drive belt pulley alignment (8-5)

ENGINE COMPARTMENT (continued)
__ __ Drive belt condition & tension (8-5)
__ __ Vibration damper (8-1)
__ __ Exhaust system (11-1)
__ __ Dipstick & dipstick guide tube (8-2)
__ __ Oil filler tube, cap and seal (8-1)
__ __ Crankcase breather tube (8-4)
__ __ Fuel pump drain hole (S-50) (9-3)
__ __ Coolant additive package (5-2)
__ __ Transmission dipstick and filler tube (12-1)
__ __ Change fuel filter(s) (not S-40) (9-1 or 9-2)
__ __ Drain water from fuel filter water separator (S-40) (9-1)
__ __ Davco fuel filter (35ft) (9-2)
__ __ Engine block heater (8-9)
__ __ Clean and spray exposed electrical terminals (4-1)
__ __ Radiator fan motor (5-5)
__ __ Cooling system fan operation (5-6)

MISC.
__ __ Batteries and tray (4-2)
__ __ Battery internal hydrometers (if equipped) (4-2)
__ __ Charging voltage (4-7)
__ __ Load test all batteries (record) (4-2)
________v ________v ________v ________v
__ __ Corrosion spray battery terminals (4-2)
__ __ Tire air pressure - record on tire card (3-1)
__ __ Tires and tire tread depth (3-1)
__ __ Wheels & lug nuts (3-1)
__ __ Heater filters (19-1)
__ __ Passenger floor heater filters (19-3)
__ __ Defrost filter (winter) (9900 & 9700 ski) (19-3)
__ __ Webasto auxiliary heater (19-4)
__ __ 3,000 mile Lift-U inspection (95/96/97)
__ __ 6,000 mile ramp inspection (9900)
__ __ Thermo King "6,000 mile" inspection (19-4)

UNDERSTRUCTURE
__ __ Front axle (14-1)
__ __ Front suspension (air springs, shock absorbers, radius rods, sway bar, & fasteners) (15-1)
__ __ Front air spring debris (95/96/97) (15-2)
__ __ Front ride height (15-2)
__ __ Tie rod ends (13-1)
__ __ Drag link ball joints and anti-rock bushing (13-1)
__ __ Fuel tank mounting and leaks (9-3)
__ __ Wiring & Brake hoses (4-1) (7-1)
__ __ Brake block wear (5/16" minimum) (7-1)
__ __ Wheel seals (17-2) (14-1)
__ __ Splash guards (20-1)
__ __ Automatic slack adjusters (7-3)
__ __ Frame cracks (20-1)
__ __ Differential (17-1)
__ __ Rear axle breather (17-1)
__ __ Rear suspension (air springs, shock absorbers, panhard rod & fasteners) 16-1)
__ __ Rear ride height (16-2 or 3)
__ __ Tire chains (96/97 ski) (20-1)
__ __ Drive shaft (18-1)
__ __ Drive shaft attaching fasteners (18-2)
__ __ Transmission mounting brackets and fasteners (12-2)
__ __ Transmission oil cooler (12-2)
__ __ Engine oil, transmission fluid and coolant leaks (5-3, 8-1, 9-1 & 12-2)
__ __ Flywheel housing inspection hole - oil leaks (8-2)
__ __ All other understructure equipment (20-1)
__ __ Clean and spray all exposed electrical terminals (4-1)

AIR & BRAKE SYSTEM CHECKS
__ __ Drain air tanks (6-5)
__ __ Air dryer (6-8)
__ __ Air dryer purge valve (6-8)
__ __ Air compressor performance (record) (6-6) Sec.________
__ __ Governor cut-in and cut-out psi (6-9)
__ __ Air leaks, brakes released ______psi. drop (6-5)
__ __ Apply brakes - 20 psi drop maximum _______psi drop (6-5)
__ __ Air leaks, brakes applied ______psi. drop (6-6)
__ __ Air safety valves (6-7)
__ __ Air leaks with Son-Tector and soap (6-4)

LUBRICATION
__ __ Change engine full flow oil filter (8-3)
__ __ Change engine oil (8-3)
__ __ Torque engine oil pan plug (8-3)
__ __ Change transmission fluid (12-3)
__ __ Torque transmission pan plug (12-3)
__ __ Check differential oil level (17-1)
__ __ Wipe off grease fittings before greasing
__ __ King pins (#2 grease) (14-1)
__ __ Steering linkage (#2 grease) (13-2)
__ __ Front stabilizer bar isolator bushing (95/96/97) #2 grease) (15-2)
__ __ Brake components (#2 grease) (7-1)
__ __ Drive shaft (#2 grease) (18-1)
__ __ Tire chains (96/97 ski) (#2 grease) (20-1)
__ __ Steering miter gear (9900) (gear lube) (13-1)
__ __ Front axle oil level (gear lube) (14-1)
__ __ Rear axle oil level (9900 35ft bus only) (gear lube) (17-2)
__ __ Passenger door linkage and bearings (JT-6) (1-8)
__ __ Driver's seat sliders (silicone spray) (2-4)
__ __ Window channels (silicone spray) (2-2)
__ __ Brake pedal (multi purpose spray lube) (1-2)
__ __ Throttle pedal (multi purpose spray lube) (1-1)
__ __ Driver's vent (95/96/97) (multi purpose spray lube) (19-3)
__ __ Dash heater and defroster temperature cables (MPS) (19-1)
__ __ Battery tray rollers and latches (multi purpose spray lube) (4-2)
__ __ Access door hinges (multi purpose spray lube) (2-5)
__ __ Bike rack pins and latch (multi purpose spray lube) (2-5)
__ __ Windshield wiper pivot points (multi purpose spray lube) (1-15)
__ __ Exterior mirrors (multi purpose spray lube) (2-2)
__ __ Run engine and check fluid levels and leaks (8-3 & 12-3)

EMPLOYEE SIGNATURE	EMPLOYEE NUMBER
1.	
2	
FOREMAN SIGNATURE	DATE

6,000 MILE "D" INSPECTION – 9500, 9600, 9700 & **9900** GILLIG **7/00**kb

BUS NUMBER	WORK ORDER NUMBER	DATE	HUBODOMETER MILES AT INSPECTION

STEAMED CLEANED	YES	NO
UNDERSTRUCTURE	___	___
ENG. COMPARTMENT	___	___
BATTERIES	___	___
FUEL TANK CAP	___	___
RADIATOR	___	___

Numbers in ( ) indicate P/M manual page number.

DIVISION	
CENTRAL	___
MEADOWBROOK	___
MT. OGDEN	___
TIMPANOGOS	___

FIRST SPACE - Inspector(s) number to be used as a check off identification for work completed.

SECOND SPACE - Use this space to indicate whether an item was okay, adjusted, or repairs needed.

" 3 " = Okay - Item checked is ready for service.

" X " = Adjusted - Item checked has been replaced and is ready for service

" O " = Repairs Needed - Any item requiring repair.

INTERIOR

___ ___ Destination signs, route boxes (2-1)
___ ___ Fare card holder and schedule boxes (2-4)
___ ___ Window visors (2-3)
___ ___ Mirrors (2-3)
___ ___ Fire extinguisher (2-3)
___ ___ Emergency reflectors and/or road flares (2-3)
___ ___ Modesty panels & driver's partition (2-3)
___ ___ Lights (4-1)
___ ___ Passenger chime and Stop Requested lights (2-1)
___ ___ Aid passenger (stop requested light) (2-1)
___ ___ Stanchions and grab rails (2-1)
___ ___ Seats and frames (2-3)
___ ___ Flooring and step wells (2-5)
___ ___ Windows and latches (2-2)
___ ___ Climate control (19-2)
___ ___ Passenger floor heaters (19-2)
___ ___ Front & rear step heaters (19-3)
___ ___ Rear door sensitive edges and alarm (1-9)
___ ___ Rear door brake/throttle interlock adjustment (7-3)

DRIVER CONTROL AREA

___ ___ Fuel filter heater (winter) (95/96/97) (9-4)
___ ___ Indicator light test (1-1)
___ ___ Low oil warning light (1-5)
___ ___ No Charge warning light (1-5)
___ ___ Master control switch (1-5)
___ ___ Starter cut-out (1-3)
___ ___ Transmission shift selector and indicator lights (1-11)
___ ___ Low air circuit (1-5)
___ ___ Headlights, dimmer switch and tell tale light (1-3)
___ ___ Fog lights (96/97 ski & 9900) (1-3)
___ ___ Turn signals and tell-tale lights (1-3)
___ ___ Four-way flashers (1-9)
___ ___ Auxiliary flasher circuit (1-9)
___ ___ Dash night lights and panel dimmer (1-3)
___ ___ Horns (1-1)
___ ___ Wiring (in DCP) (4-1)
___ ___ Vanner EM-70 (1-5)
___ ___ Steering free play (13-1)
___ ___ Steering column shaft & mounting (95/96/97) (13-3)
___ ___ Tilt & telescopic steering (95/96/97) (13-3)
___ ___ Voltmeter (1-3)
___ ___ Oil gauge (1-5)
___ ___ Fast idle (1-1)
___ ___ Driver's heater, defroster and mechanical temperature controls (19-1)
___ ___ Driver's vent (95/96/97) (19-3)
___ ___ Dash fans (19-3)
___ ___ Driver's overhead light (1-3)
___ ___ Windshield wiper and washer controls (1-12)
___ ___ Brake and throttle pedals (1-1, 1-2)
___ ___ Park brake control valve (1-4)
___ ___ Door air power (1-7)
___ ___ Doors and door control (1-7)
___ ___ Exit door tell-tale light (1-7)
___ ___ Brake/throttle interlock (1-8)
___ ___ Kneeling system (1-4)
___ ___ Driver's seat and seat belt (2-4)
___ ___ Radio and farebox mounting (2-3)
___ ___ Public address system (1-2)

EXTERIOR

___ ___ Passenger door linkage and bearings (1-8)
___ ___ Windshield wiper blades (1-15)
___ ___ Mirrors (2-2)
___ ___ Bike rack (2-5)
___ ___ Lights, lenses and reflectors (1-3) (4-1)
___ ___ Access doors and hinges (2-5)
___ ___ Ski Racks (winter) (2-5)
___ ___ Body damage (major or unsafe) (2-2)
___ ___ Windows, hinges and weather stripping (2-2)
___ ___ Wheel seals (17-2)
___ ___ Front axle hub vent (14-1)
___ ___ Fuel tank filler cap, gasket and O-ring (9-3)
___ ___ Back up lights & alarm (4-2)

DRIVE TEST

___ ___ Brakes and brake application valve (21-2)
___ ___ Steering operation (21-2)
___ ___ Retarder operation (21-1)
___ ___ Jake brake operation (96/97 ski) (21-1)
___ ___ Rattles (21-2)
___ ___ Gauges (21-1)
___ ___ Engine or transmission noise (21-2)

ENGINE COMPARTMENT

___ ___ Wiring (4-1)
___ ___ Engine compartment lights and sockets (4-1)
___ ___ Oil pressure (record) Idle ________ Full throttle ________ (8-1)
___ ___ Rear start (4-1)
___ ___ Low coolant circuit (95/96/97 M11) (1-13)
___ ___ High temperature circuit (95/96/97 M11) (1-13)
___ ___ Engine protection module (EPM) (95/96/97 M11) (1-13)
___ ___ EPM override switch (95/96/97 M11) (1-14)
___ ___ Fire detection system (8-8)
___ ___ Pressurize cooling and heating systems (5-3)
___ ___ Cooling and heating systems leaks (5-3)
___ ___ Filler cap, seal and manual pressure relief valve (5-4)
___ ___ Pressure relief valve (5-3)
___ ___ Water pump weephole (5-5)
___ ___ Air, oil and fuel leaks (5-3, 8-1, 9-1 & 12-2)
___ ___ Hose routing (5-4, 8-1, 9-1, 12-2)
___ ___ Air intake system (10-1)
___ ___ Intake restriction (10-1)
___ ___ Starting fluid bottle (not on ISC engine) (winter) (8-7 or 8-8)
___ ___ Hydraulic system (13-2)
___ ___ Radiator (5-4)
___ ___ Fan shroud (5-4)
___ ___ Drive belt guard (8-4)
___ ___ Drive belt condition & tension (8-5)
___ ___ Exhaust system (11-1)
___ ___ Dipstick & dipstick guide tube (8-2)
___ ___ Oil filler tube, cap and seal (8-1)
___ ___ Crankcase breather tube (8-4)
___ ___ Fuel pump drain hole (S-50) (9-3)
___ ___ Coolant additive package (5-2)
___ ___ Transmission dipstick and filler tube (12-1)
___ ___ Davco fuel filter (35ft) (9-2)
___ ___ Drain water from fuel filter water separator (9-1)
___ ___ Engine block heater (8-9)
___ ___ Clean and spray exposed electrical terminals (4-1)

ENGINE COMPARTMENT (CONTINUED)
__ __ Radiator fan motor (5-5)
__ __ Cooling system fan operation (5-6)

MISC.
__ __ Batteries and tray (4-2)
__ __ Battery internal hydrometers (if equipped) (4-2)
__ __ Charging voltage (4-7)
__ __ Corrosion spray battery terminals (4-2)
__ __ Tire air pressure - record on tire card (3-1)
__ __ Tires and tire tread depth (3-1)
__ __ Wheels & lug nuts (3-1)
__ __ Heater filters (19-1)
__ __ Passenger floor heater filters (19-3)
__ __ Defrost filter (winter) (9900 & 9700 ski) (19-3)
__ __ Webasto auxiliary heater (19-4)
__ __ 3,000 mile Lift-U inspection (95/96/97)
__ __ 6,000 mile ramp inspection (9900)
__ __ Thermo King "6,000 mile" inspection (19-4)

UNDERSTRUCTURE
__ __ Front axle (14-1)
__ __ Front suspension (air springs, shock absorbers, radius rods, sway bar, & fasteners) (15-1)
__ __ Front air spring debris (95/96/97) (15-2)
__ __ Front ride height (15-2)
__ __ Tie rod ends (13-1)
__ __ Drag link ball joints and anti-rock bushing (13-1)
__ __ Fuel tank mounting and leaks (9-3)
__ __ Wiring & Brake hoses (4-1) (7-1)
__ __ Brake block wear (5/16" minimum) (7-1)
__ __ Wheel seals (17-2) (14-1)
__ __ Splash guards (20-1)
__ __ Automatic slack adjusters (7-3)
__ __ Frame cracks (20-1)
__ __ Differential (17-1)
__ __ Rear axle breather (17-1)
__ __ Rear suspension (air springs, shock absorbers, panhard rod & fasteners) 16-1)
__ __ Rear ride height (16-2 or 3)
__ __ Tire chains (96/97 ski) (20-1)
__ __ Drive shaft (18-1)
__ __ Drive shaft attaching fasteners (18-2)
__ __ Transmission mounting brackets and fasteners (12-2)
__ __ Transmission oil cooler (12-2)
__ __ Engine oil, transmission fluid and coolant leaks (5-3, 8-1, 9-1 & 12-2)
__ __ Flywheel housing inspection hole - oil leaks (8-2)
__ __ All other understructure equipment (20-1)
__ __ Clean and spray all exposed electrical terminals (4-1)

AIR & BRAKE SYSTEM CHECKS
__ __ Drain air tanks (6-5)
__ __ Air dryer (6-8)
__ __ Air dryer purge valve (6-8)
__ __ Air compressor performance (record) (6-6) Sec.________
__ __ Governor cut-in and cut-out psi (6-9)
__ __ Air leaks, brakes released _______psi. drop (6-5)
__ __ Apply brakes - 20 psi drop maximum ________psi drop (6-5)
__ __ Air leaks, brakes applied _______psi. drop (6-6)
__ __ Air safety valves (6-7)
__ __ Air leaks with Son-Tector and soap (6-4)

LUBRICATION
__ __ Change engine full flow oil filter (8-3)
__ __ Change engine oil (8-3)
__ __ Torque engine oil pan plug (8-3)
__ __ Check differential oil level (17-1)
__ __ Wipe off grease fittings before greasing
__ __ King pins (#2 grease) (14-1)
__ __ Steering linkage (#2 grease) (13-2)
__ __ Front stabilizer bar isolator bushing (95/96/97) #2 grease) (15-2)
__ __ Brake components (#2 grease) (7-1)
__ __ Drive shaft (#2 grease) (18-1)
__ __ Tire chains (96/97 ski) (#2 grease) (20-1)
__ __ Front axle oil level (gear lube) (14-1)
__ __ Rear axle oil level (9900 35ft bus only) (gear lube) (17-2)
__ __ Driver's seat sliders (silicone spray) (2-4)
__ __ Window channels (silicone spray) (2-2)
__ __ Brake pedal (multi purpose spray lube) (1-2)
__ __ Throttle pedal (multi purpose spray lube) (1-1)
__ __ Driver's vent (95/96/97) (multi purpose spray lube) (19-3)
__ __ Dash heater and defroster temperature cables (MPS) (19-1)
__ __ Battery tray rollers and latches (multi purpose spray lube) (4-2)
__ __ Access door hinges (multi purpose spray lube) (2-5)
__ __ Bike rack pins and latch (multi purpose spray lube) (2-5)
__ __ Windshield wiper pivot points (multi purpose spray lube) (1-15)
__ __ Exterior mirrors (multi purpose spray lube) (2-2)
__ __ Run engine and check fluid levels and leaks (8-3 & 12-3)

EMPLOYEE SIGNATURE	EMPLOYEE NUMBER
1	
2	
FOREMAN SIGNATURE	DATE

6,000 MILE RICON RAMP INSPECTION
9900 GILLIG

|___|___|___|___| BUS NUMBER

|___|___|___|___|___|___| WORK ORDER NUMBER

______________ DATE

|___|___|___|___|___|___| HUBODOMETER READING

______________ DIVISION

First Space - Inspector's number. To be used as a check off identification for work completed.

Second Space - Use this space to indicate whether an item was okay, adjusted, or repairs were needed.

"3" Okay - Item checked is ready for service.
"X" Adjusted - Item checked, has been repaired and is ready for service.
"O" Repairs needed - Any item requiring repairs.

For information on the following procedures, refer to Section 22 in the Gillig PM manual or the Ricon Fold-Out Ramp Service Manual. NOTE: Do not use steam or solvent on chains.

____ Wheelchair securement equipment all present, clean and not damaged. Page 22-2.
____ Manual operation handle is not damaged and lays flat. Check manual operation.
____ Power and Stow/Deploy switches not damaged and operate properly.
____ Dash power light comes on with power switch
____ Brake and throttle interlocks operate when ramp power is on.
____ No dirt or debris on or under the ramp that would cause problems.
____ No unusual noises when ramp is in operation.
____ Audible alarm sounds when ramp is in operation.
____ Non-skid flooring is secure and not damaged on both sides of ramp.
____ Ramp will not operate unless vehicle is in neutral, park brake is set and door is FULLY open.
____ *Ramp power automatically releases (or cuts out) shortly after ramp goes past ramp 'midpoint' (figure 1). This is so the ramp cannot crush a foot or other object if ramp is powered all the way in either direction.*
____ Ramp lays flat when stowed.
____ No leaks in hydraulic lines to ramp. (Ramp uses fluid from power steering system.)
____ Bushings and thrust washers in each ramp and actuator arm pivot point are not damaged or worn out.

<u>Remove cover and inspect the following:</u>

____ Set screws in the following areas are tight: Driveshaft Couplings (4), Sensor Target (2), Ramp and Actuator Arms (3 per side), Pillow Blocks (2 each).
____ All fasteners are tight.
____ On each *'A' or 'B' inspection*, apply one pump of #2 grease to each pillow block (2). Sealed bearings are used, grease carefully.

THERMO KING
BUS AIR CONDITIONING
PREVENTATIVE MAINTENANCE WORKSHEET
6,000 MILE A/C INSPECTION

9/00kb(bl)

NOTE: Thermo King reserves the right to deny warranty coverage on claims due to lack of maintenance or neglect. Claims in question must be supported by maintenance records, which are in accordance with the contractual agreement.

NOTE: Refer to the appropriate maintenance manual for instructions on how to correctly perform required maintenance.

Date ________________ Thermo King Unit Model No. ________________

Bus Number ____________ Compressor Serial No. ____________________

Bus Mileage ____________ Technician ____________________________

Refrigerant/Heating

1. ______ Check refrigerant charge. Run bus at high idle for 15-20 minutes. To put a load on the A/C system, heat the bus interior temperature to above 75°F. The ball in the top receiver tank sight glass should be floating at the top of the glass and the liquid line sight glass should be full and clear - no bubbles.

   Charge OK ______ Add refrigerant ______

2. ______ Visually inspect for leaks of refrigerant and oil.

   No leaks ______ Leaks detected ______

   NOTE: If leaks are detected, leak check system and repair accordingly.

3. ______ Check dry eye in the bottom receiver tank sight glass and/or liquid line sight glass for moisture content.

   OK ________ Green Not OK ________ Yellow
   (If yellow see service manual)

4. ______ Visually check refrigerant hoses and tubing for signs of deterioration or chafing.

   Hoses and tubing OK. __________
   Hose and/or tubing needs repair or replacement.
   Specify which one. ____________________________

Compressor/Clutch

5. ________ Check compressor oil level and color (1/4 - 2 sight glass after 15 min. operation at fast idle - color must be clear.

6. ________ Visually inspect clutch armature for wear and overheating caused by slippage.

7. ________ Visually inspect compressor drive belts for excessive wear, tension and alignment.

Condition OK ________ Replace ________
Alignment OK ________ Adjusted ________
Tension OK ________ Adjusted ________

Structural

8. ________ Visually inspect the outer areas of the unit for loose, damaged, or broken parts.

OK ________ Make repairs ________

Specify defect ______________________________

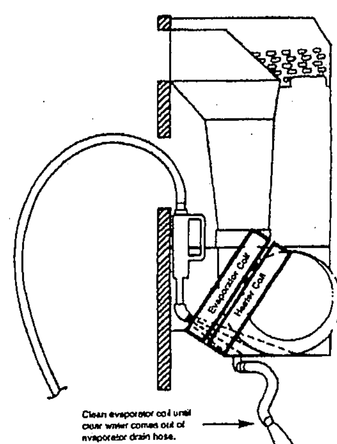
9. ________ Clean or replace return air filter and inspect evaporator coil for cleanness.

Cleaned filter ________ Replaced filter ________

10. ________ Visually inspect the top of the condenser coil for debris. Vacuum if needed.

11. ________ Cold water pressure wash A/C upper compartment area, condenser coil, and evaporator coil as follows:

To clean the coils, use a mild soap and rinse with water from a garden hose. Cleaning only the top of the coil allows dirt and debris to settle at the bottom causing a restriction that also reduces capacity. The coil should be sprayed until a clear solution comes from the evaporator drain hose.



Correct Procedure

THERMO KING
BUS AIR CONDITIONING
PREVENTATIVE MAINTENANCE WORK SHEET
24,000 MILE SEMI-ANNUAL INSPECTION

9/00kb(pk)

NOTE: *Thermo King reserves the right to deny warranty coverage on claims due to lack of maintenance or neglect. Claims in question must be supported by maintenance records that are in accordance with the contractual agreement.*

NOTE: *Refer to the appropriate maintenance manual for instructions on how to correctly perform required maintenance.*

Date: ______________________ Thermo King Unit Model No. ______________

Bus Number: ________________ Compressor Serial No. ____________________

Bus Mileage: _______________ Technician: _____________________________

REFRIGERATION/HEATING

1. ______ Install service gauge manifold set. Record operating pressures, temperature, and suction line condition.

	Fast Idle	Full Throttle
Suction	___________psig	___________psig
Discharge	___________psig	___________psig
Ambient	___________°F	___________Suction Line
Return Air	___________°F	___________°F outlet/duct temp

2. ______ Check refrigerant charge. Make sure discharge pressure is 150 psi on R-134a systems and 250 psi on R-22 systems. The ball in the top receiver tank sight glass should be floating and the liquid line sight glass (if equipped) should be full and clear - no bubbles.

   Charge OK _____ Add refrigerant_____

3. ______ Visually check refrigerant hoses and tubing for signs of deterioration or chafing.

   Hoses and tubing OK _____
   Hose and or tubing needs repair or replacement.
   Specify which one____

4. ______ Visually inspect for leaks of refrigerant and oil. Look closely at the vibrasorbers seal plate, and high pressure relief valve.

   No leaks _____ Leaks detected _____

   NOTE: If leaks are detected, leak check system.

5. ______ Check dry eye in the bottom receiver tank sight glass and/or liquid line sight glass for moisture content.

OK_____ Perform system clean-up _____

COMPRESSOR/CLUTCH

6. _______ Visually inspect clutch armature for wear and overheating caused by slippage.

7. _______ Visually inspect compressor drive belts for excessive wear, tension and alignment. Tension should be 160 to 180 lbs for a used belt.

Condition OK_________ Replace________
Alignment OK ________ Adjusted_______
Tension OK _________ Adjusted_______

8. _______ Steam clean compressor and clutch.

9. ______ Check clutch coil resistance and voltage.

Record voltage at clutch ________ VDC.
Record resistance of coil ________ ohms.

10. _____ Check compressor oil level and color (1/4-1/2 sight glass after 15 minutes of operation).

Level OK _____ Color OK _____

11. ______ Check clutch air gap .045 in. " .005 (1.143 " 0.127 mm) and surface flatness.

Air gap OK _________ Adjusted air gap _________

12. ______ Clean and re-pack clutch bearing with Exxon Unirex #2 grease.

13. ______ Lubricate clutch bearing (and idler bearing, series 50 engine) (Exxon Unirex N2).

ELECTRICAL

14. ______ Check thermostat cycle sequence on all modes (e.g., cool/vent and vent/heat).

OK ______ Diagnose Thermostat/Unit ______

15. ______ Clean ambient thermostat and check operation and connections.

Opens ______°F Closes ______°F

Add Dow Corning 4 grease to connections and ambient switch.

16. ______ Inspect evaporator/heater blower motor brushes, commutator, bearings, speed, voltage, and amperes.

Brushes (5/8" min)	____OK	____Replace		
Commutator	____OK	____Refinish		
Bearings	____OK	____Replace		
Speed	____rpm's	VDC________		Amps_______

17. ______ Inspect condenser fan motor brushes, commutator, bearings, speed, voltage, and amperes.

	Left Side Motor		Right Side Motor	
Brushes (5/8" (min)	___OK	___Replace	___OK	___Replace
Commutator	___OK	___Refinish	___OK	___Refinish
Bearings	___OK	___Replace	___OK	___Replace
Speed	_____rpm's	___Amps	_____rpm's	___Amps
	VDC _________		VDC _________	

18. ______ Clean control panel area/return air sensor with compressed air.

19. ______ Check boost pump motor (OEM Supplied) operation, voltage, and inspect brushes.

Voltage	_____VDC	
Brushes	_____OK	Replace_______
Operation	_____OK	Replace motor_____

20. ______ Inspect all wires and terminals for damage or corrosion. Clean and install corrosion preventative spray.

STRUCTURAL

21. ______ Visually inspect the outer areas of the unit for loose, damaged, or broken parts.
OK ______ Make repairs_______
Specify defect____

22. ______ Clean or replace return air filter.

23. ______ Clean condenser and evaporator drains. Make sure that the evaporator drain hose are free of obstructions, that the check valves (kazoos) are in place, and in good condition

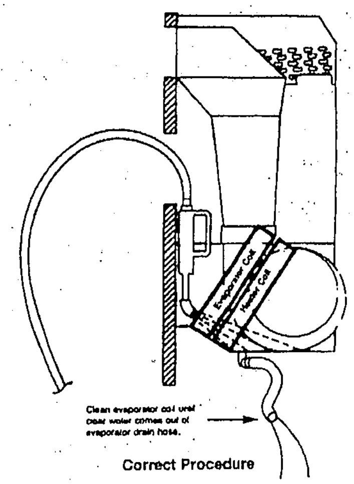
24. ______ Lubricate evaporator fan shaft bearings (Dura Lith #2).

25. ______ Check (visually) engine coolant hoses and hose clamp condition on heater coil system.

26. ______ Visually inspect condenser coil for cleanness and obstructions.

27. ______ Steam clean engine compartment. Cold water pressure wash A/C upper compartment area, condenser coil, and evaporator coil as follows:

To clean the coils, use a mild soap and rinse with water from a garden hose. Cleaning only the top of the coil allows dirt and debris to settle at the bottom causing a restriction that also reduces capacity. The coil should be sprayed until a clear solution comes from the evaporator drain hose.



Correct Procedure

THERMO KING
BUS AIR CONDITIONING
PREVENTATIVE MAINTENANCE WORK SHEET
48,000 MILE - ANNUAL INSPECTION

NOTE: *Thermo King reserves the right to deny warranty coverage on claims due to lack of maintenance or neglect. Claims in question must be supported by maintenance records which are in accordance with the contractual agreement.*

NOTE: *Refer to the appropriate maintenance manual for instructions on how to correctly perform required maintenance.*

Date: ____________________ Thermo King Unit Model NO. ____________

Bus Number: _______________ Compressor Serial No. _______________

Bus Mileage: _______________ Technician: _________________________

REFRIGERATION/HEATING

1. ______ Install service gauge manifold set. Record operating pressures, temperature, and suction line condition.

	Fast Idle	Full Throttle
Suction	______ psig	______ psig
Discharge	______ psig	______ psig
Ambient	______ °F	______ suction line
Return Air	______ °F	______ °F outlet/duct temp

2. ______ Check refrigerant charge. Make sure discharge pressure is 150 psi on R-134a systems and 250 psi on R-22 systems. The ball in the top receiver tank sight glass should be floating and the liquid line sight glass (if equipped) should be full and clear - no bubbles.

   Charge OK ______ Add refrigerant ______

3. ______ Visually check refrigerant hoses and tubing for signs of deterioration or chafing.

   Hoses and tubing OK ____
   Hose and/or tubing needs repair or replacement.
   Specify which one ____

4. ______ Visually inspect for leaks of refrigerant and oil.

   No Leaks _____ Leaks detected _____

   NOTE: If leaks are detected, leak check system.

5. _____ Check dry eye in the bottom receiver tank sight glass and/or liquid line sight glass for moisture content.

OK _____ Perform system clean-up_____

6. _____ Check evaporator pressure regulator operation if equipped.

R-22 52 psig (276 kPa)

________ psig

7. _____ Replace liquid lines dehydrator a minimum of once a year or any time the system is opened.

8. _____ Check low pressure cutout.

LPCO Opens _____ psig Closes _____ psig

NOTE: Refer to the appropriate maintenance manual for specifications. The AC fail light should come on if the unit shuts down because of high or low pressure. If the unit is equipped with a time delay, it will be necessary to turn the main AC switch off and then on again in order to make the system operative again.

CAUTION: Do not front seat the discharge service valve while the compressor is operating.

CAUTION: Any time the discharge valve is front seated, turn the battery master switch to OFF to prevent accidental compressor start up.

9. _____ Check hot water control (coolant) valve operation.

OK _______ Repair or replace _______

COMPRESSOR/CLUTCH

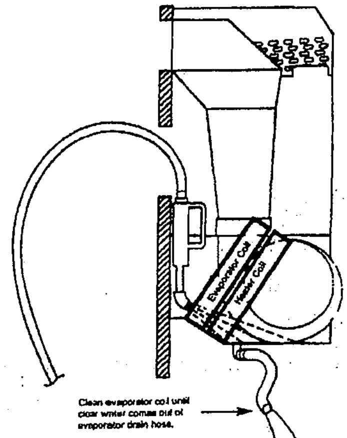
10. _____ Visually inspect clutch armature for wear and overheating caused by slippage.

11. _____ Visually inspect compressor drive belts for excessive wear tension, and alignment.

Condition	OK _____	Replace _____
Alignment	OK _____	Adjusted _____
Tension	OK _____	Adjusted _____

12. _____ Steam clean compressor and clutch. Cold water pressure wash A/C upper compartment area, condenser coil, and evaporator coil.

To clean the coils, use a mild soap and rinse with water from a garden hose. Cleaning only the top of the coil allows dirt and debris to settle at the bottom causing a restriction that also reduces capacity. The coil should be sprayed until a clear solution comes from the evaporator drain hose.



Correct Procedure

13. _____ Check clutch coil resistance and voltage.
Record voltage at clutch. _______ V dc.
Record resistance of coil _______ ohms.

14. _____ Check compressor oil level and color (1/4-1/2 sight glass after 15 minutes of operation).
Level OK _____ Color OK _____

15. _____ Record oil pump pressure at 1000 rpm's (compressor).

Pressure from oil pump port (OP)	_____psig
Suction pressure (SP)	_____psig
Net compressor oil pressure (NOP)	_____psig

NOTE: OP minus SP equals NOP.

16. _____ Check compressor oil for acidity.
Safe_____ Marginal_____ Acidic_____

17. _____ Check clutch air gap .045 in. + - .005 (1.143 + - 0.127 mm) and surface flatness.
Air gap OK _____ Adjusted air gap _____

18. _____ Check horizontal pulley/flywheel run out (side play) with dial indicator maximum acceptance is .010 in. (0.254 mm).
Run out _______in.

19. _____ Lubricate clutch bearing (and idler bearing, series 50 engine) (Exxon Unirex N2) (re-pack clutch bearing).

ELECTRICAL

20. _____ Check thermostat cycle sequence on all modes (e.g. cool/vent), and vent/heat).

OK _____ Diagnose thermostat/unit _____

21. _____ Inspect evaporator/heater blower motor brushes, commutator, bearings, speed, voltage, and amperes.

Brushes 5/8" (min)	_____ OK		_____ Replace			
Commutator	_____ OK		_____ Refinish			
Bearings	_____ OK		_____ Replace			
Hi/Low Speed _____	Rpm's	V dc _____	Amps _____			

22. _________ Inspect condenser fan motor brushes, commutator, bearings, speed, voltage, and amperes.

	Left Side Motor		Right Side Motor	
Brushes (5/8" (min)	___OK	___Replace	___OK	___Replace
Commutator	___OK	___Refinish	___OK	___Refinish
Bearings	___OK	___Replace	___OK	___Replace
Speed	_____rpm's	___Amps	_____rpm's	___Amps
	V dc_________		V dc_________	

23. _____ Clean control panel area/return air sensor with compressed air.

24. _____ Check OEM supplied boost pump motor operation.

25. _____ Check ambient temperature switch operation.

Opens at _____ °F Closes at _____ °F

Add Dow Corning 4 grease to connections and ambient switch.
Star Bright Liquid Electrical Tape can be used to seal connections on new switch.

26. _____ Inspect all wires and terminals for damage or corrosion.

NOTE: If corrosion is present, clean terminals with electrical contact cleaner.

STRUCTURAL

27. _____ Visually inspect the outer areas of the unit for loose, damaged, or broken parts.

OK _____ Make repairs

Specify defect ________________________________

28. _____ Clean or replace return air filter.

29. _____ Clean condenser and evaporator drains. Make sure that the evaporator drain hose are free of obstructions, that the check valves (kazoos) are in place, and in good condition

30. _____ Lubricate evaporator fan shaft bearings (Dura Lith #2).

31. _____ Visually check the engine coolant hoses and hose clamp condition on heater coil system.

32. _____ Check engine coolant for anti-freeze protection down to -30°F (-34°C) to prevent heater coil freeze up. Check at surge tank.

Anti-freeze protection _____ °F.

33. _____ Tighten all compressor, unit and fan motor mounting bolts and brackets (more frequently if necessary). Tighten fan guards and fan coupling set screws.

34. _____ Check condenser air seals and air deflector, if applicable.

35. _____ Visually check evaporator blower shaft coupling adjustment and alignment.

BUS NUMBER	WORK ORDER NUMBER	DATE	HUBODOMETER MILES AT INSPECTION

STEAMED CLEANED	YES	NO
UNDER STRUCTURE	___	___
ENG. COMPARTMENT	___	___
BATTERIES	___	___
FUEL TANK (not CNG)	___	___
RADIATOR	___	___

DIVISION	
CENTRAL	___
MEADOWBROOK	___
MT. OGDEN	___
TIMPANOGOS	___

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Numbers in ( ) indicate P/M manual page number.

INTERIOR
___ ___ Destination signs (2-2)
___ ___ Route sign box (2-1)
___ ___ DEC book holder, fare card holder and schedule boxes (2-3)
___ ___ Front door emergency air control (1-6)
___ ___ Sun visors (2-3)
___ ___ Mirrors (2-2)
___ ___ Passenger chime and next stop lights (2-1)
___ ___ Stanchions and grabrails (2-1)
___ ___ Seats and frames (2-2)
___ ___ Emergency exit hatches (2-2)
___ ___ Flooring and step wells (2-1)
___ ___ Windows & latches (2-3)
___ ___ Emergency escape windows (2-1)
___ ___ Side and ceiling panels (2-3)
___ ___ Lights (4-2)
___ ___ Exit doors (1-6)
___ ___ Exit door sensitive edges (1-6)
___ ___ Brake/throttle interlock adjustment (1-7)
___ ___ Fire extinguisher & tag (1-3)
___ ___ Fire suppression system (CNG)(8-7)
___ ___ Modesty panels & driver's partition (2-3)
___ ___ Emergency road reflectors (1-2)

DRIVER CONTROL AREA
___ ___ Indicator lamp test (1-9)
___ ___ No charge circuit (1-2)
___ ___ Check trans, check engine and engine stop circuits (DDEC)(1-1)
___ ___ Neutral start (4-1)
___ ___ Starter cut-out circuit (4-1)
___ ___ Low air circuit (1-1)
___ ___ Dash night lights (4-2)
___ ___ Horns (1-3)
___ ___ P.A. system (2-4)
___ ___ Tilt and telescopic steering (13-4)
___ ___ Steering column shaft and mounting (13-2)
___ ___ Steering free play (13-1)
___ ___ Oil gauge (1-2)
___ ___ Voltmeter (1-2)
___ ___ Fuel gauge (1-3)
___ ___ Fast idle operation (1-3)
___ ___ Transmission shift selector (12-1)
___ ___ Climate control (19-1)
___ ___ Blower motor operation (19-2)
___ ___ Front step well heater (19-2)
___ ___ Defrost (19-2)
___ ___ Driver's heat & temperature controls (19-2)
___ ___ Driver's front vent (1-2)
___ ___ Windshield wipers (1-4)
___ ___ Windshield washer (1-4)
___ ___ Turn signal switches and tell-tale lights (4-2)
___ ___ Four way flashers (4-2)
___ ___ Auxiliary flasher circuit (4-2)
___ ___ Headlight dimmer switch & tell tale (1-4)
___ ___ Brake and throttle treadles (1-2)
___ ___ Park brake operation (7-2)
___ ___ Brake/throttle interlock operation & speed sensing device (1-9)
___ ___ Emergency brake override switch (1-7)
___ ___ Kneeling system (9300) (1-7)
___ ___ Front door operation (1-3)

DRIVER CONTROL AREA (continued)
___ ___ Door control valve (1-4)
___ ___ Farebox mounting (1-2)
___ ___ Radio mounting (1-2)
___ ___ Driver's seat & seat belt (2-4)
___ ___ Driver's fans (1-4)

EXTERIOR
___ ___ Front & rear door bushings and hinges (1-5)
___ ___ Windshield wiper blades (1-4)
___ ___ Bike rack (2-5)
___ ___ Ski rack (9100 - winter) (2-4)
___ ___ Mirrors & mirror heaters (2-2)
___ ___ Lights, lenses & reflectors (4-1)
___ ___ Body damage (major or unsafe) (2-3)
___ ___ Wheel seals (17-1)
___ ___ Window hinges and seals (2-3)
___ ___ Fuel tank cap, gasket and O-ring (9-1)
___ ___ Back up lights & alarm (4-1)

DRIVE TEST (in yard)
___ ___ Brakes & brake application valve (21-1)
___ ___ Retarder (21-2)
___ ___ Jacobs engine brake (9100) (21-3)
___ ___ Steering (21-1)
___ ___ Rattles, engine, transmission or wind noise (21-2)
___ ___ Gauges (21-2)

ENGINE COMPARTMENT
___ ___ Engine compartment doors and hinges (2-3)
___ ___ Engine, transmission, and engine door wiring (4-1)
___ ___ Engine compartment lights and sockets (4-1)
___ ___ Fire suppression system nozzle caps (CNG)(8-7)
___ ___ Kysor alarm and shutdown system (CNG & Series 50)(1-5)
___ ___ Fuel door micro switch (9-1)
___ ___ Oil pressure (record) (8-1) Idle__________ Full throttle__________
___ ___ Cooling fan operation (5-1)
___ ___ Cooling fan speed at idle (CNG)(5-2)
___ ___ Fuel heater operation (6V-92 - winter)(9-1)
___ ___ Booster pump operation (19-2)
___ ___ Rear start (4-1)
___ ___ Temperature gauge (1-1)
___ ___ Low coolant level sensor (DDC DDEC engines) (5-2)
___ ___ Pressurize cooling system (5-1)
___ ___ Air, oil, fuel, and coolant leaks (5-1, 6-3, 8-1, 9-1, 12-1)
___ ___ Air, oil, fuel, and coolant line routing
___ ___ Air intake system (10-1)
___ ___ Intake restriction (DDC 20", CNG 15")(10-2)
___ ___ Filter Minder (10-2)
___ ___ Sending units (8-2)
___ ___ Drain wastegate accumulator can (CNG)(8-9)
___ ___ Fan hub bearing looseness (5-2)
___ ___ Fan shroud (5-1)
___ ___ Radiator & mounts (5-3)
___ ___ Surge tank mounting & sight glass (5-3)
___ ___ A/C compressor belt condition, tension and alignment (8-8)
___ ___ Alternator belt condition, tension and alignment (CNG & Series 50) (8-8)
___ ___ Exhaust system (11-1)
___ ___ Transmission dipstick and tube (12-1)
___ ___ Engine oil dipstick and tube (8-3)

ENGINE COMPARTMENT (continued)
___ ___ Oil filler tube and stopper (8-1)

__ __ Fuel pump weephole (DDC)(9-2)
__ __ Coolant additive package (5-2)
__ __ Coolant filler cap, seal and pressure relief valve (5-1)
__ __ Pressure relief cap (5-1)
__ __ Water pump weephole (5-3)
__ __ Engine block heater (8-6)
__ __ Change fuel filters (DDC)(9-1)
__ __ Hydraulic system (use C4 10W-30 oil) (13-3)
__ __ Crankcase breather tube (8-9)
__ __ Ether bottle (DDC - winter) (8-7)
__ __ Spinner II oil filter (8-4)
__ __ Clean and spray all exposed electrical terminals (4-1)

REAR SEAT ENGINE COMPARTMENT
__ __ Any leaks or problems (8-1)
__ __ Door seal and fasteners (8-1)

MISC.
__ __ Batteries and battery tray (4-3)
__ __ Battery internal hydrometers (4-3)
__ __ Corrosion spray battery terminals (4-3)
__ __ Load test batteries (4-4) (record)
________v ________v ________v ________v
__ __ Charging voltage (4-11)
__ __ Check and record voltage drop (4-7)
Starting system; positive loss __________+
negative loss __________ = Total loss __________
Charging system; positive loss __________+
negative loss __________ = Total loss __________
__ __ Tires & tire tread depth (3-1)
__ __ Tire air pressure (3-1) Record on tire card
__ __ Wheels & lug nuts (3-1)
__ __ CNG fuel tank pressure relief devices (9-5)
__ __ Perform "General Visual CNG Cylinder Inspection" (9-5)
__ __ Test fuel tank and filler (DDC; 9-3)
__ __ Heater filters - change or clean (19-2)
__ __ Driver's heater filter (92 & 9300) (19-3)
__ __ Webasto auxiliary heater (9300 with S-50) (19-4)
__ __ DDEC codes - print and clear (1-8)
__ __ 24,000 mile Lift-U inspection
__ __ Thermo King "Yearly" inspection (yellow sheet) (19-3)

UNDER STRUCTURE
__ __ King pin wear (14-1)
__ __ Front axle (14-2)
__ __ Front leveling valve and ride height (15-2)
__ __ Front air suspension (15-1)
__ __ Front shock absorbers (15-1)
__ __ Front radius rods (15-1)
__ __ Lower steering drive shaft (13-1)
__ __ Steering shaft pinch bolts (13-1)
__ __ Tie rod & drag link ends (13-1)
__ __ Steering gears (13-1)
__ __ Heating system coolant leaks (19-3)
__ __ Fuel tank leaks (DDC)(9-1)
__ __ Differential leaks & breather (17-1)
__ __ Inner wheel seals (17-1)
__ __ Brake linings (7-2)
__ __ Automatic slack adjusters (7-4)
__ __ Air lines and wires (4-1 & 7-1)
__ __ Rear air suspension (16-1)
__ __ Rear shock absorbers (16-1)
__ __ Rear radius rods (16-1)
__ __ Rear leveling valve and ride height (16-1)
__ __ Tire chains (9100) (20-1)
__ __ Drive shaft (18-1)
__ __ Companion flange (18-1)
__ __ Transmission temperature light and buzzer (1-3)
__ __ Transmission breather (12-5)
__ __ Frame cracks (20-1)
__ __ Engine oil, transmission fluid and coolant leaks (5-1, 8-1, 12-1)
__ __ Isoclad undercoating (20-1)
__ __ Splash guards (20-2)
__ __ Clean and spray all exposed electrical connections (20-1)

AIR & BRAKE SYSTEM CHECKS
SR-1 spring brake valve and double check valve (7-3)
__ __ Air dryer and purge valve (6-1)
__ __ Air compressor performance (record) (6-2) __________ seconds
__ __ Air governor cut-in & cut-out (adjust) (6-3) Cut-in __________
Cut-out __________
__ __ Air leaks, brakes released (7-1) _______psi drop in 2 min.
__ __ Air pressure drop, brakes applied (7-1) _______psi drop
__ __ Air leaks, brakes applied (7-1) _______psi drop in 2 min.
__ __ Safety valves (6-2)
__ __ Air tank single check valves (6-3)
__ __ Dash air gauges (6-2)
__ __ Rear service brake pressure (7-4)
__ __ Brake interlock pressure (7-4)
__ __ Air leaks with a Son-Tector & soap (6-3)

LUBRICATION
__ __ Drain air box canister (6V-92) (8-7)
__ __ Change engine oil filter (8-2 DDC) (8-9 CNG)
__ __ Change engine oil (8-2 DDC) (8-9 CNG)
__ __ Torque engine oil pan plug (6V-92 25-35 lb/ft, Series 50 33-37 lb/ft, CNG 65 lb/ft)
__ __ Change transmission oil (Allison 12-2) (ZF 12-3)
__ __ Torque transmission pan plug (Allison 30 lb/ft; ZF 37 lb/ft)
__ __ Change transmission filters (Allison 12-2) (ZF 12-3)
__ __ Change differential oil (17-1)
__ __ Wipe off grease fittings before greasing (23-1)
__ __ King pins (#2 grease) (23-1)
__ __ Steering components, except steering gears (#2 grease) (23-2)
__ __ Brake components: S-cams, slacks & anchor pins (#2 grease) (23-1)
__ __ Drive shaft (#2 grease) (23-3)
__ __ On Spot tire chains (9100) (#2 grease) (23-3)
__ __ Upper steering shaft (#2 grease) (23-3)
__ __ Steering gear (#1 grease) (23-2)
__ __ Steering miter gear (#1 grease) (23-2)
__ __ Exterior mirrors (#1 grease & multi purpose spray lube) (23-4)
__ __ Electrical panel door hinge (#1 grease or JT-6) (23-2)
__ __ Passenger door linkage (JT-6) (23-4)
__ __ Driver's seat (silicone spray) (23-4)
__ __ Window sliders & hinges (silicone spray) (23-4)
__ __ Driver's heat and temperature control cables (23-4)
__ __ Brake treadle/pedal (multi purpose spray lube) (23-2)
__ __ Battery tray slider & hinge (multi purpose spray lube) (23-4)
__ __ Driver's front vent (multi purpose spray lube) (23-4)
__ __ Windshield wiper pivot points (multi purpose spray lube) (1-4)
__ __ External door hinges (multi purpose spray lube) (23-4)
__ __ Bike rack pins and latch (Multi purpose spray lube) (23-3)
__ __ Battery tray "T" bolt (anti-seize) (23-4)
__ __ Run engine and check fluid levels and leaks

EMPLOYEE SIGNATURE	EMPLOYEE NUMBER
1	
2	
FOREMAN SIGNATURE	DATE

12,000 MILE "C" INSPECTION
9100, 9200 & 9300 ORION I & V

8/00kb

BUS NUMBER ______ WORK ORDER NUMBER ______ DATE ______ HUBODOMETER MILES AT INSPECTION ______

AMED CLEANED	YES NO	DIVISION	
UNDER STRUCTURE	___ ___	CENTRAL	____
ENG. COMPARTMENT	___ ___	MEADOWBROOK	____
BATTERIES	___ ___	MT. OGDEN	____
FUEL TANK (not CNG)	___ ___	TIMPANOGOS	____
RADIATOR	___ ___		

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INTERIOR

___ ___ Destination signs (2-2)
___ ___ Route sign box (2-1)
___ ___ DEC book holder, fare card holder and schedule boxes (2-3)
___ ___ Front door emergency air control (1-6)
___ ___ Sun visors (2-3)
___ ___ Mirrors (2-2)
___ ___ Passenger chime and next stop lights (2-1)
___ ___ Stanchions and grabrails (2-1)
___ ___ Seats and frames (2-2)
___ ___ Emergency exit hatches (2-2)
___ ___ Flooring and step wells (2-1)
___ ___ Windows & latches (2-3)
___ ___ Emergency escape windows (2-1)
___ ___ Side and ceiling panels (2-3)
___ ___ Lights (4-2)
___ ___ Exit doors (1-6)
___ ___ Exit door sensitive edges (1-6)
___ ___ Brake/throttle interlock adjustment (1-7)
___ ___ Fire extinguisher & tag (1-3)
___ ___ Fire suppression system (CNG)(8-7)
___ ___ Modesty panels & driver's partition (2-3)
___ ___ Emergency road reflectors (1-2)

VER CONTROL AREA

___ ___ Indicator lamp test (1-9)
___ ___ No charge circuit (1-2)
___ ___ Check trans, check engine and engine stop circuits (DDEC)(1-1)
___ ___ Neutral start (4-1)
___ ___ Starter cut-out circuit (4-1)
___ ___ Low air circuit (1-1)
___ ___ Dash night lights (4-2)
___ ___ Horns (1-3)
___ ___ P.A. system (2-4)
___ ___ Tilt and telescopic steering (13-4)
___ ___ Steering column shaft and mounting (13-2)
___ ___ Steering free play (13-1)
___ ___ Oil gauge (1-2)
___ ___ Dash voltmeter (1-2)
___ ___ Fuel gauge (1-3)
___ ___ Fast idle operation (1-3)
___ ___ Transmission shift selector (12-1)
___ ___ Climate control (19-1)
___ ___ Blower motor operation (19-2)
___ ___ Front step well heater (19-2)
___ ___ Defrost (19-2)
___ ___ Driver's heat & temperature controls (19-2)
___ ___ Driver's front vent (1-2)
___ ___ Windshield wipers (1-4)
___ ___ Windshield washer (1-4)
___ ___ Turn signal switches and tell-tale lights (4-2)
___ ___ Four way flashers (4-2)
___ ___ Auxiliary flasher circuit (4-2)
___ ___ Headlight dimmer switch & tell tale (1-4)
___ ___ Brake and throttle treadles (1-2)
___ ___ Park brake operation (7-2)
___ ___ Brake/throttle interlock operation & speed sensing device (1-9)

DRIVER CONTROL AREA (continued)

___ ___ Emergency brake override switch (1-7)
___ ___ Kneeling system (9300) (1-7)
___ ___ Front door operation (1-3)
___ ___ Farebox mounting (1-2)
___ ___ Radio mounting (1-2)
___ ___ Driver's seat & seat belt (2-4)
___ ___ Driver's fans (1-4)

EXTERIOR

___ ___ Front & rear door bushings and hinges (1-5)
___ ___ Windshield wiper blades (1-4)
___ ___ Bike rack (2-5)
___ ___ Ski racks (9100 winter) (2-4)
___ ___ Mirrors & mirror heaters (2-2)
___ ___ Lights, lenses, & reflectors (4-1)
___ ___ Body damage (major or unsafe) (2-3)
___ ___ Wheel seals (17-1)
___ ___ Window hinges and seals (2-3)
___ ___ Fuel tank cap, gasket and O-ring (9-1)
___ ___ Back up lights & alarm (4-1)

DRIVE TEST (in yard)

___ ___ Brakes and brake application valve (21-1)
___ ___ Retarder (21-2)
___ ___ Jacobs engine brake (9100) (21-3)
___ ___ Steering (21-1)
___ ___ Rattles, engine, transmission or wind noise (21-2)
___ ___ Gauges (21-2)

ENGINE COMPARTMENT

___ ___ Engine compartment doors and hinges (2-3)
___ ___ Engine, transmission, and engine door wiring (4-1)
___ ___ Engine compartment lights and sockets (4-1)
___ ___ Fire suppression system nozzle caps (CNG)(8-7)
___ ___ Kysor alarm and shutdown system (CNG & Series 50)(1-5)
___ ___ Fuel door micro switch (9-1)
___ ___ Oil pressure (record) (8-1) Idle__________ Full throttle__________
___ ___ Cooling fan operation (5-1)
___ ___ Cooling fan speed at idle (CNG)(5-2)
___ ___ Fuel heater operation (6V-92 - winter)(9-1)
___ ___ Booster pump operation (19-2)
___ ___ Rear start (4-1)
___ ___ Temperature gauge (1-1)
___ ___ Air, oil, fuel, and coolant leaks (5-1, 6-3, 8-1, 9-1, 12-1)
___ ___ Air, oil, fuel, and coolant line routing
___ ___ Pressurize cooling system (5-1)
___ ___ Engine sending units (8-2)
___ ___ Air intake system (10-1)
___ ___ Intake restriction (DDC 20", CNG 15")(10-2)
___ ___ Drain wastegate accumulator can (CNG)(8-9)
___ ___ Fan hub bearing looseness (5-2)
___ ___ Fan shroud (5-1)
___ ___ Radiator & mounts (5-3)
___ ___ Surge tank mounting & sight glass (5-3)
___ ___ A/C compressor belt condition, tension and alignment (8-8)
___ ___ Alternator belt condition, tension and alignment (CNG & Series 50) (8-8)

ENGINE COMPARTMENT (continued)

- ___ ___ Exhaust system (11-1)
- ___ ___ Transmission dipstick and tube (12-1)
- ___ ___ Engine oil dipstick and tube (8-3)
- ___ ___ Coolant additive package (5-2)
- ___ ___ Coolant filler cap, seal and pressure relief valve (5-1)
- ___ ___ Oil filler tube and stopper (8-1)
- ___ ___ Fuel pump weephole (DDC)(9-2)
- ___ ___ Pressure relief cap (5-1)
- ___ ___ Water pump weephole (5-3)
- ___ ___ Engine block heater (8-6)
- ___ ___ Change fuel filters (DDC)(9-1)
- ___ ___ Hydraulic system (use C4 10W-30 oil) (13-3)
- ___ ___ Ether bottle (DDC - winter) (8-7)
- ___ ___ Crankcase breather tube (CNG) (8-9)
- ___ ___ Clean and spray all exposed electrical terminals (4-1)

MISC.

- ___ ___ Batteries and battery tray (4-3)
- ___ ___ Battery internal hydrometers (4-3)
- ___ ___ Load test batteries (4-4) (record)
  ________v ________v ________v ________v
- ___ ___ Corrosion spray battery terminals (4-3)
- ___ ___ Charging voltage (4-11)
- ___ ___ Tires & tire tread depth (3-1)
- ___ ___ Tire air pressure (3-1) Record on tire card
- ___ ___ Wheels & lug nuts (3-1)
- ___ ___ CNG fuel tank pressure relief devices (9-5)
- ___ ___ Perform "General Visual CNG Cylinder Inspection" (9-5)
- ___ ___ Heater filters - change or clean (19-2)
- ___ ___ Driver's heater filter (92 & 9300) (19-3)
- ___ ___ Webasto auxiliary heater (9300 S-50) (19-4)
- ___ ___ DDEC codes - print and clear (1-8)
- ___ ___ 3,000 mile Lift-U inspection
- ___ ___ Thermo King "6,000 mile" inspection (blue sheet) (19-3)

UNDER STRUCTURE

- ___ ___ Front axle (14-2)
- ___ ___ Front leveling valve and ride height (15-2)
- ___ ___ Front air suspension (15-1)
- ___ ___ Front shock absorbers (15-1)
- ___ ___ Front radius rods (15-1)
- ___ ___ Lower steering drive shaft (13-1)
- ___ ___ Steering shaft pinch bolts (13-1)
- ___ ___ Tie rod & drag link ends (13-1)
- ___ ___ Steering gears (13-1)
- ___ ___ Heating system coolant leaks (19-3)
- ___ ___ Fuel tank leaks (DDC)(9-1)
- ___ ___ Differential leaks & breather (17-1)
- ___ ___ Inner wheel seals (17-1)
- ___ ___ Brake linings (7-2)
- ___ ___ Automatic slack adjusters (7-4)
- ___ ___ Air lines and wires (4-1 & 7-1)
- ___ ___ Rear air suspension (16-1)
- ___ ___ Rear shock absorbers (16-1)
- ___ ___ Rear radius rods (16-1)
- ___ ___ Rear leveling valve and ride height (16-1)
- ___ ___ Tire chains (20-1)
- ___ ___ Drive shaft (18-1)
- ___ ___ Companion flange (18-1)
- ___ ___ Transmission temperature light and buzzer (1-3)
- ___ ___ Frame cracks (20-1)
- ___ ___ All under floor equipment (20-1)
- ___ ___ Exhaust system (11-1)
- ___ ___ Engine oil, transmission fluid and coolant leaks (5-1, 8-1, 12-1)
- ___ ___ Isoclad undercoating (20-1)
- ___ ___ Splash guards (20-2)
- ___ ___ Clean and spray all exposed electrical connections (20-1)

AIR & BRAKE SYSTEM CHECKS

- ___ ___ Drain all air tanks (6-1)
- ___ ___ Air dryer and purge valve (6-1)
- ___ ___ Air compressor performance (record) (6-2) __________ seconds
- ___ ___ Air governor cut-in & cut-out (adjust) (6-3) Cut-in __________
  Cut-out __________
- ___ ___ Air leaks, brakes released (7-1) _______psi drop in 2 min.
- ___ ___ Air pressure drop, brakes applied (7-1) _______psi drop
- ___ ___ Air leaks, brakes applied (7-1) _______psi drop in 2 min.
- ___ ___ Safety valves (6-2)
- ___ ___ Air leaks with a Son-Tector & soap (6-3)

LUBRICATION

- ___ ___ Drain air box canister (8-7)
- ___ ___ Change engine oil filter (8-2 DDC)(8-9 CNG)
- ___ ___ Change engine oil (8-2 DDC)(8-9 CNG)
- ___ ___ Torque engine oil pan plug (6V-92 25-35 lb/ft, Series 50 33-37 lb/ft, CNG 65 lb/ft)
- ___ ___ Change transmission oil (12-2 & 3)
- ___ ___ Change transmission filters - ZF only on C insp. (12-3)
- ___ ___ Torque transmission pan plug (Allison 30 lb/ft; ZF 37 lb/ft)
- ___ ___ Check differential oil level (17-1)
- ___ ___ Wipe off grease fittings before greasing (23-1)
- ___ ___ King pins (#2 grease) (23-1)
- ___ ___ Steering components, except steering gears (#2 grease) (23-2)
- ___ ___ Brake components - S-cams, slacks & anchor pins (#2 grease) (23-1)
- ___ ___ Tire chains (#2 grease) (23-3)
- ___ ___ Drive shaft (#2 grease) (23-3)
- ___ ___ Steering gear (#1 grease) (23-2)
- ___ ___ Steering miter gear (#1 grease) (23-2)
- ___ ___ Exterior mirrors (#1 grease & multi purpose spray lube) (23-4)
- ___ ___ Electrical panel door hinge (#1 grease or JT-6) (23-2)
- ___ ___ Passenger door linkage (JT-6) (23-4)
- ___ ___ Driver's seat (silicone spray) (23-4)
- ___ ___ Window sliders & hinges (silicone spray) (23-4)
- ___ ___ Driver's heat and temperature control cables (multi purpose spray lube) (23-4)
- ___ ___ Brake treadle pedal (multi purpose spray lube) (23-2)
- ___ ___ Battery tray slider & hinge (multi purpose spray lube) (23-4)
- ___ ___ Driver's front vent (multi purpose spray lube) (23-4)
- ___ ___ External door hinges (multi purpose spray lube) (23-4)
- ___ ___ Bike rack pins and latch (Multi purpose spray lube) (23-3)
- ___ ___ Windshield wiper pivot points (Multi purpose spray lube) (1-4)
- ___ ___ Battery tray "T" bolt (anti-seize) (23-4)
- ___ ___ Run engine and check fluid levels and leaks

EMPLOYEE SIGNATURE	EMPLOYEE NUMBER
1	
2	
FOREMAN SIGNATURE	DATE

24,000 MILE "B" INSPECTION - 9100, 9200 & 9300 ORION I & V

BUS NUMBER	WORK ORDER NUMBER	DATE	HUBODOMETER MILES AT INSPECTION

[illegible]MED CLEANED	YES	NO	DIVISION	
UNDER STRUCTURE	___	___	CENTRAL	___
ENG. COMPARTMENT	___	___	MEADOWBROOK	___
BATTERIES	___	___	MT. OGDEN	___
FUEL TANK (not CNG)	___	___	TIMPANOGOS	___
RADIATOR	___	___		

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" X " = Adjusted - Item checked has been replaced and is ready for service.

" O " = Repairs Needed - Any item requiring repair.

INTERIOR

___ ___ Destination signs (2-2)
___ ___ Route sign box (2-1)
___ ___ DEC book holder, fare card holder and schedule boxes (2-3)
___ ___ Front door emergency air control (1-6)
___ ___ Sun visors (2-3)
___ ___ Mirrors (2-2)
___ ___ Passenger chime and next stop lights (2-1)
___ ___ Stanchions and grabrails (2-1)
___ ___ Seats and frames (2-2)
___ ___ Emergency exit hatches (2-2)
___ ___ Flooring and step wells (2-1)
___ ___ Windows & latches (2-3)
___ ___ Emergency escape windows (2-1)
___ ___ Side and ceiling panels (2-3)
___ ___ Lights (4-2)
___ ___ Exit doors (1-6)
___ ___ Exit door sensitive edges (1-6)
___ ___ Brake/throttle interlock adjustment (1-7)
___ ___ Fire extinguisher & tag (1-3)
___ ___ Fire suppression system (CNG)(8-7)
___ ___ Modesty panels & driver's partition (2-3)
___ ___ Emergency road reflectors (1-2)

[illegible]ER CONTROL AREA

___ ___ Indicator lamp test (1-9)
___ ___ No charge circuit (1-2)
___ ___ Check trans, check engine and engine stop circuits (DDEC)(1-1)
___ ___ Neutral start (4-1)
___ ___ Starter cut-out circuit (4-1)
___ ___ Low air circuit (1-1)
___ ___ Dash night lights (4-2)
___ ___ Horns (1-3)
___ ___ P.A. system (2-4)
___ ___ Tilt and telescopic steering (13-4)
___ ___ Steering column shaft and mounting (13-2)
___ ___ Steering free play (13-1)
___ ___ Oil gauge (1-2)
___ ___ Dash voltmeter (1-2)
___ ___ Fuel gauge (1-3)
___ ___ Fast idle operation (1-3)
___ ___ Transmission shift selector (12-1)
___ ___ Climate control (19-1)
___ ___ Blower motor operation (19-2)
___ ___ Front step well heater (19-2)
___ ___ Defrost (19-2)
___ ___ Driver's heat & temperature controls (19-2)
___ ___ Driver's front vent (1-2)
___ ___ Windshield wipers (1-4)
___ ___ Windshield washer (1-4)
___ ___ Turn signal switches and tell-tale lights (4-2)
___ ___ Four way flashers (4-2)
___ ___ Auxiliary flasher circuit (4-2)
___ ___ Headlight dimmer switch & tell tale (1-4)
___ ___ Brake and throttle treadles (1-2)
___ ___ Park brake operation (7-2)
___ ___ Brake/throttle interlock operation & speed sensing device(1-9)
___ ___ Emergency brake override switch (1-7)
___ ___ Kneeling system (9300) (1-7)
___ ___ Front door operation (1-3)

DRIVER CONTROL AREA (continued)

___ ___ Door control valve (1-4)
___ ___ Farebox mounting (1-2)
___ ___ Radio mounting (1-2)
___ ___ Driver's seat & seat belt (2-4)
___ ___ Driver's fans (1-4)

EXTERIOR

___ ___ Front & rear door bushings and hinges (1-5)
___ ___ Windshield wiper blades (1-4)
___ ___ Bike rack (2-5)
___ ___ Ski rack (9100 - winter) (2-4)
___ ___ Mirrors & mirror heaters (2-2)
___ ___ Lights, lenses, & reflectors (4-1)
___ ___ Body damage (major or unsafe) (2-3)
___ ___ Wheel seals (17-1)
___ ___ Window hinges and seals (2-3)
___ ___ Fuel tank cap, gasket and O-ring (9-1)
___ ___ Back up lights & alarm (4-1)

DRIVE TEST (in yard)

___ ___ Brakes and brake application valve (21-1)
___ ___ Retarder (21-2)
___ ___ Jacobs engine brake (9100) (21-3)
___ ___ Steering (21-1)
___ ___ Rattles, engine, transmission or wind noise (21-2)
___ ___ Gauges (21-2)

ENGINE COMPARTMENT

___ ___ Engine compartment doors and hinges (2-3)
___ ___ Engine, transmission, and engine door wiring (4-1)
___ ___ Engine compartment lights and sockets (4-1)
___ ___ Fire suppression system nozzle caps (CNG)(8-7)
___ ___ Kysor alarm and shutdown system (CNG & Series 50)(1-5)
___ ___ Fuel door micro switch (9-1)
___ ___ Oil pressure (record) (8-1) Idle__________ Full throttle__________
___ ___ Cooling fan operation (5-1)
___ ___ Cooling fan speed at idle (CNG)(5-2)
___ ___ Fuel heater operation (6V-92 - winter) (9-1)
___ ___ Booster pump operation (19-2)
___ ___ Rear start (4-1)
___ ___ Temperature gauge (1-1)
___ ___ Pressurize cooling system (5-1)
___ ___ Air, oil, fuel, and coolant leaks (5-1, 6-3, 8-1, 9-1, 12-1)
___ ___ Air, oil, fuel, and coolant line routing
___ ___ Engine sending units (8-2)
___ ___ Air intake system (10-1)
___ ___ Intake restriction (DDC 20", CNG 15")(10-2)
___ ___ Filter Minder (10-2)
___ ___ Drain wastegate accumulator can (CNG)(8-9)
___ ___ Fan hub bearing looseness (5-2)
___ ___ Fan shroud (5-1)
___ ___ Radiator & mounts (5-3)
___ ___ Surge tank mounting & sight glass(5-3)
___ ___ A/C compressor belt condition, tension and alignment (8-8)
___ ___ Alternator belt condition, tension and alignment (CNG & Series 50) (8-8)
___ ___ Exhaust system (11-1)
___ ___ Transmission dipstick and tube (12-1)
___ ___ Engine oil dipstick and tube (8-3)
___ ___ Oil filler tube and stopper (8-1)

ENGINE COMPARTMENT (continued)
___ ___ Fuel pump weephole (DDC)(9-2)
___ ___ Coolant additive package (5-2)
___ ___ Coolant filler cap, seal and pressure relief valve (5-1)
___ ___ Pressure relief cap (5-1)
___ ___ Water pump weephole (5-3)
___ ___ Engine block heater (8-6)
___ ___ Change fuel filters (DDC)(9-1)
___ ___ Hydraulic system (use C4 10W-30 oil) (13-3)
___ ___ Ether bottle (DDC - winter) (8-7)
___ ___ Spinner II oil filter (8-4)
___ ___ Crankcase breather tube (8-9)
___ ___ Clean and spray all exposed electrical terminals (4-1)

REAR SEAT ENGINE COMPARTMENT
___ ___ Any leaks or problems (8-2)
___ ___ Door seal and fasteners (8-2)

MISC.
___ ___ Batteries and battery tray (4-3)
___ ___ Battery internal hydrometers (4-3)
___ ___ Load test batteries (4-4) (record)
________v ________v ________v ________v
___ ___ Corrosion spray battery terminals (4-3)
___ ___ Charging voltage (4-11)
___ ___ Tires & tire tread depth (3-1)
___ ___ Tire air pressure (3-1) Record on tire card
___ ___ Wheels & lug nuts (3-1)
___ ___ CNG fuel tank pressure relief devices (9-5)
___ ___ Perform "General Visual CNG Cylinder Inspection" (9-5)
___ ___ Heater filters - change or clean (19-2)
___ ___ Driver's heater filter (92 & 9300) (19-3)
___ ___ Webasto auxiliary heater (9300 with S50) (19-4)
___ ___ DDEC codes - print and clear (1-8)
___ ___ 24,000 mile Lift-U inspection
___ ___ Thermo King "Semi Yearly" inspection (pink sheet) (19-3)

UNDER STRUCTURE
___ ___ King pin wear (14-1)
___ ___ Front axle (14-2)
___ ___ Front leveling valve and ride height (15-2)
___ ___ Front air suspension (15-1)
___ ___ Front shock absorbers (15-1)
___ ___ Front radius rods (15-1)
___ ___ Lower steering drive shaft (13-1)
___ ___ Steering shaft pinch bolts (13-1)
___ ___ Tie rod & drag link ends (13-1)
___ ___ Steering gears (13-1)
___ ___ Heating system coolant leaks (19-3)
___ ___ Fuel tank leaks (DDC)(9-1)
___ ___ Differential leaks & breather (17-1)
___ ___ Inner wheel seals (17-1)
___ ___ Brake linings (7-2)
___ ___ Automatic slack adjusters (7-4)
___ ___ Air lines and wires (4-1 & 7-1)
___ ___ Rear air suspension (16-1)
___ ___ Rear shock absorbers (16-1)
___ ___ Rear radius rods (16-1)
___ ___ Rear leveling valve and ride height (16-1)
___ ___ Tire chains (20-1)
___ ___ Drive shaft (18-1)
___ ___ Companion flange (18-1)
___ ___ Transmission breather (12-5)
___ ___ Transmission temperature light and buzzer (1-3)
___ ___ Frame cracks (20-1)
___ ___ All under floor equipment (20-1)
___ ___ Exhaust system (11-1)
___ ___ Engine oil, transmission fluid and coolant leaks (5-1, 8-1, 12-1)
___ ___ Isoclad undercoating (20-1)
___ ___ Splash guards (20-2)
___ ___ Clean and spray all exposed electrical connections (20-1)

AIR & BRAKE SYSTEM CHECKS
___ ___ SR-1 spring brake valve and double check valve (7-3)
___ ___ Drain all air tanks (6-1)
___ ___ Air dryer and purge valve (6-1)
___ ___ Air compressor performance (record)(6-2) ___________ seconds
___ ___ Air governor cut-in & cut-out (adjust)(6-3) Cut-in ___________
Cut-out ___________
___ ___ Air leaks, brakes released (7-1) ________psi drop in 2 min.
___ ___ Air pressure drop, brakes applied (7-1) ________psi drop
___ ___ Air leaks, brakes applied (7-1) ________psi drop in 2 min.
___ ___ Safety valves (6-2)
___ ___ Air tank single check valves (6-3)
___ ___ Dash air gauges (6-2)
___ ___ Rear service brake pressure (7-4)
___ ___ Brake interlock pressure (7-4)
___ ___ Air leaks with a Son-Tector & soap (6-3)

LUBRICATION
___ ___ Drain air box canister (8-7)
___ ___ Change engine oil filter (8-2 DDC)(8-9 CNG)
___ ___ Change engine oil (8-2 DDC)(8-9 CNG)
___ ___ Torque engine oil pan plug (6V-92 25-35 lb/ft, Series 50 33-37 lb/ft, CNG 65 lb/ft)
___ ___ Change transmission oil (Allison 12-2)(ZF 12-3)
___ ___ Torque transmission pan plug (Allison 30 lb/ft; ZF 37 lb/ft)
___ ___ Change transmission filters (Allison 12-2)(ZF 12-3)
___ ___ Check differential oil level (17-1)
___ ___ Wipe off grease fittings before greasing (23-1)
___ ___ King pins (#2 grease) (23-1)
___ ___ Steering components, except steering gears (#2 grease) (23-2)
___ ___ Brake components: S-cams, slacks & anchor pins (#2 grease) (23-1)
___ ___ Drive shaft (#2 grease) (23-3)
___ ___ Tire chains (#2 grease) (23-3)
___ ___ Upper steering shaft (#2 grease) (23-3)
___ ___ Steering gear (#1 grease) (23-2)
___ ___ Steering miter gear (#1 grease) (23-2)
___ ___ Exterior mirrors (#1 grease & multi purpose spray lube) (23-4)
___ ___ Passenger door linkage (JT-6) (23-4)
___ ___ Driver's seat (silicone spray) (23-4)
___ ___ Window sliders & hinges (silicone spray) (23-4)
___ ___ Driver's heat and temperature control cables (23-4)
___ ___ Brake treadle pedal (multi purpose spray lube) (23-2)
___ ___ Battery tray slider & hinge (multi purpose spray lube) (23-4)
___ ___ Driver's front vent (multi purpose spray lube) (23-4)
___ ___ Windshield wiper pivot points (multi purpose spray lube) (1-4)
___ ___ External door hinges (multi purpose spray lube) (23-4)
___ ___ Bike rack pins and latch (Multi purpose spray lube) (23-3)
___ ___ Battery tray "T" bolt (anti-seize) (23-4)
___ ___ Run engine and check fluid levels and leaks

EMPLOYEE SIGNATURE	EMPLOYEE NUMBER
1	
2	
FOREMAN SIGNATURE	DATE

6,000 MILE "D" INSPECTION - 9100, 9200 & 9300 ORION I & V

8/00kb

BUS NUMBER	WORK ORDER NUMBER	DATE	HUBODOMETER MILES AT INSPECTION

STEAMED CLEANED	YES	NO	DIVISION	
UNDER STRUCTURE	___	___	CENTRAL	___
ENG. COMPARTMENT	___	___	MEADOWBROOK	___
BATTERIES	___	___	MT. OGDEN	___
FUEL TANK (not CNG)	___	___	TIMPANOGOS	___
RADIATOR	___	___		

FIRST SPACE - Inspector(s) number to be used as a check off identification for work completed.
SECOND SPACE - Use this space to indicate whether an item was okay, adjusted, or repairs needed.
" 4 " = Okay - Item checked is ready for service.
" X " = Adjusted - Item checked has been replaced and is ready for service.
" O " = Repairs Needed - Any item requiring repair.

Numbers in ( ) indicate P/M manual page number.

INTERIOR
___ ___ Destination signs (2-2)
___ ___ Route sign box (2-1)
___ ___ DEC book holder, fare card holder and schedule boxes (2-3)
___ ___ Front door emergency air control (1-6)
___ ___ Sun visors (2-3)
___ ___ Mirrors (2-2)
___ ___ Passenger chime and next stop lights (2-1)
___ ___ Stanchions and grabrails (2-1)
___ ___ Seats and frames (2-2)
___ ___ Emergency exit hatches (2-2)
___ ___ Flooring and step wells (2-1)
___ ___ Windows & latches (2-3)
___ ___ Emergency escape windows (2-1)
___ ___ Side and ceiling panels (2-3)
___ ___ Lights (4-2)
___ ___ Exit doors (1-6)
___ ___ Exit door sensitive edges (1-6)
___ ___ Brake/throttle interlock adjustment (1-7)
___ ___ Fire extinguisher & tag (1-3)
___ ___ Fire suppression system (CNG)(8-7)
___ ___ Modesty panels & driver's partition (2-3)
___ ___ Emergency road reflectors (1-2)

DRIVER CONTROL AREA
___ ___ Indicator lamp test (1-9)
___ ___ No charge circuit (1-2)
___ ___ Check trans, check engine and engine stop circuits (DDEC)(1-1)
___ ___ Neutral start (4-1)
___ ___ Starter cut-out circuit (4-1)
___ ___ Low air circuit (1-1)
___ ___ Dash night lights (4-2)
___ ___ Horns (1-3)
___ ___ P.A. system (2-4)
___ ___ Tilt and telescopic steering (13-4)
___ ___ Steering column shaft and mounting (13-2)
___ ___ Steering free play (13-1)
___ ___ Oil gauge (1-2)
___ ___ Dash voltmeter (1-2)
___ ___ Fuel gauge (1-3)
___ ___ Fast idle operation (1-3)
___ ___ Transmission shift selector (12-1)
___ ___ Climate control (19-1)
___ ___ Blower motor operation (19-2)
___ ___ Front step well heater (19-2)
___ ___ Defrost (19-2)
___ ___ Driver's heat & temperature controls (19-2)
___ ___ Driver's front vent (1-2)
___ ___ Windshield wipers (1-4)
___ ___ Windshield washer (1-4)
___ ___ Turn signal switches and tell-tale lights (4-2)
___ ___ Four way flashers (4-2)
___ ___ Auxiliary flasher circuit (4-2)
___ ___ Headlight dimmer switch & tell tale (1-4)
___ ___ Brake and throttle treadles (1-2)
___ ___ Park brake operation (7-2)
___ ___ Emergency brake override switch (1-7)
___ ___ Brake/throttle interlock operation & speed sensing device(1-9)
___ ___ Kneeling system (9300) (1-7)
___ ___ Front door operation (1-3)

DRIVER CONTROL AREA (continued)
___ ___ Door control valve (1-4)
___ ___ Farebox mounting (1-2)
___ ___ Radio mounting (1-2)
___ ___ Driver's seat & seat belt (2-4)
___ ___ Driver's fans (1-4)

EXTERIOR
___ ___ Front & rear door bushings and hinges (1-5)
___ ___ Windshield wiper blades (1-4)
___ ___ Bike rack (2-5)
___ ___ Ski racks (9100 - winter) (2-4)
___ ___ Mirrors & mirror heaters (2-2)
___ ___ Lights, lenses, & reflectors (4-1)
___ ___ Body damage (major or unsafe) (2-3)
___ ___ Wheel seals (17-1)
___ ___ Window hinges and seals (2-3)
___ ___ Fuel tank cap, gasket and O-ring (9-1)
___ ___ Back up lights & alarm (4-1)

DRIVE TEST (in yard)
___ ___ Brakes and brake application valve (21-1)
___ ___ Retarder (21-2)
___ ___ Jacobs engine brake (9100) (21-3)
___ ___ Steering (21-1)
___ ___ Rattles, engine, transmission or wind noise (21-2)
___ ___ Exhaust gases inside coach (21-1)
___ ___ Gauges (21-2)

ENGINE COMPARTMENT
___ ___ Engine compartment doors and hinges (2-3)
___ ___ Engine, transmission, and engine door wiring (4-1)
___ ___ Engine compartment lights and sockets (4-1)
___ ___ Fire suppression system nozzle caps (CNG)(8-7)
___ ___ Kysor alarm and shutdown system (CNG & Series 50)(1-5)
___ ___ Fuel door micro switch (9-1)
___ ___ Oil pressure (record) (8-1) Idle__________ Full throttle__________
___ ___ Cooling fan operation (5-1)
___ ___ Cooling fan speed at idle (CNG)(5-3)
___ ___ Fuel heater operation (6V-92 - winter) (9-1)
___ ___ Booster pump operation (19-2)
___ ___ Rear start (4-1)
___ ___ Temperature gauge (1-1)
___ ___ Pressurize cooling system (5-1)
___ ___ Air, oil, fuel, and coolant leaks (5-1, 6-3, 8-1, 9-1, 12-1)
___ ___ Air, oil, fuel, and coolant line routing
___ ___ Engine sending units (8-2)
___ ___ Air intake system (10-1)
___ ___ Intake restriction (DDC 20", CNG 15")(10-2)
___ ___ Drain wastegate accumulator can (CNG)(8-9)
___ ___ Fan hub bearing looseness (5-2)
___ ___ Fan shroud (5-1)
___ ___ Radiator & mounts (5-3)
___ ___ Surge tank mounting & sight glass (5-3)
___ ___ A/C compressor belt condition, tension and alignment (8-8)
___ ___ Alternator belt condition, tension and alignment (CNG & Series 50) (8-8)
___ ___ Exhaust system (11-1)
___ ___ Transmission dipstick and tube (12-1)
___ ___ Engine oil dipstick and tube (8-3)

ENGINE COMPARTMENT (continued)
___ ___ Oil filler tube and stopper (8-1)

___ ___ Fuel pump weephole (DDC)(9-2)
___ ___ Water pump weephole (5-3)
___ ___ Engine block heater (8-6)
___ ___ Drain water from Racor fuel filter (9-1)
___ ___ Hydraulic system (use C4 10W-30 oil) (13-3)
___ ___ Ether bottle (DDC - winter) (8-7)
___ ___ Crankcase breather tube (8-9)
___ ___ Clean and spray all exposed electrical terminals (4-1)

MISC.
___ ___ Batteries and battery tray (4-3)
___ ___ Battery internal hydrometers (4-3)
___ ___ Clean and spray battery terminals (4-3)
___ ___ Charging voltage (4-11)
___ ___ Tires & tire tread depth (3-1)
___ ___ Tire air pressure (3-1) Record on tire card
___ ___ Wheels & lug nuts (3-1)
___ ___ CNG fuel tank pressure relief devices (9-5)
___ ___ Perform "General Visual CNG Cylinder Inspection" (9-5)
___ ___ Heater filters - change or clean (19-2)
___ ___ Driver's heater filter (92 & 9300) (19-3)
___ ___ Webasto auxiliary heater (9300 S-50) (19-4)
___ ___ DDEC codes - print and clear (1-8)
___ ___ 3,000 mile Lift-U inspection
___ ___ Thermo King "6,000 mile" inspection (blue sheet) (19-3)

UNDER STRUCTURE
___ ___ Front axle (14-2)
___ ___ Front leveling valve and ride height (15-2)
___ ___ Front air suspension (15-1)
___ ___ Front shock absorbers (15-1)
___ ___ Front radius rods (15-1)
___ ___ Lower steering drive shaft (13-1)
___ ___ Tie rod & drag link ends (13-1)
___ ___ Steering gears (13-1)
___ ___ Heating system coolant leaks (19-3)
___ ___ Fuel tank leaks (DDC)(9-1)
___ ___ Differential leaks & breather (17-1)
___ ___ Inner wheel seals (17-1)
___ ___ Brake linings (7-2)
___ ___ Automatic slack adjusters (7-4)
___ ___ Air lines and wires (4-1 & 7-1)
___ ___ Rear air suspension (16-1)
___ ___ Rear shock absorbers (16-1)
___ ___ Rear radius rods (16-1)
___ ___ Rear leveling valve and ride height (16-1)
___ ___ Tire chains (20-1)
___ ___ Drive shaft (18-1)
___ ___ Companion flange (18-1)
___ ___ Transmission temperature light and buzzer (1-3)
___ ___ Frame cracks (20-1)
___ ___ All under floor equipment (20-1)
___ ___ Exhaust system (11-1)
___ ___ Engine oil, transmission fluid and coolant leaks (5-1, 8-1, 12-1)
___ ___ Isoclad undercoating (20-1)
___ ___ Splash guards (20-2)
___ ___ Clean and spray all exposed electrical connections (20-1)

AIR & BRAKE SYSTEM CHECKS
___ ___ Drain all air tanks (6-1)
___ ___ Air dryer and purge valve (6-1)
___ ___ Air compressor performance (record) (6-2) ___________ seconds
___ ___ Air governor cut-in & cut-out (adjust) (6-3) Cut-in ___________
Cut-out ___________
___ ___ Air leaks, brakes released (7-1) _______psi drop in 2 min. (2 psi max)
___ ___ Air pressure drop, brakes applied (7-1) _______psi drop (20 psi max)
___ ___ Air leaks, brakes applied (7-1) _______psi drop in 2 min. (4 psi max)
___ ___ Safety valves (6-2)
___ ___ Air leaks with a Son-Tector & soap (6-3)

LUBRICATION
___ ___ Drain air box canister (8-7)
___ ___ Change engine oil filter (8-2 DDC)(8-9 CNG)
___ ___ Change engine oil (8-2 DDC)(8-9 CNG)
___ ___ Torque engine oil pan plug (6V-92 25-35 lb/ft, Series 50 33-37 lb/ft, CNG 65 lb/ft)
___ ___ Check differential oil level (17-1)
___ ___ Wipe off grease fittings before greasing (23-1)
___ ___ King pins (#2 grease) (23-1)
___ ___ Steering components, except steering gears (#2 grease) (23-2)
___ ___ Brake components - S-cams, slacks & anchor pins (#2 grease) (23-1)
___ ___ Tire chains (9100) #2 grease) (23-3)
___ ___ Drive shaft (#2 grease) (23-3)
___ ___ Steering gear (#1 grease) (23-2)
___ ___ Steering miter gear (#1 grease) (23-2)
___ ___ Exterior mirrors (#1 grease & multi purpose spray lube) (23-4)
___ ___ Driver's seat (silicone spray) (23-4)
___ ___ Window sliders & hinges (silicone spray) (23-4)
___ ___ Driver's heat and temperature control cables (multi purpose spray lube) (23-4)
___ ___ Brake treadle pedal (multi purpose spray lube) (23-2)
___ ___ Battery tray slider & hinge (multi purpose spray lube) (23-4)
___ ___ Driver's front vent (multi purpose spray lube) (23-4)
___ ___ Windshield wiper pivot points (multi purpose spray lube)(1-4)
___ ___ External door hinges (multi purpose spray lube) (23-4)
___ ___ Bike rack pins and latch (Multi purpose lube) (23-3)
___ ___ Battery tray "T" bolt (anti-seize) (23-4)
___ ___ Run engine and check fluid levels and leaks

EMPLOYEE SIGNATURE	EMPLOYEE NUMBER
1	
2	
FOREMAN SIGNATURE	DATE

3,000 MILE - LIFT-U INSPECTION
9100, 9200 & 9300 ORION

8/00kb

__________ BUS NUMBER

__________ WORK ORDER NUMBER

__________ DATE

__________ HUBODOMETER READING

__________ DIVISION

First Space - Inspector(s) number to be used as a check off identification for work done.

Second Space - Use this space to indicate whether an item was okay, adjusted, or repairs were needed.

"4" Okay - Item checked is ready for service.
"X" Adjusted - Item checked has been repaired and is ready for service.
"O" Repairs needed - Any item requiring repairs.

For information on the following procedures, refer to the Orion I & V P/M Manual Section 22, or the Lift-U Maintenance Manual. NOTE: Do not use steam or solvent on chains.

INSPECTION AND ADJUSTMENT

__ __ WHEELCHAIR SECUREMENT EQUIPMENT - Check securement belts (Q'straint etc.) for proper quantities, condition, and cleanliness. Clean out floor tie-down brackets with compressed air (use safety glasses). Check wheelchair caliper (clamp) for proper operation (9200). Page 22-4, item 24.

__ __ WHEELCHAIR STOP TELL TALE LIGHT (9300) - Depress the yellow press tape located under the flip up seats (1 each side). Make sure the "Stop Requested" and "Wheelchair Stop" lights operate.

__ __ BUS ENTRANCE DOORS - For proper lift operation, make sure the lift will not operate without the doors fully open.

__ __ CYCLE LIFT - Cycle the lift – up to the floor, down to the ground. Stow, and look for any signs of problems. Make sure the dash "Lift Power" and "Not Stowed" lights, and the exterior warning light and beeper function when the lift is in operation. Page 22-3.

__ __ BRAKE/THROTTLE INTERLOCK - Whenever the lift power is on, the brake/throttle should be activated (like opening the rear door). Page 22-4.

__ __ SENSITIVE MAT - The sensitive mat should not allow the lift to be stowed when it has weight on it. Clean off, and check both sections of the mat for proper operation. Page 22-4, and figure 2, #38.

__ __ SENSITIVE EDGES - Make sure the lift stops rising, and drops anytime there is pressure on each sensitive edge. Before the lift will come up again, you should have to reset it by moving the control switch to the lower position and activating the function switch. Page 22-4.

__ __ SENSOR OVERRIDE - With pressure on the sensitive mat or edge, make sure the sensor override switch on the dash will enable the lift to resume operation.

__ __ FLOOR HEIGHT - Lift platform level with bus floor when bridge barrier forms. Pages 22-9.

__ __ STOW HEIGHT - Lift platform must raise c to 3" when going into channels. Page 22-7.

__ __ MASTER CHAINS AND DRIVE SPROCKETS - Inspect for rust, damage or missing pieces. Equal tension. Adjust if necessary. Page 22-29.

__ __ SLAVE CHAINS AND SLAVE ARMS - Inspect for rust, damage or missing pieces. Ride up & down should be smooth. Adjust if necessary. Page 22-31.

__ __ DRIVE MOTOR AND PRIMARY STOW/DEPLOY CHAIN - Inspect the Drive Motor for leaks or damage. Check Drive Chain for damage, corrosion, proper sprocket alignment and proper tension (3" or more play). Inspect the Drive Motor for leaking oil. Page 22-37.

INSPECTION AND ADJUSTMENT (continued)

___ SECONDARY STOW/DEPLOY CHAINS - Inspect for rust, damage or missing pieces. Inspect for proper adjustment (with lift deployed, chain should touch channel). Page 22-34.

___ RAMP AND BRIDGE BARRIERS - Inspect and adjust both the Ramp and Bridge Barriers, and their linkages and pins. Clean all dirt and debris from all three (3) barrier hinges, with compressed air. Use multipurpose lubricant to help clean only if needed. Pages 38 & 39.

___ STOW LATCH CYLINDER - Check for excessive wear and make sure the stow latch engages fully. Page 22-4.

___ HOSES & WIRES - Inspect all hoses and wires for chafing, leaking, secure mounting and proper routing. Pages 22-26.

___ MOUNTING HARDWARE - Inspect all mounting hardware and hand rails for tightness and secure mounting.

___ CONTROL BOX AREA - Open the control box door and insect the components (control box, valves etc.) for signs of leaks or any other problems. Make sure the Manual Operation Decal is properly attached to the door. Spray electrical connections with red anti-corrosion spray.

LUBRICATION (do the best you can without removing cover pans)

___ FLUID & LEVEL - Before removing filler cap/dipstick, make sure the area around the cap is clean. The level should be checked with the lift stowed and the cap screwed in. Make sure the fluid level is between the full and add marks on the dipstick. Use Aviation Type A or E fluid. DO NOT USE TRANSMISSION FLUID. Make sure the fluid is not contaminated. If contaminated, flush system as per Lift-U service manual.

___ ALL CHAINS: MASTER CHAINS (figure 4, #17), SLAVE CHAINS (figure 4, #21), DRIVE CHAIN (figure 4, #27), STOW/DEPLOY CHAINS (figure 1, #14) - Lubriplate Chain & Cable Fluid spray chain lube as needed.

___ ALL CLEVIS PINS AND PIVOT POINTS - Spray anti-seize.

___ CURBSIDE AND ROADSIDE BARRIER CLEVIS PINS, SHOULDER BOLT AND SLIDE LINK & GUIDE - Spray Anti-seize (remove shoulder bolt). Figure 2, #39-43.

___ STOW LATCH FACE - Door Eaze. Figure 3, #10.

___ TORQUE SHAFT CRUTCH - #2 chassis grease in grease fitting. Figure 4, #29, #32.

___ LIMIT SWITCH ROLLERS AND SHAFTS - Lubricate the two (2) Limit Switch rollers and shafts with Multi Purpose Spray Lube.

___ MANIFOLD VALVE BUTTONS - Lubricate and operate the eight (8) Manifold Valve Buttons with multi purpose spray lubricant. Page 22-41 figure 21.

EMPLOYEE SIGNATURE	EMPLOYEE NUMBER
1	
2	
SUPERVISOR SIGNATURE	DATE

28,000 MILE LIFT-U INSPECTION
9100, 9200 & 9300 ORION

____________ BUS NUMBER

____________ WORK ORDER NUMBER

____________ DATE

____________ HUBODOMETER READING

____________ DIVISION

First Space - Inspector(s) number to be used as a check off identification for work done.

Second Space - Use this space to indicate whether an item was okay, adjusted, or repairs were needed.

"4" Okay - Item checked is ready for service.
"X" Adjusted - Item checked has been repaired and is ready for service.
"O" Repairs needed - Any item requiring repairs.

For information on the following procedures, refer to the Orion I & V P/M Manual, Section 22. NOTE: Do not use steam or solvent on chains.

INSPECTION AND ADJUSTMENT

__ __ WHEELCHAIR SECUREMENT EQUIPMENT - Check securement belts (Q'straint etc.) for proper quantities, condition, and cleanliness. Clean out floor tie-down brackets with compressed air (use safety glasses). Check wheelchair caliper (clamp) for proper operation (9200). Page 22-4, item 24.

__ __ WHEELCHAIR STOP TELL TALE LIGHT (9300) - Depress the yellow press tape located under the flip up seats (1 each side). Make sure the "Stop Requested" and "Wheelchair Stop" lights operate.

__ __ BUS ENTRANCE DOORS -For proper lift operation, make sure the lift will not operate without the doors fully open.

__ __ CYCLE LIFT - Cycle the lift – up to the floor, down to the ground. Stow, and look for any signs of problems. Make sure the dash "Lift Power" and "Not Stowed" lights, and the exterior warning light and beeper function when the lift is in operation. Page 22-3.

__ __ BRAKE/THROTTLE INTERLOCK - Whenever the lift power is on, the brake/throttle should be activated (like opening the rear door). Page 22-4.

__ __ SENSITIVE MAT - The sensitive mat should not allow the lift to be stowed when it has weight on it. Clean off, and check both sections of the mat for proper operation. Page 22-4, and figure 2, #38.

__ __ SENSITIVE EDGES - Make sure the lift stops rising, and drops anytime there is pressure on each sensitive edge. Before the lift will come up again, you should have to reset it by moving the control switch to the lower position and activating the function switch. Page 22-4.

__ __ SENSOR OVERRIDE - With pressure on the sensitive mat or edge, make sure the sensor override switch on the dash will enable the lift to resume operation.

__ __ FLOOR HEIGHT - Lift platform level with bus floor when bridge barrier forms. Pages 22-9.

__ __ STOW HEIGHT - Lift platform must raise c to 3" when going into channels. Page 22-7.

__ __ LIFT CYLINDER CHECK VALVES - Extend the lift, leave the weight of the lift hanging. After hanging for about 1 hour, push up on the each cylinder. If either cylinder is loose, the check valve for that cylinder should be replaced. CAUTION: To prevent injury, place a safety stand under the lift platform any time you are working under it.

__ __ MASTER CHAINS AND DRIVE SPROCKETS - Inspect for rust, damage or missing pieces. Equal tension. Adjust if necessary. Page 22-29.

__ __ SLAVE CHAINS AND SLAVE ARMS - Inspect for rust, damage or missing pieces. Ride up & down should be smooth. Adjust if necessary. Page 22-31.

__ __ DRIVE MOTOR AND PRIMARY STOW/DEPLOY CHAIN - Inspect the Drive Motor for leaks or damage. Check Drive Chain for damage, corrosion, proper alignment and proper tension (3" or more play). Make sure the drive shaft and motor sprocket set screws are tight. Pages 22-37.

INSPECTION AND ADJUSTMENT (continued)

__ __ SECONDARY STOW/DEPLOY CHAINS -Inspect for rust, damage or missing pieces. Inspect for proper adjustment (with lift deployed, chain should touch channel). Pages 22-34. Check and tighten the sprocket set screws.

__ __ STOW LATCH & CYLINDER - Make sure the stow latch engages and check for excessive wear. The stow latch can be seen through the front left-side inspection door. Pages 22-4 & 22.

__ __ RAMP AND BRIDGE BARRIERS - Inspect structure and all linkage for damage, loose fasteners and leaks. Make sure barrier angles are proper. Clean all dirt and debris from barrier hinges, with compressed air (use Multi Purpose Spray Lube to help clean only if needed). Pages 38 & 39.

__ __ HOSES, FITTINGS & WIRES - Inspect for chafing, leaking, and secure mounting. Pages 22-26.

__ __ MOUNTING HARDWARE - Inspect all mounting hardware and hand rails for tightness and secure mounting.

__ __ CONTROL BOX AREA - Open the control box door and insect the components (control box, valves etc.) for signs of leaks or any other problems. Make sure the Manual Operation Decal is properly attached to the door. Briefly check manual lift operation in each position (just make sure lift moves). Spray electrical connections with red anti-corrosion spray.

LUBRICATION (WITH COVER PANS REMOVED)

__ __ FILTER - Change pressure line filter. Figure #6.

__ __ FLUID & LEVEL - Before removing filler cap/dipstick, make sure the area around the cap is clean. The level should be checked with the dipstick cap screwed in. Make sure the level is between the full and add marks on the dipstick. Use Aviation Type A or E fluid. DO NOT USE TRANSMISSION FLUID. Make sure the fluid is not contaminated. If contaminated, flush system as per Lift-U service manual.

__ __ HYDRAULIC PRESSURE - Check Hydraulic pressure. Pressure should be 1200 psi □ 50 psi. Page 22-4, figure 22-11.

__ __ ALL CHAINS: MASTER CHAINS (figure 4, #17), SLAVE CHAINS (figure 4, #21), DRIVE CHAIN (figure 4, #27), STOW/DEPLOY CHAINS (figure 1, #14) - Clean and lube with Lubriplate Chain & Cable Fluid spray chain lube as needed.

__ __ CURBSIDE BARRIER SLIDE LINK & GUIDE - Anti-seize. Page 22-12.

__ __ LIFT CYLINDER PINS - Anti-seize (remove pins). See Figure 4, #35 for the lift cylinders (pins not shown). Pack pins in chassis grease after reinstalling.

__ __ CURBSIDE AND ROADSIDE BARRIER CLEVIS PINS, SHOULDER BOLT AND LINKAGES - Anti-seize (remove pins). Figure 2, #39-43.

__ __ STOW LATCH ASSEMBLY CLEVIS PIN - Anti-seize (remove pin). Figure 3, #4.

__ __ STOW LATCH FACE - Door Eaze. Figure 3, #10.

__ __ TORQUE SHAFT CRUTCH - #2 grease in grease fitting. Figure 4, #29, #32.

__ __ LIMIT SWITCH ROLLERS AND SHAFTS - Lubricate the two (2) Limit Switch rollers and shafts with Multi Purpose Spray Lube.

__ __ MANIFOLD VALVE BUTTONS - Lubricate the eight (8) Manifold Valve Buttons (inside Lift-U compartment) with multi purpose lubricant. Operate to make sure buttons don't stick. Figure 5, #21.

EMPLOYEE SIGNATURE	EMPLOYEE NUMBER
1	
2	
SUPERVISOR SIGNATURE	DATE

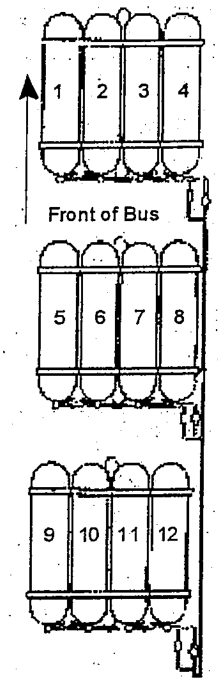
UTA

COMPRESSED NATURAL GAS CYLINDER DETAILED VISUAL INSPECTION FORM

Roof Mounted Cylinders Manufactured by Structural Composite Industries 9281-9285 Orion V

Bus Number	Mileage	Date of Inspection	Bus VIN Number

Cylinder #	Part #	Serial Number
1	050832453	
2	050832453	
3	050832453	
4	050832453	
5	050832453	
6	050832453	
7	050832453	
8	050832453	
9	050832453	
10	050832453	
11	050832453	
12	050832453	



The first box is to indicate whether an item was okay, adjusted, or if repairs are needed.
" 4 " = Okay - Item checked is ready for service.
" X " = Adjusted - Item checked has been replaced and is ready for service.
" O " = Repairs Needed - Any item requiring repair.

Insp. Symbol	**Inspection Item** (for additional information, see "Detailed Visual Inspection" section on page 6-10 of the GRI Natural Gas Vehicle Cylinder Care and Maintenance Handbook)	**Cylinder Number** (if Problem)
	Cylinder and mounting bracket area clean and ready for inspection.	
	Cylinder shows no evidence of fire or exposure to extreme temperature.	
	Cylinder shows no evidence of accident involvement.	
	Cylinder service life not expired.	
	Minimum of 2" clearance around mounted cylinder.	
	Cylinder service pressure markings equal to or greater than vehicle service pressure markings.	
	Cylinder properly vented external to vehicle.	
	Fuel and vent lines properly and securely attached to vehicle.	
	Cylinder securely mounted (no rocking or looseness).	
	Bolts which secure brackets to vehicle present and tight.	
	Mounting bracket in good condition - not bent or deformed.	
	Vehicle free of damage where mounting brackets are attached.	
	Bracket fasteners are tight.	
	Valve and relief device assemblies free of damage.	
	Valves and relief devices tightly seated. (Caution: do not loosen valves or relief	

	devices while tank is pressurized)	
	No leaks in fittings between valves or relief devices and cylinder.	
	Any cuts, gouges, or abrasions on cylinder are less than 0.010 inch deep.	
	Cylinder free of impact damage. (surface discoloration, cracked resin, chipping, loose fibers)	
	Cylinder free of surface dents.	
	Cylinder free of rust, corrosion, or etching of the outer surface.	
	Cylinder surface free of discoloration.	
	External paint, composite layer, and metal surfaces free of bubbles or bulges.	
	Pressure relief device (PRD) in good condition with no visible extrusion of fusible material.	
	Relief devices in place.	
	Brackets free of corrosion.	
	New examination sticker applied.	

Summary of inspection and description of any damage or problems: ________________________________

Repair or replace damaged or unsatisfactory components as follows: ________________________________

Cylinder Should Be Handled as Followed: (recommended disposition of fuel cylinder)		
	1. Rework cylinder as follows:	1 2 3 4 5 6 7 8 9 10 11 12
	2. Send cylinder to manufacturer for further inspection as follows:	1 2 3 4 5 6 7 8 9 10 11 12
	3. Remove cylinder from service and destroy.	1 2 3 4 5 6 7 8 9 10 11 12
	4. Return fuel container to service.	1 2 3 4 5 6 7 8 9 10 11 12

Name of Inspector	Signature of Inspector

48,000 MILE "A" INSPECTION
ORION II

8/00kb

BUS NUMBER ______ WORK ORDER NUMBER ______ DATE ______ HUBODOMETER MILES AT INSPECTION ______

AMED CLEANED	YES	NO	DIVISION	
UNDER STRUCTURE	___	___	CENTRAL	___
ENG. COMPARTMENT	___	___	MEADOWBROOK	___
BATTERIES	___	___	MT. OGDEN	___
FUEL TANK CAP	___	___	TIMPANOGOS	___
RADIATOR	___	___	RIVERSIDE	___

Numbers in ( ) indicate P/M manual page number.

FIRST SPACE - Inspector(s) number to be used as a check off identification for work completed.
SECOND SPACE - Use this space to indicate whether an item was okay, adjusted, or repairs needed.
" 3 " = Okay - Item checked is ready for service.
" X " = Adjusted - Item checked has been replaced and is ready for service.
" O " = Repairs Needed - Any item requiring repair.

INTERIOR
___ ___ Mirror (2-1)
___ ___ Front door emergency air control (1-1)
___ ___ Fire extinguisher & tag (1-2)
___ ___ Emergency road reflectors (2-1)
___ ___ Emergency exit hatch (2-1)
___ ___ Schedule boxes and route box (2-3)
___ ___ Interior and exit door lights (4-1)
___ ___ Passenger buzzer strip, next stop sign and tell tale light (2-1)
___ ___ Stanchions and grabrails (2-1)
___ ___ Passenger seats, frames and latches (2-3)
___ ___ Passenger seat belts (8800) (2-3)
___ ___ Floor covering (2-2)
___ ___ Windows & latches (2-2)
___ ___ Emergency escape windows and latches (2-3)
___ ___ Side, ceiling and modesty panels (2-3)
___ ___ Climate control (run A/C even in winter) (19-1)
___ ___ Floor heater (19-2)
___ ___ Front and rear door seals (2-2)
___ ___ Front and rear door alignment (2-2)
___ ___ Rear door authorized switch (1-4)
___ ___ Brake and throttle treadles (1-11)
___ ___ Rear door (1-4)
___ ___ Rear kneeling (1-1)
___ ___ Rear ramp (1-3)
___ ___ Rear door emergency air control (1-1)
___ ___ Electrical panel (4-2)

DRIVER CONTROL AREA
___ ___ Destination sign (2-2)
___ ___ Sun visor and side sun screens (2-2)
___ ___ Master switch (1-4)
___ ___ Low oil and Alt. circuits (lights & buzzer) (1-4)
___ ___ Neutral safety start (1-5)
___ ___ Engine start and starter cut-out (1-5)
___ ___ Transmission shift selector (12-1)
___ ___ Dash night lights and panel lamp dimmer (4-3)
___ ___ Horns (1-7)
___ ___ Steering free play (13-1)
___ ___ Tilt steering (8800) (13-1)
___ ___ Tilt & telescopic steering (8900) (13-4)
___ ___ Steering column shaft and mounting (13-1)
___ ___ Hi idle (1-7)
___ ___ Oil gauge (1-8)
___ ___ Dash voltmeter (1-8)
___ ___ Fuel gauge (1-8)
___ ___ Dual air gauge (1-8)
___ ___ Low air circuit (70 psi) (1-8)
___ ___ Air governor cut-in, cut-out, (adjust)
Cut-in ________ Cut-out ________ (1-9)
___ ___ Air dryer purge valve (6-1)
___ ___ Air leaks with brakes released (7-1) ______ psi drop per min.
___ ___ Air pressure loss with brakes applied (7-1) ______ psi drop
___ ___ Air leaks with brakes applied (7-2) ______ psi drop per min.
___ ___ Defrost (19-2)
___ ___ Driver's temp. control (19-2)
___ ___ Driver's heat control (19-2)
___ ___ Driver's overhead fan (19-3)
___ ___ Windshield fan (1-10)
___ ___ Windshield wipers (1-9)

DRIVER CONTROL (continued)
___ ___ Windshield washer (1-10)
___ ___ Turn signals and tell-tale lights (4-4)
___ ___ Four way flashers (4-4)
___ ___ Auxiliary flasher circuit (4-4)
___ ___ Headlight dimmer and high beam tell tale (4-4)
___ ___ Park brake (7-5)
___ ___ Park and service brake tell tale lights (1-11)
___ ___ Front door (1-10)
___ ___ Brake and throttle interlock (1-11)
___ ___ Brake emergency override switch (1-11)
___ ___ Front kneeling (1-1)
___ ___ Front ramp (1-3)
___ ___ Farebox mounting and trip switch (1-11)
___ ___ Radio mounting (2-3)
___ ___ Transfer cutter (2-3)
___ ___ Driver's seat (2-4)

EXTERIOR
___ ___ Body damage (major or unsafe) (2-5)
___ ___ Mirrors (2-5)
___ ___ Wiper arm adjustment and blade condition (1-9)
___ ___ Lights (4-3)
___ ___ Back-up lights and alarm (4-4)
___ ___ Window hinges and weather stripping (2-2)
___ ___ Wheels (3-2)
___ ___ Wheel gaskets (14-1 & 17-1)
___ ___ Fuel tank leaks, filler cap and O-ring (9-2)
___ ___ Fender aprons and splash guards (2-5)

DRIVE TEST (in yard)
___ ___ Brakes and brake application valve (21-1)
___ ___ Steering (21-1)
___ ___ Rattles (21-2)
___ ___ Engine noise (8-2)
___ ___ Exhaust gases inside coach (21-3)
___ ___ Gauges (21-2)

ENGINE COMPARTMENTS
___ ___ Engine cooling fan (5-1)
___ ___ Hydraulic fluid return filter (gauge) (13-1)
___ ___ Booster pump operation (winter) (19-2)
___ ___ Oil pressure (engine compartment) (record) (8-1)
Idle ________ Full throttle ________
___ ___ Alternator noise or vibration (8-2)
___ ___ Water temperature gauge (1-5)
___ ___ Low water circuit (1-6)
___ ___ High water temp. circuit (1-6)
___ ___ Engine protection circuit (1-6)
___ ___ Engine override circuit (1-7)
___ ___ Pressurize cooling system (10 psi) (5-1)
___ ___ Coolant filler cap, seal, and ventcock (5-1)
___ ___ Pressure relief cap (5-2)
___ ___ Water pump weephole (5-2)
___ ___ Exhaust system (11-1)
___ ___ Engine dipstick and tube (8-2)
___ ___ Transmission dipstick and tube (12-4)
___ ___ Oil filler cap and gasket (8-1)
___ ___ Engine breather (8-1)
___ ___ Drive belt condition (8-3)

ENGINE COMPARTMENTS (continued)

__ __ Air compressor drive belt tension (70-75 lbs.) (8-3)
__ __ A/C compressor drive belt tension (70-75 lbs.) (8-3)
__ __ Alternator drive belt tension (8-3)
__ __ Engine idler pulleys (8-3)
__ __ Coolant additive package (5-1)
__ __ Engine block heater (8-4) _______OHMS
__ __ Air intake system (10-1)
__ __ Air cleaner vacuator valve (10-1)
__ __ Intake restriction (10-1)
__ __ Filter Minder condition (10-2)
__ __ Cooling fan condition (5-2)
__ __ Fan shroud (5-2)
__ __ Radiator & mounting (5-2)
__ __ Lower steering drive shaft (13-1)
__ __ Steering shaft pinch bolts (13-1)
__ __ Service batteries and battery trays (4-5)
__ __ Battery internal hydrometers (4-5)
__ __ Load test batteries (4-6) Record readings ________v ________v
__ __ Corrosion spray battery terminals bottom and top (4-5)
__ __ Reset Vanner circuit breaker (4-9N)
__ __ Charging voltage (4-10)
__ __ Starting & charging system voltage drop (4-12)
Starting system; Positive loss________ + Negative loss ________
= Total loss________
Charging system; Positive loss________ + Negative loss ________
= Total loss________
__ __ Windshield washer bottle (2-5)
__ __ Hydraulic system (pump lines etc.) (13-2)
__ __ Engine compartment wiring (4-1)
__ __ Engine compartment lights (4-3)
__ __ Air throttle cylinder (6-2)
__ __ Air, oil, fuel, transmission fluid, hydraulic fluid or coolant leaks
__ __ Line and hose routing (5-1, 6-4, 8-1, 9-1, 12-1)
__ __ Fuel pump weephole (9-2)
__ __ Air compressor & mounting (6-2)
__ __ Clean and spray all exposed electrical connections (4-2)

UNDER STRUCTURE

__ __ Rear air suspension (16-1)
__ __ Rear trailing arm bushings (16-2)
__ __ Front air suspension (15-1)
__ __ Front axle longitudinal and lateral rods (15-1)
__ __ Front shock absorbers (15-1)
__ __ Front trailing arm bushings (15-2)
__ __ Cross tube (tie rod) & drag link ends (13-3)
__ __ Steering miter gear (13-2)
__ __ Steering gear (13-3)
__ __ Differential leaks & vent (14-1)
__ __ Transmission leaks & vent (12-1)
__ __ Shift cable adjustment (12-2)
__ __ Inspect transmission shift modulator (12-1)
__ __ Wheel seals & gaskets (17-1 & 14-1)
__ __ Brakes and lining wear (5/16 min.) (7-2)
__ __ Automatic slack adjusters (7-3)
__ __ Ride height 8.25" (16-1)
__ __ Air line leaks, cracks & routing (7-1 & 6-1)
__ __ Drive shaft (18-1)
__ __ Exhaust system (11-1)
__ __ Fluid leaks (5-1, 8-1, 12-1, and 13-2)
__ __ Mounting hardware (engine & transmission to power module, and power module to body)(8-1)
__ __ Isoclad undercoating (20-1)
__ __ All under floor equipment (loose bolts, damaged parts etc.) (20-1)

AIR & BRAKE SYSTEM CHECKS

__ __ SR-1 spring brake valve and double check valve (7-3)
__ __ Drain all air tanks (6-3)
__ __ Air dryer (6-1)
__ __ Air compressor performance (85-100 psi. in 40 sec.) record time ________sec. (6-3)
__ __ Safety valve (6-3)
__ __ Air tank single check valves (6-4)
__ __ Dash air gauges (6-4)
__ __ Rear service brake air pressure (7-4)
__ __ Brake interlock air pressure (7-4)
__ __ Air leaks with Son-Tector & soap (6-2)

LUBRICATION

__ __ Change fuel filters (9-1)
__ __ Drain engine oil (8-2)
__ __ Change engine oil filter (8-2)
__ __ Torque oil pan plug (8-2)
__ __ Drain transmission fluid (12-3)
__ __ Change internal transmission filter (12-5)
__ __ Change external transmission filter (12-2)
__ __ Torque transmission pan plug (12-3)
__ __ Drain differential fluid and take sample (14-1)
__ __ Wipe off ALL grease fittings before lubricating the following
__ __ Steering head bushings and bearings (#2 grease 22-2)
__ __ Cross tube (tie rod) & drag link ends (#2 grease 22-2)
__ __ Brake camshafts (#2 grease 22-2)
__ __ Slack adjusters (#2 grease 22-3)
__ __ Drive shaft (#2 grease 22-3)
__ __ Upper steering shaft U-joint (#2 grease 22-4)
__ __ Lower steering shaft U-joints (#2 grease 22-4)
__ __ Front and rear door shafts (#2 grease 22-5)
__ __ Exterior mirror brackets (#2 grease 22-5)
__ __ Grease front axle C.V. U-joints (if retro) (#2 grease 22-9)
__ __ Grease front axle bushings (if retro) (#2 grease by hand) (22-9)
__ __ Driver's seat (silicone spray 22-5)
__ __ Window channels (silicone spray) (22-5)
__ __ Throttle linkage (JT-6) (22-7)
__ __ Front and rear ramp clevis pins (rear on 8800 only) (JT-6) (22-7)
__ __ Engine door hinges (JT-6 & multi purpose spray lube) (22-7)
__ __ Brake and throttle treadles (multi purpose spray lube) (22-6)
__ __ Hydraulic fluid reservoir level (trans. fluid) (22-8)
__ __ Change fluid in front axle hubs (gear lube) (22-8)
__ __ Add engine oil (15W-40)(8-4)
__ __ Add transmission fluid (12-3)
__ __ Run engine and check fluid levels and leaks (8-3, 12-4 & 21-2)

MISC.

__ __ Tires - check and air (3-1) record on tire card
__ __ Measure tire tread depth (3-1)
__ __ Rear shock absorbers (16-1)
__ __ Clean heater filter (19-3)
__ __ Heater core leaks (19-1)
__ __ Air conditioning sight glass (summer) (19-3)
__ __ Wheelchair tie-down equipment (8800, eight sets of five belts; 8900, six sets) (2-5)
__ __ Clean and spray electrical connections in brake relay compartment (4-2)

EMPLOYEE SIGNATURE	EMPLOYEE NUMBER
1	
2	
FOREMAN SIGNATURE	DATE

3,000 MILE "E" INSPECTION
8800 & 8900 ORION II

BUS NUMBER ______ WORK ORDER NUMBER ______ DATE ______ HUBODOMETER MILES AT INSPECTION ______

..AMED CLEANED	YES	NO
UNDER STRUCTURE	___	___
ENG. COMPARTMENT	___	___
BATTERIES	___	___
FUEL TANK CAP	___	___
RADIATOR	___	___

Numbers in ( ) indicate P/M manual page number.

DIVISION	
CENTRAL	___
MEADOWBROOK	___
MT. OGDEN	___
TIMPANOGOS	___
RIVERSIDE	___

FIRST SPACE - Inspector(s) number to be used as a check off identification for work completed.

SECOND SPACE - Use this space to indicate whether an item was okay, adjusted, or repairs needed.

" 3 " = Okay - Item checked is ready for service.

" X " = Adjusted - Item checked has been replaced and is ready for service.

" O " = Repairs Needed - Any item requiring repair.

INTERIOR

___ ___ Air conditioning (winter) (19-1)
___ ___ Mirror (2-1)
___ ___ Interior and exit door lights (4-1)
___ ___ Passenger chime system (2-1)
___ ___ Stanchion and grabrails (2-1)
___ ___ Side, ceiling and modesty panels (2-3)
___ ___ Passenger seats, frames and latches (2-3)
___ ___ Rear door (1-4)
___ ___ Driver's seat (2-4)
___ ___ Passenger seat belts (2-3)

DRIVER CONTROL

___ ___ Master switch (1-4)
___ ___ Horn (1-7)
___ ___ Windshield washer & wipers (1-9)
___ ___ Windshield washer (1-10)
___ ___ Turn signals and tell-tale lights (4-4)
___ ___ Four way flashers (4-4)
___ ___ Auxiliary flasher circuit (4-4)
___ ___ Headlight dimmer and high beam tell tale (4-4)
___ ___ Front door (1-10)

EXTERIOR

___ ___ Mirrors (2-5)
___ ___ Lights (4-3)
___ ___ Tires - check and air (3-1) record on tire card

ENGINE COMPARTMENTS

___ ___ Air, oil, fuel, transmission fluid, hydraulic fluid or coolant leaks
___ ___ Line and hose routing (5-1, 6-4, 8-1, 9-1, 12-1)

UNDERSTRUCTURE

___ ___ Differential leaks & vent (14-1)
___ ___ Drive shaft (18-1)
___ ___ Transmission leaks & vent (12-1)
___ ___ Air line leaks, cracks & routing (7-1 & 6-1)
___ ___ Fluid leaks (5-1, 8-1, 12-1, and 13-2)

LUBRICATION

___ ___ Wipe off ALL grease fittings before lubricating the following:
___ ___ Steering head bushings and bearings (#2 grease 22-2)
___ ___ Cross tube (tie rod) & drag link ends (#2 grease 22-2)
___ ___ Brake camshafts (#2 grease 22-2)
___ ___ Slack adjusters (#2 grease 22-3)
___ ___ Drive shaft (#2 grease 22-3)
___ ___ Lower steering shaft U-joints (#2 grease 22-4)
___ ___ Exterior mirror brackets (#2 grease 22-5)
___ ___ Grease front axle C.V. U-joints (if retro) (#2 grease 22B9)
___ ___ Grease front axle bushings (if retro)(#2 grease by hand) (22-9)
___ ___ Driver's seat (silicone spray 22-5)
___ ___ Window channels (silicone spray 22-5)
___ ___ Brake and throttle treadles (multi purpose spray lube) (22-6)
___ ___ Throttle linkage (JT-6) (22-7)

EMPLOYEE SIGNATURE	EMPLOYEE NUMBER
1	
2	
FOREMAN SIGNATURE	DATE

48,000 MILE "A" INSPECTION
CLASSIC 8300, 8400 & 9000

BUS NUMBER	WORK ORDER NUMBER	DATE	HUBODOMETER MILES AT INSPECTION

STEAMED CLEANED — YES NO

UNDER STRUCTURE ___ ___
ENG. COMPARTMENT ___ ___
BATTERIES ___ ___
FUEL TANK CAP ___ ___
RADIATOR ___ ___

Numbers in ( ) indicate P/M manual page number.

DIVISION

CENTRAL ___
MEADOWBROOK ___
MT. OGDEN ___
TIMPANOGOS ___

FIRST SPACE - Inspector(s) number to be used as a check off identification for work completed.

SECOND SPACE - Use this space to indicate whether an item was okay, adjusted, or repairs needed.

" 4 " = Okay - Item checked is ready for service.
" X " = Adjusted - Item checked has been replaced and is ready for service.
" O " = Repairs Needed - Any item requiring repair.

INTERIOR

___ ___ Destination signs (2-1)
___ ___ Route sign boxes (2-1)
___ ___ Fare card holder and schedule boxes (2-3)
___ ___ Sun visors (2-1)
___ ___ Mirrors (2-2)
___ ___ Passenger chime and next stop light (2-1)
___ ___ Stanchions and grabrails (2-1)
___ ___ Seats and frames (2-3)
___ ___ Emergency exit hatches (2-2)
___ ___ Flooring and step wells (2-1)
___ ___ Windows & latches (2-3)
___ ___ Emergency escape windows (2-2)
___ ___ Side and ceiling panels (2-3)
___ ___ Lights (4-2)
___ ___ Heater blower operation (19-1)
___ ___ Booster pump operation (19-1)
___ ___ Exit doors (and touch bars if equipped) (1-8)
___ ___ Exit door sensitive edges (9000) (1-8)
___ ___ Brake/throttle interlock adjustment (1-9)
___ ___ Fire extinguisher & tag (1-10)
___ ___ Modesty panels & driver's partition (2-3)
___ ___ Emergency road reflectors (1-11)
___ ___ Front step well heater (19-1)

DRIVER CONTROL AREA

___ ___ Low oil circuit (83 & 84) (1-1)
___ ___ No generator tell-tale light (1-1)
___ ___ Check Trans, Check Engine and Engine Stop circuits (9000) (1-1)
___ ___ Neutral start (4-1)
___ ___ Front start and fuel pressure switch (4-1)
___ ___ Low air circuit (1-1)
___ ___ Dash night lights (4-2)
___ ___ Horns (1-4)
___ ___ Pull horn button, clean contacts (83 & 8400)
___ ___ Public address system (1-2)
___ ___ Tilt and telescopic steering (9000) (13-5)
___ ___ Steering column shaft and mounting (13-4)
___ ___ Steering free play (13-1)
___ ___ Oil gauge (1-5)
___ ___ Dash voltmeter (1-5)
___ ___ Exit door tell-tale light (1-7)
___ ___ Fast idle operation (1-4)
___ ___ Shift gate and lever or shift switch (12-1)
___ ___ Defrost (19-2)
___ ___ Defrost water valve & heat control (19-2)
___ ___ Driver's front vents (1-11)
___ ___ Evaporative cooling (summer)
___ ___ Windshield wipers and washer (1-6)
___ ___ Turn signal switches and tell-tale lights (4-2)
___ ___ Four way flashers (4-2)
___ ___ Auxiliary flasher circuit (4-2)
___ ___ Headlight dimmer switch & tell tale (1-6)
___ ___ Brake and throttle treadles (1-10)
___ ___ Park brake operation (7-5)
___ ___ Emergency brake release valve (7-5)
___ ___ Brake/throttle interlock operation (1-9)

DRIVER CONTROL AREA (continued)

___ ___ Interlock zero speed switch (9000) (1-9)
___ ___ Front door operation (1-7)
___ ___ Touch bar by-pass (83 & 84) (1-6)
___ ___ Radio and farebox mounting (1-11)
___ ___ Driver's seat & seat belt (2-4)
___ ___ Driver's dash fan (1-6)

EXTERIOR

___ ___ Door bushings and hinges (1-7)
___ ___ Windshield wiper blades (1-6)
___ ___ Bike rack (2-4)
___ ___ Mirrors (2-2)
___ ___ Lights & light lenses (4-1)
___ ___ Body damage (major or unsafe) (2-3)
___ ___ Wheel seals (17-1)
___ ___ Window hinges and seals (2-2)
___ ___ Fuel tank cap, gasket and O-ring (9-1)
___ ___ Back up lights & alarm

DRIVE TEST

___ ___ Brake application valve operation (21-1)
___ ___ Retarder operation (9000) (21-1)
___ ___ Steering operation (21-1)
___ ___ Excessive rattles (21-2)
___ ___ Gauges (21-2)

ENGINE COMPARTMENT

___ ___ Engine compartment doors and hinges (2-3)
___ ___ Engine, transmission, and engine door wiring (4-1)
___ ___ Engine compartment lights and sockets (4-1)
___ ___ Oil pressure (rear) (record) (8-1) Idle___________
Full throttle___________
___ ___ Cooling fan operation (5-3)
___ ___ Rear start (4-1)
___ ___ Temperature gauge (1-1)
___ ___ Low water circuit (83 & 84) (1-1)
___ ___ Hot engine circuit (83 & 84) (1-2)
___ ___ Engine protection circuit (83 & 84) (1-2)
___ ___ Overrule circuit (83 & 84) (1-2)
___ ___ Engine sending units (8-3)
___ ___ Ether injection system (winter) (8-6)
___ ___ Pressurize cooling system (5-1)
___ ___ Air, oil, fuel, and coolant leaks
___ ___ Air, oil, fuel, and coolant line routing (5-1, 6-4, 8-1, 9-1, 12-1)
___ ___ Air intake system (10-1)
___ ___ Intake restriction (10-2)
___ ___ Filter Minder (10-2)
___ ___ Fan hub bearing looseness (5-2)
___ ___ Fan drive shaft (9000) (5-3)
___ ___ Radiator & mounts (5-3)
___ ___ Surge tank mounting (5-3)
___ ___ Fan shroud (5-1)
___ ___ Exhaust system (11-1)
___ ___ Engine dipstick and tube (8-2)
___ ___ Transmission dipstick and tube (12-2)
___ ___ Transmission breather (12-2)

ENGINE COMPARTMENT (continued)

__ __ Oil filler tube and gasket (8-1)
__ __ Fuel pump weephole (9-1)
__ __ Coolant additive package (5-2)
__ __ Surge tank sight glass (5-3)
__ __ Coolant filler cap, seal and pressure relief valve (5-1)
__ __ Pressure relief cap (5-1)
__ __ Water pump weephole (5-2)
__ __ Engine block heater (8-7) _______OHMS
__ __ Change fuel filters (9-1)
__ __ Power steering system (add 10W-30) (13-4)
__ __ Change transmission fluid (12-5)
__ __ Change transmission filter (12-5)
__ __ Service Spinner II oil cleaner (9000) (8-4)
__ __ Transmission shift cable adjustment (83 & 84) (12-3)
__ __ Change shift modulator (83 & 84) (12-3)
__ __ Air throttle (83 & 84) (6-1)
__ __ Fast idle cylinder and limiting cylinder (83 & 84) (1-4)
__ __ Clean & spray all exposed electrical terminals (4-1)

REAR SEAT ENGINE COMPARTMENT

__ __ Water pump weephole (8-6)
__ __ Clean and spray starter cables (8-6)
__ __ Exhaust system (8-6)
__ __ Any other leaks or problems (8-6)
__ __ Door seal and fasteners (8-6)

MISC.

__ __ Batteries and battery tray (4-3)
__ __ Battery internal hydrometers (4-3)
__ __ Charging voltage (4-10)
__ __ Load test batteries (4-4) (record) ________v ________v ________v ________v
__ __ Corrosion spray battery terminals (4-3)
__ __ Check and record voltage drop (4-7)
Starting system; positive loss __________+ negative loss _________
= Total loss _________
Charging system; positive loss __________+ negative loss _________
= Total loss _________
__ __ Tire air pressure (3-1) Record on tire card
__ __ Tires and tire tread depth (3-1)
__ __ Wheels (3-1)
__ __ Test fuel tank and filler (9-2)
__ __ Defrost filter (winter) (19-2)
__ __ DDEC codes - print and clear (1-3)
__ __ 24,000 mile Lift-U inspection
__ __ 3,000 mile EAC inspection (summer)

UNDERSTRUCTURE

__ __ King pin wear (14-1)
__ __ Front axle (14-1)
__ __ Front ride height (15-1)
__ __ Front suspension (15-1)
__ __ Steering drive shaft (13-1)
__ __ Steering shaft pinch bolts (13-1 & 13-4)
__ __ Tie rod & drag link ends (13-1)
__ __ Steering gears (13-2)
__ __ Step well cracks (20-1)
__ __ Windshield washer bottle
__ __ Step well heater filter (winter) (19-2)
__ __ Heater compartment seal and hinges (19-1)
__ __ Leaks in heater compartment (5-1)
__ __ Heater filters - change or clean (19-1)
__ __ Fuel tank mounting and leaks (9-1)
__ __ Mud flaps (20-1)
__ __ Differential (17-1)
__ __ Differential breather (17-1)
__ __ Inner wheel seals (17-1)
__ __ Brake lining wear (7-1)
__ __ Automatic slack adjusters (9000) (7-7)
__ __ Air lines and wires (7-1)
__ __ Rear suspension (16-1)
__ __ Rear ride height (16-1)
__ __ Drive shaft (18-1)
__ __ Companion flange (18-2)

UNDERSTRUCTURE(continued)

__ __ Frame cracks (20-1)
__ __ Exhaust system (11-1)
__ __ Road draft tube (8-6)
__ __ Engine oil, transmission fluid and coolant leaks (5-1, 8-1, 12-1)
__ __ All other under floor equipment (20-1)
__ __ Clean and spray all exposed electrical connections

AIR & BRAKE SYSTEM CHECKS

__ __ SR-1 spring brake valve and double check valve (7-6)
__ __ Drain all air tanks (6-2)
__ __ Air dryer (6-2)
__ __ Air compressor performance (record) (6-3) ____________ seconds
__ __ Air governor cut-in, cut-out, and air dryer purge valve operation (6-2) Cut-in ____________ Cut-out ____________
__ __ Air leaks, brakes released (7-1) ________psi drop in 2 min. (2 psi maximum)
__ __ Air pressure drop, brakes applied (7-1) ________psi drop (20 psi maximum)
__ __ Air leaks, brakes applied (7-1) ________psi drop in 2 min. (4 psi maximum)
__ __ Safety valves (6-3)
__ __ Air tank single check valves (7-3)
__ __ Dash air gauges (7-3)
__ __ Rear service brake pressure (7-3)
__ __ Brake interlock pressure (7-4)
__ __ Air leaks with a Son-Tector & soap (6-1)

LUBRICATION

__ __ Drain air box canister (8-8)
__ __ Drain and change engine oil filter (8-1)
__ __ Change engine oil (8-1)
__ __ Torque engine oil pan plug (8-1) 25-35 ft. lbs.
__ __ Change differential oil, take oil sample (17-1)
__ __ Wipe off grease fittings before greasing
__ __ King pins (#2 grease) (14-1)
__ __ Steering components, except steering gears (#2 grease) (13-1)
__ __ Brake components (#2 grease) (7-2)
__ __ Drive shaft (#2 grease) (18-1)
__ __ Upper steering shaft (9000) (#2 grease) (13-4)
__ __ Cooling fan drive shaft (9000) (Ultra Duty #2 grease) (5-3)
__ __ Steering gears (#1 grease) (13-3)
__ __ Lower door bearings (#1 grease) (1-8)
__ __ Throttle clevis (if fitting) (#1 grease) (6-1)
__ __ Exterior mirrors (#1 grease if fitting) (Multi purpose lube on adjust ball) (2-3)
__ __ Upper door bearings (If fittings) (#1 grease) (1-8)
__ __ Driver's seat (silicone spray) (2-4)
__ __ Window sliders (silicone spray) (2-3)
__ __ Brake and throttle treadles (Multi purpose lube) (1-10)
__ __ Battery tray rollers (Multi purpose lube) (4-3)
__ __ Defroster water valve cable (Multi purpose lube) (1-6)
__ __ Engine door hinges (Multi purpose lube) (2-3)
__ __ Bike rack pins and latch (Multi purpose lube)
__ __ Passenger door linkage (hinges & clevis pins) (JT-6) (1-8)
__ __ Fast idle and shut down cylinders (if equipped) (transmission fluid) (6-1)
__ __ Run engine and check fluid levels and leaks

EMPLOYEE SIGNATURE	EMPLOYEE NUMBER
1	
2	
FOREMAN SIGNATURE	DATE

24,000 MILE "B" INSPECTION
CLASSIC 8300, 8400 & 9000

BUS NUMBER ______ WORK ORDER NUMBER ______ DATE ______ HUBODOMETER MILES AT INSPECTION ______

STEAMED CLEANED	YES	NO
UNDER STRUCTURE	___	___
ENG. COMPARTMENT	___	___
BATTERIES	___	___
FUEL TANK CAP	___	___
RADIATOR	___	___

Numbers in ( ) indicate P/M manual page number.

DIVISION
- CENTRAL ___
- MEADOWBROOK ___
- MT. OGDEN ___
- TIMPANOGOS ___

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INTERIOR
___ ___ Destination signs (2-1)
___ ___ Route sign boxes (2-1)
___ ___ Fare card holder and schedule boxes (2-3)
___ ___ Sun visors (2-1)
___ ___ Mirrors (2-2)
___ ___ Passenger chime and next stop light (2-1)
___ ___ Stanchions and grabrails (2-1)
___ ___ Seats and frames (2-3)
___ ___ Emergency exit hatches (2-2)
___ ___ Flooring and step wells (2-1)
___ ___ Windows & latches (2-3)
___ ___ Emergency escape windows (2-2)
___ ___ Side and ceiling panels (2-3)
___ ___ Lights (4-2)
___ ___ Heater blower operation (19-1)
___ ___ Booster pump operation (19-1)
___ ___ Exit doors (and touch bars if equipped) (1-8)
___ ___ Exit door sensitive edges (9000) (1-8)
___ ___ Brake/throttle interlock adjustment (1-9)
___ ___ Fire extinguisher & tag (1-10)
___ ___ Modesty panels & driver's partition (2-3)
___ ___ Emergency road reflectors (1-11)
___ ___ Front step well heater (19-1)

DRIVER CONTROL AREA
___ ___ Low oil tell-tale circuit (83 & 84) (1-1)
___ ___ No generator tell-tale light (1-1)
___ ___ Check Trans, Check Engine and Engine Stop circuits (9000) (1-1)
___ ___ Neutral start (4-1)
___ ___ Front start and fuel pressure switch (4-1)
___ ___ Low air circuit (1-1)
___ ___ Dash night lights (4-2)
___ ___ Horns (1-4)
___ ___ Pull horn button, clean contacts (83 & 8400)
___ ___ Public address system (1-2)
___ ___ Tilt and telescopic steering (9000) (13-5)
___ ___ Steering column shaft and mounting (13-4)
___ ___ Steering free play (13-1)
___ ___ Oil gauge (1-5)
___ ___ Dash voltmeter (1-5)
___ ___ Exit door tell-tale light (1-7)
___ ___ Fast idle operation (1-4)
___ ___ Shift gate and lever or shift switch (12-1)
___ ___ Defrost (19-2)
___ ___ Defrost water valve & heat control (19-2)
___ ___ Driver's front vents (1-11)
___ ___ Evaporative cooling (summer)
___ ___ Windshield wipers and washer (1-6)
___ ___ Turn signal switches and tell-tale lights (4-2)
___ ___ Four way flashers (4-2)
___ ___ Auxiliary flasher circuit (4-2)
___ ___ Headlight dimmer switch & tell tale (1-6)
___ ___ Brake and throttle treadles (1-10)
___ ___ Park brake operation (7-5)
___ ___ Emergency brake release valve (7-5)
___ ___ Brake/throttle interlock operation (1-9)
___ ___ Interlock speed sensing device (9000) (1-9)
___ ___ Front door operation (1-7)
___ ___ Touch bar by-pass (83 & 84) (1-6)

ENGINE COMPARTMENT (continued)

DRIVER CONTROL AREA (continued)
___ ___ Farebox mounting (1-11)
___ ___ Radio mounting (1-11)
___ ___ Driver's seat & seat belt (2-4)
___ ___ Driver's dash fan (1-6)

EXTERIOR
___ ___ Door bushings and hinges (1-7)
___ ___ Windshield wiper blades (1-6)
___ ___ Bike rack (2-4)
___ ___ Mirrors (2-2)
___ ___ Lights & light lenses (4-1)
___ ___ Body damage (major or unsafe) (2-3)
___ ___ Wheel seals (17-1)
___ ___ Window hinges and seals (2-2)
___ ___ Fuel tank cap, gasket and O-ring (9-1)
___ ___ Back up lights & alarm

DRIVE TEST
___ ___ Brakes & brake application valve (21-1)
___ ___ Retarder operation (9000) (21-1)
___ ___ Steering operation (21-1)
___ ___ Excessive rattles (21-2)
___ ___ Exhaust gases inside coach (21-2)
___ ___ Gauges (21-2)

ENGINE COMPARTMENT
___ ___ Engine compartment doors and hinges (2-3)
___ ___ Engine, transmission, and engine door wiring (4-1)
___ ___ Engine compartment lights and sockets (4-1)
___ ___ Oil pressure (rear) (record) (8-1) Idle__________
Full throttle__________
___ ___ Cooling fan operation (5-3)
___ ___ Rear start (4-1)
___ ___ Temperature gauge (1-1)
___ ___ Low water circuit (83 & 84) (1-1)
___ ___ Hot engine circuit (83 & 84) (1-2)
___ ___ Engine protection circuit (83 & 84) (1-2)
___ ___ Overrule circuit (83 & 84) (1-2)
___ ___ Engine sending units (8-3)
___ ___ Pressurize cooling system (5-1)
___ ___ Ether injection system (winter) (8-6)
___ ___ Air, oil, fuel, and coolant leaks
___ ___ Air, oil, fuel, and coolant line routing (5-1, 6-4, 8-1, 9-1, 12-1)
___ ___ Air intake system (10-1)
___ ___ Intake restriction (10-2)
___ ___ Filter Minder (10-2)
___ ___ Fan hub bearing looseness (5-2)
___ ___ Fan drive shaft (9000) (5-3)
___ ___ Radiator & mounts (5-3)
___ ___ Surge tank mounting (5-3)
___ ___ Fan shroud (5-1)
___ ___ Exhaust system (11-1)
___ ___ Engine dipstick and tube (8-2)
___ ___ Transmission dipstick and tube (12-2)
___ ___ Transmission breather (12-2)
___ ___ Oil filler tube and gasket (8-1)
___ ___ Fuel pump weephole (9-1)
___ ___ Coolant additive package (5-2)
___ ___ Surge tank sight glass (5-3)
___ ___ Coolant filler cap, seal and pressure relief valve (5-1)

___ ___ Pressure relief cap (5-1)
___ ___ Water pump weephole (5-2)
___ ___ Engine block heater (8-7) _______ohms
___ ___ Change fuel filters (9-1)
___ ___ Power steering system (add 10W-30) (13-4)
___ ___ Change transmission fluid (12-5)
___ ___ Change transmission filter (12-5)
___ ___ Service Spinner II oil cleaner (9000) (8-4)
___ ___ Transmission shift cable adjustment (83 & 84) (12-3)
___ ___ Change shift modulator (83 & 84) (12-3)
___ ___ Air throttle (83 & 84) (6-1)
___ ___ Fast idle cylinder and limiting cylinder (83 & 84) (1-4)
___ ___ Clean & spray all exposed electrical terminals (4-1)

REAR SEAT ENGINE COMPARTMENT
___ ___ Water pump weephole (8-6)
___ ___ Clean & spray starter cables (8-6)
___ ___ Exhaust system (8-6)
___ ___ Any other leaks or problems (8-6)
___ ___ Door seal and fasteners (8-6)

MISC.
___ ___ Batteries and battery tray (4-3)
___ ___ Battery internal hydrometers (4-3)
___ ___ Charging voltage (4-10)
___ ___ Load test batteries (4-4) (record) ________v ________v ________v ________v
___ ___ Corrosion spray battery terminals (4-3)
___ ___ Tire air pressure (3-1) Record on tire card
___ ___ Tires and tire tread depth (3-1)
___ ___ Wheels (3-1)
___ ___ Defrost filter (winter) (19-2)
___ ___ DDEC codes - print and clear (1-3)
___ ___ 24,000 mile Lift-U inspection
___ ___ 3,000 mile EAC inspection (summer)

UNDER STRUCTURE
___ ___ King pin wear (14-1)
___ ___ Front axle (14-1)
___ ___ Front ride height (15-1)
___ ___ Front suspension (15-1)
___ ___ Steering drive shaft (13-1)
___ ___ Steering shaft pinch bolts (13-1 & 13-4)
___ ___ Tie rod & drag link ends (13-1)
___ ___ Steering gears (13-2)
___ ___ Step well cracks (20-1)
___ ___ Windshield washer bottle
___ ___ Step well heater filter (winter) (19-2)
___ ___ Heater compartment seal and hinges (19-1)
___ ___ Leaks in heater compartment (5-1)
___ ___ Heater filters - change or clean (19-1)
___ ___ Fuel tank mounting & leaks (9-1)
___ ___ Mud flaps (20-1)
___ ___ Differential (17-1)
___ ___ Differential breather (17-1)
___ ___ Inner wheel seals (17-1)
___ ___ Brake lining wear (7-1)
___ ___ Automatic slack adjusters (9000) (7-7)
___ ___ Air lines and wires - leaks, cracks & routing (7-1)
___ ___ Rear suspension (16-1)
___ ___ Rear ride height (16-1)
___ ___ Drive shaft (18-1)
___ ___ Companion flange (18-2)
___ ___ Frame cracks (20-1)
___ ___ Exhaust system (11-1)
___ ___ Engine oil, transmission fluid and coolant leaks (5-1, 8-1, 12-1)
___ ___ All other under floor equipment (20-1)
___ ___ Clean & spray all exposed electrical connections

AIR & BRAKE SYSTEM CHECKS
___ ___ SR-1 spring brake valve and double check valve (7-6)
___ ___ Drain all air tanks (6-2)
___ ___ Air dryer (6-2)
___ ___ Air compressor performance (record) (6-3) ___________ seconds
___ ___ Air governor cut-in, cut-out, and air dryer purge valve operation (6-2)
Cut-in __________ Cut-out __________
___ ___ Air leaks, brakes released (7-1) _______psi drop in 2 min. (2 psi maximum)
___ ___ Air pressure drop, brakes applied (7-1) _______psi drop (20 psi maximum)
___ ___ Air leaks, brakes applied (7-1) _______psi drop in 2 min. (4 psi maximum)
___ ___ Safety valves (6-3)
___ ___ Air tank single check valves (7-3)
___ ___ Dash air gauges (7-3)
___ ___ Rear service brake pressure (7-3)
___ ___ Brake interlock pressure (7-4)
___ ___ Air leaks with a Son-Tector & soap (6-1)

LUBRICATION
___ ___ Drain air box canister (8-8)
___ ___ Drain and change engine oil filter (8-1)
___ ___ Change engine oil (8-1)
___ ___ Torque engine oil pan plug (8-1) 25-35 ft. lbs.
___ ___ Check differential oil level (17-1)
___ ___ Wipe off grease fittings before greasing
___ ___ King pins (#2 grease) (14-1)
___ ___ Steering components, except steering gears (#2 grease) (13-1)
___ ___ Brake components (#2 grease) (7-2)
___ ___ Drive shaft (#2 grease) (18-1)
___ ___ Upper steering shaft (9000) (#2 grease) (13-4)
___ ___ Cooling fan drive shaft (9000) (Ultra Duty #2 grease) (5-3)
___ ___ Steering gears (#1 grease) (13-3)
___ ___ Lower door bearings (#1 grease) (1-8)
___ ___ Throttle clevis (if fitting) (#1 grease)(6-1)
___ ___ Exterior mirrors (#1 grease if fitting) (Multi Purpose Spray Lube on adjust ball) (2-3)
___ ___ Upper door bearings (If fittings) (#1 grease) (1-8)
___ ___ Driver's seat (silicone spray) (2-4)
___ ___ Window sliders (silicone spray) (2-3)
___ ___ Brake and throttle treadles (Multi Purpose Spray Lube) (1-10)
___ ___ Battery tray rollers (Multi Purpose Spray Lube) (4-3)
___ ___ Defroster water valve cable (Multi Purpose Spray Lube) (1-6)
___ ___ Engine door hinges (Multi Purpose Spray Lube) (2-3)
___ ___ Bike rack pins and latch (Multi Purpose Spray Lube)
___ ___ Passenger door linkage (hinges & clevis pins) (JT-6) (1-8)
___ ___ Fast idle and shut down cylinders (if equipped) (transmission fluid) (6-1)
___ ___ Run engine and check fluid levels and leaks

EMPLOYEE SIGNATURE	EMPLOYEE NUMBER
1	
2	
FOREMAN SIGNATURE	DATE

12,000 MILE "C" INSPECTION
CLASSIC 8300, 8400, & 9000

BUS NUMBER ______ WORK ORDER NUMBER ______ DATE ______ HUBODOMETER MILES AT INSPECTION ______

STEAMED CLEANED	YES	NO
UNDER STRUCTURE	___	___
ENG. COMPARTMENT	___	___
BATTERIES	___	___
FUEL TANK CAP	___	___
RADIATOR	___	___

DIVISION	
CENTRAL	___
MEADOWBROOK	___
MT. OGDEN	___
TIMPANOGOS	___

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Numbers in ( ) indicate P/M manual page number.

INTERIOR
___ ___ Destination signs (2-1)
___ ___ Route sign boxes (2-1)
___ ___ Fare card holder and schedule boxes (2-3)
___ ___ Sun visors (2-1)
___ ___ Mirrors (2-2)
___ ___ Passenger chime and next stop light (2-1)
___ ___ Stanchions and grabrails (2-1)
___ ___ Seats and frames (2-3)
___ ___ Emergency exit hatches (2-2)
___ ___ Flooring and step wells (2-1)
___ ___ Windows & latches (2-3)
___ ___ Emergency escape windows (2-2)
___ ___ Side and ceiling panels (2-3)
___ ___ Lights (4-2)
___ ___ Heater blower operation (19-1)
___ ___ Booster pump operation (19-1)
___ ___ Exit doors (and touch bars if equipped) (1-8)
___ ___ Exit door sensitive edges (9000) (1-8)
___ ___ Brake/throttle interlock adjustment (1-9)
___ ___ Fire extinguisher & tag (1-10)
___ ___ Modesty panels & driver's partition (2-3)
___ ___ Emergency road reflectors (1-11)
___ ___ Front step well heater (19-1)

DRIVER CONTROL AREA
___ ___ Low oil tell-tale circuit (83 & 84) (1-1)
___ ___ No generator tell-tale light (1-1)
___ ___ Check Trans, Check Engine and Engine Stop circuits (9000) (1-1)
___ ___ Neutral start (4-1)
___ ___ Front start and fuel pressure switch (4-1)
___ ___ Low air circuit (1-1)
___ ___ Dash night lights (4-2)
___ ___ Horns (1-4)
___ ___ Public address system (1-2)
___ ___ Tilt and telescopic steering (9000) (13-5)
___ ___ Steering column shaft and mounting (13-4)
___ ___ Steering free play (13-1)
___ ___ Oil gauge (1-5)
___ ___ Dash voltmeter (1-5)
___ ___ Exit door tell-tale light (1-7)
___ ___ Fast idle operation (1-4)
___ ___ Shift gate and lever or shift switch (12-1)
___ ___ Defrost (19-2)
___ ___ Defrost water valve & heat control (19-2)
___ ___ Driver's front vents (1-11)
___ ___ Evaporative cooling (summer)
___ ___ Windshield wipers and washer (1-6)
___ ___ Turn signal switches and tell-tale lights (4-2)
___ ___ Four way flashers and auxiliary flasher circuit (4-2)
___ ___ Headlight dimmer switch & tell tale (1-6)
___ ___ Brake and throttle treadles (1-10)
___ ___ Park brake operation (7-5)
___ ___ Brake/throttle interlock operation (1-9)
___ ___ Interlock zero speed switch (9000) (1-9)
___ ___ Front door operation (1-7)
___ ___ Touch bar by-pass (83 & 84) (1-6)
___ ___ Radio & farebox mounting (1-11)
___ ___ Driver's seat & seat belt (2-4)
___ ___ Driver's dash fan (1-6)

EXTERIOR
___ ___ Door bushings and hinges (1-7)
___ ___ Windshield wiper blades (1-6)
___ ___ Bike rack (2-4)
___ ___ Mirrors (2-2)
___ ___ Lights & light lenses (4-1)
___ ___ Body damage (major or unsafe) (2-3)
___ ___ Wheel seals (17-1)
___ ___ Window hinges and seals (2-2)
___ ___ Fuel tank cap, gasket and O-ring (9-1)
___ ___ Back up lights & alarm

DRIVE TEST
___ ___ Brakes & brake application valve (21-1)
___ ___ Retarder operation (9000) (21-1)
___ ___ Steering operation (21-1)
___ ___ Excessive rattles (21-2)
___ ___ Exhaust gases inside coach (21-2)
___ ___ Gauges (21-2)

ENGINE COMPARTMENT
___ ___ Engine compartment doors and hinges (2-3)
___ ___ Engine, transmission, and engine door wiring (4-1)
___ ___ Engine compartment lights and sockets (4-1)
___ ___ Oil pressure (rear) (record) (8-1) Idle__________
Full throttle__________
___ ___ Cooling fan operation (5-3)
___ ___ Rear start (4-1)
___ ___ Temperature gauge (1-1)
___ ___ Low water circuit (83 & 84) (1-1)
___ ___ Hot engine circuit (83 & 84) (1-2)
___ ___ Engine protection circuit (83 & 84) (1-2)
___ ___ Overrule circuit (83 & 84) (1-2)
___ ___ Engine sending units (8-3)
___ ___ Pressurize cooling system (5-1)
___ ___ Ether injection system (winter) (8-6)
___ ___ Air, oil, fuel, and coolant leaks
___ ___ Air, oil, fuel, and coolant line routing (5-1, 6-4, 8-1, 9-1, 12-1)
___ ___ Air intake system (10-1)
___ ___ Intake restriction (10-2)
___ ___ Fan hub bearing looseness (5-2)
___ ___ Fan drive shaft (9000) (5-3)
___ ___ Radiator & mounts (5-3)
___ ___ Surge tank mounting (5-3)
___ ___ Fan shroud (5-1)
___ ___ Exhaust system (11-1)
___ ___ Engine dipstick and tube (8-2)
___ ___ Transmission dipstick and tube (12-2)
___ ___ Transmission breather (12-2)
___ ___ Oil filler tube and gasket (8-1)
___ ___ Fuel pump weephole (9-1)
___ ___ Coolant additive package (5-2)
___ ___ Surge tank sight glass (5-3)
___ ___ Coolant filler cap, seal and pressure relief valve (5-1)
___ ___ Pressure relief cap (5-1)
___ ___ Water pump weephole (5-2)
___ ___ Engine block heater (8-7) ________OHMS
___ ___ Change fuel filters (9-1)
___ ___ Check shift modulator (83 & 84) (12-3)
___ ___ Air throttle (83 & 84) (6-1)

ENGINE COMPARTMENT (continued)

- __ __ Power steering system (add 10W-30) (13-4)
- __ __ Change transmission fluid – not filter (12-5)
- __ __ Fast idle cylinder and limiting cylinder (83 & 84) (1-4)
- __ __ Clean & spray all exposed electrical terminals (4-1)

MISC.

- __ __ Batteries and battery tray (4-3)
- __ __ Battery internal hydrometers (4-3)
- __ __ Charging voltage (4-10)
- __ __ Load test batteries (4-4) (record) ________v ________v ________v ________v
- __ __ Corrosion spray battery terminals (4-3)
- __ __ Tire air pressure (3-1) Record on tire card
- __ __ Tires and tire tread depth (3-1)
- __ __ Wheels (3-1)
- __ __ Defrost filter (winter) (19-2)
- __ __ DDEC codes - print and clear (1-3)
- __ __ 3,000 mile Lift-U inspection
- __ __ 3,000 mile EAC inspection (summer)

UNDER STRUCTURE

- __ __ Front axle (14-1)
- __ __ Front ride height (15-1)
- __ __ Front suspension (15-1)
- __ __ Steering drive shaft (13-1)
- __ __ Steering shaft pinch bolts (13-1 & 13-4)
- __ __ Tie rod & drag link ends (13-1)
- __ __ Steering gears (13-2)
- __ __ Step well cracks (20-1)
- __ __ Windshield washer bottle
- __ __ Step well heater filter (winter) (19-2)
- __ __ Heater compartment seal and hinges (19-1)
- __ __ Leaks in heater compartment (5-1)
- __ __ Heater filters - change or clean (19-1)
- __ __ Fuel tank mounting & leaks (9-1)
- __ __ Mud flaps (20-1)
- __ __ Differential (17-1)
- __ __ Differential breather (17-1)
- __ __ Inner wheel seals (17-1)
- __ __ Brake lining wear (7-1)
- __ __ Automatic slack adjusters (9000) (7-7)
- __ __ Air lines and wires - leaks, cracks & routing (7-1)
- __ __ Rear suspension (16-1)
- __ __ Rear ride height (16-1)
- __ __ Drive shaft (18-1)
- __ __ Companion flange (18-2)
- __ __ Frame cracks (20-1)
- __ __ Exhaust system (11-1)
- __ __ Road draft tube (8-6)
- __ __ Engine oil, transmission fluid and coolant leaks (5-1, 8-1, 12-1)
- __ __ All other under floor equipment (20-1)
- __ __ Clean & spray all exposed electrical connections

AIR & BRAKE SYSTEM CHECKS

- __ __ Drain all air tanks (6-2)
- __ __ Air dryer (6-2)
- __ __ Air compressor performance (record) (6-3) __________ seconds
- __ __ Air governor cut-in and cut-out pressure (6-2) Cut-in __________ Cut-out __________
- __ __ Air dryer purge valve operation (6-2)
- __ __ Air leaks, brakes released (7-1) _______psi drop in 2 min. (2 psi maximum)
- __ __ Air pressure drop, brakes applied (7-1) _______psi drop (20 psi maximum)
- __ __ Air leaks, brakes applied (7-1) _______psi drop in 2 min. (4 psi maximum)
- __ __ Safety valves (6-3)
- __ __ Air leaks with a Son-Tector & soap (6-1)

LUBRICATION

- __ __ Drain air box canister (8-8)
- __ __ Drain and change engine oil filter (8-1)
- __ __ Change engine oil (8-1)
- __ __ Torque engine oil pan plug (8-1) 25-35 ft. lbs.
- __ __ Check differential oil level (17-1)
- __ __ Wipe off grease fittings before greasing
- __ __ King pins (#2 grease) (14-1)
- __ __ Steering components, except steering gears (#2 grease) (13-1)
- __ __ Brake components (#2 grease) (7-2)
- __ __ Drive shaft (#2 grease) (18-1)
- __ __ Cooling fan drive shaft (9000) (Ultra Duty #2 grease) (5-3)
- __ __ Steering gears (#1 grease) (13-3)
- __ __ Lower door bearings (#1 grease) (1-8)
- __ __ Throttle clevis (if fitting) (#1 grease) (6-1)
- __ __ Mirror brackets (#1 grease if fitting) (Multi Purpose Spray Lube on adjust ball) (2-3)
- __ __ Upper door bearings (If fittings) (#1 grease) (1-8)
- __ __ Driver's seat (silicone spray) (2-4)
- __ __ Window sliders (silicone spray) (2-3)
- __ __ Brake and throttle treadles (Multi Purpose Spray Lube) (1-10)
- __ __ Battery tray rollers (Multi Purpose Spray Lube) (4-3)
- __ __ Defroster water valve cable (Multi Purpose Spray Lube) (1-6)
- __ __ Engine door hinges (Multi Purpose Spray Lube) (2-1)
- __ __ Bike rack pins and latch (Multi Purpose Spray Lube)
- __ __ Passenger door linkage (hinges & clevis pins) (JT-6) (1-8)
- __ __ Fast idle and shut down cylinders (If equipped) (trans fluid) (6-1)
- __ __ Run engine and check fluid levels and leaks

EMPLOYEE SIGNATURE	EMPLOYEE NUMBER
1	
2	
FOREMAN SIGNATURE	DATE

CLASSIC 8300, 8401 to 8442 and 9000
EVAPORATIVE AIR CONDITIONING SYSTEM
3,000 MILE INSPECTION

BUS NUMBER ______ WORK ORDER NUMBER ______ DATE ______

DIVISION

PRESENT HUBODOMETER MILES ______

Meadowbrook ______ Timpanogos ______
Central ______ Mt. Ogden ______

In the space provided, use the following symbols to identify work completed on each step:

"4" - Okay - Item checked is ready for service.
"X" - Adjusted - Item checked has been repaired and is ready for service.
"O" - Repairs Needed - Any item requiring repair.

___ 1. Flush the upper water storage tank. Start the bus, turn on the cooler, fill the upper tank (it's full when the ECU cooling pump is pumping); open the ECU sump drain plug and drain the sump. Keep the cooler turned on while draining the sump. This will help flush dirt, etc., from the upper tank.

___ 2. Set the ECU water flow set valve all the way open on the 8300's, and 8401 to 8442, and 20% open on the 9000's.

___ 3. Check and clean Wye filter.

___ 4. Run the cooler and make sure both motors are turning (air flow should be equal form both sides of grill).

___ 5. With the cooler running, run your hand across the grill and check for warm spots. A warm spot would indicate a plugged header pipe.

___ 6. Add 4 ounces of bleach to the lower tank.

___ 7. Lubricate the water fill coupler and cap with Vaseline.

EMPLOYEE SIGNATURE	EMPLOYEE NUMBER
1	
2	
FOREMAN SIGNATURE	DATE

6,000 MILE "D" INSPECTION
CLASSIC 8300, 8400, & 9000

BUS NUMBER ____ WORK ORDER NUMBER ____ DATE ____ HUBODOMETER MILES AT INSPECTION ____

(STEA)MED CLEANED	YES	NO
UNDER STRUCTURE	___	___
ENG. COMPARTMENT	___	___
BATTERIES	___	___
FUEL TANK CAP	___	___
RADIATOR	___	___

DIVISION

CENTRAL ___
MEADOWBROOK ___
MT. OGDEN ___
TIMPANOGOS ___

FIRST SPACE - Inspector(s) number to be used as a check off identification for work completed.
SECOND SPACE - Use this space to indicate whether an item was okay, adjusted, or repairs needed.
" 4 " = Okay - Item checked is ready for service.
" X " = Adjusted - Item checked has been replaced and is ready for service.
" O " = Repairs Needed - Any item requiring repair.

Numbers in ( ) indicate P/M manual page number.

INTERIOR
___ ___ Destination signs (2-1)
___ ___ Route sign boxes (2-1)
___ ___ Fare card holder and schedule boxes (2-3)
___ ___ Sun visors (2-1)
___ ___ Mirrors (2-2)
___ ___ Passenger chime and next stop light (2-1)
___ ___ Stanchions and grabrails (2-1)
___ ___ Seats and frames (2-3)
___ ___ Emergency exit hatches (2-2)
___ ___ Flooring and step wells (2-1)
___ ___ Windows & latches (2-3)
___ ___ Emergency escape windows (2-2)
___ ___ Side and ceiling panels (2-3)
___ ___ Lights (4-2)
___ ___ Heater blower operation (19-1)
___ ___ Booster pump operation (19-1)
___ ___ Exit doors (and touch bars if equipped) (1-8)
___ ___ Exit door sensitive edges (9000) (1-8)
___ ___ Brake/throttle interlock adjustment (1-9)
___ ___ Fire extinguisher & tag (1-10)
___ ___ Modesty panels & driver's partition (2-3)
___ ___ Emergency road reflectors (1-11)
___ ___ Front step well heater (19-1)

DRIVER CONTROL AREA
___ ___ Low oil tell-tale circuit (83 & 84) (1-1)
___ ___ No generator tell-tale light (1-1)
___ ___ Check Trans, Check Engine and Engine Stop circuits (9000) (1-1)
___ ___ Neutral start (4-1)
___ ___ Front start and fuel pressure switch (4-1)
___ ___ Low air circuit (1-1)
___ ___ Dash night lights (4-2)
___ ___ Horns (1-4)
___ ___ Public address system (1-2)
___ ___ Tilt and telescopic steering (9000) (13-5)
___ ___ Steering column shaft and mounting (13-4)
___ ___ Steering free play (13-1)
___ ___ Oil gauge (1-5)
___ ___ Dash voltmeter (1-5)
___ ___ Exit door tell-tale light (1-7)
___ ___ Fast idle operation (1-4)
___ ___ Shift gate and lever or shift switch (12-1)
___ ___ Defrost (19-2)
___ ___ Defrost water valve & heat control (19-2)
___ ___ Driver's front vents (1-11)
___ ___ Evaporative cooling (summer)
___ ___ Windshield wipers and washer (1-6)
___ ___ Turn signal switches and tell-tale lights (4-2)
___ ___ Four way flashers and auxiliary flasher circuit (4-2)
___ ___ Headlight dimmer switch & tell tale (1-6)
___ ___ Brake and throttle treadles (1-10)
___ ___ Park brake operation (7-5)
___ ___ Brake/throttle interlock operation (1-9)
___ ___ Interlock zero speed switch (9000) (1-9)
___ ___ Front door operation (1-7)
___ ___ Touch bar by-pass (83 & 84) (1-6)
___ ___ Radio & farebox mounting (1-11)
___ ___ Driver's seat & seat belt (2-4)
___ ___ Driver's dash fan (1-6)

EXTERIOR
___ ___ Door bushings and hinges (1-7)
___ ___ Windshield wiper blades (1-6)
___ ___ Bike rack (2-4)
___ ___ Mirrors (2-2)
___ ___ Lights & light lenses (4-1)
___ ___ Body damage (major or unsafe) (2-3)
___ ___ Wheel seals (17-1)
___ ___ Window hinges and seals (2-2)
___ ___ Fuel tank cap, gasket and O-ring (9-1)
___ ___ Back up lights & alarm

DRIVE TEST
___ ___ Brakes & brake application valve (21-1)
___ ___ Retarder operation (9000) (21-1)
___ ___ Steering operation (21-1)
___ ___ Excessive rattles (21-2)
___ ___ Exhaust gases inside coach (21-2)
___ ___ Gauges (21-2)

ENGINE COMPARTMENT
___ ___ Engine compartment doors and hinges (2-3)
___ ___ Engine, transmission, and engine door wiring (4-1)
___ ___ Engine compartment lights and sockets (4-1)
___ ___ Oil pressure (rear) (record) (8-1) Idle________
Full throttle________
___ ___ Cooling fan operation (5-3)
___ ___ Rear start (4-1)
___ ___ Temperature gauge (1-1)
___ ___ Low water circuit (83 & 84) (1-1)
___ ___ Hot engine circuit (83 & 84) (1-2)
___ ___ Engine protection circuit (83 & 84) (1-2)
___ ___ Overrule circuit (83 & 84) (1-2)
___ ___ Engine sending units (8-3)
___ ___ Pressurize cooling system (5-1)
___ ___ Ether injection system (winter) (8-6)
___ ___ Air, oil, fuel, and coolant leaks
___ ___ Air, oil, fuel, and coolant line routing (5-1, 6-4, 8-1, 9-1, 12-1)
___ ___ Air intake system (10-1)
___ ___ Intake restriction (10-2)
___ ___ Fan hub bearing looseness (5-2)
___ ___ Fan drive shaft (9000) (5-3)
___ ___ Radiator & mounts (5-3)
___ ___ Surge tank mounting (5-3)
___ ___ Fan shroud (5-1)
___ ___ Exhaust system (11-1)
___ ___ Engine dipstick and tube (8-2)
___ ___ Transmission dipstick and tube (12-2)
___ ___ Transmission breather (12-2)
___ ___ Oil filler tube and gasket (8-1)
___ ___ Fuel pump weephole (9-1)
___ ___ Coolant additive package (5-2)
___ ___ Surge tank sight glass (5-3)
___ ___ Coolant filler cap, seal and pressure relief valve (5-1)
___ ___ Pressure relief cap (5-1)
___ ___ Water pump weephole (5-2)
___ ___ Engine block heater (8-7) ________OHMS
___ ___ Drain water from fuel filter sight bowl (9-1)
___ ___ Power steering system (add 10W-30) (13-4)
___ ___ Check shift modulator (83 & 84) (12-3)
___ ___ Air throttle (83 & 84) (6-1)

ENGINE COMPARTMENT (continued)

___ ___ Fast idle cylinder and limiting cylinder (83 & 84) (1-4)
___ ___ Clean & spray all exposed electrical terminals (4-1)

MISC.
___ ___ Batteries and battery tray (4-3)
___ ___ Battery internal hydrometers (4-3)
___ ___ Clean & spray battery terminals (4-3)
___ ___ Charging voltage (4-10)
___ ___ Tire air pressure (3-1) Record on tire card
___ ___ Tires and tire tread depth (3-1)
___ ___ Wheels (3-1)
___ ___ DDEC codes - print and clear (1-3)
___ ___ 3,000 mile Lift-U inspection
___ ___ 3,000 mile EAC inspection (summer)

UNDER STRUCTURE
___ ___ Front axle (14-1)
___ ___ Front ride height (15-1)
___ ___ Front suspension (15-1)
___ ___ Steering drive shaft (13-1)
___ ___ Steering shaft pinch bolts (13-1 & 13-4)
___ ___ Tie rod & drag link ends (13-1)
___ ___ Steering gears (13-2)
___ ___ Step well cracks (20-1)
___ ___ Windshield washer bottle
___ ___ Step well heater filter (winter) (19-2)
___ ___ Heater compartment seal and hinges (19-1)
___ ___ Leaks in heater compartment (5-1)
___ ___ Heater filters - change or clean (19-1)
___ ___ Fuel tank mounting & leaks (9-1)
___ ___ Mud flaps (20-1)
___ ___ Differential (17-1)
___ ___ Differential breather (17-1)
___ ___ Inner wheel seals (17-1)
___ ___ Brake lining wear (7-1)
___ ___ Automatic slack adjusters (9000) (7-8)
___ ___ Air lines and wires - leaks, cracks & routing (7-1)
___ ___ Rear suspension (16-1)
___ ___ Rear ride height (16-1)
___ ___ Drive shaft (18-1)
___ ___ Companion flange (18-2)
___ ___ Frame cracks (20-1)
___ ___ Exhaust system (11-1)
___ ___ Road draft tube (8-6)
___ ___ Engine oil, transmission fluid and coolant leaks (5-1, 8-1, 12-1)
___ ___ All other under floor equipment (20-1)
___ ___ Clean & spray all exposed electrical connections

AIR & BRAKE SYSTEM CHECKS
___ ___ Drain all air tanks (6-2)
___ ___ Air dryer (6-2)
___ ___ Air compressor performance (record) (6-3) ___________ seconds
___ ___ Air governor cut-in and cut-out pressure (6-2) Cut-in ___________ Cut-out ___________
___ ___ Air dryer purge valve operation (6-2)
___ ___ Air leaks, brakes released (7-1) _______psi drop in 2 min. (2 psi maximum)
___ ___ Air pressure drop, brakes applied (7-1) _______psi drop (20 psi maximum)
___ ___ Air leaks, brakes applied (7-1) _______psi drop in 2 min. (4 psi maximum)
___ ___ Safety valves (6-3)
___ ___ Air leaks with a Son-Tector & soap (6-1)

LUBRICATION
___ ___ Drain air box canister (8-8)
___ ___ Drain and change engine oil filter (8-1)
___ ___ Change engine oil (8-1)
___ ___ Torque engine oil pan plug (8-1) 25-35 ft. lbs.
___ ___ Check differential oil level (17-1)
___ ___ Wipe off grease fittings before greasing
___ ___ King pins (#2 grease) (14-1)
___ ___ Steering components, except steering gears (#2 grease) (13-1)
___ ___ Brake components (#2 grease) (7-2)
___ ___ Drive shaft (#2 grease) (18-1)
___ ___ Cooling fan drive shaft (9000) (Ultra Duty #2 grease) (5-3)
___ ___ Steering gears (#1 grease) (13-3)
___ ___ Lower door bearings (#1 grease) (1-8)
___ ___ Throttle clevis (if fitting) (#1 grease) (6-1)
___ ___ Exterior mirrors (#1 grease if fitting) (Multi Purpose Spray Lube on adjust ball) (2-3)
___ ___ Upper door bearings (If fittings) (#1 grease) (1-8)
___ ___ Driver's seat (silicone spray) (2-4)
___ ___ Window sliders (silicone spray) (2-3)
___ ___ Brake and throttle treadles (Multi Purpose Spray Lube) (1-10)
___ ___ Battery tray rollers (Multi Purpose Spray Lube) (4-3)
___ ___ Defroster water valve cable (Multi Purpose Spray Lube) (1-6)
___ ___ Engine door hinges (Multi Purpose Spray Lube) (2-1)
___ ___ Bike rack pins and latch (Multi Purpose Spray Lube)
___ ___ Fast idle and shut down cylinders (if equipped) (transmission fluid) (6-1)
___ ___ Run engine and check fluid levels and leaks

EMPLOYEE SIGNATURE	EMPLOYEE NUMBER
1	
2	
FOREMAN SIGNATURE	DATE

CLASSIC 8443 to 8463
EVAPORATIVE AIR CONDITIONING SYSTEM
3,000 MILES INSPECTION

BUS NUMBER WORK ORDER NUMBER DATE

DIVISION

______________________ PRESENT HUBODOMETER MILES

Meadowbrook ______ Timpanogos ______
Central ______ Mt. Ogden ______

In the space provided, use the following symbols to identify work completed on each step.

"4" - Okay - Item checked is ready for service.
"X" - Adjusted - Item checked has been repaired and is ready for service.
"O" - Repairs Needed - Any item requiring repair.

___ 1. Open the ECU Water Flow Set Valve to full open. Remove the Header Cleaning Plug and drain the header pipe. When finished, turn the Water Flow Set Valve so that it is only open about 20%.

___ 2. Flush the Upper Water Storage Tank. Start the bus, turn on the cooler, and fill the upper tank (it's full when the ECU Cooling pump is pumping); open the ECU Sump Drain Plug and drain the sump. Keep the cooler turned on while draining the sump. This will help flush dirt, etc., from the upper tank.

___ 3. Check for clogged Wye filter.

___ 4. Run the cooler and make sure both motors (Gillig) or all three motors (Classic) are turning (air flow should be equal form both sides of grill).

___ 5. With the cooler running, run your hand across the grill and check for warm spots. A warm spot would indicate a plugged header pipe.

___ 6. Add 4 ounces of bleach to the lower tank.

___ 7. Lubricate the Water Fill coupler and cap with Vaseline.

EMPLOYEE SIGNATURE	EMPLOYEE NUMBER
1	
2	
FOREMAN SIGNATURE	DATE

P/M INSPECTION RE[illegible]Y REFERENCE CHART

"INITIAL" FLUID REFILLS

BUS	ENGINE TYPE	ENGINE OIL TYPE	AMOUNT	ENGINE PAN PLUG TORQUE	TRANSMISSION TYPE	AMOUNT DEXRON III OIL	TRANS PAN PLUG TORQUE	HYDRAULIC OIL TYPE	AMOUNT HYD. OIL
83/8400 Classic	6V-92	15W-40	27 qts	25-35 lb/ft	V-730	23 qts	15-20 lb/ft	10W-30	7 qts
8701-8758 Gillig	6V-92	15W-40	28 qts	25-35 lb/ft	HTB-748	35 qts	old: 15-20lb/ft new: 30 lb/ft	Dexron ATF	16 qts
8759-8764 Gillig	Cummins L10	15W-40	36 qts	65 lb/ft	ZF	13 qts	37 lb/ft	Dexron ATF	16 qts
Trolley	Caterpillar 3208	15W-40	18 qts	50 lb/ft	AT-545	11 qts	15-20 lb/ft	10W-30	3 qts
88/8900 Orion II	8.2	15W-40	**12 qts**	18-25 lb/ft	AT-545	11 qts	15-20 lb/ft	Dexron ATF	56 qts
9000 MCI	6V-92	15W-40	27 qts	25-35 lb/ft	VR-731	23 qts	15-20 lb/ft	10W-30	7 qts
9100 Orion I, 92/ 9300 Orion V	6V-92	15W-40	28 qts	25-35 lb/ft	HTB-748	35 qts	old: 15-20 lb/ft new: 30 lb/ft	10W-30	44 qts
9344-9347 Orion	Series 50	15W-40	28 qts	33-37 lb/ft	ZF	13 qts	37 lb/ft	10W-30	44 qts
9200 Orion CNG	Cummins L10 240/260G	15W-40 HADX low ash	34 qts	65 lb/ft	ZF	13 qts	37 lb/ft	10W-30	44 qts
9400 ElDorado	Cummins B5.9	15W-40	13 qts	60 lb/ft	MT-643	22 qts	15-20 lb/ft	10W-30	12 qts
9600 ElDorado	Cummins B5.9	15W-40	13 qts	60 lb/ft	B 300	17 qts	18 lb/ft	10W-30	12 qts
95/96/9700 Gillig Transit	Cummins M11	15W-40	34 qts	65 lb/ft	B 400R	17 qts	18 lb/ft	10W-30	18 qts
95/96/9700 Gillig Transit	Series 50	15W-40	28 qts	33-37 lb/ft	B 400R	17 qts	18 lb/ft	10W-30	18 qts
96/9700 Gillig Ski	Series 50	15W-40	28 qts	33-37 lb/ft	B 500R	17 qts	18 lb/ft	10W-30	18 qts

VOLTAGE DROPS

BUS	STARTING SYSTEM		CHARGING SYSTEM	
	Amp Draw	Max Volt Drop	Amp Draw	Max Volt Drop
83/84/9000 CLASSIC	500	1.1 volt	290	0.15 volt
8701-8758 Gillig	500	1.0 volt	300	0.5 volt
8759-8764 Gillig	500	1.0 volt	220	0.5 volt
88/8900 Orion II	250	0.8 volt	140	0.5 volt
9100 Orion I, 92/9300 Orion V	250	0.8 volt	270	0.5 volt
94/9600 ElDorado National	500	0.5 volt	200	0.5 volt
95/96/9700 Gillig (ski &	250	0.8 volt	270	0.5 volt

RIDE HEIGHTS

BUS	FRONT	REAR
83/8400 Classic	6 ⅛" ± ⅛"	9 ¾" ± ⅛"
8700 Gillig	12" ± ⅛"	14.5" ± ¼"
Trolley	7" ± ⅛"	8" ± ⅛"
88/8900 Orion II	8 ¼" ± ⅛"	8 ¼" ± ⅛"
9000 MCI	7 ⅛" ± ⅛"	9 ¾" ± ⅛"
9100 Orion I, 92/9300	16 ½" ± ⅛"	8 ¾" ± ⅛"
94/9600 ElDorado	6 ¾" ± ¼"	8 5/16" ± ¼"
95/9600 Gillig	12" ± ⅛"	3 ⅝" ± ⅛"

HOSE CLAMP TORQUES

BREEZE:
- Small (5/16" hex head) - 40 in/lb
- Large (3/8" hex head) - 108 in/lb

OETIKER:
- Tighten until spring is fully compressed, then add 2-3 revolutions.

24,000 MILE "B" INSPECTION
ORION II

BUS NUMBER ____ WORK ORDER NUMBER ____ DATE ____ HUBODOMETER MILES AT INSPECTION ____

STEAMED CLEANED	YES	NO	DIVISION	
UNDER STRUCTURE	___	___	CENTRAL	___
ENG. COMPARTMENT	___	___	MEADOWBROOK	___
BATTERIES	___	___	MT. OGDEN	___
FUEL TANK CAP	___	___	TIMPANOGOS	___
RADIATOR	___	___	RIVERSIDE	___

Numbers in ( ) indicate P/M manual page number.

FIRST SPACE - Inspector(s) number to be used as a check off identification for work completed.
SECOND SPACE - Use this space to indicate whether an item was okay, adjusted, or repairs needed.
" 3 " = Okay - Item checked is ready for service.
" X " = Adjusted - Item checked has been replaced and is ready for service.
" O " = Repairs Needed - Any item requiring repair.

INTERIOR
___ ___ Mirror (2-1)
___ ___ Front door emergency air control (1-1)
___ ___ Fire extinguisher & tag (1-2)
___ ___ Emergency road reflectors (2-1)
___ ___ Emergency exit hatch (2-1)
___ ___ Schedule boxes and route box (2-3)
___ ___ Interior and exit door lights (4-1)
___ ___ Passenger buzzer strip, next stop sign and tell tale light (2-1)
___ ___ Stanchions and grabrails (2-1)
___ ___ Passenger seats, frames and latches (2-3)
___ ___ Passenger seat belts (8800) (2-3)
___ ___ Floor covering (2-2)
___ ___ Windows & latches (2-2)
___ ___ Emergency escape windows and latches (2-3)
___ ___ Side, ceiling and modesty panels (2-3)
___ ___ Climate control (run A/C even in winter) (19-1)
___ ___ Floor heater (19-2)
___ ___ Front and rear door seals (2-2)
___ ___ Front and rear door alignment (2-2)
___ ___ Rear door authorized switch (1-4)
___ ___ Brake and throttle treadles (1-11)
___ ___ Rear door (1-4)
___ ___ Rear kneeling (1-1)
___ ___ Rear ramp (1-3)
___ ___ Rear door emergency air control (1-1)
___ ___ Electrical panel (4-2)

DRIVER CONTROL AREA
___ ___ Destination sign (2-2)
___ ___ Sun visor and side sun screens (2-2)
___ ___ Master switch (1-4)
___ ___ Low oil and Alt. circuits (lights & buzzer) (1-4)
___ ___ Neutral safety start (1-5)
___ ___ Engine start and starter cut-out (1-5)
___ ___ Transmission shift selector (12-1)
___ ___ Dash night lights and panel lamp dimmer (4-3)
___ ___ Horns (1-7)
___ ___ Steering free play (13-1)
___ ___ Tilt steering (8800) (13-1)
___ ___ Tilt & telescopic steering (8900) (13-4)
___ ___ Steering column shaft and mounting (13-1)
___ ___ Hi idle (1-7)
___ ___ Oil gauge (1-8)
___ ___ Dash voltmeter (1-8)
___ ___ Fuel gauge (1-8)
___ ___ Dual air gauge (1-8)
___ ___ Low air circuit (70 psi) (1-8)
___ ___ Air governor cut-in, cut-out, (adjust)
Cut-in ________ Cut-out ________ (1-9)
___ ___ Air dryer purge valve (6-1)
___ ___ Air leaks with brakes released (7-1) ______ psi drop per min.
___ ___ Air pressure loss with brakes applied (7-1) ______ psi drop
___ ___ Air leaks with brakes applied (7-2) ______ psi drop per min.
___ ___ Defrost (19-2)
___ ___ Driver's temp. control (19-2)
___ ___ Driver's heat control (19-2)
___ ___ Windshield wipers (1-9)
___ ___ Windshield washer (1-10)
___ ___ Turn signals and tell-tale lights (4-4)

DRIVER CONTROL (continued)
___ ___ Driver's overhead fan (19-3)
___ ___ Windshield fan (1-10)
___ ___ Four way flashers (4-4)
___ ___ Auxiliary flasher circuit (4-4)
___ ___ Headlight dimmer and high beam tell tale (4-4)
___ ___ Park brake (7-5)
___ ___ Park and service brake tell tale lights (1-11)
___ ___ Front door (1-10)
___ ___ Brake and throttle interlock (1-11)
___ ___ Brake emergency override switch (1-11)
___ ___ Front kneeling (1-1)
___ ___ Front ramp (1-3)
___ ___ Farebox mounting and trip switch (1-11)
___ ___ Radio mounting (2-3)
___ ___ Transfer cutter (2-3)
___ ___ Driver's seat (2-4)

EXTERIOR
___ ___ Body damage (major or unsafe) (2-5)
___ ___ Mirrors (2-5)
___ ___ Wiper arm adjustment and blade condition (1-9)
___ ___ Lights (4-3)
___ ___ Back-up lights and alarm (4-4)
___ ___ Window hinges and weather stripping (2-2)
___ ___ Wheels (3-2)
___ ___ Wheel gaskets (14-1 & 17-1)
___ ___ Fuel tank leaks, filler cap and O-ring (9-2)
___ ___ Fender aprons and splash guards (2-5)

DRIVE TEST (in yard)
___ ___ Brakes and brake application valve (21-1)
___ ___ Steering (21-1)
___ ___ Rattles (21-2)
___ ___ Engine noise (8-2)
___ ___ Exhaust gases inside coach (21-3)
___ ___ Gauges (21-2)

ENGINE COMPARTMENTS
___ ___ Engine cooling fan (5-1)
___ ___ Hydraulic fluid return filter (gauge) (13-1)
___ ___ Booster pump operation (winter) (19-2)
___ ___ Oil pressure (engine compartment) (record) (8-1)
Idle __________ Full throttle __________
___ ___ Alternator noise or vibration (8-2)
___ ___ Water temperature gauge (1-5)
___ ___ Low water circuit (1-6)
___ ___ High water temp. circuit (1-6)
___ ___ Engine protection circuit (1-6)
___ ___ Engine override circuit (1-7)
___ ___ Pressurize cooling system (10 psi) (5-1)
___ ___ Coolant filler cap, seal, and ventcock (5-1)
___ ___ Pressure relief cap (5-2)
___ ___ Water pump weephole (5-2)
___ ___ Exhaust system (11-1)
___ ___ Engine dipstick and tube (8-2)
___ ___ Transmission dipstick and tube (12-4)
___ ___ Oil filler cap and gasket (8-1)
___ ___ Engine breather (8-1)
___ ___ Drive belt condition (8-3)

ENGINE COMPARTMENTS (continued)
___ Air compressor drive belt tension (70-75 lbs.) (8-3)
___ A/C compressor drive belt tension (70-75 lbs.) (8-3)
___ Alternator drive belt tension (8-3)
___ Engine idler pulleys (8-3)
___ Coolant additive package (5-1)
___ Engine block heater (8-4) _______OHMS
___ Air intake system (10-1)
___ Air cleaner vacuator valve (10-1)
___ Intake restriction (10-1)
___ Filter Minder condition (10-2)
___ Cooling fan condition (5-2)
___ Fan shroud (5-2)
___ Radiator & mounting (5-2)
___ Lower steering drive shaft (13-1)
___ Steering shaft pinch bolts (13-1)
___ Service batteries and battery trays (4-5)
___ Battery internal hydrometers (4-5)
___ Load test batteries (4-6) Record readings ________v ________v
___ Corrosion spray battery terminals bottom and top (4-5)
___ Reset Vanner circuit breaker (4-9N)
___ Charging voltage (4-10)
___ Windshield washer bottle (2-5)
___ Hydraulic system (pump lines etc.) (13-2)
___ Engine compartment wiring (4-1)
___ Engine compartment lights (4-3)
___ Air throttle cylinder (6-2)
___ Air, oil, fuel, transmission fluid, hydraulic fluid or coolant leaks
___ Line and hose routing (5-1, 6-4, 8-1, 9-1, 12-1)
___ Fuel pump weephole (9-2)
___ Air compressor & mounting (6-2)
___ Clean and spray all exposed electrical connections (4-2)

UNDER STRUCTURE
___ Rear air suspension (16-1)
___ Rear trailing arm bushings (16-2)
___ Front air suspension (15-1)
___ Front axle longitudinal and lateral rods (15-1)
___ Front shock absorbers (15-1)
___ Front trailing arm bushings (15-2)
___ Cross tube (tie rod) & drag link ends (13-3)
___ Steering miter gear (13-2)
___ Steering gear (13-3)
___ Differential leaks & vent (14-1)
___ Transmission leaks & vent (12-1)
___ Shift cable adjustment (12-2)
___ Inspect transmission shift modulator (12-1)
___ Wheel seals & gaskets (17-1 & 14-1)
___ Brakes and lining wear (5/16 min.) (7-2)
___ Automatic slack adjusters (7-3)
___ Ride height 8.25" (16-1)
___ Air line leaks, cracks & routing (7-1 & 6-1)
___ Drive shaft (18-1)
___ Exhaust system (11-1)
___ Fluid leaks (5-1, 8-1, 12-1, and 13-2)
___ Mounting hardware (engine & transmission to power module, and power module to body)(8-1)
___ Isoclad undercoating (20-1)
___ All other under floor equipment (loose bolts, damaged parts etc.) (20-1)

AIR & BRAKE SYSTEM CHECKS
___ SR-1 spring brake valve and double check valve (7-3)
___ Drain all air tanks (6-3)
___ Air dryer (6-1)
___ Air compressor performance (85-100 psi. in 40 sec.) record time _______sec. (6-3)
___ Safety valve (6-3)
___ Air tank single check valves (6-4)
___ Dash air gauges (6-4)
___ Rear service brake air pressure (7-4)
___ Brake interlock air pressure (7-4)
___ Air leaks with Son-Tector & soap (6-2)

LUBRICATION
___ Change fuel filters (9-1)
___ Drain engine oil (8-2)
___ Change engine oil filter (8-2)
___ Torque pan plug (8-2)
___ Drain transmission fluid (12-3)
___ Torque transmission pan plug (12-3)
___ Drain differential fluid and take sample (14-1)
___ Wipe off ALL grease fittings before lubricating the following
___ Steering head bushings and bearings (#2 grease 22-2)
___ Cross tube (tie rod) & drag link ends (#2 grease 22-2)
___ Brake camshafts (#2 grease 22-2)
___ Slack adjusters (#2 grease 22-3)
___ Drive shaft (#2 grease 22-3)
___ Upper steering shaft U-joint (#2 grease 22-4)
___ Lower steering shaft U-joints (#2 grease 22-4)
___ Front and rear door shafts (#2 grease 22-5)
___ Exterior mirror brackets (#2 grease 22-5)
___ Grease front axle C.V. U-joints (if retro) (#2 grease 22-9)
___ Grease front axle bushings (if retro) (#2 grease by hand) (22-9)
___ Driver's seat (silicone spray 22-5)
___ Window channels (silicone spray) (22-5)
___ Throttle linkage (JT-6) (22-7)
___ Front and rear ramp clevis pins (rear on 8800 only) (JT-6) (22-7)
___ Engine door hinges (JT-6 & multi purpose spray lube) (22-7)
___ Brake and throttle treadles (multi purpose spray lube) (22-6)
___ Hydraulic fluid reservoir level (trans. fluid) (22-8)
___ Change fluid in front axle hubs (gear lube) (22-8)
___ Add engine oil (15W-40) (8-4)
___ Add transmission fluid (12-3)
___ Run engine and check fluid levels and leaks (8-3, 12-4 & 21-2)

MISC.
___ Tires - check and air (3-1) record on tire card
___ Measure tire tread depth (3-1)
___ Rear shock absorbers (16-1)
___ Clean heater filter (19-3)
___ Heater core leaks (19-1)
___ Air conditioning sight glass (summer) (19-3)
___ Wheelchair tie-down equipment (8800, eight sets of five belts; 8900, six sets) (2-5)
___ Clean & spray electrical connections in brake relay compartment (4-2)

EMPLOYEE SIGNATURE	EMPLOYEE NUMBER
1	
2	
FOREMAN SIGNATURE	DATE

12,000 MILE "C" INSPECTION
ORION II

BUS NUMBER ______ WORK ORDER NUMBER ______ DATE ______ HUBODOMETER MILES AT INSPECTION ______

( )AMED CLEANED	YES	NO	DIVISION	
UNDER STRUCTURE	___	___	CENTRAL	___
ENG. COMPARTMENT	___	___	MEADOWBROOK	___
BATTERIES	___	___	MT. OGDEN	___
FUEL TANK CAP	___	___	TIMPANOGOS	___
RADIATOR	___	___	RIVERSIDE	___

Numbers in ( ) indicate P/M manual page number.

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" O " = Repairs Needed - Any item requiring repair.

INTERIOR

___ ___ Mirror (2-1)
___ ___ Front door emergency air control (1-1)
___ ___ Emergency road reflectors (2-1)
___ ___ Fire extinguisher & tag (1-2)
___ ___ Emergency exit hatch (2-1)
___ ___ Schedule boxes and route box (2-3)
___ ___ Interior and exit door lights (4-1)
___ ___ Passenger buzzer strip, next stop sign and tell tale light (2-1)
___ ___ Stanchions and grabrails (2-1)
___ ___ Passenger seats, frames and latches (2-3)
___ ___ Passenger seat belts (8800) (2-3)
___ ___ Floor covering (2-2)
___ ___ Windows & latches (2-2)
___ ___ Emergency escape windows and latches (2-3)
___ ___ Side, ceiling and modesty panels (2-3)
___ ___ Climate control (run A/C even in winter) (19-1)
___ ___ Floor heater (19-2)
___ ___ Front and rear door seals (2-2)
___ ___ Front and rear door alignment (2-2)
___ ___ Rear door authorized switch (1-4)
___ ___ Brake and throttle treadles (1-11)
___ ___ Rear door (1-4)
___ ___ Rear kneeling (1-1)
___ ___ Rear ramp (1-3)
___ ___ Rear door emergency air control (1-1)
___ ___ Electrical panel (4-2)

DRIVER CONTROL AREA

___ ___ Destination sign (2-2)
___ ___ Sun visor and side sun screens (2-2)
___ ___ Master switch (1-4)
___ ___ Low oil and Alt. circuits (lights & buzzer) (1-4)
___ ___ Neutral safety start (1-5)
___ ___ Engine start and starter cut-out (1-5)
___ ___ Transmission shift selector (12-1)
___ ___ Dash night lights and panel lamp dimmer (4-3)
___ ___ Horns (1-7)
___ ___ Steering free play (13-1)
___ ___ Tilt steering (8800) (13-1)
___ ___ Tilt & telescopic steering (8900) (13-4)
___ ___ Steering column shaft and mounting (13-1)
___ ___ Hi idle (1-7)
___ ___ Oil gauge (1-8)
___ ___ Dash voltmeter (1-8)
___ ___ Fuel gauge (1-8)
___ ___ Dual air gauge (1-8)
___ ___ Low air circuit (70 psi) (1-8)
___ ___ Air governor cut-in, cut-out, (adjust)
Cut-in ________ Cut-out ________ (1-9)
___ ___ Air dryer purge valve (6-1)
___ ___ Air leaks with brakes released (7-1) _______ psi drop per min. (1-psi max.)
___ ___ Air pressure loss with brakes applied (7-1) _______ psi drop (20 psi maximum)
___ ___ Air leaks with brakes applied (7-2) _______ psi drop per min. (2-psi max.)
___ ___ Driver's heat control (19-2)
___ ___ Driver's overhead fan (19-3)
___ ___ Windshield fan (1-10)

DRIVER CONTROL (continued)

___ ___ Defrost (19-2)
___ ___ Driver's temp. control (19-2)
___ ___ Windshield wipers (1-9)
___ ___ Windshield washer (1-10)
___ ___ Turn signals and tell-tale lights (4-4)
___ ___ Four way flashers (4-4)
___ ___ Auxiliary flasher circuit (4-4)
___ ___ Headlight dimmer and high beam tell tale (4-4)
___ ___ Park brake (7-5)
___ ___ Park and service brake tell tale lights (1-11)
___ ___ Front door (1-10)
___ ___ Brake and throttle interlock (1-11)
___ ___ Brake emergency override switch (1-11)
___ ___ Front kneeling (1-1)
___ ___ Front ramp (1-3)
___ ___ Farebox mounting and trip switch (1-11)
___ ___ Radio mounting (2-3)
___ ___ Transfer cutter (2-3)
___ ___ Driver's seat (2-4)

EXTERIOR

___ ___ Body damage (major or unsafe) (2-5)
___ ___ Mirrors (2-5)
___ ___ Wiper arm adjustment and blade condition (1-9)
___ ___ Lights (4-3)
___ ___ Back-up lights and alarm (4-4)
___ ___ Window hinges and weather stripping (2-2)
___ ___ Wheels (3-2)
___ ___ Wheel gaskets (14-1 & 17-1)
___ ___ Fuel tank leaks, filler cap and O-ring (9-2)
___ ___ Fender aprons and splash guards (2-5)

DRIVE TEST (in yard)

___ ___ Brakes and brake application valve (21-1)
___ ___ Steering (21-1)
___ ___ Rattles (21-2)
___ ___ Engine noise (8-2)
___ ___ Exhaust gases inside coach (21-3)
___ ___ Gauges (21-2)

ENGINE COMPARTMENTS

___ ___ Engine cooling fan (5-1)
___ ___ Hydraulic fluid return filter (gauge) (13-1)
___ ___ Booster pump operation (winter) (19-2)
___ ___ Oil pressure (engine compartment) (record) (8-1)
Idle__________ Full throttle__________
___ ___ Alternator noise or vibration (8-2)
___ ___ Water temperature gauge (1-5)
___ ___ Low water circuit (1-6)
___ ___ High water temp. circuit (1-6)
___ ___ Engine protection circuit (1-6)
___ ___ Engine override circuit (1-7)
___ ___ Pressurize cooling system (10 psi) (5-1)
___ ___ Coolant filler cap, seal, and ventcock (5-1)
___ ___ Pressure relief cap (5-2)
___ ___ Water pump weephole (5-2) ___ ___ Exhaust system (11-1)
___ ___ Engine dipstick and tube (8-2)
___ ___ Engine breather (8-1)
___ ___ Transmission dipstick and tube (12-4)

ENGINE COMPARTMENTS (continued)

__ __ Oil filler cap and gasket (8-1)
__ __ Drive belt condition (8-3)
__ __ Air compressor drive belt tension (70-75 lbs.) (8-3)
__ __ A/C compressor drive belt tension (70-75 lbs.) (8-3)
__ __ Alternator drive belt tension (8-3)
__ __ Coolant additive package (5-1)
__ __ Engine block heater (8-4) _______OHMS
__ __ Air intake system (10-1)
__ __ Air cleaner vacuator valve (10-1)
__ __ Intake restriction (10-1)
__ __ Cooling fan condition (5-2)
__ __ Fan shroud (5-2)
__ __ Radiator & mounting (5-2)
__ __ Lower steering drive shaft (13-1)
__ __ Steering shaft pinch bolts (13-1)
__ __ Service batteries and battery trays (4-5)
__ __ Battery internal hydrometers (4-5)
__ __ Load test batteries (4-6) Record readings ________v ________v
__ __ Corrosion spray battery terminals bottom and top (4-5)
__ __ Reset Vanner circuit breaker (4-9N)
__ __ Charging voltage (4-10)
__ __ Windshield washer bottle (2-5)
__ __ Hydraulic system (pump lines etc.) (13-2)
__ __ Engine compartment wiring (4-1)
__ __ Engine compartment lights (4-3)
__ __ Air throttle cylinder (6-2)
__ __ Air, oil, fuel, transmission fluid, hydraulic fluid or coolant leaks
__ __ Line and hose routing (5-1, 6-4, 8-1, 9-1, 12-1)
__ __ Fuel pump weephole (9-2)
__ __ Drain water from Racor fuel filter (9-1)
__ __ Clean and spray all exposed electrical connections (4-2)

UNDER STRUCTURE

__ __ Rear air suspension (16-1)
__ __ Rear trailing arm bushings (16-2)
__ __ Front air suspension (15-1)
__ __ Front axle longitudinal and lateral rods (15-1)
__ __ Front shock absorbers (15-1)
__ __ Front trailing arm bushings (15-2)
__ __ Cross tube (tie rod) & drag link ends (13-3)
__ __ Steering miter gear (13-2)
__ __ Steering gear (13-3)
__ __ Differential leaks & vent (14-1)
__ __ Transmission leaks & vent (12-1)
__ __ Inspect transmission shift modulator (12-1)
__ __ Wheel seals & gaskets (17-1 & 14-1)
__ __ Brakes and lining wear (5/16 min.) (7-2)
__ __ Automatic slack adjusters (7-3)
__ __ Ride height 8.25" (16-1)
__ __ Air line leaks, cracks & routing (7-1 & 6-1)
__ __ Drive shaft (18-1)
__ __ Exhaust system (11-1)
__ __ Fluid leaks (5-1, 8-1, 12-1, and 13-2)
__ __ Mounting hardware (engine & transmission to power module, and power module to body)(8-1)
__ __ Isoclad undercoating (20-1)
__ __ All other under floor equipment (loose bolts, damaged parts etc.) (20-1)

AIR & BRAKE SYSTEM CHECKS

__ __ Drain all air tanks (6-3)
__ __ Air dryer (6-1)
__ __ Air compressor performance (85-100 psi. in 40 sec.) record time ________sec. (6-3)
__ __ Safety valve (6-3)
__ __ Air leaks with Son-Tector & soap (6-2)

LUBRICATION

__ __ Drain engine oil (8-2)
__ __ Change engine oil filter (8-2)
__ __ Torque pan plug (8-2)
__ __ Drain transmission fluid (12-3)
__ __ Torque transmission pan plug (12-3)
__ __ Check differential fluid level (14-1)
__ __ Wipe off ALL grease fittings before lubricating the following
__ __ Steering head bushings and bearings (#2 grease 22-2)
__ __ Cross tube (tie rod) & drag link ends (#2 grease 22-2)
__ __ Brake camshafts (#2 grease 22-2)
__ __ Slack adjusters (#2 grease 22-3)
__ __ Drive shaft (#2 grease 22-3)
__ __ Upper steering shaft U-joint (#2 grease 22-4)
__ __ Lower steering shaft U-joints (#2 grease 22-4)
__ __ Exterior mirror brackets (#2 grease 22-5)
__ __ Grease front axle C.V. U-joints (if retro) (#2 grease 22-9)
__ __ Grease front axle bushings (if retro) (#2 grease by hand) (22-9)
__ __ Driver's seat (silicone spray 22-5)
__ __ Window channels (silicone spray) (22-5)
__ __ Throttle linkage (JT-6) (22-7)
__ __ Front and rear ramp clevis pins (rear on 8800 only) (JT-6) (22-7)
__ __ Engine door hinges (JT-6 & multi purpose spray lube) (22-7)
__ __ Brake and throttle treadles (multi purpose spray lube) (22-6)
__ __ Hydraulic fluid reservoir level (trans. fluid) (22-8)
__ __ Change fluid in front axle hubs (gear lube) (22-8)
__ __ Add engine oil (15W-40)(8-4)
__ __ Run engine and check fluid levels and leaks (8-3, 12-4 & 21-2)

MISC.

__ __ Tires - check and air (3-1) record on tire card
__ __ Measure tire tread depth (3-1)
__ __ Rear shock absorbers (16-1)
__ __ Clean heater filter (19-3)
__ __ Heater core leaks (19-1)
__ __ Air conditioning sight glass (summer) (19-3)
__ __ Wheelchair tie-down equipment (8800, eight sets of five belts; 8900, six sets) (2-5)
__ __ Clean & spray electrical connections in brake relay compartment (4-2)

EMPLOYEE SIGNATURE	EMPLOYEE NUMBER
1	
2	
FOREMAN SIGNATURE	DATE

6,000 MILE "D" INSPECTION
ORION II

______ BUS NUMBER ______ WORK ORDER NUMBER ______ DATE ______ HUBODOMETER MILES AT INSPECTION

STEAMED CLEANED	YES	NO
UNDER STRUCTURE	___	___
ENG. COMPARTMENT	___	___
BATTERIES	___	___
FUEL TANK CAP	___	___
RADIATOR	___	___

DIVISION	
CENTRAL	___
MEADOWBROOK	___
MT. OGDEN	___
TIMPANOGOS	___
RIVERSIDE	___

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" O " = Repairs Needed - Any item requiring repair.

Numbers in ( ) indicate P/M manual page number.

INTERIOR
__ __ Mirror (2-1)
__ __ Front door emergency air control (1-1)
__ __ Fire extinguisher & tag (1-2)
__ __ Emergency road reflectors (2-1)
__ __ Emergency exit hatch (2-1)
__ __ Schedule boxes and route box (2-3)
__ __ Interior and exit door lights (4-1)
__ __ Passenger buzzer strip, next stop sign and tell tale light (2-1)
__ __ Stanchions and grabrails (2-1)
__ __ Passenger seats, frames and latches (2-3)
__ __ Passenger seat belts (8800) (2-3)
__ __ Floor covering (2-2)
__ __ Windows & latches (2-2)
__ __ Emergency escape windows and latches (2-3)
__ __ Side, ceiling and modesty panels (2-3)
__ __ Climate control (run A/C even in winter) (19-1)
__ __ Floor heater (19-2)
__ __ Front and rear door seals (2-2)
__ __ Front and rear door alignment (2-2)
__ __ Rear door authorized switch (1-4)
__ __ Brake and throttle treadles (1-11)
__ __ Rear door (1-4)
__ __ Rear kneeling (1-1)
__ __ Rear ramp (1-3)
__ __ Rear door emergency air control (1-1)
__ __ Electrical panel (4-2)

DRIVER CONTROL AREA
__ __ Destination sign (2-2)
__ __ Sun visor and side sun screens (2-2)
__ __ Master switch (1-4)
__ __ Low oil and Alt. circuits (lights & buzzer) (1-4)
__ __ Neutral safety start (1-5)
__ __ Engine start and starter cut-out (1-5)
__ __ Transmission shift selector (12-1)
__ __ Dash night lights and panel lamp dimmer (4-3)
__ __ Horns (1-7)
__ __ Steering free play (13-1)
__ __ Tilt steering (8800) (13-1)
__ __ Tilt & telescopic steering (8900) (13-4)
__ __ Steering column shaft and mounting (13-1)
__ __ Hi idle (1-7)
__ __ Oil gauge (1-8)
__ __ Dash voltmeter (1-8)
__ __ Fuel gauge (1-8)
__ __ Dual air gauge (1-8)
__ __ Low air circuit (70 psi) (1-8)
__ __ Air governor cut-in, cut-out, (adjust)
Cut-in ________ Cut-out ________ (1-9)
__ __ Air dryer purge valve (6-1)
__ __ Air leaks with brakes released (7-1) ______ psi drop per min. (1 psi max.)
__ __ Air pressure loss with brakes applied (7-1) ______ psi drop (20 psi maximum)
__ __ Air leaks with brakes applied (7-2) ______ psi drop per min. (2 psi max.)
__ __ Driver's heat control (19-2)
__ __ Driver's overhead fan (19-3)
__ __ Windshield fan (1-10)

DRIVER CONTROL (continued)
__ __ Defrost (19-2)
__ __ Driver's temp. control (19-2)
__ __ Windshield wipers (1-9)
__ __ Windshield washer (1-10)
__ __ Turn signals and tell-tale lights (4-4)
__ __ Four way flashers (4-4)
__ __ Auxiliary flasher circuit (4-4)
__ __ Headlight dimmer and high beam tell tale (4-4)
__ __ Park brake (7-5)
__ __ Park and service brake tell tale lights (1-11)
__ __ Front door (1-10)
__ __ Brake and throttle interlock (1-11)
__ __ Brake emergency override switch (1-11)
__ __ Front kneeling (1-1)
__ __ Front ramp (1-3)
__ __ Farebox mounting and trip switch (1-11)
__ __ Radio mounting (2-3)
__ __ Transfer cutter (2-3)
__ __ Driver's seat (2-4)

EXTERIOR
__ __ Body damage (major or unsafe) (2-5)
__ __ Mirrors (2-5)
__ __ Wiper arm adjustment and blade condition (1-9)
__ __ Lights (4-3)
__ __ Back-up lights and alarm (4-4)
__ __ Window hinges and weather stripping (2-2)
__ __ Wheels (3-2)
__ __ Wheel gaskets (14-1 & 17-1)
__ __ Fuel tank leaks, filler cap and O-ring (9-2)
__ __ Fender aprons and splash guards (2-5)

DRIVE TEST (in yard)
__ __ Brakes and brake application valve (21-1)
__ __ Steering (21-1)
__ __ Rattles (21-2)
__ __ Engine noise (8-2)
__ __ Exhaust gases inside coach (21-3)
__ __ Gauges (21-2)

ENGINE COMPARTMENTS
__ __ Engine cooling fan (5-1)
__ __ Hydraulic fluid return filter (gauge) (13-1)
__ __ Booster pump operation (winter) (19-2)
__ __ Oil pressure (engine compartment) (record) (8-1)
Idle ________ Full throttle ________
__ __ Alternator noise or vibration (8-2)
__ __ Water temperature gauge (1-5)
__ __ Low water circuit (1-6)
__ __ High water temp. circuit (1-6)
__ __ Engine protection circuit (1-6)
__ __ Engine override circuit (1-7)
__ __ Pressurize cooling system (10 psi) (5-1)
__ __ Coolant filler cap, seal, and ventcock (5-1)
__ __ Pressure relief cap (5-2)
__ __ Water pump weephole (5-2)
__ __ Exhaust system (11-1)
__ __ Engine dipstick and tube (8-2)
__ __ Transmission dipstick and tube (12-4)

ENGINE COMPARTMENTS (continued)

__ __ Oil filler cap and gasket (8-1)
__ __ Drive belt condition (8-3)
__ __ Air compressor drive belt tension (70-75 lbs.) (8-3)
__ __ A/C compressor drive belt tension (70-75 lbs.) (8-3)
__ __ Alternator drive belt tension (8-3)
__ __ Coolant additive package (5-1)
__ __ Engine block heater (8-4) ________OHMS
__ __ Air intake system (10-1)
__ __ Air cleaner vacuator valve (10-1)
__ __ Intake restriction (10-1)
__ __ Cooling fan condition (5-2)
__ __ Fan shroud (5-2)
__ __ Radiator & mounting (5-2)
__ __ Lower steering drive shaft (13-1)
__ __ Steering shaft pinch bolts(13-1)
__ __ Service batteries and battery trays (4-5)
__ __ Battery internal hydrometers (4-5)
__ __ Corrosion spray battery terminals bottom and top (4-5)
__ __ Reset Vanner circuit breaker (4-9N)
__ __ Charging voltage (4-10)
__ __ Windshield washer bottle (2-5)
__ __ Hydraulic system (pump lines etc.) (13-2)
__ __ Engine compartment wiring (4-1)
__ __ Engine compartment lights (4-3)
__ __ Air throttle cylinder (6-2)
__ __ Air, oil, fuel, transmission fluid, hydraulic fluid or coolant leaks
__ __ Line and hose routing (5-1, 6-4, 8-1, 9-1, 12-1)
__ __ Fuel pump weephole (9-2)
__ __ Drain water from Racor fuel filter (9-1)
__ __ Clean and spray all exposed electrical connections (4-2)

UNDER STRUCTURE

__ __ Rear air suspension (16-1)
__ __ Rear trailing arm bushings (16-2)
__ __ Front air suspension (15-1)
__ __ Front axle longitudinal and lateral rods (15-1)
__ __ Front shock absorbers (15-1)
__ __ Front trailing arm bushings (15-2)
__ __ Cross tube (tie rod) & drag link ends (13-3)
__ __ Steering miter gear (13-2)
__ __ Steering gear (13-3)
__ __ Differential leaks & vent (14-1)
__ __ Transmission leaks & vent (12-1)
__ __ Inspect transmission shift modulator (12-1)
__ __ Wheel seals & gaskets (17-1 & 14-1)
__ __ Brakes and lining wear (5/16 min.) (7-2)
__ __ Automatic slack adjusters (7-3)
__ __ Ride height 8.25" (16-1)
__ __ Air line leaks, cracks & routing (7-1 & 6-1)
__ __ Drive shaft (18-1)
__ __ Exhaust system (11-1)
__ __ Fluid leaks (5-1, 8-1, 12-1, and 13-2)
__ __ Mounting hardware (engine & transmission to power module, and power module to body)(8-1)
__ __ Isoclad undercoating (20-1)
__ __ All other under floor equipment (loose bolts, damaged parts etc.) (20-1)

AIR & BRAKE SYSTEM CHECKS

__ __ Drain all air tanks (6-3)
__ __ Air dryer (6-1)
__ __ Air compressor performance (85-100 psi. in 40 sec.) record time ________sec. (6-3)
__ __ Safety valve (6-3)
__ __ Air leaks with Son-Tector & soap (6-2)

LUBRICATION

__ __ Drain engine oil (8-2)
__ __ Change engine oil filter (8-2)
__ __ Torque pan plug (8-2)
__ __ Check differential fluid level (14-1)
__ __ Wipe off ALL grease fittings before lubricating the following
__ __ Steering head bushings and bearings (#2 grease 22-2)
__ __ Cross tube (tie rod) & drag link ends (#2 grease 22-2)
__ __ Brake camshafts (#2 grease 22-2)
__ __ Slack adjusters (#2 grease 22-3)
__ __ Drive shaft (#2 grease 22-3)
__ __ Lower steering shaft U-joints (#2 grease 22-4)
__ __ Exterior mirror brackets (#2 grease 22-5)
__ __ Grease front axle C.V. U-joints (if retro) (#2 grease 22-9)
__ __ Grease front axle bushings (if retro) (#2 grease by hand) (22-9)
__ __ Driver's seat (silicone spray 22-5)
__ __ Window channels (silicone spray) (22-5)
__ __ Throttle linkage (JT-6) (22-7)
__ __ Front and rear ramp clevis pins (rear on 8800 only) (JT-6) (22-7)
__ __ Engine door hinges (JT-6 & multi purpose spray lube) (22-7)
__ __ Brake and throttle treadles (multi purpose spray lube) (22-6)
__ __ Hydraulic fluid reservoir level (trans. fluid) (22-8)
__ __ Fluid level in front axle hubs (gear lube) (22-8)
__ __ Add engine oil (15W-40)(8-4)
__ __ Run engine and check fluid levels and leaks (8-3, 12-4 & 21-2)

MISC.

__ __ Tires - check and air (3-1) record on tire card
__ __ Measure tire tread depth (3-1)
__ __ Rear shock absorbers (16-1)
__ __ Clean heater filter (19-3)
__ __ Heater core leaks (19-1)
__ __ Air conditioning sight glass (summer) (19-3)
__ __ Wheelchair tie-down equipment (8800, eight sets of five belts; 8900, six sets) (2-5)
__ __ Clean & spray electrical connections in brake relay compartment (4-2)

EMPLOYEE SIGNATURE	EMPLOYEE NUMBER
1	
2	
FOREMAN SIGNATURE	DATE

BASICS OF ELECTRICAL SYSTEMS

Learning Objectives: The Student will have an understanding of the basic principles of electrical systems.

Task: The student should be able to identify and explain the following terms.

Standard: The student will complete a written examination in which he/she will attain a minimum score of 80% to pass the written test.

Term	
Basic definition of electricity	Circuit protection devices
Voltage	Relays
Amperage	Electrical schematic
Resistance	Short circuit
Voltmeter	Direct current
Ammeter	Alternating current
Ohmmeter	Series-parallel circuit
Closed circuit	Parallel circuit
Open circuit	Series Circuit
Continuity	Insulator
Chassis ground	Conductor

ELECTRICITY—How It Works / CHAPTER 1

INTRODUCTION

In this chapter we will cover the basics of electronics and electricity:

- **Electron Theory**
- **Putting Electrons to Work**
- **Electronics vs. Electricity**
- **Introduction to Current, Voltage, and Resistance**
- **Magnetism**
- **Electromagnetism**
- **Electromagnetic Induction**

Let's discuss each of these subjects in detail.

ELECTRON THEORY

Because all matter contains electrons, all matter has an essential ingredient called electricity.

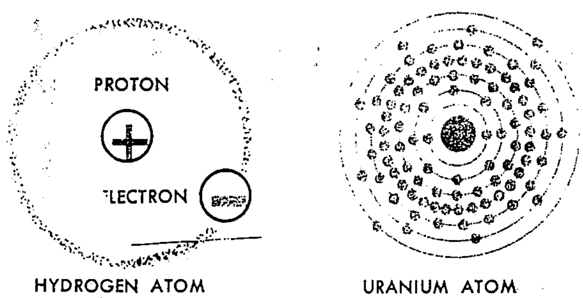


Fig. 1—All Matter is Made Up of Atoms

To understand this, let's look at the smallest unit of all matter—the atom (Fig. 1). All **atoms** have particles called **electrons** in orbit around a core of **protons.**

The simplest element is hydrogen. As shown, its atom has a single electron in orbit around a core of one proton.

One of the most complex elements is uranium. It has 92 electrons in orbit around a core of 92 protons.

Each element has its own atomic structure.

But each atom of an element has an *equal number of protons and electrons.*

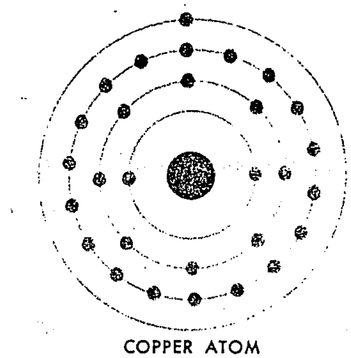


Fig. 2—Structure of a Copper Atom

The element copper is widely used in electrical systems because it is a good conductor of electricity.

The reasons for this can be seen in Fig. 2. The copper atom contains 29 protons and 29 orbiting electrons. The electrons are distributed in four separate orbits or rings. Those electrons beyond the second orbit are more or less free to move from one orbit to another, but still keeping the same amount of electrons per orbit.

But notice that the outer ring has only one electron. This is the secret of a good conductor of electricity.

Elements whose atoms have less than four electrons in their outer rings are generally good **conductors.**

Elements whose atoms have more than four electrons in their outer rings are poor conductors and are called **insulators.**

Litho in U.S.A.

The fewer electrons in the outer ring of conductors are more easily dislodged from their orbits by a low voltage to create a flow of current from atom to atom.

In summary:

- **Atoms have electrons in orbit around a core of protons.**
- **Each atom contains an equal number of electrons and protons.**
- **The electrons occupy shells or rings in which they orbit around the core.**
- **Atoms which have less than four electrons in their outer rings are good conductors of electricity, as with copper.**
- **Atoms which have more than four electrons in their outer rings are good insulators of electricity, as with plastic or rubber.**

PUTTING ELECTRONS TO WORK

We have seen that atoms contain particles called protons and electrons.

These particles have a potential force:

- **Protons = positive (+) charges**
- **Electrons = negative (–) charges**

The protons in the core attract the electrons and hold them in orbit. Since the positive charge of the protons is equal to the negative charge of the electrons, the atom is said to be *neutral.*

However, this neutral state can be altered. If the orbiting electrons can be forced away from the atom, the atom becomes positive (+) charged and the collection of the orbiting electrons taken away become negative (–) charged. Thus:

Positive charged atoms = too few electrons

Negative charged atoms = too many electrons

The atom does not give up its orbiting electrons except by force. This force must be used to take the electrons from their position around the neutral atom and induce them into another atom's orbit.

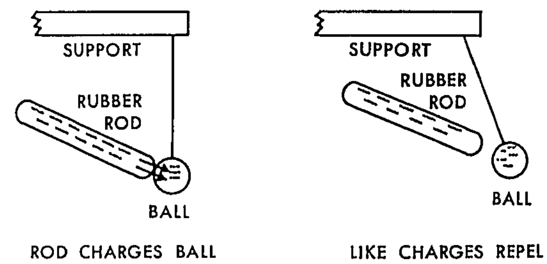


Fig. 3—Like Charges Repel

Let's show this transfer of electrons in an experiment.

When a rubber rod is rubbed with wool, orbiting electrons from the wool are removed and collected on the rod. The wool now has too few electrons and becomes positive (+) charged and the rod has too many electrons and becomes negative (–) charged.

Now let's touch the negative charged rubber rod to a hanging pith ball and remove the rod (Fig. 3). What happens is that some of the extra electrons on the rod move into the orbit of the atom of the ball. The ball then becomes negative (–) charged while the rod also retains part of its negative (–) charge.

When the rod is moved toward the ball again, the ball will swing away from the rod as shown.

In other words, *like charges repel.*

In the experiment, both charges were negative. If both charges were positive (+) the same thing would occur.

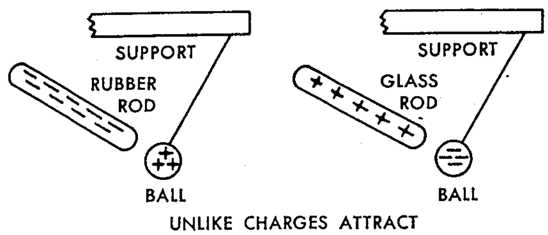


Fig. 4—Unlike Charges Attract

What happens if we move a positive (+) charged rod toward a negative (–) charged ball?

When a glass rod is rubbed with silk, the silk becomes negative (–) charged and the glass rod becomes positive (+) charged. Fig. 4 shows that a negative charged hanging pith ball will be attracted to the positive charged glass rod. (In the same way a positive charged pith ball will be attracted to a negative charged rubber rod.)

In other words, *unlike charges attract.*

The rubbing force that causes this electron movement is called *static electricity.*

In summary:

- **Electrons can be made to leave their atoms in some materials**
- **A force such as friction is needed to cause electrons to leave their atoms.**
- **Like charges repel and unlike charges attract.**

DYNAMIC ELECTRICITY

Now let's look at another type of electron flow. Fig. 5 shows what happens with a conductor such as copper wire when it has a negative charge on one end and a positive charge at the other end. This can be accomplished by connecting the ends of the copper wire to the positive and negative terminals of a dry cell battery.

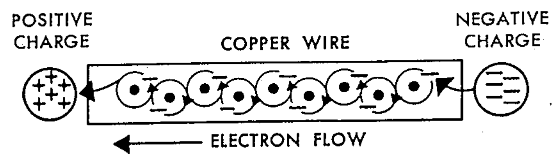


Fig. 5—Flow of Electrons in a Conductor

What happens is that an electron (–) of the copper atom is forced out of its orbit and attracted to the positive (+) end of the battery. This atom is now positive (+) charged because it now has too few electrons. It in turn attracts an electron from its neighbor. The neighbor in turn receives an electron from the next atom and so on until the last copper atom receives an electron from the negative (–) end of the battery.

The net result of this chain reaction movement of electrons is that the electrons move through the wire from the negative end of the battery to the positive end of the battery.

This flow or current of electrons will continue as long as the positive and negative charges from the battery are maintained at each end of the wire (unlike charges attracting each other).

The use of a battery to force electrons to flow through a conductor is known as *dynamic electricity.*

ELECTRONICS VS. ELECTRICITY

From our previous study of the flow of electrons we would conclude: **Electricity is the flow of electrons from atom to atom in a conductor.**

What then is electronics?

Electronics is the control of electrons and the study of their behavior and effects.

This control of electrons is accomplished by devices that resist, carry, control, select, steer, switch, store, manipulate, and exploit the electrons.

For a better understanding let's review the previous experiment of electron flow (electricity). The pith ball would not have reacted to the electrons in the rubber and glass rods unless the rods were rubbed with wool and silk. Thus, the rubber and glass rods, along with the respective rubbing of the wool and silk, constitute electronic devices that control electron flow.

INTERESTING SIDELIGHTS

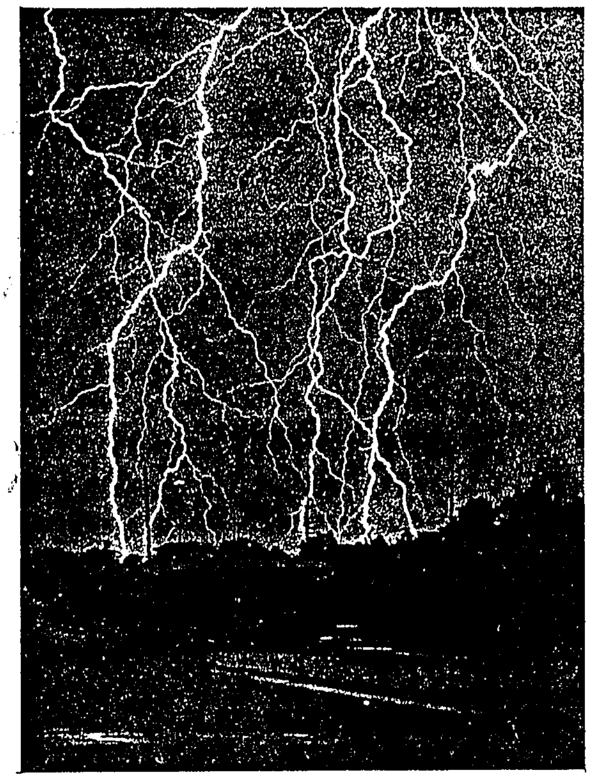


Fig 6—Lightning During an Electrical Storm

During warm weather clouds acquire a static charge that moves from cloud to cloud and cloud to earth. This static charge between clouds and earth may grow to more than one million volts before it is discharged as lightning.

Lightning with its accompanying thunder is the result of a great number of electrons forcing their way through the atmosphere, which is normally an insulator and does not allow electrons to flow through it. The release of this much energy is what can cause vast damage during a bad electrical storm.

INTRODUCTION TO CURRENT, VOLTAGE, AND RESISTANCE

When electricity goes to work, we are dealing with three basic factors:

- **Current**
- **Voltage**
- **Resistance**

These terms are basic to the understanding of electricity as we'll see now.

CURRENT

The flow of electrons through a conductor is called a current and is measured in amperes. It is represented by the letters A or I.

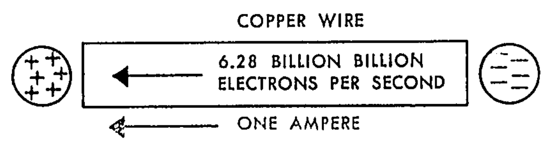


Fig. 7—How Current Is Measured

One ampere is an electric current of 6.28 billion *billion* electrons passing a certain point in the conductor in one second (Fig. 7).

Thus, current is the rate of electron flow and is measured in amperes or electrons per second. You can compare this with hydraulics where the flow of oil in a pipe is measured in gallons per minute.

There are two ways to describe current flow through a conductor (Fig. 8). In the electron flow theory, of which we are now familiar, the electron flow or current through a conductor is from a negative (–) power source to a positive (+) power source.

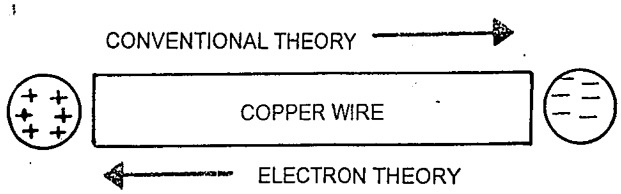


Fig. 8—Two Theories of Current Flow through a Conductor

The second theory is called the *conventional flow pressure theory,* where the current flow through a conductor is from a positive (+) power source to a negative (–) power source.

In the sixteenth century, long before the electron flow theory was discovered and when the basic laws of electricity were being developed it was believed that the current flow through a conductor was due to positive carriers. Even today, the majority of educational and industrial institutions teach the conventional flow theory.

Either theory can be used, but we will use the more popular conventional flow pressure theory (+ to –) in the remainder of this manual.

VOLTAGE

Voltage is the force that causes a flow of current in a conductor. Voltage is measured in **volts.** It is represented by the letters V or E (electromotive force). Voltage depends on the difference in the charges at each end of the conductor.

Voltage can be generated by a storage battery using chemicals, or by a generator using mechanical means. Voltage is a *potential* force and can exist even when there is no current flow in a circuit.

A storage battery, for example, may have a potential of 12 volts between its (+) and (–) terminal posts, and this potential exists even though no current-consuming devices are connected to the posts.

Thus, voltage can exist without current, but current cannot exist without the "push" of voltage.

Fig. 9—Voltage

Voltage is produced between two points when a positive charge exists at one point and a negative charge exists at the other point (Fig. 9).

The greater the charges at each point, the greater the voltage.

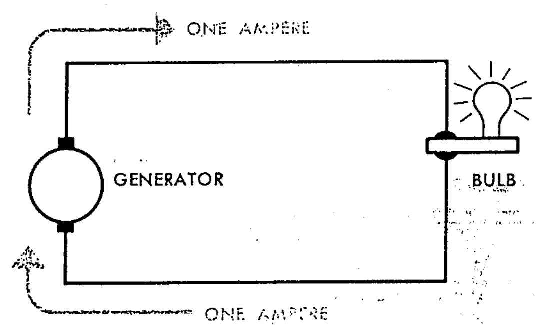


Fig. 10—The Generator as an Electron Pump

Look at a battery or generator as an electron pump (Fig. 10). The generator, for example, will supply a continuous flow of electrons (current) through the light bulb connected to it. The movement of electrons is continuous: In the generator, if one ampere of current is leaving, one ampere is entering to keep a constant flow of current.

RESISTANCE

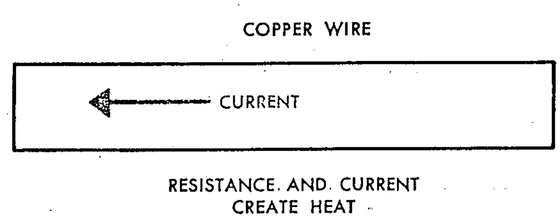


Fig. 11—Resistance to the Flow of Current in a Conductor

Resistance is the *opposition* of electron flow in a conductor. It is represented by the letter R and is measured in **ohms.** One ohm is the resistance that will allow one ampere to flow when the potential is one volt.

All conductors offer some **resistance** to the flow of current. Resistance is caused by:

1. Each atom resisting the removal of an electron due to attraction toward the core.

2. Collisions of countless electrons and atoms as the electrons move through the conductor.

The collisions create resistance and cause heat in the conductor.

This is an expression of Ohm's Law. (See later in chapter 2.) Resistance is often shown by the Greek symbol omega (Ω); thus 5Ω means five ohms.

MAGNETISM

Another form of force that causes electron flow or current is magnetism.

The effects of magnetism were first observed when fragments of iron ore called lodestone, found in nature, were seen to attract other pieces of iron (Fig. 12).

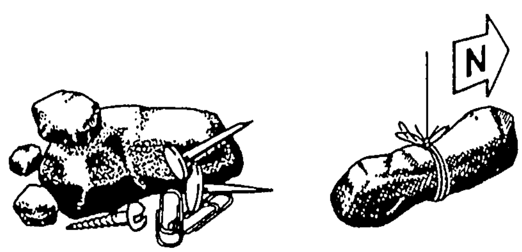


Fig. 12—Magnetism

It was further discovered that a long piece of this iron ore suspended in air would align itself so that one end always pointed toward the North Pole of the earth. This end of the iron bar was called the north pole, or **N pole,** and the other end the south or **S pole.** Such a piece of iron ore was called a **bar magnet.** This principle became the basis for the compass, which has been used as an aid in navigation for over 1000 years.

MAGNETIC FIELDS

Further study of the bar magnet revealed that an attractive force was exerted upon bits of iron or iron filings even though the iron filings were some distance away from the bar magnet. From this it was clear that a force existed in the space close to the bar magnet. This space around the magnet in which iron filings are attracted is called the field of force or **magnetic field.**

The magnetic field is described as invisible lines of force which come out of the N pole and enter the S pole.

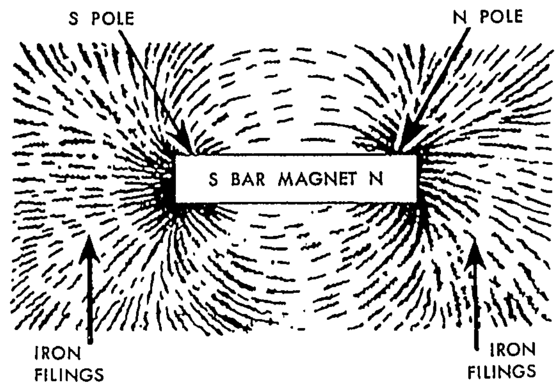


Fig. 13—Magnetic Field of a Bar Magnet

The theory of magnetic lines of force can be dramatically shown by sprinkling iron filings on a piece of paper resting on top of a bar magnet. When the paper is lightly tapped by hand, the iron filings line up to form a clear pattern around the bar magnet (Fig. 13).

The pattern shows that the lines of force are heavily concentrated at the N and S poles of the magnet, and then spread out into the surrounding air between the poles. The concentration or number of lines at each pole is equal, and the attractive force on the iron filings at each pole is equal. Notice that the force of attraction on bits of metal is greatest where the concentration of magnetic lines is greatest. For a bar magnet, this area is next to the two poles.

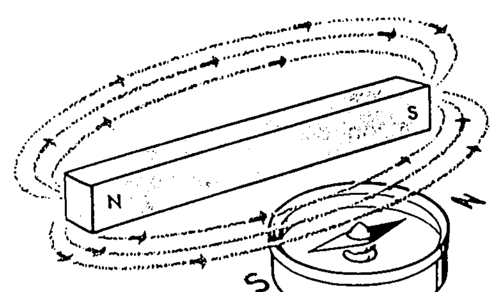


Fig. 14—Magnetic Lines of Force Come Out of N Pole and Enter S Pole

We have said that the lines of force always leave the N pole and enter the S pole of a magnet. When a small compass needle, which is a small bar magnet, is located in the magnetic field of a strong bar magnet, the compass needle will align itself so it is parallel with the lines of force of the bar magnet (Fig. 14).

This alignment takes place because the strong magnetic lines from the bar magnet must enter the S pole and leave the N pole of the compass needle.

We can also see that the unlike poles of the two magnets are attracted towards each other.

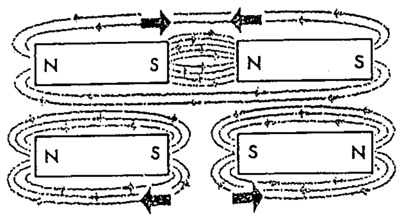


Fig. 15—Magnetic Forces between Poles of Bar Magnets

To demonstrate further the force of attraction between the unlike poles of two magnets, a force of attraction is seen to exist between two bar magnets lying end to end with an N and S pole facing each other (Fig. 15). The force of attraction increases as the two magnets are moved closer together.

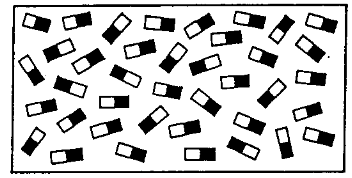
If, on the other hand, the magnets are aligned so the N poles or the S poles face each other, a force of repulsion is seen to exist between the two magnets, and this repulsion increases as the two magnets are moved closer together.

From these experiments, a fundamental law of magnetism can be stated:

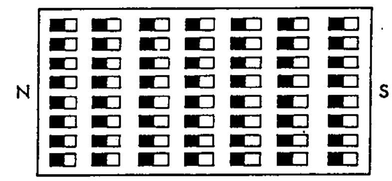
Unlike poles attract each other and like poles repel each other.

THEORIES OF MAGNETISM

Exactly what magnetism is, and how it exerts a field of force, can best be explained by either one of two theories.



UNMAGNETIZED IRON



MAGNETIZED IRON

Fig. 16—First Theory of Magnetism—Particles Are Aligned

Theory No. 1 states that a magnet is made up of a very large number of small magnetized *particles.* When a bar of iron is not magnetized, the small magnetic particles are arranged in a random manner (Fig. 16). But when the bar of iron becomes a magnet, the magnetic particles are aligned so that their individual effects add together to form a strong magnet.

Theory No. 2 about magnetism concerns the *electron.* The electron has a circle of force around it, and when the electron orbits are aligned in a bar of iron so that the circles of force add together, the bar of iron is magnetized.

While iron is one of the better known magnetic materials, remember that some materials are non-magnetic since they never exhibit any of the properties of magnetism. Some of the non-magnetic materials are wood, paper, glass, copper, and zinc.

HOW MAGNETS ARE MADE

An ordinary iron bar can be converted into a magnet in a number of different ways.

One method is to stroke the iron with another piece of iron that has already been magnetized. The effect of inducing magnetism into the iron bar is called **magnetic induction.**

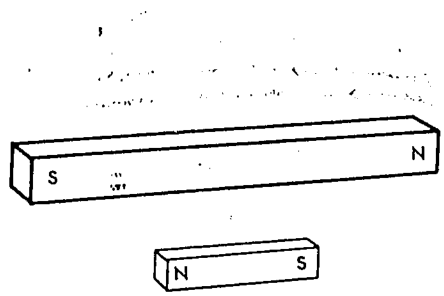


Fig. 17—Magnetic Induction of an Iron Bar

Another method of magnetic induction is simply to place an iron bar in a strong magnetic field (Fig. 17). The lines of force in the field passing through the iron bar will cause the bar to become a magnet as long as it is located in the field. If the bar is withdrawn from the field of force, and if its composition is such that it retains some of its induced magnetism, it is then said to be permanently magnetized and is called a **permanent magnet.**

Most permanent magnets are made of hard metals composed of alloys since soft metals will not retain much of their magnetism. Some of the more common alloys are nickel-iron and aluminum-nickel-cobalt.

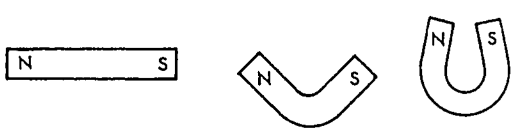


Fig. 18—Forming a Horseshoe Magnet

Permanent magnets are found in many shapes including the horseshoe magnet which concentrates the lines of force at the two poles in a small area (Fig. 18).

The most effective way of inducing a high level of magnetism in a material to form a permanent magnet is by the principles of electromagnetic induction. This principle is covered in a section which follows.

SUMMARY: MAGNETISM

In summary:

- **Every magnet has an N and S pole, and a field of force surrounding it.**
- **Magnetic materials are acted upon when located in a field of force.**
- **Unlike poles attract and like poles repel.**
- **An unmagnetized piece of iron can become a magnet through induction.**

ELECTROMAGNETISM

It was not until the year 1820 that *the relation between electricity and magnetism* was discovered. Before this time it was generally believed that magnetism existed only in the lodestone or iron ore found in nature, and there was no relationship at all between electricity and magnetism.

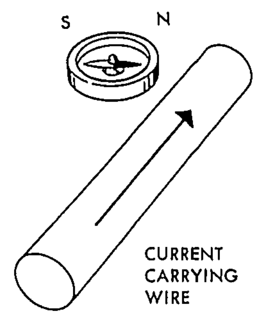


Fig. 19—Electric Current Creates Its Own Magnetic Field

An experiment with a compass and a wire carrying current revealed the connection between electricity and magnetism. When the compass was held over the wire, the needle turned so it was crosswise of the wire (Fig. 19). Since the only thing known that would attract a compass needle was magnetism, it was obvious that *the current in the wire created a magnetic field around the wire.*

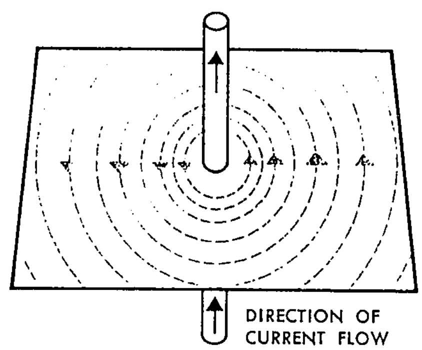


Fig. 20—Shape of Magnetic Field Around
Wire Carrying a Current

The nature of the magnetic field around the wire is revealed when the current-carrying wire is run through a piece of cardboard, and iron filings are sprinkled on the cardboard. The iron filings align themselves to show a clear pattern of concentric circles around the wire (Fig. 20). The circles are more concentrated near the wire than farther away. Although the iron filings on the cardboard show only the pattern in one plane, remember that the concentric circles extend the entire length of the current-carrying wire.

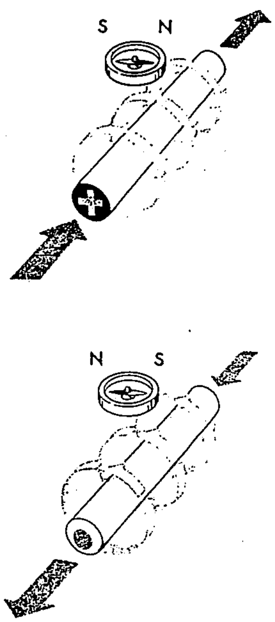


Fig. 21—Magnetic Lines Change Direction When Current Is Reversed

In Fig. 21, when current is flowing in a wire in the direction indicated by the cross, the N pole of a compass needle will always point in one direction. However, when current is flowing in the wire in the opposite direction as indicated by the dot, the north pole of the compass needle reverses and points in the opposite direction.

Since the needle always has a tendency to align itself so magnetic lines, or flux lines, enter its S pole and leave its N pole, we can conclude:

Magnetic lines have direction, and change direction when the current flow changes in the wire from one direction to another.

The Right Hand Rule for a Straight Conductor can be used to find the direction of the lines of force around the wire.

Fig. 22—Right Hand Rule Shows Direction of Lines of Force in a Straight Conductor

To apply the rule, grasp the wire with the thumb extended in the direction of conventional current flow (positive to negative); the fingers will then point in the direction in which the lines of force surround the conductor (Fig. 22). These lines of force are always at right angles to the conductor, and the compass needle confirms the direction as determined by the Right Hand Rule.

Unlike the flow of electrons in the conductor, which actually move, the magnetic lines of force do not move or flow around the wire; instead they merely have direction as indicated by their effect upon the compass needle.

The number of lines of force, or strength of the magnetism, increases as the current through the conductor is increased.

If a compass is moved farther away from the conductor, a point finally is reached where the compass is unaffected by the field (Fig. 23). If the current is then increased, the compass needle will be affected and will again indicate the direction of the magnetic field as shown.

The number of lines of force, and the area around the conductor which they occupy, increase as the current through the conductor increases.

In other words:

More current creates a stronger magnetic field.

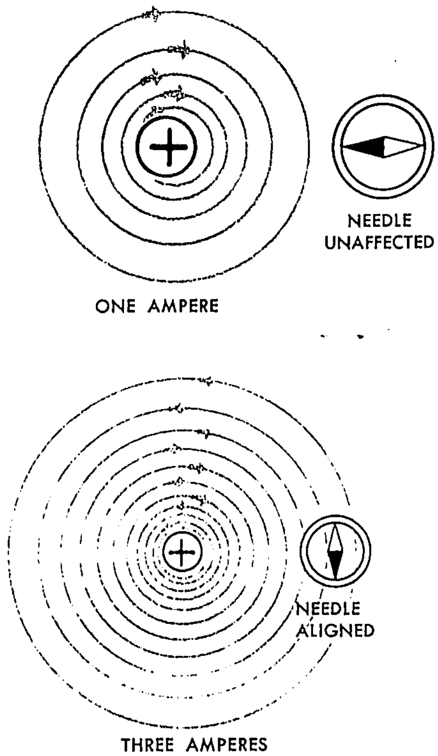


Fig. 23— More Current Creates a Stronger Magnetic Field

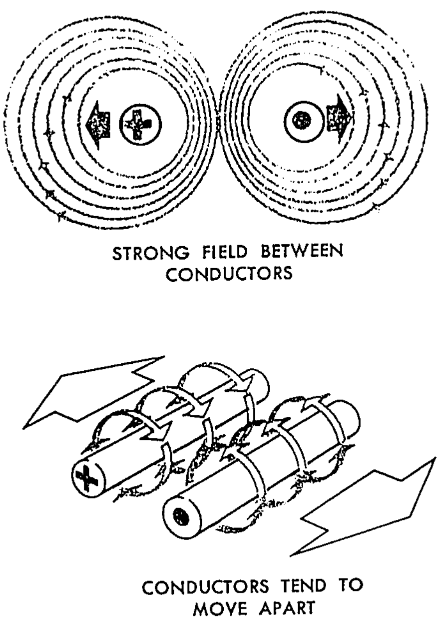


Fig. 24—How Conductors Are Affected By Strong Magnetic Fields

If two adjacent parallel conductors are carrying current in opposite directions, the direction of the field is clockwise around one conductor and counterclockwise around the other (Fig. 24). The lines of force are more concentrated between the conductors than on the outside of the conductors. The force lines between the two wires add together to form a strong magnetic field. Under this condition, the two wires willl tend to move apart, leading us to conclude:

A current-carrying conductor will tend to move out of a strong field and into a weak field.

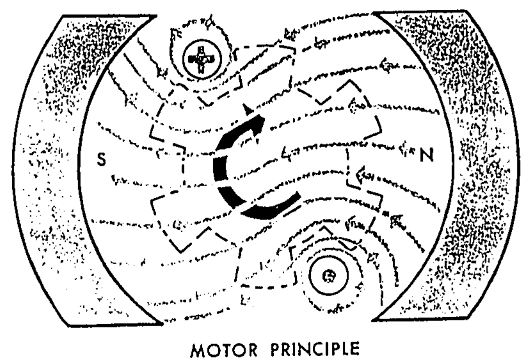


Fig. 25—Principle of the Starting Motor

In Fig. 25 two conductors are placed on an armature located between a strong N and S pole, and the conductors are made to carry current in opposite directions. The result is that a strong and a weak field are formed on opposite sides of each conductor as shown.

By the Right Hand Rule, current flowing into the top conductor will form magnetic lines on the underneath side of the conductor that add to the lines of the N and S poles. The conductor will then tend to move upward or clockwise into the weakened field.

Similarly, current flowing out of the lower conductor forms a strong field on top and a weak field underneath, causing the conductor to move downward or clockwise.

Thus, a rotation is caused by the current flowing in the conductors. This is the principle of the starting motor (Fig. 25). For more detail on starting motors, see Chapter 7, Starting Circuits.

 Litho in U.S.A.

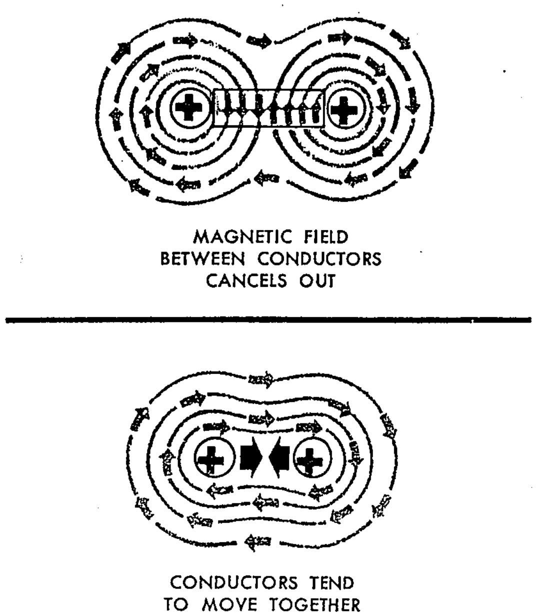


Fig. 26—How Conductors Are Affected By Weak Magnetic Fields

A different condition exists when two parallel conductors are carrying equal currents in the same direction (Fig. 26). A magnetic field, clockwise in direction, will be formed around each conductor, with the magnetic lines between the conductors opposing each other in direction. The magnetic field between the conductor is canceled out, leaving essentially no field in this area. The two conductors will then tend to move toward each other; that is, from a strong field into a weak field.

Two conductors lying alongside each other carrying equal currents in the same direction create a magnetic field equivalent to one conductor carrying twice the current (Fig. 27).

When several more conductors are placed side by side, the magnetic effect is increased as the lines from each conductor join and surround all the conductors.

Using the Right Hand Rule, we can see that all the lines of force enter the inside of the loop of wire on one side, and leave the other side as shown.

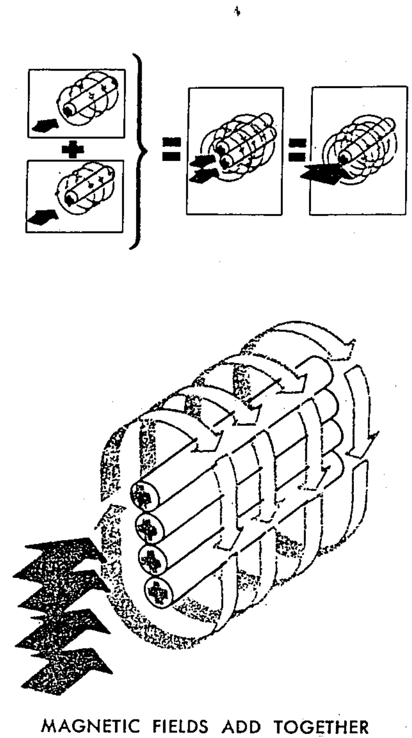


Fig. 27—How Two or More Adjacent Conductors Increase the Magnetic Field

The lines of force are concentrated inside the loop. A single loop of wire carrying current is called a **basic electromagnet.**

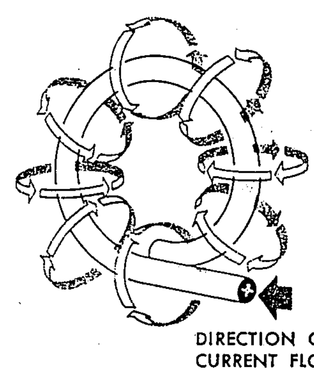


Fig. 28—Conductor in a Single Loop Has No Increase in Magnetic Field

A straight current-carrying wire when formed into a *single* loop has the same magnetic field surrounding it as when it was straight (Fig. 28).

HOW ELECTROMAGNETS WORK

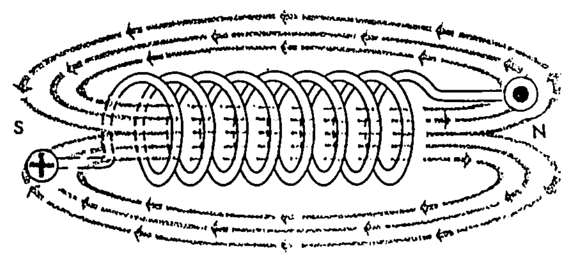
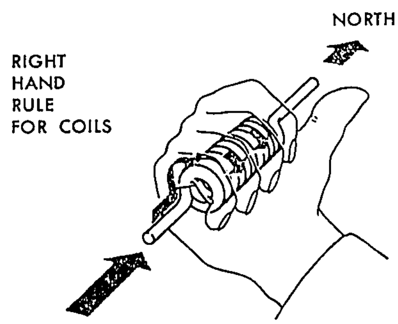


Fig. 29—Conductor in Several Loops Multiplies the Magnetic Field

But what happens when a current-carrying wire is wound into a *number* of loops to form a coil as shown in Fig. 29? Now the resulting magnetic field is the sum of all the single loop magnetic fields added together, since this is the same as several conductors lying side by side carrying current in the same direction.

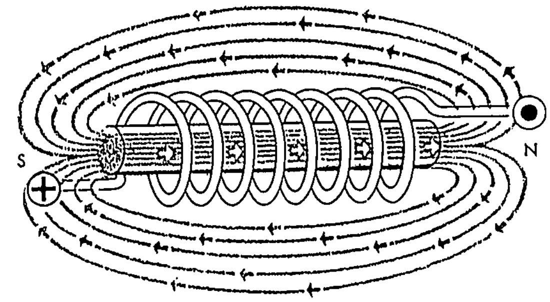
With lines of force leaving the coil at one end and entering at the other end, a north and south pole are formed at the coil ends the same as in the bar magnet.



DIRECTION OF CURRENT FLOW
Fig. 30—Right Hand Rule for Coils

To find polarity of the coil ends, apply the Right Hand Rule for Coils by grasping the coil with the fingers pointed in the direction of current flow; the thumb will then point toward the N pole of the coil as shown in Fig. 30. If the current direction through the coil is reversed, the polarity of the coil ends will also reverse.

When a coil is wound over a core of magnetic material such as iron, the assembly becomes a usable **electromagnet** (Fig. 31).



IRON CORE INCREASES FIELD STRENGTH

Fig. 31—Use of Iron Core to Increase Field Strength of Coil and form an Electromagnet

The strength of the magnetic field at the N and S poles is increased greatly by adding the iron core. The reason for this increase is that air is a very poor conductor of magnetic lines, while iron is a very good conductor. Relatively speaking, the use of iron in a magnetic path may increase the magnetic strength by 2500 times over that of air.

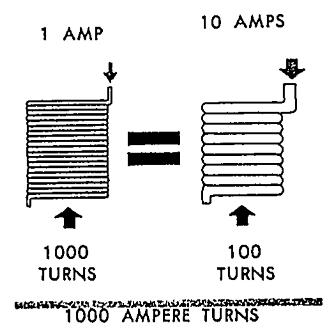


Fig. 32—Strength of Electromagnet Depends Upon Turns of Coil

The strength of the magnetic coils in an electromagnet is directly proportional to the number of turns of wire and the current in amperes flowing in the coil as shown in Fig. 32.

An electromagnet having one ampere flowing through 1000 turns and another electromagnet having 10 amperes flowing through 100 turns will each create 1000 ampere-turns, which is a measure of the magnetic field strength. The attraction on magnetic materials located in the magnetic field of each of these electromagnets will be the same.

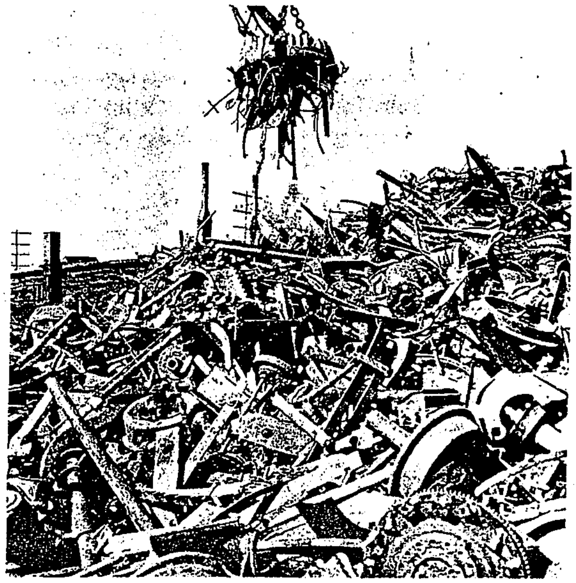


Fig. 33—Electromagnet Picking Up Junk Metal

Just as electric current flows through a closed circuit, so do the lines of force created by a magnet occupy a closed magnetic circuit. Since the same number of lines that come out of the N pole must also enter the S pole, a complete circuit must be present for each magnetic field.

The resistance that a magnetic circuit offers to lines of force, or flux, is called **reluctance.** The reluctance is comparable to resistance in an electrical circuit.

There is an equation for an electromagnetic circuit that is similar to Ohm's Law for the electric circuit. This equation is:

$$\text{Number of Magnetic Lines is Proportional to: } \frac{\text{Ampere-Turns}}{\text{Reluctance}}$$

Two facts related to this equation are important to us here:

1) The number of magnetic lines, or strength of the field, is directly proportional to the ampere-turns. In an electromagnet, more current through the coils means greater field strength.

2) The number of lines or field strength is inversely proportional to the reluctance; that is, if the reluctance increases the field strength decreases. Since most magnetic circuits consist of iron and short air gaps, the reluctance of such a series circuit is equal to the iron reluctance added to the air gap reluctance.

The effect of an air gap on the total reluctance of a circuit is very pronounced. This is true because air has a much higher reluctance than iron.

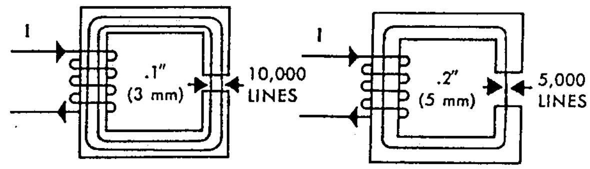


Fig. 34—Effect of Air Gap on Reluctance of a Circuit

To illustrate this fact, consider a magnetic circuit with a short air gap that has a field of strength of 10,000 lines of force (Fig. 34). If the length of the air gap is doubled, the reluctance will almost double, and the field strength will be reduced to approximately 5,000 lines of force. Although the air gap represents only a very short segment of the total magnetic path, increasing the air gap from, say, 0.1 inch (3 mm) to 0.2 inch (5 mm) may cut the field strength almost in half.

SUMMARY: ELECTROMAGNETISM

In summary:

- **Electricity and magnetism are related, because a magnetic field is established around a conductor that is carrying current.**
- **An electromagnet has an N pole at one end and an S pole at the other end of the iron core, much like a bar magnet.**
- **Every magnetic field has a complete circuit that is occupied by its lines of force.**
- **An electromagnetic field gets stronger as more current flows through its coils.**

ELECTROMAGNETIC INDUCTION

When a conductor is moved across a magnetic field, a voltage is induced in the conductor. This principle is called **electromagnetic induction,** and is defined as *the inducing of voltage in a conductor that moves across a magnetic field.*

HOW VOLTAGE IS INDUCED

To show this, move a straight wire conductor across the magnetic field of a horseshoe magnet (Fig. 35). Connect a sensitive voltmeter to the ends of the wire and the needle will register a small voltage as the wire is moved across the magnetic field.

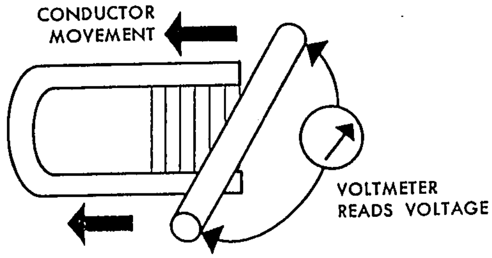


Fig. 35—Moving Conductor Across Magnetic Field—Voltage Is Induced

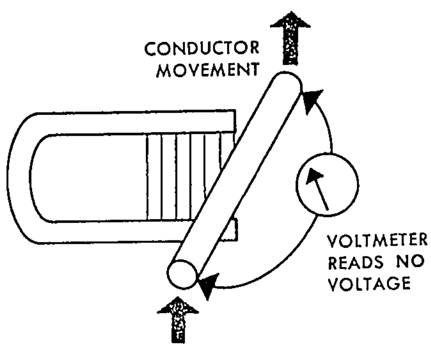


Fig. 36—Moving Conductor Parallel to Magnetic Field—No Voltage Is Induced

However, if the wire is moved *parallel* with the lines of force, no voltage will be induced (Fig. 36). *The conductor must cut across the lines of force in order to induce a voltage.*

We have observed that voltage has polarity; that is, positive and negative poles. We have also stated that current flows from the positive terminal of a voltage source through the external circuit and then back to the negative terminal of the source.

Now we can also see that a wire cutting across a magnetic field also becomes a source of electricity, and must have a positive and negative end, just like a battery.

However, unlike the battery, we will now see that the polarity at the ends of the wire can change. This polarity depends upon the relative direction of wire movement and the direction of the magnetic field.

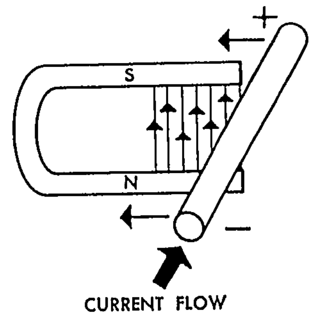


Fig. 37—Finding Polarity at Ends of a Conductor

To determine the polarity at the ends of a conductor and the consequent direction of current flow, consider a straight wire moving to the left across a magnetic field as shown in Fig. 37. With this direction of motion, the magnetic lines are striking the wire on the left side, and this side of the wire is called the leading side.

By applying the Right Hand Rule for an Induced Voltage, the voltage polarity and current flow direction can be determined as follows: Grasp the conductor with the fingers on the leading side of the wire, and pointed in the direction of the magnetic lines of force. The thumb will then point in the direction of current flow.

In Fig. 37, current is seen to flow into the page, or away from the reader, as indicated. This means that the polarities at the wire ends must be as shown in order to meet the condition that current flows from the positive side of a source through the external circuit and returns to the negative side of the source.

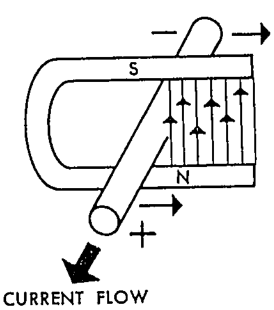


Fig. 38—Reversed Polarity in a Conductor

When the direction of motion of the conductor is changed to move toward the right, the right side of the conductor becomes the leading side (Fig. 38). By applying the Right Hand Rule, the current is seen to reverse its direction from Fig. 37, and to flow out of the page or toward the reader. This means that the voltage polarities at the wire ends have reversed.

In the previous examples, if, instead of moving the wire to the left, we move the magnetic field to the right across a stationary conductor, the same voltage and current flow will be induced in the wire. The same holds true for moving the field to the left across the conductor, because in each case the leading side of the conductor and the magnetic field direction are unchanged. Therefore, we can conclude: *A voltage will be induced in a conductor cutting across a magnetic field when there is relative motion between the two. Either the conductor can move, or the magnetic field can move.*

MAGNITUDES OF INDUCED VOLTAGE

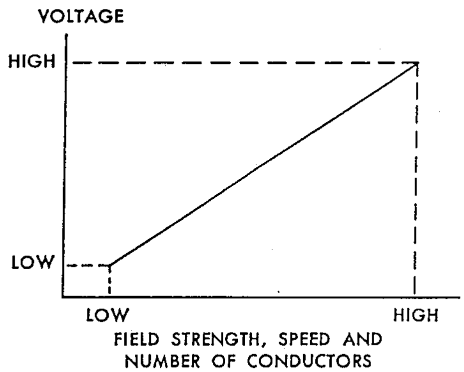


Fig. 39—Factors Which Determine the Magnitude of Induced Voltage

Now that we have observed the factors that determine the polarity of the induced voltage and the direction of current flow, let's consider the factors that determine the magnitude of the induced voltage (Fig. 39). These factors are:

1. *The strength of the magnetic field.*

2. *The speed at which lines of force are cutting across the conductor.*

3. *The number of conductors that are cutting across the lines of force.*

If the magnetic field is made stronger, such as by using a larger horseshoe magnet, more lines of force will be cut by the conductor in any given interval of time and the induced voltage will be higher.

If the *relative motion* between the conductor and magnetic field is increased, more lines of force will be cut in any given interval of time and so the voltage will be higher.

If the straight wire conductor is wound into a coil which is then moved across the field, all the loops of wire are in series and the voltage induced in all the loops will add together to give a higher voltage.

To summarize:

- **Stronger magnetic field = more induced voltage**
- **Faster relative motion = more voltage**
- **More conductors in motion = more voltage**

METHODS OF INDUCING VOLTAGE

There are three ways in which a voltage can be induced by electromagnetic induction:

- **Generated Voltage**
- **Self-Induction**
- **Mutual Induction**

Let's discuss each form of induction.

GENERATED VOLTAGE

A direct-current generator operates by moving conductors across a stationary magnetic field to produce voltage and current.

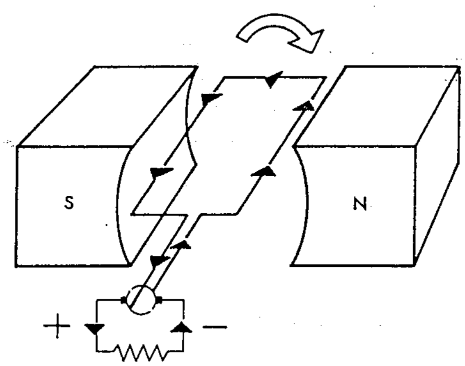


Fig. 40—Basic DC Generator

To show this, take the most basic type of DC generator where a single loop of wire is rotating between the N and S poles of a magnetic field (Fig. 40).

By applying the Right Hand Rule for Induced Voltage to both sides of the wire loop, current is seen to flow in the direction indicated, and the voltages induced in the wire loop give a coil voltage that appears at the two commutator segments attached to the wire ends. The current then flows through brushes riding on the commutator to the external circuit. The voltage polarities are as shown.

Another application of the principle of generated voltage is the alternating-current generator, or alternator, where the magnetic field is made to cut across stationary conductors in order to produce voltage and current.

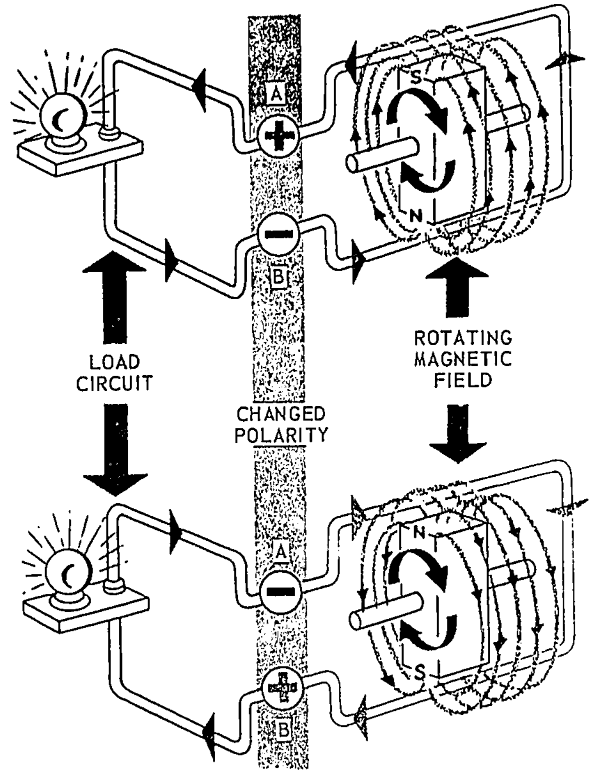


Fig. 41—Basic Alternator Operation

Fig. 41 shows the most basic type of alternating current generator, with a rotating magnetic field cutting across stationary conductors that are mounted on the generator frame.

By applying the Right Hand Rule, with the rotating magnetic field as shown, current flow through the conductors will alternate, thus causing an *Alternating Current* output.

The voltage induced in a conductor by physically moving the conductor or the field is referred to as *Generated Voltage.* This principle is used in DC generators and alternators, both of which are covered in detail in Chapter 6.

SELF-INDUCTION

Self-induction is the induction of a voltage in a current-carrying wire when the current in the wire itself is changing.

Earlier in this chapter we used a separate magnetic field provided by a horseshoe magnet to generate voltage in a conductor. In self-induction no separate field is used; instead the magnetic field created by a changing current through the wire itself is seen to induce a voltage in the wire. Hence, the voltage is **self-induced.**

The reason that a voltage is induced in a wire carrying a changing current is this: Since the current creates a magnetic field in the form of concentric circles around the wire which expand and contract as the current increases and decreases, these magnetic circles cut across the conductor and thereby induce a voltage in the conductor. Since there is relative motion between the field and conductor, the condition necessary for inducing a voltage has been met.

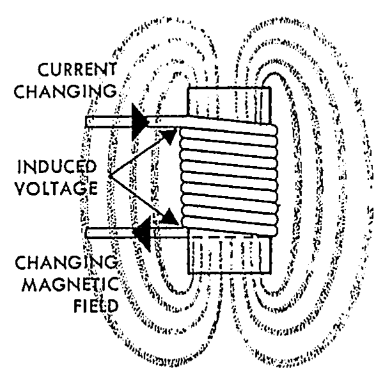


Fig. 42—Self-Induction in a Coil

Let's take a coil of wire with the turns wound tightly together over an iron core (Fig. 42). When the current increases in one loop the expanding magnetic field will cut across some or all of the neighboring loops of wire; thus inducing a voltage in these loops. The coil of wire wound over an iron core is often called an inductor, and possesses the property of inductance which causes a voltage to be induced in the coil when the current is changing.

Polarity of Induced Voltage in a Coil

Now, let's make a statement that determines the voltage polarity of the self-induced voltage in a conductor or coil of wire, and then explain this statement more fully.

The polarity of an induced voltage will oppose a change in the current that produced it.

"Change in current" refers to current which is either increasing or decreasing in value.

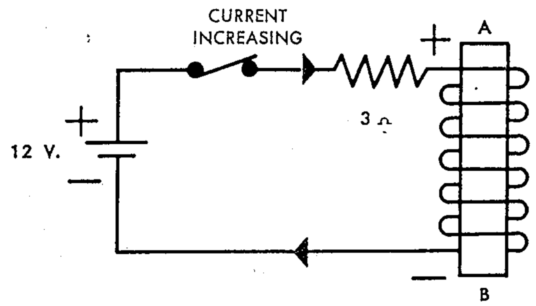


Fig. 43—Self-Induction in a Circuit When Current Increases

Fig. 43 shows a circuit containing a coil of wire (inductor).

After the switch is closed, the current increases from zero to its maximum value of, say, four amperes. During this time a voltage will be induced in the inductor in a direction opposing the increasing current; *the inductor itself becomes a source of voltage that attempts to prevent the current from increasing in the circuit.*

To oppose the increasing current, the inductor will have to generate a voltage in a direction opposite to the battery current, hence the polarity at A is positive (+) and at B is negative (−). The induced voltage opposes the change in current; that is, the induced voltage tries to maintain the "status quo" and keep the battery current at zero when the switch is closed.

The induced voltage polarities at the coil are therefore as shown.

However, the battery current in time overcomes the inductive effect of the coil, and reaches its final steady value of four amperes.

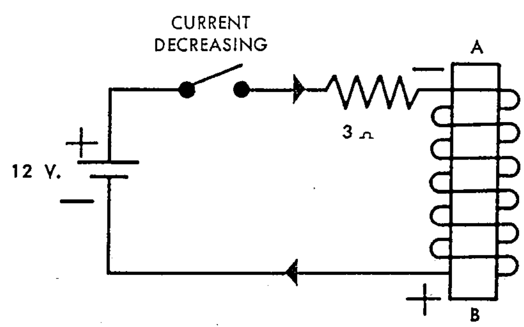


Fig. 44—Self-Induction in a Circuit When Current Decreases

When the switch is opened (Fig. 44), the current decreases from four amperes to zero. This changing current induces a voltage in the coil that again tries to maintain the "status quo" or to keep the current flow at four amperes. The polarity of the induced coil voltage, therefore, must be as shown, because the coil attempts to supply current in the same direction as originally supplied by the battery. It attempts to keep the current flow at the four-ampere value, and this may cause the switch to arc when it is opened.

Note that the induced voltage polarity for any direction of current flow is determined by whether the current is increasing or decreasing. For example:

	Induced Voltage	
	A	**B**
Current Increasing (Fig. 43)	+	−
Current Decreasing (Fig. 44)	−	+

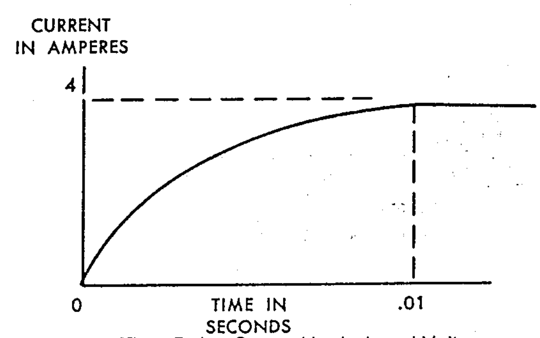


Fig. 45—Time Delay Caused by Induced Voltage

Although the inductive voltage tries to prevent any change in current value, the effects of the battery voltage and the closed or open switch in time cause the current to reach a constant value. The induced voltage, however, does cause a time delay while the current reaches its final value after the switch is closed or opened (Fig. 45).

Consider first the case when the switch is closed. Due to the inductive effect of the coil the current slowly rises to its maximum value of four amperes. When the final current of four amperes is reached, there is no changing magnetic field, no induced voltage, and the resistor alone acts to establish the final current value.

There is a certain amount of energy stored in an inductive coil when current is flowing through it. This energy is directly related to the amount of current (I) and the inductance of the coil, whose symbol is (L). The inductance of any coil is determined primarily by the number of turns of wire, their spacing, and the type of material used in the core of the coil. The amount of energy stored in a coil is given by the following equation:

$$\text{Coil's energy} = \frac{\text{Inductance} \times \text{current} \times \text{current}}{2} = \frac{L \times I \times I}{2}$$

This equation shows that the higher the inductance and the higher the current, the greater will be the energy stored in the coil.

Use of Self-Induction in Ignition Circuit Coils

A standard ignition circuit operates on the principle of energy stored in the primary winding of an ignition coil. When the distributor contacts open, the current suddenly drops to zero, and from the energy equation the energy in the coil suddenly drops to zero. Some of this energy is transferred by mutual induction (see the next section) to the secondary winding of the ignition coil, and the energy is dissipated in the form of an arc across the spark plug. In an ignition circuit, the time delay in build-up of primary winding current when the distributor contacts close is very important.

If the contacts open before the final maximum value of current is reached, the energy stored in the coil (see the energy equation) is reduced, making less energy available to fire the plug.

Although the inductance of the ignition coil may cause a time delay of only a fraction of a second, this interval of time must be closely correlated with the time the distributor contacts are closed. (See Chapter 8 for more details on ignition circuits.)

MUTUAL INDUCTION

If a changing magnetic flux created by current flow in one coil cuts across the windings of a second coil, a voltage will be induced in the second coil.

This induction of voltage in one coil because of a changing current in another coil is called **mutual induction.**

Mutual Induction in Coils

Fig. 46 illustrates the principle of mutual induction in a circuit where the blue winding (the secondary) is wound over an iron core, while the red winding (the primary) is wound over the blue winding.

When the switch is closed, current will increase in the primary, and the expanding lines of force will cut across the secondary, causing a voltage to be induced in the secondary.

Mutual Induction in Coils

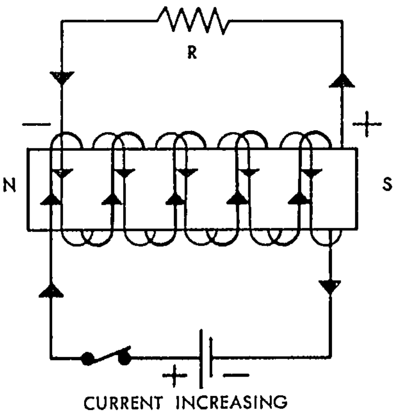


Fig. 46—Mutual Induction in Primary and Secondary Coils

Similarly, when the switch is opened, the sudden decrease in current in the primary will induce a voltage in the secondary. The blue secondary winding then becomes a source of voltage, and will supply current to resistor R.

Finding Polarity of Induced Voltage in Secondary Coil

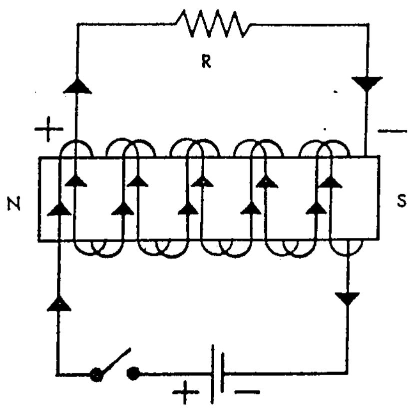
The polarity of the induced voltage in the secondary can be determined in a number of different ways.

One of the simplest methods is to observe the direction of current in the primary, and note that the current direction in the secondary must oppose any change in the primary current. Thus when the primary current is increasing, the secondary current must flow in the opposite direction around the core in order to oppose the increase, and the secondary voltage polarity is established as shown in Fig. 46.

However, if the primary current is decreasing, the secondary current must flow in the same direction around the core in order to oppose the change; that is, to attempt to keep the flux in the core from changing. The secondary polarity is then as shown in Fig. 47.

An alternate method of finding the secondary induced voltage polarity is to use the Right Hand Rule for an Induced Voltage. Taking a lengthwise cross-sectional view of the assembly, when current increases in the primary, the circular lines of force expand and strike the secondary on the top side.

By using the Right Hand Rule for an Induced Voltage, the current flow direction is determined as shown in Figs. 48 and 49.

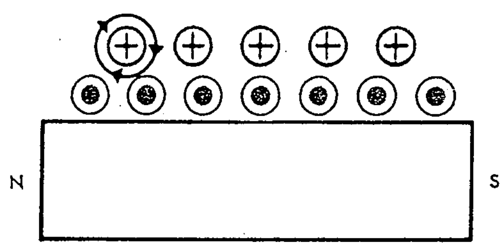


CURRENT DECREASING

Fig. 47—Polarity in Coils with Primary Current Decreasing

As stated, the two coils carry current in opposite directions around the core when the primary current is increasing (Fig. 48).

When the primary current decreases (Fig. 49), the circular lines of force strike the secondary windings on the underneath side, and the current flows in both coils in the same direction around the core. The voltage polarity is determined accordingly, with current coming out of the secondary positive terminal and returning to the negative terminal.

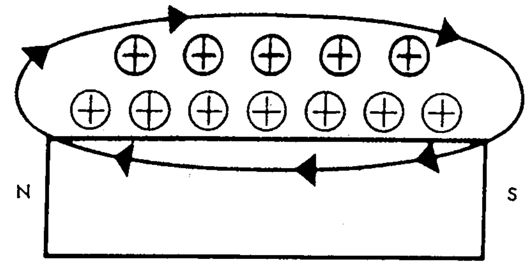


CURRENT INCREASING

Fig. 48—Finding Polarity of Secondary Voltage When Current Is Increasing

The magnitude of the voltage induced in the secondary winding is determined primarily by the number of turns in the primary and in the secondary.

The ignition coil uses the principles of mutual induction in its primary and secondary windings.



CURRENT DECREASING

Fig. 49—Finding Polarity of Secondary Voltage When Current Is Decreasing

SUMMARY: ELECTROMAGNETIC INDUCTION

In summary:

- **Electromagnetic induction is inducing voltage in a conductor that moves across a magnetic field.**
- **Conductor must cut *across* the field, not move parallel to it.**
- **Conductor and field must be moving in relation to each other.**
- **Faster relative motion = more voltage induced.**
- **More conductors in motion = more voltage.**
- **Stronger magnetic field = more voltage.**
- **Three ways of inducing voltage are generated voltage, self-induction, and mutual induction.**
- **Generated voltage by relative motion is used in generators and alternators.**
- **Self-induction creates its own voltage by a change of current in the conductor (as in the primary of ignition coils).**
- **Mutual induction occurs when changing current in one coil induces voltage in a second coil (as in the two windings of ignition coils).**

MEASUREMENT OF ELECTRONS / CHAPTER 2

INTRODUCTION

Electronics would be nothing without measurement, numbers, and electronic circuits. In this chapter we will cover the following:

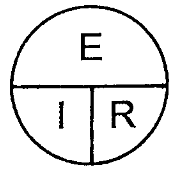
- **Ohm's Law**
- **Basic Electronic Circuits**
- **Electronic Circuits — Three Types**
- **Power (Watts)**
- **Pulses, Waves, Frequency, and Signals**
- **Multimeters**
- **Basic Testing of Circuits**
- **Other Types of Electronic Test Equipment**
- **Wire Diagrams and Schematics**

OHM'S LAW

In 1827 a mathematic reasoning to electronics was established by a German, Georg Simon Ohms. At that time, electromotive force (Volts) and electron flow (Amperes) through a conductor had been established, but nothing had been established for the resistance within a conductor. Ohm assumed that if the electromotive force and amperes were established from a certain length and material of a conductor, doubling the length of the same conductor would allow a passage of electrons at half the rate of the shorter conductor. This is known as Ohm's Law, whereby, the ratio of the electromotive force (E) and amperes (I) can be taken as a measure of resistance (R) within a conductor. Thus, R=E/I, where E is the electromotive force (volts), I is the electron flow or current in amperes, and R is the resistance in ohms.

The formula for Ohm's Law can be expressed in three different ways (Fig. 1). When any two quantities are known, the third can be calculated as shown.

$$\text{VOLTS (E)} = \text{AMPERES (I)} \times \text{OHMS (R)}$$



$$\text{AMPERES (I)} = \frac{\text{VOLTS (E)}}{\text{OHMS (R)}}$$

$$\text{OHMS (R)} = \frac{\text{VOLTS (E)}}{\text{AMPERES (I)}}$$

Fig. 1 — Ohm's Law—The Three Formulas

BASIC ELECTRONIC CIRCUITS

An electronic circuit is a schematic of electronic components that permits the flow of electrons. It is also the same as and can be called an electrical circuit. This manual will refer to the circuits as *electronic circuits*.

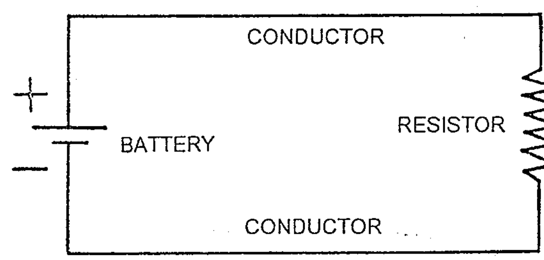


Fig. 2—A Basic Electronic Circuit

A basic electronic circuit consists of three parts:

- **A Voltage Source such as a battery**
- **A Resistor such as a light bulb.**
- **Conductors such as copper wires to connect the circuit together.**

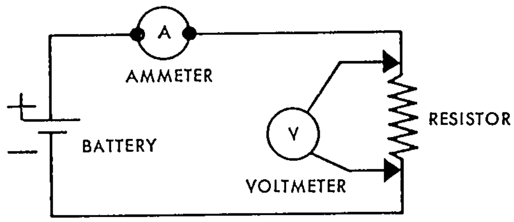


Fig. 3—Basic Gauges for Testing a Circuit

The basic gauges for testing an electronic circuit are: An *Ammeter* to measure current (flow), and a *Voltmeter* to measure voltage (pressure) between any two points in a circuit. (These will be covered in more detail later in this chapter.)

ELECTRONIC CIRCUITS—THREE TYPES

The three types of electronic circuits are:

- **Series Circuits**
- **Parallel Circuits**
- **Series—Parallel Circuits**

These circuits are compared in Fig. 4.

Series Circuits have several resistors connected so that current can flow along only one path.

Parallel Circuits have more than one path for current to flow. The resistors are side-by-side and provide separate routes for current.

Series-Parallel Circuits have some resistors connected in series and some in parallel.

SERIES CIRCUITS

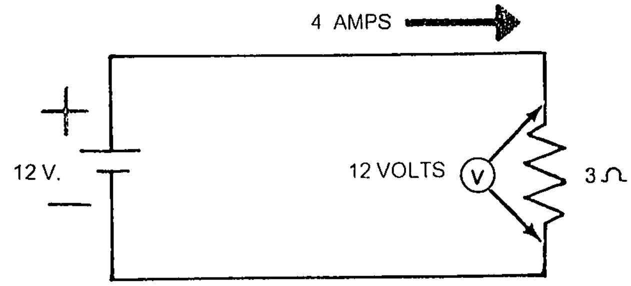


Fig. 5—A Basic Series Circuit

A **basic series** circuit may have a three-ohm (3Ω) resistor connected to a 12-volt battery. See Fig. 5.

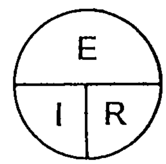


Fig. 6—Ohm's Law Formula Circle

To find the current, use Ohm's Law Formula Circle (Fig. 6), where I=E/R or 12/3=4 Amperes or 4 Amps. The voltage across the three ohm resistor would be E=I x R=4 x 3=12 volts.

Another series circuit is shown in Fig. 7. This circuit has a two-ohm resistor and a four-ohm resistor connected to a 12-volt battery.

In a series circuit, the total circuit resistance is equal to the sum of all the resistors. In this circuit, the total circuit resistance is 4+2=6 ohms. The current from Ohm's Law is: $I=\frac{E}{R}=\frac{12}{6}=2$ amperes.

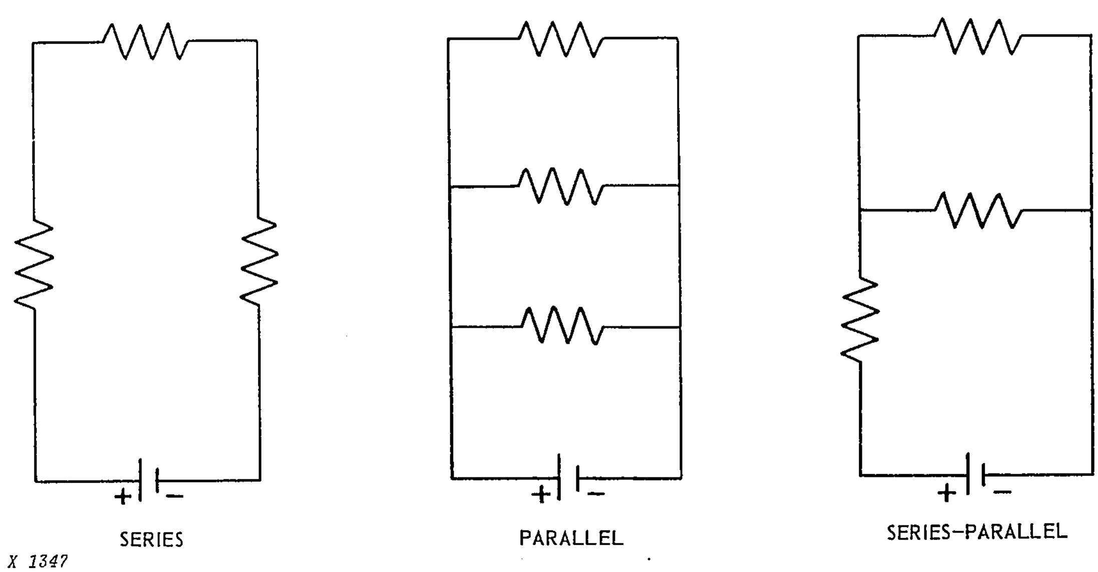


Fig. 4—Three Types of Electronic Circuits

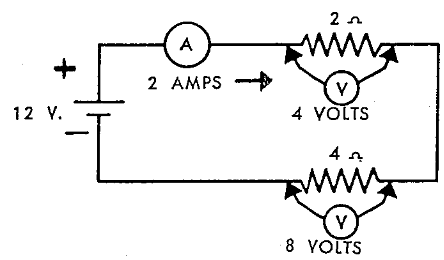


Fig. 7—Series Circuit with Two Resistors

Voltage across the two-ohm resistor can be figured using Ohm's Law: thus E = IR = 2 x 2 = 4 volts. For the four-ohm resistor, E = 2 x 4 = 8 volts. These values are called the **voltage drops,** and the sum of all voltage drops in the circuit must equal the source voltage, or 4 + 8 = 12 volts.

You will note that in order to calculate the voltage drops across the resistors you had to first calculate the current (amperes) of the circuit. Voltage drops are also known as *Voltage Division.*

The **voltage division** rule allows us to calculate the voltage across one or a combination of series resistors without first having to solve for the current. The basic formula for the voltage division rule is:

$$\frac{R_1 \times E}{R_1 + R_2} = V_1$$

Where R_1 is the resistor where the voltage division is to be found, E is the battery source. R_2 is the other resistor in the series circuit. If there are more resistors in the series they would have to be added into the formula too. V_1 would be the voltage division result. Using this rule let's find the voltage division of the four-ohm resistor in Fig. 7.

$$\frac{4 \times 12}{4 + 2} = \frac{48}{6} = 8 \text{ Volts (divided)}$$

Voltage Division is used extensively in the field of electronics to supply lower voltages to other circuits. Let's calculate the divided voltage outputs of each of the connections in a series circuit with three resistors (Fig. 8).

Using the **voltage division rule,** the first voltage output between the two-ohm and three-ohm resistors would be:

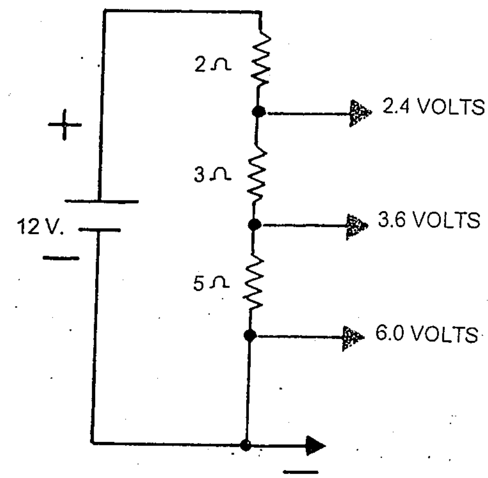


Fig. 8—Voltage Division in a Series Circuit

$$\frac{2 \times 12}{2 + 3 + 5} = \frac{24}{10} = 2.4 \text{ Volts}$$

The second voltage output would be:

$$\frac{3 \times 12}{2 + 3 + 5} = \frac{36}{10} = 3.6 \text{ Volts}$$

The third voltage division output would be:

$$\frac{5 \times 12}{2 + 3 + 5} = \frac{60}{10} = 6.0 \text{ Volts}$$

What would be the current (amperes) for each of the voltage outputs?

In a *series circuit,* the total resistance is equal to the sum of the resistors. Thus, using Ohm's Law:

$$I = \frac{E}{R} = \frac{12}{2 + 3 + 5} = \frac{12}{10} = 1.2 \text{ Amperes}$$

for each of the divided voltage outputs.

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In summary, **series circuits** have the following features:

1. The current through each resistor is the same.

2. The voltage drops across each resistor will be different if the resistances are different.

3. The sum of the voltage drops equals the source voltage.

PARALLEL CIRCUITS

In a **parallel circuit,** the voltage drop across each resistor is equal to the potential of the current source since there is a separate path for current to flow through each resistor. This means:

1. The voltage across each resistor is the same.

2. The current through each resistor will be different if the resistance values are different.

3. The sum of the separate currents equals the total current in the circuit.

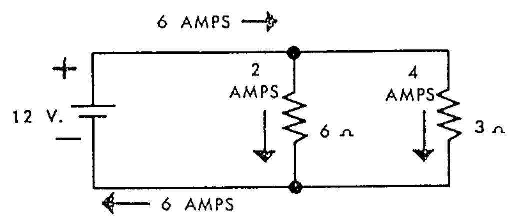

Fig. 9—Parallel Circuit with Two Resistors

The parallel circuit in Fig. 9 has a six-ohm and a three-ohm resistor connected to a 12-volt battery. The resistors are in parallel with each other, since the battery voltage (12 volts) flows across each resistor.

The current through each resistor or branch of the circuit can be figured using Ohm's Law. For the six-ohm resistor, $I = \frac{E}{R} = \frac{12}{6} = 2$ amps. For the three-ohm resistor, $I = \frac{12}{3} = 4$ amps. The total current supplied by the battery is 2 + 4 = 6 amps. The equivalent resistance of the entire circuit has to be two ohms, since $R = \frac{E}{R} = \frac{12}{6} = 2$ ohms. You will note that before the equivalent resistance of the entire circuit could be found the amperage had to be calculated across each resistor. The Current-Divider Rule for parallel circuits allows us to calculate the equivalent resistance of the circuit without having first to solve for the amperes. The formula for **two** resistors is:

$$R = \frac{R_1 \times R_2}{R_1 + R_2}$$

Where R_1 and R_2 are the resistors in the circuit and R is the equivalent resistance of the circuit. Let's calculate the equivalent resistance of the parallel circuit in Fig. 10 using the current-divider rule.

$$R = \frac{6 \times 3}{6+3} = \frac{18}{9} = 2 \text{ ohms}$$

But the current-divider rule formula changes when there are **three** or **more** resistors within a parallel circuit. The formula changes to:

$$R = \frac{1}{1/R_1 + 1/R_2 + 1/R_3 \ldots\ldots}$$

The complication of calculating this formula makes the calculating of the amperes for each resistor easier.

SERIES-PARALLEL CIRCUITS

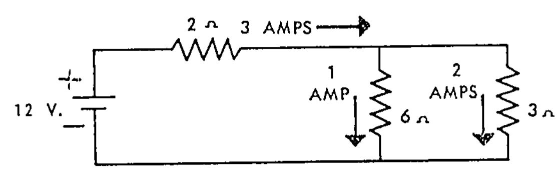

Fig. 10—Series-Parallel Circuit

A *series-parallel circuit* is shown in Fig. 10. Note that the 2Ω resistor is in series with a parallel combination (the three- and six-ohm ones).

Since there are two resistors in parallel, we can use the current-divider rule to calculate the resistance of the two resistors.

$$R = \frac{6 \times 3}{6+3} = \frac{18}{9} = 2 \text{ ohms}$$

Add this two ohms to the other two-ohm resistor because it is in series, for a total circuit resistance of four ohms. The total current of the circuit, using Ohm's Law is:

$$R = \frac{E}{I} = \frac{12}{4} = 3 \text{ amps}$$

With three amps flowing through the two-ohm resistor nearest the battery, the voltage drop across this resistor is E = IR = 3 x 2 = 6 volts, leaving six volts across the parallel six- and three-ohm resistors.

The current through the six-ohm resistor is $I = \frac{E}{R} = \frac{6}{6} =$ 1 amp, and through the three-ohm resistor is $I = \frac{6}{3} = 2$ amps.

Total current is the sum of these two current values or 1 + 2 = 3 amps.

CURRENT FLOW IN SERIES AND PARALLEL CIRCUITS

We have learned from Ohm's Law that there is a definite relationship between current, voltage, and resistance in an electrical circuit.

Now let's see how this applies to series and parallel circuits with a given resistance.

Each type of circuit shown in Fig. 11 has three four-ohm resistors. What is the total current flow in each case?

In the *series* circuit there is only one path for the current to flow, so the total resistance is 12 ohms. Therefore, current $= \frac{\text{volts}}{\text{ohms}} = \frac{12}{12} = 1$ amp for the circuit.

In the *parallel* circuit there are three different paths for current, each with 12 volts of force. Since current for each resistor $= \frac{\text{volts}}{\text{ohms}} = \frac{12}{4} = 3$ amps, the total current is 3 (amps) $\times$ 3 (resistors) $= 9$ amps for the circuit.

In the *series-parallel* circuit the total resistance is 4 ohms plus the resistance of the parallel resistors $\frac{(4 \times 4 = 16)}{(4 + 4 = 8)} = 2\ \Omega$ or a total of $4 + 2 = 6$ ohms.

Therefore, current $= \frac{\text{volts}}{\text{ohms}} = \frac{12}{6} = 2$ amps for the circuit.

What does this mean for the design of electrical circuits?

- **Series circuit = high resistance**
- **Parallel circuit = low resistance**
- **Series-parallel circuit = medium resistance**

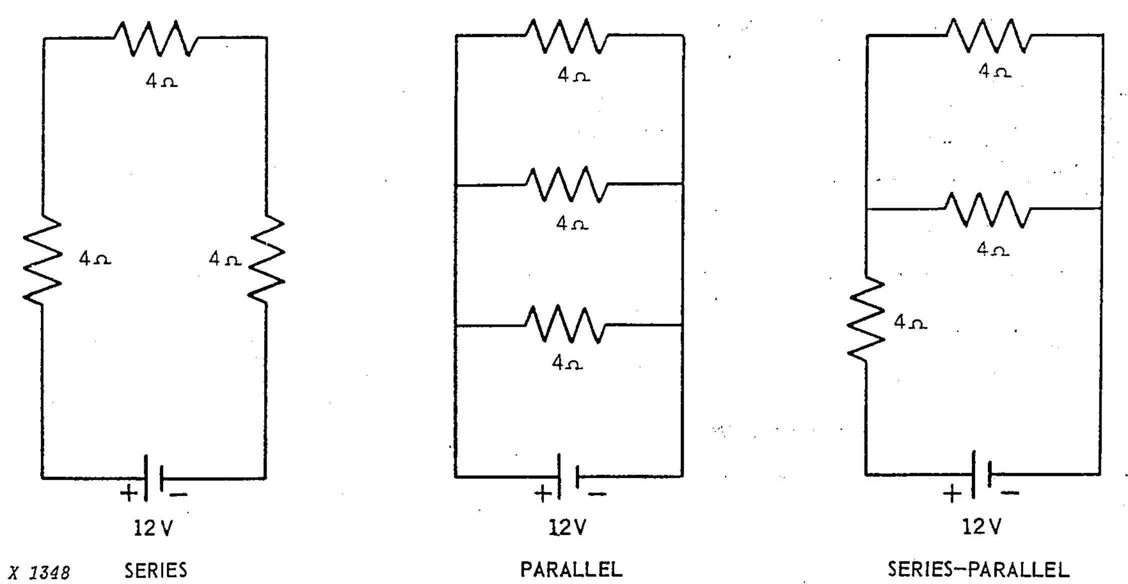

Fig. 11—Current Flow in Series and Parallel Circuits

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POWER (WATTS)

In any system, *power* is a measure of the rate of energy conversion of that system. In an engine, the output horsepower rating is a measure of its ability to do mechanical work. In electronics, power is the measure of the rate at which electrical energy is converted into heat by the resistive elements within a conductor. This power is represented by the letter P and its measurement is in *Watts.* The formula for **power (watts)** is P = I times E, where I is amperes and E is the electromotive force (volts). To incorporate the resistive elements (ohms) into the formula, we can substitute the factor of I from Ohm's Law. The power formula can now be expressed as P = E/R times E or $P = E^2/R$. Many electronic components are labeled with watts or their capacity to withstand heat, which we will talk about in the next chapter.

PULSES, WAVES, FREQUENCY AND SIGNALS

PULSES

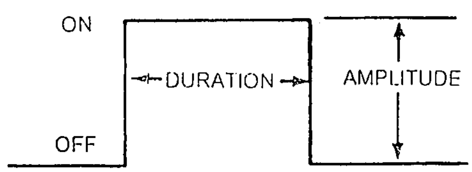
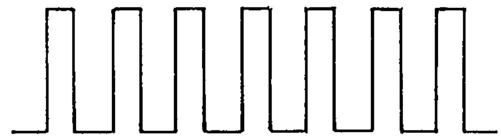


Fig. 12—A Pulse

A *pulse* is a sudden **On** and **Off** of direct current flow within a circuit (Fig. 12). In its basic form, an on-off switch will cause a pulse of electron flow within a circuit when the switch is turned on and off.

The width of a pulse is the length of time the switch was on. The height of the pulse is known as the amplitude and is determined by the amount of the voltage. An early electronic device that generated pulses was the telegraph key. Voltage (amplitude) generated a sound by manually turning a contact switch on and off (duration) to create a code of dots and dashes that were used to convey information.



CONTROLLED PULSE OUTPUT

Fig. 13—A Typical Controlled Pulse Output

Today pulses (Fig. 13) are processed, generated and controlled by *Logic* or *Digital* electronic circuit devices, discussed in the next chapter.

WAVES

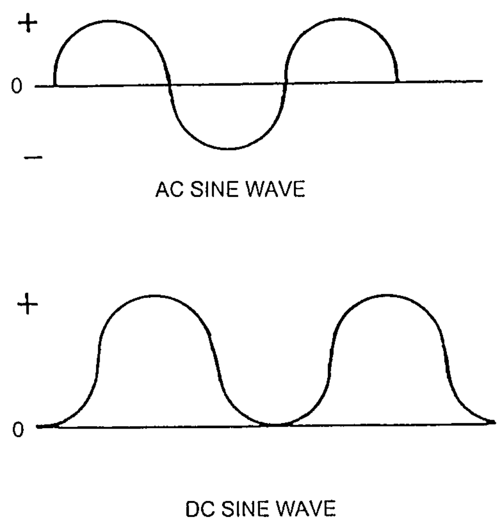


Fig. 14—Some Typical Waveforms

Unlike pulses created by the on-off flow of electrons, waves are created by varying a continuous flow of electrons within a circuit. This variation of current is accomplished by different types of devices within a circuit. In its basic form a manual variable resistor, known as a potentiometer (See Chapter 3), can vary the current flow and create waves within a circuit. Such a circuit is called an *Analog* or *Linear* circuit and the process that generates the waveform is known as **Modulation.** Obviously, manually varying the electron flow to control a constant waveform would be too slow to be of any use, so electronic devices are used to control and vary the electron flow. Waveforms can be created by either direct or alternating current to form signals (Fig. 14).

FREQUENCY

Controlled pulses and waves require a certain amount of time for one cycle to be completed. *Frequency* is the number of cycles occurring in one unit of time, generally one second. These cycles per second (cps) are measured in Hertz (Hz). The alternating current supplied to our homes is 60 Hz—a frequency of 60 cycles per second.

SIGNALS

The periodic waveforms (frequencies) caused by controlled variations of current can convey information in *Signals*. These signal waveforms can be modulated from devices designed to monitor various functions of a modern engine such as voltage, temperature, oil pressure, etc. These signal waveforms "trigger" digital circuits that display visual information to the operator. The information contained in the signal waveforms also can be stored in a computer chip and recalled later for diagnostic purposes when an engine system malfunctions. The use of signals is covered in more detail in the next chapter.

MULTIMETER

Just as circuit components in the field of electronics have become miniaturized, so too current flows have become smaller, so that the volts, ohms, and amperes within a circuit often total less than one. When this is the case, their names and values carry a "milli" prefix: millivolts, milliohms, and milliamps. To test for these small amounts in an electronic system, the very least you will need is a *Multimeter.* There are two types of multimeters that can be used to test electronic circuits.

ANALOG MULTIMETER

The Analog Multimeter (Fig. 15) gives less-precise value readings. It's also very hard to accurately gauge "milli" readings on the dial. It is best used for observing the trend of a slowly changing voltage, current, or resistance.

DIGITAL MULTIMETER

The Digital Multimeter (Fig. 16) is commonly referred to as **DMM.** It is highly accurate and easier to read than analog-type multimeters for certain signals. It is used to find the precise value of any type of voltage, current, or resistance.

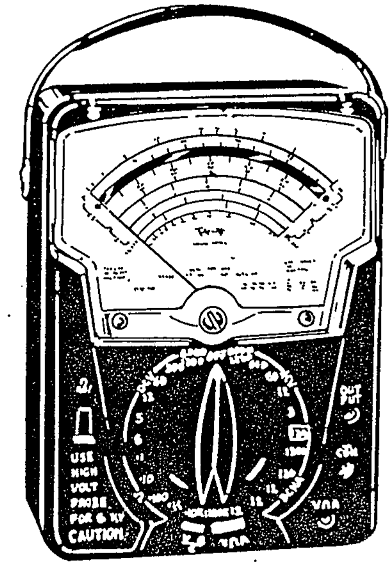


Fig. 15—A Typical Analog Multimeter

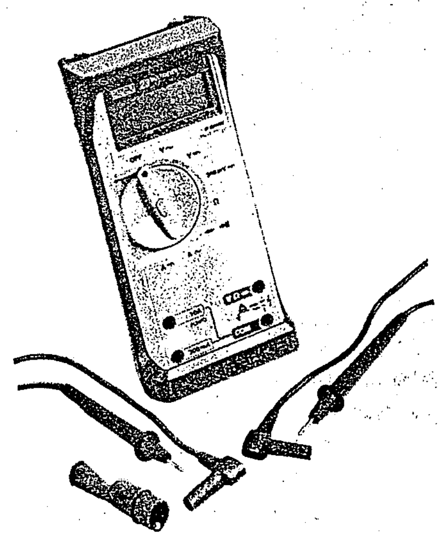


Fig. 16—A Digital Multimeter

Test Light vs. Multimeters

Both test lights and multimeters may be used to check the voltage in a circuit. Both operate by drawing current from the circuit that is being tested. A typical multimeter (digital or analog) draws 0.05 milliamps to operate and a test light draws 250 to 300 milliamps. This makes the current draw of the test light 5,000 times higher than the multimeter. The test light can be used for measuring battery voltage within a circuit, but for circuits with voltage lower than battery voltage a multimeter should be used for testing.

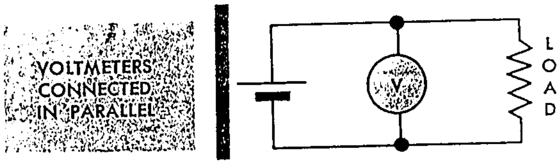


Fig. 17—Connect Voltmeter in Parallel

Whenever using these DMMs or any other test instrument, always follow the applicable instruction manual. However, we will make two points here. When using the DMM to measure voltage, connect the DMM in parallel (Fig. 17) by connecting the red lead to the high side of the circuit and the black lead to the grounded side. When using the DMM to measure current flow (amperes), connect it in series with the circuit (Fig. 18).

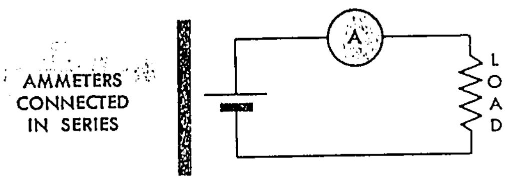


Fig. 18—Always Connect Ammeter in Series

SAFETY PRECAUTIONS

When using a DMM, double check the switch setting and lead connection before making measurements. Make sure you follow all the instructions in the manual. Disconnect the DMM or turn off the power before changing switch positions. Do not connect to circuits with voltage present when the switch or push buttons are in any ohms or current positions.

BASIC FAILURES OF CIRCUITS

Meters can be used in a circuit (Fig. 19) to locate four basic failures:

- **High Resistance**
- **Open**
- **Ground**
- **Short**

A HIGH RESISTANCE within a circuit can result in slow, dim, or complete failure of the component to operate. High resistance is caused by loose, corroded, dirty or oily terminals, or by broken strands within a circuit wire that reduce the capacity of the wire to carry current. Generally, circuits are protected from high resistance by circuit breakers and/or fuses, but high resistance may cause improper operation of a component and still not trip a circuit breaker or cause a fuse to fail.

An OPEN is a break in a circuit wire that results in a complete failure of the component to operate. An open in a circuit is caused by a failed protective device such as a fuse or circuit breaker, a disconnected terminal, a broken wire, or another failed component.

A GROUND in a circuit also results in component failure. A ground in a circuit is caused by non-insulated wire connections or frayed insulation on wire that accidentally or unintentionally comes in contact with the grounded frame of the unit.

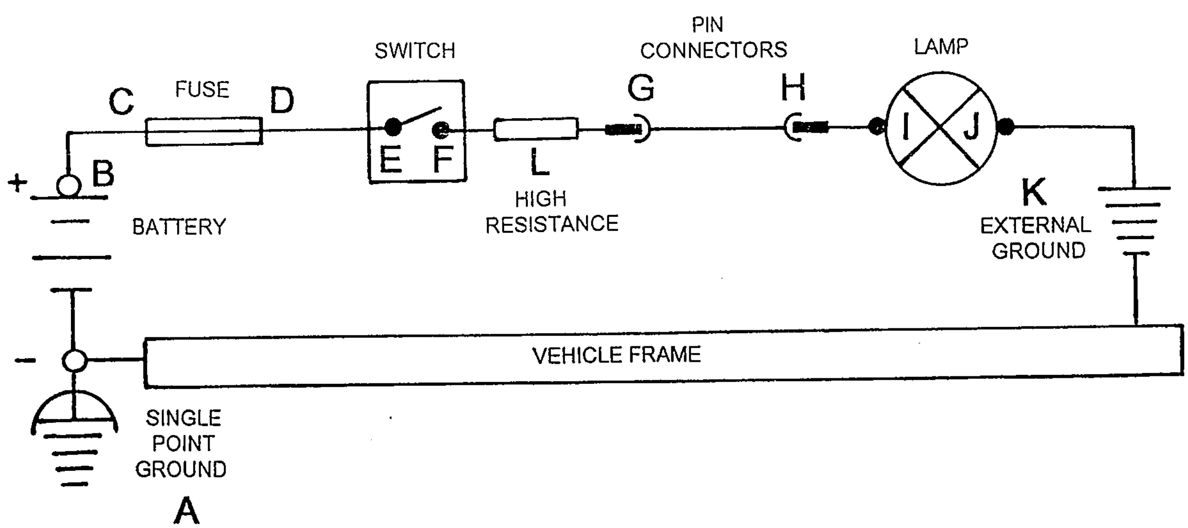


Fig. 19—A Typical Circuit for Testing

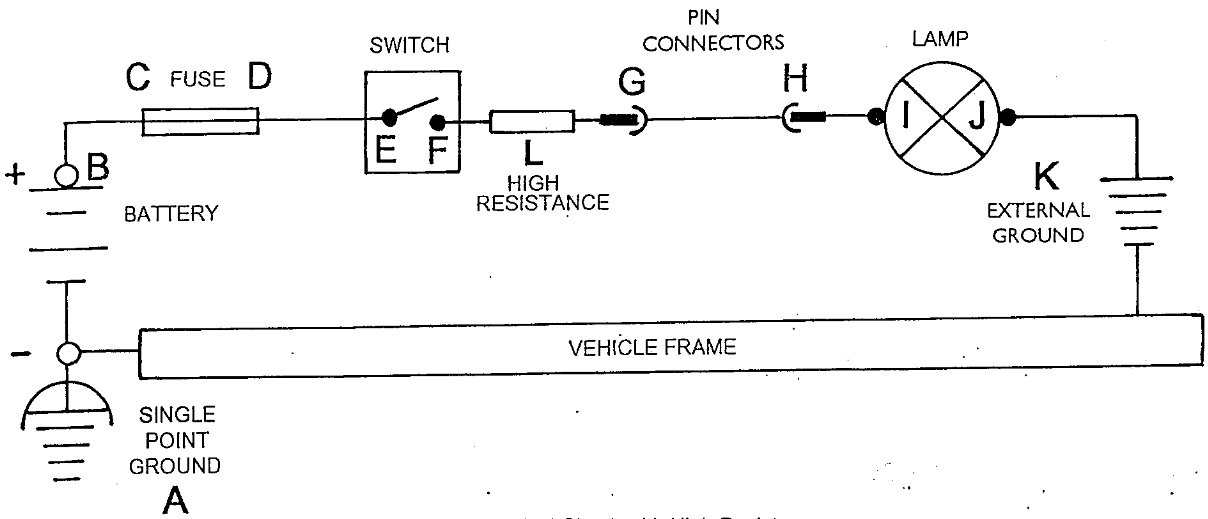


Fig. 20—A Typical Circuit with High Resistance

A SHORT usually results in two components operating when only one of two switches is turned on. A short happens when two wires from two different circuits inadvertently touch each other and make contact electrically.

BASIC TESTING OF CIRCUIT FAILURES

A High Resistance Circuit Failure

High resistance failure in a circuit can result in an improper or component non-operation. In testing a circuit with high resistance (Fig. 20) we will do the following:

Remove the fuse from the circuit and visually inspect it for being warped or open. If the fuse is warped or cannot be visually inspected, check the fuse for continuity with a meter. Set the meter for the ohm or resistance position. Place each lead of the meter to each end of the fuse. The reading of the meter should read zero if the fuse is good. If any resistance is read on the meter the fuse should be replaced. If the meter reads infinite the fuse is open and should be replaced. If the fuse is found to be open, some high resistance within the circuit has caused the fuse to fail to protect the circuit. Replace the fuse if it is found to be open but do not operate the circuit until after the next step, otherwise you may have to replace the fuse again.

Visually inspect connections A, B, C, D, G, H, and K for being loose, corroded, or dirty. Clean and tighten terminals as necessary. If the components of the circuit are exposed to the environment, visually inspect connection E, F, I, and J for corrosion. Clean and/or replace components if necessary. Generally, in a circuit with high resistance, cleaning all connections within a circuit will solve the problem and complete the testing, but if the corrosion has worked its way under the wiring insulation, as in our example at point L, further testing must be done.

Disconnect connection I from the circuit. We start at point I because it is the beginning of the component that causes the load in the circuit. The connection is disconnected from the circuit to prevent the fuse from failing while testing for voltage. Set the meter to read DC voltage and connect the red lead to the wire at I and the black lead to the vehicle frame. Turn the controlling switch on and read the meter.

If voltage is less than battery voltage move toward the battery source within the circuit by disconnecting connections and checking for battery voltage, separately, with the meter at points H, G, F, E, D, and C. In our example, battery voltage would be found at point F, indicating the wire between points F and G should be replaced.

If the battery voltage was found at point I, you would have to reconnect the wire and move toward the ground source. Check voltages, separately, at the disconnected points of J and K until low voltage is found. In our example circuit, either the ground wire or lamp would have to be replaced.

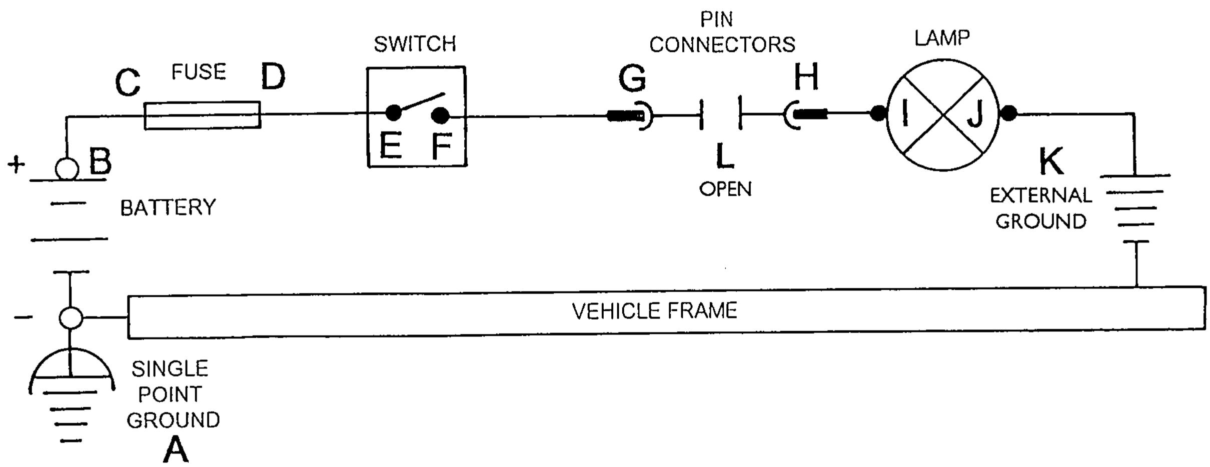


Fig. 21—A Typical Circuit With An Open

An Open Circuit Failure

An open circuit will result in component non-operation. In testing for an open in the circuit (Fig. 21) we will do the following:

Remove the fuse from the circuit and visually inspect it for being open. If the fuse cannot be visually inspected, check the fuse for continuity with a meter. Set the meter for the ohm or resistance position. Place each lead of the meter to each end of the fuse. The reading of the meter should read zero if the fuse is good. If the meter reads infinite the fuse is open and should be replaced. If the fuse is found to be open some high resistance within the circuit has caused the fuse to fail to protect the circuit. Replace the fuse if it is found to be open but do not operate the circuit until further testing.

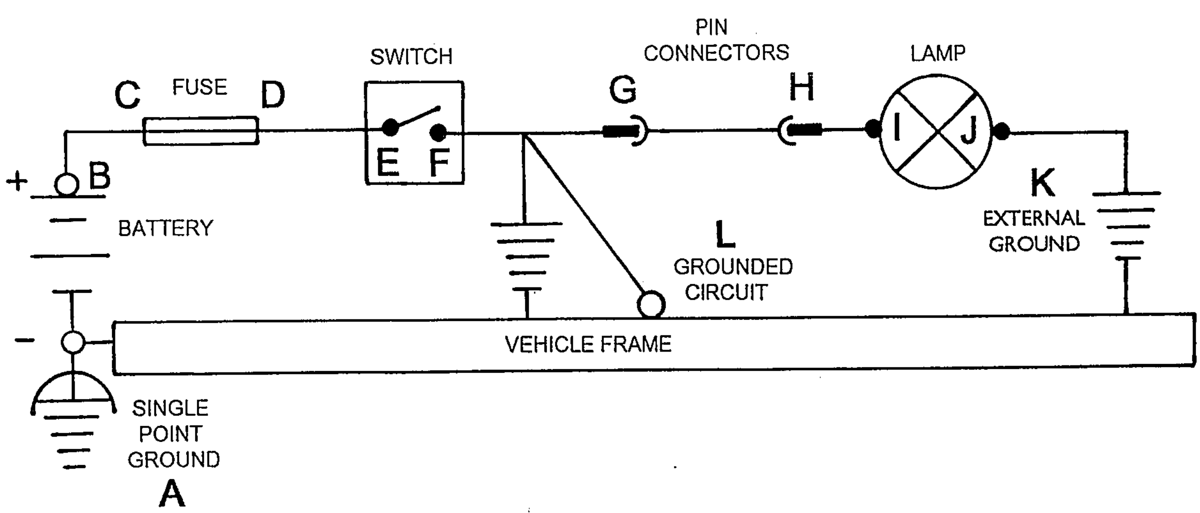
Visually inspect connections A, B, C, D, G, H, and K for being loose, corroded, or dirty. Clean and tighten terminals as necessary.

Set the meter to read DC voltage and connect the red lead to any wire connection that is easily accessible between the points F and I and connect the meter's black lead to the vehicle frame. Turn the controlling switch on and read the meter.

In our circuit example, the meter will read zero voltage at points H and I and battery voltage at points F and G. This would indicate an open in the wire between points G and H and the wire should be replaced. When replacing a wire in a circuit make sure the proper wire gauge is used.

If battery voltage was read at all points between F and I then move to the next point toward ground until zero volts is found. Replace any component or wire prior to the point where the zero volts was found.

Fig. 22—A Typical Grounded Circuit



If zero voltage were read at all points between F and I then move to the next points toward the battery source until battery voltage is found. Replace any component or wire after the point where battery voltage was found.

A Grounded Circuit Failure

A grounded circuit results in component non-operation. If the battery or power wire is grounded, as it is in our example (Fig. 22), the fuse will be opened or failed.

Remove the fuse from the circuit and visually inspect it for being open. If the fuse cannot be visually inspected, check the fuse for continuity with a meter. Set the meter for the ohm or resistance position. Place each lead of the meter to each end of the fuse. The reading of the meter should read zero if the fuse is good. If the meter reads infinite the fuse is open and would indicate that the power wire is grounded. Do not install a replacement fuse until the grounded wire is found.

With the fuse removed, disconnect point K or external ground connection. Make sure point K connection does not come into contact with the frame during testing. Turn controlling switch of circuit on (closed). Set meter to read resistance or ohms. Check continuity of the circuit by touching the red lead to any point between D and I that is easily accessible. Touch the black lead to the frame of the unit or ground. In our example the reading on the meter will be zero, indicating the circuit is grounded. If the meter reading showed infinite the circuit would not be grounded.

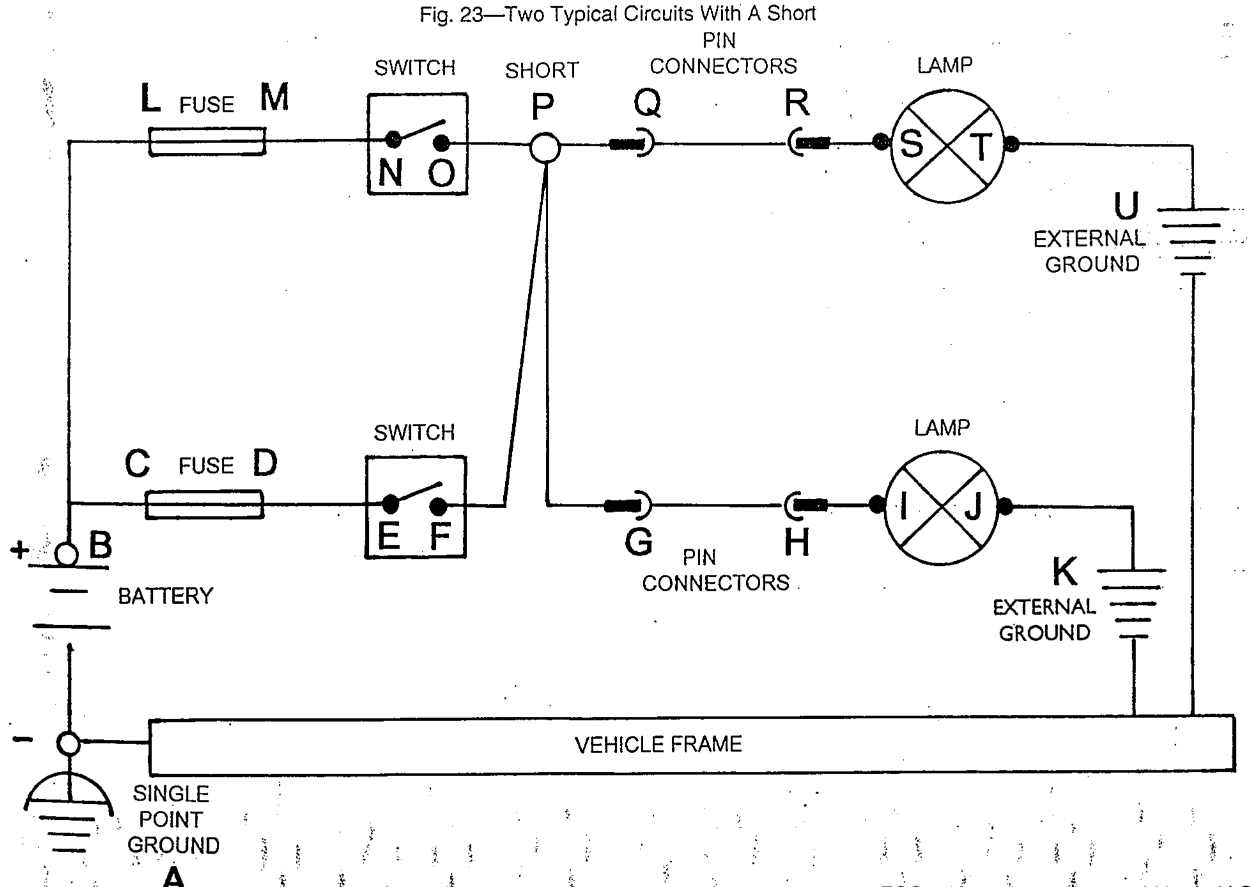
Turn switch off or open and check continuity between point D or E and frame of unit. In our example the reading will be infinite, indicating circuit wire between D and E was not grounded. Disconnect connections at Point G. Check continuity of both connections of point G to frame or ground of unit. The blade or switch side of the wire will read zero, indicating a grounded wire between F and G. The reading at the other connection at G or to the lamp side will read infinite. The wire F-G will have to be replaced. If there were no connections in the circuit, the entire harness between points F and I would have to be replaced. After harness or wire is replaced, recheck circuit for continuity to ground.

A Shorted Circuit Failure

A shorted circuit will result in the operation of two or more circuits when either of the circuits are put into operation. To isolate the shorted circuit (Fig. 23) we will do the following:

Remove the fuses or circuit protection devices from both circuits. Depending upon the load of the circuits it may be possible that a fuse from either or both circuits may have failed during operation. Remove the

Fig. 23—Two Typical Circuits With A Short



fuses from the circuits and visually inspect them for being open or warped. Replace any warped or failed fuse but do not install fuses until shorted circuit is found.

With fuses removed, disconnect point K and leave point U connected. Set meter to read resistance or ohms and close switch E-F. Touch the red lead of the meter to any points between D and I. Touch the meter's black lead to the frame or ground. In our example, the meter will read close to or at zero, indicating the circuit is shorted to the other circuit. Open switch E-F and check continuity at point D or E to frame or ground. The reading will be infinite indicating that wire (D-E) is not shorted to the other circuit. Disconnect any connections, separately, between points F and I and check continuity between each connection to ground. In our example, the switch side of connection G will read close to or at zero, indicating the wire F-G is shorted to the other circuit. The component side of connection G will read infinite on the meter.

Reconnect external ground K to frame and disconnect external ground U from the frame. Check continuity of points M through S to frame to locate shorted wire the same way we did in the lower circuit. In our example, the switch side of connection Q will have the zero or close to zero reading, indicating the shorted location. Be sure to use proper gauge of wire when replacing wires.

Note: It can be possible that both circuits can have the same external ground. If this exists, remove either points T or J and treat them as external grounds.

The service technician who has a good knowledge of electrical fundamentals and knows how to use test meters will soon find that this job becomes much easier.

WIRE DIAGRAMS AND SCHEMATICS

In order to understand electrical diagrams and schematics, various electrical standards organizations have tried to make diagrams and schematics more uniform. These groups include The International Electrotechnical Commission (IEC), International Standards Organization (ISO), Institute of Electrical and Electronic Engineers (IEEE), and American National Standards Institute (ANSI).

There are five electrical schematics and diagrams available to provide information to service and understand the operations of the electrical system of a machine. They are:

- **System Functional Schematic**
- **Subsystem Functional Schematic**
- **System Wiring Diagram**
- **Component Location Drawing**
- **Subsystem Diagnostic Schematic**

SYSTEM FUNCTIONAL SCHEMATIC

The System Functional Schematic is an electrical diagram of the complete machine and is made up of several foldouts of circuits divided into subsections. Each subsection is an electrical subsystem that contains one or more electrical circuits and is indicated by a letter/number and circuit description. When these subsections are laid out side by side they show a logical sequence of the relationship between all the various electrical devices and shows how they are connected to one another. The purpose of the System Functional Schematic is to show the operation, function, and interaction of each electrical subsystem of a machine. Each wire is identified by a number and/or color and all electrical devices are identified by a letter/number designation and description, and are represented by an international schematic symbol. When applicable, a device will also be represented by an SAE (Society of Automotive Engineers) pictorial symbol. The System Functional Schematic contains no harness or connector information.

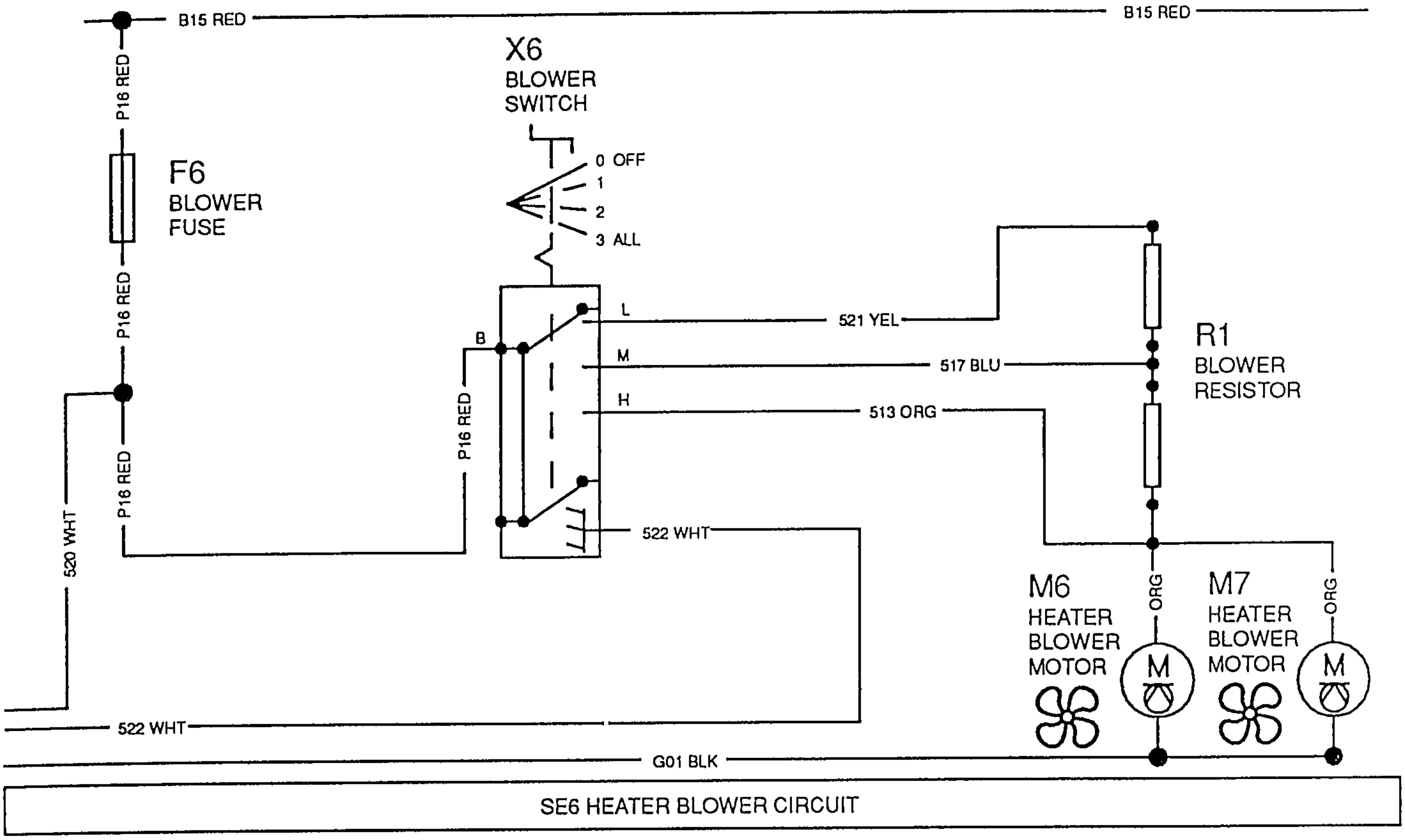


Fig. 31—A Subsystem Functional Schematic

SUBSYSTEM FUNCTIONAL SCHEMATIC

The Subsystem Functional Schematic (Fig. 31) is a sectional division of the System Functional Schematic and shows the same letter/number designations of wires, as well as component symbols. The section division circuit is identified in a rectangle at the bottom of the schematic. In our example, a heater blower circuit is shown and it is the sixth section (SE6) of the System Functional Schematic. All power supply wires are shown across the top of the drawing; the ground wires are shown across the bottom, with the components shown in between. The pictorials of the fans in our example are SAE symbols that indicate the function (blower fans) of the components (electrical motors).

SYSTEM WIRING DIAGRAM

A System Wiring Diagram (Fig. 32) is an illustration of the actual wire harness flattened out (dark lines) with extension of wires and connections to components. The wiring harness is laid out to allow identification of each connector, pin (male or female), wire numbers and/or color, and terminal location. Final terminal locations show the component symbol, letter/number identifier, and name of the component. A wire size given in mm² if it deviates from 1 mm² or 16-gauge wire. Specific wiring harnesses are identified in bold lettering (W15) at main connectors to allow one to follow a circuit through a diagram to additional diagrams. In our example (Fig. 32), note that the actual harness has wires and connections to the air conditioning pressure switch which were not shown in the Subsystem Functional schematic. The SAE symbol for air conditioning is a snowflake.

COMPONENT LOCATION DRAWING

A Component Location Drawing (Fig. 33) is a pictorial view of a harness showing location of all electrical components, connectors, harness main ground locations, and harness band and clamp locations. Each component is identified by the same identification letter/number and description used in the Subsystem Functional Schematic. When applicable, components also are shown with an SAE symbol.

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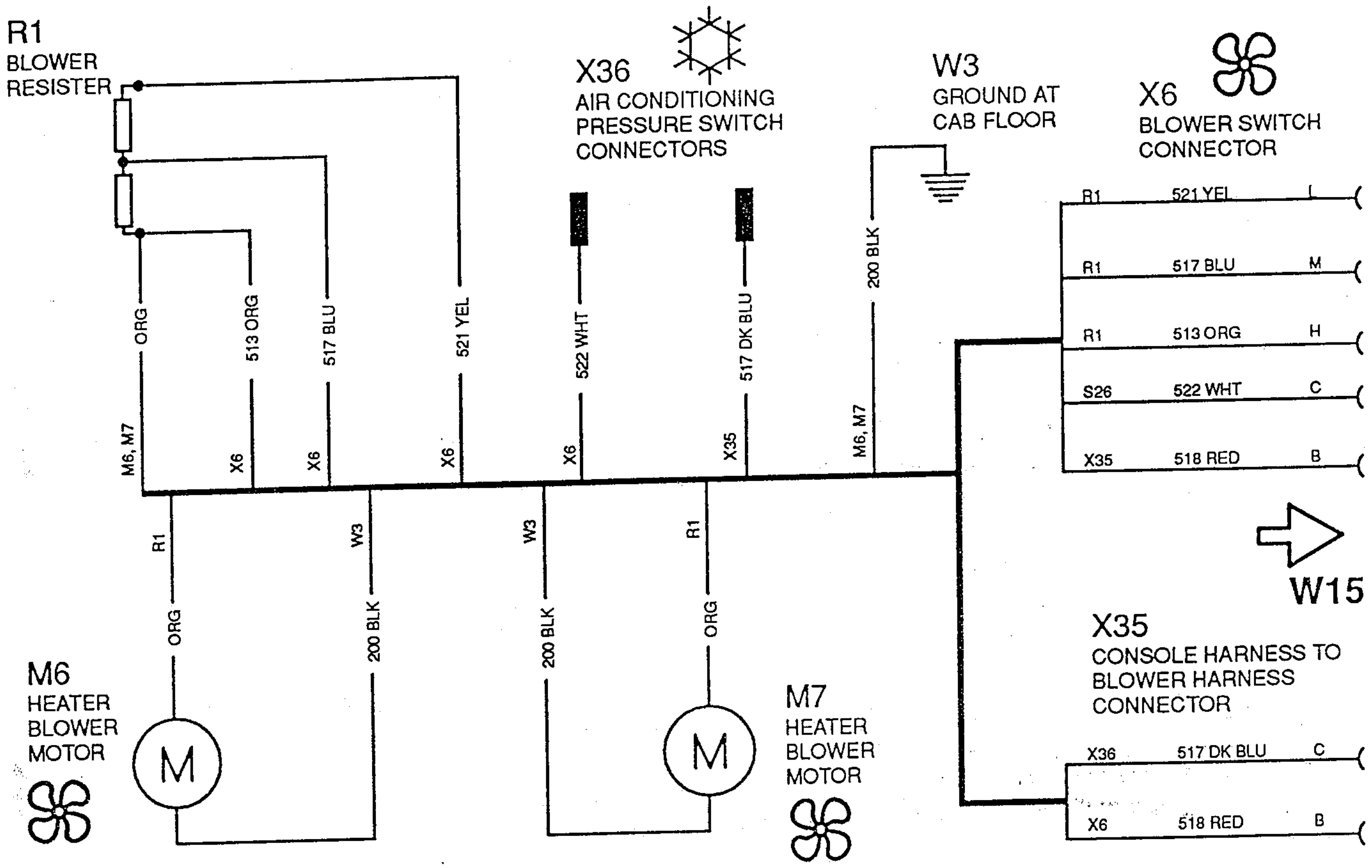

Fig. 32—A System Wiring Diagram

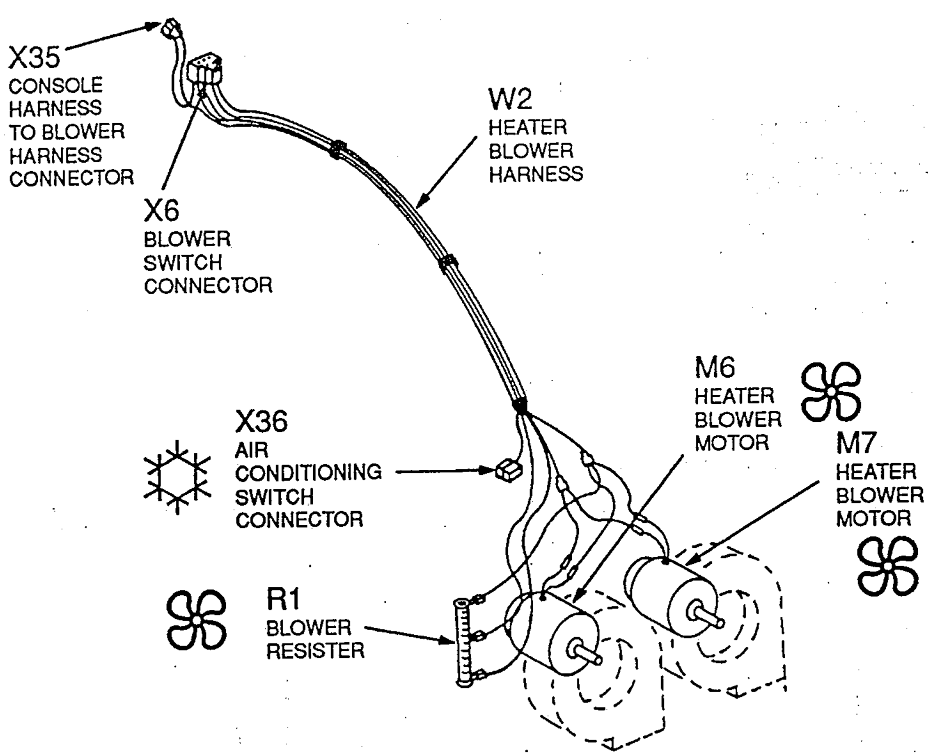

Fig. 33—A Component Location Drawing

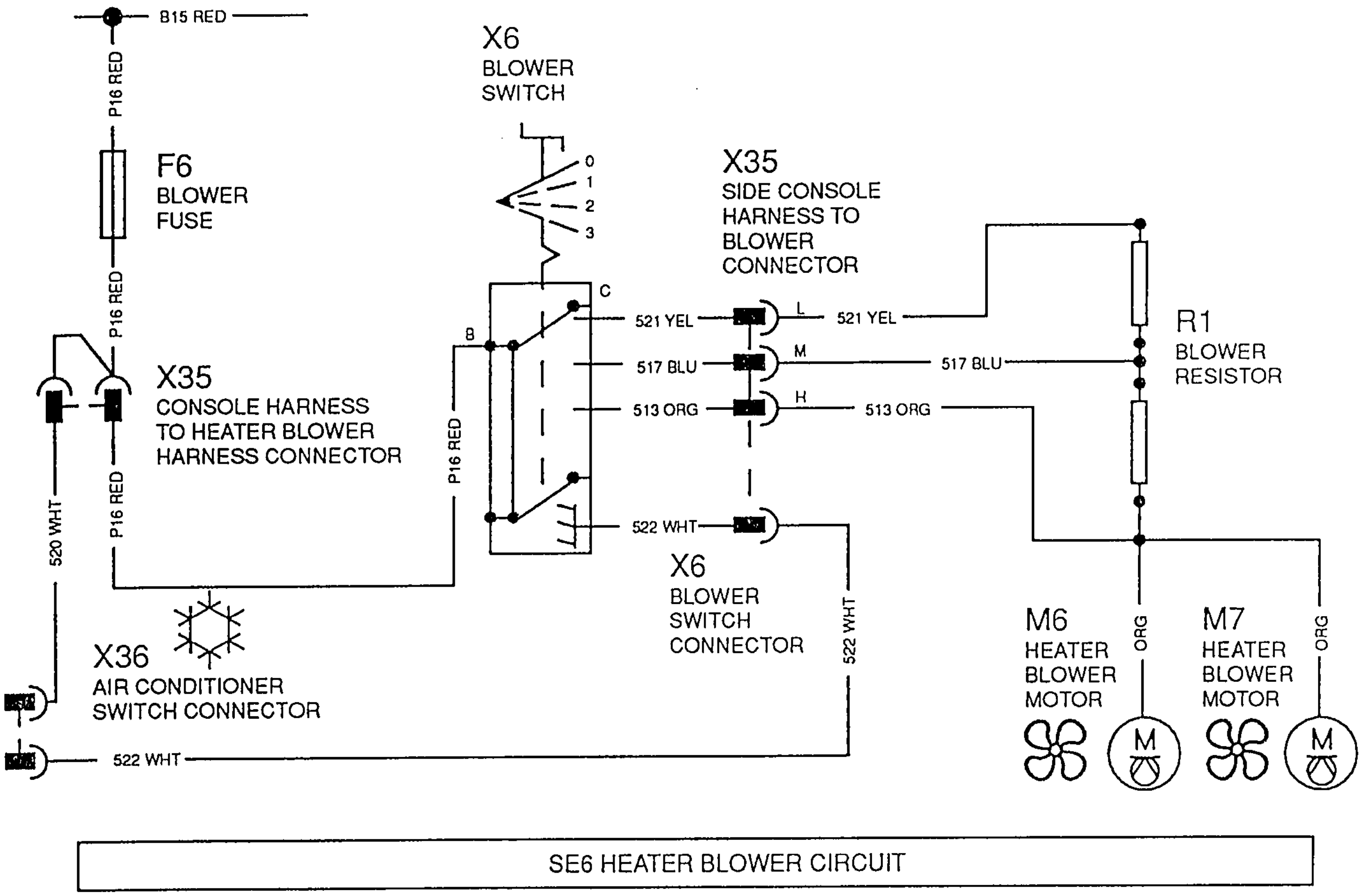

Fig. 34—A Subsystem Diagnostic Schematic

SUBSYSTEM DIAGNOSTIC SCHEMATIC

The Subsystem Diagnostic Schematic (Fig. 34) is a diagram that combines the Subsystem Functional Schematic with all harness connectors and pin locations to aid in diagnosing subsystems.

COMPONENT IDENTIFICATION LETTERS

Component identification letters have been developed by standard organizations to comply to all electrical components. Each electrical component and main harness connections will have an identification letter assigned to it. A number is added to the letter to separate and indicate the total components and main connections within that letter group. The letters I, O, and Q are not used. The following is a list of identifying letters and some examples of what they represent.

Identification letter		Examples
A	—	ABS control units, radios, and control units.
B	—	All types of sensors, horns, and microphones
C	—	Condensers and capacitors
D	—	Digital devices, pulse counters, and integrated circuits
E	—	Heaters, air conditioning, lights, distributors, and spark plugs
F	—	All protection devices such as fuses and circuit breakers
G	—	All power supply such as batteries, alternators, and generators
H	—	Any signal device such as alarms, buzzers, or signal lights

Identification letter	Examples
L —	Any inductor device such as coil windings
M —	Any electrical motor
N —	Regulators
P —	Any measuring instruments such as ammeters and tachometers
R —	Resistors
S —	Any switch
T —	Ignition coil or any transformer
U —	Converters and modulators
V —	Any semiconductors such as diodes
W —	All conductors of an electrical path
X —	All electrical connection devices
Y —	Any electrically-actuated mechanical device
Z —	Any electrical filter or suppressor device

An alphabetical listing of devices and their identifying letters are listed on page 22 in the back of this book.

WIRE NUMBER AND COLOR CODES

There is no set standard for wire number codes. Most major manufacturers of machines create their own number codes and list the information and show how to use these codes in their technical manuals, but most all manufacturers use standard color abbreviations to identify wires in a circuit. Red-colored wires are generally used for power source wires that can be traced back to the battery. Black-colored wires are generally used for grounds. Listed here are some of the abbreviations for colors.

Color	Abbreviation
Black	BLK or BK
Brown	BRN or BN
Red	RED or R
Orange	ORG or O
Yellow	YEL or Y
Green	GRN or G
Dark Green	DK. GRN or DG
Light Green	LT. GRN or LG
Blue	BLU or B
Dark Blue	DK. BLU or DB
Light Blue	LT. BLU or LB
Purple	PUR or P
Gray	GRY or GY
White	WHT or W

If the wire is bi-colored, both abbreviations are used, separated with a slash. BLK/WHT means a black wire with a white tracer.

DIAGRAM AND SCHEMATIC SYMBOLS

Standards organizations such as the American National Standards have developed international symbols for components that are used on electrical diagrams and schematics worldwide.

The Society of Automotive Engineers (SAE) also has established symbols to identify the operation and function of components on diagrams.

International Symbols

International electrical symbols (Fig. 35) have been established by standards organizations for components used for diagrams and schematics intended for worldwide distribution.

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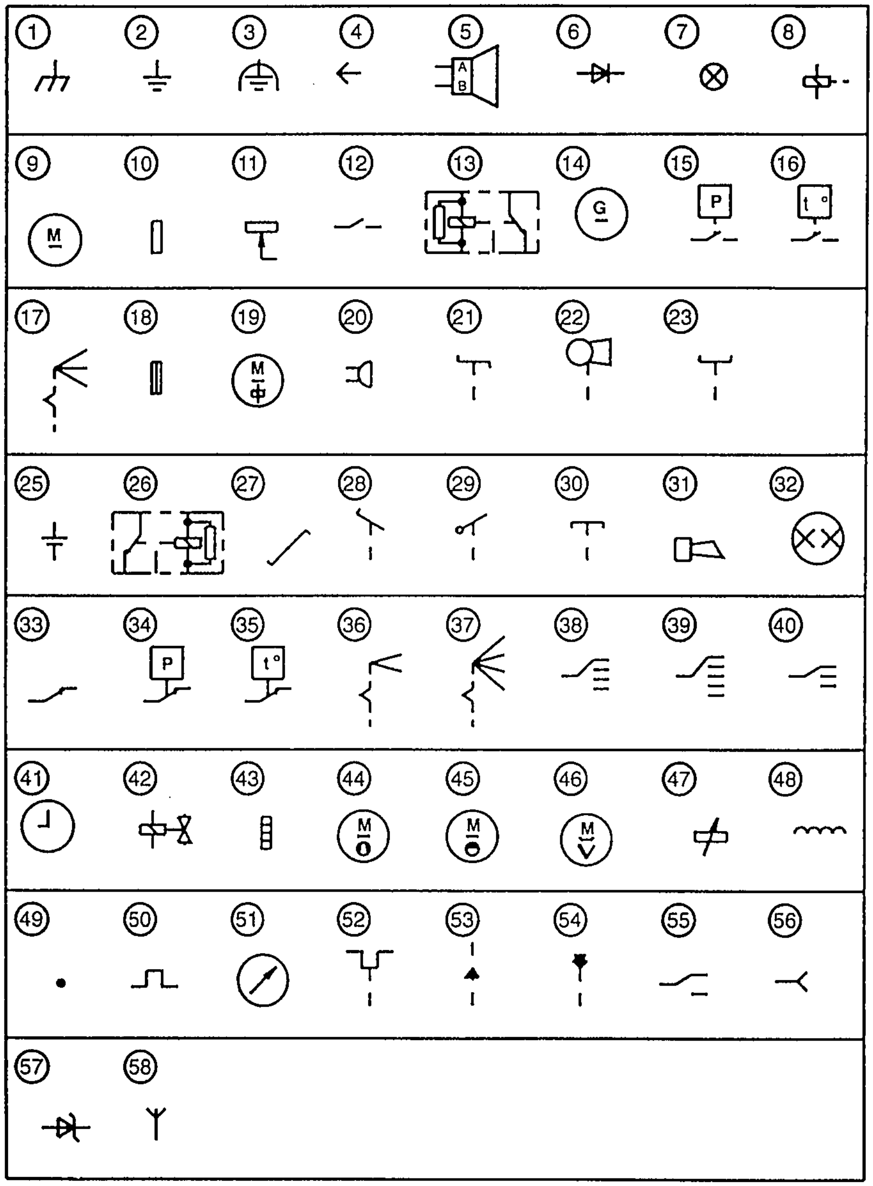
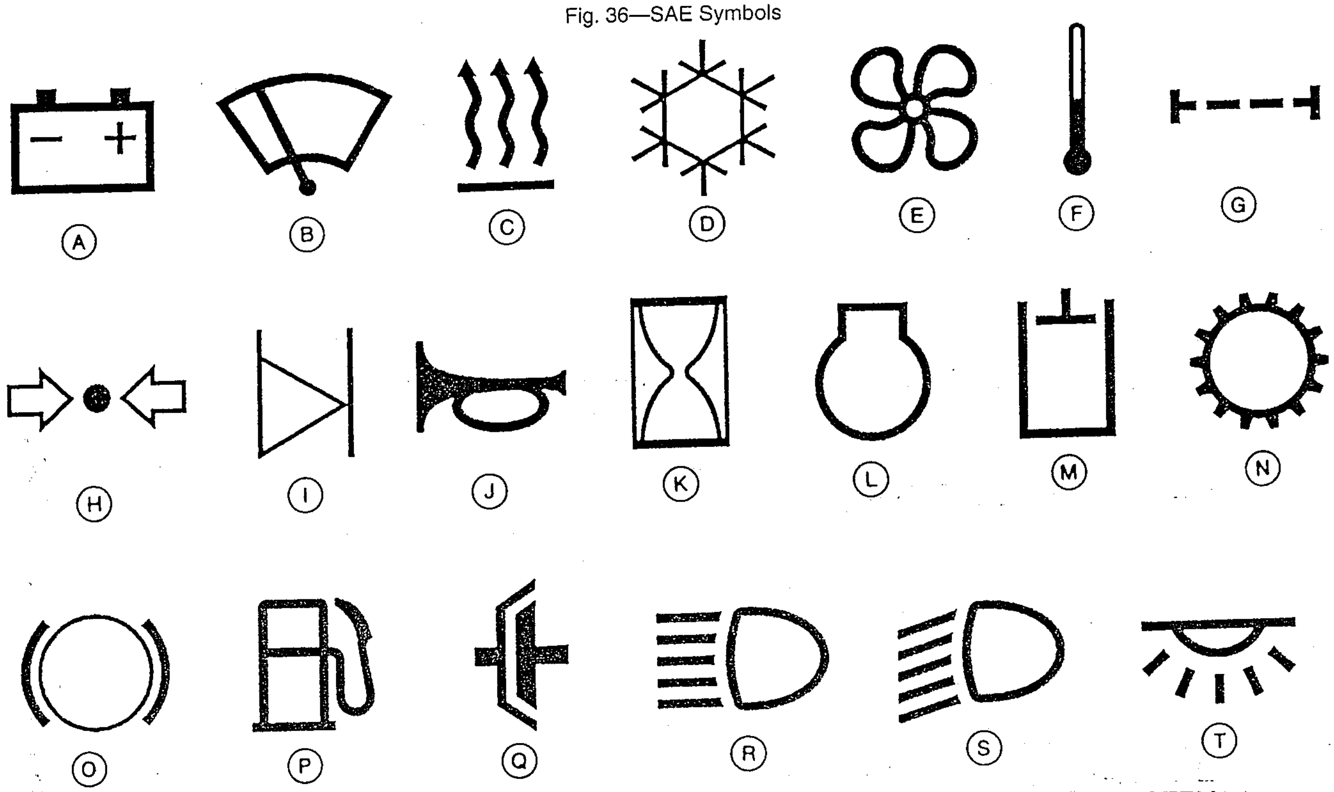
Fig. 35—International Electrical Symbols



rame ground
iround
hielded ground, (Single point ground)
'in, male
oudspeaker
lectifying junction, (Semiconductor diode)
amp with single element
ctuator with one winding, (Solenoid)
)irect Current Motor
use
/ariable resistor
/lake contact, normally open
lelay, normally closed
)irect current generator
'ressure activated switch, normally open
emperature activated switch, normally open
Three position detent
use
)irect current motor with solenoid
Buzzer

21. Operated by turning
22. Operated by key
23. Operated by pulling
25. Battery
26. Relay, normally closed
27. Twisted pair of wires
28. Operated by pedal
29. Operated by lever
30. Operated by pushing
31. Horn
32. Lamp with two filaments
33. Break contact, normally closed
34. Pressure activated switch, normally closed
35. Temperature activated switch, normally closed
36. Two position detent
37. Four position detent
38. Four position contact
39. Five position contact
40. Three position contact
41. Clock
42. Solenoid valve
43. Heating element
44. Direct current motor with fan
45. Direct current motor with pump
46. Windshield wiper motor
47. Variable resistor
48. Windings, (Coil of wire)
49. Connection point
50. Thermal effect
51. Analog meter
52. Thermal activated
53. Automatic reset
54. Operated by touching
55. One position contact
56. Socket, female
57. Zener diode
58. Antenna

Fig. 36—SAE Symbols



A—BATTERY
B—WINDSHIELD WIPER
C—HEATER
D—AIR CONDITIONING
E—BLOWER FAN
F—TEMPERATURE
G—FILTER
H—PRESSURE
I—LEVEL INDICATOR
J—HORN
K—HOUR METER
L—ENGINE
M—HYDRAULIC SYSTEM
N—TRANSMISSION
O—BRAKE SYSTEM
P—FUEL SYSTEM
Q—CLUTCH
R—HIGH BEAM LIGHTS
S—LOW BEAM LIGHTS
T—INTERIOR DOME LIGHT

SAE Symbols

SAE symbols are bold-faced symbols designed by the Society of Automotive Engineers. These symbols can easily be identified when reading an electrical schematic. Some of these symbols that may appear on electrical diagrams and schematics are shown in Fig. 36.

SUMMARY: MEASUREMENT OF ELECTRONS

In summary:

- **The measurement of volts, amperes, or resistance is calculated using Ohm's Law.**
- **The three types of electronic circuits are Series, Parallel, and Series-Parallel Circuits.**
- **Power (watts) is a measure of the rate at which electrical energy is converted into heat.**
- **Pulses are processed, generated, and controlled by Logic or Digital Circuits**
- **Waves are processed by varying a continuous flow of electrons within a circuit.**
- **Frequency is the measurement of time for one pulse or wave cycle and is measured in Hertz.**
- **The two types of Multimeters are Analog and Digital Multimeters.**
- **The basic failures of circuits are High Resistance, an Open, a Ground, or a Short.**
- **The five types of diagrams and schematics are System Functional Schematic, Subsystem Functional Schematic, System Wiring Diagram, Component Location Drawing, and Subsystem Diagnostic Schematic.**

HYDRAULICS AND PNEUMATICS

Learning Objective: The student will have an understanding of basic Hydraulics and Pneumatic principles.

Task: The student should be able to identify and explain the following terms and conditions.

Standard: The student will complete a written examination in which he/she will attain a minimum score of 80% to pass the written test.

Term	
Coefficient of Friction	Force
Energy of Motion To Heat Energy	Pound
Forces involved in braking	Resistance
Effect of weight in braking	Friction
Effect of speed in braking	Energy
Leverage	Kinetic Energy
Deceleration	Potential Energy
Air compressor	Work
Brake valves	Foot-Pound
Check valves	Power
Reservoir	Horsepower
Control Valve	Pressure
Relief valve	Viscosity
Closed-Center System	Pump
Open-Center System	Cylinder

HYDRAULICS—How it works / CHAPTER 1

BASIC PRINCIPLES OF HYDRAULICS

The basic principles of hydraulics are few and simple:

- **Liquids have no shape of their own.**
- **Liquids are practically incompressible.**
- **Liquids transmit applied pressure in all directions, and act with equal force on all equal areas and at right angles to them.**
- **Liquids provide great increases in work force.**

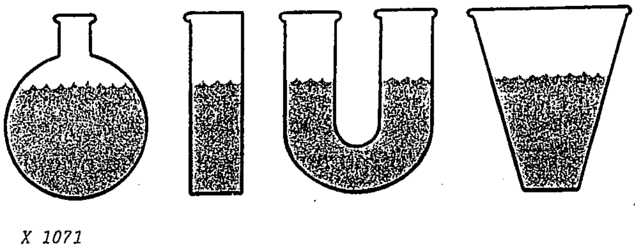


Fig. 1—Liquids Have No Shape of Their Own.

LIQUIDS HAVE NO SHAPE OF THEIR OWN. They acquire the shape of any container (Fig. 1). Because of this, oil in a hydraulic system will flow in any direction and into a passage of any size or shape.

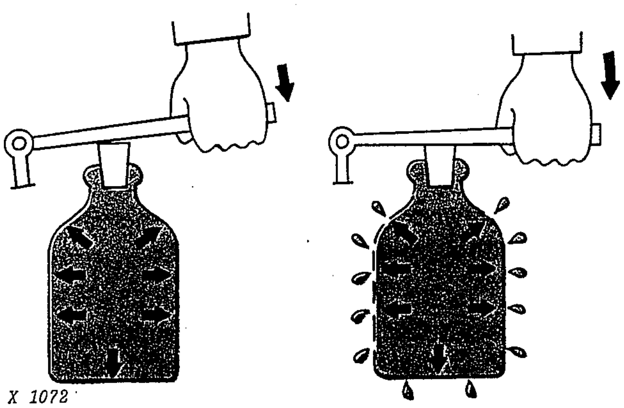


Fig. 2 — Liquids Are Practically Incompressible

LIQUIDS ARE PRACTICALLY INCOMPRESSIBLE. This is shown in Fig. 2. For safety reasons, we obviously wouldn't perform the experiment shown. However, if we were to push down on the cork of the tightly sealed jar, the liquid in the jar would not compress. The jar would shatter first. (NOTE: Liquids *will* compress slightly under pressure, but for our purposes they are incompressible.)

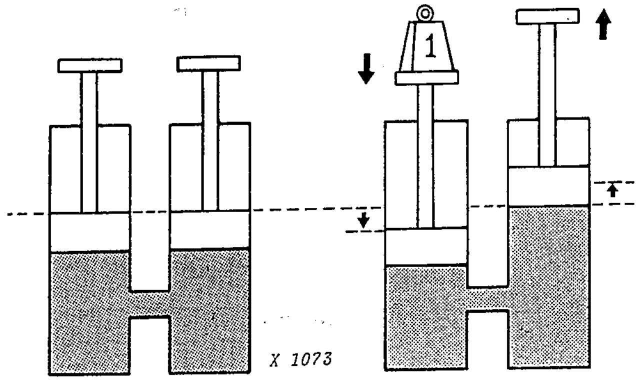


Fig. 3—Liquids Transmit Applied Pressure in All Directions

LIQUIDS TRANSMIT APPLIED PRESSURE IN ALL DIRECTIONS. The experiment in Fig. 2 shattered the glass jar and also showed how liquids transmit pressure—in all directions when they are put under compression. This is very important in a hydraulic system. In Fig. 3, take two cylinders of the same size (one square inch) and connect them by a tube. Fill the cylinders with oil to the level shown. Place in each cylinder a piston which rests on the columns of oil. Now press down on one cylinder with a force of one pound. This pressure is created throughout the system, and an equal force of one pound is applied to the other piston, raising it as shown.

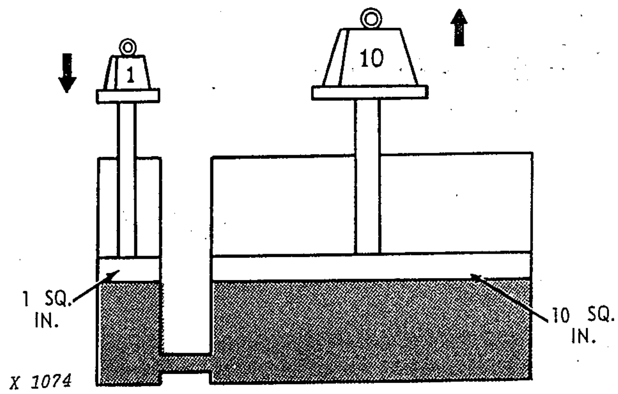


Fig. 4—Liquids Provide Great Increases in Work Force

LIQUIDS PROVIDE GREAT INCREASES IN WORK FORCE. Now let's take two more cylinders of different sizes and connect them as shown in Fig. 4. The first cylinder has an area of one square inch, but the second has an area of ten square inches. Again use a force of one pound on the piston in the smaller cylinder. Once again the pressure is

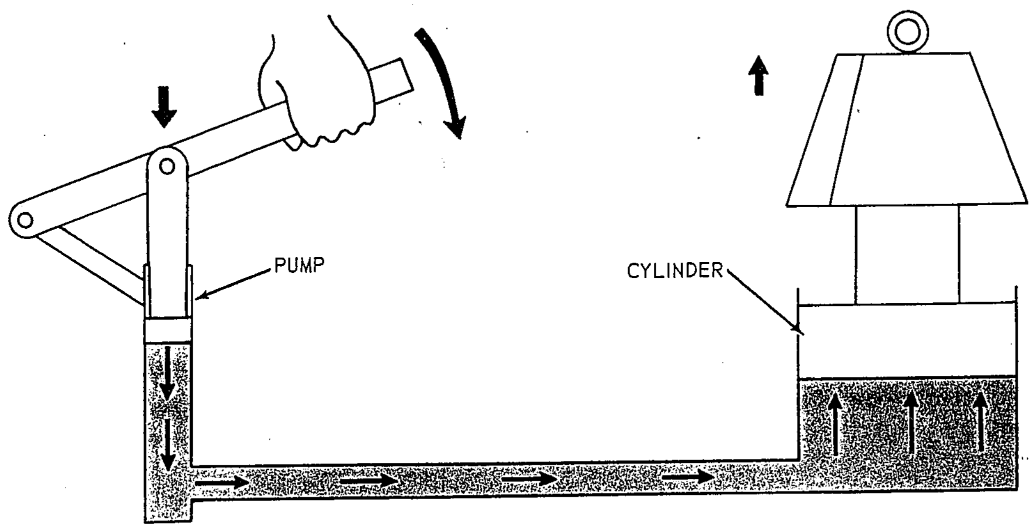


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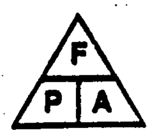
Fig. 5—A Basic Hydraulic System

created throughout the system. So a pressure of one pound per square inch is exerted on the larger cylinder. Since that cylinder has a piston area of ten square inches, the total force exerted on it is *ten* pounds. In other words, we have a great increase in work force.

This principle helps you to stop a large machine by pressing a brake pedal.

The force (F) exerted by a piston can be determined by multiplying the piston area (A) by the pressure (P) applied.



CAUTION: The forces in a hydraulic system can be very high. Use extreme caution.
See Chapter 14 for safety instructions.

HOW A HYDRAULIC SYSTEM WORKS

Let's build up a hydraulic system, piece by piece.

The basic hydraulic system has two parts:

1. The PUMP which moves the oil.

2. The CYLINDER which uses the moving oil to do work.

In Fig. 5, when you apply force to the lever, the hand *pump* forces oil into the *cylinder*. The pressure of this oil pushes up on the piston and lifts the weight.

In effect, the *pump* converts a mechanical force to hydraulic power, while the *cylinder* converts the hydraulic power back to mechanical force to do work.

But for continued operation of the system, we must add some new features (Fig. 6).

3. CHECK VALVES to hold the oil in the cylinders between strokes and to prevent oil from returning to the reservoir during the pressure stroke. The ball-type valves open when oil is flowing but close when the flow stops.

4. A RESERVOIR to store the oil. If you keep on pumping to raise the weight, a supply of extra oil is needed. The reservoir has an air vent which allows oil to be forced into the pump by gravity and atmospheric pressure when the pump piston is retracted.

Notice that the pump is smaller than the cylinder. This means that each stroke of the pump would only move enough oil to move the piston a small amount. However, the load lifted by the cylinder is much greater than the force applied to the pump piston. If you want to lift the weight faster, then you must work the pump faster, increasing the volume of oil to the cylinder.

The system we have just described is a system which might be found on a hydraulic jack or a hydraulic press; however, to meet the hydraulic requirements in most other applications, we must provide a greater quantity of oil at a more consistent rate and also have better control of the oil movement.

Let's complete the circuit and add some new features as shown in Figs. 7 and 8.

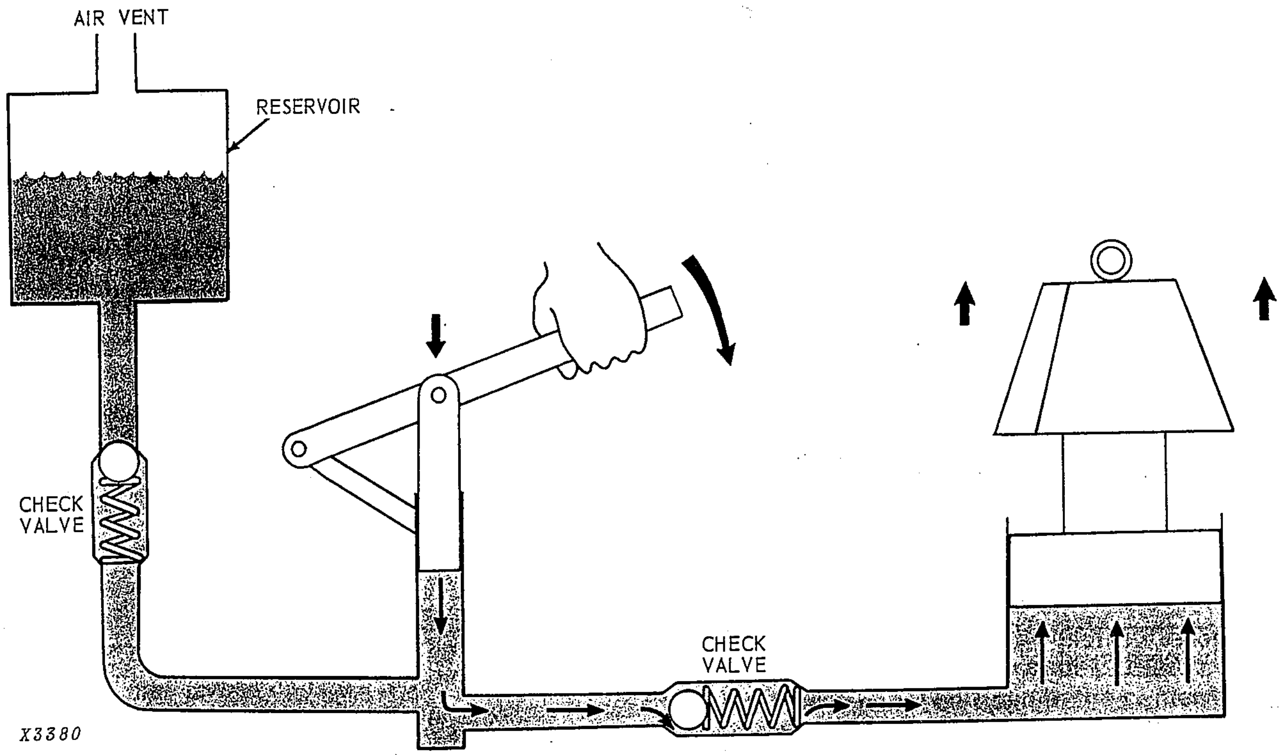


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Fig. 6—Hydraulic System with Reservoir and Check Valves Added

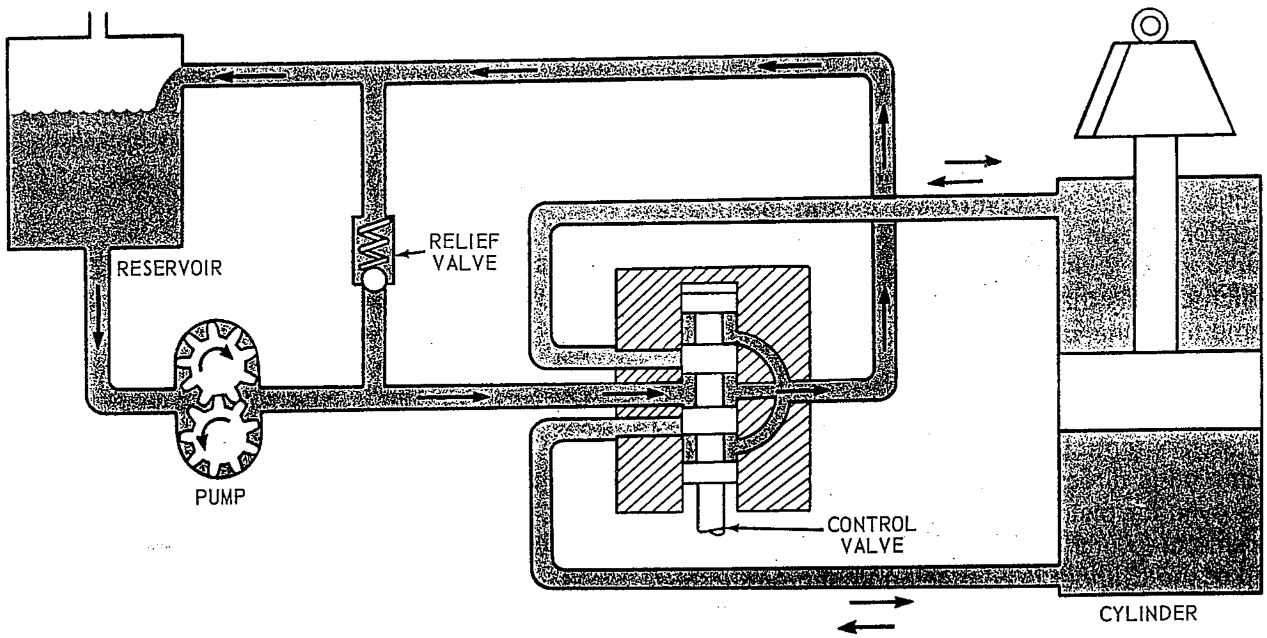

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Fig. 7 — Hydraulic System with Relief Valve and Double-Acting Cylinder Added

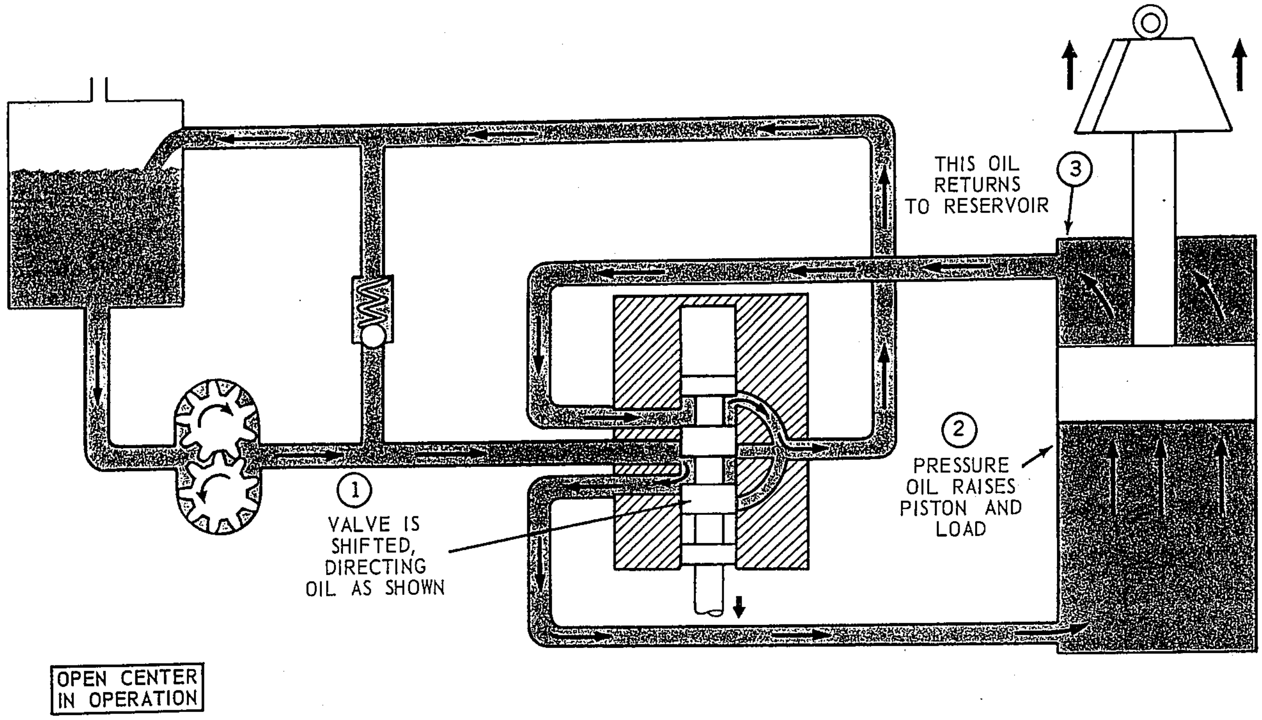

Fig. 8—Hydraulic System in Operation—Raising a Load (Open-Center Type)

We have now added a *gear-type pump.* This is one of many types of pumps which transform the rotary force of a motor or engine to hydraulic energy. For more on pumps, see Chapter 2.

5. The CONTROL VALVE directs the oil. This allows the operator to control the constant supply of oil from the pump to and from the hydraulic cylinder. When the control valve is in the neutral position shown in Fig. 7, the flow of oil from the pump goes directly through the valve to a line which carries the oil back to the reservoir. At the same time, the valve has trapped oil on both sides of the hydraulic cylinder, thus preventing its movement in either direction.

When the control valve is moved down (Fig. 8), the pump oil is directed to the cavity on the bottom of the cylinder piston, pushing up on the piston and raising the weight. At the same time, the line at the top of the cylinder is connected to the return passage, thus allowing the oil forced from the top side of the piston to be returned to reservoir.

When the control valve is moved up (not shown), oil is directed to the top of the cylinder, lowering the piston and the weight. Oil from the bottom of the cylinder is returned to the reservoir.

6. The RELIEF VALVE protects the system from high pressures. If the pressure required to lift the load is too high, this valve opens and relieves the pressure by dumping the oil back to the reservoir. The relief valve is also required when the piston reaches the end of the stroke. At this time there is no other path for the oil and it must be returned to the reservoir through the relief valve.

This completes our basic hydraulic system.

SUMMARY

To summarize:

- **The pump = generating force**
- **The cylinder = working force**
- **The valve = oil flow and direction control**
- **The reservoir = oil storage**

For more details on how these parts operate, refer to Chapter 2—Pumps, Chapter 3—Valves, Chapter 4—Cylinders, and Chapter 8—Reservoirs.

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THE PROS AND CONS OF HYDRAULICS

As you have seen in the simple hydraulic system, we have just developed, the purpose is to transmit power from a source (engine or motor) to the location where this power is required for work.

To look at the advantages and disadvantages of the hydraulic system, let's compare it to the other common methods of transferring this power. These would be mechanical (shafts, gears, belts, chains, or cables) or electrical.

ADVANTAGES

1. FLEXIBILITY—Unlike the mechanical method of power transmission where the relative positions of the engine and work site must remain relatively constant with the flexibility of hydraulic lines, power can be moved to almost any location.

2. MULTIPLICATION OF FORCE—In the hydraulic system, very small forces can be used to move very large loads simply by changing cylinder sizes.

3. SIMPLICITY—The hydraulic system has fewer moving parts, fewer points of wear. And it lubricates itself.

4. COMPACTNESS—Compare the size of a small hydraulic motor with an electric motor of equal horsepower. Then imagine the size of the gears and shafts which would be required to create the forces which can be attained in a small hydraulic press. The hydraulic system can handle more horsepower for its size than either of the other systems.

5. ECONOMY—This is the natural result of the simplicity and compactness which require relatively low cost for the power transmitted. Also, power and frictional losses are comparatively small.

6. SAFETY—There are fewer moving parts such as gears, chains, belt and electrical contacts than in other systems. Overloads can be more easily controlled by using relief valves than is possible with the overload devices on the other systems.

DISADVANTAGES

1. EFFICIENCY—While the efficiency of the hydraulic system is much better than the electrical system , it is lower than for the mechanical transmission of power.

2. NEED FOR CLEANLINESS—Hydraulic systems can be damaged by rust, corrosion, dirt, heat and breakdown of fluids. Cleanliness and proper maintenance are more critical in the hydraulic system than in the other methods of transmission.

COMPARING HYDRAULIC SYSTEMS

Two major types of hydraulic systems are used today:

- **Open-Center Systems**
- **Closed-Center Systems**

The simple hydraulic system which we developed earlier in this chapter (Fig. 8) is what we call an OPEN-CENTER SYSTEM. This system requires that the control valve spool be *open* in the center to allow pump flow to pass through the valve and return to the reservoir. The pump we have used supplies a *constant* flow of oil and the oil must have a path for return when it is not required to operate a function.

In the CLOSED-CENTER SYSTEM, the pump is capable of "taking a break" when oil is not required to operate a function. Therefore, the control valve is *closed* in the center, which stops (dead ends) the flow of oil from the pump—the "closed center" feature.

The open-center system is shown in neutral position in Fig. 9 on the next page, while the closed-center system is shown in Fig. 10.

To summarize:

- **Open-Center System—oil is pumped constantly, with valve open in center to allow oil to return to reservoir.**
- **Closed-Center System — valve spool closed in center to dead end pump oil in neutral.**

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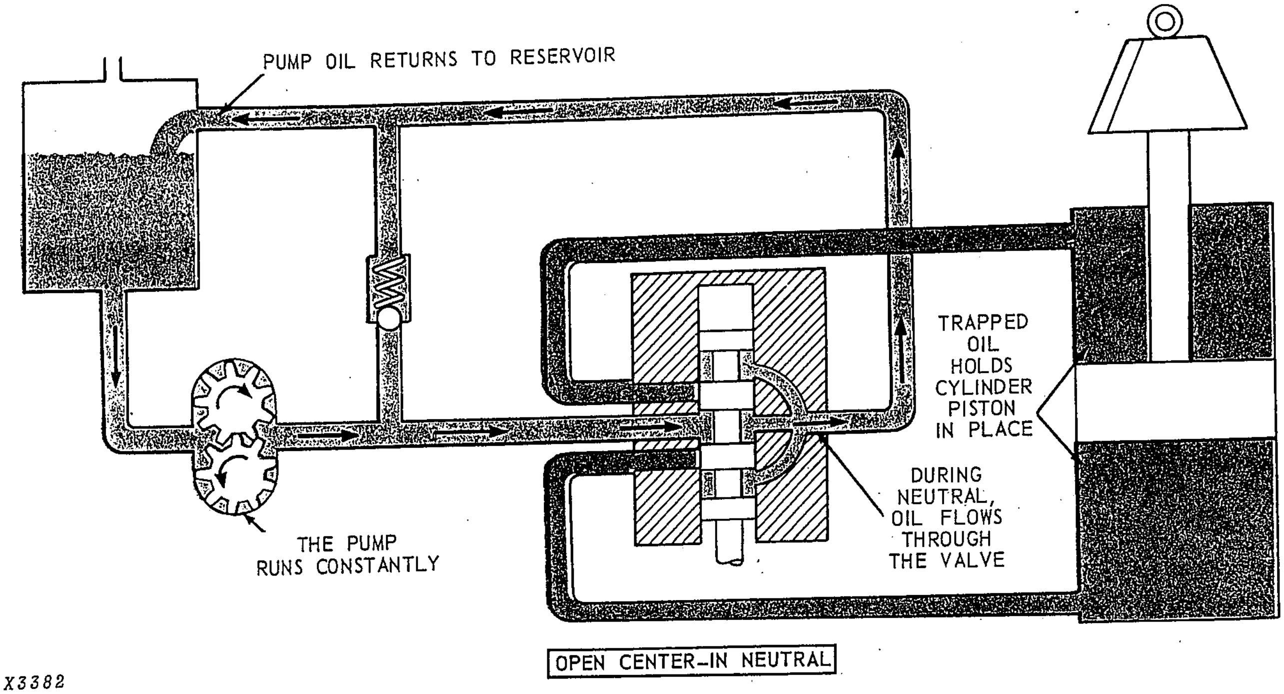

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Fig. 9—Open-Center System in Neutral

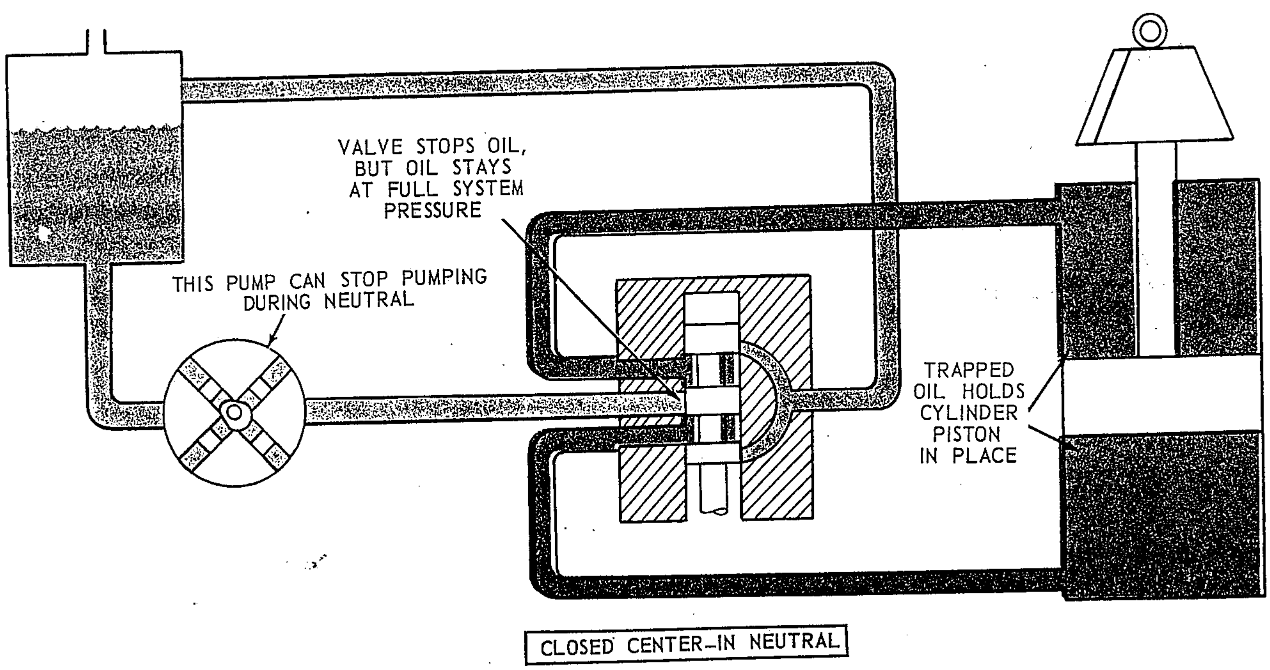

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Fig. 10—Closed-Center System in Neutral

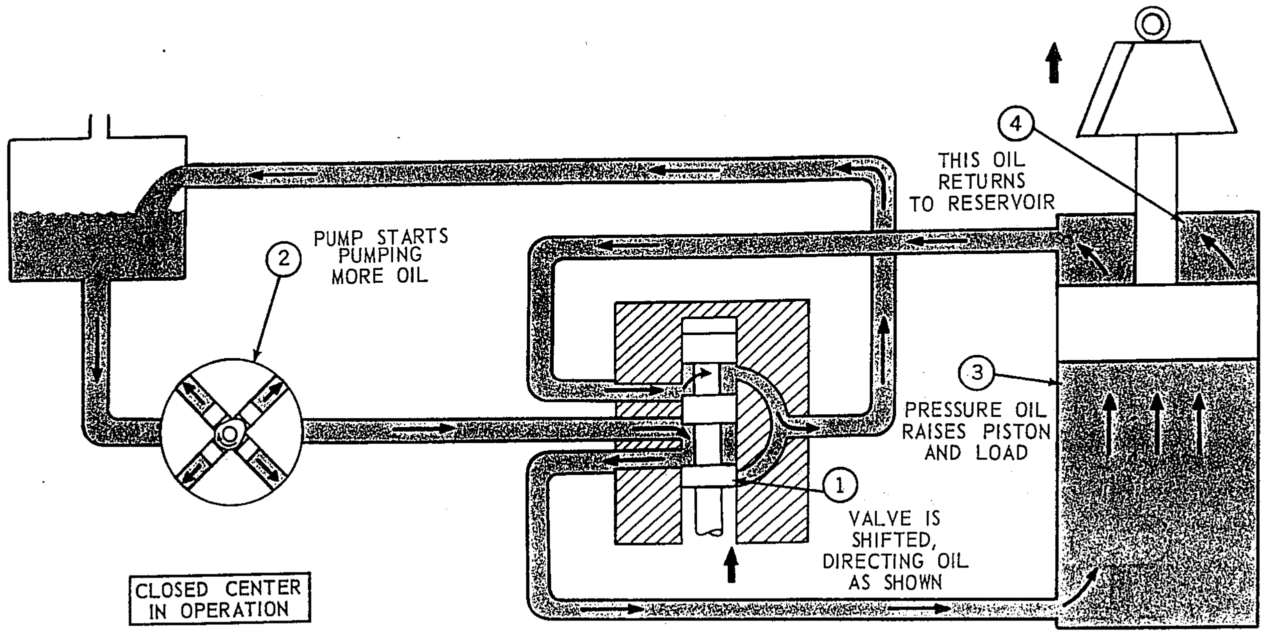

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Fig. 11—Closed-Center System in Operation—Raising a Load

CLOSED CENTER SYSTEM

Let's look at a closed-center system with a variable displacement pump.

In neutral, the pump pumps oil until pressure rises to a predetermined level. Then a pressure regulating valve allows the pump to shut itself off and to maintain this pressure to the valve.

When the control valve is operated as shown in Fig. 11, oil is diverted from the pump to the bottom of the cylinder.

The drop in pressure caused by connecting the pump pressure line to the bottom of the cylinder causes the pump to go back to work, pumping oil to the bottom of the piston and raising the load.

When the valve was moved, the top of the piston was connected to a return line, thus allowing return oil forced from the piston to be returned to the reservoir or pump.

When the valve is returned to neutral, oil is again trapped on both sides of the cylinder and the pressure passage from the pump is dead ended. At this time the pump again takes a break.

Moving the spool in the downward position (not shown), directs oil to the top of the piston, moving the load downward. Then oil from the bottom of the piston is sent into the return line.

With the closed center system, if the load exceeds the predetermined standby pressure or if the piston reaches the end of its stroke, the pressure build-up simply tells the pump to take a break, thus eliminating the need for relief valves to protect the system.

We have now built the simplest of open- and closed-center systems. However, most hydraulic systems require their pump to operate more than one function.

Let's look at how this is done and compare the advantages and disadvantages of each system.

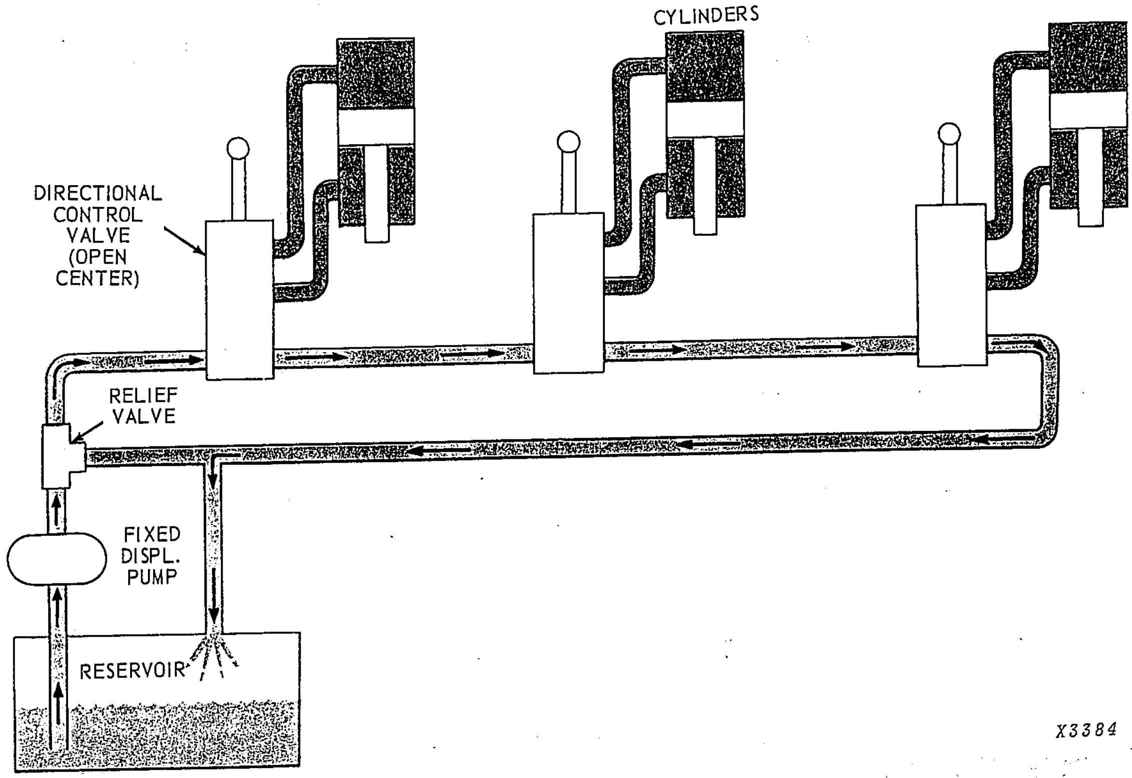

Fig. 12—Open-Center System with Series Connection

VARIATIONS ON OPEN- AND CLOSED-CENTER SYSTEMS

To operate several functions at once, hydraulic systems have the following connections:

OPEN-CENTER SYSTEMS

- *Open-Center with Series Connection*
- *Open-Center with Series Parallel Connection*
- *Open-Center with Flow Divider*

CLOSED-CENTER SYSTEMS

- *Closed-Center with Fixed Displacement Pump and Accumulator*
- *Closed-Center with Variable Displacement Pump*

Let's discuss each of these systems.

OPEN-CENTER SYSTEMS

Open-Center System with Series Connection

Fig. 12 shows a series connection of the open-center system. Oil from the pump is routed to the three control valves in series. The return from the first valve is routed to the inlet of the second, etc.

In neutral, the oil passes through the valves in series and returns to the reservoir as shown by the arrows. When a control valve is operated, incoming oil is diverted to the cylinder which that valve serves.

Return oil from the cylinder is directed through the return line and on to the next valve.

This system is satisfactory as long as only one valve is operated at a time. In this case the full output of the pump at full system pressure is available to that function. However, if more than one valve is operated, the total of the pressures required for each individual function cannot exceed the system relief setting.

Open-Center System with Series Parallel Connection

This system, shown in Fig. 13, is a variation on the series connected type. Oil from the pump is routed through the control valves in series—but also in parallel. The valves are sometimes "stacked" to allow for the extra passages.

In neutral, the oil passes through the valves in series as shown by the arrows. But when any valve is operated, the return is closed and oil is available to *all* valves through the parallel connection (upper blue line).

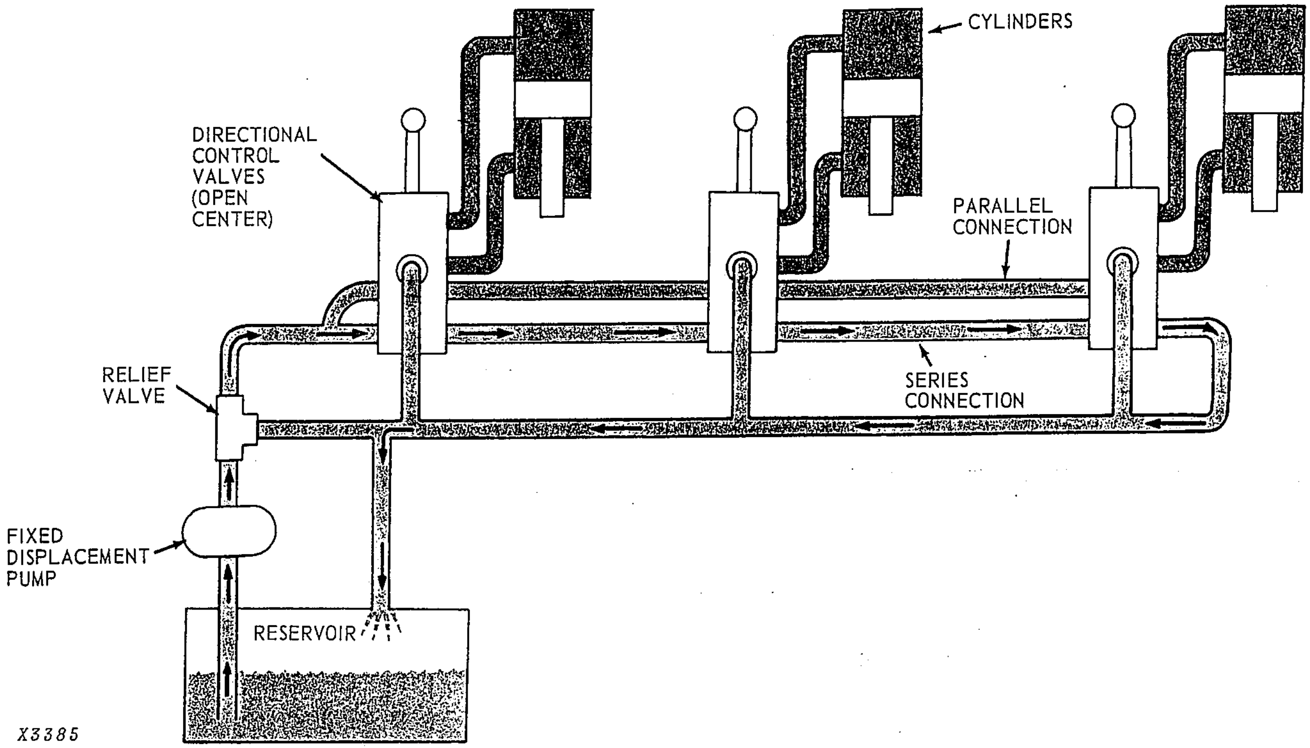

Fig. 13—Open-Center System with Series Parallel Connection

When two or more valves are operated at once, the cylinder which needs least pressure will operate first, then the next least, etc. However, this ability to satisfy two or more functions at once is an advantage over the *series* connection in Fig. 12.

Open-Center System with Flow Divider

Fig. 14 shows a flow divider used with an open-center system. The flow divider takes the volume of oil from the pump and divides it between two functions. For example, the flow divider might be designed to open the left side first in case both control valves were actuated at the same time. Or it might divide oil to both sides—either equally or by percentage. With this system, the pump must be large enough to operate all the functions at once. And the pump must supply all this oil at the maximum pressure of the highest function. This means that a lot of horsepower is wasted when operating only one control valve.

We can see now that while the open-center system is efficient on single functions, it has a limited value for use with multiple functions.

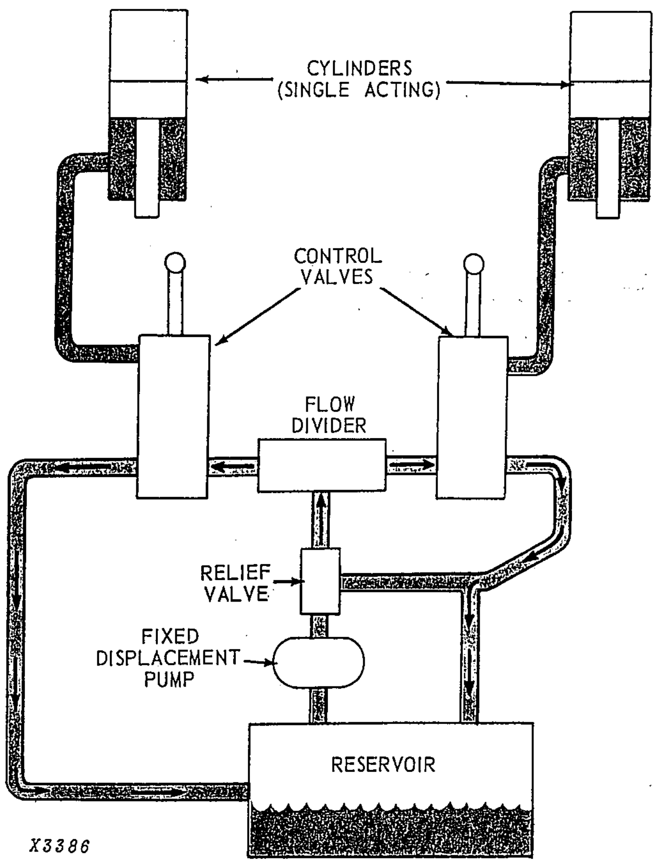

Fig. 14—Open-Center System with Flow Divider

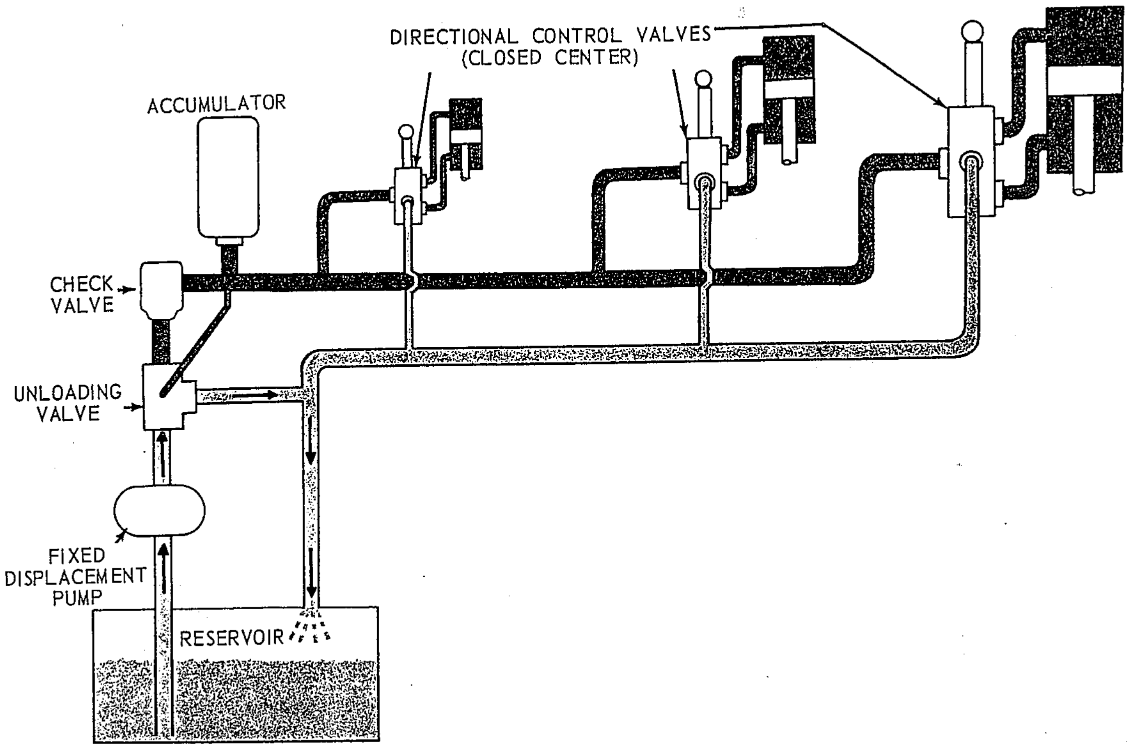

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Fig. 15—Closed-Center System with Fixed Displacement Pump and Accumulator

CLOSED-CENTER SYSTEMS

Closed-Center System with Fixed Displacement Pump and Accumulator

This system is shown in Fig. 15. A pump of small but constant volume charges an accumulator. When the accumulator is charged to full pressure, the unloading valve diverts the pump flow back to the reservoir. The check valve traps pressure oil in the circuit.

When a control valve is operated, the accumulator discharges its oil and actuates the cylinder. As pressure begins to drop, pump flow is again directed by the unloading valve to the accumulator to recharge it.

This system, using a small capacity pump, is effective when operating oil is needed only for a short time. However, when the functions need a lot of oil for longer periods, the accumulator system cannot handle it unless the accumulator is very large.

Closed-Center System with Variable Displacement Pump

This system is shown in Fig. 16. We have already shown much of this system in Fig. 10, but now we are adding a charging pump. This pumps oil from the reservoir to the variable displacement pump. The charging pump supplies only the make-up oil required in the system and provides some inlet pressure to make the variable displacement pump more efficient. Return oil from the system functions is sent directly to the inlet of the variable displacement pump as shown.

We saw earlier that the open-center system is the simplest and least expensive for hydraulic systems which have only a few functions. But as more functions are added with varying demands for each function, the open-center system requires the use of flow dividers to proportion the oil flow to these functions. The use of these flow dividers in an open-center system reduces efficiency with resulting heat build-up.

Today's machines need more hydraulic power and *the trend has been to the closed-center system.*

On a modern tractor, for example, oil may be required for power steering, power brakes, remote cylinders, three-point hitch, loaders, and other mounted equipment.

In most cases, each of these functions has a requirement for different quantities of oil. With the closed-center system, the *quantity of oil to each function can be controlled* by line size, valve size, or by orificing with less heat build-up when com-

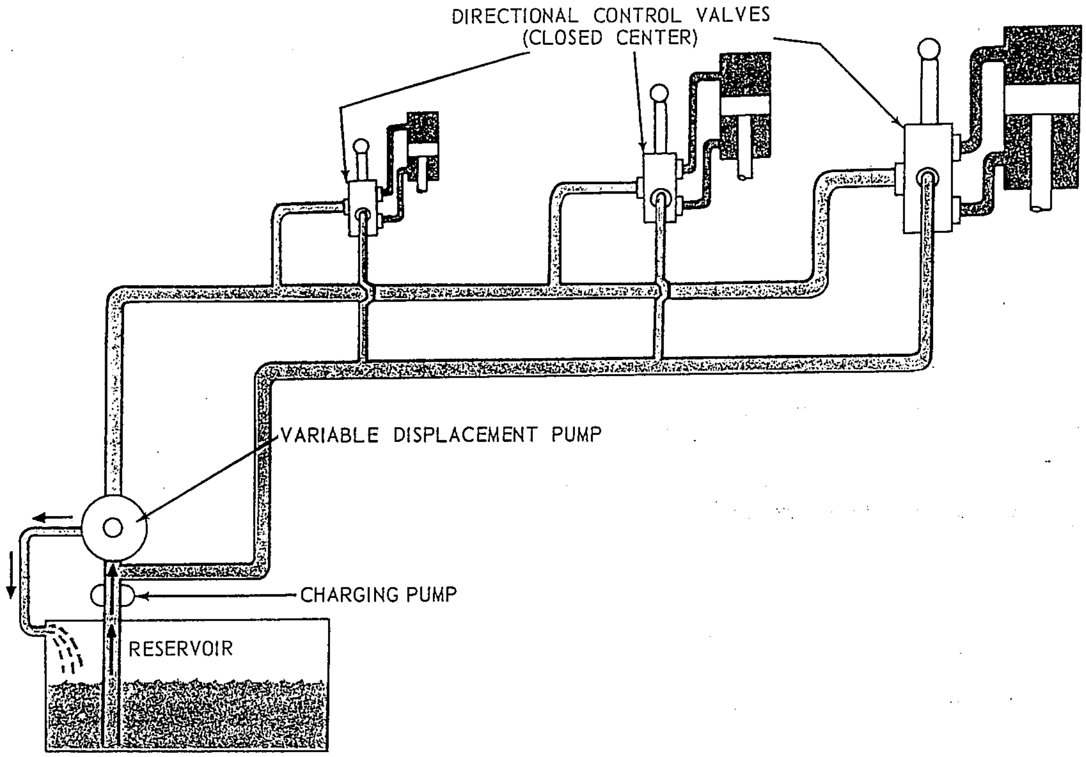


Fig. 16—Closed-Center System with Variable Displacement Pump

pared to the flow dividers necessary in a comparable open-center system.

Other Advantages of Closed-Center Systems

1. There is *no requirement for relief valves* in a basic closed-center system because the pump simply shuts itself off when standby pressure is reached. This prevents heat build-up in systems where relief pressure is frequently reached.

2. The *size of lines, valves, and cylinders can be tailored* to the flow requirements of each function.

3. By using a larger pump, *reserve flow is available* to insure full hydraulic speed at low engine rpm. More functions can also be served.

4. On functions such as brakes which require force but very little movement on a piston, the closed-center system is very efficient. By holding the valve open, *standby pressure is constantly applied* to the brake piston with no loss of efficiency because the pump has returned to standby.

In a similar open-center system, the pump would operate in relief to maintain this pressure.

HYDRAULIC FACTS

1. Hydraulic power is nearly always generated from mechanical power. Example: A hydraulic pump driven by an engine crankshaft.

2. Hydraulic power output is nearly always achieved by converting back to mechanical energy Example: A cylinder, which raises a heavy Plow.

3. There are three types of hydraulic energy:

    a. potential or pressure energy
    b. kinetic energy, the energy of moving liquids
    c. heat energy, the energy of resistance to flow, or friction

4. Hydraulic energy is neither created nor destroyed; only converted to another form.

5. All energy put into a hydraulic system must come out either as work (gain) or as heat (loss).

6. When a moving liquid is retricted, heat is created and there is a loss of potential energy (pressure) for doing work. Example: A tube or hose that is too small or is restricted. Orifices and relief valves are also restrictions but they are purposely designed into systems.

7. Flow through an orifice or restriction causes a pressure drop.

8. Oil must be confined to create pressure for work. A tightly sealed system is a must in hydraulics.

9. Oil takes the course of least resistance.

10. Oil is normally pushed in a pump, not drawn into it (Atmospheric pressure supplies this push. For this reason, an air vent is needed in the top of the reservoir.)

11. A pump does not pump pressure: it created flow. Pressure is caused by resistance to flow.

12. Two hydraulic systems may produce the same power output- one at high pressure and low flow, the other at low pressure and high flow.

13. A basic hydraulic system must include four components:

    a. A reservoir to store the oil
    b. A pump to push the oil through the system
    c. Valves to control oil pressure and flow
    d. A cylinder (or motor) to convert the fluid movement into work

14. Compare the two major hydraulic systems:
    a. Open-Center System = pressure is varied but flow is constant.
    b. Closed-Center System = flow is varied but pressure is constant.

15. There are two basic types of hydraulics:
    a. Hydrodynamics is the use of fluids at high speeds “on impact” to supply power. Example: a torque converter.
    b. Hydrostatics is the use of fluids at relatively low speeds but at high pressures to supply power. Example: most hydraulic systems, and all those covered in this manual.

THE FUNDAMENTALS OF BRAKES

All types of automotive brakes are mechanical devices for retarding the motion of a vehicle by means of friction, and perhaps the most important requisite in respect to the fundamentals of brakes is an understanding of the laws of friction.

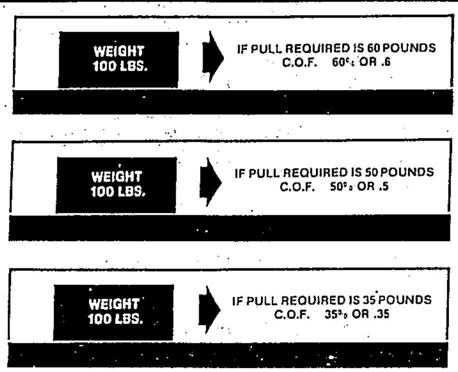


FIG. 1 — Coefficient of Friction

COEFFICIENT OF FRICTION

Friction is the resistance to relative motion between any two bodies in contact, and it varies not only with different materials but also with the condition of the materials. The amount of friction developed by any two bodies in contact is said to be their coefficient of friction, and this is expressed by stating the amount of force required to move the one body while it remains in contact with the other; the amount of force being expressed in relation to the weight of the moving body.

Thus, if the moving body weighs 100 pounds, and a force of 60 pounds is required to keep it moving while it remains in contact with another body, the coefficient of friction between the two bodies is said to be 60% or .6. If 50 pounds force is necessary to keep it moving, the coefficient of friction is said to be 50% or .5. If only 35 pounds force is required, the coefficient of friction is 35% or .35.

The coefficient of friction between any two surfaces changes with any variation in the condition of one or both surfaces. As an example, the introduction of oil or grease between two dry, flat metal surfaces will greatly reduce the friction between them, which proves that the condition of these surfaces plays a great part in the actual friction they develop. This possible variation in the coefficient of friction is always present when any factor contributing to the frictional value of any material is subject to change either permanent or temporary.

Heat is always present where friction is being developed. For example, when a bearing is not properly lubricated, the lack of lubrication causes a rise in the coefficient of friction with a resultant rise in the heat that causes the bearing to fail.

ENERGY OF MOTION TO HEAT ENERGY

Since friction is the resistance to relative motion between two bodies in contact and since friction results in heat, a more complete definition of a brake would be that it is a mechanical device for retarding the motion of a vehicle by means of friction, thereby changing the energy of motion into heat energy.

Thus, when the speed of a vehicle is reduced by applying the brakes, the energy of motion is actually changed into heat energy, and the brakes must dissipate or absorb the heat developed.

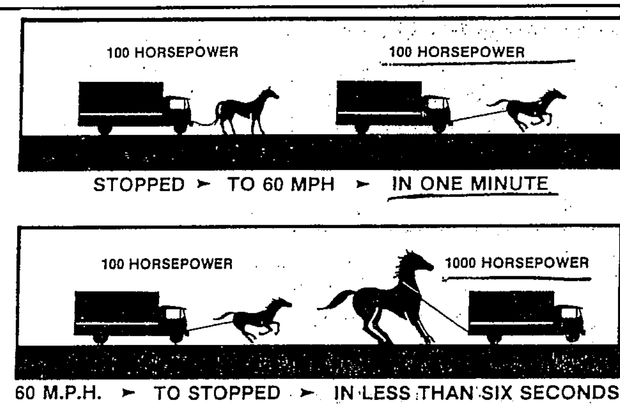


FIG. 2 — Forces Involved in Braking

FORCES INVOLVED IN BRAKING

It is difficult to appreciate the tremendous forces involved in stopping a modern commercial vehicle, particularly from the higher speeds.

A simple method of explaining this is to make a comparison between the horsepower required to accelerate a vehicle and the horsepower required to stop it. A truck with an engine capable of developing 100 horsepower will require about one minute to accelerate to 60 miles per hour. The same vehicle should be capable of easily stopping from 60 miles per hour in not more than six seconds. Ignoring the unknown quantities, such as rolling friction and wind resistance which play a part in all stops, the brakes must develop the same energy in six seconds as the engine develops in 60 seconds; in other words, the brakes do the same amount of work as the engine in one-tenth the time and must develop approximately 1,000 horsepower during the stop.

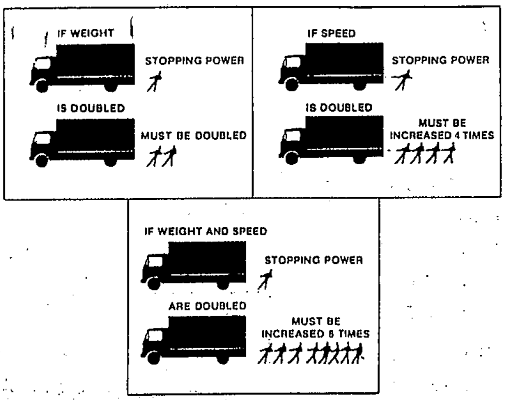


FIG. 3 — Effect of Weight and Speed on Brakes

EFFECT OF WEIGHT AND SPEED ON BRAKES

EFFECT OF WEIGHT

Another factor to be considered is the effect on braking when the weight and speed of a vehicle are increased. Brake systems are designed to properly control a vehicle loaded to its gross vehicle weight (GVW). If the GVW is exceeded, braking performance is affected; if the weight of the vehicle is doubled, the energy of motion to be changed into heat energy is also doubled. The brake cannot properly dissipate and absorb the increased heat and braking performance of the vehicle is lessened.

EFFECT OF SPEED

The effect of higher speeds on braking is much more serious. Not so many years ago the average speed of a commercial vehicle was only 20 miles per hour. Today, even conservative estimates place the average speed of commercial vehicles at 40 miles per hour. Comparing stops from a speed of 20 miles per hour with stops from a speed of 40 miles per hour, engineering calculations show there is actually four times as much energy of motion to be changed to heat energy during a stop from 40 miles per hour as there is during a stop from 20 miles per hour. Thus, if the speed is doubled, four times as much stopping power must be developed, and the brakes must absorb or dissipate four times as much heat.

It naturally follows that if both the weight and speed of a vehicle are doubled, the stopping power must be increased eight times and the brakes must absorb or dissipate eight times as much heat.

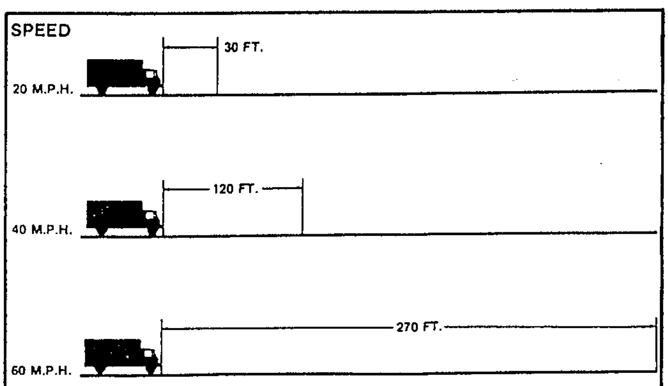


FIG. 4 — Stopping Distances

Another way of illustrating the effect of speed on stopping ability is to compare the stopping distance if the speed is increased without the stopping power also being increased.

As shown in Figure 4, a vehicle which will just stop in 30 feet from 20 miles per hour will require 120 feet to stop from 40 miles per hour and 270 feet to stop from 60 miles per hour. Introducing both weight and speed into the comparison again, a 10,000 pound vehicle traveling 60 miles per hour has 18 times as much energy of motion as a 5,000 pound vehicle travelling at 20 miles per hour. If a stopping power is used on both vehicles which will only stop the 5,000 pound vehicle from 20 miles per hour in 30 feet, the 10,000 pound vehicle from 60 miles per hour will require 18 times as much distance or 540 feet to stop.

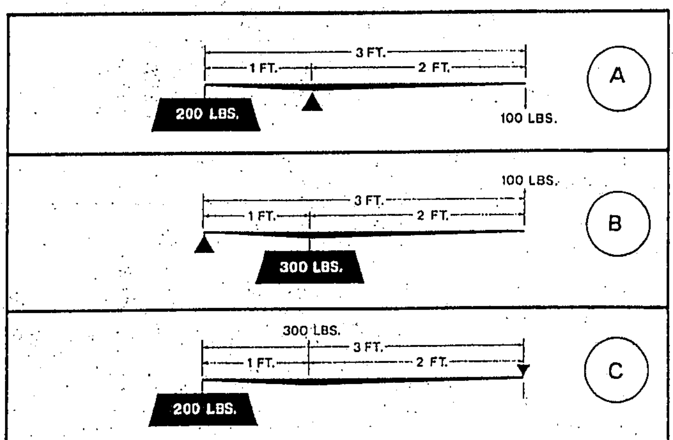


FIG. 5 — Leverage

LEVERAGE

Having reviewed the forces involved in braking a vehicle, consideration must also be given to how these forces are developed and directed to do the braking work. It is difficult even to imagine a braking system which does not, in some way, make use of one of the oldest mechanical devices governing the transmission and modification of force and motion, the lever.

A lever is defined as an inflexible rod or beam capable of motion about a fixed point called a fulcrum, and it is used to transmit and modify force and motion.

Figure 5 illustrates three simple types of levers; the only difference in them being the location of the fulcrum in relation to the applied force and the delivered force. All shapes and sizes of levers used in a brake system are one of these three types.

The simple law of levers is that the applied force multiplied by the perpendicular distance between the line of force and the fulcrum always equals the delivered force multiplied by the perpendicular distance between the fulcrum and the line of force. Thus, with a leverage arrangement as shown in view 5A, an applied force of 100 pounds two feet from the fulcrum will give a delivered force of 200 pounds at a point one foot from the fulcrum. With a leverage arrangement as shown in Figure 5B, an applied force of 100 pounds three feet from the fulcrum will lift 300 pounds at a point one foot from the fulcrum.

Note that in both cases the delivered force exceeds the applied force because the applied force is farther from the fulcrum than the delivered force. With a leverage arrangement as shown in Figure 5C, the delivered force is the farthest from the fulcrum; therefore, it is less than the applied force. If the applied force in this case is 300 pounds at a point two feet from the fulcrum, the delivered force at a point three feet from the fulcrum will be 200 pounds.

The delivered force of any lever is determined by multiplying the applied force by the distance it is from the fulcrum and then dividing this answer by the distance the delivered force is from the fulcrum.

In determining the distance at which any force is acting on a lever, the true length of the lever arm is the perpendicular distance from the force to the fulcrum, regardless of the shape of the lever. The lever arm is always measured at right angles to the direction of the force.

The product of the force acting on a lever, multiplied by the distance the force is from the fulcrum, is called the turning moment, and when this relates to a shaft it is called torque. The turning moment or torque is usually expressed in inch pounds, foot pounds, foot tons, etc., depending upon whether the force is measured in pounds or tons and whether the distance is measured in inches or feet. As an example—a force of 100 pounds acting on a lever arm five inches long would result in a turning moment or torque of 500 inch pounds.

The most easily recognized lever in an air system is the slack adjuster. The length of the lever arm of a slack adjuster is always the perpendicular distance between the center line of the brake camshaft opening and the center line of the clevis pin opening in the arm.

Another form of lever—not always recognized—is the brake cam. All brake cams are levers and are used to transmit and modify the torque and turning motion of the brake camshaft in such a way that the brake shoes are spread and forced against the brake drum, not only in the proper direction but also with the proper force. Spreading the shoes in the proper direction, of course, depends on the proper location of the cam in respect to the location of the brake shoes. The transmission of the proper force is partially determined by the effective lever length of the cam. If the effective lever length of the cam is not considered, and is too long or too short, the brake shoe force will be correspondingly too little or too much. Full consideration must therefore be given to the effective lever length of any brake cam, if the final shoe pressure is to be correct. It is also important that the effective lever length of the cam remains constant as the lining wears and the shoes have to be spread further; otherwise, the brake performance will vary as the lining wears.

Another form of lever found in all forms of braking systems is the brake shoe. This is one of the simpler forms because it is easily recognized as a beam, fulcrumed at one end on the hinge pin, which forces the brake lining against the drum when the brake cam force is applied to the other end.

Perhaps the least easily recognized lever in a brake system is the relation of the brake drum diameter to the tire diameter. In order to understand this fully it must be remembered that although the brakes stop the brake drums and wheels, it is always the tires and road surface that stop the vehicle. This is clearly demonstrated when quick stops are attempted on wet or icy roads. Under these conditions the brake equipment may still be as efficient as ever in stopping the wheels, but its ability to stop the vehicle quickly disappears because there is not sufficient friction between the tire and road to develop the necessary retarding force.

Returning to the principles of leverage involved in the relation of the tire and brake drum size, the retarding force developed by the brake shoes acting against the drum is working on an effective lever length of the brake drum radius. Counteracting this is the retarding force developed between the tire and the road, working on an effective lever length of the rolling radius of the tire. Since it is not practical to have brake drums as large as the tires, the principles of leverage require development of a greater retarding force between the brake shoes and the drums than between the tire and the road. Also, since a rubber tire on a good road surface has a higher coefficient of friction than brake lining against a brake drum, it is necessary to develop additional retarding force between the brake shoes and brake drum in order to overcome the difference in friction.

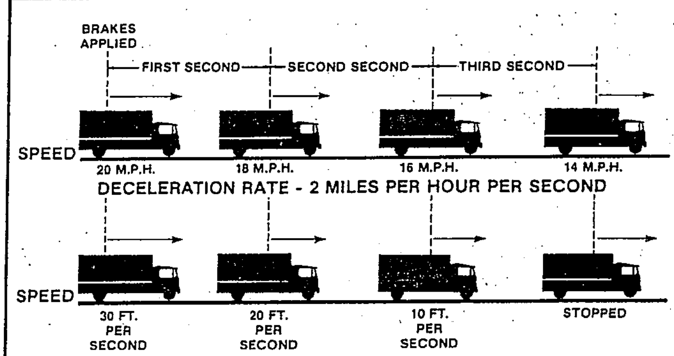


FIG. 6 — Deceleration

DECELERATION

In discussing brakes, the term deceleration is often used. This term expresses the actual rate at which a vehicle is losing speed and usually denotes the speed being lost each second, in terms of miles per hour or feet per second.

As an example as shown in Figure 6—if a vehicle is moving at the rate of 20 miles per hour, and one second later its speed is only 18 miles per hour, the vehicle has lost a speed of two miles per hour during one second. Its speed has dropped two miles per hour in one second, therefore, its deceleration rate is two miles per hour per second.

In the same way, if a vehicle is moving at a rate of 30 feet per second, and one second later its speed is only 20 feet per second, then it is decelerating at the rate of ten feet per second per second.

Therefore, the change in the rate of speed of a vehicle during a slow-down or stop is expressed by first stating the rate of speed being lost, such as miles per hour or feet per second, and then by stating the time required for this rate of speed to be lost.

Thus, in examining the expression covering a deceleration rate of say, "ten feet per second per second," the first part—"ten feet per second"—is the rate of speed being lost, and the second part—"per second"—is the time in which the loss of ten feet per second takes place.

If a vehicle is moving at a known rate, and is decelerating at a known rate, the stopping time will be the initial speed divided by the deceleration rate, provided both the rate of speed and the deceleration rate are expressed on the same basis. As an example— if a vehicle is moving at the rate of 30 feet per second and is decelerating at the rate of ten feet per second, the stopping time will be the initial speed of 30 feet per second divided by the deceleration rate of ten feet per second per second, or a stopping time of three seconds.

This perhaps can be more easily understood if explained in the following manner; if a vehicle is moving at the rate of 30 feet per second and begins to decelerate at the rate of ten feet per second per second, at the end of the first second it will be travelling 20 feet per second; at the end of the second second, it will be travelling ten feet per second, and at the end of the third second, it will be stopped. Thus, by losing speed at the rate of ten feet per second per second, it would lose its initial speed of 30 feet per second in three seconds.

Similarly, if the initial speed is 20 miles per hour and the deceleration rate is two miles per hour per second, the stopping time will be ten seconds.

One important thing to remember in respect to stopping vehicles is the fact that while the deceleration rate may be constant for each second during the stop, the distance the vehicle travels each second during the stop varies greatly as the speed decreases.

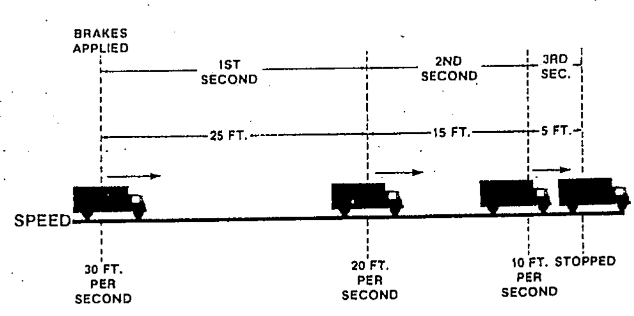


FIG. 7 — Deceleration

This is illustrated in Figure 7 which also shows a vehicle decelerating at the rate of ten feet per second per second from an initial speed of 30 feet per second, but the positions of the vehicles are shown in relation to the distance travelled each second during the stop. This shows that although the rate of deceleration remains constant throughout the stop, the vehicle actually travels 25 feet during the first second after the brakes were applied, 15 feet during the second second, and only five feet during the third second.

The distance being travelled each second during the stop is always greater at the beginning of the stop. To keep stopping distance as short as possible, it is important that the brakes become fully effective when the pedal is depressed by the driver.

Any time lost between the instant the brake pedal is depressed and the instant actual deceleration begins is important because the vehicle continues to travel at close to its initial speed. In this case, the loss of only one second between the instant the driver depresses the brake pedal and the point where the brakes are really applied will result in lengthening the actual stopping distance by 30 feet. Thus, if four seconds instead of three elapse between the instant the driver depresses the brake pedal and the instant the vehicle stops, the actual stopping distance will be increased from 45 feet to 75 feet. In other words, by reducing the stoping time under these conditions by only one second or 25%, the actual stopping distance is reduced by 30 feet or 40%.

It is this part of brake fundamentals which is not often considered in judging brake performance, particularly when different forms of brakes are involved. A common method of testing brakes is by the use of a decelerometer—a device that determines the maximum rate of deceleration developed during a stop and which shows a calculated stopping distance from a speed of 20 miles per hour based on the maximum rate of deceleration developed during a stop. Such instruments do not, however, make allowances for lost time before the braking system develops full power and therefore are not suitable for analyzing time lag factors in brake performance.

The true performance of any type of brake system in terms of stopping time or stopping distance can only be determined by actually measuring the time and distance the vehicle travels from the instant the driver depresses the brake pedal to the point where the vehicle actually stops. Such tests can, of course, be made comparative only by using instruments to determine accurately the speed of the vehicle at the instant the brake pedal is depressed.

In so far as brakes are concerned, a driver is mainly interested in the amount of time and the distance required to bring his vehicle safely to a stop under emergency conditions as measured from the instant he depresses the brake pedal. Any lag in the time between the instant he does his part and the instant the brakes become effective affects stopping distance.

THE FUNDAMENTALS OF COMPRESSED AIR

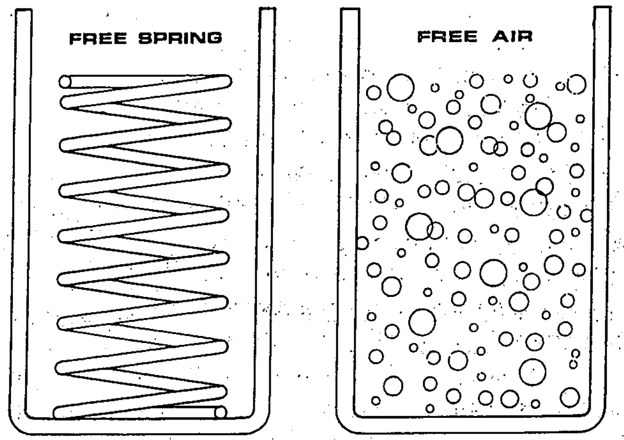


FIG. 8 — Free Spring—Free Air

Compressed air is air which has been forced into a smaller space than that which it would ordinarily occupy in its free or atmospheric state.

Free air which we breathe—or atmosphere—is normally always under pressure because of the weight of the air above it. This pressure amounts to 14.7 pounds per square inch at sea level, and it decreases as the altitude increases.

The normal atmospheric pressure of 14.7 pounds per square inch is usually ignored and the atmosphere is considered as being free air under no pressure. Thus, the pressure of compressed air is commonly indicated by stating the amount the pressure, in pounds per square inch, is above the atmosphere. This is the reason air pressure gauges register zero when connected only to atmosphere.

FREE SPRING — FREE AIR

The energy of compressed air is best compared to the energy of a coiled spring. Figure 8 shows a coiled spring in its free position and air in its free or atmospheric state.

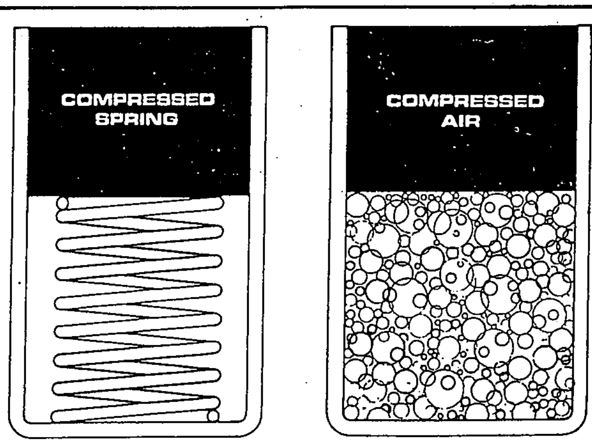


FIG. 9 — Compressed Spring—Compressed Air

COMPRESSED SPRING — COMPRESSED AIR

When the spring is compressed, as shown in Figure 9, energy is stored in it. Similarly when free air is compressed, energy is stored in the air. This energy can be used to do work, and due to the flexibility of air such energy can be stored in a relatively small space.

FUNDAMENTALS OF COMPRESSED AIR

If two reservoirs are connected—one containing air above atmospheric pressure and the other air at only atmospheric pressure - air will flow from the reservoir charged with the higher pressure until the pressures in both reservoirs equalize or until the flow is interrupted by some outside force, such as the closing of a valve in the connecting line. This is similar to the action of liquids except that pressure is the controlling medium whereas the force of gravity would ordinarily be the controlling medium in the case of liquids.

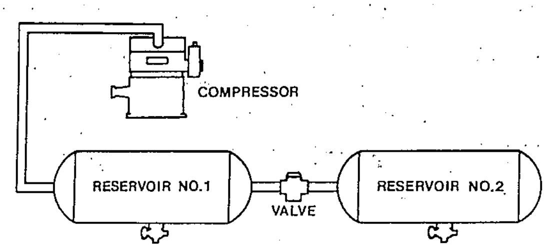


FIG. 10 — Fundamentals of Compressed Air

As shown in Figure 10, if reservoir No. 1 has a volume of six cubic feet, and the compressor forced another six cubic feet of free air into it, the gauge pressure of the air in the reservoir, which orginally read zero, would rise to 14.7 pounds. It follows that the more air that is forced into any reservoir the higher the air pressure in that reservoir will be, and that each time a quantity of free air equal to the volume of the reservoir is forced into it, the gauge pressure will rise another 14.7 pounds per square inch.

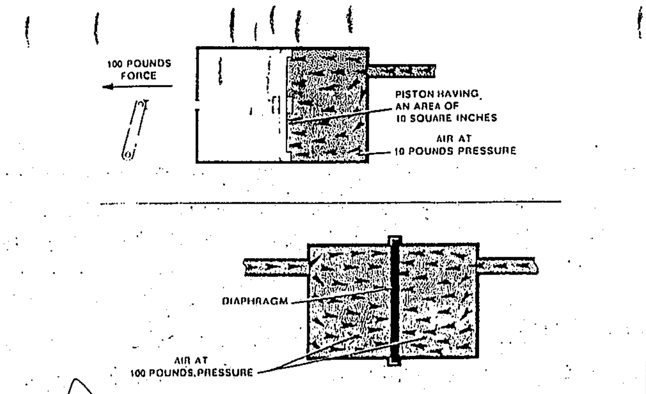


FIG. 11 — Fundamentals of Compressed Air

As illustrated in Figure 11, if compressed air is admitted to an air-tight chamber behind a movable object, the compressed air will cause the movable object to move until it encounters a resistance equal to the force developed by the compressed air. Because the air pressure is based on pounds per square inch, it follows that the compressed air will develop a force in pounds on the movable object equal to the product of the air pressure multiplied by the effective area of the movable object. Thus, if a piston or a flexible diaphragm has an area of ten square inches and air at a pressure of ten pounds per square inch is acting upon it, a force of 100 pounds will be developed. Similarly, if air at only five pounds per square inch pressure is acting on the piston or diaphragm, the developed force will be only 50 pounds. One point to be remembered is that the quantity of air acting on the piston or diaphragm does not affect the force developed. The only factors involved are the air pressure and the area of the piston or diaphragm on which the air pressure is acting. Thus, by controlling the air pressure, the developed force is also controlled.

The pressure exerted by compressed air is not only developed in all directions, but it is also equal in all directions. The compressed air in a reservoir exerts pressure equally in all directions against the entire inside surface of the reservoir, the pressure of the compressed air being overcome by the mechanical strength of the reservoir. Similarly, the force developed by the air pressure acting on one side of a piston or a diaphragm may be overcome by an opposing force acting on the opposite side, and the opposing force may be compressed air or it may be mechanical. If the opposing forces are equal, a balanced condition is reached and there is no movement of the piston or diaphragm. If the opposing forces are not equal, the piston or diaphragm will move, if possible, to assume a position where the opposing forces are equal.

This law of balanced pressures and forces is the basic principle governing the design and operation of the control and actuating devices in an air brake system.

THE FUNDAMENTALS OF COMPRESSED AIR BRAKES

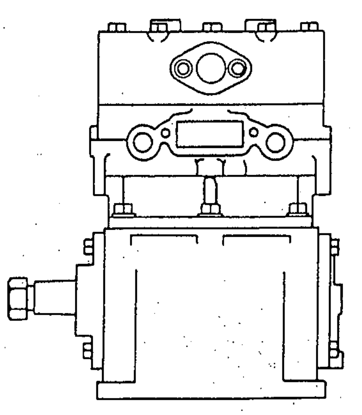


FIG. 12 — Compressor

COMPRESSOR

In an Air Brake system, the compressor furnishes the compressed air for brake operation by taking free air or atmosphere and compressing it to 100-120 P.S.I. (Maximum pressure in an air brake system is generally 150 P.S.I.)

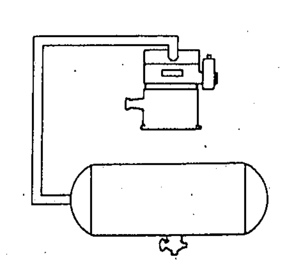


FIG. 13 — Compressor and Reservoir

COMPRESSOR AND RESERVOIR

The compressed air passes from the compressor into the reservoir where it (and its energy) are stored until needed.

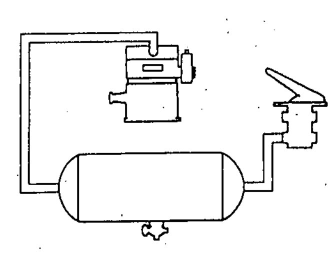


FIG. 14 — Compressor, Reservoir and Brake Valve

COMPRESSOR, RESERVOIR AND BRAKE VALVE

The compressed air is held in the reservoir until released by the driver operating air control valves.

SERVICE BRAKE SYSTEM

When the brake valve is operated by the driver, air flows to the chambers where its energy is transformed into the mechanical force and motion necessary to apply the brakes.

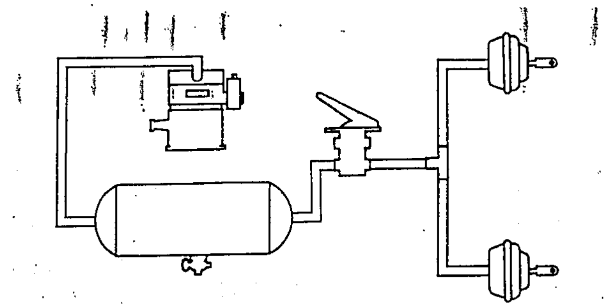
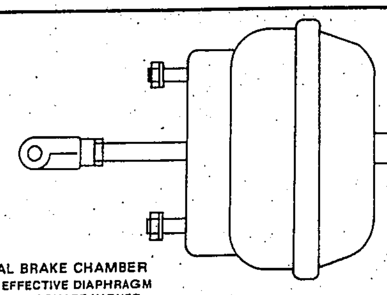


FIG. 15 — Compressor, Reservoir, Brake Valve, and Chambers

BRAKING FORCES — EFFECT OF AIR PRESSURE

This control of the braking force by controlling the air pressure in the chambers is illustrated in Figure 16. It shows the resulting forces in pounds of various air pressures with a chamber having an effective diaphragm area of 30 square inches.

The important point is that the air pressure in a brake chamber can be controlled so the brake chamber will develop the required force.



TYPICAL BRAKE CHAMBER
HAVING EFFECTIVE DIAPHRAGM
AREA OF 24 SQUARE INCHES

AIR PRESSURE (P.S.I.)	5	10	20	30	40	60	80	100
DEVELOPED FORCE (P.S.I.)	120	240	480	720	960	1440	1920	2400

FIG. 16 — Braking Forces—Effect of Air Pressure

BRAKING FORCES — EFFECT OF BRAKE CHAMBER SIZE

Different sizes of vehicles and different axles of the same vehicle may require different braking forces, depending on the weight of the vehicle or the weight distribution between axles of the same vehicle. These variations in the braking force are design variations because the maximum and minimum force required must be properly provided before good performance can be obtained throughout the entire braking range.

Figure 17 illustrates the developed force in pounds of each of several different sizes of chambers when supplied with air pressure at 60 pounds per square inch. The effective area of the different brake chambers generally varies from six square inches to 36 square inches and their developed force at 60 pounds air pressure generally varies from 360 pounds to 2,160 pounds. This permits the choice of a chamber size suitable for properly operating any size or type of foundation brake.

BRAKING FORCES
EFFECT OF BRAKE CHAMBER AND ROTOCHAMBER SIZES

CLAMP RING TYPE BRAKE CHAMBER		9	12	16	20	24	30	36	
ROTO CHAMBER		9	12	16	20	24	30	36	50
EFFECTIVE AREA OF DIAPHRAGM (SQUARE INCHES)	6	9	12	16	20	24	30	36	50
POUNDS FORCE DEVELOPED WITH 60 P.S.I.	360	540	720	960	1200	1440	1800	2160	3000

FIG. 17 — Braking Forces—Effect of Brake Chamber Size

BRAKING FORCES — EFFECT OF SLACK ADJUSTER ARM LENGTH

Figure 18 illustrates how the principles of leverage apply when a brake chamber and slack adjuster combination is being selected to meet specific requirements.

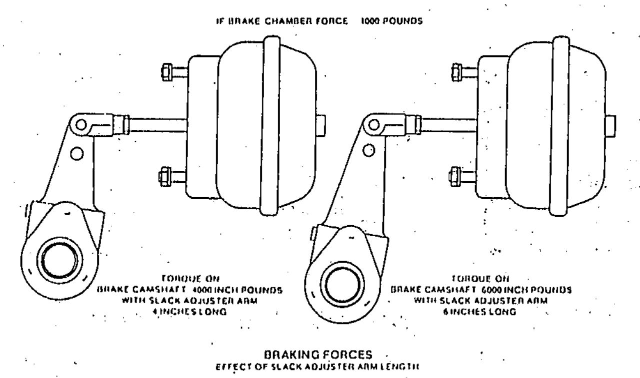


FIG. 18 — Braking Forces—Effect of Slack Adjuster Arm Length

With the same brake chamber force of 1,000 pounds, the torque on the brake camshaft can be increased from 4,000 inch pounds to 6,000 inch pounds merely by using a slack adjuster with a 6" arm instead of one with a 4" arm.

In an S-Cam foundation brake, the full range of braking forces for any vehicle is provided by the use of different sizes of brake chambers and slack adjusters.

A term which is used to express the relation of the brake chamber size and slack adjuster arm length is "AL" factor. The "AL" factor differs from torque or turning moment in that only the variable factors which determine the force are expressed. The reason for this is that an air pressure of 60 pounds is generally used in calculating air braking forces and therefore, is considered constant. The length of the slack adjuster lever arm and the size or effective area of the brake chamber acting on the slack adjuster are the two variables altered to meet braking requirements. The product of the effective area of the brake chamber and the length of the slack adjuster arm is expressed as the "AL" factor, which, when multiplied by the 60 pounds air pressure used in making brake calculations, determines the torque on the brake camshaft. As an example: If a brake chamber having an effective area of 16 square inches is acting on a slack adjuster having an arm length of five inches, the "L" factor is 80. The actual torque on the brake camshaft is therefore the "AL" factor (80) multiplied by the air pressure used in making brake calculations (60), or 4,800 inch pounds.

BRAKING—FORCES — WEDGE BRAKES

Wedge brakes use the wedge effect to accomplish force multiplication. This replaces the leverage and torque principle of the slack adjuster applied in the S-cam brakes. The wedge brake uses linear (straight line) motion to spread the brake shoes apart; unlike the S-cam brake which uses torque to turn an "S" shaped cam, spreading the brakes shoes. The wedge angle determines the force multiplication factor. A thinner wedge and smaller wedge angle produces more force multiplication. Figure 19 (a & b) illustrates this point. A 1,000 lb. chamber force producing 5,720 lbs. of force into each shoe. Figure 19 (b) illustrates an 18° wedge angle producing 3,184 lbs. of force into each shoe.

To tailor the braking forces to the requirements of any vehicle, chamber sizes and wedge angle combinations are varied. Figure 20 illustrates the effect of these combinations, as chamber sizes increase and wedge angles decrease, the multiplication or power factor increases.

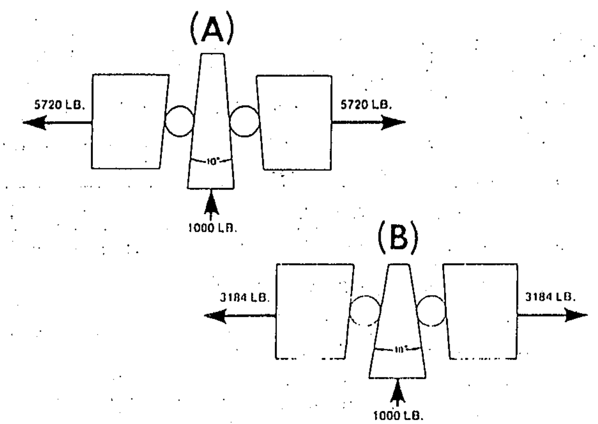


FIG. 19 — Braking Forces—Effect of Wedge Angle

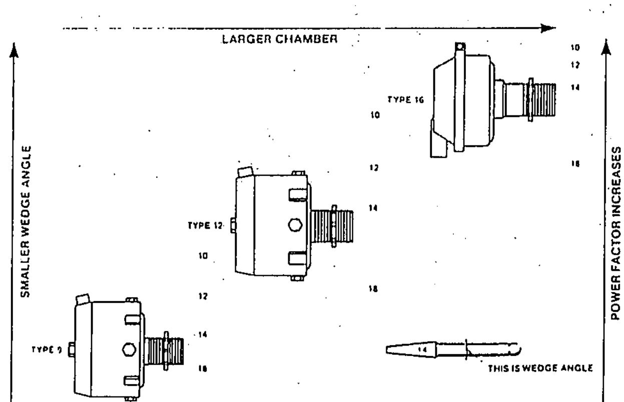


FIG. 20 — Wedge Brake Power Combinations

WELDING SAFETY

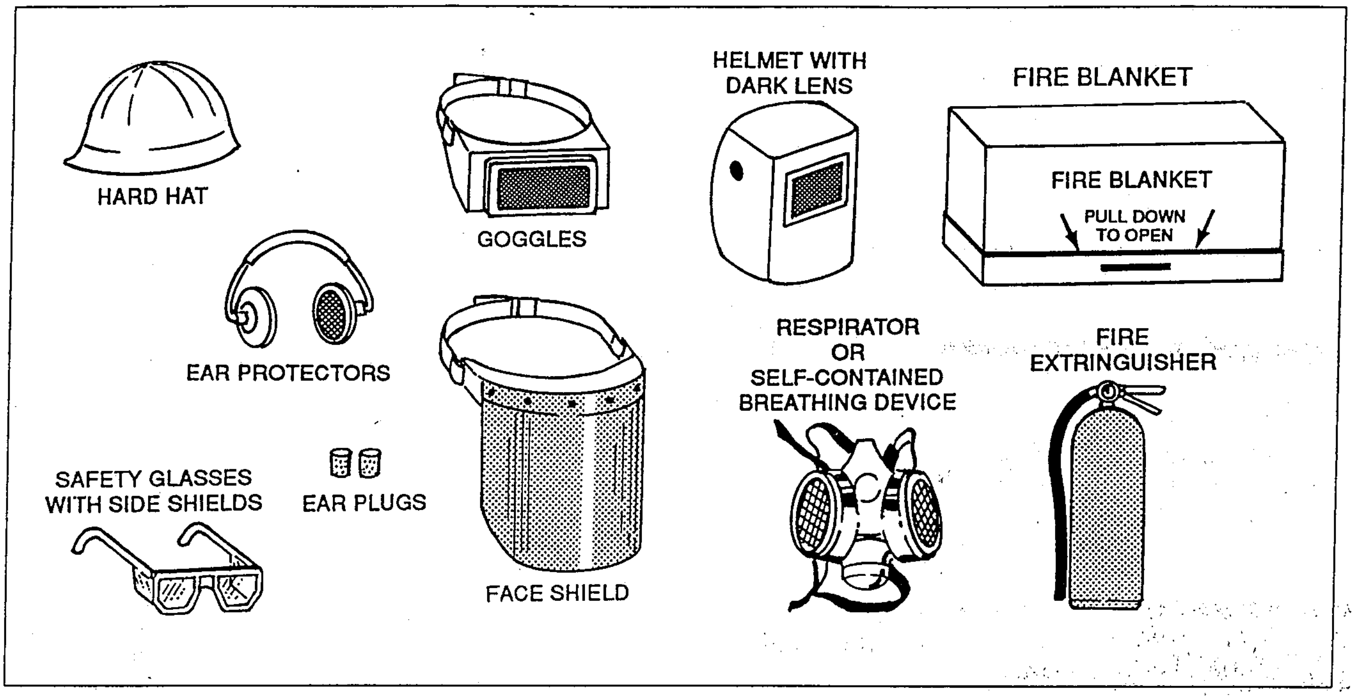


Fig. 160 — Protective Equipment

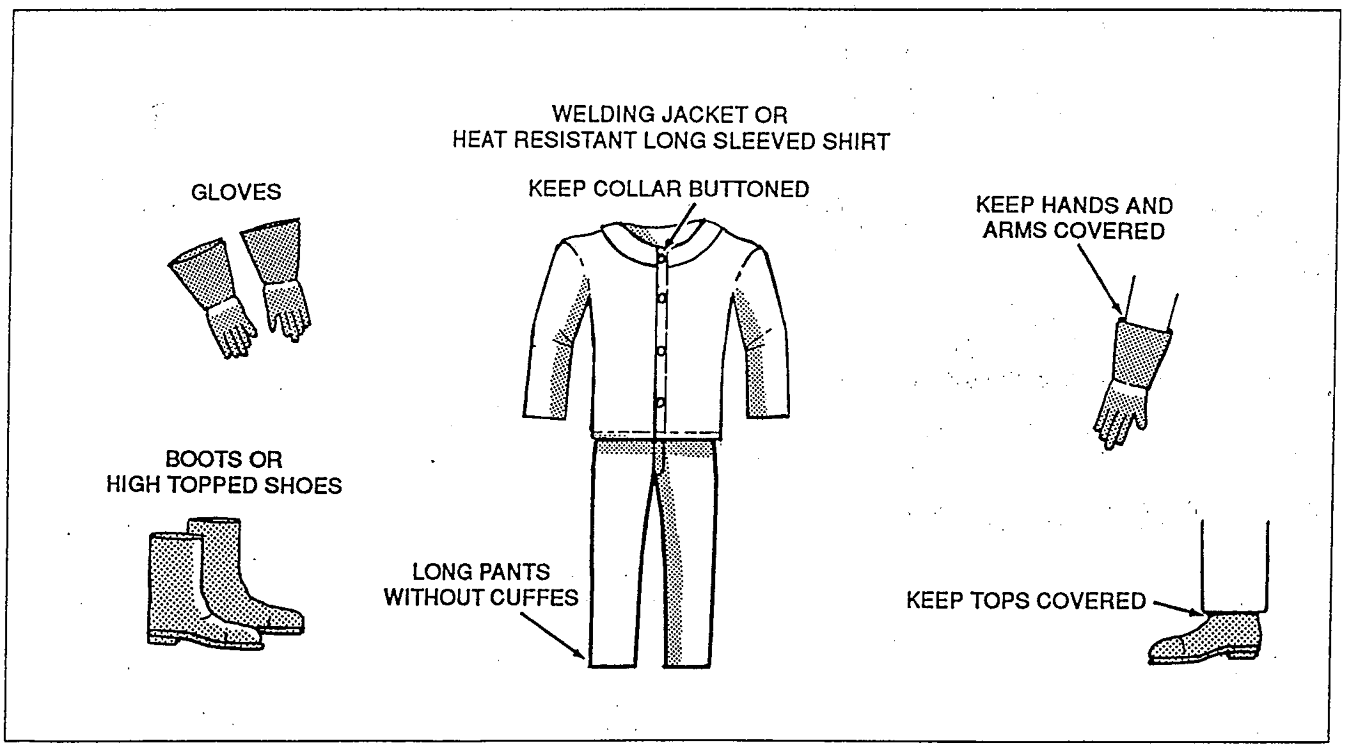


Fig. 161 — Protective Clothing

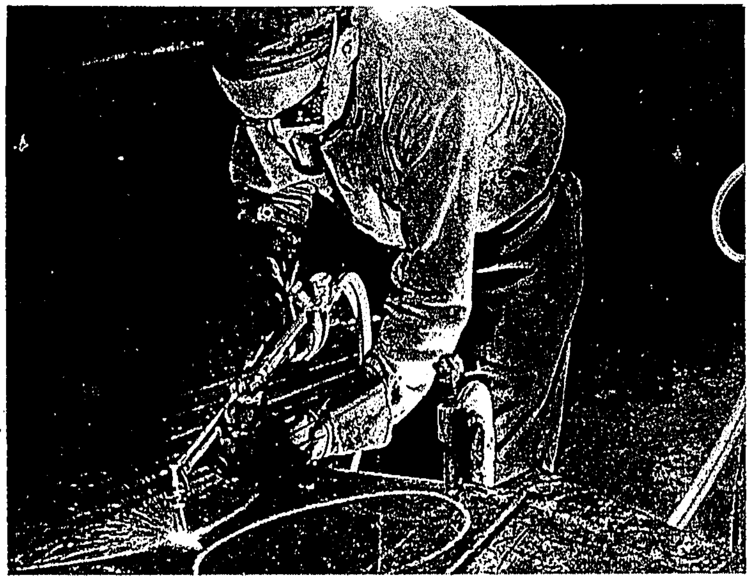


Fig. 162 — Safety in Welding

Fig. 163 — Always Wear Protective Equipment and Clothing

INTRODUCTION

We learn by experience. But learning safety through your own personal experience would be foolhardy — and unnecessary.

The safety rules for welding given here are based on someone else's experience. For your own good, learn these rules **before** you start welding. Someone learned them the hard way.

For more complete safety recommendations, refer to the joint American Welding Society AWS-ANSI Standard Z49.1-1967.

When safety precautions refer to acetylene, they apply as well to other fuel gases such as natural gas, propane, hydrogen, etc.

PROTECTIVE EQUIPMENT (For Arc and Oxyacetylene Work)

Wear ear protection at all times. Welding equipment and the welding process is noisy. Hot sparks also can get into unprotected ears.

Always wear goggles with suitable filter lenses when using a torch. Also wear a head shield or helmet with suitable filter plates when arc welding. Wear flash goggles having side shields and suitable lens at all times — even when adjusting controls, etc. Goggles and helmets protect your eyes from sparks and flying slag, and also from the strong light and injurious rays of the flame or arc. They also help you to see your work better.

Wear leather or treated canvas gloves and aprons, and suitable shoes and other protective clothing (Fig. 163 and 164).

Keep protective equipment dry and free of oil.

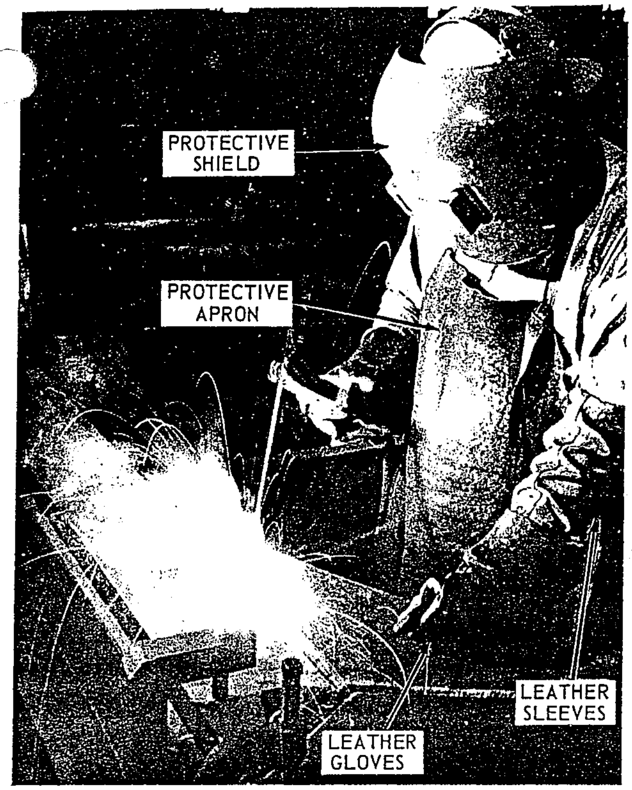


Fig. 164 — Protective Clothing for Welder
(Always wear ear protection)

Take care that your own clothing is not oily and that pockets and cuffs are not open and ready to receive sparks or hot slag.

Don't use rope to suspend staging for support of cutting or welding operations.

Do not weld metals coated with zinc or paint. Do not weld galvanized metals unless you have the proper breathing apparatus and your work place is well ventilated.

VENTILATION

Working areas must have adequate ventilation. When toxic fumes from lead, cadmium, or beryllium materials or any other substances are present in harmful concentrations, always use an air-supplied respirator. Make sure that oxygen concentrations above normal cannot develop in the work area.

Never use oxygen for ventilation. That is, never try to replace oxygen in the atmosphere that has been consumed during a welding or cutting operation — ventilate with air.

Avoid leaks or open valves in small enclosures. Leave gas cylinders outside when working in such enclosures. Don't weld or cut for at least 15 minutes after contamination of clothing with oxygen.

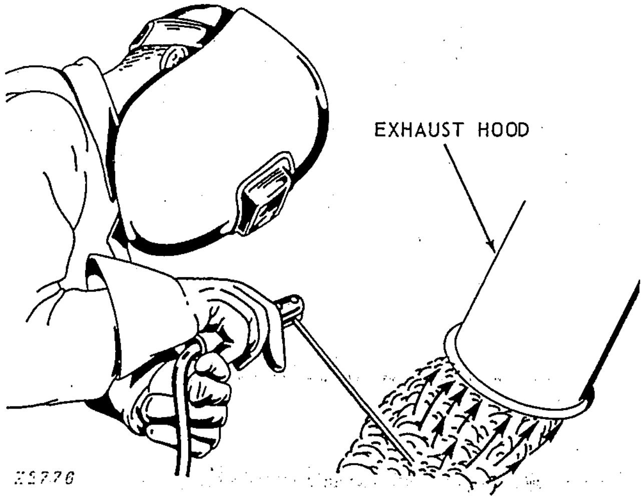


Fig. 165 — Welding Areas Must Have Ventilation

WORKING ON TANKS AND CONTAINERS

Welding of containers should be done only by personnel familiar with American Welding Society's standard practice recommendations (A.W.S.-A6.0-65).

Don't weld or cut containers such as drums, barrels, tanks, until you know there is no danger of fire or explosion.

Don't depend on your eyes or nose to decide if it is safe to weld or cut a closed container — find out what was in the container or use an explosimeter. A very small amount of residual flammable gas or liquid can cause a serious explosion.

Never use oxygen to ventilate a container.

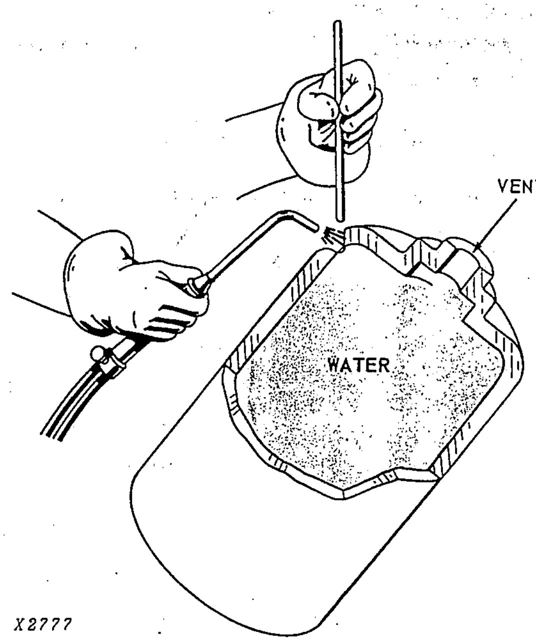


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Fig. 166 — Proper Way to Weld a Container

When you know the container held a gas or liquid which will readily dissolve in water:

Do not weld on metals that have been cleaned with chlorinated hydrocarbon-type solvents or degreasers. Solvents or degreasers left on the metal can produce harmful gases when they are decomposed during the welding or cutting process.

(1) **Flush out with water** several times and *then fill with water* as fas as work permits, positioning container to permit introduction of as much water as possible (Fig. 166).

(2) Before welding or cutting, be sure there is a vent or opening to provide for release of air pressure as shown.

When you know the container held a gas or liquid which will not readily dissolve in water:

(1) Clean out thoroughly with steam or a cleansing agent and fill with an inert gas such as carbon dioxide or nitrogen before repairing. Carbon dioxide is heavier than air and will tend to remain in the container if the opening is at the top.

(2) Use steam to clean out light materials.

(3) Use a strong caustic soda solution to clean out heavy oils or grease.

(4) Be sure to fill with inert gas, such as nitrogen or carbon dioxide, no matter how well you have cleaned — there may still be traces of oil, grease, or other readily oxidizable material under the seams.

Be careful when cleaning with steam or caustic soda — wear goggles and gloves. Don't clean where there is poor ventilation. Ventilation is necessary to carry away harmful or explosive vapors. When scraping or hammering to remove heavy sludge or scale, use a spark resistive tool and keep it wet to avoid sparks. Keep your head and arms as far away from your work as possible.

FIRE PREVENTION

Fires may result from gas or arc welding and cutting operations if combustible materials are allowed to come in contact with *flying sparks, falling slag, hot metal,* or the *arc or flame* itself.

Remember:

- *flying sparks can travel as much as 35 feet (11*
- *falling slag can pass through cracks out of sight of the goggled operator, or*
- *the metal being cut or welded (or the arc or flame itself) can be hot enough to ignite combustibles.*

To prevent fires:

1. *Keep flames and sparks away* from cylinders and hose.

2. *Move the job,* if possible, to an area free of combustibles. Never work near explosive atmospheres. Avoid paint spray rooms, dip tanks, storage areas, ventilators, etc.

3. *Move combustiles* at least 30 to 40 feet (9.1 to 12 m) away from the job. Sweep the floor before lighting torch. Wet down wooden floors.

4. *Cover combustibles* with fire resisting shields or covers, if they cannot be moved. Covers should be large enough to completely shield the material and tight enough to prevent sparks from gc under, over, or between the covers to the materiai. Use heat resisting asbestos shields to protect nearby walls, ceilings and floors.

5. Use stand-by *watchers* equipped with suitable fire extinguishers where the risk of serious fire damage is great.

6. *Inspect the area* on completion of the job to make sure that it is free of sparks, glowing embers and flames. Check 30 minutes later.

7. *Do not bring cylinders into confined spaces.*

8. *Avoid oxygen leaks* in enclosed spaces. Do not leave oxy-fuel gas torches in enclosed spaces when not in use.

9. Never use oxygen to dust off clothing or work. A spark will cause clothing in an oxygen atmosphere to burst into flame immediately.

10. *Never use oxygen* in pneumatic tools, in oil preheating burners, to start engines, to blow out pipelines, to create pressure in a container — anywhere, as a substitute for compressed ai other gases.

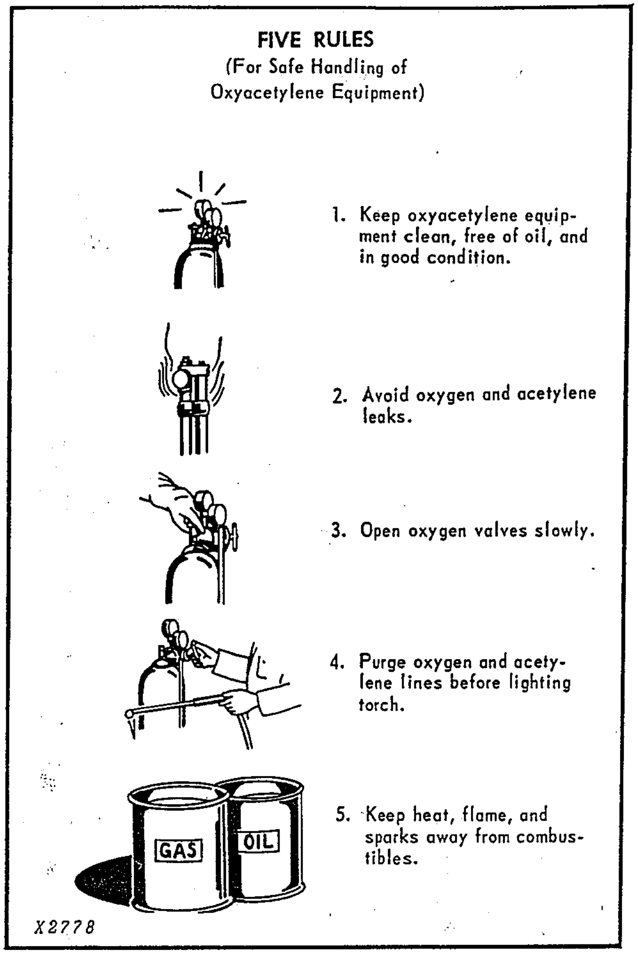

Fig. 167 — Five Rules For Safe Handling of Oxyacetylene Equipment

OXYACETYLENE SAFETY

Oxyacetylene welding safety will be covered under the following subjects:

- **Cylinders**
- **Torches and Regulators**
- **Hoses**
- **Setting Up**
- **Adjusting Pressures**
- **Operating the Torch**
- **Backfires and Flashbacks**
- **Stopping Work**

Let's look at safety for each subject in detail.

CYLINDERS

Use approved cylinders. They are safe so long as they are properly handled. **Don't drop cylinders.**

Always call acetylene "acetylene" — not "gas." Call oxygen "oxygen" — not "air." The word gas is a general term and confusion here is dangerous. The use of the term "air" instead of the word "oxygen" may lead to serious accidents.

Identify gas content by the *name marked on the cylinder.* If the cylinder is unmarked, do not use it! Return it to the supplier. Do not rely on color codes.

Never use a cylinder or its contents for other than intended purposes.

Keep oil and grease away from cylinders and cylinder valves.

Separate oxygen from fuel gas cylinders, in storage.

Keep cylinders away from exposure to sparks, hot slag, open flame and all possible sources of excessive heat.

Be careful that cylinders are not placed so as to become a part of an electrical circuit. Avoid third rails, wires and electric welding circuits.

Never strike an arc on, or tap an electrode against a cylinder.

Take care to place cylinders clear of passageways for personnel and equipment.

Always secure upright cylinders to a suitable support with a chain or other holder (Fig. 168).

Always transport, store and use acetylene cylinders in the vertical position to avoid "spitting" acetone.

When transporting cylinders by crane, use cradle, platform or other suitable support.

Never lift the cylinders by slings, by the caps or by electric magnets.

Never use cylinders as support or rollers.

Never try to mix any gases in a cylinder.

Never try to refill a cylinder.

Mark empty cylinders "Empty" or "MT."

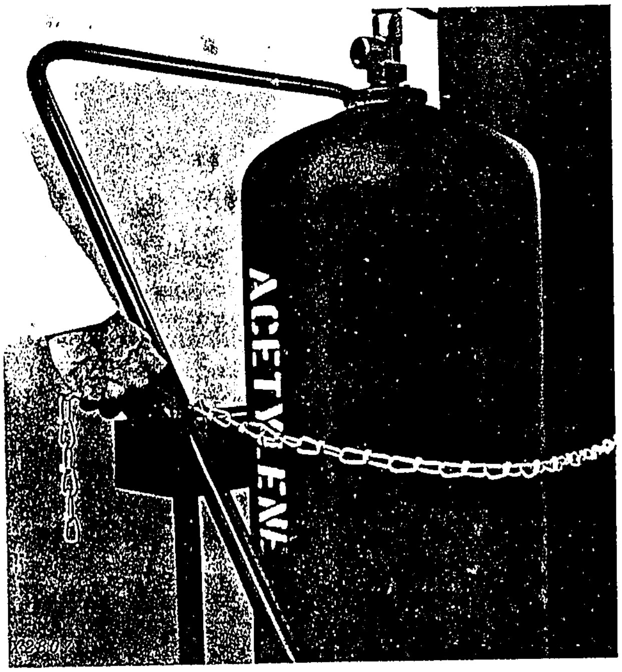

Fig. 168 — Always Secure Upright Cylinders

Send "Emptys" back to the supplier promptly.

Keep "Emptys" and "Fulls" separate.

Never tamper with or alter cylinder numbers or other markings. This is not only foolish but may be illegal.

Do not tamper with or change fittings on cylinders.

If valves cannot be opened by hand, do not use hammer or wrench. Notify supplier.

Leaks may be found in acetylene cylinder valves, when valves are open, that cannot be stopped by closing the valve and tightening the packing gland. Leaks may also be found at acetylene fuse plugs or in the cylinder. If these types of leaks are found (1) remove cylinder out of doors away from possible sources of ignition; (2) tag cylinder properly to explain the trouble; (3) notify supplier as soon as possible.

Protect cylinder valves from bumps, falls, falling objects, and from weather. Keep them covered with cylinder caps when moving cylinders.

Keep valves closed on empty cylinders.

If an adapter is required between cylinder and regulator, always use a standard adapter. These may be obtained from your supplier. Where right- and left-hand threads are used on adapter, use two wrenches to insure leakproof connections.

Never use other than approved wrenches for opening acetylene cylinder valves not equipped with handles. These should be obtained from the sup pliers.

Do not store cylinders in unventilated areas.

TORCHES AND REGULATORS

Do not work with defective equipment. Have leaking or damaged equipment repaired by authorized servicemen.

Give Your Oxyacetylene Equipment the Same Good Care and attention you would any other dependable tool. Your work will be easier — and safer.

Keep your equipment clean. Oil and grease in the presence of oxygen may burn with explosive violence if ignited. Do not use oil, grease or other readily oxidizable substances on any torch or regulator. Do not handle equipment with oily rags or gloves. Check systems for leaks under operating pressure.

Inspect union nuts, connections and all seating surfaces on regulators and torches before use. Damaged connectors should be removed and faulty seats repaired at once — they are apt to cause fires, backfires or flashbacks.

Never connect a regulator to a cylinder containing a gas other than that for which the regulator is designed.

If a regulator shows excessive creep (pressure building up when torch valves are closed), close cylinder valve and have regulator repaired at once.

Have pressure gauges on regulator tested periodically for accuracy.

If the pressure gauge needle does not return to the stop pin when pressure is released, do not merely adjust the pin. Have the gauge checked for accuracy.

Never test or calibrate regulator pressure gauges with oil.

Never use a torch as a hammer or to knock slag from work. Deformation of the torch or tips may cause trouble. Keep slag hammers and wire brushes handy.

Never use a hard, sharp tool for cleaning tips, except where specifically recommended by the tip manufacturer. Use appropriate tip cleaners or a copper or brass wire. When possible, clean orifices from the inner end. An oversize or bellmouth orifice may lead to trouble.

Fig. 169 — Use Special Wrenches To Make Connections (If Recommended)

Make connections using wrenches designed for that purpose (Fig. 169). A standard wrench which fits your connections may be obtained from your supplier. Wrenches need not be used on connections using an O-ring seal which can be made gas-tight by hand.

If a leak develops around the torch valve stem, tighten the packing nut. If necessary, have valve repacked. *(Use only packing* supplied or *recommended* by the torch *supplier.)*

The gases used on oxyacetylene jobs should never be drawn from cylinders except through properly attached pressure regulators approved for oxygen or acetylene service. *Uncontrolled, pressure is dangerous in itself.* The regulator, properly adjusted, also acts as a safety device tending to stop any flashback from entering the cylinder, (or manifold) where it might cause serious damage.

HOSES

All new hose is dusted inside with talcum powder — blow this out before using. Do not use compressed air hose. This hose may contain oil.

Use only hose designed for use with the gas source to which it is to be connected.

Hoses should be color-coded to avoid mixing, and a groove in the nut will generally indicate a left-hand thread. Oxygen hoses are usually green, while acetylene hoses are normally red — but be sure.

Standard hose connections are threaded, right-hand for oxygen and left-hand for acetylene, to prevent accidental interchange of oxygen and acetylene hoses. Do not interchange fittings on hoses or use other than standard hose fittings.

Never use ordinary wire as a binding in making up hose connections. Use binders or clamps designed for hose use.

Use only standard brass splices for splicing hose — never use copper tubing.

Avoid long lengths of hose. They tend to kink and to be mistreated. When long lengths are necessary, be sure all connections are tight.

Keep oil and grease away from hoses.

Protect hoses from sparks, hot slag, hot objects, sharp edges, and open flame.

If a hose is burned by a flashback, discard that length of hose. A flashback burns the inner walls and makes the hose unsafe.

Examine all hose periodically for leaks, worn places, and loose connections. Escaping acetylene may start a serious fire or cause severe burns.

Test for leaks by immersing the hose — under normal working pressure — in water. Repair leaks and worn places at once by cutting the hose and remaking the joint with standard fittings.

Do not try to repair hoses with tape.

SETTING UP

See that your cylinders and equipment are clean, in a safe location, in good working order and adequate for the job intended.

Be sure your gloves are not oily and that your clothing is designed to protect you properly.

Before connecting regulators to cylinders, crack the cylinder valve carefully to blow out any foreign matter that might harm seats, clog orifices, or become ignited.

Never crack an acetylene valve near other welding work, sparks, open flames or persons.

Never force connections.

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Before opening the cylinder or manifold valve, make sure that the regulator is drained of gas by engaging regulator adjustment screw and allowing gas to flow out of the regulator. This will allow the high-pressure seat to open when pressurizing the regulator and will prevent excessive compression temperatures at the high-pressure seat.

After all the residual gas has been drained, completely release the adjusting screw. This will prevent the regulator from feeding gas into the line when the regulator is pressurized, until the adjusting screw is turned in.

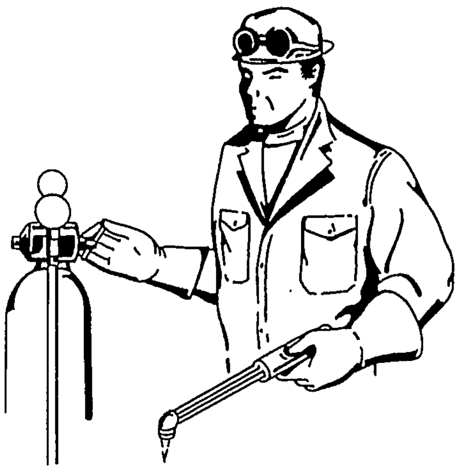

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Fig. 170 — Always Stand To One Side When Opening Cylinder Valves

Stand to One Side of the Regulator Gauge when the cylinder valve is opened (Fig. 180). Open all cylinder valves **slowly**. When pressurizing the regulator with the HP gauge, particularly the oxygen regulator, open valve slightly so that the HP gauge pointer moves slowly to maximum reading.

Never open an acetylene cylinder valve more than 1-1/2 turns and preferably less than a single turn — but open oxygen cylinder valves completely. Opening acetylene cylinder valves wide is unnecessary, but opening oxygen valves wide seals the clearance around the stem and prevents leakage. Inert gas cylinders also must be opened completely when in use.

Leave valve wrench in position whenever acetylene cylinder valves are open. This will allow quick closing in an emergency.

Standard hose is not always color-coded although connections are thread-coded. Follow your connections through when setting up and make sure oxygen and acetylene lines are not interconnected.

Be sure all connections are tight. Never try to locate a leak with a flame — use soapy water.

Coil excess hose neatly so it cannot kink or tangle. Place hose so it will not be stepped on or run over and so it is clear of sparks and slag from your work.

ADJUSTING PRESSURES

Improper pressures are not only wasteful, they prevent you from doing your best work and they can be **dangerous.** Flashbacks can be caused by improper pressures.

Use manufacturer's charts as a guide to correct pressures for your job.

The use of acetylene at pressures in excess of 15 psig (103 kPa) [30 psia (206 kPa)] for welding, cutting and heating (or in pressurized chambers) is not recommended.

In adjusting oxygen pressure, first be sure that the torch acetylene valve is closed. Open the torch oxygen valve. Adjust your oxygen regulator until low-pressure gauge indicates proper pressure, while torch valve is open and oxygen is flowing through the tip. Close torch oxygen valve.

In adjusting acetylene pressure, first be sure that the torch oxygen valve is closed. Then follow same procedure as for oxygen.

OPERATING THE TORCH

Purge each hose before lighting the torch.

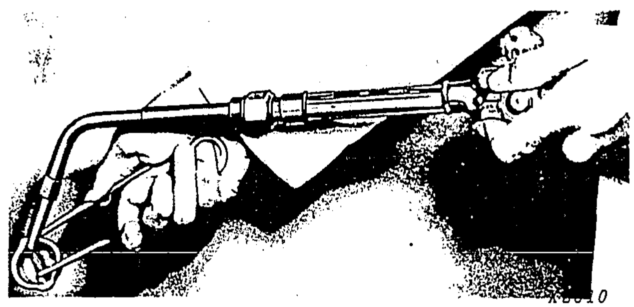

Fig. 171 — Light Torch with Sparklighter or Pilot Light — Don't Use Matches

Light Torch With Sparklighter or Pilot Light (Fig. 171). Don't use matches.

Never direct gas stream towards self or others. When lighting or handling torch, be careful to keep flame and sparks directed away from personnel, flammables and equipment. (See "Fire Prevention.")

Do not bring cylinders into confined spaces.

Take all precautions for ventilation, protective clothing, etc. covered in earlier sections.

BACKFIRES AND FLASHBACKS

A **backfire** is a loud noise associated with the momentary extinguishment or re-ignition of the flame at the torch tip. It may be caused by touching the tip against the work, by particles entering the tip and obstructing the gas flow, or by over-heating the tip. Sometimes the trouble will clear itself immediately and, if work is hot enough, the torch will relight automatically. If this does not happen, close oxygen torch valves immediately (cutting and then pre-heating valve). Close acetylene valve. Then relight, using standard lighting procedure which includes purging the hose lines. Before relighting, check your pressures.

A **flashback** is the burning back of the flame into the tip or torch (or the hose if an explosive mixture is present in one of the lines). It is sometimes accompanied by a hissing or squealing sound and a smoky or sharp-pointed flame. This condition requires extinguishing the flame by closing first the torch oxygen valve and then the torch acetylene valve. Then wait a few moments to be sure the fire in the torch or hose has a chance to burn out. Flashbacks can be caused by failure to purge, improper pressures, distorted or loose tips or mixer seats, kinked hose, clogged tip or torch orifices or over-heated tip or torch.

Flashbacks mean that something is radically wrong with your equipment or your handling of it.
Before attempting to relight your torch, check for trouble as follows:

First of All, Did You Purge Your Lines individually before lighting? Did you check your pressures? Are they near recommended pressures? Then remove hoses from torch and inspect for damage. If the flame has burned back into the hose, cut back to undamaged portion of the hose and remake connections (with standard clamp device). Again: In setting up, be sure hose does not lay where it may be stepped on or run over. Avoid long lengths of hose. Use recommended pressures.

STOPPING WORK

Close oxygen torch valve first, then acetylene torch valve, making sure that flame left at the tip is extinguished and the acetylene torch valve is closed tight.

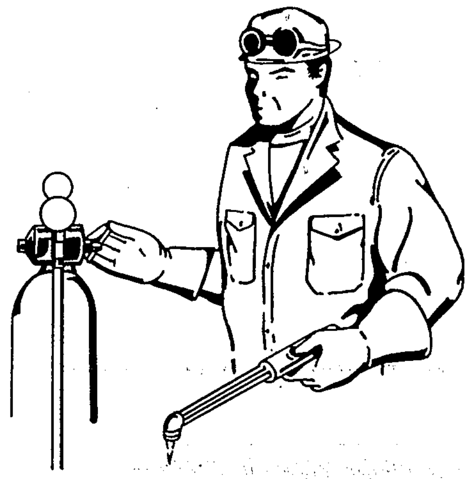

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Fig. 172 — Stopping Work

When shutting down for a brief interval, close torch valves only and leave the hose and torch in orderly fashion so they will not be injured or disturbed.

Never hang a torch or hose on a regulator or cylinder valve unless the cylinder and torch valves are closed, and the hose is drained of gas.

Do not crimp hose to stop flow of gases temporarily as in changing torch or tip.

When work is completed, or when leaving area for any reason, proceed after closing torch valves as follows:

1. *Close cylinder valves (Fig. 172).*
2. *Drain all oxygen from hose and regulator by opening torch oxygen valve. Then close torch oxygen valve.*
3. *Drain acetylene in the same manner.*
4. *Release regulator pressure adjusting screws.*

When shutting down for an extended period, disconnect all apparatus and store it. In this way, unauthorized personnel will not be using the equipment, and equipment will not be damaged accidentally.

Make sure cylinder valve is tightly closed before removing regulator.

SAFETY IN ARC WELDING

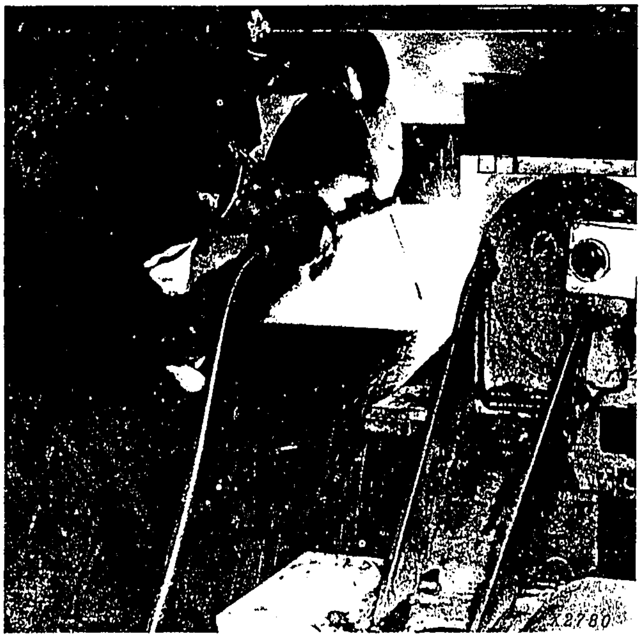

Fig. 173 — Arc Welder at Work

Arc welding includes shielded metal-arc, gas-shielded arc and carbon-arc welding. Only general safety measures can be indicated for these areas because arc welding equipment varies considerably in size and type. Equipment may range from a small portable shielded metal-arc welder to highly mechanized production gas-shielded arc welders. In each case, follow the specific recommendations of the manufacturer.

Safety practices which are generally common to all types of arc welding operations are as follows:

1. Welding equipment should be installed according to provisions of the National Electric Code.
2. A welding machine should be equipped with a power disconnect switch which is conveniently located at or near the machine so the power can be shut off quickly.
3. Repairs to welding equipment should never be made unless the power to the machine is shut off. The high voltage used for arc welding machines can inflict severe and fatal injuries.
4. Welding machines must be properly grounded. Stray current can cause severe shock when undergrounded parts are touched.
5. Never change the polarity switch while the machine is under a load. Wait until the machine idles and the circuit is open. Otherwise, the contact surface of the switch may be burned and the resulting arcing could cause an injury.
6. Welding cables should not be overloaded or a machine operated with poor connections. Operating with currents beyond the rated cable capacity causes overheating. Poor connections may cause the cable to arc when it touches metal grounded in the welding circuit.
7. Avoid damp areas and keep the hands and clothing dry at all times. Dampness on the body may cause an electric shock.
8. Never strike an arc on a compressed gas cylinder.

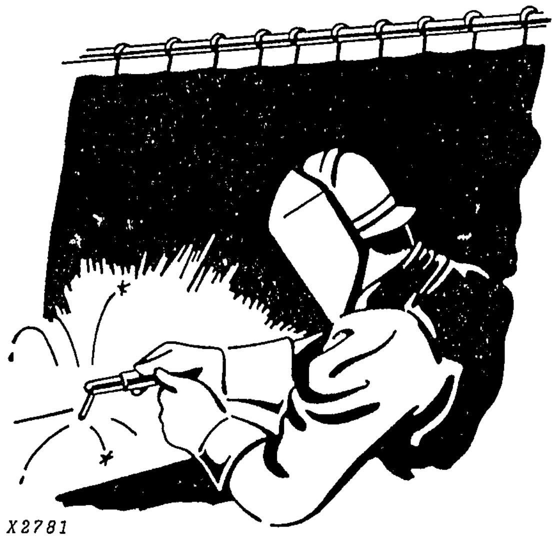

Fig. 174 — Use a Protective Screen To Protect Others From Arc Rays

9. Do not strike an arc if someone is nearby without proper eye protection. Arc rays are harmful to the eyes and skin. Use a screen to protect others (Fig. 174).
10. Robotic welding machines should be effectively guarded at all times.
11. Suitable spark shields must be used around equipment in flash welding.
12. Keep the uninsulated portion of the electrode holder from touching the welding ground when the current is on. This will cause a flash.

13. Keep welding cables dry and free from oil and grease.

14. Never carry welding cable coiled around the shoulders when they are carrying power.

15. Observe all the general precautions on protective clothing, ventilation, and fire prevention which are outlined in the earlier part of this section. Be sure to wear adequate ear protection.

16. Put hot electrodes in a container and not on the floor or in the work area.

17. Remove electrodes from the holder when you stop working.

18. Check your welding helmet for cracks and other defects such as broken lenses by holding it in front of a direct light source before welding. Do not use a helmet that allows light to shine through cracks or separations in the material.

19. Avoid breathing fumes when welding galvanized metal, paint, or zinc.

SAFETY IN CUTTING

Fires often occur in cutting simply because precautions were not taken. Too often an operator forgets that sparks and falling slag can travel as much as 35 feet (10.5 m) and can pass through cracks out of sight of the goggled operator.

Observe these rules when cutting:

1. *Never use a cutting torch where sparks will be a hazard such as near rooms containing flamable materials, especially dipping or spraying rooms.*

2. *If you must do cutting over a wooden floor, sweep the floor clean and wet it down before starting. Use a bucket or pan containing water or sand to catch the dripping slag.*

3. *Keep a fire extinguisher nearby whenever any cutting is done.*

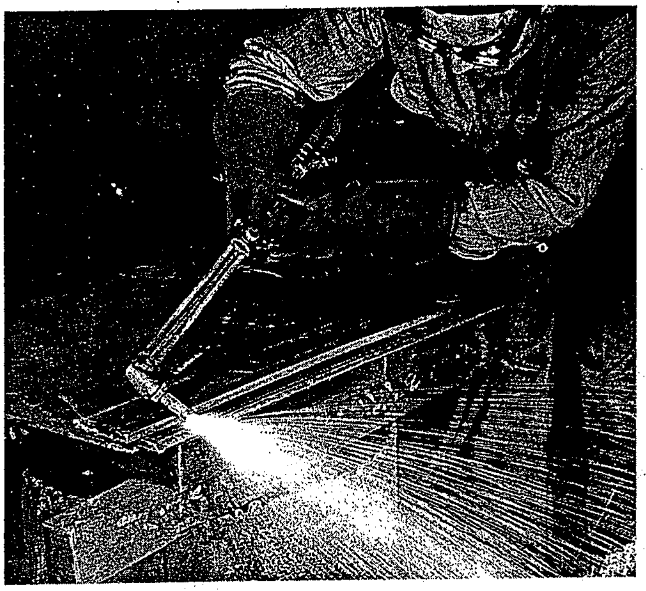

Fig. 175 — Sparks Can Be A Fire Hazard In Cutting Operations

4. *Whenever possible, do cutting in wide open areas so sparks and slag will not become lodged in crevices or cracks.*

5. *If cutting is to be done near flammable materials and the materials cannot be moved, suitable fire resisting guards must be securely installed.*

6. *In shops where there is a dirty or gassy atmosphere, take extra precautions to avoid explosions resulting from electric sparks or open fire during a cutting operation.*

7. Do not weld or cut directly on concrete surfaces.

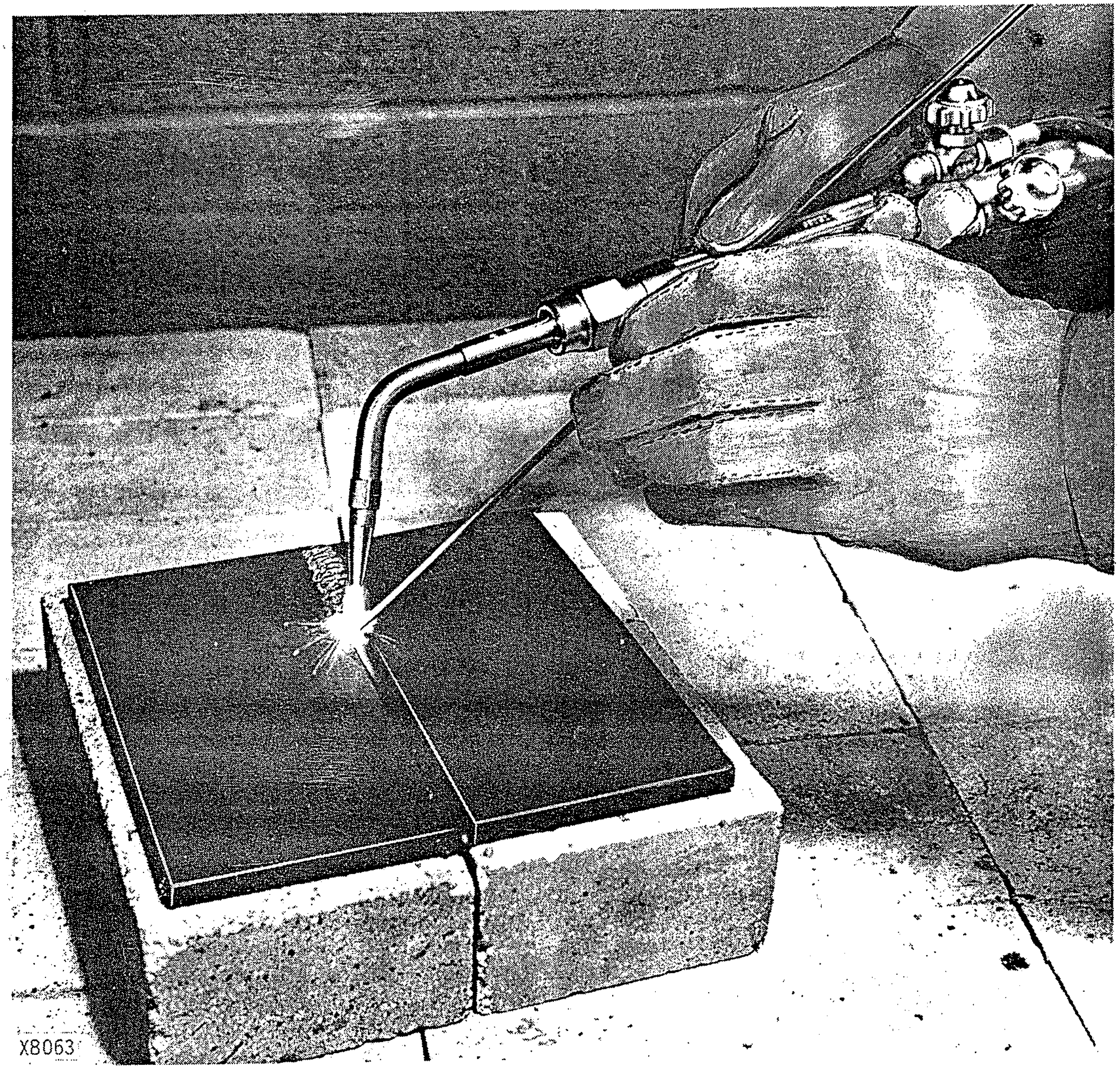

Fig. 1 — Gas Welding

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UNDERSTANDING WELDING AND CUTTING: A GENERAL INTRODUCTION FOR ALL PROCESSES

Processes And Their Applications In The Metal Trades

Processes	Welding	Cutting	Brazing	Soldering	Surfacing
	Methods of Application				
--Basic--					
Oxy-fuel	-----	X	X	X	X
Arc (SMAW)	X	X	-----	-----	X
MIG (GMAW)	X	-----	-----	-----	X
TIG (GTAW)	X	-----	-----	-----	X
Plasma	X	X	-----	-----	X
Resistance	X	-----	-----	-----	-----
--Exotic--					
Laser	X	X	-----	-----	-----
Electron Beam	X	X	-----	-----	-----
Others	X	X	X	X	X

X = Currently Being Used In Industry
----- = Not Currently Being Used In Industry

Fig. 2 — Process Chart

Craftsmen who work in the metal trades must understand and know the uses for the welding and cutting related processes in the Process Chart (Fig. 2). These processes are the tools used by the people responsible for fabricating and repairing products we depend upon in our daily activities.

A tool is only as good as the craftsman using it. A good craftsman cannot do satisfactory work unless they are equipped with the proper tools. Tools cannot be utilized to their full capability unless the craftsmen using them have a thorough understanding of their use.

IMPORTANT CONCEPTS ABOUT WELDING AND CUTTING

Welding is both an art and a craft. A weld must be applied in a craftsman-like manner so that when it is seen on a completed product it is recognized as good workmanship. Technology from many of the sciences must be utilized in selecting the proper combination of base metal, filler metal, and process for producing effects that meet today's demanding service requirements. Welding must be done with the proper combination of these variables so that quality and productivity are obtained at competitive costs.

Welding and cutting requires eye-mind-hand coordination. A person must see and then understand the activity in the molten metal as the joining or cutting process is occurring. This means that the welder must be in a position to look left and right, and ahead and behind the molten metal — all at the same instant. They must maintain the proper torch or electrode to work distance by having good depth perception. They must be able to recognize the time and place to apply heat and/or filler metal. Most of all, they must understand the operation of the equipment and be able to set and adjust it for maximum results.

LEARNING TO WELD AND CUT

Each person must teach himself or herself how to weld and cut. Teachers, textbooks, and visual aids only identify the things that must be developed. A student must first identify and learn basic concepts, quality, standards, and related safe work habits.

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WELD QUALIFICATION TESTS

Three organizations that govern weld testing are the American Welding Society (AWS), the American Society of Mechanical Engineers (ASME), and the American Petroleum Institute (API). These organizations supply "welding codes" which outline weld qualifications and welder qualifications. The AWS provides guidelines for welding products made of sheet metal, plates, structural shapes, tubing, and pipe. The ASME provides guidelines for the construction and repair of pressure vessels and piping. The API provides guidelines for welding cross-country pipelines.

Welding procedure tests must be applied first to establish the welding process, filler metal type and diameter; type current and amperage; joint preparation, preheat, interpass, and post-heat temperatures. They also help establish the correct welding technique to produce sound welds on a base metal in a specific position of welding.

Welder performance tests are given to determine whether a person has the ability to make sound welds using an established welding procedure. A performance test is given after a welding procedure has been given and approved.

There is not a "universal" welder performance test. Taking into account the many combinations of base metals, welding processes, welding positions, and welding codes, there is an infinite number of procedure and performance tests. A change in any variable usually requires requalification of the welder.

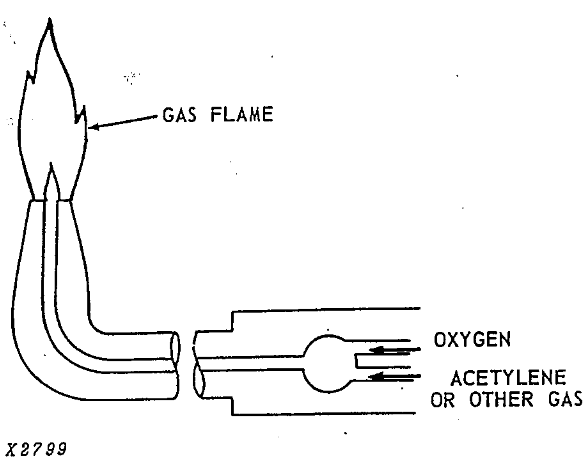


Fig. 3 — Basic Principle Of Gas Welding

OXYACETYLENE WELDING

The **oxyacetylene flame** is probably the most widely used for gas welding because of its higher flame temperature. The flame is generated by burning a mixture of acetylene and oxygen. A ratio of 2½ parts oxygen to 1 part acetylene produces a very hot flame of about 5800°F (3172°C).

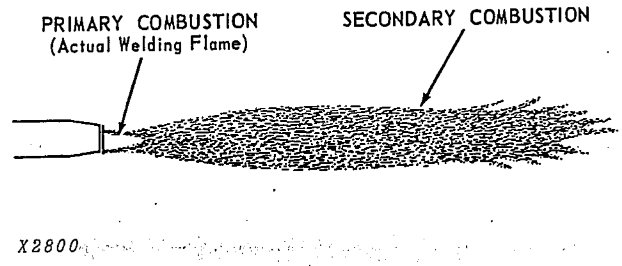


Fig. 4 — Oxyacetylene Flame

Combustion occurs in two stages (Fig. 4). *Primary combustion*, which is the actual flame for welding, is the *inner cone*.

Secondary combustion is the *outer flame* and serves as a protective shield, to prevent the air from contaminating the molten puddle, as well as preheating the welding operation.

The primary flame results when oxygen and acetylene are mixed in the welding torch in a one-to-one ratio. This mixture flowing from the torch tip burns to form the inner cone when one volume of acetylene combines with one volume of oxygen to produce two volumes of carbon monoxide and one volume of hydrogen.

The carbon monoxide and hydrogen produced by the first reaction combine with oxygen in the atmosphere to form the secondary flame.

Thus a complete combustion of acetylene results from one volume of oxygen provided by the torch and 1½ volumes provided from the surrounding atmosphere.

EQUIPMENT

The following equipment is needed for oxyacetylene welding:

- **Cylinders of oxygen and acetylene**
- **Pressure regulators**
- **Welding torch**
- **Hoses**
- **Welder's clothing**

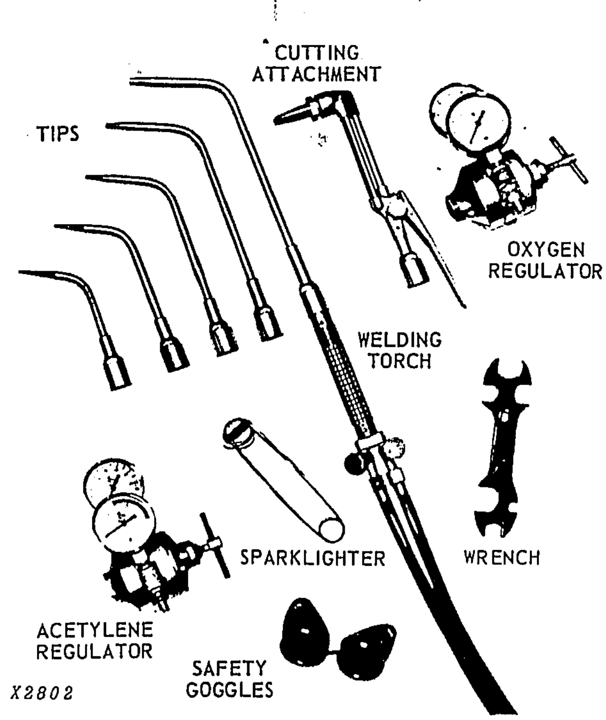


Fig. 5 — Oxyacetylene Welding Outfit

CYLINDERS

Oxygen and acetylene cylinders are made from seamless drawn steel and tested very carefully. Sizes of cylinders are based on the cubic feet (cubic meters) of gas they contain. The three common sizes of oxygen cylinders are 244, 122, and 80 cu. ft. (6.75, 3.5, and 2.25 m^3). Acetylene cylinders are made to hold 300, 100, and 60 cu. ft. (8.5, 2.75, and 1.75 m^3).

Cylinders are equipped with a safety device to permit the gases to drain slowly in the event that heat raises the pressure beyond the safety load of the cylinder. Since gases expand when heated and contract when cooled, the safety device is a must.

The flow of oxygen from the cylinder is controlled by a high-pressure valve which is opened and closed by turning a hand wheel. The hand wheel must be turned slowly to permit a gradual pressure load on the regulator and opened as far as the valve will turn to get full gas pressure.

Acetylene cylinders are packed with a porous material saturated with acetone. The acetone absorbs large quantities of acetylene under pressure without changing the nature of the gas itself. This is necessary because free acetylene cannot be stored in cylinders since it becomes dangerously unstable when under pressure in a free state. (Actually, acetylene should never be used beyond a 15 psi (100 kPa) pressure.)

The cylinder valve on acetylene cylinders is opened with a special wrench. The valve should be opened to not more than one and one-half turns. A slight opening is advisable since it permits closing the valve in a hurry in case of an emergency.

When the volume demand of gas is high, especially for continuous operation over a long period of time, the oxygen and acetylene cylinders are attached to separate manifold systems. The gas in each system flows into the main stream and is controlled by a single master regulator.

Oxygen and acetylene cylinders are usually placed on a two-wheel cart to facilitate moving wherever welding is to be done. If cylinders are to be used at a permanent work station, be careful to chain them so they cannot be overturned accidentally.

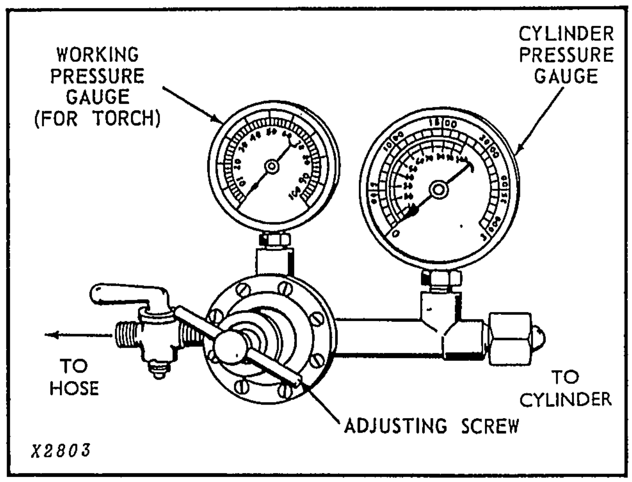


Fig. 6 — Regulators For Gas Pressures In Cylinders (Oxygen Regulator Shown)

REGULATORS

Oxygen and acetylene regulators are fastened to the cylinders. Their function is to reduce cylinder gas pressure to suitable values for welding.

For example, if an oxygen cylinder has a pressure of 1800 psi (12 400 kPa) and a pressure of 10 psi (70 kPa) is needed at the torch, the regulator must maintain a constant pressure of 10 psi (70 kPa) even if the cylinder pressure drops down to 500 psi (3450 kPa).

Both oxygen and acetylene regulators have two gauges (Fig. 6). One gauge tells the actual pressure in the cylinder and the other shows the working or line pressure used at the torch.

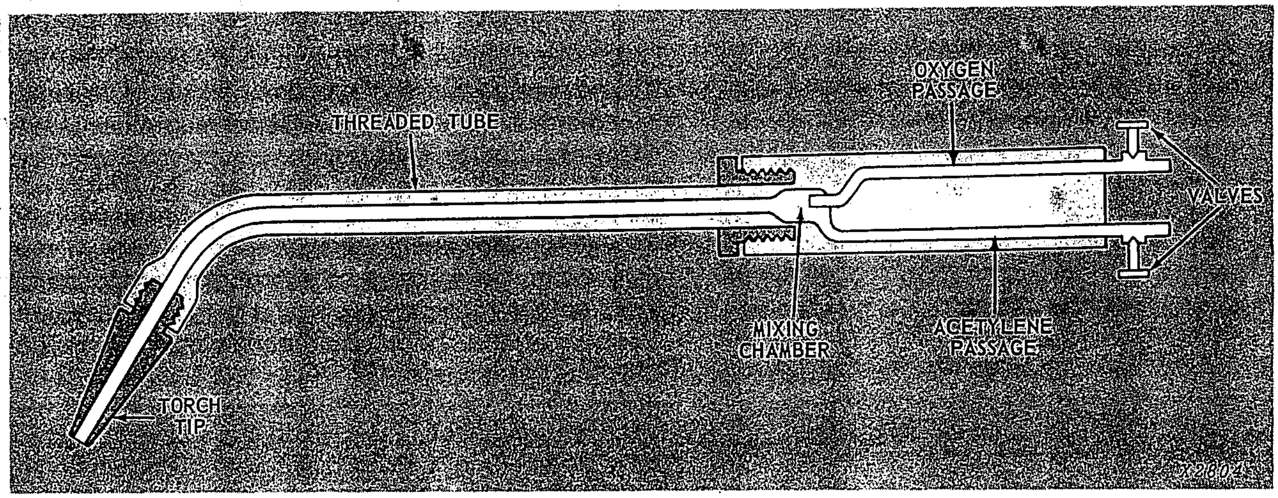


Fig. 7 — Welding Torch

Gas flow from a cylinder is regulated by an adjusting screw. This screw must always be released before a cylinder valve is opened; otherwise, the tremendous pressure of the gas in the cylinder is forced on the working pressure gauge which may damage the regulator.

Torch Operating Pressures*

Tip Number	*Thickness Of Metal* *(Inches)*	*(mm)*	*Oxygen Pressure* *psi*	*kPa*	*Acetylene Pressure* *psi*	*kPa*
00	1/64	0.4	2½	17	1	7
0	1/32	0.8	2½	17	1	7
1	1/16	1.6	2½	17	1	7
2	3/32	2.4	5	34	2	14
3	⅛	3.2	7½	52	3	21
4	3/16	4.8	10	70	4	28
5	¼	6.4	12½	86	5	34
6	5/16	8	15	103	6	41
7	⅜	9.5	17½	120	7	48
8	½	12.7	17½	120	7	48
9	⅝	15.9	18¾	130	7½	52
10	¾ & up	19 & up	22½	155	9	62

Pressures are with torch adjusted for neutral flame — used in most welding jobs.

WELDING TORCH

The essential elements of a welding torch are a mixing chamber where the two gases are brought together and mixed, two needle control valves which control the flow of oxygen and acetylene, hose connections, and welding tip. See Fig. 7.

Different sizes of tips can be inserted in the mixing chamber to permit welding a range of metal thicknesses. The size of a tip is indicated by the diameter of its orifice which is usually designated by a number. Manufacturers of welding equipment provide charts to show the normal operating pressures for various tip sizes. See the table at left.

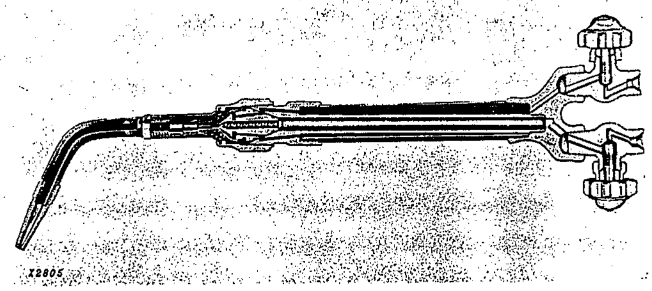


Fig. 8 — Typical Welding Torch

HOSE

Special non-porous hose is used to convey oxygen and acetylene from the cylinders to the torch. To prevent a mix-up, the oxygen hose is either green or black in color and the acetylene hose is red. Acetylene hose connections have left-hand threads while oxygen hose connections have right-hand threads.

WELDER'S CLOTHING

The operator must wear *protective goggles* while doing oxyacetylene welding. The flame and molten metal emit ultraviolet and infrared rays and both could possibly cause eye injury if viewed at close range. Goggles also protect the eyes from glare and, most important, *flying sparks*. the goggle lenses must be tinted, not clear.

Fire-resistant gloves should also be used for most welding. Heavy clothing or aprons are also suggested.

PREPARING TO WELD

Before welding, be aware of the rules below for safety, cleaning, and bevelling.

SAFETY

Observe all **safety precautions** when you are preparing to weld. The prime rules are:

1. Be sure the work area has a cement or masonry floor.

2. Keep all combustible materials at a safe distance.

3. Do not use gloves or other clothing which contain oil or grease.

4. Keep firefighting equipment handy at all times.

NOTE: For complete safety rules, see Part 11, "Welding Safety."

CLEANING METAL TO BE WELDED

Clean the metal joints to be welded of all rust, scale, paint, dirt — and especially oil. Also be sure the metals are dry.

NOTE: Any foreign material which gets into the molten metal will change the resulting metal and may weaken it.

BEVELLING METAL JOINTS

Bevel the adjoining metal before welding it — except on very thin work.

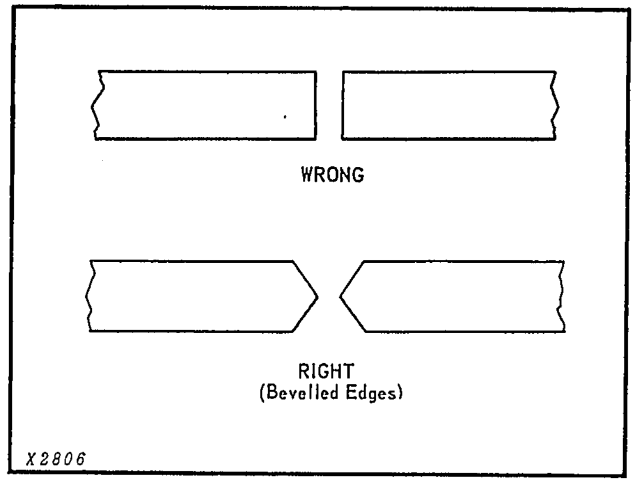


Fig. 9 — Bevelling Metal Joints Before Welding

On work less than one-fourth inch (6.4 mm) thick, bevel the edges to be welded at a 45 degree angle (Fig. 9). For work thicker than one-fourth inch (6.4 mm), bevel the edges at a 60 degree angle.

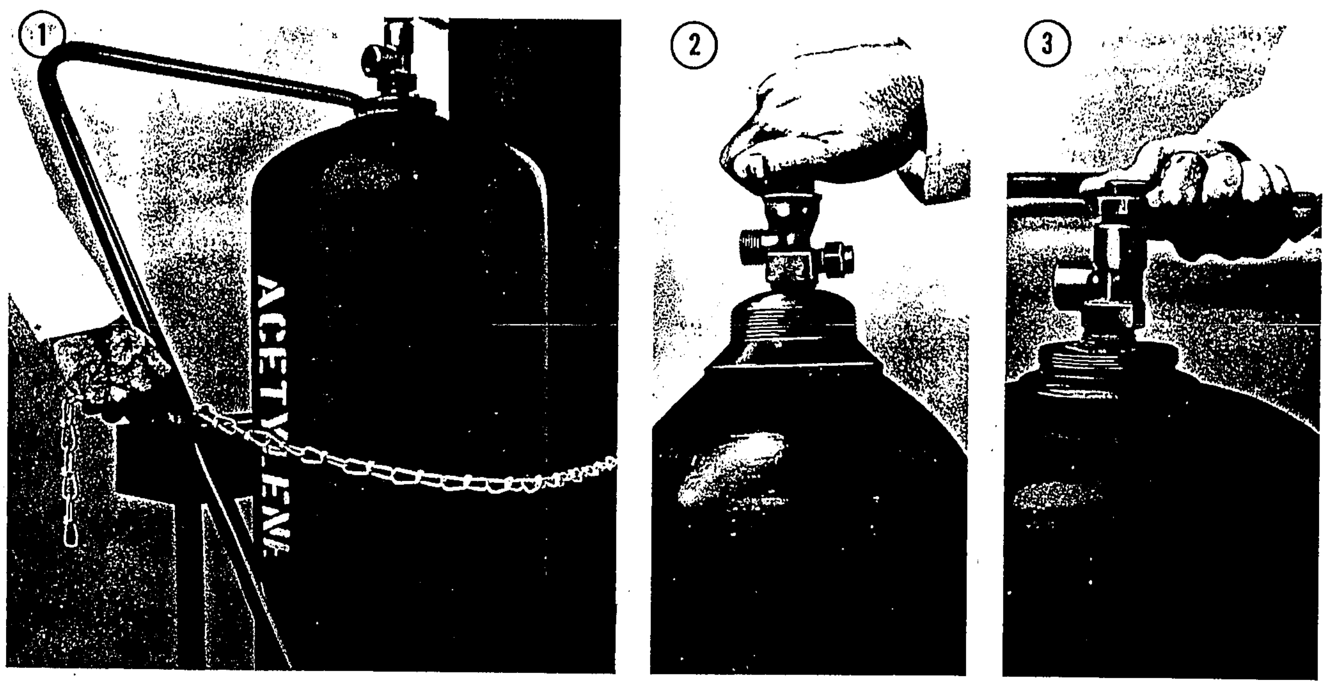


Fig. 10 — Setting Up Cylinders

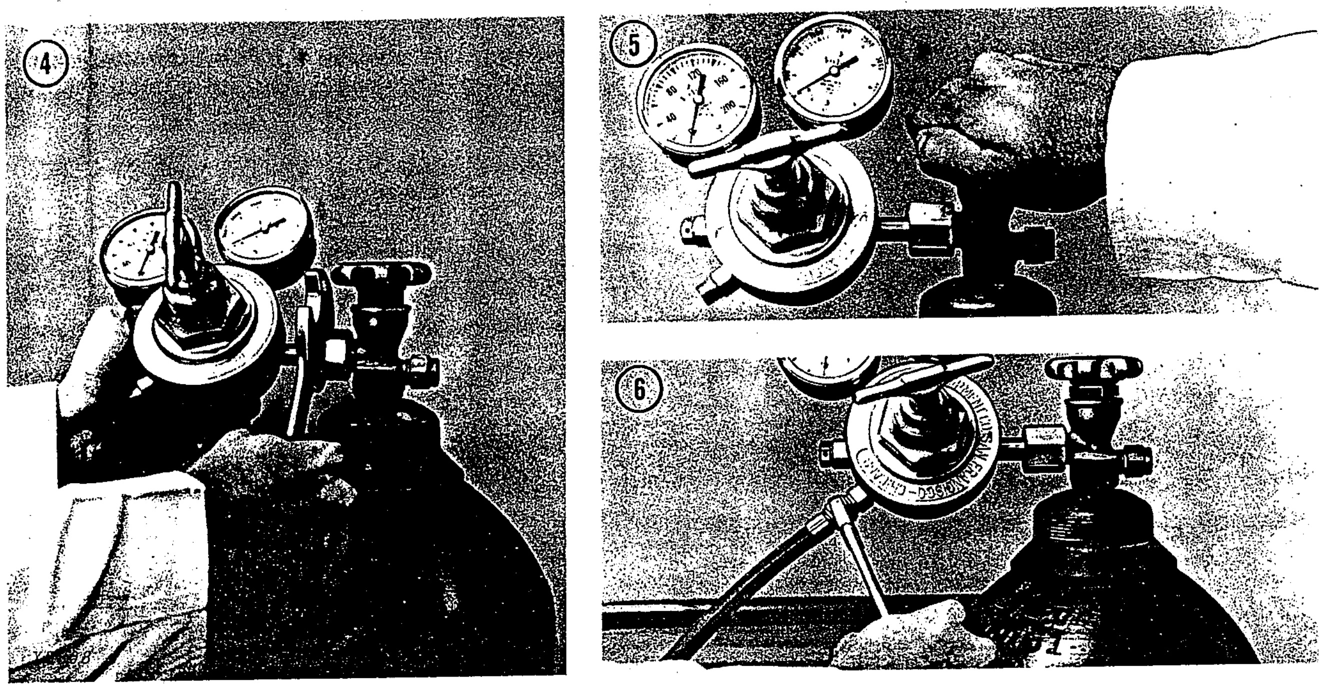


Fig. 11 — Setting Up Regulators

SETTING UP CYLINDERS

To set up new welding equipment, use the following numbered steps.

1. Place the oxygen and fuel gas cylinders together where they are to be used and secure them from falling (1, Fig. 10).

2. Unscrew the valve protection caps (2, Fig. 10). Put the caps away safely as they must be replaced on the empty cylinders before they are returned.

NOTE: Examine the cylinder valve threads. Wipe off any accumulation of dirt with a clean cloth to be certain no dirt will enter the regulator. (Cloth cannot have even a trace of oil or grease on it).

3. Slightly open (called "cracking") the oxygen and fuel gas cylinder valves to make sure they do not stick and to blow out any dirt or dust lodged in the valve (3, Fig. 10). Close the valve.

SETTING UP REGULATORS

4. Be sure that the regulator inlet connection is absolutely clean and free of all traces of dirt, grit, grease, etc. Attach the oxygen regulator to the oxygen cylinder valve using an open end wrench (Fig. 11). Do not use excessive force but tighten the regulator connection nut firmly.

NOTE: Be sure the regulator adjusting screw is in the "out" position. The adjusting screw is turned counterclockwise to release the tension.

5. Open the oxygen cylinder valve SLOWLY so the high-pressure regulator gauge needle will move up slowly until approximately 2000 psi (13 800 kPa) pressure is registered (if the cylinder is full). *Never stand directly in front or back of a regulator when an oxygen cylinder valve is opened. Always stand to one side.* After full pressure has been reached, open the valve completely.

If the valve leaks, immediately close it again and notify the supplier.

NOTE: Never use force on a cylinder valve to either open or close it. If the valve will not open or close by hand, notify the supplier and have the cylinder replaced.

Connect the fuel gas regulator in the same manner as you did the oxygen regulator.

NOTE: Open an acetylene cylinder valve only one complete turn — never more than 1½ turns.

6. Connect the oxygen hose (green) to the outlet of the oxygen regulator. The oxygen hose has right-hand thread connections. Turn the adjusting screw on the regulator clockwise or "in" until a reading of 5 psi (35 kPa) shows on the low pressure gauge. Allow the oxygen to escape until you are sure the hose is clean on the inside.

New hose may have talcum powder in it to protect the hose lining while in storage. Dust, dirt, and especially talcum powder, if left in the hose, may enter the small gas passages in the torch and plug them or cause a flashback.

Connect the fuel hose (red) to the fuel gas regulator outlet. The fuel has left-hand thread connections. Blow out the hose in the same way as you did the oxygen hose. **Remember that fuel gas will burn. Keep it away from open flames as you are blowing out the hose.**

SETTING UP TORCH

7. Connect the free ends of the oxygen hose (green) and fuel hose (red) to the welding or cutting torch you are to use. See Fig. 12. (Torch connections are normally marked "oxy" or "fuel".)

8. Select the tip or nozzle size that is suitable for the job you are to do. Refer to the Welding Tip Selection Charts furnished by the manufacturer.

9. Tighten the welding tip into the torch. Be sure that any sealing rings are in place. Tighten the tip only hand tight unless the manufacturer specifies otherwise.

10. Partially open the torch oxygen valve and adjust the oxygen regulator until the pressure corresponds to that listed for the tip you have selected.

11. Close the torch oxygen valve. Partially open the torch fuel valve and adjust the regulator pressure, using the chart as you used it for the oxygen pressure. Close the fuel valve.

NOTE: Observe that the regulator pressure rises slightly when the torch valves are closed. That is the reason for setting the regulator at required pressure with the valve open. All pressures in welding and cutting charts are **flowing** *pressures with the torch valves open.*

This is the time to check for leaks in the system — before operation. Follow the manufacturer's instructions.

OPERATING THE TORCH

12. Hold the torch in one hand and the sparklighter in the other (Fig. 13). *Don't use matches.*

13. Open the torch fuel valve approximately ½ turn and ignite the acetylene. Point the flame away from persons, the cylinders, or any flammable materials.

14. Keep opening the torch fuel valve until the flame stops excessive smoking and leaves the end of the tip about one-eighth of an inch (3.2 mm), then reduce slightly to bring flame back to the tip.

15. Open the torch oxygen valve until a bright inner cone appears on the flame. The point at which the feathery edges of the flame disappear and a

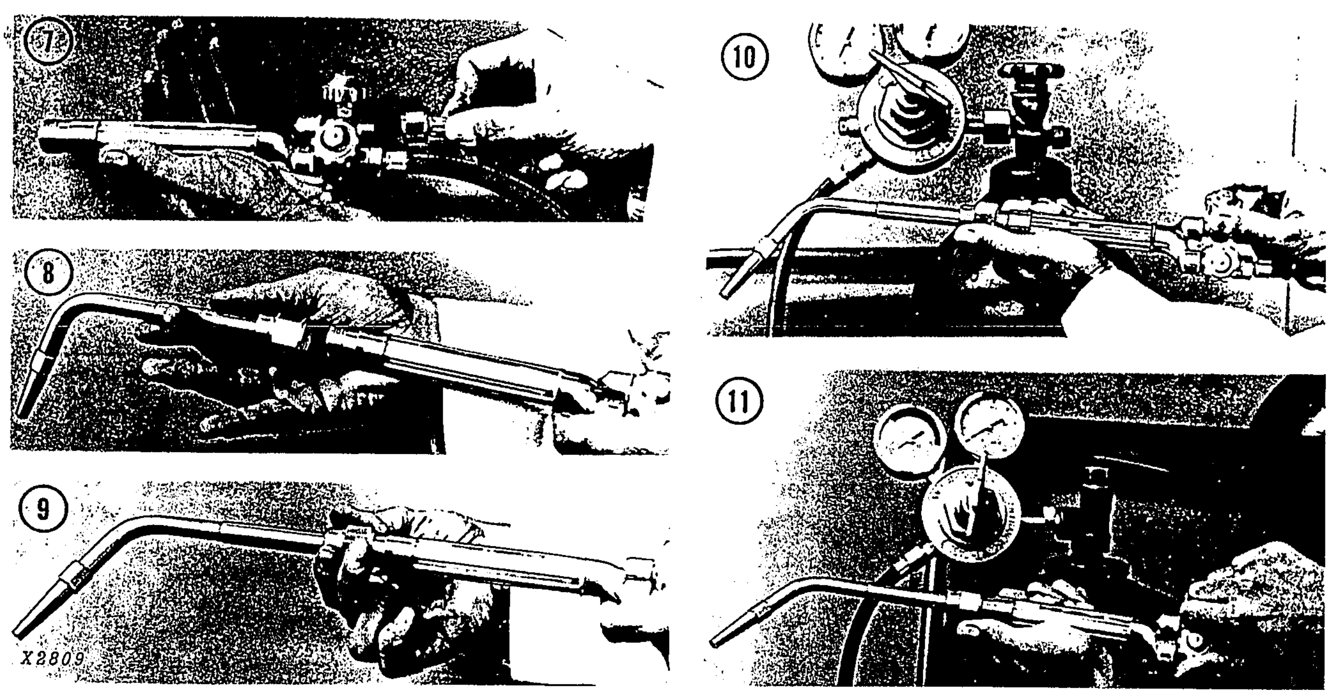


Fig. 12 — Setting Up Torch

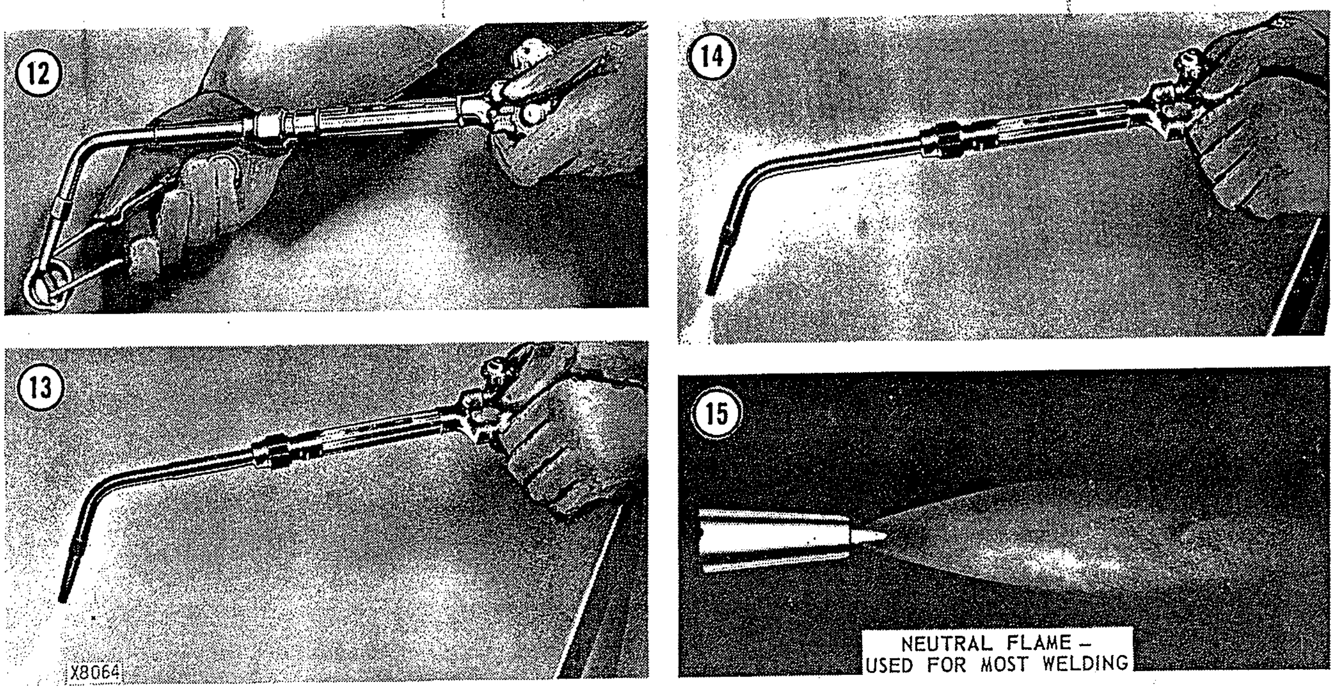


Fig. 13 — Operating The Torch

sharp inner cone is visible is called the **Neutral Flame.** Keep adjusting the torch oxygen valve back and forth until you are sure what a neutral flame looks like.

X2811 Fig. 14 — Carburizing Flame

The **Carburizing Flame,** shown in Fig. 14, is the flame you have before reaching the Neutral Flame. It is distinguished by its long carburizing feather. This flame is caused by an excess of acetylene.

An **Oxidizing Flame** is the flame that has an excess of oxygen beyond the Neutral Flame. It is a pale blue color without the clearly defined inner cone of the "Neutral Flame" shown in Fig. 13 (No. 15) above.

The neutral flame is used for most welding because it does not burn or carburize the metal.

The three flames are compared in Fig. 15.

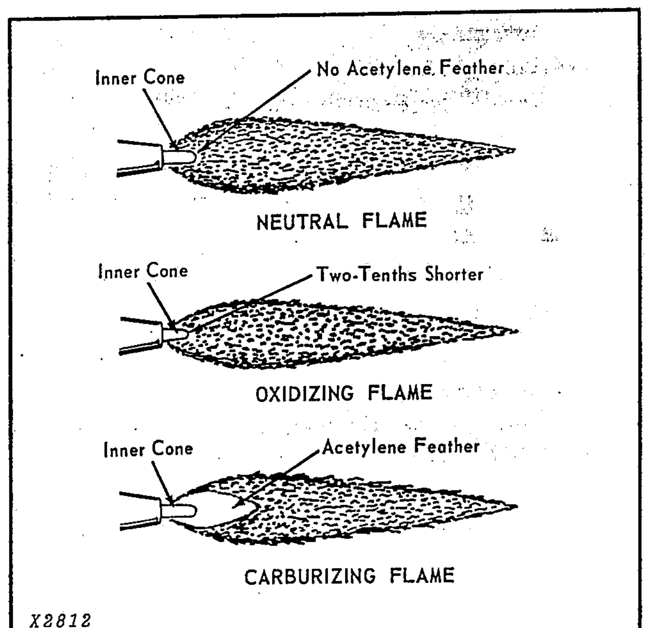
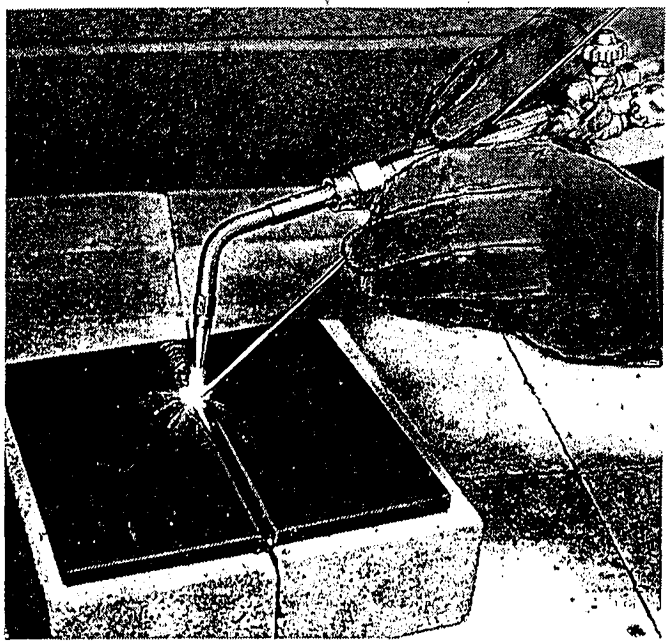
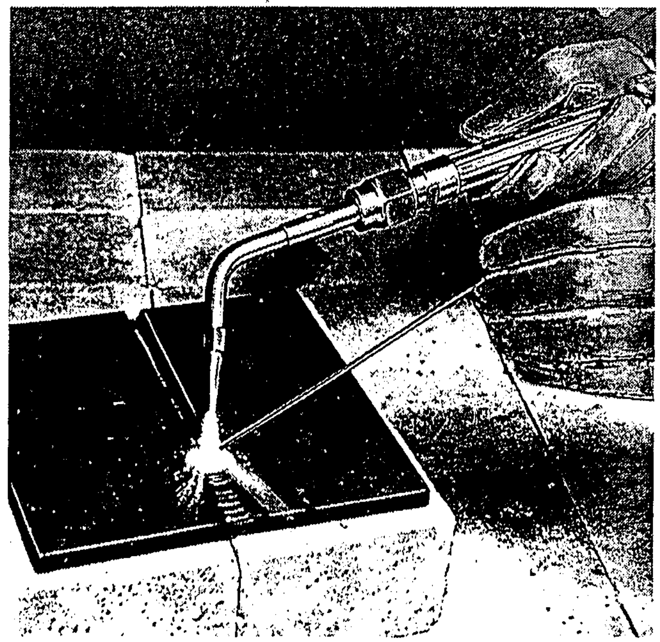


Fig. 15 — Comparison Of Three Flames

HOW TO WELD

Actual fusion of metal is achieved by moving the torch along the seam with the inner cone of the flame over the metal. The neutral flame has approximately a 1 to 1 oxygen-acetylene ratio. When the amount of oxygen is increased, the flame is oxidizing. A carburizing flame develops when there is an excessive amount of acetylene.

X8065 FOREHAND WELDING BACKHAND WELDING

Fig. 16 — How To Weld — Two Methods

A flame can also be made soft or harsh by varying the gas flow. If the flow of gas is too low for a given tip size, the flame will not fuse the metal properly and will be sensitive to backfire (popping). Too high a gas flow produces a high-velocity flame that blows the molten metal from the puddle.

The welding torch can be operated in one of two ways:

- **Forehand welding**
- **Backhand welding**

FOREHAND WELDING is performed with the torch tip pointed forward in the direction in which the weld progresses and the rod precedes the flame (Fig. 16).

In BACKHAND WELDING the tip is pointed back toward the weld which has been deposited and the filler rod is interposed between the flame and the weld (Fig. 16).

Generally, the forehand method is best for welding thin materials of ⅛ inch (3.2 mm) or less in thickness, since there is better control of the weld puddle and smoother welds are possible.

The backhand technique is usually recommended for metals that are heavier than ⅛ inch (3.2 mm) because sound welds can be made at a greater speed.

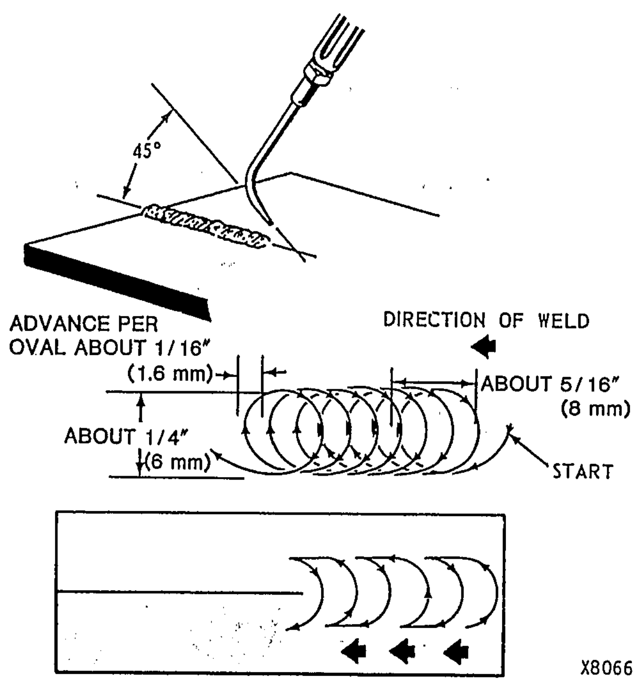


Fig. 17 — Position And Motion Of The Torch For Welding

The torch is always held at an angle of approximately 45° with the completed part of the weld (Fig. 17). As the torch is moved over the weld seam using the forehand method, it is often rotated in a circular or semi-circular motion as shown.

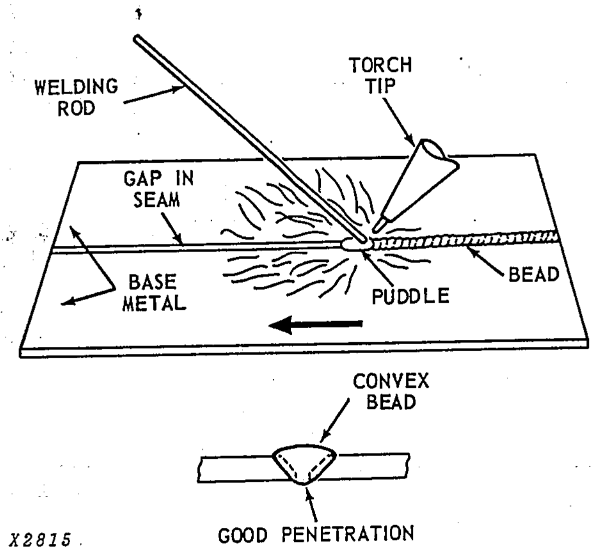


Fig. 18 — Position Of The Welding Rod

A *filler rod* of the same composition as the base metal is used in welding most types of joints. The rod is held at about the same angle as the torch but slanted away from the torch. See Fig. 18. The diameter of the rod should be equal to the thickness of the base metal. If the rod is too large, the heat of the molten pool will be insufficient to melt the rod. If the rod is too small, the heat cannot be absorbed by the rod and a hole is burned in the plate.

As the molten puddle is carried forward along the seam, the rod is dipped in and out of the molten metal. When the rod is not in the puddle, the tip is kept just inside the outer envelope of the flame.

Try not to stop in the middle of the weld as the "break" will be difficult to hide.

GOOD AND BAD WELDS

A good weld will usually have an even, slightly convex shape and will just penetrate the complete joint as shown in Fig. 19.

WELDING HINTS

1. Keep the puddle small.

2. Hold the rod in the puddle, away from the edges.

3. Concentrate the flame in the puddle and around the rod to preheat the plates ahead of the weld.

ALLOWING FOR CONTRACTION AND EXPANSION OF METAL

All metals expand when heated and contract when cooled. When welding steel plates of fairly small size, you must allow for closing of the joint opening as the welding progresses.

When two metal plates are welded in a butt joint, the following occurs:

As the weld proceeds along the joint, the metal shrinks in cooling from the molten state and tends to pull the two pieces of metal together. This shrinkage may cause the edges to lap one over the other, or warp the metal.

The operator may prepare the metal for the expansion and contraction which occurs during welding by:

1. Fusing (or *tacking*) the ends of the two pieces of the metal together before welding as in Fig. 20, A. This method will produce some internal strain, but will keep the ends sufficiently in line to enable the

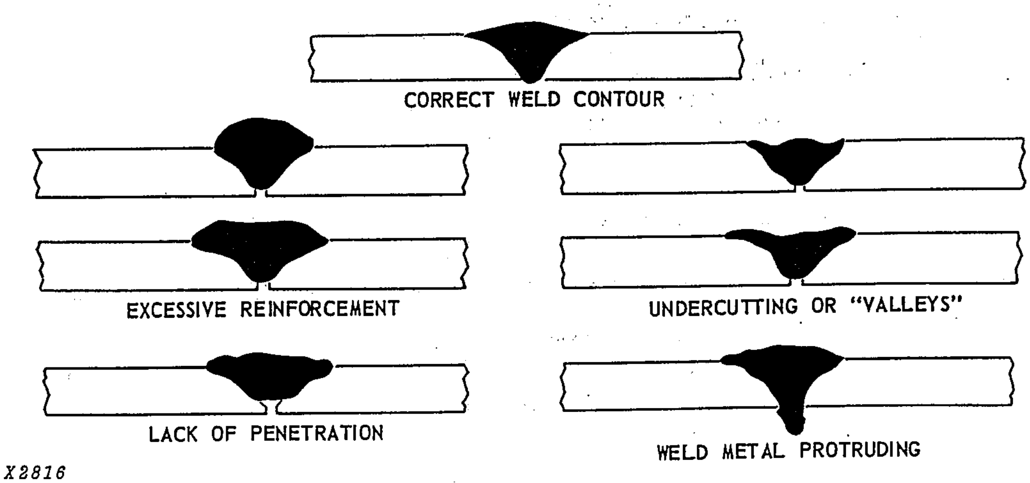


Fig. 19 — Good And Bad Welds

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operator to make a good weld. Tacking each inch or so along the joint is popular practice.

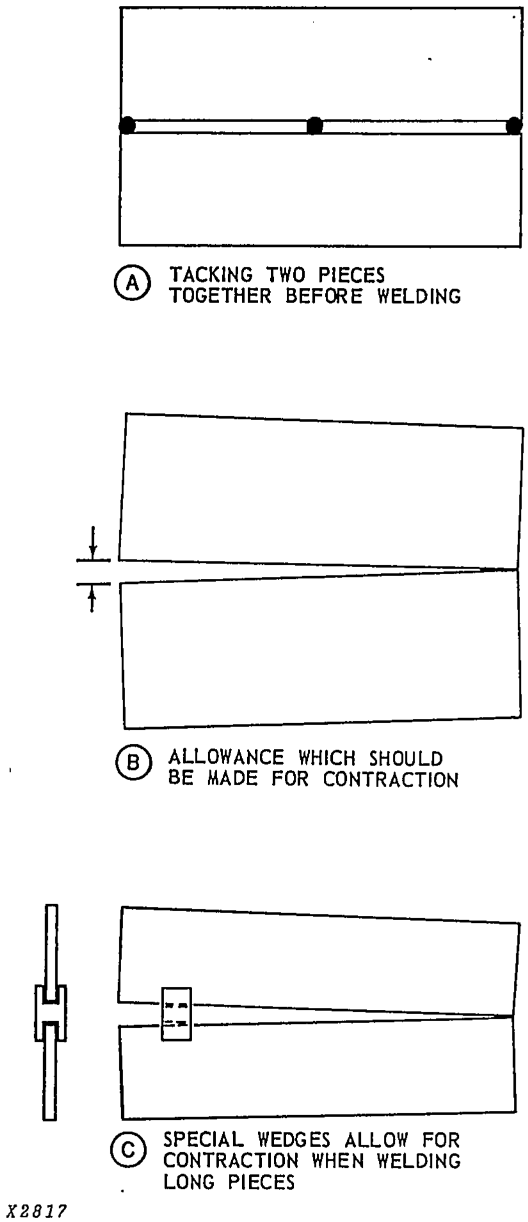

Fig. 20 — Allowing For Contraction And Expansion Of Metal Plates When Welding

2. *Tapering* the gap between the two pieces of metal to allow for contraction as shown in Fig. 20, B. The approximate contraction is from ⅛ to ¼ in. per foot (3.2-6.4 mm per 300 mm) of length of the metal (the wider the puddle, the greater the contraction).

3. Using especially prepared *wedges* which may be placed between the two pieces of the joint to prevent the contraction of the metals as the weld cools as in Fig. 20, C. This method is more generally used with long joints.

4. *Clamping* the metal in a heavy fixture to reduce movement.

MELTING POINTS OF METALS

Know the melting points of the metals you are welding. When welding two different metals, be sure to heat the one having the higher melting point first to prevent destroying the other.

Melting Points Of Metals (°F — °C)

	°F	°C
Platinum	*3200°*	*1780°*
Iron, wrought	*2900°*	*1610°*
malleable	*2500°*	*1370°*
cast	*2400°*	*1320°*
pure	*2760°*	*1520°*
Steel, mild	*2700°*	*1485°*
medium	*2600°*	*1430°*
hard	*2500°*	*1370°*
Copper	*1950°*	*1055°*
Brass	*1800°*	*985°*
Silver	*1750°*	*955°*
Bronze	*1700°*	*925°*
Aluminum	*1175°*	*635°*
Antimony	*1150°*	*620°*
Zinc	*800°*	*430°*
Lead	*620°*	*330°*
Babbitt	*500-700°*	*260-370°*
Solder	*500-575°*	*260-300°*
Tin	*450°*	*230°*

NOTE: Temperatures have been rounded.

The chart above tells you when different metals will melt.

Remember — The oxyacetylene flame is 5800° F (3172C). and will rapidly heat anything it touches directly under the flame tip.

For more information, see Part 10, "Properties of Metals."

STOPPING WORK

To stop work, close the oxygen valve first, then close the acetylene valve.

A popping noise will occur when the oxygen is shut off. A low flame of burning acetylene will remain until the acetylene valve is closed.

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Test for acetylene valve leaks after both torch valves are closed. If the torch lights, check to be sure the acetylene valve is closed. If a small flame lingers at the end of the tip, a slight leak is present in the torch and should be repaired.

When the welding is to be stopped for considerable periods of time **such as during lunch hour or overnight, the cylinder valve should be closed and all gas pressures released from the regulators. Follow the steps listed below.**

1. Close the oxygen cylinder valve.

2. Open the torch oxygen valve to release all pressure from the hose and regulator.

3. Turn "out" on the pressure-adjusting screw of the acetylene regulator.

4. Close the torch oxygen valve.

5. Close the acetylene cylinder valve.

6. Open the torch acetylene valve to release all pressure from the hose and regulator.

7. Turn "out" on the pressure adjusting screw of the acetylene regulator.

8. Close the torch acetylene valve.

Closing the cylinder valve and then opening the torch valve relieves all pressures in the regulator and hose line. After the gauge readings (both gauges) have reached zero, the pressure adjusting screw should always be released, since this must be done before the cylinder valve is opened again. The acetylene and oxygen pressures should not be released simultaneously and care should be taken that the release of acetylene does not create a fire hazard. If acetylene is supplied through a hydraulic back-pressure valve, first simply close the service valve. After regulators are removed from cylinders, the dust plugs should be screwed in place on the cylinder connection nuts.

When regulators are to be out of service for several weeks or longer, it is good practice to turn the pressure adjusting screw "in" just enough to relieve the spring pressure on the valve seat. This aids in lengthening the life of the valve seat, especially when the seat is made of relatively soft material.

Before putting the regulator into service again, turn the pressure adjusting screw "out" until tension is released.

BACKFIRE AND FLASHBACK

The torch may go out with a loud snap or pop. This is called a **backfire.** Shut the torch valves, check the connections and operation, and then relight. A backfire may be caused by touching the tip against the work, by over-heating the tip, by operating the torch at unrecommended gas pressures, by a loose tip or head, or by dirt on the seat.

If the flame flashes back inside the torch, close the torch oxygen valve at once. Then close the acetylene valve. A **flashback** occurs when the flame burns back inside the torch, usually with a shrill hissing, squealing. Closing the torch oxygen valve stops the flashback at once. With the oxygen and acetylene regulators closed, let the torch cool before relighting. Also, blow oxygen through the torch tip for a few seconds to clear out soot that may have accumulated in the passages.

Flashbacks may extend back into the hose or regulators. When flashbacks occur, they mean that something is radically wrong with the torch or with the way it is being operated. Any case should be investigated to determine the cause before relighting the torch. A clogged orifice or incorrect oxygen and acetylene pressures are often responsible. Avoid using gas pressures higher than those recommended by the manufacturer.

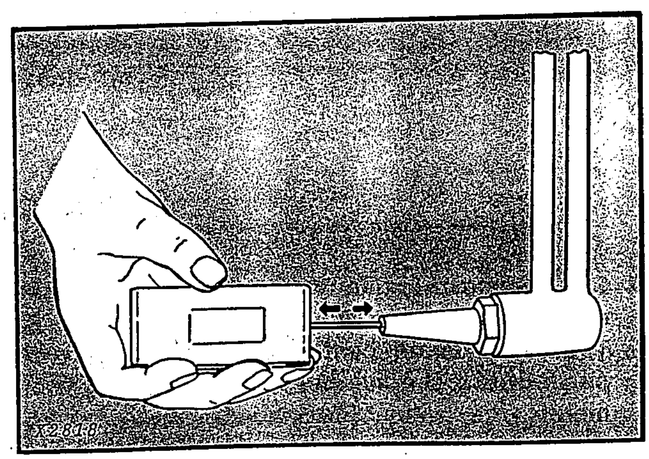

Fig. 21 — Using A Welding Tip Orifice Cleaner

CARE AND CLEANING OF TORCH TIPS

The welding tip is subjected to mechanical wear, flame erosion, and plugging.

Here are some hints for the care of torch tips:

1. Inspect threads on threaded tips periodically. (Never use pliers — use only box end wrenches.)

2 Never try to remove a hot tip from its torch tube. Allow it to cool first. Also, do not install a cold tip onto a hot torch tube.

3. Use a sized tip cleaner to unplug tip orifices (Fig. 21). When welding, molten metal droplets may be thrown into the tip orifices. Also, carbon soot may deposit in the tip. A good sign that the tip is clogged is difficulty in getting a neutral flame.

4. Check tips for flame erosion periodically. Always use tips made for a particular torch.

5. On tips with gasket seals, tighten only hand tight. A wrench is not recommended.

6. Avoid dropping a tip as the seat which seals the joint may be damaged.

7. Try to avoid contacting the torch tip with the welding work, bench, or firebricks. This may damage the end of the tip and cause the flame to burn with a "fishtail."

OTHER TYPES OF GAS WELDING

We will briefly review these other types of gas welding:

- **OxyMapp welding**
- **Oxyhydrogen welding**
- **Airacetylene welding**

These methods are less common than oxyacetylene, especially for general maintenance work.

OXYMAPP WELDING

Mapp gas is a Dow Chemical Company product developed as a fuel for welding, brazing, cutting, flame hardening, and metallizing operations. It has many of the physical properties of acetylene but lacks its shock sensitivity. Mapp gas is the result of rearranging the molecular structure of acetylene and propane.

Fuel	*Maximum Flame Temperature In Oxygen* (°F)	(°C)	*Maximum Burning Velocity In Oxygen* ft./sec	m/s
Acetylene	5589	3090	9.8	3
Mapp Gas	5301	2930	7.9	2.4
Propane	4579	2528	5.5	1.7
Propylene	5193	2867		

Fig. 22 — Flame and Temperature Comparison of Fuel Gases

Acetylene is unstable under heat, but this produces a very high flame temperature which is one reason for its extensive use as a welding gas. Although propane itself has the desired stability its limiting factor for welding is its low flame temperature. The table above shows the flame temperatures and burning velocities of these gases. Notice that while acetylene produces a hotter flame it has a higher burning rate in oxygen, which often means greater gas consumption.

Since Mapp gas is not sensitive to shock it can be stored and shipped in lighter cylinders. Acetylene, to be kept safe, must be stored in cylinders filled with a porous filler and acetone. Where empty acetylene cylinders weigh around 220 pounds (100 kg), Mapp cylinders weigh only 50 pounds (23 kg). Normally a filled cylinder of acetylene weighs 240 pounds (109 kg), while a filled cylinder of Mapp gas weighs 120 pounds (54 kg).

Mapp gas has a very distinct odor so any leakage can readily be detected. For actual welding, the same equipment and operations can be used. However, a slightly larger tip is required because of the greater gas density and slower flame propagation rate. The only significant difference is in the flame appearance. A neutral flame will produce a long inner cone and needs fuel-to-oxygen ratio of 1 to 2.3.

The explosive limits of the vapor of Mapp gas in air and oxygen are much narrower than acetylene and about the same as propane and natural gas. It can be used at full pressure safely [up to 375 psi (2590 kPa)] for jobs that are dangerous with acetylene.

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OXYHYDROGEN WELDING

The oxyhydrogen flame is produced by burning two volumes of hydrogen (H_2) with one volume of oxygen (O_2). The resulting combustion generates a low-temperature flame which is used primarily for welding thin sections of aluminum, aluminum alloys, and lead, and for brazing operations where lower temperatures are required.

The equipment for oxyhydrogen welding is essentially the same as used in oxyacetylene welding except that a special hydrogen pressure regulator is used.

One of the unusual characteristics of oxyhydrogen is that the flame is practically nonluminous. Consequently, it is often difficult to adjust for a neutral flame. To avoid welding with what might be an oxidizing flame, the practice is to adjust the regulator so it provides a greater flow of hydrogen. The excess hydrogen is harmless since the reducing atmosphere does not leave carbon deposits.

AIRACETYLENE WELDING

The airacetylene flame is generated by burning a mixture of acetylene with air. The torch operates on the same principle as the Bunsen burner. As the acetylene flows to the torch under pressure, it draws in the right amount of air for proper combustion.

The temperature of the airacetylene flame is even lower than that of the oxyhydrogen and so it has restricted uses for welding. Generally, the airacetylene flame is used for soldering and brazing very light metal sections. It has wider applications in the plumbing industry where it is used for soldering and brazing of copper tubing.

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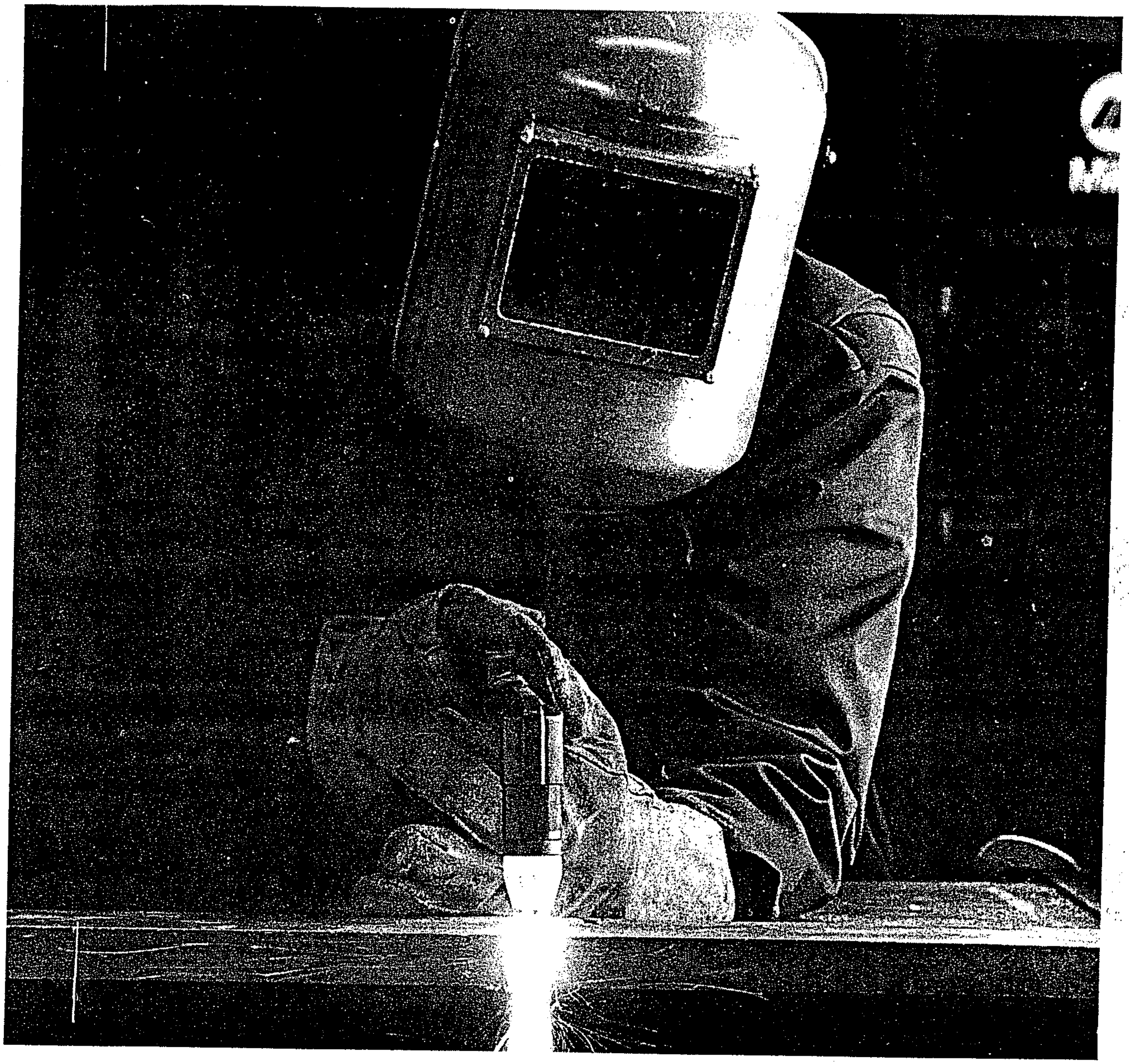

Fig. 76 — Plasma Arc Cutting

INTRODUCTION

Metal cutting in welding is the severing or removal of metal by a flame or arc.

The most common cutting processes are:

- **Oxygen Cutting — metal is heated by gas flame and an oxygen jet does the cutting**
- **Arc Cutting — intense heat of electric arc melts away the metal**

Let's look at each type of metal cutting.

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OXYGEN CUTTING

Severing metal by the oxygen or flame cutting process is possible because of the reaction of metal to oxidation. For example, when a piece of iron or steel is exposed to various atmospheric conditions, a reaction known as rusting takes place. This rusting is simply the result of oxygen in the air uniting with the metal, causing it gradually to decompose and wear away. Naturally this action is very slow but if the metal is heated and permitted to cool, heavy scales form on the surfaces, showing that the iron oxidizes much faster when subjected to heat. If a piece of steel were to be heated red hot and dropped in a vessel containing oxygen a burning action would immediately take place.

For rapid cutting of metal, you must have a device that heats the metal to a certain temperature and then delivers a blast of oxygen on the heated section. The *oxygen cutting torch* does this job.

Oxygen cutting can be used on plain carbon steels, low-alloy steels, manganese steels, and low-content chromium steels. Nonferrous metals and stainless steels or steels with a high chromium or tungsten content cannot be cut with the oxygen process, but they can be cut by the plasma and other methods, as we'll see later.

THE CUTTING PROCESS

The process of cutting is actually a progressive a- tion, especially in cutting thick sections. The is started by preheating a section of metal to the ignition temperature. Oxygen is then turned on which ignites the iron or steel at the upper surface. This burning releases heat, thereby raising the temperature of the metal below the surface and melting it. The cutting oxygen now ignites the molten metal which, in turn, releases heat to the metal below. The same action progresses downward until the metal is severed.

During cutting a slag is formed. The slag is principally iron oxide (Fe_3O_4), alloying elements in the

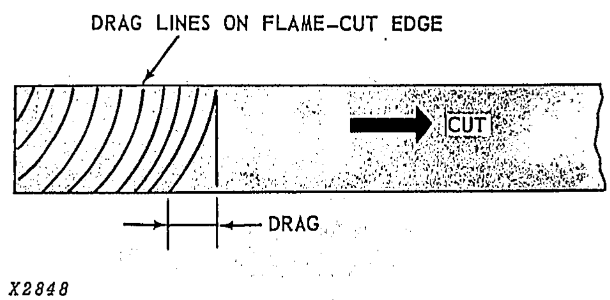

Fig. 77 — Effective Cutting Is Related To Drag

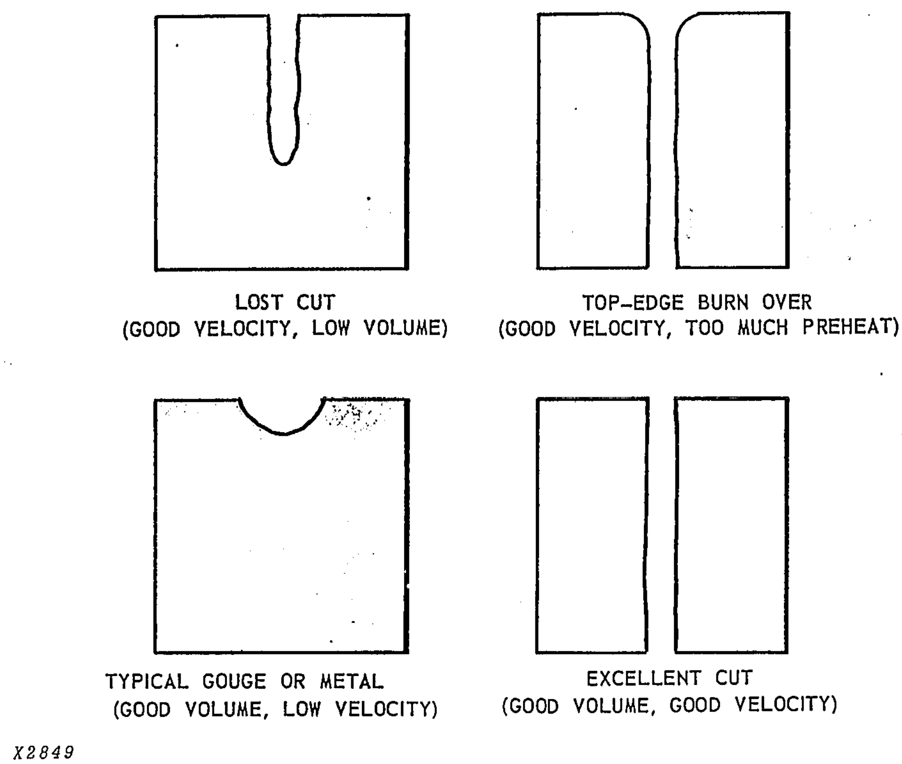

Fig. 78 — Effective Cutting Depends On The Volume Of Oxygen

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iron, plus some of the pure iron itself. This slag is blown out of the cut by the force of the oxygen stream.

Effective cutting depends on the amount of oxygen supplied for combustion and the correct tip size. Once the metal is ignited, the type of fuel gas used for preheating has no influence on the cutting.

The volume of cutting oxygen has a direct relationship to the formation of what is known as **drag.** The drag of a cut is the distance between the point where the oxygen stream enters the top of the metal and the point where the slag emerges from the bottom of the cut. See Fig. 77.

Conceivably the most efficient cut is where there is zero drag, that is, no lag between the top and bottom distance of the cutting reaction. However, to achieve zero drag, a high volume of oxygen is necessary and this may not always be the most economical.

On the other hand, if the oxygen volume is low, an excessive amount of drag may develop. Too long a drag will leave uncut corners and even cause the steel fire to extinguish before the slot or kerf reaches the bottom of the metal. When the supply of oxygen is too high, the top edges of the kerf usually burn over, producing rough surface edges, and considerable waste of oxygen (Fig. 78).

Most shops, where a great deal of cutting is done, attempt to find the most economical drag for the type of cutting.

This so-called "standard drag" is generally the longest possible drag that will produce the required accuracy of cut with a minimum amount of uncut corners.

The use of a correct **tip size** is also important because it affects the speed, accuracy, and economy of the cutting process.

A tip that is *too small* will fail to generate sufficient kindling temperature to keep the cutting progressing forward.

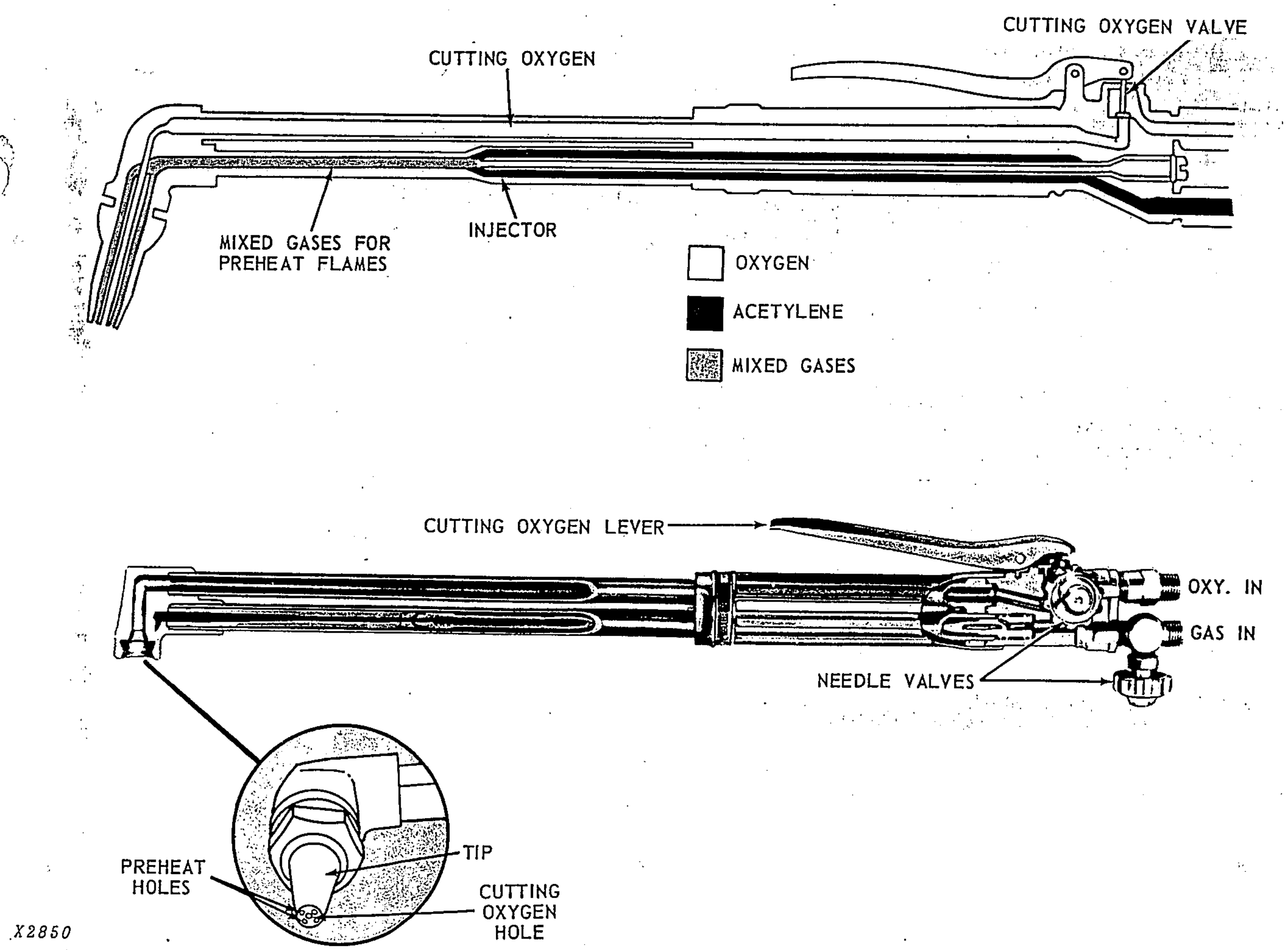

Fig. 79 — Oxyacetylene Cutting Torch And Tip

If the tip size is *too large*, the waste of oxygen becomes extremely high.

Orifices in cutting tips must be kept clean to produce a good flame.

FUEL GASES

The function of the fuel gas is to raise the temperature of the metal to start and continue the cutting process. Several types of gases are used for this purpose. The most common are acetylene, propane, Mapp, and acetogen.

The type of fuel gas selected depends on such factors as cost of gas, ease of handling gas containers, heat intensity of the flame, type of cutting to be done, and kind of metal to be cut.

The chart below lists the flame temperatures of different fuels for cutting purposes. Special cutting tips must be used with each type of fuel gas.

FLAME TEMPERATURES OF FUEL GASES USED FOR CUTTING

Fuel Gases	Flame Temperat
Acetylene	5,420°F (2,995°C)
Propane	5,190°F (2,870°C)
Hydrogen	4,600°F (2,540°C)
Mapp	5,300°F (2,930°)
Acetogen	5,400°F (2,985°)
Natural Gas	5,000°F (2,760°)

MANUAL CUTTING

The *cutting torch* is equipped with a special leve for control of the oxygen and a cutting tip whic has an orifice in the center surrounded by severa smaller ones. See Fig. 79 on page 57. The cente opening permits the flow of the cutting oxygen an the smaller holes are for the heating flame.

MANUAL AND MACHINE CUTTING OF CLEAN MILD STEEL (NOT PREHEATED)

Thickness of Steel, In. (mm)		Diameter of Cutting Tip Orifice, In. (mm)		Cutting Speed In./min. (mm/min)		Gas Consumptions, Ft³/h (m³/h)							
						Cutting Oxygen		Acetylene		Natural Gas		Propan	
⅛	3.2	0.020-0.040	(0.5-1)	16-32	(400-800)	15-45	(0.4-1.3)	3-9	(0.08-0.25)	9-25	(0.25-0.7)	3-10	(0.08-0.3)
¼	6.4	0.030-0.060	(0.8-1.5)	16-26	(400-660)	30-55	(0.8-1.6)	3-9	(0.08-0.25)	9-25	(0.25-0.7)	5-12	(0.14-0.34)
⅜	9.5	0.030-0.060	(0.8-1.5)	15-24	(380-610)	40-70	(1.1-2.0)	6-12	(0.17-0.34)	10-25	(0.3-0.7)	5-15	(0.14-0.4)
½	12.7	0.040-0.060	(1-1.5)	12-23	(305-585)	55-85	(1.6-2.4)	6-12	(0.17-0.34)	15-30	(0.4-0.8)	5-15	(0.14-0.4)
¾	19	0.045-0.060	(1.1-1.5)	12-21	(305-535)	100-150	(2.8-4.2)	7-14	(0.20-0.40)	15-30	(0.4-0.8)	6-18	(0.17-0.5)
1	25.4	0.045-0.060	(1.1-1.5)	9-18	(230-455)	110-160	(3.1-4.5)	7-14	(0.20-0.40)	18-35	(0.5-1)	6-18	(0.17-0.5)
1½	38	0.060-0.080	(1.5-2)	6-14	(150-355)	110-175	(3.1-5.0)	8-16	(0.2-0.45)	18-35	(0.5-1)	8-20	(0.2-0.6)
2	50.8	0.060-0.080	(1.5-2)	6-13	(150-330)	139-190	(3.6-5.4)	8-16	(0.2-0.45)	20-40	(0.6-1.1)	8-20	(0.2-0.6)
3	76.2	0.065-0.085	(1.7-2.2)	4-11	(100-280)	190-300	(5.4-8.5)	9-20	(0.25-0.6)	20-40	(0.6-1.1)	9-22	(0.25-0.61)
4	102	0.080-0.090	(2-2.3)	4-10	(100-255)	240-360	(6.8-10.2)	9-20	(0.25-0.6)	20-40	(0.6-1.1)	9-24	(0.25-0.7)
5	127	0.080-0.095	(2-2.4)	4-8	(100-200)	270-360	(7.6-10.2)	10-24	(0.3-0.7)	25-50	(0.7-1.4)	10-25	(0.3-0.7)
6	152	0.095-0.105	(2.4-2.7)	3-7	(75-180)	260-500	(7.4-14.2)	10-24	(0.3-0.7)	25-50	(0.7-1.4)	10-30	(0.3-0.8)
8	203	0.095-0.110	(2.4-2.8)	3-5	(75-125)	460-620	(13.9-17.6)	15-30	(0.4-0.8)	30-55	(0.8-1.5)	15-32	(0.4-0.9)
10	254	0.095-0.110	(2.4-2.8)	2-4	(50-100)	580-700	(16.4-19.8)	15-35	(0.4-1)	35-70	(1-2)	15-35	(0.4-1)
12	305	0.110-0.130	(2.8-3.3)	2-4	(50-100)	720-850	(20.4-24.1)	20-40	(0.6-1.1)	45-95	(1.3-2.7)	20-45	(0.6-1.3)

Preheat oxygen consumptions: Preheat oxygen for acetylene = 1.1 to 1.25 × acetylene flow (ft.³/h or m³/h); preheat oxyge for natural gas = 1.5 to 2.5 × natural gas flow (ft.³/h or m³/h); preheat oxygen for propane = 3.5 to 5 × propane flow (ft.³/h c m³/h).

Operating notes: Higher gas flows and lower speeds are generally associated with manual cutting, whereas lower gas flows an higher speeds apply to machine cutting. When cutting heavily scaled or rusted plate, use high gas flows and low speeds. Maximu indicated speeds apply to straight line cutting; for intricate shape cutting and best quality, lower speeds will be required.

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Tip size will depend on the thickness of the metal to be cut. The chart on page 58 includes the various tip orifice sizes for different thicknesses of metal. Cutting speeds and gas consumption for each thickness of metal is also shown.

HOW TO SET UP CUTTING TORCH

Before starting to cut, observe all safety rules (see Part 11).

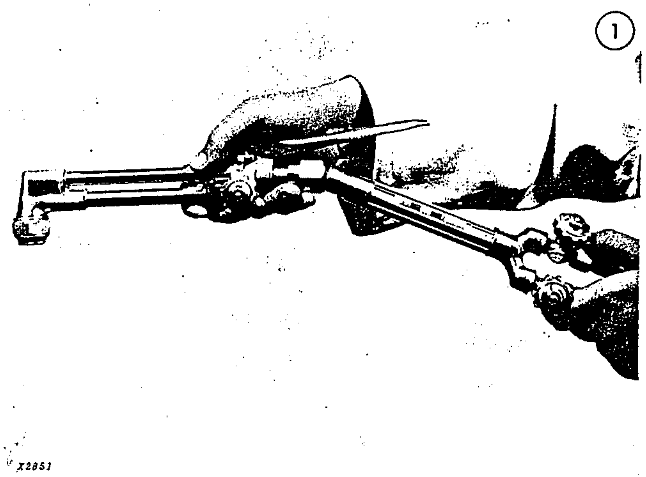

Fig. 80 — Installing Cutting Attachment On Torch

1. Attach the cutting attachment to the welding torch by holding the attachment in one hand and the welding torch in the other (Fig. 80). Tighten the fittings.

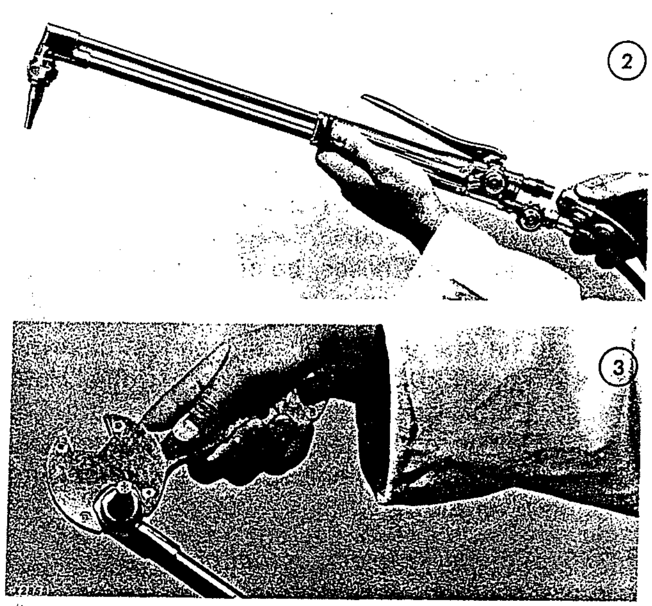

Fig. 81 — Setting Up Cutting Torch

Select the cutting tip size suitable for the job (see chart on page 58). Be sure the taper cone seat on the tip is not damaged and is free from all dirt before inserting into cutting attachment or cutting torch head.

Open the oxygen valve on the welding torch completely. The preheat oxygen is not adjusted by this valve, but by the preheat oxygen valve on the cutting attachment. Therefore, the welding torch oxygen valve must be wide open at all times to supply the attachment with both preheat and cutting oxygen.

2. Connect hoses in the same manner as for the welding torch (Fig. 81, top).

3. Secure the cutting tip into the torch head with a wrench, using firm but not excessive force.

OPERATING THE CUTTING TORCH

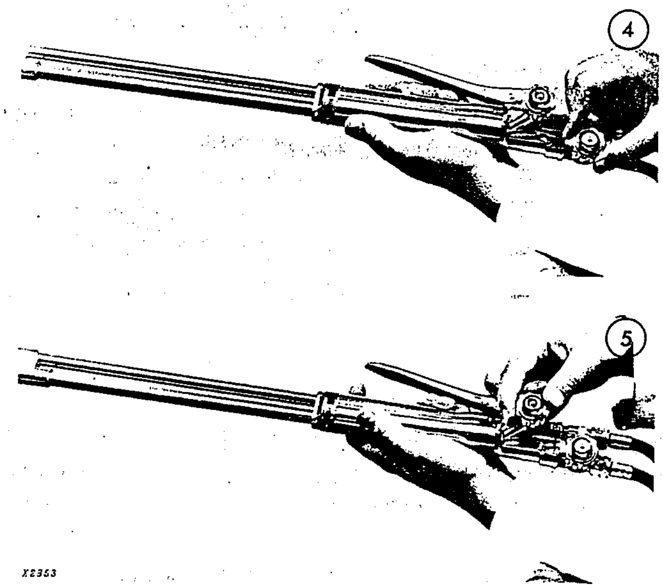

Fig. 82 — Opening The Cutting Torch Valves

4. The bottom wheel valve normally controls the flow of acetylene or fuel gas (Fig. 82, top). (This corresponds to the fuel valve on the welding torch).

5. The top wheel valve normally controls the oxygen for the preheat flames. (This is the same valve on the cutting attachment. Remember the oxygen valve on the welding torch must be *wide open*).

The lever valve controls the cutting oxygen which passes through the center hole of the tip.

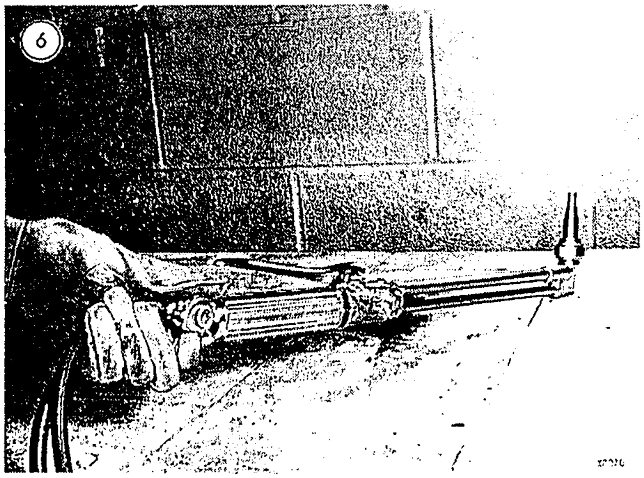

Fig. 83 — Lighting The Cutting Torch

The following procedure is for **acetylene** only.

6. Light the torch (Fig. 83).

IMPORTANT: Always purge the cutting oxygen passages by depressing the cutting oxygen lever before lighting the torch. Open the fuel valve approximately ½ turn and ignite the gas with a spark-lighter. Adjust the fuel valve until the flame clears the end of the tip about ⅛ inch (3 mm), then reduce slightly to return the flame to the tip.

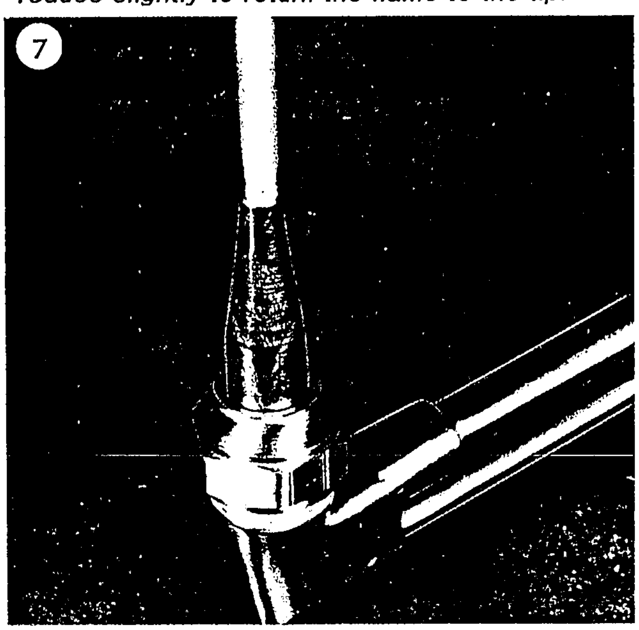

Fig. 84 — Adjusting The Cutting Torch Flame (Neutral Flame Shown)

7. Slowly open the preheat oxygen valve until a neutral flame is established (a sharp inner cone). See Fig. 84. After the neutral flame has been established, depress the cutting oxygen lever. N that the preheat flames change slightly from neutral to a carburizing flame with a feather. With the cutting oxygen lever depressed, readjust the preheat oxygen valve until the preheat flames are again neutral as shown.

NOTE: A neutral preheat flame is shown, but often an oxidizing flame is more efficient. Follow the specific recommendations of the torch manufacturer.

HOW TO CUT

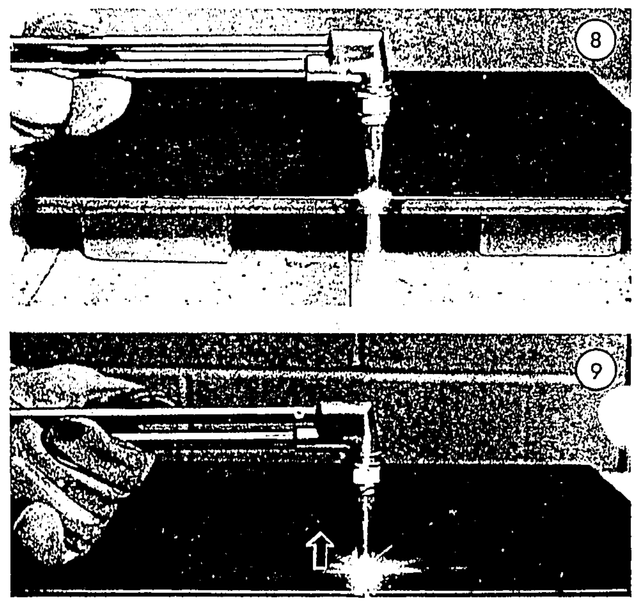

Fig. 85 — How To Cut Metal

Check to see where the molten metal and sparks will fall from cutting or welding. Serious fires and explosions have been caused by careless torch operations. TAKE ALL POSSIBLE PRECAUTIONS — have fire extinguisher available — remove or protect flammable substances, including the oxygen and acetylene hoses, before starting work.

8. Direct the preheat flames on the spot where the cut is to be started with the flames just clearing the surface. (Fig. 85, top). Take your time. Hold steady. Before the cutting action can start, the steel must be preheated to a bright cherry red. When the red spot appears, depress the cutting oxygen lever slowly.

NOTE: If the lever is depressed too soon the oxygen will chill the preheated area and prevent cutting.

9. When the cut has started, move the torch in the direction you wish to cut (Fig. 85). Moving too fast will lose the cut. Moving too slowly will make a ragged or fused cut. (The path of the cut can be marked with chalk or center punch marks.)

Hold the torch so the cone ends of the preheat flames just clear the metal. Hold the tip at right angles to the work for straight cuts or at the desired angle for bevel cuts. Take your time. Do not move too fast or too slowly. Keep the tip out of the molten metal.

Too much speed will cause the slag to emerge from the bottom and lag behind at too great an angle.

Too slow a speed will cause the edges of the cut to appear to melt and look ragged.

HOW TO PIERCE METAL

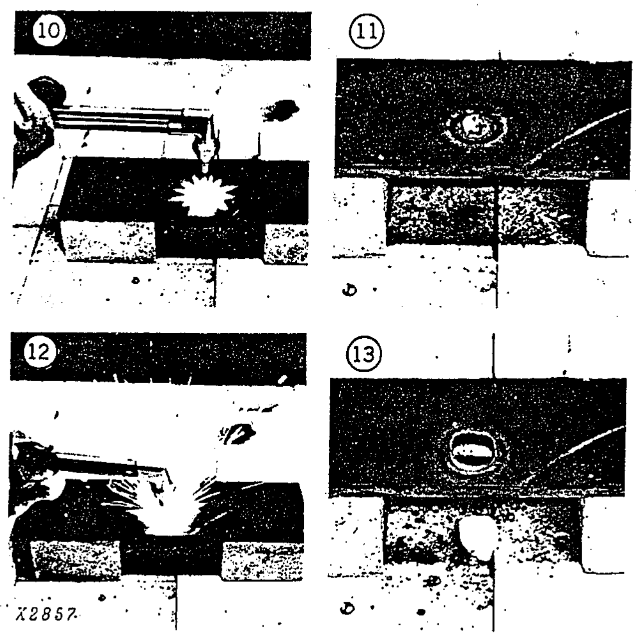

Fig. 86 — How To Pierce Metal

10-11. To pierce metal, hold the torch so the preheat flame just clears the work. When the spot becomes a bright cherry red, press down slowly on the cutting oxygen lever.

12-13. To prevent the sparks and slag from blowing toward you, tilt the torch tip slightly to one side so the sparks blow away from you and draw the torch head away slightly from the work.

When the metal is pierced, move the torch steadily in the direction you wish to cut. If the metal will not pierce all the way through, it probably means that not enough cutting oxygen pressure is being used.

For larger holes, trace the opening with a piece of soapstone before you start to pierce.

STOPPING WORK

When cutting is to be stopped, close the torch oxygen valve, then the torch acetylene valve.

To stop welding for considerable periods of time, such as during lunch hour or overnight, the cylinder valve should be closed and all gas pressure released from the regulators. Follow these steps:

1. Close the oxygen cylinder valve.
2. Open the torch oxygen valve to release oxygen pressure from the hose and regulator.
3. Turn out the pressure-adjusting screw of the oxygen regulator.
4. Close the torch oxygen valve.
5. Close the acetylene cylinder valve.
6. Open the torch acetylene valve to release acetylene pressure from the hose and regulator.
7. Turn out the pressure-adjusting screw on the acetylene regulator.
8. Close the torch acetylene valve.

Closing the cylinder valve and then opening the torch valve relieves pressure in the regulator and hose. After the gauge readings (both gauges) have reached zero, the pressure-adjusting screw should always be released, since this must be done before the cylinder valve is opened again. The acetylene and oxygen pressure should not be released simultaneously, and care should be taken that the release does not create a fire hazard.

If acetylene is supplied through a hydraulic back-pressure valve, first close the service valve. After regulators are removed from cylinders, the dust plugs should be screwed in place on the cylinder connection nuts.

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When regulators are to be out of service for several weeks or longer, it is good practice to turn in the pressure adjusting screw just enough to relieve the spring pressure on the valve seat. This aids in lengthening the life of the valve seat, especially when the seat is made of relatively soft material. Before putting the regulator into service again, the pressure-adjusting screw should be turned to the left until tension is released.

OTHER FLAME CUTTING OPERATIONS

Flame cutting is also used for stack cutting, lancing, gouging, and powder cutting.

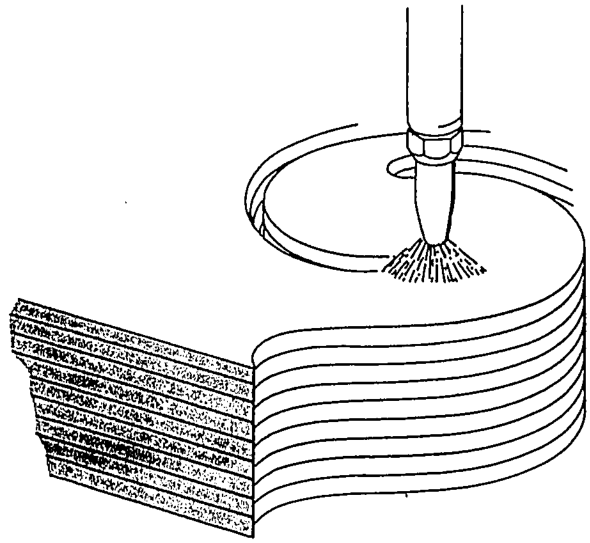

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Fig. 87 — Stack Cutting

Stack Cutting

Stack cutting is the cutting of several plates simultaneously while stacked together (Fig. 87). The advantage of stack cutting is increased productivity at lower unit cost. The resulting pieces will usually have less stressed edges with squarer surfaces and fewer burrs and drag.

In stack cutting, the pieces must form a solid slab. The surfaces must obviously be free of all foreign matter and be absolutely flat. Sufficient clamping devices are often required to eliminate all air gaps between the stacked plates.

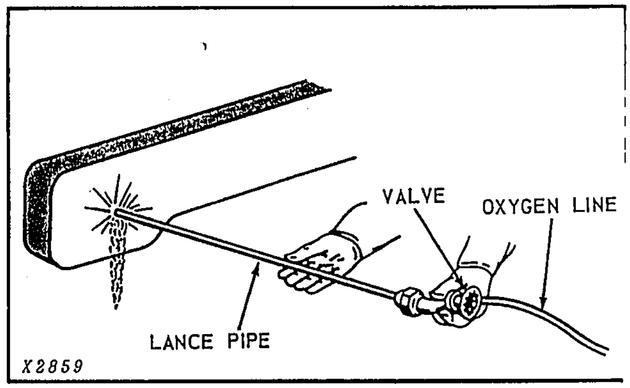

Fig. 88 — Lancing Is Used To Cut Deep Holes In Thick Metal Sections

Lancing

Lancing is used to cut a long or deep hole in a thicl metal body. The lance is simply a piece of stee pipe 1/8 or 3/4 inch (3 or 19 mm) in diameter equip ped with a globe valve to control the flow of oxyger See Fig. 88.

Preheating is done with a welding or cutting torcl or any other means for supplying heat. As soon a the preheating is completed, the lance pipe i brought over the area where the hole is to b pierced and the oxygen turned on. The lance nip is rotated slightly to produce a hole larger the diameter of the lance, permitting the slag t be blown out of the hole.

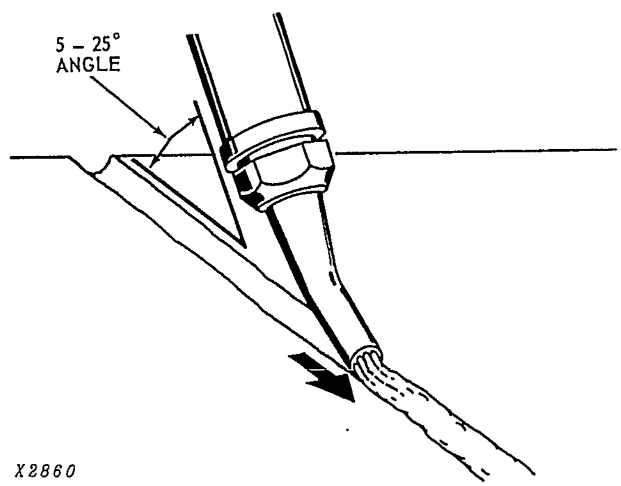

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Fig. 89 — Gouging Is Used To Produce An Even Groove

Gouging

Gouging is another form of scarfing used to pro duce a fully controlled groove. The torch is held sta tionary until the correct preheat is reached and th nozzle then lower and moved forward as shown ir Fig. 89.

POWDER CUTTING

The regular oxy-fuel cutting process is ineffective for cutting metals that form refractory oxides such as aluminum, bronzes, stainless steel, cast iron, and high nickel alloys.

One process of cutting these metals employs a special powder-cutting torch which is connected to a source of oxygen and fuel gas such as acetylene. An iron powder (some applications require the addition of aluminum powder) from the torch is directed on the line of cut before the cutting oxygen valve is opened. Plasma cutting is replacing this process in many applications.

ARC CUTTING

Special cutting electrodes are available that will allow cutting metal with an arc welder. Coated electrodes such as E-6010 (used on DCEP) or E6011 (used on AC or DCEP) may also be used. If coated mild steel electrodes are used, soaking them in water 30 minutes before use will extend their life.

The diameter of the electrode will depend on the thickness of the metal to be cut and the amperage capacity of the machine. The chart below provides guidelines for arc cutting.

WARNING! Observe the duty cycle rating of the welding power source when doing arc cutting. This information is on the name plate of the welder and in the owners manual. Unless the power source is equipped with overload protection, failure to observe the duty cycle will ruin the power source by breaking down the insulation in the windings.

Cutting with the arc is possible because of the high temperature produced by the arc. Heat of the arc ranges from about 6500° to 10,000°F (3590° to 5540°C) while 2600°F (1430°C) will melt steel.

SUGGESTED AMPERAGE SETTING FOR ARC CUTTING

Metal Thickness (Inch)	(mm)	Electrode Diameter (Inch)	(mm)	Ampere Range
up to ⅛	(3.2)	3/32	(2.4)	75-100
up to ⅛	(3.2)	⅛	(3.2)	125-140
over ¼	(6.4)	5/32	(4.0)	140-180

The limitation of the arc process for cutting is that it leaves a very rough, ragged edge. However, it is effective for cutting cast iron and steel for salvage purposes and in areas which are hard to reach.

The chart at left below gives the approximate ampere setting for cutting.

In a cutting operation, the metal is placed in a flat position and the cut started at the bottom edge of the plate.

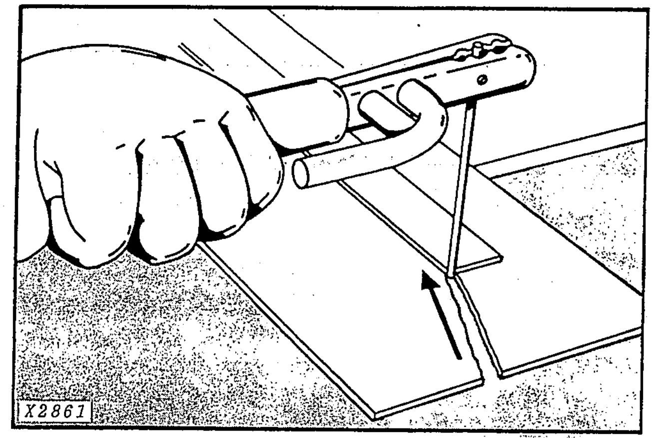

Fig. 90 — Cutting Thinner Plate With The Metallic Arc

When the diameter of the electrode is larger than the thickness of the plate being cut, the electrode is simply moved in a straight line as in Fig. 64.

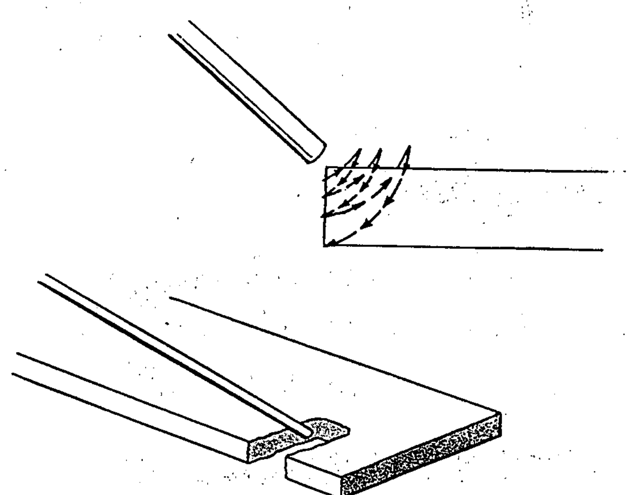

Fig. 91 — Cutting Heavier Plate With The Metallic Arc

When the material is heavier than the electrode, a weaving motion is used to make the cut. The electrode is moved upward with a quick motion and then pushed downward as shown in Fig. 91. Flat

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stock over 1/8-inch (3.2 mm) thick is often easier to cut if placed in a vertical position. The cut is made from top to bottom as illustrated in Fig. 92.

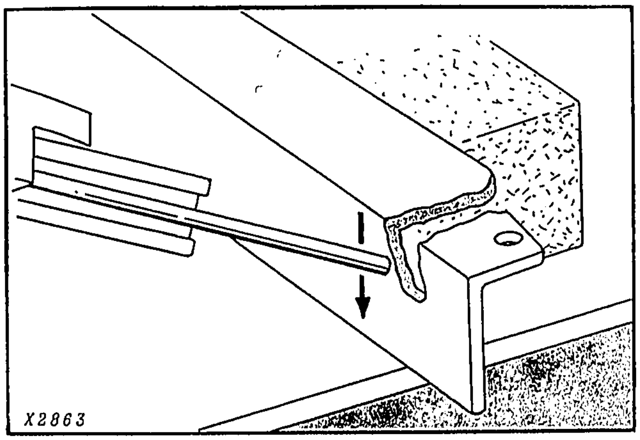

Fig. 92 — Arc Cutting Heavier Stock In A Vertical Position

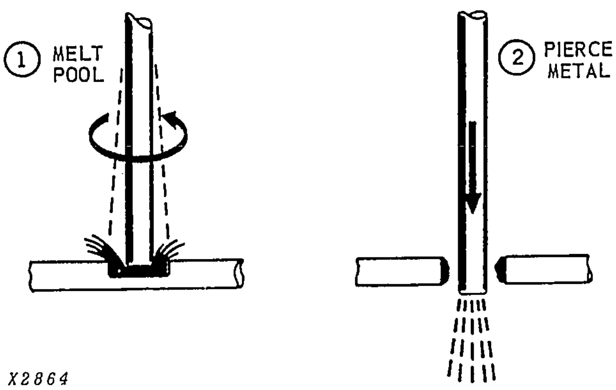

Fig. 93 — Piercing Holes With Arc

Holes can be pierced by keeping the arc over the spot until the plate begins to sweat. The arc is then brought down into the molten pool of metal and the electrode moved in a circular motion. See Fig. 93.

Piercing holes in metal over ¼ inch (6.4 mm) thick is best done with the plate in vertical position. This permits the metal to run out of the hole.

OTHER TYPES OF ARC CUTTING

Two other types of arc cutting are used today:

- **Air-Carbon Arc**
- **Plasma-Arc Cutting**

GOUGING AND CUTTING

INTRODUCTION

An air-carbon arc torch and a plasma torch are useful tools for the preparation of a weld joint, backgouging, or repairing a crack; for removing defective welds; for removing welds when dismantling a welded assembly; and for cutting metals that cannot be readily cut with another process. See Fig. 94.

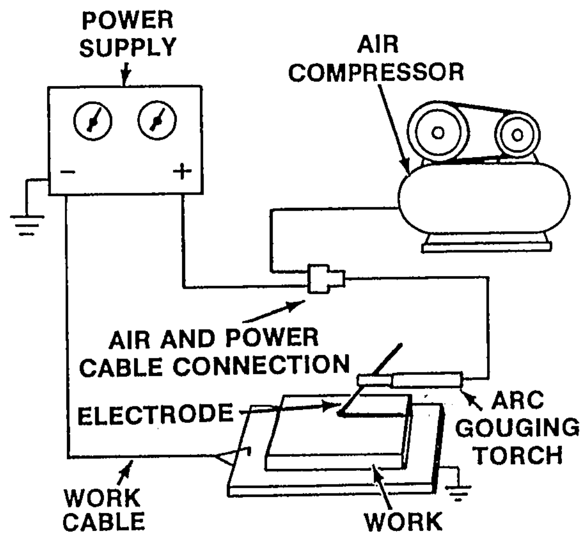

Fig. 94 — Air-Carbon Arc Gouging Equipment

USING THE TORCH

The torch is held so the electrode slopes back from the direction of travel forming a 45 degree angle to the workpiece. The torch should not be held more than 4 inches (102 mm) from the work, and the orifices on the nozzle should be on the bottom side of the carbon so the air blasts are behind the electrode. (See Fig. 95 and 98). The arc should be kept as short as possible without touching the work and moved fast enough to keep up with the metal removal. The depth of the groove is controlled by the electrode angle and travel speed. For a narrow deep groove, a steep electrode angle and slow speed is used. For shallow grooves, use a flat electrode angle and a fast speed. It is very important that the air blast be on before striking an arc.

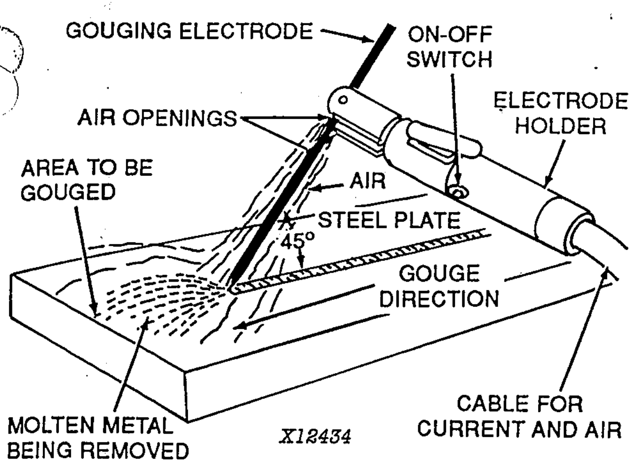

Fig. 95 — The Air-Carbon Arc Processes

A fillet weld has been completely removed when the line of intersection of the two plates becomes visible. (Fig. 96). When repairing a part that is cracked or when backgouging the back side of groove weld to obtain 100% penetration, the proper depth has been reached when the bottom of the groove becomes smooth indicating that there is no line of separation.

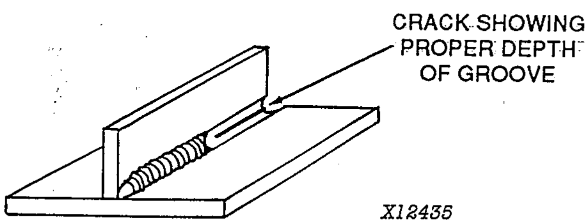

Fig. 96 — Removing A Fillet Weld

When the proper technique has been learned, the air-carbon arc process produces little, if any, slag on the finished cut. (Fig. 97). However, the slag that remains is rich in carbon and must be removed by either chipping or ginding before any welding is done. If the slag is not completely removed before welding, the resulting weld will be of very low quality.

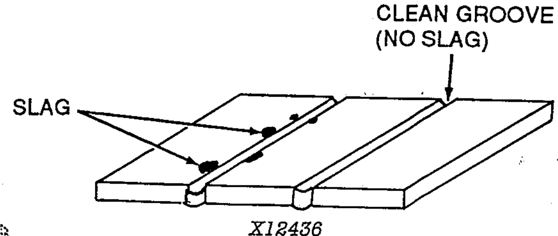

Fig. 97 — Back Gouging

A grinder should be used to check for slag that is in or attached to the sides of the completed groove. When grinding an area that was cut with the air-carbon arc process, an increase in the volume of sparks being produced indicates an area of slag, and no change in the spark volume indicates that the area does not contain slag deposits.

Electrodes for manually operated torches are available in 12-inch (305 mm) lengths for either AC or DCEP operation. Either plain or copperclad electrodes can be used. Copperclad electrodes last longer, carry higher current, and produce more uniform cuts.

An adequate air compressor should be available. Air pressure requirements range from 60 psi to 100 psi (415 kPa to 690 kPa) and air flow rates range from 8 cfm to 30 cfm (0.23 m^3/min to 0.85 m^3/min). This means that usage will have to be intermittent if less than a 3 hp 2.2 kw compressor is available.

Before using this process check the duty cycle for the power supply, the current requirements for the electrodes to be used, and the delivery capabilities of the air compressor that will be used. A heavy duty AC or DC welding machine should be used for a power source. The carbon-graphite electrodes require high amperages that can ruin a light duty power source in a short time if it is operated above its rating. Unsatisfactory results will be obtained by operating at amperages below those recommended by the manufacturer.

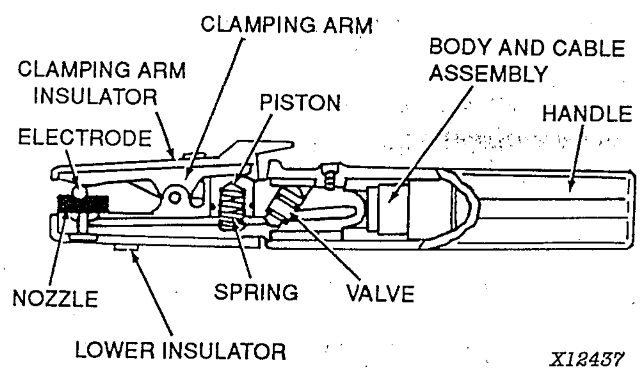

Fig. 98 — Typical Gouging Torch

ARC GOUGING SAFETY

The same rules apply to arc gouging that apply to any electric welding or cutting process. Additional rules include the following:

• Remove combustible materials from the work area and take adequate precautions necessary to prevent a fire or explosion.

- Use appropriate ear protective devices to prevent sparks or hot metal from getting into the ears and to reduce noise levels.

- Use adequate ventilation or a breathing device that provides protection from the fumes.

- Be sure the welding lens is the proper shade, and offers adequate protection. The lens selected should be rated for the maximum amperage drawn by the carbon used.

- Clothing should provide adequate protection from the intense arc rays, the heat, and the hot sparks.

- To prevent arc damage to the work, be sure the electrical connection between the torch and power supply are covered by the insulating boot.

PLASMA-ARC CUTTING

INTRODUCTION

Plasma-arc cutting is widely used in factories for both manual and automated cutting applications. It is one of the most effective processes available for cutting both ferrous and nonferrous metals.

Advantages of the process include no preheat. Cuts can be started instantly. The heat affected zone from cutting is minimal. High travel speeds are possible because it is a thermal process rather than an oxidation process like oxygen cutting; and it can be used for cutting almost any material that will conduct electricity and, in many situations, at faster speeds than any other process. A plasma torch has the ability to cut metals such as aluminum, copper, brass, cast iron, carbon steel, nickel, stainless steel, refractory metal, and other ferrous and nonferrous metals.

THE PLASMA ARC CUTTING PROCESS

Plasma jets are hotter than any flame and may reach temperatures near 50,000°F (27,800°C). This heat melts any known metal and its velocity blasts the molten metal through the slot or kerf (Fig. 101). Precise control of the plasma jet is possible by varying the current, voltage, type of plasma gas, gas velocity, and gas flow (cfh).

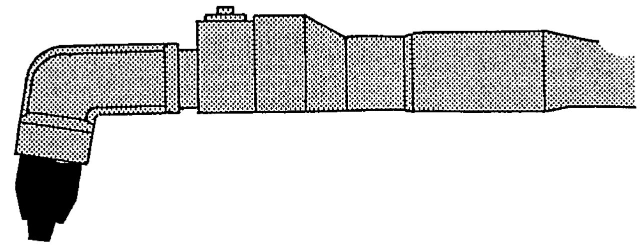

Fig. 99 — Plasma Cutting Torch

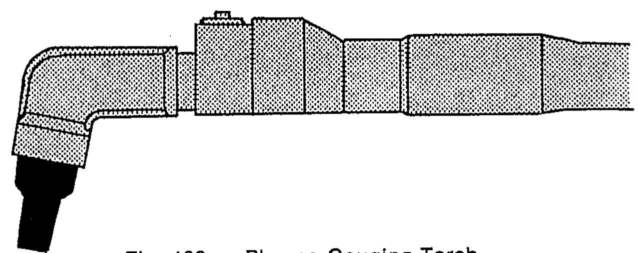

Fig. 100 — Plasma Gouging Torch

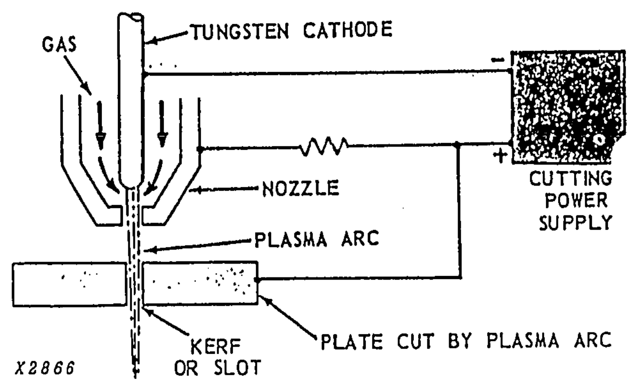

Fig. 101 — Plasma-Arc Cutting

The two most commonly used orifice gases (cutting gas) for plasma cutting are nitrogen and compressed air. Trial cuts with each gas will determine which works best for a specific cutting application. Special air filters must be used when using existing compressed air.

SAFETY

The same clothing and basic safety rules apply to plasma cutting that apply to electric welding. In addition, the safety rules for air carbon arc and oxy-fuel cutting must be followed. Equipment owners manuals should be thoroughly read and understood before attempting to do plasma cutting.

BRAZING AND SOLDERING / PART 7

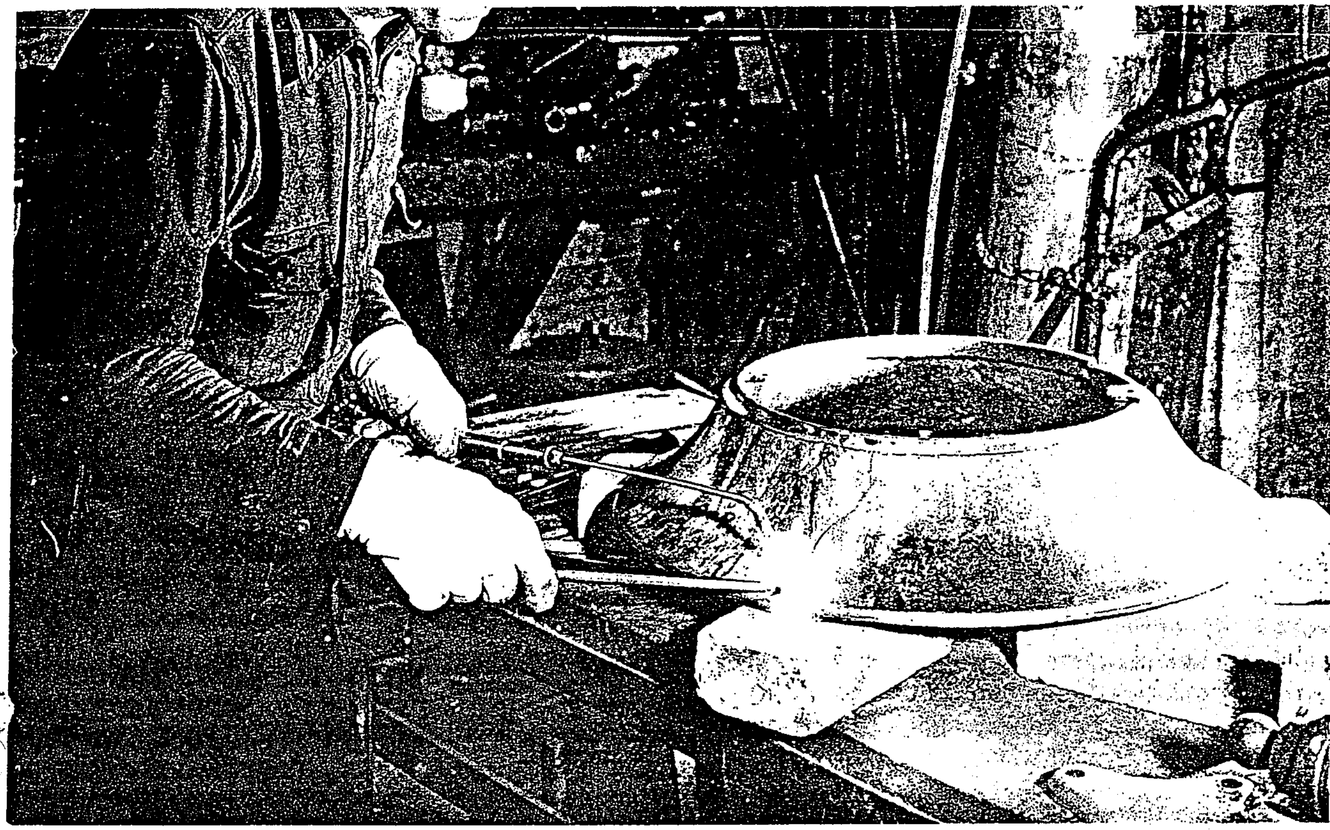

Fig. 102 — Brazing With A Torch

INTRODUCTION

Other methods besides fusion welding are often used to join metals.

The two most common processes are:

- **Brazing**
- **Soldering**

These methods are widely used in joining most metals, especially where it is not practical nor economical to use regular fusion welding.

Both *brazing* and *soldering* join metals using a filler metal which is melted between the two closely fitted metal surfaces. The major difference is that in brazing the filler metal melts at a higher temperature and fuses by capillary action, giving a stronger joint (Fig. 103).

The metal work to be joined is not melted in either process, but is only heated enough to cause the filler metal to fuse. This is what makes it different from fusion welding.

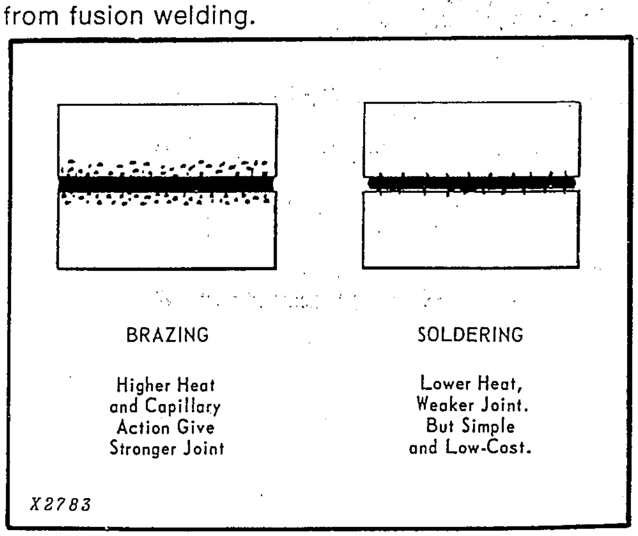

Fig. 103 — Brazing and Soldering Compared

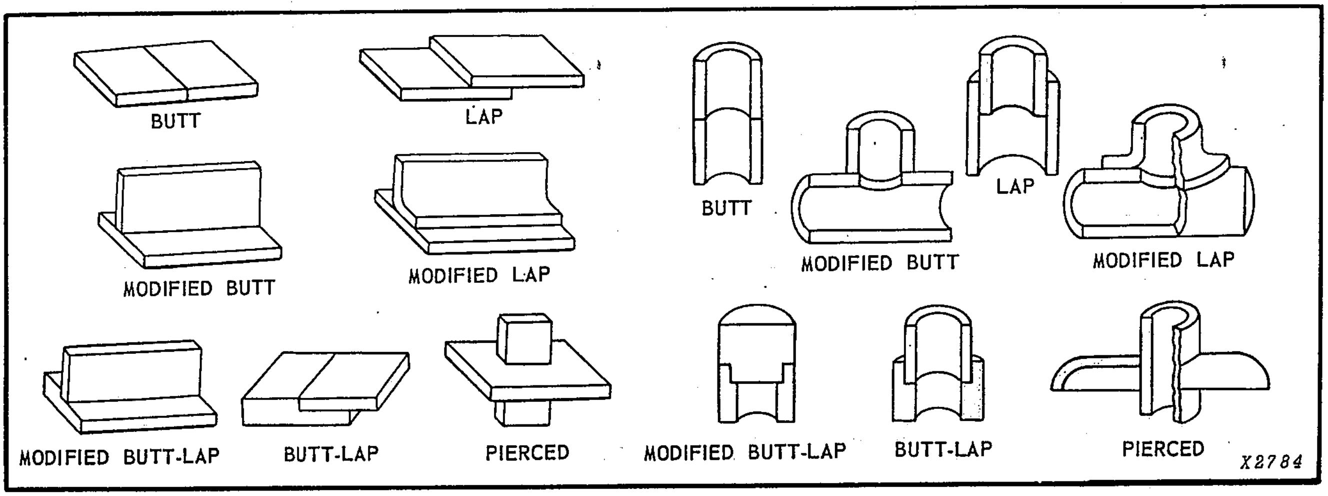

Fig. 104 — Types of Joints for Brazing

BRAZING

Brazing is a group of welding processes where metals are joined by heating to suitable temperatures above 800°F (425°C) and by using a nonferrous filler metal having a melting point below that of the base metals. The filler metal is distributed between the closely fitted surfaces of the joint by capillary action.

Most commercial metals can be brazed. Although a brazed joint has a relatively high tensile strength, it is not recommended when the full strength of a joint is required.

An important factor in **brazing** is that there is *less danger of destroying the mechanical properties of the base metal* since lower bonding temperatures are used than normally required for fusion welding.

Brazing can also be used to join dissimilar metals.

REQUIREMENTS FOR BRAZING

The success of any brazing operation depends on joints having relatively small clearances and surfaces that are free of oxide and other contaminants. Cleaning is done by coating the surfaces with a special flux which when heated is capable of dissolving all foreign matter. Once the surfaces are properly fluxed, a brazing filler metal is melted at some point along the seam. Capillary action then draws the molten brazing metal between the surfaces of the joint. Upon cooling, the solidified brazing metal forms a solid bond at the joint. During heating and cooling, precautions are taken to prevent any movement of the surfaces. For most production work, a fixture is used to hold parts in alignment during brazing.

TYPES OF JOINTS FOR BRAZING

The two basic joints for brazing are the **lap** and **butt** (Fig. 104). (Tee and corner joints are considered as butt joints.)

The lap joint offers the maximum strength. The overlap should be at least three times the thickness of the thinnest section.

Since the cross-sectional area of a butt joint is limited to that of the thinnest section, maximum joint strength is impossible.

Where a lap joint cannot be used, the weakness of the butt joint can be reduced by using a scarf joint. However, the scarf joint is more difficult to prepare and often special care is required to keep the pieces in alignment.

The strength of a butt joint can also be improved by increasing the cross-sectional area as shown or by using a sleeve over the joint.

Joint clearance, which is the distance between the interface of the pieces, is an important factor in the performance of a brazed joint, whether the joint is subjected to loadings of fatigue, impact, or static. Too tight a joint may hinder the plastic flow of the filler metal, while too much clearance may prevent the full effects of the capillary action, leaving voids and uneven distribution of filler metal.

In general, joint clearance should be between 0.001 and 0.010 inch (0.025 and 0.25 mm).

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BASE METALS AND RECOMMENDED FILLER METALS, BRAZING FLUXES AND APPLICATIONS

AWS Brazing Flux Type No.	Metal Combinations for Which Various Fluxes Are Suitable: Base Metals	Filler Metals	Effective Temperature Range of Flux, °F (°C)	Major Materials of Flux	Physical Form	Methods of Application*
1	Aluminum and aluminum alloys	BAISi	700-1190 (370-645)	Fluorides; Chlorides	Powder	1 ,2, 3, 4,
2	Magnesium alloys	BMg	900-1200 (480-650)	Fluorides; Chlorides	Powder	3, 4,
3A	Copper and copper-base alloys (except those with aluminum) iron base alloys; cast iron; carbon and alloy steel; nickel and nickel base alloys; stainless steels; precious metals.	BCuP BAg	1050-1600 (565-870)	Boric Acid, Borates, Fluorides, Fluoborate Wetting Agent	Powder Paste Liquid	1, 2, 3,
3B	Copper and copper-base alloys (except those with aluminum); iron base alloys; cast iron; carbon and alloy steel; nickel and nickel base alloys; stainless steels; precious metals.	BCu BCuP BAg BAu R B CuZn BNi	1350-2100 (730-1150)	Boric Acid Borates Fluorides Fluoborate Wetting Agent	Powder Paste Liquid	1, 2, 3,
4	Aluminum-bronze; aluminum-brass	BAg, BCuZn, BCuP	1050-1600 (565-870)	Borates Fluorides Chlorides	Powder Paste	1, 2, 3,
5	Copper and copper-base alloys (except those with aluminum) nickel and nickel-base alloys; stainless steels; carbon and alloy steels; cast iron and miscellaneous iron-base alloys; precious metals (except gold and silver).	BCu, BCuP BAg-(8-19) BAu, BCuZn BNi	1400-2200 (760-1205)	Borax Boric Acid Borates	Powder Paste Liquid	1, 2, 3.

* For proper method of application see pages 72 and 73, methods 1-4.

FILLER METALS FOR BRAZING

A brazing filler metal should meet these requirements:

1. Enough fluidity so the metal will flow evenly by capillary action.

2. Good melting to form a sound metal bond.

3. Melting point consistent with the type of metal to be joined.

Brazing filler metals fall into seven groups: silver, aluminum-silicon, copper-phosphorus, gold, copper and copper-zinc, magnesium, and nickel.

The table above lists the principal metals which are joined with these filler metals.

FLUXES

Any form of oxide on the surface of a metal will prevent a uniform flow of the brazing metals. For this reason, a **flux** of some kind is necessary to eliminate the oxide. The common commercial fluxes are in paste, liquid, or powder form. Fluxes have as their main ingredients: borates, fused borax, boric acid, fluorides, chlorides, and fluoborates. There is no single flux which can be used for all brazing operations. See the Table above. All traces of flux residues must be removed after brazing to prevent corrosion.

For some mass-production jobs, applying fluxes is a time-consuming task. So controlled atmospheres are used to remove oxide and prevent the formation of oxide during brazing. This method is often used with induction brazing of titanium, zirconium, and other refractory metals.

In a controlled atmosphere, a gas is continuously supplied to a furnace and circulated within it at slightly higher than atmospheric pressure. Gas may consist of high-purity hydrogen, carbon dioxide, carbon monoxide, nitrogen, argon, ammonia or some form of combusted fuel gas.

HEATING METHODS FOR BRAZING

Applying heat for brazing is done by a variety of methods depending on the kind of material to be brazed, quantity of production, and sizes of parts to be joined.

The following techniques are used:

1. **Torch heating**
2. **Furnace heating**
3. **Induction heating**
4. **Dip brazing**

Let's look at each method.

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1. Torch Heating

Torch heating is probably the most common for brazing (Fig. 105). The gas mixture may be oxy-acetylene, air-gas, gas-oxygen, or oxy-hydrogen. The type of gas mixture depends on the thermal conductivity, type, and thickness of the material to be joined.

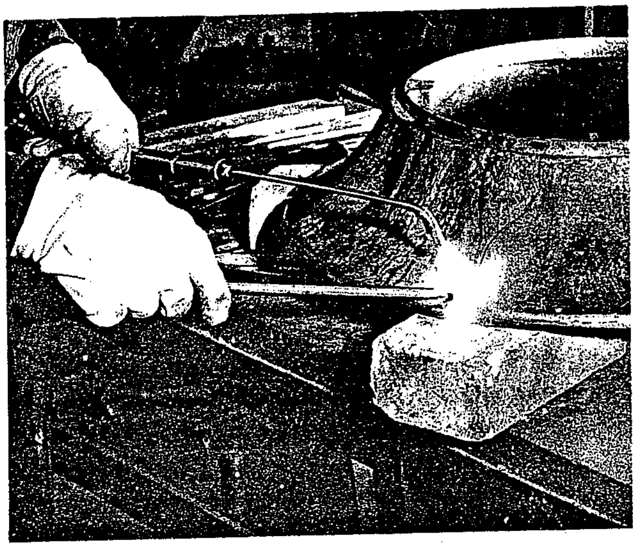

Fig. 105 — Torch Heating Is Commonly Used For Brazing

Oxyacetylene is often more versatile for torch brazing because of its wide range of heat control. A slightly reducing flame is required and care must be taken to prevent the core of the flame from coming in contact with the metal. Close flame contact may cause the base metal to melt and restrict the flow of the brazing metal.

The *air-gas* torch provides the lowest heat and is far more adaptable for brazing thin sections. The air-gas mixture may consist of air at atmospheric pressure and city gas or air and acetylene.

The *gas-oxygen* process uses oxygen with natur gas, bottled gas, propane, or butane. This mixtur produces a high flame temperature and is use where greater brazing heat is required.

The *oxy-hydrogen* torch is very useful for brazin aluminum and other nonferrous metals because its low heat. This prevents possible overheatir of the metal. Hydrogen also provides extra clea ing action and shielding during the brazing pr cess.

2. Furnace Heating

Furnace heating is a production process for bra ing parts that can be assembled and positioned c trays. The trays are loaded in a furnace eith manually or automatically. Some automatic loa ing consists of a conveyor belt on which the par are placed. The conveyor belt then moves into th furnace at regulated speeds (Fig. 106). The brazi filler metal, which can be in the form of wire, fc powder or paste, is placed in the right position ne the joint and the heat of the furnace melts the fil metal. Fluxing is used except when the heating done in a controlled atmosphere.

Most high-production brazing in a controlled mospheric furnace is done with hydrogen a either endothermic or combusted gas. Inert gas such as helium or argon are also used for co trolled atmospheric furnace brazing.

Some furnace brazing is done in a vacuum whe continuous pumping prevents oxidation and moves volatile materials that are liberated duri the brazing process. Vacuum brazing has wic applications in aero-space and nuclear industr where reactive materials are joined and any fo of trapped fluxes must be avoided.

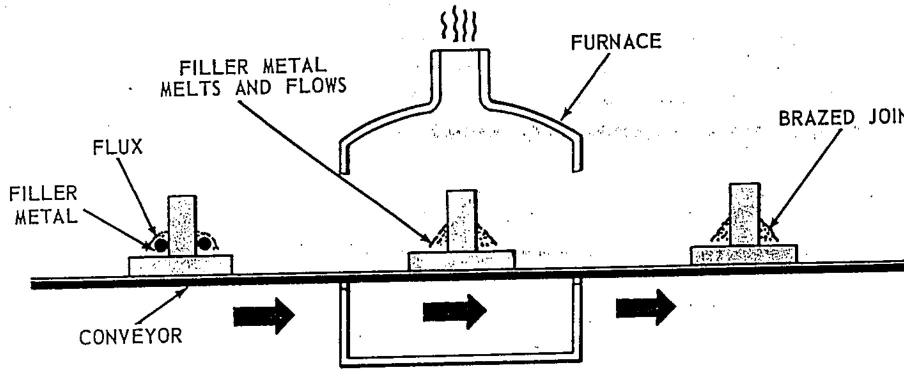

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Fig. 106 — Furnace Heating For Production Brazing

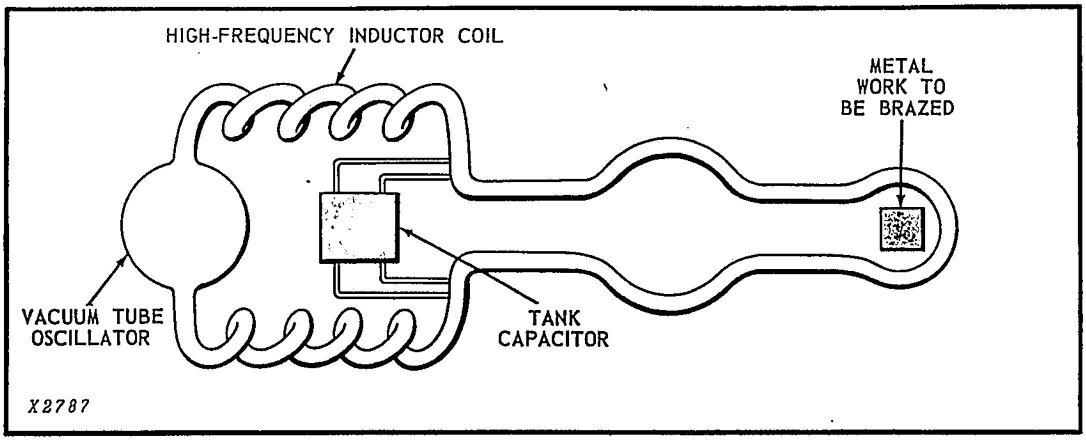

Fig. 107 — Induction Heating Coil for Brazing

3. Induction Heating

In this process, heat is generated by an inductor coil which is not in contact with the parts being brazed (Fig. 107).

A power supply unit converts regular line 60-cycle current into a high-frequency low voltage current.

As the current flows through the inductor coil, which surrounds the object to be brazed, a magnetic field is created. When conducting object is placed in a magnetic field, an electro-motive force is induced in the conductive material. This sets up a current and the resistance of the object to the flow of current causes instant heating to occur. The heat is relatively near the surface of the metal and any interior heating results from thermal conduction from the hot surface.

The power supply for the high-frequency current is either a motor generator, spark gap unit, or a vacuum tube oscillator.

The size of the power supply depends on the parts to be brazed and the production rate. Low-frequency power units produce deeper heating and are designed for brazing heavy sections, while high-frequency units produce light or shallow heating.

The work or inductor coil usually is of tubing but can be a copper block with an internal passage for water. The work coil has to be kept cool with circulating water. The size of the coil, that is the number of turns of copper tubing or the thickness of the copper block, is governed by the required heat zone to be developed.

Induction heating is used in brazing parts which can be aligned in a fixture and require rapid heating. It is very economical for quantity production when parts can be adapted to the induction furnace.

4. Dip Brazing

There are two dip brazing methods:

1. *Molten metal bath*
2. *Molten flux bath*

Molten Metal Bath

This technique consists of immersing parts in a bath of molten brazing metal. The brazing material is melted in a crucible with a cover of flux maintained over the molten filler metal. The parts to be brazed are first cleaned and fluxed and then dipped into the bath. The process is limited to brazing small assemblies such as wire connections or metal strips when they can be easily held in fixtures.

Molten Flux Bath

Flux in the form of a chemical salt is melted in a container or flux pot by a gas flame or electrical resistance. The most common method is passing an electric current through the bath. With resistance heating, the initial charge of flux is first melted by some other heating source and the molten salt poured into the fluxing container. Once the flux is in a molten state the resistance of the bath to the electrical current provides sufficient heat to keep the flux at the proper temperature. A thermocouple immersed in the molten bath and a temperature control unit keeps the molten flux at the required brazing heat.

The parts to be brazed are cleaned and assembled in a suitable fixture. Brazing filler metal in the form of rings, washers, slugs or paste mixture is preplaced on the base metal. In production brazing with molten salts, the parts and holding fixtures are usually pre-heated in a furnace to a tempera-

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ture near the melting point of the molten flux. The parts are then dipped in the molten flux where the heat is sufficient to melt the brazing material.

Molten flux bath dip brazing is often used to fabricate radiators or other cooling units.

BRAZE WELDING

Braze welding is slightly different from regular brazing. While brazing is the joining of two surfaces by a thin bond of brazing metal, braze welding is much like fusion welding except that the base metal is not melted. The base metal is brought up to its tinning temperature and then a weld bead is deposited over the seam with a filler rod.

Although the base metal is never actually melted, the bond formed by the brazing metals are often comparable to those secured through fusion welding.

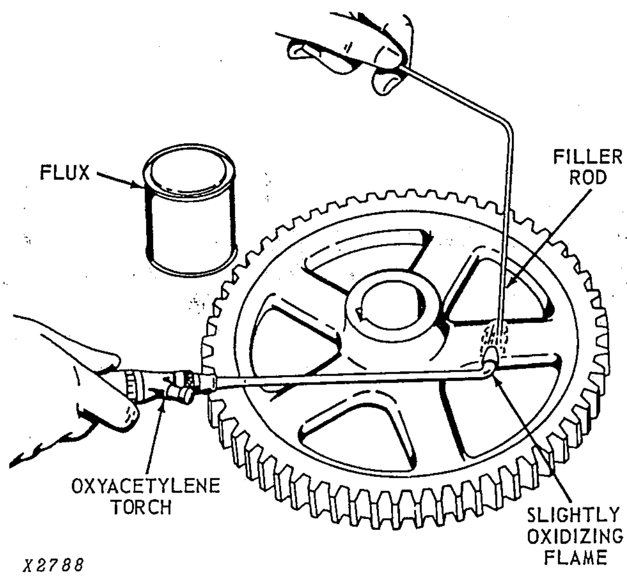

Fig. 108 — Braze Welding

Bronze welding is a typical braze welding operation. This technique is frequently used for joining or repairing such metals as cast iron, malleable castings, copper, brass, and various dissimilar metals. See Fig. 108. The bronze filler rod which is applied to the seam consists of copper and zinc with small quantities of tin, iron, maganese, and silicon.

The welding procedure involves cleaning the surface and then applying a coating of flux to diffuse the oxide. The flux is applied by dipping the heated rod into the powdered flux. The flux can also be mixed with water and spread over the seam.

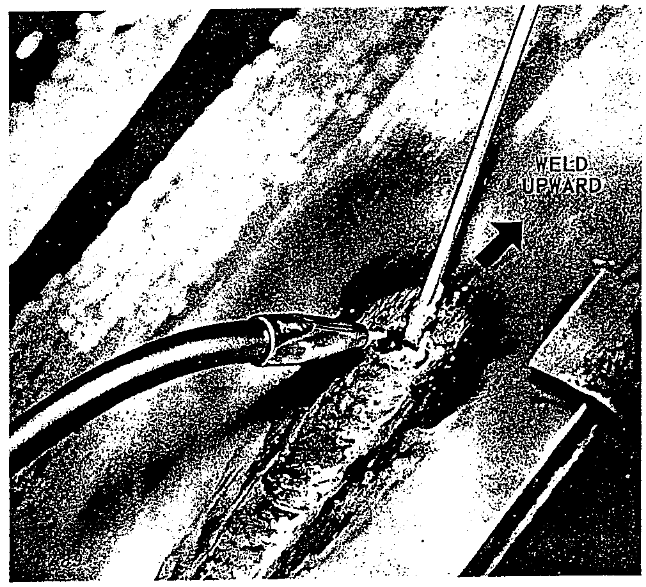

Fig. 109 — In Bronze Welding, The Weld Should Travel Upward At An Incline

Any type of joint is suitable for bronze welding. On thick sections, the edges should be beveled to form a 90-degree V-groove. The work is positioned so the weld travels upward on an incline (Fig. 109). In this position, the molten bronze cannot flow ahead of the heated welding area and the surface in front of the weld is left open to heating.

Generally, bronze welding is performed with an oxyacetylene torch with a flame that is *slightly oxidizing*. The flame is concentrated on the starting end until the metal begins to turn a dull red color. A small amount of bronze is melted on the surface and allowed to spread along the entire seam. The flow of this thin film of bronze is known as the tinning operation. Unless the surfaces are tinned properly, the remaining bronzing cannot be done successfully.

If the surface of the metal is heated properly, the bronze should spread out evenly over the metal. A surface that is too hot will cause the bronze to bubble or run around like drops of water on a warm stove. When the bronze forms into balls which tend to roll off, the base metal is not hot enough.

Once the base metal is well tinned, a weld bead is deposited over the seam using a slight circular torch motion. The rod must be constantly dipped into the flux as the weld progresses.

BRAZING WITH CARBON ELECTRODES

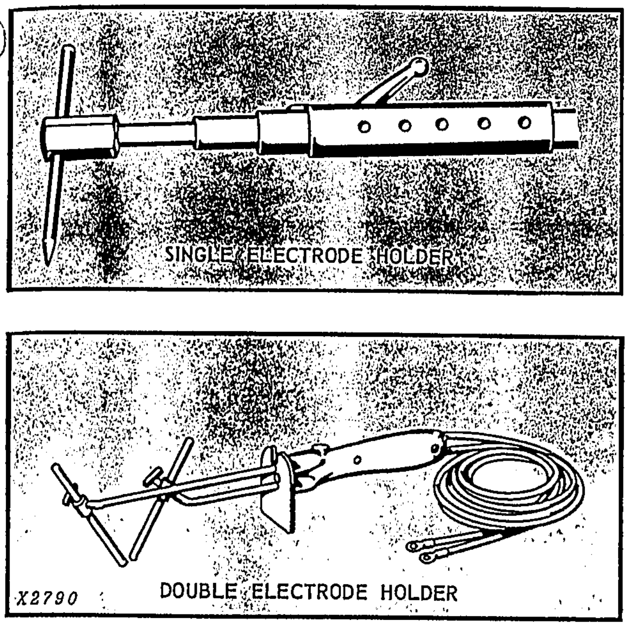

Fig. 110 — Carbon-Arc Electrode Holder

Some brazing is performed with a carbon-arc. The process is very similar to the metal electrode arc except that the electrode does not melt or provide filler metal. Here the carbon electrode serves only as the medium of generating the arc. The electrode is either of pure graphite or in the form of a copper-coated carbon and held in a special holder (Fig. 110).

The regular metal electrode holder is not suitable since the carbon electrode becomes very hot and the intense heat soon ruins the ordinary holder. A shield is often located near the handle to protect the operator's hand from the heat. The handle of the holder is made so air can circulate around it and keep it cool. When the carbon-arc is used for continuous operations, the holder is often water-cooled.

The electrode for brazing is shaped by grinding it to a long tapering point. See Fig. 111.

Either a DC or AC power source can be used for brazing. With an AC unit, the arc is formed between two carbon electrodes held in a holder as shown in Fig. 110. In the single carbon electrode with DC current, the machine must be set for straight polarity. Reverse polarity produces too much of an unstable arc and causes greater quantities of vaporized carbon to enter the molten brazing material.

Brazing is done by striking an arc and feeding a brazing rod into the arc. Most carbon arc brazing is done with a bare silicon bronze rod. The filler rod is held as illustrated in Fig. 111 and moved along the surface with the arc over the rod.

With the AC holder, the formed arc between the two electrodes remains intact even though the electrodes are withdrawing from the work. The arc is established by moving the electrodes with a push button located on the holder until the electrodes touch. Pressure on the button is then released to permit the points of the electrode to part and establish the arc. When the distance between the two electrodes is correct, there will be a quiet, soft flame. Striking the arc with a DC current is done in the same way as in metal electrode-arc welding.

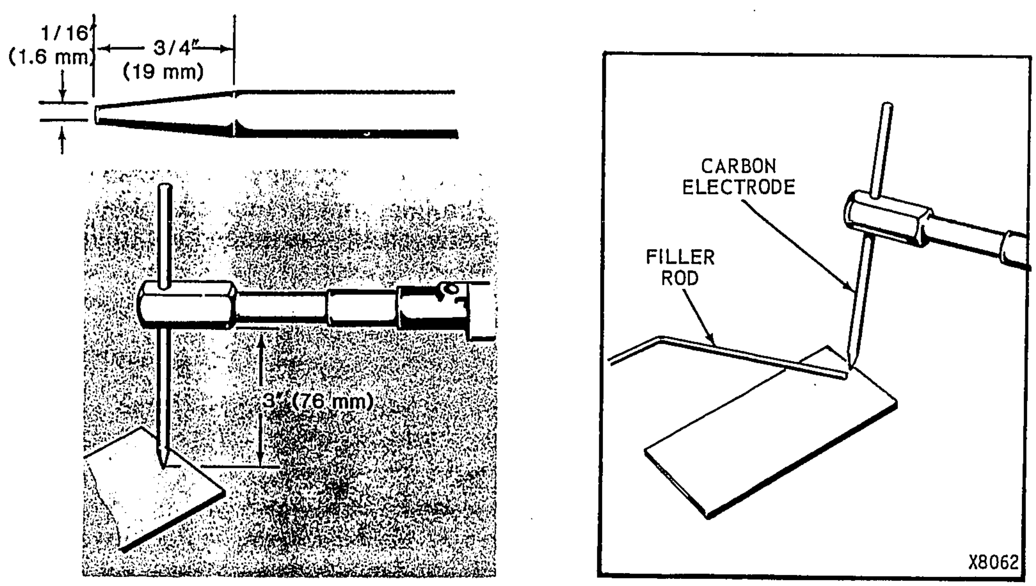

Fig. 111 — Brazing With The Carbon-Arc

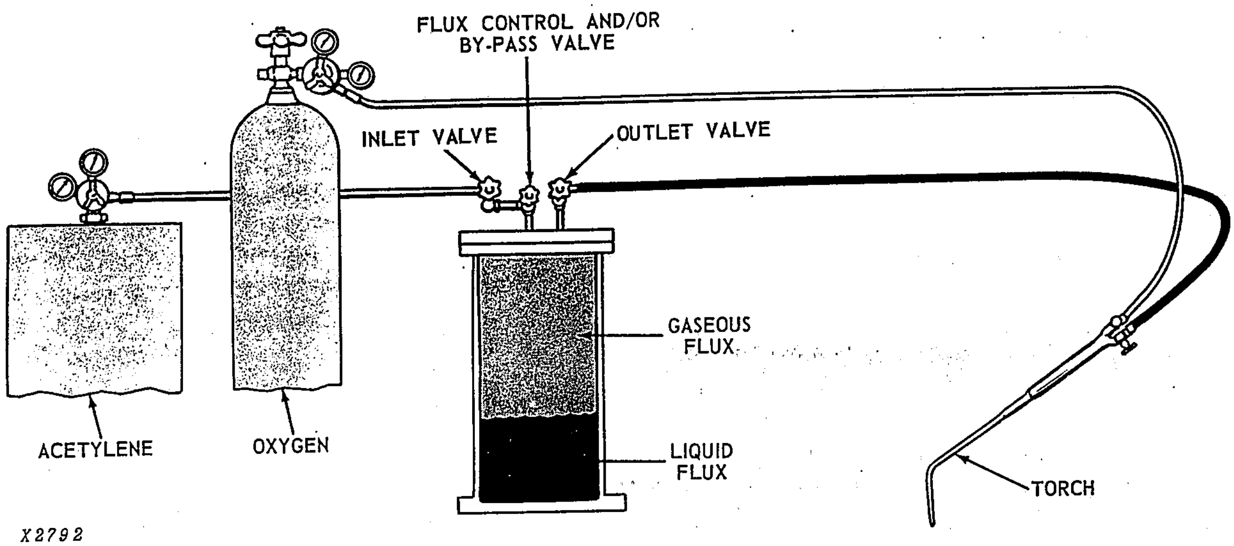

Fig. 112 — Brazing With A Liquid Flux

BRAZING WITH A LIQUID FLUX

Liquid flux eliminates the need of applying flux to metal surfaces before beginning the actual brazing operation.

A liquid fluxing material is placed in a separate tank that is connected to the regular gas line (Fig. 112). The flow of gas into the tank vaporizes the flux and induces it into the gas stream where it passes through the welding torch and into the flame. As the flame contacts the metal, the flux in the flame cleans and fluxes the surface for brazing. No pre-cleaning or post-cleaning of the parts is necessary.

As a rule, less heat is required with liquid flux than when a powder or wet flux is used. The weld metal is not oxidized and the strength of the brazed joint is greater.

Except for the fluxing tank, no other special equipment is needed as a standard welding torch is utilized.

The tank is equipped with a three-valve control unit. The inlet valve regulates the entry of gas into the tank, the flux or bypass valve controls the amount of flux used or eliminates the flux entirely, and the outlet valve supplies the flux gas through the line of the torch. See Fig. 112.

Liquifluxer can be used for brazing brass, bronze, copper, cast aluminum, cast and malleable iron, nickel and steel.

SOLDERING

Soldering is the joining of two metal pieces by using a nonferrous filler metal which melts below 800°F (427°C), or below those of the base metal. The filler metal is called solder and is distributed between the surfaces by capillary action.

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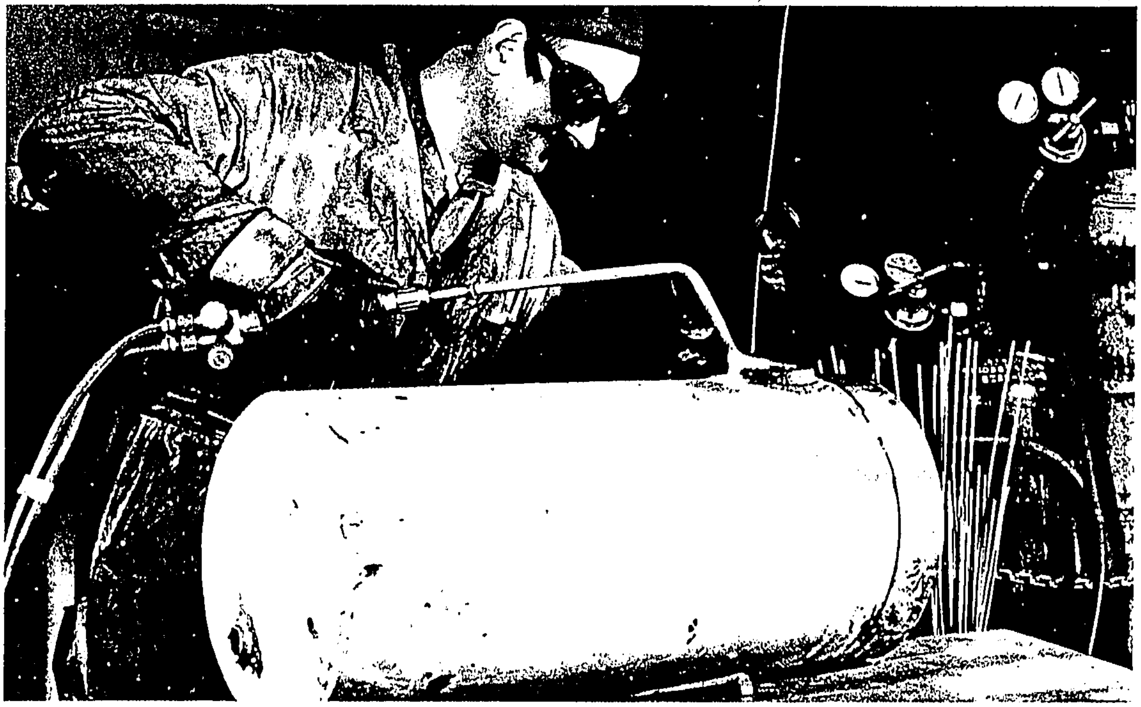

Fig. 113 — Soldering With A Torch

CAUTION: Do not breathe fumes from soldering. Some solders contain lead, cadmium and materials that are health hazards. See American National Standard Z49.1 Safety in Welding and Cutting and OSHA STANDARDS 29 CFR 1910 for specific hazards and precautions for soldering.

Soldering is used to join surfaces not under high-strength forces, since solder has a relatively low tensile strength. Soldered joints are also not suitable where temperatures approach the melting point of solder.

Soldering is a simple operation, providing five basic requirements are observed:

1. The right type and amount of solder and flux are used for the base metal being joined.

2. The pieces being soldered fit tightly together.

3. The pieces are absolutely clean.

4. The pieces are held together until the solder solidifies.

5. The correct amount of heat is applied to the seam.

See the Chart on the next page for metals which can be soldered.

SOLDERS

Most soft solders are alloys of tin and lead. The percentage of each metal determines its melting point and other characteristics. The melting range is from about 370°F (188°C) for a mixture of 70 percent tin and 30 percent lead to about 590°F (310°C) for 5 percent tin and 95 percent lead.

The most common general-purpose solder is known as half-and-half or 50-50 solder. It contains 50 percent tin and 50 percent lead and melts at about 471°F (244°C).

A variety of other alloys are used for soldering purposes. See the Chart on the next page for composition of solders.

In general, alloys with a low-tin content have higher melting points and do not flow as readily as the high-tin alloys. The low-tin alloys are less expensive and are used where large volumes of soldering are done. Solders with a high amount of tin have better wetting properties and produce less cracking. High-tin solders are used considerably in electrical work.

Solders with a tin content of 60 percent or more are classified as fine solders and are used in soldering instruments where temperatures are critical.

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Many commercial types of metals can be soldered. The chart below lists the various metals which are recommended or not recommended for soldering.

METALS AND SOLDERING

Base Metal, Alloy or Applied Finish	Flux Requirements			Soldering Not Recommended
	Non-Corrosive	Corrosive	Special Flux and/or Solder	
Aluminum			X	
Aluminum-Bronze			X	
Beryllium				X
Beryllium Copper		X		
Brass	X	X		
Cadmium	X	X		
Cast Iron			X	
Chromium				X
Copper	X	X		
Copper-Chromium		X		
Copper-Nickel		X		
Copper-Silicon		X		
Gold	X			
Inconel			X	
Lead	X	X		
Magnesium			X	
Manganese-Bronze (High Tensile)				X
Monel		X		
Nickel		X		
Nichrome			X	
Palladium	X			
Platinum	X			
Rhodium		X		
Silver	X	X		
Stainless Steel			X	
Steel		X		
Tin	X	X		
Tin-Bronze	X	X		
Tin-Lead	X	X		
Tin-Nickel	X	X		
Tin-Zinc	X	X		
Titanium				X
Zinc		X		
Zinc Die Castings			X	

Special solders are also available. Thus a tin-antimony solder is designed to solder food-handling vessels where lead contamination must be avoided. Tin-zinc solders are intended primarily for joining aluminum. Lead-silver solders are used where strength at high temperatures is required.

Solders are available in bar, cake, solid wire, flux-core wire, ribbon and paste forms. Flux-core wire solder has an acid or resin flux in the center of the wire. With these solders, no additional flux is needed.

COMPOSITION OF ASTM SOLDERS

ASTM Number	Composition %				Melting Range
	Tin	Lead	Antimony	Copper	
5A	5	bal.	0.12 max.	0.08	572-596
5B	5	bal.	0.50 max.	0.08	572-596
10B	10	bal.	0.50 max.	0.08	514-573
20B	20	bal.	0.50 max.	0.08	364-535
20C	20	bal.	1.0-1.2	0.08	364-535
30A	30	bal.	0.25	0.08	361-477
30B	30	bal.	0.50	0.08	361-477
40A	40	bal.	0.12	0.08	361-455
50A	50	bal.	0.12	0.08	361-421
60A	60	bal.	0.12	0.08	361-374
63A	63	37	0.12	0.08	361-361

FLUXES

Oxides and rust will form on surfaces of most metals when exposed to air. Solder will not adhere if such impurities are present. By applying a flux, the oxide is removed and the formation of new oxide during the soldering process is prevented. Fluxes also increase the wetting action, allowing the solder to flow more freely.

Fluxes come in paste, liquid, powder, and cake form. Some are general-purpose fluxes usable on most all metals. Others are special fluxes such as those for aluminum soldering.

All fluxes are classified as *corrosive* or *noncorrosive.* Although the corrosive types are most effective, they must be washed from the metal after soldering. They should never be used for electrical or electronic work.

Resin is the most common noncorrosive flux. Zinc chloride is the most frequently used corrosive flux.

HEATING TOOLS

In any soldering operation, both pieces of metal to be joined must be hot enough to melt the solder. A strong bond is achieved only if the molten solder spreads evenly over the surface. A number of devices are available for heating purposes. The type used depends on the size and shape of the assembly. The major types of heating tools are:

1. **Soldering coppers**

2. **Electric soldering tools**

3. **Flame-heating devices**

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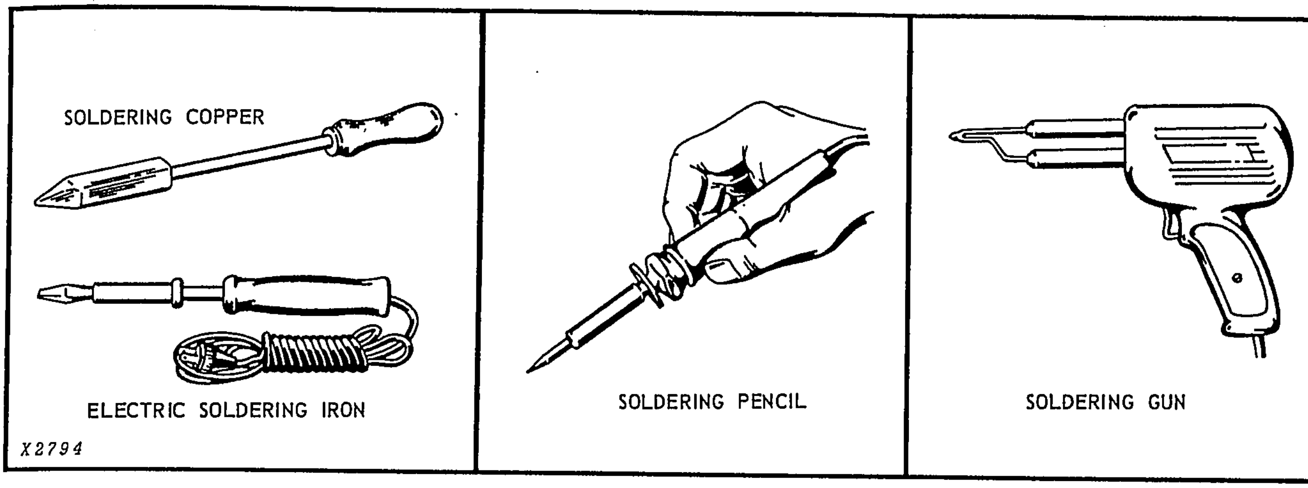

Fig. 114 — Heating Tools For Soldering

Soldering Coppers

A soldering copper consists of a forged piece of copper fastened to an iron rod with a wooden handle on one end. These coppers vary in size with heads forged in several shapes. See Fig. 114.

Generally, a lightweight copper is used for soldering light-gauge metal and a heavyweight copper for soldering heavy-gauge metal. A lightweight copper on heavy metal does not hold enough heat to heat the metal or allow the solder to flow smoothly. Soldering coppers are heated in a furnace or with a torch.

Electric Soldering Tools

These devices are often more convenient than soldering coppers because they maintain a uniform heat. See Fig. 114. They vary in sizes from 25 watts to 550 watts.

Lightweight, low-voltage *irons* with replaceable heating elements and tips are called *soldering* pencils and are preferred for electrical and electronic work. Electric soldering *guns* produce instant heat at the tip of a long small point when the trigger is pulled. On most guns, the trigger also turns on a light which focuses at the point. For these reasons, the soldering gun is very popular for electronic work.

Flame-Heating Devices

Some soldering operations are impossible or very difficult to perform with a soldering copper iron. For these jobs, a flame is used as the source of heat. See Fig. 115.

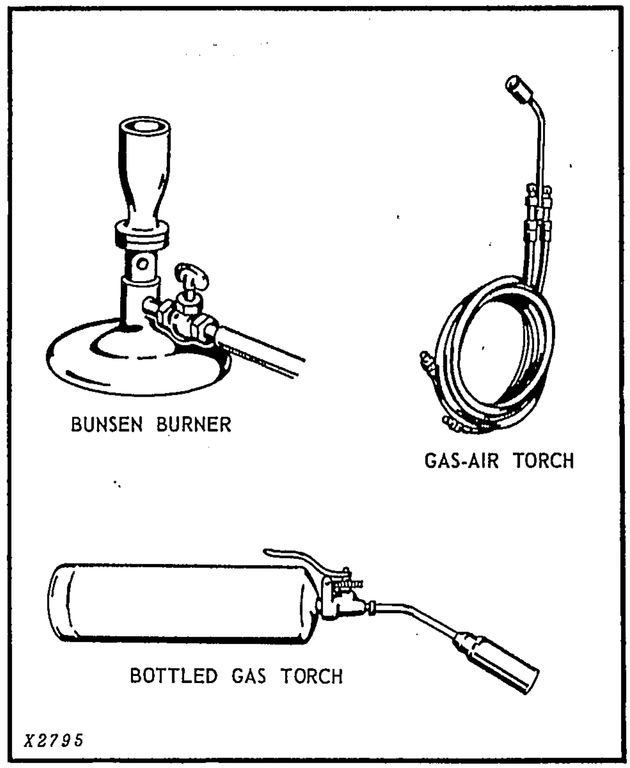

Fig. 115 — Flame-Heating Devices For Soldering

The flame is produced either with an ordinary *Bunsen burner* or a *gas torch,* depending on the nature of the job.

The most efficient, safe, and versatile gas torch is one that burns city gas and compressed air. These torches are often equipped with changeable tips which can produce a wide range of flame sizes. The gas-air torch has two needle valves; one valve controls the pressure of gas and the other valve the compressed air. To light the torch, the gas-needle valve is opened slightly and ignited. Then the oxygen valve is turned on and adjusted until a blue flame results. The length of the flame is controlled by the amount of gas and air allowed to flow to the tip.

Bottled-gas torches are also used for soldering, especially when the work is not at a fixed station where a gas-air torch is available. The bottled-gas torch must be operated with care; follow the manufacturer's instructions carefully.

PREPARING TO SOLDER

1. **Parts to be soldered must fit perfectly** so the solder can travel by capillary action between the two surfaces. Solder will cease to flow where there is a gap between the two workpieces.

2. **Parts to be soldered must be absolutely clean** because the solder will not stick to a dirty, oily or oxide-coated surface. Dirt and grease can be removed with a cleaning solvent. Steel wool or other abrasive cloth is used to eliminate the oxide. Applying a flux completes the cleaning and keeps the metal free from oxide during heating and soldering.

3. **Parts must be held together** during soldering so there is no movement. Any movement during the heating will cause the pieces to be misaligned and the slightest disturbance of the solder as it solidifies will cause it to crystallize. The result is a weak joint.

4. **Parts to be soldered must have a suitable joint design** to withstand the loads imposed on it. The strength of the joint cannot depend on the bond itself because a soldered joint, for example, will seldom develop shear strength greater than 250 psi (1700 kPa). If greater strength is needed, make some type of mechanical joint by lapping or folding before you solder.

TINNING A COPPER

The point of a soldering copper must be covered with a thin coat of solder to operate properly. A tinning operation is performed by first smoothing the surfaces of the point with a file and then heating the copper until it is hot enough to melt solder. The point is next rubbed on a block of sal ammoniac and a small amount of solder melted during the rubbing action (Fig. 116).

Tinning can also be done by dipping the point in a liquid or paste flux and applying solder.

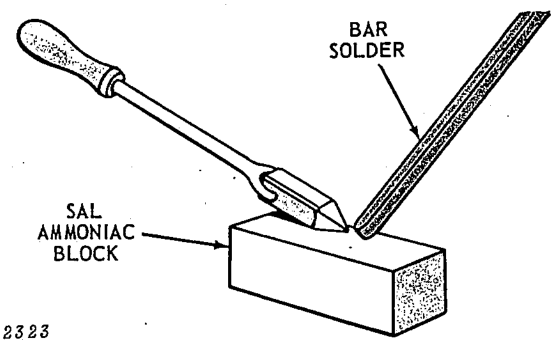

Fig. 84 — Tinning A Soldering Copper Over A Block Of Sal Ammoniac

SWEAT SOLDERING

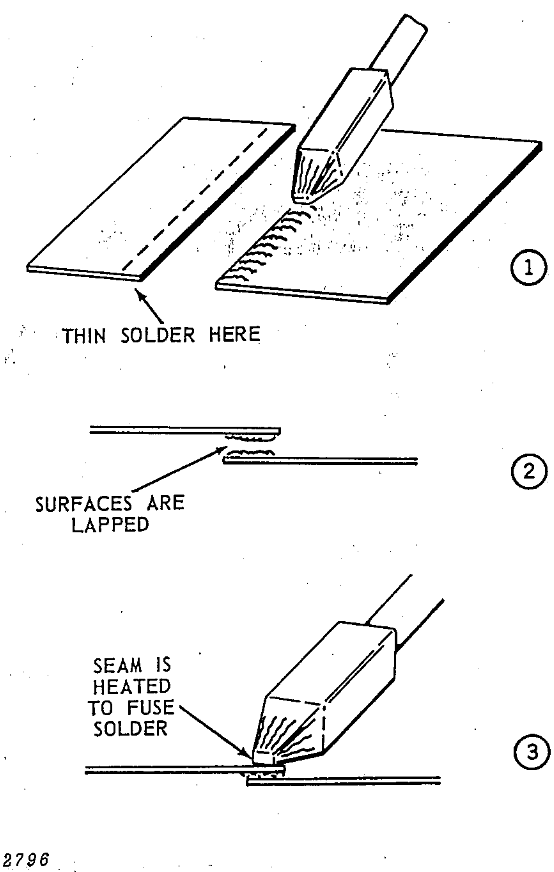

Fig. 117 — Sweat Soldering A Joint

In this process, two surfaces are soldered without the solder being visible. This is done by applying a coating of solder to each of the surfaces to be joined (1, Fig. 117). The coated surfaces are then placed together (2) and a heated copper held over the seam (3). To avoid smearing the exposed sur-

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faces of the metal with solder, the excess solder on the copper is removed by quickly wiping the joint with a damp cloth.

When the solder between the two surfaces begins to melt and show evidence of flowing out from the edges, pressure is applied on the metal. As the copper is drawn slowly along the seam, pressure must be maintained until the solder solidifies.

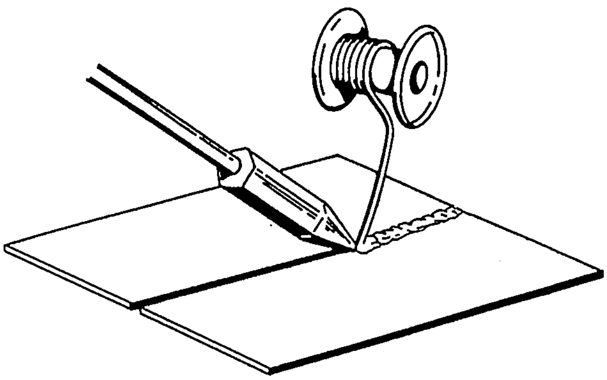

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Fig. 118 — Seam Soldering A Joint

SEAM SOLDERING

Seam soldering is running a layer of solder along the outside edge of the joint (Fig. 118). As a rule, the surfaces of the joint are first tacked to hold them in position. Tacking is done by depositing a small drop of solder at several places on the seam. The point of the copper is then moved along the edge of the seam as shown and solder applied directly in front of the point.

FLAME SOLDERING

Many soldering jobs are difficult when using a soldering copper or electric-soldering iron. In these cases a torch flame is often more practical, especially where fast soldering is required. The flame can be adjusted to the required size and directed to the exact spot where it is needed and moved to heat both pieces properly as well as to melt the solder.

INDUCTION SOLDERING

This is used where large-scale production is involved and the pieces can be kept in alignment by a fixture.

Induction heating is produced by a motor generator, spark-gap unit, or vacuum tube oscillator and the rate of heating is governed by the amount of induced current that flows.

The pieces to be soldered are aligned near the induction work coil with the solder preplaced on the joint. Cleaning and fluxing must be completed before soldering is started.

Solders for induction heating should spread rapidly and have good capillary flow. Preforms combining solder and flux are the best means of supplying the correct amount of solder and flux for induction soldering.

RESISTANCE SOLDERING

Here the electrical resistance of the metal provides the necessary heat for soldering. The work to be soldered is placed between a ground and one or two movable electrodes. Solder is fed directly into the joint when the surfaces of the workpieces reach the proper temperature.

DIP SOLDERING

Dip soldering consists of a pot with molten solder. The joint to be soldered is simply dipped into the molten solder. The bath supplies both the heat and solder to complete the soldering operation.

This soldering technique is very economical since an assembly with several joints can be soldered at once.

Any dip soldering operation requires suitable jigs and fixtures to keep the unit in alignment until the solder has solidified. These fixtures must be well made to prevent movement of the parts during the operation when they are being dipped and handled.

OVEN SOLDERING

Gas or electric ovens are used for soldering when the entire assembly can be heated without damaging any of its components. Since the assembly must be moved before and during the solidification of the solder, suitable jigs and fixtures are required to hold parts together. Without proper clamping, the joint will fail because solder is easily disturbed before it becomes solid.

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Basic Principle Of The Internal Combustion Engine

Learning Objective : The student will have a working knowledge of the operation of the internal combustion engine, it's varying configurations and types.

Task :

1. The student will correctly explain the following:

KEY CONCEPT
The four strokes of an engine
The difference between a four stroke and a two stroke engine
What is meant by the term "V-type" engine
What is an "in-line" engine
What is an overhead valve engine
What is an overhead cam engine
Valve and camshaft operation
The purpose of the air system
The purpose of the ignition system
The purpose of the cooling system
The purpose of the exhaust system
The purpose of the emission control system
What is bore and stroke
What is displacement
What is compression ratio
What is torque
What is horsepower
The major difference between gasoline and diesel engines
What is the purpose of a crankshaft
What is the purpose of a camshaft
What is an engine's firing order

Standard : The student will complete a written examination with a minimum score of 80%.

Task Check-Off Sheet

Name	Engines	
Task	**Date**	**Instructor**
1. The student will correctly explain the following:		
a. the four strokes of a four stroke engine		
b. the difference between a four stroke and a two stroke engine		
c. what is meant by the term "V-type" engine		
d. what is an in-line engine		
e. what is an Overhead Valve Engine		
f. what is an Overhead Cam Engine		
g. Valve and Camshaft operation		
h. the purpose of the air system		
i. the purpose of the ignition system		
j. the purpose of the lubrication system		
k. the purpose of the cooling system		
l. the purpose of the exhaust system		
m. the purpose of the emission control system		
n. what is bore and stroke		
o. what is displacement		
p. what is compression ratio		
q. what is torque		
r. what is horsepower		
s. the major difference between gasoline and Diesel engines		
t. the purpose of a crankshaft		
u. what is the purpose of a camshaft		
v. what is an engine's firing order		

ENGINES—How They Work / CHAPTER 1

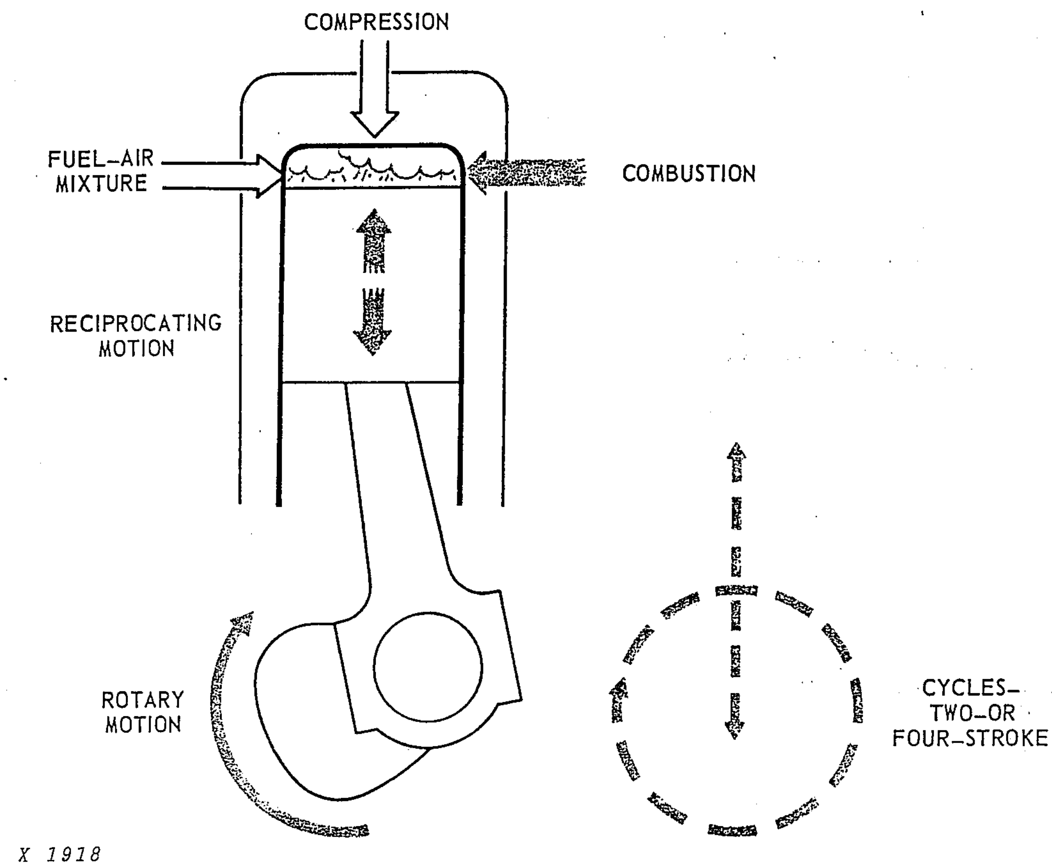

Fig. 1 — Basic Elements Of An Engine

WHAT IS AN "INTERNAL COMBUSTION" ENGINE?

Let's see what the term "internal combustion" means:

- **"Internal" means "inside" or "enclosed"**
- **"Combustion" is the "act of burning"**

Thus an internal combustion engine is one that *burns fuel internally.*

Basically this engine is a container in which we put fuel and air and start them burning.

The mixture expands rapidly while burning and pushes outward. This push can be used to move a part of the engine, and transmitted to drive the machine.

In summary, an engine is a device which converts heat energy into mechanical energy to do work.

WHAT ELEMENTS ARE NEEDED FOR AN ENGINE?

These elements are needed to construct a simple engine:

- **Air, Fuel, and Combustion**
- **Reciprocating and Rotary Motion**
- **Compression of Fuel-Air Mixture**
- **Engine Cycles—Two-or Four-Stroke**

Let's discuss these items one by one.

AIR, FUEL AND COMBUSTION

Three basic elements are needed to produce heat energy in the engine:

- **Air**
- **Fuel**
- **Combustion**

AIR is needed to combine with fuel and give it oxygen for fast burning. Air also has two other properties which affect the engine:

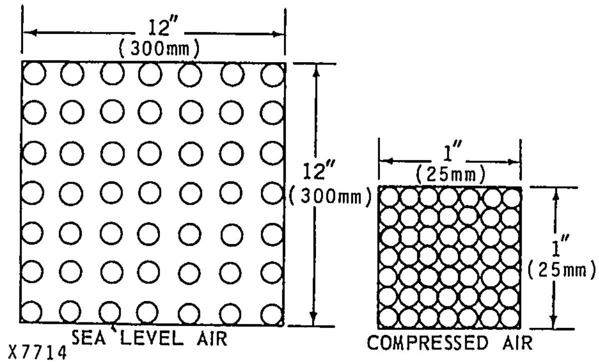

Fig. 2 — Air Can Be Compressed

(1) Air will compress; one cubic foot (28 L) of air can be packed into one cubic inch (16 cm^3) or less (Fig. 2).

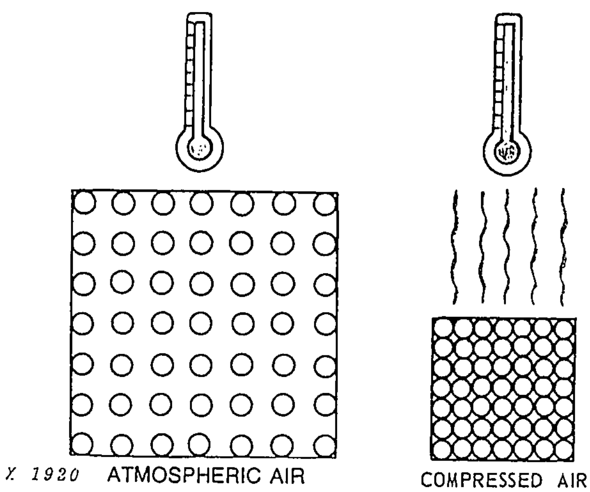

Fig. 3 — Air Heats When Compressed

(2) Air heats when it is compressed. The molecules of air rub against each other and produce heat (Fig. 3).

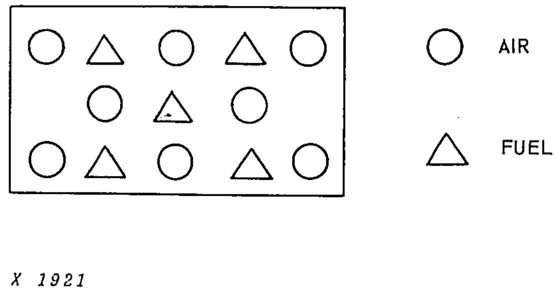

Fig. 4 — Fuel Must Mix Readily With Air And Ignite Easily

FUEL must mix readily with air and ignite easily (Fig. 4). The three we will cover are gasoline, LP-gas, and diesel fuel.

These fuels ignite easily and are readily broken down or vaporized.

Why do we want to vaporize the fuel? To help each particle of fuel contact enough air to burn fully.

COMBUSTION is the actual igniting and burning of the fuel-air mixture. It is the *oxygen* in the air that combines with the fuel for combustion.

What is important here is *how fast* the fuel burns, for this force must be "explosive" to get full power from the engine.

If a container of gasoline is ignited in calm outside air, it burns rather lazily (Fig. 5). This is because the air contacts only the surface of the fuel. To make the fuel burn faster, two things can be done:

1) Heat up the fuel

2) Vaporize the fuel (Fig. 5)

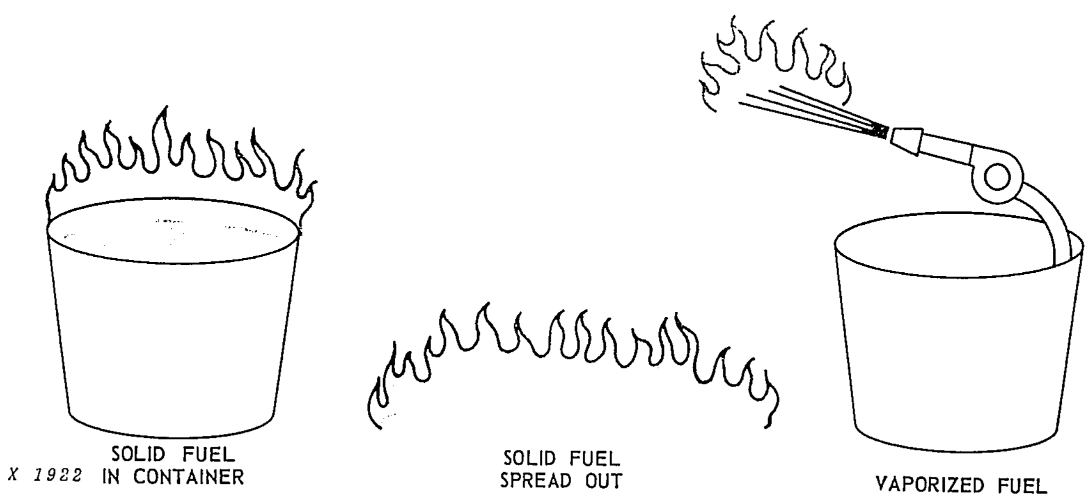

Fig. 5 —Vaporized Fuel Burns Faster

However, too powerful an explosion would destroy an engine, since combustion takes place in a closed container.

We can control the rate of burning by 1) how far we compress the air (and so heat it up), 2) how much fuel we use and 3) how volatile it is.

RECIPROCATING AND ROTARY MOTION

The engine uses two forms of motion to transmit energy:

- **Reciprocating Motion—up-and-down or back-and-forth motion**
- **Rotary Motion—circular motion around a point**

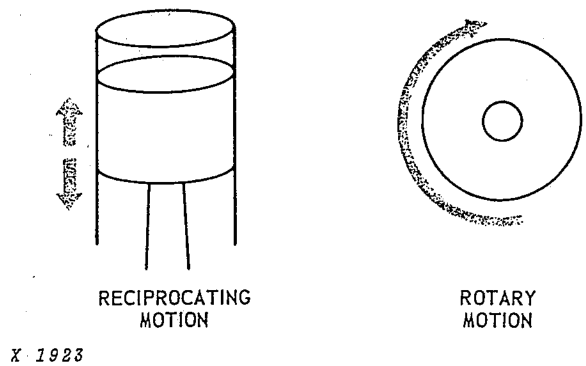

Fig. 6 — Reciprocating And Rotary Motion

The engine converts reciprocating motion into rotary motion (Fig 6).

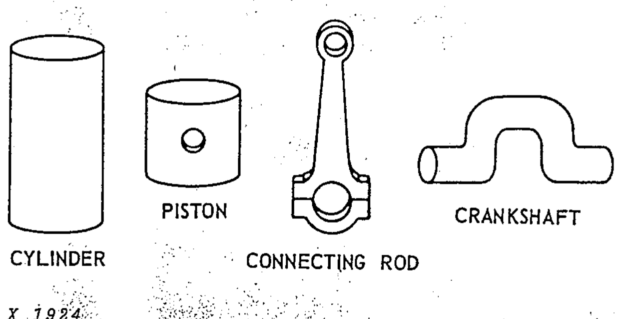

Fig. 7 — Basic Parts Of The Engine

Four basic parts are needed to make the engine work in this way:

- **Cylinder**
- **Piston**
- **Connecting Rod**
- **Crankshaft**

The *piston* and *cylinder* are mated parts, fitted closely so that the piston glides easily in the cylinder but with little clearance at the sides. The

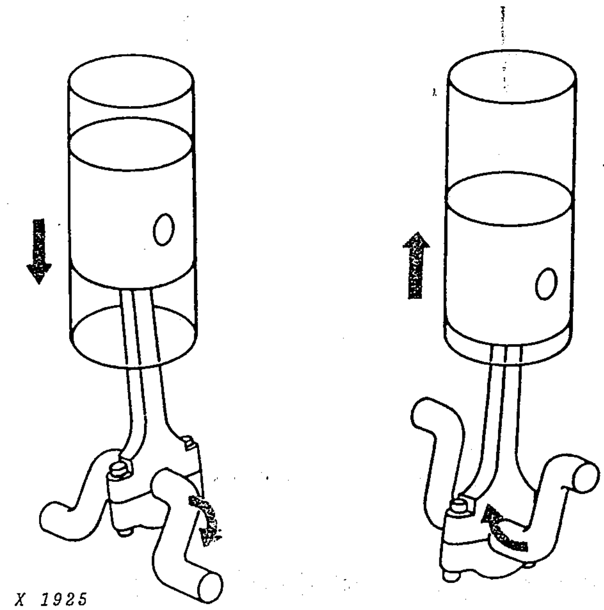

Fig. 8 — How Reciprocating Motion Is Transmitted To The Crankshaft As Rotary Motion

top of the cylinder is closed, but has extra space for the combustion chamber. A cylinder head of the engine generally closes the end of the cylinder.

The *connecting rod* is the link which transmits the motion of the piston to the crankshaft.

A simple *crankshaft* has a section offset from the center line of the shaft so that it "cranks" when the shaft is turned.

The motion is basically the same as when you pedal a bicycle. Your leg is like the connecting rod while the pedal crank and sprocket are like the crankshaft.

As a result, we have a way of converting the reciprocating motion of the piston into useful rotary motion (Fig. 8).

The stroke of the piston (how far it travels in the cylinder) is set by the "throw" of the crankshaft (how far it is offset).

COMPRESSION OF THE FUEL-AIR MIXTURE

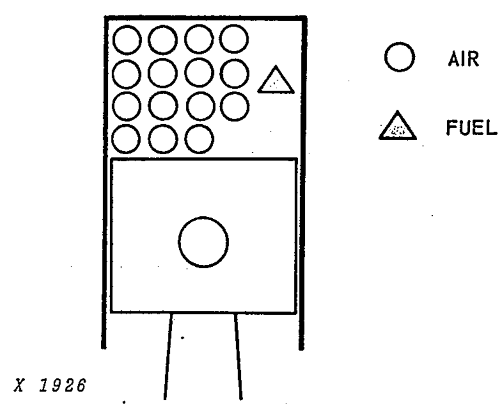

Fig. 9 — Fuel-Air Ratio For Gasoline Engine

The modern gasoline engine works best when about 15 parts of air are mixed with 1 part of fuel (Fig. 9).

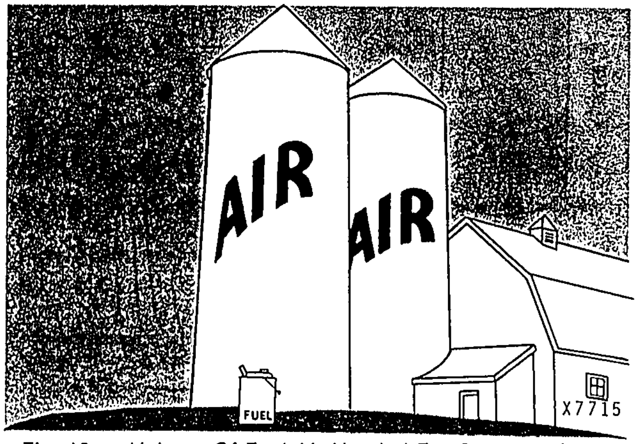

Fig. 10 — Volume Of Fuel-Air Needed For Gasoline Engine

Fig. 10 shows how much greater the *volume* of air needed is than the volume of fuel. The gasoline engine mixes one gallon (4 L) of gasoline with about 9,000 (34 000 L) gallons of air.

As a result, we must **compress** the fuel-air mixture to get the desired ratio.

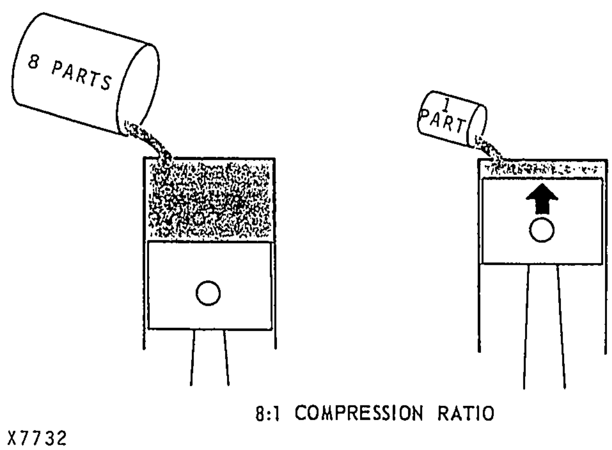

Fig. 11 — Compression Ratios Tell How Much The Fuel-Air Mixture Is Compressed By Volume

Compression ratios tell us how much the fuel-air mixture is compressed by volume. Fig. 11 shows an imaginary case.

When the piston is at the bottom of its stroke, let's measure the amount of liquid the cylinder will hold and say it takes 8 pints (3.75 L).

Now if we remove all the liquid and move the piston to the top of its stroke, we can again pour the cylinder full of liquid. Let's say it only holds one pint (0.5 L).

The ratio is then 8 to 1, which is the *compression ratio.*

In other words, air in this engine is compressed to one-eighth of its former volume by the moving piston. Later we'll see how compression affects the engine.

ENGINE CYCLES

For an engine to operate, a definite series of events must occur in sequence. They are:

1. *Fill the cylinder with a combustible mixture.*
2. *Compress this mixture into a smaller space.*
3. *Ignite the mixture and cause it to expand, producing power.*
4. *Remove the burned gases from the cylinder.*

The sequence above is generally called:

- **Intake**
- **Compression**
- **Power**
- **Exhaust**

To produce sustained power, the engine must repeat this sequence over and over again.

One complete series of these events in an engine is called a *cycle.*

Most engines have one of two types of cycles:

- **Two-Stroke Cycle**
- **Four-Stroke Cycle**

In the TWO-STROKE CYCLE engine, there are two strokes of the piston, one up and one down, during each cycle (Fig. 12). Then it starts over again on another cycle of the same two strokes. This whole cycle occurs during one revolution of the crankshaft.

In the FOUR-STROKE CYCLE engine, there are four strokes of the piston, two up and two down, during each cycle (Fig. 12). Then it starts over again on another cycle of the same four strokes. This cycle occurs during *two* revolutions of the crankshaft. Most engines today operate on the four-stroke cycle.

Let's see how each type of cycle works in detail.

TWO-STROKE CYCLE ENGINE

In the **two-stroke cycle** engine, the complete cycle of events—intake, compression, power, and exhaust—takes place during two piston strokes.

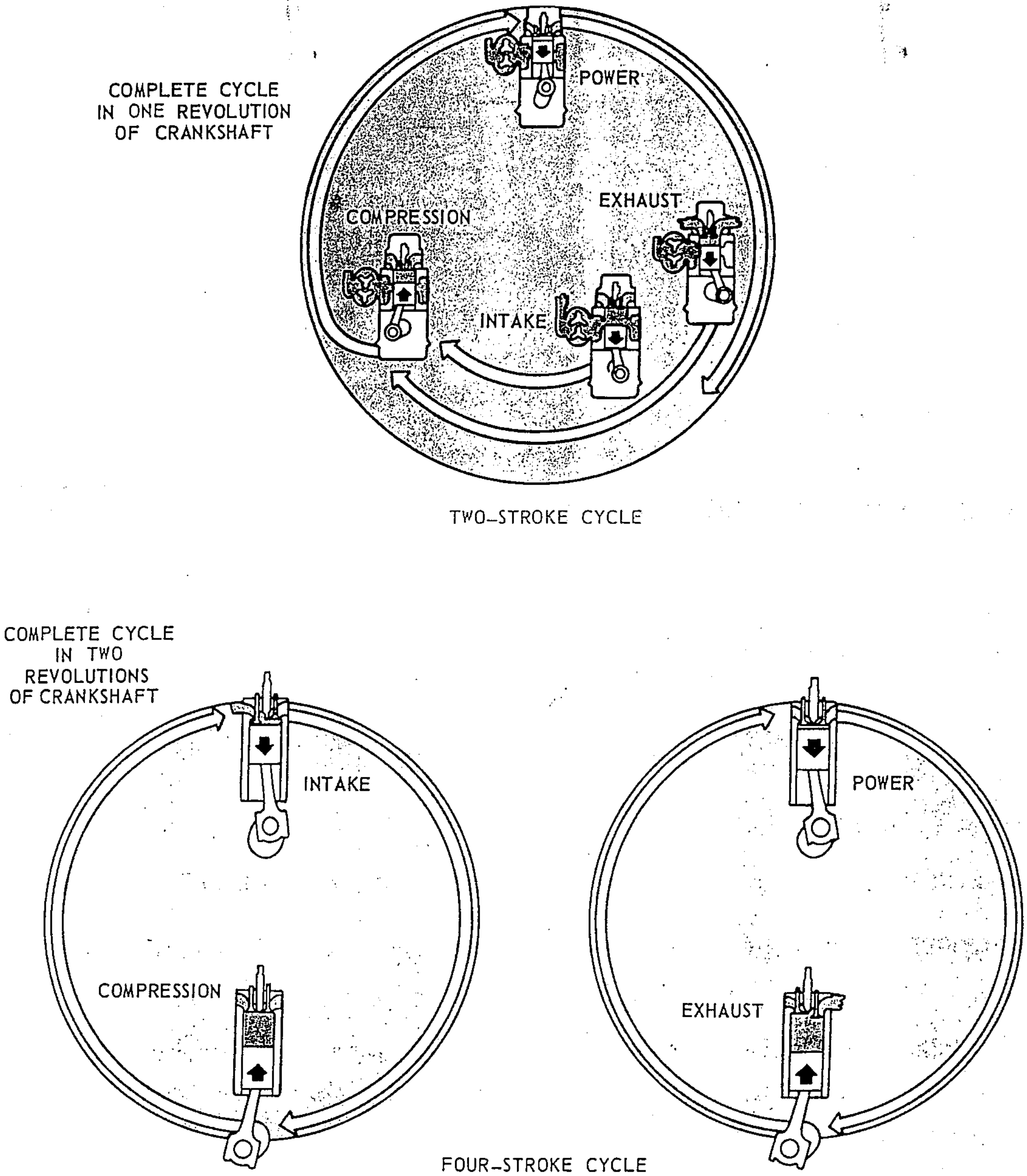

Fig. 12 — Two-Stroke And Four-Stroke Cycles Compared

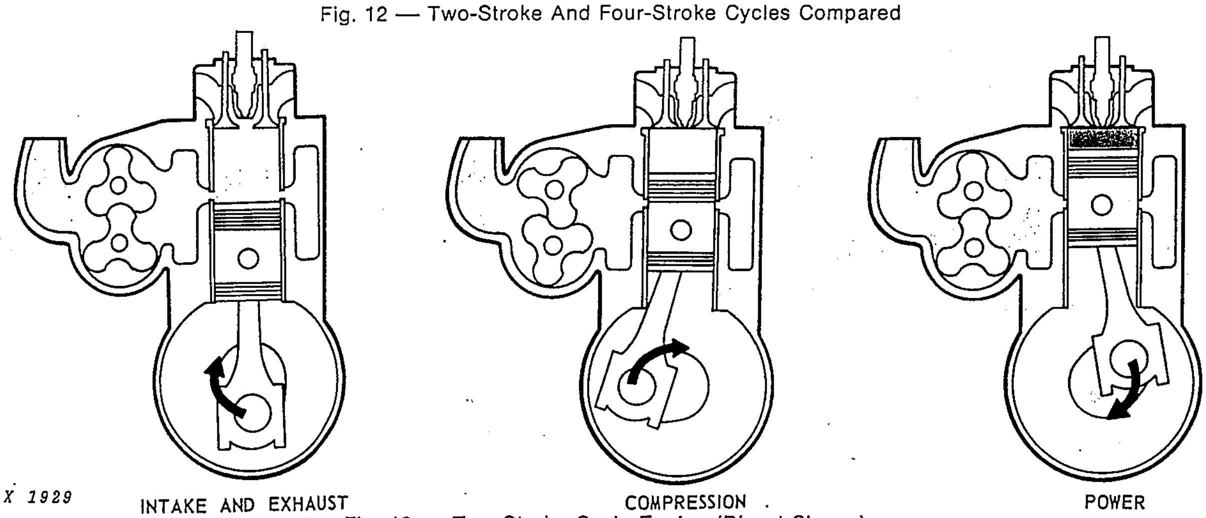

Fig. 13 — Two-Stroke Cycle Engine (Diesel Shown)

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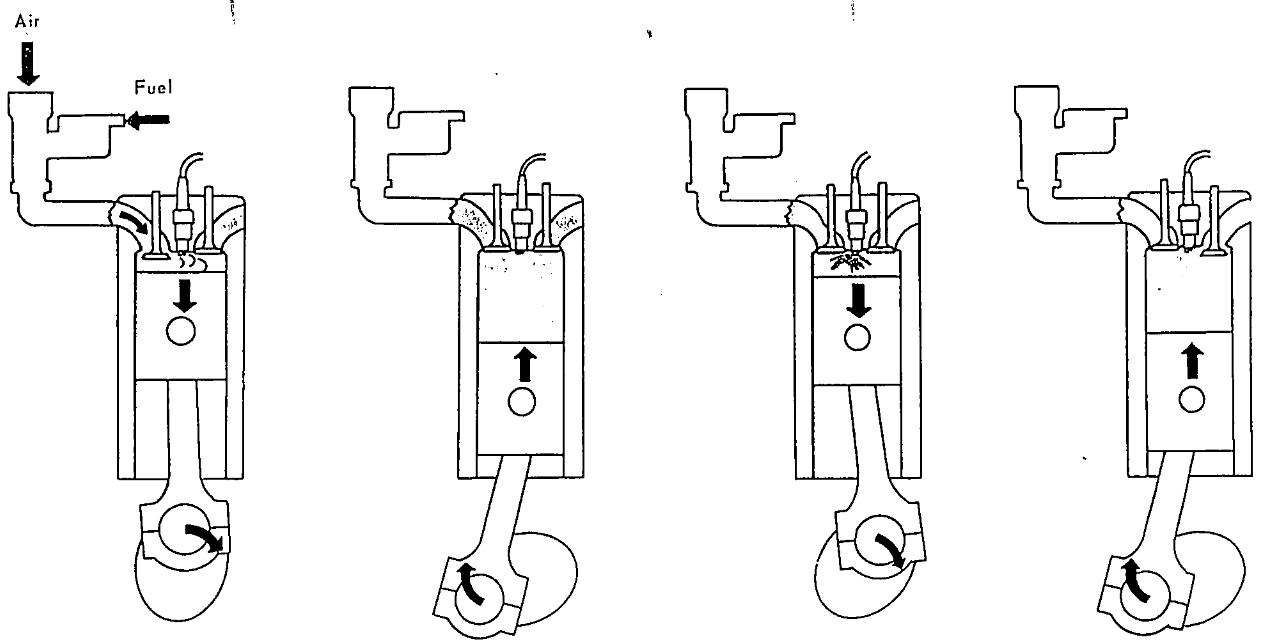


Fig. 14 — Four-Stroke Cycle Engine (Gasoline Shown)

Fig. 13 shows a two-cycle diesel engine in operation. Every other stroke is a power stroke; each time the piston moves down it is a power stroke.

In the diesel engine shown, air alone is compressed in the cylinder. A charge of fuel is then sprayed into the cylinder and ignites from the heat of compression.

In the two-cycle engine, intake and exhaust take place during part of the compression and power strokes.

A blower is sometimes used to force air into the cylinder for expelling exhaust gases and to supply fresh air for combustion. The cylinder wall contains a row of ports which are above the piston when it is at the bottom of its stroke. These ports admit air from the blower into the cylinder when they are uncovered (during *intake).*

The flow of air toward the exhaust valves pushes the *exhaust* gases out of the cylinders and leaves them full of clean air when the piston again rises to cover the ports (during *compression).*

At the same time, the exhaust valves close and the fresh air is compressed in the closed cylinder.

When the piston almost reaches the top of its *compression* stroke, fuel is sprayed into the combustion area as shown. The heat of compression ignites the fuel and the resulting pressure forces the piston down on its *power* stroke.

As the piston nears the bottom of its stroke, the *exhaust* valves are again opened and the burned gases escape.

The piston then uncovers the *intake* ports and the cycle begins once more.

This entire cycle is completed in *one* revolution of the crankshaft or *two strokes* of the piston—one up and one down.

FOUR-STROKE CYCLE ENGINE

In **four-stroke cycle** engines, the same four operations occur—intake, compression, power, and exhaust. However, four strokes of the piston—two up and two down—are needed to complete the cycle. As a result, the crankshaft will rotate *two* complete turns before one cycle is completed (Fig. 14).

Intake Stroke

The intake stroke starts with the piston near the top and ends shortly after the bottom of its stroke. The intake valve is opened, allowing the cylinder as the piston moves down to receive the fuel-air mixture. The valve is then closed, sealing the cylinder.

Compression Stroke

The compression stroke begins with the piston at bottom and rising up to compress the fuel-air mixture. Since the intake and exhaust valves are closed, there is no escape for the fuel-air and it is compressed to a fraction of its original volume.

Power Stroke

The power stroke begins when the piston almost reaches the top of its stroke and the fuel-air mixture is ignited. As the mixture burns and expands, it forces the piston down on its power stroke. The valves remain closed so that all the force is exerted on the piston.

Exhaust Stroke

The exhaust stroke begins when the piston nears the end of its power stroke. The exhaust valve is opened and the piston rises, pushing out the burned gases. When the piston reaches the top, the exhaust valve is closed and the piston is ready for a new four-stroke cycle of intake, compression, power, and exhaust.

As it completes the cycle, the crankshaft has gone all the way around twice.

TWO-CYCLE VS. FOUR-CYCLE ENGINES

It might seem that the two-cycle engine can produce twice as much power as a four-cycle engine.

However, this is not true. With the two-cycle engine, some power may be used to drive the blower that forces the fuel-air charge into the cylinder under pressure. Also, the burned gases are not completely cleared from the cylinder, this results in less power per power stroke.

The actual gain in power with a two-cycle engine is about 75 percent (over a four-cycle engine of the same displacement).

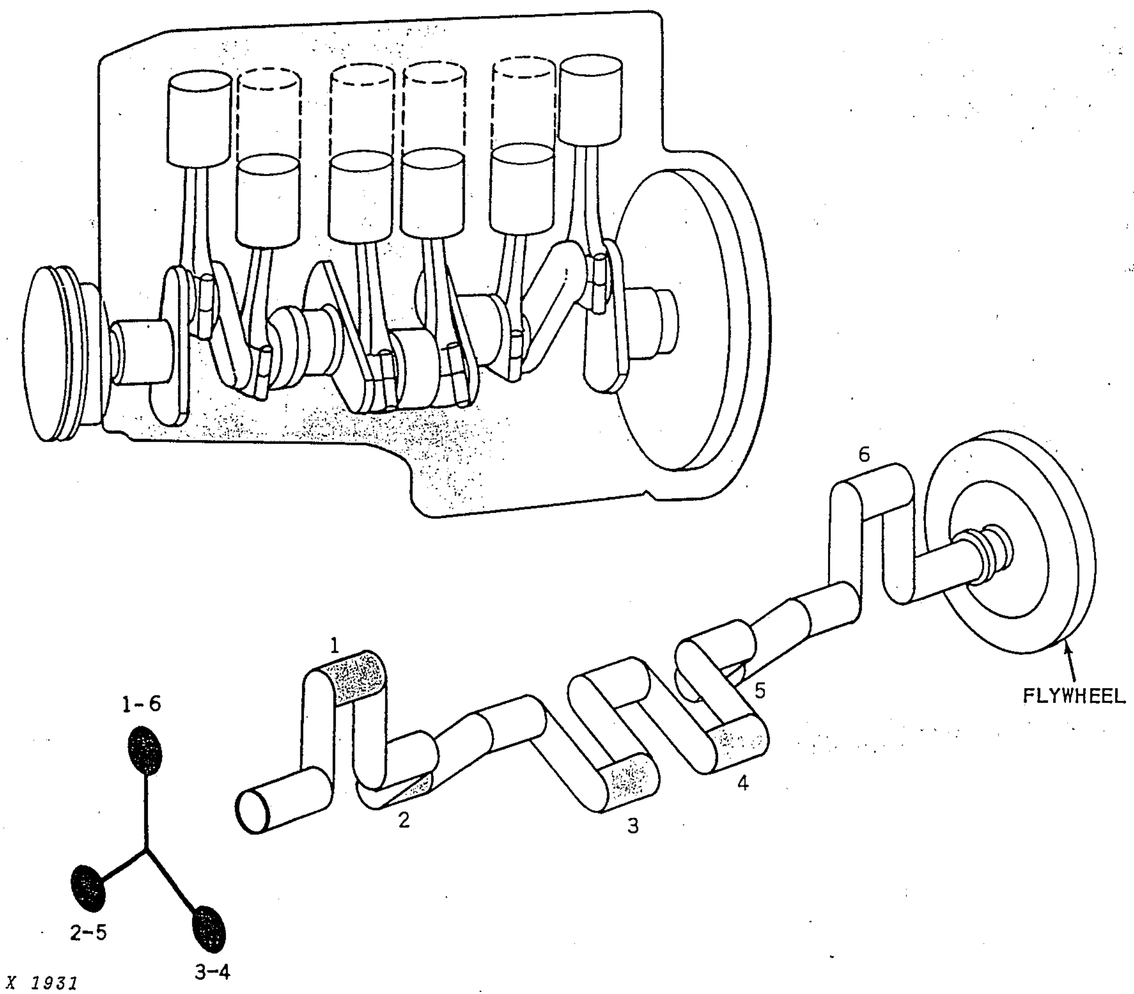


Fig. 15 — Crankshaft For A Six-Cylinder Engine

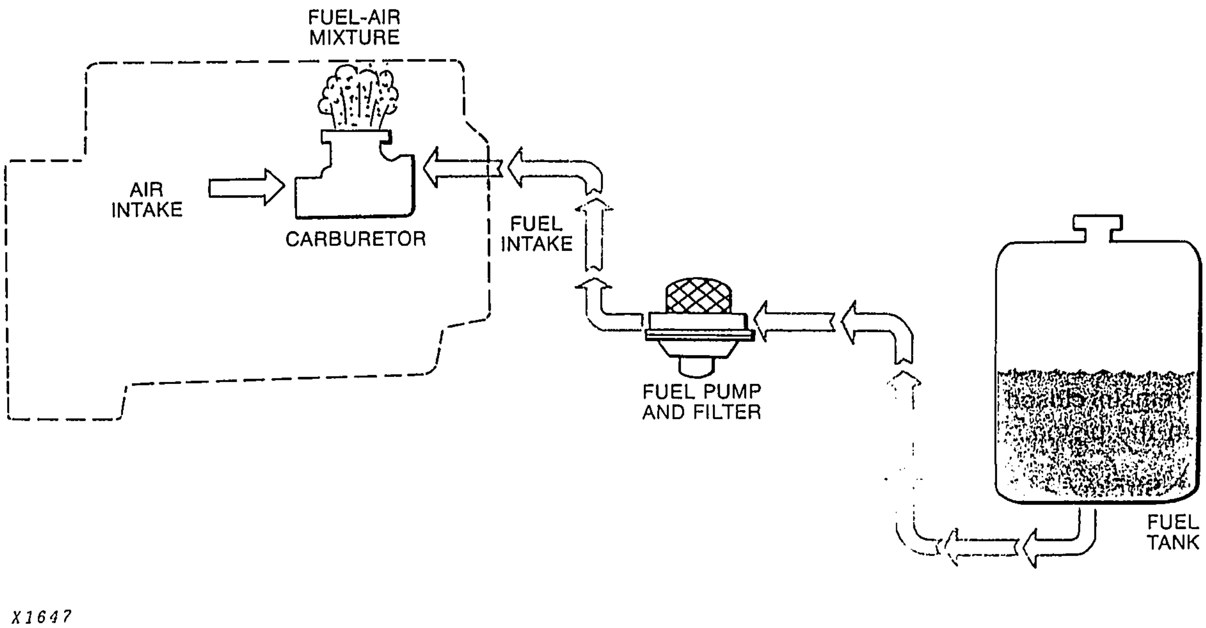


Fig. 16 — Gasoline Fuel System

MULTIPLE-CYLINDER ENGINES

So far we have covered only basic one-cylinder engines.

A single cylinder gives only one power impulse every two revolutions of the crankshaft in a four-cycle engine. Thus it is producing power only one-fourth of the time.

For a more continuous flow of power, modern engines use four, six, eight, or more cylinders. The same series of cycles takes place in each cylinder.

For example, in a typical four-stroke cycle engine having six cylinders, the cranks on the crankshaft are set 120 degrees apart (Fig. 15). The cranks for cylinders 1 and 6, 2 and 5, 3 and 4 are in line with each other as shown.

The cylinders normally fire and deliver their power strokes in the following order: 1-5-3-6-2-4. Thus the power strokes follow each other so closely that there is a fairly continuous and smooth delivery of power to the crankshaft.

The heavy *flywheel* attaches to the rear of the crankshaft and gives it momentum to return the pistons to the tops of the cylinders after each power stroke. Weights on the crankshaft are used to help balance the forces created in the engine by the rapidly moving parts.

For more details on construction of the basic engine, see Chapter 2.

Now let's look at some of the auxiliary systems that help the engine to operate.

ENGINE SYSTEMS

Now that we've put together a basic engine, let's look at some other systems that are required for good operation:

- **Fuel System**
- **Intake and Exhaust System**
- **Lubrication System**
- **Cooling System**
- **Governing System**

Let's discuss these systems one by one.

FUEL SYSTEMS

A fuel system must deliver clean fuel, in the quantity required, to the fuel intake of an engine. It must provide for safe fuel storage and transfer.

The three fuel systems of concern to us are:

- **Gasoline**
- **LP-Gas**
- **Diesel**

GASOLINE FUEL SYSTEMS

The gasoline fuel system supplies a combustible mixture of fuel and air for the engine.

The basic gasoline fuel system (see Fig. 16) has three parts.

- **Fuel Tank—stores fuel**
- **Fuel Pump—moves fuel to carburetor**
- **Carburetor—atomizes fuel and mixes with air**

In operation, the *fuel pump* moves gasoline from the tank to the carburetor bowl.

The *carburetor* is basically an air tube which atomizes fuel and mixes it with air by a difference in air pressure. It meters both the fuel and air for the engine.

On its intake stroke, the engine creates a partial vacuum. This allows outside air pressure to force the fuel-air vapor mixed in the carburetor into the engine cylinder.

Fuel Supply Systems

Fuel can be supplied to the carburetor in two ways:

- **Gravity-Feed**
- **Force-Feed**

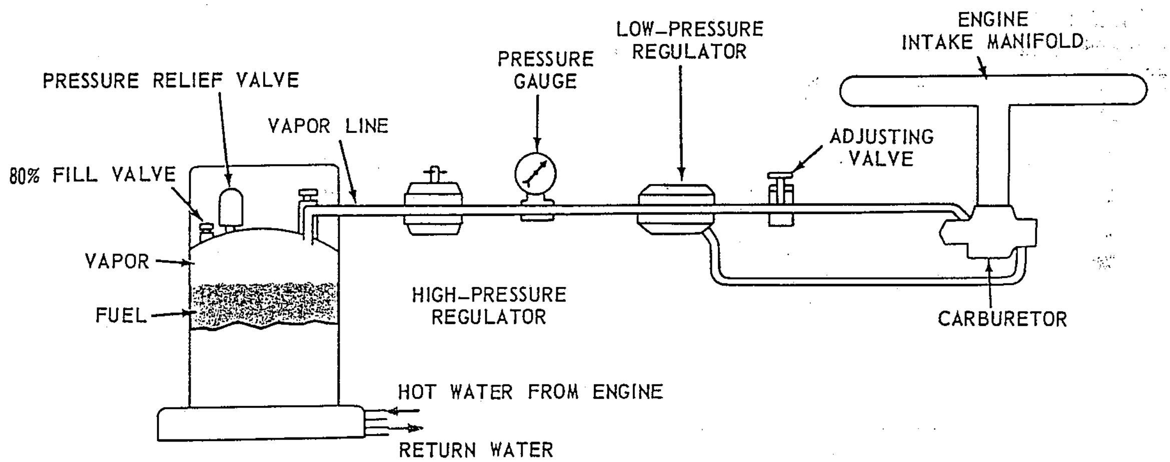
The GRAVITY-FEED system has the fuel tank placed *above* the level of the carburetor. This system does *not* use a fuel pump. Instead, the fuel flows by *gravity* to the carburetor.

The FORCE-FEED system allows the fuel tank to be located *below* the carburetor if necessary. A fuel pump moves the fuel from the tank to the carburetor as shown in Fig. 16.

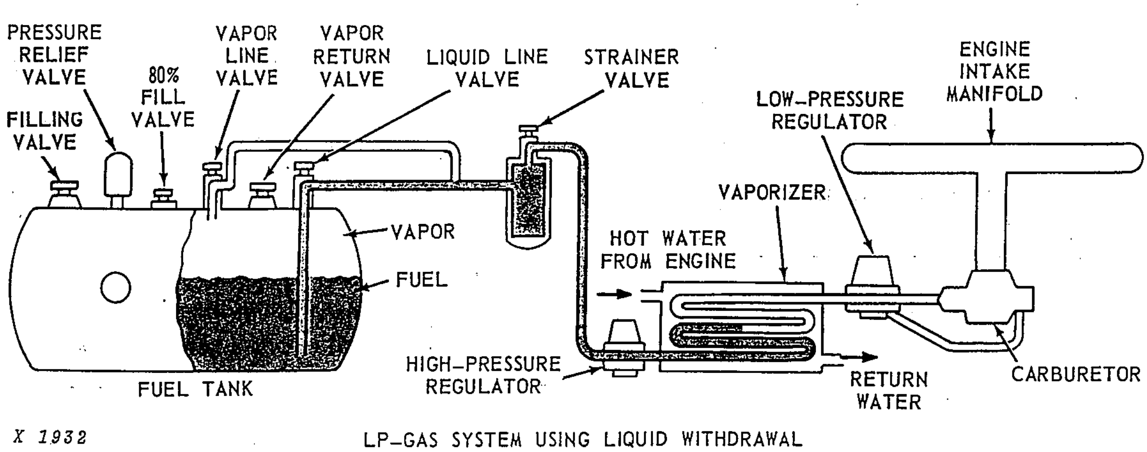
More details on gasoline fuel systems are given in Chapter 3.

LP-GAS FUEL SYSTEMS

The LP-gas fuel system (Fig. 17) also supplies a combustible mixture of fuel and air to its engine. However, LP-gas vaporizes at low temperatures.



LP-GAS SYSTEM USING VAPOR WITHDRAWAL



LP-GAS SYSTEM USING LIQUID WITHDRAWAL

Fig. 17 — LP-Gas Fuel System

Thus the fuel tank must be a closed unit to prevent vapor from escaping.

To withdraw fuel from the tank, two methods are used:

- **Liquid Withdrawal**
- **Vapor Withdrawal**

VAPOR withdrawal of fuel is used in starting; the fuel system is later switched to liquid withdrawal after warm-up. This is because in a cold engine the heat exchanger cannot change the liquid fuel to vapor, and the carburetor operates only on vapor.

The liquid and vapor line valves shown in Fig. 17 provide for safety and for selection of fuel—liquid or vapor. The filters remove moisture and dirt. The pressure regulators keep a constant pressure of fuel at the carburetor for accurate fuel metering.

In the LIQUID withdrawal system, a heat exchanger converts the liquid fuel to vapor. The heat exchanger does this by circulating hot water from the engine cooling system around the fuel line. As the fuel heats up and pressure is reduced, it vaporizes. The *liquid* withdrawal system is most common today.

The LP-gas carburetor is simpler than the gasoline type, since the fuel is already vaporized. It meters the vapor and mixes it with the proper amount of air for the engine.

Chapter 4 of this manual gives more details on LP-gas systems.

DIESEL FUEL SYSTEMS

In the diesel fuel system, fuel is sprayed directly into the engine combustion chamber where it mixes with hot compressed air and ignites. No electrical spark is used to ignite the mixtures (as in gasoline and LP-gas engines).

Instead of a carburetor, a fuel injection pump and spray nozzle are used.

The major parts of the diesel fuel system are:

- **Fuel Tank—stores fuel**
- **Fuel Pump—moves fuel to injection pump**
- **Fuel Filters—help clean the fuel**
- **Injection Pump—times, measures, and delivers fuel under pressure**
- **Injection Nozzles—atomize and spray fuel into cylinders**

Fig. 18 shows these major parts of the diesel system.

In operation, the *fuel pump* moves fuel from the tank and pushes it through the *filters*. Clean fuel

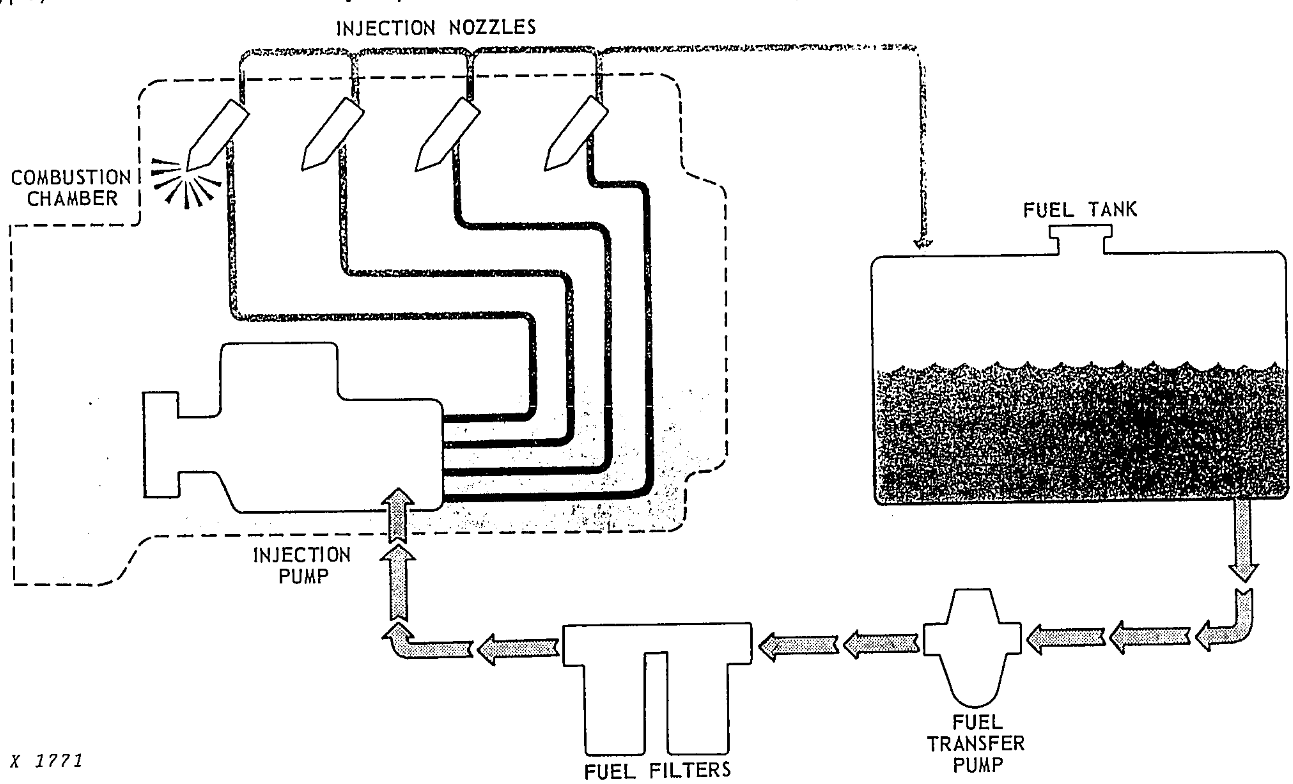


Fig. 18 — Diesel Fuel System

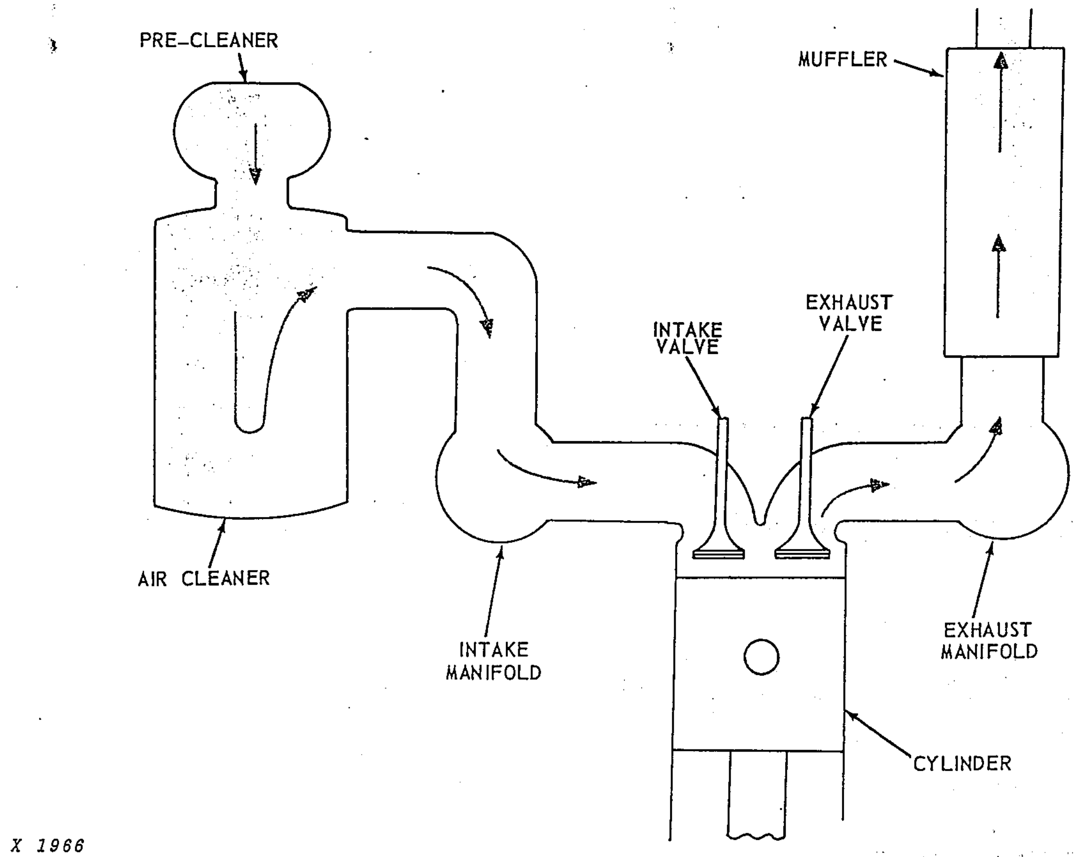


Fig. 19 — Intake And Exhaust Systems

free of water is very vital to the precision parts of the diesel injection system. Extra filters are often used to assure clean fuel, but buying clean fuel and storing it properly are also prime needs.

The fuel is then pushed on to the *injection pump* where it is metered, put under high pressure, and delivered to each *injection nozzle* in turn.

The nozzles each serve one cylinder; they atomize the fuel and spray it under controlled high pressure into the combustion chamber at the proper moment.

High-pressure fuel is needed at each nozzle to get a fine spray of fuel. This assures good mixing of fuel with the hot compressed air for full combustion.

Chapter 5 of this manual gives more details on the diesel fuel system.

INTAKE AND EXHAUST SYSTEMS

Intake and exhaust systems carry the fuel-air mixture into the engine and remove the exhaust gases after combustion (Fig. 19).

INTAKE SYSTEM

The intake system supplies the engine with clean air of the proper quantity, temperature, and mix for good combustion.

The intake system has five parts:

- **Air cleaners**
- **Blower or turbocharger (optional)**
- **Intake manifold**
- **Carburetor air inlet**
- **Intake valves**

Air cleaners filter dust and dirt from the air passing through them enroute to the carburetor. Precleaners prevent larger particles from reaching the air cleaners and plugging it.

Blowers can be used on two-cycle engines to force air into the cylinder while exhaust gases are driven out. The blower is an air pump which pressurizes air.

Turbochargers increase horsepower by packing more air or fuel-air mixture into the engine cylinders than the engine could take in by natural aspiration.

Intake manifolds transport the air-fuel mixture (pure air on diesel engines) to the engine cylinders.

Carburetors mix incoming air with fuel in the proper proportion for combustion, and control engine speed.

Intake valves admit air to diesel engines and the fuel-air mixture to spark-ignition engines. They are normally opened and closed by mechanical linkage from the camshaft.

For more details on intake systems, see Chapter 6.

EXHAUST SYSTEMS

The exhaust system collects the exhaust gases after combustion and carries them away. This is really three jobs:

1) Removing heat

2) Muffling engine sounds

3) Carrying away burned and unburned gases

The exhaust system has these basic parts:

- **Exhaust valves**
- **Exhaust manifold**
- **Muffler**

Exhaust valves open to release the burnt gases on four-cycle engines. The valves are normally operated by the camshaft.

The *exhaust manifold* collects the exhaust gases and conducts them away from the cylinder.

The *muffler* reduces the sounds of the engine during the exhaust period.

See Chapter 6 for details on exhaust systems.

LUBRICATION SYSTEMS

The lubrication system does these jobs for the engine:

1) Reduces friction between moving parts

2) Absorbs and dissipates heat

3) Seals the piston rings and cylinder walls

4) Cleans and flushes moving parts

5) Helps deaden the noise of the engine

With lubricating oil, the system is able to do all these jobs at once (Fig. 20). Without oil, the engine would soon wear out, burn up, or seize. For oil not only reduces friction by forming a film between parts, it also conducts heat away from these parts.

The lubrication system may work by splashing oil on the moving parts or it may feed oil under pressure to the parts via internal oil passages as shown in Fig. 20. In some cases, both methods are used at the same time.

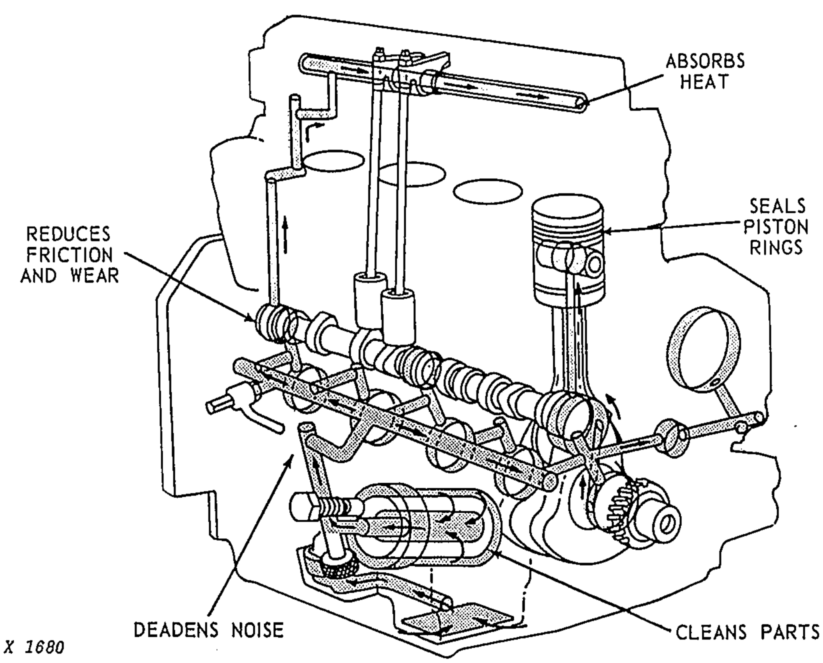


Fig. 20 — Lubrication System

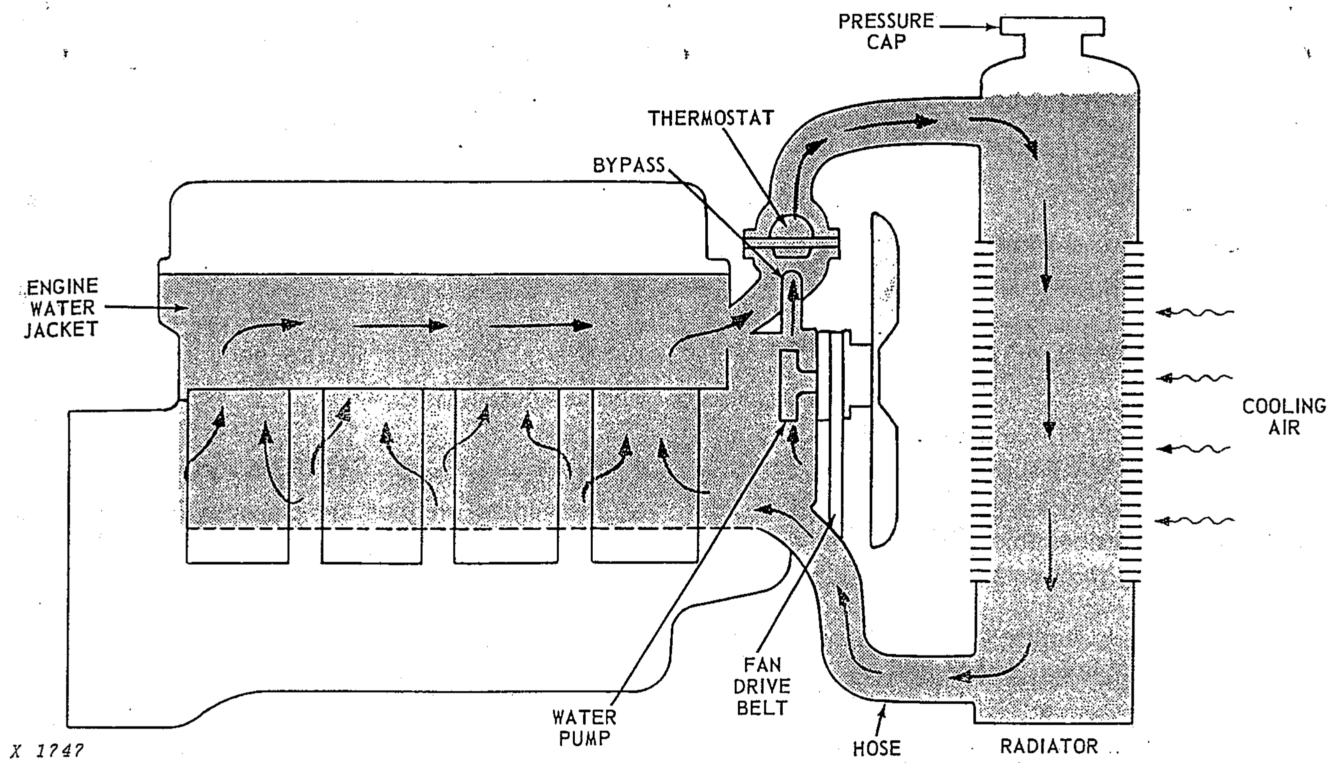


Fig. 21 — Cooling System (Liquid Type Shown)

The engine crankcase forms an oil reservoir where oil is stored and also cooled.

The crankcase must be vented to prevent pressure build-ups from the blow-by of gases past the pistons.

Modern venting sometimes includes a system which routes crankcase vapors back to the intake system to reduce air pollution.

See Chapter 7 for further details on lubrication systems.

COOLING SYSTEMS

The cooling system prevents overheating of the engine. Some heat is necessary for combustion, but the working engine generates too much heat. The cooling system carries off this excess heat.

Cooling systems are designed to use parts that are *matched* in capacity. A matched cooling system will provide adequate heat rejection. If one part is replaced that is under or overcapacity, the effectiveness of the system will be decreased. Parts include: water pump, radiator, coolant, piping, thermostat, and fan.

TYPES OF COOLING SYSTEMS

Two types of cooling systems are used on modern engines:

- *Air Cooling—uses air passing around the engine to dissipate heat*
- *Liquid Cooling—uses water around the engine to dissipate heat*

AIR COOLING is used primarily on small engines or aircraft as it is difficult to route air to all the heat points of larger engines. Metal baffles, ducts, and blowers are used to aid in distributing air.

LIQUID COOLING normally uses water as a coolant. In cold weather, anti-freeze solutions are added to the water to prevent freezing. The water circulates in a jacket around the cylinders and cylinder head. As heat radiates, it is absorbed by the water, which then flows to the radiator. Air flow through the radiator cools the water and dissipates heat into the air. The water then recirculates into the engine to pick up more heat (Fig. 21).

See Chapter 8 for more details on cooling systems.

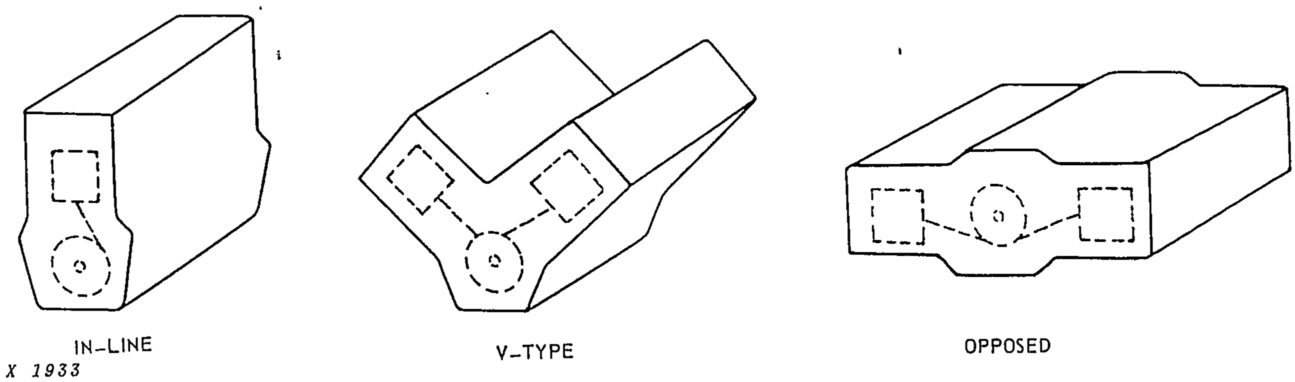


Fig. 22 — Arrangement Of Cylinders—Three Types

GOVERNING SYSTEMS

The governing system keeps the engine speed at a constant level. It does this by varying the amount of fuel on fuel-air mixture supplied to the engine, according to the demands of the load. The level of engine speed is controlled by the position of the speed control lever, connected by linkage to the governor.

The object is to get the engine's power to match the load at all times, to keep the speed at a steady level.

Governors can be either mechanical, hydraulic, or electrical. See Chapter 9 for details.

TYPES OF ENGINES

Engines can be typed in three ways:

- **Cylinder arrangement**
- **Valve arrangement**
- **Type of fuel used**

ARRANGEMENT OF CYLINDERS

Multi-cylinder engines are classified according to the arrangement of cylinders:

- *In-Line—all cylinders in straight line above crankshaft*
- *V-Type—two banks of cylinders in V-shape above crankshaft*
- *Opposed—two rows of cylinders opposite the crankshaft*

The IN-LINE model (Fig. 22) is most popular on farm and industrial machines. The V-TYPE is most popular on automobiles although its use in farm and industrial machines is increasing, while the OPPOSED is limited primarily to small cars and aircraft. The cylinders are normally numbered. With in-line models, the No. 1 cylinder is normally at the end opposite the flywheel. The others are 2, 3, 4 etc. from front to rear. In V-and opposed types, the sequence varies with the manufacturer.

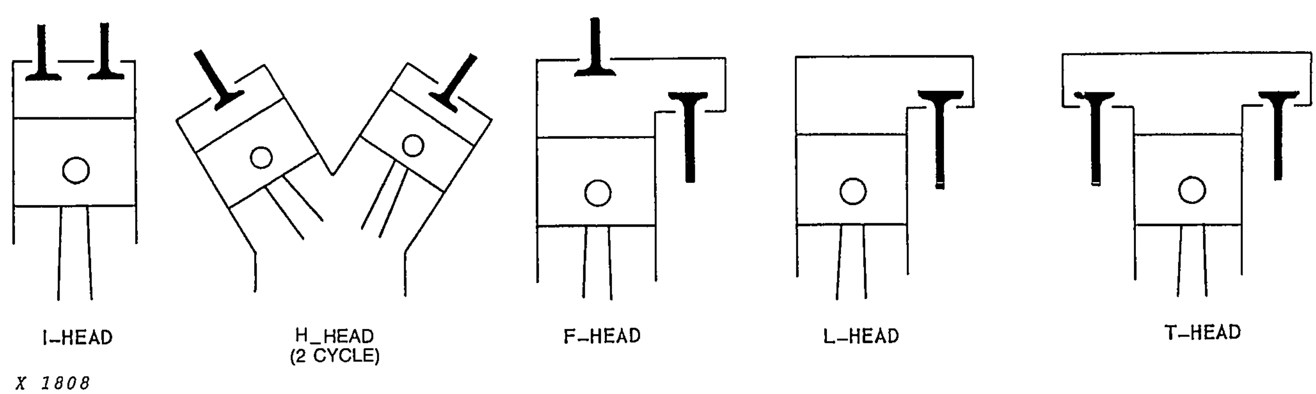


Fig. 23 — Valve Arrangement — Five Types

VALVE ARRANGEMENT

Engines can also be classified by the position and arrangement of the intake and exhaust valves. This normally depends on whether the valves are located in the cylinder block or the cylinder head. The most common types are the *I-head*, *H-head* (2 cycle), *F-head*, *L-head* and *T-head* (Fig. 23). See Chapter 2 for details.

FUEL TYPES OF ENGINES

The most common way to type engines is by the type of fuel used. Three fuel types are most common:

- **Gasoline Engine**
- **LP-Gas Engine**
- **Diesel Engine**

The basic operation of each engine is the same and we have already compared the methods of fueling. But now let's look at the overall performance of each one while comparing gasoline and diesel.

What Are The Main Differences Between Gasoline And Diesel Engines?

1. *The method of supplying and igniting fuel.*
2. *The higher compression ratio in diesels.*
3. *The generally more rugged design of diesels.*
4. *The grade and type of fuel used.*

Let's look at each of these differences.

METHODS OF SUPPLYING AND IGNITING FUEL: GASOLINE VS. DIESEL

In *gasoline engines,* fuel and air are mixed *outside* the cylinders, in the carburetor and manifold. The mixture is forced in due to the partial vacuum of the pistons' intake stroke.

In *diesel engines,* there is no premixing of air outside the cylinder. Air only is taken into the cylinder through the intake manifold and compressed. Fuel is then sprayed into the cylinder and mixed with air as the piston nears the top of its compression stroke. See Fig. 24.

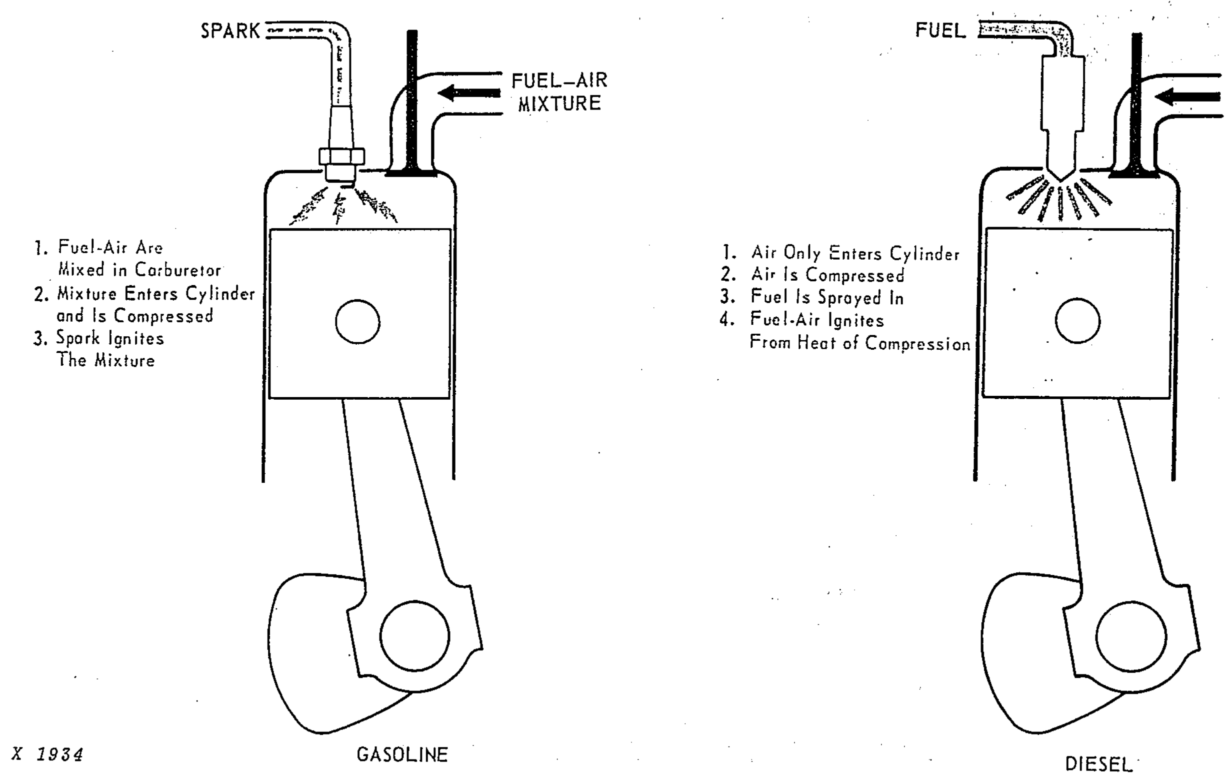


Fig. 24 — Methods Of Supplying And Igniting Fuel (Power Stroke)

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Gasoline engines use an electric spark to ignite the fuel-air mixture, while diesels use the heat of the compressed air for ignition.

COMPRESSION RATIOS: GASOLINE VS. DIESEL

Compression ratio compares the volume of air in the cylinder before compression with the volume after compression.

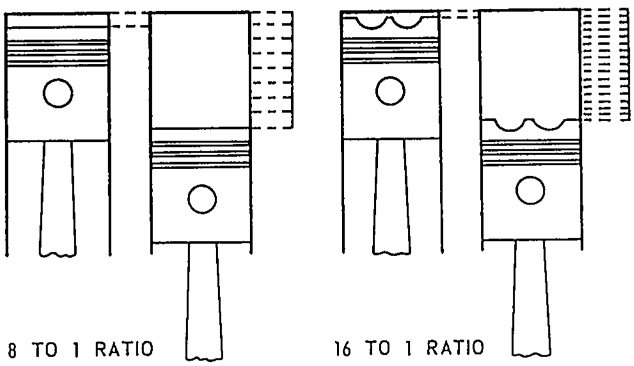

Fig. 25 — Compression Ratios Compared

An 8 to 1 compression ratio is typical for gasoline engines, while a 16 to 1 ratio is common for diesels (Fig. 25).

The higher compression ratio of the diesel raises the temperature of the air high enough to ignite the fuel without a spark.

This also gives the diesel more efficiency because the higher compression results in greater expansion of gases in the cylinder following combustion. Result: a more powerful stroke.

The higher efficiency which results from diesel combustion must be offset by the need for sturdier, more expensive parts to withstand the greater forces of combustion.

DESIGN OF ENGINE PARTS: GASOLINE VS. DIESEL

We have just touched on the next point: diesels must be built sturdier to withstand the greater forces of combustion. This is generally done by "beefing up" the pistons, pins, rods, and cranks, and by adding more main bearings to support the crankshaft.

GRADES AND TYPES OF FUEL: GASOLINE VS. DIESEL

Fuel energy is measured in standard heat units or "British Thermal Units" (BTU) or watts and gives a comparison of the power possible from each fuel.

Diesel fuel has more heat units (BTU) watts per gallon, and so gives more work per gallon of fuel. In addition, diesel fuel is normally cheaper than gasoline.

However, diesel fuel injection equipment is more expensive than gasoline equipment.

When selecting the fuel type for the engine, the deciding factor is how much fuel is consumed per year in the engine operation.

LP-Gas Engines

The LP-gas engine is similar to the gasoline model, but requires special fuel handling and equipment.

LP-gas engines have higher compression ratios than gasoline engines but not as high as diesels.

In areas where LP-gas fuel is available at low prices, these engines are very popular. However, in many areas, LP-gas fuel is not competitive with the other fuels.

Summary: Comparing Engines

The chart below compares gasoline, LP-gas, and diesel engines.

The comparisons assume that each fuel is available at reasonable prices. Performance is based on general applications which are suited to the engine and fuel type. It is also assumed that the engines are all in good condition.

COMPARING THE ENGINES

	Gasoline	**LP-Gas**	**Diesel**
Fuel Economy	Fair	Good	Best
Hours Before Maintenance	Fair	Good	Good
Weight per Horsepower	Low	Low	High
Cold Weather Starting	Good	Fair	Fair
Acceleration	Good	Good	Fair
Continuous Duty	Fair	Fair	Good
Lubricating Oil Contamination	Moderate	Lowest	Low

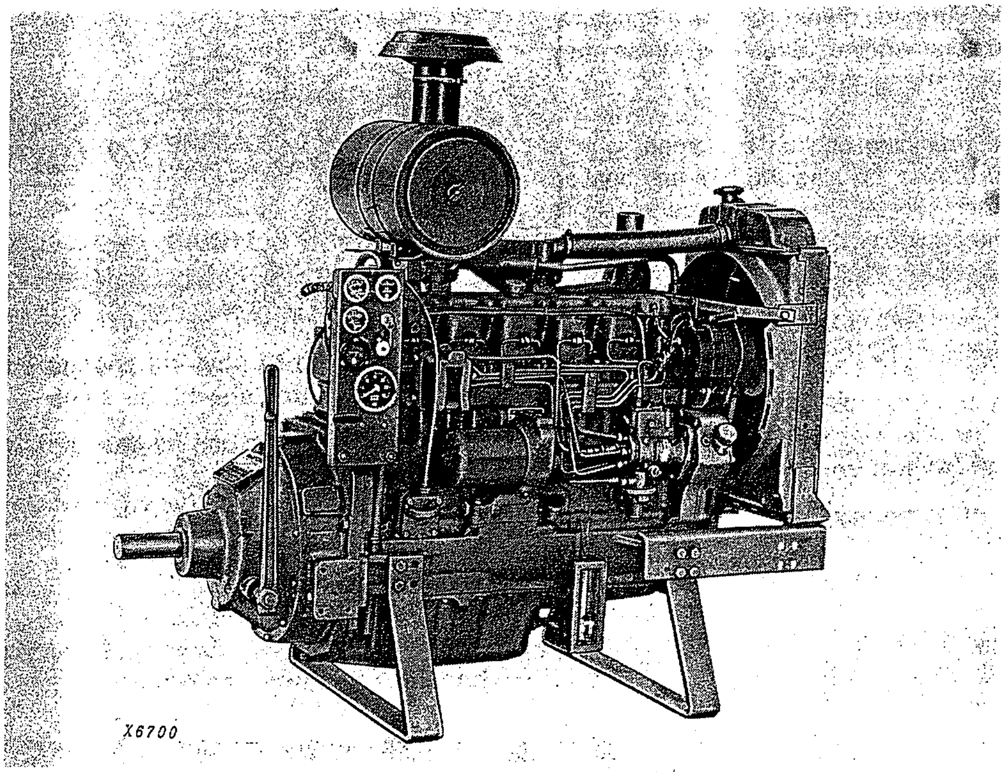

Fig. 26 — Stationary Engine

USES OF ENGINES

There are two basic uses for engines:

- **Stationary**
- **Mobile**

STATIONARY ENGINES

Stationary engines supply power from a fixed location (Fig. 26). Couplers, belts, chains and drive shafts transfer the engine power to other machines.

Because they are in a "fixed" location, they can be designed for one application. Stationary engines, or "power units," drive such machines as compressors, motor driven pumps, and generators.

MOBILE ENGINES

Mobile engines supply power on the move. They power a wide variety of vehicles from road graders to race cars. Mobile engines can be subdivided into two basic types:

- **Structural**
- **Non-structural**

A *structural* engine is mounted to and becomes part of the vehicle frame. It helps to support and carry the load of the vehicle. The structural engine *block* must be strong enough to withstand the load and road stress.

Structural engines are used on some construction equipment and other off-the-road vehicles. An example of this type is a farm tractor engine that is bolted directly to the sides of the main machine frame. The engine helps support and hold the tractor together.

A *non-structural* engine is not a part of the vehicle frame. The vehicle frame in this example is just as strong with or without the engine. Non-structural engine *blocks* do not have to withstand load and road stress like a structural engine. The non-structural engine block can be made of lighter metals, such as aluminum.

These "lighter" engines are usually mounted on rubber pads on the vehicle frame. The main application for non-structural engines is over-the-road vehicles, such as cars and trucks. The lighter engine block weight helps boost vehicle fuel economy and load carrying ability.

A non-structural engine may supply the same performance and reliability of a comparable structural engine. However, when a new engine is used to replace original

equipment, make sure you do not replace a structural with a non-structural engine. Structural stress may severely damage the engine block.

Also, if you are replacing original equipment with a different type of engine, be sure the fuel and cooling systems are compatible. These systems must be matched with the engine performance and load carrying ability.

THE BASICS OF ENGINES

We have seen how the engine works. Now let's look at some of the basics which go into the design and operation of engines.

First the laws of mechanics:

- **Matter**
- **Mass**
- **Energy**
- **Inertia**
- **Force**
- **Momentum**
- **Torque**
- **Work**
- **Mechanical Power**

Let's discuss these basics one by one.

MATTER

The substances we encounter in engines are: **solids, liquids** and **gases;** they are the three physical states of matter.

If you look at Fig. 27, you will see the following truths:

1. *Solids* have a definite volume and shape.
2. *Liquids* have a definite volume but no definite shape.
3. *Gases* have no definite volume or shape.

All matter can be changed from one state to another by heating or cooling. Water is a liquid which can be changed to ice (solid) or steam (gas) by changing its temperature. However, if the temperature is returned to the original point, the water will become liquid again; the water has

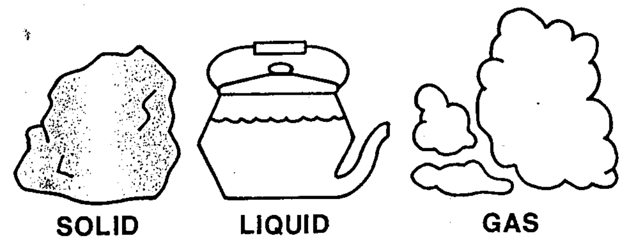

Fig. 27 — Three Physical States Of Matter

been subjected to physical change only, because its characteristics stayed the same.

In summary, matter can be changed, but it cannot be destroyed.

MASS

Mass is often confused with weight. *Mass is the measure of how much matter is in a body.* Weight is the measure of Earth's gravitational pull. A body has the same mass on Earth as it has 2,000 miles (3200 km) out in space, but its weight is much less out in space.

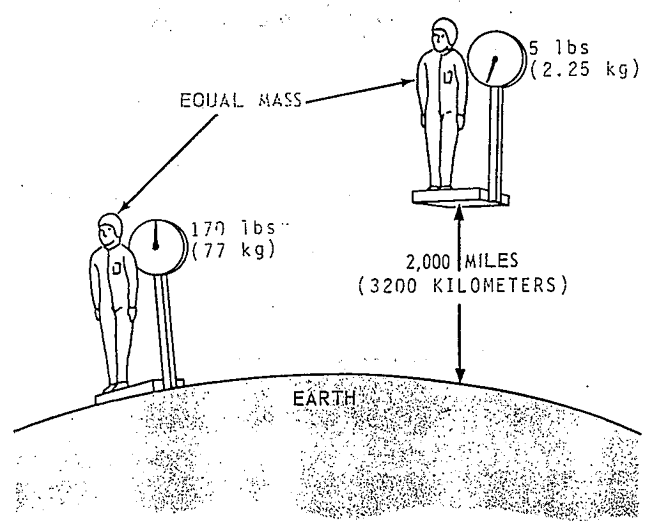

Fig. 28 — Mass Versus Weight

In Fig. 28, the man weighs 170 pounds (77 kg) while standing on the earth. Out in space he may weigh only 5 pounds (2.25 kg). However, in either location he has the same amount of *matter* (or mass) in his body.

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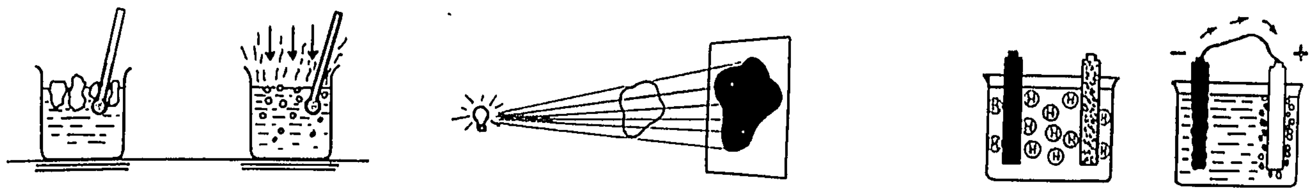

X 1939 HEAT LIGHT CHEMICAL

Fig. 29 — Energy At Work

ENERGY

Things like electricity, light, sound and heat are forms of **energy.** They do not occupy space or have weight in the usual sense. *Energy is the thing that produces changes in matter.*

Fig. 29 shows heat energy converting water, light energy forming an image on film, and electrical energy working in a chemical cell. Chemical energy heats your home and runs an engine, and mechanical energy does work.

INERTIA

Inertia is the tendency of a body to keep its state of rest or motion.

If you're sitting in the wagon shown in Fig. 30 and someone gives you a push from behind, your body will fall backward. Nothing actually pushed you backward, your body just tried to stay at rest.

If someone stops you while you're in motion, you will pitch forward. This is because your body wants to keep moving at the same speed. The larger the mass of your body, the more you will be affected by inertia.

FORCE

A **force** is a push or pull which starts, stops, or changes the motion of a body.

From this we conclude that if all the forces acting on a body are equal from all directions, the body will be at rest. If any one of the forces is greater, the body will be set into motion in the direction of the force.

If six men push equally hard where shown in Fig. 31, the box will retain its position. When the top man pushes harder, the box will move downward.

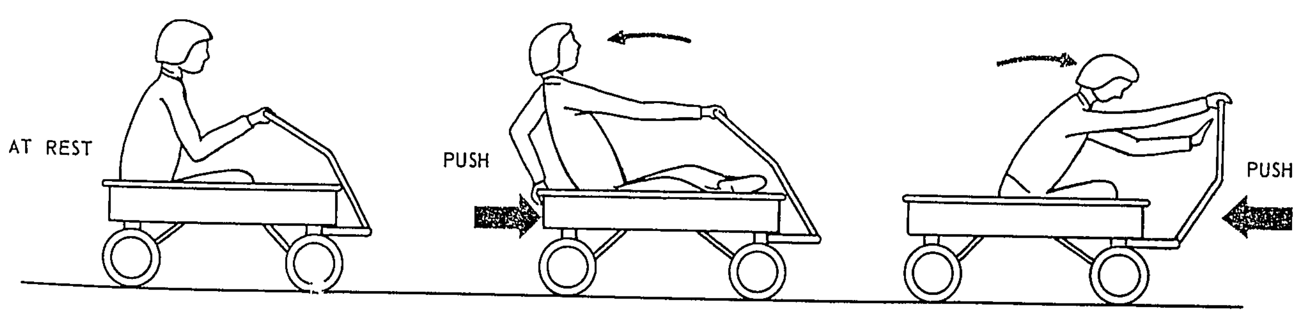

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Fig. 30 — Inertia

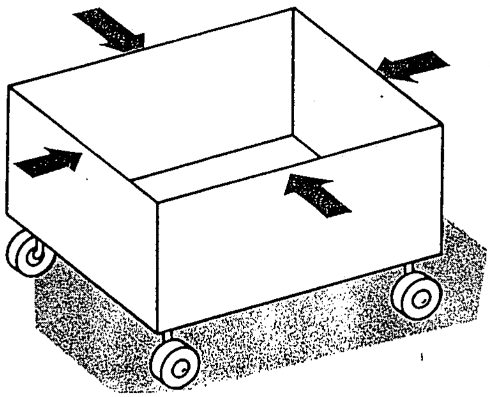

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Fig. 31 — Applied Forces

MOMENTUM

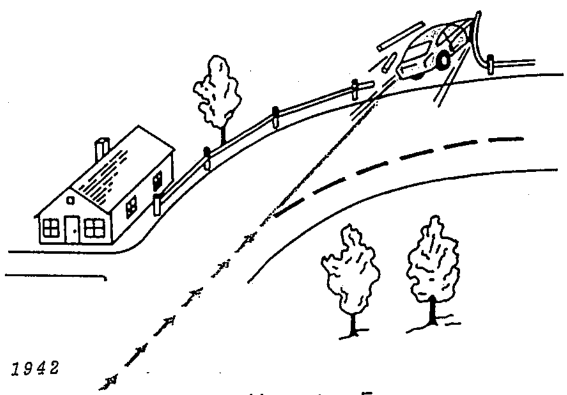

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Fig. 32 — Momentum Forces

When a body is in motion, it is said to have **momentum** which is the product of its mass and velocity (speed). A body moving in a straight line will keep going in a straight line at the same speed forever if no other forces act upon it (Fig. 32). The laws of momentum are equally effective when a body is rotating; it would continue to rotate. Momentum and inertia are sources of energy because of their mass.

TORQUE

If the forces applied to a body do not all act at a single point, the body will tend to rotate. The turning effect of any force applied to a body is found by multiplying the amount of the force by the distance from the pivot point to the line of the force.

This *turning* effect of a force is called **torque** and the distance mentioned is the torque arm.

Consider the torque wrench shown in Fig. 33. If we apply more force at the point shown or apply the force farther out, the torque will be increased. This increased torque will cause the wrench to rotate faster or give us more turning force at the pivot point.

An engine crankshaft reacts to the pushing force of the piston and connecting rod in the same manner.

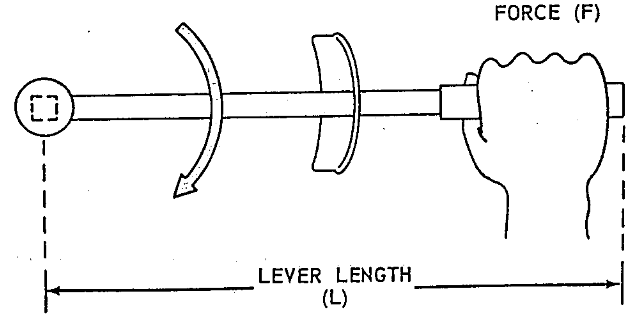

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Fig. 33 — Torque (Or Turning Force)

WORK

When you're pushing on a large rock and it fails to move, you feel like you're working hard. In Physics, **work** is accomplished only when the rock is moved by the pushing you're doing. Work is expressed as a force unit multiplied by a distance unit.

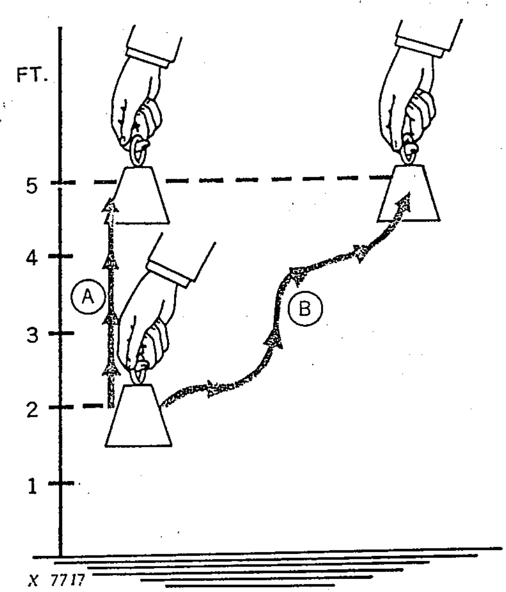

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Fig. 34 — Work

If you stand and hold a weight at the 2-foot (600 mm) level as shown in Fig. 34, you aren't really doing any work, as the weight is stationary. However, if you move it to the 5-foot (1.5 m) level, you have moved the weight 3 feet (900 mm), and work was done. The path you take to get to the 5-foot (1.5 m) level is not important; the amount of work done is 20 lbs (9 kg) times 3 feet (900 mm) = 60 lb. ft. (80 J) as shown, whether you take path A or B.

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MECHANICAL POWER

Power is a rate of doing work and the term **mechanical** is the energy method used. Other energy methods include chemical, electrical, heat and sound.

Because we are mainly concerned with engines, our unit of power is the **horsepower (watt-metric).** One horsepower is equal to the lifting of a weight of 550 lbs. (250 kg) one foot (300 mm) in one second [or 33,000 lbs (15,000 kg), one foot (300 mm) in one minute].

Energy conversion allows us to compare different types of power. A diesel engine produces *mechanical power* by chemical change (Fig. 35). Fuel (liquid) and air (gas) is burned (chemical change) in the combustion chamber and the engine crankshaft rotates.

An electric motor also produces mechanical power when connected to a battery (Fig. 35). The electrolyte in the battery reacting on the battery plates produces electricity by chemical change and the electric motor runs.

When diesel fuel burns and produces heat at the rate of 2545 BTU per hour (746 watts), the fuel energy is being expended in the engine at the rate of one horsepower per hour.

If a battery delivers electricity to a motor for one hour at the rate of 746 watts, the motor will consume 746 watt-hours or 1 hp-hr of energy.

It is interesting to note that by simple conversion, 746 watts of electrical power equals 2545 BTU per hour when converted to heat.

This completes our discussion of the basic **laws of mechanics.**

HORSEPOWER

The term horsepower is a unit of measurement in rating engines and motors. There are several categories of horsepower, all very necessary for the design of an efficient engine. To sum them up quickly, we talk about **theoretical horsepower** and **net horsepower (useful)** and of those in between.

The most common horsepower terms are:

- **Indicated (IHP)**
- **Friction (FHP)**
- **Flywheel or Brake (BHP)**
- **Drawbar**
- **Power Take-Off (PTO)**
- **Rated**

Let's see what each type of horsepower means.

INDICATED HORSEPOWER (IHP)

Indicated horsepower (IHP) is measured in the combustion chamber of a cylinder by special instruments. The instrument measures the actual gas pressure developed. Using this measurement, an engineer can calculate the amount of energy that is released in the cylinder.

However, here we're more interested in the measurements we can do something about, for *indicated* horsepower neglects such things as friction and the type of power we actually need to do our work. Indicated horsepower is *theoretical* horsepower (Fig. 36).

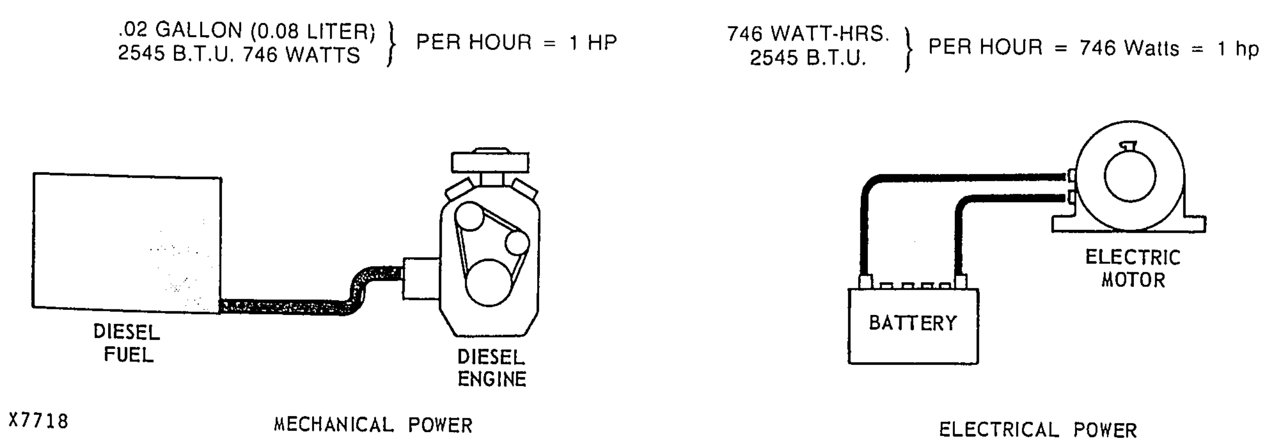

Fig. 35 — Mechanical And Electrical Power Compared

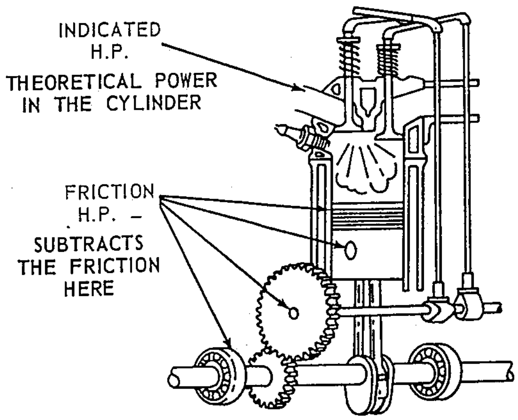

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Fig. 36 — Indicated And Friction Horsepower

Friction horsepower (FHP) allows for the friction between engine parts such as pistons and cylinder walls, and the power needed for compression. Friction is a loss factor and a producer of heat.

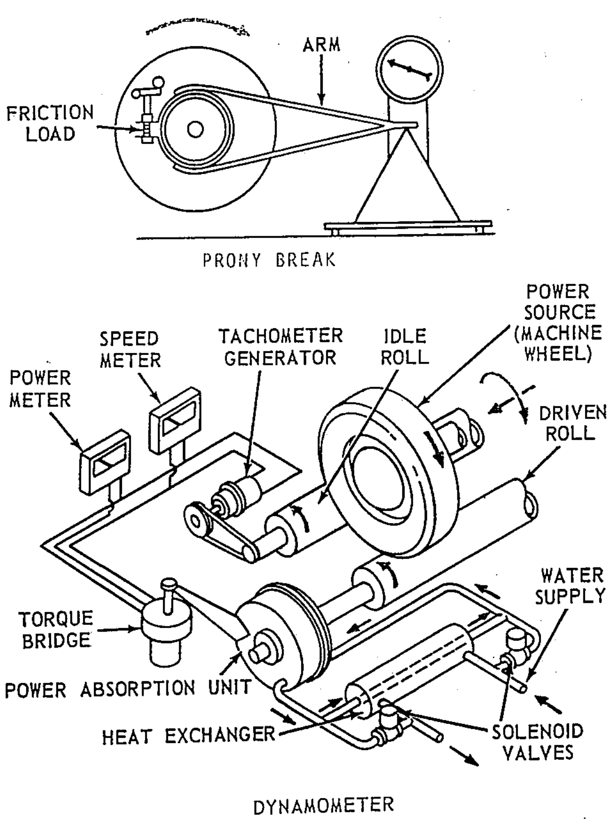

Fig. 37 — Units Which Measure Horsepower Of An Engine

Remember, energy cannot be destroyed, merely converted or divided. If the bearings are heating up while the mechanical energy is working, some of that mechanical energy is being converted to heat and is lost into the cooling system.

Friction horsepower then is the difference between *indicated* horsepower and *usable* horsepower (Fig. 36). So it is a factor in engine *efficiency.*

Lubricating oils place a thin film between two surfaces to reduce friction. In most engines, bearings are lubricated with oil under pressure to make the shafts float on an oil film and so reduce friction.

FLYWHEEL HORSEPOWER OR BRAKE HORSEPOWER (BHP)

Now we come to the first really practical unit of measurement for an engine. This is the point where we can couple to the engine and actually draw power. **Flywheel horsepower** is the FHP (friction losses) subtracted from the IHP (theoretical horsepower). For simplicity, FHP is all the engine losses; friction, etc. If the losses equal 10 horsepower (7.5 kW), and if IHP equals 50 horsepower (37 kW), the result is 50-10=40 (37-7.5=29.5 kW) which is the flywheel horsepower.

Flywheel horsepower is also called brake horsepower (BHP). It is the maximum horsepower the engine can produce without alteration.

Flywheel or brake horsepower is measured by a *Prony brake or a dynamometer* (Fig. 37). Both test instruments apply a load to the engine which is measured in pounds (kilograms). If the length of the lever arm is known in feet (meters), we can measure foot-pounds (newton-meters) of force as engine load. Speed is measured with a tachometer in revolutions per minute (rpm).

DRAWBAR HORSEPOWER

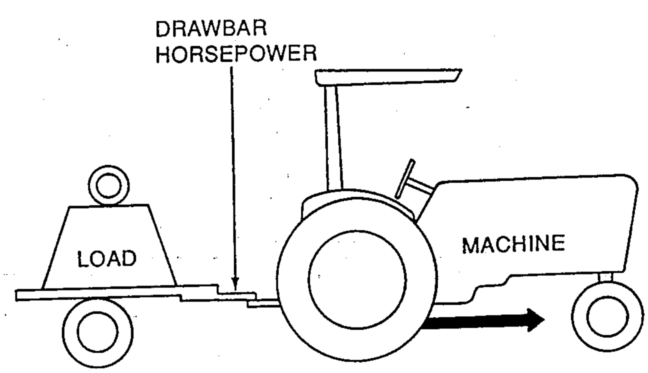

Fig. 38 — Drawbar Horsepower

Drawbar horsepower is the measure of pulling power an engine can produce when mounted in a moving machine. The load is attached to the machine and the horsepower required to move the machine is calculated by knowing the force required to pull the machine and the speed with which it is moved (Fig. 38).

PTO HORSEPOWER

PTO or power take-off horsepower is a function of torque and speed (rpm) and is measured at the machines' power take-off shaft.

A power take-off usually has some gear reduction between the engine and the PTO shaft. This reduction increases the torque value but reduces the speed. When measuring PTO horsepower, the speed is usually held constant at 1,000 rpm, so the horsepower can be read directly on a gauge measuring torque but having its scale calibrated in horsepower.

RATED HORSEPOWER

Rated horsepower is a value used by engine manufacturers to indicate the horsepower an engine should produce under normal operating conditions. This rating takes into account the maximum pressure forces in the engine as well as the speed and torsional forces. If these values are exceeded, the engine can be damaged.

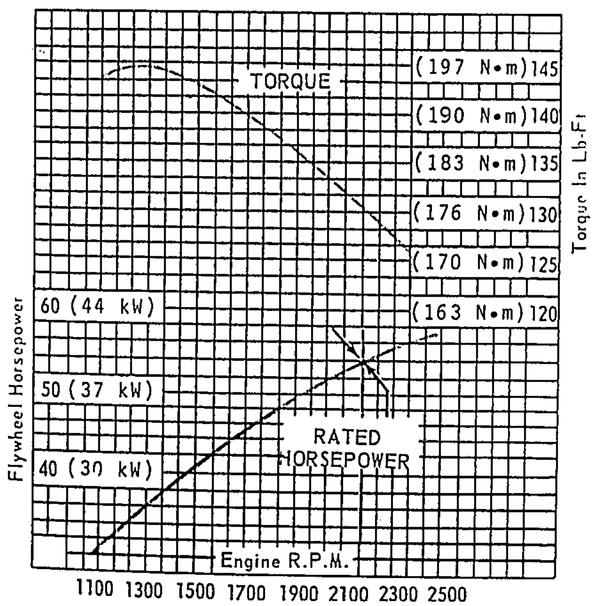

Fig. 39 — Typical Rated Horsepower Chart

Rated horsepower depends in part on the total cubic inches of piston displacement in the engine. From this, the manufacturer determines the maximum pressure stresses and rpm the engine can tolerate without internal damage. He then tests and develops the engine for long life and reliability at a given rated horsepower (Fig. 39).

Rated horsepower may not be the most efficient operating point for the best fuel consumption; this rating is expressed in terms of recommended operating horsepower and rpm.

ENGINE EFFICIENCY

We talk a lot about efficiency, and its importance can't be overstressed. It represents more than fuel economy; it also means the ability to do work at a constant rate with low maintenance.

Here are the prime efficiency factors in engines:

- **Mechanical Efficiency**
- **Volumetric Efficiency**
- **Thermal Efficiency**
- **Effective Pressure**
- **Fuel Consumption**
- **Compression Efficiency**
- **Load Effects**

Let's take a look at each type of engine efficiency.

MECHANICAL EFFICIENCY

We've mentioned some losses in horsepower between IHP and BHP—friction losses, etc. But in a functional engine other things also absorb horsepower:

1) *Fuel Pump*
2) *Water Pump*
3) *Cooling Fan*
4) *Generator or Alternator*
5) *Ignition System*
6) *Valves*
7) *Oil Pump*
8) *Blowers and Superchargers*
9) *Hydraulic Pumps (on standby)*
10) *Air Conditioner Compressor*

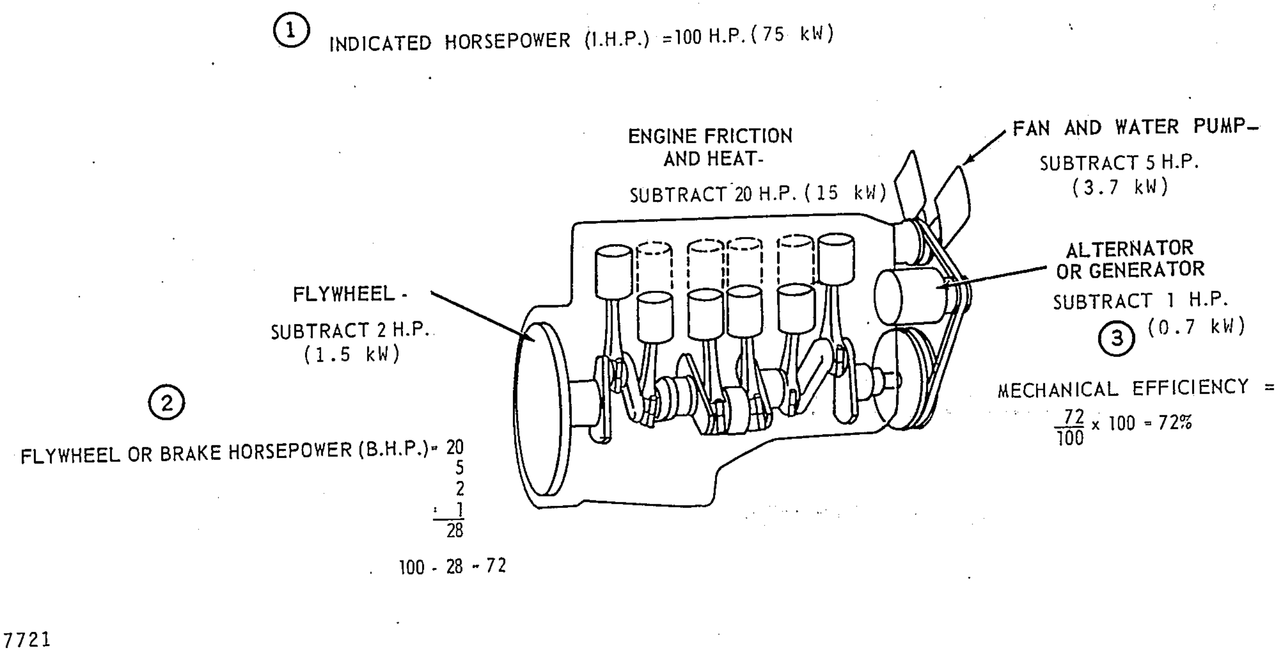

Fig. 40 — Mechanical Efficiency

Driving all these extra devices draws power from the engine and reduces its efficiency.

Mechanical efficiency then takes into account all these losses as well as frictional losses. To get a true value for mechanical efficiency the engine must be operating at its rated output, with all accessories performing their normal functions when we measure flywheel or brake horsepower (BHP). Then we divide the BHP by the IHP and multiply by 100 to get the mechanical efficiency of the engine (Fig. 40).

VOLUMETRIC EFFICIENCY

Most engines get intake air into the cylinders by creating a partial vacuum as the piston travels down on the intake stroke. However, the intake manifold, carburetor, air cleaner and intake system restrict the amount of air that can actually get into the cylinder.

Volumetric efficiency (Fig. 41) is calculated by dividing the actual amount of engine air taken in by the piston displacement and multiplying by 100.

Volumetric efficiency is one of the main factors governing the maximum torque output of an engine. The rpm at which an engine "breathes" the best will often determine the point of maximum torque.

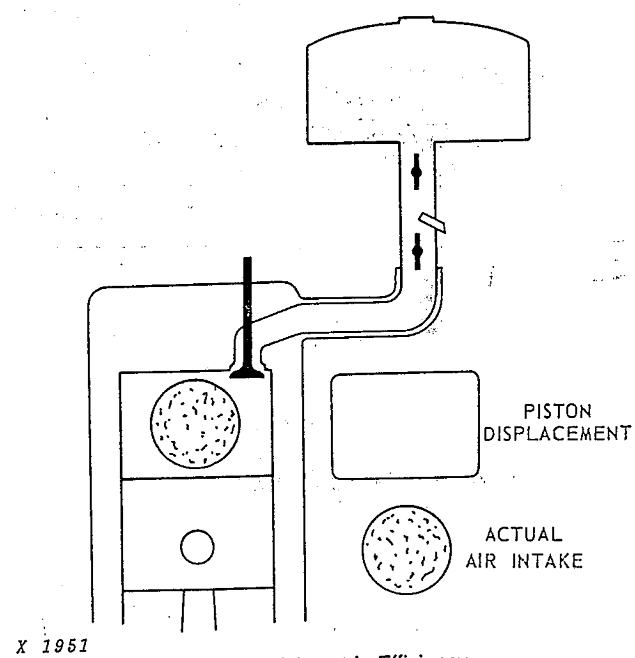

Fig. 41 — Volumetric Efficiency

THERMAL EFFICIENCY

The ratio of the work done by the gases in a cylinder (indicated work) to the heat energy (thermal energy) of the fuel is called **thermal efficiency.** Thermal efficiency is a laboratory value. We want something more practical—**brake thermal efficiency.**

Brake thermal efficiency is the brake horsepower, converted to BTU, divided by the fuel heat input in BTU, and multiplied by 100.

Thus, the brake thermal efficiency tells us how effectively an engine converts heat energy into usable power.

Brake thermal efficiency takes into account all engine losses and is sometimes called overall efficiency.

1. ENGINE DEVELOPS 100 FLYWHEEL OR BRAKE H.P. (75 kW) PER HOUR
2. 2545 x 100 B.H.P. = 254,500 B.T.U. (75 kW)
3. FUEL BURNED PER HOUR = 800,000 B.T.U. (234 kW)
4. BRAKE THERMAL EFFICIENCY

$$\frac{254{,}500}{800{,}000} \times 100 \quad 31.8\%$$

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Fig. 42 — Brake Thermal Efficiency For A Typical Engine

Fig. 42 shows the formula applied to a typical engine.

MEAN EFFECTIVE PRESSURE

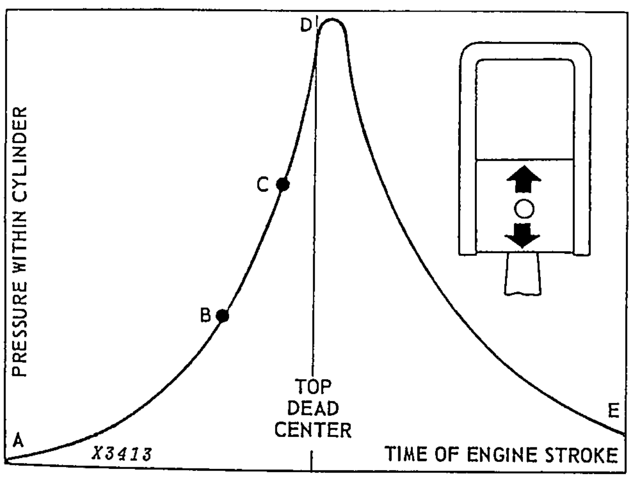

Fig. 43 — Typical Diesel Engine Pressure Indicator Tracing

Mean effective pressure consists of two types:

- **Indicated mean effective pressure (IMEP)**
- **Brake mean effective pressure (BMEP)**

The elements shown in Fig. 43 are:

A) Beginning of compression stroke

B) Start of injection

C) Beginning of injection

D) Peak firing pressure

*BC) Ignition delay**

DE) Power stroke

**Ignition delay is the period of time from the beginning of injection until the actual burning starts.*

These pressures are those developed within the cylinder. Pressures increase from the beginning of the compression stroke become maximum at peak firing pressure, and decrease as the power stroke progresses until the exhaust valve opens (Fig. 43).

Indicated (IMEP) mean effective pressure is the average pressure in the cylinder. This is measured by an instrument which records a tracing on a calibrated chart (Fig. 43). From this tracing the actual horsepower developed within the cylinder can be calculated.

Calculating the indicated mean effective pressure from the tracing is a complicated process requiring instruments not commonly available outside of engineering establishments. For those interested in more detail, refer to engineering publications on the subject.

Indicated (IMEP) mean effective pressure is used to calculate the horsepower the engine develops without taking into consideration the losses due to friction and other losses (heat, volumetric efficiency, etc.). Obviously this calculated horsepower is much higher than the usable horsepower obtained from the engine.

Brake (BMEP) mean effective pressure is calculated from the actual horsepower developed by the engine as measured by a dynamometer.

COMPRESSION RATIO

Compression ratio is the ratio of the volume of the combustion chamber at the beginning of the upstroke of the piston to the volume at the end of that stroke.

Thus, if the volume of the combustion chamber at the end of the upstroke is one-tenth (1/10) of the volume at the bottom of the upstroke, the compression ratio of the engine would be ten to one—commonly expressed 10:1.

FUEL CONSUMPTION

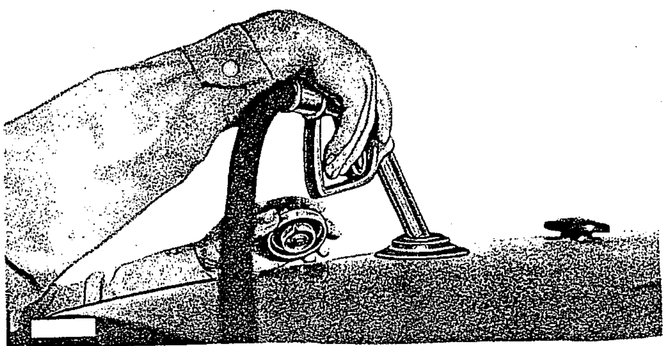

Fig. 44 — The Amount Of Fuel Used Is Measured By Pounds (kilograms) Per Horsepower-hour (kilowatt-hour)

Fuel consumption is generally measured by pounds (kilograms) of fuel per horsepower-hour (kilowatt-hour).

In a gasoline engine, fuel-air ratio is considered best at 15 pounds (7 kg) of air to one pound (0.5 kg) of fuel. Pounds (kilograms) of fuel per horsepower-hour (kilowatt-hour) is the measure of engine efficiency.

Each engine manufacturer can furnish a chart which indicates fuel consumption at various speeds and horsepower outputs.

COMPRESSION EFFICIENCY

Increased compression ratio permits the fuel-air mixture to be compressed more, which in turn gives greater heat and expansion during combustion.

Also, the higher compression and the resulting extra heat and pressure gives better burning and more energy.

There are limiting factors in the thermal efficiency produced by increasing the compression ratio. These include mechanical stresses, temperatures, and combustion chamber pressures.

Increased compression ratio may reduce fuel consumption, but certain fuels do not permit high compression ratios.

LOAD EFFECTS

Every phase of engine efficiency is affected by the nature of the load the engine drives.

A fluctuating load can set up serious vibration and, in extreme cases, "lugging" of the engine.

"Lugging" slows an engine while the throttle is still wide open. The result is excessive heat and firing pressures. This may cause the engine to be damaged.

Lean fuel mixtures result in high cylinder temperatures and possible detonation with certain fuels.

USES OF THERMODYNAMICS

Thermodynamics is the science that deals with heat and mechanical energy and their conversion one to the other.

The basics are as follows:

- **Laws of Thermodynamics**
- **Boyle's Law**
- **Charles' Law**
- **Boyle's and Charles' Law Combined**
- **Conservation of Energy**
- **Heat and Energy**
- **Adiabatic Compression**
- **Compression Ratio Vs. Pressure**

Let's see what each of these means to the engine.

LAWS OF THERMODYNAMICS

Two basic laws of thermodynamics apply to engine fundamentals: *The first states that energy is conserved. The second deals with the irreversibility of this process.*

Mechanical energy can be converted completely to heat but heat energy can never be converted completely to mechanical energy.

These fundamental truths are based upon the fact that heat naturally travels to a lower temperature object and seeks equilibrium.

An engine burns fuel and develops heat to produce mechanical energy for doing work. However, a major portion of the heat in the combustion chamber is absorbed by the cylinder walls or blown out the exhaust system; it is lost as far as mechanical energy resulting in BHP output is concerned.

Therefore, the efficiency of an engine is limited in part by the engine temperature range.

BOYLE'S LAW

Boyle's Law says that a gaseous mass can be compressed and that its volume is inversely proportional to the pressure on it, as long as the temperature stays the same.

This law is a governing factor in engine design, relative to piston displacement and compression ratio.

CHARLES' LAW

Charles' Law says that temperature changes on a gaseous mass result in direct changes of volume and pressure.

If the temperature of the gas is raised and the volume is held constant, the pressure will increase; raising the temperature and holding the pressure constant will increase the volume of the gas.

The heat energy in an engine combustion chamber causes the fuel-air mixture to expand. The combustion chamber is somewhat restricted in volume (compression ratio) and the change in volume is quite large over the entire power stroke. However, the change is not as great as the gas would need for full expansion at combustion, so the pressure is raised appreciably.

BOYLE'S AND CHARLES' LAWS COMBINED

The diesel engine takes advantage of the laws just discussed.

Air (a gas) is fed into the combustion chamber. Reducing the volume during the compression stroke raises the air temperature and the pressure.

Fuel injected into this mixture will then ignite due to the high temperatures of compression. Ignition further raises the temperature and the gases expand to force the piston down on the power stroke.

The pressure applied is dependent on the rate of burning and the heat retained in the gases and not lost through the cylinder walls and exhaust system.

This same principal is the cause of detonation or the preignition in gasoline engines. Gasoline will ignite at much lower temperatures than diesel fuel. If the temperature is raised too much by compression, spontaneous ignition will take place before the compression stroke is complete and the engine will tend to run backwards.

Engine design must, therefore, take into account all known conditions resulting from the three laws.

CONSERVATION OF ENERGY

Energy can neither be created nor destroyed. The different forms (work, heat, etc.) are mutually convertible. When, in some thermodynamic change, a quantity of one form disappears, an equivalent quantity must necessarily appear.

HEAT AND ENERGY

Heat is the greatest source of energy loss, as most engines operate in the varying temperature of the atmosphere.

Remember that heat energy lost to the engine cannot be recovered. This includes the normal losses of heat through the engine cooling and exhaust systems.

COMPRESSION RATIO VS. PRESSURE

The compression ratio of an engine is fixed by the design engineer. He then determines the combustion pressures which result under normal operation of the engine.

Tampering with the fuel rate or combustion rate can change the cylinder pressure and may damage the engine.

The higher the compression ratio of gasoline and LP-gas engines, the more critical become fuel quality and operating temperatures.

Detonation is the stray, unwanted explosions that take place in the engine as a result of too-high compression or heat, or low-quality fuels. These explosions cause piston and cylinder damage by creating excess pressure.

"Lugging" a high-compression engine at low rpm can cause serious detonation as the charge is in the combustion chamber a longer interval.

The laws of thermodynamics cannot be ignored when efficient, trouble-free engine performance is required.

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SAFETY

After a shop has been planned to be as hazard-free as possible, *it must be managed* to keep it that way. Consider these key management procedures:

Make sure someone knows you are working in the shop and will check on you and render aid if you are injured.

1. Keep all tools and service equipment in good condition.
2. Use personal protective equipment, goggles, face shields, gloves.
3. Keep floors and benches clean to reduce fire and tripping hazards.
4. Clean up as you go while doing a job, and clean the area completely after the job is done.
5. Empty trash containers regularly.
6. Keep lighting, wiring, heating, and ventilation systems in good shape.
7. Lock your shop to prevent accidents. A shop is an attraction to a child.
8. Don't let anyone use tools or service equipment unless they've had adequate instruction.
9. Keep guards and other safety devices in place and functioning.
10. Use tools and service equipment for the jobs they were designed to do.
11. Supervise children carefully when they are in the shop.
12. Keep the fire extinguishers serviced, and the first aid kit replenished with supplies.

CHEMICALS AND CLEANING EQUIPMENT

In service operations, cleaning is needed in order to:

- **Keep dirt from entering the machine when parts are disassembled**
- **Inspect parts for wear and damage**
- **Install and adjust parts properly during reassembly**

Let's discuss the safe use of solvents, steam cleaners, and high-pressure washers.

SOLVENTS

Most solvents are toxic, caustic, and flammable. Be careful, therefore, to keep them from being taken internally, from burning the skin and eyes, and from catching on fire. Read the manufacturer's instructions and precautions before using any commercial cleaner or solvent.

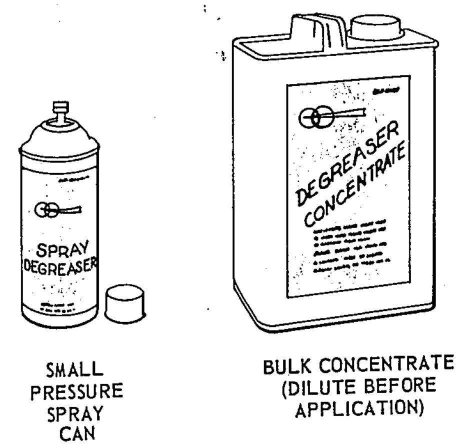


Fig. 45—Use Commercial Cleaning Solvents—Not Gasoline

Whenever possible, use a commercially available solvent (Fig. 45). Many types are available for general-purpose cleaning and for specific cleaning jobs. Always read and follow the manufacturer's instructions to get the best results and to be able to handle each product safely.

Never clean with gasoline. It vaporizes at a rate sufficient to form a flammable mixture with air at temperatures as low as 50° F below zero. It is *always* unsafe to use. If you don't use a commercial solvent, use diesel fuel or kerosene. These *will* burn, but not as easily or as explosively as gasoline (Fig. 46).

Follow these general safety practices when using chemical cleaners:

1. *Follow the manufacturer's instructions.* Cleaning agents intended for the same purpose may be quite different in chemical composition. Read the label on each container you buy and follow instructions carefully.

Fig. 46—One Gallon Of Gasoline Mixed With The Right Amount Of Air Can Have The Explosive Force Of 83 Pounds of Dynamite

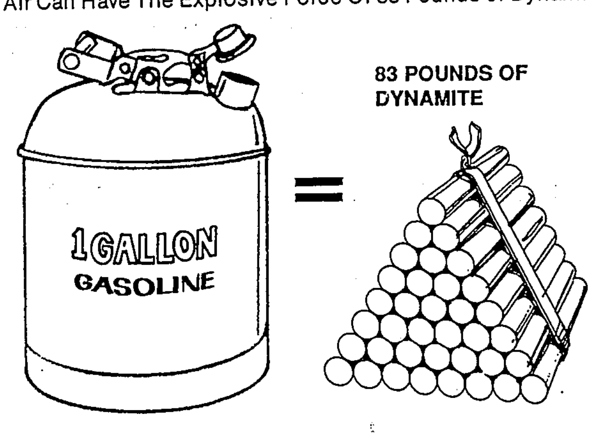


Fig. 47—Use Cleaning Solvents Only In A Ventilated Area, Outdoors If Possible

2. *Work in a well-ventilated area (Fig. 47).* Do the cleaning outdoors if possible. If you can't, provide ventilation by opening doors and windows.

3. *Keep solvents away from sparks and flame.* Don't let anyone smoke in the immediate area. Don't use solvents near heaters, sparks or open flames. Some solvent tanks and tubs should be "grounded." Contact your solvent supplier for instructions on how to ground your solvent tank or tub.

4. *Never heat solvents unless instructed to do so.* And don't mix them, because one might vaporize more readily and act as a fuse to ignite the other.

5. *Wipe up spills promptly.* Keep soaked rags in closed metal containers and dispose of them promptly.

6. *Store solvents in their original containers or in sealed metal cans properly labeled.* In a sealed container, the solvent will be kept clean from further contamination, toxic fumes will be controlled, the fire hazard will be reduced, and there will be less likelihood of spillage. Never use open pans (Fig. 48).

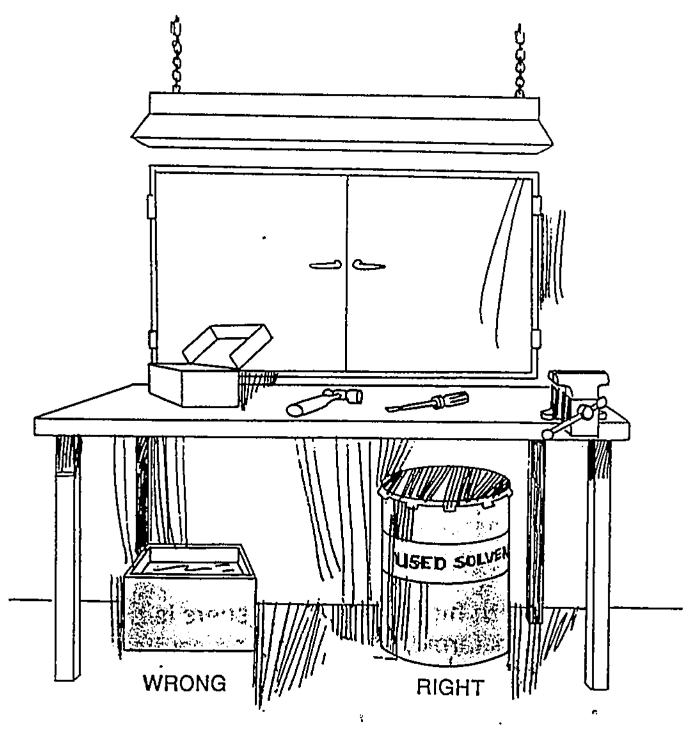
7. *If a commercially made parts washer is used, close the lid when you're finished cleaning.* Never destroy the fusable link that closes the lid automatically in case of fire.

8. *Protect your skin and eyes.* Wear a face shield and rubber gloves when working with strong, concentrated cleaning solutions (Fig. 49). Some are caustic, and they can destroy the natural oils of the skin and burn it severely. Always read and follow the manufacturer's instructions carefully. Even when gloves are not called for, avoid long exposures to solvents, and wash your hands when the job is done. Wear an apron if it's needed to keep your clothing dry.

9. *Avoid accidental poisoning.* Wash your hands and arms before eating or smoking. Keep all solutions in labeled containers. Never use empty containers, no matter how thoroughly cleaned, for carrying food or beverages. Keep poison containers sealed even when they are empty. Keep them out of the reach of children.

10. *Be prepared for emergencies.* Keep fire-fighting equipment near your cleaning area. Save the original containers for all solvents until they are completely used. In case of accidental poisoning, follow the instructions provided by the manufacturer immediately, and when going for medical aid, take the container with you so the chemical can be quickly identified.

Fig. 48—Store Solvents In Sealed And Labeled Cans, Never In Open Pans



ELECTRICAL SYSTEM

Avoid these hazards when servicing an electrical system:

- **Battery explosions**
- **Being burned by the battery electroyte**
- **Electrical shock**
- **Bypass start hazard**

NOTE: When servicing the electrical system, always follow the steps outlined in your operator's or service manual to avoid damaging the electrical system. Lock out or disconnect the electrical power source from the electrical system before you begin your service procedure.

BATTERY EXPLOSIONS

When charging and discharging, a lead-acid storage battery generates hydrogen and oxygen gas. Hydrogen will burn, and is very explosive in the presence of oxygen. A spark or flame near the battery could ignite these gases, rupturing the battery case and throwing acid all over.

To prevent battery explosions:

1. *Maintain the electrolyte at the recommended level.* Check this level frequently. When properly maintained, less space will be available in the battery for gases to accumulate. Refer to your operator's manual. Put only water or battery electrolyte in the battery.

2. *Use a flashlight to check the electrolyte level.* Never use a match or lighter, because these could set off an explosion.

3. *Do not short across the battery terminals.* If the battery isn't completely dead, the resulting spark may set off an explosion if hydrogen gas is present.

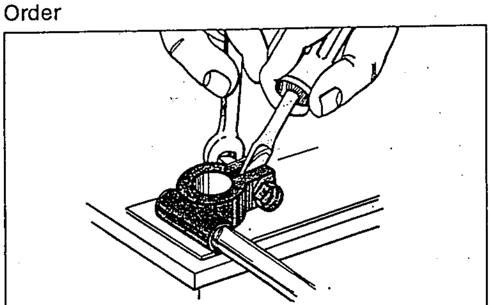
4. *Remove and replace battery clamps in the right order (Fig. 53).* This is very important. If your wrench touches the ungrounded battery post and the tractor chassis at the same time, the heavy flow of current will produce a dangerous spark. To prevent this, follow these rules:

a) *Battery removal:* disconnect the grounded battery clamp first. *Note: Some systems may be positive ground. Make sure you know which post is grounded.*

b) *Battery installation:* connect the grounded battery clamp *last.*

5. *Prevent sparks from battery charger leads.* Turn the battery charger off or pull the power cord before connecting or disconnecting charger leads to battery posts (Fig. 54). If you don't, the current flowing in the leads will spark at the battery posts. These sparks could ignite the explosive hydrogen gas which is always present when a battery is being charged.

Fig. 53—Remove And Replace Battery Clamps In The Correct Order



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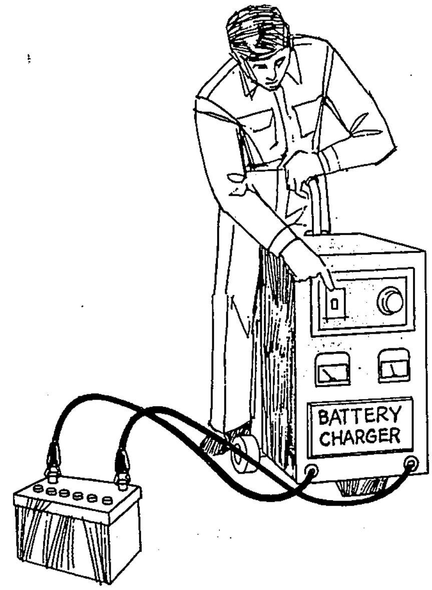

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Fig. 54—Turn Charger Off Before Disconnecting Clamps From Battery Posts

CONNECTING A BOOSTER BATTERY

Improper jump-starting of a dead battery can be dangerous. Follow these procedures when jump starting from a booster battery.

1. Remove cell caps (if so equipped).

2. Check for a frozen battery. Never attempt to jump start a battery with ice in the cells.

3. Be sure that booster battery and dead battery are of the same voltage.

4. Turn off accessories and ignition in both vehicles.

5. Place gearshift of both vehicles in neutral or park and set parking brake. Make sure vehicles do not touch each other.

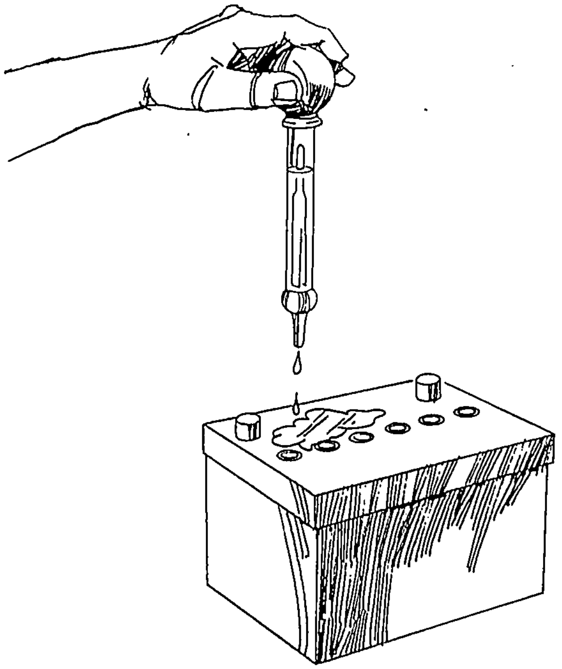

Fig. 55—Avoid Dripping Electrolyte When Reading Specific Gravity

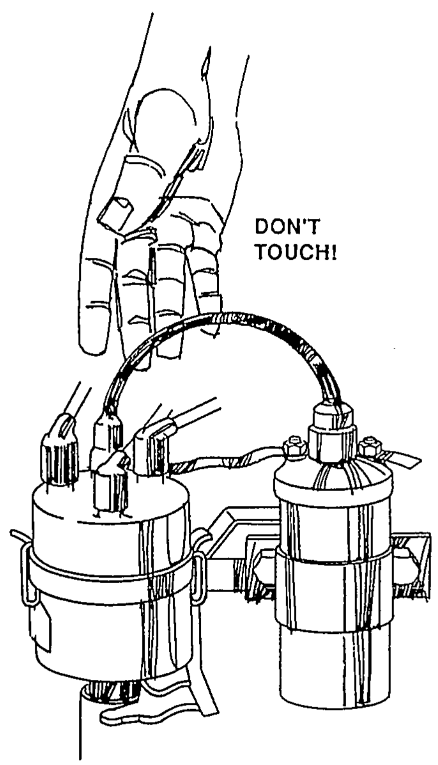

Fig. 56—Never Touch Wires In The Secondary Circuit Or Spark Plug Terminals While The Ignition Switch Is Turned On

6. Remove vent caps from both batteries (if so equipped). Add electrolyte if low. Cover the vent holes with a damp cloth, or if caps are safety vent type, replace the caps before attaching jumper cables.

7. Attach one end of one jumper cable to the booster battery positive terminal. Attach other end of the same cable to the positive terminal of the dead battery. Make sure of good, metal-to-metal contact between cable ends and terminals.

8. Attach one end of the other cable to the booster battery negative terminal. Make sure of good, metal-to-metal contact between the cable end and the battery terminal.

CAUTION: Never allow ends of the two cables to touch while attached to batteries.

9. Connect other end of second cable to engine block or vehicle metal frame *below* dead battery and as far away from dead battery as possible. That way, if a spark should occur at this connection, it would not ignite hydrogen gas that may be present above dead battery.

10. Try to start vehicle with dead battery. Do not engage the starter for more than 30 seconds or starter may overheat and booster battery will be drained of power. If vehicle with dead battery will not start, start the other vehicle and let it run for a few minutes with cables attached. Try to start second vehicle again.

11. Remove cables in exactly the reverse order from installation. Replace vent caps.

ACID BURNS

Battery electrolyte is approximately 36 percent full-strength sulfuric acid and 64 percent water. Even though it's diluted, it is strong enough to burn skin, eat holes in clothing, and cause blindness if splashed into eyes. Fill new batteries with electrolyte in a well ventilated area, wear eye protection and rubber gloves, and avoid breathing any fumes from the battery when the electrolyte is added. Avoid spilling or dripping electrolyte when using a hydrometer to check specific gravity readings (Fig. 55).

If you spill acid on yourself, flush your skin immediately with lots of water. Apply baking soda or lime to help neutralize the acid. If acid gets in your eyes, flush them *right away* with large amounts of water, and see a doctor at once.

ELECTRICAL SHOCK

The voltage in the secondary circuit of an ignition system may exceed 25,000 volts. For this reason, don't touch spark plug terminals, spark plug cables, or the coil-to-distributor high-tension cable when the ignition switch is turned on or the engine is running (Fig. 56). The cable insulation should protect you, but it could be defective.

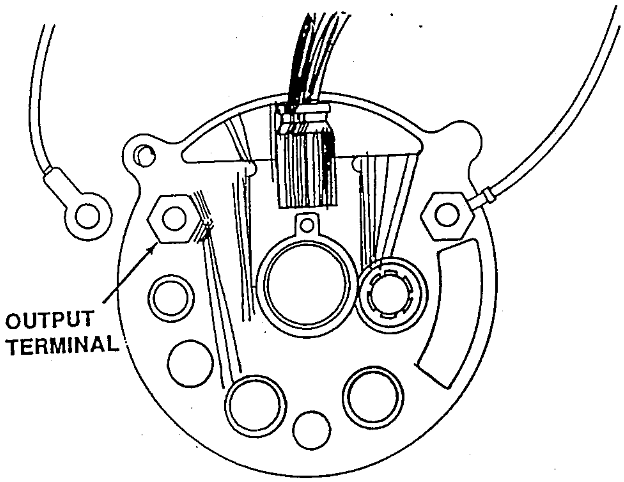

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Fig. 57—Don't Run The Engine When The Wire Has Been Disconnected From The Alternator Or Generator Output Terminal

Never run an engine when the wire connected to the output terminal of an alternator or generator is disconnected (Fig. 57). If you do, and if you touch the terminal, you could receive a severe shock. When the battery wire is disconnected, the voltage can go dangerously high, and it may also damage the generator, alternator, regulator, or wiring harness.

BASIC ENGINE / CHAPTER 2

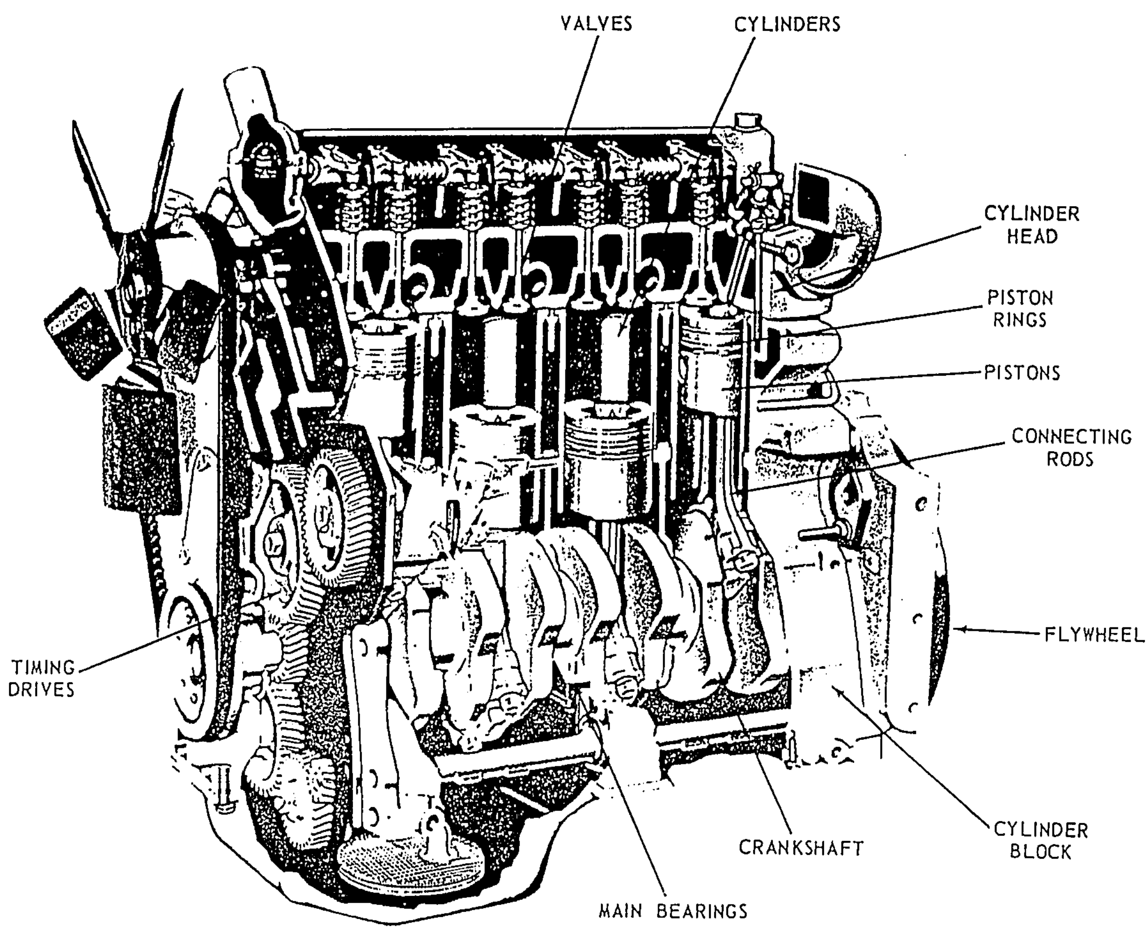

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Fig. 1 — Cutaway of Basic Engine

INTRODUCTION

This chapter covers the *basic* engine—parts common to *all* internal combustion engines.

Chapter 1 told how the engine works, while later chapters cover the fuel systems and other accessories.

General testing and diagnosis of the engine is outlined in Chapter 11.

In this chapter you will learn about these parts of the engine:

- **Cylinder Head** is at the top of the engine and houses the valves and the intake and exhaust passages.
- **Valves** open and close to let fuel in and exhaust gases out of each cylinder.
- **Camshaft** rotating in the engine block opens the valves by cam action.
- **Cylinder Block** is the main housing of the engine and supports the other main parts.
- **Cylinders** are hollow tubes in which the piston works. They may be cast into the cylinder block or made of liners or sleeves.
- **Pistons** move up and down in the cylinders by the force of combustion.
- **Piston Rings** seal the compression in the combustion chamber and also help to transfer heat.

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Basic Principles of Automatic Transmissions

Learning Objective: The student will have an understanding of the basic principles involved in the operation of automatic transmission.

Task:
1. The student will be able to correctly explain the following:

KEY CONCEPT
How does a fluid coupling work
What is a planetary gearset
What is the relationship between gear size and speed in meshed gearsets
What is underdrive
What is overdrive
What is constant drive
What is a multi-disk clutch and what is its function

2. The student will be able to correctly define:

TERM
Converter lock up
Valve body
Governor
Rotary flow
Vortex flow
List and define the three main parts of a torque converter

Standard: The student will complete a written examination in which he/she will correctly define or explain the items from the list with a minimum score of 80%.

Task Check-Off Sheet

Name	Transmission	
Task	**Date**	**Instructor**
1. The student will be able to correctly explain each of the following:		
How does a fluid coupling work?		
What is a planetary gearset?		
What is the relationship between gear size and speed in meshed gearsets?		
What is underdrive?		
What is overdrive?		
What is constant drive?		
What is a multi-disk clutch and what is its function?		
2. The student will be able to correctly define:		
Converter lock up		
Valve body		
Governor		
Rotary flow		
Vortex flow		
List and define the three main parts of a torque converter		

Chapter 14

AUTOMATIC TRANSMISSIONS

After studying this chapter, you will be able to:
- Describe the parts of an automatic transmission.
- Explain how an automatic transmission functions.
- Identify the major components of an automatic transmission.
- Compare the different types of automatic transmissions.

Like the standard transmission, the automatic transmission is designed to adapt the power of the engine to meet varying road and load conditions. In this case, however, the transmission does this automatically. Instead of three set forward gear ratios, it can produce an infinite number of ratios between engine and wheels.

The automatic transmission eliminates the clutch pedal and, instead of a solid type conventional clutch, it utilizes a fluid coupling between the engine and transmission.

After the driver has selected the necessary range (speed or ratio selection) by shifting a lever or pushing a button, the transmission shifts itself up or down depending on road speed, throttle position and engine loading.

BASIC CONSTRUCTION

Basically, in addition to the metal housing, the automatic transmission assembly consists of:

1. A fluid coupling or torque converter to transmit power from the engine to the transmission proper.
2. One or more planetary gearsets and shafts to secure the necessary forward and reverse speeds.
3. A series of brake bands and multiple disc clutches designed to control the planetary gearsets.
4. Hydraulic servos and pistons to actuate the bands and clutches.
5. One or more oil pumps to provide the necessary hydraulic pressure.
6. Numerous valves (control, check, pressure regulation, balanced, transition, downshift, etc.), all designed to control, direct and administer hydraulic pressures throughout the transmission.
7. Some means of cooling the oil.
8. Manual control system used by the operator to select certain speed ranges; high, low, etc.

FLUID COUPLING

The fluid coupling utilizes a special lightweight oil to transmit engine power from one member to another.

For purposes of illustration, imagine cutting a hollow steel doughnut down the center, Fig. 14-1. You now have two halves, each shaped like the unit shown in Fig. 14-2.

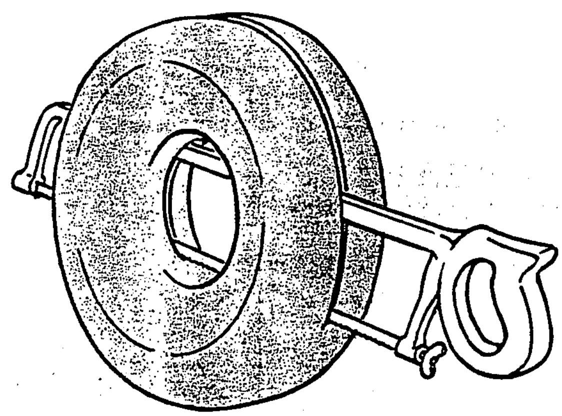


Fig. 14-1. Cutting a hollow steel doughnut.

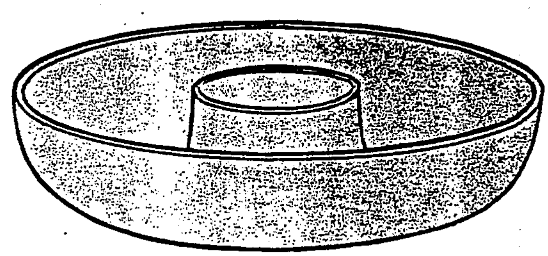


Fig. 14-2. One half of the steel doughnut.

TORUS

Each half, or member, is called a TORUS. Vanes or fins are placed in each torus. The vanes are straight and are spaced at equal intervals. Fig. 14-3.

The two torus members are fastened to shafts. One member to an input, the other to an output shaft. They are placed face to face with a slight clearance between them. Fig. 14-4.

As indicated in Fig. 14-4, the flywheel holds the driving torus. A thin housing from the flywheel also extends around the driven member. An oil seal is placed between the transmission shaft and this housing. The housing is filled with oil.

You will also notice that the driven member is splined to the transmission or output shaft. The shaft is supported by a pilot bushing in the crankshaft. When the crankshaft turns the flywheel, the driving member and housing will spin. The driven member is entirely free since there is no mechanical connection between it and the driving member.

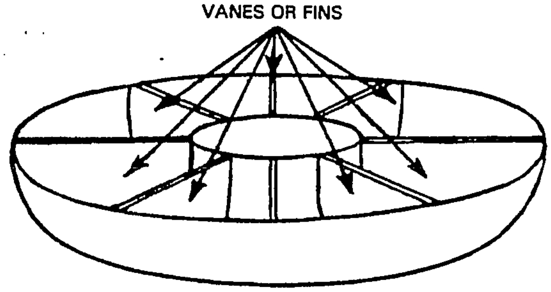


Fig. 14-3. Vanes are placed in each torus. Notice that vanes are straight and equally spaced. In an actual torus, a greater number of vanes are used.

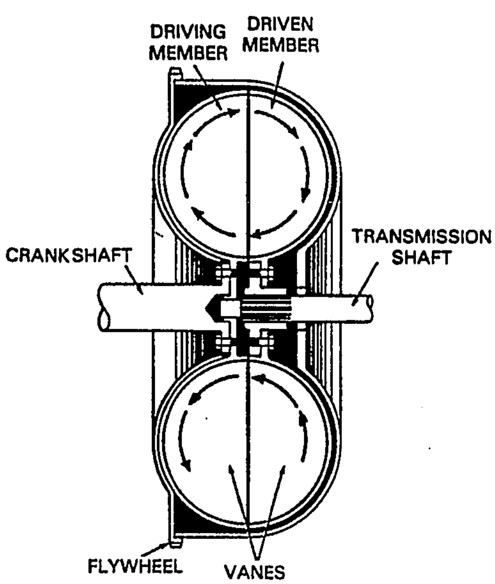


Fig. 14-4. Torus members in place. One torus member is fastened to each shaft. Notice how transmission shaft is supported by bushing in end of crankshaft.

HOW FLUID COUPLING FUNCTIONS

Imagine two fans facing each other, at reasonably close range. If one fan were plugged in, the air blast from the driving fan would cause the other fan to spin. Air is the medium of power transfer. Since the two fans are not in an enclosed area, the power transfer would not be very efficient. Fig. 14-5.

The fluid coupling works on somewhat the same principle as the fan. However, oil is used instead of air, and since the driving and driven torus are mounted very close together in an enclosed space, power transfer is excellent.

If oil were placed in a horizontal torus, and if the torus were spun, the vanes would carry the oil around at high speed. This motion of oil would be referred to as a ROTARY motion. The centrifugal force set up by the whirling would cause the oil to fly outward and upward. Fig. 14-6.

If the driven torus were placed above the driving torus, the oil that is thrown out would strike the vanes in the driven torus. After striking the vanes it would travel up, over and back down into the driving torus. As the driving torus is whirling, it would be thrown outward and upward back against the vanes of the driven torus. This around and around motion of the oil is termed VORTEX flow. The same action takes place when the torus members are in the vertical position. Figs. 14-7, 14-8, and 14-9.

As the speed of the driving torus is increased, the

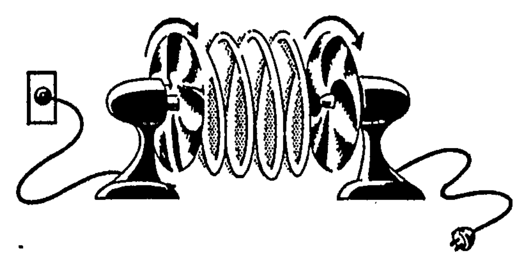


Fig. 14-5. Coupling drive using fans and air. Air from driving fan will cause other fan to spin. (Chevrolet)

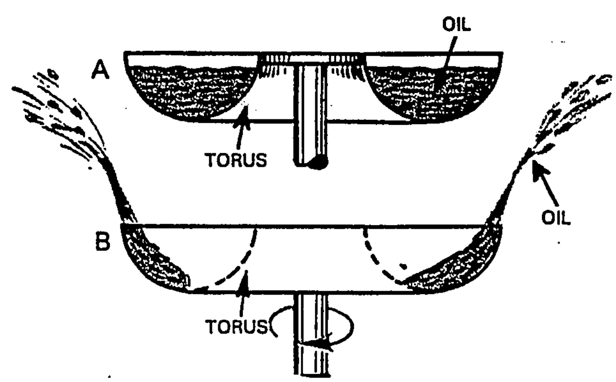


Fig. 14-6. Oil action in torus. A—Cutaway of torus at rest. Oil is level. B—Torus is spinning. Oil is thrown outward and is directed upward by curved torus edge.

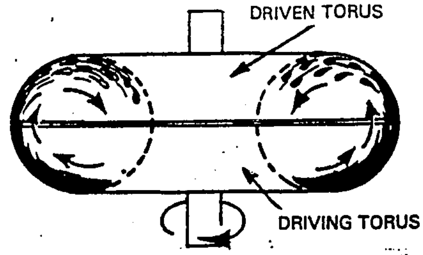


Fig. 14-7. Start of vortex flow. When driving torus starts to spin, oil is thrown out, up into driven torus, around and back into driving torus. This action, around and around, is termed vortex action.

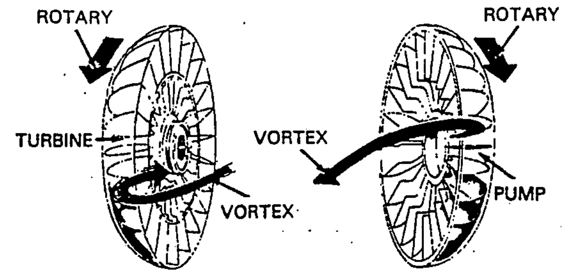


Fig. 14-9. Rotary and vortex flow. (Pontiac)

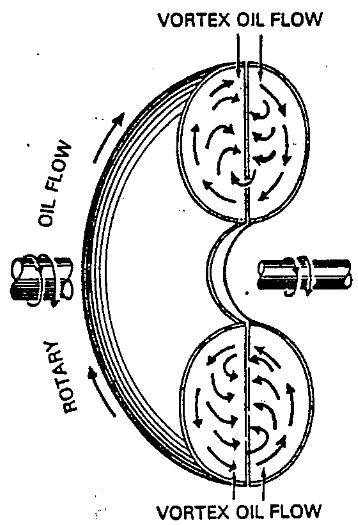


Fig. 14-8. Rotary and vortex oil flow.

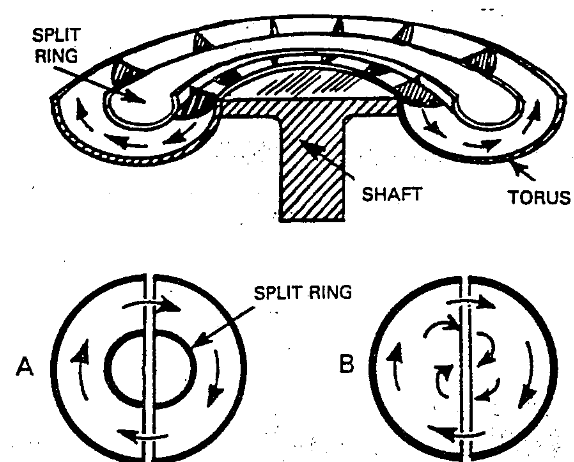


Fig. 14-10. Use of a split ring to smooth vortex flow. Top view illustrates split ring as installed in a torus. Vanes are cut away to receive ring. A shows how oil vortex flow is guided and smoothed by split ring. B shows turbulence present in center when split ring is not used.

rotary and vortex flow of the oil becomes more violent. This will cause the driven torus to turn faster and faster.

Finally the speed of the driver and driven members will become equal. At this point the rotary flow is constant, but there is little or no vortex flow. You will remember that vortex flow is caused by centrifugal force throwing the oil outward. If both members are whirling at the same speed, each member will attempt to throw oil into the other, canceling the vortex flow.

SPLIT RING

To assist the oil in maintaining a smooth vortex flow, a hollow ring is sometimes placed in each member. The oil is guided around, and there is less tendency for the oil to work against itself in the center area. Fig. 14-10.

FLUID COUPLING EFFICIENCY

The fluid coupling effects a smooth transfer of power from the engine to the transmission.

At high engine speeds, the coupling is very efficient. It gives a one to one ratio between driven and driving members. At medium speeds the coupling is not quite as effective. At low engine speeds there is little power transfer.

This allows the coupling to act as a clutch. When engine speed is low, there is no power transfer. This is the same as having a conventional clutch in the disengaged position. As engine speed is increased, power transfer becomes more effective. All jerking and roughness is eliminated by the use of the fluid coupling. This provides smooth takeoff and reduces wear and strain on the drive train.

The fluid coupling cannot increase torque above that produced by the crankshaft.

When the engine is accelerating, the driving torus transmits engine torque to the driven torus. When coasting, the driven torus becomes the driver and allows the engine to act as a brake.

TORQUE CONVERTER

A torque converter is similar to the fluid coupling but there is one very important difference. The fluid coupling can transmit all available engine torque, but it cannot multiply this torque. The torque converter can and does multiply engine torque. The amount of multiplication depends on the type and design of converter used, as well as road and engine speeds.

The ability to multiply torque makes it possible to reduce the number of gears in the transmission.

The torque converter uses a driving and driven torus but, in this case, they are generally referred to as the pump (driver) and the turbine (driven). In some cases, more than one pump and turbine are used. The pump is sometimes referred to as the impeller.

VANES

The converter blades or vanes are curved to facilitate proper vortex flow. The pump vanes are curved one way, and the turbine blades the other. Fig. 14-11.

STATOR

The secret of torque multiplication lies in the use of one or more STATORS. Fig. 14-12.

A stator is a small, wheel-like arrangement that is inserted between the pump and turbine. The job of the stator is to intercept the oil thrown off by the turbine and redirect the path of this oil so it will enter the pump smoothly. The stator is mounted between the pump and the turbine. As the pump begins to spin, oil is thrown outward into the curved vanes of the turbine. The oil then circulates around through the turbine vanes. Instead of being discharged back into the pump vanes (as in fluid couplings), the oil is first passed through the stator.

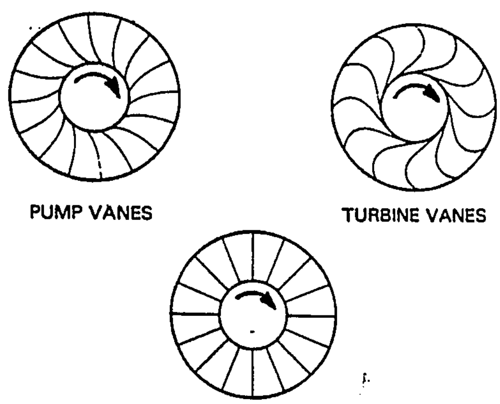


Fig. 14-11. Fluid coupling and torque converter vanes. Torque converter vanes are curved. Fluid coupling vanes can be straight. (Chevrolet)

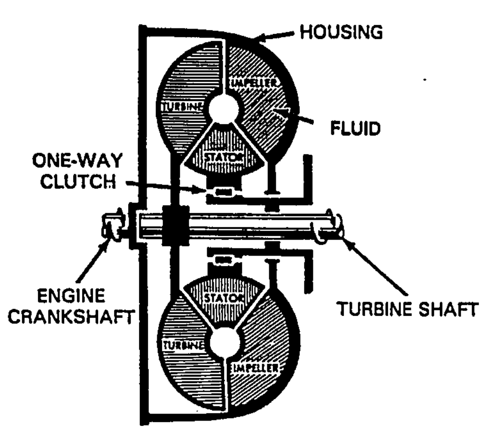


Fig. 14-12. One type of stator. (Ford)

In the fluid coupling, which uses no stator, torque transmission and multiplication efficiency is reduced by having turbine oil enter the pump at various angles, depending on speed and load conditions. This poor entry angle can work against the pump and absorb valuable torque.

The stator is mounted on a stationary shaft, and is allowed to spin in the direction of the pump. Any attempt to rotate the stator against pump rotation, causes it to lock to the shaft.

SPRAG AND ROLLER ONE-WAY CLUTCHES

Stator locking action is produced by using either a roller or a sprag one-way (overrunning) clutch. The roller clutch is described in Chapter 13.

The sprag clutch is similar to the overrunning type used in the overdrive. Instead of using round rollers that walk up a tapered step to lock up the clutch, the sprag clutch uses a flat unit with curved edges. When the outer race is turned one way, the sprags tip and present their narrow diameter. This allows the outer race (fastened to stator) to turn.

When the stator attempts to rotate in the opposite direction, the sprags tip the other way and present the long diameter. This causes them to jam between the two races, locking them together and preventing rotation in this direction. Fig. 14-13. Note location of stator one-way clutch. Fig. 14-12. See roller clutch in Fig. 14-20.

TORQUE MULTIPLICATION

As the pump discharges oil into the vanes of the turbine, the force of the oil tends to turn the turbine. In A, Fig. 14-14, you see a wheel (turbine) with cups (vanes) attached. Oil is being sprayed into the cup by

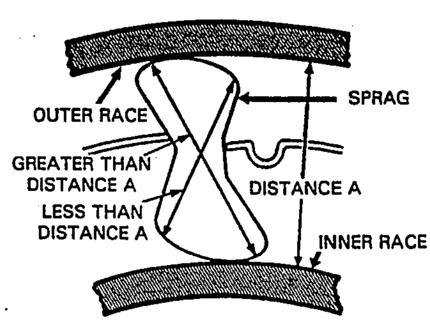


Fig. 14-13. Cross section showing sprag clutch construction. (Cadillac)

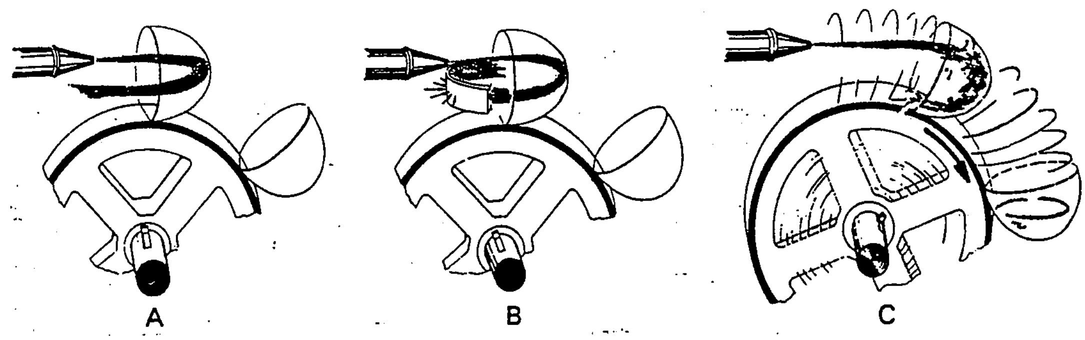


Fig. 14-14. Torque multiplication by using a stator.

a pressure gun (pump).

The oil strikes the cup (vanes) and exerts some force. The force, however, is not enough to cause the heavy wheel to turn. You can see that the oil is striking one side of the cup, then is directed around and out (vortex action). Obviously a great deal of potential force of the oil is being lost.

In B, Fig. 14-14, a stationary curved piece (stator) has been placed so the oil is redirected into the cup (vane). The oil can now strike the cup and, instead of leaving, will continue to circulate back into the cup. The torque produced by the oil in A, has been increased in B, by adding the extra torque that was lost when the oil left the cup. By redirecting the stream of oil, the torque has been multiplied. This is the job of the stator.

As the wheel (turbine) turns faster and faster, it will finally approach the speed of the oil stream (pump). Look at C, Fig. 14-14. When this happens, the cup will be moving at about the same speed as the oil stream. In this case the oil will not fly out of the cup and cannot be redirected. Torque multiplication is no longer possible. TORQUE MULTIPLICATION IS ONLY POSSIBLE WHEN THERE IS A DIFFERENCE IN THE SPEED OF THE PUMP AND TURBINE! THE GREATER THE DIFFERENCE–THE GREATER THE MULTIPLICATION, A, B, and C, Fig. 14-14.

NEWTON'S LAW

Newton's law says: "For every action there is an equal and opposite reaction."

Applying Newton's law to the torque converter, we find three areas of action and reaction caused by the oil flow. A–Pump, B–Stator, C–Turbine. Look at Fig. 14-15.

As the stator blades are held in a fixed position during the torque multiplication period, the reaction of these blades to the oil flow is to direct the force in the same direction as that of pump A.

Using Newton's law, the reaction of the turbine blades on the oil stream will be equal to the force exerted by both pump A and stator B. If A is the action force of the pump, B the reaction force of the stator,

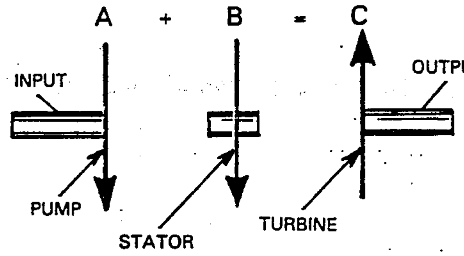


Fig. 14-15. Newton's law as applied to converter forces. Force of pump A, plus force of stator B, combine to produce force C, which is greater than original force A.

and C the reaction force of the turbine, then: $C = A + B$.

The original force A has been increased by B, giving a reaction force of C that is greater than A. In short, original torque A has been multiplied to C. See Fig. 14-15.

WHY CONVERTER BLADES ARE CURVED

The pump vanes are curved in such a manner as to direct the vortex flow leaving the vanes in a direction that will exert as much force as possible against the turbine vanes. The leading edge (part of the vane where oil first enters), or inner portion of the pump vane, is curved to assist smooth reentry of oil being discharged by the stator.

The turbine blades are curved in an opposite direction. This curve produces two favorable functions. When pump oil is thrown against the turbine vanes, the curved leading edge (that portion where oil first enters) assists in a smooth entry. This reduces breakup of the smooth oil stream and prevents a buildup or damming effect that reduces entry oil velocity.

The last portion of the turbine vane is curved to increase the turbine energy absorption by deflecting the oil stream as much as possible. The more it is deflected, the more energy it will give up to the deflecting object.

Fig. 14-16 illustrates this principle. Note in A, Fig. 14-16, that a stream of oil is striking a flat vane. Notice how the stream is broken up. This imparts a

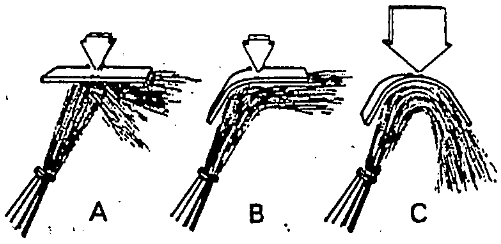


Fig. 14-16. Oil stream deflection. Bending direction of oil stream so a maximum amount of oil stream energy will be absorbed by deflecting object. (Dodge)

small force to the vane. In B, Fig. 14-16, the leading edge of the vane has been curved. The oil stream is now entering in a smooth fashion and will retain its velocity. However, no greater force is imparted to the vane. In C, Fig. 14-16, the last portion of the vane has been curved to provide a much greater deflection of the oil stream.

As the oil stream velocity was maintained by the curved leading edge, oil stream deflection by bending the last portion will now provide a much greater absorption of energy by the vane.

STATOR IS NECESSARY

Since the curved turbine blades discharge oil in a direction opposite to pump rotation, the work of the pump would be hampered since oil could not reenter the pump blades in a smooth manner. As a result, vortex flow would be impaired and torque transmission would fall off. Fig. 14-17.

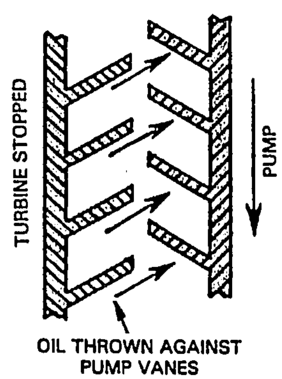


Fig. 14-17. Oil transfer without stator. As oil leaves turbine blades and attempts to reenter pump, oil works against pump rotation. Oil is entering at wrong angle.

The stator blades are curved at an angle that will intercept the oil leaving the turbine blades smoothly. At the same time, this adds to the force of the pump and increases vortex velocity. Fig. 14-18.

A in Fig. 14-19, shows how the oil stream from the curved turbine blades is redirected by the stator so it enters the pump vanes with an initial velocity. B in Fig. 14-19 illustrates the same action.

Stator vanes, as well as a roller overruning or one-

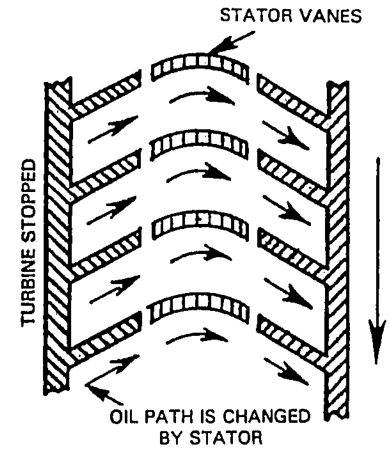


Fig. 14-18. Oil transfer with a stator. As oil leaves turbine vanes, it strikes stator vanes. As stator is locked, vanes bend oil stream so it enters pump at proper angle. It will now assist pump as it will enter with some initial velocity.

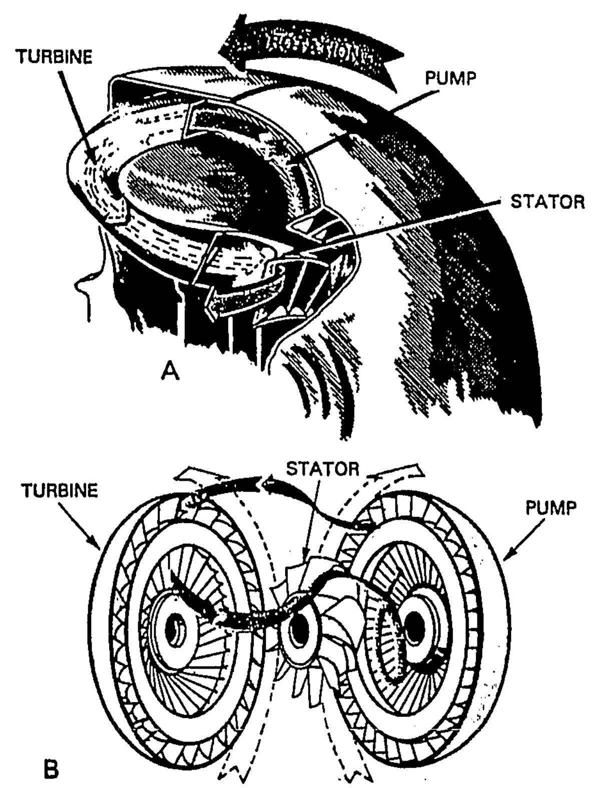


Fig. 14-19. Stator action. A—Stator bends oil stream leaving turbine blades in direction that will allow it to enter pump with initial velocity. B—Follow oil flow from pump to turbine, stator, and back into pump. Note how stator redirects oil into pump in direction of pump rotation. (Dodge, AMC)

way clutch, are shown in Fig. 14-20. The one-way clutch hub is stationary and the stator can turn only in the direction shown by the arrow.

VARIABLE PITCH STATOR

To further increase the usefulness of the stator, and to adapt it to different load requirements, one type of

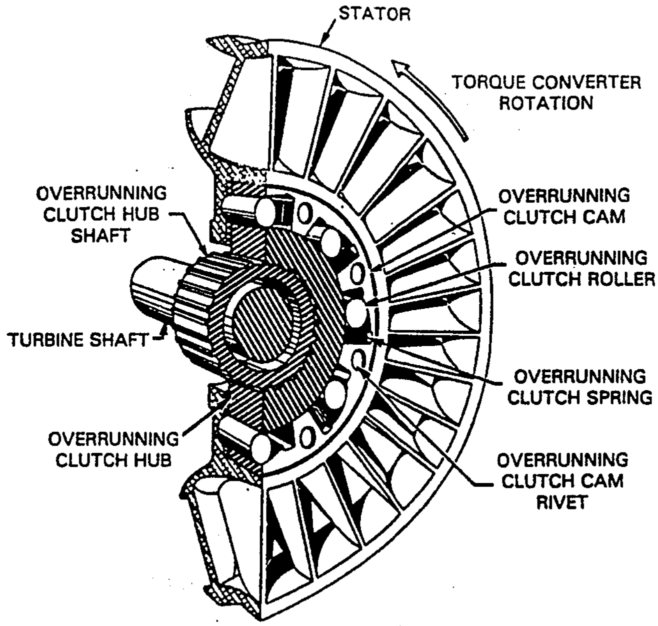


Fig. 14-20. Stator. One form of stator. This unit uses a one-way roller clutch. Notice that stator can turn in one direction only.

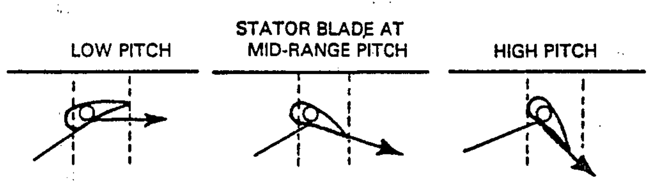


Fig. 14-21. Variable pitch stator. Pitch or angle of stator blades can be changed to meet different requirements. (Buick)

stator is built with adjustable vanes. It is referred to as a VARIABLE PITCH stator. Fig. 14-21.

VORTEX FLOW

Vortex flow in the torque converter is much faster than that of the fluid coupling. This is accomplished by: the initial velocity of pump oil reentry provided by the stator; the curved vanes; smooth turbine oil entry. The higher the vortex flow velocity, the greater the torque transfer.

As road speed builds up, the turbine speed approaches that of the pump. Vortex flow is slowed down and the torque converter acts much like the fluid coupling. Figs. 14-22 and 14-23 illustrate the vortex flow during torque multiplication, and during the fluid coupling condition.

OTHER VARIATIONS

Some converters use a pump, turbine and one stator. Others use a pump, turbine and two or more stators. Another type uses a pump, three turbines, a small inner stator and a larger outer stator. Some use two pumps. All are designed to facilitate torque transfer and multiplication. The pump, turbine and one stator design is in common use today.

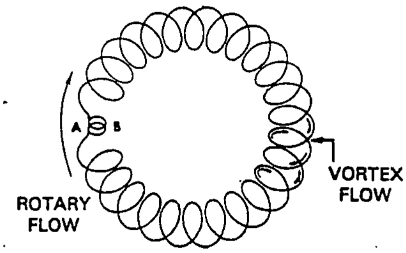


Fig. 14-22. Torque converter—vortex flow. Vortex flow is very rapid in torque converter. This is especially true at stall. (Chevrolet)

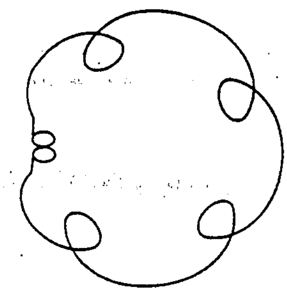


Fig. 14-23. Vortex flow at coupling point. Vortex flow has almost stopped when coupling point is reached. Coupling point is when pump and turbine are traveling at same speed and torque multiplication is no longer possible. (Chevrolet)

TORQUE CONVERTER IN ACTION

When the car is standing still with the transmission in DRIVE range and engine idling, there is very little transfer of torque from pump to turbine.

AT STALL

As the engine is accelerated, pump speed rapidly increases. Oil is thrown into the turbine with increasing force, A, Fig. 14-24. Leaving the turbine, the oil strikes the stator, B, Fig. 14-24. As the stator is forced backward by the oil, the one-way clutch will lock it up. The oil is then diverted, and enters the whirling pump, C, Fig. 14-24. As this vortex flow increases in speed, more and more torque is applied to the turbine. Fig. 14-24.

The maximum torque multiplication is delivered when the pump has reached its highest velocity, and the turbine is at stall (standing still). This condition is shown in Fig. 14-25. Notice that this converter uses two stators. Both are in operation.

INCREASING SPEED

As the turbine begins to turn, torque multiplication tapers off. When turbine speed increases, the oil leaving the trailing edges of the turbine will change its angle so it begins to strike the rear face of the primary stator.

This change of angle is caused by the fact that even though the oil is being thrown toward the stator, the turbine is moving by the stator faster than the oil is moving toward the stator.

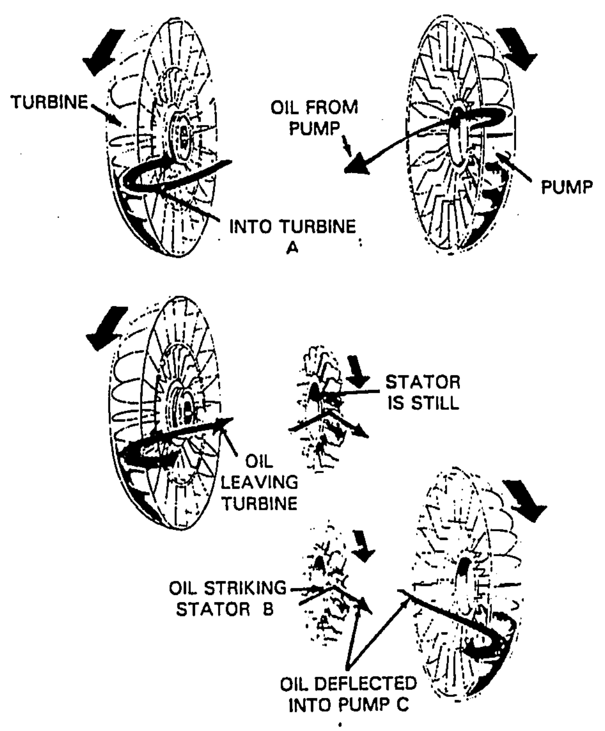


Fig. 14-24. Oil travel path. Oil is thrown from pump into turbine at A. Oil leaving turbine strikes stator at B, and is deflected into pump at proper angle, and with initial velocity at C. (Pontiac)

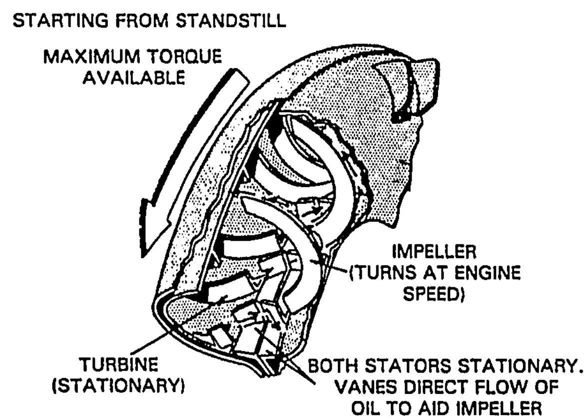


Fig. 14-25. Torque converter—at stall. Stall condition, as illustrated, will provide maximum amount of torque multiplication. Turbine and both stators are stopped and pump is spinning very fast. (Plymouth)

If you parked your car (turbine) alongside a target (stator), you could throw a rock (oil) backward and strike the target (stator blade). Say that you threw the rock at 50 mph, it would strike the target (stator blade) on the front face at 50 mph.

Then, if you drove the car (turbine) past the target (stator blade) at 100 mph and threw a rock, instead of striking the target, the rock would actually travel away from the target at about 50 mph. If there was a row of targets (stator blades), instead of striking the front face of the one you aimed at, the rock would actually strike the rear face of one of the other targets.

A similar action takes place with the turbine oil. As the turbine rotary speed surpasses the vortex velocity, the oil strikes the back of the stator blades causing the stator to start freewheeling. This causes the primary stator sprag clutch to uncouple, and the primary stator will freewheel with the turbine. As the secondary stator angles still deflect the oil, it remains stationary. Fig. 14-26.

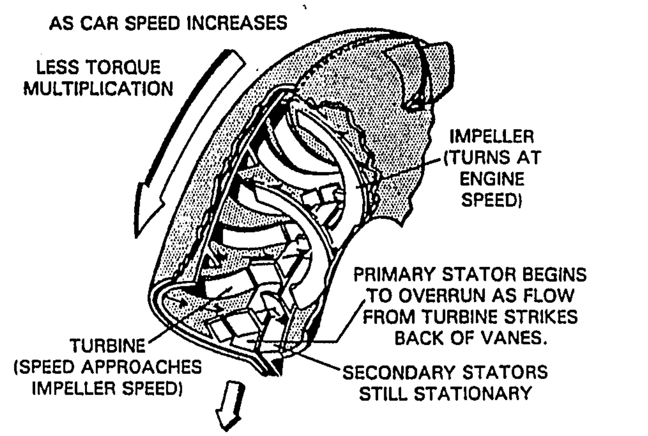


Fig. 14-26. Torque converter—increasing car speed. Turbine is starting to approach pump or impeller speed. One stator is freewheeling and other is still stopped and is deflecting oil into pump. (Plymouth)

CRUISING SPEED

As car speed reaches the cruising range, the turbine speed approaches that of the pump.

The angle of oil discharge from the turbine causes the oil stream to strike the back of both primary and secondary stators. Both stators are now freewheeling and there is no torque multiplication.

Vortex flow is slow and the converter is performing much like a fluid coupling. This condition is known as the COUPLING POINT. Fig. 14-27.

TORQUE MULTIPLICATION CURVE

The ratio between torque multiplication with the turbine at STALL and the COUPLING POINT is illustrated in Fig. 14-28. Notice how torque multiplication drops off as turbine speed increases.

INFINITE GEAR RATIOS

The torque converter provides an infinite number of ratios as opposed to the standard transmission's three or four ratios. This provides a smooth flow of power that automatically adjusts to varying load conditions, within limit of unit. See Fig. 14-29.

PLANETARY GEARSETS

As you learned in the overdrive section, a planetary gearset can be used to step up the speed of the output

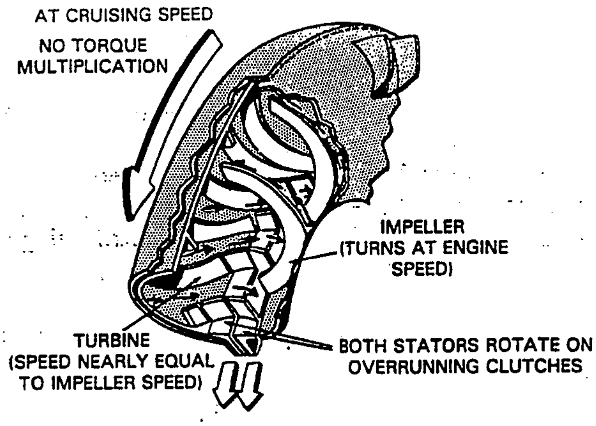


Fig. 14-27. Torque converter—cruising speed. Pump and turbine are turning at about same speed and both stators are freewheeling. Vortex flow is almost nil. This is referred to as coupling point. (Plymouth)

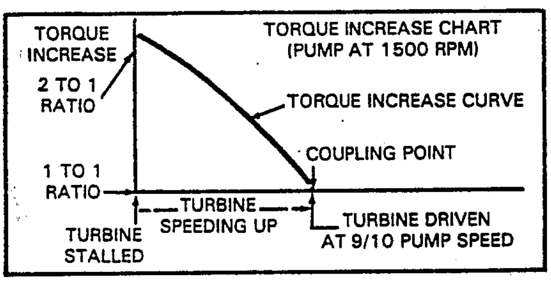


Fig. 14-28. Torque curve chart. (Mercury)

shaft to reduce torque. The planetary gearset can also be used to reduce output speed, thereby increasing torque. The gearset can transmit motion at the same torque, and can be used to reverse torque. The automatic transmission makes full use of these features of the planetary gearset.

The planetary gearset is compact. Its gears are in constant mesh. It is quiet and strong. Fig. 14-30 illustrates a typical planetary gearset. Learn the names of all parts.

TORQUE INCREASE—LARGE

If the planetary gearset internal gear is held, and power is applied to the sun gear, the planet pinions are forced to turn and walk around the internal gear. This action causes the pinion carrier to revolve at a lower speed than the sun gear. Torque increase is large. Fig. 14-31.

TORQUE INCREASE—SMALL

If the sun gear is held, and the internal gear is driven, the planet pinions must walk around the sun gear. This causes the pinion carrier to move slower than the internal gear, and torque will increase. See Fig. 14-32.

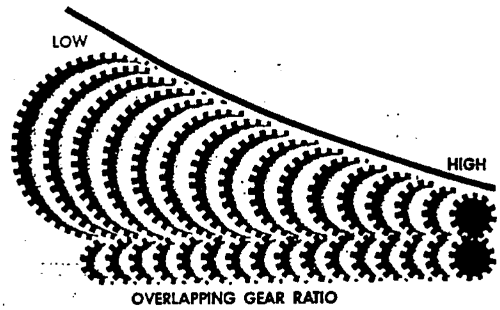


Fig. 14-29. Torque converter provides an extensive number of possible gear ratios. (Chevrolet)

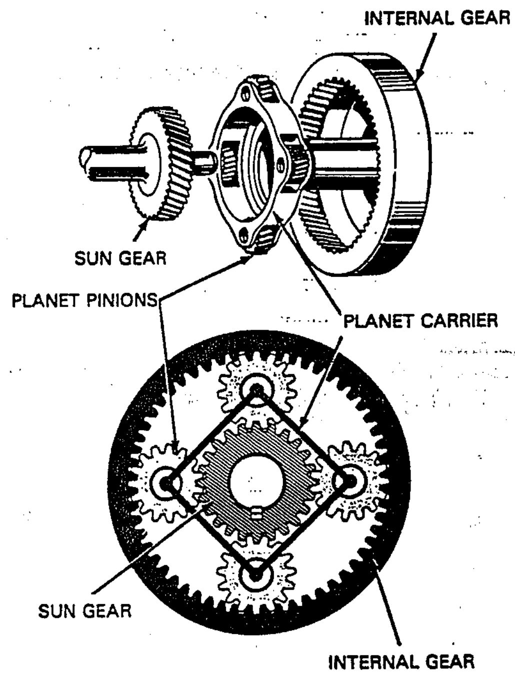


Fig. 14-30. Typical planetary gearset. (Cadillac)

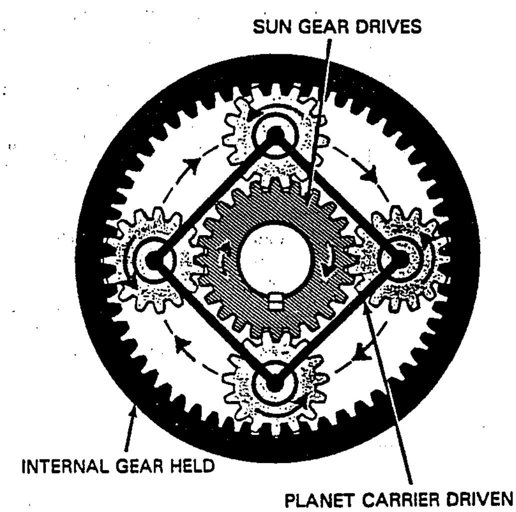


Fig. 14-31. Planetary gearset in large torque increase. (Cadillac)

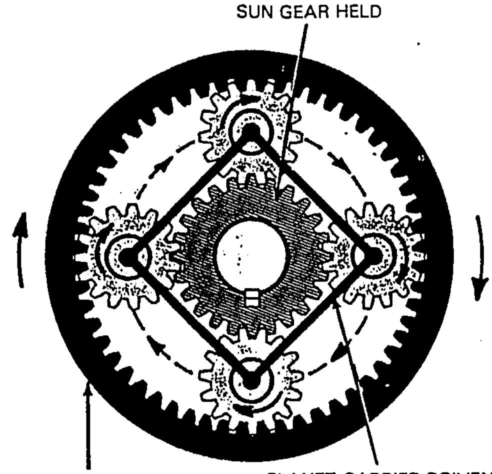


Fig. 14-32. Planetary gearset in small torque increase. (Cadillac)

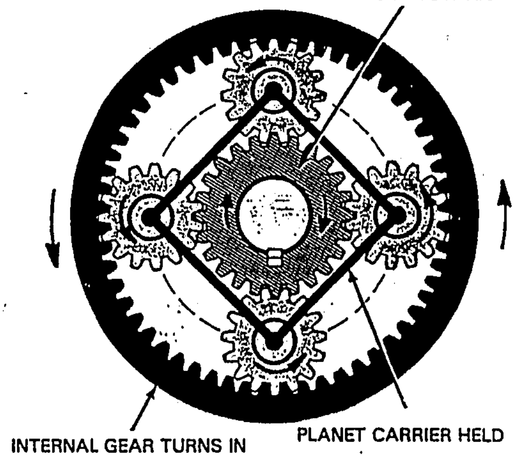


Fig. 14-34. Planetary gearset in reverse. (Cadillac)

TORQUE TRANSMISSION—CONSTANT

When any two members of the gearset are locked together, planetary action is stopped. Under these conditions, the gearset will revolve as a solid unit, providing a means of torque transmission with no increase or decrease. Fig. 14-33.

TORQUE TRANSMISSION—REVERSE

By holding the planet carrier and driving the sun gear, the planet pinions are forced to rotate about their pins. This causes them to drive the internal gear in a reverse direction at a reduced speed. Fig. 14-34.

USE OF THE PLANETARY GEARSET IN A TYPICAL AUTOMATIC TRANSMISSION

Detail 1, Fig. 14-35, shows the start of a planetary gearset as used in a two-speed transmission. Notice that the primary sun gear and shaft are one piece, and they are splined to the converter turbine. The arrow indicates the constant direction of rotation for the sun gear and shaft.

In detail 2, Fig. 14-35, the output shaft, planet carrier (one piece), one long and one short pinion have been added. The long and short pinions always rotate in the direction of the arrows. The long pinions are in constant mesh with both the sun gear and the short pinions. At this point, drive is not yet possible.

Detail 3, Fig. 14-35 illustrates the addition of a forward sun gear and flange. The integral flange and forward sun gear are free to turn independently of the primary sun gear and shaft. The forward sun gear is in constant mesh with the short pinions.

A brake drum has been placed on the forward sun gear flange, and a brake band surrounds the drum. If the band were applied (squeezed against the drum), the drum would be stopped. This would stop the forward sun gear. As the shaft turns the primary sun gear, it drives the long pinions counterclockwise. The long pinions turn the short pinions clockwise. The short pinions then walk around the stationary forward sun gear, turning the pinion carrier and output shaft at a ratio of 1:75 to 1 in this transmission.

BRAKE BANDS

A brake band is a steel band that encircles the drum. It is usually faced with a bonded friction lining. One end of the band is secured. The other end is fastened to a servo actuating rod. When the band is tightened, it will stop the drum.

SERVO OPERATES BAND

A hydraulic piston called a SERVO is used to apply the band. It consists of a cylinder in which is placed a piston. An opening is provided at one end to admit oil. The piston is held in the released position by a spring pressing against the piston.

When oil, under pressure, is admitted to the cylinder, the piston is forced forward, either ac-

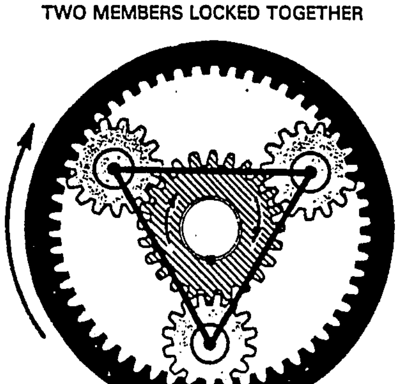


Fig. 14-33. Planetary gearset in direct drive. (Cadillac)

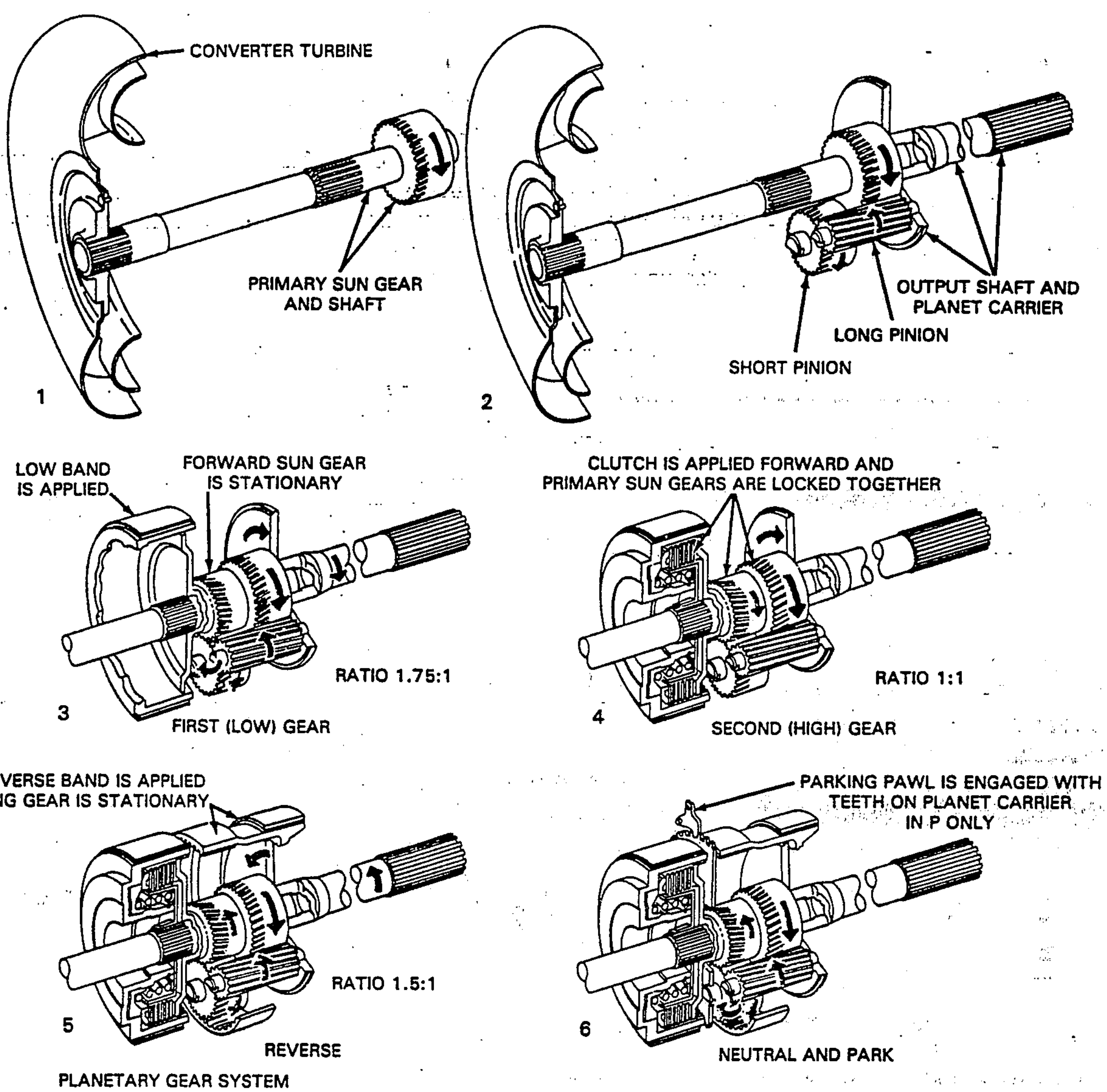


Fig. 14-35. Step-by-step construction of two-speed automatic transmission gearset. (Ford)

tuating the band through direct contact or by actuating linkage. When the oil pressure is reduced, the spring will return the piston and the band will release.

Some servos have openings on both sides of the piston. In this case, oil can be used to assist in servo release. Other servos have two pistons.

Fig. 14-36 is a schematic drawing of a typical servo. This unit acts directly on the band through a piston rod or stem.

The servo in Fig. 14-37 is of the direct acting type. Note the band adjusting screw and how the piston may be applied and released by oil pressure.

ACCUMULATOR PISTON

Often an accumulator piston is used to assist the servo in engaging the band quickly and smoothly. Fig. 14-38 illustrates one type. Note use of lever and strut design.

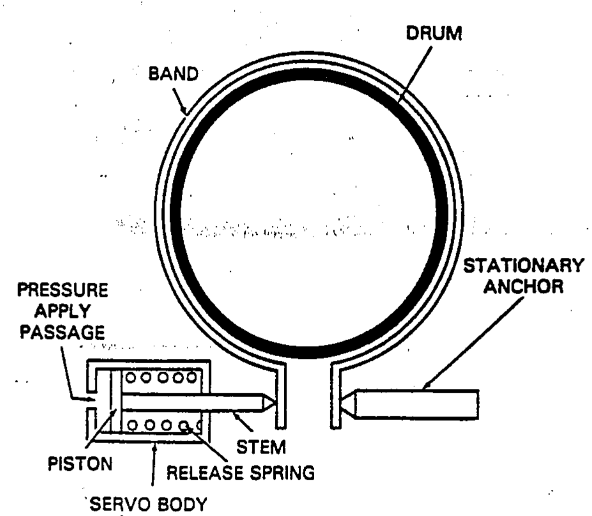


Fig. 14-36. Schematic of one type of band servo. (Cadillac)

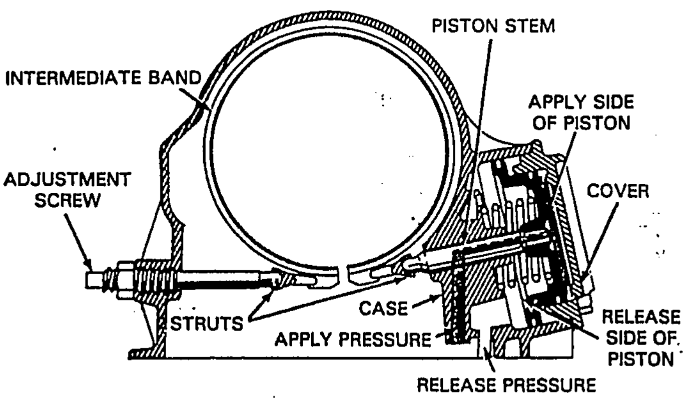


Fig. 14-37. Direct acting servo. Note that oil pressure may be applied to either side of piston, causing it to move in direction desired. (Ford)

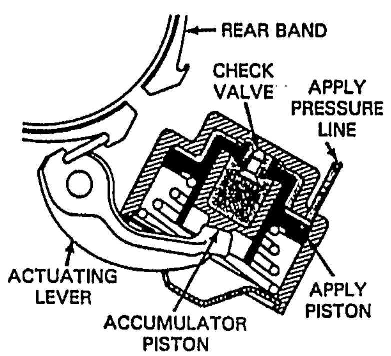


Fig. 14-38. One type of accumulator piston.

Oil entering the cylinder presses on the large apply piston. As the apply piston is held back by a spring, oil enters a small check valve and pushes on the accumulator piston.

Being small in diameter, the accumulator piston is not held back by a spring. It moves outward against the actuating lever rapidly but with light pressure. After the actuating lever has started to engage the band, it takes additional pressure to provide further band application. The large apply piston will move forward. Its pressure is added to that of the accumulator and the band is applied firmly.

The accumulator piston gives a fast, soft application that is immediately followed by additional heavy pressure for firm engagement. Not all servos use the accumulator piston.

Oil pressure and its control will be covered later in this chapter.

CLUTCH

Detail 4, Fig. 14-35, shows the addition of a multiple disc clutch. The clutch hub is splined to the primary sun gear shaft. A stack of clutch discs (the number varies) is arranged in alternate fashion. The driving discs are splined to the clutch hub; the driven discs are splined to the clutch drum.

A piston in the clutch drum squeezes the plates together when oil pressure from the transmission is applied to the piston. A heavy spring releases the discs when oil pressure drops.

When the clutch is applied, the discs are pressed together to lock the clutch hub and drum together. The clutch hub is splined to the primary sun gear shaft, and the drum is part of the forward sun gear. With the clutch applied, both primary and forward sun gears will be locked together. This stops all gear action and the parts revolve as a solid unit. The transmission is in direct or high gear. A typical clutch is shown in Figs. 14-39, 14-40, and 14-41.

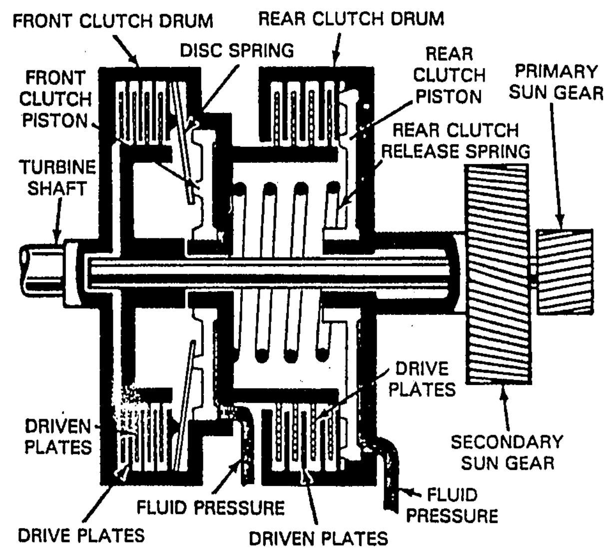


Fig. 14-39. Pair of multiple disc clutches. One is released by a coil spring, other is released by disc type spring. (Ford)

INTERNAL GEAR FOR REVERSE

Detail 5, Fig. 14-35, shows the addition of a ring or internal gear that is in constant mesh with the short pinions. An additional band and actuating servo are provided to either stop or release the internal gear. This is the reverse band and servo.

With low band and high gear clutch released, and reverse band applied, the internal gear will be held. This causes the short pinions to walk around, pulling the pinion carrier with them and imparting reverse motion to the output shaft.

NEUTRAL AND PARK

Detail 6, Fig. 14-35, illustrates the transmission in neutral and park. Notice the parking pawl that engages teeth on the planet carrier. This locks the output shaft, and prevents the car from rolling when parked.

The use of a torque converter makes it possible to have only two forward ratios, direct and low. Common practice, however, favors the use of three or four

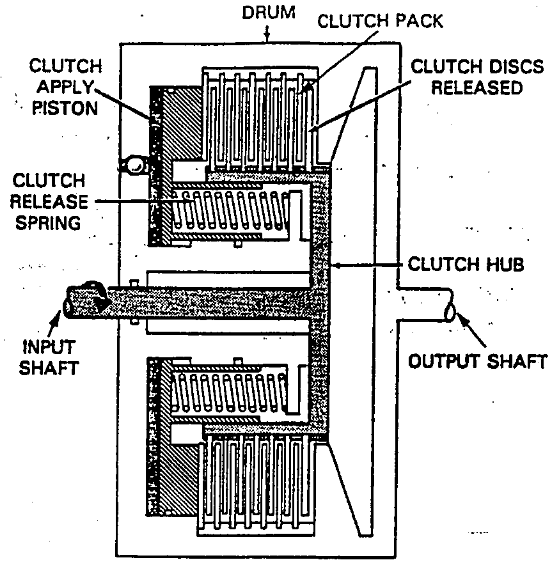


Fig. 14-40. Multiple disc clutch schematic. Note that hydraulic pressure is not acting on the clutch apply piston. With no oil pressure, clutch release springs separate clutch discs. Clutch hub turns but cannot drive output shaft—drum assembly. (GM)

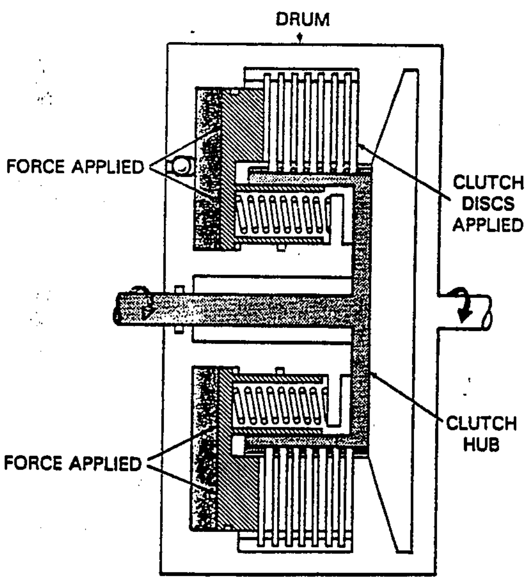


Fig. 14-41. Multiple disc clutch. Oil pressure is now acting against clutch apply piston. Piston overcomes spring pressure and squeezes clutch discs and plates tightly together. In that some discs are attached to drum output shaft assembly and others to hub (in an alternating arrangement), squeezing action locks hub and drum together. Hub now turns output shaft. (GM)

forward ratios or ranges. This provides better mileage and performance. Study the illustration in Fig. 14-35 until you have learned the action in each gear.

PRINCIPLES ARE THE SAME

There have been numerous types of automatic transmissions. Some utilize a fluid coupling, others have torque converters. Designs encompass two, three, and four speed ranges. Even through construction and design have varied, and still does, the general operating principles are much the same. Each automatic transmission uses a torque converter, or fluid coupling, to transmit torque to one or more planetary gearsets. These gearsets are controlled by servos and clutches that are actuated by oil pressure. The pressure is controlled by various devices.

CONTROL SYSTEM

For purposes of illustration, you will now "build" a simple control system for a two-speed automatic transmission.

OIL PUMP

There have been several types of pumps used in automatic transmissions. One is the variable output, VANE type. Output is altered by moving the outer vane cylinder. Fig. 14-42.

Another, in current use, is the ROTOR pump. Study the exploded view in Fig. 14-43.

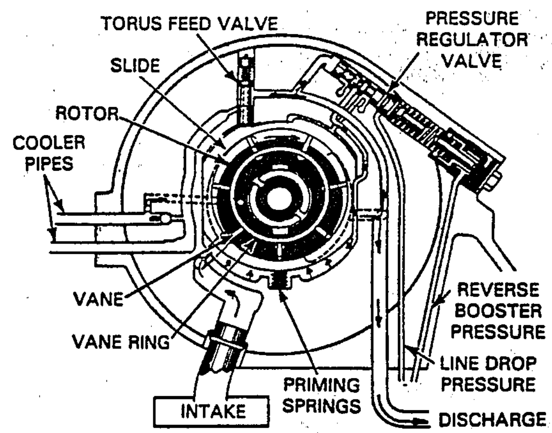


Fig. 14-42. Variable output vane oil pump. Pump is shown in position that will produce maximum output. Note that slide is up. (Pontiac)

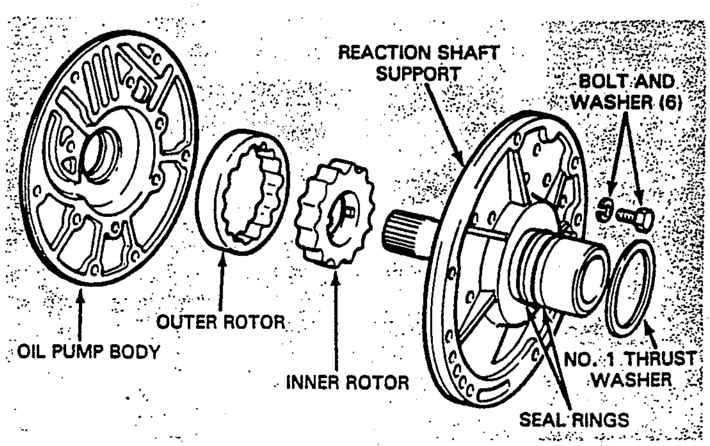


Fig. 14-43. A rotor oil pump. (AMC)

Still another widely used pump is the "internal-external" GEAR pump. Look at Fig. 14-44.

The start of your oil actuating and control system will be the gear oil pump drawing oil from the transmission oil sump or pan. The pressure output of the pump is controlled by a pressure regulator valve. When pressure exceeds the amount required, the valve opens and bypasses oil back to the sump. This produces constantly regulated main line pressure. See Fig. 14-45.

MANUAL CONTROL VALVE

The next addition is a manually operated control valve that will allow the driver to cut off, or open, the main line pressure. Fig. 14-46.

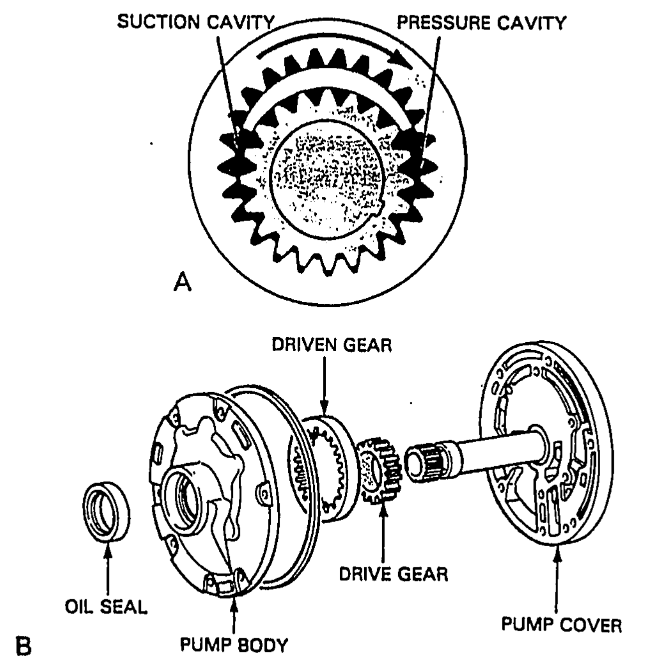


Fig. 14-44. A—Note action in transmission internal-external gear oil pump. B—Exploded view of gear type oil pump. (Toyota)

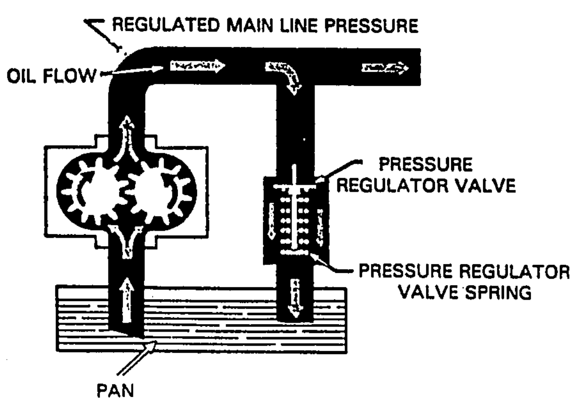


Fig. 14-45. Gear oil pump and pressure regulator. (GMC)

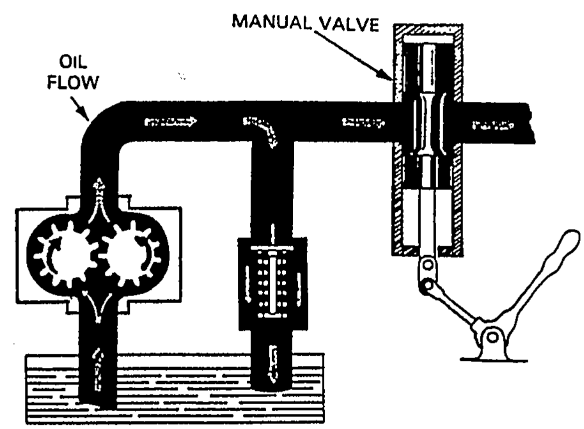


Fig. 14-46. Manual control valve. Valve is shown in open position.

LOW RANGE

From the manual control valve, the main line will go to the low range band servo. To place the car in the low range, the driver merely opens the manual valve via linkage. As the engine turns the input shaft, the oil pump will build up pressure. The oil pressure will travel to the servo and tighten the band. When the car is accelerated, torque will be imparted and the car will move forward in the LOW range. Fig. 14-47.

HIGH RANGE

Another line must be added. This will run from the main line to a shifter valve. It will leave the shifter valve and branch out. One line will go to the high range clutch unit, another to the low range servo. In Fig. 14-48, you can see that the main line pressure has traveled to the shifter valve. The low range circuit is not shown.

HOW SHIFTER VALVE IS OPENED

GOVERNOR

You will note an opening on the right end of the shifter valve marked "oil passage from governor."

As the car moves forward in low range, the output shaft spins a governor unit. Oil pressure from the main line is piped to the governor unit, then to the shifter valve. When the car is not moving, the governor weight is in and oil pressure is stopped at the governor. Fig. 14-49.

As the car gathers road speed, the governor unit will spin faster and faster. At a predetermined speed, the governor valve will open and oil pressure will travel to the shifter valve. See A, Fig. 14-50. Note governor in B, Fig. 14-50.

When governor pressure reaches a certain level, the tension of the shifter spring will be overcome and the shifter valve will open. Fig. 14-51 shows the governor pressure building up against the shifter valve.

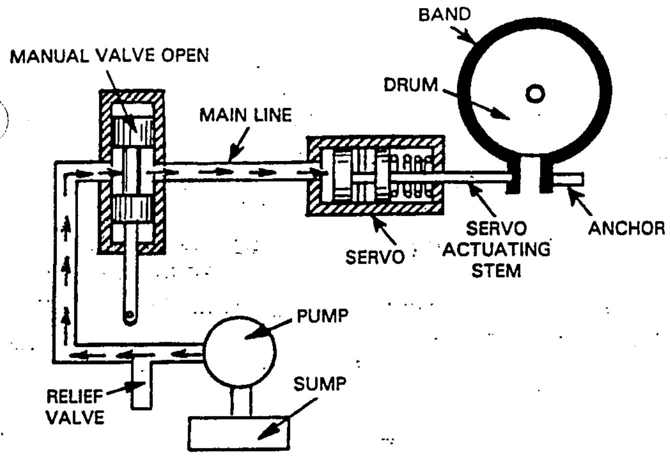


Fig. 14-47. Low range. When manual valve is opened, oil under pressure from pump travels via main line to servo. Oil will press on servo piston, causing it to tighten band. Car is now in low range.

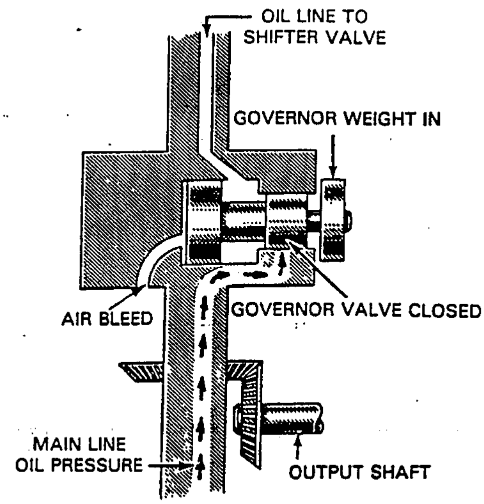


Fig. 14-49. Schematic of governor valve in closed position. Note that main line oil pressure cannot pass governor valve. (GMC)

SHIFT RANGE CHANGES

When the manual valve is opened, oil pressure actuates the low band servo. The car will then move forward in low range. Oil pressure also travels to the shifter valve and the governor. Fig. 14-52.

When the car reaches a predetermined road speed, the governor will have opened enough to allow oil pressure to flow to the shifter valve and force it open. When the shifter valve opens, oil pressure flows to the clutch and band servo units.

As the pressure builds up in the clutch, a corresponding pressure builds up in the servo. As the pressure from the shifter valve is working on two pistons of the servo, as opposed to the pressure from the manual valve working on one servo piston, the servo will be forced to move to the left and free the low band.

When the servo pistons stop moving to the left, the pressure in the clutch unit will build up rapidly, thus locking the clutch unit. The transmission is now in high range and will remain there until car speed falls below the shift point. When this happens, governor pressure is lost, clutch disengages and manual valve pressure reapplies low band servo. All this is done automatically. Fig. 14-53 shows the circuit in HIGH range.

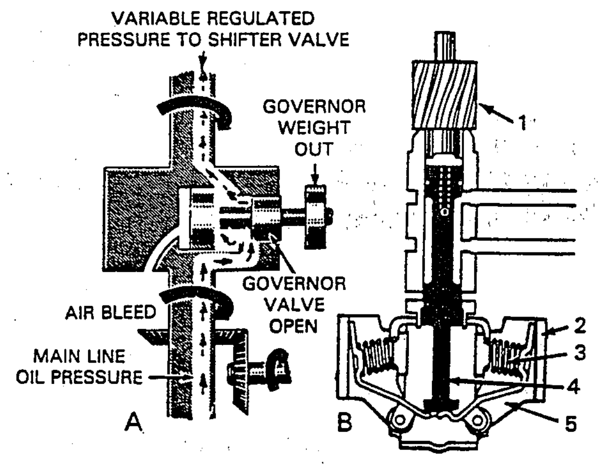


Fig. 14-50. A—Schematic of governor valve in open position. Note main line oil pressure is now passing through valve. B—Cross section of a different type of governor. 1—Driven gear. 2—Primary weight. 3—Spring. 4—Valve. 5—Secondary weight. (GMC)

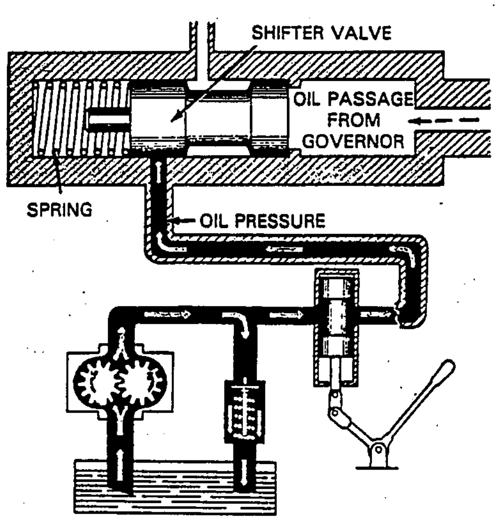


Fig. 14-48. Schematic of shifter valve. Valve is shown in closed position. (GMC)

SHIFT POINT SHOULD VARY

The point at which the transmission upshifts into high and downshifts into low range is controlled by the governor. These points are always constant.

It is very desirable to have the shift points vary according to load requirements. For rapid acceleration, the transmission should stay in low range longer.

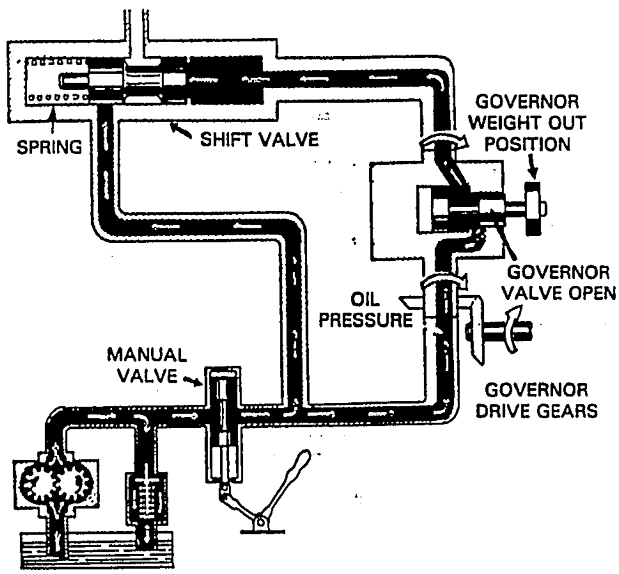


Fig. 14-51. Governor pressure acting on shifter valve. Governor weight has been thrown out by centrifugal force. Governor valve is open and main line pressure is passing through governor to shifter valve. (Lincoln)

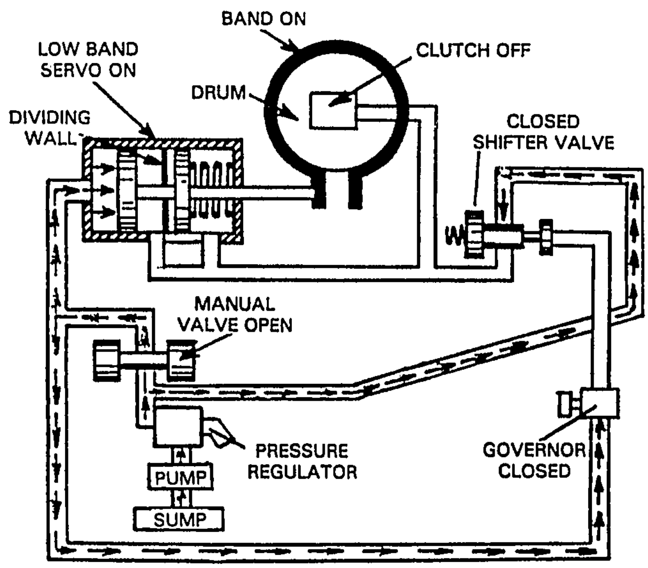


Fig. 14-52. Low range—schematic. Manual valve open. Pressure to low band servo. Pressure to governor. Pressure to shifter valve. Governor closed; no pressure to open shifter valve. Shifter valve closed; no pressure to offsides of low band servo or clutch.

When attempting to pass at low speeds just above the downshift point, it is desirable to have the downshift occur when needed.

DELAYING THE UPSHIFT

You will notice a spring in the shifter valve in Fig. 14-51. As mentioned, the spring tension is overcome by governor pressure at a certain road speed. By placing a regulator plug to the left of the spring, and then connecting linkage to the throttle, it is possible to vary the spring tension.

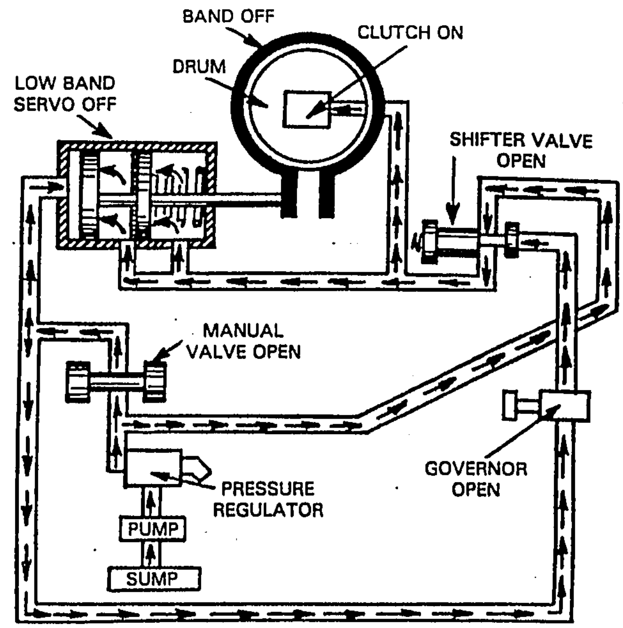


Fig. 14-53. High range—schematic. Road speed has opened governor. Governor pressure opens shifter valve. Main line pressure now flows through shifter valve to offside of both servo pistons and to clutch. Servo releases and clutch applies. Transmission is now in high range.

When the throttle is depressed, the regulator plug is forced against the spring, increasing its tension. The car must gain more road speed to boost governor pressure, to overcome shifter spring tension. This will delay the upshift from low to high range. Fig. 14-54.

THROTTLE VALVE

Instead of moving the regulator plug by mechanical means, a throttle valve is used. The throttle valve is connected to the foot throttle through linkage. This rod is often referred to as the TV (throttle valve) rod. When the throttle is depressed, the throttle valve is moved and transmits oil pressure to the regulator plug. The amount of pressure depends on the distance the throttle is moved.

The throttle valve is an application of the spool balanced valve. Pressure is admitted to the valve at A, Fig. 14-55. It travels around the small spool section and exits through B. It is bypassed to chamber C at the spool end D. The pressure pushes on the shifter valve regulator plug and on the spool at D, Fig. 14-55.

Spring pressure E is controlled by the TV rod. When the throttle opening is small, spring pressure E is light. Oil pressure at D forces the spool to the right against the light spring pressure.

As the spool moves to the right, it starts to block opening A. As opening A size is reduced, the oil pressure entering the valve is also reduced.

If the spring is pushing to the left with a pressure of 15 lbs., the spool will be forced to the right until the entrance A is small enough to admit oil at 15 lbs. pressure. The valve will then be balanced. If spring pressure is increased, it will force the spool to the left, increasing opening A and oil pressure will build up in C. This will force the spool to the right until opening A is again closed far enough to balance oil pressure with spring pressure.

FORCED DOWNSHIFT

Another valve (it can be part of the throttle valve) is provided to admit high main line pressure to the shifter valve. This valve is sometimes called the T valve.

When the driver depresses the accelerator almost to the floor, the throttle valve strikes a detent plug and

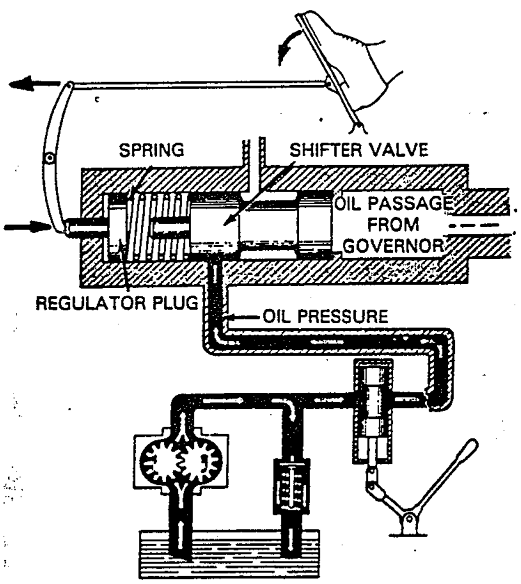


Fig. 14-54. Shifter valve regulator plug. Throttle pressure will change spring tension and cause shifter valve to open under various pressures. (GMC)

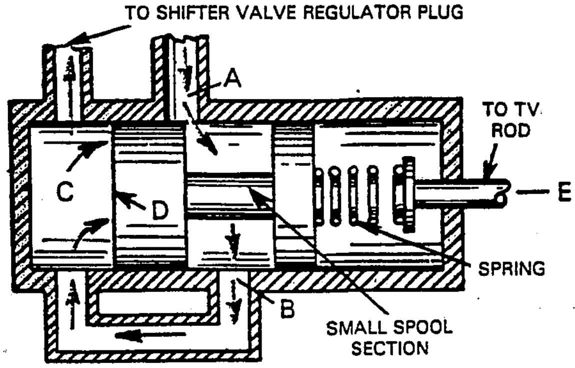


Fig. 14-55. Throttle valve. Oil pressure balances spring pressure by moving spool until opening A admits proper pressure. TV rod adjusts spring pressure.

spring. When the accelerator is pressed beyond this point, the TV rod forces the T valve open. This directs main line pressure to the off side of the shifter valve. The shifter valve will close, cutting off pressure to the clutch and off side of the band servo. Now the servo will be actuated by manual valve pressure, and the low range band will tighten. This places the car in low range before road speed is slow enough to cause sufficient drop in governor pressure. This is called a forced downshift. Fig. 14-56.

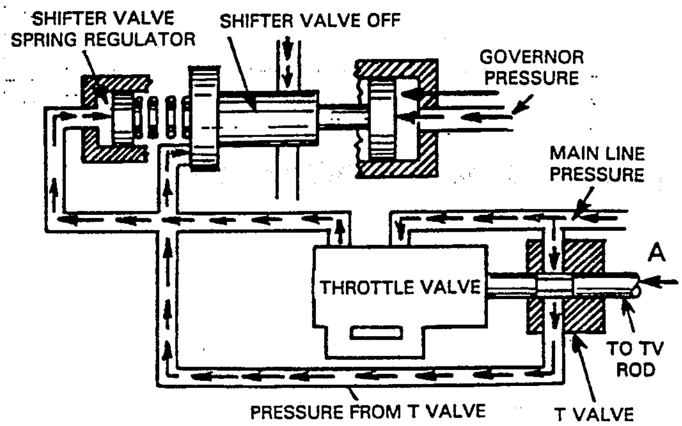


Fig. 14-56. Forced downshift. When TV rod forces throttle valve rod in at A, main line pressure passes through T valve to offside of shifter valve. This additional pressure overcomes governor pressure and shuts shifter valve. Transmission will now downshift.

VACUUM MODULATOR

Makers now use a vacuum modulator in preference to the TV rod. The modulator utilizes engine vacuum, a very reliable indicator of engine loading. Therefore, the modulator provides very accurate means of controlling the throttle valve (also called modulator valve).

The vacuum modulator consists of a container separated into two areas by a flexible diaphragm. A spring forces the diaphragm rod to apply pressure to the throttle valve to increase TV pressure. In operation, engine vacuum causes the diaphragm to move away (against spring pressure) from the throttle valve, lowering the pressure. As engine loading varies, vacuum fluctuates. So the modulator is constantly altering throttle valve pressure in accordance with engine vacuum. See A, Fig. 14-57.

An altitude sensitive modulator is illustrated in B, Fig. 14-57. It incorporates an evacuated (air removed) bellows. The collapsing bellows tends to force the diaphragm toward the throttle valve. At sea level, the collapsing force is highest, adding to diaphragm pressure and raising TV pressure. As altitude increases, the collapsing force lessens and TV pressure is decreased.

The altitude compensating bellows provides a more

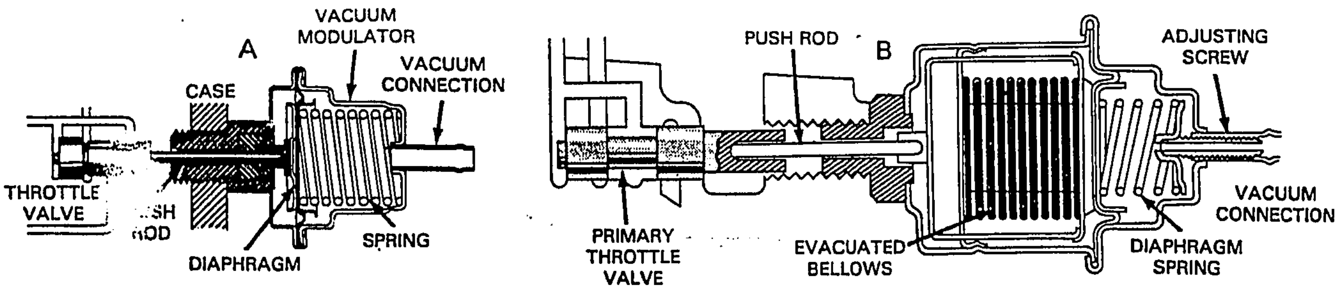


Fig. 14-57. A—Vacuum modulator controlling throttle valve by varying pressure on the push rod. B—Altitude sensitive modulator. Note evacuated bellows. (Ford)

uniform shift feel regardless of elevation. Look at B in Fig. 14-57.

COMPENSATOR VALVE

To add to the pressure on the band during heavy acceleration, a compensator valve is often used. This valve is controlled by foot throttle pressure on the throttle valve. During rapid acceleration (when torque is heavy), the compensator valve admits additional pressure to the band servo. Fig. 14-58.

COMPLETE CONTROL CIRCUIT

Fig. 14-59 shows the complete hydraulic system as used in one model of the Chrysler TorqueFlite, three-speed automatic transmission. Trace each circuit and study its construction and application. A similar transmission is illustrated in Fig. 14-60.

HYDRAULIC CONTROL CIRCUITS

The various oil circuits are extremely compact, and every possible means is used to avoid open tubing. Many of the shafts and other units are drilled to carry oil. Figs. 14-61 and 14-62. Most of the control valves are housed in one compact control valve body. An exploded view of the many components of a control valve body is shown in Fig. 14-63. Also, see Fig. 14-64.

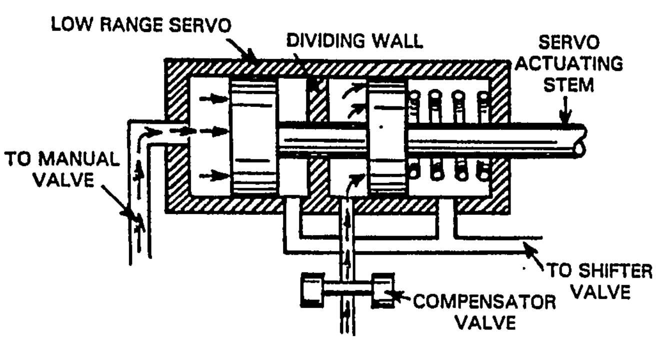


Fig. 14-58. Compensator valve. Heavy throttle pressure opens compensator valve, admitting additional pressure to operate servo. Compensator pressure acts on on side of second servo piston.

OIL COOLING

Transmission oil is generally cooled by circulating it, via tubes, to a unit housed in the lower radiator. In cross-flow radiators, the tubes are connected to the right or left hand side tank. Fig. 14-65.

LUBRICATION

The transmission is lubricated by special oil which circulates through the unit. Never use any oil but AUTOMATIC TRANSMISSION FLUID, TYPE "A", SUFFIX "A." The container will be marked AQ - ATF - (several numbers) - A. Some makers specify an exact fluid (such as Dexron II, Ford Type F, CJ Type, etc.) for their own transmission. ALWAYS FOLLOW THESE RECOMMENDATIONS!

SHIFTING

The transmission may be placed in any desired range by moving a gearshift lever, usually located on the steering column. This moves a selector lever on the transmission. The range indicator with a sliding arrow shows the operator which range is "in." See Fig. 14-66.

A console floor shift mechanism is shown in Fig. 14-67. A push-button shift control also has been used.

DIFFERENT TYPES OF AUTOMATIC TRANSMISSIONS

Automatic transmission design has grown quite sophisticated, resulting in a more compact, smoother acting and highly reliable unit.

The use of the straight fluid coupling, once popular, has been replaced with the more efficient torque converter.

Torque converters have used both multiple turbines and stators. Current practice uses the basic converter design consisting of one pump, one turbine and a single stator. The stator is generally of FIXED PITCH (angle cannot be changed) construction.

The transmission and torque converter, as used in some front wheel drive cars, are separated. The

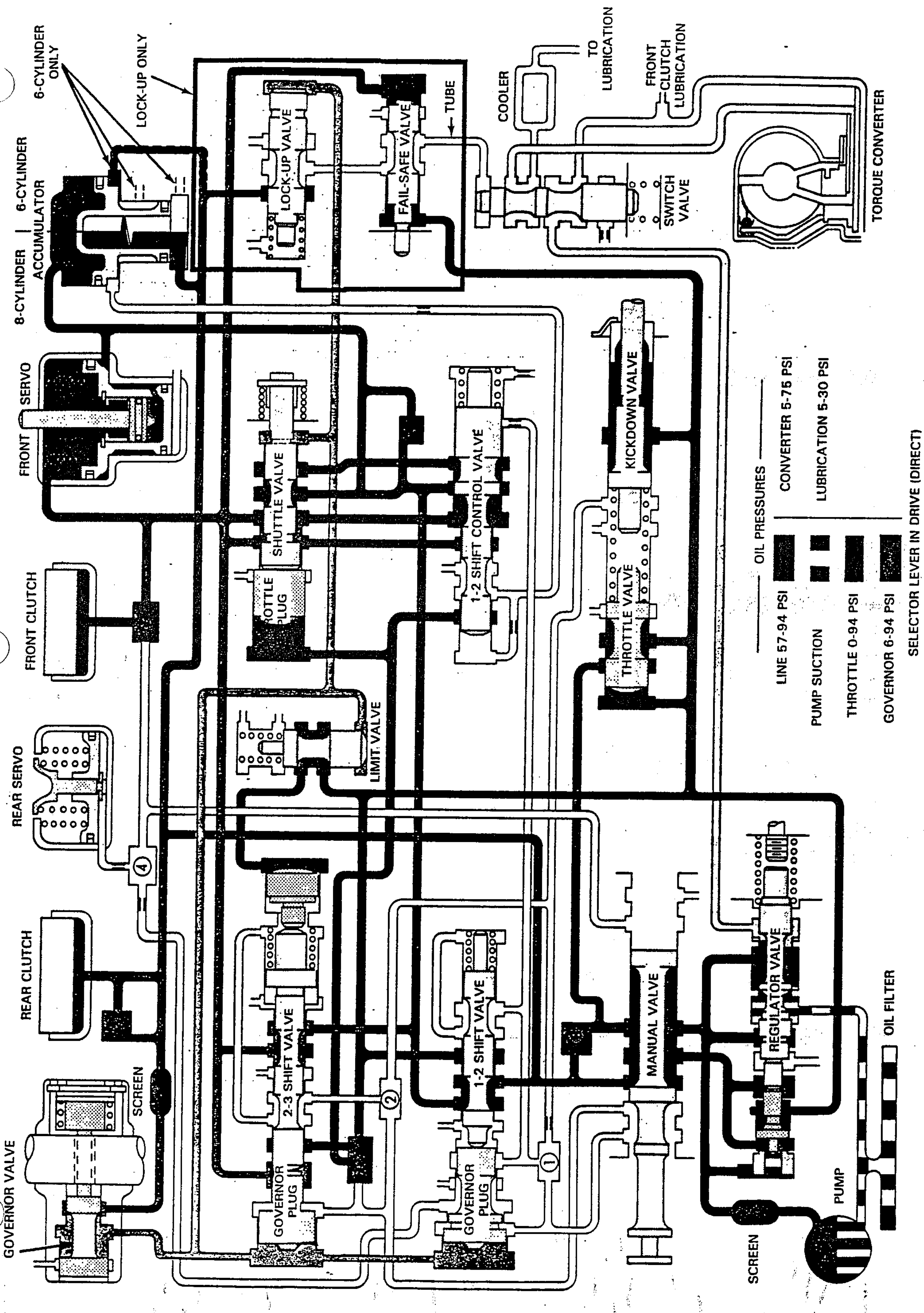


Fig. 14-59. Complete hydraulic control for a TorqueFlite, 3-speed transmission. (Chrysler)

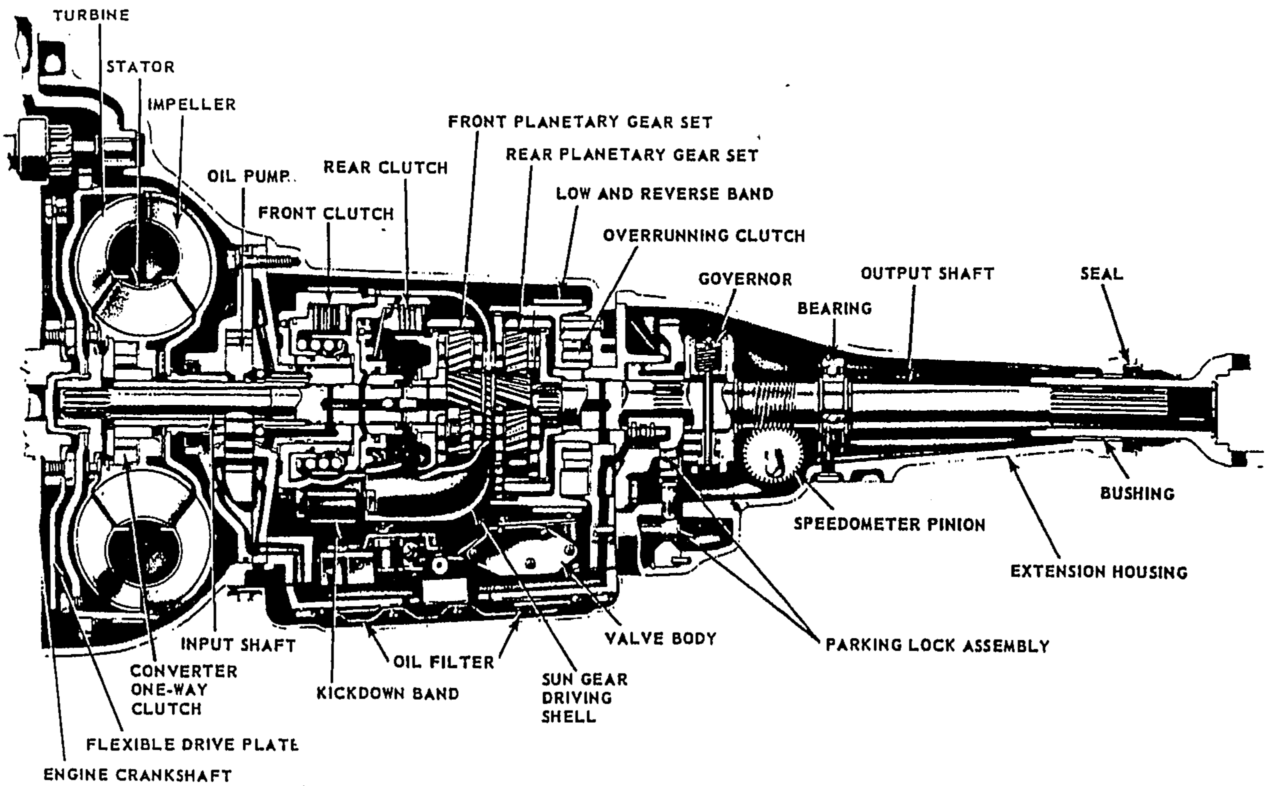


Fig. 14-60. Plymouth TorqueFlite, three-speed transmission. (Plymouth)

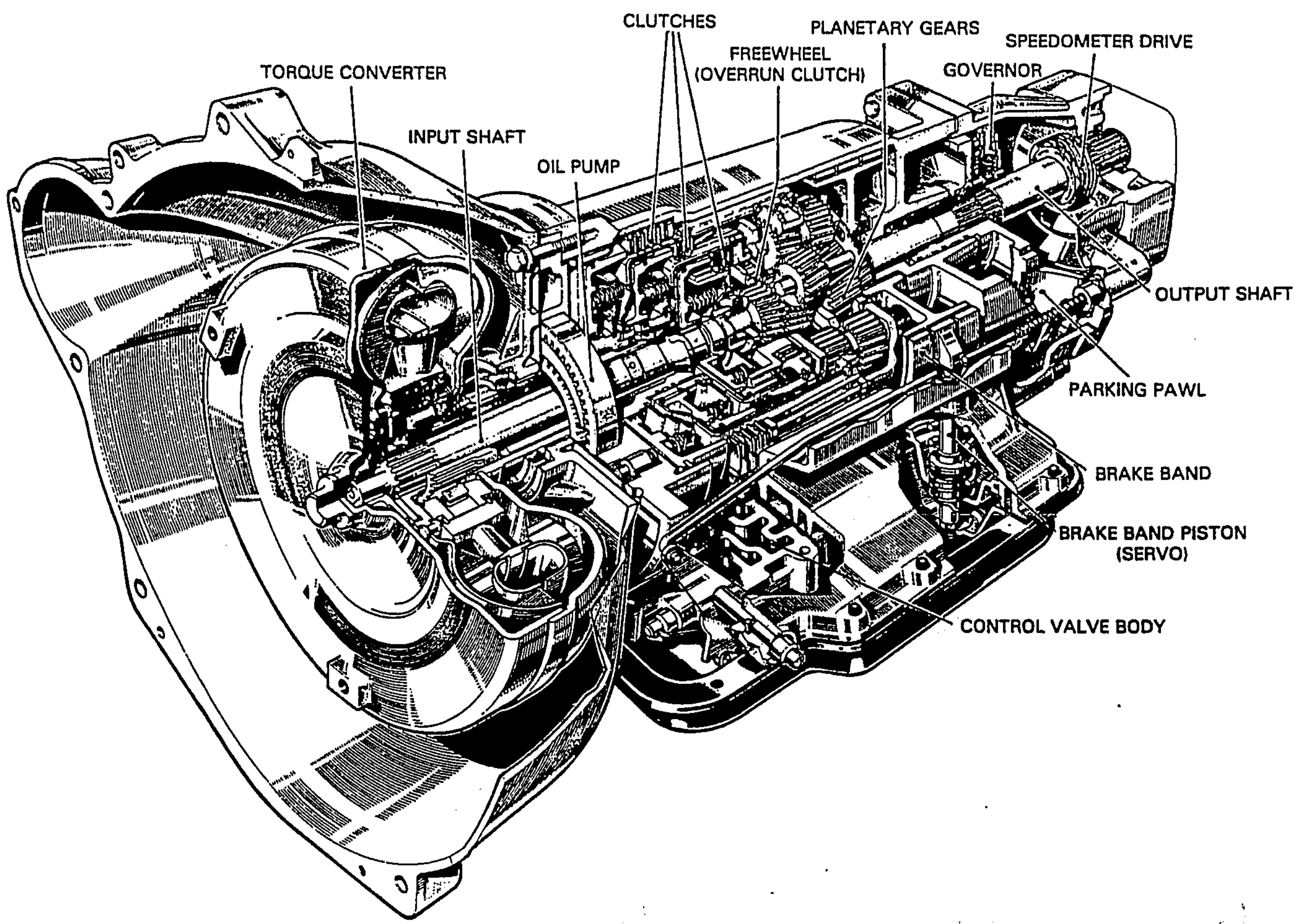


Fig. 14-61. Cutaway of a Peugeot 3-speed automatic transmission. Study part arrangement. (Peugeot)

torque converter drives the transmission via a link belt (chain) assembly.

Figs. 14-68, 14-69, 14-70, and 14-71, illustrate the clutch and band action in a two-speed transmission. Study the power flow in each range.

A cutaway view of a three-speed transmission is illustrated in Fig. 14-72.

A four-speed transmission is shown in Figs. 14-73, 14-74, and 14-75.

Fig. 14-76 illustrates the Ford "torque-splitter" transmission. Note its very unique design and see how many components you can identify.

Figs. 14-77 and 14-78 show cutaways of a three-speed transmission.

Another three-speed transmission design is illustrated in Fig. 14-79.

The clutch and band action of one three-speed transmission is shown in Fig. 14-80. Study the action and power flow in each range.

Figs. 14-81 and 14-82 feature front wheel drive transaxle setups.

Study all the transmission illustrations. Make certain you know the various part names and can explain their basic functions.

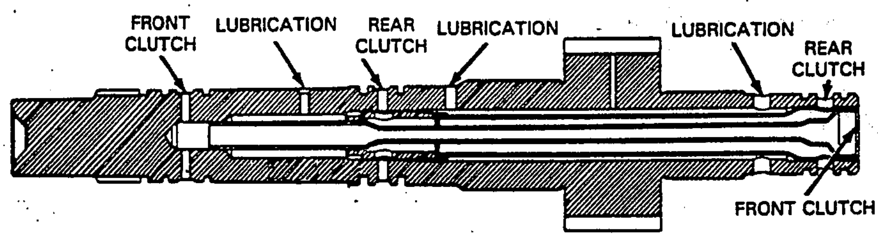


Fig. 14-62. Sun gear shaft showing drilled passageways. (Ford)

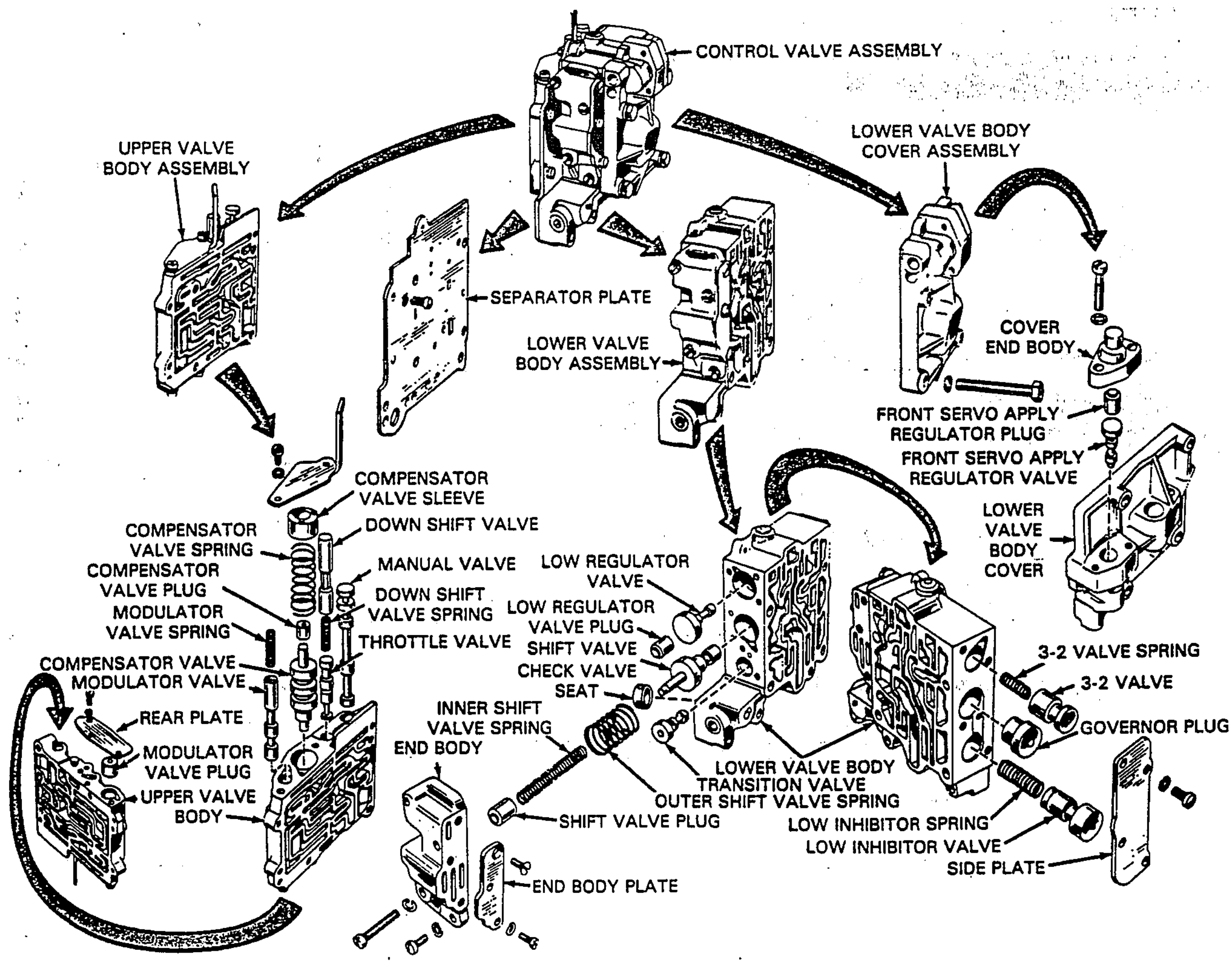


Fig. 14-63. Exploded view of control valve body. (Ford)

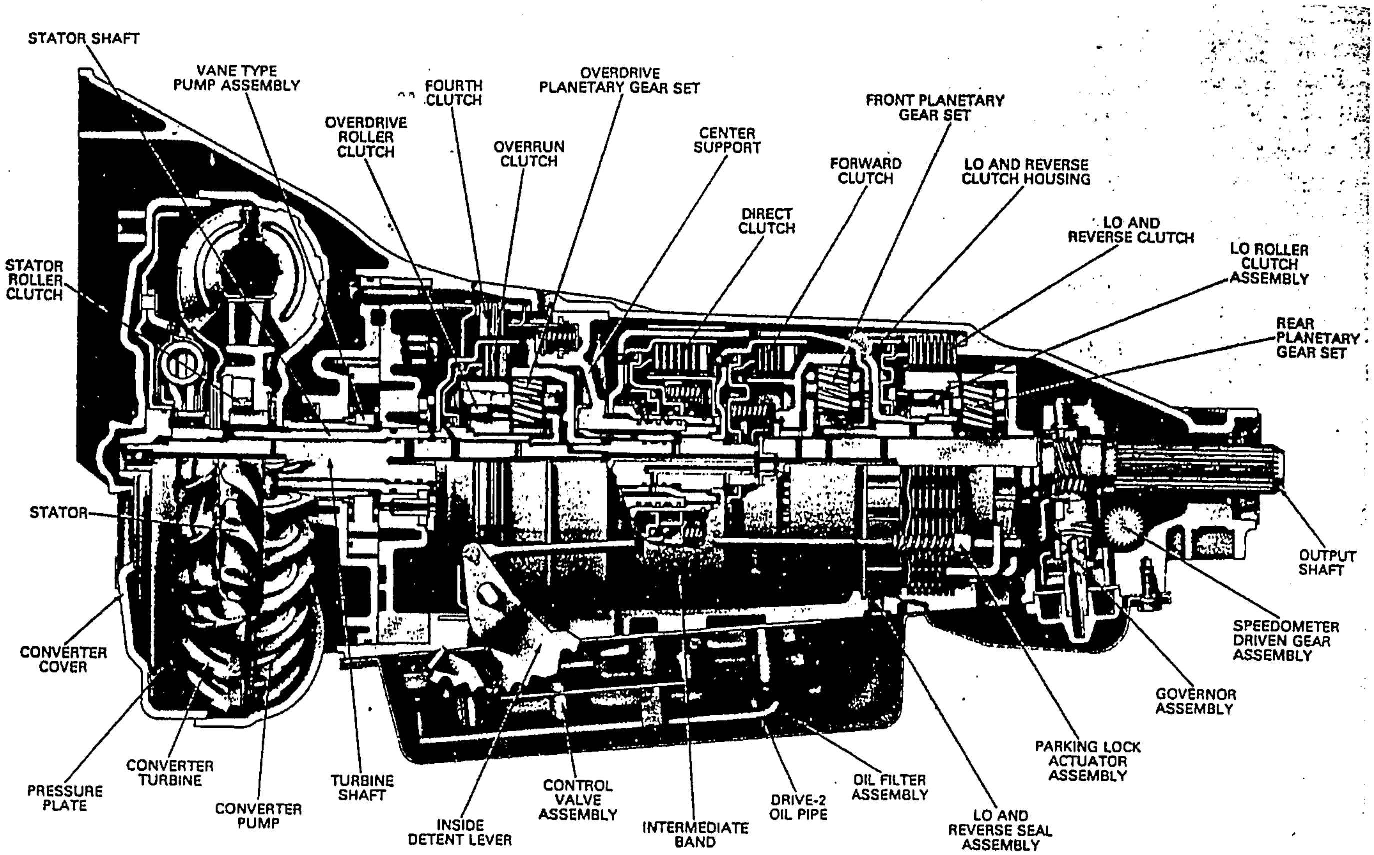


Fig. 14-64. A General Motors 200-4R automatic transmission. This four-speed unit provides an overdrive ratio in top range. It also utilizes a converter lockup clutch. (GM)

LOCKING CONVERTER

The normal converter allows some slippage, even at cruising speeds. This is due to the fact that the only connection between pump and turbine is the transmission fluid.

To prevent this slipping action, and thus improve fuel economy, a number of converters are equipped

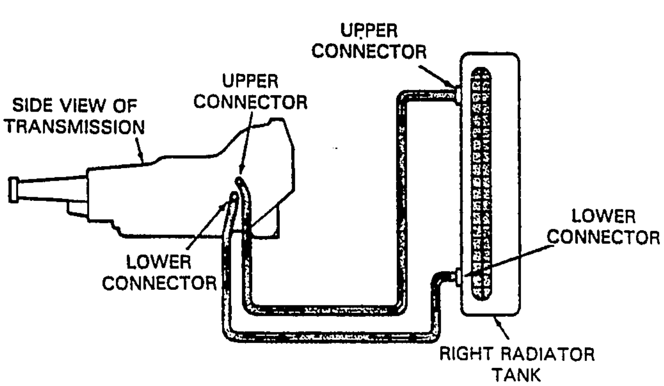


Fig. 14-65. Method of cooling transmission oil. This side view shows oil cooler located in right-side radiator tank. (Cadillac)

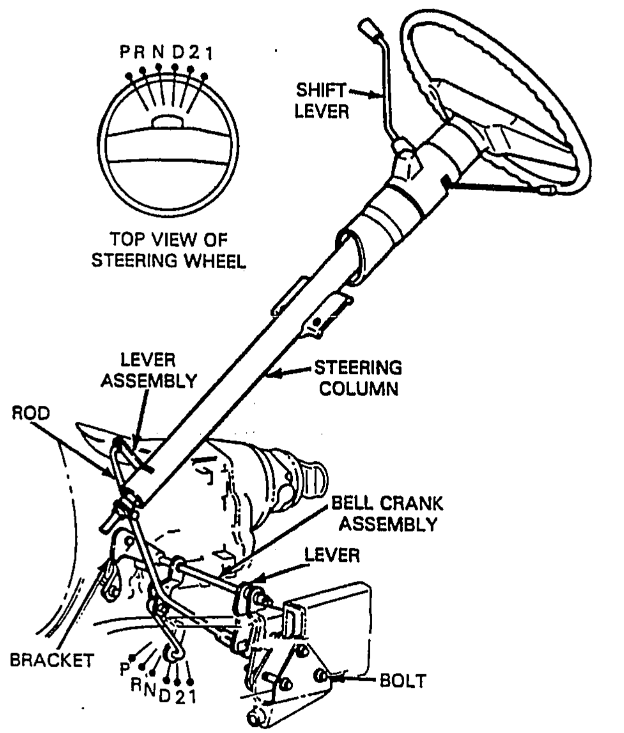


Fig. 14-66. Column gearshift linkage. (Ford)

with a lockup feature. When the lockup unit is activated, the pump (impeller) and turbine are mechanically locked together. To allow a lockup condition, most setups are arranged so that the transmission must be in high range, speed above around 35 to 40 mph (56–64 km/h) and in a cruise condition (no hill, acceleration, or other engine loading situation).

There are several lockup designs. A schematic of one type is pictured in Fig. 14-83. Study A carefully. Note part names.

LOCKUP OPERATION

Before lockup, the turbine and pump (impeller) are mechanically free of each other and drive is through

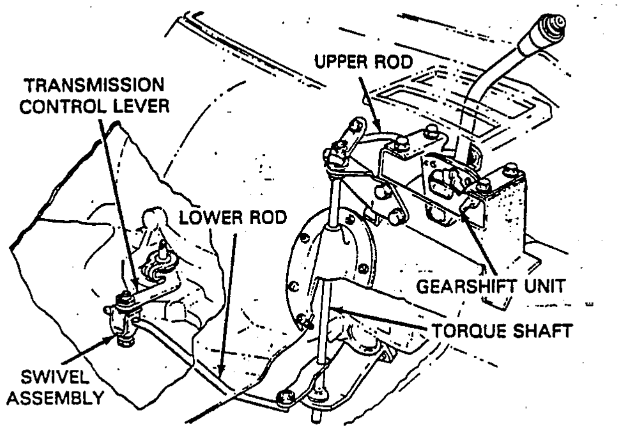


Fig. 14-67. A console (floor) gearshift linkage arrangement. (Plymouth)

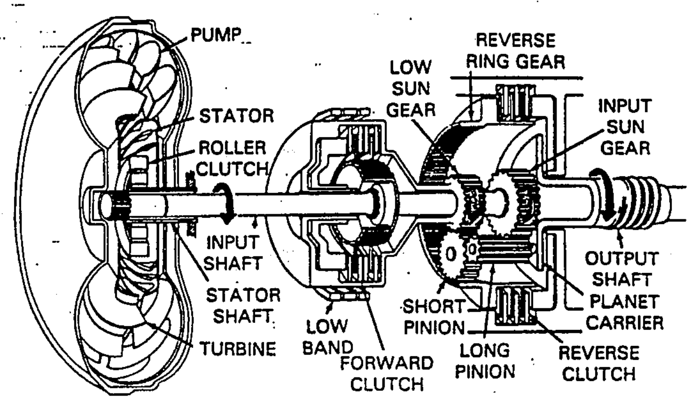


Fig. 14-70. Transmission in direct drive range. Forward clutch applied. Low band and reverse clutch released.

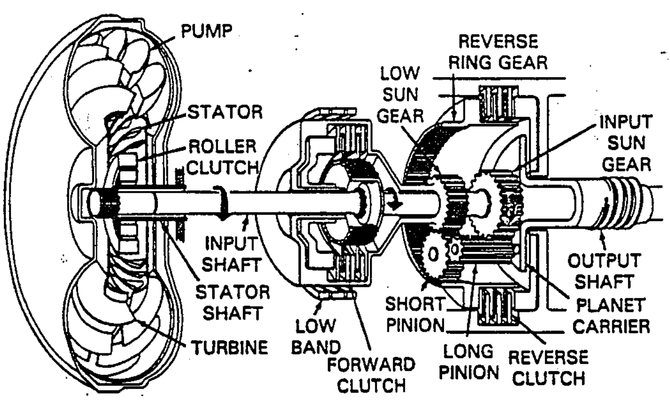


Fig. 14-68. Schematic illustrates Pontiac two-speed transmission action in neutral. Clutches and band are released.

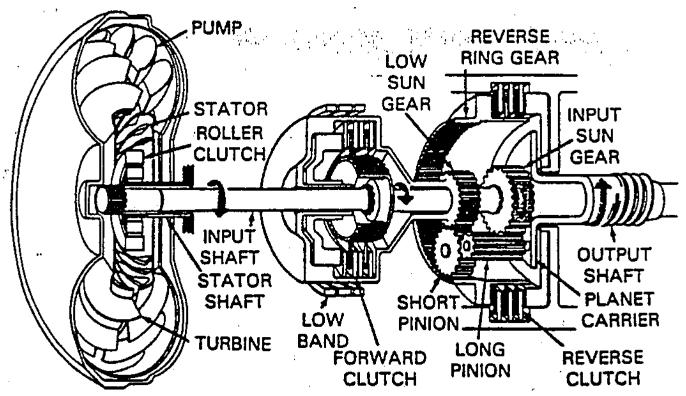


Fig. 14-71. Transmission in reverse. Reverse clutch applied. Low band and forward clutch released.

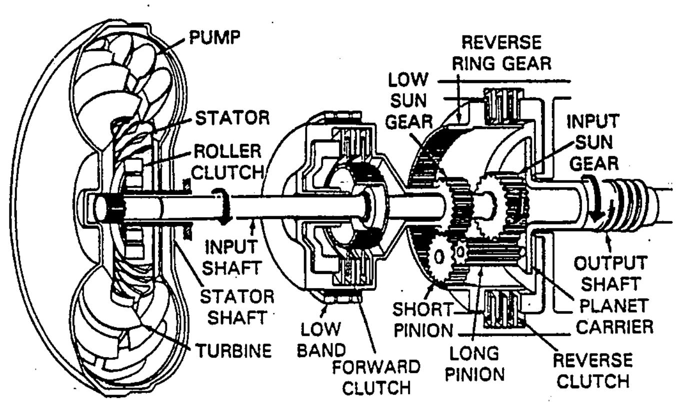


Fig. 14-69. Transmission in low range. Note power flow. Low band is applied while clutches are released.

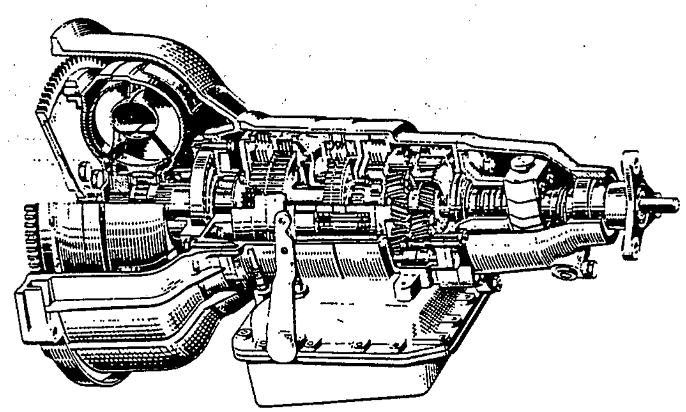
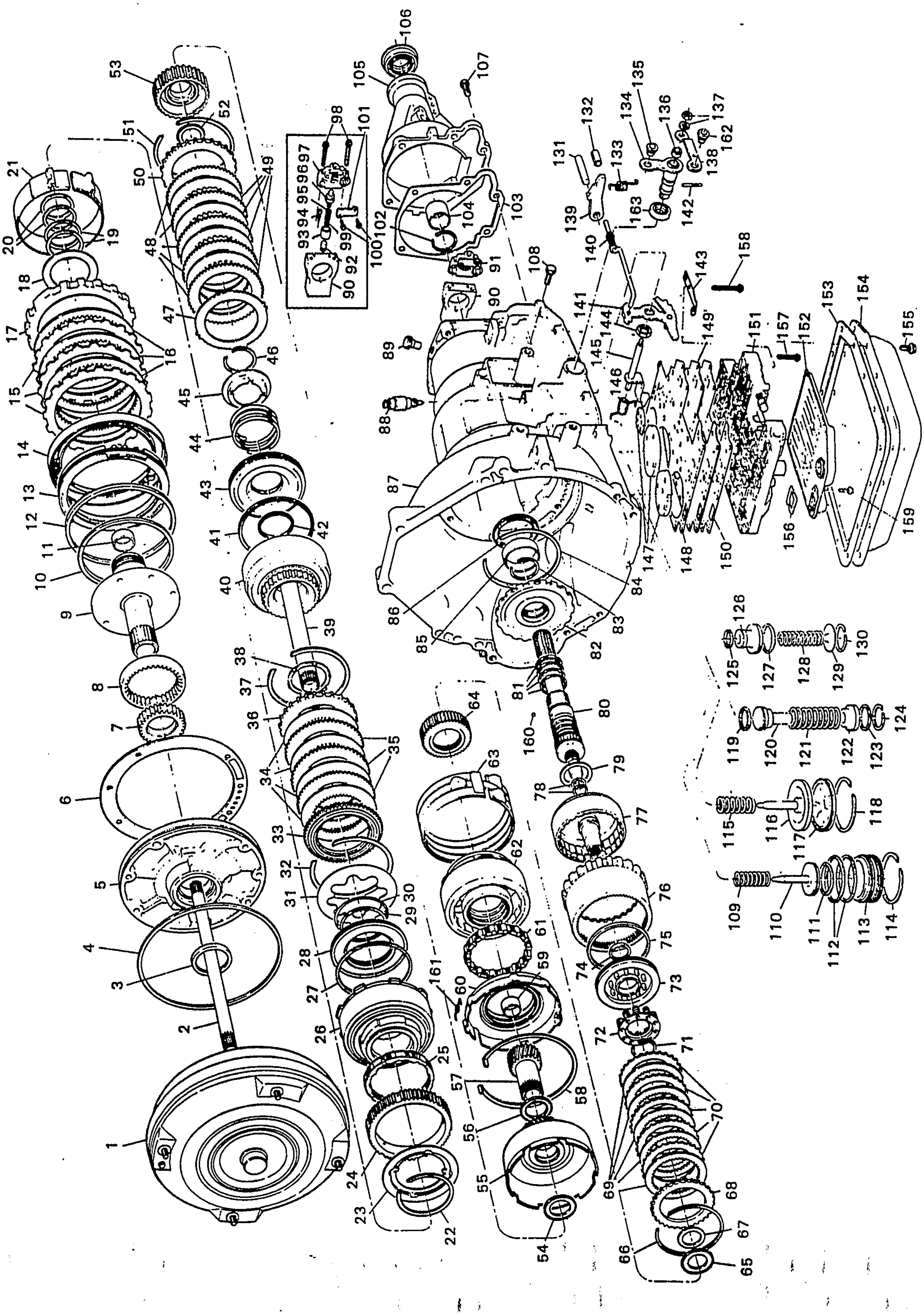


Fig. 14-72. Cutaway of an automatic transmission as used by BMW. How many parts can you identify? (BMW)



1. TORQUE CONVERTER
2. DIRECT DRIVE SHAFT
3. FRONT PUMP SEAL
4. FRONT PUMP 'O' RING
5. FRONT PUMP BODY
6. FRONT PUMP GASKET
7. FRONT PUMP DRIVE GEAR
8. FRONT PUMP DRIVEN GEAR
9. STATOR SUPPORT – FRONT PUMP
10. INTERM. CLUTCH PISTON INNER LIP SEAL
11. INTERM. CLUTCH PISTON OUTER LIP SEAL
12. FRONT PUMP BUSHING
13. INTERM. CLUTCH PISTON
14. INTERM. CLUTCH PISTON RETURN SPRINGS & RETAINER
15. INTERM. CLUTCH EXTERNAL SPLINE STEEL PLATES (SEL.)
16. INTERM. CLUTCH INTERNAL SPLINE FRICTION PLATES
17. INTERM. CLUTCH PRESSURE PLATE
18. NO. 1 THRUST WASHER (FRONT PUMP) SELECTIVE
19. STATOR SUPPORT SEAL RINGS (REV. CLUTCH)
20. STATOR SUPPORT SEAL RINGS (FWD. CLUTCH)
21. OVERDRIVE BAND
22. INTERM. OWC RETAINING SNAP
23. INTERM. OWC RETAINING PLATE
24. INTERM. OWC OUTER RACE
25. INTERM. ONE-WAY CLUTCH ASSY.
26. REVERSE CLUTCH DRUM
27. REVERSE CLUTCH PISTON SEAL (OUTER)
28. REVERSE CLUTCH PISTON
29. REVERSE CLUTCH PISTON SEAL (INNER)
30. THRUST RING
31. REVERSE CLUTCH PISTON RETURN SPRING
32. RETAINING SNAP RING
33. REVERSE CLUTCH FRONT PRESSURE PLATE
34. REVERSE CLUTCH INTERNAL SPLINE FRICTION PLATE
35. REVERSE CLUTCH EXTERNAL SPLINE STEEL PLATE
36. REVERSE CLUTCH REAR PRESSURE PLATE
37. REVERSE CLUTCH RETAINING RING (SEL.)
38. NO. 2 THRUST WASHER (REV. CLUTCH)
39. TURBINE SHAFT
40. FORWARD CLUTCH CYLINDER & TURBINE SHAFT
41. FORWARD CLUTCH PISTON SEAL (OUTER)
42. FORWARD CLUTCH PISTON SEAL (INNER)
43. FORWARD CLUTCH PISTON
44. FORWARD CLUTCH PISTON RETURN SPRING
45. RETURN SPRING RETAINER
46. RETAINING SNAP RING
47. WAVED PLATE
48. FORWARD CLUTCH EXTERNAL SPLINE STEEL PLATE
49. FORWARD CLUTCH INTERNAL SPLINE FRICTION PLATE
50. FORWARD CLUTCH PRESSURE PLATE
51. RETAINING SNAP RING (SELECTIVE)
52. NO. 3 NEEDLE BEARING (FWD. CLUTCH)
53. FORWARD CLUTCH HUB
54. NO. 4 NEEDLE BEARING
55. REVERSE SUN GEAR & DRIVE SHELL ASSY.
56. NO. 5 NEEDLE BEARING
57. FORWARD SUN GEAR
58. CENTER SUPPORT RETAINING RING
59. FORWARD SUN GEAR PRECISION BUSHING
60. CENTER SUPPORT PLANETARY
61. PLANETARY OWC CAGE SPRING & ROLLER ASSY.
62. PLANETARY ASSY.
63. REVERSE BAND
64. DIRECT CLUTCH HUB
65. NO. 7 NEEDLE BEARING (DIRECT CLUTCH INNER)
66. RETAINING SNAP RING (SELECTIVE)
67. THRUST SPACER
68. DIRECT CLUTCH PRESSURE PLATE
69. DIRECT CLUTCH INTERNAL SPLINE PLATES
70. DIRECT CLUTCH EXTERNAL SPLINE PLATES
71. RETAINING SNAP RING
72. RETURN SPRING & RETAINER
73. DIRECT CLUTCH PISTON
74. DIRECT CLUTCH PISTON SEAL (INNER)
75. DIRECT CLUTCH PISTON SEAL (OUTER)
76. RING GEAR & PARK GEAR
77. DIRECT CYLINDER
78. OUTPUT SHAFT SMALL (2) STEEL SEAL RINGS (DIRECT CLUTCH)
79. NO. 8 NEEDLE BEARING (DIRECT CLUTCH OUTER)
80. OUTPUT SHAFT
81. OUTPUT SHAFT LARGE (4) STEEL SEAL RINGS
82. OUTPUT SHAFT HUB
83. RETAINING SNAP RING (O.P.S. HUB TO O.P.S.)
84. RETAINING SNAP RING (O.P.S. HUB TO RING GEAR)
85. REAR CASE BUSHING
86. NO. 9 NEEDLE BEARING (REAR CASE)
87. CASE ASSY.
88. NEUTRAL START SWITCH
89. VENT CAP
90. GOVERNOR COUNTERWEIGHT
91. BODY ASSY. – GOVERNOR
92. PLUG GOVERNOR
93. SLEEVE GOVERNOR
94. SCREEN ASSY. – GOV. OIL
95. SPRING GOV. VALVE
96. VALVE GOVERNOR
97. BODY GOVERNOR
98. BOLT (GOVERNOR BODY TO COUNTERWEIGHT)
99. CLIP–(GOVERNOR COVER TO GOVERNOR BODY)
100. BOLT (GOVERNOR COVER TO GOVERNOR BODY)
101. COVER – GOVERNOR VALVE BODY
102. RETAINING SNAP RING (GOVERNOR ASSY. TO O.P.S.)
103. EXTENSION HOUSING BRACKET
104. EXTENSION HOUSING BUSHING
105. EXTENSION HOUSING
106. EXTENSION HOUSING SEAL
107. BOLT (EXT. HSG. TO CASE) M6-12.5 X 30 (6 REQ'D.)
108. PIPE PLUG – 1/8-27 DRY SEAL
109. OVERDRIVE SERVO PISTON RETURN SPRING
110. OVERDRIVE SERVO PISTON
111. OVERDRIVE SERVO PISTON SEAL
112. OVERDRIVE SERVO COVER SEAL RINGS
113. OVERDRIVE SERVO COVER
114. RETAINING SNAP RING (O/D SERVO TO CASE)
115. REVERSE SERVO PISTON RETURN SPRING
116. REVERSE SERVO PISTON (SELECTIVE)
117. REVERSE SERVO COVER
118. RETAINING SNAP RING (REV. SERVO TO CASE)
119. 3-4 ACCUMULATOR VALVE SEAL
120. 3-4 ACCUMULATOR VALVE
121. 3-4 ACCUMULATOR VALVE RETURN SPRING
122. 3-4 ACCUMULATOR COVER
123. 3-4 ACCUMULATOR COVER SEAL
124. RETAINING SNAP RING (3-4 ACCUM. TO CASE)
125. 2-3 ACCUMULATOR VALVE SEAL (SMALL)
126. 2-3 ACCUMULATOR VALVE
127. 2-3 ACCUMULATOR VALVE SEAL (LARGE)
128. 2-3 ACCUMULATOR VALVE RETURN SPRING
129. 2-3 ACCUMULATOR COVER
130. RETAINING SNAP RING (2-3 ACCUM. TO CASE)
131. PARK PAWL SHAFT
132. GUIDE CUP
133. PARK PAWL RETURN SPRING
134. MANUAL LEVER
135. GROMMET
136. THROTTLE LEVER OIL SEAL
137. ATTACHING NUT & LOCK WASHER – M8 X 1.25
138. THROTTLE LEVER (OUTER)
139. PARK PAWL
140. PARK PAWL ACTUATING ROD
141. MANUAL LEVER (INNER)
142. ROLL PIN – 1/8 X 0.95 GROOVED
143. DETENT SPRING
144. ATTACHING NUT (MANUAL LVR) – M14 X 1.5 HEX
145. THROTTLE LEVER (INNER)
146. THROTTLE TORSION SPRING
147. VALVE BODY REINFORCEMENT PLATE
148. SEPARATOR PLATE GASKET (UPPER)
149. SEPARATOR PLATE
150. SEPARATOR PLATE GASKET (LOWER)
151. VALVE BODY (MAIN CONTROL)
152. FILTER & GROMMET ASSY. – OIL PAN
153. OIL PAN GASKET
154. OIL PAN
155. BOLT (OIL PAN TO CASE) – M8-1.25 X 15 (17 REQ'D.)
156. OIL FILTER GASKET
157. BOLT (VALVE BODY TO CASE) M6 1.0 X 30 (8 REQ'D.)
158. BOLT (VALVE BODY TO CASE) M6 1.0 X 40 (17 REQ'D.)
159. BOLT (SCREEN TO VALVE BODY) M6 1.0 X 16 (3 REQ'D.)
160. BALL (GOVERNOR DRIVE)
161. SPRING (ANTI CLUNK)
162. GROMMET
163. OIL SEAL ASSY.

Fig. 14-73. Exploded view of a Ford four-speed automatic transmission. Study parts, names, and their relationship to overall unit. (Ford)

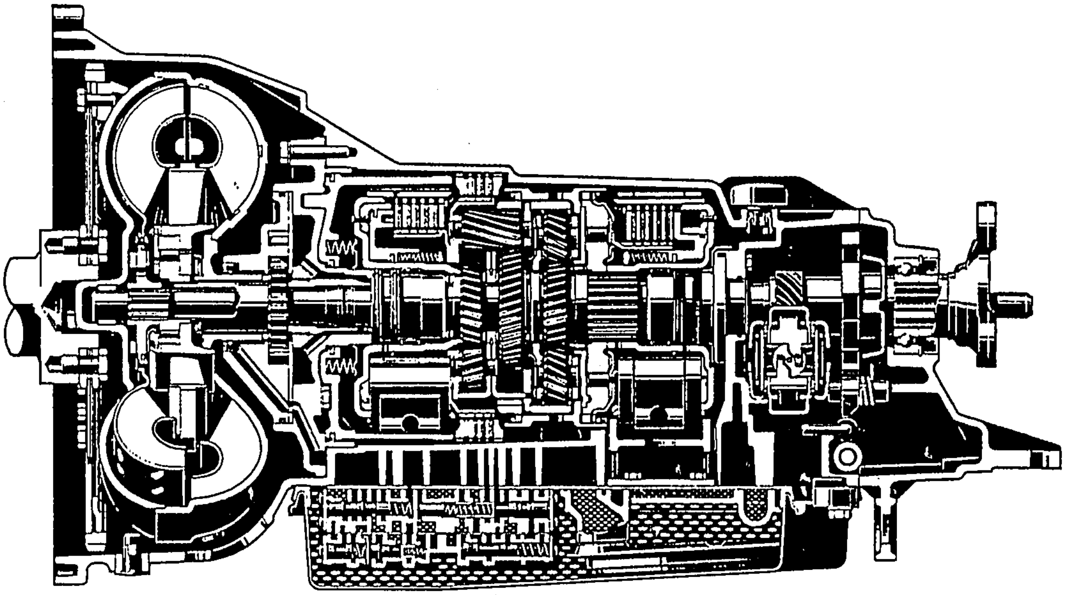


Fig. 14-74. Mercedes-Benz four-speed automatic. Study parts carefully. How many can you identify? (Mercedes-Benz)

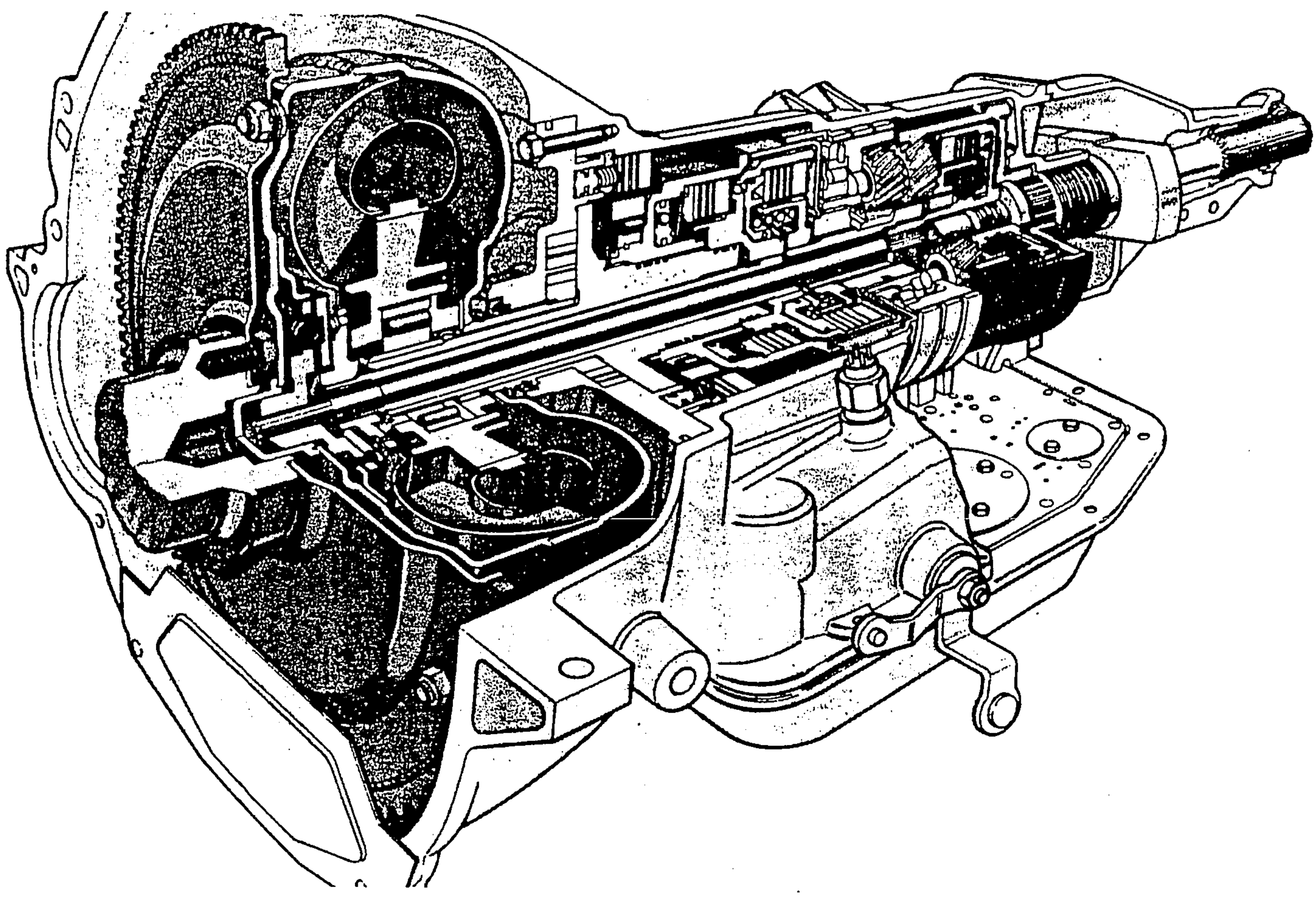


Fig. 14-75. Four-speed automatic transmission with overdrive in fourth gear. Unit is equipped with a lockup converter that is actuated in fourth gear. How many parts can you name? (Lincoln-Mercury)

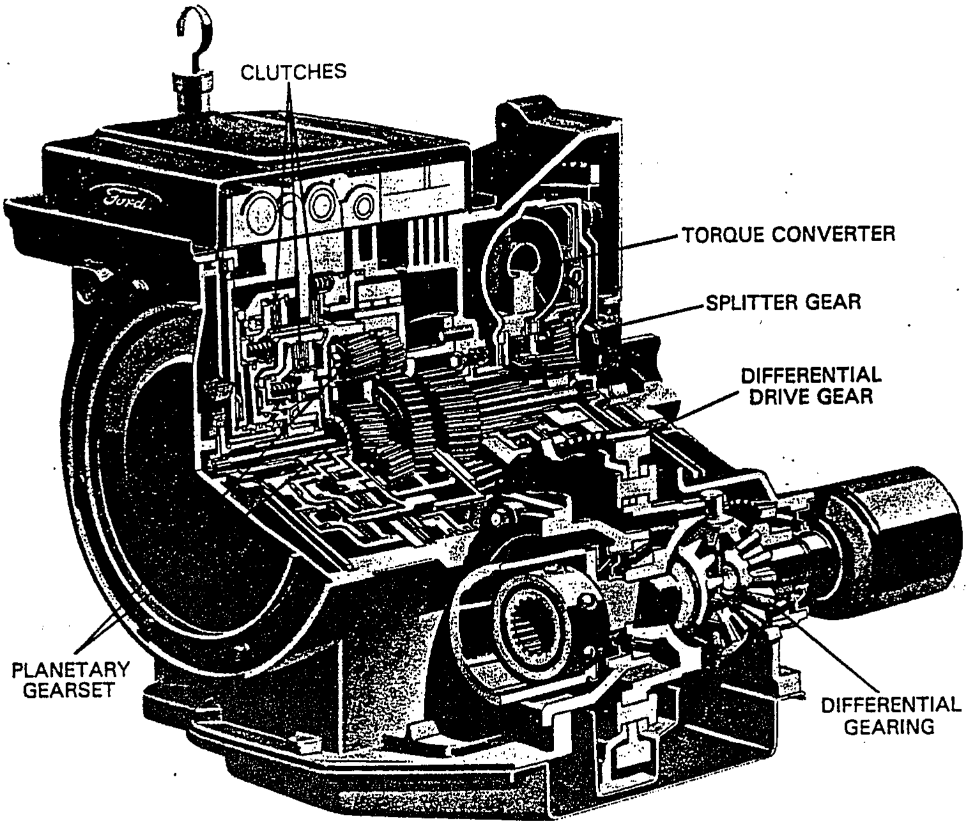


Fig. 14-76. Ford split-torque, three-speed automatic transaxle. Note "splitter gear." This arrangement divides engine torque in second and drive gears. In second gear, 38 percent of the torque transmission (output) is through the converter and 65 percent mechanically. In drive, 93 percent of torque is transmitted mechanically with only 7 percent through the converter. This prevents most converter slippage. (Ford)

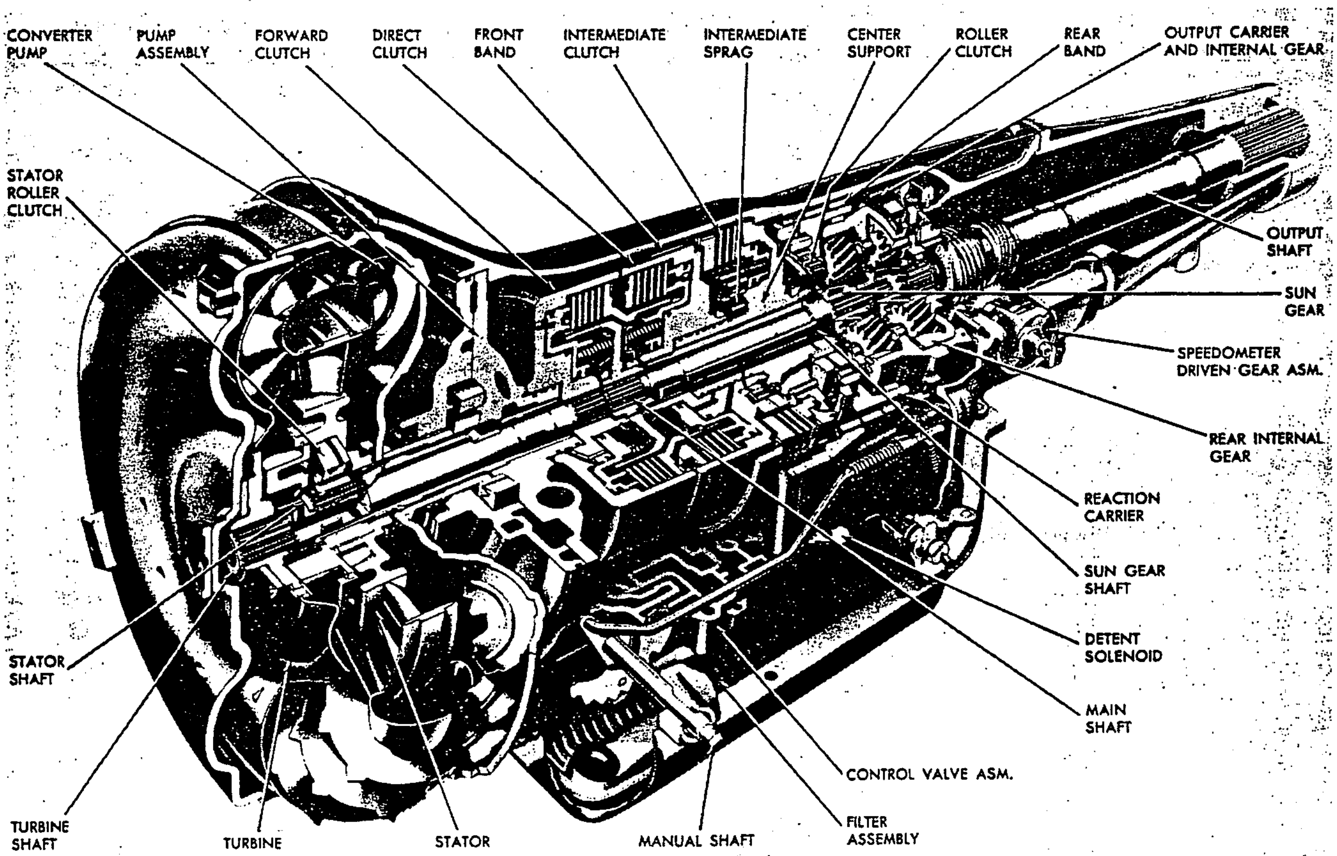


Fig. 14-77. Turbo-Hydramatic 400, three-speed transmission. (GM)

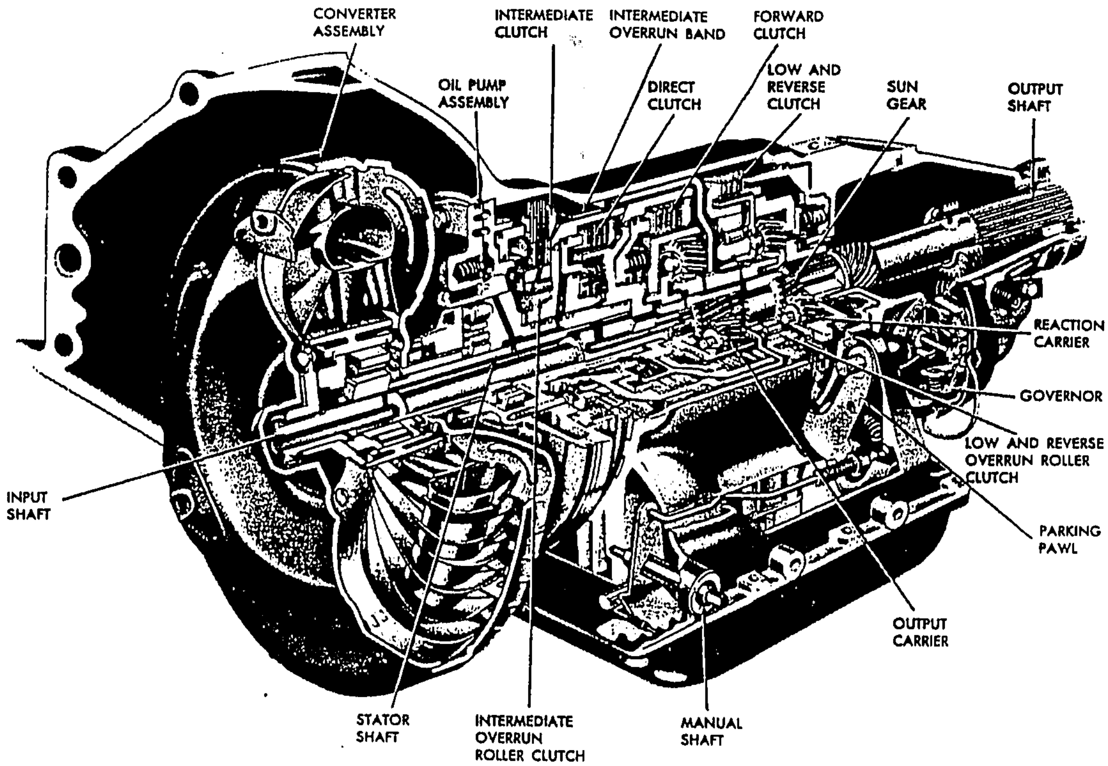


Fig. 14-78. Turbo-Hydramatic 350 automatic transmission. This is a three-speed unit employing four multiple disc clutches, two planetary gearsets, two roller clutches, and an intermediate overrun band. (Chevrolet)

the fluid. There is NO contact between turbine and clutch friction surface. Action is like that of a conventional converter. See B, Fig. 14-83.

When lockup conditions are all present, transmission fluid will move through a passage in the transmission input shaft. It will flow into the space between the turbine and clutch apply piston. Piston will move, engage clutch friction surface to lock pump and turbine together. This action is shown in C, Fig. 14-83.

SUMMARY

The automatic transmission shifts in accordance with speed and load conditions.

It uses one or more planetary gearsets to produce the desired gear ratios. Multiple disc clutches and bands are used to control gearsets.

The clutches and bands are actuated by hydraulic pressure produced by one or two oil pumps. The oil pressure is directed and controlled by a series of valves. Distribution is via oil passageways in the various units.

Definite speed ranges such as drive, low, reverse, etc., can be selected by the driver through mechanical linkage connected to a control valve in transmission.

Power transmission from engine to transmission is through a fluid coupling or a torque converter.

The torque converter can multiply the engine torque, thereby giving a wide range of power. The amount of multiplication is dependent on converter design and position between "stall" and "coupling point."

Lubrication is provided by special transmission oil as it circulates through the unit.

Oil is cooled by piping it to a cooler unit in one of the radiator tanks.

A complete study and mastery of the automatic transmission involves a great deal of material. This chapter has endeavored to give you a working knowledge of the basic principles involved. For further study, manufacturers' shop manuals are an excellent source of information.

KNOW THESE TERMS

Fluid coupling, Torus, Torque converter, Stator, One-way clutches, Stall, Planetary gearsets, Brake bands, Accumulator piston, Clutch, Oil pump, Manual control valve, Governor, Throttle valve, Vacuum modulator, Compensating valve.

REVIEW QUESTIONS—CHAPTER 14

1. What unit eliminates the conventional clutch as used on standard transmission installations?
2. What is a planetary gearset?
3. Name the parts in a planetary gearset.

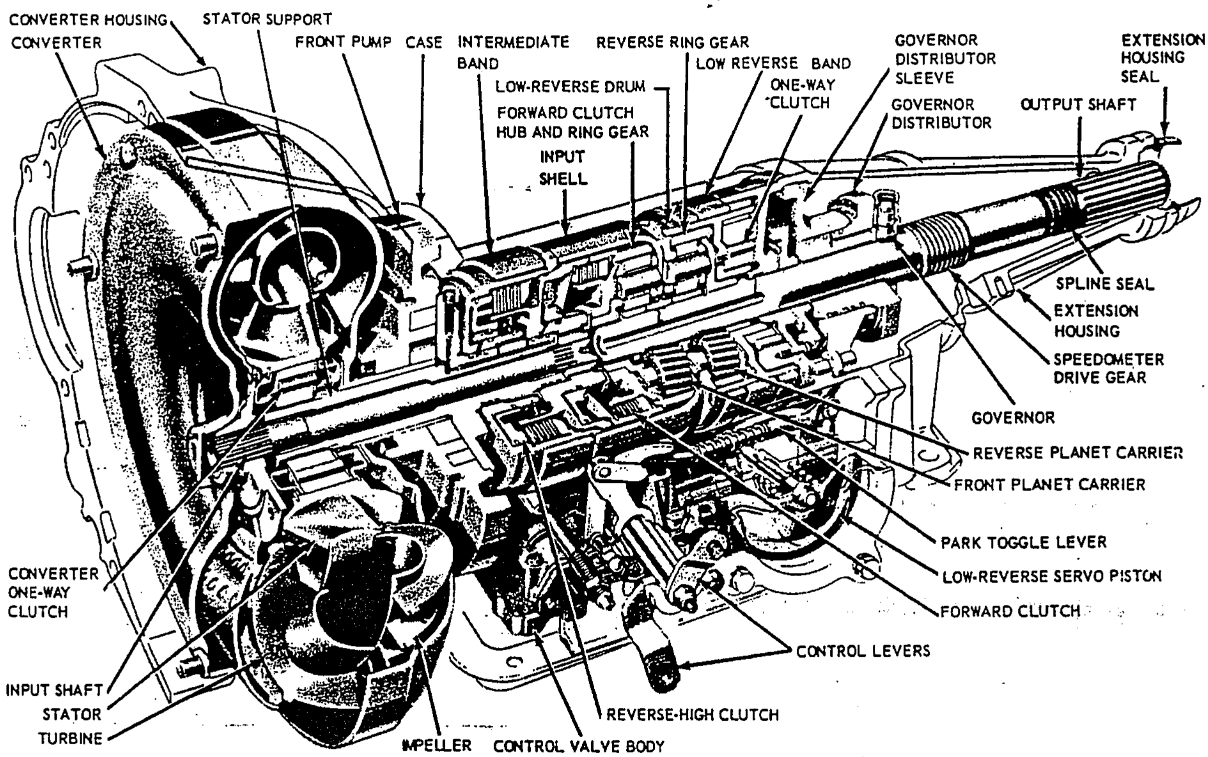
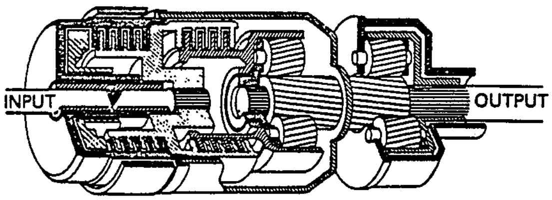


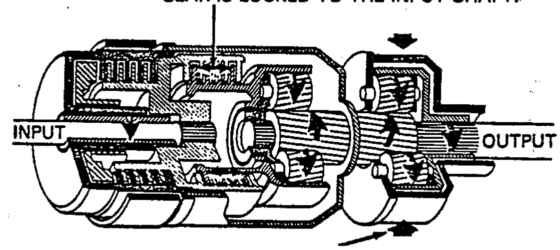
Fig. 14-79. Ford C4, three-speed transmission.



CLUTCHES AND THE BAND ARE RELEASED

NEUTRAL

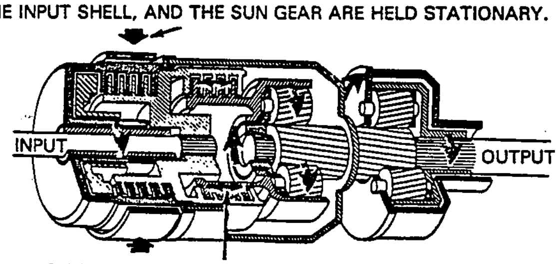
THE FORWARD CLUTCH IS APPLIED. THE FRONT PLANETARY UNIT RING GEAR IS LOCKED TO THE INPUT SHAFT.



THE LOW AND REVERSE CLUTCH (LOW RANGE) OR THE ONE-WAY CLUTCH (D1 RANGE) IS HOLDING THE REVERSE UNIT PLANET CARRIER STATIONARY.

FIRST GEAR

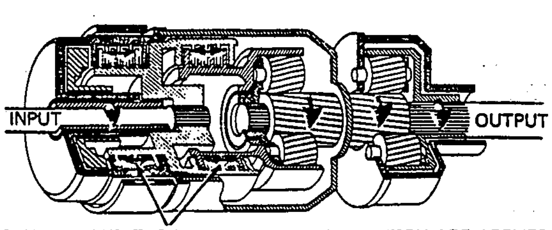
THE INTERMEDIATE BAND IS APPLIED. THE REVERSE AND HIGH CLUTCH DRUM, THE INPUT SHELL, AND THE SUN GEAR ARE HELD STATIONARY.



THE FORWARD CLUTCH IS APPLIED. THE FRONT PLANETARY UNIT RING GEAR IS LOCKED TO THE INPUT SHAFT.

SECOND GEAR

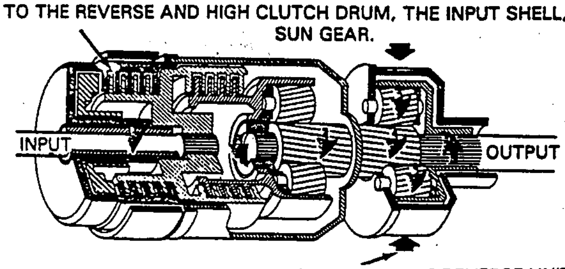
GEAR RATIOS
FIRST 2.46:1
SECOND 1.46:1
HIGH 1.00:1
REVERSE 2.17:1



BOTH THE FORWARD AND THE REVERSE AND HIGH CLUTCH ARE APPLIED. ALL PLANETARY GEAR MEMBERS ARE LOCKED TO EACH OTHER AND ARE LOCKED TO THE OUTPUT SHAFT.

HIGH GEAR

THE REVERSE AND HIGH CLUTCH IS APPLIED. THE INPUT SHAFT IS LOCKED TO THE REVERSE AND HIGH CLUTCH DRUM, THE INPUT SHELL, AND THE SUN GEAR.



THE LOW AND REVERSE CLUTCH IS APPLIED. THE REVERSE UNIT PLANET CARRIER IS HELD STATIONARY.

REVERSE

Fig. 14-80. Transmission action during various speed ranges in Ford C6, three-speed transmission.

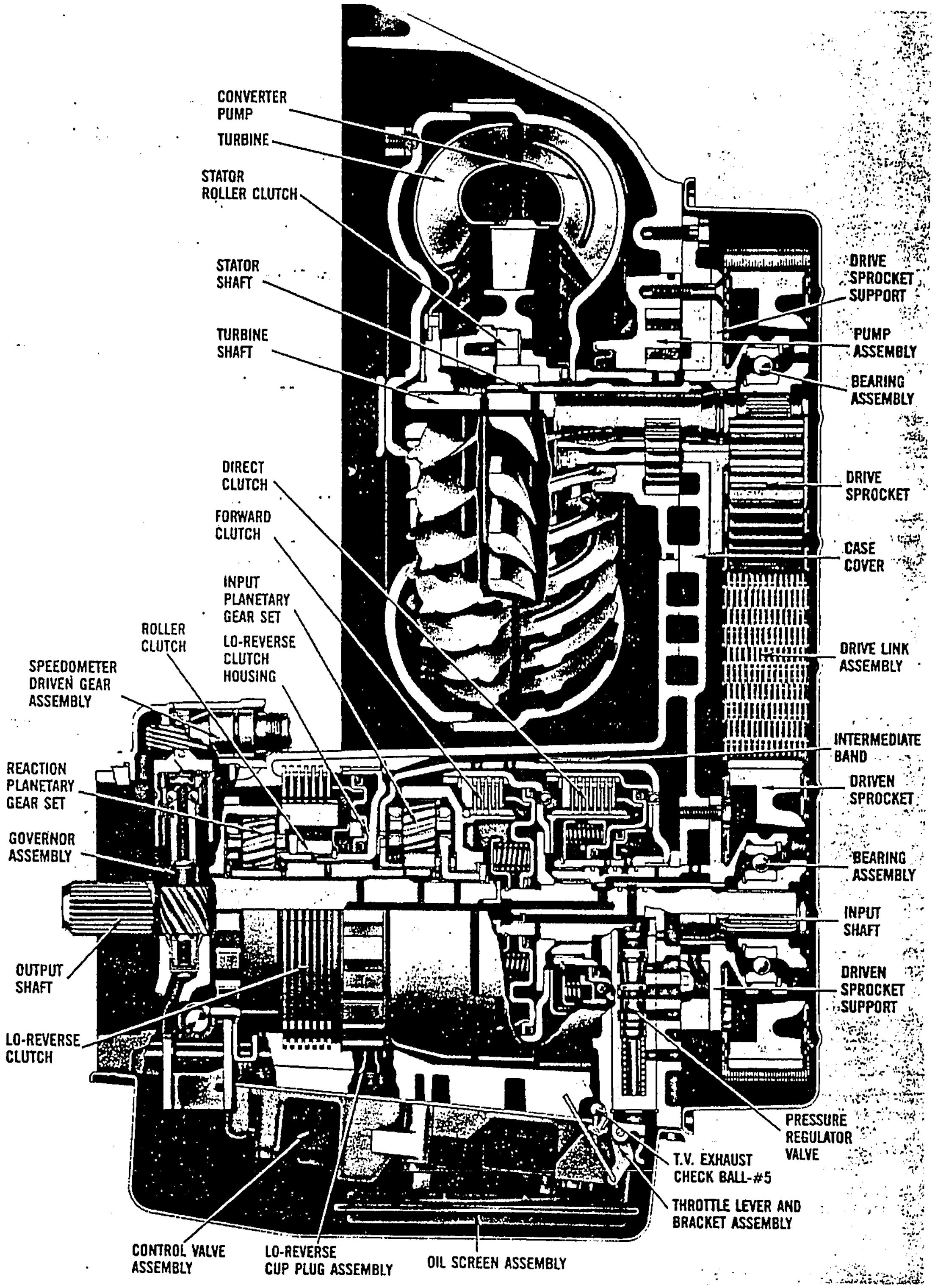


Fig. 14-81. A front wheel drive automatic transmission. This three-speed unit transfers torque from turbine shaft to transmission input shaft via a drive chain. (Oldsmobile)

4. A planetary gearset can be used to __________ or __________ torque and it can also be used to __________ the direction of rotation.
5. What unit is used to stop the planetary internal gear?
6. The planetary gearset can be used to transmit torque as a solid unit by __________ any two __________ of the gearset together.
7. The action in question 6 is accomplished by applying oil pressure to what unit?
8. What is a fluid coupling?
9. How does a fluid coupling work?

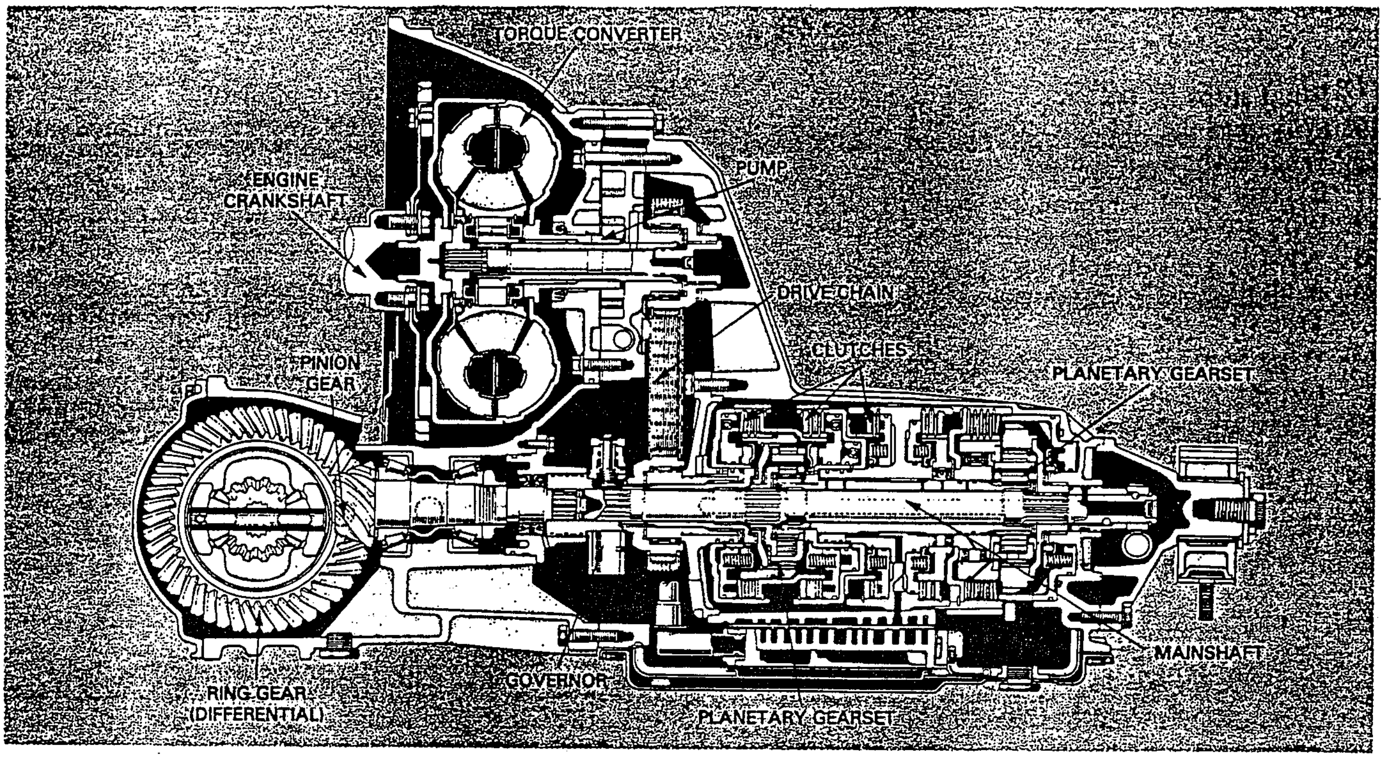


Fig. 14-82. Three-speed automatic transaxle (transmission and drive axle make up an integrated assembly). (Toyota)

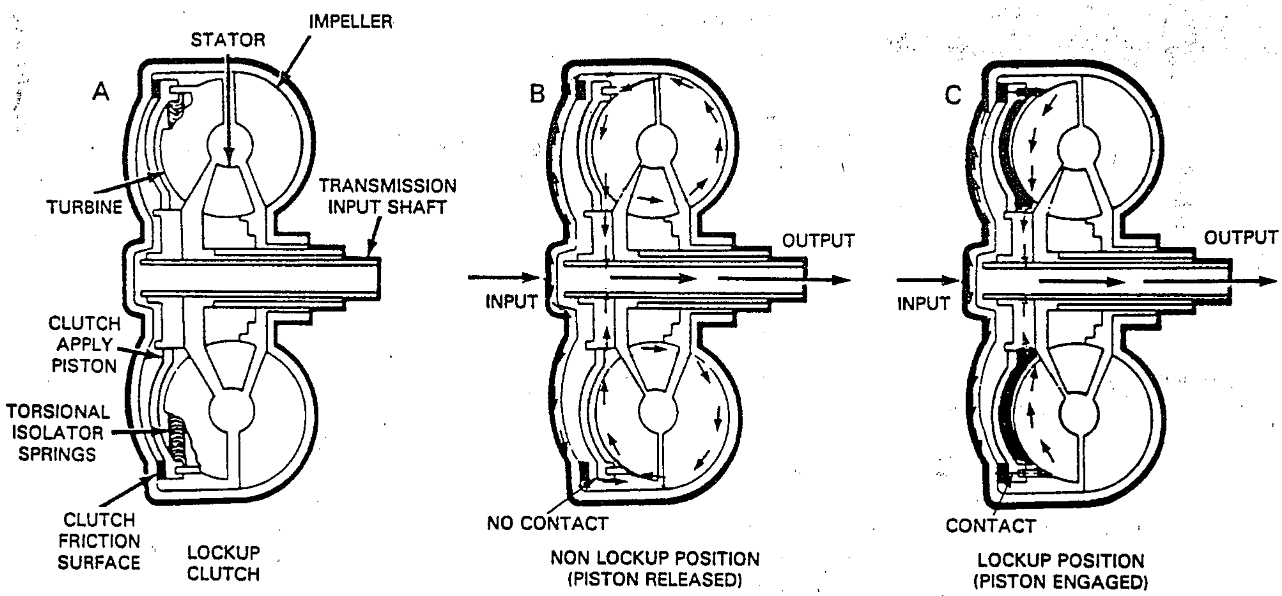


Fig. 14-83. Operation of a lockup torque converter. A—Lockup clutch design. B—Lockup apply piston has released and unit is unlocked. In this mode (condition or stage), it will operate as a standard torque converter. C—Apply piston has moved against clutch friction surface thus locking converter. In this mode, it will operate as a solid drive unit with no slippage between turbine and pump (impeller).

10. What is the principal difference between a fluid coupling and a torque converter?
11. The fluid coupling can multiply torque. True or False?
12. The vanes in a torque converter are straight. True or False?
13. Fluid motion in both the torque converter and the fluid coupling is in two directions. One motion is called the ________ flow, the other the ________ flow.
14. Of what value is the split ring in the fluid coupling and torque converter.
15. What is a stator?
16. How does a stator work?
17. The fluid coupling uses a stator. True or False?
18. The stator can revolve in one direction only.

What stops its rotation in one direction?

19. Why must the stator revolve in one direction only?
20. What is the stall point?
21. Explain what we mean by coupling point.
22. Why are torque converter vanes curved?
23. What is a servo and what does it do?
24. A multiple disc clutch uses a servo to actuate it. True or False?
25. What value is there in the use of an accumulator piston?
26. There are two types of oil pumps in general usage in the automatic transmission. Name them.
27. What is a shifter valve?
28. What opens the shifter valve?
29. What controls the source that opens the shifter valve?
30. Explain the action when the simple two-speed automatic transmission is placed in Low Range; in High Range.
31. What unit is used to delay the upshift?
32. How is downshift accomplished?
33. Draw a sketch showing how a spool balance valve works.
34. To apply extra pressure on the brake band during heavy acceleration, a ________ valve is often used.
35. What lubricates an automatic transmission?
36. SAE 20W MS engine oil will work well in an automatic transmission. True or False?
37. Explain, step-by-step, how a typical two-speed automatic transmission functions. Start with the shift lever in neutral.
38. When all other lockup conditions are present, converter lockup will take place in:
    a. Low range.
    b. High range.
    c. Reverse.
    d. Neutral.
39. The lockup converter prevents slippage between the pump and turbine. Explain how it functions.

Section 2. DESCRIPTION AND OPERATION

2-1. SCOPE

This section describes the transmission components and explains their functions. Also explained are the torque paths and hydraulic system.

2-2. MOUNTING, INPUT DRIVE

a. Mounting (foldout 1)

The transmission housing 6 is bolted to the engine flywheel housing. The transmission mounting flange is machined to an SAE 1-1/2 configuration. Vehicle mounting provisions include two 7/16-14 tapped bosses in the converter housing. Three 3/4-10 tapped bosses on the side of the transmission housing are normally used for the turnover stand, but also may be used for rear mount installations.

b. Input Drive (foldout 1)

A flexible coupling, equipped with damper springs, is bolted to the engine flywheel. An input shaft, splined at both ends, connects the flexible coupling hub to the bevel drive gear 37 in the transmission. The flexible coupling and input shaft are not furnished as part of the transmission.

2-3. TORQUE CONVERTER

a. Description (foldout 1)

The torque converter consists of three elements; a pump, stator, and turbine. These elements are vaned, cast aluminum. The pump is the input element and is driven by the engine through bevel gears 37 and flywheel 40. The turbine is the output element and is splined to the input shaft of forward clutch 9. The stator is the reaction element (torque multiplying element). The stator provides an over-running clutch which permits the stator to rotate freely in one direction but locks (stationary) in the opposite direction.

b. Operation (foldout 1)

(1) The converter is continually filled with oil. The pump, driven by the engine through the bevel gears, directs oil against the turbine vanes which causes the turbine to rotate. The stator is the reaction element. The turbine returns the oil through the stator element. The stator vanes redirect the oil flow so that it strikes the pump vanes in the same direction that the pump is turning. As the pump turns faster in relation to the turbine, the velocity of the oil flow increases and so does the torque multiplication. Thus the greatest torque multiplication occurs when the pump is at full speed and the turbine (connected to transmission gearing) is stalled.

(2) However, when the turbine speed approaches the speed of the pump, oil flowing to the stator begins striking the backside of the stator vanes. This causes the stator to rotate (freewheel) in the same direction as the pump and turbine. At this point the converter functions as a fluid coupling and torque multiplication stops.

2-4. LOCKUP CLUTCH

a. Description (foldout 1)

The lockup clutch 41 consists of three elements; a piston, clutch plate, and backplate. These elements are located inside converter flywheel 40. The piston and backplate rotate with converter pump 1. The clutch plate, located between the piston and backplate, is splined to and rotates with converter turbine 3.

b. Operation

The lockup clutch solenoid is energized when an increase in output speed produces a value that matches a pre-programmed value in the ECU. The energized solenoid causes the clutch apply pressure to be directed against the lockup piston. The pressure compresses the clutch plate between the piston and the backplate. Thus, the converter pump and turbine are locked together and provide a mechanical drive from the engine. When the speed sensor tells the ECU that output speed has decreased to a programmed value, the ECU de-energizes the lockup solenoid. This permits the clutch apply pressure to escape through an exhaust port releasing the clutch.

2-5. OIL PUMP

a. Description (foldout 1)

Oil pump 38 is a positive displacement type pump that consists mainly of three elements; a drive gear, driven gear, and pump body. The oil pump is attached to pump support 5.

b. Operation (foldout 1)

The pump is driven by flattened pads on the driven bevel gear sleeve. The sleeve rotates anytime the bevel gears rotate. Thus anytime the engine is running, the pump gears rotate and draw oil from the sump and into a port near the unmeshing gear teeth. The oil is carried by the gears to the outlet port where the remeshing teeth force the oil into the hydraulic system.

2-6. MATCHED BEVEL GEAR SET

a. Description (foldout 1)

Matched bevel gear set 37 consists of two spiral bevel gears; a 24-tooth drive gear and a 21-tooth driven gear. These gears are matched by the manufacturer and are serialized to maintain set identity. The drive gear is supported by two tapered roller bearings. The driven gear is supported by and keyed to the driven bevel gear sleeve. Both gears are shimmed to establish proper tooth contact pattern and backlash.

b. Operation (foldout 1)

When the engine is running, the drive gear drives the driven gear at an 0.875 to 1 ratio. Rotation of the driven gear drives the oil pump and converter through the flats and splines (respectively) of the driven gear sleeve.

2-7. POWER TAKEOFF (PTO)

a. Description (foldout 1)

The PTO is engine driven and is located on the right side of the transmission. The PTO consists mainly of PTO drive gear 7 and the PTO shaft. The PTO drive gear is keyed to the bevel drive gear, and the PTO shaft is splined to the PTO driven gear. The output end of the PTO shaft is machined to accept a vehicle-furnished drive key, belt pulley, and a 1-20 self-locking nut.

b. Operation (foldout 1)

An idler gear transmits the engine torque from the PTO drive gear to the PTO driven gear. Thus, when the engine is running the PTO shaft rotates at 1.48 times engine speed. The PTO is rated to provide a maximum of 50 horsepower (37.5 kW) for a continuous duty cycle, with instantaneous torque, not exceeding -25 to +125 lb ft (-33 to +170 N•m).

2-8. FORWARD CLUTCH AND TURBINE SHAFT

a. Description (foldout 1)

Forward clutch and turbine shaft assembly 9 consists mainly of the clutch housing and integral shaft, clutch piston, ten clutch plates, forward clutch hub 10 and third-clutch driving hub 35. The clutch and shaft assembly is supported by front bearing retainer 8 and the splined hub of converter flywheel 40. The forward clutch and shaft assembly connects converter turbine 3 to the rest of the transmission clutches and gearing.

b. Operation (foldout 1)

(1) The forward clutch and shaft assembly is driven by the converter turbine. The third-clutch driving hub, splined to the clutch housing, also rotates. Rotation of the driving hub drives the internal-splined plates of third clutch 34.

(2) The forward clutch hub is splined to the main shaft assembly 36. When the forward clutch is applied, the forward clutch hub rotates with the clutch housing. Thus, torque from the converter turbine is transmitted to the main shaft assembly (and rear planetary ring gear 26) through the forward clutch hub.

(3) The forward clutch is applied during operation in forward gear only. In neutral and reverse operation, torque from the converter turbine is transmitted through the forward clutch housing and the third-clutch driving hub.

2-9. THIRD CLUTCH

a. Description (foldout 1)

Third clutch 34 consists mainly of the third-clutch housing, clutch piston, and ten clutch plates. Five internal-splined clutch plates engage the splines of third-clutch driving hub 35, and five external-tanged clutch plates engage machined grooves in the clutch housing. The clutch housing is supported by and splined to sun gear shaft 16.

b. Operation (foldout 1)

When the third clutch is applied, torque from the third-clutch driving hub is transmitted through the third-clutch housing to the sun gear shaft. Rotation of the sun gear shaft drives sun gear 15 in the front planetary and pinions 25 in the rear planetary. Third clutch is applied in third- and reverse-gear operations only. In first- and second-gear operations, converter torque is transmitted through forward clutch hub 10 to the main shaft assembly.

2-10. FIRST, SECOND CLUTCHES

a. Description (foldout 1)

First clutch 28 and second clutch 33 consist mainly of twenty clutch plates (twelve in first clutch and eight in second clutch) and two identical pistons positioned back-to-back in center support 11. The ten external-tanged plates (six in first clutch and four in second clutch) engage machined grooves within transmission housing 6. The six internal-splined plates of the first clutch engage the splines of front planetary carrier 12. The four internal-splined plates in the second clutch engage the splines of the third clutch housing.

b. Operation (foldout 1)

When the first clutch is applied, the front planetary carrier is held stationary. When the second clutch is applied, the third clutch housing (and sun gear shaft) is held stationary. The first clutch is applied in neutral, first-gear, and reverse operations. The second clutch is applied only in second-gear operation.

2-11. PLANETARY GEARING

a. Description (foldout 1)

The planetary gearing consists mainly of two planetary gear sets (front and rear), connecting drum 27, sun gear shaft 16, and a main shaft. The planetary gear sets are so named because of their locations in relation to the transmission and to each other. The interconnection of these planetary gear sets produces three forward gear ratios, and one in reverse.

b. Operation (foldout 1)

(1) The front planetary is active in first and reverse gear operations. In first gear, the front planetary interacts with rear planetary elements to produce the desired output ratio. In reverse gear, the front planetary reverses the torque from the converter and transmits it through the connecting drum to the output.

(2) The rear planetary, in addition to being compounded in first gear, is also active in second- and third-gear operation. In second gear, the rear planetary acts alone to produce an intermediate ratio, and in third gear, the bevel gears produce an overdrive which is transmitted by the rear planetary to the output.

2-12. OIL PAN, OIL FILTER

a. Description (foldout 1)

(1) Oil pan 32 is a pressed steel assembly that provides a flanged opening for mounting a vehicle-supplied filler tube, and a threaded opening at the end for the oil drain plug. A third fitting, on the filler tube side of the pan, provides an opening for return of oil from the engine bell housing. The oil pan is bolted to the bottom of oil transfer plate 29 and forms the oil sump for the transmission.

(2) Oil filter 32 is a box-like sheet metal frame with a perforated sheet metal reinforcement covered by a fine-mesh screen across the bottom. The oil filter is attached to the bottom of control valve body assembly 36.

b. Function

(1) The oil pan (sump) holds the oil supply for the transmission. It envelops the control valve body assembly, solenoid assembly and oil filter.

(2) The oil filter screens all oil entering the hydraulic system.

2-13. SPEEDOMETER DRIVE

a. Description (foldout 1)

(1) The speedometer drive consists of drive gear 21 and a driven gear bushing in rear cover 17. The rear cover has 13/16-20 tapped boss to receive a vehicle-furnished speedometer driven gear.

(2) The drive gear is a worm gear with a right hand helix. The gear is concentric with the output shaft and has no drive keys or splines. The gear is clamped between speed sensor gear 20 and the output shaft support bearing.

b. Operation (foldout 1)

When the transmission output shaft rotates, the speedometer drive gear rotates with it. The vehicle-furnished gear is driven clockwise (viewed at cable connection in rear cover) during forward operation.

2-14. ALLISON TRANSMISSION ELECTRONIC CONTROL (ATEC)

a. Description

(1) The ATEC consists of seven main components:
- Electronic control unit (ECU)
- Range selector
- Throttle sensor
- Output speed sensor
- Cab electrical harness
- Chassis electrical harness
- Electro-hydraulic valve body

(2) These seven components control the entire shifting of the transmission. The throttle sensor, range selector, and ECU are externally located from the transmission. The cab wiring harness connects the range selector and ECU to the vehicle power supply. The chassis wiring harness connects the ECU to the electro-hydraulic valve body (transmission main connector), throttle sensor, and speed sensor.

2-15. ELECTRONIC CONTROL UNIT (ECU)

The ECU is located in a protected area within the coach. The unit contains the electronic microcomputer which is the brain of the control system. The ECU receives information, in the form of electronic signals from the various switches and sensors, processes the information, and sends electronic signals to the appropriate solenoids which control the transmission operation. The ECU also features diagnostics which can sense many electronic system malfunctions and identify them with a displayed code.

2-16. RANGE SELECTOR

a. Description

The range selector displays five pads - R (reverse), N (neutral), D (drive), 2 (second), and 1 (first). The range selector also has a "DO NOT SHIFT" light and a warning tone or buzzer.

b. Operation

When any one of the pads is pressed, a "beep" sound is produced and the pad lights up to indicate the transmission is ready to operate in the selected range. When the ATEC detects a serious problem in the system, a buzzing tone is produced for 5 seconds, and a "DO NOT SHIFT" light comes on to warn the driver that the transmission is held-in-gear. If the range selector is moved, a continuous buzzing sound is heard and will continue until the original range is selected.

2-17. THROTTLE POSITION SENSOR

a. Description

The throttle position sensor is located in the engine compartment, mounted remote from the transmission. This sensor consists mainly of a push-pull cable and a potentiometer. On early models, one end of the cable is attached by means of an adjustable link to the engine fuel lever. (The adjustable link attaches to the carburetor butterfly valve on gasoline engines or to the governor fuel lever on diesel engine.) On later models, the cable is attached to the fuel level by means of a hitch pin. The other end of the cable is attached to a potentiometer which is inside a protective housing. Output voltage from the potentiometer is directed to the ECU through the chassis harness.

b. Operation

Movement of the throttle causes a change in the electronic signal to the ECU. The ECU is programmed to recognize the signal as a percent of throttle. When the throttle is wide open, the ECU will cause upshifts to occur near the engine governed speed. Part throttle will cause upshifts to occur at a lower engine speed. When the throttle is closed, the ECU delays the release of the lockup clutch which will provide better engine braking.

2-18. OUTPUT SPEED SENSOR

a. Description

The speed sensor (magnetic pickup) is located in the rear cover of the transmission. The magnetic end of the sensor is positioned near the 16-tooth speed sensor gear located on the transmission output shaft. The chassis harness connects the speed sensor to the ATEC.

b. Operation

Rotation of the output shaft causes the gear teeth to pass through the magnetic field at the end of the sensor. The passing of each gear tooth generates an electrical pulse which is directed to the ECU (a 16-tooth gear would produce 16 pulses for each revolution of the output shaft). The ECU uses this signal (speed) and the throttle sensor signal and shift selector position to control the upshifts, downshifts, and lockup operations.

2-19. ELECTRICAL HARNESSES

Two separate wiring harnesses are used to connect the ATEC components. The cab harness 1 (foldout 9,A) connects the components located in the coach; ECU and range selector. This harness also connects to the ECU to the coach electrical system. The chassis harness 1 (foldout 9,B) connects the ECU to the components located in the engine compartment; the transmission, throttle sensor, and speed sensor. In some applications, an adapter harness 1 (foldout 10,B) is used between the chassis harness and the transmission.

2-20. ELECTRO-HYDRAULIC VALVE BODY

a. Solenoids

The hydraulic circuits and valves within the electro-hydraulic valve body are controlled by seven solenoids. Range shifts and forward and reverse are controlled by four latching solenoids (C, D, F, and J). These solenoids permit the transmission to hold-in-gear. A latching solenoid is so named because its plunger "magnetically latches" in either one of two positions and stays there without being continuously powered by the ECU. Movement of the plunger occurs only when an electrical pulse creates a large magnetic field which overcomes the permanent magnetic field. The three nonlatching solenoids (H, G, and E) control the trim boost, lockup shifts, and the neutral-to-range shift. A nonlatching solenoid requires continuous power to hold the plunger in one position. When the power is turned off the plunger returns to the off position.

b. Pressure Switches

In early models, three pressure switches are mounted on the valve body. In later models, these switches are located on the solenoid and wiring harness assembly. Two of these switches tell the ECU that the transmission is in forward, reverse, or neutral. The ECU checks the signals from these switches with the signal from the range selector. If a system malfunction causes a discrepancy of signals, the ECU may shift the transmission to neutral and the CHECK TRANS light will illuminate. The third switch tells the ECU when the oil level is too low. The switch is activated by low oil pressure in the lubrication circuit. The ECU will prevent shifting to third gear if it does not receive a signal from this switch.

c. Sump Temperature Sensor

In early models, the sump temperature sensor (thermistor) is mounted near the bottom side of the valve body. In later models, the sensor is held in place with a cable tie on the solenoid and harness assembly. The sensor is immersed in the sump oil. Signals from the sensor tell the ECU the sump temperature. When the sump temperature is below 20°F (-7°C) and above 300°F (150°C) the ECU will only permit operation in the ranges best suited for the temperature condition and the CHECK TRANS light will illuminate.

2-21. HYDRAULIC SYSTEM

a. System Description

The hydraulic system generates, directs, and controls the pressure and flow of the hydraulic fluid within the transmission. The hydraulic fluid is also the power transmitting medium in the torque converter. It drives the converter turbine. It lubricates the transmission, and it applies the clutches. The hydraulic system is monitored and controlled by the ATEC.

b. System Schematic

A color-coded illustration of the hydraulic system is presented at the back of this manual (foldout 2). The illustration represents the system as it would function during neutral operation with the engine idling.

c. Oil Filter, Pump Circuit

Sump oil (blue) is drawn from the transmission oil pan (sump) through a fine-mesh filter screen by the input-driven pump. The pump delivers its entire flow out of the transmission to an external filter (customer supplied) and back to the bore of the main-pressure regulator valve.

d. Converter, Cooler, Lubrication Circuit

(1) The converter-in circuit (yellow) originates at the main-pressure regulator valve. Converter-in oil flows to the torque converter. Oil must flow through the converter continuously to keep it filled and to remove heat generated within the converter.

(2) The converter-out circuit (orange) directs oil from the converter out of the transmission to an external cooler (supplied

by vehicle manufacturer). A flow of air or water over or through the cooler removes the heat from the transmission oil prior to returning it to the lubrication circuit.

(3) The lubrication circuit (green) directs the oil throughout the transmission to the components requiring continuous lubrication and cooling. All lubrication oil drains to the sump. Oil in excess of that required for the lubrication circuit escapes to the sump through the lubrication pressure regulator valve. If the pressure in this circuit drops below a certain level, the lubrication pressure switch will send a signal to the electronic control unit (ECU). The ECU will then command the transmission to inhibit operation in third gear and the CHECK TRANS light will illuminate. When the pressure returns to a satisfactory level, the switch will close, the ECU will allow normal operation in all three ranges. The CHECK TRANS light will go off.

e. Range Selection Circuit

When shifting from neutral to range, solenoid F latches to direct main pressure to the forward-reverse valve. The pressure enters the valve bore and forces the valve against a return spring directing main pressure to apply the forward clutch. When solenoid F unlatches, the forward-reverse valve reseats due to the return spring and directs main pressure to apply third clutch (which in combination with the already applied first clutch yields reverse). At the same time that solenoid F is being latched for forward operation, solenoid H directs main pressure to one side of the neutral-range valve. Main-pressure on the other side of the neutral-range valve, supplied from solenoid J is exhausted when solenoid J is unlatched. Thus, the neutral-range valve moves against the return spring and directs main pressure from the first priority valve through the forward-reverse valve to both the forward regulator land at the main pressure regulator valve and to the forward clutch.

f. Main Pressure Circuit

(1) During neutral or reverse operation, main pressure (red) is determined simply by the amount of pump pressure required to force the main-pressure regulator valve against its return spring until it reaches and stabilizes at a height allowing flow to escape into the converter circuit. The resulting pressure for the V731 transmission is around 250 psi (1725 kPa).

(2) When forward clutch is applied, forward regulator pressure (which originates from main pressure) is directed to an additional land on the main-pressure regulator valve. This effectively increases the overall cross-sectional area on which the pump pressure is exerted, thus less pump pressure is required to force the valve to its stabilizing height. This resulting pressure is around 160 psi (1100 kPa).

g. Trimmer Circuit

(1) The trimmer regulator valve reduces main pressure to a regulated level of about 21 psi (145 kPa) (blue and white). This pressure is applied to the first and second clutch trimmer valves to assist the trimmer springs in boosting clutch apply pressure during higher torque demands (sensed from throttle position). During lower torque demands, the ECU energizes solenoid E which directs main pressure to fully stroke the trimmer regulator valve, thus exhausting the boost pressure and allowing smoother shift quality.

(2) The purpose of the trimmer valves is to regulate clutch apply pressure during a shift. This permits the clutch to be applied properly to avoid harsh shifts.

(3) Although each trimmer valve is calibrated for the clutch it serves, all trimmers function in the same manner. Each trimmer includes a trimmer valve, trimmer valve plug, trimmer springs and stop pin.

(4) When any clutch (except forward) is applied, apply pressure is also sent to the valve end of the trimmer valve. Initially, as apply pressure rises, the valve and plug are immediately forced against the trimmer springs until a height is reached allowing the apply oil to escape to exhaust. However, the apply oil also flows through an orifice in the trimmer valve to the cavity between the trimmer valve and plug. As pressure in this

cavity rises, it works with the return springs to push the valve back against the apply pressure gradually raising it at a rate depending on the orifice size and the spring force. It also pushes the plug gradually toward the stop. Once the plug hits the stop, the valve is quickly pushed against the apply pressure, blocking off the exhaust port. This immediately causes the apply pressure to step up to the level of main pressure. The clutch friction plates usually engage with the reaction plates during the gradual increase in clutch apply pressure. The trimmer plug remains downward against the stop until the clutch is released.

(5) When the clutch is released, the trimmer spring pushes the plug to the top of the bore exhausting the oil in the cavity between the valve and the plug. In this position, the trimmer is reset and ready to repeat the trimming action when the clutch is applied again.

(6) Movement of the trimmer plug toward the stop during trimming action displaces a volume of oil back into the trimmer regulator circuit. The trim boost accumulator valve absorbs this displaced volume of oil until normal circuit pressure is regulated by the trimmer regulator valve.

h. Lockup Circuit

On signal from the ECU, solenoid G is energized and directs main pressure to the lockup valve where it causes the valve to move against its spring. This position opens a path for main pressure to flow to the lockup trimmer and piston to apply the clutch. Release of the lockup clutch occurs when the ECU de-energizes solenoid G and exhausts main pressure from the lockup valve permitting the spring to move the valve to its original position. In this position, the clutch apply pressure is released through an exhaust port in the valve bore.

i. Priority Valve

(1) The priority valves ensure that the control system upstream from the valves will retain sufficient pressure during shifts to perform its functions.

(2) During clutch engagement, the priority valve protects system control pressures that would otherwise be momentarily affected by the volume of oil from the pump required to fill the clutch piston cavity.

j. Clutch Circuits

(1) There are four clutches besides lockup in the V731 transmission. These are the first clutch, second clutch, third clutch, and forward clutch. The clutches are applied during the following conditions:

Conditions	Clutches Applied
Neutral	First
First	First and forward
Second	Second and forward
Third	Third and forward
Reverse	First and third

(2) Each of the four clutches has its own circuit, and each clutch except the forward clutch is connected to a trimmer valve. A trimmer valve is not required for the forward clutch because it is not applied at higher power loads.

(3) In neutral, the 1-2 shift valve is held in position by spring force, and main pressure is directed into the first-clutch circuit.

(4) Shifting from neutral to any forward range causes the ECU to actuate the following solenoids J, H, D, and F. Solenoid J exhausts neutral signal pressure, solenoid H charges the range signal circuit, solenoid D exhausts main pressure from the 2-3 shift valve, and solenoid F charges the forward signal circuit. First clutch remains applied.

(5) With the circuits charged as described, the neutral/range valve and forward/reverse valve stroke against their spring and apply pressure is directed to the forward clutch. Pressure in the forward clutch circuit also actuates the forward pressure switch to signal the ECU that the transmission is in a forward range.

(6) Shifting from neutral to reverse causes the ECU to activate the following solenoids J, H, and D. Solenoid J exhausts neutral signal pressure, solenoid H charges the range signal circuit, and solenoid D exhausts main pressure from the 2-3 shift valve. First clutch remains charged.

(7) With the circuits charged as described, the neutral/range valve is stroked against its spring, the 2-3 shift valve is pushed by its spring to normal position, and apply pressure is directed to the third clutch. Pressure in this portion of the third clutch circuit also actuates the reverse pressure switch to signal the ECU that the transmission is in reverse range.

(8) A shift from first gear to second gear occurs when the ECU sends a signal to solenoid C (solenoids F and H remain charged). Solenoid C charges the 1-2 shift signal circuit which causes the 1-2 shift valve to stroke against its spring. In this position, the 1-2 shift valve exhausts the first clutch pressure and directs apply pressure, through the 2-3 shift valve bore, to the second clutch (forward clutch remains engaged).

(9) A shift from second gear to third gear occurs when the ECU sends a signal to solenoid D (solenoids C, F, and H remain charged). Solenoid D charges the 2-3 signal circuit which causes the 2-3 shift valve to stroke against its spring. In this position, second clutch pressure is exhausted and apply pressure is directed to third clutch (the forward clutch remains engaged).

k. Automatic Upshifts, Downshifts

Signals from the speed sensor and throttle sensor are sent to the ECU. The ECU checks the signal values against the shift points programmed into its memory. When these three values are precisely matched, the ECU sends a signal(s) to the appropriate solenoid(s) and the shift is effected.

l. Downshift and Reverse Inhibiting

The ECU is programmed to prevent downshifts when the coach speed is too fast or a reverse shift when the coach is moving forward too fast to change direction. Signals from the range selector, speed sensor, and direction switches are sent to the ECU. The ECU checks the signal values against the programmed values to ensure that the shifts can be made safely. When all values are appropriate, the ECU sends a signal to certain solenoid(s) and the shift is effected.

2-22. TRANSMISSION TORQUE PATHS

a. Converter Operation

Power is transmitted hydraulically through the torque converter. The engine drives the converter pump through a matched set of bevel gears. The pump throws oil against the vanes of the turbine, imparting torque to the converter turbine shaft. From the turbine, oil flows between the vanes of the stator, and re-enters the pump where the cycle begins again. When the engine is idling, impact of the oil upon the turbine blades is negligible. When the engine is accelerated, the impact is increased and the torque directed through the turbine shaft can exceed the engine torque (by an amount equal to the torque ratio of the converter). Converter operation is illustrated for neutral, first-, second-, and reverse-range explanations.

b. Lockup Operation

Power is transmitted mechanically through the lockup clutch. Application of the lockup clutch occurs in each forward range as a function of the pre-programmed schedule in the ECU. When the lockup clutch is applied, the converter elements rotate as a unit at approximately 1.14 times engine speed. This provides a mechanical drive from the engine to the turbine shaft. Lockup operation is illustrated for the third-range explanation.

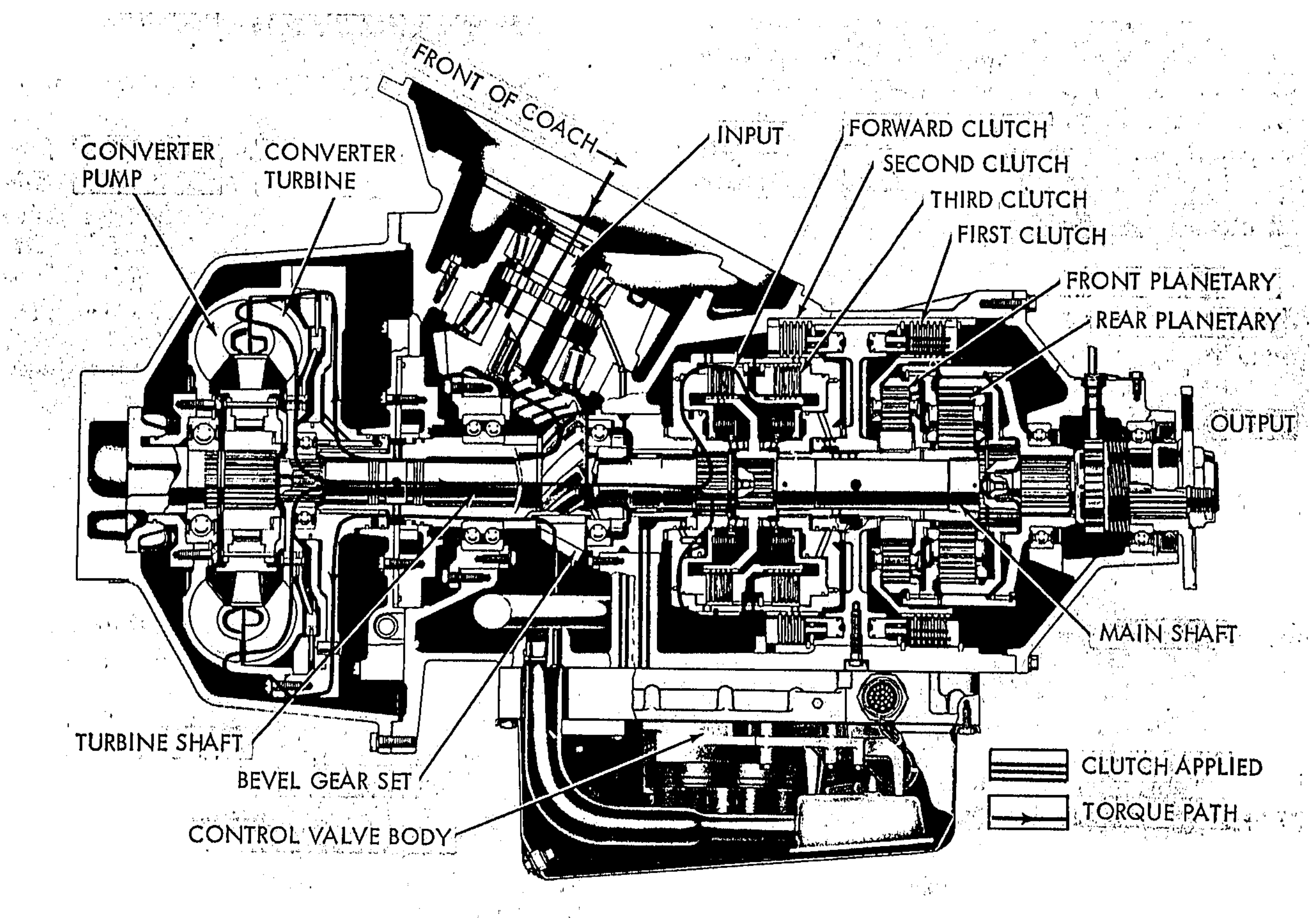


Fig. 2-1. Neutral torque path

c. Neutral Operation (fig. 2-1)

Engine torque is transmitted through the torque converter as described in paragraph 2-22a. The forward clutch is not applied. Thus, no drive is transmitted beyond the third-clutch hub. (Although the first clutch is applied, two clutches must be applied to produce torque at the transmission output).

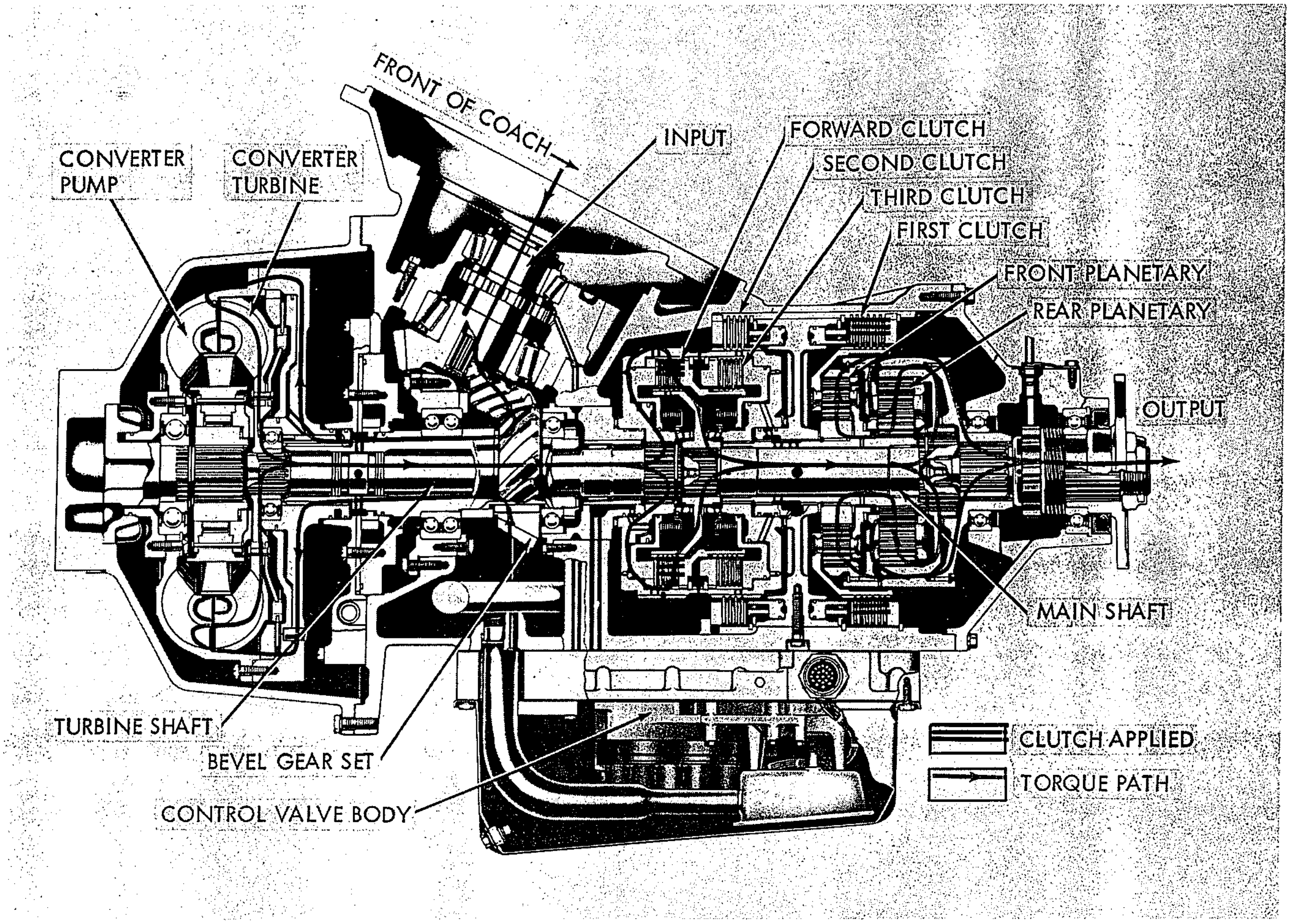


Fig. 2-2. First-range torque path

d. First-Gear Operation (Fig. 2-2)

Engine torque is transmitted through the torque converter as described in paragraph 2-22a. The forward and first clutches are applied. Application of the forward clutch locks the turbine shaft and main shaft together, and they rotate as a unit. Rotation of the main shaft drives the ring gear of the rear planetary. Application of the first clutch holds the front planetary carrier stationary. The ring gear of the front planetary and the carrier of the rear planetary are joined together on a common spline and rotate as a unit. The sun gear of the front planetary is splined to the shaft of the rear planetary sun gear, and therefore, the sun gears also rotate as a unit. When two planetaries are functionally interconnected to obtain a desired gear ratio, the gearing is referred to as compound. The interaction within this compound arrangement drives the output member at a 1.81 to 1 ratio.

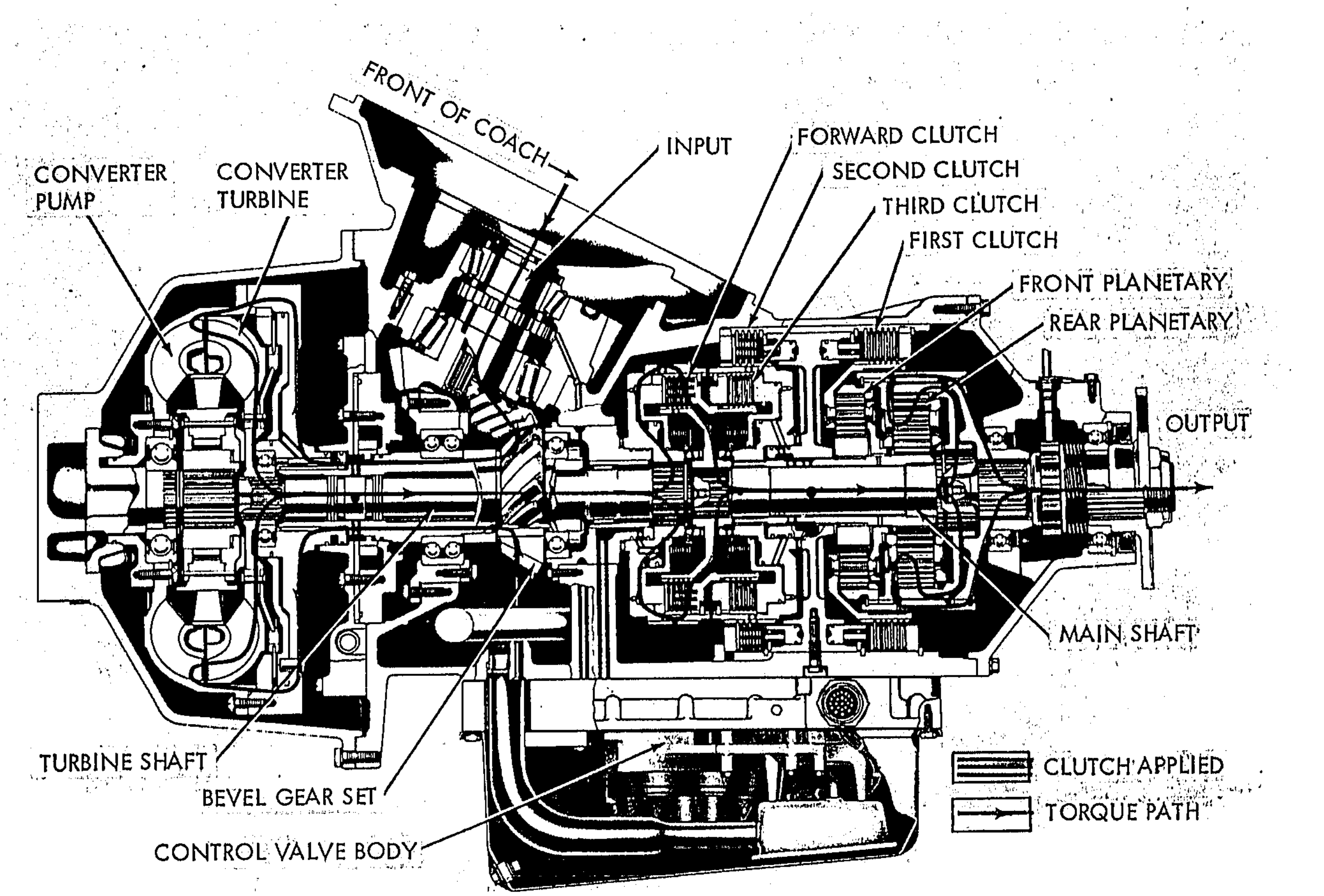


Fig. 2-3. Second-range torque path

e. Second-Gear Operation (Fig. 2-3)

Engine torque is transmitted through the torque converter as desribed in paragraph 2-22a. The forward and second clutches are applied. Application of the forward clutch locks the turbine shaft and main shaft together, and they rotate as a unit. Rotation of the main shaft drives the ring gear of the rear planetary. Application of the second clutch prevents rotation of the rear planetary sun gear. This causes the pinions to rotate and drive the rear carrier which is splined to the output member. When the sun gear is stationary and the ring gear is the driving member, the carrier is driven at a reduced speed. Thus, the output member is driven at a 1.22 to 1 ratio.

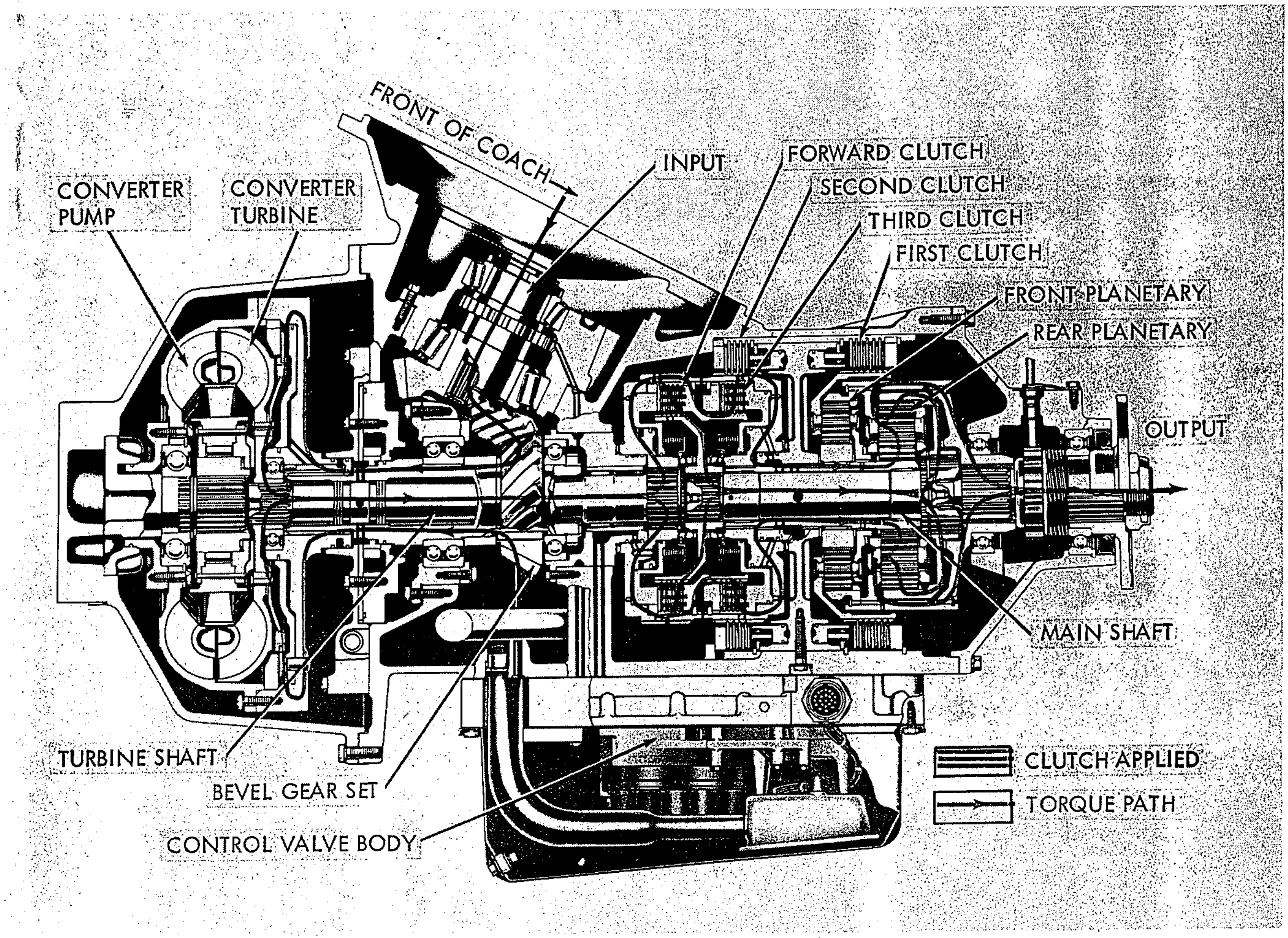


Fig. 2-4. Third-range torque path, lockup operation

f. <u>Third-Gear Operation</u> (Fig. 2-4)

Engine torque is transmitted through the torque converter as described in paragraph 2-22a. The forward and third clutches are applied. Application of the third clutch locks the turbine shaft and rear planetary sun gear together, and they rotate as a unit. When two members of a planetary (sun and ring gear) rotate at the same speed, the planetary is locked and rotates as a unit. The rear planetary carrier is splined to the output. Thus, the output member rotates at the same speed as the turbine shaft to produce a 0.875 to 1 ratio.

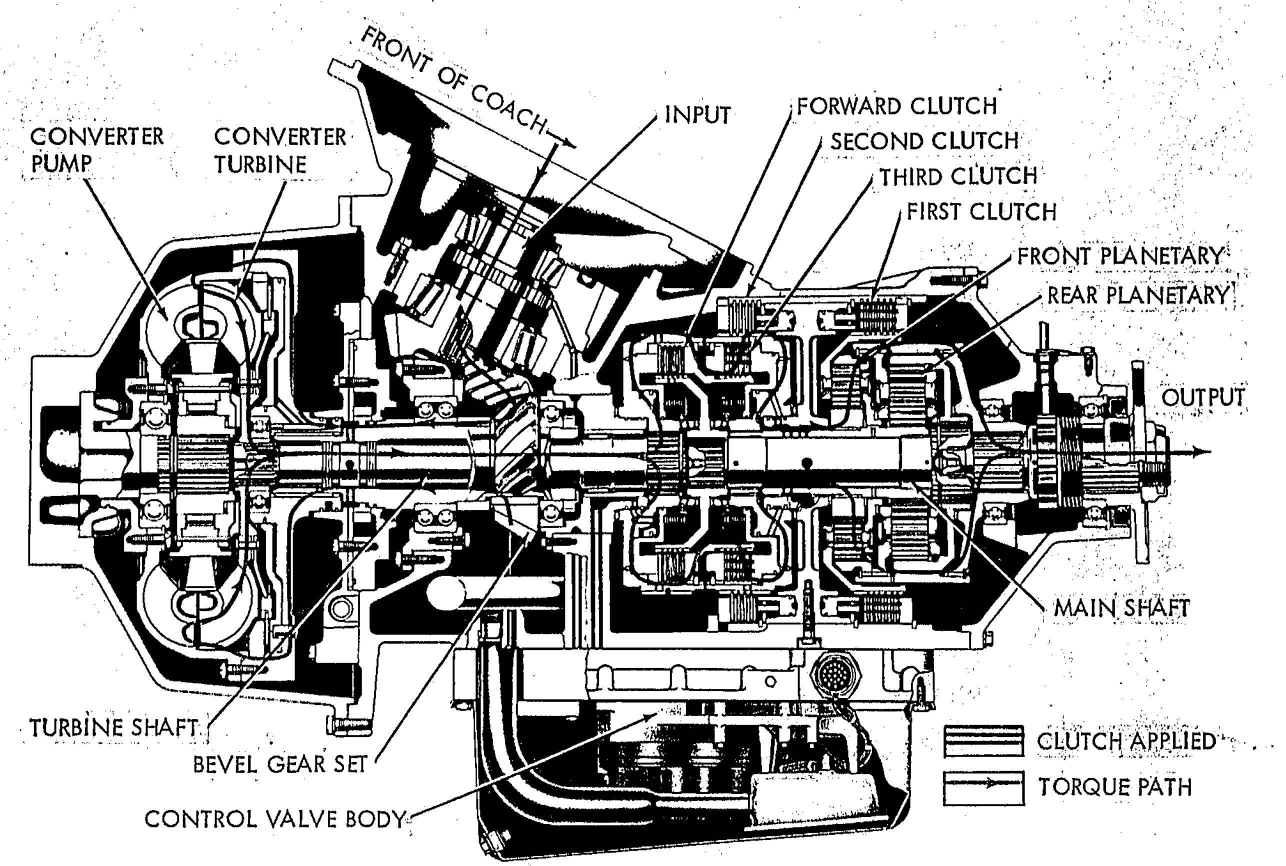


Fig. 2-5. Reverse-range torque path

g. Reverse-Gear Operation (Fig. 2-5)

Engine torque is transmitted through the torque converter as described in paragraph 2-22a. The third and first clutches are applied. Application of the first clutch holds the front planetary carrier stationary. When the sun gear is the driving member and the carrier is held stationary, the ring gear is driven in a reverse direction and at a reduced speed. The ring gear is splined via connecting drum to the output. Thus, the output member is driven in reverse at a 1.46 to 1 ratio.