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ABSTRACT

This training manual, the second of two volumes, comprises the final three blocks in a nine-block in-service training course for apprentices working in heavy duty mechanics. Addressed in the individual blocks included in this volume are engines, basic electricity, and winches. Each block contains a section on parts theory that gives the purpose, topics, operations, and applications of the parts and systems being discussed; a set of questions on parts theory; a section on scheduled maintenance and service repair; a set of questions on service; and a list of validated tasks to be completed during the course of daily on-the-job routines. The manual is illustrated with photographs and drawings. (MN)

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Heavy Duty Mechanics Apprenticeship Training, Module One

VOLUME II

Province of British Columbia

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INTRODUCTION

This is an in-service training manual for apprentices working in heavy duty mechanics shops who wish to complete **Module One, Heavy Duty Mechanics Apprenticeship Training** in-service. It covers the same material that is taught in the 14 week training program for Module One at the vocational schools. Although you don't have an instructor to assist you like apprentices at school, you will receive assistance from your employer and the journeyman you work with.

The manual is divided into nine blocks: (1) Shop Equipment and Practices, (2) Starting, Stopping, Moving Equipment, (3) Hydraulics, (4) Brakes, (5) Power Trains, (6) Frames, Suspension, Running Gear and Working Attachments, (7) Engines, (8) Electricity, and (9) Winches, Hoists and Cables. The material in blocks 1, 2, 6 and 9 is dealt with in a fairly thorough manner as these subjects won't be covered again in your training courses. The other blocks, blocks 3, 4, 5, 7 and 8, are introductions that give a basic grounding in their subjects. The topics in these blocks will be covered in greater detail in later courses. The main idea behind the depth that subjects are studied in this manual is to try to relate course material to the work you will actually be doing in the shop at this level of your apprenticeship. This is the reason, for example, that detailed information is given on frames, suspensions and running gear, whereas only basic information is given on electricity it is assumed that you will be doing a lot of work on suspension and running gear, but little on electrical systems.

Each of the blocks is laid out in the following pattern: the block begins with a section on parts theory that gives the purpose, types, operations (how they work) and applications (where they are used) of the parts and systems being discussed. A set of questions follows the parts theory, the answers to which are given at the end of the block. Next is a section on service that is divided into Daily Routine Maintenance, Scheduled Maintenance and Service Repair. Daily Routine Maintenance deals with watchful visual checks and adjustments; Scheduled Maintenance with scheduled lubrication and checks; Service Repair with removal, disassembly, repair or replacement and installations. The Service Repair sections in the blocks that are written at a basic level are limited to the types of repair that you are likely to be doing in your shop. Another set of questions follows the service section The blocks end with a list of practical tasks that should be done during daily work at your job Your employer has a Task Check Chart, that he will complete to vouch that you have done all the tasks listed in the manual.

Following is some advice on how to approach the course:

- It is expected that the program will be completed within a three month period; however, provision is made for up to a three month extension if required. Try to space the blocks out over the time you set to do the course There is a lot of material here, and if you leave it all to the end, you won't get finished. Monitoring of your progress in the course is done by your employer and by contact with the Apprenticeship Branch. Since this is an individualized learning package, there is no one standing over you telling you to do so much today and so much tomorrow. The onus is on you to keep a regular progress through the course. And it won't be easy.
- Don't skip out a section thinking that you already know it. There probably will be material in it that you are uncertain of. And besides, if you know most of the material already you'll be able to go through it quickly.
- Blocks 1, 2, 3, 4 and 5 should be done first. The other blocks can be taken in any order, although it's probably best to take them in the order in which they come.
- The questions are straightforward; there are no trick ones. They can all be answered from a close study of the text. Try to do as many of the questions as you can, without going back to the text. If you can't get a question, then open the text and seek the answer rather than turning to the answers. This way you re-read the topic and get a more complete understanding of it than if you just look up the answer.
- The practical tasks should normally be completed as you work on the material in each block; however, this may not be

practical due to other work commitments in the shop.

N.B. Some tasks may have already been covered in your day to day work.

Check with your employer to ensure that all areas of practical training have been covered.

— When you complete this manual and the practical tasks you will be required to write an Apprenticeship Branch examination.

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BLOCK 7 ENGINES

BLOCK 8 BASIC ELECTRICITY

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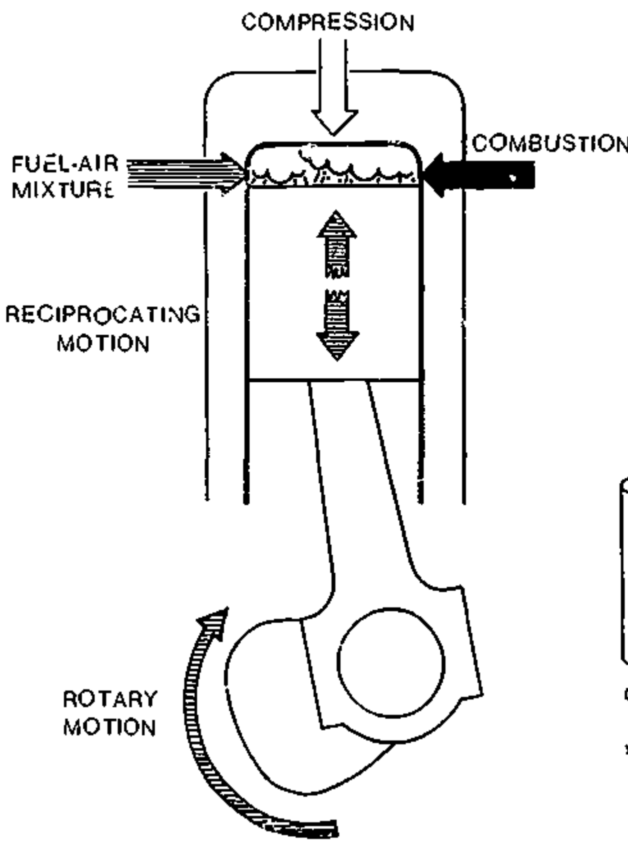
BLOCK

7

Engines

BASIC INTERNAL COMBUSTION ENGINE

An internal combustion engine is basically a container in which a mixture of air and fuel is burned. This mixture rapidly expands while it burns, creating a force that pushes against a piston. With the force of expanding gas acting on it, the piston has the potential to perform work. Thus an internal combustion engine converts the heat energy of fuel into mechanical work energy A simple internal combustion engine is shown in Figure 7-1



(7-1)

Courtesy of John Deere Ltd

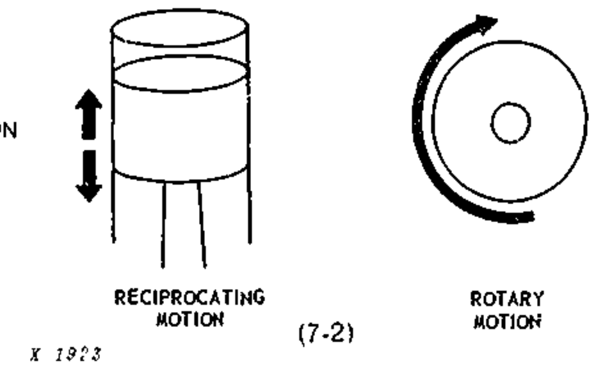
An engine performs the following series of events

1. Fills the cylinder with a combustible mixture of fuel and air (intake)
2. Compresses this mixture into a smaller space (compression)
3. Ignites the mixture and causes it to expand, producing power (power)
4. Removes the burned gases from the cylinder (exhaust)

One complete series of these events is called a cycle. To produce sustained power the engine must repeat this cycle over and over again.

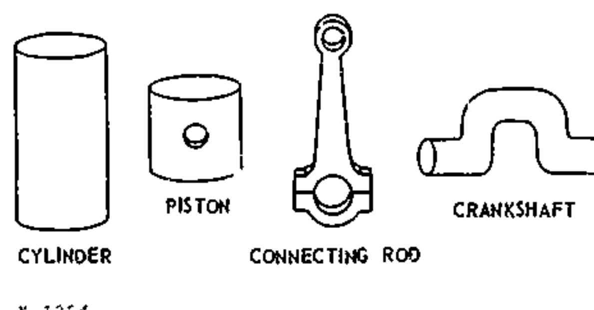
An engine uses two forms of motion to transmit energy (Figure 7-2)

- — reciprocating motion: up-and-down or back-and-forth motion
- — rotary motion circular motion around a point



(7-2)

Courtesy of John Deere Ltd

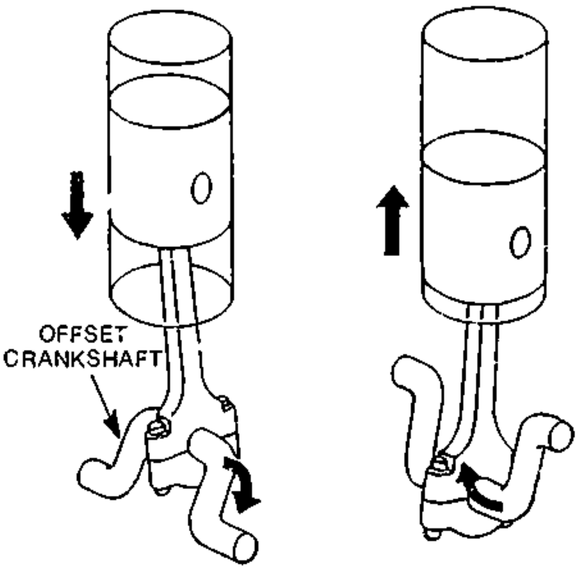


(7-3) BASIC PARTS OF THE ENGINE

Courtesy of John Deere Ltd

Using four basic parts an engine converts reciprocating motion into rotary motion (Figure 7-3). The piston and cylinder are mated parts, closely fitted so the piston glides easily in the cylinder with a minimum of clearance at the sides There is sufficient space above the piston for the combustion chamber, and the top of the cylinder is closed by a cylinder head. The connecting rod transmits the motion of the piston to the crankshaft. A simple crankshaft has a section offset from the centerline of the shaft so that it cranks when the shaft is turned. 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).

Thus, the swing of the connecting rod and the offset of the crankshaft convert the vertical motion of the piston to rotary motion at the crankshaft (Figure 7-4). This change in motion is basically the same as that created when pedalling a bicycle. The up and down motion of your leg is changed to rotary motion at the sprocket and wheels.



(7-4) HOW RECIPROCATING MOTION IS TRANSMITTED TO THE CRANKSHAFT AS ROTARY MOTION

Courtesy of John Deere Ltd

COMBUSTION THEORY

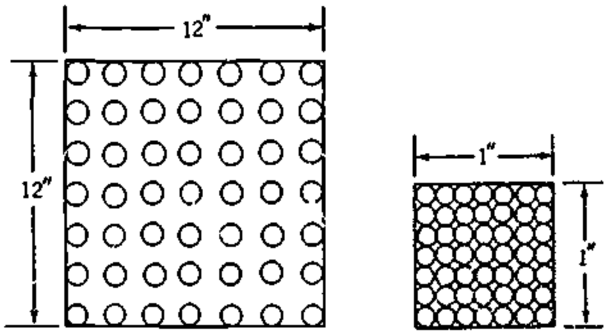
Three basic elements are needed to produce heat energy in an engine:

— air
— fuel
— combustion

When fuel is mixed with air and ignited, the mixture will burn. It's the oxygen in the air that allows the fuel to burn. fuel can't burn without oxygen. The characteristics of air and fuel that affect combustion are discussed below.

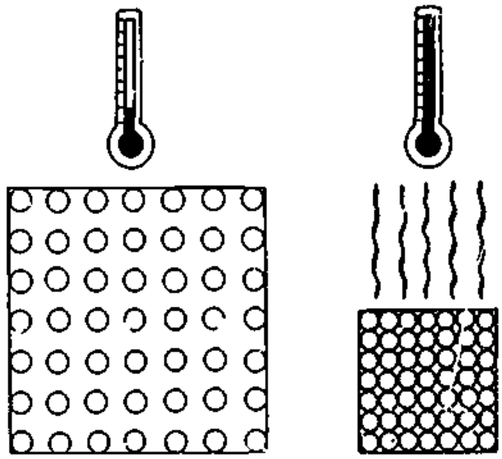
Air

1. Air can be compressed. One cubic foot of air can be packed into one cubic inch or less (Figure 7-5). Since air does compress, a large volume of it can be packed into a cylinder to surround the fuel and help it burn



(7-5) Courtesy of John Deere Ltd

2. Air heats when it's compressed (Figure 7-6). The air molecules rub against each other and produce heat. The heat aids combustion because it vaporizes the fuel and fuel burns best in a vaporized state.

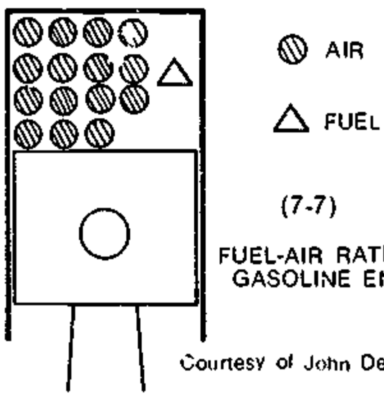


(7-6) AIR HEATS WHEN COMPRESSED

Courtesy of John Deere Ltd

Fuel and Combustion

1. Fuel mixes readily with air. The modern gasoline engine works best when about 15 parts of air are mixed with one part of fuel (Figure 7-7).



(7-7)

FUEL-AIR RATIO FOR GASOLINE ENGINE

Courtesy of John Deere Ltd

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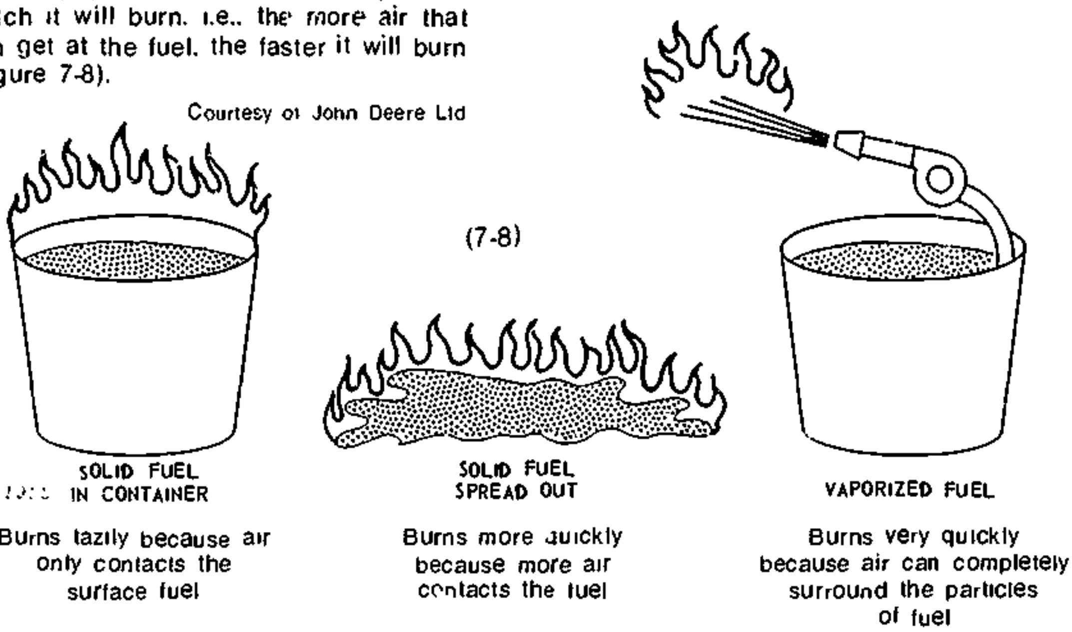
Fuel-Air Ratio For Gasoline Engine

These parts are measured by weight, not by volume. Since air is very light 90,000 gallons would be needed to make up the weight necessary to mix with 10 gallons of fuel.

2. Fuels are volatile. That is, they vaporize at low temperatures. The ability of a fuel to vaporize allows each particle of fuel to contact enough air to burn fully.

3. A fuel's physical state affects the speed at which it will burn, i.e., the more air that can get at the fuel, the faster it will burn (Figure 7-8).

Courtesy of John Deere Ltd



(7-8)

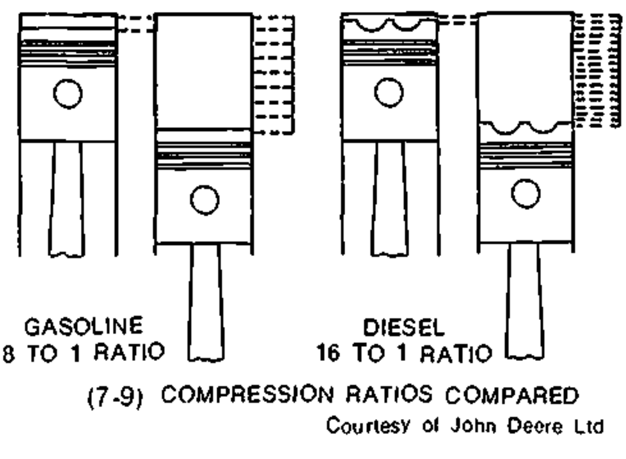
In an engine only vaporized fuel is burned.

4. Fuel must burn quickly to give the explosive force necessary for full engine power, yet it can't burn too explosively or it could blow up the engine. The rate of burning can be controlled by regulating.
   - the volatility of the fuel
   - the proportion of fuel in the fuel air mixture
   - the pressure and the heat of the air

Supplying, Compressing and Igniting Fuel Air Mixtures

In gasoline engines, fuel and air are mixed outside the cylinders in the carburetor and manifold. The mixture is drawn into the cylinder by the partial vacuum created during the piston's intake stroke. In diesel engines, there is no pre-mixing of air and fuel outside the cylinder. Air only is taken into the cylinder through the intake manifold.

After entering the cylinder the air fuel mixture in a gasoline engine, and only the air in a diesel engine, are compressed. The amount that are compressed is called the compression ratio. An 8 to 1 compression ratio is typical for gasoline engines while a 16 to 1 ratio is common for diesels (Figure 7-9).

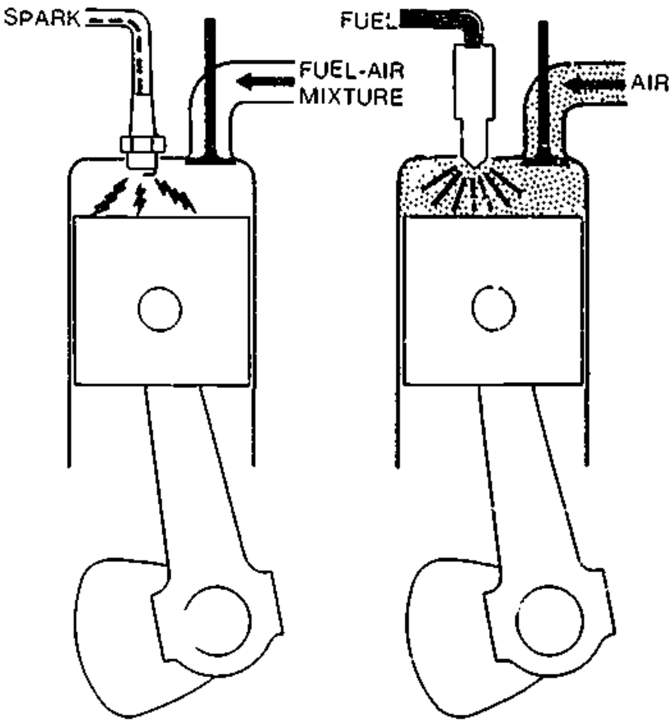


(7-9) COMPRESSION RATIOS COMPARED

Courtesy of John Deere Ltd

The fuel in the compressed fuel air mixture in a gasoline engine is ignited by a spark plug. In a diesel engine, as the piston nears the top of its compression stroke, fuel is injected or sprayed into the cylinder and mixes with the compressed air. The fuel is then ignited by the heat (approximately 538 C) of the densely compressed air.

Figure 7 to 10 summarizes fuel combustion in gasoline and diesel engines.



GASOLINE (7-10) DIESEL

1 Fuel-Air Are Mixed in Carburetor	1 Air Only Enters Cylinder
2 Mixture Enters Cylinder and Is Compressed	2 Air Is Compressed
3 Spark Ignites The Mixture	3 Fuel Is Sprayed In
	4 Fuel-Air Ignites From Heat of Compression

Courtesy of John Deere Ltd

Note that the higher compression ratio makes a diesel more efficient than a gasoline engine. The higher ratio allows for a greater expansion of gases in the cylinder after combustion and this results in a more powerful stroke. A consequence of the higher compression ratio is that diesel engines have to be built of sturdier, more expensive parts than gasoline engines to withstand the greater combustion forces. A diesel's pistons, pins, rods and cranks are beefed up, and it has more main bearings to support the crankshaft.

CHARACTERISTICS OF ENGINES

Engines can be characterized or classified according to:

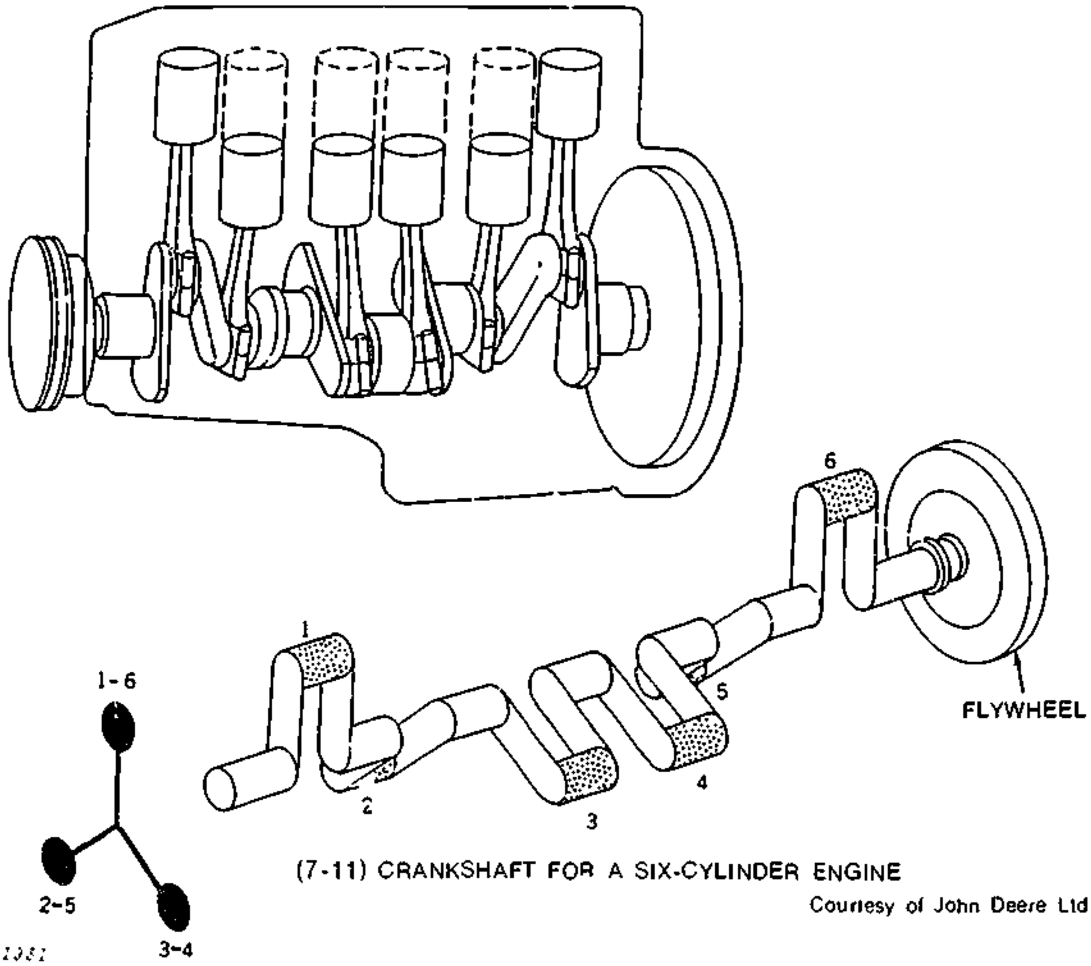
- number of cylinders
- arrangement of cylinders
- arrangement of valves
- number of strokes per cycle
- type of cooling
- type of fuel burned

These engine characteristics are discussed below.

NUMBER OF CYLINDERS

The previous discussion of basic engine principles focused on a single cylinder engine. Single cylinder engines are used on small equipment such as lawnmowers. Other engines have multiple cylinders: 2, 3, 4, 5, 6, 8, 12 and 16. An even number of cylinders is most common. Multiple cylinder engines give a smoother more continuous power flow than single cylinder engines.

Multiple cylinder engines have one common crankshaft with all the pistons and connecting rods connected to it (Figure 7-11).



(7-11) CRANKSHAFT FOR A SIX-CYLINDER ENGINE

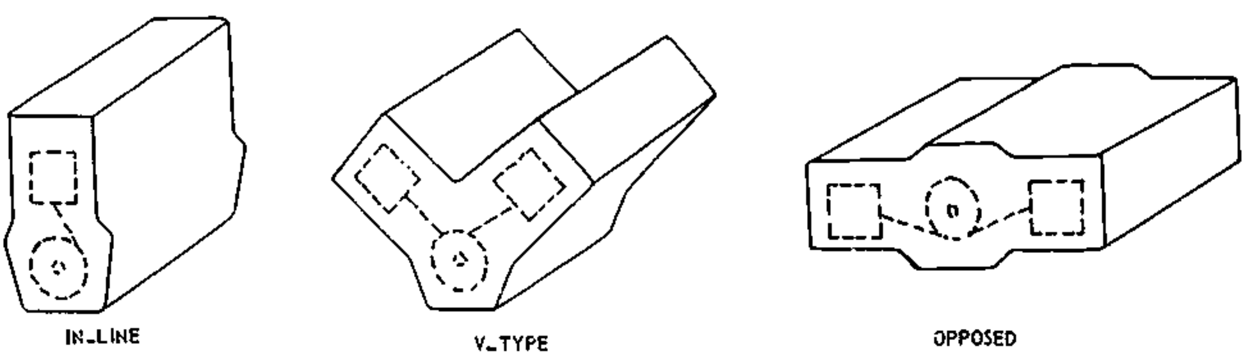
Courtesy of John Deere Ltd

The crankshaft is shaped so that the pistons will all complete one cycle intake, compression power and exhaust within one, or in some engines two, crankshaft revolutions. Weights on the crankshaft balance the forces from the rapidly moving parts within the engine. A heavy flywheel connected to the rear of the crankshaft also balances or evens out the power impulses from the pistons.

ARRANGEMENT OF CYLINDERS

Multi-cylinder engines are made in one of three configurations (Figure 7-12):

— in-line
— V
— opposed



(7-12)

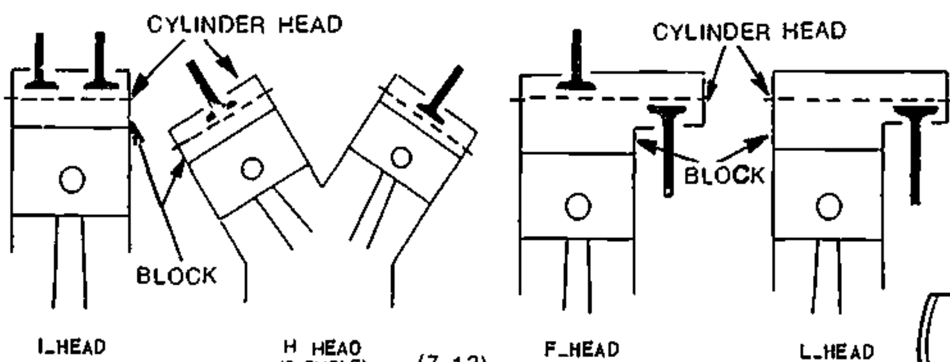
Courtesy of John Deere Ltd

The in-line cylinder arrangement has all the cylinders in a straight line above the crakshaft; the V has two banks of cylinders arranged in a V above the crankshaft; the opposed has two rows of horizontal cylinder, one on either side of the crankshaft The in-line and V are the two most common cylinder arrangements found on heavy duty machines

The cylinders in an engine are usually numbered In-line engine cylinders are numbered 1, 2, 3, 4, etc , starting at the end of the engine furthest from the flywheel. The cylinder numbering for V and opposed cylinder arrangements varies with the manufacturer.

VALVE ARRANGEMENT

Another common way to classify engines is by the arrangement of the intake and exhaust valves. The valves can be located in different positions in the cylinder head or the cylinder block. Figure 7-13 shows four types of valve arrangments.



(7-13)

Courtesy of John Deere Ltd

The I-Head and H-Head are combined under the name of overhead valves and are the most common valve arrangements used today.

NUMBER OF STROKES PER CYCLE

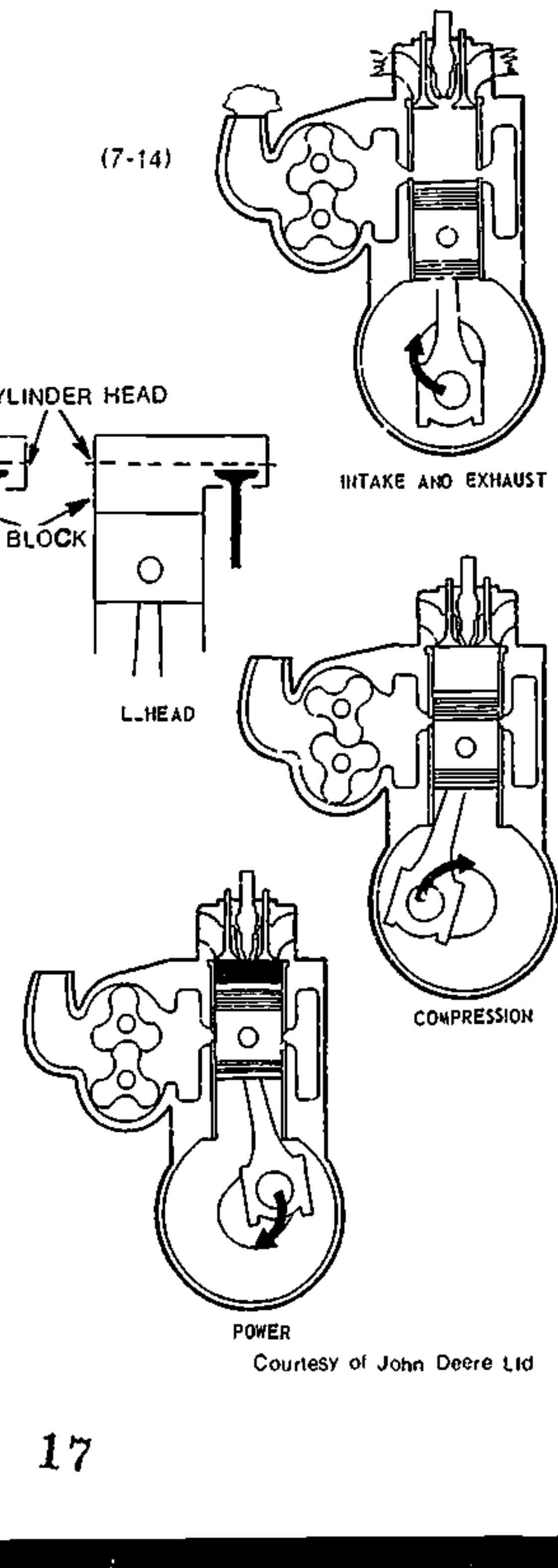
Most engines have either a two or a four stroke cycle. The two stroke cycle engine has two strokes of the piston, one up and one down, during each cycle. These two strokes occur during the one revolution of the crankshaft and are repeated over and over again.

The four stroke cycle engine has four strokes of the piston, two up and two down, during each cycle. The four strokes occur during two revolutions of the crankshaft. Most engines today have a four stroke cycle.

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. Every time the piston moves down it's a power stroke, every time it moves up it's a compression stroke The intake and exhaust take place during part of the compression and power strokes Figure 7-14 illustrates the cycle of events on a two stoke diesel engine.

(7-14)



Courtesy of John Deere Ltd

Occasionally, in this type of diesel engine, a blower (also called a scavenge blower) forces air into the cylinder for the expulsion of exhaust gases and the supply of fresh air for combustion. In place of intake valves 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.

As the piston nears the top of its compression stroke, fuel is sprayed into the combustion area. The heat of compression ignites the fuel and the resulting pressure forces the piston down on its power stroke. The piston then uncovers the intake ports, the exhaust valves open, and the cycle begins once more.

This entire cycle is completed in one revolution of the crankshaft or two stokes of the piston. The number of pistons the engine has makes no difference, all pistons in this two cycle engine will fire during one revolution of the crankshaft.

Four Stroke Cycle Engine

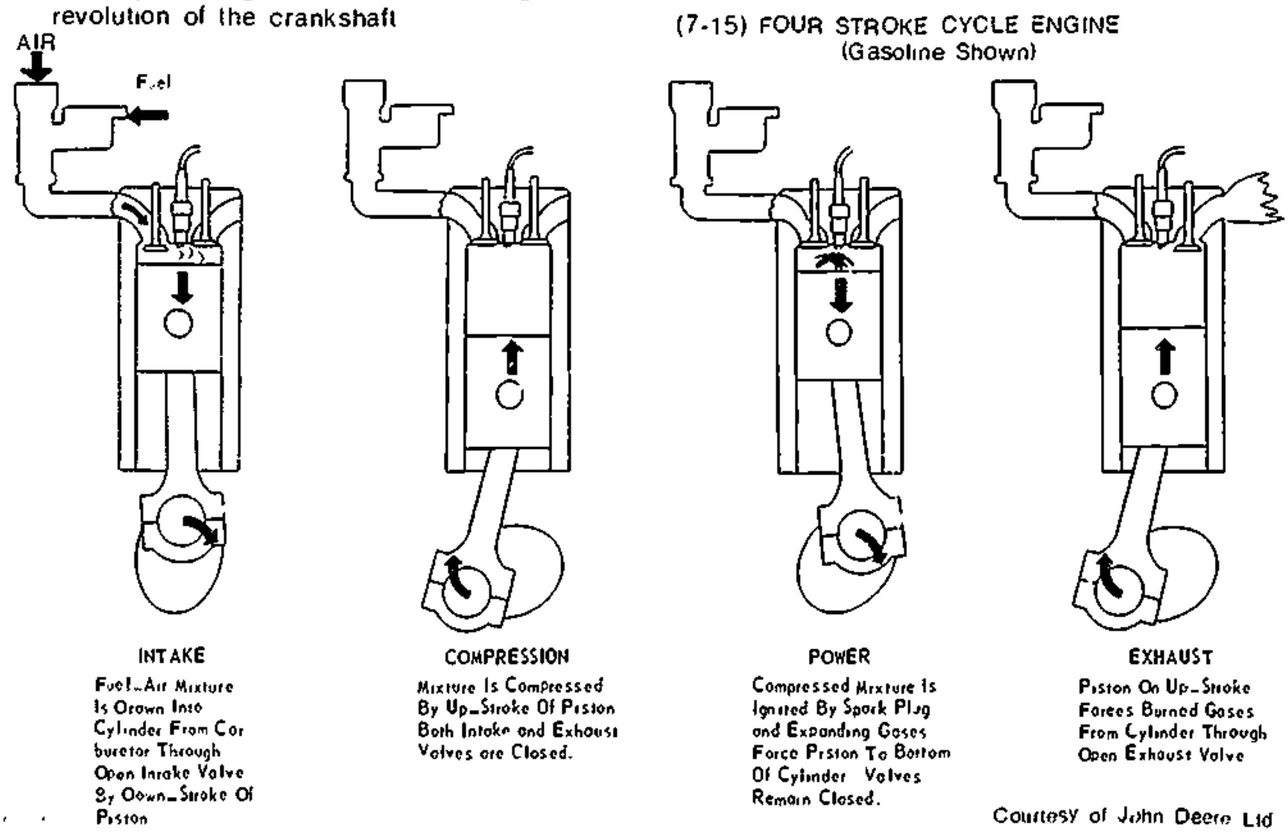
In four stroke cycle engines, the same four operations occur -- intake, compression, power, and exhaust; however, four strokes of the piston, two up and two down, are needed to complete the cycle. As a result, the crankshaft will rotate two turns before one cycle is completed.

Figure 7-15 shows the strokes of a four stroke cycle gasoline engine.

The **intake stroke** starts with the piston near the top and ends with it near the bottom of its stroke. The intake valve is opened and as the piston moves down a low pressure is created within the cylinder. Atmospheric pressure then forces the air-fuel mixture in a gasoline engine, or air only in a diesel engine, into the cylinder.

The **compression stroke** begins with the piston at the bottom of the cylinder. Next the piston rises, compressing the fuel-air mixture. Since the intake and exhaust valves are closed, there is no escape and the mixture is compressed to a fraction of its original volume.

(7-15) FOUR STROKE CYCLE ENGINE
(Gasoline Shown)



Courtesy of John Deere Ltd

The **power stroke** begins when the piston nears 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

The **exhaust stroke** begins when the piston reaches 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 When the piston completes the cycle the crankshaft will have gone around twice

Two Cycle versus Four Cycle Engines

It might be reasoned that the two cycle engine can produce twice as much power as a four cycle engine However, this is not quite true In 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, resulting in less power per power stroke Another loss in the effective power stroke occurs because the exhaust valves open earlier in a two cycle engine

The actual gain in power of a two cycle engine over a four cycle engine of the same displacement is about 75%

TYPES OF ENGINE COOLING

Engines can also be classified according to their cooling system There are two types of cooling water cooled and air cooled Air cooled systems are generally used on small engines although one manufacturer of diesel engines, Duetz uses air cooling on its engines Water or liquid cooled is the most common method of engine cooling Cooling systems are detailed later

TYPE OF FUEL BURNED

The three most common types of engine fuel are

- gasoline
- diesel
- Liquid Petroleum Gas (usually propane) (LPG)

The three fuel systems are discussed in detail further on in this section The chart in Figure 7-16 compares the performance of gasoline, LPG, and diesel engines

The comparisons assume that each fuel is available at a reasonable price. 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

(7-16)

COMPARING THE ENGINES

	Gasoline	LPG	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
Compression Ratio	Low	Higher	Highest

Courtesy of John Deere Ltd

QUESTIONS — INTRODUCTION TO INTERNAL COMBUSTION ENGINE

1. An internal combustion engine converts the __________ energy of fuel into __________ energy that does work.

2. What are the three basic elements needed to produce heat energy in an engine?

3. What happens to the air in a cylinder when it is compressed?

4. In what physical state is fuel burnt in an engine?

5. True or False? It is the nitrogen in air that causes fuel to burn.

6. An engine changes reciprocating motion into __________ motion to transmit energy.

7. For an engine to operate, which sequence of events must occur?
   (a) intake, exhaust, compression and power
   (b) compression, intake, power and exhaust
   (c) exhaust, power, compression and intake
   (d) intake, compression, power and exhaust

8. One complete series of the events in the last question is called a
   (a) stroke
   (b) circle
   (c) cycle
   (d) stroke-cycle

9. When both intake and exhaust valves are located in the cylinder head, the engine is said to be a
   (a) F-Head
   (b) I-Head
   (c) L-Head
   (d) N-Head

10. Briefly explain the basic difference between a two stroke cycle engine and a four stroke cycle engine.

11. Engines can either be __________ cooled or __________ cooled.

12. What are the three most common types of fuel burned in internal combustion engines?

13. What is the basic difference in the combustion processes of diesel and gasoline engines?

14. Why is the compression ratio higher in a diesel engine?

The remainder of this block on Engines will discuss the five basic engine support systems: cooling, lubrication, air induction, exhaust and fuel.

COOLING SYSTEMS

The cooling system has two functions.

1. To prevent overheating of the engine.

   Overheating could burn up engine parts in a short time. Some heat is needed for combustion, but a working engine generates too much heat. The cooling system must carry off this excess heat.

2. To regulate engine temperature.

   Regulating the temperature allows the engine to be maintained at the best heat level for good combustion during each stage of operation. During starting, no cooling is necessary since the engine must be warmed up as fast as possible. Later, during peak operations, the engine must be cooled.

TYPES OF COOLING SYSTEMS

Two types of cooling systems are used on modern engines:

Air cooling — air passes around the engine to dissipate heat.

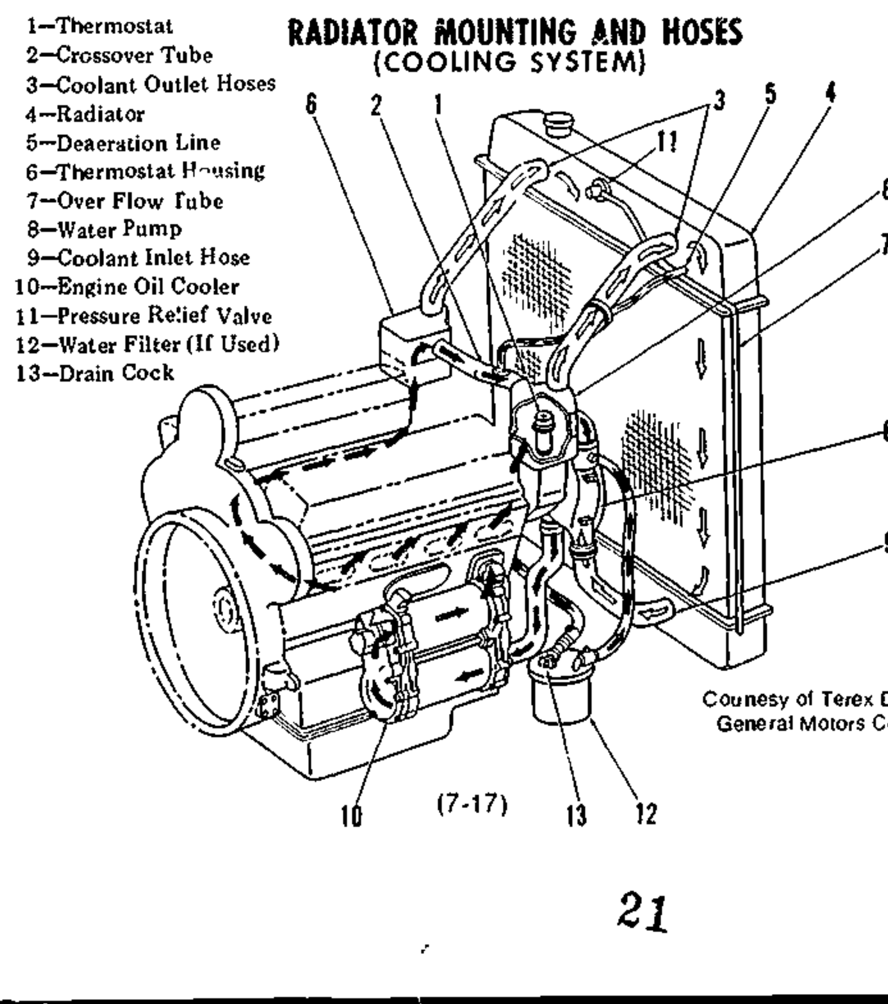
Liquid Cooling — water circulates around the engine to dissipate heat.

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 to engine parts.

Liquid Cooling normally uses water as a coolant. In cold weather, anti-freeze solutions are added to the water to prevent freezing.

The circulation of the coolant through the cooling system can be followed in Figure 7-17. A water pump (8), mounted on the engine, draws coolant from the radiator bottom, through the coolant inlet hose (9). The coolant is then forced through the oil cooler (10), and into the cylinder block. The coolant then circulates around the cylinder bores and up into the cylinder head water jacket, through the thermostat housings (6), up through coolant outlet hoses (3) and back to the radiator (4). 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.

RADIATOR MOUNTING AND HOSES (COOLING SYSTEM)



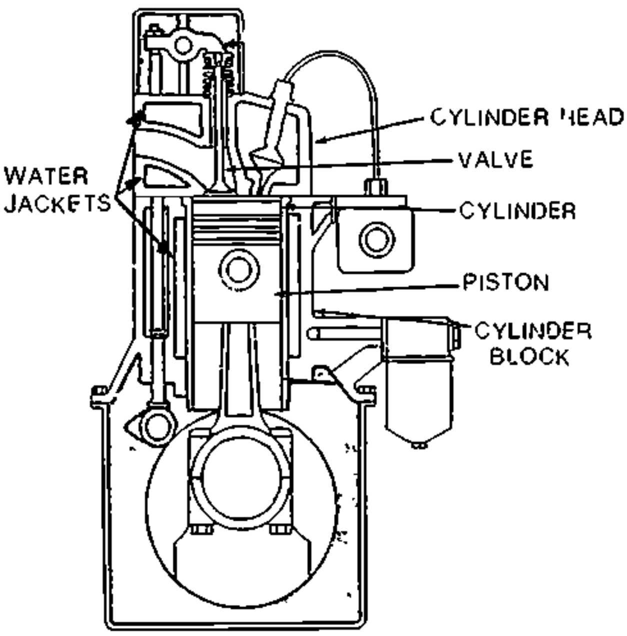
Courtesy of Terex Division of General Motors Corporation

(7-17)

COOLING SYSTEM COMPONENTS

Blocks, Heads and Manifolds

The engine cylinder block and head contain a number of connecting passages to allow coolant to flow completely around all of the cylinders, combustion chambers and valves. Together these passages make up the water jacket (Figure 7-18)

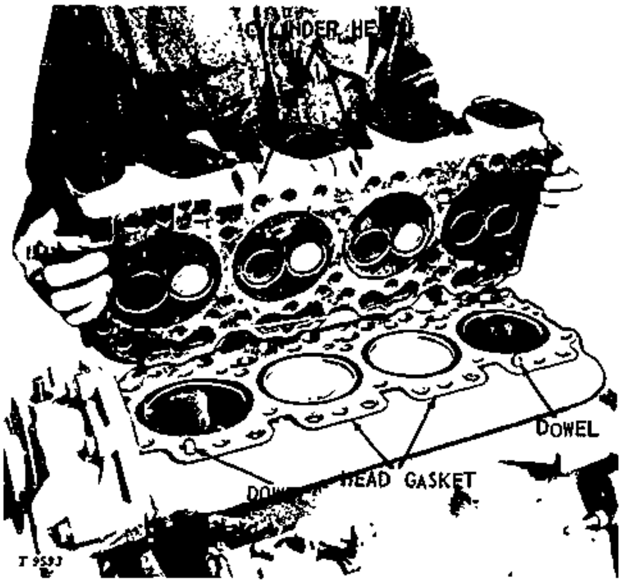


(7-18) IN-LINE BLOCK Courtesy of John Deere Ltd

The water jacket holds only a small amount of coolant This small amount allows for rapid warm up while the thermostat is closed when first starting the engine, but is still enough to provide efficient cooling to all the vital areas when the thermostat is open and the engine warm

Note the holes in the cylinder block and cylinder head in Figure 7-19 Not all, but many, of these holes are water passages

As well as the internal connecting passages of the water jacket, some engines use external connecting passages called water manifolds. They are bolted onto the outside of the engine by a flange mount and have a gasket between the two mating surfaces. Water manifolds are used, for example, between cylinder heads when an engine has multiple cylinder heads, or between the oil cooler and engine block.



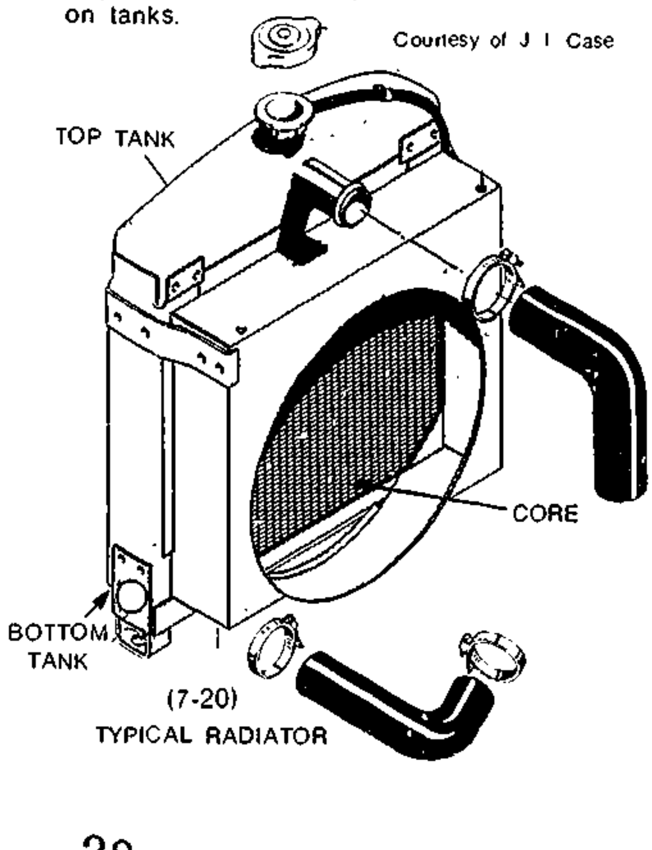
(7-19) REMOVING THE CYLINDER HEAD

Courtesy of John Deere Ltd

Radiator

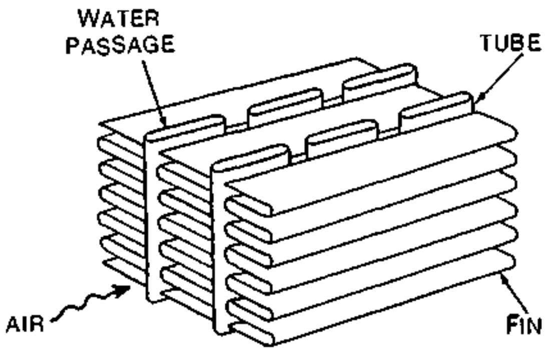
The radiator is the heat exchanger for the cooling system (Figure 7-20). It consists of a top tank, a bottom tank and a finned core section. The bottom tank is equipped with a drain at its lowest point. The tanks may be soldered to the core section like the one shown below, or the tanks and side pieces may be bolted to the core sections. Radiators used for large engines and machines generally have bolted-on tanks.

Courtesy of J I Case

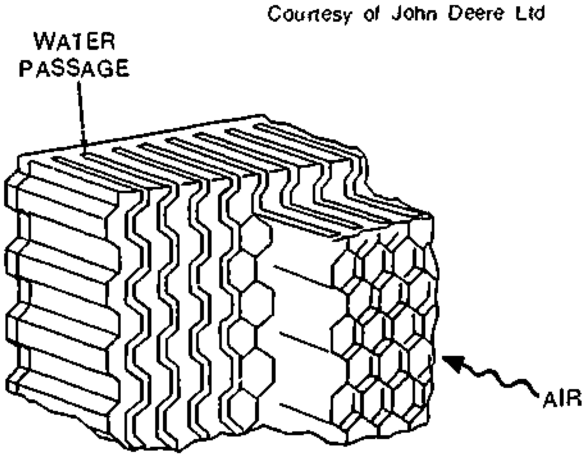


(7-20)
TYPICAL RADIATOR

Two types of radiator cores are illustrated in Figure 7-21, a tube and fin core and a cellular core. Variations on the tube and fin core are the most commonly used in radiators today.



(7-21) TUBE and FIN-TYPE RADIATOR CORES
Courtesy of John Deere Ltd



(7-21) CELLULAR-TYPE RADIATOR CORE
Courtesy of John Deere Ltd

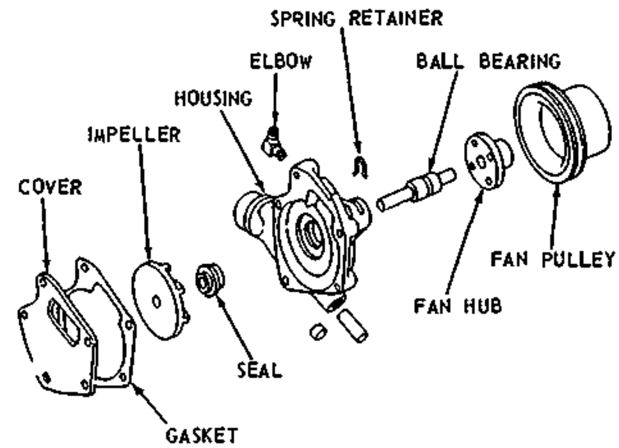
Radiators work on the principles of convection (circulation of the coolant) and radiation (sending heat in waves into the air). Flow created by the water pump and by thermal syphon action carries heated coolant from the engine to the radiator. The heated coolant enters the radiator by the upper radiator connection hose. As the coolant flows down through the core, heat from the coolant is transferred to the fins. From the fins the heat is radiated out into the air currents that pass through the core and is carried away.

Water Pump

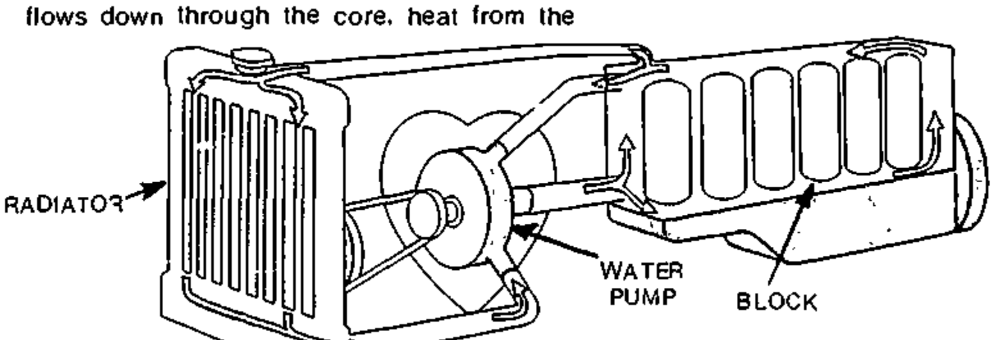
The water pump is said to be the heart of the cooling system: it must circulate the water throughout the cooling system (Figure 7-22).

The pump is located at the front of the engine and is generally driven directly or indirectly by V belts attached to the crankshaft pulley. The pump shaft is mounted on lubricated and sealed anti-friction bearings. The impeller, the part of the pump that propels the coolant, is pressed on the inner end of the shaft. The size and design of the impeller will depend on the coolant flow requirements of a particular engine.

Most cooling systems use a centrifugal pump similar to the one in Figure 7-23.



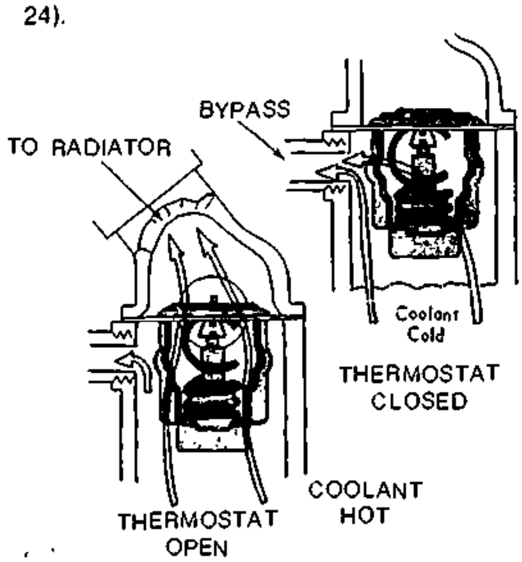
(7-23) WATER PUMP DISASSEMBLED
Courtesy of John Deere Ltd



(7-22) WATER PUMP Courtesy of John Deere Ltd

Thermostats

The thermostat provides automatic control of engine temperature to get the best performance from an engine The thermostat is basically a temperature sensing device and a valve. The temperature of the coolant acts on the heat sensory unit which opens and closes the valve creating a flow of coolant that maintains the desired engine temperature. Only a small part of the engine's cooling capacity is required under light lc Js, even during warm weather. During warm-up the thermostat remains closed; by means of a bypass the water pump circulates coolant through only the engine water jacket. The engine quickly warms up to its operating temperature before the thermostat opens. When the thermostat opens, hot coolant flows from the engine to the radiator and back to the engine (Figure 7-24).



(7-24) COOLING SYSTEM THERMOSTAT

Courtesy of John Deere Ltd

The thermostat is located between the coolant outlet of the cylinder head and the top tank of the radiator The exact location will vary from engine to engine. Large engines sometimes use two thermostats to reduce the restriction of water flow that can be caused by one thermostat.

The two most common types of thermostats are:

1. Wax pellet type — wax pellet expands with increased temperature to open the valve.
2. Bellows type — gas inside a bellows expands when heated causing the valve to open.

Thermostats are made in a variety of temperature ranges to meet various working conditions. A high temperature thermostat has some advantages. High-temperature thermostats, which open at 82°C (180 F) or more, improve engine operation and reduce crankcase sludging and corrosive wear of engine parts. An engine operating above 82°C (180 F) is hot enough to:

- improve combustion
- burn impurities out of the oil in the crankcase
- thin the oil to provide good lubrication

Caution: Do not use low-boiling-point alcohol or methanol anti-freeze with high-temperature thermostats.

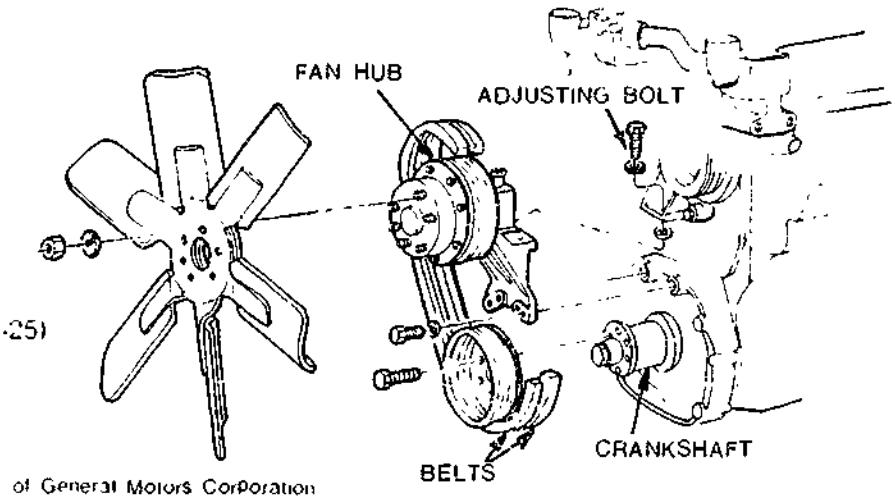
Overheating may so damage a thermostat that the valve won't function properly. Rust can also interfere with thermostat operation. If a thermostat is not running properly the engine will run too hot or too cold. The following practices should be observed with thermostats:

- Always keep a thermostat in good working condition.
- Never operate the engine without a thermostat.
- Always use the thermostat (design) specified for the make and model of the engine being used.)

Fans, Belts and Drives

The purpose of the engine fan is to create a draft of air through the radiator. When the engine runs, the fan pulls or pushes air across the radiator core to cool the liquid in the radiator. The ideal location of the fan is approximately 2½ inches from the radiator core. The size and number of blades on the fan will vary depending on the cooling requirements of the machine.

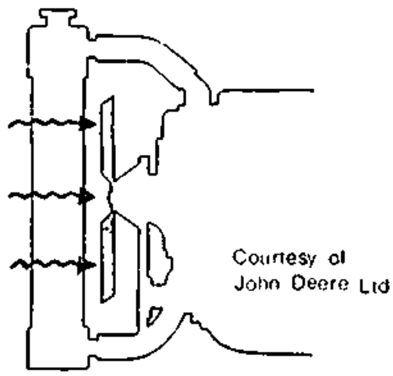
Fans on smaller engines are bolted to a flange on the water pump shaft. Larger engines have the fan mounted on a separate fan hub; this fan is generally driven by a belt(s) from the engine crankshaft, as seen in Figure 7-25.



(7-25)

Courtesy of General Motors Corporation

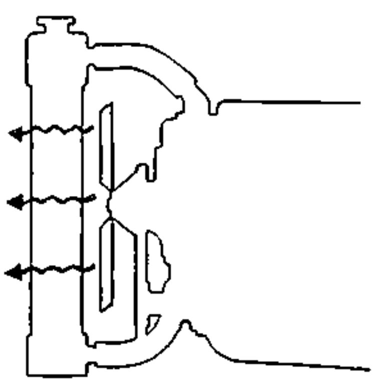
Fans can be either suction or blower fans, depending upon the design of the cooling system. Suction fans (Figure 7-26) pull air through the radiator and push it over the engine. The suction design permits the use of a smaller fan and radiator than is required for blower fans. Suction fans are used when machine motion aids air movement through the radiator such as on a truck.



(7-26)

Courtesy of John Deere Ltd

Blower fans (Figure 7-26) pull air across the engine, then push it through the radiator. They are used in slow-moving machines and on equipment where harmful materials might be drawn into the radiator by a suction fan.



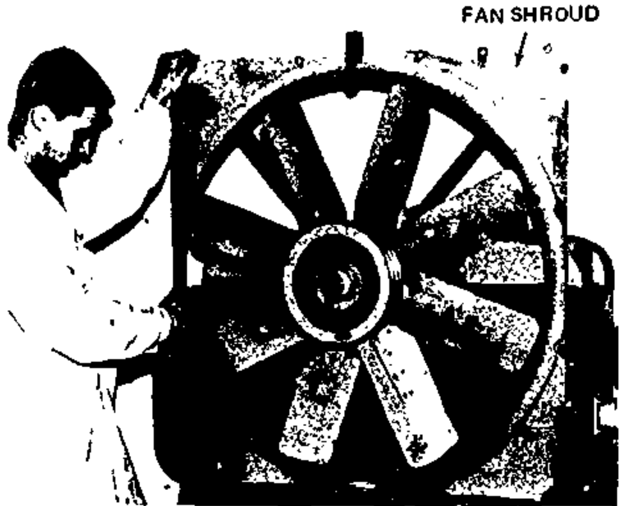
(7-26)

Courtesy of John Deere Ltd

The fan can be fixed drive or thermostatically-operated drive. The fixed drive fan turns continuously as the crankshaft turns, the thermostatic drive fan is temperature controlled and operates only when it is required. The thermostat drive has the advantage of not wasting engine horsepower to turn the fan when it isn't needed.

Some machines have a shrouding around the fan (Figures 7-27 and 7-28). Shrouding increases fan efficiency by controlling or directing air flow through the radiator. Fan shrouds fit close to the fan blades to prevent recirculation of air at the blade tips. A blower fan is usually set 1/3 into the shroud and a suction fan is usually set 2/3 into the shroud.

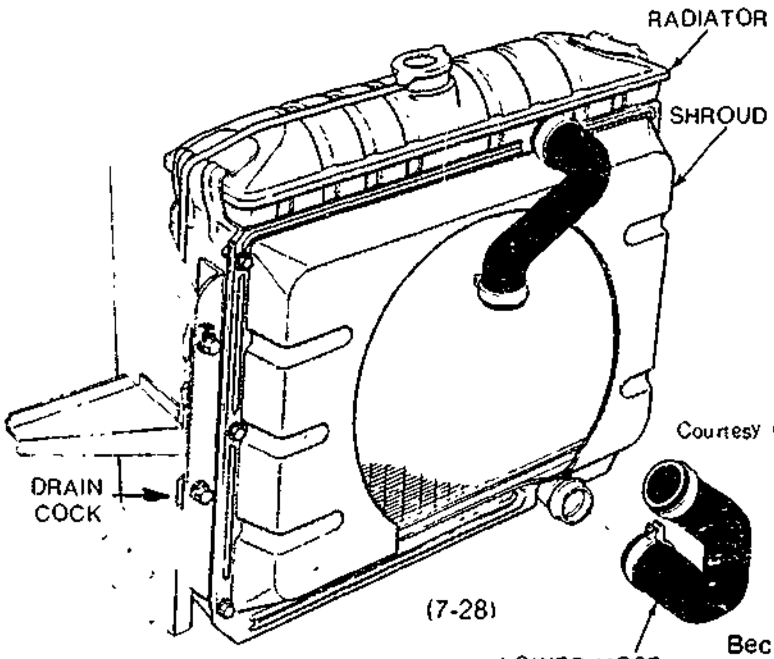
FAN SHROUD



Fan Shroud.

(7-27)

Courtesy of Caterpillar Tractor Co



(7-28)

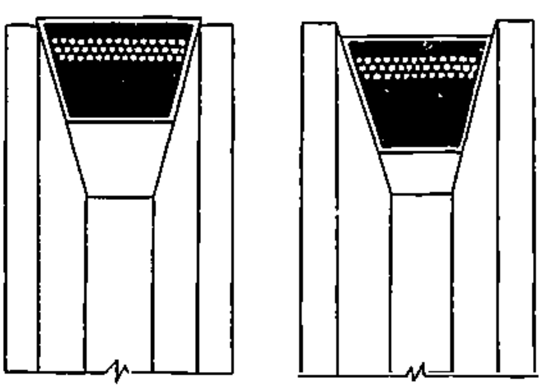
Courtesy of Ford Motor Company

Belts that drive fans are called V belts because of their V shape. A belt's ability to transmit power from the crankshaft depends on:

1. The tension holding the belt to the pulley. Belt tension is a very important service point and will be covered later.

2. Friction between the belt and pulleys. Belts should run dry. Oil on belts causes them to slip, and so any oil leaks in the area of the belts must be quickly repaired.

3. Arc of contact or wrap between the belt and pulleys. Wrap is built into a belt and pulley when manufactured. Figure 7-29 illustrates how a V-belt runs in a sheave both at rest and under load.



(7-29)

Courtesy of John Deere Ltd

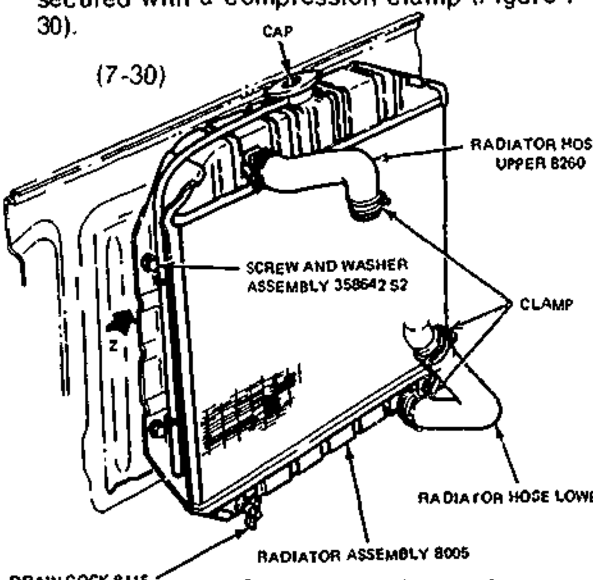
Because there is a definite fit to a belt and pulley, replace belts only with the type recommended in the service manual.

Small engines (on automobiles and light trucks) generally use one belt and this belt performs three jobs — drives the water pump, the fan, and the alternator. Larger gasoline and diesel engines use multiple belts in matched sets that may drive just the fan or they may drive all three: the fan, water pump and alternator.

Hoses and Clamps

Flexible hoses connect the radiator to the engine. Flexible hose is used rather than rigid pipe because the hose stands up better under vibration. Radiator hose slide fits over the radiator and engine connections and is secured with a compression clamp (Figure 7-30).

(7-30)



Courtesy of Ford Motor Company

Various types of hose are made:

1 **Straight hoses** will collapse if bent, and so is only used between two in-line fittings. Available in various I.D sizes and in three or four foot lengths to be cut as desired.

2 **Universal flex-hose** has spiral wire moulded into the hose to prevent it from collapsing when installed where a curved hose is required It too comes in various I D sizes and in three or four foot lengths to be cut as desired.

3 **Moulded hoses** are manufactured to the correct size, length and angle to fit a specific location.

As durable as hoses are, they still have weak points Radiator hoses can be damaged by hot air or over heated water and generally will deteriorate over long periods of usage. Two common types of hose damage are

1 Hardening or cracking which destroys hose flexibility, causing leakage and allowing small pieces of rubber from the hose's inner liner to clog the radiator.

2. Softening and swelling which deteriorates the hose lining and can cause the hose to rupture or break

Radiator Shutters

Shutters help to maintain optimum engine temperature by controlling air flow through the radiator

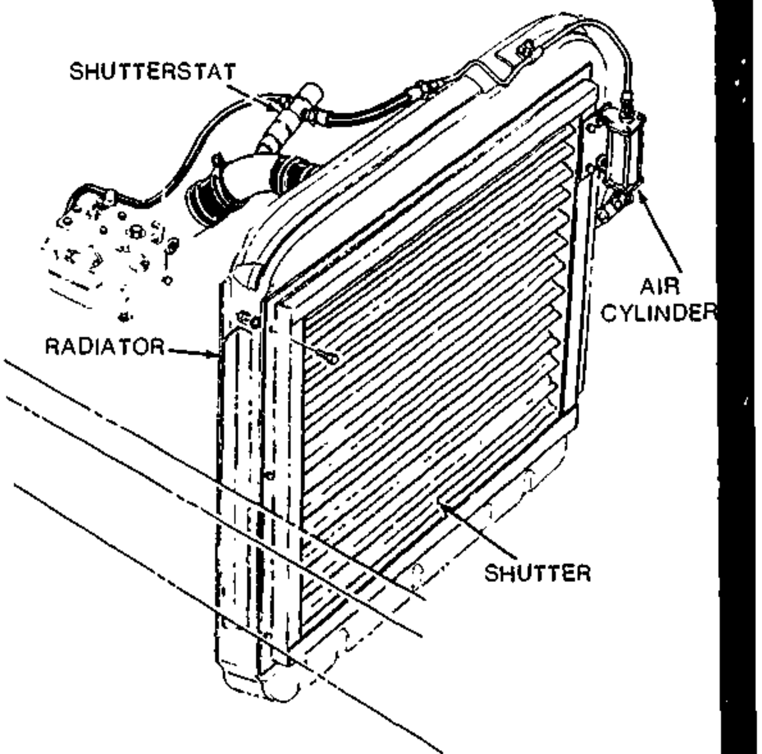
The system consists of (Figure 7-31):

1 the shutter

2 shutter control bar

3 air cylinder

4 shutterstat (temperature control valve)



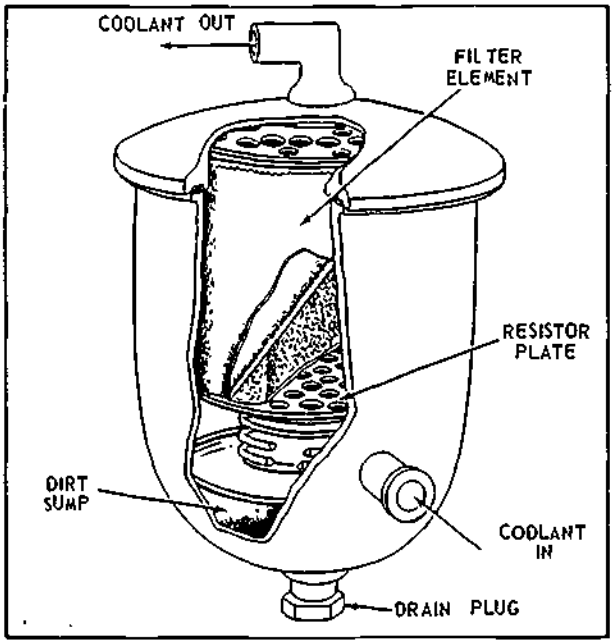
(7-31) AIR-OPERATED RADIATOR SHUTTER ASSEMBLY — GAS ENGINE

Q1015-A Courtesy of Ford Motor Company

Shutter action depends upon engine temperatures as sensed by the shutterstat. The shutterstat is located so that it responds to coolant temperature. Until coolant temperature rises to approximately 185 F (85 C), the shutters remain closed. When the shutterstat operating temperature is reached, thermostatic action shuts off air supply to the air cylinder and simultaneously exhausts air pressure from the cylinder. Shutter spring action then opens the shutters. Note that the shutters don't partially open; they are either fully open or fully closed.

Coolant Filter

Some engines use a filter in the cooling system The coolant filter (Figure 7-32) softens the water and removes dirt As a result, the cooling system dissipates heat better and its working parts wear longer



(7-32) COOLANT FILTER

Courtesy of John Deere Ltd

The coolant filter has a replaceable element. It also has a sump at the bottom of the filter where dirt settles. The sump drain plug should be opened periodically to dispose of the sediment.

Instead of replaceable element coolant filters, some manufacturers use spin-on filters that are thrown away after the engine has gone a certain number of miles For servicing their vehicle these manufacturers supply a set of spin-on-throw-away filters for oil, fuel and coolant They reason that the coolant filter is less likely to be overlooked (which does happen with replaceable element filters) if it is included with the other filters

Chemicals in the filter element and resistor plates soften the water by removing corrosives The softer water helps to keep the radiator and water jackets free of scale Another chemical in the filter dissolves into the water to alkalize it just enough to prevent acid corrosion of the metal parts. Rust inhibitors are also placed in the element which dissolve into the water and form a rust-protective film on the metal surfaces of the cooling system

The filter shown in Figure 7-32 is a bypass type If it clogs, all water will bypass the filter and go straight to the engine.

Different types of coolant filters are available One factor that has a bearing on filter type is the kind of anti-freeze used in the cooling system. Filters and anti-freezes must be compatible.

COOLANT

Coolant Requirements

A suitable coolant solution must meet the following basic requirements:

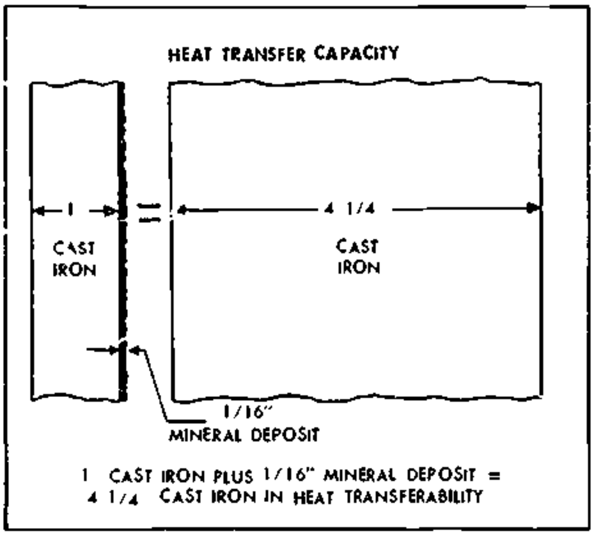
- provide for adequate heat transfer
- provide a corrosion-resistant environment within the cooling system
- prevent formation of scale or sludge deposits in the cooling system
- be compatible with the cooling system hose and seal materials
- provide adequate freeze protection during cold weather operation.

When freeze protection is not required a solution of suitable water plus corrosion inhibitors (assuming no coolant filter) will satisfy these requirements When freeze protection is required a solution of suitable water plus permanent anti-freeze (which contains corrosion inhibitors) will be a satisfactory coolant.

The Need For Corrosion Inhibitors

Any water, whether of drinking quality or not, will produce corrosion in the cooling system Also, scale deposits may form on the internal surfaces of the cooling system due to the mineral content of the water. Therefore, water used as a coolant, must be properly treated with inhibitors to protect the metallic surfaces of the cooling system against corrosion and scale deposits.

Figure 7-33 illustrates the harm done by mineral deposits, cast iron with mineral deposit withholds its heat rather than readily transferring it to the coolant.



(7-33)

Courtesy of Detroit Diesel Division of General Motors Corporation

All inhibitors become depleted through normal operation, and additional inhibitors (or anti-freeze) must be added to the coolant at prescribed intervals to maintain original strengths. Also, after a scheduled amoun' of hours or miles the coolant should be completely drained and replenished. Always follow the manufacturer's recommendations on inhibitor and anti-freeze usage.

Anti-freeze

When freeze protection is required, a permanent anti-freeze must be used. An inhibitor system is included in this type of anti-freeze, and no additional inhibitors are required if, on initial fill a minimum anti-freeze concentration of 30% by volume is used. Solutions of less than 30% concentration do not provide sufficient corrosion protection. Conversely, concentrations over 67% adversely affect freeze protection and heat transfer rates.

There are two kinds of anti-freeze: ethylene glycol base anti-freeze and methoxy propanol base anti-freeze. Ethylene glycol is most common. The methoxy propanol base anti-freeze is incompatible with the seals used in some cooling systems and should not be used unless recommended by the manufacturer.

The inhibitors in permanent anti-freeze should be replenished at approximately 500 hours or 20,000 mile intervals. Commercially available inhibitors may be used to restore inhibitor strengths in anit-freeze solutions. However, most manufacturer's will recommend changing the coolant and adding a new anti-freeze-water solution at certain hour or mileage intervals.

As was mentioned earlier, coolant filters which are found on some machines have corrosive inhibiting chemicals in their filtering material. Additional inhibitors are not needed and shouldn't be added. Cooling systems which have a filter and need permanent anti-freeze (which has corrosion inhibitors) will use a special type of filtering element.

Summary of Coolant Recommendations

1. Always use a properly inhibited coolant and maintain the inhibitor strength.
2. Do not use soluble oil as an inhibitor.
3. Always follow the manufacturer's recommendations on inhibitor and anti-freeze usage and handling.
4. If freeze protection is required, always use a permanent anti-freeze.
5. To keep up inhibitor strength in anti-freeze add a recommended non-chromate inhibitor or drain the system and change the anti-freeze.
6. Do not use a chromate inhibitor with permanent anti-freeze.
7. Do not use methoxy propanol base anti-freeze unless recommended by the manufacturer.
8. Do not mix ethylene glycol base anti-freeze with methoxy propanol base anti-freeze in the cooling system.
9. Do not use an anti-freeze containing sealer additives.
10. Use extreme care when removing the radiator pressure control cap.

PREVENTIVE MAINTENANCE SERVICE ON COOLING SYSTEMS

The cooling system should be visually inspected during the daily walk around check. and during scheduled maintenance on the system. Minor problems should be immediately repaired. and major ones should be reported Inspection checks on the cooling system can be found in the service manual and should include the following.

1 Check the coolant level and add water if low.

   (a) System without reserve tanks. remove the radiator cap and check the coolant level. Caution: If the system is hot. it contains pressure. Removing the radiator cap when the coolant is hot could cause injury. Wait until the coolant cools down. and then slowly remove the cap. Hissing after a slight turn of the cap will indicate the system is still under pressure and too hot to open.

   (b) Cooling system with reserve tanks: check the coolant level by checking the level of the see-through plastic reserve tank or by removing the cap.

2. Inspect for leaks. Leaks can occur in the radiator, on the outside of the engine waterjacket. in hoses and at hose connections. Internal water leaks can also occur. but they won't be dealt with here. Leakage is the most common problem in a cooling system and can increase during winter due to metal shrinkage. Air pressure leakage testers can be helpful in locating external leaks. Leaks are easiest found when the system is cold.

   Minor leaks can be repaired with a sealing compound. However. only practical experience enables a serviceman to tell if a leak can be corrected with a sealing solution. Follow instructions when using sealing solutions; some react chemically with anti-freeze and rust inhibitors and may seriously affect coolant performance.

Radiator Leakage

Most radiator leakage is due to cracking of soldered joints caused by engine vibration. frame vibration. and cooling system pressure.

Carefully examine radiator for leaks before and after cleaning. Some leakage points may have gone undetected because they were plugged with rust. White. rusty. or colored stains indicate previous radiator leakage. If water or an alcohol-based anti-freeze is used these spots may be dry because such coolants evaporate quickly. If the stains are damp it's because an ethylene glycol anti-freeze was used and it doesn't evaporate.

Always seal a radiator leak before installing anti-freeze coolant. Depending on size and number. radiator leaks can be repaired with a sealing compound. by soldering. or they may have to be tended to by a radiator repair shop. Note that sealing compounds are not recommended by some manufacturers because:

1. they aren't a permanent repair.
2. they can ultimately cause plugging of the radiator.

Other Radiator Checks

1. Check radiator baffles (Figure 7-34). Missing or damaged baffles can allow enough air recirculation to cause overheating.

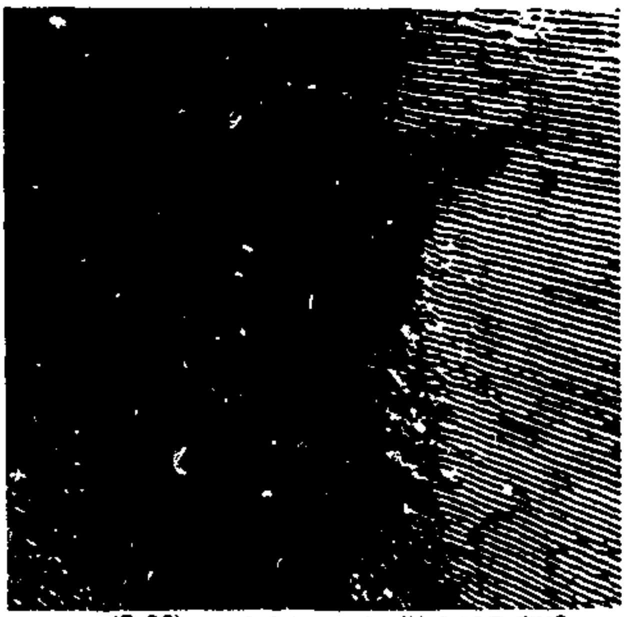
BAFFLES

(7-34)

Courtesy of Caterpillar Tractor Co

2. Check for radiator plugging. The major cause of reduced air flow is the accumulation of foreign material in the radiator core air passages (Figure 7-35). In land clearing, sanitary land fill and other jobs where trash is present, leaves, weeds and other debris are drawn into the radiator core. As the core becomes plugged, the effective cooling area is reduced and heat transfer rapidly decreases.

Courtesy of Caterpillar Tractor Co.



(7-35) DIRT CAKED IN CORE FINS

PLUGGED RADIATOR CORE

Keep the radiator clean and free of dirt and trash. A quick visual observation usually won't detect core plugging. A close inspection is necessary. Check the radiator core area outside the fan circle. The core is usually free of plugging within the fan circle, but a close look often reveals extensive plugging in the outer core areas. An air flow meter can be used to measure the flow of air through the radiator and thus pinpoint plugged areas

The radiator core can be cleaned with water or air pressure (Figure 7-36).

(7-36) CLEANING THE RADIATOR CORE

Courtesy of Caterpillar Tractor Co

External Waterjacket Leakage

Inspect the engine cylinder block while the engine is running both before and after it gets hot. Leakage of the engine block is aggravated by pressure in the cooling system and temperature changes of the metal. Small leaks may appear only as rust, corrosion, or stains due to evaporation.

Other Leakage Areas

Watch for leaks at these trouble spots

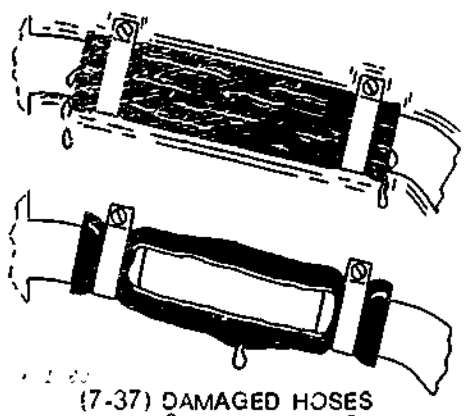
1. Core-Hole or Frost Plugs: Remove the old plug then clean the plug seat and coat it with a sealing compound. Drive a new plug into place with the proper tool

2. Gaskets: Tighten the joint or install a new gasket. Use a sealing compound when required.

3. Stud Bolts and Cap Screws Apply sealing compound to threads.

4. Check for leaks in hose lengths and at hose clamps. Also check for hose deterioration (Figure 7-37).

   Cooling systems are constantly expanding and contracting as the engine starts, runs and shuts down. Owing to such variations in temperature, clamps can loosen and the hose material can deteriorate.



(7-37) DAMAGED HOSES
Courtesy of John Deere Ltd

Hoses and clamps should be examined at least twice a year. Check the outside of hoses for

(a) hardening, cracking
(b) softening, swelling

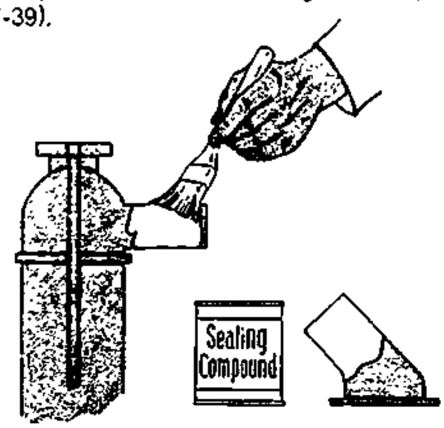
Cracked or swollen hoses should be replaced immediately. Also check the inside of hoses for:

(a) corrosion of any reinforcing springs.
(b) material failure. Hoses can deteriorate on the inside and still appear all right on the outside (Figure 7-38).

(7-38) INTERIOR OF DAMAGED HOSE
Courtesy of John Deere Ltd

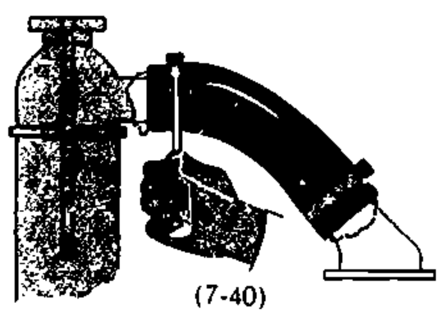
To be safe replace hoses often enough so that they are always pliable and able to pass coolant without leakage. When replacing hoses:

1. Use the best quality hose available.
2. If universal flex hose is used, allow enough hose for movement, but not so much that buckling or wrinkling occurs.
3. Straight hose must only be used when connections are in-line.
4. Moulded hoses must be of the correct shape and length.
5. Clean the pipe connections and apply a thin layer of non-hardening sealing compound when installing hoses (Figure 7-39).



(7-39) SEAL THE CONNECTIONS
Courtesy of John Deere Ltd

Locate the hose clamps properly over the connections as shown in Figure 7-40 to provide a secure fastening. An improperly installed hose (1) will be blown off by the pressurized cooling system or (2) will allow air to be drawn into the inlet side of the pump, causing aeration of the coolant which is very harmful to the engine.



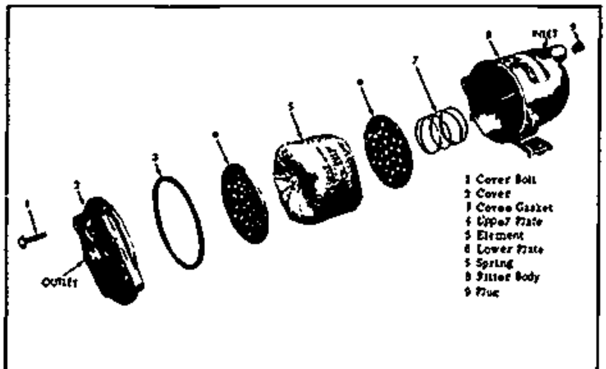
(7-40)
TIGHTEN HOSE CLAMPS SECURELY
Courtesy of John Deere Ltd

CHANGING THE COOLING FILTER

Cooling filters should be changed at the time intervals stated in the service manuals. A typical maintenance procedure is given below.

Cooling Filter Service

1 Check the condition of the electro-chemical plates. 4 and 6 in Figure 7-41, after every 500 hours of operation. If the plates are rusted, pitted or corroded, they should be cleaned with steel wool, and then rinsed in cleaning solvent and dried with filtered, compressed air. When the plates are badly deteriorated, install new ones.



1 Cover Bolt	6 Lower Plate
2 Cover	7 Spring
3 Cover Gasket	8 Filler Body
4 Upper Plate	9 Plug
5 Element	

(7-41) WATER FILTER COMPONENTS
Courtesy of General Motors Corporation

2. The sump at the bottom of the housing (8) should be drained and cleaned out every 500 hours.
3. Change the filter element (5) every 500 hours (see Manual for Procedures).

After the filter has been reassembled and installed, check the following points:

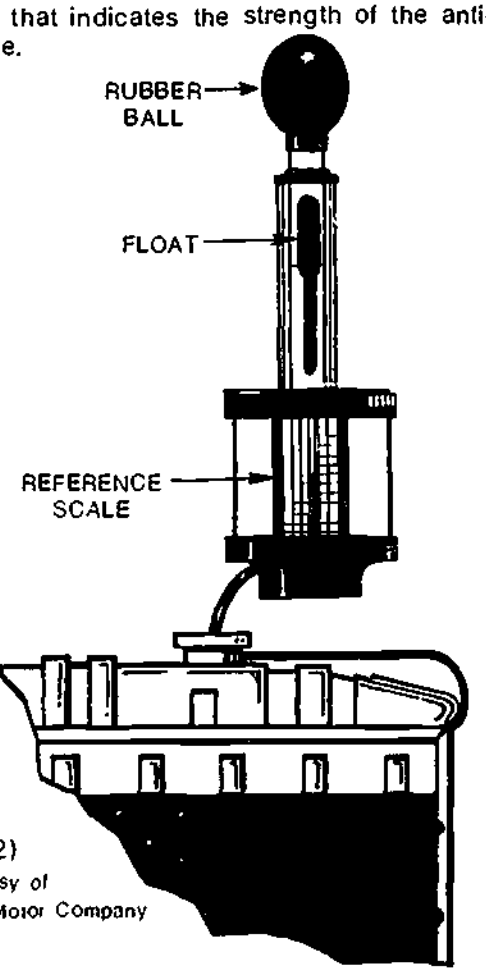
1. Make sure the inlet and outlet shut-off valves are open
2. Check all hoses, fittings and connections for leaks.
3. Check the coolant level in the radiator and replenish as neccesary to compensate for losses during cooler servicing.

These points are extremely important. For example, you can imagine what would happen if the valves were not opened.

Sometimes the filter may be serviced when the complete cooling system is drained and flushed. When installing new coolant remember the following: never add rust inhibitor to a cooling system that has a water filter. The filter contains a corrosion inhibitor

Testing Anti-freeze

The strength of anti-freeze solution must be sufficient to prevent freezing at the lowest temperature expected. A number of testers are made to check the strength of anti-freeze but a hydrometer is the most common one (Figure 7-42). The hydrometer works on the principle of a float in a sight glass rising to a level that indicates the strength of the anti-freeze.



(7-42)
Courtesy of
Ford Motor Company

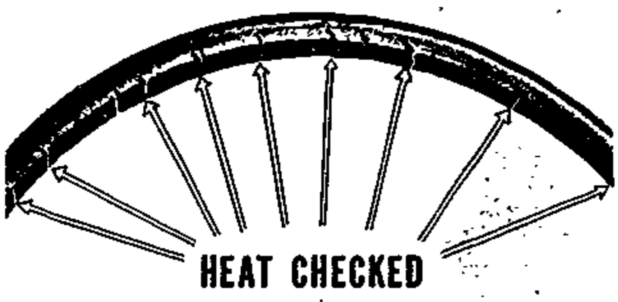
To use the hydrometer, insert the hydrometer rubber hose into the coolant at the top of the radiator. Squeeze the rubber ball of the hydrometer to draw up the coolant into the sight glass. The float will rise to a certain level. Compare this level to a reference scale to determine the strength of the anti-freeze solution.

BELTS

Belts have to be checked for their condition, alignment and tension

Belt Condition

Belts are not meant to ride on the bottom of the groove When they do, they heat check and crack (Figure 7-43) or grow hard and polished A heat damaged belt indicates that either it's badly worn, forcing it to ride too low in the sheave, or that the sheave is dished out (Figure 7-44).

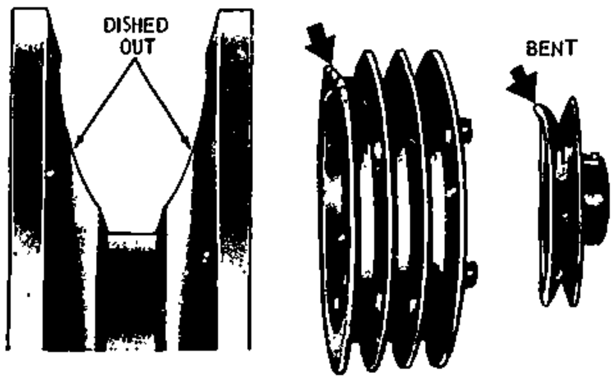


(7-43) BELT RUINED BY TOO MUCH HEAT
Courtesy of John Deere Ltd

In addition to heat, grease and oil can also ruin drive belts If oil or grease is allowed to soak into a belt, it can soften, swell and generally deteriorate very rapidly. Note that oil resistant belts are available for certain engine locations that are unavoidably greasy or oily. When oil or grease is found on a belt, wipe it off with a clean cloth dampened with a detergent solution. Then dry the belt with a clean dry cloth.

CAUTION: Never try to clean a belt while it is operating.

While inspecting the belts, the condition of the pulleys or sheaves should be checked. Examine pulleys for chips, cracks, bent sidewalls, rust, corrosion or other damage (Figure 7-44). Damaged sheaves cause rapid belt wear and should be repaired or replaced immediately



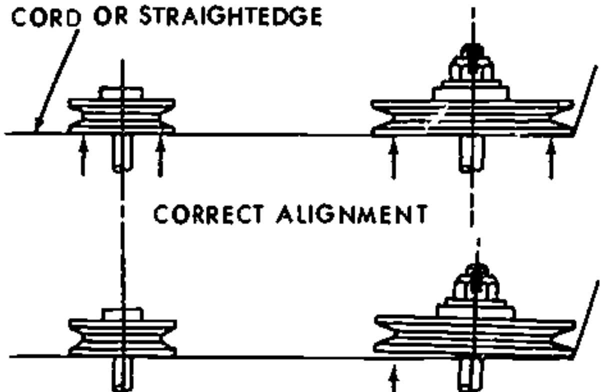
(7-44) DAMAGED SHEAVES
Courtesy of John Deere Ltd

Other points on belt condition:

- A tear on the outside cover could be caused by something interfering with the belt. Ticking sounds when the belt is running may indicate interference.
- A belt that has operated while rolled over in the sheave groove is probably damaged. Replace it.
- Store belts in a cool, dry place. If stored on a machine, relieve tension on the belts.

Belt Alignment

Misalignment soon causes a good belt to fail. Misalignment usually occurs when the mounting for the component that the belt is driving comes loose or has been improperly installed Belt alignment can be checked by lining up a cord or straight edge on the side of the two pulleys, as shown in Figure 7-45 Make at least two checks, 180 apart



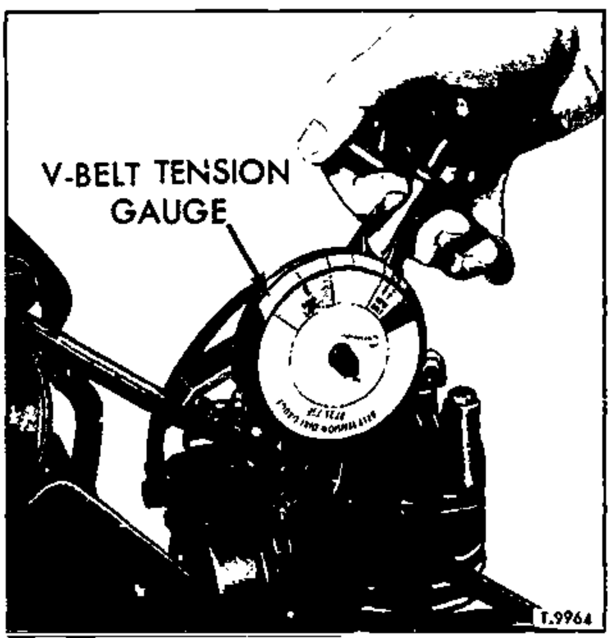
(7-45) PULLEY ALIGNMENT
Courtesy of General Motors Corporation

Belt Tension and Adjustment

To carry their full load, drive belts must grip the entire area of contact with the pulley. Improperly adjusted belts can damage the pulleys. Loose belts undergo unnecessary wear; they can slip, tear, burn or grab and snap. Belts that are too tight, can also cause problems. They can damage the engine by over-loading the crankshaft, crankshaft bearings, and accessories or accessory bearings. Also, excessive tension on a belt will stretch and weaken it.

To get maximum life and performance from a belt it must be run at the correct tension. Belt tension can be checked by:

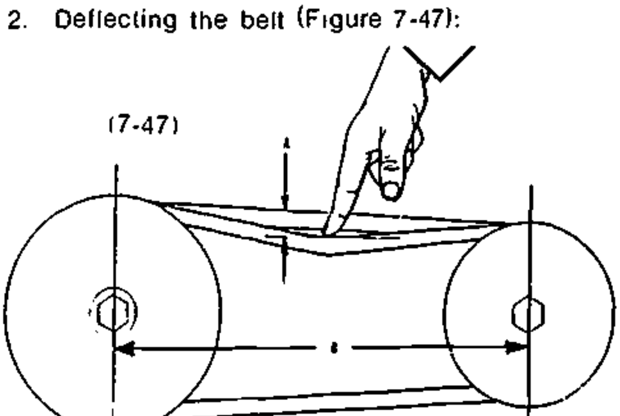
1. A belt tension gauge. Markings on the gauge will indicate correct or incorrect tension (Figure 7-46).



(7-46) Courtesy of General Motors Corporation

2. Deflecting the belt (Figure 7-47):

(7-47)



Courtesy of Cummins Engine Company

The chart in Figure 7-48 shows the amount of deflection different size belts should have. If a belt deflects 1/8 of an inch too much or too little, readjust it.

(7-48)

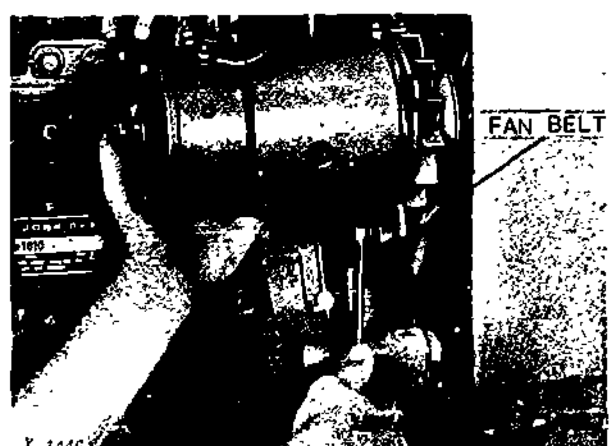
Table 2: Fan Belt Tension

Belt Width Inch (mm)		Deflection Per ft. of Span Inch (mm)	
1/2	(12.700)	13/32	(10.3187)
11/16	(17.4625)	13/32	(10.3187)
3/4	(19.0500)	7/16	(11.1125)
7/8	(22.2250)	1/2	(12.7000)
1	(25.4000)	9/16	(14.2875)

Courtesy of Cummins Engine Co

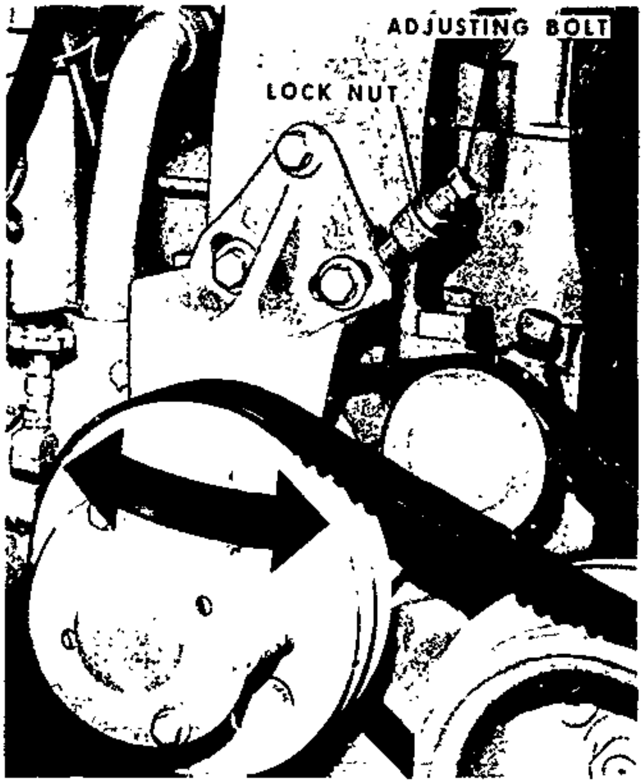
The gauge is the most accurate method to check belt tension but the deflection method is very reliable too.

Figures 7-49, 7-50 and 7-51 show three types of belt adjusting methods using either slotted or elongated holes. Adjusting a belt requires moving one of the pulleys away from the other if the belt is too loose, or vice versa, closer to the other if the belt is too tight.



(7-49) ADJUSTING BOLT IS IN A SLOTTED BRACKET (Gasoline Engine)

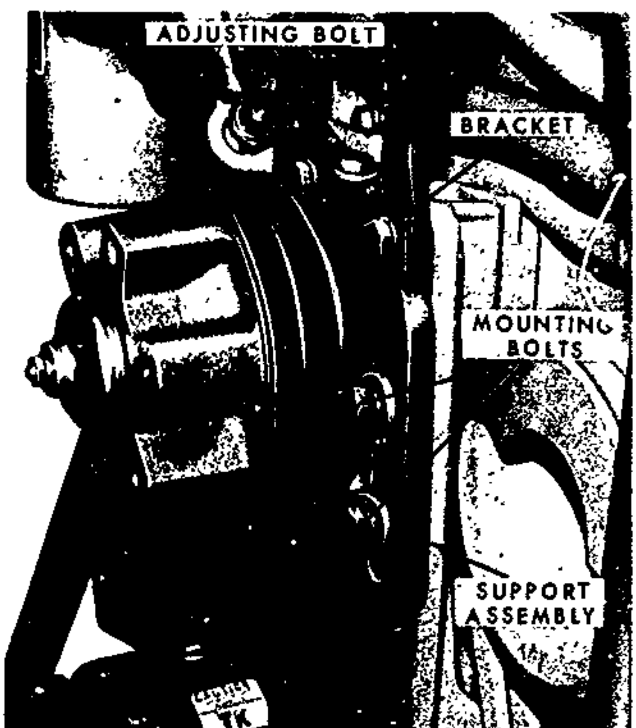
Courtesy of John Deere Ltd



(7-50)

ADJUSTING BOLT
(Diesel Engine)

Courtesy of General Motors Corporation

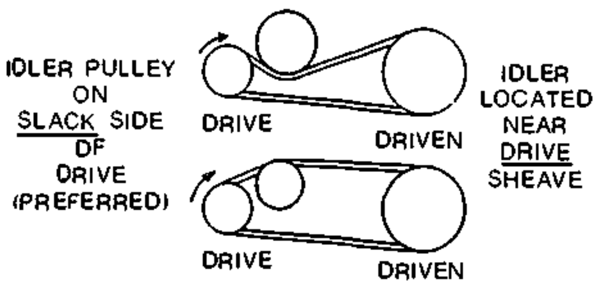


(7-51)

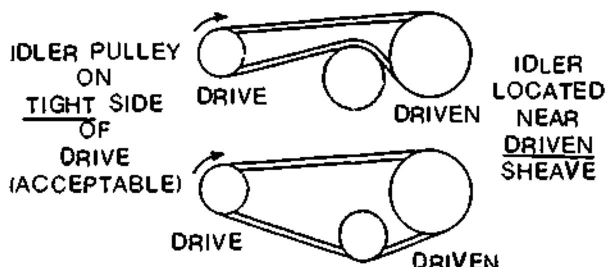
ADJUSTING BOLT IN
ELONGATED HOLE
(Diesel Engine)

Courtesy of General Motors Corporation

Some belt-pulley systems use a third pulley called an idler which is moved to adjust the belt tension (Figure 7-52).



(7-52) Courtesy of John Deere Ltd



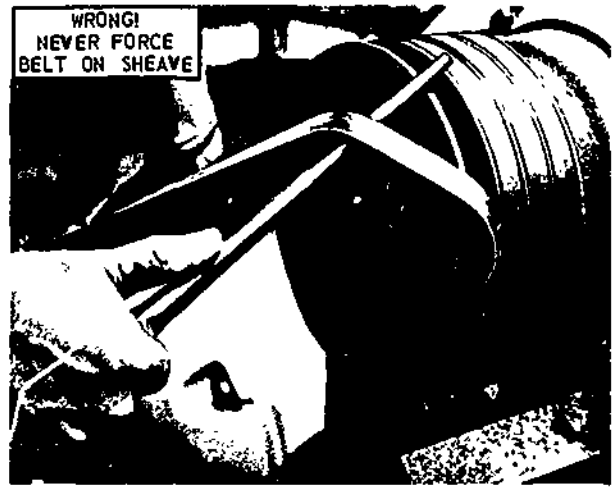
(7-52)

An idler pulley can be used on both a continuous and an intermittent drive fan For continuous drive the idler is adjusted in a set position For intermittent drive the idler is moved in to apply tension and start the fan, and out to slacken the tension and stop it The idler on the intermittent fan is operated by a temperature controlled air cylinder.

Good Practices When Installing and Adjusting Belts

1. When replacing dual or triple running drive belts, replace the complete set of belts at the same time. Uneven operation would result from running a new belt with worn ones. Install them in the sets supplied by the manufacturer. Never combine belts from different sets.

2. Never pry a V-belt or force it into the sheave groove. You can damage both the belt and the drive component. Loosen the tightener before installing the belt. (Figure 7-53).



(7-53)
NEVER FORCE A V-BELT ONTO A SHEAVE

Courtesy of John Deere Ltd

3. Never attempt to check or adjust belts while they are running.

4. V-belts stretch most during their first 24 hours of operation. Check the tension of a new belt after it has run for a few shifts.

5. Never attempt to correct belt slippage by using a belt dressing. If belts slip even when properly tensioned, check for overload, worn sheave grooves, oil or grease on belts, or seized bearings.

6. Note that more fan belts fail from being too loose than from being too tight. However, don't overtighten belts: you'll damage the drive component's bearings.

QUESTIONS — COOLING SYSTEM

1 What are the two basic purposes of the cooling system?

2. True or False? In a liquid cooled system the coolant flows into the bottom of the radiator and out through the top.

3 What is the purpose of having the water jackets hold only a small amount of coolant?

4 The radiator is a ______________ for the cooling system.

5 Radiators work on the principle of

(a) currents
(b) convention
(c) convection
(d) circulation

6 What is the function of the water pump?

7 Engine temperature is automatically controlled by the use of a ______________.

8 True or False? Thermostats that operate at 180°F or more improve engine operation and reduce both crankcase sludging and corrosive wear of engine parts.

9. On what type of machines are blower fans used rather than suction fans? What is the reason?

10. Shrouding is used around a fan to:

(a) simply protect the fan blades.
(b) to increase fan efficiency
(c) quieten fan operation
(d) make it look neater

11. True or False? All belts fit the same just the lengths are different.

12. Radiator shutters are:

(a) closed by spring pressure and opened by air
(b) closed by spring pressure and opened by spring pressure
(c) closed by air pressure and opened by air pressure
(d) closed by air pressure and opened by spring pressure

13. What is the purpose of the water filter?

14. True or False? Any water, whether of drinking quality or not, will produce a corrosive environment in the cooling system. Thus the need for ______________.

15 On an engine equipped with a coolant filter and using anti-freeze, what precaution must be taken when changing the filter?

16. What is the most common problem with a cooling system?

17. Leaks are easiest found when the system is ______________.

18. Give two reasons why some manufacturers do not recommend sealing compounds to fix radiator leakage.

19. What is the major cause of air flow restriction in a radiator and how can it be improved?

20. What is the obvious sign of a hose that is deteriorated?

21. List the three things belts should be checked for during a P.M. of the cooling system.

22 List the three important checks that should be made after installing a new water filter element.

23 The strength of the anti-freeze solution is checked with a:

(a) water meter
(b) ammeter
(c) hydrometer
(d) any of the above

24. True or False? A V-belt is designed to ride on the sides and bottom of the pulley.

25. A good maintenance practice for V-belts on a vehicle that is to be stored for a period of time is to:

(a) adjust it for the correct tension
(b) relieve all belt tension
(c) remove the belt entirely
(d) cover the belt to protect it

26. When replacing dual or triple drive belts the recommended practice is to:
    (a) replace all as a set
    (b) replace only the worn one(s)
    (c) remove the worn one(s) and run the other(s) until they need replacing

27 Referring to the fan belt tension chart, find out how much a 3/4 inch belt with a span of $1^1/_2$ feet should deflect.

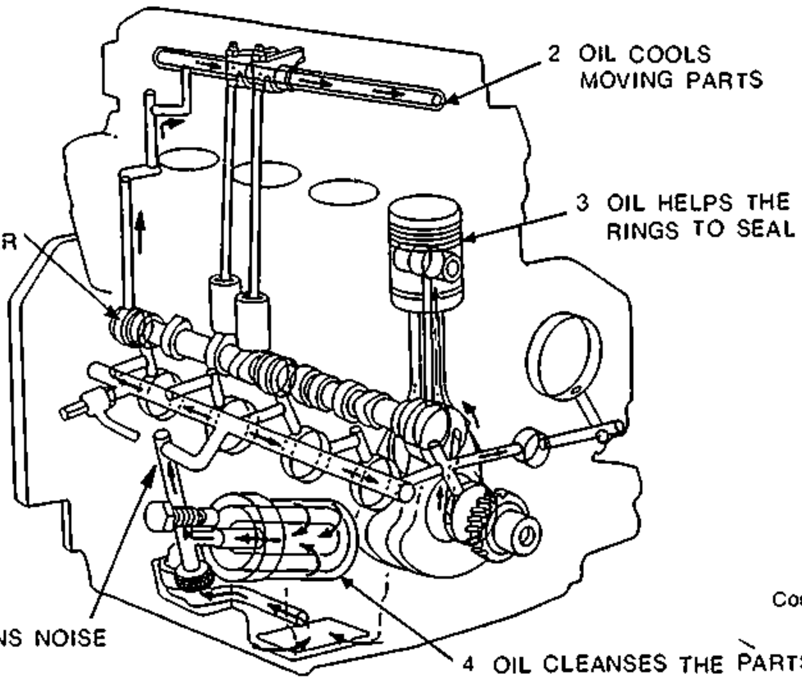
LUBRICATION SYSTEM

The lubrication system is another one of the five support systems common to all engines

The lubrication system does the following jobs for the engine (Figure 7-54).

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.

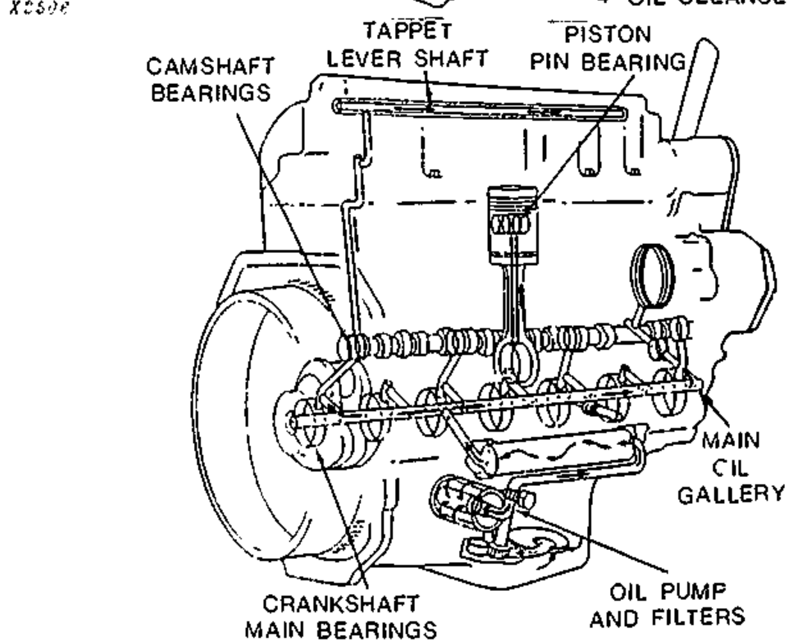
The basic lubrication system used on today's engines is called a full pressure system. Full pressure means that oil is delivered under pressure created by the oil pump to all the vital lubrication areas of the engine Figure 7-55 shows a full pressure system and some of the areas that it must serve.



(7-54)

WHAT AN ENGINE OIL MUST DO

Courtesy of John Deere Ltd



(7-55)

Courtesy of John Deere Ltd

LUBRICATION SYSTEM COMPONENTS

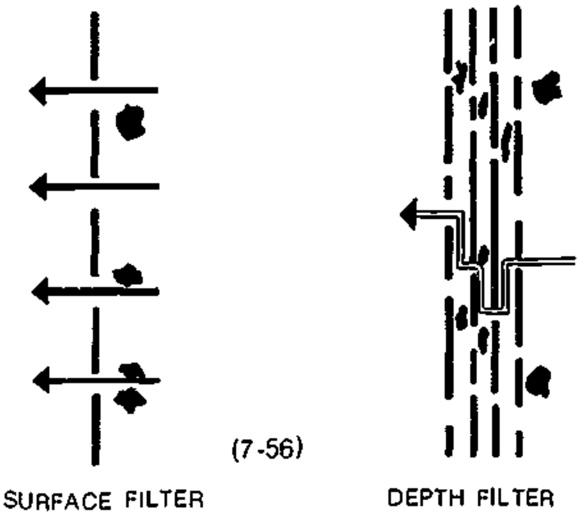
1. Oil pump and relief valve.
2. Oil Sump — usually referred to as Engine Oil Pan.
3. Filter(s)
4. Oil Cooler.
5. Pressure Differential Valves for coolers and filters.
6. Breathers and vents.

Oil Pump

The oil pump is a positive displacement gear pump which can be mounted internally in the sump or externally on the engine block. Oil pumps are driven either by the crankshaft or the camshaft or by the timing gear train. The pump must distribute oil under pressure throughout the lubrication system Oil pressure varies in different engines usually from 20 P.S.I. to 65 P.S.I., although some will go even higher. To protect the pump from pressures higher than it is designed for, a maximum pressure relief valve is located in or near the pump. A further protection to the pump is a pick-up screen on the intake line that prevents large pieces of contaminant from getting into the pump.

Oil Filters

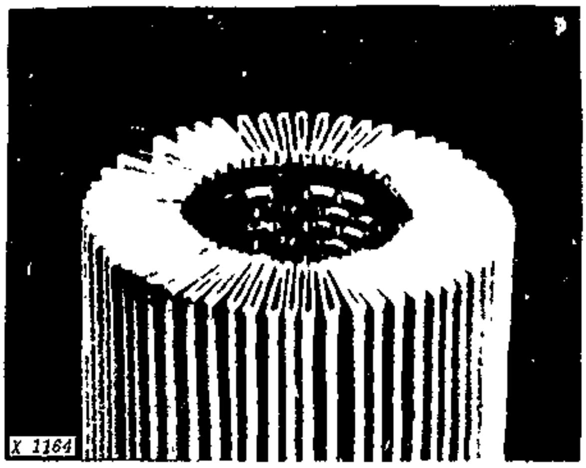
Oil contamination reduces engine life more than any other factor. To help combat it oil filters are built into all modern engine lubrication systems. The two basic types of oil filters are surface filters and depth filters (Figure 7-56). In surface filters oil flows straight through the filtering material, whereas in depth filters the oil takes an irregular path.



(7-56)

Courtesy of John Deere Ltd

Surface Filters have a single surface that catches and removes dirt particles larger than the holes in the filter. Dirt is strained or sheared from the oil and stopped outside the filter as oil passes through the holes in a straight path. Many of the large particles will fall to the bottom of the reservoir or filter container, but eventually enough particles will wedge in the holes of the filter to prevent further filtration. At this point the filter must be cleaned or replaced. The pleated paper filter in Figure 7-57 is a surface filter.



(7-57) PLEATED PAPER FILTER

Courtesy of John Dee Ltd

Depth Filters in contrast to surface filters, use a large volume of filter material to make the oil move in many different directions before it finally gets into the lubrication system. The filter made of cotton waste in Figure 7-58 is an example of a depth filter.

X 1114

(7-58)

DEPTH FILTER – COTTON WASTE TYPE
Courtesy of John Deere Ltd

FILTERING SYSTEMS

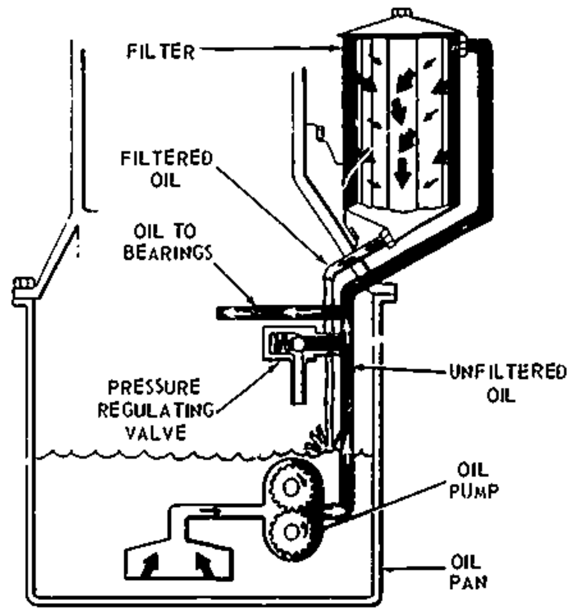
There are two basic types of filtration systems: bypass and full-flow. Some larger diesel engines use a combination of the two systems.

Bypass Filtration System

In the bypass filtration system there are two separate oil flows, one to the bearings and one to the filter (Figure 7-59).

In this system, five to ten percent of the oil delivered by the pump is routed or bypassed to the filter instead of to the bearings. After filtering, the oil is returned to the crankcase. This system is sometimes called a partial flow because only part of the supply oil is filtered at one time.

The volume of oil bypassed through the filter is initially controlled by a restriction in the filter outlet. However, as the flow passages become clogged, the volume of oil through the filter is reduced and thus so is the volume of filtered oil returning to the crankcase. Obviously then, the filter and the oil must be changed regularly to provide properly filtered oil to the system.

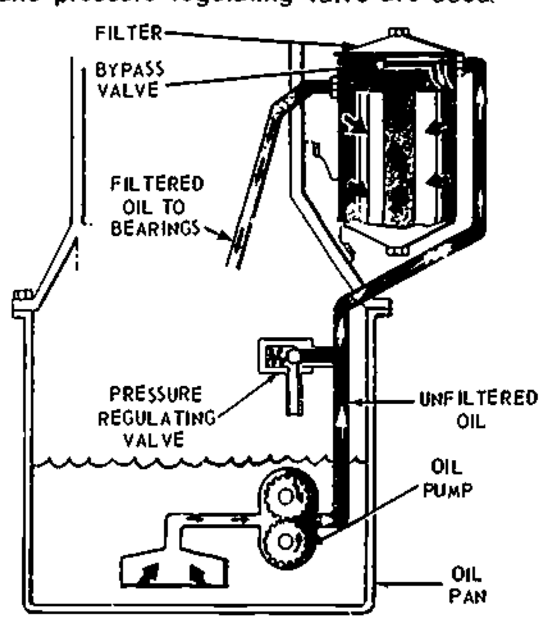


BYPASS OIL FILTER
(7-59) Courtesy of John Deere Ltd

A main advantage of the bypass filtration system is that because of the direct feed from the pump to the bearings there is a constant oil pressure at the bearings, regardless of the condition of the filter.

Full-Flow Filtration System

In the full-flow filtration system there is only one oil flow that travels from the pump to the filter and then to the bearings (Figure 7-60). As in the bypass system, a pressure gauge and pressure regulating valve are used.

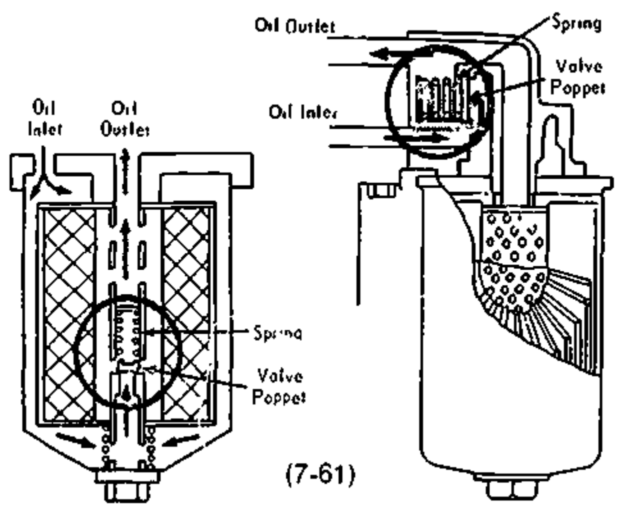


FULL-FLOW OIL FILTER
(7-60) Courtesy of John Deere Ltd

Filter Bypass Valves (Pressure Differential Valves)

Note the filter relief or bypass valve in the above diagram Every filter in a full-flow lubrication system must have a bypass valve When the filter is new, there is very little pressure drop through it. However, if the filter gets clogged, the resulting additional pressure will open the relief valve and allow unfiltered oil to bypass the filter and go directly to the bearings. What would happen if a bypass valve was not provided? When the filter became completely clogged, pressure would build up on its inlet side. This pressure would cause the regulating valve to open completely, allowing all of the oil to return directly to the crankcase. The result: a burned-up engine

The bypass valve, then, is a safety device to ensure that the oil, filtered or dirty, will get to the bearings. The valve is usually set to open before the filter becomes completely clogged. Figure 7-61 shows the filter bypass valve in two locations, inside the filter and in the filter mounting pad.



(7-61)

BY-PASS VALVE INSIDE FILTER HOUSING

BY-PASS VALVE IN MOUNTING PAD OF FILTER

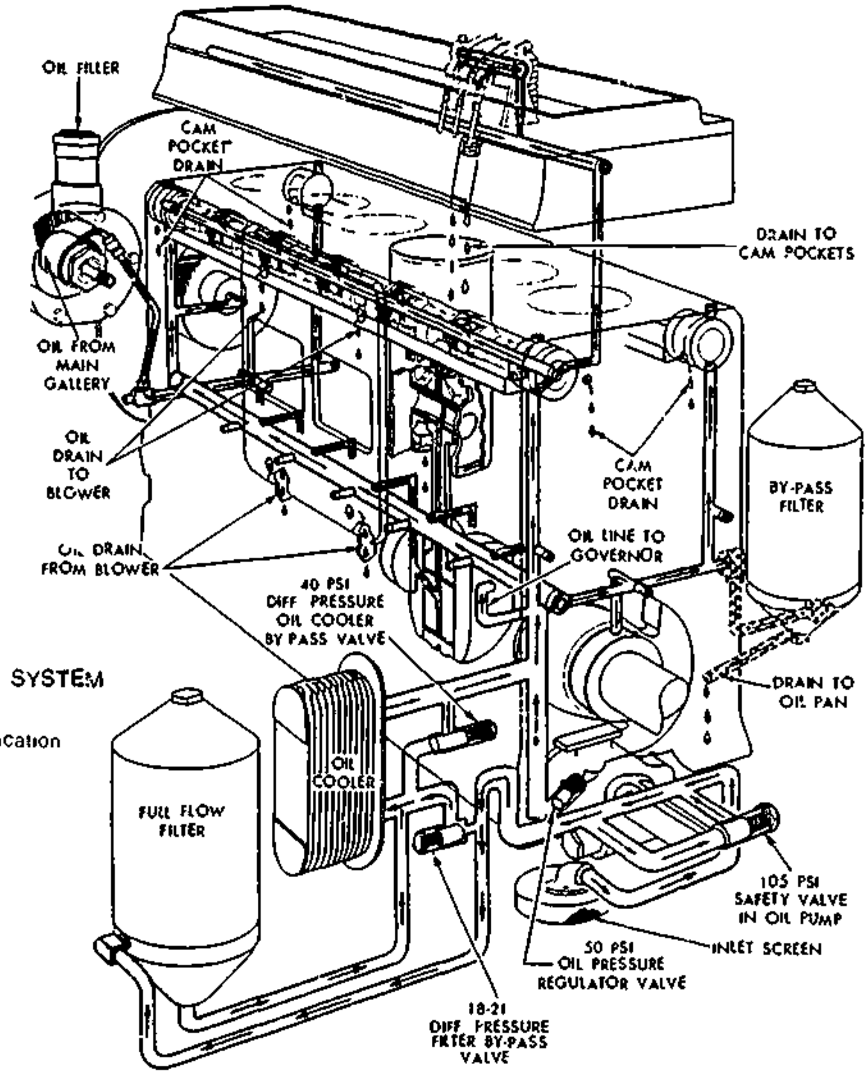
Courtesy of John Deere Ltd

Many spin-on filter elements have the bypass built into the element. When replacing a filter, be sure to use only the recommended filter because another type may not have the built-in bypass valve.

Bypass valves are often used with oil coolers for the same reason that they are used with filters. If the oil cooler becomes clogged, oil flows through the valve and back into the lubrication system

Combination Full-Flow and Bypass System

A combination of full-flow and bypass lubrication systems is found in many large diesel engines. The full-flow filter does the primary filtering and the bypass filter the secondary filtering. As full-flow filtered oil is distributed to all the vital lubrication areas, a small amount flows through the bypass filter from where it drains back to the sump. An example of a full-flow bypass system is shown in Figure 7-62. Note the filter bypass valve, or as it's sometimes called, the pressure differential valve.



(7-62)

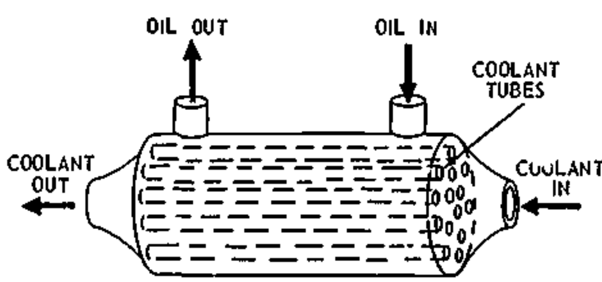
TYPICAL LUBRICATING SYSTEM

Courtesy of Ministry of Education

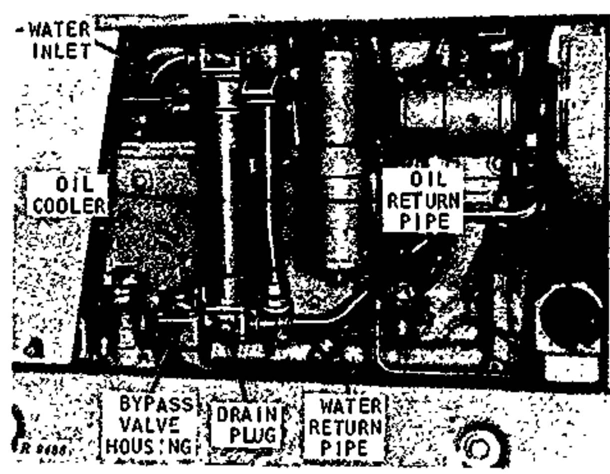
Oil Coolers

Many lubrication systems use an oil cooler to cool hot oil, and thus help dissipate heat created by the engine. Most coolers use engine coolant to cool the oil. The oil cooler may be mounted internally in the crankcase or externally on the outside of the engine block. Most engines use an externally mounted oil cooler, like the one in Figure 7-63.

When the cooler is mounted externally both coolant and lubricating oil are pumped through it (Figure 7-64).



(7-64) OPERATION OF ENGINE OIL COOLER
Courtesy of John Deere Ltd



(7-63) OIL COOLER MOUNTED OUTSIDE ENGINE
Courtesy of John Deere Ltd

Coolant flows through the tubes in the cooler and oil circulates around the tubes. Heat from the oil is transferred to the coolant which then travels to the radiator and is itself cooled

Another common type of cooler works opposite to the one above. Instead of coolant flowing through tubes, oil is pumped through a small radiator-like core and coolant is circulated around it.

A bypass valve is used with some oil coolers to assure oil circulation if the cooler should become clogged. Note the location of the oil cooler bypass valve in the diagram of the combined full-flow bypass lubrication system. Trace the oil flow that would occur on a cold start when thick oil could cause both the filter and the cooler bypass valves to open (Figure 7-62)

Breathers and Vents

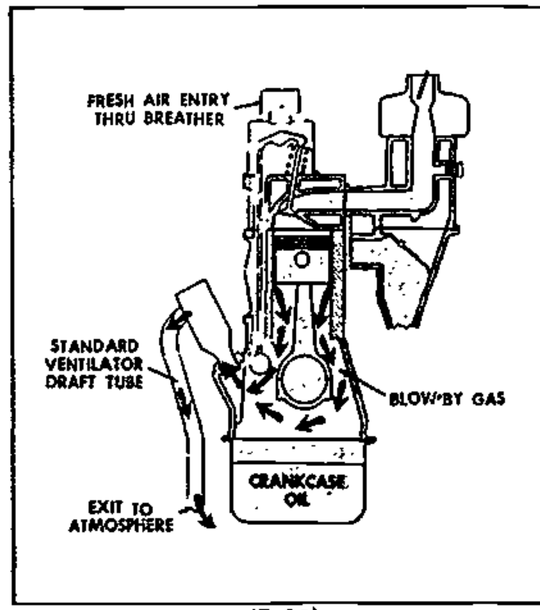
In every internal combustion engine some unburned gases pass by the piston rings. If these gases, called blow-by, are not vented they will tend to build-up pressure in the oil pan, both contaminating the oil and forcing the front and rear pan seals to leak. Breathers and vents remove the blow-by gases and the pressure.

Two basic methods are used to allow the engine to breathe:

1. open crankcase ventilation using a road draft tube or cover vents.
2. positive crankcase ventilation.

Open crankcase ventilation removes blow-by gas through the road draft tube attached to the side of the engine (Figure 7-65).

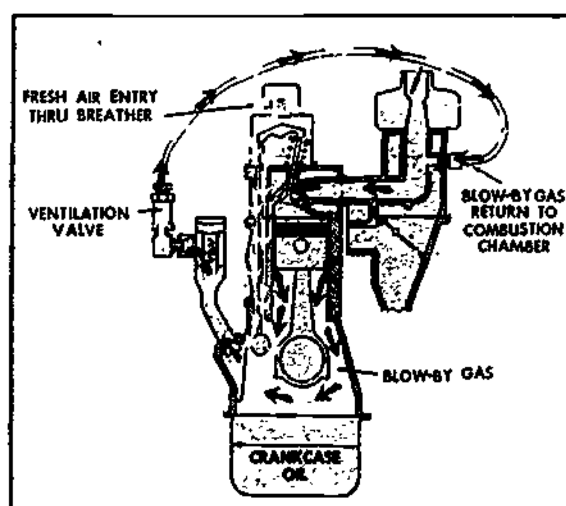
Movement of the vehicle forward at speeds of 20 mph or faster creates a low pressure at the bottom end of the tube. Fresh air is taken in through the fresh air breather at the top of the engine, combines with the gases in the crankcase, and then exits through the road tube. The mixture of gas and air flows out the tube because the pressure of this mixture is higher than the pressure at the road end of the tube (gases at higher pressure always move in the direction of lower pressure). Most diesel engines use the open ventilation system, having either a tube going from the top of the engine down the side or vents on the valve covers.



(7-65)

Courtesy of General Motors Corporation

Open ventilation is not used on gasoline engines today because gasoline blow-by contains harmful hydrocarbon fumes that contribute greatly to air pollution. Instead, positive crankcase ventilation is used.



(7-66)

Courtesy of General Motors Corporation

In this system a hose passes from the crankcase, through a ventilation valve to the intake manifold. Fresh air enters the breather cap on the valve cover, mixes with the blow-by gases, and is drawn up by manifold vacuum through the ventilation valve and into the intake manifold. Thus the blow-by gases finally end up in the combustion chamber again. The ventilation valve, usually called a PCV valve, is a spring loaded metering valve which regulates the amount of flow from the crankcase to the intake manifold

Besides contributing to cleaner air in the environment another advantage of the positive ventilation system is that the gases are removed even when the engine is idling. The open system requires vehicle movement (20 mph) to create the low pressure and the draft necessary to remove the gases

MOTOR OILS

Motor oils — are often taken for granted. It isn't generally appreciated that they must lubricate despite high oxidizing conditions, extreme temperatures, and large amounts of contaminants High-output engines coupled with reduced crankcase capacities and extended drain intervals have all compounded the severe conditions under which the oil must perform

MOTOR OIL FUNCTIONS (Courtesy of Imperial Oil Limited)

1 **Wear Prevention**

Wear takes place due to metal-to-metal contact of moving parts, as well as from acidic corrosion, from rusting and from the abrasive action of contaminants carried in the oil. To prevent metal-to-metal contact, motor oil must maintain sufficient viscosity to provide a full fluid film between moving parts under all operating temperatures. The viscosity must not be so thick, however, as to make starting the engine difficult

2 **Engine Cooling**

Motor Oil is largely responsible for piston cooling. The cooling is done by transferring heat directly from the piston through the oil film to the cylinder walls and then out to the cooling system, and by carrying heat from the underside of the piston, crown and skirt to the crankcase. Oils must therefore have good heat conductivity, but at the same time the oil must have adequate thermal stability to resist decomposition when in contact with these hot surfaces.

3 **Engine Cleaning**

Over a period of time oil starts to deteriorate and oxidize The oxidation causes the formation of harmful contaminants acids, varnish, carbon, sludge. Motor oil must minimize the formation of these contaminants in the first place, but when they inevitably do form, the oil must keep the contaminants in suspension so that they don't settle inside the engine.

Oil must also act as a cleansing agent, carrying to the oil filter abrasive contaminants that form in the engine.

4. **Cylinder Sealant**

Cylinder pressures of 145 p.s.i. at cranking speeds are not unusual, while combustion pressures may reach 900 p.s.i. Piston rings alone cannot seal off this pressure; they need the help of the oil film between the rings and the cylinder wall.

5 **Control Engine Octane Requirement**

Motor Oil must minimize the formation of oil deposits in the combustion chamber. These deposits decrease the volume of the chamber thereby increasing the compression ratio and thus the octane requirement of the gasoline. The deposits are also a source of hot spots that can glow and cause pre-ignition.

6. **Control Rust**

Engine components such as valve stems, hydraulic valve lifters, piston rings and cylinder walls are subjected to severe rusting conditions Extended periods of engine idling or short trip stop and go driving allow water to accumulate in the oil Also, condensation of water on engine parts can occur overnight when the engine isn't running. An essential function of the motor oil is to provide a protective film on engine parts to prevent rusting when it's not being used.

7. **Control Corrosion**

Products of combustion include corrosive materials, such as acids, which accumulate in the engine crankcase. Unless the engine oil can control the tendency of these products to corrode bearings and other finely finished surfaces, corrosive wear will reduce engine life.

MOTOR OIL COMPOSITION

Motor oils are manufactured from base stocks and fortified with additives to provide the performance level required.

Motor Oil Additives

1. Anti-Oxidant — prevents oil oxidation, sludge and acid formation.
2. Corrosion Inhibitors — prevent bearing corrosion.
3. Detergent/Dispersal — cleans engine parts and disperses sludge and other solid contaminants. These detergents act similarly to soaps to remove deposits and then to retain the deposits as finely dispersed particles in the oil. Detergents may become depleted and after prolonged continued service they may not be able to keep the contaminants in suspension.
4. Rust Inhibitors — prevent rusting of engine parts, particularly hydraulic valve lifters.
5. Pour Point Depressant — provides free-flowing qualities at low temperatures.
6. Viscosity Index Improver — viscosity index can be defined as a measurement of the change in the viscosity as the temperature changes. The improver additive reduces the rate at which the oil thins out with increasing temperature.
7. Anti-wear Agent — prevents galling and scoring of heavily loaded engine parts, particularly the valve train. A widely used material is a zinc-sulphur-phosphorous additive often referred to as "ZDDP".
8. Reserve Alkalinity — new engine oils are basic in composition to neutralize acids formed by the combustion processes
9. Foam Suppressor — does not prevent foam from forming, but renders the foam unstable so that it settles quickly.

While there may seem to be a great many additives used in motor oils, the concentrations are often very low. Anti-oxidants and corrosion inhibitors, for example, are used at concentrations as low as 0.1%. High additive oils may have as much as 12% detergent present. The quantity of additive, it should be pointed out, is not necessarily an indication of the quality or the strength of an oil.

CLASSIFYING MOTOR OILS

S.A.E. Classification

The most important single property of a lubricating oil is viscosity. Viscosity, as stated earlier, is a measurement of the resistance of a liquid to flow. The viscosity of an oil is determined at specific temperatures; 0°F and 100°F and 210°F are the most widely used. The viscosities of different oils can be compared only at the same temperature. The Society of Automotive Engineers (S.A.E.) identify oils by their viscosity ranges. Motor oils can have S.A.E. numbers of:

$$\left.\begin{array}{r}5\text{ W}\\10\text{ W}\\20\text{ W}\\30\text{ W}\\40\text{ W}\\50\text{ W}\end{array}\right\}$$ — The higher the number the greater the viscosity (the thicker) the oil.

Engine Service Classification

As well as an S.A.E. classification, motor oils are also classified according to the service conditions under which they will be used. In 1970 a new crankcase oil performance classification called "Engine Service Classification" was established to replace the API Service Classification formerly used. It specifically lists the tests and performance requirements for each of the classifications, and in addition, is open-ended to allow for the addition of new performance levels as they are developed.

The Engine Service Classification is divided into two categories. The "S" category refers mainly to gasoline engine low temperature requirements while the "C" category refers mainly to diesel engine high temperature requirements (Figure 7-67). Many applications will call for a dual rated oil such as SD/CD which requires both extremely low and high temperature performance levels.

Engine Service Classification

LETTER DESIGNATION	SERVICE DESCRIPTION
SA	Non-additive oils. Not recommended for crankcase service
SB	Light Duty Gasoline Non-detergent Not normally recommended for crankcase service.
SC	1967 and earlier gasoline engine service in passenger cars and trucks
SD	1971 and earlier gasoline engine service in passenger cars and trucks
SE	Current and earlier gasoline engine service in passenger cars and trucks
CA	MIL-L-2104A Light duty diesel engine service
CB	Supplement 1 Moderate duty diesel engine service
CC	MIL-L-2104B Moderate duty diesel and gasoline engine service
CD	Caterpillar Series 3 Severe duty diesel engine service.

Refer to Block 4, Power Trains, for information on handling and storing oil.

(7-67)

Courtesy of The Society of Automotive Engineers (S A E)

PREVENTIVE MAINTENANCE SERVICE ON LUBRICATION SYSTEMS

As part of the daily walk around check before start up the lube system should be inspected for leaks, damage or deterioration. When minor leaks are spotted, tighten fittings or bolts; if this doesn't stop the leak report the condition to a supervisor. Oil leaks should be attended to immediately. To be able to see leaks better, keep a machine clean by regular steam cleaning or high pressure washing.

Oil level checks are a vital part of routine maintenance on a vehicle. Correct oil levels should be maintained at all times. Follow these practices when checking oil levels and when topping up the oil.

1. Park the vehicle on level ground.
2. Practise cleanliness. Use a clean rag to wipe the area around the dipstick and to wipe oil off the stick.
3. Check the oil level before starting the engine. An engine should be stopped for at least five minutes before the oil level is checked. Some manufacturer's call for a running as well as a stopped check. The dipstick on these machines will be marked on both sides, on "Engine Stopped" and the other "Engine Running".

   Figure 7-68 gives an example of a manufacturer's directions for an oil level check on a crawler dozer. Note that the check must be done when the engine is running.

EVERY 10 SERVICE HOURS
DIESEL ENGINE CRANKCASE

Check oil level with engine at low idle and oil hot. Maintain oil level between FULL and ADD marks on ENGINE RUNNING side of gauge (7-68)

Courtesy of Caterpillar Tractor Co

4. Check for evidence of water or fine metal particles in the oil. When such contaminants are found, further checking will be necessary to determine where they are coming from.
5. Keep records of quantities of oil added between changes; a sharp increase of top-up oil usually indicates a rapidly developing problem.
6. Contaminated oil can seriously reduce engine life. When top-up oil is required be certain that the oil container has no water or dirt in it. Human error in not

keeping oil clean is one of the most common ways that contaminants enter an engine

7 Use only oil recommended in the service manual

8 Do not mix engine oils

9 Do not overfill the crankcase

10 Never operate an engine if the oil quantity is below the low-level mark

CHANGING ENGINE OIL

Over a period of time oil gets dirty and wears out making it unfit for use. On the other hand. just because crankcase oil is black, doesn't necessarily mean the oil has to be changed Since it s difficult to tell by just looking at oil when it should be changed. the best policy is to follow the manufacturer's recommendations on oil and filter changes.

In addition to scheduled oil changes many companies are now carrying out oil analysis programs The term oil analysis refers to a laboratory analysis of used oil which determines the types and amounts of wear metals present in the oil By charting on a regular basis the amount of certain metals in oil. the condition of the parts that the oil lubricates can be watched When a concentration higher than has been the pattern of a certain metal begins to appear, it indicates that the part from which the metal has worn off is starting to wear more rapidly. The laboratory can warn the customer to take protective action prior to the unit failing Laboratories have considerable experience in detecting wear patterns from used oil and can fairly accurately state the condition of internal components providing that sampling is done on a regular basis

In an oil analysis program. oil samples must be taken from each lubrication system on the machine. e g engine oil, hydraulic oil, final drive oil. brake and transmission fluid For oil analysis to be successful samples must be taken on a regular basis: between 125 and 250 hours for engine oil and 250 to 500 hours for all other lubrication systems Oil samples must be taken when the oil is warm and thoroughly mixed There are various methods of taking the samples a valve or petcock put straight into a main oil line. a suction gun with a sample jar to take oil from dipstick and oil-fill holes. a thick rubber bulb including a one-way check valve a vac cap and a sample jar.

It must be stressed that a good oil sample. one that is not cross-contaminated with another oil system. is essential for an accurate laboratory analysis

SER . 3 WEAR/CONTAMINATION (SAMPLE)

XYZ TRUCKING CO.

Lubricon
BOX 41506
INDIANAPOLIS IND 46241

ACCT NO ________ S ________

UNIT 1550
MFR DETROIT DIESEL
MODEL 8V-71
TYPE DIESEL
OIL Mfr TEXACO Grade URSA

AA
3

UNIT CONDITION AND RECOMMENDATIONS

1 Piston pin bushing metal; Resample at NORMAL interval.

2 Piston metals; Ring/cylinder metals; Check blow-by (compression); Resample at NORMAL interval.

3 Piston metals, Ring/cylinder metals; Inspect cylinder areas; Resample at NORMAL interval.

4 Piston metals. Ring/cylinder metals, Inspect cylinder areas, Resample at NORMAL interval. FEEDBACK. Several broken rings and scored liners. Wrist pins excessively worn

5 TESTS INDICATE UNIT IS IN SATISFACTORY CONDITION. Resample at NORMAL interval.

6

TEST NO	LAB NO	DATE Sample Taken / Sample Rec'd	MILES HRS Since Drain / Since O Haul	OIL MAKEUP QTS	IRON	CHROMIUM	ALUMINUM	COPPER	LEAD	TIN	SILVER	NICKEL	SILICON	SODIUM	BORON	MAGNESIUM	CALCIUM	BARIUM	PHOSPHORUS	ZINC		CONTAMINATION Fuel %Vol	Solids %Vol	Water %Vol	LUBE DATA VIS 210°F SUS	Total Base No
1	82	5-2 5-4	9000 119129	13	032.	002.	003.	045.	008.	002.	000.	000.	006.	023.	001.	010.	2300	0000	0900	0920		1.5	2.8	.05		
2	1225	6-17 6-19	10587 132539	27	070.	003.	002.	014.	009.	002.	000.	000.	007.	030.	001.	010.	24[illegible]	0000	0910	0950		1.0	3.0	.05		
3	1430	7-17 7-19	11524 144163	24	130.	005.	002.	013.	009.	003.	000	000.	006.	034.	001.	010.	2400	0000	0920	0930		1.0	2.9	.05		
4	103	8-20 8-21	10423 154586	32	140.	003.	002.	006.	006.	001.	000.	000.	007.	031.	002.	010.	2420	0000	0900	0910		1.0	4.2	.05		
5	1010	10-6 10-8	10000 19590	9	030.	001.	001.	006.	005.	001.	000.	000.	006.	030.	002.	010.	2390	0000	0940	0930		1.0	2.7	.05		
6																										

Our Product is KNOWLEDGE and EXPERIENCE in Lubrication and Related Maintenance.

NOTE Our comments are ... only and are based on the assumption that the sample and data submitted ... about a report ... the Lab No and data ...

Form A
© LUBRICANT CONSULTANTS INC 1975

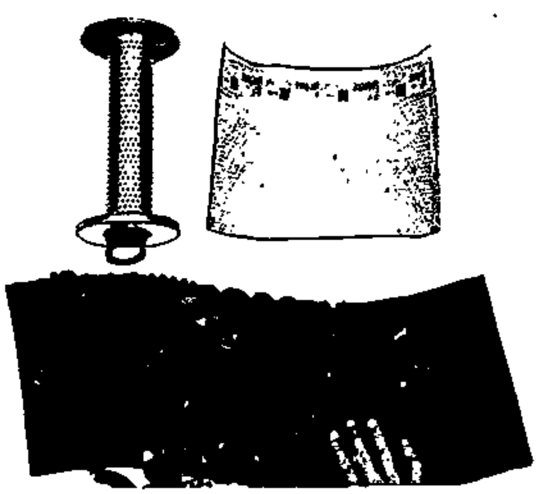
(7-69)

Courtesy of Lubricon Consultants Inc

PROCEDURES FOR CHANGING OIL AND OIL FILTERS

Procedures for changing oil and filters are much the same for all engines However, the number of filters, the drain location and the capacity of the system will vary from engine to engine Some good practices to follow are:

1. Move the vehicle to a level area.
2. Run the engine long enough (15 minutes) to warm the oil, and then stop the engine. When the oil is warm contaminants will mix with the oil and will drain out with it.
3. Make sure you know the capacity of the system and have a container large enough to hold all the drained oil.
4. If an oil sample is to be taken, do so at this point (Within 15 minutes of shut-down.)
5. Remove the plug carefully. Caution: Hot oil can burn.
6. Drain the filter(s) if they are equipped with a drain, and then remove the filter element. Take a few seconds to inspect the old filter element (Figure 7-70), especially if oil sampling is not done. Evidence of metal ships will indicate that there are problems within the engine requiring immediate attention.

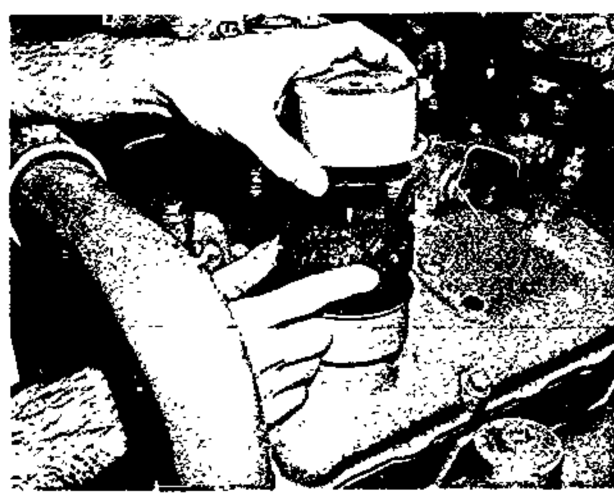


(7-70) INSPECTING PAPER ELEMENT PLEATS

Courtesy of Cummins Engine Co

7. Wash the filter housing(s) and install a new filter element. Replacing some oil filters requires installing new gaskets or sealing rings. Be sure the sealing surfaces on the engine and filter are clean.
8. Replace all drain plugs.
9. Referring to the service manual for the correct type and amount of oil, fill the crankcase with oil.
10. Remove crankcase breathers and thoroughly wash them with solvent or kerosene. Below are typical directions from a service manual on how to clean a breather:

    Clean breather element (Figure 7-71) in cleaning solvent and dry with compressed air. Wipe out breather housing. Soak element in oil; drain out excess. Check gasket; replace if damaged.



(7-71) CRANKCASE BREATHER — MESH ELEMENT

Courtesy of Cummins Engine Co

11. Start the engine, run for ten minutes and check for leaks.
12. Check oil level with engine stopped and top-up as required.
13. Keep a record of all oil and filter changes to be sure of regular engine service
14. New or rebuilt engines require oil and filter changes after a specified break-in period. Performing this service on time is very important since foreign materials accumulate in the oil at a faster rate during initial operation than later when the engine is broken in.

Flushing The Lubrication System

A lubrication system is generally flushed when it becomes contaminated with coolant, fuel, or metal chips What flushing amounts to is changing the oil twice To flush the engine follow the same procedure as changing the oil drain, change filters, refill Refill with the same grade of engine oil as regularly used or with a recommended flushing oil Run the engine until the oil is warm, and then completely drain the system and discard the filters

Renew the filters, including new seal rings Refill the crankcase Run the engine and check for leaks Shutdown the engine and check the oil level

For an engine that is contaminated with metal chips such as would occur after an internal failure, the same flushing procedures would apply as above, but with these additional flushing and precautionary measures:

1 Remove the oil cooler and flush it.

2 Remove any external lines such as a bypass filter line, flush and blow them clean with compressed air

3 If the engine has a turbo charger, remove, flush and blow clear the turbo lube lines

QUESTIONS — LUBRICATION SYSTEM

1 Two of the functions of the lube system in an engine are to reduce ________ ________ between moving parts and absorb and dissipate ________

2 True or False? Most engines today use a full-pressure lube system.

3 What protects the oil pumps from over pressurizing?

4 What are the two common types of oil filter systems

(a) Full pressure and low pressure

(b) Full flow and bypass

(c) Full flow and medium flow

(d) Partial flow and bypass

5 Give an example of a surface filter-element.

6 On a bypass filter system when the oil has passed through the filter it goes to the:

(a) bearings

(b) valve cover

(c) camshaft

(d) crankcase

7 On a full-flow filtration system the oil after passing through the filter goes to the:

(a) bearings

(b) valve cover

(c) camshaft

(d) crankcase

8 What occurs within a full-flow oil filter if the filter becomes plugged?

9 What is the function of the pressure differential valve between an inlet and outlet line of an oil cooler?

10 Why is crankcase ventilation so important?

12 True or False? There is a simple equation between additives and oil quality: the more additives, the better the oil

13 The S A E number identifies oils by their ________ range The higher the number the ________ the oil

14 What are the two categories that engine oils are divided into for service classification?

15 What is oil classified as CC suitable for?

16. True or False? An engine should be stopped for at least five minutes before the oil level is checked.

17 What does the term oil analysis refer to?

18 What is considered to be an ideal sampling interval for engine oil analysis?

(a) 10 to 50 hours

(b) 50 to 100 hours

(c) 125 to 250 hours

(d) 250 to 500 hours

19. What information can a regular oil analysis program give you?

20. Why should oil be warm when it is drained for changing?

21 Under what three conditions would it be necessary to flush the engine's lube system?

AIR INDUCTION SYSTEM

The air induction system must:

1. Supply an abundance of clean air for combustion. The air must be at the right degree of coolness and the air intake must not be too noisy.
2. Supply air to aid in scavenging burned gases from the cylinder.

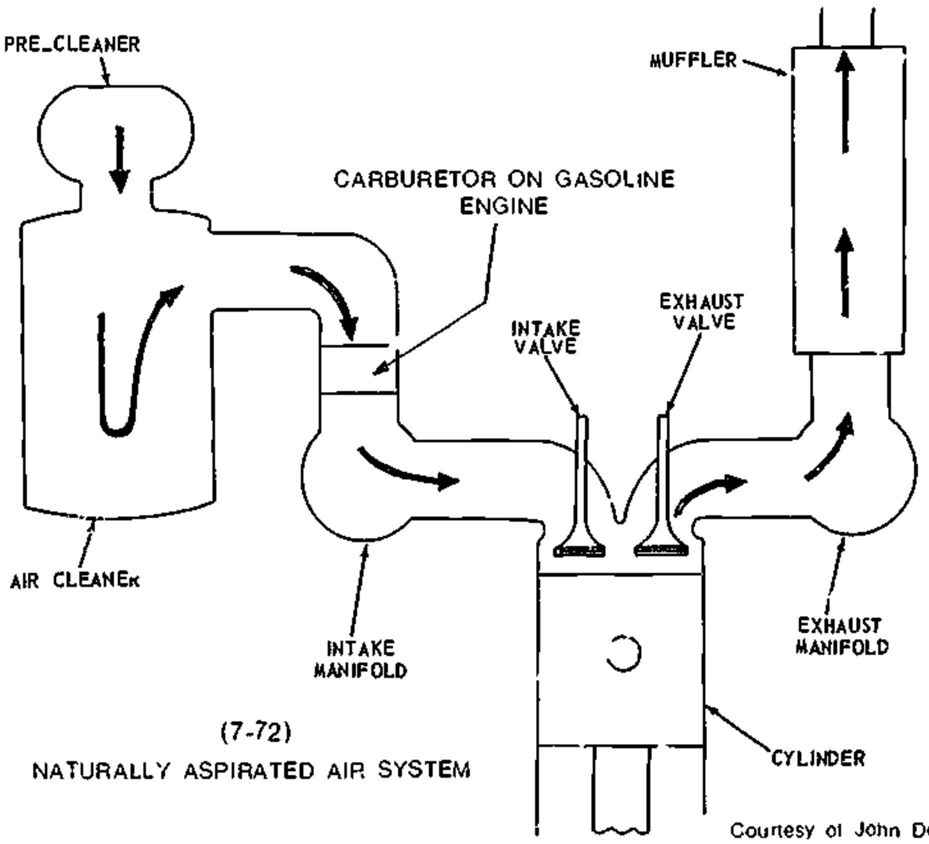
Three types of systems are used to supply air to an engine:

1. Naturally aspirated, and naturally aspirated and scavenge blown.
2. Turbo charged.
3. Turbo charged and after cooled.

The naturally aspirated system, often referred to as N.A., is the simplest of the air induction systems. The term naturally aspirated is explained as follows: aspirating refers to the drawing in of air. A naturally aspirated engine is said to draw in air or breathe naturally. On the piston's intake stroke, air via the air cleaner is drawn into the engine. No aids are used to help get the air in or out of the engine, air is drawn in because atmospheric pressure is higher than the pressure in the cylinders.

In a naturally aspirated or N.A. engine (Figure 7-72) air enters the cleaner and flows to the carburetor where it mixes with gasoline. From the carburetor the mixture travels through the intake manifold and enters the combustion chamber at the intake valve.

In a naturally aspirated engine, since there is no carburetor, air travels directly from the cleaner through the intake manifold and into the combustion chamber where it is mixed with injected fuel.



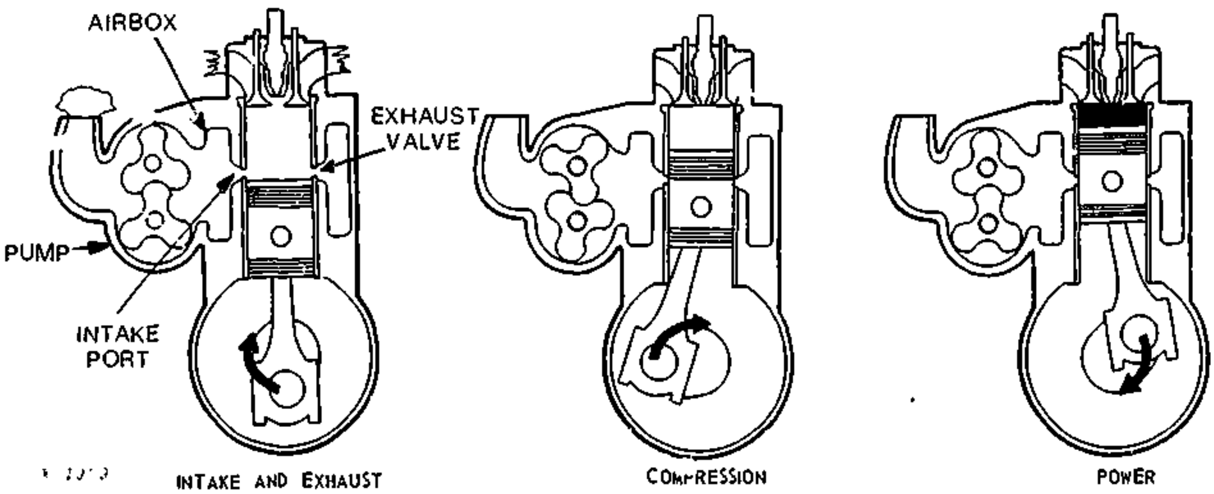
(7-72)
NATURALLY ASPIRATED AIR SYSTEM

Courtesy of John Deere Ltd

A naturally aspirated, scavenge blown air system is similar to the basic N.A. system except that an air pump, driven by the engine is used to supplement the natural intake stroke breathing. This scavenged blown system is used on two stroke cycle diesel engines (e g., Detroit Diesels) when intake ports rather than intake valves are used (Figure 7-73).

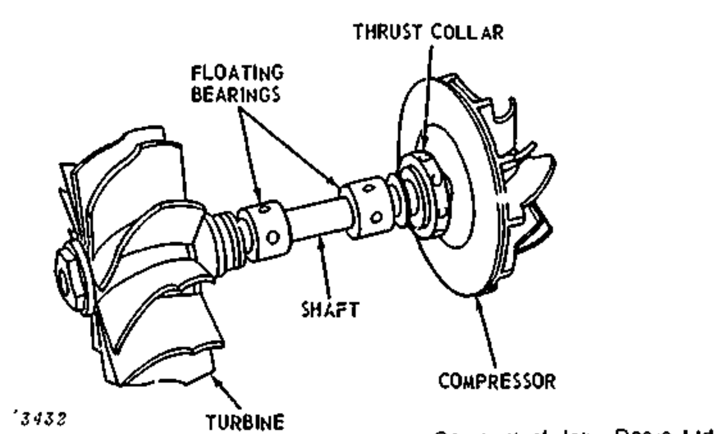
The air pump, called a Roots Blower, creates a positive pressure approximately 4 psi within a chamber that completely surrounds all the cylinders The chamber is called the air box When the piston is at its lowest point the intake ports are open and the exhaust valves are also open Fresh pressurized air in the air box rushes into the cylinder forcing the exhaust gases out through the open exhaust valves. The pump ensures complete scavenging of all the exhaust gases (thus the name scavenge blown), as well as ensuring a plentiful supply of fresh air for the next power stroke

One of the drawbacks of a naturally aspirated air system is that the amount of air that the engine can take in is limited and therefore the engine's horsepower is limited A turbo charged system brings more air into the engine cylinder and thereby increases the engine's horsepower The turbo charged system uses an exhaust driven turbine to drive an air compressor. By compressing the air more of it can be packed into the combustion chamber. With more air (i.e., oxygen) in the cylinder, more fuel can be burned on the power stroke and thus the increase in horsepower. Although a turbo charger is a precision built device that can operate at speeds up to 130,00 RPM, it is a relatively simple, durable piece of machinery Figure 7-74 shows the basic parts of a turbo charger.



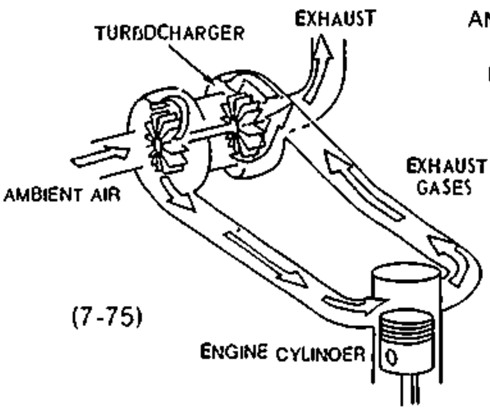
(7-73) ONE-VALVE TWO-CYCLE ENGINE WITH BLOWER

Courtesy of John Deere Ltd



(7-74) Courtesy of John Deere Ltd

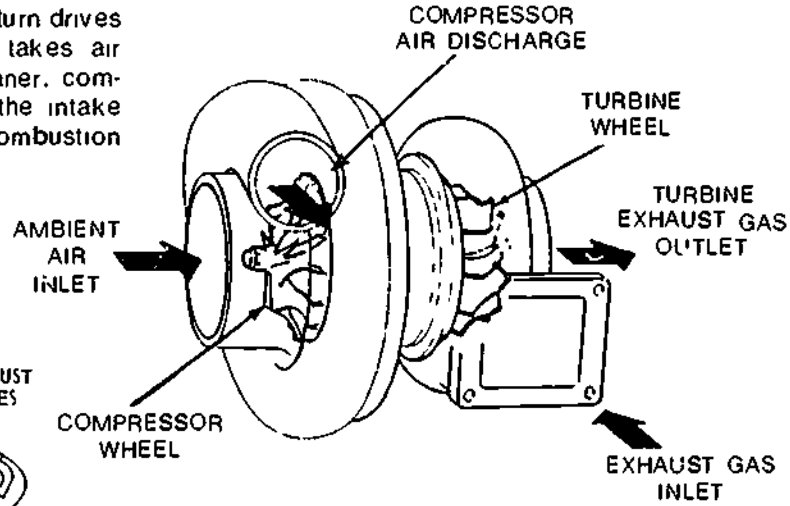
Exhaust gases on their way to the muffler pass through the turbine housing and rotate the turbine wheel The turbine wheel in turn drives the compressor The compressor takes air that has come in from the air cleaner, compresses it, and discharges it into the intake manifold where it travels to the combustion chamber (Figures 7-75 and 7-76).



(7-75)

OPERATION OF BASIC TURBO CHARGER

Courtesy of John Deere Ltd



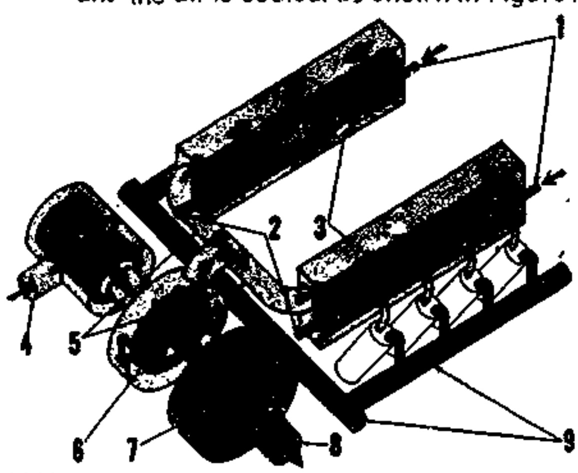
(7-76) TURBO CHARGER

Courtesy of Detroit Diesel General Motors Corporation

The increase in the pressure of the compressed air delivered by the turbo charger is called boost pressure The beauty of a turbo charger is that boost pressure is at its highest when the engine needs it most. Since the compressor is run by exhaust gases, boost pressure is at maximum when the engine is operating at full load The boost can reach 15 p s i or higher The increase in boost pressure as the engine load increases is important in terms of getting the air into the cylinder When an engine is running at 2500 RPM the intake valves are open less than .017 seconds. With the air under greater pressure, it takes less time for it to get into the cylinder In addition to turbo chargers, some engines are equipped with a cooler installed between the turbo charger and the intake manifold. It is referred to as an after-cooler or intercooler Such an arrangement is called turbo charged and after cooled

INTERCOOLERS

When the turbo charger compresses the engine intake air, the air becomes heated (due to compression) and expands. When the heated air expands, it becomes less dense. The result is that part of the purpose of the turbo charger is defeated because less air is forced into the engine. To overcome this condition, some turbo charged engines are equipped with an intercooler. An intercooler is nothing more than a heat exchanger; the heated intake air flows over a series of tubes through which engine coolant is circulated and the air is cooled, as shown in Figure 7-77.



(7-77)

AIR INDUCTION AND EXHAUST (SCHEMATIC)

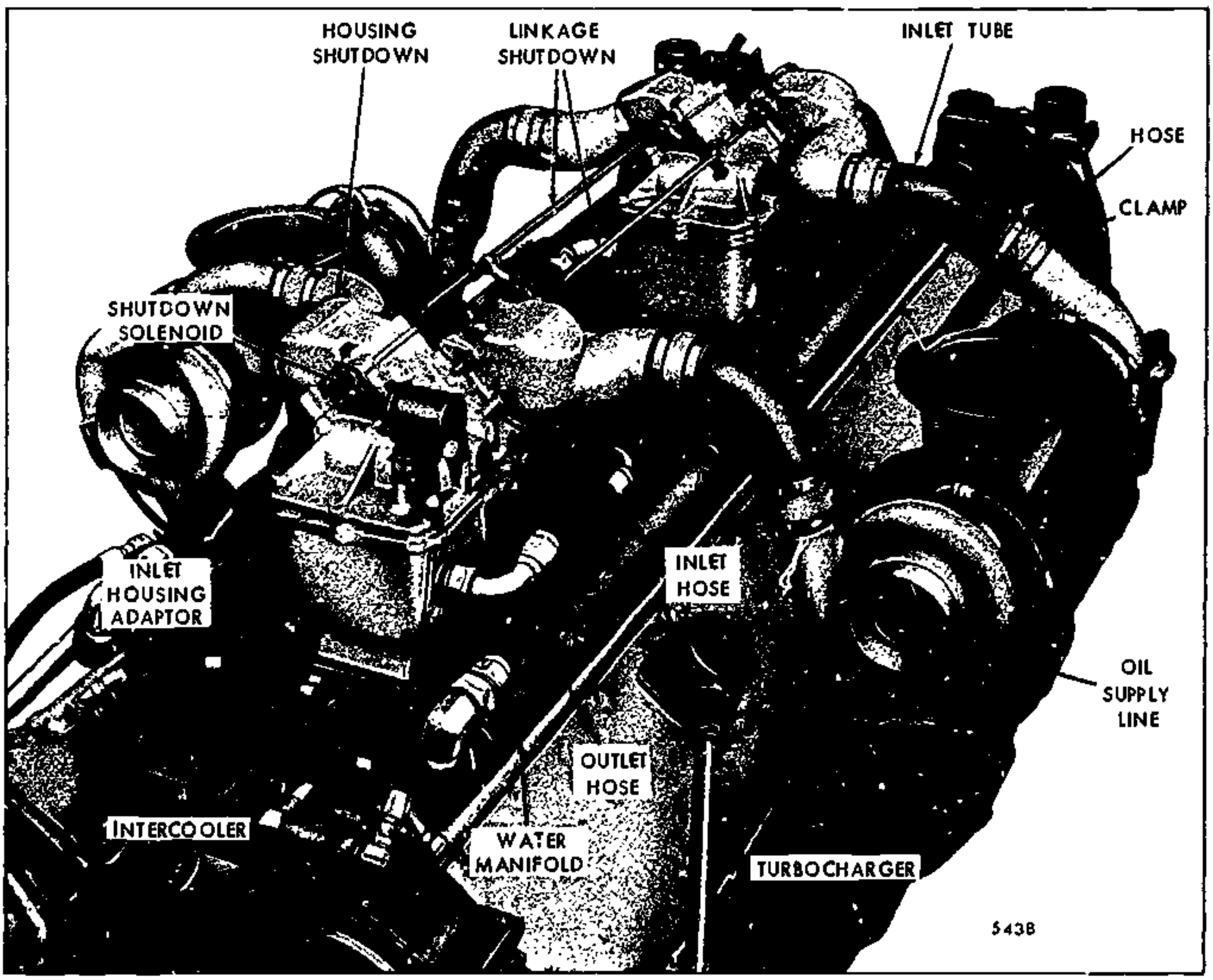
Courtesy of Caterpillar Tractor Company

1—Coolant inlets to aftercoolers 2—Coolant outlets from aftercoolers 3—Aftercoolers 4—Aircleaner air inlet 5—Air transfer pipes 6—Turbo charger compressor impeller 7—Turbo charger turbine wheel 8—Exhaust outlet 9—Exhaust manifold

The intercooler reduces the temperature of the compressed air by 25 to 30°C. The reduced temperature makes the air denser allowing more to be packed into the combustion chambers. The result is.

1. More power: Sufficient air is provided to burn the fuel resulting in higher horsepower.
2. Greater economy: The fuel is burned more completely, giving more power from a given amount of fuel.
3. Quieter combustion: By lowering the temperature of the air for fuel-air mixing, there is a smoother pressure rise in the engine cylinder. Figure 7-78 shows a typical intercooler mounting.

(7-78) TYPICAL INTERCOOLER MOUNTING



Courtesy of General Motors Corporation

AIR CLEANERS

Clean air is essential to satisfactory engine performance and long engine life. The air cleaner must remove fine materials such as dust and blown sand as well as coarser materials such as chaff or lint. This residue collects in a reservoir which must be large enough that operation is maintained over a reasonable period of time before cleaning and servicing is necessary. If an air cleaner is not cleaned buildup of dust and dirt in its passages will eventually choke off the air supply, causing incomplete combustion and heavy carbon deposits on valves and pistons. Multiple air cleaner installations are sometimes used where engines are operated under extremely dusty air conditions or where two small air cleaners must be used in place of a single large one.

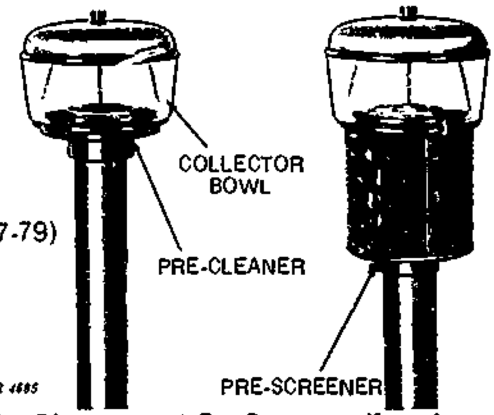
The most common types of air cleaners are

1. Pre-cleaners
2. Dry element cleaners
3. Oil bath cleaners

Pre-Cleaners

Pre-cleaners (Figure 7-79) are usually installed at the end of a pipe extended upward into the air from the air cleaner inlet. In this location pre-cleaners are relatively free of dust. Pre-cleaners are simple devices which remove large particles of dirt or other foreign matter from the air before it enters the main air cleaner. They relieve much of the load on the air cleaner and allow longer intervals between servicing. Most pre-cleaners have a pre-screener which prevents lint, chaff, and leaves from entering the air intake.

(7-79)



Pre-Cleaners and Pre-Screeners Keep Large Foreign Particles From Reaching the Air Cleaner

Courtesy of John Deere Ltd

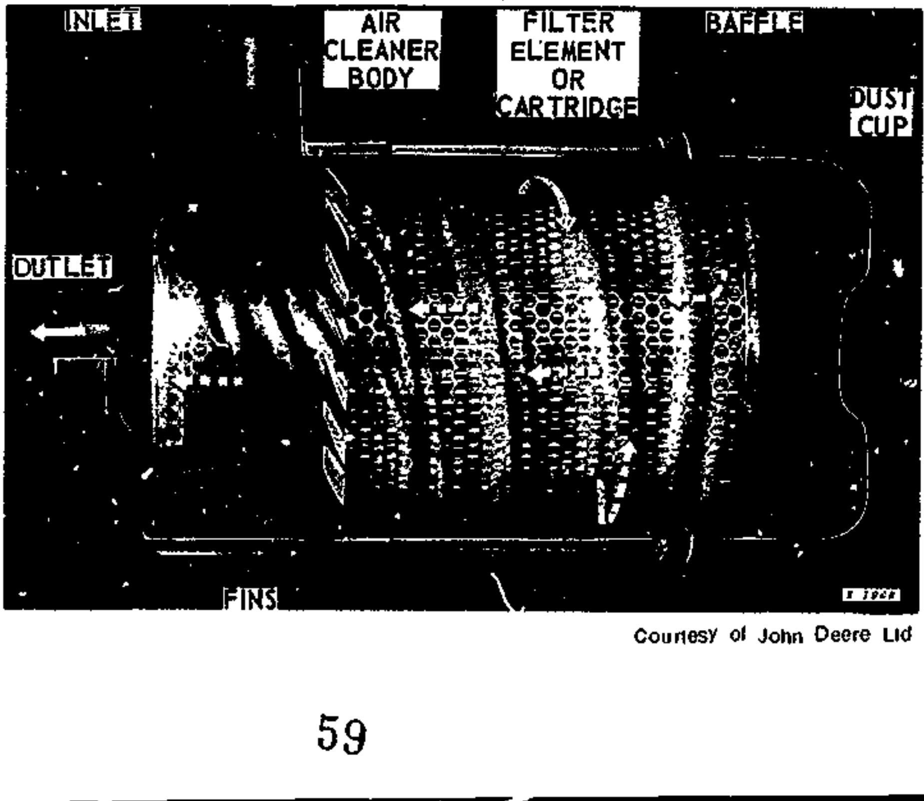
Dry Element Air Cleaners

Cylindrical Dry Element Cleaner (vane and tube type)

Atmospheric air enters the inlet opening of a dry element air cleaner (Figure 7-80) where it immediately travels through a ring of vanes or tubes which create a cyclonic twist to the air. The air twist throws most of the dust and dirt particles outward and down into a removable dust cup. The air, now cleaner, passes through a paper filter which removes the remaining dust.

(7-80)

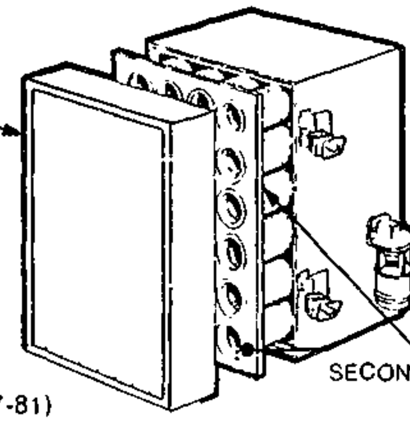
Dry Element Type Air Cleaner



Courtesy of John Deere Ltd

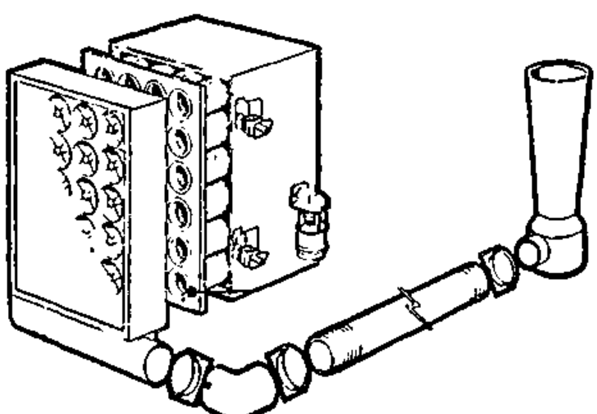
Panel Cartridge Dry Element Cleaner

Pane cartridge dry element cleaners (Figure 7-81) have a two-stage cleaning process similar to the cylindrical models Deflector vanes create a twist in the incoming air which throws out most of the dust. The air then spirals back through the cleaner's element which removes the remaining dust.



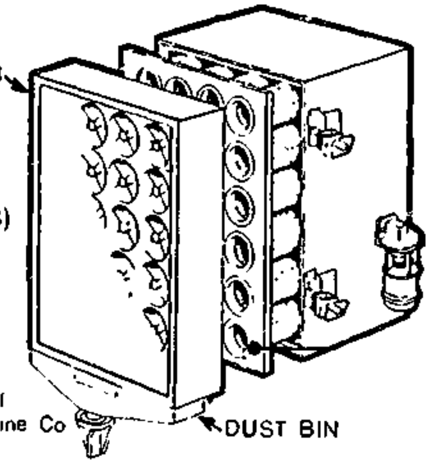
(7-81)
PANEL CARTRIDGE AIR CLEANER
Courtesy of Cummins Engine Co

Some panel cartridge air cleaners use an exhaust aspirator to remove the dust through the exhaust system (Figure 7-82)



(7-82)
CARTRIDGE TYPE-AIR CLEANER-TWO STAGE
Courtesy of Cummins Engine Co

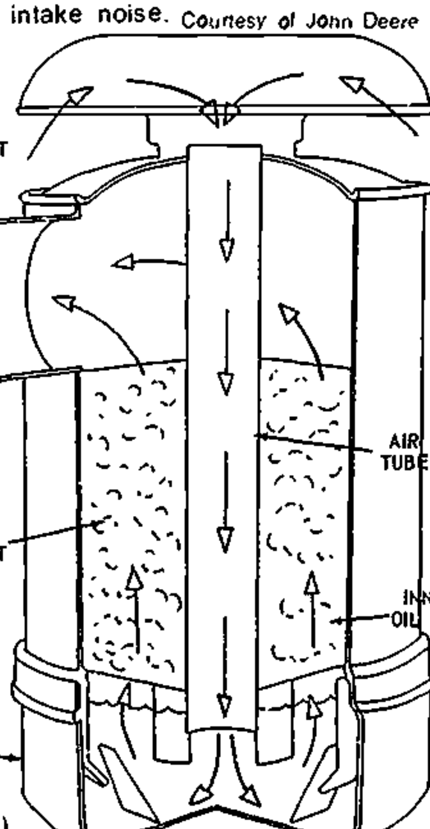
Other panel cartridge air cleaners replace the first stage of cleaning with a moisture eliminator Some vehicles such as on-highway trucks are subjected to water/salt spray and the incoming air needs to have the moisture removed from it before it reaches the dry filter element Attached to the front of the cleaner, the eliminator traps and expells the moisture from the wet air and then sends the dry air to be further cleaned by the paper filters (Figure 7-83)



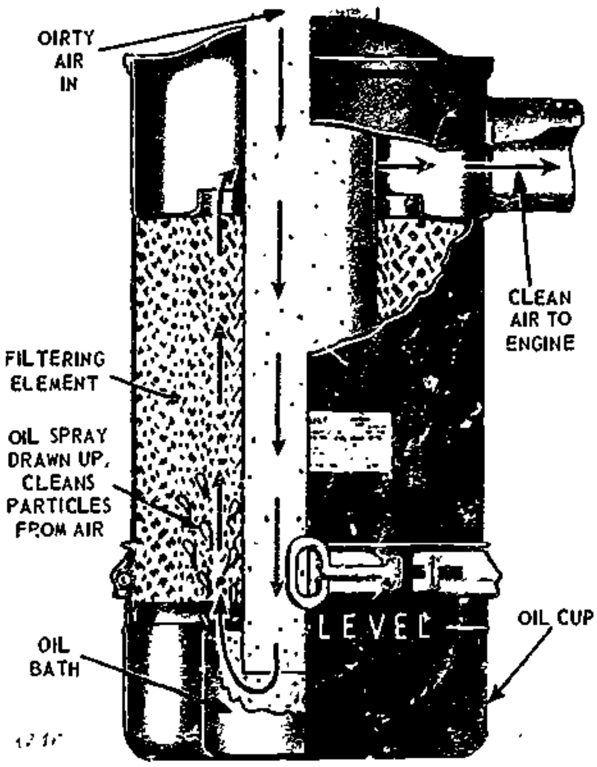
(7-83)
Courtesy of Cummins Engine Co

Oil Bath Cleaners

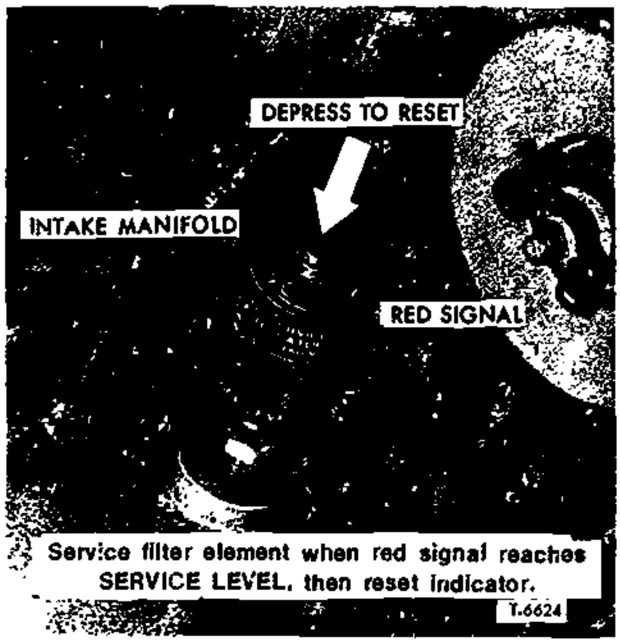
Oil bath cleaners have a cleaning element inside a housing that contains oil (Figure 7-84). Incoming air reverses when it strikes the surface of the oil causing most of the dirt to become trapped by the oil and settle in the sump. The air then passes upward through the main cleaner element where more dust and suspended oil is removed. These second-stage filtered contaminants drain back into the sump and also settle out of the oil. Clean air leaves the cleaner at the air outlet. Light, medium and heavy duty cleaners are available. Note that the space above the main element in the air cleaner acts as a silencer to subdue intake noise. Courtesy of John Deere Ltd



(7-84)
AIR FLOW THROUGH HEAVY-DUTY OIL BATH AIR CLEANER



(7-84) MEDIUM-DUTY OIL BATH AIR CLEANER
Courtesy of John Deere Ltd



(7-85) AIR FILTER RESTRICTION INDICATOR
Courtesy of General Motors Corporation

AIR FILTER RESTRICTION INDICATOR

The air filter restriction indicator (Figure 7-85) is a warning device that tells when the air filter is dirty and needs to be serviced. The indicator is constructed so the warning notice is given before any damage occurs to the engine as the result of a clogged filter element. The restriction indicator is located in the air inlet manifold and is readily visible when the engine compartment is open. The indicator itself requires no service other than resetting.

When the filter element is clogged to such a degree that air flow is restricted, a red indicator ring appears in the transparent area of the body marked "service level". This is the signal that the air cleaner must be serviced. After servicing the cleaner, the indicator is reset by depressing the button on top of it. The red ring will then move out of the transparent area of the indicator.

NOTE Some vehicles will have an air restriction gauge rather than an indicator. The restriction gauge (Figure 7-86) is located on the panel board in the cab and performs the same function as the indicator.

(7-86) AIR FILTER RESTRICTION GAUGE (TYPICAL)
Courtesy of General Motors Corporation

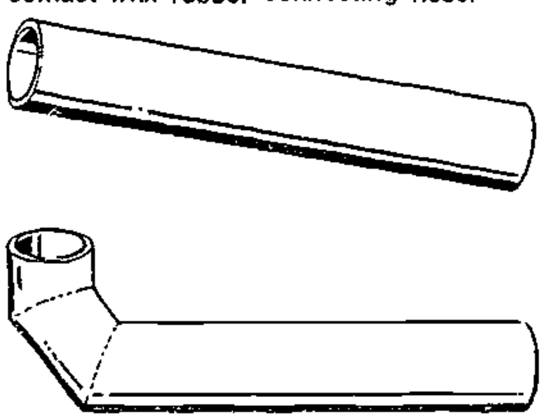
TUBING, HOSE AND CLAMPS FOR AIR INDUCTION SYSTEMS

Air induction piping works in conjunction with the air cleaner to carry clean air to the engine. It is important that all the piping joints are properly sealed and free of leaks. An air cleaner is completely ineffective if leaks occur in the piping between the air cleaner and the engine.

Dirt is the basic cause of wear on pistons, rings, liners and valves. One of the most probable places for dirt to enter an engine is through an opening in air induction piping. Field experience has shown that most air leaks occur when wire reinforced hoses are used in the air induction system. The leaks are caused by wire wearing through the hose fabric and they are often barely visible to the naked eye. Even a very small hole can allow large quantities of dirty air to enter an engine. Therefore, wire reinforced hose is not recommended for air induction tubing.

Smooth-Welded Steel Tubing

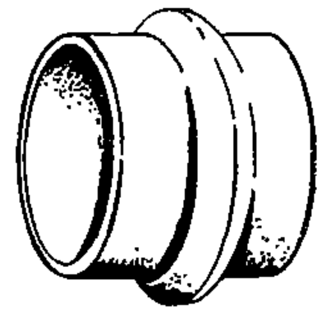
Smooth-welded steel tubing (Figure 7-87) should be used instead of flexible hose or metal tubing that has rough-weld steel tubing angle joints Smooth welded steel tubing has a smooth surface that gives a good sealing contact with rubber connecting hose.



(7-87) SMOOTH-WELDED STEEL TUBING
Courtesy of Cummins Engine Co

Connecting Hose

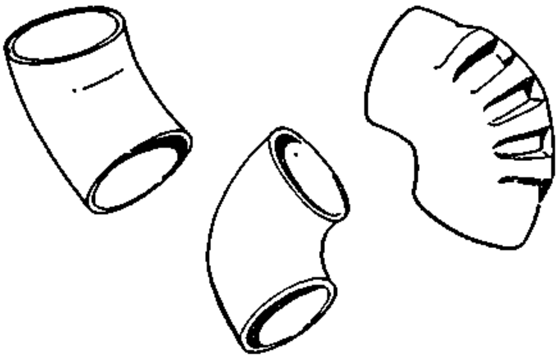
Steel tubing is joined by connecting hose (Figure 7-88). The hose has a built-up hump at its center to give it strength and durability. Note that ideally two pieces of tubing when connected by a hose should be 3/4 inch (19 mm) apart.



(7-88) CONNECTING HOSE
Courtesy of Cummins Engine Co

Molded Rubber Elbows

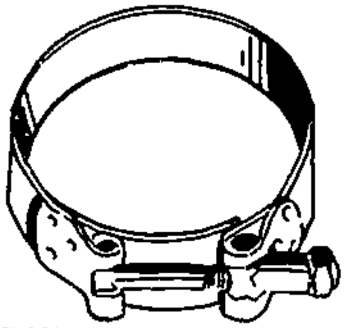
To make angular connections molded rubber elbows are used (Figure 7-89) Elbows are available in both 90° and 45° angles A 90° elbow with ribbed reinforcement is also available to prevent possible collapsing under high temperature conditions or high inlet restriction.



(7-89) MOLDED RUBBER ELBOWS
Courtesy of Cummins Engine Co

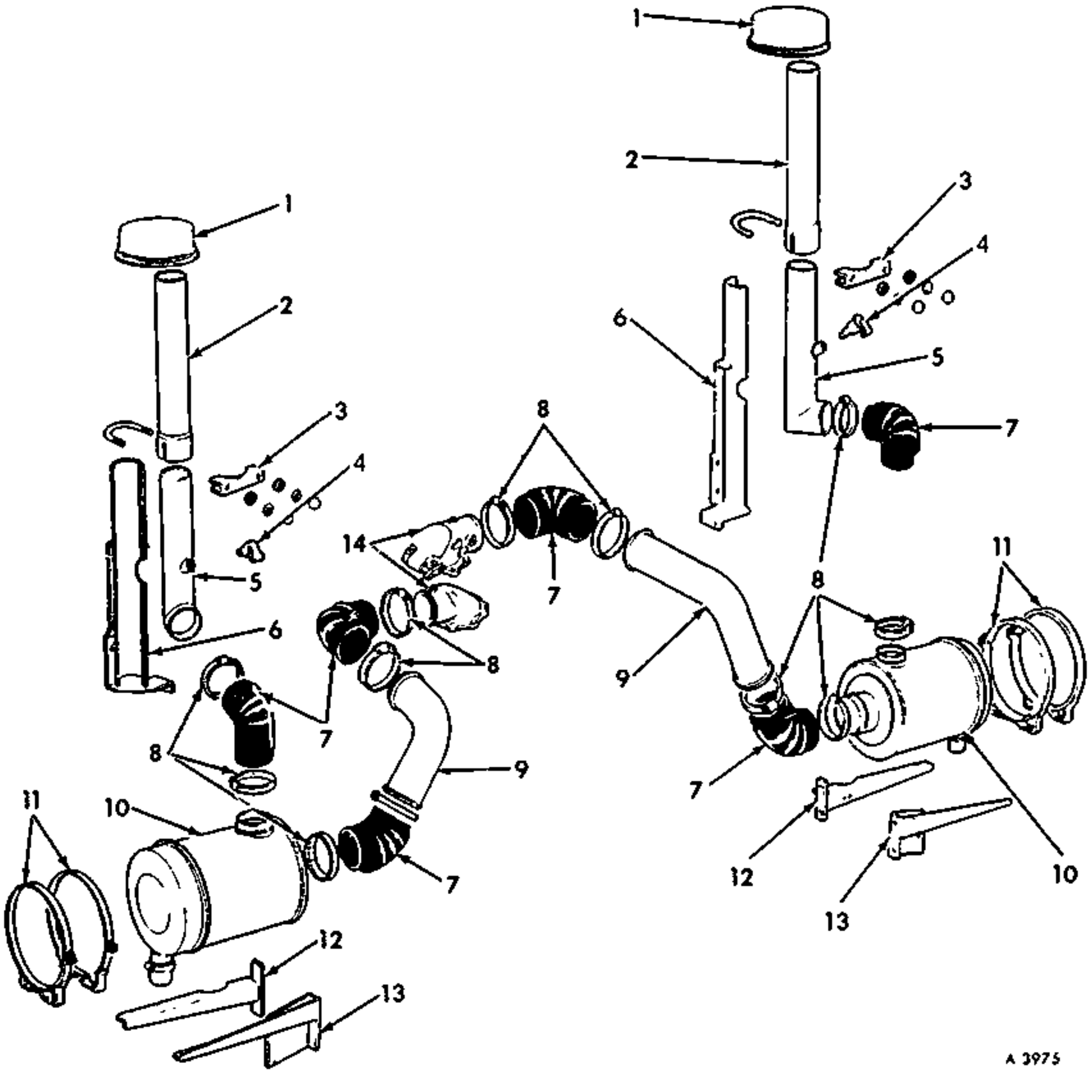
Hose Clamps

"T" bolt type non crimping hose clamps (Figure 7-90) should be used on air induction systems When tightened, the clamp exerts equal pressure around the circumference of the hose. A lock nut prevents the clamp from slipping, and thus assures a tight permanent seal



(7-90) T-BOLT HOSE CLAMP
Courtesy of Cummins Engine Co

Figure 7-91 illustrates the tubing, connecting hose and clamps used on a typical dual inlet air induction system for a large engine



1	Inlet Cap	8	Clamp
2	Extension	9	Tube
3	Clamp Assembly	10.	Air Cleaner Assembly
4	Either Starting Aid	11	Band Brackets
5	Tube	12	Front Supports
6	Support	13	Rear Supports
7	Elbow	14	Engine Inlets

(7-91) Courtesy of General Motors Corporation

PREVENTIVE MAINTENANCE ON AIR INDUCTION SYSTEMS

Good maintenance practices on air induction systems:

1. Keep the air cleaner-to-engine connections tight.
2. Keep the air cleaner properly assembled so all joints are oil and air tight.
3. Periodically make a careful examination of the air induction system for leaks. Over a period of time enough dusty air can pass through even a small crack to severely damage the engine
4. When conditions are dusty frequently inspect the cleaner.
5. Service oil bath cleaners often enough to prevent oil from becoming thick with sludge
6. Use the correct grade of oil. Keep the oil at the proper level in the cup. Do not overfill.

   NOTE Oil from an overfilled cup can be drawn into an engine. The overflow oil can cause a diesel engine to run away (overspeed) and severely damage itself.

7. Always practice cleanliness when working on air systems. Some points of caution are:

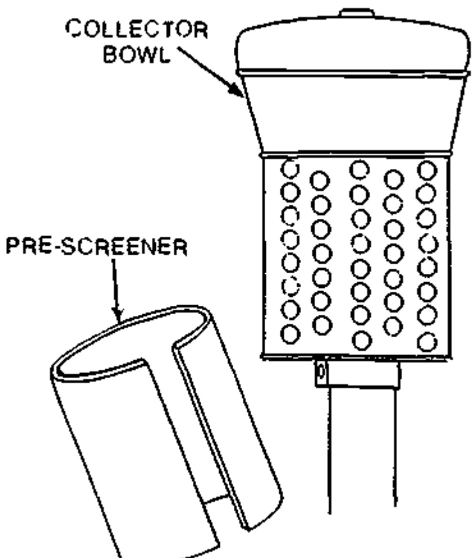
   (a) Be careful when working around an open air intake with the engine running. Rags, loose clothing or other objects can be drawn into the engine and severely damage it.

   (b) Never leave an intake pipe open. Articles can be dropped into an open pipe and cause serious damage when the engine is started. Don't cover the opening with a rag but with something hard such as a piece of plywood.

AIR CLEANER SERVICE

Refer to the service manual about cleaning procedures for particular air cleaners. Typical air cleaner service procedures are given below.

Pre-Cleaner and Pre-Screenar Service



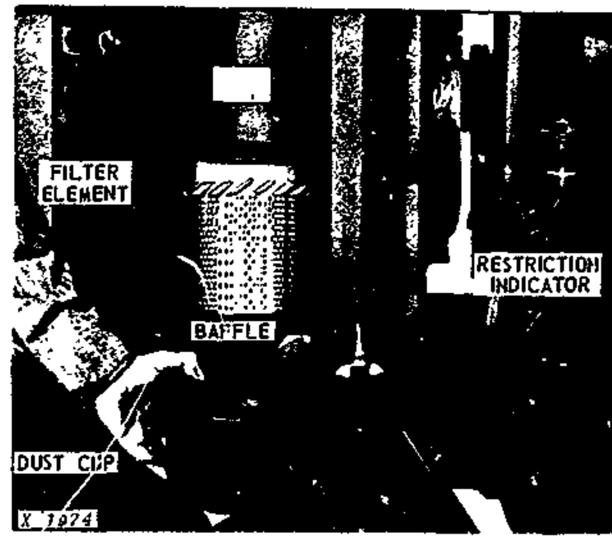
(7-92)

Courtesy of John Deere Ltd

If too much dirt is allowed to collect in the pre-cleaner, it becomes clogged and a greater load is placed on the main cleaner. Remove the pre-screener and blow or brush off any accumulation of lint, chaff, or other foreign matter (Figure 7-92) If the pre-cleaner has a removable collector bowl, take it off and thoroughly clean it.

Dry Element Air Cleaner Service

Servicing dry element air cleaners involves emptying the dust cup and either cleaning or replacing the dry element (Figure 7-93) The element should be replaced if it is damaged or if it has been in normal service for one year.



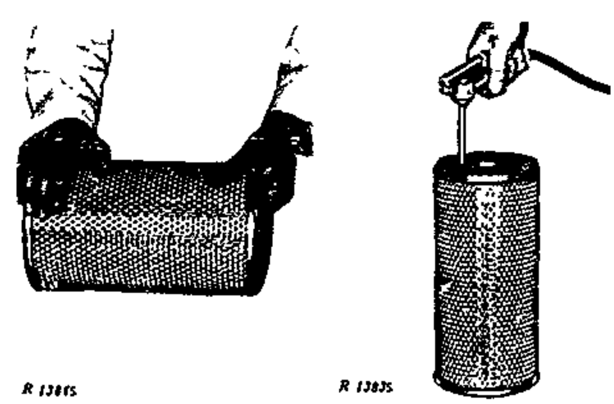
(7-93) DRY ELEMENT TYPE AIR CLEANER

Courtesy of John Deere Ltd

Clean the filter element at the following times:

1. Units with restriction indicators: clean the element whenever the indicator signal shows a restriction.
2. Units without indicators: clean the element at recommended intervals or more often during dusty or unusual operation

To clean the filter element shake it vigorously to remove most of the dust Use compressed air or a vacuum cleaner to remove any remaining dirt (Figure 7-94).



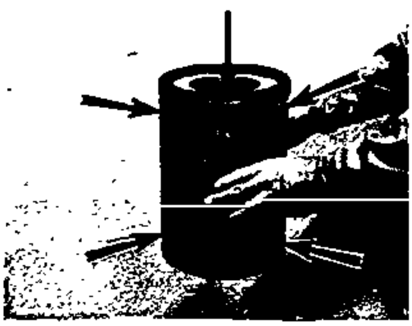
Patting The Element   Blowing The Element

(7-94) CLEANING THE DRY ELEMENT

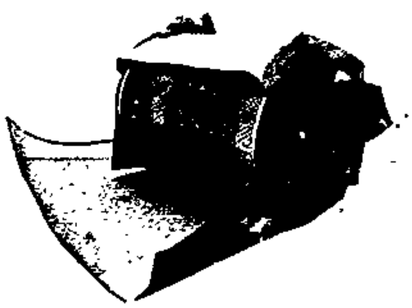
Courtesy of John Deere Ltd

If the element is still dirty, it can be washed in a solution of luke warm water and commercial filter-element cleaner or similar non-sudsing detergent Washing dry elements has become quite common because of the high cost of the elements They can be washed up to six times The washing can be done in a shop but more likely the elements will be sent out to companies who provide this service. Spare elements should be kept on hand to use in vehicles while others are being washed and dried. After an element is washed it should be checked and stored as shown in Figure 7-95)

CHECKING ELEMENT



1 Insert light inside clean and dry element Check element. Discard element if pin holes or tears are found



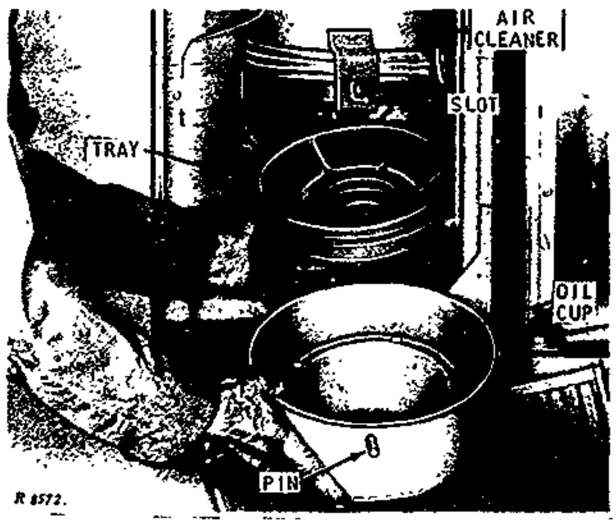
2 Wrap and store elements in a clean dry place

(7-95)

Courtesy of Caterpillar Tractor Co

Medium and Heavy Duty Oil Bath Air Cleaner Service

For a medium-duty air cleaner, remove the oil cup, pour out the oil, remove the sediment and thoroughly clean the cup (Figure 7-96). When refilling the cup use the same oil as is used in the engine Inspect the under-surface of the fixed element for a collection of lint, trash, or other foreign matter If any of these are present, the cleaner should be removed and cleaned.



(7-96)

HEAVY-DUTY AIR CLEANER OIL CUP AND TRAY

Courtesy of John Deere Ltd

To clean the element soak it in solvent to loosen accumulated dirt. Thoroughly flush the element by running solvent through it from the air inlet end. Allow excess solvent to drip out Blow out the element with compressed air

CAUTION: Never attempt to clean the element with a steam cleaner. The force of the steam cannot be maintained throughout the element and will only force the dirt to the center of the element.

Wipe out the center tube with a clean lint-free cloth. Inspect the inside of the air cleaner-to-manifold pipe for accumulation of oil and dirt. If necessary, remove the pipe and clean it. A heavy duty oil bath cleaner is cleaned in a similar way to a medium duty one. In addition, though, some heavy duty cleaners have a collector screen(s) attached to the inlet tube which must be cleaned. Wash the screen in solvent and blow it out with compressed air. When a clean screen is held up to the light, an even pattern of light should be visible If the screen doesn't pass this test repeat the cleaning operation or replace it.

NOTE. The fixed elements of heavy-duty air cleaners are self-cleaning However, it may be necessary to remove and clean these elements periodically See the operator's manual for complete information.

QUESTIONS — AIR INDUCTION SYSTEMS

1 What are the three types of air induction systems used to supply air to the engine?

2 Briefly explain how a scavenge blown engine differs from a natural aspirated engine.

3. The Turbo charger is driven by

(a) gears in the engine

(b) oil pressure

(c) exhaust driven turbine

(d) intake driven compressor

4 How does a turbo charger get more air into the combustion chambers than a naturally aspirated engine?

5 Under what condition does a turbo charged engine receive its maximum boost pressure?

6 An after cooler (intercooler) is used on a turbo charged engine to:

(a) cool the exhaust gases

(b) cool the inlet air before it enters the engine

(c) cool the inlet air before it enters the turbo charger

(d) cool the exhaust manifold

7 What are the three most common types of air cleaners?

8 True or False If an engine has a pre-cleaner it doesn't need a main air cleaner

9 What is the purpose of the circular or deflector vanes in the dry element air cleaner?

10 In an oil bath air cleaner, what happens to the air when it strikes the surface of the oil?

11 What indication does an air restrictor indicator give when the air filter needs servicing?

(a) a light comes on

(b) a buzzer sounds

(c) a red band is visible on the indicator

(d) it won't allow the engine to start

12 When servicing an oil bath air cleaner, what is the danger of over filling the cup?

13 List two safety practices to be observed when working on an air induction system

14 How often should a dry air filter element be cleaned?

15 Why should an oil bath air cleaner not be steam cleaned?

16 True or False? A minor leak in air induction piping between the air cleaner and the engine probably won't do too much damage.

17 What type of oil is used in an oil bath air cleaner.

18 In a medium-duty oil bath cleaner the cleaner should be removed and cleaned if:

(a) the oil is low

(b) the oil appears to be dirty

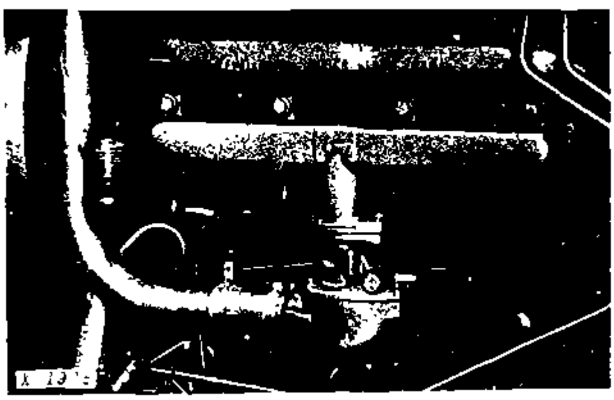
(c) lint and other contaminants appear on the underside of the element

EXHAUST SYSTEMS

The function of the exhaust system is to collect exhaust gases from the engine cylinders and disperse them quietly. The exhaust system consists of the following parts:

Exhaust Valves seal the burning gases within the cylinder until most of the energy has been expended, and then open so that the cylinder can clear before the next air or fuel-air charge is admitted.

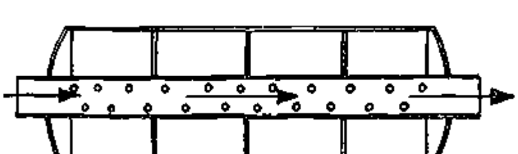
Exhaust Manifolds receive burned gases from each cylinder and carry them away from the engine (Figure 7-97). Some heat from the exhaust manifold is used in gasoline engines to maintain the intake manifold at the proper temperature.



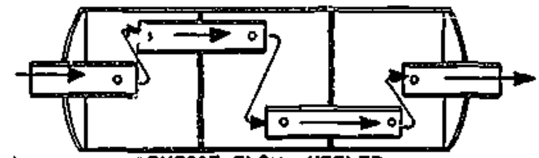
(7-97)
EXHAUST MANIFOLD (GASOLINE ENGINE)
Courtesy of John Deere Ltd

Turbo Chargers use exhaust gases to drive the compressor turbine.

Mufflers carry away exhaust gases and heat, and muffle engine noise. The exhaust ports in the engine and the passages in the exhaust manifold are large enough to allow complete scavenging and expansion of the escaping gases. If any burned gases were left in the cylinders following the exhaust stroke, the amount of air or fuel-air mixture that could be taken in on the next intake stroke would be limited. Engine power would be reduced and fuel consumption increased.



STRAIGHT_THROUGH MUFFLER
(7-98)
Courtesy of John Deere Ltd



REVERSE_FLOW MUFFLER
(7-98)
Courtesy of John Deere Ltd

MUFFLERS

There are two common types of mufflers:

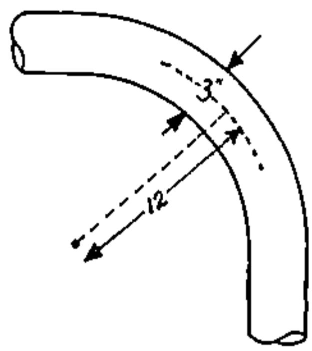
— Straight-through
— Reverse-flow

Straight-through mufflers consist of a perforated inner pipe enclosed by an outer pipe roughly three times larger in diameter. The space between the pipes is sometimes filled with a sound-absorbing and heat-resistant material (Figure 7-98).

Reverse-flow mufflers are hollow chambers using short pieces of pipe and baffles to force the exhaust gases to travel a back-and-forth path before being discharged (Figure 7-98).

Mufflers reduce engine noise, but at the same time they must not restrict the flow of exhaust gases enough to cause back pressure in the exhaust system. Back pressure causes incomplete cylinder scavenging which in turn causes loss of power and increased fuel consumption. Excessive back pressure can even damage combustion chamber components. For each two p.s.i. of back pressure about four engine horsepower are lost. The trade-off in muffler design then is to keep back-pressure at a minimum while keeping the noise at an acceptable level. Note that special mufflers are made to minimize the additional noise on systems that have engine brakes.

Muffler and piping size is related to engine capacity Usually the muffler volume is equal to six to eight times engine displacement (engine displacement is the total volume of air/fuel mixture an engine theoretically can take into all cylinders in one cycle) Bends in exhaust piping should be gradual, not sharp, so that gas flow is not restricted. The general rule for bends is that the radius of the bend be four to five times the diameter of the tubing For example 3 inch tubing should have a 12 inch radius bend (Figure 7-99)



(7-99) RADIUS OF BEND

Bends in exhaust pipe are not usually made in shops: custom lengths and bends are available from manufacturers.

Vehicles working in forested and industrial areas where fire may be a hazard have a further addition to their exhaust system — a spark arrester A spark arrester is a screen over the exhaust outlet to reduce the chances of hot pieces of carbon or sparks being discharged.

PREVENTIVE MAINTENANCE ON EXHAUST SYSTEMS

Exhaust systems should be inspected periodically for restrictions and leaks. Restrictions such as kinked or crimped pipes result in harmful back pressure, while exhaust leaks create unwanted noise and a danger of poisonous gas seeping up into the cab Restrictions are caused by pipes being struck Leaks are usually caused by:

1 loose clamp assemblies
2 defective connections between manifold and exhaust pipe, and exhaust pipe and muffler(s)
3 corroded pipes
4 punctured muffler.

Leaks can be detected by running your hand a few inches above the pipe while the engine is running. Damaged or corroded exhaust system components should be replaced without delay for both engine efficiency and ve safety.

SOME POINTS ON EXHAUST SYSTEM REMOVAL AND INSTALLATION

1 Caution: One of the products of combustion is carbon monoxide This is a deadly, odorless, poisonous gas. Provide good ventilation anytime the engine is operating

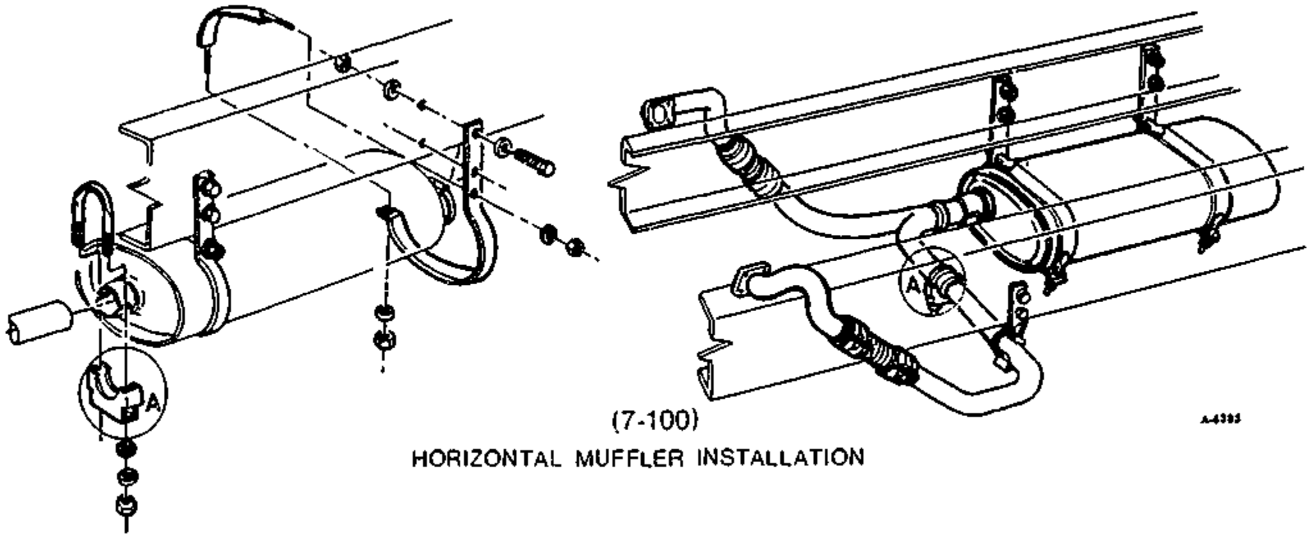
2. Be careful of hot pipes and muffler(s) if the engine has been running recently. When removing pipes and the muffler, support the whole assembly to prevent it from falling on you when the clamps and bolts are removed.

3. Exhaust components must have a 3/4 inch clearance with the frame or the cab. Components without proper clearance are frequently the cause of annoying noises and rattles. The 3/4 inch clearance is also necessary to prevent overheating of the cab paneling. If needed, a metal or asbestos heat shield can be installed on the part of the pipe that passes a critical area To get proper clearance, leave all clamp assemblies and muffler strap bolts loose temporarily until the entire system has been inspected to determine if there is adequate clearance between exhaust components and frame members. While the clamp and bolts are loose also check to see that the weight of the exhaust system is properly distributed on all supporting brackets and hangers. If the load is not properly balanced reposition pipes at connecting joints.

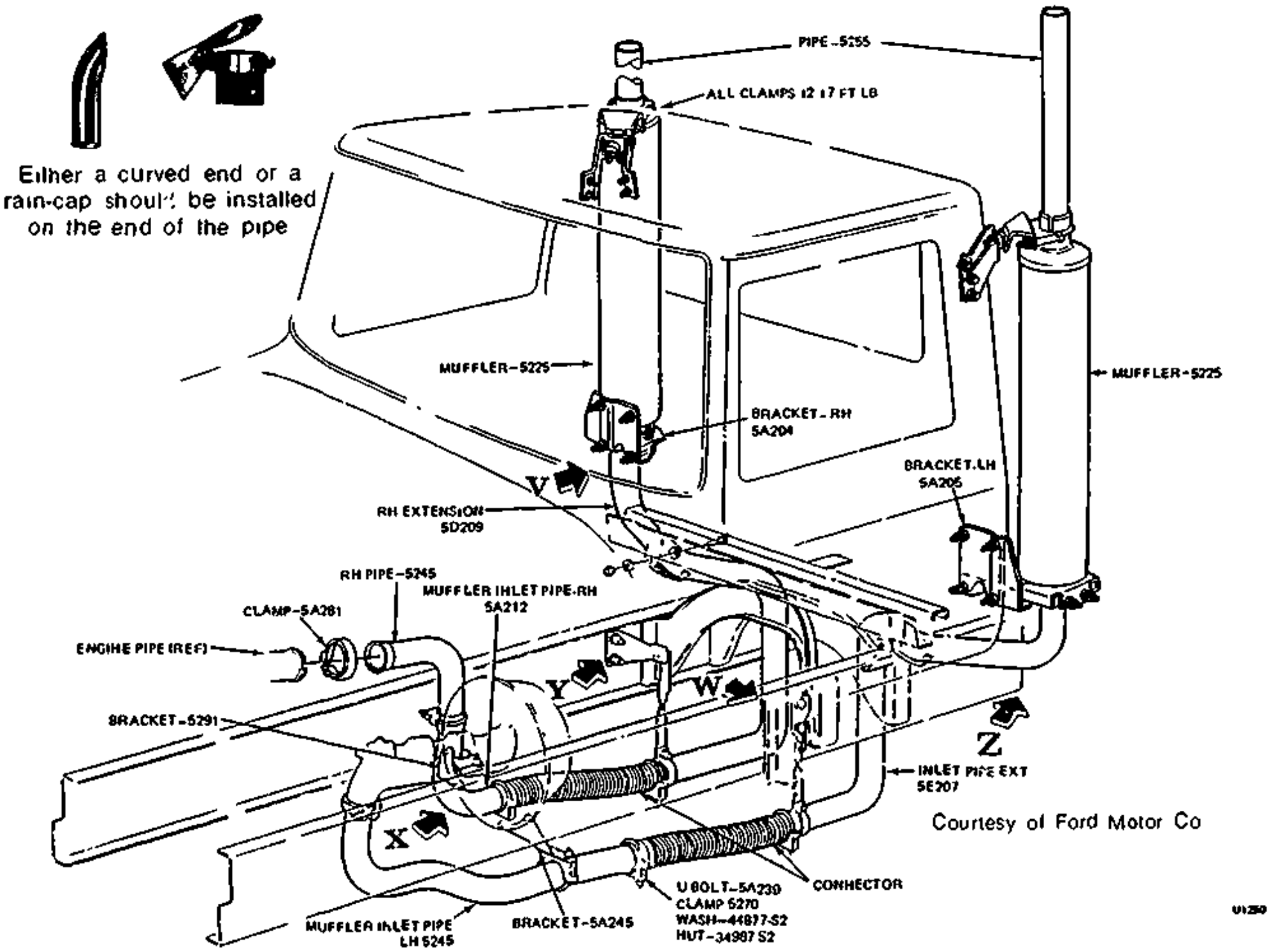
   When the clearance and balance are correct, tighten all bolts and clamps, working from front to rear. Note when installing the exhaust pipe to the manifold, always use new packing and new nuts or bolts Be sure to clean the manifold stud threads with a wire brush before installing the new nuts

   After everything is tightened start the engine and check the connections for leaks A horizontal muffler installation is shown in Figure 7-100 and a verticle muffler installation in Figure 7-101 Note how the clamps and support brackets are positioned to balance the weight of the pipes and muffler(s)

Courtesy of General Motors Corportion



(7-100)
HORIZONTAL MUFFLER INSTALLATION



Courtesy of Ford Motor Co

(7-101) Typical Heavy Tr..k Dual Exhaust System—L-, LT-, LNT-9000 with V-903 Dual Vertical Mufflers Shown Others Similar

QUESTIONS — EXHAUST SYSTEM

1 Besides carrying away exhaust gases and heat a muffler must:

(a) increase horsepower
(b) help control engine temperature
(c) muffle engine noise
(d) all of the above

2 Back pressure causes.

(a) incomplete cylinder scavenging
(b) loss of power (four horsepower for every two p.s.i. back pressure)
(c) increased fuel comsumption
(d) a, b and c are all correct

3 Usually muffler volume is equal to ________ times engine displacement.

(a) 6 to 8
(b) 4 to 6
(c) 7 to 9
(d) 2 to 4

4 Why are gradual bends better than sharp bends in an exhaust system?

5 What is the danger of leaks in exhaust piping?

6 From a safety point of view, what is the most important precaution to take when running an engine indoors?

7 How can you check exhaust pipe connections for leaks?

FUEL SYSTEMS

The basic purpose of a fuel system is to supply enough fuel to meet engine speed and load demands Gasoline, diesel and L.P gas engines all have a different type of fuel system.

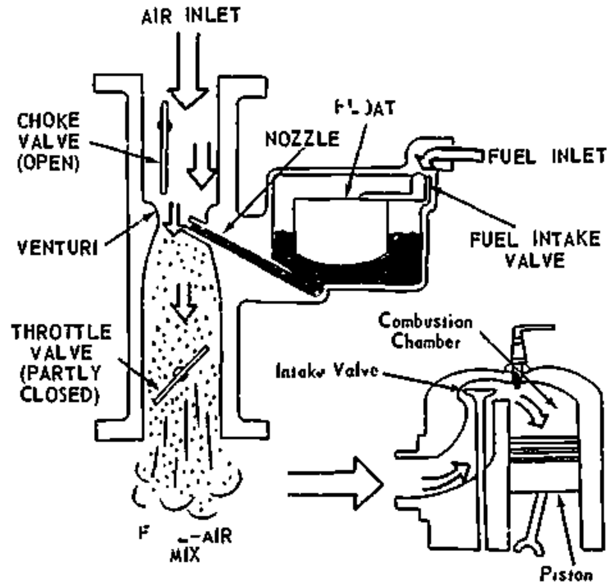
GASOLINE FUEL SYSTEMS

The gasoline fuel system supplies a combustible mixture of fuel and air to power the engine The gasoline fuel system has three basic parts (Figure 7-102):

fuel tank — stores gasoline for the engine

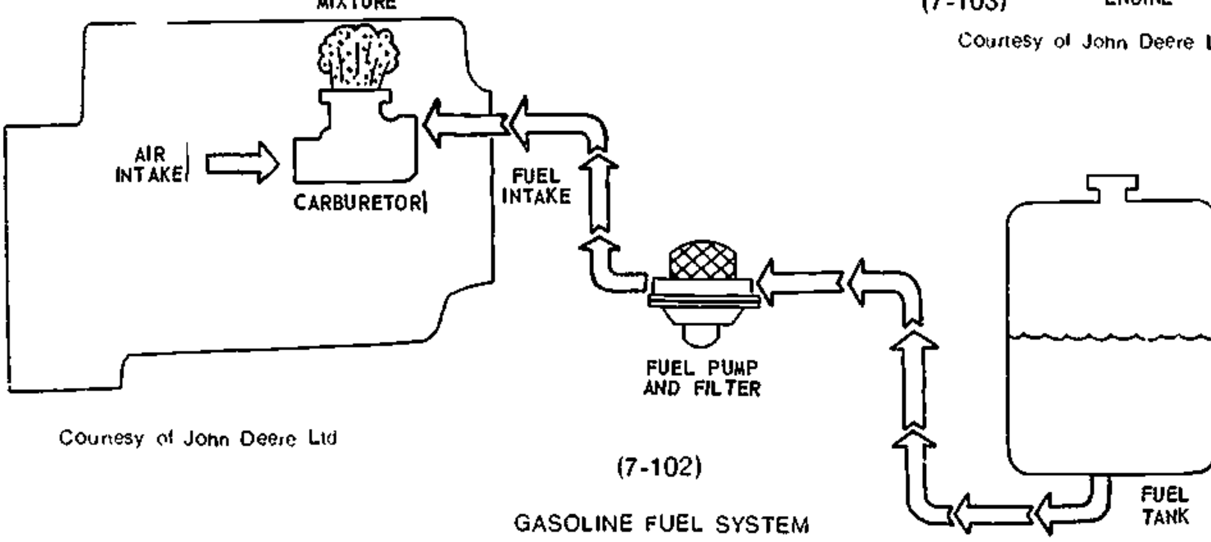
fuel pump — moves the fuel from the tank to the carburetor

carburetor — atomizes the fuel and mixes fuel and air in the proper ratio



(7-103) ENGINE

Courtesy of John Deere Ltd



Courtesy of John Deere Ltd

(7-102)

GASOLINE FUEL SYSTEM

The fuel pump draws the gasoline through a fuel line from the tank and forces it in to the float chamber of the carburetor where it is stopped. The carburetor is basically an air tube connected to a float chamber that operates by a difference in air pressure (Figure 7-103)

The pressure difference in the carburetor is created when air flows through a narrow neck called the venturi. In order to maintain its rate of flow air traveling through a tube at a given rate will speed up as it goes through a narrowing in the tube (i.e., at the narrowing not as much air can get through. Therefore, the air must travel faster By speeding up, the same amount of air per second can travel through the narrow neck, and the rate of flow is maintained) When the air speeds up its molecules spread out and consequently its pressure is reduced For example, air traveling at 14 7 lbs per square inch can drop to 8 p.s.i. passing through the venturi This drop creates a pressure difference between the carburetor float chamber and the carburetor nozzle that opens onto the venturi

The pressure difference at the nozzle tip draws fuel from the float chamber and delivers it to the nozzle in the form of tiny droplets The droplets mix with the air and vaporize giving the air-fuel mixture for combustion.

The fuel-air mixture must pass a throttle valve before it goes to the engine. The throttle controls the amount of mixture going to the cylinders, and thereby controls engine speed.

The other basic part of a carburetor is the choke which is needed for starting an engine in cold weather. The choke is located in the incoming air passage and partially or fully closing it causes a vacuum to form underneath it. The vacuum causes the carburetor to produce a mixture which has a greater percentage of fuel. This richer mixture is necessary because when gasoline is cold it does not vaporize as readily as it does when it's hot; so, more fuel is needed to supply an adequate amount of vapors. The choke may be automatically controlled, opening as the engine warms up, or it may be manually controlled by the operator.

Of course, actual carburetors are more complex; they will be studied in future training.

Recommended reading: Chapter 18 and 19, Automotive Fuel Systems and Automotive Carburetors, in **Automotive Mechanics, Seventh Edition.**

LIQUIFIED PETROLEUM GAS FUEL SYSTEMS

Facts About Liquified Petroleum Gas (LPG)

LPG is

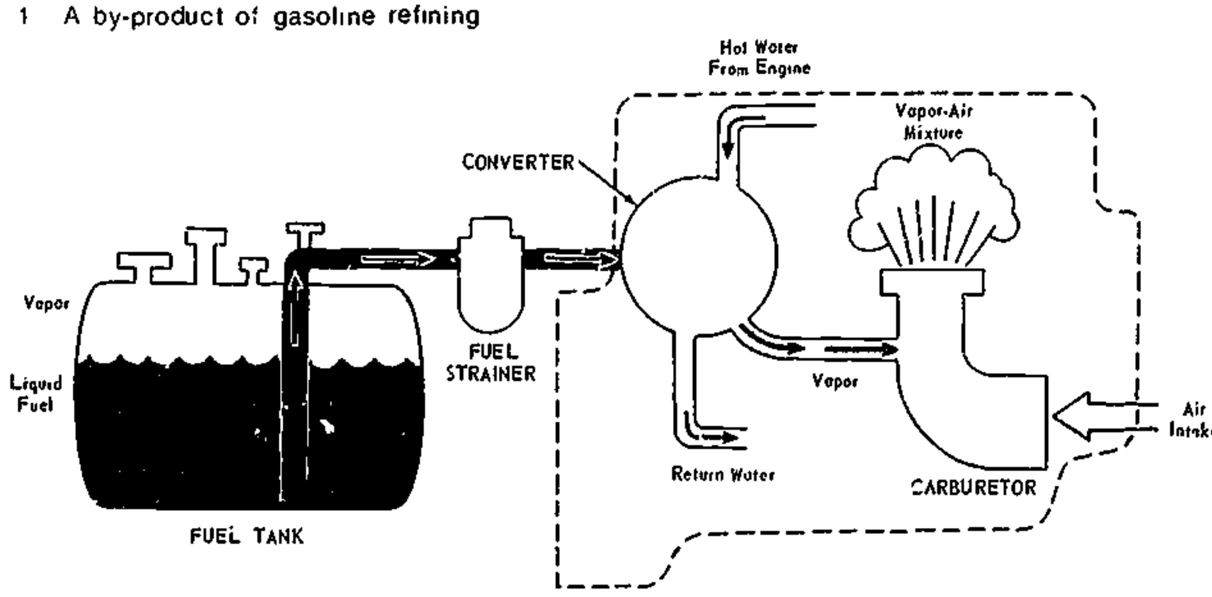
1. A by-product of gasoline refining.
2. Also obtained from natural gas.
3. Made up of propane, butane or a mixture of the two.
4. Vaporizes very easily. Remains a liquid only when under pressure.
5. Liquified by compressing many gallons of vapor to make one gallon of liquid.
6. Easy to handle and store as a liquid. Stored in strong, heavy tanks with pressure relief valves.
7. Expansive when heated (due to more vaporization).
8. Converted to vapor again on way to the engine.

The basic difference in the operations of an LPG fuel system and a gasoline fuel system is that LPG is vaporized before it reaches the carburetor whereas gasoline is vaporized in the carburetor.

Parts Of A LPG Fuel System

The LPG fuel system has four basic parts (Figure 7-104):

- Pressurized Fuel Tank
- Fuel Strainer
- Converter
- Carburetor



(7-104) LPG FUEL SYSTEM

Courtesy of John Deere Ltd

The pressurized fuel tank stores the liquid fuel under pressure. A space for vapor is left at the top of the tank. To withdraw LPG from the tank two methods are used liquid withdrawal and vapor withdrawal.

Most modern systems use the liquid withdrawal method The fuel is drawn from the tank under pressure as a liquid and then vaporized. The vapor withdrawal method is normally used only for starting when the engine is cold and hasn't enough heat to convert liquid fuel to vapor. Vapor is drawn off the top of the tank to provide vaporized fuel for start up. Once the engine is warm, the fuel system is switched to liquid withdrawal.

The fuel strainer cleans the liquid fuel. It normally has a solenoid which permits flow only when the engine ignition is turned on.

The converter changes the liquid fuel to vapor by warming it and lowering its pressure.

The carburetor mixes the fuel vapor with air in the proper ratio for the engine.

Comparing LPG and Gasoline

1. Both propane and butane produce slightly less heat per gallon than gasoline However. LPG has a higher octane rating which means that the compression ratio of LPG engines can be raised to offset the heat losses.
2. LPG burns slower than gasoline because it ignites at a higher temperature. For this reason. the spark is often advanced farther on LPG engines.
3. More voltage at the spark plugs may be needed for LPG engines than for gasoline.
4. LPG engines do not require as much heat at the intake manifold as gasoline models because LPG will vaporize at lower temperatures The result: less heat is wasted and more heat goes into engine power.

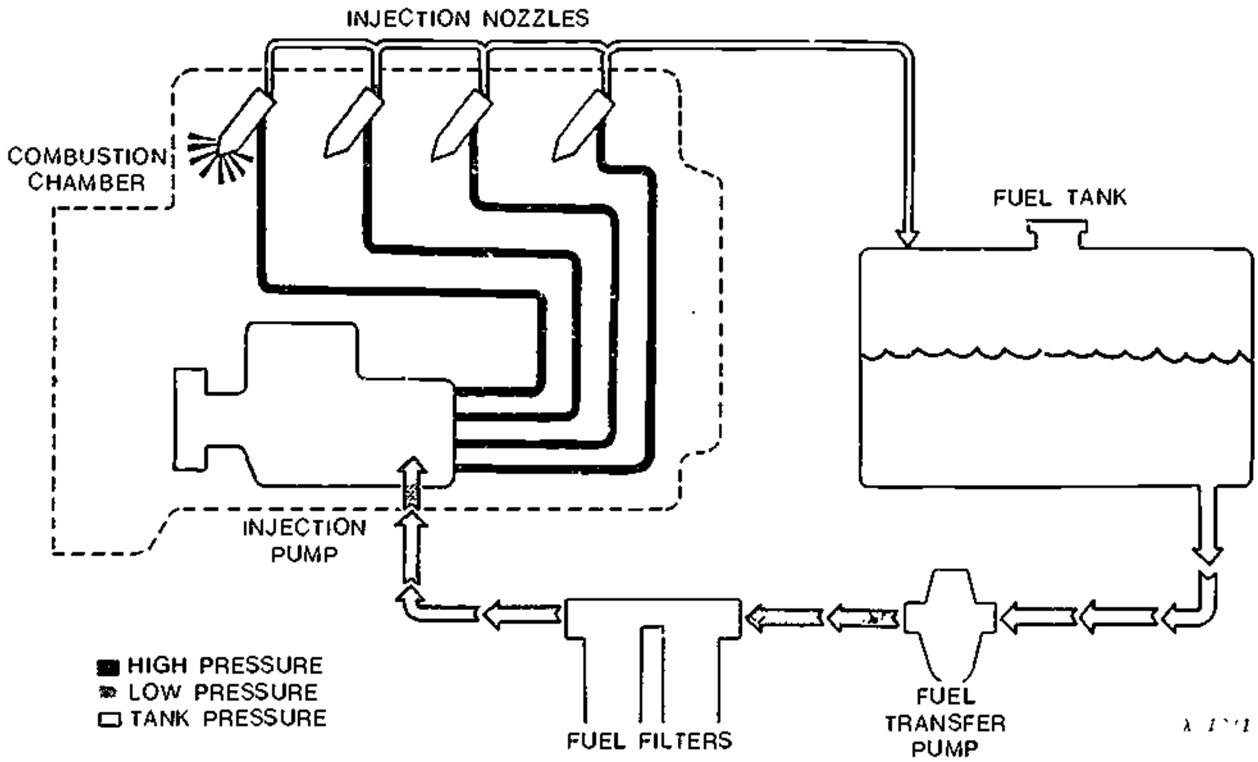
Advantages and Disadvantages of LPG

The advantages of LPG are:

- — Burns much cleaner than gasoline or diesel fuel; its exhaust contains less carbon monoxide and other harmful emissions. For this reason it is used in machines such as fork lifts that operate in warehouses or other closed environments.
- — Cheaper fuel especially where close to source.
- — Less oil consumption due to less engine wear.
- — Reduced maintenance costs, longer engine life between overhauls.
- — Smoother power from slower, more even burning of LPG fuel.

The disadvantages of LPG are:

- — Equipment costs are high. Bulk storage and carburetion equipment are costly.
- — Fewer accessible fueling points. Not many LPG filling stations.
- — Harder to start engines on LPG in cold weather (0°F or below) because oil on the cylinder walls remains undiluted and makes the engine harder to turn.



Courtesy of John Deere Ltd

(7-105)
DIESEL FUEL SYSTEM
(DISTRIBUTOR TYPE SHOWN)

DIESEL FUEL SYSTEMS

The prime job of a diesel fuel system is to inject a precise amount of atomized and pressurized fuel into each engine cylinder at the proper time

Combustion in the diesel engine occurs when this charge of fuel is mixed with the hot compressed air that ignites the fuel.

The major parts of the diesel fuel system are (Figure 7-105):

- Fuel tank — stores fuel
- Fuel Transfer Pump — pushes fuel through filters to the injection pump.
- Fuel filters — cleans the fuel.
- Injection Pump — times, measures and delivers fuel under pressure to the cylinders
- a governor — controls engine speed.
- Injection Nozzles — atomizes and sprays fuel into the cylinders.

Fuel either flows by gravity pressure from the fuel tank to the transfer pump or it is drawn from the tank by the transfer pump. From the transfer pump fuel is pushed through filters and cleaned (It is very important that diesel fuel be absolutely clean so that the closely fitted parts in the injection system are not damaged. The fuel then travels to the injection pump where it is metered and highly pressurized and then delivered to each of the injection nozzles. The injection nozzles atomize the fuel and spray it into the combustion chambers

Function Of Fuel Injection

The Diesel Fuel Injection must.

1. Supply Fuel — The fuel injection system must supply the exact amount of fuel to each cylinder on each cycle.
2. Timed Fuel Delivery — Fuel delivered too early or too late during the power stroke causes a loss of power. Fuel must be injected into the cylinder at the instant maximum power can be realized.

3 Control Delivery Rate — Smooth operation from each cylinder depends on the length of time it takes to inject the fuel Fuel must be injected at a rate that controls combustion and cylinder pressure. The higher the engine speed the faster the fuel must be injected.

4 Atomize Fuel — The fuel must be thoroughly mixed with the air for complete combustion. For this reason the fuel must be broken up into fine particles.

5 Distribute Fuel — The fuel must be spread evenly in the cylinder to unite with all the available oxygen This makes the engine run smoothly and develop maximum power

There are a number of different fuel injection systems. but they all must perform these five basic functions Diesel fuel supply systems will be dealt with in greater detail at a later date

BASIC COMPONENTS OF GASOLINE, DIESEL AND LPG FUEL SYSTEMS

Following is a closer look at some of the fuel supply components of the three fuel systems that you are most likely to be in contact with at this level of training.

Fuel Tanks

Fuel tanks for gasoline. LPG and Diesel all have the same purpose — to provide a safe method for storing fuel. The location, size and tank material for the three systems. however. will vary

Gasoline and Diesel tanks generally have the following features:

1 A drain plug or drain cock on the bottom of the tank which allows water or sediment to be periodically drained.

2 A shut-off valve on the outlet line

3 A filler cap that is twist lock or threaded

4 A vent mechanism It may be built into the filler cap or be located separately The vent allows air to enter the tank to replace the space of the fuel that is drawn out. thus preventing restriction of the fuel flow or a vacuum in the tank

5 An outlet pipe is raised slightly from the bottom of the tank to prevent dirt or water getting into the fuel line. As an added precaution against dirt. the fuel pick up line will have a coarse filter such as a screen at the fuel entry point

6. Diesel fuel systems generally have a return line as well. This line returns at the opposite end to the outlet so that any entrapped air can escape.

7. Baffles to strengthen the tank and prevent sloshing of the fuel.

8. A gauge or some means of checking the fuel level.

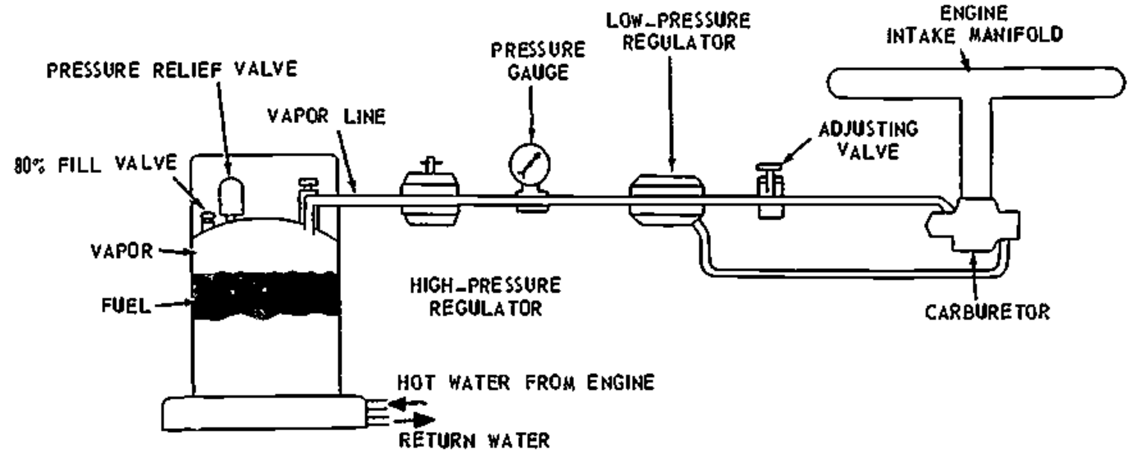
9. Dual tanks have connecting lines and possibly a three-way valve to switch from one tank to the other.

Gasoline fuel tanks in small vehicles are usually made of light gauge metal pressed into shape and treated to prevent rusting. Fuel tanks for larger vehicles, whether for gasoline or diesel, are made of much heavier gauge metal. and are rolled and welded with stamped ends. These tanks are also treated internally to prevent rusting

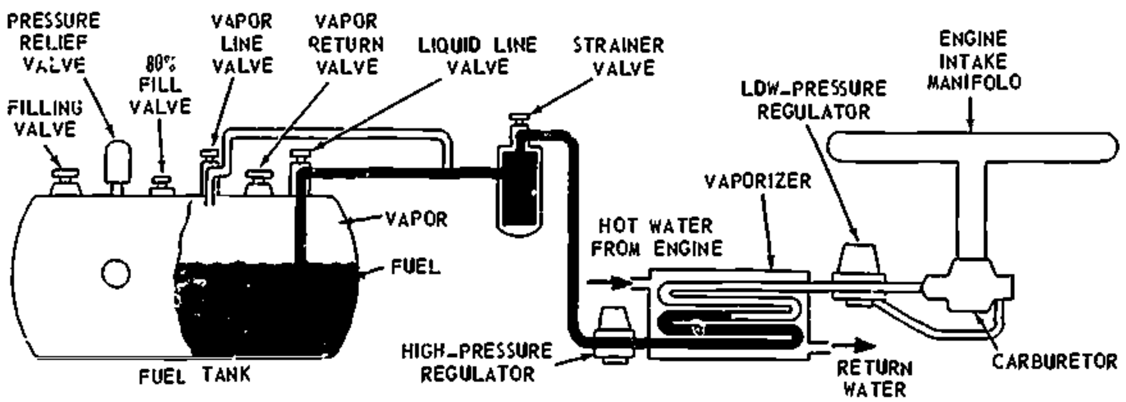
Fuel tanks come in many different sizes and shapes. The tank must be capable of storing enough fuel to operate the engine for a reasonable length of time. The shape of the tank is made to conform to the space available on the machine. A tank can be tall. short. round. square. whatever shape that will fit into the allotted space.

LPG Tanks

An L.P gas fuel tank must be strong and heavy to withstand the pressure of its fuel. The fuel tank is never filled completely full of liquid fuel (usually to 80%) because room must be left for vapors and expansion. The tanks require special equipment to fill them Two types of tanks are shown in Figure 7-106. a vapor withdrawal tank and a liquid withdrawal tank



LP—GAS SYSTEM USING VAPOR WITHDRAWAL



LP—GAS SYSTE'' 'SING LIQUID WITHDRAWAL

Courtesy of John Deere Ltd

(7-106)

LPG FUEL SYSTEM

Fuel Filters

Contamination of fuel can be a major cause of wear to internal engine parts that eventually leads to engine failure Fuel filter must clean the fuel before it gets into the carburetor in gasoline and L P gas engines, or into the injection pump in a diesel engine

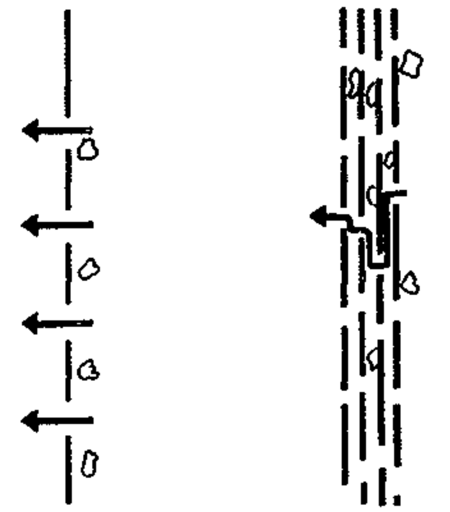
Types Of Filters

Filtration removes suspended matter from the fluid Some filters will also remove soluble impurities

Filtration can be done in three ways·

- straining
- absorption
- magnetic separation

Straining is a mechanical way of filtering (Figure 7-107). A screen blocks and traps particles larger than the openings. The screen may be wire mesh for coarse filtering or paper or cloth for finer filtering.



(7-107)

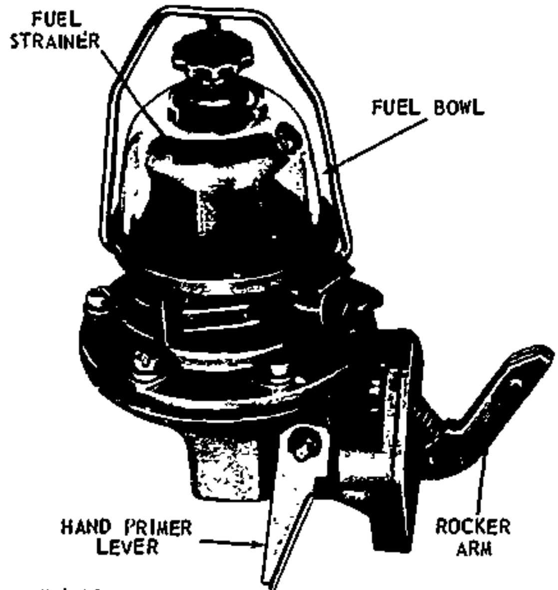
Courtesy of John Deere Ltd

Absorption is a way of trapping solid particles and some moisture by forcing these contaminants to stick to the filter media — cotton waste, cellulose, woven yarn, or felt (Figure 7-107).

Magnetic Separation is a method of removing water from fuel. A paper filter is treated with chemicals that cause any water in the fuel to separate and drip into a water trap (The filter also removes solid particles by one of the other methods of filtration)

Filters are rated according to the degree to which they filter out particles Filtration degree is usually measured in microns. One micron is approximately .00004 inch or one 40 millionth of an inch. To get an idea of how small a micron is it would take 25,000 microns laid side to side to make up an inch. The smallest particles that can be seen with the unaided eye are about 40 microns. Since some of the finer fuel filters (diesel) are rated at two microns, many of the particles they filter out are invisible.

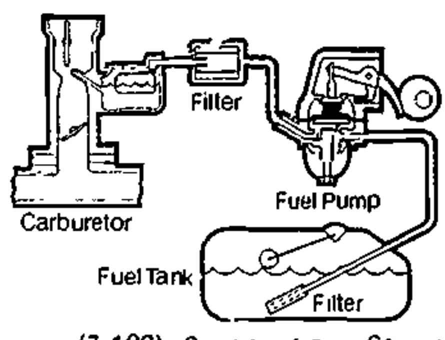
Fuel filters in gasoline engines are usually incorporated into the fuel pump, as below:



(7-108) Courtesy of John Deere Ltd

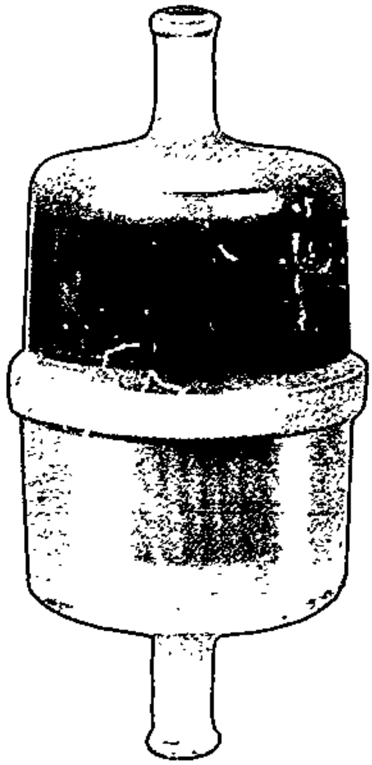
The filter acts as a water trap and provides a place where sediment can settle out of the fuel. Sediment build up can be examined through the glass bowl and should be cleaned when necessary. In addition to this filter many gasoline fuel systems use an **in-line-filter** between the pump and the carburetor (Figure 7-109).

WITHOUT VAPOR RETURN LINE

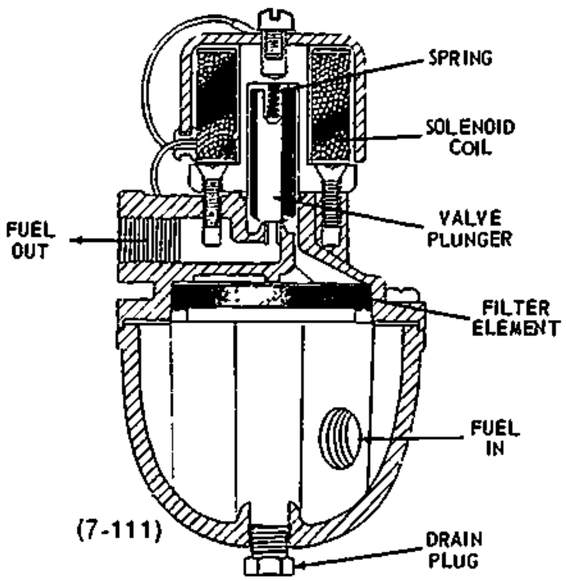


(7-109) Courtesy of Fram Corporation

An in-line fuel filter usually has a pleated paper filtering element (porous bronze or ceramic is also used) enclosed in a sealed plastic container In-line filter cartridges are throw-away items replaced after so many hours of service (Figure 7-110).



(7-110) TYPICAL IN-LINE FILTER CARTRIDGE
Courtesy of Fram Corporation



(7-111)

Courtesy of John Deere Ltd

Another location for a filter is at the inlet of the carburetor The filter is threaded into the inlet and has a tube connector at the other end. This filter generally uses a screen as a filtering element.

L.P. gas systems use a **fuel strained** (Figure 7-111) located between the fuel tank and the converter.

The fuel strainer has two functions:

1. Strains fuel to clean it.
2. Shuts off fuel when system is not operating.

The strainer has stages including a screen, a felt filter, a chamois filter (to remove water), and another screen. A sediment bowl with a drain plug collects the foreign matter.

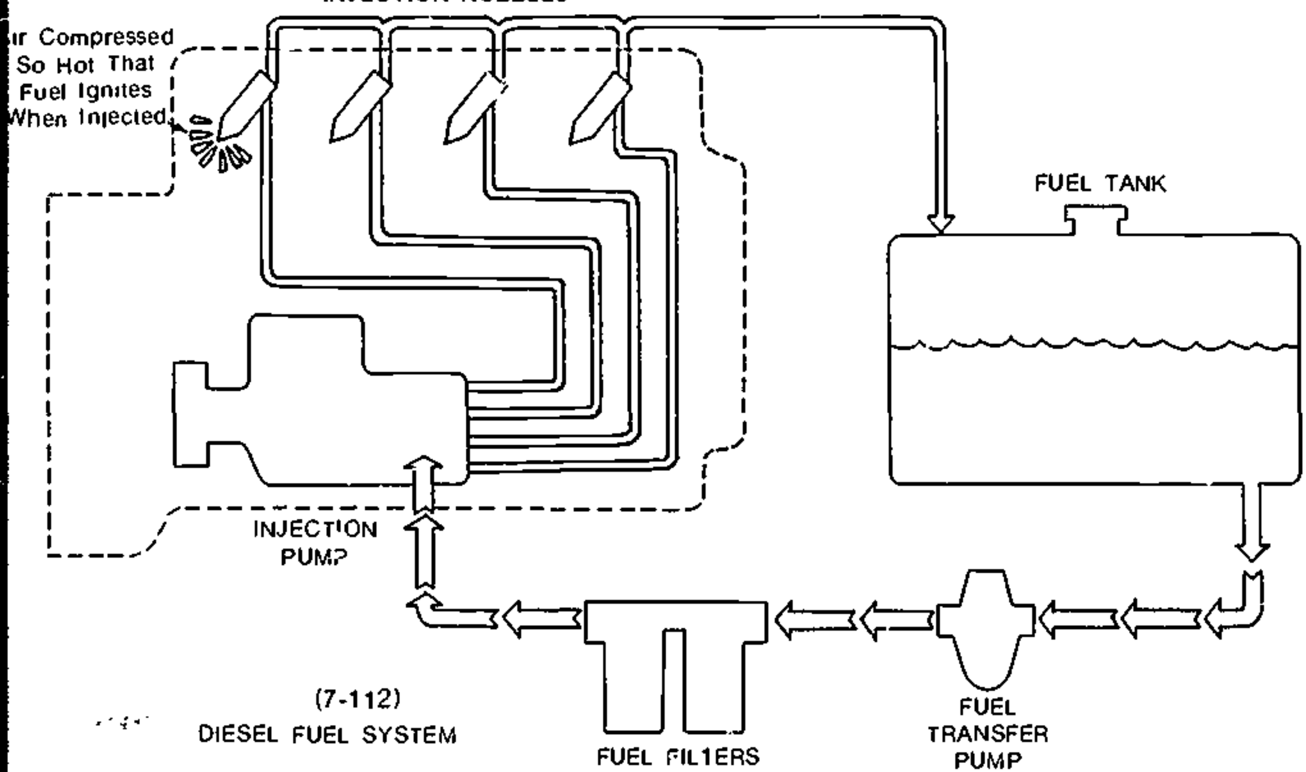
The shut-off is an electrical solenoid coil generally referred to as a filter lock. When the engine ignition is turned on, the solenoid magnetizes the valve plunger and opens it, allowing fuel to flow. When the ignition is turned off or fails, the valve closes automatically. Pressure of the fuel holds it tightly on its seat.

Diesel Fuel Filter

Although important to gasoline engines, fuel filtration is even more important to diesel operation because:

1. Diesel fuels tend to be impure.
2. Injection parts are precision made and dirty fuel will damage them.

Because filtration is so important to a diesel fuel system, the fuel will be filtered not once but several times. A typical system like the one in Figure 7-112 has three progressive stages of filters, a primary filter, a secondary filter and a final stage filter.



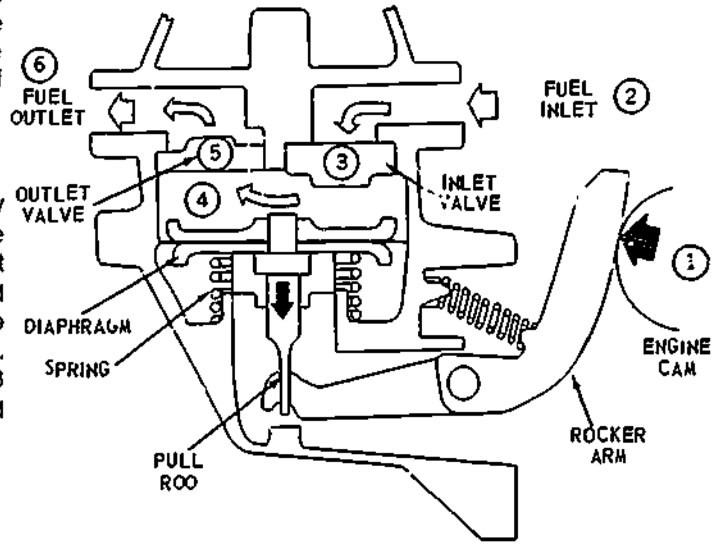
(7-112)
DIESEL FUEL SYSTEM

Courtesy of John Deere Ltd

Primary filters are generally a combination of a coarse filter that removes large particles and a water trap; secondary filters are finer filters that remove most small particles; final stage filters are very fine (rated as low as two microns) and remove tiny, invisible particles. Fuel will pass through all three filters before reaching the injection pump. Note in the diagram the drain screws at the bottom of each stage filter.

Transfer Pumps

Gasoline and diesel fuel systems generally require a fuel supply or transfer pump to move the fuel from the tank to the engine. The most common type of pump is the mechanical diaphragm pump which is found on gasoline and diesel engines. There are also, electric, gear and piston transfer pumps. Figure 7-113 illustrates the operation of a typical mechanical fuel pump



(7-113)

Courtesy of John Deere Ltd

The pump operates as follows:

Power is applied to the pump rocker arm at (1) by an eccentric (an offset disc) on the engine camshaft. As the camshaft rotates, the eccentric causes the rocker arm to rock back and forth. The inner end of the rocker arm is linked to a flexible diaphragm located between the upper and lower pump housing. As the rocker arm rocks, it pulls the diaphragm down, and then releases it. A spring located under the diaphragm forces it back up. Thus the diaphragm moves up and down as the rocker arm rocks.

When the diaphragm is pulled down, a vacuum or low pressure area is created above the diaphragm. This causes atmospheric pressure in the fuel tank to force fuel into the pump at (2). The inlet valve (3) opens to admit fuel into the center chamber (4).

When the diaphragm is released, the spring forces it back up, causing pressure in the area above the diaphragm. This pressure closes the inlet valve and opens the outlet valve (5), forcing fuel from the pump through the outlet (6) to the carburetor.

If the needle valve in the float bowl of the carburetor closes the inlet so that no fuel can enter the carburetor, the fuel pump can no longer deliver fuel. In this case, the rocker arm continues to rock but the diaphragm remains at its lower limit of travel so the spring cannot force the diaphragm up. Normal operation of the pump resumes as soon as the needle valve in the float bowl opens the inlet valve, allowing the spring to force the diaphragm up.

HIGH PRESSURE FUEL LINES AND FITTINGS

Some diesel fuel systems have a bank of pumping units in one housing and require high pressure lines to deliver the metered and pressurized fuel to the injectors. Special thick walled tubing and fittings are required to withstand the extremely high pressures. Care must be used not to bend or kink these lines and not to cross thread the fittings when removing and installing them.

Preventive Maintenance Service On Fuel Lines and Fittings

1. Periodically inspect the fuel lines for loose connections, leaks, or kinks.
2. Keep the line connectors tight, but not too tight. Tighten the connectors until snug, but don't strip the threads. To avoid bending the lines, use only one hand with two wrenches for final tightening, as shown in Figure 7-114.

(7-114)

TIGHTENING LINE CONNECTIONS TO AVOID BENDING THE LINES (FINAL TIGHTENING SHOWN)

Courtesy of John Deere Ltd

3. When replacing a fuel line, be sure to use an identical line in size, shape and length. The inside diameter is very critical with injection lines.

FUELS

COMPRESSION AND FUELS

When discussing fuels, the term compression ratio often comes up. Compression ratio, as stated earlier, is the relation between the total volume inside the engine cylinder when the piston is at its greatest distance from the cylinder head, compared to the volume when the piston has traveled closest to the cylinder head.

The type of fuel an engine uses is directly related to the engine's compression ratio. Each fuel has its limits on how much it can be compressed and still burn properly

1 Kerosene or distillate, when used in a spark ignition engine, operates best at about a 4 to 1 compression ratio

2 Gasoline operates at a 7 or 8 to 1 compression ratio.

3 L.P. gas has an 8.5 or 9 to 1 compression ratio

4 Diesel fuel operates usually at about a 16 to 1 compression ratio, although some diesel engines can have a ratio as high as 20 to 1.

Gasoline fuel has certain characteristics that make a gasoline engine run efficiently. The same can be said of diesel fuel and L.P. gas. As well, there are different grades or qualities of these fuels. Below is a discussion of some of the basic characteristics and qualities of gasoline, diesel and L.P. gas fuels.

GASOLINE

Octane Rating

To understand octane rating, you have to know what engine knock is. The following diagram illustrates how knock occurs in a gasoline engine.

Fuel knock is a serious problem because it is hard on valves, pistons and bearings and causes a loss of power. Tests have found that even a very light knock, one that probably wouldn't sound harmful, increases the wear on the top piston ring about four times.

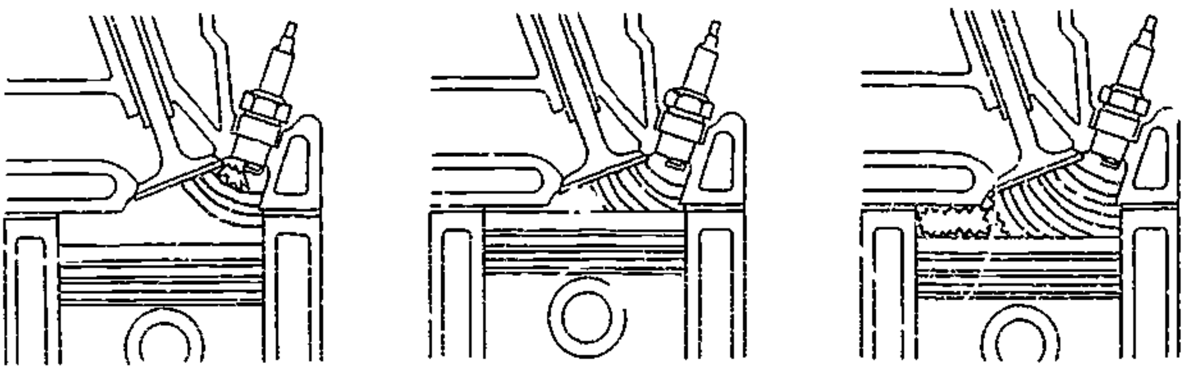
The octane rating of a gasoline is a measure of the gasoline's antiknock properties. The higher the octane rating, the less tendency the fuel has to knock.

The names premium and regular are rough comparative measures of octane ratings:

1. regular — 88 to 94 octane
2. premium — approximately 100 octane

Premium, high octane gasoline is made for use in gasoline engines that have a higher than normal compression ratio. Most gasoline engines today, however, are built to run on regular gas.

What is the result of using premium gasoline on an engine designed to use regular? Premium grade gasoline can be used but there is usually no advantage since most engines haven't a high enough compression ratio to utilize the benefits of the higher octane rating. Premium in this case is a waste of money. The best policy is to use an octane rated gasoline that matches the octane requirements of the engine.



1 Spark Begins Fuel-Air Mixture Burning

2 Flame Advances Smoothly, Compressing and Heating End-Charge

3 End-Charge Suddenly Self Ignites With Violence, Producing A Knock. Knocking And Compression Ratio Are Directly Related The Higher The Compression The Greater Likelihood The Gasoline Will Knock

Courtesy of John Deere Ltd

(7-115)

Volatility

The gasoline property most important in engine starting is volatility (tendency to evaporate). If volatility is too low, insufficient vapor may be drawn into the cylinder to allow easy starting in cold weather. Warm-up will also be slow. On the other hand, a gasoline with too high a volatility is apt to cause carburetor icing or vapor lock under certain atmospheric conditions.

Oil companies change the volatility of gasoline with the seasons. In summer they produce a gasoline with low volatility since the warm temperatures aid in vaporizing the gasoline. In winter, on the other hand, they produce a high volatility gasoline so that it will vaporize more readily in the colder temperatures. For this reason if a summer supply of gasoline is held over to winter, difficulties in engine starting will probably result.

Gasoline Additives

Additives are put into gasoline to improve its performance and storage life. Some of the main ones are:

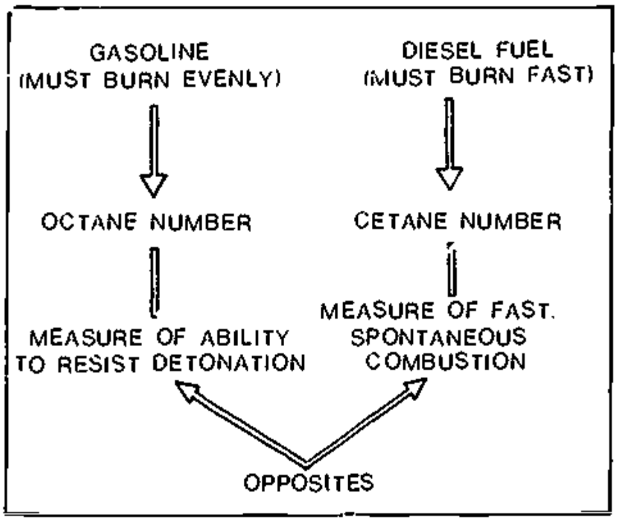
1. Antiknock components to increase the octane rating.
2. Alcohol anti-freezes to prevent any water in the gasoline from freezing and to prevent ice-plug formation.
3. Anti-icers to prevent the carburetor throttle plate from icing.
4. Detergents to clean the carburetor and keep it free of rust.
5. Anti-oxidents to improve storage stability and retard gum formation.
6. Phosphorus compounds to minimize spark plug fouling and surface ignition.
7. Metal deactivators to protect the gasoline against harmful metals that may get into the gasoline.

DIESEL FUEL

Diesel fuel is made by distilling crude oil. Just as the octane rating is probably the most important characteristic of a gasoline, the **cetane number** is the most important quality of a diesel fuel. Cetane number is a measure of the way the fuel ignites in the combustion chamber. In a diesel engine there is a slight delay between the time the fuel is injected and the time it begins to burn. This delay is called the ignition delay period. The delay period is important because if it is too long the fuel, when it does start to burn, will burn explosively causing engine knock. Cetane number measures the ignition delay period; the higher the cetane number the shorter the period.

The speed of an engine prescribes the cetane number that the engine requires. Diesel engines whose rated speeds are below 500 RPM are classed as slow speed engines, from 500 to 1200 RPM as medium speed, and over 1200 RPM as high speed. Cetane numbers of fuels readily available range from 40 to 60 with values of 45 to 50 most common. These cetane values are satisfactory for medium and high speed engines, but low speed engines may use fuels in the 25 to 40 cetane number range.

It is interesting to note that the octane rating of gasoline and the cetane rating of diesel fuel measure opposite fuel qualities (Figure 7-116). A high octane rating means that the gasoline has a low tendency to combust spontaneously. By contrast, a high cetane number means that the diesel fuel will combust quickly and spontaneously.



(7-116) OCTANE AND CETANE NUMBERS ARE OPPOSITES

Courtesy of John Deere Ltd

An important difference exists when using octane and cetane numbers to judge the quality of the fuel. Theoretically the higher the octane rating the better the fuel, assuming of course that the engine can take advantage of the high octane fuel by increasing the compressing ratio or by super-charging the air/fuel mixture The same is not true of the cetane number Too high a cetane number may lead to incomplete combustion and exhaust smoke if the ignition delay period is too short to allow proper mixing of the fuel and air within the combustion space

There are two classes of diesel fuels. No. 1-D and No 2-D These classes set standards for fuel characteristics such as cetane number, volatility, viscosity, pour and cloud point, carbon residue, sulfur content and others The numbers 1 and 2 do not mean that No. 1 is a higher grade than No 2; both are of good quality but each has characteristics that are suitable for different engines and operating conditions Some manufacturers will recommend using either 1-D or 2-D depending on working conditions For example, the table on diesel fuel usage in Figure 7-117 is taken from a John Deere Ltd tractor operator's manual

Type of Engine Service	Ambient Air Temperature	Diesel Fuel Grade No
Light load low speed considerable idling	Above 80 F Below 80 F	2-D 1-D
Intermediate and heavy load high speed, minimum of idling	Above 40 F Below 40 F	2-D 1-D
At altitudes above 5 000 feet	All	1-D

Courtesy of John Deere Ltd (7-117)

LPG

As stated earlier LPG can be all propane, all butane, or a mixture of the two Today, however LPG is usually all or mostly propane LPG, [illegible] gasoline, has an octane rating: propane [illegible] and butane 95. The high octane ratings of LPG make it suitable for high compression engines LPG does not come in different grades or qualities

STORING FUELS

There are two main areas of concern when storing fuel:

— protection of fuel quality

— safety

STORING GASOLINE

Three conditions must be controlled to maintain satisfactory supplies of gasoline:

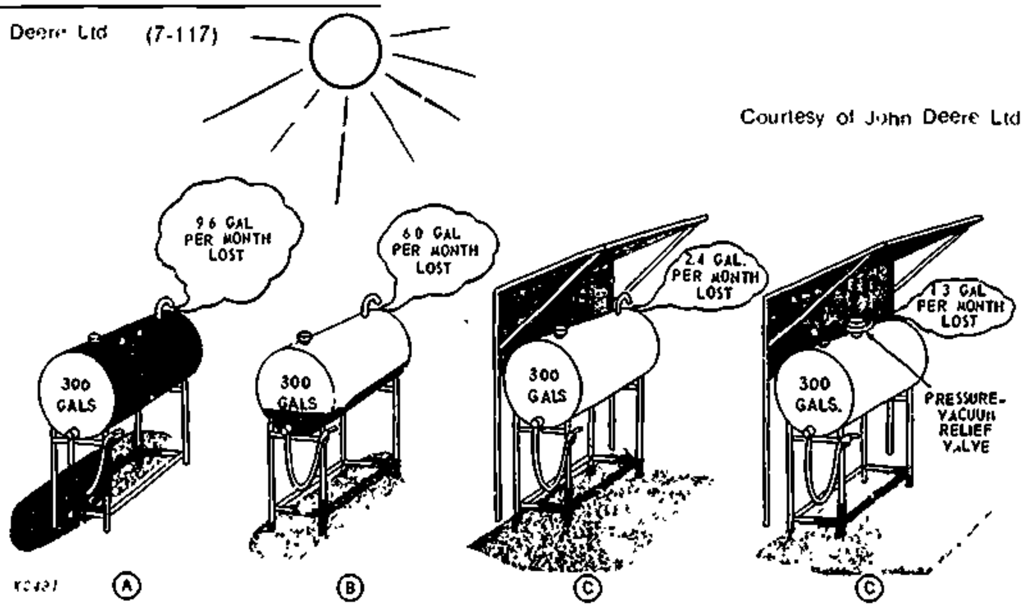
— Control loss through evaporation.

— Avoid gum deposits in gasoline.

— Protect gasoline from water and dirt

Controlling Evaporation Loss

Figure 7-118 illustrates the effects of coloring, shading, and a pressure vacuum relief valve on gasoline evaporation.



Courtesy of John Deere Ltd

A — Red Tank Exposed To Sun's Heat
B — White Or Aluminum Tank Exposed To Sun's Heat
C — White Tank Protected By A Shade
D — White Shaded Tank Equipped With A Pressure-Vacuum Relief Valve

(7-118) SUMMER EVAPORATION LOSSES FROM 300-GALLON GASOLINE STORAGE TANKS

Although this test is conducted under summer temperatures, similar results would occur in winter because winter fuel, as was described earlier, is more volatile and evaporates quicker

If an underground tank is used the temperature of the stored fuel remains low enough all through the year so that evaporation losses are small

Avoiding Gum Deposits

Gasoline will oxidize and form gum deposits if kept for long periods. Oil companies add an inhibitor that will protect the fuel for six months to a year under normal storage conditions, but the interval is greatly reduced if the gasoline is exposed to sunlight and to high storage temperatures To limit gum formation avoid storing more gasoline that you can use conveniently in a period of about 30 days Gum deposit is less of a problem with underground tanks since the fuel remains cooler

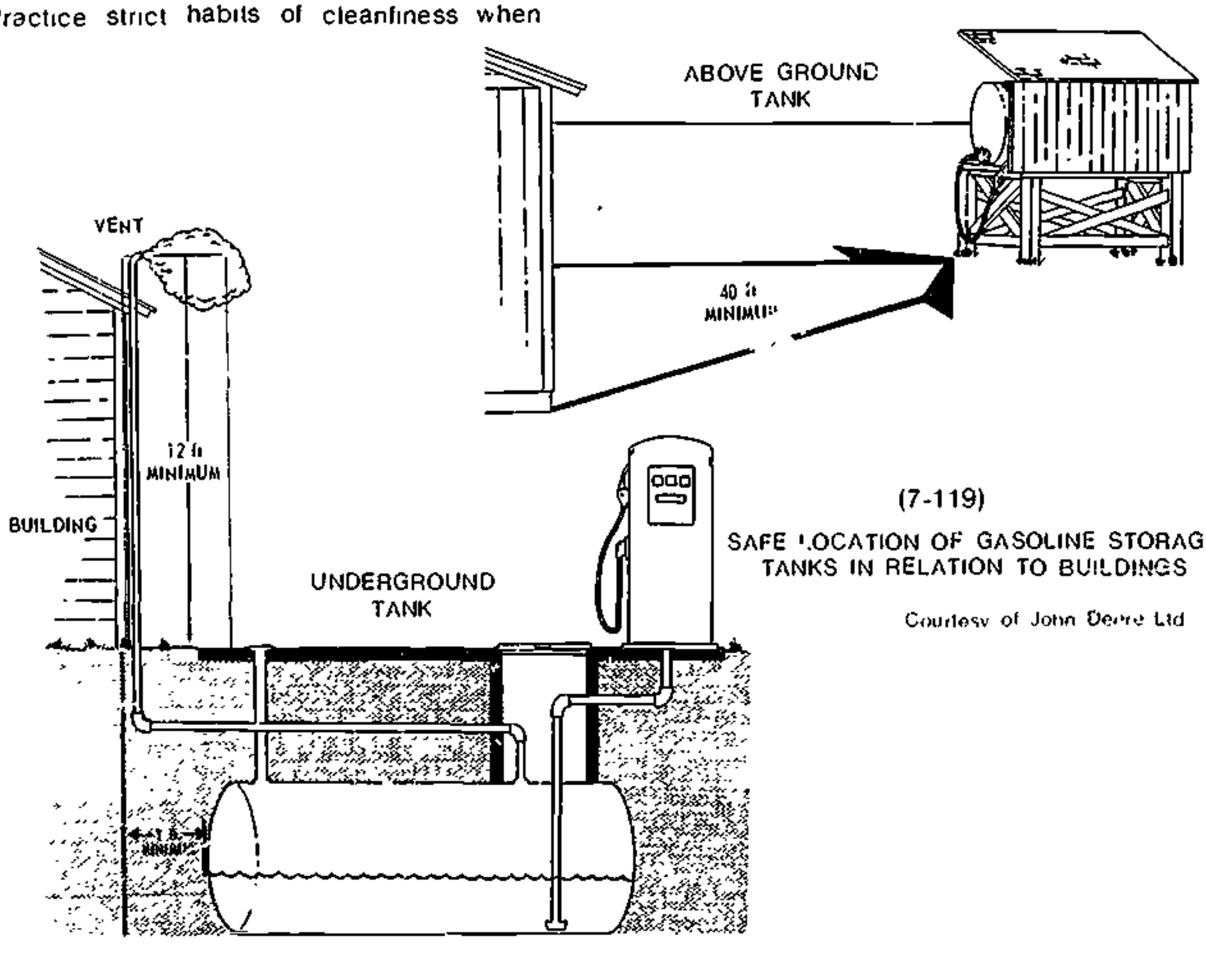
Protecting Gasoline From Water and Dirt Contamination

Practice strict habits of cleanliness when adding fuel to a tank or taking it out No matter how careful you are, though, water and dirt will still enter the tank Condensation forms on the inside of the tank and the moisture drops to the bottom of the tank because water is heavier than gasoline. The more the temperature of the tank varies, the greater the amount of condensation. Thus the same precautions that are taken to keep evaporation down will also limit condensation. Water must be occasionally drained or pumped out of the tank

Like condensation dirt in the fuel will settle to the bottom of the tank. This sediment must occasionally be drained or pumped out of the tank See the next section on storing diesel fuels for illustrations of pumping and draining tanks

Safety

Fire prevention regulations regarding tank placement are shown in Figure 7-119. The distance that the tank must be away from a building is intended to protect the building in case of fire



(7-119)
SAFE LOCATION OF GASOLINE STORAGE TANKS IN RELATION TO BUILDINGS

Courtesy of John Deere Ltd

STORING DIESEL FUELS

Evaporation during storage, whether above or below ground, is not rapid enough with diesel fuel to be a concern. More important with diesel fuel is to

1. keep it free of dirt and water
2. prevent gum deposit

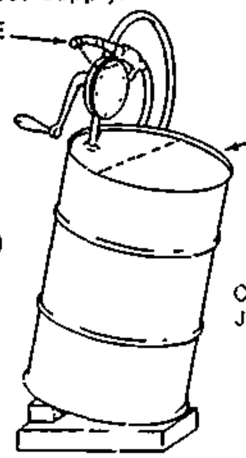
Keep Fuel Free Of Dirt and Water

It is important that all fuels be kept free of dirt and water, but it is especially important with diesel fuel. The reason: the fuel injection system on a diesel engine is fitted with parts that are held within millionths of an inch clearance. Very fine dirt particles soon ruin the parts and cause an expensive repair job. Water, even extremely small amounts, causes corrosion which ruins the high-polished surfaces of the injector nozzles. All operator's manuals for diesels emphasize the importance of clean fuel.

Water is about the same weight as diesel fuel so it settles out very slowly. For this reason allow 24 hours for water and dirt to settle to the bottom of the storage tank after it has been refilled. Use two storage tanks: when one is refilled, the other can be used to supply fuel. If you have only one storage tank, be sure to fill your machine's fuel tank before the supplier refills the storage tank. Another good policy is to fill engine tanks at the end of each day to reduce overnight condensation in them.

If drums are used for storing fuel, be sure that they are mounted rigidly in place. Any handling will remix the dirt particles and water from the bottom of the tank with the fuel. When portable drums are used for refueling in the field, be sure they are in place at least 24 hours before fuel is drawn from them. Also don't let water collect on top of drums (Figure 7-120) because

1. water resting on the top tends to rust the drum.
2. as fuel is drawn from the tank, water may be drawn through the air vent directly into the fuel supply.

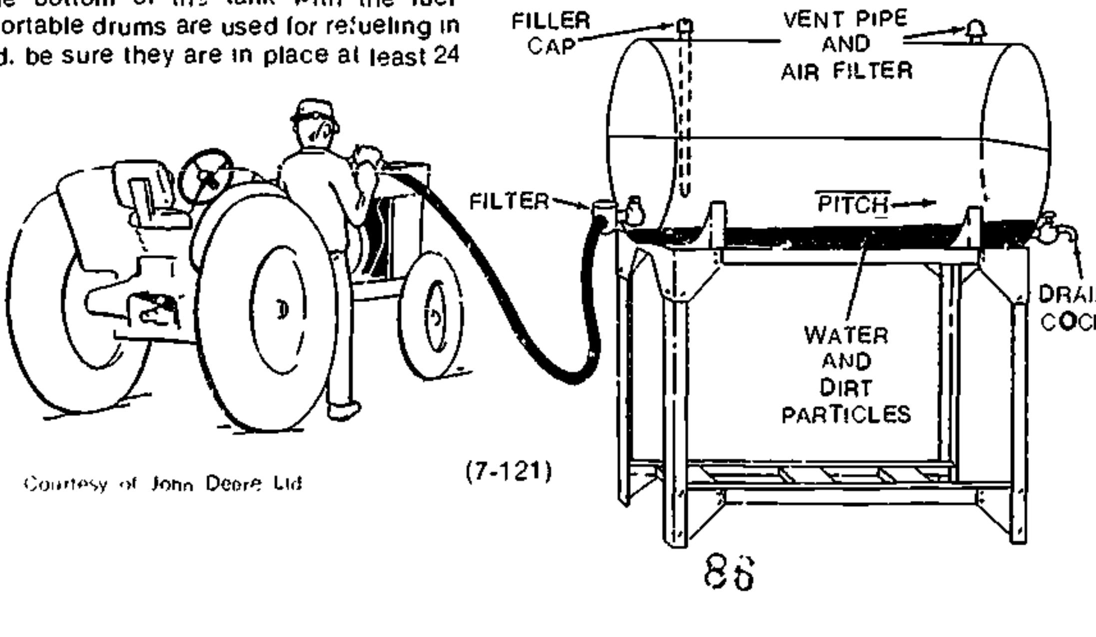


(7-120)

Courtesy of John Deere Ltd

Dirt particles may come from several different sources. Some particles may be present in the fuel when delivered, but dirt is far more likely to come from carelessness or improper storage. Some rules for preventing dirt in the fuel supply are:

1. Don't use an open container to transfer fuel from the storage tank to the machine tank. It will greatly increase the chance of dirt entering the fuel tank. To transfer fuel, equip aboveground tanks with a pump and hose (Figure 7-120) or a gravity hose (Figure 7-121). Be sure to cap the end of the hose nozzle while the hose isn't in use.



Courtesy of John Deere Ltd

(7-121)

2 Don't store diesel fuel in a galvanized tank A galvanized tank is satisfactory for gasoline, but when diesel fuel is stored in it, the fuel reacts with the galvanized finish causing powdery particles to form. These particles soon clog the fuel filters on a diesel engine. Use steel tanks to avoid this problem

3 Don't use a tank formerly used for gasoline to store diesel fuel. Fine rust and dirt particles that settled out of gasoline and accumulated on the bottom of the tank, mix readily with diesel fuel and may remain suspended in it until drawn from the tank

4 Don't let the suction pipe to the fuel pump extend to the bottom of the storage tank. This permits the pump to pick up water and sediment that has settled out of the fuel The end of the pipe should be three or four inches from the bottom If possible, slope the tank away from the pipe or outlet valve

5 Always drain the storage tank before refilling and clean the tank twice a year otherwise the dirt and water residue may rise high enough to be drawn out with the fuel (Figure 7-122)

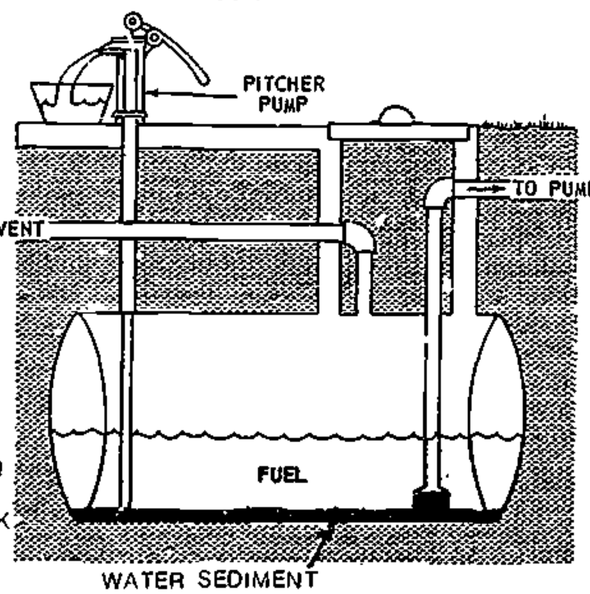
Preventing Gum Deposits

Diesel fuel, like gasoline, contains a gum inhibitor which retards the formation of gum and varnish for about three months Keeping above-ground tanks shaded will help to limit gum deposits.

Diesel fuel may be stored longer than gasoline; while gasoline should not be stored longer than 30 days, diesel fuel may be kept for about three months.

Safety

Although diesel fuel is safer than gasoline, the safety precautions that apply to gasoline should also apply to diesel fuel

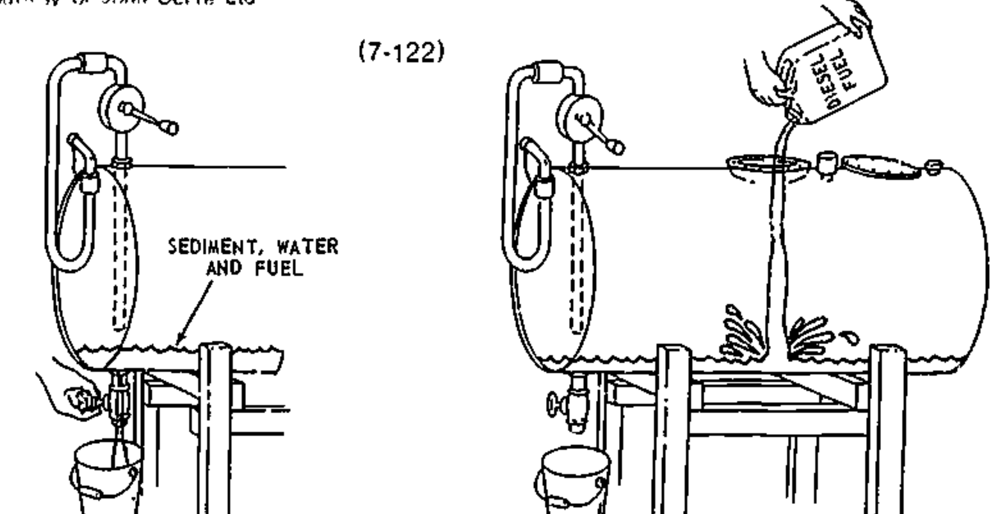


(7-123)
USING HAND PUMP TO CLEAN DIRT AND WATER FROM UNDERGROUND STORAGE TANK

Courtesy of John Deere Ltd

Courtesy of John Deere Ltd

(7-122)



1 DRAIN SEDIMENT, WATER AND FUEL FROM TANK

2 FLUSH TANK WITH CLEAN DIESEL FUEL

STORING LPG

Since LPG is stored in pressurized tanks, there are no problems in maintaining the quality of the fuel, nor problems with the fuel evaporating. Also the fuel will not change chemically, during storage. Therefore, LPG can be stored for as long as necessary.

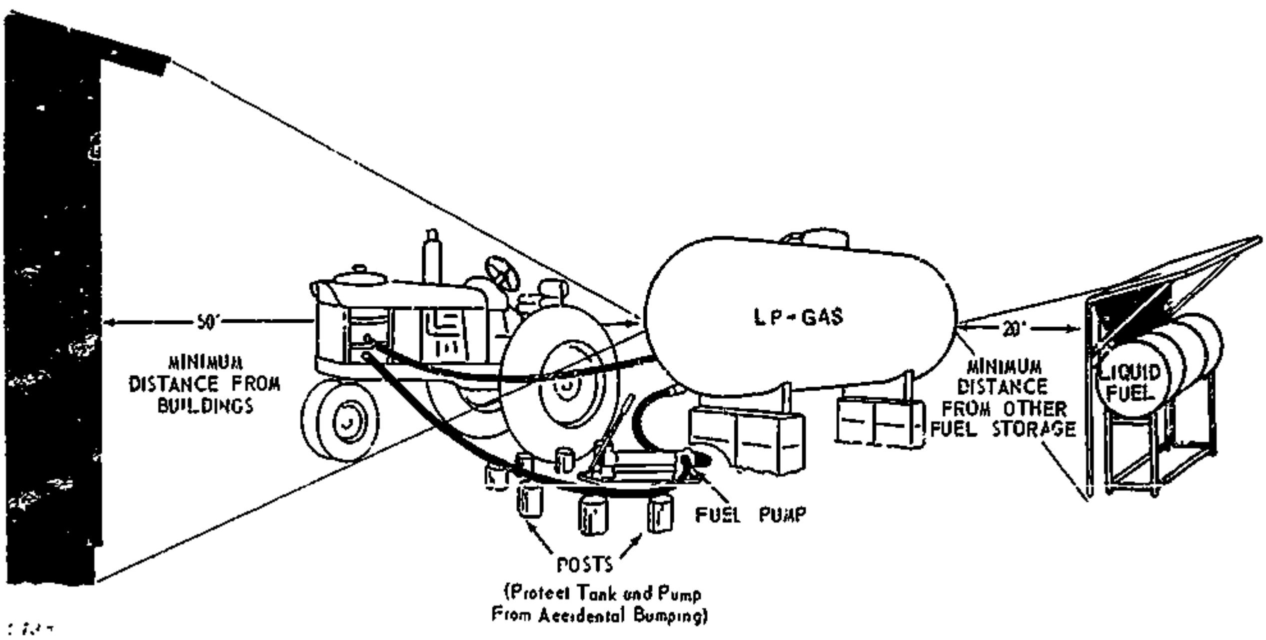
Safety With LPG

1 Remember that LPG is always under pressure and the fuel supply components must be leak proof

2 Never smoke or use any flame near the fuel

3 Fill holes and low spots in the vicinity of the storage Gas fumes that leak from the tank or escapes while filling the machine are heavier than air. The fumes will accumulate in low spots and become a fire hazard

Large storage tanks for LPG like those gasoline and diesel fuel have to be located at a safe distance from buildings and from other fuel tanks. In Figure 7-124 note the posts protecting the pump and hose connections.



(7-124) SAFE LOCATION OF LP-GAS STORAGE TANKS IN RELATION TO BUILDINGS AND OTHER FUEL STORAGE

Courtesy of John Deere Ltd

PREVENTIVE MAINTENANCE SERVICE OF FUEL SYSTEMS

DAILY WALK AROUND CHECKS

The following checks on the fuel system would be made as part of the daily walk around check and at any time that scheduled maintenance is done on the fuel system

1 Look for leaks in fuel lines, in the tank, at connections and generally throughout the system Also check for damaged or kinked fuel lines.

2 Check for water or dirt accumulation in the primary filter glass bowl (if equipped) and clean the bowl if contaminants are found On primary filters that don't have a glass bowl, open the drain momentarily to check for water or dirt

3 Momentarily open the fuel tank drain to check for contamination

4 Remove the fuel tank filler cap clean the cap and the area around it

CHANGING FUEL FILTERS

Fuel filters are changed at intervals specified by the manufacturer The two main types of filter elements are

1 cartridge filters installed in a case or housing

2 spin on, throw away filters

Water traps with washable elements are also used on some ... systems

Below are good practices when changing filters These practices apply to filters for both diesel and gasoline fuel systems

1 Always be aware of potential fire hazards when working on fuel systems especially with gasoline and take the necessary precautions

2 If the system has a shut-off on the fuel tank(s) or fuel line close it before removing the filter

3 Since clean lines are of utmost importance when working fuel systems (particularly on diesels) thoroughly clean the entire area around a filter before removing it Also clean the inside of the housing on cartridge filters, and make sure that the gasket sealing surface on spin on filters is absolutely clean

4. Always install new gaskets.

5 On diesel fuel systems, fill new filter cartridges or filter housings with fuel before installing them: this will lessen the chance of air getting into the system and making the engine difficult to start. Diesel fuel systems must be completely free of air to function properly

6 Bleed the fuel system of air. Bleeding is described later in this section

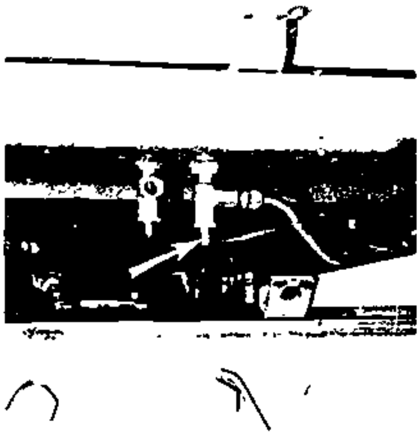
7 After installing the filter, start the engine making absolutely sure that there are no leaks

Figures 7-124, 7-125, 7-126 give examples of typical fuel filter changing procedures taken from service manuals.

Water Trap With Washable Parts (Figure 7-124)

FUEL SYSTEM FILTERS — Service When Fuel Pressure Gauge Registers OUT with Engine Running.

Primary Fuel Filter



(7-124)

Courtesy of Caterpillar Tractor Co

1 Close fuel supply valve

2 Remove bowl and element

3 Wash element and bowl in clean kerosene

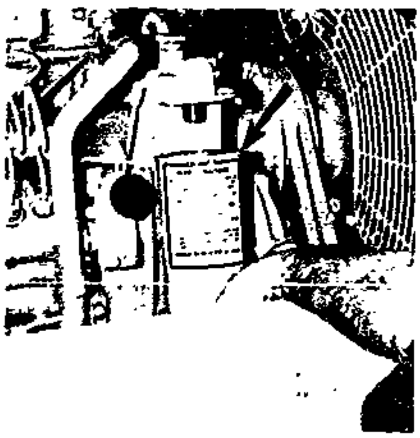
4 Install element and bowl

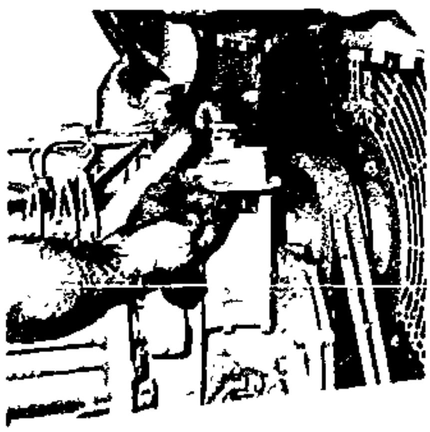
5 Open fuel valve and start engine

If fuel pressure gauge still registers OUT change final fuel filter

Throw Away Filter (Figure 7-125)

Final Fuel Filter





(7-125)

Courtesy of Caterpillar Tractor Co

1 Close fuel supply valve and remove filter

2 Clean filter base gasket surface Lubricate new filter gasket with clean diesel fuel

3 Install new filter Tighten filter until gasket surface contacts base then tighten additional 1/2 turn

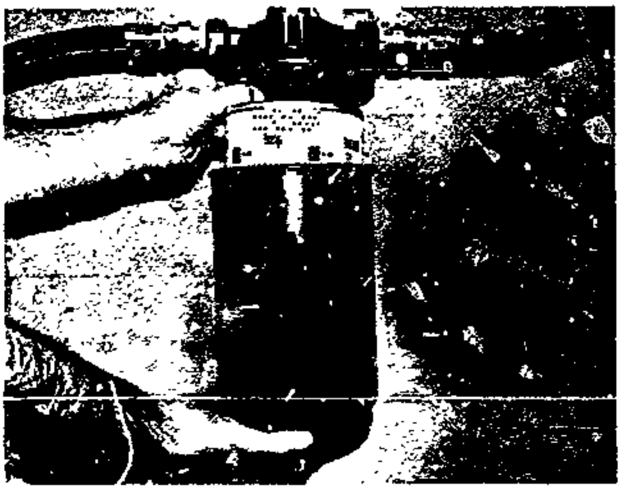
4 Open fuel valve and prime fuel system

5 Start engine and check for leaks

Cartridge Filter (Figure 7-126)

1 Remove drain plug from bottom of filter case and drain contents

2 Loosen bolt at top of fuel filter Take out dirty element. clean filter case and install a new element.



(7-126) INSTALLING REPLACEABLE FUEL FILTER ELEMENT

Courtesy of Cummins Engine Co

3 Fill filter case with clean fuel to aid in faster pick-up of fuel. Install a new gasket in filter head and assemble case and element Tighten center bolt to specified torque

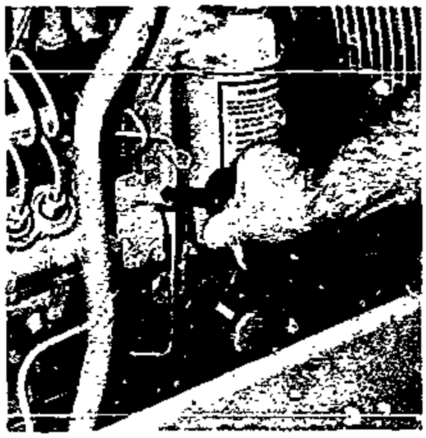
Bleeding A Diesel System

Whenever lines are disconnected. a fuel pump is changed or new filter(s) are installed, the fuel system will generally have to be bled or purged of air Bleeding is sometimes referred to as priming

Some fuel systems are easier to bleed than others Cranking the engine will purge the air on one system. whereas another system will require loosening the injector lines or filter bleeders and then cranking the engine. A third type of system is equipped with a hand pump that must be activated to prime the fuel system Operating instructions for such a pump are given in Figure 7-127

(7-127) **Priming Fuel System**

1 Move governor control to off position Open vent valve.



2 Unlock priming pump plunger and operate pump until . .

3 Flow of fuel from drain line is free of air bubbles Lock pump plunger and close vent valve

Courtesy of Caterpillar Tractor Co

Once the pump has bled the system. start the engine The engine may run rough for a little while until all the air is gone

SERVICING THE FUEL STRAINER IN A LPG FUEL SYSTEM

If the fuel strainer frosts up. its filter element is probably clogged and needs cleaning Before attempting to clean the strainer. make sure both withdrawal valves are closed. the engine is cold. and the lines and strainer are emptied of gas To clean the strainer. first remove the drain plug and clean out foreign matter Follow service manual instructions on blowing out the strainer and cleaning the strainer parts

A failed solenoid in the strainer is indicated when the ignition is turned on and gas fails to flow to the converter The problem is likely a sticking valve plunger.

QUESTIONS — FUEL AND FUEL SYSTEMS

1 List the three basic parts of a gasoline fuel system.

2 Besides metering the fuel a carburetor

(a) atmoizes the fuel

(b) mixes fuel and air in the proper ratio

(c) distributes this fuel-air mixture into the manifold

(d) all of the above

3. A carburetor works on the basic principle of:

(a) difference in power

(b) difference in pressure

(c) difference in speed

(d) all of the above

4 A choke valve is required on a carburetor to

(a) increase the power when the engine is hot

(b) increase the power when the engine is cold

(c) clean out the mixture during cold starts

(d) give a richer mixture for cold starts

5 LPG is made up of ________, ________ or a mixture of the two

6 LPG will only remain a liquid when it is:

(a) stored outside

(b) stored in large containers

(c) stored under pressure

(d) stored in a heated area

7 What is the basic difference in the operation of an LPG fuel system and a gasoline fuel system?

8. In an LPG fuel system the ________ changes the liquid gas to a vapor

9 Why is LPG commonly used in such warehouse machines as fork lifts?

10. How does a diesel engine's method of delivering fuel to the engine differ from that used by a carbureted gasoline engine?

11 The function of the injection pump in the diesel fuel system is to:

(a) time the injection and measure or meter the fuel

(b) pressurize and deliver the fuel to each cylinder

(c) both (a) and (b) are right.

12. What is the difference between an LPG fuel tank and a gasoline or diesel tank?

13 The degree of filtration of a filter is measured in.

(a) Protons

(b) Electrons

(c) Microns

(d) Neutrons

14 When an in-line fuel filter is used in a gasoline fuel system. it is usually placed between the:

(a) gas tank and fuel pumps

(b) carburetor and manifold

(c) fuel pump and air cleaner

(d) fuel pump and carburetor

15 The filter in a LPG fuel system serves two purposes. It strains impurities from the fuel and:

(a) pre-heats the fuel

(b) cools the fuel

(c) shuts off the fuel when the system is not operating

(d) stores extra fuel

16 Give two reasons filtering is so important in a diesel fuel system

17. A mechanical diaphragm fuel pump operates by an arm that runs on a cam on the engine's

(a) crankshaft

(b) camshaft

(c) water pump shaft

(d) rocker shaft

18 True or False? When replacing fuel injection lines, any line size or length will do provided the connections fit properly.

19 Care must be taken not to ________ fuel line connectors

20 How does compression ratio relate to the fuel in engine uses?

21 Which of the following fuels is burned at the highest compression ratio?

(a) gasoline

(b) diesel

(c) LPG

22 What does octane rating refer to in gasoline?

23 How does low volatility gasoline effect cold starting?

24 What does the cetane number refer to in diesel fuel?

25 List the two main areas of concern when storing fuel

26 How does the color of a fuel tank effect the loss of gasoline through evaporation?

27 When gasoline and diesel fuel are stored for long periods of time, they will oxidize forming deposits. Gasoline should not be stored for periods over __________. Diesel fuel can be stored up to __________

28 How can gum deposits be minimized in above ground diesel fuel tanks?

29 How long should you wait before drawing fuel from a newly filled diesel tank or drum?

(a) 5 to 10 minutes

(b) 3 or 4 hours

(c) overnight

(d) 24 hours

30 What is the best policy to follow to reduce overnight condensation in a machine's fuel tank?

(a) store the machine in a warm place

(b) drain the water trap at the beginning and end of each shift

(c) fill the tank at the end of each shift or day

(d) fill the tank before it runs out

31 True or False? Galvanized tanks are suitable for storing diesel fuel?

32 What advantage does LPG have over gasoline and diesel with respect to storing?

33. How far should a pump intake pipe be from the bottom of a fuel storage tank? Why?

34. Briefly list items that should be checked during a daily p.m. of the machine's fuel system.

35 To aid in starting a diesel engine after a fuel filter change it is a good practice to:

(a) change the filter quickly

(b) don't shut the engine off while changing the filter

(c) have the fuel tank full before changing the filter

(d) fill the new filter with fuel before installing it

36. Bleeding or priming a diesel fuel system is necessary to remove all the __________ in the fuel system after fuel lines have been disconnected or a pump or filter changed.

37. An obvious sign of a clogged filter on an LPG fuel system is the:

(a) engine is hard to start

(b) engine runs rough

(c) fuel strainer frosts up

(d) engine will miss at high speed

ANSWERS — INTERNAL COMBUSTION ENGINE

1 heat mechanical

2 (a) air
(b) fuel
(c) combustion

3 It's heated

4 In a vaporized state

5 False Oxygen causes the fuel to burn

6 rotary

7 (d) intake. compression. power. and exhaust

8 (c) cycle

9 (b) I-Head

10 In a two stroke cycle engine, the cycle is completed during **one revolution** of the crankshaft The piston makes two strokes, one up and one down. In a four stroke cycle engine, the cycle is completed during **two revolutions** of the crankshaft The piston makes four strokes, two up and two down.

11 water air

12 1 gasoline
2 diesel
3 LPG

13 In a gasoline engine fuel and air are mixed in the carburetor and then sent to the combustion chamber where the mixture is compressed and ignited by a spark plug In a diesel engine air is compressed in the combustion chamber and then injected with fuel. The heat of the compressed air ignites the fuel.

14 To raise the temperature high enough to ignite the fuel without a spark.

ANSWERS — COOLING SYSTEM

1. Prevents overheating of the engine. Regulates temperatures at best level for engine operation.
2. False.
3. Allows for rapid warming at start-up.
4. . . heat exchanger . . .
5. (c) Convection.
6. To circulate the water throughout the cooling system.
7. . . . thermostat.
8. True.
9. Blower fans are used on slow moving machines because there is a possibility of harmful materials being drawn into the radiator with a suction fan.
10. (b) to increase fan efficiency.
11. False.
12. (d) closed by air pressure and opened by spring pressure.
13. Softens the water (i.e.. removes the corrosives) and removes the dirt.
14. True. . . . corrosive inhibitors.
15. A special element that is compatible with the anti-freeze needs to be used in the filter.
16. Leakage.
17. . . . cold
18. 1. They don't give a permanent repair.
    2. They will ultimately cause plugging of the radiator.
19. Accumulation of foreign material in the core air passages. Regularly check and blow out the radiator with water or air pressure.
20. Cracked or swollen.
21. 1. Condition.
    2. Alignment.
    3. Tension.
22. 1. Make sure inlet and outlet valves are opened.
    2. Check all hoses, fittings and connections for leaks.
    3. Check and top-up the coolant level.
23. (c) hydrometer.
24. False.
25. (b) relieve all belt tension.
26. (a) replace all as a set.
27. 7/16" for one foot, and so half of that again for one and a half feet.

$$7/16 + \frac{3^1/_2}{16} = \frac{10^1/_2}{16} \text{ or approximately}$$

$$\frac{10''}{16} = \frac{5''}{8}$$

ANSWERS — LUBRICATION SYSTEM

1. .... friction ... heat.
2. True.
3. A maximum pressure-relief valve.
4. (b) full flow and bypass.
5. Pleated paper filter.
6. (d) crankcase.
7. (a) bearings.
8. The filter's bypass valve opens.
9. If the cooler becomes clogged or there is too much internal resistance within the cooler on a cold start-up, the pressure differential valve opens allowing oil to still reach the bearings.
10. If the blow-by gases in the pan are not vented, they will build pressure and cause the front and rear crankshaft seals to leak. Also, if not vented the blow-by gases would contaminate the oil.
11. Base stock oil fortified with additives to provide the required performance level
12. False. Each type of oil with its additives is right for the operating conditions it is designed for.
13. .. viscosity ... thicker
14. "S" Gasoline engines.
    "C" Diesel engines
15. Moderate duty diesel and gasoline service.
16. True.
17. It refers to laboratory analysis of used oil to determine the types and amounts of worn metals in the oil.
18. (c) 125 to 250 hours.
19. The condition of the internal parts that the oil lubricates.
20. So that contaminants will mix with the oil and be drained out with it.
21. When it becomes contaminated with either fuel, coolant, or metal chips.

ANSWERS — AIR INDUCTION SYSTEM

1 1 Naturally aspirated. and naturally aspirated and scavenge blown.
  2 Turbo charged
  3 Turbo charged and after cooled

2 A naturally aspirated engine uses no aids to get air into and out of the engine. The scavenge blown engine has an engine driven air pump that forces fresh air into the cylinders and drives the exhaust gases out.

3 (c) exhaust driven turbine

4 By compressing the air.

5 When operating under full load.

6 (b) cool the inlet air before it enters the engine

7 Dry element cleaners. pre-cleaners. oil bath cleaners

8 False

9 The vanes create a twist or cyclonic movement in the air which throws the dust and dirt particles outward and down into a removeable dust cup. The air then passes through the air filter to be further cleaned

10 It reverses direction causing most of the dirt to become trapped by the oil and settle out in the sump

11 (c) A red band is visible on the indicator

12 Oil from an overfilled cup can be drawn into the engine causing it to run away

13 1 Use caution when working around a running engine with an open intake because rags. loose clothing. etc. can be drawn into the intake.
  2 Never leave an open intake on a stopped engine Cover it with something hard such as plywood.

14 When the restriction indicator indicates the need. or at the intervals recommended by manufacturers. More often in severely dusty conditions.

15 The steam will only force the dirt to the center of the element

16 False

17. The same oil as is used in the engine.

18 (c) Lint and other contaminants appear on the underside of the element.

ANSWERS — EXHAUST SYSTEM

1. (c) muffle engine noise.
2. (d) a, b and c are all correct.
3. (a) 6 to 8.
4. Sharp bends cause too much restriction.
5. Carbon monoxide can find its way into the cab.
6. Ensure that there is adequate ventilation for the deadly exhaust gas, carbon monoxide.
7. By running your hand a few inches above the pipe.

ANSWERS — FUEL AND FUEL SYSTEMS

1. fuel tank
   fuel pump
   carburetor
2. (d) all of the above.
3. difference in pressure.
4. (d) give a richer mixture for cold starts.
5. . . . propane. butane.
6. (c) stored under pressure
7. vaporizes before it reaches the carburetor. whereas gasoline is vaporized in the carburetor.
8. . . . converter . .
9. It burns cleaner than the other two fuels: its exhaust contains less carbon monoxide.
10. A diesel engine injects fuel directly into each cylinder. A gasoline engine delivers a mixture of fuel and air to the combustion chambers.
11. (c) both (a) and (b) are right.
12. LPG tanks must be heavier and stronger because the fuel is stored under pressure.
13. (c) Microns.
14. (d) fuel pump and carburetor.
15. shuts off the fuel when the system is not operating.
16. 1. the fuel tends to be impure.
    2. injection parts are precision made and dirty fuel will damage them.
17. (b) camshaft.
18. False.
19. . . . overtighten . . .
20. Each fuel has its limits as to how much it can be compressed and still burn properly.
21. (b) diesel.
22. Octane is a measure of anti-knock properties. The higher the octane rating the less tendency the fuel has to knock.
23. It does not vaporize readily and could cause hard starting.
24. Cetane number measures the ignitability of the fuel; the higher the cetane number the shorter the period.
25. 1. protection of fuel quality.
    2. safety
26. A light-colored tank reflects sunlight. Thus the tank is cooler and not as much fuel evaporates.
27. . . . gum . . . . . one month . . . . . three months.
28. Paint the tank a light color. and shade the tank.
29. (d) 24 hours.
30. (c) fill the tank at end of each shift or day.
31. False.
32. LPG is stored in a pressurized tank and therefore has no loss due to evaporation and no deterioration with time.
33. three to four inches so that the dirt and water that have settled don't get drawn up with the fuel.
34. 1. fuel lines for leaks and damage.
    2. water accumulation in water trap or primary filter.
    3. momentarily open the tank drain to check for contaminants.
    4. clean the tank breather.
35. (d) fill the new filter with fuel before installing it.
36. . . . . . air . . .
37. (c) fuel strainer frosts up.

TASKS — ENGINES

PREVENTIVE MAINTENANCE SERVICE ON COOLING SYSTEMS

DAILY AND ROUTINE MAINTENANCE CHECK

1. Check any liquid cooling system for leaks, for the condition of hoses, the tension of belt(s), the condition and operation of the shutters and fan, for dirt accumulation and possible air flow restriction of radiator, and for the level and condition of coolant. Perform any minor repairs such as adjusting, tightening, cleaning, or report any suspected unsafe operating conditions to a journeyperson.

SCHEDULED MAINTENANCE

1. Using the correct tools and procedures stated in the service manual.
   (a) Drain the coolant.
   (b) Reverse-flush the radiator and engine block.
   (c) Remove, test, install thermostat.
   (d) Install new filter element (if equipped).
   (e) Fill the system with water/anti-freeze solution and run the engine until the system is up to operating temperature. Check the coolant level, and top up if low. Check the cooling system to ensure it has no leaks.
2. Using an anti-freeze hydrometer, test the coolant to make certain there is sufficient range against freezing of coolant for your region.

PREVENTIVE MAINTENANCE SERVICE ON LUBRICATION SYSTEMS

DAILY AND ROUTINE MAINTENANCE CHECKS

1. Check the oil for water or fuel contamination. Report if contamination is found.
2. Check the oil level, and if low, top it up with the correct type of oil.
3. Check the lubrication system for leaks, for the condition of lines or hoses, and check the operation of breathers and vents. Do any minor repairs, or report suspected unsafe operating conditions.

SCHEDULED MAINTENANCE

Using the correct tools and procedures stated in the service manual:

1. Drain the oil sump and filters.
2. Remove and clean the filter housings, and correctly install new filters, being careful to keep filters and gaskets clean.
3. Insert and tighten drain plugs, and fill the sump with the correct types and amount of oil.
4. Start and run the engine and check the complete system to ensure there are no leaks.
5. Stop the engine, wait for five minutes and recheck the oil level, adding oil if required.

SERVICE REPAIR ON LUBRICATION SYSTEMS

When oil contamination is found in a machine or an internal component has failed, perform flushing procedures.

1. Drain the complete system.
2. Remove, flush and re-install the oil cooler and connecting lines, and clean the filter housings.
3. Install the flushing oil, run the engine, stop and drain the system.
4. Repeat normal filter installation, oil fill-up and running and checking procedures.

PREVENTIVE MAINTENANCE ON AIR INDUCTION SYSTEM

DAILY AND ROUTINE MAINTENANCE CHECKS

1. Practice safety when working around open air inlets on a running engine — rags, loose clothing, etc., can be sucked into the manifold

   Practice cleanliness when working on air induction systems — all pipes, ducting, filter housings must be absolutely clean on assembly

2. Run the engine and check the air cleaner restriction indicator (if equipped). Stop the engine, carefully inspect all air induction piping and replace any cracked or damaged sections, remembering to tighten all clamps.

3. Inspect the turbo charger and/or blower for evidence of oil leaks, and if any are found make minor repairs. With the engine running check the turbo charger and/or blower for excessive noise. Report if a problem is suspected.

SCHEDULED MAINTENANCE

Consulting the service manual, do preventive maintenance service on pre-cleaner and air cleaner(s):

1. Oil bath type — thoroughly wash the oil cup and the element and change the oil.
2. Dry type — disassemble the cleaner, clean the container housing, clean or replace the filter element and reassemble.

EXHAUST SYSTEMS

SAFETY

1. Practice safety when removing and installing exhaust parts. If the engine has just been running the parts will be hot. Exhaust parts, especially on large machines, can be heavy.

ROUTINE MAINTENANCE CHECK

1. Completely inspect an exhaust system for leaks and for loose components and make any necessary minor repairs.

SERVICE REPAIR

1. Get experience installing exhaust sy... n components such as mufflers, piping and mounts. When installation is complete run the engine and check to ensure there are no leaks.

FUEL SYSTEM

SAFETY

1. Practice safety with regard to fuel combustibility. Practice absolute cleanliness when working with fuel and fuel systems.

ROUTINE MAINTENANCE CHECK

1. Visually inspect a complete fuel system from the tank to the engine (to include shut-off valve, lines or hoses, filters, transfer pump and return line) for leaks or damage. Do any minor repairs and/or report unsafe operating conditions.

SCHEDULED MAINTENANCE

1. On a vehicle equipped with a diesel engine:

   (a) Open the drain on the fuel supply tank sufficiently to remove any accumulation of water and dirt.

   (b) Check the water trap and drain if required.

   (c) Install new fuel filter(s).

   (d) Bleed the system to remove air.

   (d) Start the engine and check to ensure there are no leaks.

BLOCK

8

Basic Electricity

FUNCTIONS OF ELECTRICITY IN HEAVY DUTY VEHICLES

Electricity performs many important functions in the Heavy Duty Vehicle and Equipment field. Electricity is used to:

1 Supply power to turn the engine over for starting.

2. Provide the spark ignition for each cylinder in a gasoline engine.

3. Provide power for all the lights on a vehicle:

   — head lights
   — tail lights
   — stop lights
   — signal lights
   — dash warning lights
   — cab light

4. Operate the horn.

5. Supply power for electrical gauges such as:

   — fuel level gauge
   — oil pressure gauge
   — temperature gauge

6. Power electrical accessories such as.

   — radio
   — heater
   — air conditioner
   — wipers

7 Power many varieties of magnetically operated controls such as:

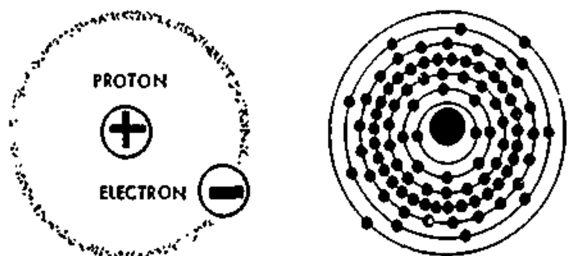
   — starter switches
   — transmission shift controls
   — hydraulic valves

8. Supply power to maintain the battery charge level.

ELECTRON THEORY

This block begins with a discussion of the Electron Theory. the most widely accepted explanation of electricity.

Before you can understand what electricity is. you first have to have a basic picture of an atom. All elements are made of billions of atoms. Atoms have particles called electrons in orbit around a core of protons; the number of electrons is the same as the number of protons. Electrons have a negative (−) charge. while protons have a positive (+) charge. The simplest atom is hydrogen having a single electron in orbit around a single proton. Uranium is one of the most complex elements with 92 electrons and 92 protons. Models of the two atoms are shown in Figure 8-1.

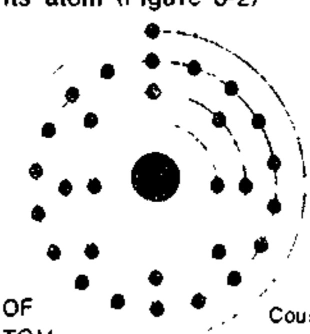


HYDROGEN ATOM (8-1) URANIUM ATOM

Courtesy of John Deere Ltd

In their natural state atoms have an equal number of positive protons and negative electrons. The atoms are therefore electrically neutral. This neutral state, however can be altered. If an electron is attracted away from an atom. the atom will have a positive charge since it will have one more proton than electron. Or vice versa, if an electron is added to an atom, the atom will have a negative charge because it has one extra electron.

The element copper is widely used in electrical systems because it is a good conductor of electricity. The reason for copper's good conductivity can be explained by looking at a diagram of its atom (Figure 8-2)



(8-2)
STRUCTURE OF A COPPER ATOM

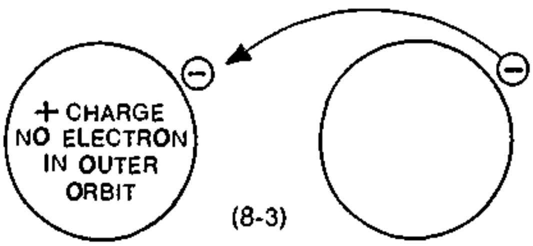
COPPER ATOM

Courtesy of John Deere Ltd

The copper atom contains 29 electrons distributed in four separate shells or rings. Notice that the outer ring has only one electron; it is this one electron that makes copper a good conductor of electricity. Because there is only one electron in its outer orbit where many could theoretically fit, and because this electron is quit; a distance from the positively charged nucleus that attracts or binds the electrons to the atom, the copper atom does not hold onto the electron too strongly. Therefore, copper atoms have the tendency to both give up or accept an electron in its outer orbit.

Consider what happens in a copper wire where there are a string of copper atoms with a positively charged atom at one end (i.e., the atom has no electron in its outer ring) and an atom with negative charges at the other end (i.e., the atom has an extra electron, that is two electrons in its outer ring). Since positive charges attract negative charges, the positively charged first atom will attract the negatively charged electron in the outer orbit of the second atom.

This electron will jump over to the positively charged atom giving the atom the electron it was missing in its outer ring (Figure 8-3).



(8-3)

The first atom has achieved a neutral state, out now the second atom is left with no electron in its outer ring, and so it has a positive charge Its positive charge attracts the negatively charged electron from the third atom. The third atom will attract an electron from the fourth, the fourth from the fifth, and so on The second to last atom will take an electron from the last atom which being negatively charged has two electrons in its outer orbit. Now all the atoms along the row have the right number of electrons in the outer ring. In the process electrons have passed from atom to atom, drawn to the positive end along the line of atoms from the negative end. Looked at in terms of the direction that the electrons move, a flow of electrons has taken place from the negative end to the positive end. This last statement is the definition of electricity. Electricity is the flow of electrons from atom to atom in a conductor in the direction of negative to positive.

Of course, the above description of electron flow is simplified On an actual cross section of a copper wire there are billions of copper atoms and so billions of electrons will be passing amongst them. These electrons will continue to flow as long as the positive and negative charges are maintained at each end of the wire By adding new electrons to the negative end of the wire and by taking electrons away from the positive end of the wire as they get there (this is what a battery does) the electrons or electric current will flow indefinitely.

A basic idea of electricity is by no means easy to grasp Electricity is spoken of as flowing in a wire, just as water is said to flow in a hose. But water is a real substance that you can see and touch Elect icity on the other hand, is not a substance You cannot point to a material and say that is electricity Rather, electricity is a force of attraction that causes conductor electrons to move and thus to have energy. Having no substance itself, the force of electricity uses the substance of the conductor to carry its energy. Like the wind, electricity can be felt, the results of its energy can be seen, but electricity, itself, can't be looked at and examined.

BASIC FACTORS OF ELECTRICITY

There are three basic factors of electricity:

— current
— voltage
— resistance

Current

The flow of electrons through a conductor is called an electric current and is measured in amperes. One ampere is a current of 6.28 billion billion electrons passing a given point in the conductor in one second. The current or amperage of a circuit, then, is a measure of how many electrons are flowing in the circuit.

Voltage

One end of a current carrying conductor has a positive charge, and the other end a negative charge. The strength of the charge depends on how many extra electrons there are at the negative end or conversely how many electrons are missing at the positive end. The greater the number of extra electrons (or missing electrons) the greater the charge or the difference between the two ends. Voltage is the term used to measure the strength or force of the attraction between the positive and negative charges. Of course, the stronger the charges at either end the greater will be their force of attraction for one another, or their voltage.

Voltage is the force that causes a flow of current in a conductor. Voltage can be generated by a storage battery or by a generator. Note that voltage is a potential force and can exist even when there is no current flow. For example, a storage battery can have a potential of 12 volts between its positive and negative terminals, and this potential exists even though no conductors are connected to the posts. Voltage, also called potential differences is stored in a battery in the form of a surplus of electrons at the negative post and a corresponding lack of electrons at the positive post. When a conductor is attached to the posts the surplus electrons at the negative post will travel to the positive post. As the electrons arrive, the positive post transfers them back through the battery to the negative post, maintaining the difference between the posts.

Resistance

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 its attraction toward the core.
2. Collisions of countless electrons and atoms as the electrons move through the conductor. The amount of resistance depends on the material of the conductor, its thickness or diameter, and its length.

In a circuit the resistors are the electrical accessories, the lights, the electrical motors, the gauges, etc.

The basic unit of resistance is the ohm. One ohm is the resistance that will allow one ampere to flow when the potential is one volt. The symbol for ohms is Ω.

ELECTRIC CIRCUIT VERSUS A HYDRAULIC CIRCUIT

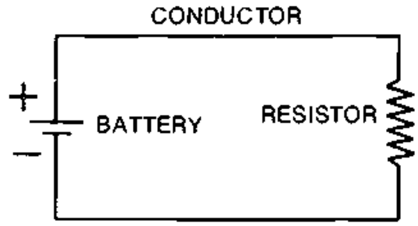
The chart below compares an electrical circuit with a hydraulic circuit.

Element Compared	Hydraulic Circuit	Electric Circuit
circuit	fluid flows in hydraulic lines to operate hydraulic cylinders	electrons flow in copper wires to operate electric accessories
source of energy	pump	battery, generator
flow rate	gallons per minute	amperes (electrons per second) (I)
working energy	pressure	voltage (E)
resistance	friction loss	ohm (R)

BASIC ELECTRICAL CIRCUIT

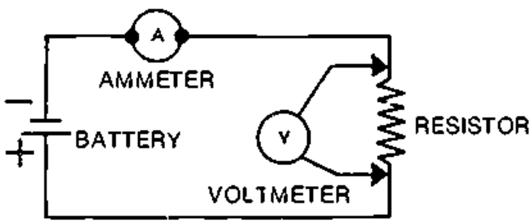
A basic electrical circuit has three parts (Figure 8-4):

— **voltage source** such as a battery
— **resistor** such as a light bulb
— a **conductor** such as copper wire to connect the circuit



(8-4)
Courtesy of John Deere Ltd

An ammeter measures the current in an electrical circuit, a voltmeter the volts, and an ohmmeter the ohms (Figure 8-5).



(8-5) Courtesy of John Deere Ltd

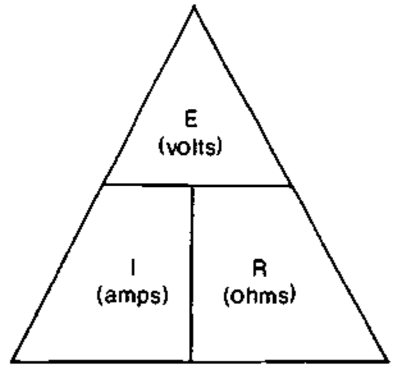
Knowing the basic information about an electrical circuit means knowing the volts, amps and ohms in the circuit. An electrical formula called Ohm's Law relates these three quantities:

E (volts) = I (amps) × R (resistance)

Because there are three quantities, there are three formulas:

$$E = IR \qquad I = \frac{E}{R} \qquad R = \frac{E}{I}$$

If you know any two of the quantities you can find the third by applying the above formulas. For example, if you know the amps (I) and the ohms (R), multiplying the amps times the ohms will give the volts (**E**). Or if you know the ohms (R) and the volts (**E**), dividing the volts by the ohms will give the amps. An easy way to remember these formulas is by using the triangle in Figure 8-6 (A similar triangle was used in Hydraulics with pressure, force and area.)



(8-6)

Look at the triangle, as you read these formulas $E = IR$, $I = \frac{E}{R}$ and $R = \frac{E}{I}$ to see how the triangle works.

Sample Problems

1 A circuit has 12 volts and a resistance of three ohms What is its amperage?

Solution:

You know the volts and the ohms so use the formula for the amps:

$$I = \frac{E}{R} \qquad \text{or amps} = \frac{\text{volts}}{\text{ohms}}$$

$$I = \frac{12}{3} = \text{four amps.}$$

2 What voltage is needed to send a five amp current through a 8.7 ohm resistor?

Solution:

You know the amps and the ohm so use the formula for the volts:

$E = IR$ or volts = amps × resistance

$E = 5 \times 8.7$

$= 43.5$ volts

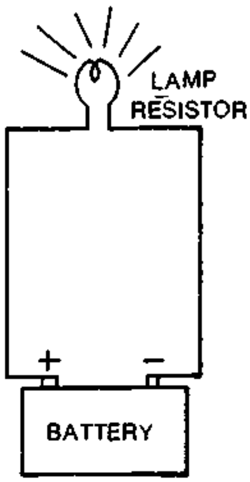
ELECTRICAL TERM DEFINITIONS

Conductor — Any substance that is a good transmitter of electricity All metals and many liquids are considered conductors. In general any substance composed of atoms with less than four electrons in its outer orbit is a conductor.

Insulator — Opposite to a conductor. Any substance that is a poor transmitter of electricity. Insulators usually have more than four electrons in their outer ring. Glass, plastic, mica, bakelite and rubber are examples of insulators.

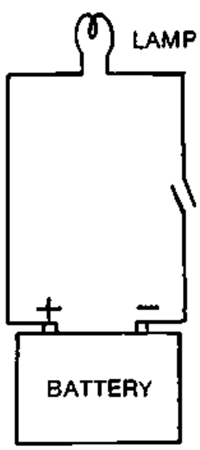
Closed Circuit — A closed circuit has (Figure 8-7):

1. a circuit path with no breaks in it.
2. a resistor to control the amount of current flow.



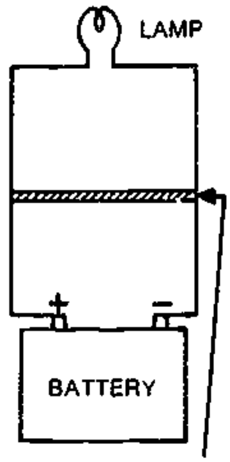
(8-7)

Open Circuit — In an open circuit the circuit path is opened either by a switch or by a broken wire. In Figure 8-8 the current can't reach the light because its path is broken. All light circuits in homes are open circuits when the switch is in the off position.



(8-8)

Short Circuit — A short circuit occurs in a circuit when the current can take a shorter course, bypassing the route it was supposed to take. In Figure 8-9 the lamp won't light because the current is short-circuited.



(8-9)

In a short circuit there is little resistance since the current is not travelling through the resistor (the light). Looking at the formula amps = $\frac{\text{volts}}{\text{ohms}}$, if the ohms, the quantity you are dividing by, is very small because of the short circuit, it means that the amps will be large. So large, in fact, that the conductor would be burned up and destroyed.

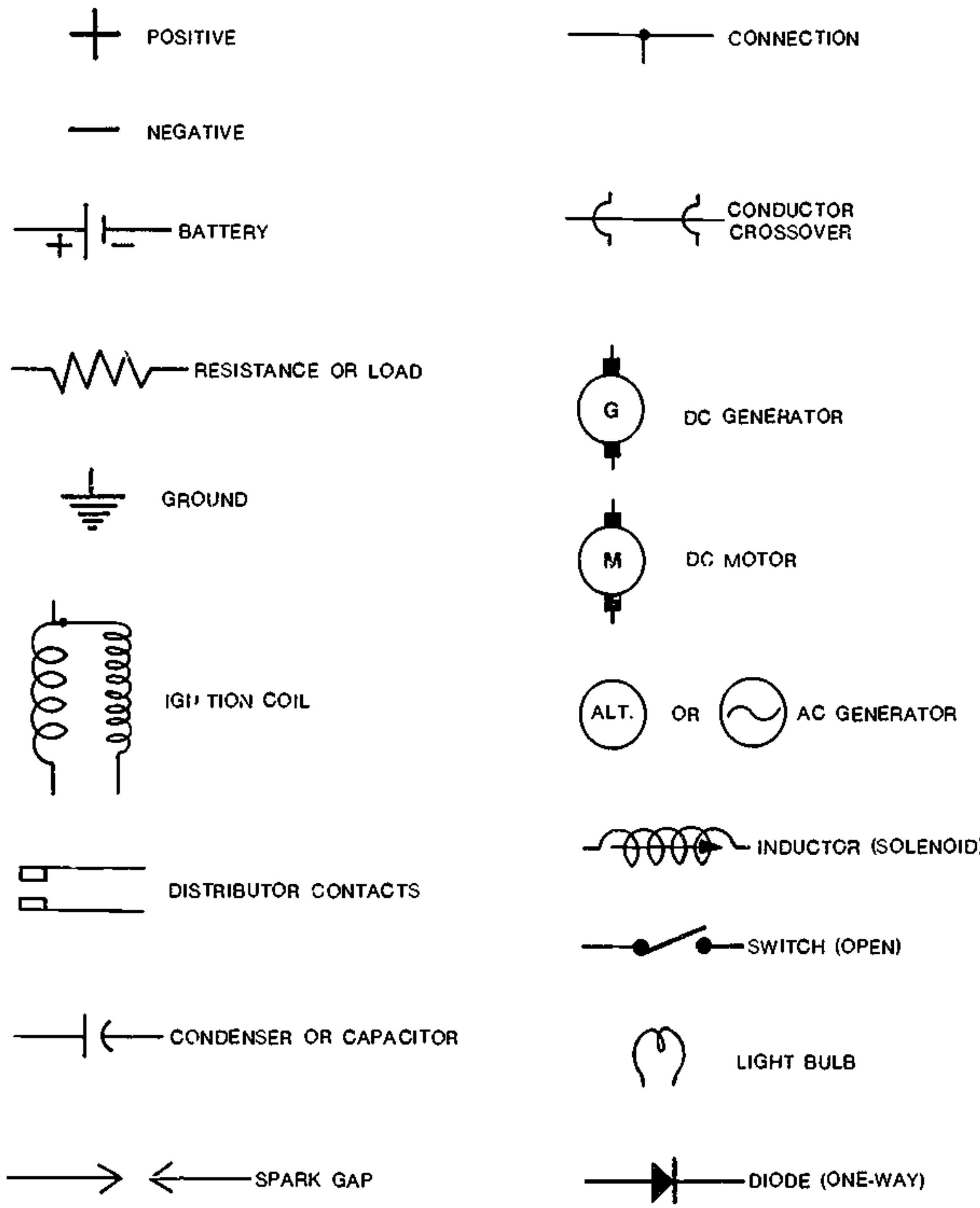
DIRECT CURRENT AND ALTERNATING CURRENT

Direct current (DC) travels in one direction only whereas alternating current (AC) constantly reverses direction. Batteries produce DC and therefore all the electrical accessories used on heavy duty vehicles operate on DC.

WATTS

Watts measure electrical power; watts are found by multiplying volts × amps. In a simple closed circuit having 12 volts and 2 amps, the number of watts is 12 × 2 = 24. The circuit is consuming 24 watts of electrical power. The amount of electrical power is usually stated in kilowatts (kw): 1000 watts = 1 kilowatt.

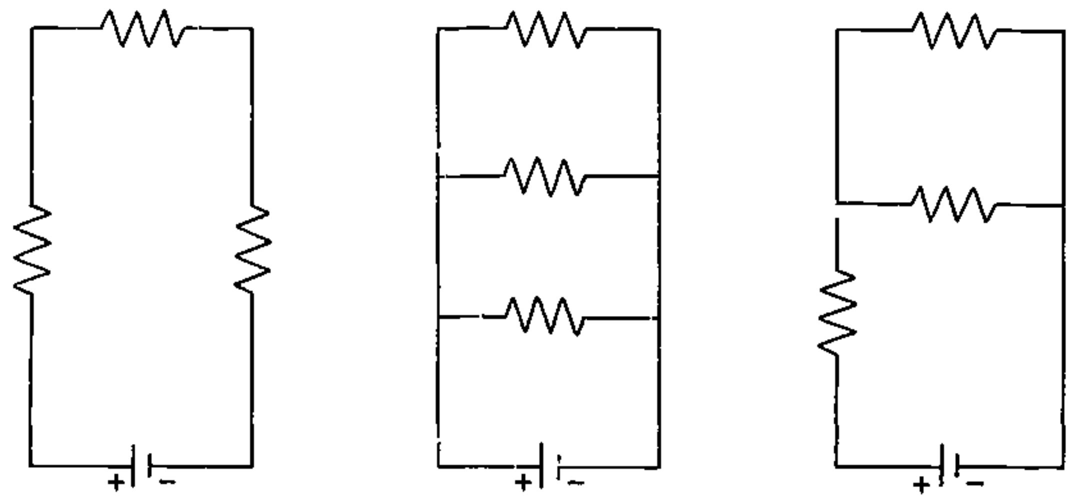
BASIC ELECTRICAL SYMBOLS



TYPES OF ELECTRICAL CIRCUITS

There are three types of circuits (Figure 8-11)

(8-11) Courtesy of John Deere Ltd



SERIES | PARALLEL | SERIES PARALLEL

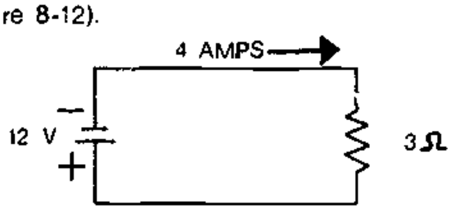
SERIES several resistors connected so that current can take only one path

PARALLEL: more than one path for the current to flow. Resistors are side by side and provide separate routes for the current.

SERIES PARALLEL: has some resistors connected in series and some connected in parallel.

Series Circuits

A basic series circuit may have a three-ohm (3 Ω) resistor connected to a 12-volt battery (Figure 8-12).



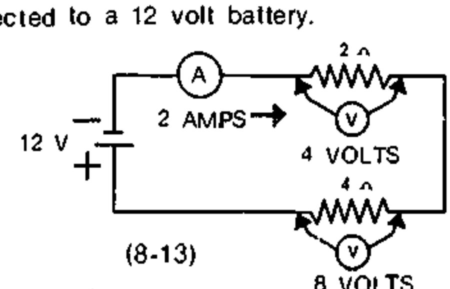
(8-12)

Courtesy of John Deere Ltd

To find the current, use Ohm's Law, where

$$I = \frac{E}{R} = \frac{12}{3} = 4 \text{ amperes, or 4 amps.}$$

The series circuit in Figure 8-13 has a two chm resistor and a four ohm resistor connected to a 12 volt battery.



(8-13)

Courtesy of John Deere Ltd

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:

$$1 = \frac{E}{R} = \frac{12}{6} = 2 \text{ amperes.}$$

Voltage across the two-ohm resistor can be figured using Ohm's Law: $E = IR = 2 \times 2 = 4$ volts. For the four-ohm resistor, $E = 2 \times 4 = 8$ 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. An ammeter connected in the circuit will read two amps, and a voltmeter connected across each resistor will read four volts and eight volts.

In summary, series circuits have the following features:

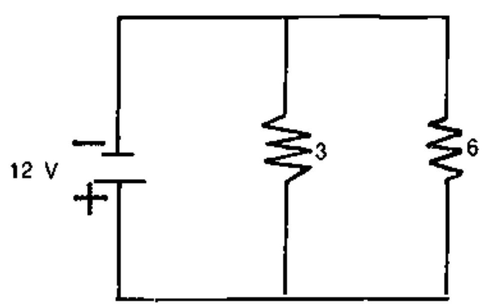
1. The current through each resistor is the same. Ohm's Law states that if a circuit has a given amount of volts and ohms, then a set quantity of amps will be drawn through the circuit. Since the amps travel only one path, they are the same throughout the circuit. Think of this current travel in terms of the electron theory. A set number of electrons set out from the negative terminal to travel to the

positive terminal. Since they can take only one route, the number of electrons traveling (i e , the number of amps) will be the same at any point in the circuit

2 The voltage drops in a series circuit. Unlike current, voltage is not the same throughout the circuit When an electron sets out from the negative terminal it has a certain strength of charge or attraction (i e., volts) for the positive terminal. But there are resistors in its path. These resistors weaken the electrons force of attraction because part of their force or strength is needed to get through the resistor. Thus as the electron progressively travels through resistors more and more of its strength or attraction for the positive terminal is used up. Over a series of resistors, so many volts will be used to get the electrons through the first resistor, so many through the second and so on, the amount of volts used up at each resistor depending on how large the resistance is. After pushing their way through the last resistor they have little strength or voltage left. This progressive consumption of voltage to get through resistors is called voltage drop. Since the voltage drops after each resistor, voltage varies throughout the circuit Note that the sum of the drops equals the total voltage at source.

Parallel Circuits

1. In a series c cuit the electrons (or amps) have one path to follow and thus the amperage is the same throughout the circuit Not so in a parallel circuit. In a parallel circuit the amps have two or more paths to follow The parallel circuit in Figure 8-14 has two paths for electrons to take



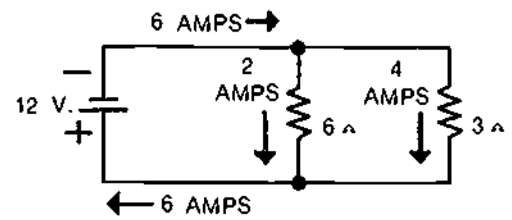
(8-14)

Electrons set out from the negative terminal. Some of them take the 3Ω route to the positive terminal, and some the 6Ω route. (Note the electrons will take the path of least resistance so that twice as many will take the 3Ω route as will take the 6Ω route.) Since the number of electrons is split up among the two circuits, the amps will vary at different locations of the parallel circuit. The sum of the amps from all the circuits will equal the total amps of the circuit.

The current through each resistor or branch of the circuit can be figured using Ohm's Law. For the six-ohm resistor,

$$I = \frac{E}{R} = \frac{12}{6} = 2 \text{ amps.}$$

For the three-ohm resistor, $I = \frac{12}{3} = 4$ amps. The total current supplied by the battery is 2 + 4 = 6 amps (Figure 8-15).

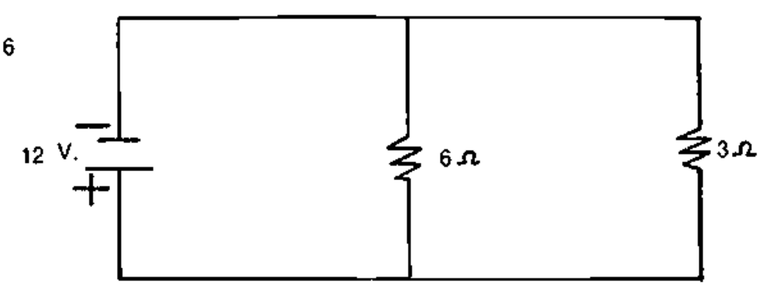


(8-15)

Courtesy of John Deere Ltd.

The total resistance of the parallel circuit is equal to the voltage divided by the total current or $\frac{12}{6} = 2\Omega$.

2. In a series circuit voltage drops after each resistor and therefore full voltage is not present at each resistor. The opposite is true in a parallel circuit: full voltage is available at each resistor. Why is full voltage present in parallel circuits? Examine the parallel circuit in Figure 8-16.



(8-16)

An electron starts out from the negative terminal with a 12 volt charge or attraction for the positive terminal As seen above, some of the electrons will take the route through the 6Ω resistor to get to the positive terminal and some electrons will take the route through the 3 ohm resistor. The electron reaching the 6 Ω resistor has a 12 volt attraction because it hasn't gone through any other resistors to drop nor will it have to go through any other ones. The same can be said of the electron reaching the 3 Ω resistor. This electron too has a 12 volt attraction because it hasn't gone through nor will it have to go through any other resistors.

In summary, parallel circuits have the following features:

(a) The voltage across each resistor is the same.

(b) The sum of the separate currents equals the total current in the circuit.

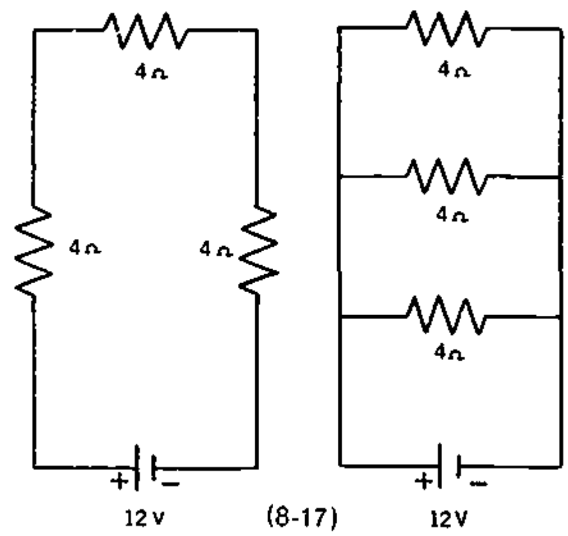
(c) The current through each resistor will be different if the resistance values are different.

Series Parallel Circuits

Series parallel circuits are not commonly found on vehicles; therefore, they won't be discussed here.

COMPARISON OF SERIES AND PARALLEL CIRCUITS

Both the series and parallel circuits in Figure 8-17 have three 4 ohm circuits.



(8-17)

X 1348 SERIES PARALLEL

Courtesy of John Deere Ltd

Series Circuit

Resistance: 4 + 4 + 4 = 12 ohms

Amperage: $\text{amps} = \dfrac{\text{volts}}{\text{ohms}} = \dfrac{12}{12} = 1 \text{ amp}$

Power: volts × amps = 12 × 1 = 12 watts

resistance = 12 ohms:	amperage = 1 amp	power = 12 watts

Parallel Circuit

Amperage: circuit 1 $\text{amps} = \dfrac{\text{volts}}{\text{ohms}} = \dfrac{12}{4} = 3 \text{ amps}$

circuit 2 3 amps

circuit 3 3 amps

TOTAL 9 amps

Resistance: equivalent resistance is:

$$\text{ohms} = \frac{\text{volts}}{\text{amps}} = \frac{12}{9} = 1.3 \text{ ohms}$$

Power: = volts × amps = 12 × 9 = 108 watts

resistance = 1.3 ohms:	amperage = 9 amps	power = 108 watts

In Summary:

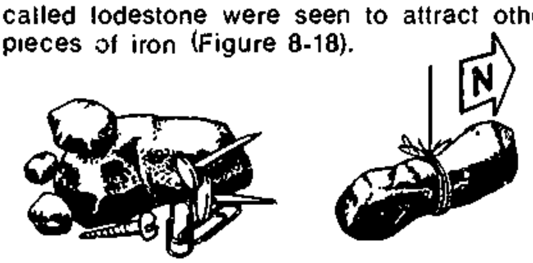
Series circuit — high resistance. low amperage. low power (wattage)

Parallel circuit — low resistance. high amperage. high power

Most circuits in vehicles are parallel circuits.

MAGNETISM

Electricity is closely related to magnetism. The effects of magnetism were first observed when naturally found fragments of iron ore called lodestone were seen to attract other pieces of iron (Figure 8-18).



(8-18) MAGNETISM

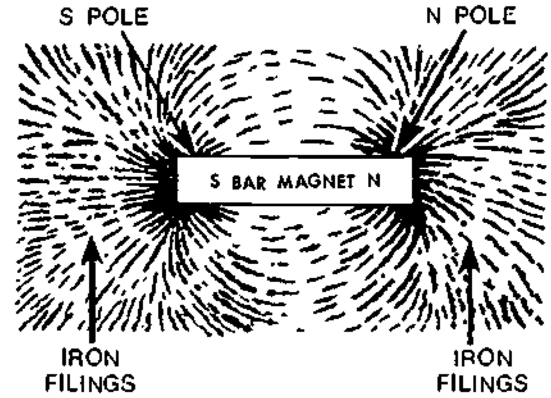
Courtesy of John Deere Ltd

It was further discovered that a long piece of lodestone iron ore. when suspended in air, would align itself so that one end always pointed toward the North Pole of the earth (Figure 8-18). 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. The bar magnet is the basic part of the compass, a navigational aid that has been used for over 1,000 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. It was clear that a force existed in the space close to the bar magnet. This space around the magnet to which iron filings are attracted is called the field of force or magnetic field.

The theory of magnetic lines of force can be dramatized by sprinkling iron filings on a piece of paper resting on top of a bar magnet. When the paper is lightly tapped, the iron filings line up to form a clear pattern around the bar magnet (Figure 8-19).

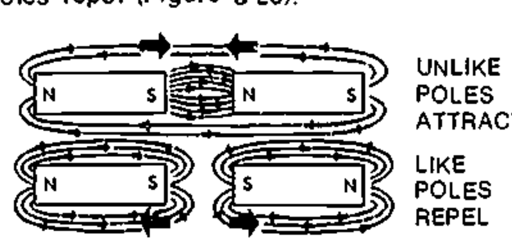


(8-19) MAGNETIC FIELD OF A BAR MAGNET

Courtesy of John Deere Ltd

The pattern shows that the lines of force are heavily concentrated at the N and S poles of the magnet. and then spread 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.

Taking two bar magnets and experimenting with their polarities, you will find that unlike poles, north and south, are attracted to one another while like poles, north and north or south and south, repel one another. The force of attraction gets stronger as the two unlike poles are drawn closer together, and correspondingly, the force of repulsion gets stronger as the two like poles are pushed closer together. Stated briefly this basic law of magnetism is: unlike poles attract, like poles repel (Figure 8-20).



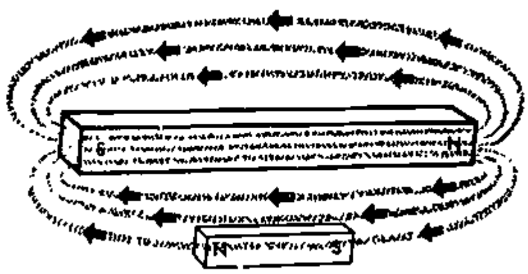
(8-20) MAGNETIC FORCES BETWEEN POLES OF BAR MAGNETS

Courtesy of John Deere Ltd

Just as there are good and poor conductors of electricity, so there are good and poor magnetic materials. Iron has good magnetic properties whereas wood, paper, glass, copper, zinc are less magnetic.

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. Another method of magnetic induction is simply to place an iron bar in a strong magnetic field (Figure 8-21).



(8-21) MAGNETIC INDUCTION OF AN IRON BAR
Courtesy of John Deere Ltd

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. (Soft metals will not retain much of their magnetism.) Some of the more common magnetic alloys are nickel-iron and aluminum-nickel-cobalt and magnets using the alloys are trade-named ALNICO magnets. Permanent magnets are found in many shapes, including the horseshoe magnet which concentrates the lines of force in a small area between two poles (Figure 8-22). Horseshoe magnets are widely used in voltmeters and ammeters.

(8-22) FORMING A HORSESHOE MAGNET
Courtesy of John Deere Ltd

Summary of Magnetism

— Every magnet has an N and S pole, and a field of force surrounding it.

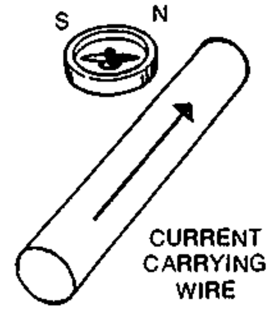
— Magnetic materials are acted upon when located in a field of force.

— Unlike poles attract and like poles repel.

— An unmagnetized piece of iron can become a magnel through induction.

ELECTROMAGNETISM

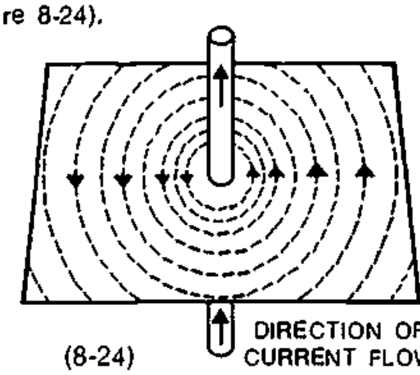
An experiment with a compass and a wire carrying current reveals the connection between electricity and magnetism. When a compass is held over the wire, the needle turns crosswise to the wire (Figure 8-23). Since the only thing known that will attract a compass needle is magnetism, it is obvious that the current in the wire creates a magnetic field around the wire.



(8-23)

ELECTRIC CURRENT CREATES ITS OWN MAGNETIC FIELD
Courtesy of John Deere Ltd

The nature of the magnetic field around the wire can be seen when a 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 (Figure 8-24).



(8-24)

Courtesy of John Deere Ltd

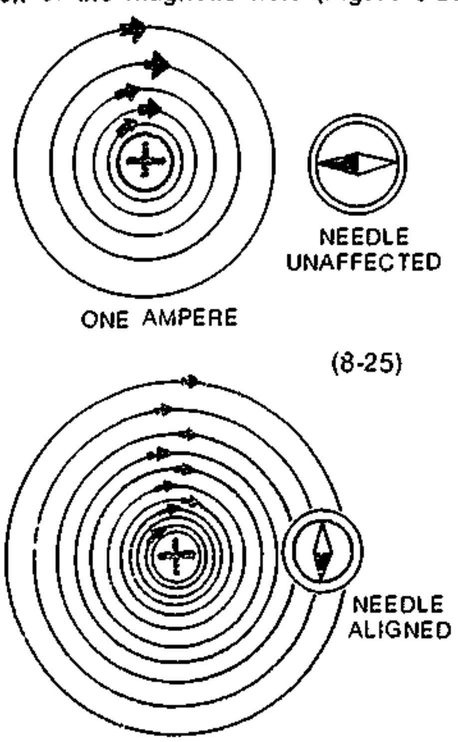
The circles are more concentrated near the wire than farther away. Although the iron filings on the cardboard show only the pattern in one plane, remember that the concentric circles extend the entire length of the current-carrying wire.

When a current is travelling in one direction and a compass is placed in the electromagnetic field, the needle aligns itself so that magnetic lines enter its S pole and leave its N pole. If the direction of the current is changed the compass needle reverses its position and points in the opposite direction. Thus it can be concluded that:

> Electro-magnetic lines have direction, and they change that direction when the current flow is reversed in the wire.

Points About Electromagnetism

1 The number of lines of force, or strength of the magnetism, increases as the current through the conductor is increased. More current creates a stronger field. If a compass is moved farther away from the conductor, a point finally is reached where the compass is unaffected by the field. If the current is then increased, the compass needle will be affected and will again indicate the direction of the magnetic field (Figure 8-25).



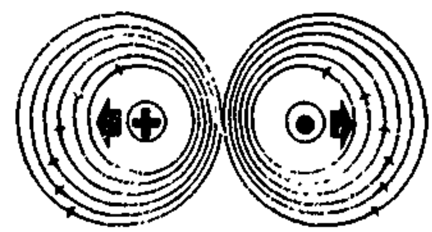
(8-25)

Courtesy of John Deere Ltd

When a number of conductors are placed side by side, the magnetic effect is increased as the lines from each conductor join and surround all the conductors. The ratio of increase can be seen in the following:

> 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.

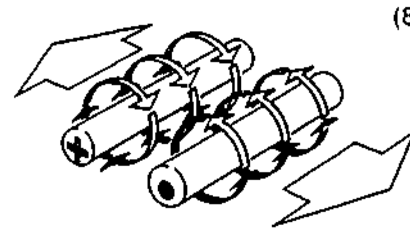
2 If two adjacent parallel conductors are carrying current in opposite directions, the direction of the field is clockwise around one conductor and counterclockwise around the other. When the two wires are placed close together, as in Figure 8-26, you can see that there is a concentrated field between them because the fields from the two wires merge together. Since both lines of force are running in the same direction there is a strong field between the conductors. A much weaker field exists to the outside of the wires.



STRONG FIELD BETWEEN CONDUCTORS

CARRYING CURRENT IN OPPOSITE DIRECTIONS

(8-26)

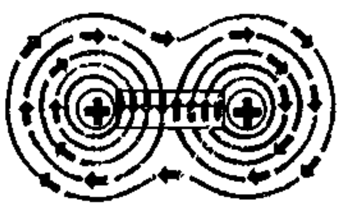


CONDUCTORS TEND TO MOVE APART

Courtesy of John Deere Ltd

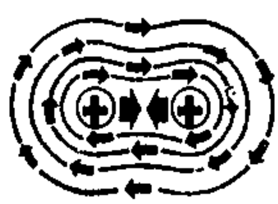
The strong field has an important effect on the two conductors in as much as they have a tendency to move away from one another. Putting this observation into a general statement current carrying wires will tend to move out of a strong field and into a weak field.

3. When two adjacent parallel conductors are carrying current in the same direction a magnetic field, clockwise in direction, will be formed around each conductor, with the result that the magnetic lines between the conductors oppose each other in direction. Thus the magnetic field between the conductors is cancelled out, leaving essentially no field in this area (Figure 8-27). The two conductors will then tend to move toward each other, that is, from a strong field into a weak one.



MAGNETIC FIELD
BETWEEN CONDUCTORS
CANCELS OUT

(8-27)

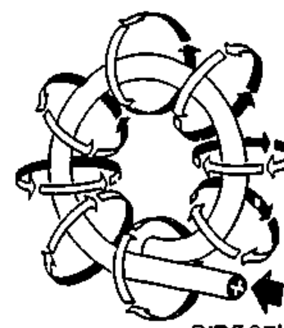


CONDUCTORS TEND
TO MOVE TOGETHER

Courtesy of John Deere Ltd

In points 2 and 3 above, the magnetic fields were from two current carrying conductors. The same principle could be deduced using a conductor and a magnetic field from a magnet: the conductor would be pushed away from the magnetic field when the conductor's field and the magnet's field ran in the same direction; and conversely the conductor would be pulled towards the magnet's field when the two fields run in opposite directions. This push and pull reaction between a conductor and a magnet's field is the basic principle of an electric motor as will be seen in the discussion of a starting motor.

4. A straight current-carrying wire when formed into a single loop still has a magnetic field surrounding it. The lines of magnetic force, however, have a different pattern (Figure 8-28).



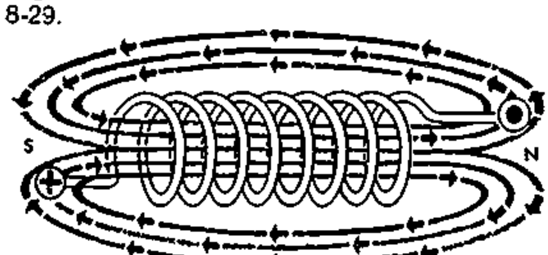
(8-28) DIRECTION OF CURRENT FLOW

Courtesy of John Deere Ltd.

All the lines of force enter the inside of the loop of wire on one side and leave it on the outside. Given the angles of the forces and the fact that the inside diameter of the conductor is smaller than the outside diameter, the lines of force are more concentrated on the inside of the loop than on the outside. A single loop of wire carrying current is called a basic electromagnet.

Electromagnets

Rather than one loop, an electromagnet has a number of current carrying loops combined together to make a coil as illustrated in Figure 8-29.

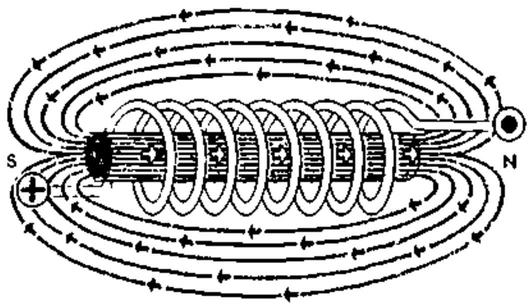


(8-29)

CONDUCTOR IN SEVERAL LOOPS MULTIPLIES THE MAGNETIC FIELD

Courtesy of John Deere Ltd

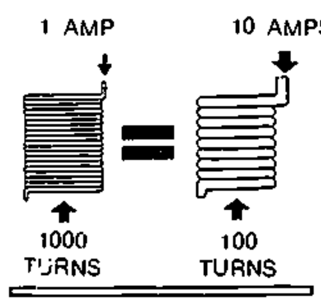
The strength of the resulting magnetic field is the sum of all the single loop magnetic fields added together. With lines of force leaving the coil at one end and entering at the other, a north and south pole are formed at the coil ends, the same as in a bar magnet. If the current direction through the coil is reversed, the polarity of the coil ends will also reverse. The above core could be called an electromagnet. Useable electromagnetics, however, have another element, an iron core around which the coil wires are wrapped (Figure 8-30).



(8-30)
IRON CORE INCREASES FIELD STRENGTH
Courtesy of John Deere Ltd

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 while air is a very poor conductor of magnetic lines, iron is a very good one. The use of iron in a magnetic path may increase the magnetic strength 2500 times over that of air.

The strength of the magnetic poles in an electromagnet is directly proportional to both the number of turns of wire and the amount of current flowing in the coil (Figure 8-31).



(8-31)
Courtesy of John Deere Ltd

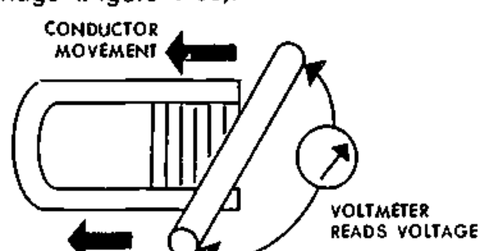
An electromagnet having one ampere flowing through 1000 turns, and another electromagnet having 10 amperes flowing through 100 turns will each have a field strength of 1000 ampere turns. The attraction on magnetic materials located in the magnetic field of each of these electromagnets will be the same.

Summary Of Electromagnetism

- Electricity and magnetism are related because a magnetic field surrounds a conductor that is carrying current.
- An electromagnet has a N pole at one end of the iron core and an S pole at the other end, 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

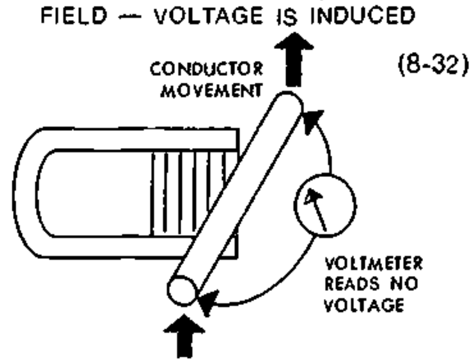
ELECTROMAGNETIC INDUCTION

From the point of view of electricity, something very important happens when a conductor is moved across a magnetic field: a voltage is induced in the conductor. This voltage is called electromagnetic induction. Electromagnetic induction (i.e., induced voltage) can be observed by doing the following: connect a sensitive voltmeter to the ends of a straight wire conductor. Move the wire conductor across the magnetic field of a horseshoe magnet. As the wire moves across the field the voltmeter will register a small voltage (Figure 8-32).



MOVING CONDUCTOR ACROSS MAGNETIC FIELD — VOLTAGE IS INDUCED

(8-32)

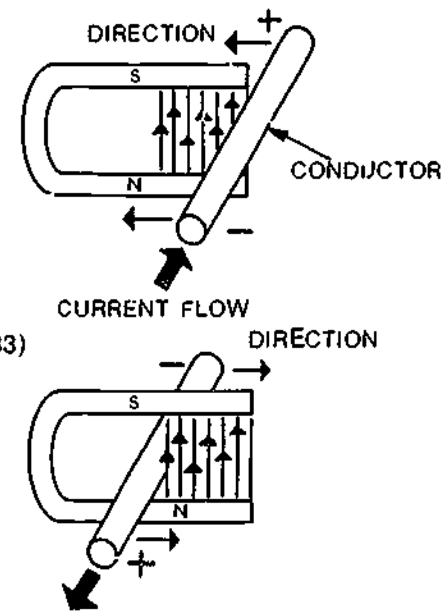


MOVING CONDUCTOR PARALLEL TO MAGNETIC FIELD — NO VOLTAGE IS INDUCED
Courtesy of John Deere Ltd

If the wire is moved parallel wtih the lines of lorce, no voltage will be induced (Figure 8-32). The conductor must cut across the lines of force in order to induce a voltage.

Since a conductor cutting across the field has voltage, it is a source of electric current, just as a battery is, and must have a positive and a negative end.

In a battery the positive and negative terminals are permanent. Electromagnetically induced voltage, on the other hand, does not have permanent polarity; the positive and negative end can change depending on which direction the wire is moved through the magnetic field. Figure 8-33 illustrates this change in polarity and corresponding change in current flow.



(8-33)

Courtesy of John Deere Ltd

In the previous examples, if, instead of moving the wire across the field, the field is moved across the wires, the same voltage and current flow will be induced in the wire. Therefore, it can be concluded that voltage will be induced in a conductor cutting across a magnetic lield when there is relative motion between the two. Either the conductor can move, or the magnetic field can move.

Strength Of Induced Voltage

Three factors affect the strength of induced voltage:

1. The **strength** of the magnetic field.

   If the magnetic field is made stronger, by using a larger horseshoe magnet for example, more lines of force will be cut by the conductor in any given interval of time and the induced voltage will be higher.

2. The **speed** at which lines of force are cutting across the conductor.

   If the relative motion between the conductor and magnetic lield is increased, more lines of lorce will be cut in any given interval of time and so the voltage will be higher.

3. The **number** of conductors that are cutting across the lines of force.

   In the example on the previous page one conductor was passed through tne field and a voltage was induced. If two wires were moved across the field twice as much current would be induced; if three wires, three times as much, and so on. Electrical motors, generators, coils, use loops of wire rather then straight wire as conductors. When a straight wire conductor is wound into a coil and 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.

Note that the strength of induced voltage is related to the power needed to move the conductors across the magnetic field, or vice versa. When current is induced in a conductor, a magnetic field forms around the conductor. So the magnetic field of the conductor moves through the magnetic lield of the magnet Since an interaction occurs between the two fields, a resistance is set up against the movement The more induced current, the stronger the resistance Therefore, as the amount of induced current increases and thus resistance increases, more power will be needed to move the conductors across the field The practical application of this fact is that the more current a generator or alternator produces, the more power is needed to turn them.

Summary Of Electromagnetic Induction

- Stronger magnetic field equals more induced voltage.
- Faster relative motion equals more voltage.
- More conductors in motion equals more voltage.
- More current induced equals more power to move conductors through the magnetic field.

The basic electricity, magneticism, and electromagnetism discussed above give the principles that electrical components are built on. Clearly understood, these principles will help you in diagnosing and repairing electrical parts.

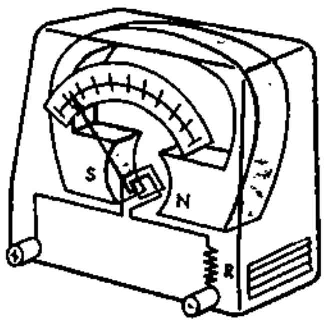
ELECTRICAL TEST EQUIPMENT

To accurately test and diagnose electrical problems, good test equipment is necessary. If values for voltage, current and resistance are not measured with suitable test meters, only a guess can be made as to what defect exists in the circuit.

The following discussion will look at voltmeters, ammeters, and ohmmeters. What is said about the three meters separately also applies to modern testers which often combine two of the three meters in one test unit (e.g., battery starter tester).

Voltmeter

A voltmeter (Figure 8-34) measures the strength of electrical potential or voltage in a circuit.



(8-34) VOLTMETER

Courtesy of John Deere Ltd.

Because the moving coil in the voltmeter is very small and sensitive, the current through the coil must be limited to safe values. To limit current to a safe amount, voltmeters are constructed with a high resistor in series with the coil. The voltmeter scale is calibrated accordingly to indicate the true voltage.

Voltmeters are connected across (in parallel with) the voltage to be measured, as shown in Figure 8-35.

(8-35)

CONNECT VOLTMETER IN PARALLEL

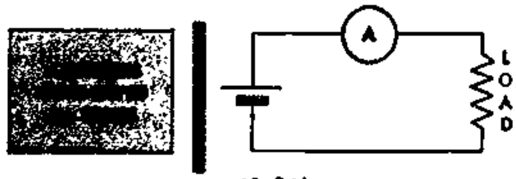
Courtesy of John Deere Ltd

Ammeters

An ammeter measures the flow of electrical current in amperes. Two types of ammeters are used, a shunt ammeter and a tong ammeter.

Shunt Ammeters

Opposite to a voltmeter, the shunt ammeter has a low resistance shunt connected in parallel with the moving coil. The shunt section of the parallel circuit, therefore, conducts most of the current being measured leaving only a small portion to flow through the coil. Always connect an ammeter in series in a circuit: never connect it across the voltage source (Figure 8-36). If connected across, or in parallel, the meter could be damaged.



(8-36)

ALWAYS CONNECT AMMETER IN SERIES

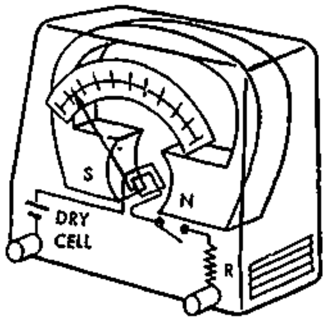
Courtesy of John Deere Ltd.

Tong Ammeter

Tong ammeters measure the amps in a circuit by measuring the strength of the magnetic field that surrounds the current carrying conductor. The advantage of a tong ammeter is that you can test without disconnecting any wires. Current is measured by simply opening the tongs and placing them over the wire. However, a tong ammeter is not as accurate as a shunt ammeter.

Ohmmeters

An ohmmeter (Figure 8-37) measures the resistance or ohms in a circuit

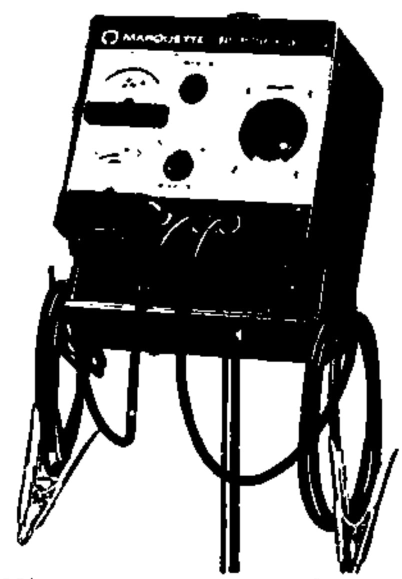


(8-37) OHMMETER
Courtesy of John Deere Ltd

An ohmmeter has its own current supply, a dry cell battery, and should always be used on a dead circuit. Never connect an ohmmeter to a live circuit as the external voltage may damage it. Keep the dry cell switched off when the ohmmeter is not in use.

Battery-Starter Tester

A battery starter tester (Figure 8-38) has a voltmeter and an ammeter combined into one unit. The tester will do a complete test on the battery and starting circuit.



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(8-38) BATTERY-STARTER TESTER (VOLT-AMPERE TESTER)

Courtesy of John Deere Ltd

CARE AND SAFE PRACTICES WITH ELECTRICAL TESTING EQUIPMENT

The accuracy of electrical test equipment will depend on how well it is looked after. Follow these simple rules for care and use of the equipment:

1. If in doubt of voltmeter, ammeter, ohmmeter hook-up procedures, refer to instructions for the machine.
2. Do not overload the meter. Check the meter setting before connecting the meter into the circuit. For example, some voltmeters can have four different setting ranges that fall between 4 and 40 volts. One setting would be used when testing a 12 volt system, and a higher setting would be used on a 24 volt system.
3. Remember the basic rule applied to each meter:
   (a) Voltmeter — connected in parallel
   (b) Ammeter — connected in series
   (c) Ohmmeter — connected to a dead circuit only.
4. Avoid connecting the meter backwards as reversing the connections is hard on the meter. Most meter connectors are color coded, red for positive, black for negative.
5. Keep the instruments clean. Cover them when not in use or store them in a clean area.
6. Avoid testing in hot areas around an engine as heat can burn or damage the meter connectors.

QUESTIONS — ELECTRICITY THEORY

1. Electricity flows in a conductor in the direction of:
   (a) negative to neutral
   (b) negative to positive
   (c) positive to negative
   (d) positive to neutral
2. Electricity is a form of:
   (a) heat
   (b) light
   (c) energy
   (d) magnetism
3. True or False? The term current means the flow of electrons through a conductor.
4. Briefly explain the term voltage.
5. All conductors offer some resistance to the flow of current; the basic unit of resistance is the:
   (a) diode
   (b) thermistor
   (c) ampere
   (d) ohm
6. List the three basic parts of an electrical circuit.
7. Match the unit of electricity with the meter used to measure it.

(a) Voltage	(a) Ohmmeter
(b) Current	(b) Voltmeter
(c) Resistance	(c) Ammeter

8. Use the formula for Ohm's Law to calculate the current flow in a circuit that has 12 volts potential and a resistance of four ohms.
9. Briefly describe a conductor.
10. Briefly explain the difference between a closed circuit and a short circuit.
11. Current flow can be direct or alternating. All accessories used on automotive and heavy duty vehicles operate on ______________ current generally referred to as __________.
12. What does the term watt refer to and how is it determined?
13. List the three types of electrical circuits.
14. Parallel circuits are most commonly used in automotive and heavy duty vehicles. Parallel circuits have:
   (a) high resistance low amperage
   (b) high resistance high amperage
   (c) low resistance high amperage
   (d) medium resistance medium amperage
15. The lines of force created around a bar magnet is referred to as the ____________. The law of magnetism states that ___________.
16. What does a bar magnet and a wire conducting electricity have in common?
17. An electromagnet is made by forming a conductor into a coil and passing a current of electricity through the coil. What is needed to complete this basic electromagnet?
18. A common term for expressing the strength of an electromagnet found by multiplying the current flow times the number of turns in the coil is:
   (a) flux turns
   (b) current turns
   (c) magnetic turns
   (d) ampere turns
19. What is the term used to describe voltage produced by a conductor cutting across lines of force?
20. True or False? Current is induced when a conductor moves across a magnetic field but not when the field moves across the conductor.
21. Match the following test instruments with the correct method of connecting them into a circuit:

(a) Ohmmeter	(a) connected in series
(b) Ammeter	(b) connected in parallel
(c) Voltmeter	(c) connected to a dead circuit

22. To avoid damaging test meters through reverse polarity the test leads are color coded for identification. The standard combination is:

    (a) red for negative, yellow for positive

    (b) black for positive, green for negative

    (c) red for negative, black for positive

    (d) red for positive, black for negative

23. What are the three factors that affect the strength of the induced voltage created by electromagnetic induction?

24. Two adjacent conductors carrying current in the same direction will tend to ______________ one another.

25. Two adjacent conductors carrying current in the opposite direction will tend to ______________ one another.

LEAD ACID STORAGE BATTERIES

A battery stores energy for all the electrical circuits in a vehicle — the starting, charging, ignition, and accessory circuits. On demand the battery produces a flow of direct current to operate the electrical components in these circuits. Battery current is produced by chemical reaction between the active materials of the plates and the sulfuric acid in the battery fluid or electrolyte Electrolyte consists of 36% sulfuric acid and 64% water.

BATTERY CONSTRUCTION

A battery is made up of a number of individual cells in a hard rubber case. The basic units of each cell are positive and negative plates (Figure 8-39). Negatively charged plates have a lead surface, gray in color; the positive plates have a brown lead peroxide surface. Both negative and positive plates are welded together in separate groups. Plate groups are interconnected, as shown below. N· ; that there is one more plate in the negative gi. up than in the positive, allowing negative plates to form the two outsides when the groups are interconnected.

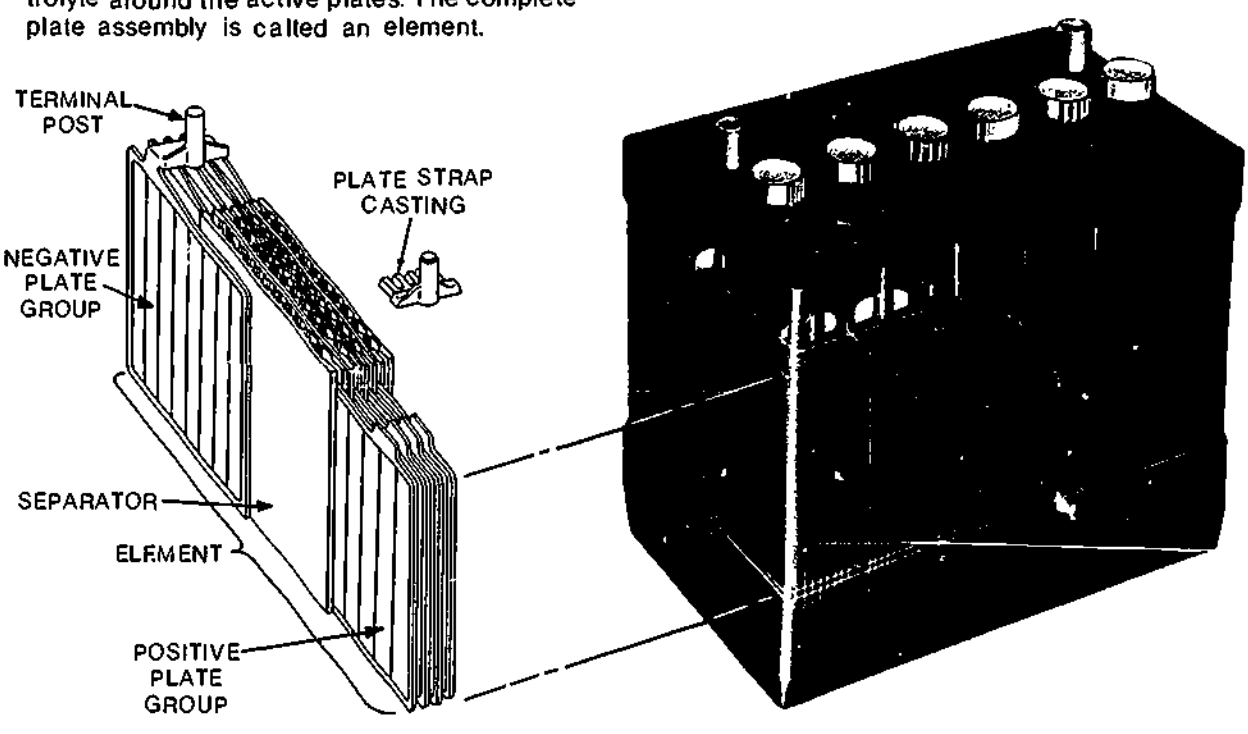
Each plate in the interlaced plate group is kept apart from its neighbor by porous separators which allow a free flow of electrolyte around the active plates. The complete plate assembly is called an element.

Elements in different cells are connected in series. The cells are separate from one another and so there is no flow of electrolyte between them.

Batteries have negative and positive posts or terminals. The positive post is larger to help prevent the battery from being connected in reverse polarity. The positive terminal has a + marked on i.s top, and the negative post a −. Other possible identifying marks on or near the Posts are a "pos" and a "neg".

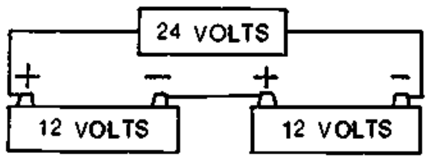
Conventional batteries have vent caps for each cell; these caps cover access holes through which the electrolyte level can be checked and water added. The access holes also provide a vent for the escape of gases formed when the battery is charging. The new so called maintenance-free batteries have no vent caps. The electrolyte, for all practical purposes, is sealed in. There is however one small vent hole to allow any internal pressure to escape.

Courtesy of John Deere Ltd.



(8-39) CONSTRUCTION OF A STORAGE BATTERY

Each cell in a storage battery has a potential of about two volts. Six-volt batteries contain three cells connected in series, while 12-volt batteries have six cells in series. For higher voltages, combinations of batteries are connected in series. In Figure 8-40 two 12-volt batteries are combined to give 24 volts



(8-40)
Courtesy of John Deere Ltd

Note that batteries of the same voltage can produce different amounts of current. The reason for this is that the amount of current a battery can produce is dependent on the number and size of its plates. The more plates there are the more chemical reactions can take place between the electrolyte and the plates and, therefore, a greater amount of current is produced. Thus, if two 12-volt batteries have a different number of plates, the one with the greater number will supply more current.

BATTERY ELECTROLYTE

The electrolyte in a fully charged battery is a concentrated solution of sulfuric acid in water. It has a specific gravity of about 1.270 at 27°C, which means it weighs 1.270 times more than water. The solution is about 36% sulfuric acid (H_2SO_4) and 64% water (H_2O).

Battery Water

The purity of water for battery use has always been a controversial subject It is a fact that water with impurities hurts the life and performance of a battery. The question is does the impure water harm it in a significant amount? The controversy can be simply resolved by saying that you don't have to use distilled water, but it is better for the battery if you do.

BATTERY OPERATING CYCLES

A battery has two operating cycles:

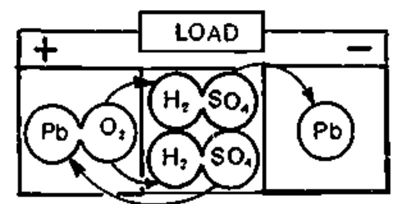
- — discharging cycle
- — charging cycle

Discharging Cycle

When a battery is supplying current, it is discharging. The chemical reactions in a discharging battery are as follows:

Positive Plates are made of lead peroxide (PbO_2). The lead (Pb) reacts with the sulphate radical (SO_4) in the electrolyte (H_2SO_4) to form lead sulfate ($PbSO_4$). At the same time the oxygen (O_2) in the lead peroxide joins with the hydrogen (H_2) in the electrolyte to form water (H_2O).

Negative Plates are made of lead. This lead also combines with the sulfate radicals in the electrolyte to form lead sulfate ($PbSO_4$). These reactions are illustrated in Figure 8-41.



DISCHARGING
(8-41) Courtesy of John Deere Ltd

In the discharging process, then, lead sulphate forms on both the positive and negative plates making the two plates similar. These sulphate deposits account for the loss of cell voltage because voltage depends on the positive and negative plates being different. As the battery progressively discharges more lead sulphate is formed at the plates and more water is formed in the electrolyte.

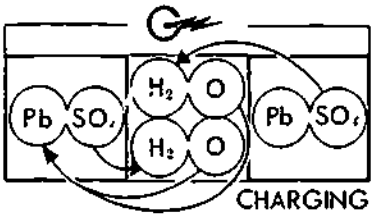
Note that although the SO_4 radical leaves the electrolyte, it never leaves the battery. Therefore, never add any additional sulfuric acid (H_2SO_4) to a battery. The extra SO_4 would only cause the battery to self discharge at a higher than normal rate. Water is the only substance in a battery that has to be replaced.

Charging Cycle

The chemical reactions that take place in the battery cell during the charging cycle are essentially the reverse of those which occur during the discharging cycle:

1. The sulphate radical leaves the plates and goes back to the electrolyte replenishing the strength of sulphuric acid.

2 Oxygen from the water in the discharged electrolyte joins with the lead at the positive plate to form lead peroxide. The chemical reactions during charging are illustrated in Figure 8-42.



(8-42)
Courtesy of John Deere Ltd

THE BATTERY AND THE CHARGING CIRCUIT

Batteries operate in a charging circuit with a generator or alternator. The battery supplies current to circuits and becomes discharged. The generator or alternator sends current to the battery to recharge it. Operation of the charging circuit varies with the engine speed. When the engine is shut off, the battery alone supplies current to the accessory circuits. At low speeds, both the battery and generator may supply current. At higher speeds, the generator may take over and supply enough current to operate the accessories and also recharge the battery.

TYPES OF BATTERIES

There are three types of batteries:

— dry-charged
— wet-charged
— maintenance-free

Dry-Charged Batteries

A dry-charged battery contains fully-charged elements, but it contains no electrolyte. Once activated with electrolyte it is essentially the same as a wet-charged battery. A dry-charged battery retains its full state of charge as long as moisture is not allowed to enter the cells. If stored in a cool, dry place, this type of battery will not lose part of its charge on the shelf prior to being used.

Activating Dry-Charged Batteries

The activation of a dry-charged battery is usually done at the warehouse where the battery is purchased or in the field by a dealer. To make sure the correct electrolyte is used and the battery is properly activated, many manufacturers furnish a packaged electrolyte for their dry-charged batteries along with instructions for activation. These instructions must be carefully followed.

Wet-Charged Batteries

Wet-charged batteries contain fully-charged elements and are filled with electrolyte at the factory. A wet-charged battery will not maintain its state of charge during storage, and must be recharged periodically. During storage, even though a battery is not in use, a slow reaction takes place between the electrolyte and the plates causing the battery to lose its charge. This reaction is called self-discharge.

The rate at which self-discharge occurs varies directly with the temperature of the electrolyte. A fully charged battery stored at a temperature of 38°C will be almost completely discharged after a storage period of 90 days. The same battery stored at 15°C will be only slightly discharged after 90 days.

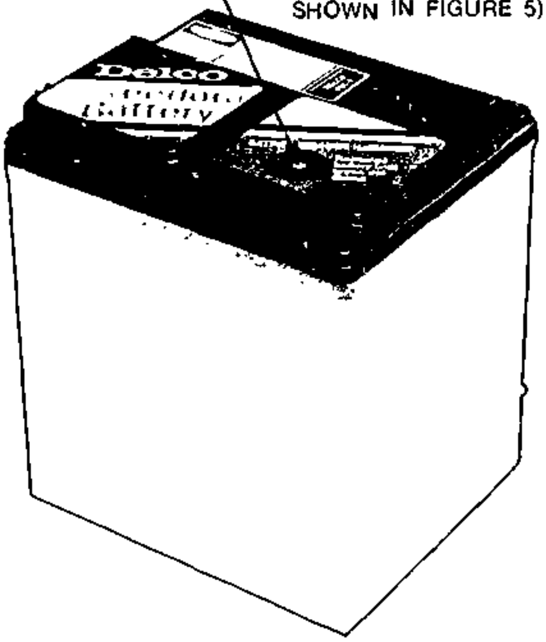
Wet-charged batteries, therefore, should be stored in the coolest place possible which doesn't allow the electrolyte to freeze. Note that a wet-battery which is kept fully charged will not freeze unless the temperature goes below −60°C, where as a discharged battery with a specific gravity of 1.100 will freeze at −8°C.

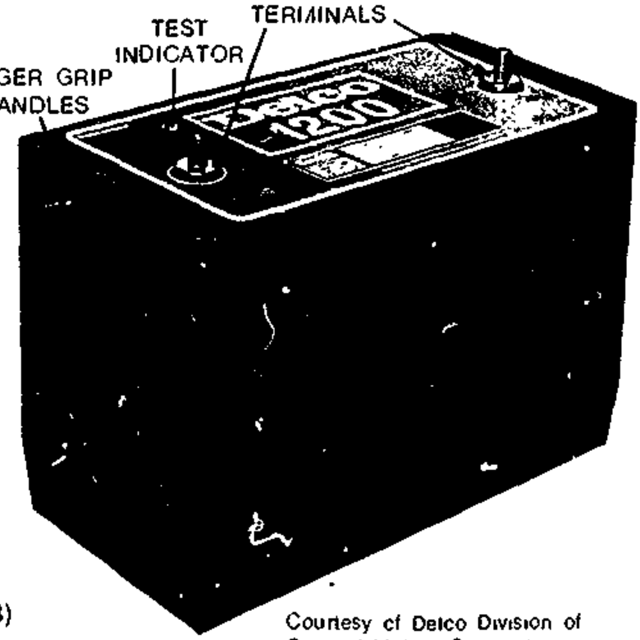
Sulfated Wet-Charged Batteries

Wet-charged batteries which are stored for long periods of time without recharging may be permanently damaged by the formation of hard dense lead sulfate crystals on the plates. To prevent these crystals from forming, wet-batteries in storage should be brought to full charge every 30 days.

Comparison Of Wet and Dry-Charged Batteries

In terms of storage, dry-charged batteries have a big advantage over wet-charged batteries because they require less maintenance. For this reason most parts supply places, have stocked the dry-charged batteries. It now appears, however, that maintenance-free batteries with their sealed-in electrolytes are going to replace the conventional batteries, and so parts suppliers won't have a choice. The maintenance-free batteries, will have to be maintained in storage like the conventional wet type.





(8-43)

Courtesy of Delco Division of General Motors Corporation

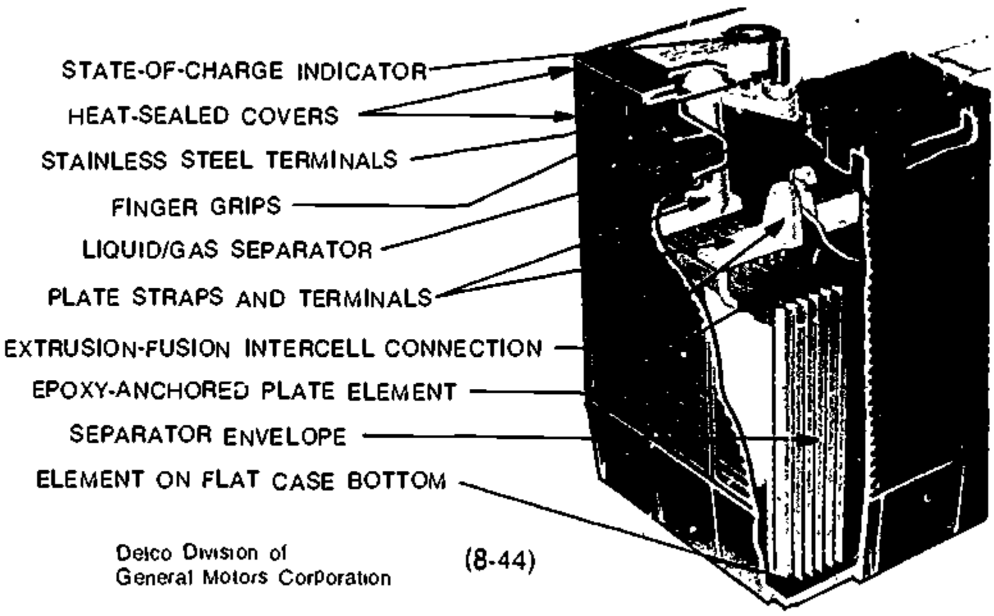
Maintenance-Free Batteries

In an effort to reduce battery maintenance, and to make batteries more dependable and last longer, the "maintenance-free" battery has been developed. Indications are that these new batteries will make the conventional battery obsolete. A maintenance-free battery is similar in shape to a conventional battery but it has no filler caps. The electrolyte is completely sealed in. Note the terminals on the two maintenance-free batteries in Figure 8-43: one has stainless steel threaded terminals and the other has sealed terminals located on the side of the battery.

Also note on these batteries the state of charge indicator. To date this indicator is found only on Delco batteries. The indicator is a built-in hydrometer having a small green ball that floats when the gravity of the electrolyte is 1.225 or higher. The indicator should not be used as a quick and easy way of telling if the battery is good or bad, charged or discharged. It must be read according to conditions set down by the manufacturer

Characteristics Of Maintenance-Free Batteries

1. Since the electrolyte is sealed in, the battery has a life time supply of it. Thus the battery level doesn't have to be checked and problems of over or underfilling the cells are eliminated.
2. Gases are produced during the discharge and charging process The gases rise to the top of the case, are trapped by the liquid gas separator, cool and condense, then drain back to the electrolyte reservoir. Internal pressure that may occur is released through a small vent hole, the flame arrestor vent, in the side of the cover.
3. Maintenance-free batteries have plate groups like conventional batteries, but the groups are constructed differently. Another difference is that the plates are enclosed in envelopes that act as the separators and also collect sediment as the plates crumble with age (Figure 8-44). The envelopes are bonded together and permit the element to be placed on the bottom of the case. In contrast, the element in a conventional battery is raised in the case to give room for sediment to collect and not touch the plates. Having the element rest on the bottom of the tank allows considerably more electrolyte to cover the plates and thus battery efficiency is improved



Delco Division of General Motors Corporation (8-44)

CAPACITY RATINGS OF BATTERIES

As was mentioned earlier, the factors influencing battery capacity, i.e., the amount of current a battery can produce, are the number, size and thickness of the plates and the quantity and strength of the electrolyte. New capacity ratings for batteries were adopted in 1971 by the Society of Automotive Engineers (SAE) and the Battery Council International.

Batteries are given two ratings:

— cold power rating

— reserve capacity

Cold Power Rating

Cold power rating gives the amount of power the battery has for starting on cold days; this rating is the number of amperes the battery at −18 C (0 F.) can deliver over 30 seconds and not fall below a voltage of 1.2 volts per cell, the minimum voltage required for dependable starting.

The cold power rating is the more important of the two ratings because it deals with the batteries main job, starting. Many low priced batteries can deliver only 200 amps; more powerful batteries will deliver 525 amps under the same conditions The cold power rating of the battery should match the power requirements of the engine it has to start If an engine under cold conditions required 400 amps to start, obviously the cheaper battery delivering only 200 amps would be inadequate.

Reserve Capacity

The reserve capacity rating gives the number of minutes a new fully charged battery will deliver 25 amperes at 27°C while maintaining a voltage of 1.75 volts per cell. Since 25 amps is the power drain required to keep ignition, lights and other electrical accessories going, what this rating indicates is how long the vehicle will operate if the generator or alternator fails. In other words, if the charging system of the machine breaks down, how many minutes do you have to seek help?

VARIATION IN BATTERY EFFICIENCY OR TERMINAL VOLTAGE

Battery voltage is not constant; a 12-volt battery does not deliver 12-volts at all times. Three main factors affect the terminal voltage of a battery:

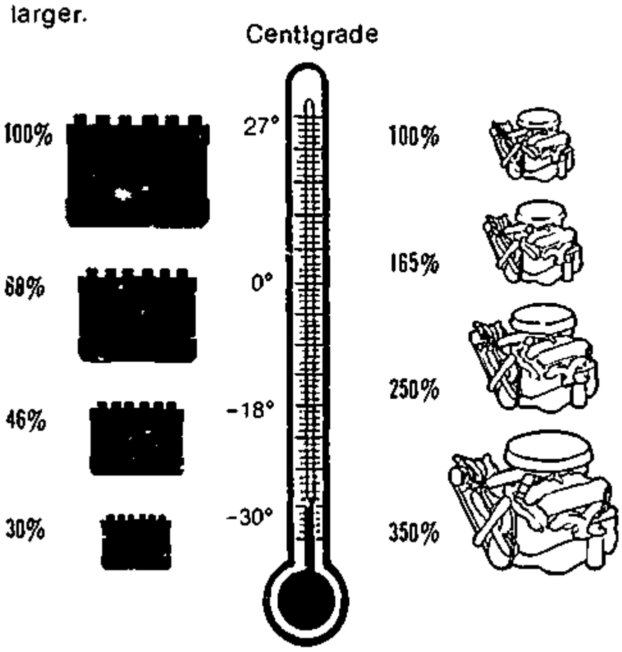
— temperature

— operating cycle (charging or discharging)

— state of charge

Temperature

A battery produces current by chemical reactions, by sulfuric acid acting on the positive and negative plates. At lower temperatures the chemicals don't react as fast and therefore the battery has a lower voltage. The effect of temperature on terminal voltage is illustrated in Figure 8-45. At 27 C a battery is 100% efficient; it has full cranking power. At −39 C a battery is only 30% efficient. Since the engine is harder to turn over in cold temperatures, the net effect of temperature on starting is that as it gets colder the battery becomes smaller while the engine becomes larger.



(8-45)

HOW COLD WEATHER AFFECTS THE BATTERY AND THE ENGINE WHEN STARTING

Courtesy of John Deere Ltd

Starting difficulties may occur during hot weather after a machine has been worked and the engine is hot Difficult hot starts are more common with large, high compression engines. An air conditioning unit is also a contributing factor. The point here is that you cannot use a lower capacity battery when a machine is working in a warm climate. The same size battery as the machine would have in a cold climate must be used.

Operating Cycle (Charging or Discharging)

When a battery is being charged, its terminal voltage increases, the amount of increase depends on the charging rate. Note that regulators are required on charging systems to control the voltage increase so that the battery is not overcharged. When a battery is discharging, its terminal voltage decreases, the amount of decrease depends on the discharging rate.

State of Charge

The higher a battery's state of charge (up to maximum charge), the greater is its terminal voltage.

POINTS ON BATTERY USE AND REPLACEMENT

1. When replacing batteries, be sure to replace the battery with one at least equal in capacity to the original.
2. A larger battery than the original may be needed if accessories such as an air conditioning unit are added to the vehicle's electrical circuit.
3. A high-output generator may be needed in cases where electrical loads are excessive or where a vehicle operates mostly at idle speeds. This high-output generator will help keep the battery charged and increase its service life.
4. The cheapest battery is not always the best buy. For example, three batteries in the same group size may vary in price, but they also vary in cold power rating, in construction and in warranty period. Divide the price by the months of warranty and you may find the most expensive batteries are really the cheapest per month of expected service.
5. A final word on replacing batteries: one out of every four batteries returned for warranty has nothing wrong with it except that it is discharged. Be sure to check whether a battery can be recharged before thinking about replacing it.

PREVENTIVE MAINTENANCE ON BATTERIES

Visual Inspection

A battery should be visually inspected during the daily-walk-around check, and also inspected at any time that scheduled maintenance is done on the battery. Points to look for are:

1. Inspect the battery case for cracks and leaks. A leaking battery should be replaced. Before putting in a new battery wash down the battery box with a solution of water and baking soda.

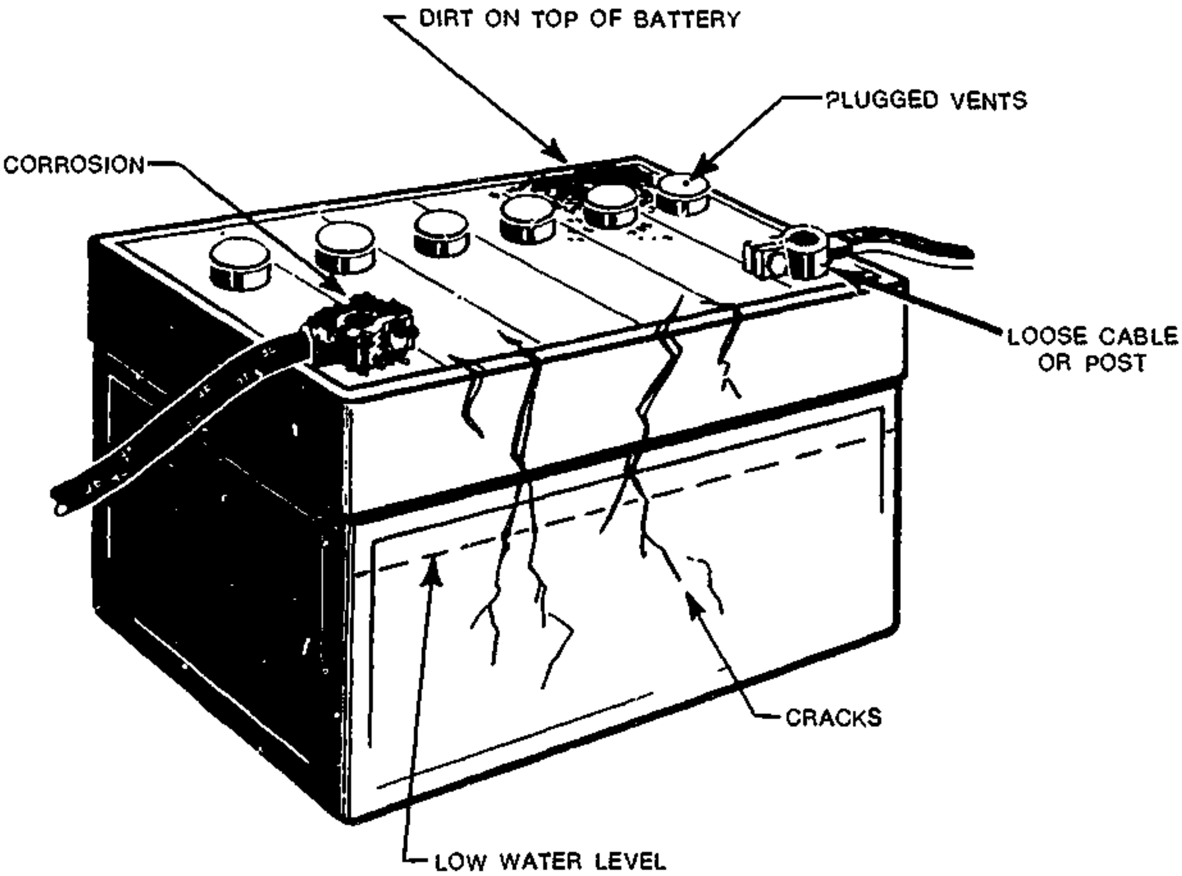
2 Inspect battery posts, clamps and cables for breakage, loose connections, corrosion.

3. Note whether the top of the battery is clean and dry. Dirt and electrolyte on top of the battery causes excessive self-discharge.

4. Nothing will damage a battery quicker than allowing it to jump around. Be sure the battery carrier is solidly mounted and in good condition and that the hold-down firmly grips the battery. Also look for any bolts protruding into the bottom of the battery box.

5. Inspect the battery for raised cell covers or a warped case, either of which may indicate the battery has been overheated or overcharged.

Any problems found during the battery inspection should be attended to immediately. If a battery case is damaged and leaks, the battery will have to be replaced. Before installing a new one, thoroughly wash the battery box with a solution of baking soda and water. This will neutralize any acid that has leaked from the battery. Similarly, corroded battery cables should be removed from the battery and washed in a baking soda solution. When reconnected they should be coated with an anti-corrosive agent such as a spray or a small amount of grease. Hold-downs that are loose or missing must be repaired. Also watch for bolts protruding in the bottom of the battery box. Placing a thin sheet of plywood under the battery is always a good idea.



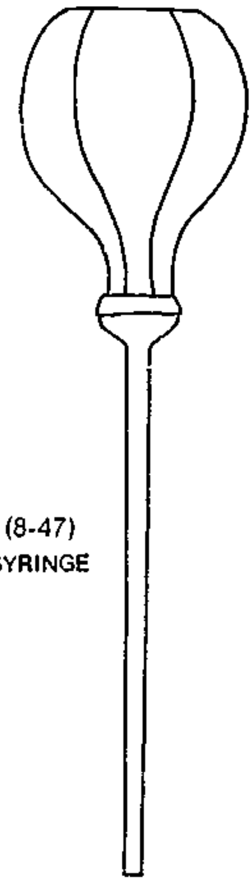
(8-46)

Checking and Adding Water

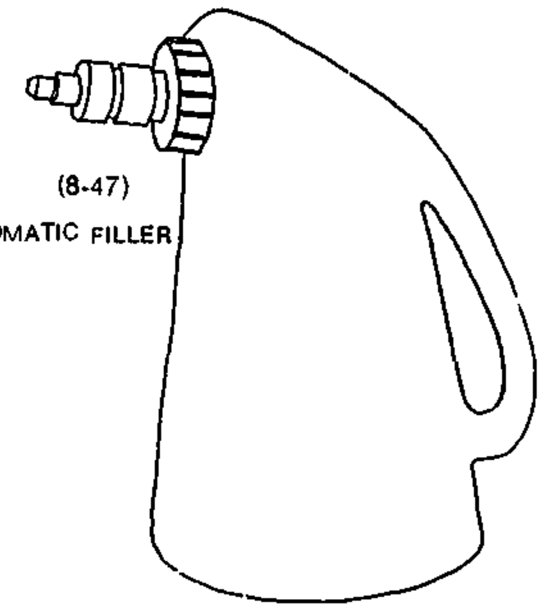
(This information will of course not apply to new maintenance-free batteries.)

Of the four chemicals in a conventional battery — lead, lead peroxide, sulphuric acid and water — water is the one that has to be replenished. The usual recommended interval for checking a battery is every 30 hours of operation or 1,000 miles. During warm weather, checks may be required more often. Evidence of large amounts of condensation on the top of the battery and low electrolyte level can indicate an overcharging condition. If this problem continues to occur, have the charging system checked.

Fill the battery with clean water, preferably distilled water. In any case, avoid using water that has a high mineral content as the mineral will ultimately shorten the life of the battery. Fill only to the bottom of the fill hole; any higher will cause unnecessary spillage. Avoid spilling water on the battery top and use a paper towel to dry the top when completed. Figure 8-47 shows two types of battery fillers.



(8-47)
SYRINGE

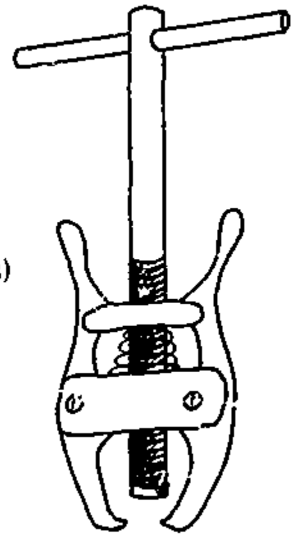


(8-47)
AUTOMATIC FILLER

Removing, Cleaning and Installing Batteries

When removing a battery or batteries, follow these recommendations:

1. If multiple batteries are used, make a diagram of the circuit so that you can correctly reconnect the batteries.
2. Disconnect the ground cable first, using a box wrench to loosen the terminal bolts. Use a terminal puller to remove the cables; do not hammer on the battery posts When installing the battery, connect the ground strap last. A terminal puller is shown in Figure 8-48.



(8-48)
TERMINAL PULLER

3. Remove the battery hold-downs and carefully lift the battery out. The metl od of lifting will depend on the location and size of the battery. For conventional batteries with lead posts, a carrying strap (Figure 8-49) is th; safest method.

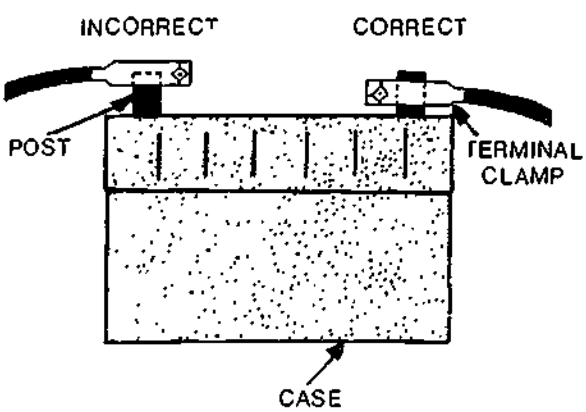
STRAP CARRIER
(8-49)

Whatever the method of lifting out the battery, be careful not to drop it because the case easily cracks. Try to keep the battery clear of your clothing since battery acid eats through cloth.

4. Clean the battery with a solution of water and baking soda, then dry it. Clean the terminals with a terminal brush or scrape them with a knife or screwdriver. Clean the cables in a similar fashion.

5. When installing the battery, use caution not to over tighten the hold-down as it could crack the case. It is a good practice to protect the bottom of the case with a thin piece of plywood.

6. Make sure that the cables sit down on the posts (Figure 8-50). Coat the cables with an anti-corrosive agent such as grease or vaseline. Anti-corrosive sorays are also available.



(8-50)

BATTERY QUESTIONS

1. The current a battery will produce depends upon chemical reactions within the battery between the sulphuric acid and both the sponge lead in the negative plate, and the:
   (a) lead sulphate in the positive plate
   (b) lead acid compound in the positive plate
   (c) lead peroxide in the positive plate
   (d) lead zinc in the positive plate
2. Basically what does the element in a battery cell consist of?
3. When does this battery element become a cell?
4. Each cell of a lead-acid battery is capable of producing approximately how much voltage?
   (a) 3 volts
   (b) 1 volt
   (c) 2.6 volts
   (d) 2 volts
5. True or False? The positive post of a battery is the larger of the two.
6. The electrolyte in a fully charged battery has a specific gravity at 80°F. of approximately:
   (a) 1.380
   (b) 1.160
   (c) 1.250
   (d) 1.270
7. True or False? When a battery becomes discharged the two plates become chemically similar thus accounting for the loss in cell voltage.
8. When a battery is discharged the electrolyte has an increased percentage of.
   (a) sulphur
   (b) sulphuric acid
   (c) water
   (d) hydrogen
9. Briefly state the advantage of a dry-charged battery over a wet-charged one.
10. Is a maintenance-free battery dry or wet-charged?
11. What provision is made within a maintenance-free battery to permit the elements to be placed on the bottom of the case?
12. What claims are made of maintenance-free batteries?
13. What three factors affect batteries' terminal voltage?
14. What are the two ratings given to batteries and briefly explain each.
15. True or False? At lower temperatures battery chemicals react faster and therefore the battery has higher voltage.
16. When selecting a battery, the cold power rating should match ____________ ____________.
17. The presence of dirt and electrolyte on top of the battery causes excessive ____________.
18. To neutralize spilled battery electrolyte (a necessary safety precaution) a mechanic should keep on hand a quantity of:
   (a) distilled water
   (b) baking soda
   (c) sulphuric acid
   (d) vaseline
19. Of the four essential chemicals in a lead-acid battery which one has to be replenished occasionally?
   (a) lead
   (b) lead peroxide
   (c) sulphuric acid
   (d) water
20. When removing a battery you should first:
   (a) disconnect the insulated terminal cable
   (b) loosen the battery hold-down
   (c) disconnect the grounded terminal cable
   (d) drain the electrolyte

21. A good practice to prevent corrosion and bad connections when reinstalling battery cables is to:

    (a) make sure they are clean and dry

    (b) make sure they are properly tightened

    (c) coat them with grease or vaseline

    (d) all of the above are necessary

BATTERY TESTING

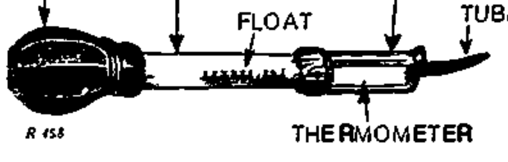
A battery must supply a flow of current and maintain a voltage Tests can be carried out that will tell if a battery is doing its job The tests for conventional batteries and the tests for maintenance-free batteries will be discussed separately. Four tests are used on conventional batteries:

1. Hydrometer — for specific gravity.
2. Load tester — capacity test.
3. Light load test — individual cell voltage.
4. Three minute fast charge test.

The state of the battery must be considered when deciding what test to use. Questions such as these would be asked: was water added before testing? Is the battery charge partially down or is it completely dead? Not all of these tests are required to fully test a battery. Usually two tests will give a fair indication of the battery's condition.

Hydrometer Test

A battery hydrometer (Figure 8-51) works on a principle similar to the antifreeze-testing hydrometer discussed earlier. Electrolyte is drawn into the hydrometer's sight glass and the float in the glass rises to a level of specific gravity. This level indicates the strength of the battery's charge. Good hydrometers have a thermometer built into them to give a temperature correcting factor. Battery hydrometers, it should be pointed out, will not be used on the new maintenance-free batteries because the electrolyte in these batteries is sealed in.



(8-51) HYDROMETER
Courtesy of John Deere Ltd

Hydrometers are the most common battery tester found in shops. Although a hydrometer can give a fairly good indication of a battery's condition, they are not foolproof. For example, a battery could have a poor internal connection between the cells making it unable to produce a high current flow. Yet when tested with a hydrometer the battery could give a good specific gravity reading. Hydrometer readings on old batteries can also be deceptive. The old battery could maintain an even specific gravity reading, say 1.235, but it may not be able to produce an adequate amount of current.

Below are the procedures for making a specific gravity reading on a battery with a hydrometer.

Caution: Always have a paper towel handy to hold over the end of the hydrometer when it is lifted from the cell. A paper towel is better than a rag because the towel will be discarded whereas the rag is likely to be left around or put into an overall pocket and the acid will quickly eat the cloth. Be very careful not to spatter acid on your skin or worse still to get it in your eyes. If acid contacts the skin, rinse the contacted area with running water for 10 to 15 minutes. If acid splashes into the eyes, force the lids open and flood the eyes with running water for 10 to 15 minutes. Then see a doctor at once. Don't use any medication or eye drops unless prescribed by a doctor.

Specific Gravity Test: 6 and 12 Volt Batteries

Note: If water has been recently added to a battery, a hydrometer will not give an accurate reading of the battery's state of charge.

1. Using a hydrometer, remove enough electrolyte from one cell to allow the float to move freely without touching the top or bottom. Hold the hydrometer vertically to prevent the float from touching the sides of the barrel.
2. With your eye level with the float take the float reading and record it.
3. Note the electrolyte temperature:

   If the battery temperature is not at 27°C, add 4 points (.004) soecific gravtiy to the float reading for each 5° above 27°C, or subtract 4 points (.004) specific gravity from the float reading for each 5° below 27°. Most good hydrometers have a temperature corrected scale.

4 Repeat the above test on all remaining cells.

5. Note the amount of variation in the cell's specific gravities.

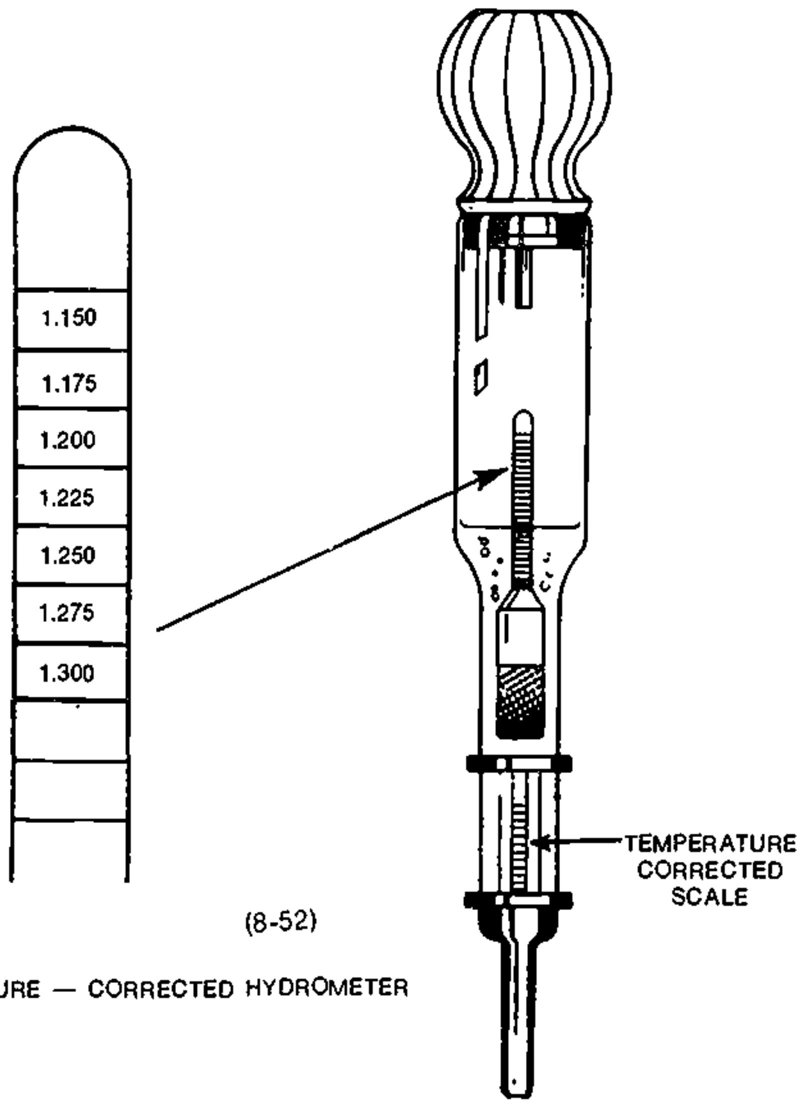
Unless otherwise specified, all cell readings should be within 30 points (.030). If cell variation exceeds this amount, an unsatisfactory condition is indicated. Further tests should be performed.

6. Determine the battery's state of charge by locating its specific gravity on the Percentage of Charge Table below.

Percentage of Charge Table

Fully charged specific gravity varies in different types of batteries. Typical values are given below:

State of Charge	Standard Specific Gravity as Used in Temperate Climates	Specific Gravity in Cells Built with Extra Water Capacity	Specific Gravity as Used in Tropical Climates
Fully charged	1.280	1.260	1.225
75% charged	1.250	1.230	1.195
50% charged	1.220	1.200	1.165
25% charged	1.190	1.170	1.135
Discharged	1.130	1.110	1.075

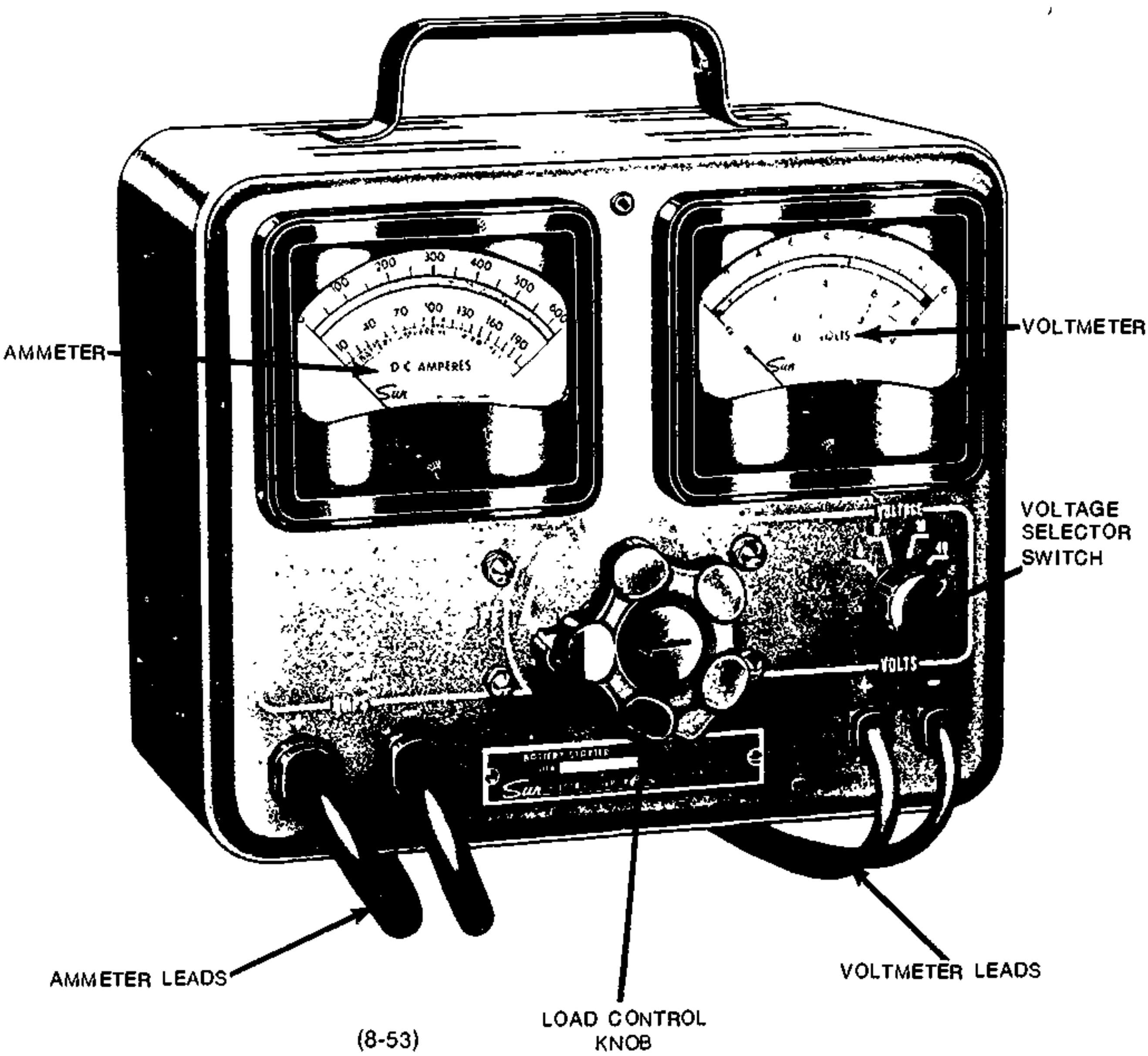


(8-52)

TEMPERATURE — CORRECTED HYDROMETER

Load Tester

A load tester gives the truest picture of a battery's condition. If the specific gravity is 1.225 or better, a load test (capacity test) can be done on the battery. If, however, the specific gravity is less than 1.225, then a light load test (a test of the individual cells) will have to be used. Also, if water had to be added to the cells at the time of testing, use the light load test since you can't take the specific gravity and know that it is 1.225 or better. Figure 8-53 shows a typical battery load tester or battery starter tester



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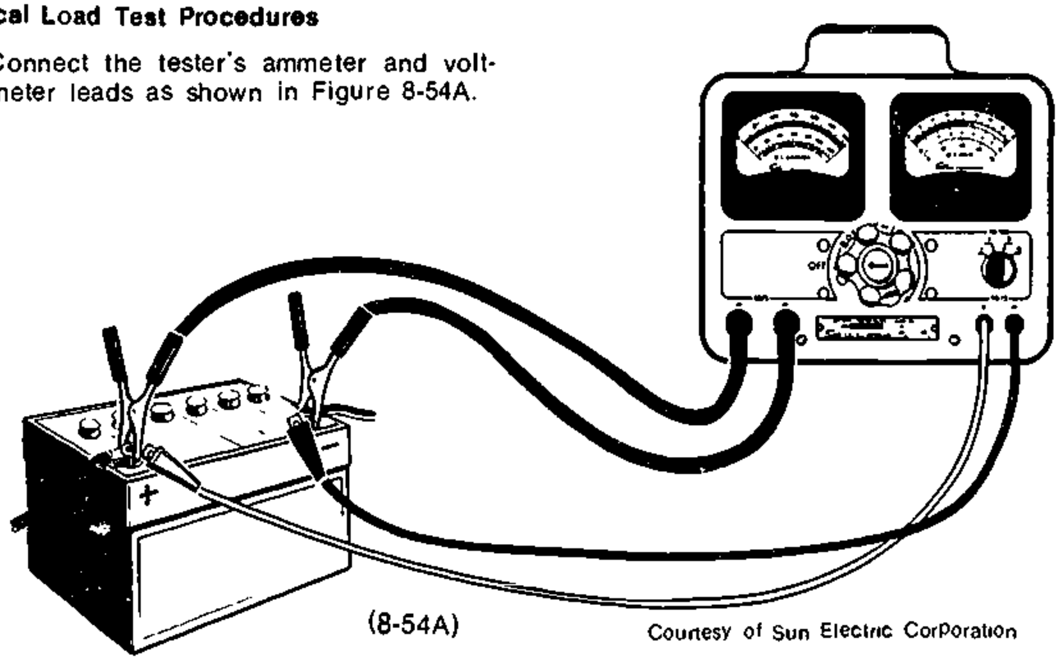
Courtesy of Sun Electric Corporation

Typical Load Test Procedures

1. Connect the tester's ammeter and voltmeter leads as shown in Figure 8-54A.



(8-54A) Courtesy of Sun Electric Corporation

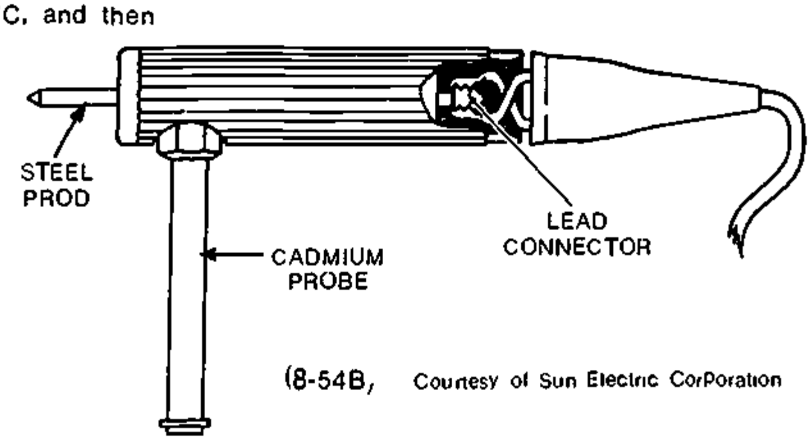
2. Turn Control Knob clockwise until the Ammeter reading is exactly three times the Ampere Hour Rating of the battery. (Example: 180 Amperes for a 60 AH battery.)
3. Maintain the load for 15 seconds, note the voltmeter reading, and then turn the Control Knob back to OFF position.

   If the voltmeter reading was within the green band, 9.6 volts for a 12 volt battery, or 4.8 volts for a 6 volt battery, or was higher, the battery has good output capacity. Although the battery may pass the load test it may still require some charging to bring it up to peak performance.

   Note: When cold, a battery has a lower discharge capacity. If a cold battery fails to pass the capacity test, let it stand until the battery temperature reaches 27°C, and then retest it.

Light Load Or Individual Cell Voltage Test

A light load test is used rather than a load test if the specific gravity of the electrolyte is less than 1.225. This test is done with what are called battery cell probes which are attached to the load tester voltmeter leads (Figure 8-54B) with the voltmeter set on the 4 volt scale, the voltage of each cell is tested and if a variance of more than .1 volt between individual cells is found, the battery should be replaced. See the load tester instruction manual for light load testing procedures.



(8-54B) Courtesy of Sun Electric Corporation

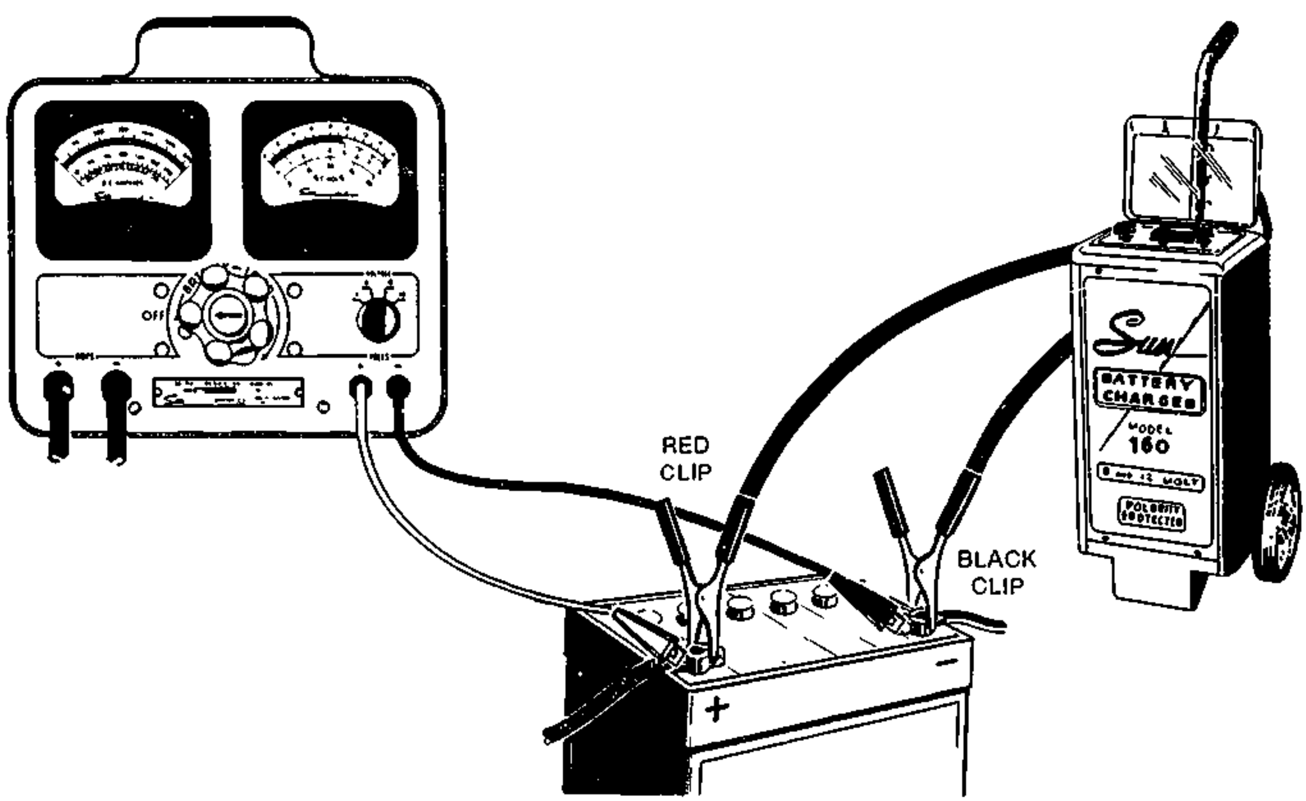
Three Minute Fast Charge Test

The three minute fast charge test is done on a very low or dead battery (one that has failed the load test) and indicates whether the battery will accept a charge. The three minute test can be done with equipment found in most shops today — a fast charger and an accurate voltmeter.

Note that performing the three minute test on a battery that has nearly a full charge will give an inaccurate reading. Below are a voltmeter and a charger connected to a battery for a three minute fast charge test.

Typical Procedures For A Three Minute Fast Charge

1. Connect the voltmeter and the charger as shown below.
2. Adjust the charging switch to obtain a charge rate as close as possible to 40 amps. for a 12 volt battery, or 75 amps. for a 6 volt battery.
3. After three minutes, while the charger is still operating on fast charge, observe the voltmeter reading. If the reading is beyond the green band or exceeds 15.5 volts on a 12 volt battery of 7.75 volts on a 6 volt battery, the battery is sulphated or worn-out and should be replaced.



(8-55) Courtesy of Sun Electric Corporation

SUMMARY OF TESTING CONVENTIONAL BATTERIES

1. Take the specific gravity reading and note the result. No more than .030 points between cells is acceptable.

2. If 1.225 or better, do a Capacity or Load test. At the end of 15 seconds, the voltage should not be less than 9.6 volts for a 12 volt battery or 4.8 volts for a 6 volt battery.

   If the battery passes these two tests, it is considered to be satisfactory for service. If a battery fails the load test, do a three minute fast charge on it to see if it will take a charge

3. If the specific gravity is less than 1.225 and there is not more than .030 volts between cells, perform a light load test. If there is a variation of more than .1 volts between cells, the battery is defective.

4. If the electrolyte is too low for a reading and water is added to the cells, perform a light load test.

5. If the battery is really low or dead, perform a three minute fast charge test on it. If the voltage does not exceed the maximum limit (see fast charge instruction manual), do a light load test to finalize the diagnosis. If the voltage exceeds the maximum limit in three minutes, it usually indicates that the battery is sulphated or old.

TESTING MAINTENANCE-FREE BATTERIES

Since the electrolyte is sealed into maintenance-free batteries, obviously a specific gravity test or a light load test can't be used. A load test, therefore, is the test used on maintenance-free batteries. Below are testing procedures recommended by Delco for their maintenance-free batteries.

Step 1: Test Indicator (Figure 8-56)

1. **Green Dot Visible**

   Proceed to Step 3. **Note:** On rare occasions, after prolonged cranking, the green dot may still be visible. Should this occur, charge battery as described in "Battery Charging Procedures" section, then proceed to Step 2.

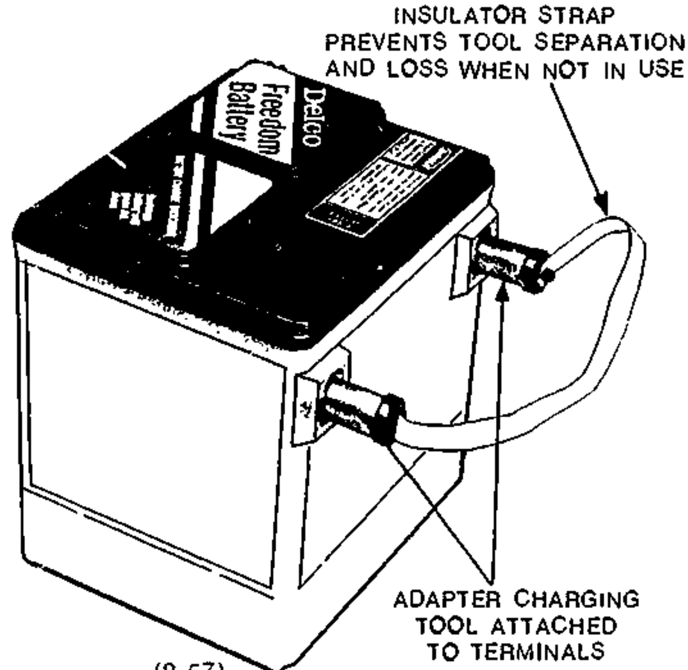
2. **Dark — Green Dot Not Visible**

   Charge the battery as outlined under "Battery Charging Procedures" section and proceed to Step 2.

On rare occasions, the test indicator may turn light yellow. In this instance the battery should not be tested. Replace the battery.

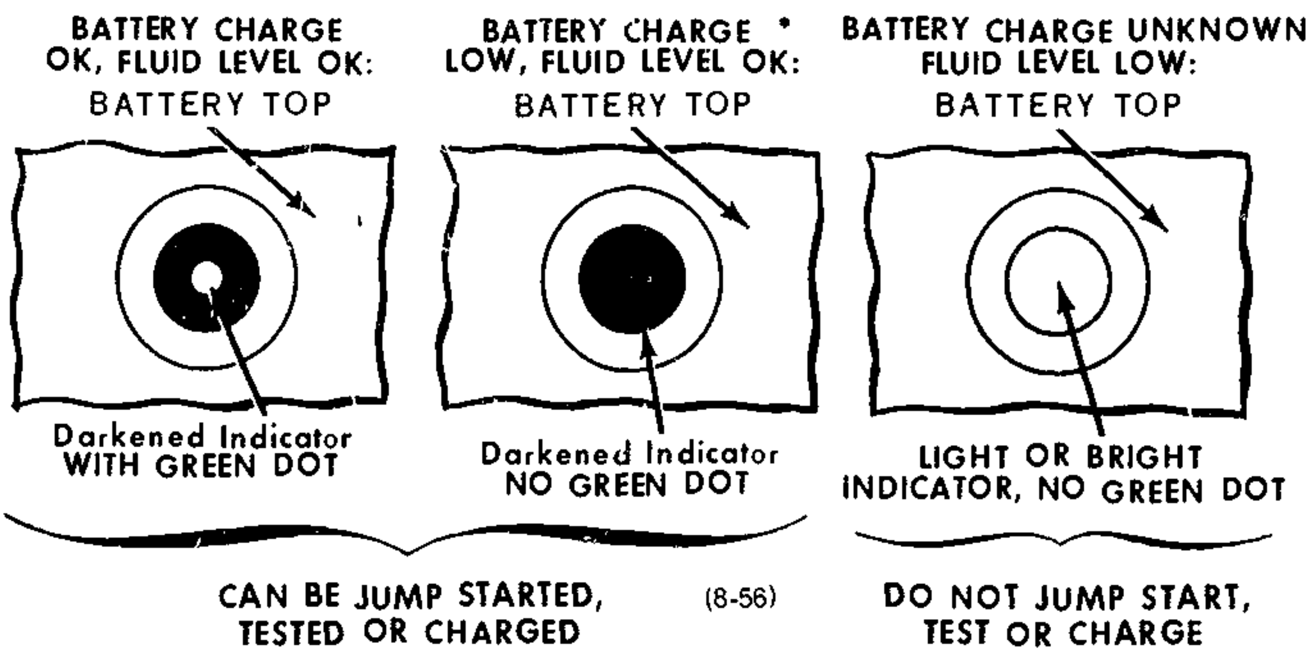
Step 2: Remove Surface Charge

Connect 300-ampere load across terminals for 15 seconds to remove surface charge from the battery. If maintenance-free battery is in vehicle, connect to terminals. If out of vehicle, attach load clamps to adapter charging tool as shown (Figure 8-57). For Delco 1200, remove cables, attach load alligator clamps to contact lead pad as shown (Figure 8-58).



(8-57)

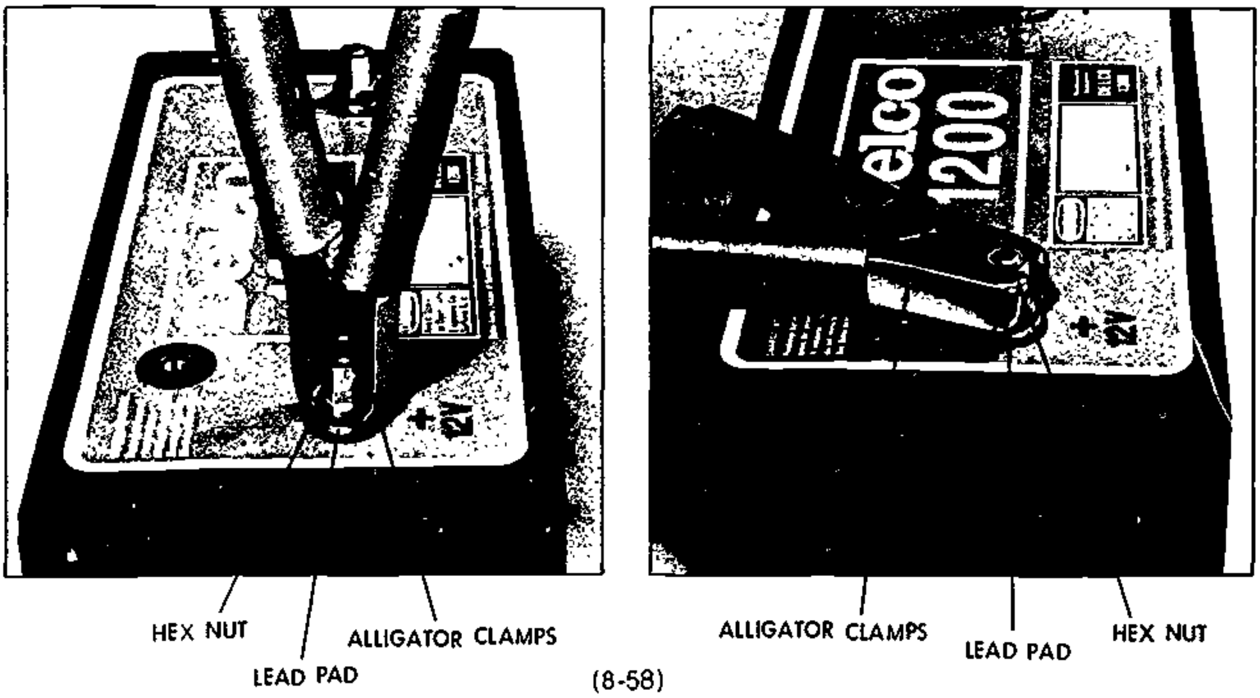
Courtesy of Delco Division of General Motors Corporation



(8-56)

*CHARGE MAY STILL BE SUFFICIENT TO START VEHICLE

Courtesy of Delco Division of General Motors Corporation



(8-58)

ALLIGATOR CLAMPS CONTACTING LEAD PAD FOR TESTING AND CHARGING DELCO 1200 BATTERY

Courtesy of Delco Division of
General Motors Corporation

Step 3: Load Test

1 Connect voltmeter and specified load across terminals.

MODEL	LOAD*	MODEL	LOAD*
49-5	210 Amperes	85-4	130 Amperes
55-5	180 Amperes	85-5	170 Amperes
59-5	210 Amperes	87-5	210 Amperes
71-5	230 Amperes	89-5	230 Amperes
81-5	230 Amperes	1200	235 Amperes

* See "Charging and Testing Adapters" section

2. Read voltage after 15 seconds with load connected, then disconnect load.
3. If minimum voltage is 9.6** or more, battery is good.
4. If minimum voltage is less than 9.3**, replace battery.

** This voltage is to be used for battery ambient temperatures of 70 F and above For temperatures below 70 F, use the following:

	(21 C) 70 F & Above	(16 C) 60 F	(10 C) 50 F	4 C) 40 F	(−1 C) 30 F	(−7 C) 20 F	(−12 C) 10 F	(−18 C) 0 F
Minimum Voltage	9.6	9.5	9.4	9.3	9.1	8.9	8.7	8.5

QUESTIONS — BATTERY TESTING

1. The chemical energy within a battery can be determined by the use of:

   (a) a hydrometer

   (b) a voltmeter

   (c) an ammeter

   (d) an ohmmeter

2. When testing the specific gravity of a battery, the allowable variation between cells should not exceed:

   (a) .060

   (b) .010

   (c) .300

   (d) .030

3. A typical load or capacity test of a 12-volt battery requires that 180 ampere load be applied for 15 seconds and that the voltage must not fall below:

   (a) 6.9 volts

   (b) 9.6 volts

   (c) 11.1 volts

   (d) 8.6 volts

4. When doing a light load or individual cell voltage test, the allowable voltage difference between cells should not exceed:

   (a) 1 volt

   (b) .5 volts

   (c) .01 volt

   (d) .25 volts

5. True or False? A three minute fast charge must only be done on a low or dead battery and tells whether or not the battery will accept a charge.

6. What is the recommended test for maintenance-free batteries?

CHARGING BATTERIES

While an engine is running, the battery is charged by the generator. Eventually, however, the battery charge wears down and if not attended to it won't have enough power to start the engine. When a battery's state of charge is low, it should be recharged. The recharging can be done while the battery is in the vehicle or it can be taken out.

There are a number of different battery chargers, but they can be classified under two general types:

Constant Current Chargers

A constant current charger does just what its name implies, supplies a constant or set amount of current to the battery. The recommended charging rate is 1 amp per positive battery plate per cell; e.g., if a battery has five positive plates per cell, it should be charged at 5 amps. Most batteries that are slow charged with a constant current charger will take five to six amps

Constant Voltage Chargers

A constant voltage charger supplies the battery with a constant voltage during the charging period, for example, 15 volts for a 12-volt battery. This charger will charge the battery at a fairly high amperage when the battery is low, and then as the battery builds up charge the amperage tapers off, almost to nothing as the battery becomes fully charged

Constant current are much more common than constant voltage chargers.

Chargers can be either (1) slow chargers, (2) fast charger or (3) trickle chargers, or they can be a combination of these.

Slow chargers are used to completely recharge a dead battery: they can take up to 48 hours. **Fast chargers** are used for a quick boost (from 1/4 hour to 1 hour) and won t do as complete a job as slow chargers. Some chargers have the dual capacity to provide either a fast or slow charge.

Trickle chargers are used to keep a battery up to full charge, they are especially good for batteries that are little used or for wet charged batteries being stored

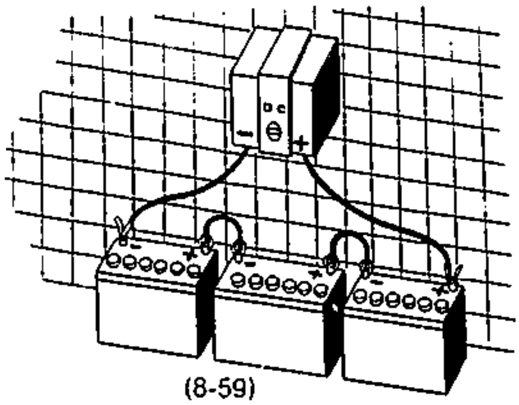
CHARGING CONVENTIONAL BATTERIES

Time is usually the main factor when deciding whether to fast charge or slow charge a battery. Obviously, it's better to slow charge a battery because you get a more thorough charging job (fast charging takes place only on the surface of the plates). However, you don't always have the time (24 to 48 hours) to do a slow charge, and in such cases fast charges have to be done.

Slow Chargers

Constant Current Chargers

A slow charger can be either constant current or constant voltage (constant current, however, is most common). The constant current charger in Figure 8-59 is charging three 12-volt batteries connected in series.



(8-59)
CONSTANT CURRENT SLOW CHARGER
Courtesy of John Deere Ltd

Chargers have printed on them the maximum number of batteries that they can charge, e.g., five 12-volt batteries (total 60 volts) and ten 6-volt batteries (total 60 volts).

The example shown would have the voltage control set at 36 volts (3 × 12), and the charge rate control set at approximately one amp per positive plate per cell, usually five to six amps. When there are a number of batteries of different sizes on the charger, average out the charge rate. On some of the new chargers, you don't have to bother counting or averaging out the positive plates. These chargers have a yellow, green and red band on the charge rate indicator and recommend the control be set to stay in the green range.

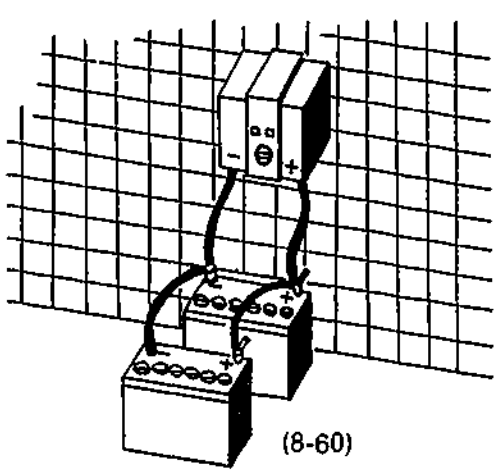
To connect a constant current charger start with the black lead (negative) from the charger and connect it to the negative post of the first battery Then take the red positive lead from the charger and connect it to the positive post of the last battery. Now using good jumpers. connect the batteries. positive to negative to complete the series circuit.

Recheck all the connections by turning the connectors slightly on the posts. Finally turn the charger on and adjust it to the correct charge rate.

The state of charge of a battery being charged should be checked with a hydrometer twice a day if possible. The total charging time wil. vary depending on the strength of the charge to begin with, but at the end of 48 hours batteries should be fully charged If a battery becomes fully charged (i e . its specific gravity is 1.275 or over) before 48 hours is up. remove it.

Constant Potential (Voltage) Chargers

Constant potential chargers are connected to batteries in parallel as shown in Figure 8-60. The maximum number of batteries a charger can handle will be marked on the charger.



(8-60)

Courtesy of John Deere Ltd

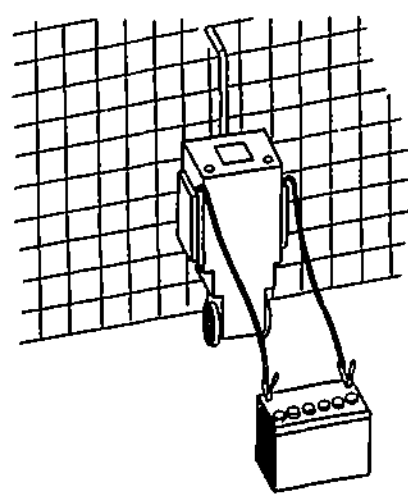
The voltage control is set at a specified voltage. e.g., 15 volts for a 12-volt battery. The charge rate is automatically sensed by the charger; the rate will be high when the discharged battery is first connected to the charger and will gradually taper off as the battery becomes fully charged.

When connecting up batteries in parallel to a constant voltage charger. start with the black lead (negative) and connect it to the negative (−) post of the first battery. Then take the red lead (positive) from the charger and connect it to the positive (+) post of the first battery. Now using good jumper cables connect up the battery's negative to negative and positive to positive.

As with a constant current charger. check the specific gravities of the charging batteries twice a day and remove the batteries when they are fully charged.

Fast Chargers

Fast chargers will give a battery a high charge rate for a short period of time. usually no more than an hour. They are portable (Figure 8-61) in contrast to slow chargers that are usually mounted on a wall or sit in the same position on a bench. Portable fast-chargers can charge a battery while it is in the vehicle. Generally. only one battery at a time is charged on a fast charger. Note that many modern fast chargers have a capacity to slow charge a battery as well.



(8-61)

Courtesy of John Deere Ltd

POINTS TO WATCH FOR WHEN FAST CHARGING

1. Whenever a battery is charged, especially fast charged, never allow the electrolyte to exceed 51 C (125 F). Overheating, in effect overcharging, can drastically shorten the life of a battery. The temperature on conventional batteries can be taken with the hydrometer thermometer. The rubber case of maintenance-free batteries will be hot to the touch when the electrolyte reaches 51 C.
2. Watch the color of the electrolyte when fast charging batteries. As a battery ages the electrolyte will become discolored by sediment. During a fast charge the sediment is stirred up and could get trapped between the plates, causing a short. If such a short occurs lower the charge rate.

SUMMARY OF GOOD PRACTICES WHEN CHARGING BATTERIES

1. Before connecting conventional batteries to a charger make sure:
   (a) the battery tops are clean
   (b) the electrolyte is up to the correct level
   (c) the caps are loosened or removed to allow the gases formed during charging to escape.
2. All chargers, slow or fast, need 110 volts alternating current supply.
3. Always make sure a charger is turned off when connecting it to a battery. Also when charging a battery while it is in the vehicle, turn off all electrical accessories.
4. Disconnect the battery cable before fast charging the battery in the machine. This is especially important with AC charging systems where the alternator can be damaged.
5. When connecting any charger, observe the correct polarity — negative to negative and positive to positive. Most chargers today are polarity protected.
6. Make sure connections are solid before turning on the charger.
7. Charger settings:

   Voltages:
   (a) on a constant slow charger set the voltage to match the number of volts in the batteries you are charging.
   (b) on a constant potential charger set the voltage for a 12-volt or 6-volt battery(ies).
   (c) on a fast charger set the voltage for a 12-volt or 6-volt battery.

   Amperage:
   (a) on constant current slow charger set amperage to one amp per positive plate per cell (usually five to six amps); or if the charger has a color indicator set it in the green band.
   (b) on a constant potential charger there is no current setting.
   (c) on a fast charger set the amperage to either a high or low setting.
8. Charging Time:
   (a) When slow charging a battery do a specific gravity check twice a day to see if the battery is fully charged. Do not go on charging a fully charged battery.
   (b) Set the fast charge time 1/4 hour to 1 hour. Watch that the battery does not overheat.
9. Always turn the charger off before disconnecting it to prevent any sparks from accidentally igniting explosive hydrogen gases given off during charging.

(8-62) —Sparks or flames near a battery that is being charged may ignite explosive gases causing a dangerous explosion.

Courtesy of Delco Division of General Motors Corporation

10. Never charge a battery in a place where there maybe any chance of sparks. e.g.. in any area where welding or grinding is done (Figure 8-62).

11. Check with the hydrometer thermometer to see that the electrolyte does not exceed 51°C. On maintenance-free batteries touch the battery case to see that it is not hot.

12. Recheck the electrolyte level on completion of the charge.

CHARGING MAINTENANCE-FREE BATTERIES

Maintenance-free batteries are charged with conventional battery charging equipment. One manufacturer's recommendations for charging their maintenance-free batteries are given in Figure 8-63. Note the difference in charging times compared with conventional batteries the slow charging rate for maintenance-free batteries is less than that for conventional batteries, and vice versa the fast charging rate is longer.

12 VOLT MAINTENANCE-FREE BATTERY CHARGING GUIDE (Delco)

DO NOT CHARGE A BATTERY IF THE GREEN DOT IS VISIBLE

NOTE On rare occasions following prolonged cranking, the green dot may still be visible Should this occur, a boo charge of 20 ampere-hours is recommended

DO NOT CHARGE A BATTERY IF THE TEST INDICATOR IS LIGHT YELLOW. DISREGARD IT

(Stop charging when the green dot appears or when the maximum charge shown below is reached)

Battery Model	Constant Current Slow Charging Rate	Fast Charging Rate
55-5, 85-4, 85-5	5A @ 10 Hours	20A @ 2½ Hours
	10A @ 5 Hours	30A @ 1¾ Hours
49-5; 59-5	5A @ 15 Hours	20A @ 3¾ Hours
71-5, 81-5	10A @ 7½ Hours	30A @ 2½ Hours
87-5, 89-5; 1200		40A @ 2 Hours
		50A @ 1½ Hours

To avoid DAMAGE, the charging rate must be reduced or temporarily halted if

1 The battery case feels hot (51 C).

2 Violent gassing or spewing of electrolyte occurs.

After charging in accordance with the tables, even though the green dot does not appear, the battery is still sufficiently charged for testing.

(8-63) Courtesy of Delco Division of General Motors Corporation

JUMPER CABLES

When a charger is not available, a common practice to start a vehicle with a dead battery is to use jumper cables and a battery pack.

Good Practices When Jumping

1 Before connecting jumper cables be sure all the electrical accessories, lights, radio, wipers, etc. are off.

2. Observe voltage when jumping. Jump a 6-volt battery with a 6-volt battery, not a 12-volt as arcing (electricity jumping across a gap) could occur, bringing with it the danger of fire.

3. Observe polarity when jumping. Connect the jumper cables negative to negative and positive to positive (since you are just replacing the existing power source). Connect the cables in this order:

   (a) connect one cable clamp to the positive terminal of the dead battery and then connect the other end to the positive terminal of the booster battery.

   (b) connect the second clamp to the negative terminal of the dead battery and then connect the other end to the negative terminal of the booster battery. Wrong polarity will cause arcing.

4. When removing the cables be sure to keep the clamps separated until they are disconnected from the source. If they get too close arcing could occur

5. Never use a fast charger as a booster to start an engine.

6 Maintenance-free batteries have jumping procedures that can differ from jumping a conventional battery. Check the manufacturer's recommendations.

7. Use the shortest cables possible because the longer the cables the more the voltage drops.

8. Maintain good clamps on the jumpers to ensure the best possible connection with a minimum voltage drop.

QUESTIONS — BATTERY CHARGING

1 The recommended slow charging rate for a battery is one amp per positive plate per cell If you have a 15 plate 6-volt battery, i.e., 15 plates per cell, what would be the correct charge rate?

(a) 15 amps

(b) 7 amps

(c) 8 amps

(d) 45 amps

2 Which does a better job of charging a battery, a fast charger or a slow charger? Briefly explain why

3 Wt. slow charging batteries on a constant current charger connect the batteries in

(a) parallel

(b) series

(c) series or parallel

4 What are the two important things to watch for when fast charging a battery?

5 Care must be taken while working near batteries that are charging because a spark could explode the ________ gases being given off from the charging process

(a) nitrogen

(b) hydrogen

(c) carbon dioxide

(d) helium

6 True or False? Overcharging a battery doesn't hurt it.

7 When fast charging a battery in a vehicle with an AC charging system, it is a good practice to

(a) remove the fan belt

(b) keep the charge rate low

(c) disconnect a battery cable

(d) disconnect the voltage regulator

8 Compared to a conventional battery, a maintenance-free battery when fast charged requires·

(a) a longer charge

(b) a shorter charge

(c) about the same

(d) a very low charge

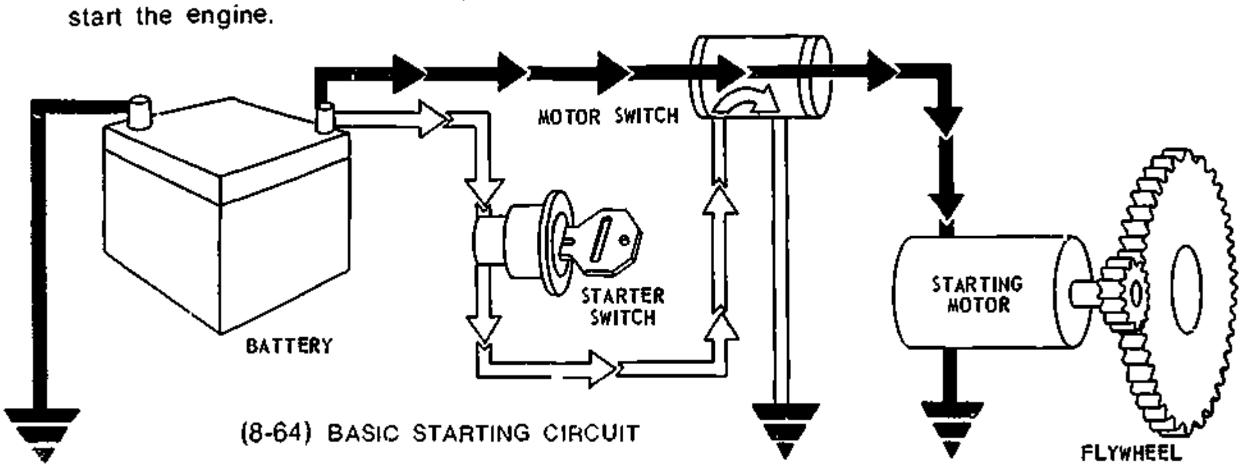
9 A charger should be turned ________ before connecting it to a battery.

10. True or False? When boosting with jumper cables doubling the voltage of the boosted battery is permissible provided that the polarity is the same and the cables are quickly removed after the boost is given.

BASIC STARTING CIRCUIT

A basic starting circuit has four parts (Figure 8-64):

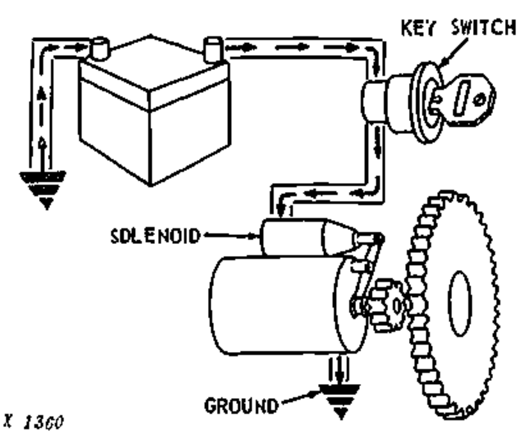
1. The **Battery** supplies energy for the circuit.
2. The **Starter Switch** activates the circuit.
3. The **Starting Motor Switch** connects the battery to the starter motor and in some cases engages the motor drive with the engine flywheel.
4. The **Starting Motor** drives the flywheel to start the engine.



(8-64) BASIC STARTING CIRCUIT

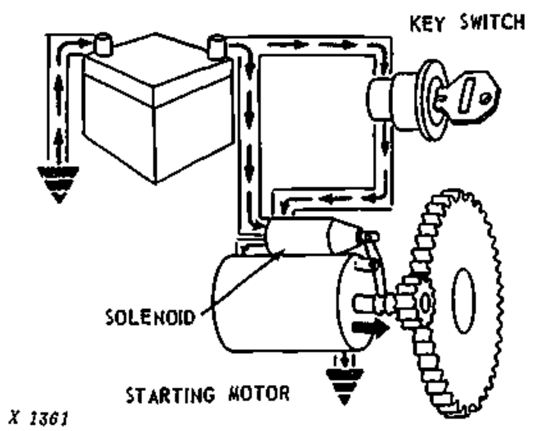
Courtesy of John Deere Ltd

The starting circuit converts battery electrical energy into starting motor mechanical energy to crank the engine. How do the four basic parts of the starting circuit work together to start a vehicle? When the starter key is turned on by the operator, a small amount of electrical energy flows from the battery to the solenoid and back to the battery through the ground circuit (Figure 8-65)



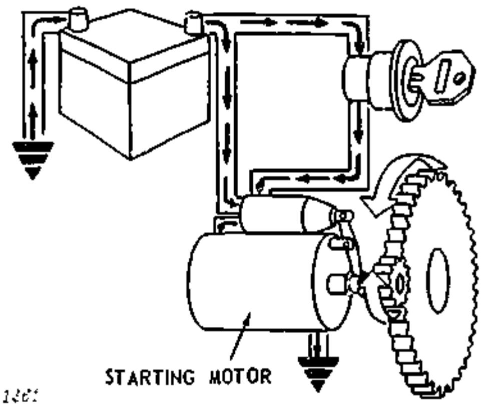
(8-65) Courtesy of John Deere Ltd

The current received by the solenoid moves the solenoid plunger and engages the pinion with the flywheel (Figure 8-66)



(8-66) Courtesy of John Deere Ltd

The plunger also closes the switch inside the solenoid between the battery and starting motor completing the circuit and allowing a large amount of electrical energy to flow into the starting motor The starting motor rotates the pinion which in turn rotates the flywheel to crank the engine (Figure 8-67).



(8-67) STARTING CIRCUIT IN OPERATION
3) STARTING MOTOR CRANKS ENGINE
Courtesy of John Deere Ltd

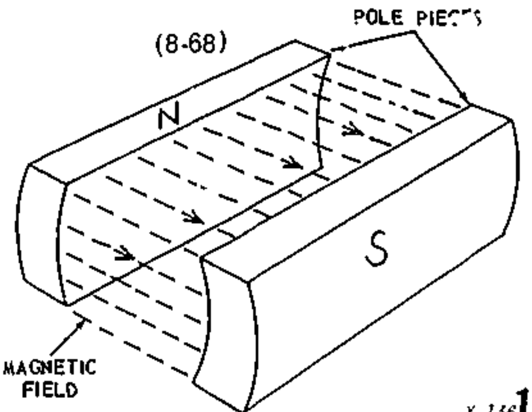
In the basic starting circuit above a solenoid switch was used. There are other types of starting motor switches which will be discussed later.

THE STARTING MOTOR

The starting motor cranks the engine. Performing this heavy job requires a special type of electrical motor that must:

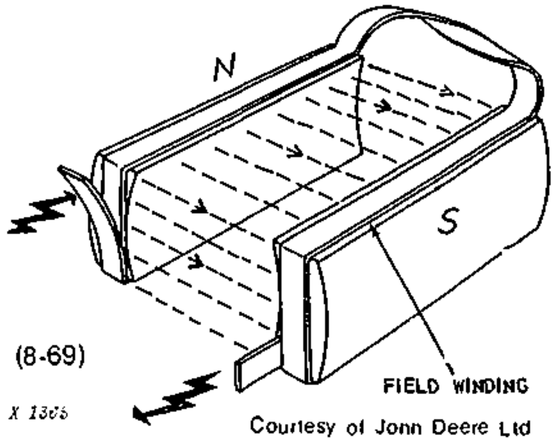
1. Operate for short intervals under great overload.
2. Produce very high horsepower for its size.

To give the principles of a starting motor a basic electric motor is constructed below: First start with two pole pieces. The poles set up a magnetic field between them running in a direction from north to south (Figure 8-68).



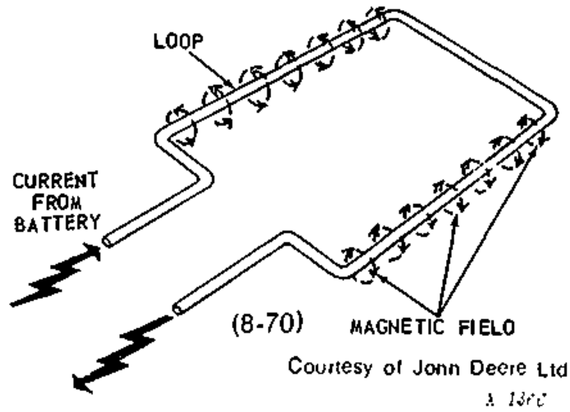
Courtesy of John Deere Ltd

To increase the strength of the magnetic field between the pole pieces, wrap a wire over the poles and pass a current through it. This wire is called a field winding (Figure 8-69).



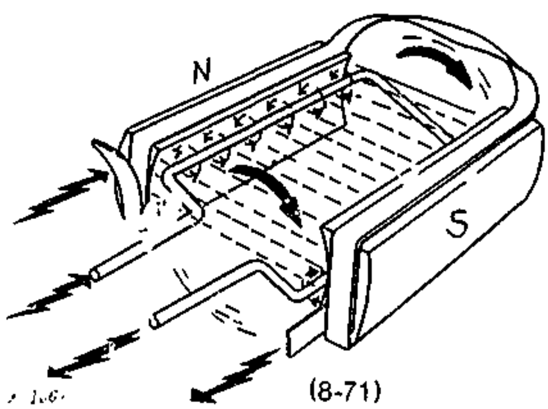
Courtesy of John Deere Ltd

Now take a loop of wire and pass a current through it A circular magnetic field is formed around the wire. Note the direction of the electromagnetic field (Figure 8-70).



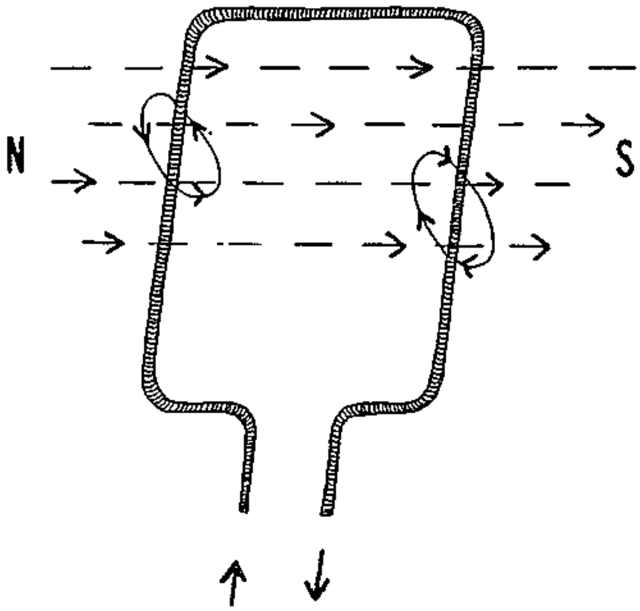
Courtesy of John Deere Ltd

Place the loop of wire in the magnetic field between the pole pieces and pass a current through the wire (Figure 8-71).



Courtesy of John Deere Ltd

Recall from the earlier discussion on electromagneticism the principle that a current carrying wire with its surrounding magnetic field has a tendency to move from a strong to a weak magnetic field Look at the field patterns when the loop cuts through the magnetic field (Figure 8-72)



(8-72) DIRECTION OF CURRENT

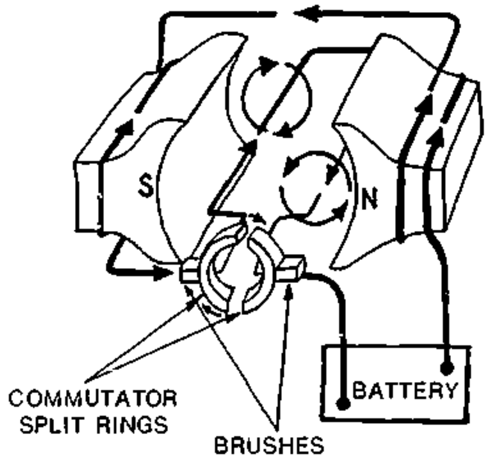
Lefthand side of loop: The lines of force of the loop run in a circular pattern, counterclockwise The polar lines of force run in a straight-line from north to south On the underside of the loop, the loop lines of force run the same way as the polar lines of force creating a strong combined force However, on the top side of the loop, the loop lines of force run counter to or against the polar lines of force, cancelling each other out and creating a weak field

Now applying the principle that the wire will move from a strong to a weak field, the loop is pushed upwards

Righthand side of loop: The opposite of the lefthand side occurs By looking at the lines of force you can see that a strong field is created on top of the loop and a weak field underneath it Thus the loop gets a pull downwards

Since the loop is pushed upwards on the lefthand side and pulled downwards on the righthand side, it moves This loop represents a simple armature Note that if the direction of the current was changed in the loop, the loop would move in the opposite direction

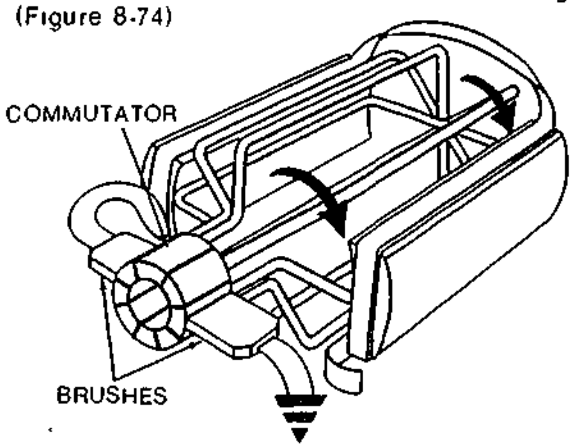
So far the loop (armature) has moved But it must do more than move, it must rotate Here's where the commutator and the brushes come in (Figure 8-73) Attached to each end of the loop is a split ring half. These half rings are the commutator Resting against these rings are two blocks of copper compound called brushes The brushes are connected to the battery



(8-73)

Current comes from the battery to the brushes via the field winding. The brush on the lefthand side passes current to a commutator half ring and the current travels through the loop out the other commutator split ring, to the other brush and back to the battery. As the loop begins to move each brush slides on a commutator half ring. When the loop reaches the top of its circle, the brushes will slide from one half ring to the other. Thus, the current will always enter on the left side and exit on the right, and the loop will keep getting its push upwards on the lefthand side and push downwards on the righthand side. The result: the loop keeps rotating in the same direction. (Note that this explains why the commutator ring is split, if it wasn't split the loop would get pushed first one way and then the other, and it wouldn't rotate.)

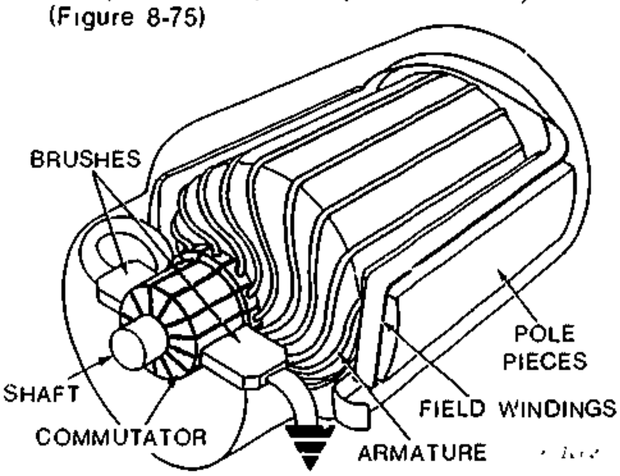
An actual starting motor will have not one, but a number of loops, and each loop will be attached to a section of the commutator ring (Figure 8-74)



(8-74) ARMATURE FOR STARTING MOTOR

Courtesy of John Deere Ltd

In summary, a starting motor has pole pieces and field windings, an armature, brushes and commutator, and a drive shaft to carry the rotary motion to the pinion and flywheel (Figure 8-75)



(8-75) ARMATURE AND BRUSHES IN STARTING MOTOR

Courtesy of John Deere Ltd

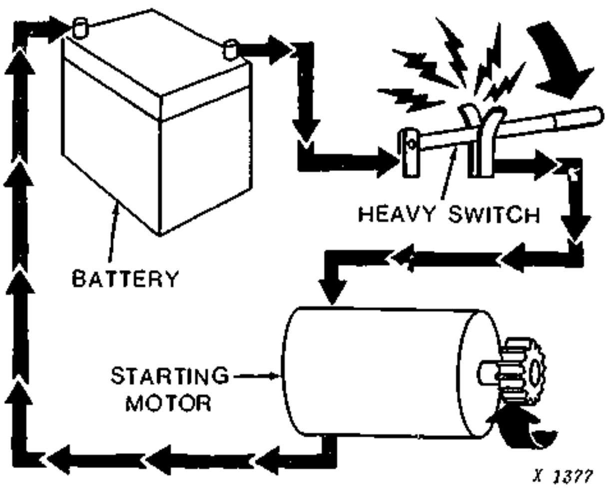
SWITCHES FOR STARTING MOTORS

Starting motors must be switched on to start an engine, but must be immediately switched off once the engine starts Four types of starting motor switches are used

- manual switch
- magnetic switch
- solenoid switch
- series-parallel switch

Manual Switch

A manual switch (Figure 8-76) is a simple hand-operated device that opens or closes a circuit Everytime you flick a light switch in a room you are operating a manual switch.



(8-76) A MANUAL SWITCH

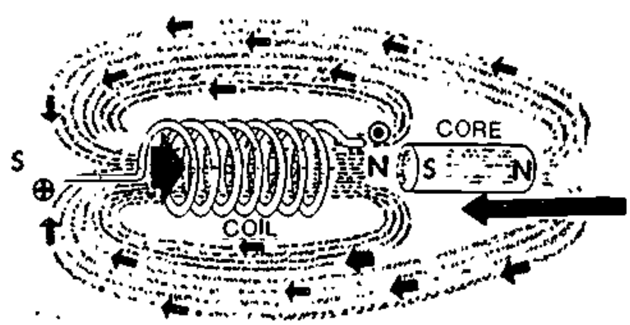
Courtesy of John Deere Ltd

The manually operated starting switch may be mounted where it is directly accessible to the operator, or it may be mounted on the starting motor and made accessible by various devices such as a hand lever

Magnetic Switches

A review of electromagnetism is necessary to understand a magnetic switch and a solenoid switch A current carrying coil, you remember, has a magnetic field

The electromagnetic field is made stronger by placing a soft iron core in the coil; the core has the same polarity as the coil If the core has freedom to move and is placed at one end of the coil, it will also assume the polarity of the coil (Figure 8-77)

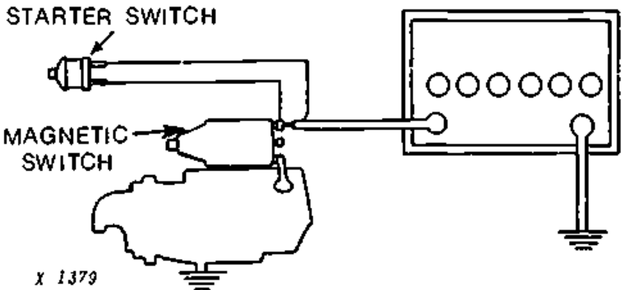


(8-77)

Courtesy of John Deere Ltd

Therefore, the adjacent poles of the core and coil have opposite polarity, and the core will be drawn into the center of the coil when current flows through it. As soon as the current stops flowing the field collapses and the core is free to move away from the coil. This movement of the core in and out of the coil is the principle of operation of the magnetic and solenoid switches.

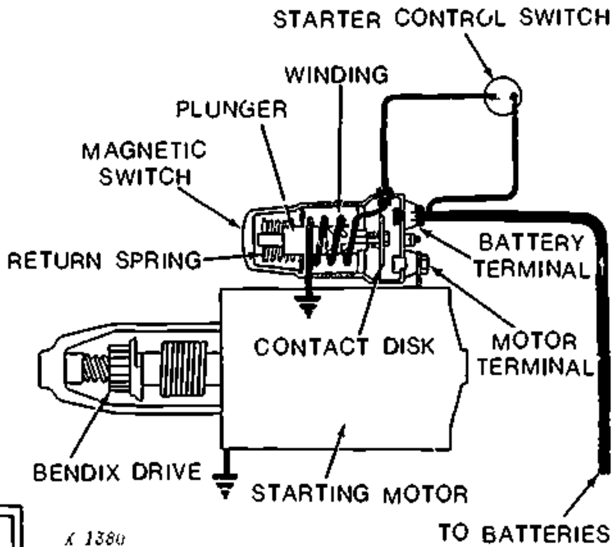
The magnetic switch is mounted on the starting motor frame like some manual switches. It is operated by a magnetic coil that is connected to the battery through a start control on the starter switch.



(8-78) MAGNETIC SWITCH CIRCUIT
Courtesy of John Deere Ltd

The magnetic switch works as follows: the switch (Figure 8-79) has many turns of a small wire wound around a hollow core. Floating in the core is a plunger with one end acting as a contact between the two main switch terminals. These terminals are connected in series with the starting motor. Usually a small spring holds the plunger away from the main terminal contacts.

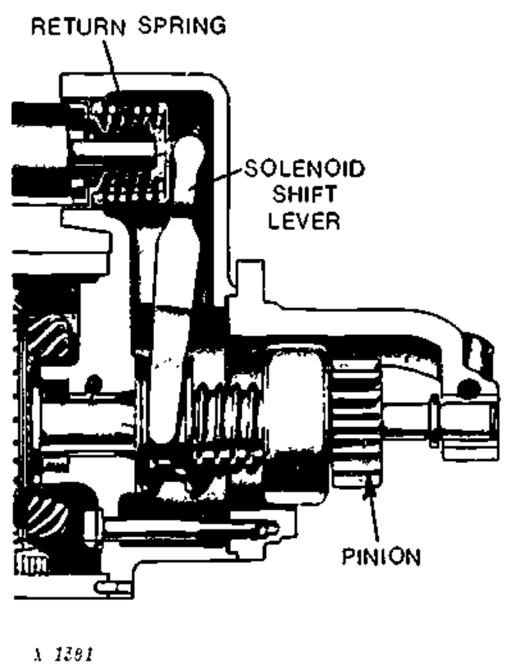
When the circuit to the coil is closed, a strong magnetic field is created in the core, causing the plunger to overcome the spring tension and complete the circuit between the terminal contacts. When the core contacts the terminals, the main circuit to the starting motor is completed and the engine is turned over. When the engine starts and the control circuit is opened at the starter switch, the magnetic field collapses and the spring forces the plunger to its original position. The starting motor circuit is open and the starting motor stops turning.



(8-79) A TYPICAL MAGNETIC SWITCH CIRCUIT
Courtesy of John Deere Ltd

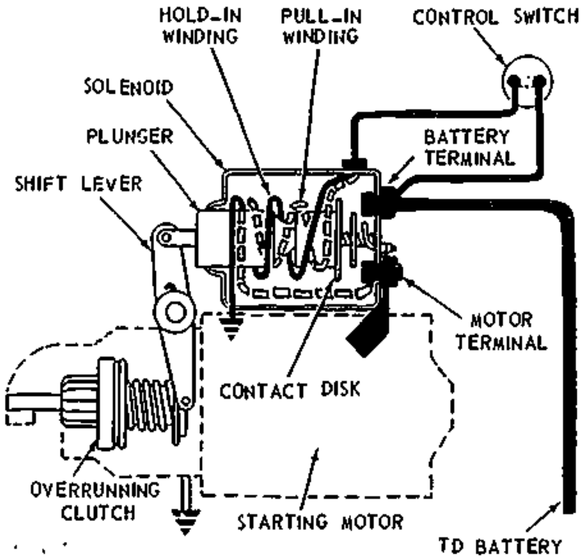
Solenoid Switch

The solenoid switch (Figure 8-80) is very similar to a magnetic switch, but in addition to closing the circuit, the solenoid provides a mechanical means of shifting the starting motor pinion into mesh with the flywheel ring gear.



(8-80) SOLENOID SHIFT LEVER
Courtesy of John Deere Ltd

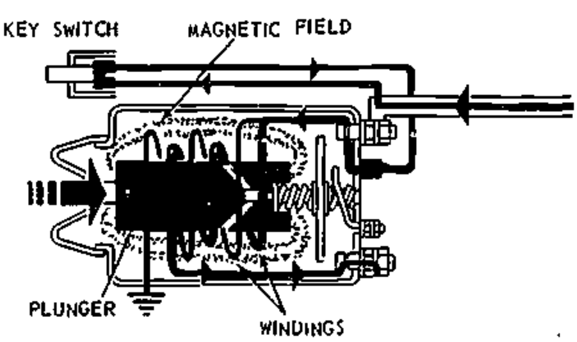
The solenoid switch has two coils of wire wound in the same direction (Figure 8-81) The pull-in winding is made up of heavy wire connected to the motor terminal of the solenoid and through the motor to ground The hold-in winding has an equal number of turns of fine wire with one end connected to the ground These coils are energized directly from the battery through the start position on the starter switch



(8-81) SOLENOID CIRCUIT

Courtesy of John Deere Ltd

When the operator turns the starter switch, current flows to the starter solenoid Since the solenoid coils are wound in the same direction, current flows in the same direction, creating a strong magnetic field which pulls the plunger into the field (Figure 8-82).



(8-82) SOLENOID PLUNGER STARTING TO MOVE AS STARTER SWITCH IS TURNED ON

Courtesy of John Deere Ltd

The initial plunger movement engages the drive pinion with the flywheel ring gear. Further movement of the plunger closes the switch contact points within the solenoid, permitting a heavy flow of current from the battery into the starting motor to crank the engine Note that this heavy flow of current does not enter the solenoid. When the points within the solenoid close the heavy pull in winding is shorted out. Thus the only current in the solenoid during the starting period is in the fine hold-in winding.

When the engine begins to run and the starter switch is released, several things happen quickly First, current through the starter switch to the solenoid is cut off. Then a strong return spring pushes out the solenoid plunger, breaking the circuit from the battery to the starting motor and simultaneously pulling the pinion out of mesh with the flywheel ring gear.

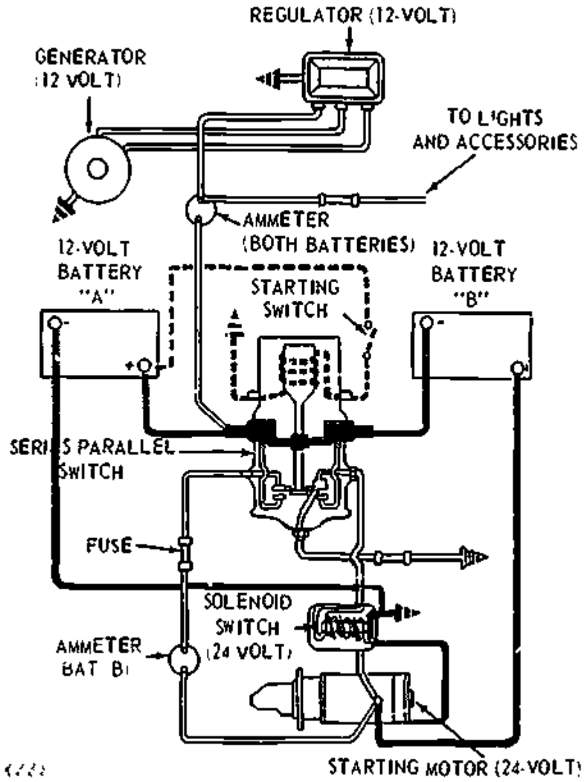
Series Parallel Switch

Some heavy duty engines, especially diesels, require a high voltage to start Cold weather and other adverse starting conditions contribute to the need for the high starting voltage.

A high output starting motor on a 12-volt circuit is adequate to start some large engines. Other heavy duty engines, however, require starting motors that will use two 12-volt batteries for a total of 24 volts. By using a 24-volt battery supply, these high volt motors can produce much greater starting speeds.

The problem with this high voltage circuit is that although the 24-volts is needed for starting, 12-volts is adequate for electrical accessories once the engine is going A series-parallel switch solves this problem. When the two batteries are needed for starting, they are connected in series to deliver the 24-volts to the starting motor. Once the engine is started the circuit is connected in parallel so that only one battery is used for normal electrical operations

(Figure 8-83) shows a series-parallel switch for a 24-volt starting circuit.



(8-83) SERIES-PARALLEL SWITCH FOR 24-VOLT STARTING MOTOR OPERATION

Courtesy of John Deere Ltd

Operation during starting is as follows

As the starting switch is closed, the solenoid coil within the series-parallel switch is energized creating a magnetic force which attracts the series-parallel switch plunger. The plunger closes the two main switch terminals and connects the two batteries in series with the starting motor

At the same time, the starting motor solenoid circuit is completed by a set of points mechanically closed by the series-parallel switch plunger The battery-to-starting motor circuit is completed and the starter turns over

After the engine is started and the starting switch is released, the two batteries become connected in parallel when the series-parallel switch goes into a neutral position This circuit permits operation of the machine's electrical equipment at a normal system voltage of 12-volts A more detailed description of the series-parallel starter switch and circuit will be given in future training

STARTING MOTOR DRIVES

After electrical power is transmitted from the battery through a switch to the starting motor, some type of connection is needed to put this energy to work. The last link in the starting circuit is the starting motor drive. The drive makes it possible to use the mechanical energy produced by the starting motor.

The starting motor armature revolves at a high speed to produce turning power. Since the turning speed required to start an engine is comparatively slow, the starting motor is equipped with a small drive pinion which meshes with the teeth of the flywheel ring gear. The result is a gear reduction with the armature revolving as much as twenty times for every revolution of the flywheel. Thus the starting motor can develop high armature speeds and considerable power while turning the engine over at a lower speed. When the engine starts it speeds up immediately and may soon reach 2000 RPM. Two thousand RPM's at the flywheel would mean twenty times that much at the starting motor pinion Such a terrific speed would destroy the armature, and so a method is necessary to demesh the pinion from the flywheel once the engine starts. Starter drives, therefore must have the capacity to both mesh and demesh the pinion with the flywheel ring gear.

Types Of Starter Drives

There are many different starter drives, but they all can be classified under two basic types according to the way they are engaged

1 Inertia drive

2 Clutch drive

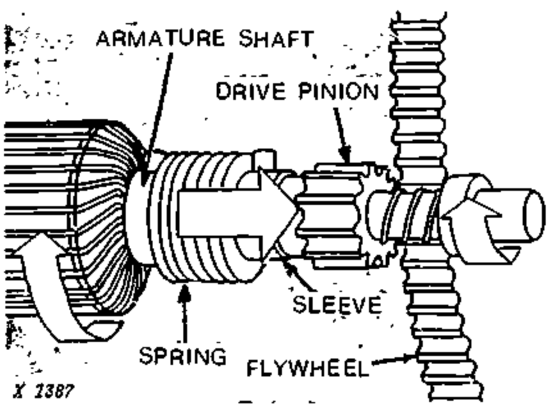
Inertia Drives have a pinion gear that is weighted on one side to aid in meshing and demeshing with the flywheel A Bendix drive is an example of an inertia drive.

Clutch Drives are shifted into mesh by solenoid switches Two examples of clutch drives are Overrunning and Sprag clutch drives Note that there is a direct relationship between starter drives and starter switches Inertia drives use straight magnetic switches, while clutch drives use solenoid switches which have a shifting mechanism

Inertia Drives

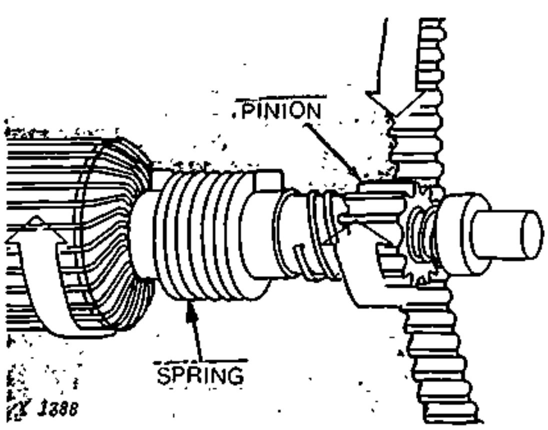
Bendix Drive

The Bendix drive uses both the acceleration of the armature and centrifugal force acting on the counter weighted pinion to move the pinion into mesh with the flywheel. Before the ignition switch is turned on, the Bendix drive is out of mesh with the flywheel ring gear (Figure 8-84)



(8-84)
BENDIX DRIVE ENGAGING FLYWHEEL AS ENGINE IS CRANKED
Courtesy of John Deere Ltd

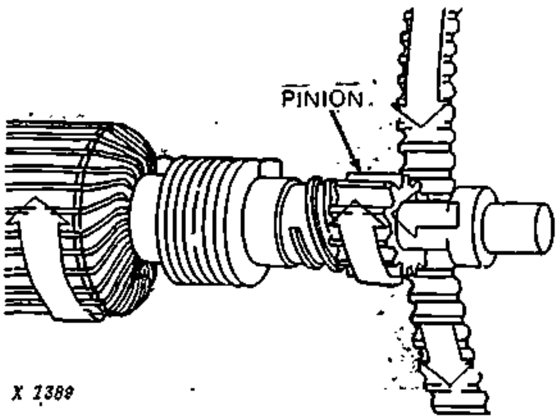
When the starting switch is closed and the battery voltage is fed to the motor, the armature shaft accelerates rapidly. The pinion gear, due to centrifugal force acting on the counter-weight, runs forward on the revolving screw sleeve until it meets or meshes with the flywheel gear (Figure 8-85).



(8-85) BENDIX DRIVE PINION FULLY MESHED
Courtesy of John Deere Ltd

When the pinion becomes fully meshed, its forward motion stops, locking the pinion to the rotating armature shaft. The heavy spring cushions the shock to the armature shaft, as the shaft starts to turn the flywheel. This spring also acts as a cushion when cranking the engine and when the engine backfires

When the engine starts, the flywheel rotates faster than the armature shaft, causing the pinion to turn in the opposite direction on the screw and spin itself out of mesh (Figure 8-86). Thus the engine is prevented from driving the starting motor at an excessive speed.



(8-86) BENDIX DRIVE PINION SPINNING OUT OF MESH AFTER ENGINE STARTS
Courtesy of John Deere Ltd

When spun from the flywheel the centrifugal effect of the weight on one side of the pinion, holds the pinion to the sleeve in an intermediate position until the starting switch is opened and the motor armature comes to rest. As long as the operator keeps the starting motor switched on with the engine running, the starting motor will free speed in the intermediate position. This free speeding is not good for the armature and is the reason that the starter switch should be released immediately after the engine has started

Certain precautions must be observed in operating a Bendix-type starting motor. If the engine backfires with the pinion meshed with the engine flywheel, and the starting motor is operating, a terrific stress is placed on the parts. The stress occurs because the motor armature attempts to spin the drive pinion in one direction while the engine, having backfired, turns the drive pinion in the opposite direction. This clash of opposing forces sometimes breaks or wraps up the Bendix spring

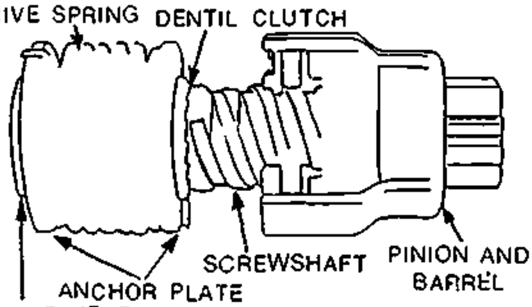
Engine ignition timing should be checked and corrected to overcome backfiring

Another problem with a Bendix drive can occur during repeated attempts to start an engine When the engine is coming to rest it often rocks back. or rotates in reverse. for part of a revolution If the operator attempts to re-engage the drive pinion at the instant the engine is rocking back. the drive housing or the Bendix spring may be damaged.

To prevent such damage. the operator should always wait at least five seconds between attempts to crank so that the engine stops turning

Variations In Bendix Drives

1 The **folo-thru starter drive** (Figure 8-87) incorporates some designs into the standard Bendix drive that overcome the problems with the Bendix mentioned above A folo-thru has a detent pin which locks the drive in the cranking position to prevent disengagement on false starts. This pin is thrown out by centrifugal force when the engine runs and the pinion then disengages



(8-87)

Courtesy of Delco Division of General Motors Corporation

Another protective feature of the folo-thru drive is the dentil clutch. a precision made one way clutch which drives in one direction and slips in the other Since the shaft will slip in the non drive direction. the starting motor is protected from engine backfire

The folo-thru is the most common type of inertia drive used today.

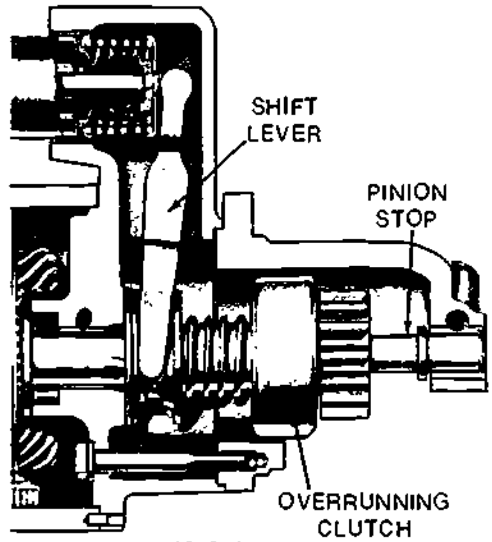
2 Some heavy-duty cranking motors use a friction-clutch Bendix drive. This type of drive functions in much the same manner as other Bendix drives. However. it uses a series of spring-loaded clutch plates. instead of a drive spring. that slip momentarily during engagement to relieve shock.

Clutch Drives

Overrunning Clutch Drive

The overrunning clutch drive (Figure 8-88) is one of the most widely used drive mechanisms: it meshes and demeshes the drive pinion with the flywheel

The overrunning clutch uses a shift lever to actuate the drive pinion The pinion. together with the overrunning clutch mechanism, is moved endwise along the armature shaft and into. or out of. mesh with the flywheel. The shift lever may be operated either manually or by a solenoid.



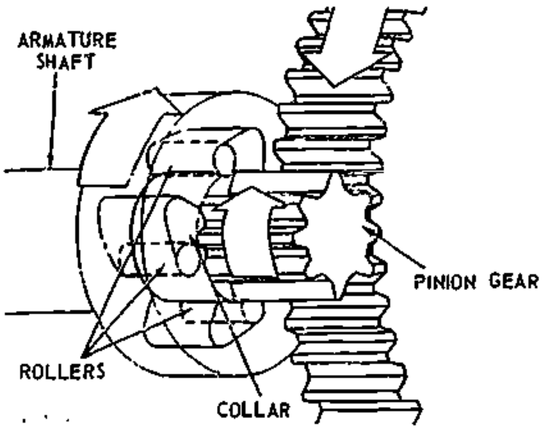
(8-88)

Courtesy of John Deere Ltd

Operation of the overriding clutch is as follows:

The drive pinion in its neutral position is out of mesh and separated from the flywheel ring gear When the starting switch is closed. current flows to the solenoid. closing the switch circuit As the solenoid switch closes. the shift lever moves the pinion into mesh and then completes the circuit to the starting motor. If the pinion and the flywheel teeth meet instead of meshing. the spring-loaded pinion rotates the width of one-half tooth and drops into mesh as the armature starts to rotate

When the armature shaft rotates during cranking. small rollers in the clutch become wedged against the shift collar attached to the pinion. This wedging action locks the pinion gear to the clutch which is splined to the armature shaft, and causes the pinion to rotate with the shaft (Figure 8-89).



(8-89)
OVERRUNNING CLUTCH DRIVE ENGAGED
Courtesy of John Deere Ltd

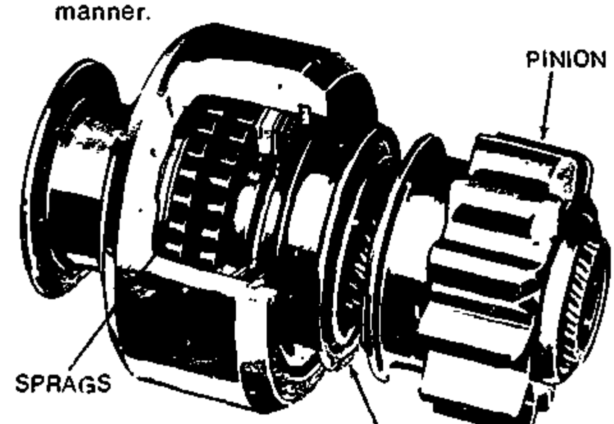
When the engine starts, the flywheel spins the pinion gear faster than the armature, releasing the rollers and unlocking the pinion from the armature, releasing the rollers and unlocking the pinion from the armature shaft. The unlocked pinion still meshed with the flywheel, runs at flywheel speed (overruns) safely and freely until the switch is opened and the shift lever pulls the pinion out of mesh. This feature prevents the armature from being driven at excessive speed by the engine.

Sprag Clutch Drive

The Sprag Clutch Drive (Figures 8-90 and 8-91) is used primarily on larger starting motors to carry the high torque required to turn over high-compression engines. The Sprag Clutch Drive is constructed and operates like the Overrunning Clutch Drive, except that a series of sprags replace the rollers in the clutch assembly.

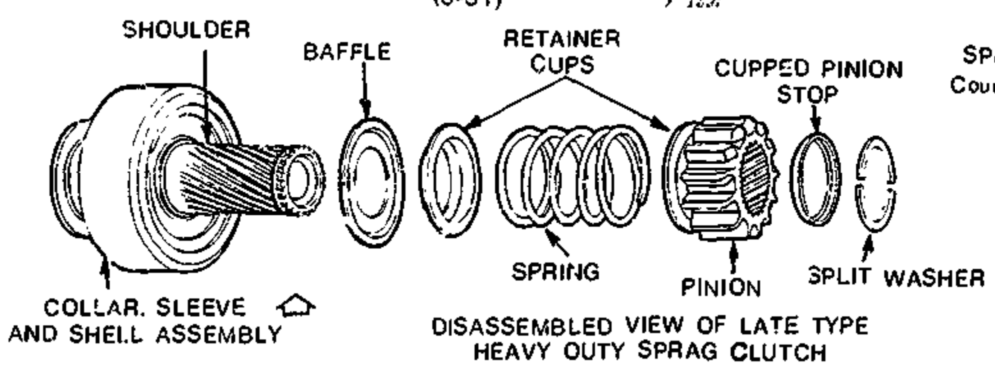
The Sprag Clutch Drive operates as follows:

Movement of the shift lever against the collar causes the entire clutch assembly to move along the splined shaft until the pinion teeth engage the flywheel ring gear. If the teeth meet instead of meshing, continued movement of the shell and spiral splined sleeve causes the pinion to rotate and clear the teeth. The compressed meshing spring then forces the pinion into mesh with the ring gear. If the pinion does not clear before the two retainer cups meet, shift lever movement is stopped by the retainer cups and the operator must start the engagement cycle over again. The shift lever stopping prevents closure of the switch contacts to the motor with the pinion not engaged. On the second attempt, the pinion will engage in a normal manner.



(8-90)
SPRAG CLUTCH DRIVE
Courtesy of John Deere Ltd

(8-91)



DISASSEMBLED VIEW OF LATE TYPE HEAVY DUTY SPRAG CLUTCH DRIVE ASSEMBLY

Courtesy of Delco Division of General Motors Corporation

With the pinion engaged and the switch closed, torque is transmitted to the pinion through the sprags. The sprags tilt slightly and are wedged between the shell and sleeve. When the engine starts, the ring gear drives the clutch faster than the armature, and the sprags tilt in the opposite direction freeing the sleeve and pinion and allowing them to overrun the shell and armature. When the switch is opened the shift lever pulls the pinion out of mesh To avoid prolonged overrunning, the starting switch should be opened as soon as the engine starts.

REMOVING AND INSTALLING STARTERS

When removing and installing starter motors, the following precaution and good work practices should be followed:

1. First, remove the ground strap from the battery Then install a DO NOT OPERATE TAG on the controls.
2. Tag all wires before disconnecting them. Pieces of masking tape work well for tagging
3. Starter motors, especially large ones, are heavy, so be sure to support a motor when removing the flange bolts
4. Check the flywheel ring gear condition before reinstalling the starter motor. If it is badly worn or damaged, the ring gear should be repaired
5. When installing the motor be sure to tighten the flange bolts evenly

QUESTIONS — STARTER MOTOR

1. The starting circuit converts electrical energy of the battery into ________ to crank the engine
   (a) kinetic energy
   (b) hydraulic energy
   (c) pneumatic energy
   (d) mechanical energy

2. True or False? A starting motor is designed to operate for short intervals under great overload.

3. The principle of an electric motor is that a current carrying conductor is placed in a magnetic field and the interaction between the two fields causes:
   (a) current to flow in the field winding
   (b) a force to be exerted on the conductor
   (c) current to stop flowing in the conductor
   (d) an equal force on the conductor

4. The operation of magnetic, solenoid and series-parallel starter switches depends on:
   (a) friction and magnetism
   (b) a core tightly wrapped around a coil
   (c) movement of a magnetized core into and out of an electromagnetic coil
   (d) two bar magnets applying a force to each other

5. What is the main difference between a magnetic starter switch and a solenoid starter switch?

6. A series-parallel switch is used to
   (a) connect two batteries in series for starting and in parallel for charging
   (b) connects four batteries in parallel for starting and returns two of them to series for charging and accessory loads
   (c) keeps the starter from overloading the batteries
   (d) connects two batteries in parallel for starting and in series for charging

7. List the two basic functions of the starter drive

8. What is the first step before attempting to remove a starter motor?
   (a) jack the vehicle up
   (b) check the ring gear condition
   (c) remove the battery ground strap
   (d) remove the fan belt

9. Why is the drive pinion center weighted on an inertia drive such as a Bendix?

10. An overrunning clutch mechanism allows a clutch drive pinion to safely ______ the starter motor armature shaft when the engine starts

11. There is a direct relationship between starter drives and starter switches. Inertia drives use ______ switches. Clutch drives use ______ switches.

CHARGING CIRCUITS

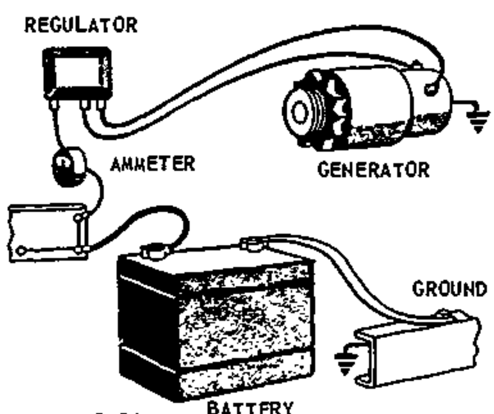
A charging circuit does two jobs:

- recharges the battery
- generates current to operate electrical accessories

There are two kinds of charging circuits:

- DC charging circuits (use generators)
- AC charging circuits (use alternators)

DC Charging Circuits have a generator and regulator (Figure 8-92).



(8-92)
DC CHARGING CIRCUIT

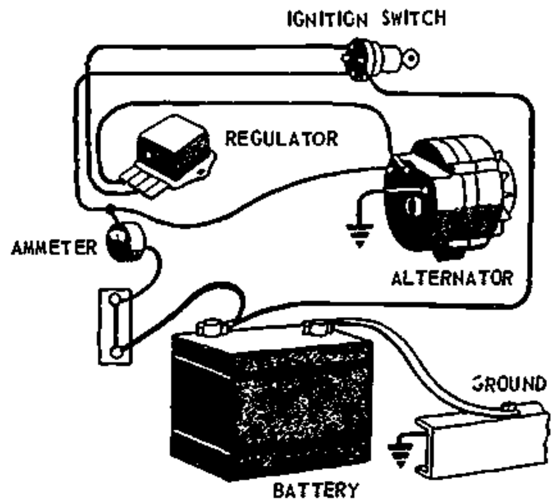
Courtesy of John Deere Ltd

Driven by the engine, the generator makes electrical power in the form of alternating current (current that moves in one direction, and then in the other). Through the use of a commutator and brushes, the generator changes the alternating current (AC) into direct current or DC which moves in one direction only.

The regulator does the following three jobs:

1. Opens and closes the charging circuit between the battery and generator.
2. Prevents overcharging of the battery.
3. Limits the generator's output to a safe amount.

AC charging circuits have an alternator and a regulator (Figure 8-93).



(8-93) AC CHARGING CIRCUIT

Courtesy of John Deere Ltd

An alternator is similar to a generator in that it produces AC current, but it differs in the way it changes AC to DC. Alternators use an electronic device called a diode rather than brushes and a commutator to change the AC to DC.

The function of a regulator in an AC charging circuit is to prevent overcharging of the battery and to limit the alternator's voltage output to a safe amount. Many modern regulators are made with transistors and are referred to as solid state.

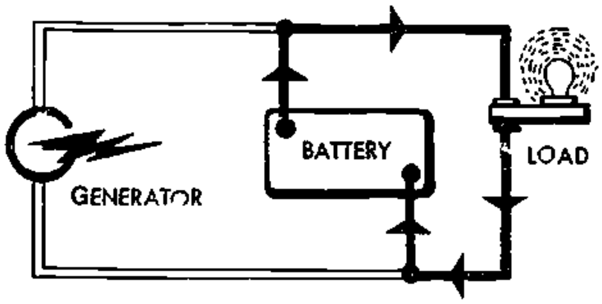
OPERATION OF A CHARGING CIRCUIT

All charging circuits operate in three stages:

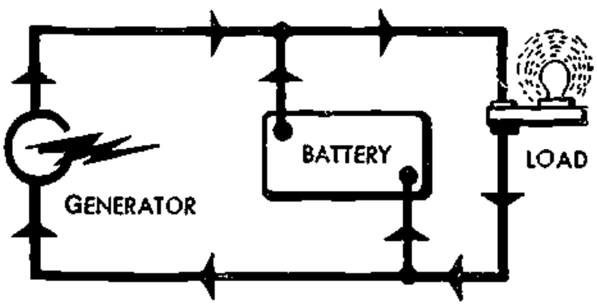
1. During starting the battery supplies all the current.
2. During peak operation the battery helps the generator supply current.
3. During normal operation the generator supplies all current and recharges the battery.

In both AC and DC charging circuits, the battery starts the circuit when it supplies the current to start the engine. The engine then drives the generator (or alternator) which produces current to take over the operation of the ignition, lights and other electrical accessories. The battery will help out during peak operation when the electrical loads are too much for the generator (or alternator).

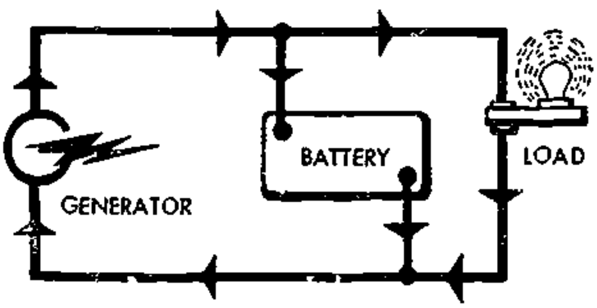
The three stages of the charging circuit are illustrated in Figure 8-94



BATTERY SUPPLYING LOAD CURRENT



GENERATOR AND BATTERY SUPPLYING LOAD CURRENT



GENERATOR SUPPLYING LOAD CURRENT AND CHARGING BATTERY

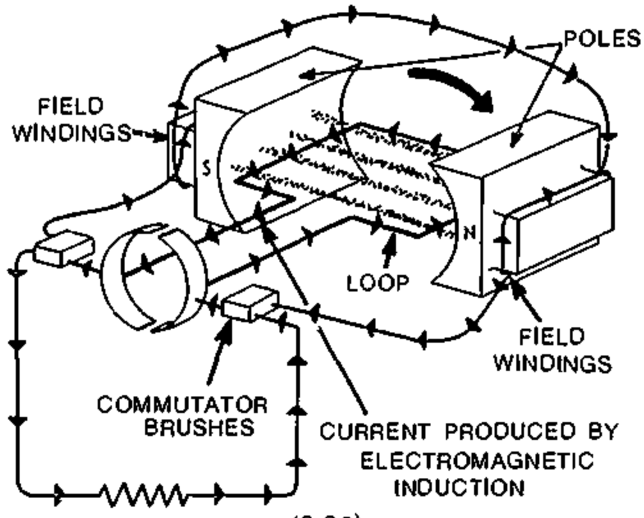
(8-94)

Courtesy of John Deere Ltd

DC CIRCUITS

GENERATORS

The make-up of a basic generator is similar to that of the basic starting motor previously described. Both have an armature, poles, a field winding, brushes and a commutator. However, there is a major difference in their operation and function. A starting motor uses current to turn its armature and shaft and its function is to produce working power. A generator uses engine power to turn its armature and its function is to produce electricity. Figure 8-95 illustrates the parts of a basic generator. (Note that an actual generator has not one but many loops.)



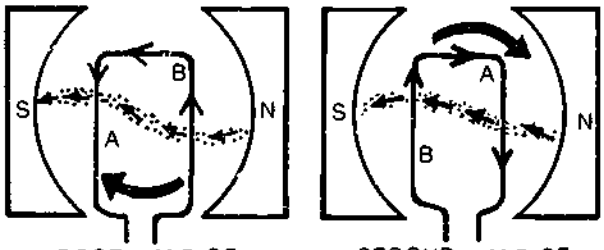
(8-95)

COMPLETE PARTS OF BASIC GENERATORS

Courtesy of John Deere Ltd

The earlier discussion of electromagnetism showed that when a conductor was moved through a magnetic field, a current was induced in the conductor. The direction of induced current depended on the direction in which the conductor passed through the field. Generators use this principle of electromagnetic induction to produce current.

Looking at the illustration of the basic generator in Figure 8-96, consider the clockwise rotation of the loop through the magnetic field During the first half of the revolution (Figure 8-96) the top of Side A cuts through the magnetic field first, whereas the bottom of side B is first to cut the field. In this half of the revolution, then, the loop has current induced in it that travels away from Side B towards Side A. During the second half of the revolution, the field cutting is reversed. The top of Side B is the leading edge, while the bottom of Side A is leading. Thus the current flows in the opposite direction, away from Side A towards Side B The result is alternating current



(8-96)

The generator must convert this AC to DC. The commutator and brushes perform the conversion. The brushes slide on, or brush, the commutator ring. Since the ring is split the brush on the left side is always in contact with the side of the loop that is pushing up through the magnetic field, and the brush on the right side is always in contact with the side of the loop that is going down through the field. Thus the current always flows in the same direction

Three factors will affect the induced current that an actual generator produces:

1 The **strength** of the magnetic field.

2 The **number** of wire conductors on the armature (i e. the number of loops)

3 The **speed** of the armature.

Note here, as was mentioned earlier, that the more current a generator (or an alternator) produces, the more resistance there is against the armature Thus, the more current you draw from a generator or alternator, the harder it is to turn. This is the reason that drive belts for generators and alternators must have the proper tension so that they don't slip during peak demands

Need To Regulate The Generator

Looking at the diagram of a basic generator, you can see that current produced by the generator is also used to supply its own field circuit. Such an arrangement causes a spiralling increase in the amount of current produced The reason is as follows:

1 The more current the armature produces, the more current is sent to the field circuit

2 With this additional current, the magnetic field becomes stronger

3 With a stronger magnetic field, more current is induced in the armature

4 And so it goes, the amount of current spiralling upwards.

If this increase in current went unchecked, the generator would burn up Thus, the need for a regulator The regulator controls the amount of current and voltage the generator can produce. Besides having current and voltage limiters, the regulator has a cutout relay that closes the circuit between the generator and the battery when the generator is running and opens it when the generator is stopped. This relay allows the generator to charge the battery, but does not allow the battery to discharge through the generator when the generator is not running.

AC CIRCUITS

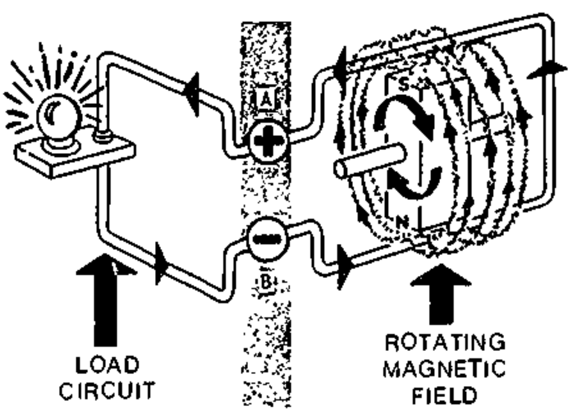
Alternators

The alternator (also called an AC generator) is the heart of the AC changing circuit. Alternators are generally more compact than generators and can supply a higher current at low engine speeds. Since in recent years there has been an increase in the use of electrical accessories at low or idle engine speeds, alternators are more common today than generators

Basic Operation Of An Alternator

Whereas a generator induces current by moving a conductor through a stationary field, an alternator induces a current by doing the opposite, by moving the field across a stationary conductor.

A basic alternator can be made by rotating a bar magnet inside a single loop of wire As it's rotated current is induced in the wire (Figure 8-97)

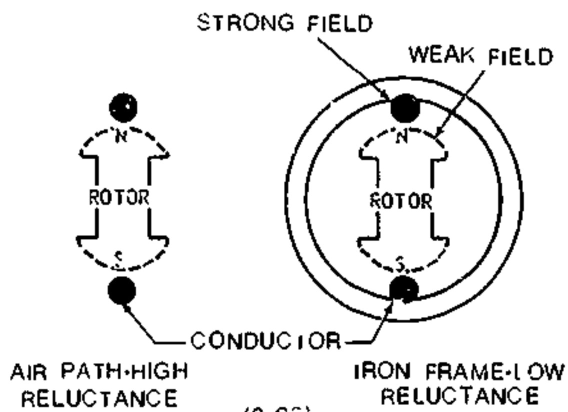


(8-97)

Courtesy of John Deere Ltd

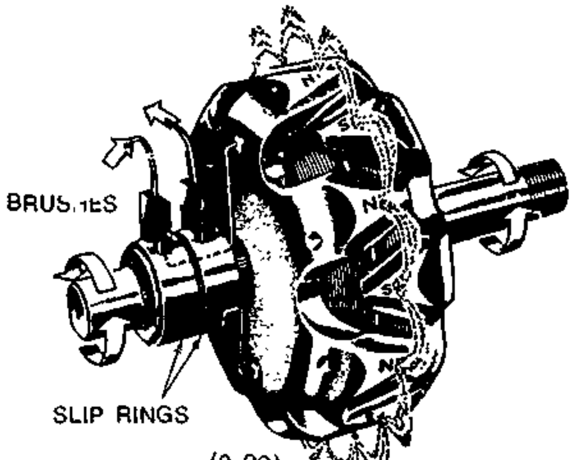
If the magnet is rotated the other way, the current will flow in the opposite direction. The faster the magnet is turned the more current is induced.

However, an alternator made with a bar magnet rotating inside a single loop of wire is not practical because very little voltage and current are produced. Air is not a good transmitter of magnetism, and only a few lines of force will come out of the North pole and enter the South pole. Production of current is improved when the loop of wire and the magnet are placed inside an iron frame (Figure 8-98). The iron frame provides a form to which the loop of wire can be attached. It also acts as a conducting path for the magnetic lines of force, greatly increasing the number of lines of force between the N and S poles. With the increased lines of force comes more induced voltage, and thus a more useful alternator.

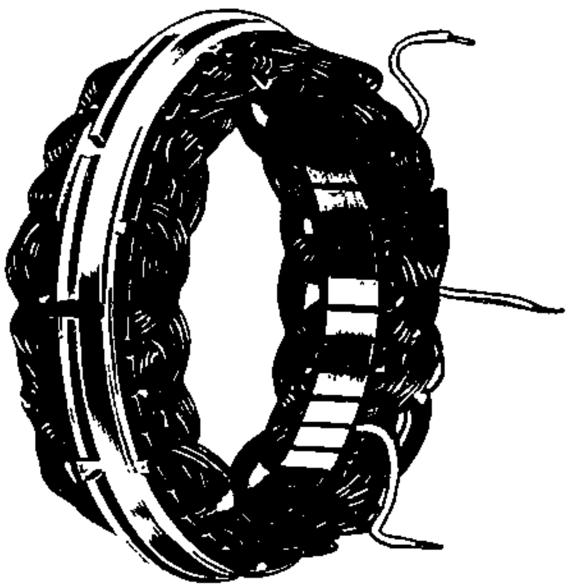


(8-98)
MAGNETIC LINES OF FORCE
Courtesy of John Deere Ltd

In an alternator the rotating magnet is called the rotor, and the loop and outside frame assembly is called the stator. A rotor and a stator from an actual alternator are shown in Figure 8-99. Note that the stator has not one but many loops of wire wound in three separate coils. Also note that the rotor is not a bar magnetic but pole pieces and an electromagnetic field winding. The rotor is driven by the engine and the field winding is supplied current from the battery.



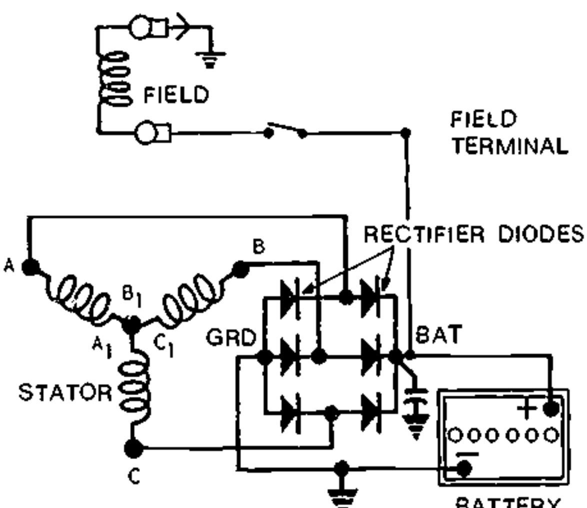
(8-99)
ROTOR
Courtesy of Delco-Remy
Division of General Motors Corporation



(8-99) STATOR
Courtesy of Delco-Remy Division of General Motors Corporation

The current induced in the stator by the rotor is alternating current and it must be changed to AC before it can be used by the electrical accessories. An alternator uses diodes to change the AC current to DC. A diode is an electronic device that will allow electricity to flow through it in one direction but not in the other. The discussion here won't go into why the diode allows passage of electricity one way but not the other; this information can be found in any modern book on electricity. In electrical diagrams the symbol for a diode is, —►|—, which means that current can flow through the arrow but not through the vertical line. Without going into detail, the diodes are located in circuits such that they send the alternating current received from the three stator coils all in the same direction resulting in a DC current. To understand how diodes work follow the path of the current through the six diodes in Figure 8-100. Remember that the current can only flow in the direction of the arrow through the diode.

1. From coil A through coil B and C and back to A again
2. From B through A and C and back to B again
3 From C through A and B and back to C again



(8-100)

Courtesy of John Deere Ltd

Need To Regulate The Alternator

Alternators like generators must have regulation. The type of regulation, however, is different in the two systems. Generators, as you will recall, required a cutout between the battery and generator, in addition to current and voltage limiters. Since alternators use diodes, they don't need a cutout (i.e., current can only go from the alternator to the battery, it can't go the other way). Nor do they need a current limiter because the coils are constructed so that the current they produce is self limiting What regulation alternators do need, though, is a voltage limiter. Voltage output is controlled by limiting the amount of current in the field circuit. By limiting the voltage output of the alternator, the amount of current produced is in correct proportion to both the demands of the battery in its various states of charge and the demands of the electrical system (up to, of course, the alternator's limitations).

There are many variations of alternator and generator regulators and these will be discussed in later courses.

PREVENTIVE MAINTENANCE SERVICE OF CHARGING SYSTEMS

Removing and installing generators and alternators is a fairly straight forward job. However, there are a few suggestions that will help you do a better, safer job:

1. First, remove the ground strap from the battery.

2. When multiple wires are used on the generator, tag the wires as they are disconnected

3. On some vehicles, several accessories may be driven from a multiple groove crankshaft pulley, and to replace any of the inside drive belts you will have to remove all the outside belts first. Also, on vehicles where special equipment has been installed or accessories relocated, it may be necessary to remove these items before you can replace a drive belt.

4. Generators, especially large ones, are heavy; support a generator when removing the mounting bolts.

5. Check the condition of the drive belt and its sheaves and check the sheave alignment (see the section on belt maintenance in Block 7, Engines).

6. When installing generators, position them so that the spacers are in the right location.

7. Check belt tension using a belt tension gauge or the belt depression method (see "Engines"). The most common charging system problems are caused by worn or improperly adjusted drive belts. Preventive maintenance on generators stresses, therefore, that belts be checked regularly for alignment and tension.

QUESTIONS — CHARGING SYSTEMS

1. During normal engine operation the generator or alternator:

   (a) helps the battery supply current

   (b) supplies all current

   (c) recharges the battery

   (d) both (b) and (c)

2. A generator changes the alternating current it produces to direct current by the use of:

   (a) an accumulator and brushes

   (b) a commutator and windings

   (c) a commutator and brushes

   (d) an accumulator and diodes

3. List the three jobs the regulator must do in a DC charging system.

4. An alternator changes AC to DC by the use of:

   (a) resistors

   (b) transistors

   (c) diodes

   (d) thermistors

5. A regulator on an AC charging system has one job to do:

   (a) limit the voltage to a safe value

   (b) limits the current to a safe value

   (c) opens and closes the charging circuit

   (d) control alternator speed to control current output

6. Briefly explain the difference in the way that current is induced in a generator and in an alternator

7. True or False? The most common charging system problems are caused by worn or improperly adjusted drive belts.

IGNITION SYSTEM

The purpose of the ignition system is to take the low voltage of the battery and create high voltage at the spark plugs to fire the engine. This purpose is accomplished by means of an induction coil. points and a condenser. The ignition system must deliver the high voltage to the right spark plug at the right time in order to get maximum power from combustion.

The ignition circuit has two separate circuits (Figure 8-101)

Primary — low-voltage circuit

Secondary — high-voltage circuit

The **Primary Circuit** is the path for low-voltage current from the battery

It includes these parts:

1 Ignition Switch

2 Coil Primary Winding

3 Distributor Contact Points

4 Condenser

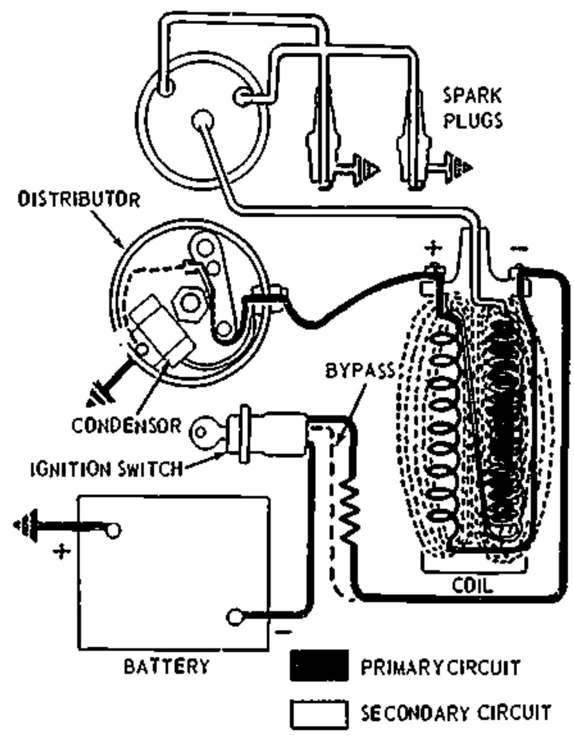
The **Secondary Circuit** is the high-voltage path for current stepped up by the coil It includes these parts

1 Coil Secondary Winding

2 Distributor Rotor

3 Distributor Cap and Secondary Winding

4 Spark Plugs



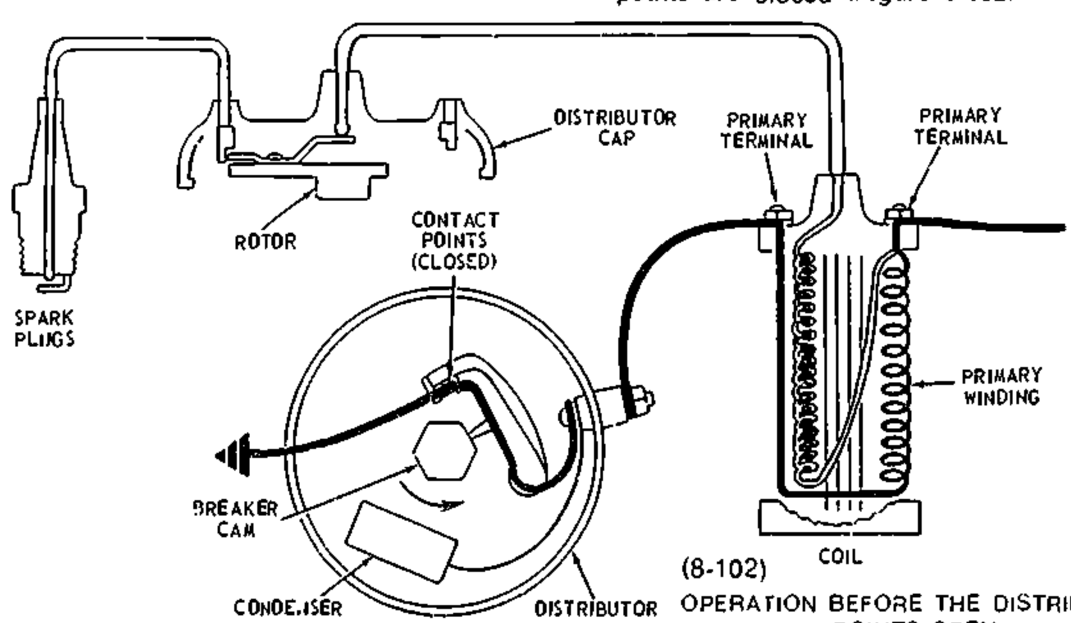
(8-101)
IGNITION CIRCUIT (BYPASS TYPE SHOWN)
Courtesy of John Deere Ltd

IGNITION CIRCUIT OPERATION

The ignition circuit can be naturally separated into (1) the operations before the distributor points open and (2) the operations after they open.

Operation Before The Distributor Points Open

Before the engine is started. the distributor points are closed (Figure 8-102)

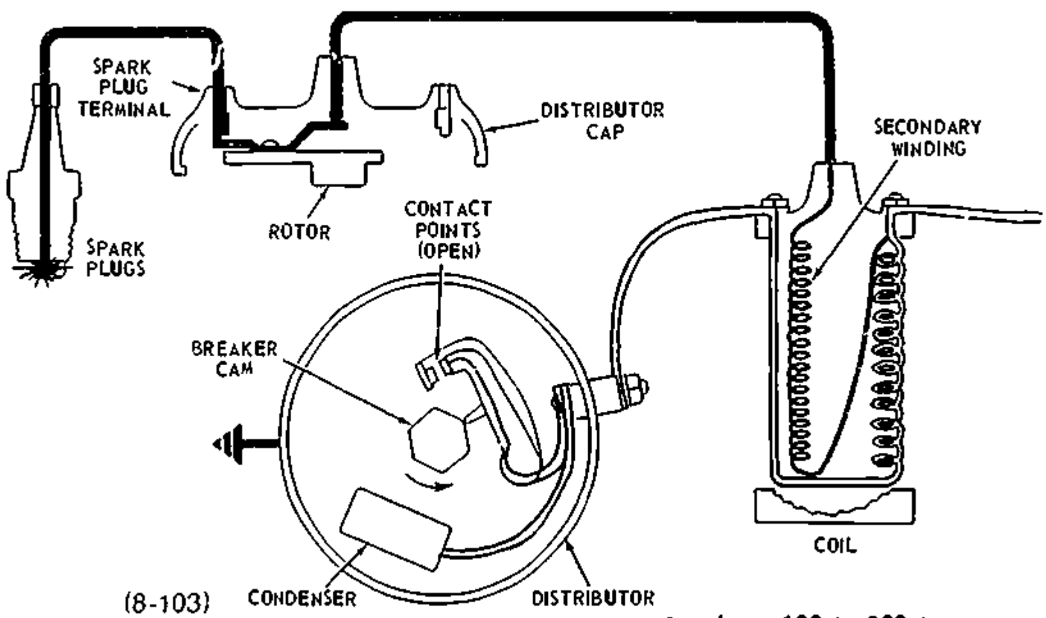


(8-102)
OPERATION BEFORE THE DISTRIBUTOR POINTS OPEN
Courtesy of John Deere Ltd

When the ignition switch is turned on, current flows from the battery into the primary windings of the coil, as shown in dark lines. From the primary winding the current at low voltage simply travels through the closed distributor points and back to ground. The current creates a magnetic field around the primary winding and since the secondary wiring is wound underneath the primary, the secondary, too, has a magnetic field around it.

Operation After The Distributor Points Open

As the engine rotates in starting, it drives the distributor shaft and the breaker cam. The breaker cam opens the distributor points, and the second phase of ignition begins as illustrated in Figure 8-103.



(8-103)
OPERATION AFTER THE DISTRIBUTOR POINTS OPEN
Courtesy of John Deere Ltd

As the points open, the flow of current in the primary circuit is stopped instantly. Stopping this current collapses the magnetic field that has built up around the two windings. Collapsing the field induces a current (discussed more fully below) in the two coils, since there is a magnetic field moving across a conductor. You remember that, if a conductor is moved through a magnetic field (the principle of a generator) or vice versa if the magnetic field is moved across the conductor (the principle of the alternator) a current is induced in the conductor.

The surge of induced voltage in the primary winding is absorbed by the condenser. The surge of induced voltage in the secondary winding which, for reasons that will be explained later, is much higher, travels to the distributor cap. The rotor inside the distributor cap turns to a spark plug terminal and directs the voltage surge to the correct plug through insulated cables. At the spark plug, high voltage current flows down the center wire or electrode and on reaching the tip jumps the gap to the plug's ground electrode. As the current jumps it creates a spark.

The complete cycle of current coming into the primary winding, stopping, and induced current travelling from the secondary winding to the distributor cap and spark plugs happens from 100 to 300 times a second depending on the speed of the engine.

One other point must be made about the ignition circuit as a whole. Going back to the first diagram in this section, notice the resistor on the primary circuit and also note the dotted line that bypasses this resistor. Such an arrangement is called a bypass ignition system. When the ignition key is turned on, full battery voltage flows through the dotted red line, resulting in a hotter spark for first ignition. When the ignition switch is released, primary current flows through the solid line and resistor to the coil. In a 12-volt system, the resistor reduces voltage by half and allows the use of a 6-volt coil. The smaller coil gives longer life to the distributor points, condenser, and coil because it creates less heat.

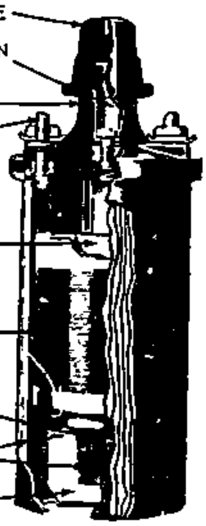
Having seen how current flows in an ignition system the individual parts of the system will be discussed

Wiring In The Primary Circuit

Primary wiring is low voltage wiring. 16 or 18 gauge plastic insulated, stranded copper wire, that carries current at battery voltage through the primary ignition circuit The connectors at the ends of the wire are usually crimped or soldered on

Ignition Coil and Condenser

The center of the coil (Figure 8-104) is a soft iron core The secondary winding of fine wire is wrapped around this core. One end of the secondary winding is connected to the high-tension terminal, the other end to the primary winding



(8-104) IGNITION COIL
Courtesy of John Deere Ltd

The primary winding of heavy wire is wrapped around the secondary winding. There are approximately 100 times less primary loops than secondary ones. The two ends of the primary winding are attached to the primary terminals in the coil cap. One of these terminals is connected to the power source. the other is connected to the distributor points.

\ shell of laminated material is placed around the windings and core as shown. The core. windings. and shell are then encased in a metal container. The container is filled with either oil or insulating material and sealed with the coil cap The cap is made of a shaped insulating material with the two primary terminals and one high-tension terminal molded into it.

The coil performs the key function in the ignition circuit. it steps up battery voltage from 6 or 12-volts to 15 to 20 thousand volts. enabling a spark to occur at the spark plug.

Coil Operation

Keep in mind the electromagnetic principle of the coil. when a magnetic field crosses over a conductor a voltage is induced in that conductor. The faster the field travels and the more conductors there are. the greater the induced voltage.

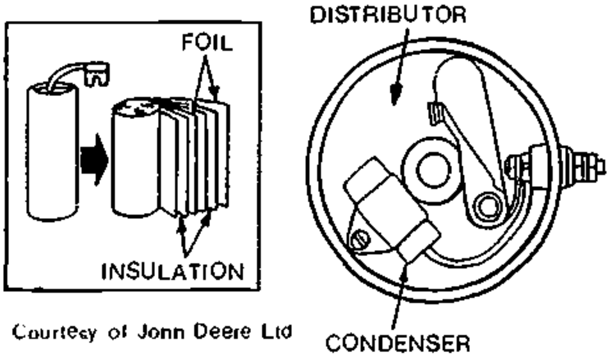
1 Current at battery voltage travels to the primary winding in the coil. As current begins to come into the primary winding, a magnetic field starts to build around it. and since the secondary winding is wrapped underneath the primary the same magnetic field crosses over to the secondary winding. As the field builds up. some voltage is induced in the secondary winding but not enough to send a spark across the gap at the spark plug.

2 This greater voltage that produces the spark is induced as follows The contact points are opened and current is immediately cut off to the primary coil. Cutting off the current causes the field to collapse very quickly. and thus the field travels back over the secondary windings much faster than it came across. (Note that the electromagnetic field doesn't just disappear when current is cut off: it must collapse or fall down much like. a brick building would) The fast collapsing field crossing back over the many loops in the secondary winding induces a very high voltage that sends a surge of current up to a spark plug to jump the gap and cause the spark needed for ignition of the fuel.

3 While the high voltage is being induced in the secondary winding. what is happening in the primary winding? As the field collapses. a voltage is self-induced in the primary winding as well as the secondary. However. the voltage is much less than that of the secondary because the primary has approximately 100 times fewer loops.

The self-induced voltage in the primary winding tries to push a spark across the points in an attempt to keep the current flowing And there is enough induced voltage to send a spark across when the points first start to open and are not very far apart Such a spark would damage the points and decrease the rale of field collapse. To prevent sparks at the points a condenser is used.

The condenser is connected across the points as illustrated in Figure 8-105.



Courtesy of John Deere Ltd

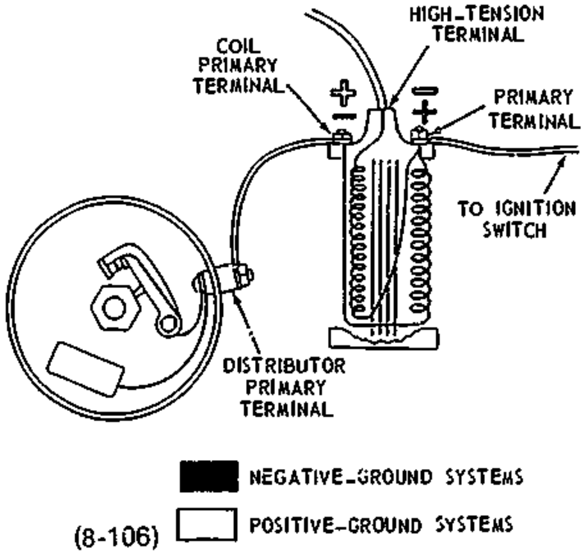
(8-105)

Instead of the induced voltage pushing current across the points, the current is sent into the condenser. The condenser in effect catches the induced voltage from the primary winding. The condenser is soon full or charged up and the voltage is ready to try again to push the spark across the points, but by this time the points are open too wide for a spark to be pushed across. The delaying tactics of the condenser prevent current from crossing the points and in so doing allow the field in the coil to continue to collapse.

It should be pointed out that contrary to what was said above sparking is not 100% eliminated from the points. During the first millionth of a second that the points separate, there is a very small spark produced across the points. It is this small spark that accounts for some pitting and wear on the points.

Service Note On The Polarity Of The Coil

Whenever the primary leads are disconnected from the coil, observe the correct polarity when reconnecting them. Wrong polarity of the coil is not a serious problem, but can cause damage over a long period of time. A coil that is incorrectly connected to the power source and the distributor will require an extra 4000 to 8000 volts to create the spark. Misfiring can result as the voltage required to jump the spark gap increases. Figure 8-106 illustrates proper coil connections.



(8-106)
CORRECT POLARITY OF THE COIL

Courtesy of John Deere Ltd

On negative-ground systems, the negative primary terminal is connected to the distributor.

On positive-ground systems, the positive primary terminal is connected to the distributor.

Most coils have the polarity signs imprinted in the cap by each terminal.

IGNITION DISTRIBUTOR

The distributor does three jobs. It:

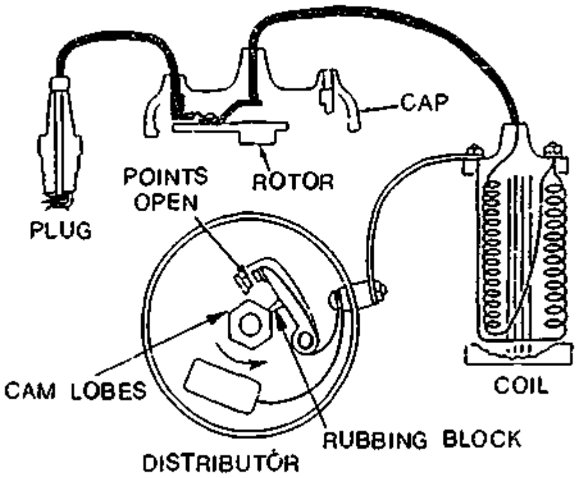
- opens and closes the primary circuit
- times the high voltage surges
- delivers current to the spark plugs

Distributor Parts Can Be Put Into Three Groups

Primary Circuit Operation	Timing	Delivery
drive shaft	drive shaft	drive shaft
breaker cam	breaker cam	rotor
breaker plate	centrifugal advance	cap
contact points	contact points	

Operation Of The Distributor

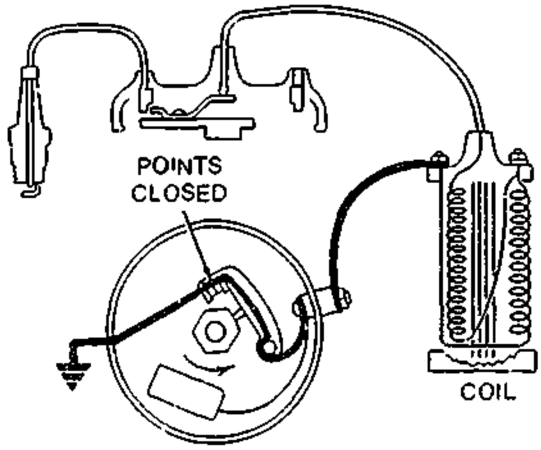
As the distributor drive shaft turns, a cam lobe pushes the breaker lever rubbing block. This action opens the contact points, stopping the current flow in the coil's primary circuit (Figure 8-107)



(8-107)
Courtesy of John Deere Ltd

The collapsing field and the resulting high-voltage surge in the coil's secondary winding forces current into the center terminal of the distributor cap. The distributor rotor receives this current and delivers it to the proper spark plug to fire the engine

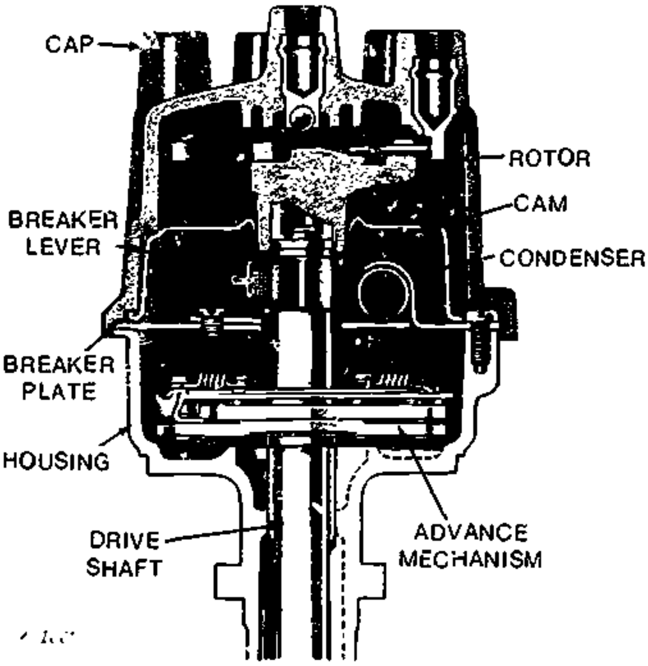
Meanwhile, the distributor cam lobe has moved away from the rubbing block and spring tension brings the points back into contact (Figure 8-108)



(8-108)
Courtesy of John Deere Ltd

The primary circuit is again complete and current flows until the next lobe opens the points. The cycle then repeats itself.

In this way a spark is created as each lobe of the cam opens the contact points. The complete cycle for each spark takes place at a very high speed. A typical distributor is shown in Figure 8-109.



(8-109) CUTAWAY OF DISTRIBUTOR
Courtesy of John Deere Ltd

Distributor Parts

Drive Shaft — is driven at one-half engine or crankshaft speed by the engine camshaft. It drives the centrifugal advance mechanism (described later), the breaker cam, and the rotor.

Breaker Cam — is slip-mounted on the drive shaft and pinned to the centrifugal advance. The cam has one lobe for each engine cylinder.

Breaker Plate — is a mounting for the contact points and condenser. It also has a terminal which connects the points and condenser to the primary circuit.

Contact Points Assembly — consists of two contact points, a breaker lever and a breaker lever spring. All three are mounted on a base which is attached to the breaker plate. The two points are usually made of tungsten. One is fixed to the base, the other is attached to the breaker lever and aligned with the first.

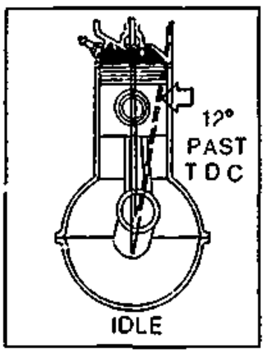
The breaker lever is mounted on a pivot pin to the assembly base. The lever is made of metal and has a nylon or bakelite rubbing block. The breaker lever spring is attached to the breaker lever. The spring holds the lever to the cam after each cam lobe passes the rubbing block.

Rotor — is mounted on the upper part of the breaker cam. A flat side of the rotor hub fits on a flat side of the cam. In this way the rotor will fit in only one position. On the top of the rotor, a spring metal piece is in contact with the center terminal of the distributor cap. A rigid piece completes the circuit to each spark plug terminal in the cap as the rotor turns. The rotor itself is molded of a plastic material which makes it a good insulator.

Distributor Cap — is also molded of a plastic material. Brass or copper contact inserts are embedded in the cap. These contacts are equally spaced around the cap and lead to the spark plug terminals in the top of the cap. The cap is notched into the housing to prevent incorrect installation.

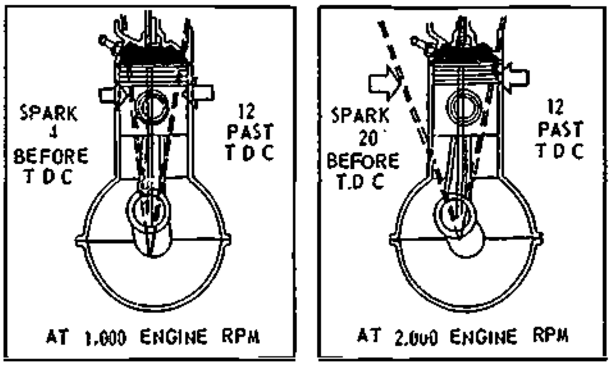
CENTRIFUGAL ADVANCE MECHANISM

An advance mechanism is a device which takes engine speed into account and times the spark to occur while the piston is in its best position to be driven by the expanding gases. For the purpose of discussion, assume that the engine piston must be at 12° past top dead center for full combustion force (Figure 8-110). The 12° past top center stays the same regardless of the engine speed.



(8-110)
Courtesy of John Deere Ltd

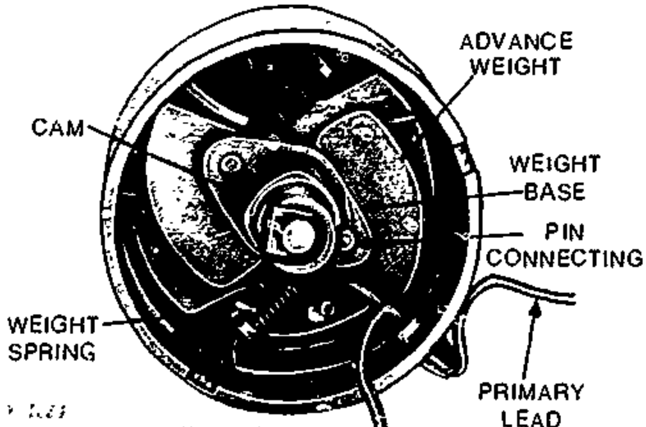
Assume also that it takes 0.002 seconds to reach the full force of combustion, and that at 1000 revolutions-per-minute (RPM) the piston will travel 16 degrees during this time. The spark at this speed, therefore, must come at four degrees before top dead center so that the piston will be at its optimum 12° position at combustion (Figure 8-111). If the engine speed is doubled to 2000 RPM, the distance the piston would travel is also doubled to 32 degrees, and the spark, therefore, must occur at 20 degrees before top dead center to give maximum power to the piston (Figure 8-111).



SPARK TIMING OF THE ENGINE COMBUSTION
(8-111)
Courtesy of John Deere Ltd

It has been shown that spark timing must be adjusted to engine speed. The advance mechanism makes this adjustment. The most popular type of advance mechanism is a centrifugal advance. Its main parts are two weights, a weight base and two springs (Figure 8-112).

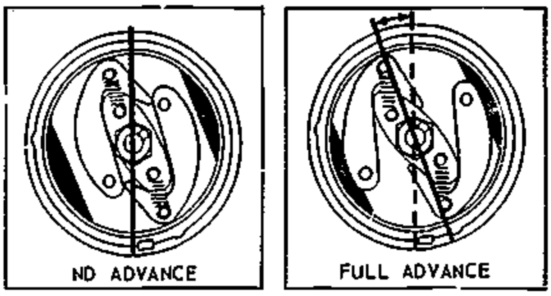
CENTRIFUGAL ADVANCE MECHANISM



(8-112) Courtesy of John Deere Ltd

The weight base is part of the distributor drive shaft. The springs are connected to the base, while the weights are placed on the base. The distributor breaker cam has two pins which connect it to the springs and weights.

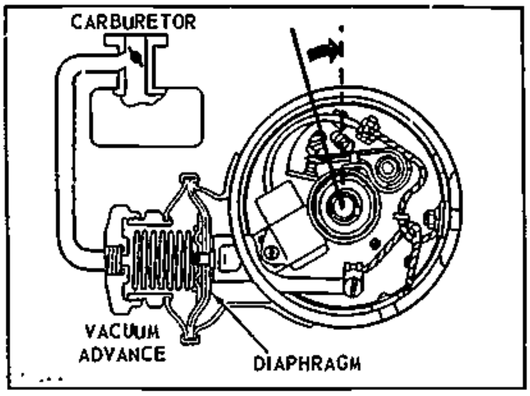
At idle speed the breaker cam is pinned to the base and rotates with the drive shaft. The cam lobes then open the points at a preset time such as four degrees before top dead center.



OPERATION OF CENTRIFUGAL ADVANCE
(8-113) Courtesy of John Deere Ltd

As the engine speeds up, centrifugal force throws the weights out against spring tension (Figure 8-113). When the weights move out they twist the breaker cam so that the cam lobes strike the breaker lever earlier. Thus the contact points open earlier and the spark is advanced. As the engine slows down, the springs gradually return the breaker cam and weights to their original position.

The centrifugal advance is calculated in a set ratio of spark advance to engine speed; at full throttle it gives complete spark advance. Cylinder conditions, however, are not as regular as the set advance-speed ratio might imply. There is a time, at part throttle for example, when the conditions during compression and combustion are such that more spark advance could be used. At part throttle the amount of air taken into the engine is restricted and a vacuum can develop in the engine intake manifold, allowing less fuel and air into the cylinder. The amount of vacuum in the manifold is determined by the engine speed and the throttle opening. With less air-fuel mixture entering the cylinder and with the mixture being slightly richer (i.e., not as much air), the mixture will burn slower. In such a situation spark must take place sooner. The centrifugal advance can't advance the spark any further because it is in a set speed-advance ratio. The further advance is accomplished by a vacuum advance mechanism (Figure 8-114).



(8-114) VACUUM ADVANCE MECHANISM
Courtesy of John Deere Ltd

The vacuum advance uses an air-tight diaphragm connected to an opening in the carburetor by a vacuum passage. The diaphragm is connected by linkage to the distributor housing or the breaker plate.

When a vacuum at the intake manifold draws air from the diaphragm chamber, it causes the diaphragm to rotate the distributor breaker plate in the opposite direction of drive shaft rotation. The breaker lever contacts the breaker cam lobes sooner and advances the spark.

A combination of the centrifugal and the vacuum advance mechanisms gives a spark advance unit which is sensitive to all speed and load conditions.

Other parts of the ignition system yet to be discussed are secondary wiring, a ballast resistor, and spark plugs.

SECONDARY WIRING

Secondary wiring carries the induced coil voltage (20,000 volts or more) first from the coil's high tension terminal to the distributor cap and then from the outside distributor cap terminals to the spark plugs. Because of the high voltage they carry, these wires must be heavily insulated. The insulation must be oil resistant and must also be able to withstand a fair amount of heat as the wires run close to the manifolds.

Until the early sixties, secondary wiring was made of about 16 gauge copper or aluminum wire. At that time, wiring with carbon impregnated liners or cores was introduced. The carbon impregnated core provides a resistance path for the high voltage surges which helps eliminate radio and television interference from the ignition system.

Other improvements have followed, such as graphite saturated fiberglass cores and soft silicone insulation that allow the wire to withstand more heat and generally make it more durable.

The ends of secondary wiring that fit onto the distributor cap, the coil tower, and the spark plugs are equipped with insulating boots. The boots either slide over the cable or are bonded to it

BALLAST RESISTOR

Earlier, a bypass ignition system was mentioned. When starting, a bypass circuit takes full voltage to the coil for a hotter spark, but once the engine starts, battery voltage passes through a resistor which cuts the voltage to the coil. The decreased voltage, because it generates less heat, gives longer life to the points, condenser and coil. The resistor used is called a ballast resistor.

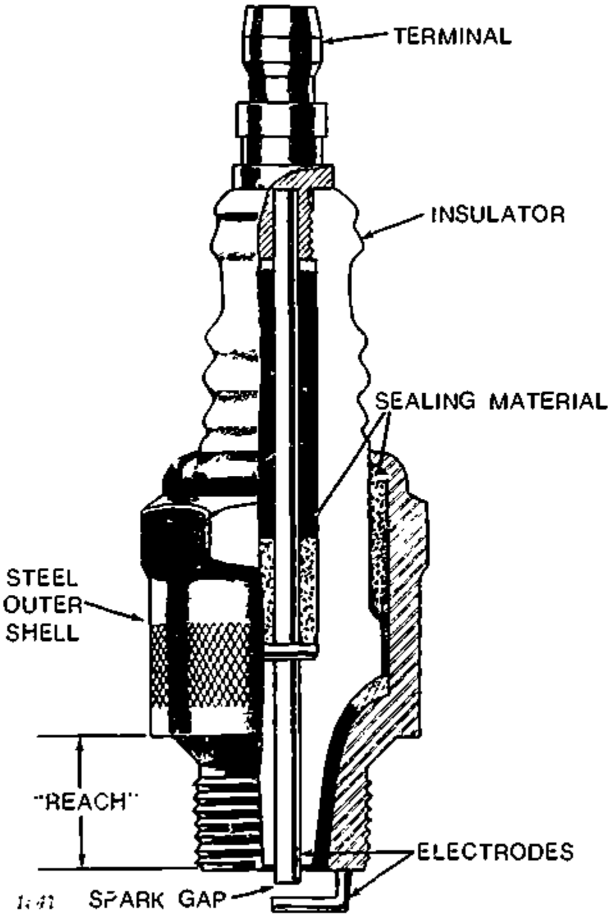
Instead of a ballast resistor, some manufacturers use a resistance wire which is connected between the ignition switch and the coil. Note that there is no bypass circuit here. When the conductor is cold at starting, virtually full voltage is sent to the coil, but as the conductor heats up the resistance increases and reduces the voltage.

SPARK PLUGS

When the topic of electrical circuits was introduced, it was said that no current flowed in an open circuit In most cases this is true. However, if the opening in the circuit is small and a strong voltage is present, the circuit can still be completed. Strong voltage will force the current to jump the opening or gap to complete the circuit. Such a jumping of current occurs at the spark plug gap to complete the ignition circuit

Spark Plug Operation

A spark plug (Figure 8-115) has two conductors or electrodes One is connected by wire to the distributor cap and the other is connected to ground The two electrodes are separated by a small opening or gap



(8-115) SPARK PLUG CONSTRUCTION
Courtesy of John Deere Ltd

The high voltage surge comes in through the terminal, travels down the central electrode and then jumps the gap to the bottom electrode. After the complex ignition action that you have seen at the coil and distributor, current jumping the gap to create a spark seems rather simple. The spark, however, is not just any spark, it must be of the correct intensity and duration to cause efficient fuel combustion. Spark plugs must be carefully constructed to give such a controlled spark

Plug Construction

All spark plugs have basically the same parts as the one shown above. Variations in plugs result from these parts being designed differently. Spark plug parts are discussed below.

Outer Shell

Each spark plug has a steel outer shell. The top of the shell is hex-shaped for tightening the plug when installing it The lower part of the shell is threaded and screws into the cylinder head. The grounded electrode extends out from the lower part of the shell A gasket slips over the threaded portion of the plug and rests against the flange at the bottom of the upper part of the shell The gasket serves two purposes. it seals the plug against compression loss and provides a path for the transfer of heat to the cooling system. Note that instead of a gasket and flat flange some plugs will use a tapered seat.

The distance from the flange to the end of the plug threads is called the reach. The reach of a spark plug is very important in plug selection A plug with too long a reach will extend too far into the combustion area Not only will the plug run hotter, but it is also in danger of being hit by a piston or valve A plug with too short a reach will run cold and cause misfiring due to fouled electrodes

The engine's Service Manual will give the exact spark plug specifications for each engine.

Spark Plug Insulator

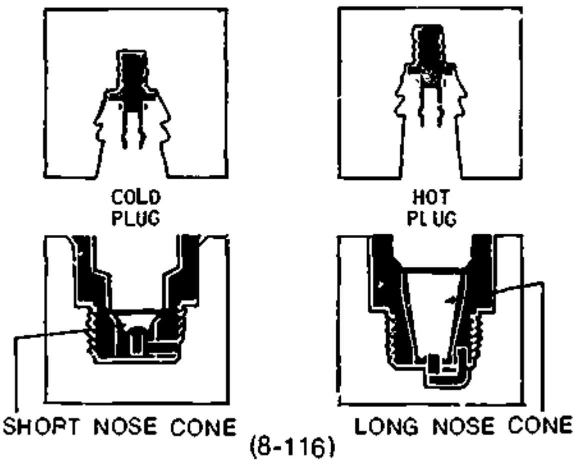
The insulated core or insulator is mounted . the outer shell Insulators are usually made of such insulating materials as white ceramic or porcelain The material must withstand extreme heat. cooling and vibration The insulator is held in position and shielded from the outer shell by an inside gasket and sealing compound Besides holding the center electrode. the insulator is a shield for the electrode so that current will flow only through the electrode The exposed upper portion of the insulator must be kept clean to prevent current from escaping Many plugs have ribbed insulators to discourage dirt build-up.

Spark Plug Electrodes

The electrodes are usually made of a metal alloy that can withstand constant burning and erosion The gap between the two electrodes is of prime importance in plug operation. This gap must be set to exact engine specifications If the gap is too narrow the spark will be weak and fouling and misfiring will result; if too wide. the gap may work well at low speeds. but at high speeds or heavy loads it will strain the coil and cause misfiring. The surfaces of the two electrodes at the sparking point or gap should be parallel and have squared corners to give the current a better jump across the gap.

Heat Range Of Plugs

The heat range of a spark plug is another important plug characteristic. Heat range refers to the plugs ability to transfer heat at the firing tip to the engine's cooling system. A plug's ability to transfer heat is determined by the distance the heat must travel. A short insulator seat quickly carries heat from the core leaving a cold plug A long insulator seat allows the core to retain maximum heat and makes a hot plug (Figure 8-116).



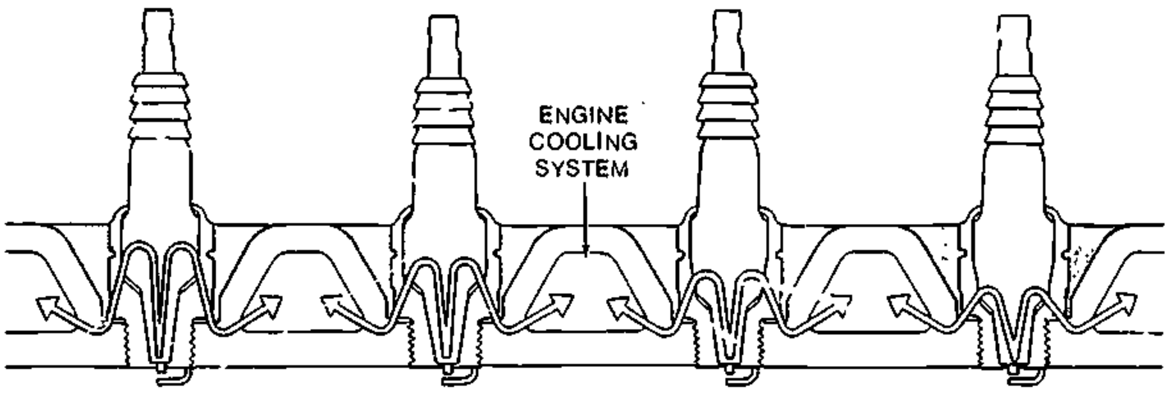
(8-116)

Courtesy of John Deere Ltd

Engine design and operating conditions will decide whether a hot or a cold plug should be used.

Generally. an engine which operates at fast speeds or heavy loads. i.e.. the engine operates hot. will require a cold plug so that the heat will transfer quickly. On the other hand. an engine that usually operates at low or idle speeds will use a hot plug. The hot plug will burn off the deposits that form on a plug's electrodes when an engine operates at low speeds for long periods of time.

Hot and cold plugs, the two extremes, are not the only plugs available. For more normal engine operations, a plug that is somewhere between hot and cold is used. In Figure 8-117 note the length of heat travel in the different plugs, as indicated by the length of the arrows.

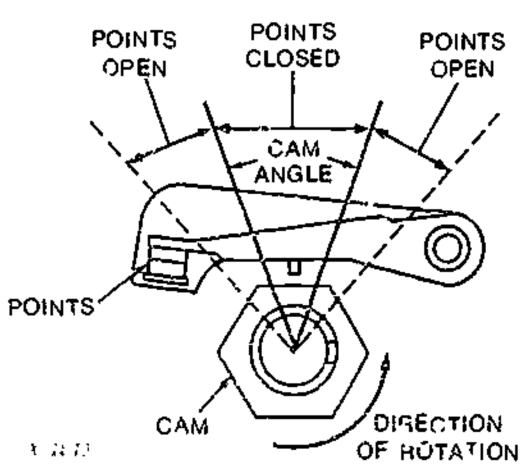


(8-117) SPARK PLUGS OF VARIOUS HEAT RANGES Courtesy of John Deere Ltd.

CAM ANGLE (DWELL) AND BASIC TIMING

Cam Dwell

Cam dwell is the number of degrees during the rotation of the cam that the points remain closed (Figure 8-1 8).



(8-118) CAM ANGLE (DWELL)
Courtesy of John Deere Ltd

Cam dwell is necessary to insure complete build-up of the magnetic field within the coil, or wha s called coil saturation. If coil saturation is not reached, the amount of induced voltage from the coil will be reduced.

Cam angle will give a low spark at high speeds and cause misfiring. Excess cam angle allows the points to remain closed too long resulting in burned points that make starting difficult.

Cam angle and timing are directly related: one degree of cam angle change equals one degree of timing change. The relationship is important because as the rubbing block on the contact points wears, the cam angle will increase and so throw the timing out.

Cam dwell defines contact point operation in terms of cam rotation and closed points. Another way to look at point operation is in terms of the length of the gap between the points when they are fully open. If points are set according to cam dwell, a dwell meter is used; if they are set by point gap, a feeler gauge is used. Both the cam dwell and the point gap should be measured to get a correct setting of the contact points.

Basic Timing

Setting the cam dwell or point gap is the first step in adjusting the distributor. The second step is called setting the basic or initial timing. Basic timing is adjusting the distributor so that the spark occurs at the correct time to give full combustion power. The distributor is adjusted by loosening the clamp and rotating the distributor in its mounting.

Basic timing is set with a timing light or stroboscope (described later) while the engine is idling and there is no influence from the centrifugal advance.

PREVENTIVE MAINTENANCE OF IGNITION SYSTEMS

Removing And Installing Spark Plugs

1 Pull the wire from the plug by grasping the terminal, not by pulling on the wire.

After loosening the plug, but before removing it, always clean the area around the spark plug by blowing, wiping, or brushing (Be sure to protect your eyes.) Cleaning in this way will prevent dirt from falling into the cylinder after plug removal.

3 Use a deep-well socket to remove the spark plugs Also remove the gaskets with the plugs (if used).

4 If the plugs are to be reused, be sure to note which cylinder each came from. The condition of the spark plug can tell you a lot about the operation of a particular cylinder

5 When replacing spark plugs, it is best to replace all of them at the same time to take full advantage of new plug performance and economy.

6 When installing spark plugs with gaskets, be sure the gaskets are in place The gaskets act as a seal to prevent loss of compression around the plug. Without a gasket, the reach of the plug would also change, affecting plug operation.

7 Remember another point about gaskets: Most manufacturers recommend installing new gaskets with both new and reconditioned spark plugs Always remove the old gasket from the spark plug Never use both the old and the new gaskets as plug reach would be affected

8 Tighten the spark plugs to the torque specified in the service manual If a torque wrench is not available, tighten the plug until you feel it seat, then turn it one-half to three-quarter turn more (With steel gaskets, tighten one-quarter turn after seating)

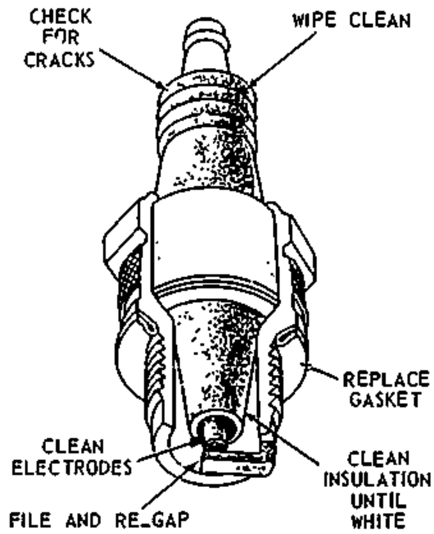
9 Connect the spark plug wires to the proper plugs

Tightening spark plugs to the correct specifications cannot be over-emphasized Over torquing at best can make the plugs difficult to remove and at worst can break the plug off at the threads Under torqued, loose plugs result in poor heat transfer and reduced plug life

SPARK PLUG SERVICING

Spark plug service has three steps (Figure 8-119)

— inspection
— cleaning
— gap adjustment



(8-119)
MAINTENANCE OF SPARK PLUGS
Courtesy of John Deere Ltd

Inspection Of Spark Plugs

In most shops the practice is to replace plugs after a reasonable service life or if they give trouble. Whether plugs are reused or not, all failed plugs should be carefully examined, as their condition can tell you many things about the state of the engine.

Cleaning Spark Plugs

Although cleaning spark plugs probably won't be a general practice, occasionally you may want to clean them.

1 A sand-blasting machine is used to remove deposits from the insulator and electrodes. Carefully inspect the plug after blasting to insure that all the sand has been removed, as engine damage could result if any was left on the plugs.

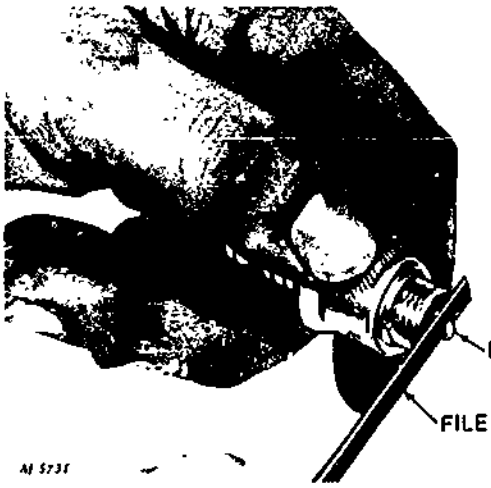
2 Do not use a power wire brush to clean the plugs Most plug manufacturers do not recommend this method.

3 Badly fouled plugs should be replaced It is doubtful that sand blasting can remove all the deposits from such plugs

4 Clean the threads with a wire hand brush or a powered soft wire brush wheel.

5 Wet, oily plugs may require cleaning with a petroleum solvent before abrasive cleaning

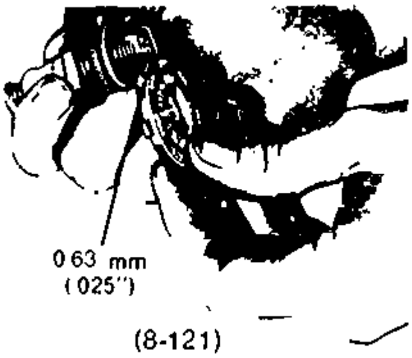
6 Before gapping the electrodes, file them with a small point file to flatten their surface at the firing point and to square up the edges (Figure 8-120). Squaring the surface edges can reduce spark voltage requirements even more than cleaning the plugs does.



(8-120)
FILLING THE SPARK PLUG ELECTRODES
Courtesy of John Deere Ltd

Adjusting Spark Plug Gaps

1 Whether a plug is new or used, always check the gap before you install it (Figure 8-121)



(8-121)
CHECKING THE SPARK PLUG GAP
Courtesy of John Deere Ltd

Use a wire spark plug gauge to check the gap The wire gauge will give a true gap reading even if the electrode surface is not flat

2. If the gap is too wide, the plug may need replacing.

3. Use a bending tool to adjust the gap to specificati... Often the bending tool is part of the ... uge as shown. After adjusting, check ... be sure the electrode surfaces are parallel.

4 Never bend the center electrode as you may crack or break the insulator tip.

ADJUSTING THE CONTACT POINT GAP OR CAM DWELL

Generally points, like plugs, are replaced after a reasonable service life or when they give trouble. If it is necessary to reuse contact points because new ones are not available, dress the contact surfaces with a fine oil stone. Be sure to clean the points thoroughly before installing them.

The correct way to set points is first with a feeler gauge and then with a dwell meter. If a dwell meter is not available extra care should be taken with the feeler gauge settings.

1. Adjust points with a feeler gauge: With the breaker cam positioned so that the rubbing block touches a cam lobe at its highest point, adjust the points with a feeler gauge to manufacturer's specifications

2 Adjust points with a dwell meter: A dwell meter can be part of a distributor machine or it may be a separate portable unit. The latter is the most likely to be found in a heavy duty shop Following directions, connect up the dwell meter, crank the engine and adjust the points to the specific dwell angle.

Note:

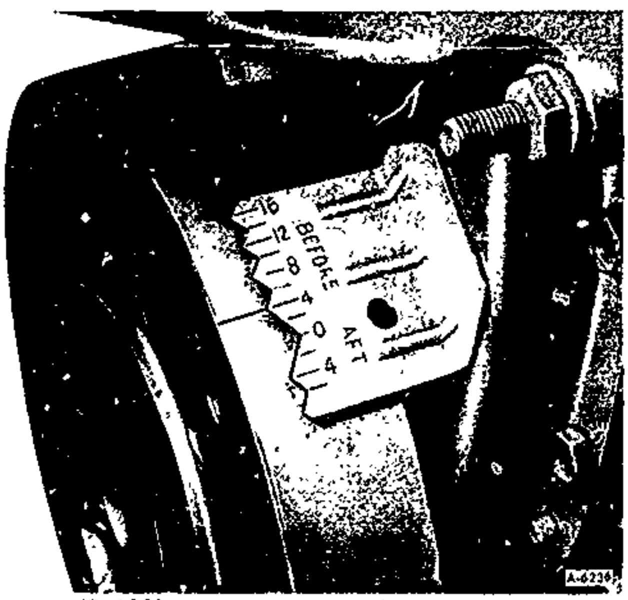
If the cam angle reading on the meter varies more than two degrees between lobes look for a worn drive shaft or bushings.

If a problem is encountered in trying to obtain the correct setting, check for the following possibilities:

— improper spring tension
— wrong contact point assembly
— worn breaker cam
— worn distributor shaft and bushing

USE OF TIMING LIGHT

Once the point gap or cam dwell has been adjusted, the basic or initial timing can be set. Basic timing is done while the engine is idling. The object of basic timing is to match up the timing mark on the turning crankshaft pulley (on the flywheel on some older engines) with a fixed mark or timing pointer on the timing cover or housing. To match up these marks a timing light (a stroboscopic light) is used. The timing light is connected to the vehicle's battery and to the number one cylinder spark plug lead. Every time number one cylinder fires, the light will flash. Directed at the fixed mark and the crankshaft pulley, the flashing light will make the pulley appear to stand still, and you will be able to see how far the two marks are out. Once you have seen that the timing is out, loosen the distributor holding clamp and while still watching the timing light turn the distributor one way or the other to bring the two marks together (Figure 8-122). With the marks matched up, tighten the holding clamp, stop the engine and remove the timing light.



(8-122) TIMING MARKS (TYPICAL)
Courtesy of General Motors Corporation

Two points to note when setting the timing:

1. Be sure the idle speed is as specified by the manufacturer.
2. Most manufacturers recommend that the vacuum line to the advance unit be disconnected when setting basic timing. Don't forget to reconnect the line after the timing has been set.

WIRING HARNESS

Wiring for electrical accessories in vehicles is bound together in trunk lines called a wiring harness. A vehicle may have four or five harness lines supplying electricity to different parts of the vehicle. Branch wires come off the harness trunk and connect up to their specific accessories. The harness sheath can be made of rubber, cloth, plastic, plastic tubing or can simply be electrical tape wrapped around the wires. Two points when working on a harness:

1. Care must be taken when installing a harness not to interfere with any moving parts of the vehicle. Install clips correctly so that they do not pinch the wires and cause short circuits.
2. Individual wires can be replaced by running a new wire around the harness. Do not try to thread new wires through the harness. Attach the new wires to the harness with tape or clips. Be sure to cut off the defective wire right where it comes out the harness.

Replacing Wiring

1. Since the size of wiring is related to the load it must carry, always replace a defective wire with the same gauge wiring as the original. Never use undersized wiring because it will overheat and possibly burn through.
2. When installing additional accessories on a vehicle, such as extra lights, and an existing circuit is used, the circuit may have to be rewired with heavier wire to carry the au[illegible] load.

   The gauge or size of an electrical wire depends on:

   (a) Total length of the wire in the circuit.

   (b) Total amperes that the wire will carry.

   Refer to a wire catalogue for wire size and load carrying capacity.
3. When replacing a faulty wire end, it is best to solder the connection onto the wire. Use only rosin core solder. The other alternative is a crimp-on wire connector. Crimp-on connections are okay in a clean environment, but if they are used in a corrosive area the connections tend to deteriorate. Crimp-on connectors should be fastened with crimping pliers.

FUSES

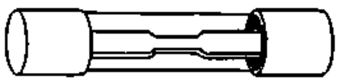
From the discussion on basic electricity you remember that given a set voltage source, such as a battery, the amount of current is governed by the amount of resistance in the circuit. You can see the current — resistance relationship in the formula:

$$\text{amps} = \frac{\text{volts}}{\text{ohms}}.$$

As the resistance (ohms) gets greater the current (amps) gets smaller, and vice versa, as the resistance gets smaller the current gets greater.

In a vehicle all electrical circuits have a resistor of some kind to control the amount of current flow. What would happen, though, if an overload or a short circuit occurred? Current would rapidly increase to the point where the wire would burn up. To protect against such excessive amounts of current, fuses or circuit breakers are connected to the circuit. When the current gets beyond a safe level the fuse blows, breaking the circuit and stopping the flow of current

A fuse consists of a fine wire or thin metal strip enclosed in a glass or fire resistant piece of tubing Most fuses used in industrial equipment are of the small replaceable type as shown in Figure 8-123.



(8-123)

Courtesy of John Deere Ltd

The fuses for all the circuits in the vehicle are located in a central fuse panel where they can be easily replaced.

Points On Fuses

1 BLOWN FUSES ARE USUALLY CAUSED BY:

(a) A short circuit in the electrical circuit caused by defective wiring or a defective component (lights, motor, etc)

(b) An overload in the circuit caused by a surge of electricity passing through the circuit.

(c) Poor contacts in the electrical circuit

(d) Overheating in the circuit caused by overloads or poor contacts.

(e) Use of incorrect size fuses in the circuit.

(f) Fuse located too near a hot area such as an engine or a heater.

(g) Vibrations near the fuse, causing the fuse contacts to come loose.

2. If a fuse is blown by overloading the glass will be clear; if blown from a short circuit the glass will be dark.

3 If the fuse in a circuit repeatedly blows, and no short circuit exists, it means that the circuit is overloaded and is not meant to carry the loads being placed upon it.

4 Always replace a blown fuse with one of the same size. Never use a fuse with a higher amperage rating as it may cause serious damage to the circuit it is supposed to protect.

QUESTIONS — IGNITION CIRCUIT

1. Briefly slate the purpose of the ignition system
2. What are the two circuits of an ignition system. State what each circuit consists of and what, in general terms, is the voltage.
3. What is the purpose of the primary circuit in the ignition system?
4. What occurs in the ignition coil when the points open?
5. Self-induced voltage in the primary winding of the coil is absorbed by the.
   (a) wires
   (b) battery
   (c) distributor
   (d) condensor
6. The ignition ballast resistor in the primary circuit:
   (a) is connected in series for cranking and parallel for operation.
   (b) is connected to bypass for starting and series for operation
   (c) is used to decrease ignition current during cranking
   (d) is only required for dual ignition systems.
7. In the ignition coil one end of the secondary winding is connected to the high tension terminal and the other end to the
   (a) rotor
   (b) primary winding
   (c) condensor
   (d) points
8. How can reverse coil polarity be corrected?
   (a) change the battery polarity
   (b) change the ignition coil
   (c) reverse the secondary wires
   (d) reverse the primary wires
9. What three jobs must the distributor perform?
10. The distributor is driven at:
    (a) crankshaft speed
    (b) one-half crankshaft speed
    (c) twice crankshaft speed
    (d) one-quarter crankshaft speed
11. The centrifugal advance mechanism controls the spark timing by sensing engine:
    (a) temperature
    (b) power
    (c) speed
    (d) oil pressure
12. A __________ is used in conjunction with a centrifugal advance mechanism to improve spark timing.
13. A ballast resistor used in the ignition system improves the life of the:
    (a) coil
    (b) condensor
    (c) points
    (d) all the above
14. A spark plug:
    (a) makes the spark to fire the air-fuel mixture
    (b) increases the spark intensity
    (c) controls the spark timing
    (d) provides a gap for the spark to jump across inside the combustion chamber
15. What term is used for spark plug operating temperature?
    (a) heat travel
    (b) reach
    (c) the number system
    (d) heat range
16. What determines the heat range of a spark plug?
    (a) engine horsepower
    (b) number of cylinders
    (c) engine design and operating conditions
    (d) whether the engine is a two stoke or four stroke

17 Dwell may be defined as the number of degrees of cam rotation when the points are ______

18 As the cam angle increases the spark timing will

(a) advance

(b) retard

(c) not change

19. What two methods can be used to set the points?

20 What are the effects of loose or under-torqued spark plugs?

21 True or False? Generally speaking, spark plugs should be replaced as a set

22. True or False? Badly fouled plugs should be replaced rather than cleaning them.

23 What effect does filing the gap have on a used spark plug's performance?

24 What is the recommended tool for checking spark plug gap?

(a) flat feeler gauge

(b) stepped feeler gauge

(c) wire feeler gauge

(d) dial indicator

25 When adjusting the initial timing using a timing light, it is recommended that the engine be ________ and the ____________ be disconnected

26 The gauge or size of electrical wiring depends on

(a) the size of battery

(b) the total length of the wire in the circuit

(c) the total amperage that the wire will carry

(d) both (b) and (c) are correct

27 True or False? If a fuse keeps blowing and there is no short circuit, put in a heavier fuse

28 To obtain the best possible connection when replacing wire ends, they should be

(a) crimped on

(b) pushed on

(c) soldered on

ANSWERS — ELECTRICITY THEORY

1. (b) negative to positive.
2. (c) energy.
3. True.
4. Voltage is the force that causes current to flow in a conductor.
5. (d) ohm.
6. Voltage source, e.g., battery
   Resistor, e.g., light bulb
   Conductor, e.g., copper wire
7. (a) to (b)
   (b) to (c)
   (c) to (a)
8. $I = \frac{E}{R} = \frac{12}{4} = 3$ amperes
9. Any substance that is a good transmitter of electricity.
10. A closed circuit has a resistor to control the amount of current flowing in the circuit. In a short circuit the current takes a short cut by passing the resistor. Since the short circuit has no resistor, current becomes very high and will usually burn out the conductor (or fuse if there is one).
11. . . direct DC
12. Watt a measurement of electrical power found by multiplying volts times amperes
13. Series, Parallel, Series-Parallel
14. (c) low resistance high amperage.
15. . . . magnetic field. Like poles repel. unlike poles attract
16. Both have a magnetic field surrounding them. The stronger the current in a conductor, the stronger its magnetic field.
17. Place an iron core in the center of the coil.
18. (d) ampere turns
19. Electromagnetic induction
20. False Either the conductor moving across the field or the field across the conductor will induce a current.
21. (a) to (c)
    (b) to (a)
    (c) to (b)
22. (d) red for positive, black for negative
23. 1. Strength of the magnetic field.
    2. The speed at which the lines of force are cut.
    3. The number of conductors cutting across the lines of force.
24. . . . move towards . . .
25. . . move away from . . .

ANSWERS — BATTERIES

1 (c) lead peroxide in the positive plate.

2. negative plate group
   positive plate group
   separators and connecting straps

3. When it is immersed in the electrolyte

4. (d) 2-volts.

5. True.

6. (d) 1.270

7. True

8. (c) water

9. Prior to use, a dry-charged battery retains its full state of charge provided no moisture enters the cells, whereas a wet charged battery requires periodic recharging to maintain its charge

10. Wet-charged.

11. The plates are enclosed in envelopes which act as separators.

12. They require less maintenance, are more dependable and will last longer.

13. Temperature, battery's operating cycle, and the state of the battery's charge.

14 Cold power rating — the amount of power or amperage that a battery will supply for starting on cold days.

   Reserve capacity — the period of time that a battery by itself (i.e., without the generator or alternator) will supply an adequate amount of power to operate a vehicle's electrical circuits.

15 False.

16. . . . the power requirements of the engine it must start.

17. . . . self discharge.

18 (b) baking soda

19 (d) water

20 (c) disconnect the grounded terminal cable

21 (d) all of the above are necessary.

ANSWERS — BATTERY TESTING

1. (a) a hydrometer
2 (d) 030
3. (b) 9.6-volts
4 1-volt
5. True
6. A load test.

ANSWERS — BATTERY CHARGING

1 (b) 7 amps — 7 positive plates and 8 negative plates.

2 A slow charger because it does a more thorough job of chemically renewing the plates.

3 (b) series.

4 1 The temperature should not exceed 15 C (125 F)

1 The electrolyte shouldn't become cloudy with sediment.

5 (b) Hydrogen

6 False. It is damaging to batteries to overcharge them

7 (c) disconnect a battery cable

8 (a) a longer charge

9 . off . .

10 False

ANSWERS — STARTER MOTOR

1 (d) mechanical energy.

2 True

3 (b) a force to be exerted on the conductor

4 (c) movement of a magnetized core into and out of an electromagnetic coil.

5 The magnetic switch completes the circuit between the battery and the starter motor, whereas the solenoid not only completes the circuit, but also provides a mechanical means of shifting the starter motor pinion into mesh with the flywheel.

6 (a) connect two batteries in series for starting and in parallel for charging.

7. 1 Transmits drive torque from the starter motor to the engine flywheel

   2 Provides a gear reduction.

8 (c) remove the battery ground strap

9. Centrifugal force acts on the counterweight and causing the pinion to spin into and out of mesh with the flywheel.

10 . . . overrun . . .

11. . . . magnetic . . . solenoid . . .

ANSWERS — CHARGING SYSTEM

1. (b) supplies all current.
2. (c) a commutator and brusnes.
3. 1. opens and closes the charging circuits.
   2. prevents overcharging of the battery.
   3. limits the generator's outout to a safe limit
4. (c) diodes
5. (a) Limit the voltage to a safe value.
6. In a generator current is induced by moving conductors through a stationary field.

   In an alternator current is induced by moving a field by a stationary conductor.
7. True.

ANSWERS — IGNITION CIRCUIT

1 To take low voltage from the battery and create high voltage to fire the engine.

2 Primary Circuit — ignition circuit. primary winding in coil. points and condenser. low voltage.

Secondary Circuit — secondary winding in coil. distribution cap and rotor and spark plugs; high voltage.

3 To create and collapse a magnetic field in the ignition coil.

4 The magnetic field created by the current flow through the primary winding collapses across the secondary winding inducing a high voltage in the secondary winding.

5 (d) condenser

6. (b) is connected to bypass for starting and series for operation.

7 (b) primary winding

8 (d) reverse the primary wires

9 1. opens and closes the primary circuit.
   2 times the high voltage surges.
   3 delivers the current to the spark plugs.

10. (b) one-half crankshaft speed.

11 (c) speed

12. . . vacuum advance . . .

13. (d) All of the above.

14. (d) provides a gap for the spark to jump across inside the combustion chamber.

15. (d) heat range

16. (c) engine design and operating conditions.

17 . . closed.

18. (b) retard

19. Use a dwell meter to set the cam dwell. or a feeler gauge to set the point gap. The dwell meter is the most accurate method.

20. Poor heat transfer which will shorten plug life.

21. True.

22. True.

23. Filing reduces the voltage requirement to send a spark across the gap.

24. (c) wire feeler gauge.

25. . . . idling . . . vacuum line to the advance . . . .

26. (d) both (b) and (c) are correct.

27. False.

28. (c) soldered on.

ELECTRICITY TASKS

BATTERIES

Preventive Maintenance On Batteries

1. Safely use jumper cables to start a vehicle.
2. Completely service a battery:
   - (a) Remove the battery using correct tools and safety procedures.
   - (b) Clean the battery with baking soda and water and dry off the case.
   - (c) Check the water level and add water if low.
   - (d) Test the battery as accurately as you have equipment for. If you have a battery test meter, follow the meter's operating instructions.
   - (e) Charge the battery. Get experience using both slow and fast chargers.
   - (f) Install the battery ensuring that the battery box and holddown are in good condition.

STARTING MOTOR AND GENERATOR

Safety

1. Practice safety by disconnecting the battery before working on any electrical component to prevent short circuits.

Routine Maintenance Check

1. Check the condition and tension of the generator belt(s). If necessary adjust the tension. If the belt(s) are not serviceable install and adjust a new one(s).
2. Check the condition of the generator pulleys, and repair or replace, if necessary. Check pulley alignment.

Service Repair

1. Remove and install a starter motor and a generator using the correct tools and procedures outlined in the service manual.

IGNITION SYSTEM

1. Service the spark plugs on an engine. Remove the plugs, clean, gap and reinstall them, or if the plugs are not serviceable replace them with ones of the correct type and heat range as stated in the service manual. Using a torque wrench, tighten the plugs to the torque given in the service manual.
2. If ignition testing equipment is available, check and adjust dwell and ignition timing to the specifications stated in the service manual.
3. Get experience working with electrical wiring:
   - (a) Select correct wire sizes.
   - (b) Solder wire ends using rosin core solder.
   - (c) Fuse circuits for a safe amperage draw.
   - (d) Install a light or similar electrical component, ensuring it has good grounding.

BLOCK

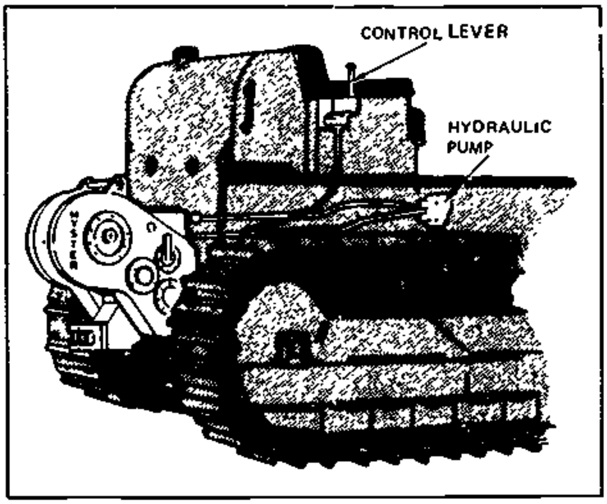
9

Winches

TRACTOR MOUNTED WINCHES

A tractor mounted winch (Figure 9-1) is a simple gear reduction assembly mounted at the rear of the machine. By using cables, these winches can reel in heavy loads or hold the loads while they are dragged The winches are driven either by a:

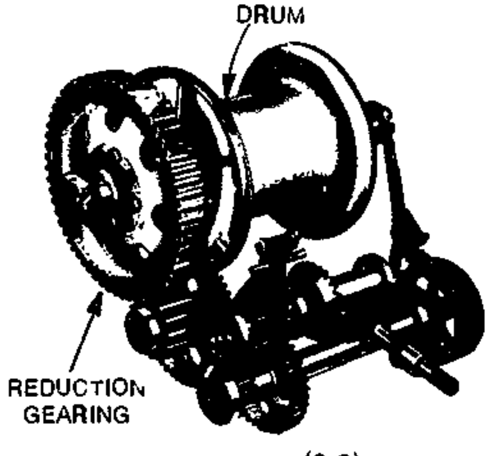
1. Live power take-off (P.T.O.) shaft (Figure 9-2) from the torque converter
2. Live P.T.O. shaft from a manual transmission (not common today)
3. Hydraulic motor.



(9-1)

Courtesy of Hyster Company

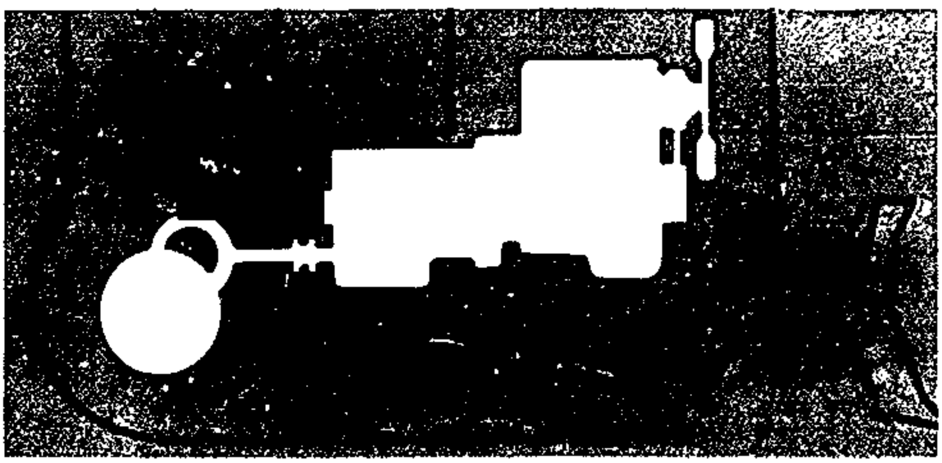
Drums on winches are large, spool-shaped, steel castings. They're driven by the winches reduction gearing (Figure 9-3). Cable (wire rope) is attached to the drum and is wound onto the drum's surface or lagging.



Constant mesh gear train (9-3)

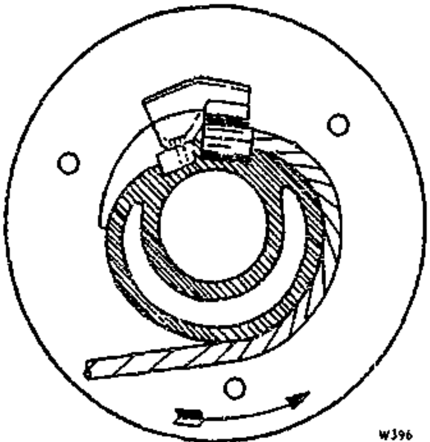
Courtesy of Carco Winch Products

Most crawler tractors have single drum winches However, some special application tractors will use two or more drums and each drum will have its own controls. For example, multiple drum winches would be used on a tractor doing yarding work in logging or on a tractor working in electrical transmission line construction. The discussion in this manual limits itself to single drum winches.



(9-2) Courtesy of Caterpillar Tractor Company

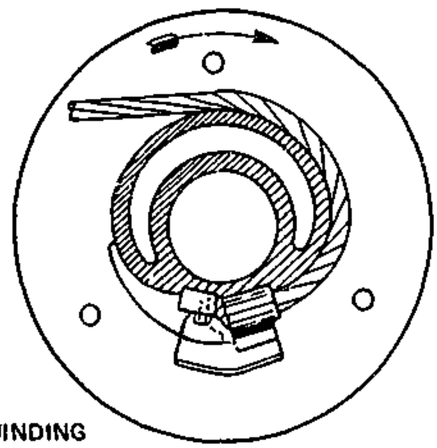
Cable may be wound onto the drum in one of two ways overwind or underwind Overwind winds from the top of the drum and underwinds from the bottom (Figure 9-4)



UNDERWINDING

(9-4)

Courtesy of Hyster Company



OVERWINDING

(9-4)

Courtesy of Hyster Company

There are advantages and disadvantages in both ways of winding. Overwind lifts the load so it doesn't dig in. but when loads are heavy this lifting can cause the tractor to rear. Conversely. underwind gives a straight pull that won't cause the tractor to rear but the load will have a tendency to dig in. Unless an underwind is requested. winches come from the factory set for overwind.

It is a major job to change from overwind to underwind or vice versa. Internal changes to both the winch gearing and the line position have to be made. Also. if the machine has an automatically applied mechanical brake. it too requires alterations.

TRACTOR WINCH RATINGS

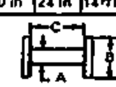
Tractor winches are rated according to their "line pull" and their "line speed". Line pull means the maximum amount (in kilograms or lbs.) of pulling strength a winch can exert on its cable. while line speed is simply the speed at which the cable travels faster. Line speed will vary with the tractor horsepower. the size of the drum. and the layers of cable wrapped around the drum (i e.. cable travels slower as more of it wraps around the drum) Drum size (i.e.. cable capacity) is another factor in rating a winch. One manufacturer's ratings or specifications for its different winch models are shown in Figure 9-5

Performance and Specifications (9-5)

PS/PSM (Power Shift/Power Shift Manual)

MODEL		APPROXIMATE SHIPPING WT	BARE DRUM LINE PULL	LINE SPEED (depending on tractor H P)	CABLE CAPACITIES								DRUM DIMENSIONS		
					1⅛"	1¼"	1"	⅞"	¾"	⅝"	9/16"	½"	A	B	C
F-50	Std. Drum	2427 lb	50 000 lb	50 to 150 fpm			180 ft	230 ft	300 ft	440 ft			11 in	19 in	12½ in
F-50	Hi-Cap. Drum	2427 lb	50.000 lb	50 to 150 fpm			215 ft	305 ft	420 ft	600 ft			6 in	19 in	13¾ in
G-80	Std. Drum	3254 lb	80.000 lb	50 to 150 fpm		185 ft	250 ft	340 ft	475 ft				12 in	22 in	13¼ in
G-80	Hi-Cap. Drum	3254 lb	80.000 lb	50 to 150 fpm		250 ft	315 ft	420 ft	575 ft				9 in	22 in	14¾ in
J 20	Std. Drum	4056 lb	120 000 lb	50 to 150 fpm	165 ft	200 ft	270 ft	360 ft					13 in	24 in	12 in
J-120	Hi-Cap. Drum	4056 lb	120.000 lb	50 to 150 fpm	225 ft	300 ft	400 ft	525 ft					10 in	24 in	14½ in

NOTE Performance figures based on power takeoff at full engine throttle Winch line speeds will vary with torque converter output which is dependent on engine load and speed



Courtesy of Garco Winch Products

TYPES OF SINGLE-DRUM TRACTOR-MOUNTED WINCHES

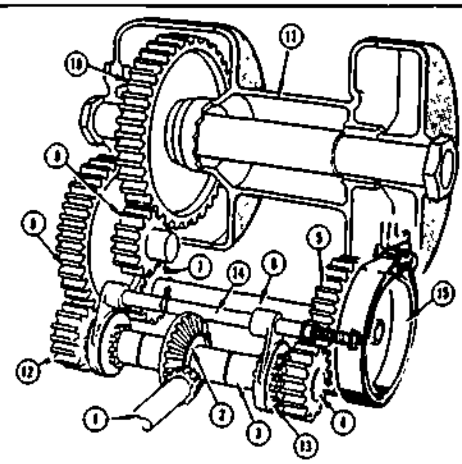
There are three main types of tractor-mounted winches

1. direct drive — sliding gear
2. power shift — hydraulic control constant mesh gear
3. hydraulic drive

Direct drive and power shift winches are driven by the tractor engine through use of a P.T.O. shaft. A hydraulic drive winch is driven by a hydraulic motor.

DIRECT DRIVE SLIDING GEAR

A simplified view of a direct drive sliding gear winch is shown in Figure 9-6. A direct drive winch has no clutch. Before the winch can be shifted, the master clutch between the engine and transmission has to be disengaged so that power to the P.T.O. shaft is interrupted.

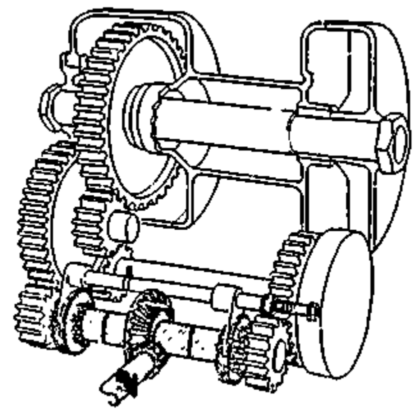


1 PTO SHAFT
2 BEVEL GEAR
3 BEVEL GEAR SHAFT
4 2ND REDUCTION PINION
5 2ND REDUCTION GEAR
6 BRAKE SHAFT
7 INTERMEDIATE PINION
8 INTERMEDIATE GEAR
9 DRUM PINION
10 DRUM GEAR
11 DRUM
12 INTERMEDIATE PINION
13 CLUTCH
14 SHIFTER SHAFT
15 BRAKE WHEEL

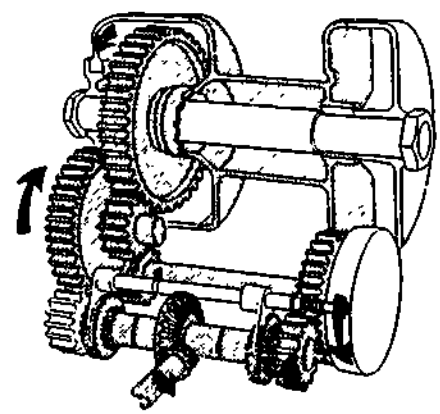
(9-6)

Courtesy of Hyster Company

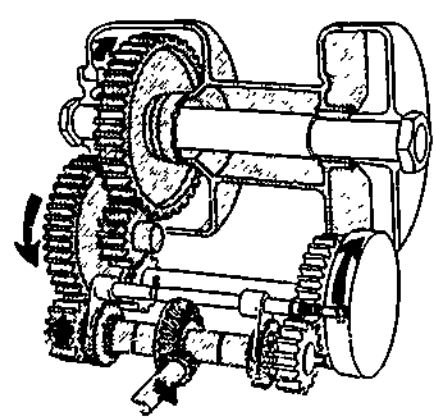
Figure 9-7 shows the power flow or gear movement when the winch is in neutral, forward and reverse. The shaded gears and shafts are moving, the unshaded ones are stationary. The gear positions would be mechanically actuated by a shift lever after the engine clutch had interrupted power to the P.T.O. shaft. Note that free spool for quick wind out can be obtained by releasing the brake when the winch is in neutral.



(9-7) NEUTRAL, DIRECT DRIVE



(9-7) FORWARD, DIRECT DRIVE

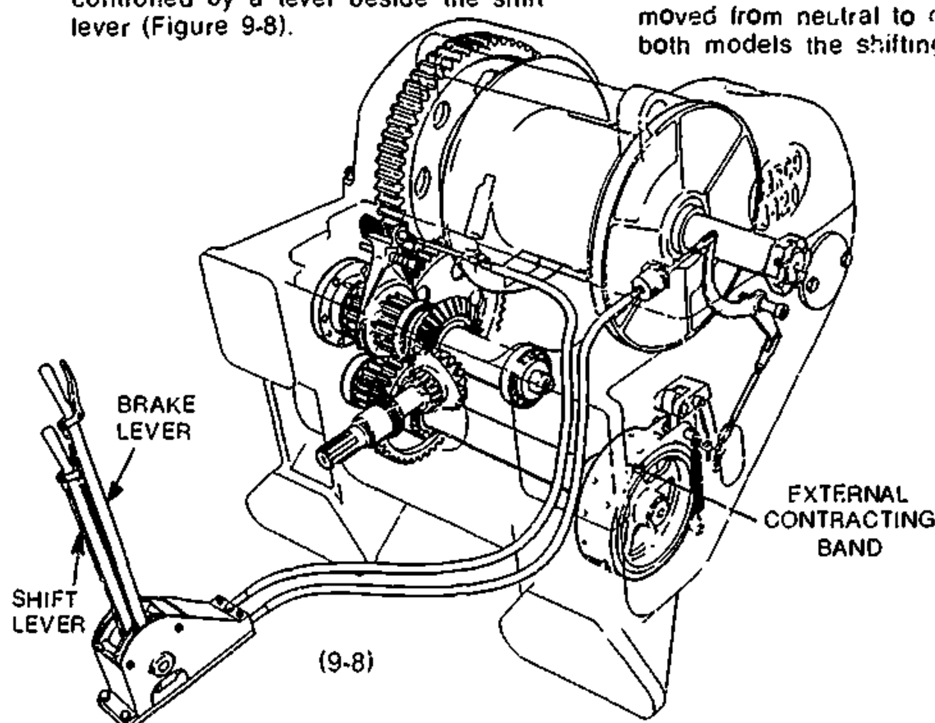


(9-7) REVERSE, DIRECT DRIVE

Courtesy of Hyster Company

Other points about direct drive winches

- Lubrication is by splash. The winch case or housing serves as the oil reservoir and it has drain, fill, and oil level plugs
- Line pull power is controlled by the engine speed.
- Brakes for these winches are usually an external contracting band-type located outside the gear case in a separate compartment. The band contracts around a gear shaft, thus holding the gear and stopping the drum from turning. The brake is a dry-type and is controlled by a lever beside the shift lever (Figure 9-8).



(9-8)

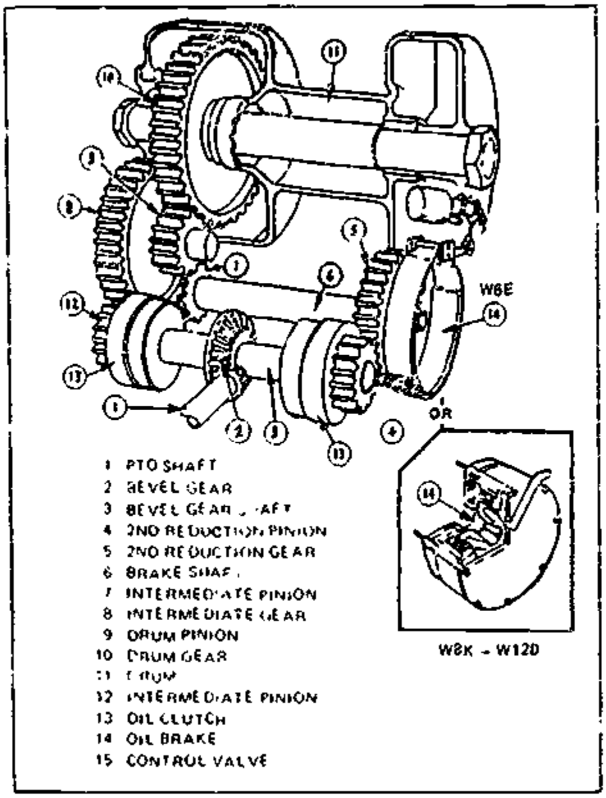
Courtesy of Carco Winch Products

POWER SHIFT WINCHES

A power shift winch has virtually the same drum and set of gears as a direct drive winch. Both winches are driven by a live P.T.O shaft Where they differ is in the way that the winches are shifted To shift a direct drive winch the engine master clutch is disengaged and the winch s sliding gear is mechanically shifted. Power shift winches, on the other hand, have hydraulically activated clutch packs and constant mesh gears for shifting. Two clutch packs are used, one forward and one reverse A hydraulic pump, located either outside or inside the winch supplies the pressure and flow to operate the clutch packs. Power shift winches have the advantage over direct drive winches of being able to winch-in or winch-out while the machine is moving. Figures 9-9 and 9-10 show power shift winches.

Power shift winches have either a single or double lever control The double lever model has one lever for shifting into forward, reverse or neutral and another lever to apply the brake A single lever model carries out all of these operations with one lever: the brake is applied automatically when the lever is moved from forward or reverse to neutral, and vice versa, the brake is released when the lever is moved from neutral to one of the gears. On both models the shifting lever activates the hydraulic control valve which sends hydraulic pressure to apply one of the multi-disc clutch packs. The clutch packs then set the constant mesh gears in a forward or reverse mode. Generally, brakes on power winches are spring applied and hydraulically released The brakes are external contracting band or multi-disc.

Power shift winches, like direct drive winches, can free spool. Some manufacturers offer an optional free spool lever which operates a disconnect gear that allows cable to be freely drawn from the drum. In the case of a single lever power shift, the lever has a free spool position where the winch is in neutral and the brake is not applied. Figures 9-9 and 9-10 show power shift winches, note the clutches

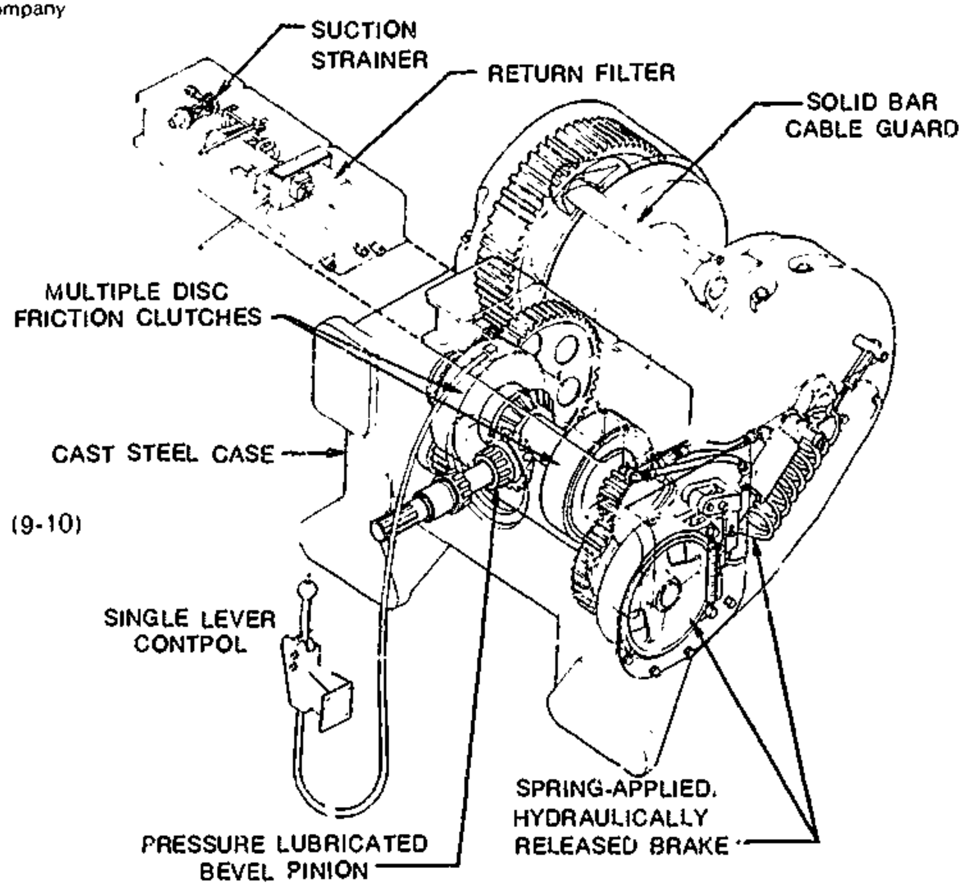


Courtesy of Hyster Company

The housing of both powershift and direct drive winches serves as an oil reservoir. However, lubrication is only partly by splash. The remainder of the lubrication (and cooling) is carried out by pressure fed oil. The oil is pressurized from an engine driven pump.

(9-9)

Power Controlled



(9-10)

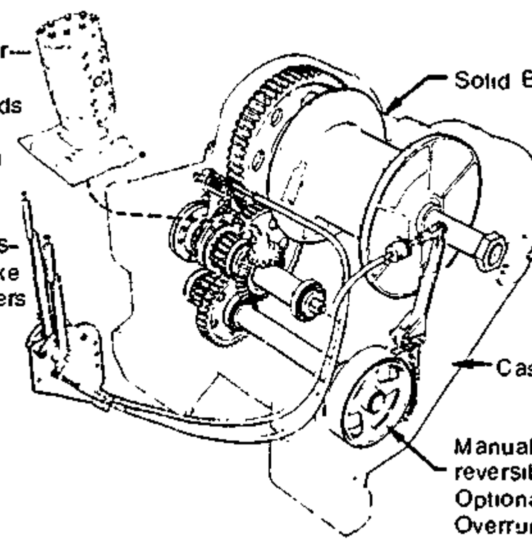
Courtesy of Carco Winch Products

HYDRAULIC WINCHES

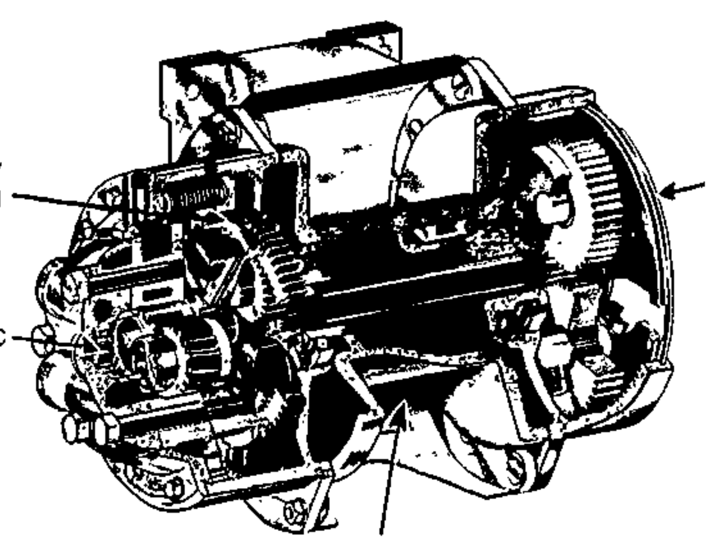
Hydraulic winches can be installed on any vehicle that has an adequate hydraulic system They are not limited to crawlers. The main advantage of a hydraulic winch over P T O shaft-driven power shift and direct drive winches is that the hydraulic winch can be mounted wherever you want it providing that hydraulic lines can be connected to it.

Two types of hydraulic winches, sliding gear and planetary, are illustrated in Figures 9-11 and 9-12 and are discussed below.

The sliding-gear hydraulic winch works the same as the direct drive model described earlier. The only difference is that it's driven by a hydraulic motor rather than by a P.T.O. shaft. The hydraulic motor is driven by a hydraulic pump mounted on the engine. The planetary model shown here has two planetary gear sets, one in the primary drive housing and one in the final drive housing. The primary drive housing contains a hydraulic motor which drives the sun gear of the primary reduction gear set The ring gear is held by a spring-applied brake, and output power is transmitted by the planet carrier to a shaft which passes through the center of the



(9-11) SLIDING GEAR HYDRAULIC DRIVE WINCH
Courtesy of Carco Winch Products



(9-12) PLANETARY HYDRAULIC DRIVE WINCH
Courtesy of Gearmatic Company

winch barrel to the sun gear of the final planetary reduction. The ring gear in the final planetary is also held. The planet carrier is connected directly to the winch drum by a splined hub and thus transmits power to the drum. In this planetary arrangement a double reduction is obtained. Note that the planetary gear sets operate in either direction depending on which way the hydraulic motor is driven.

Two types of brakes are used on this planetary winch; one brake permits a high reverse line speed and the other gives a uniform line speed in both reel-in and reel-out directions. Lubrication is by splash, as it is in the sliding gear hydraulic winch.

Hydraulic planetary winches are very common and are available in a variety of sizes and capacities.

Winch clutches, brakes and hydraulic systems are described below.

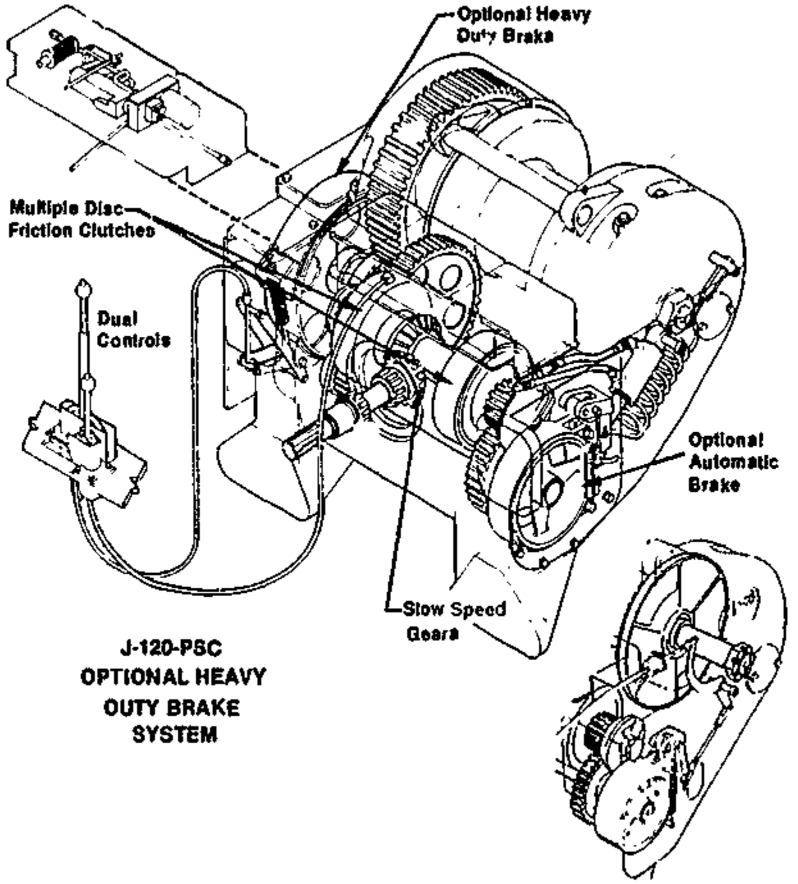
WINCH BRAKES

There are two main types of winch brakes:

1. External contracting band brakes
2. Multi-disc brakes

EXTERNAL CONTRACTING BAND BRAKES

External contracting band brakes are the same type of brakes that are used for crawler steering. The band brake works in conjunction with forward and reverse gears giving control over the load when it is being raised or lowered. Some band brakes are manually applied with a separate lever, whereas others are applied automatically. Automatic brakes are usually spring-applied and hydraulic-release. Hand applied brakes are used where more accurate winch control is desired. In the powershift winch in Figure 9-13 the automatic band brake is shown on the winch, while the manual brake is inset. Note on the automatic brake the hydraulic release cylinder and the large brake apply spring. Also note the optional heavy duty brake just to the left of the large gear driving the drum. Some winch models offer dual braking for added safety and load control. This second band brake is lever applied.

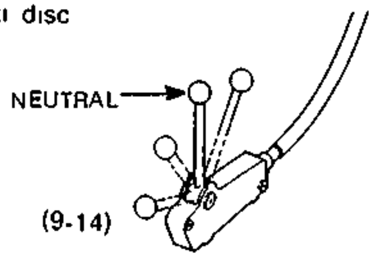


(9-13) STANDARD MANUAL BRAKE SYSTEM
Courtesy of Carco Winch Products

AUTOMATIC BRAKE OPERATION

AUTOMATIC BRAKE ON POWERSHIFT WINCHES

The brake is applied in neutral position (Figure 9-14) When the control lever is moved away frc ~eutral. eithe' to reel-in or reel-out position. oil pressure is fed to the brake release cylinder to release the brake At the same time oil is sent to the clutch packs to engage the clutch. Moving the control back to neutral simultaneously releases the clutch and dumps oil from the brake release cylinder allowing the brakes to be spring applied The brake itself can either be a contracting band or multi disc

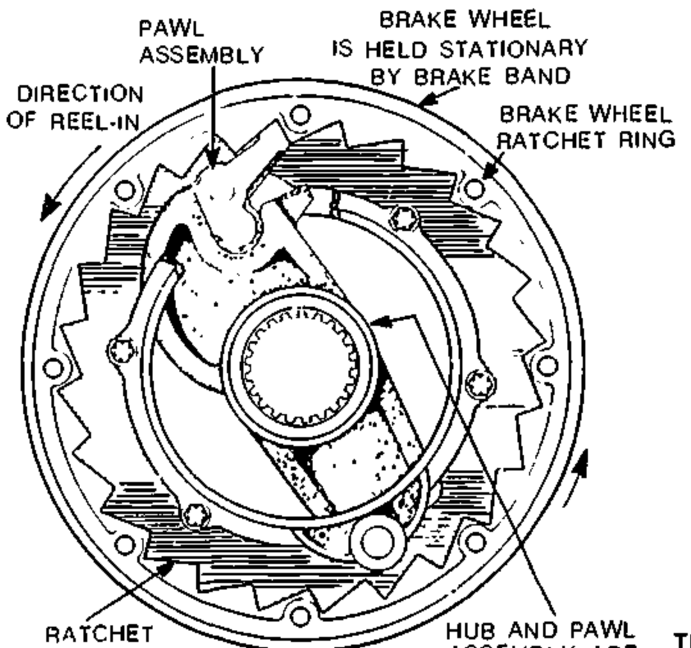


(9-14)

Couresty of Carco Winch Products

AUTOMATIC BRAKES ON DIRECT DRIVE WINCHES

One manufacturer of winches. Hyster. has an over-running brake referred to as automatic. This brake is offered as an option to the standard brake band. Its operation is shown in Figure 9-15 and described below.



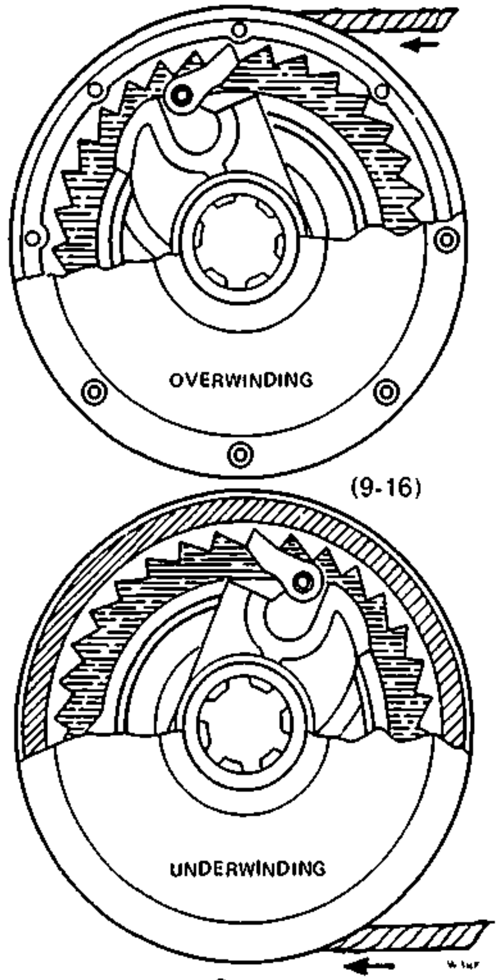
(9-15)

Courtesy of Hyster Company

The brake wheel is held stationary by a brake band that is applied with a lever. The hub is splined to a driven shaft. and the hub and pawl assembly rotate around the inside of the brake wheel ratchet ring. When cable is reeled in. the panel slides over the ratchet ring When the control is moved from reel-in to neutral. the pawl engages with the nearest ratchet tooth and locks the hub to the brake wheel automatically stopping any further feed out.

If cable reel-out or free spool is desired the band brake is released by the brake lever. When the band is released. the brake wheel will revolve with the engaged pawl assembly and the cable will feed out.

This automatic brake can be used for underwind or overwind. Overwinding is stamped on one side of the brake assembly. and underwinding on the other side (Figure 9-16).



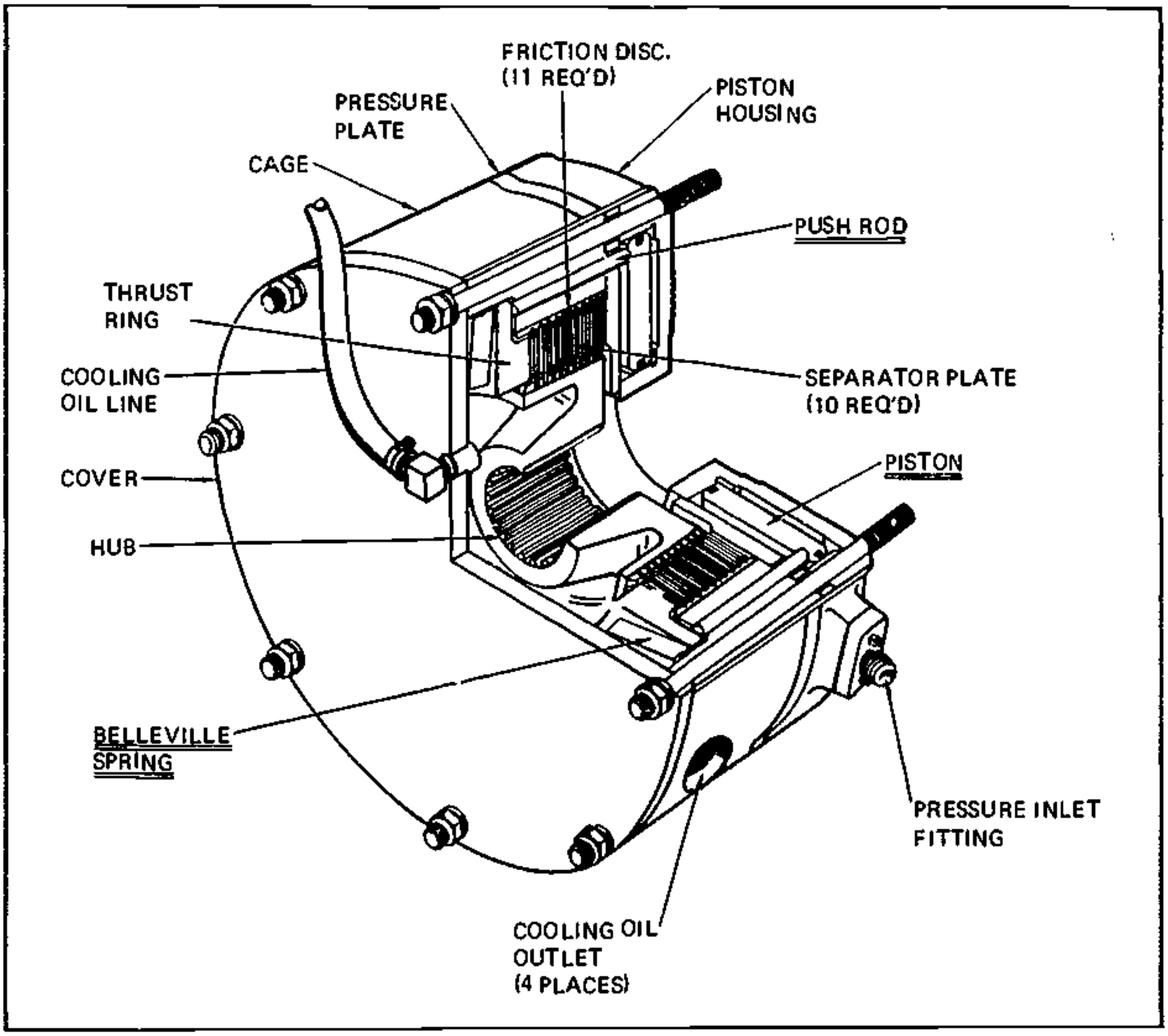
(9-16)

Courtesy of Hyster Company

The assembly must be installed on the brake shaft so that the desired wind faces outward. Also. the brake wheel must match the wind.

MULTI-DISC BRAKES

Some models of winches are now using an oil cooled multi-disc brake similar to that in Figure 9-17. This disc brake is spring-applied by the belleville spring and hydraulically released When the tractor is stopped, or the winch control is in neutral, spring pressure applies the brake by squeezing the splinded discs of the pack together against a pressure plate. When the control is moved to reel-in (forward) or reel-out (reverse), oil pressure is applied to the piston and releases the brakes.



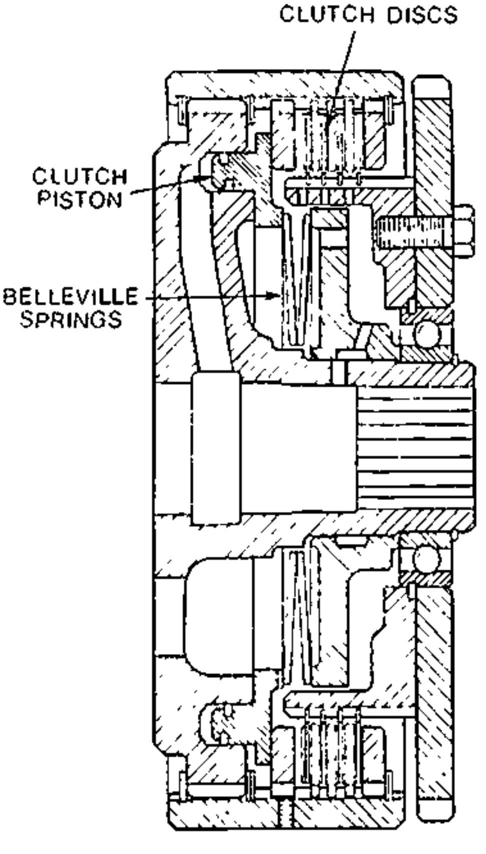
(9-17)

Courtesy of Hyster Company

POWER SHIFT CLUTCHES

Clutch packs used in powershift winches are similar to those used in powershift transmissions and in crawler steering clutches The packs are multi-disc made up of externally splined steel discs alternating with internally splined. lined discs (Figure 9-18) The size of the pack its diameter and thickness, is dependent on the size of the winch Clutch packs for forward and reverse are usually identical on larger winches. but on smaller winches the packs for the two gears can vary in size Winch clutch packs are hydraulically applied and spring released

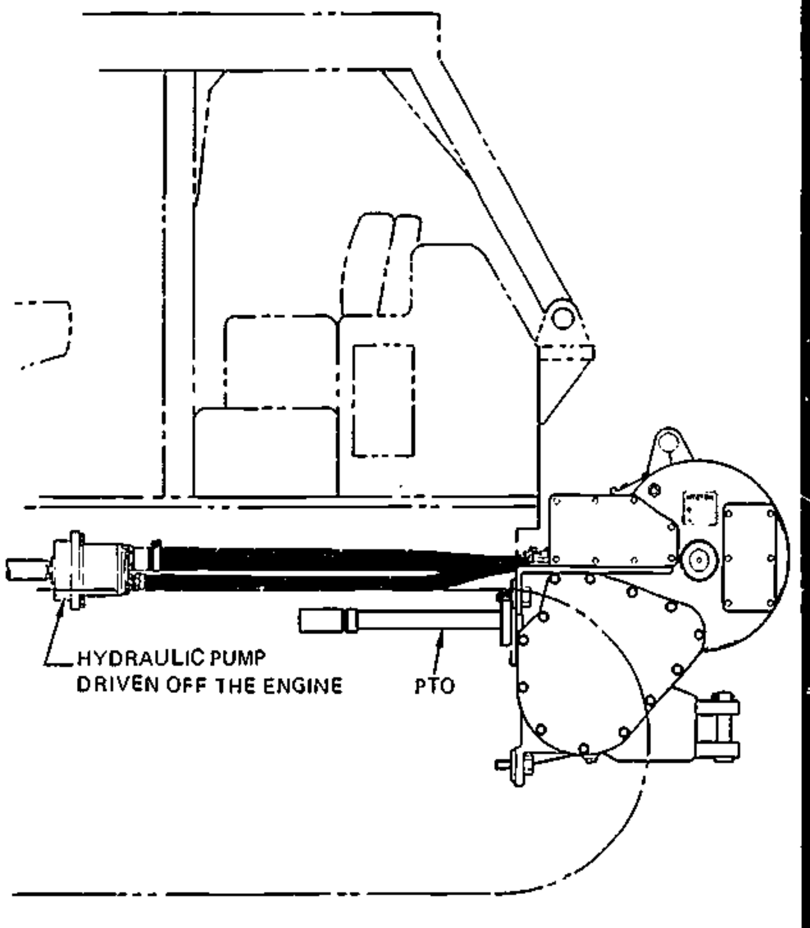
Besides lubricating the gears. oil in the winch housing also acts as a hydraulic fluid to apply the clutch packs. Winch oil is usually the same type as that used in the tractor's transmission. Oil pressure for the winch is usually supplied by an engine driven pump (Figure 9-19). Hoses connect the pump with the winch. When the engine is running. the pump circulates pressurized oil through the control system to apply the clutches and release the brake and also to lubricate the winch. Note that the winch housing acts as a radiator to cool the oil as well as acting as the oil reservoir



(9-18)

Courtesy of Hyster Company

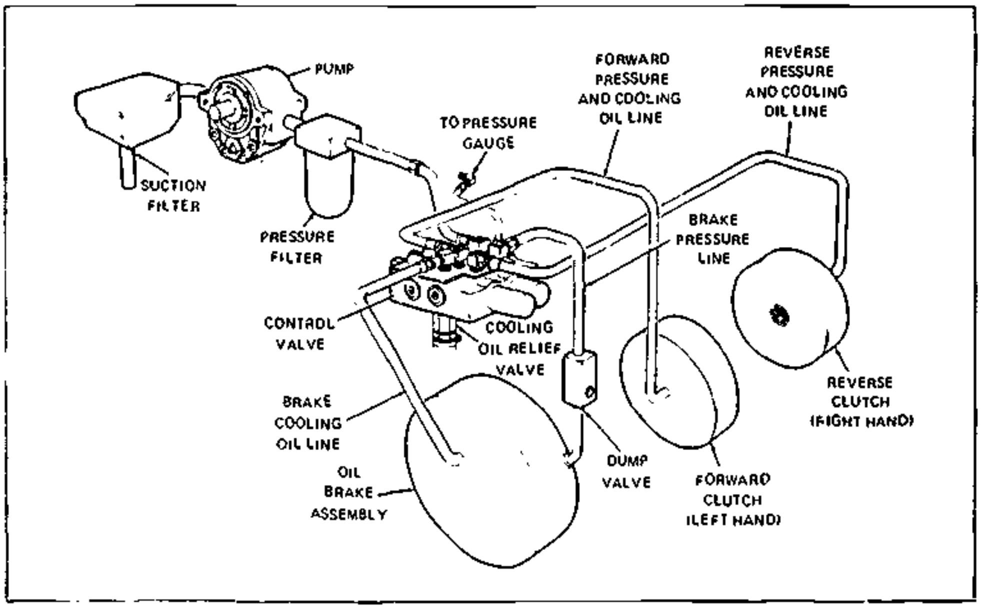
(9-19)



Courtesy of Hyster Company

Figure 9-20 shows a winch hydraulic system. Note the suction and pressure filters which protect the pump, control valve, clutches and the rest of the system from any contaminants in the oil. Also note the relief valve which regulates oil pressure in the system.

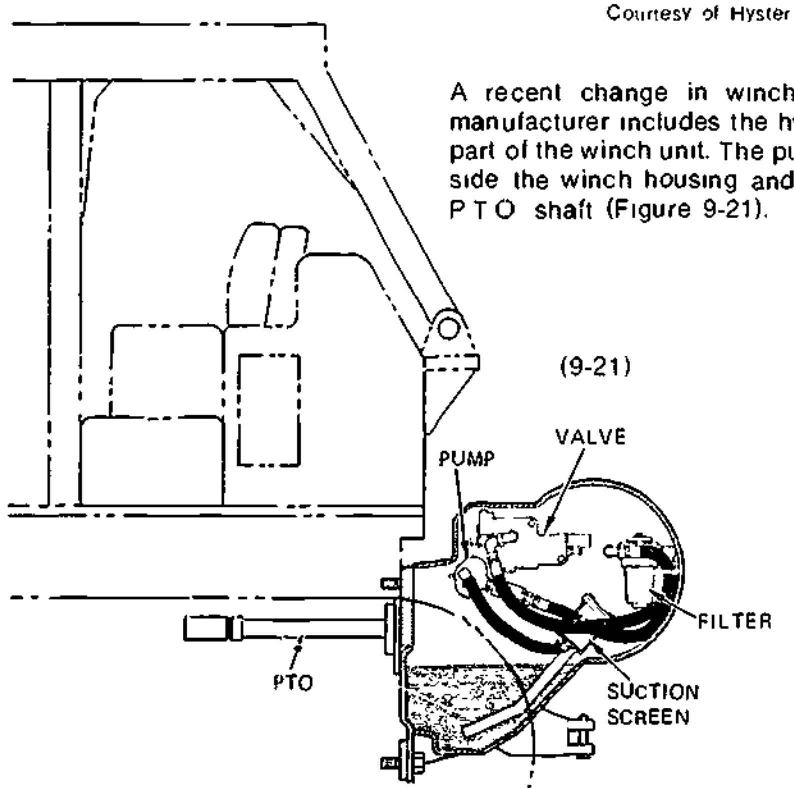
(9-20)



Courtesy of Hyster Company

A recent change in winch design by one manufacturer includes the hydraulic pump as part of the winch unit. The pump is located inside the winch housing and is driven by the P.T.O. shaft (Figure 9-21).

(9-21)

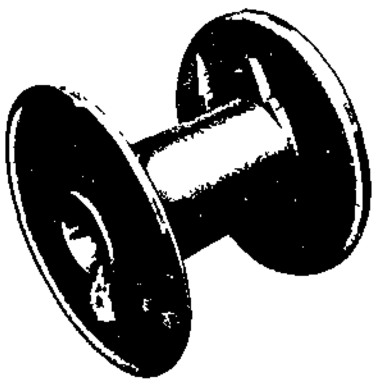


Courtesy of Hyster Company

The advantage of a winch with a self-contained hydraulic pump is that it eliminates the need for hydraulic lines between the tractor and the winch thus greatly simplifying removal and installation procedures (especially on machines using other back-end equipment such as a ripper) The only lines from the winch to the tractor are a control cable and a gauge pressure line Eliminating the hydraulic lines means that there is no chance for a suction hose leak and much less chance of contaminating the oil when removing and installing the winch

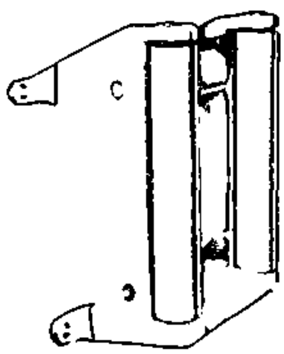
WINCH OPTIONS

A high capacity drum and a fairlead (Figure 9-22) are two examples of options offered for winches A bolt-on fairlead permits the cable to be reeled-in at an angle without damaging the cable.



(9-22) **High-capacity drum**

Courtesy of Carco Winch Products



(9-22) **Three-roller fairlead**

Courtesy of Carco Winch Products

QUESTIONS — TRACTOR MOUNTED WINCHES

1 List the three methods used to drive tractor mounted winches

2 Cable may be wound on a drum in one of two ways

(a) Left or right.

(b) Tight or loose

(c) Forward or backward

(d) Overwind or underwind.

3. True or False? Overwind lifts the load so that it does not dig in. but on a heavy load this lifting can cause the tractor to rear

4 Winches are normally shipped from the factory set for ________________.

5 Tractor winches are rated by the

(a) Line speed.

(b) Size of drum

(c) Line pull in (Kilograms or lbs.).

(d) (a), (b) and (c) are all correct.

6 List the three common types of tractor winches

7 To shift gears on a sliding gear, tractor mounted winch the

(a) Engine must be slowed down

(b) Tractor's master clutch must be disengaged.

(c) Tractor must be moving.

(d) Transmission must be in gear.

8. How are gears shifted in a powershift winch?

9 Both sliding gear and powershift winches depend mainly on a ____________ ____________ system for lubrication.

10 What is the main advantage of a hydraulic winch over a mechanical drive winch?

11 The two common types of brakes used on winches are

(a) Hydraulic and air.

(b) Disc and shoe

(c) Band and multi-disc

(d) Band and shoe.

12 On a powershift winch equipped with a single lever control, the brake will be:

(a) Spring-applied and spring-released.

(b) Hydraulic-applied and spring-released.

(c) Spring-applied and hydraulic-released.

(d) Hydraulic-applied and hydraulic-released.

13 On a direct drive winch with an automatic ratchet and pawl brake, the operator may, without releasing the brake,

(a) reel-in.

(b) reel-out

(c) do neither.

14 Besides housing the components and acting as the oil reservoir, what other important function does the winch housing perform?

15. What is the function of a fairlead?

16. What are the two main hydraulic components that are needed to drive a hydraulic winch?

PREVENTIVE MAINTENANCE SERVICE OF TRACTOR MOUNTED WINCHES

SCHEDULED MAINTENANCE CHECKS

The location of the winch often hinders its maintenance. being situated by itself at the back of the tractor. it tends to get forgotten A winch. like any other gear component. requires periodic inspection of the unit and oil level checks and oil changes Scheduled oil changes are necessary because after a winch has worked a complete shift. its housing is warm. and when the machine is shut down the housing is surrounded by cool. night air. This cool air causes condensation to form in the housing thereby contaminating the oil. If this water-contaminated oil is *not* changed at regular intervals. damage such as premature bearing failure or faulty hydraulic control will occur.

Following is an example of a Preventive Maintenance Table (Hyster Company) for both a direct drive and a power controlled winch. The table has two schedules. an hourly schedule and a daily-weekly-monthly schedule. If the winch is operated more than eight hours a day the hourly schedule should be followed. If the winch operates eight hours or less a day the daily-weekly-monthly schedule should be used. The alphabetical letters in the table refer to letters in Figures 9-23 following the table.

SAFEGUARD MAINTENANCE AND SERVICE INSPECTION SCHEDULE

ITEM	SCHEDULE (Hour/Period) 8/ dy	50/ wk	500/ 3 mo	1000/ 6 mo	2000/ 1 yr	QUAN	TYPE	PROCEDURE
Oil Level (Direct Drive)		√		CHANGE		18 Gals	SAE 90 MIL-L-2105B. for temperatures above +10°F SAE 10. MIL-L-2104B. or MIL-L-45199 Series 3. for temperatures +10°F and lower	Check winch oil at level plug Ⓐ on right side of winch Add oil as required at plug Ⓑ. Drain oil at plug Ⓒ and Ⓓ. NOTE When checking winch oil level on winches mounted on power-shift tractors stop engine to obtain correct reading
Oil Level (Power Controlled)		√		CHANGE		20 Gals	Automatic Transmission Fluid "DEXRON". for temperatures above -10°F SAE 5W. MIL-L-2104B. or MIL-L-45199 Series 3. for temperatures 10°F and lower	For winches mounted on direct drive tractors. disengage tractor master clutch to obtain correct reading CAUTION. If winch is new or overhauled drain after 50 hours of operation. then flush refill. replace pressure filter element and service suction filter
Brake and Transmission Compartments (Direct Drive)		√				Variable	Water and or oil	Remove plug Ⓓ and drain any accumulation of water or oil in brake compartment Replace plug Ⓓ. Loosen plug Ⓒ and drain any accumulation of water in a heavy film of

SAFEGUARD MAINTENANCE AND SERVICE INSPECTION SCHEDULE

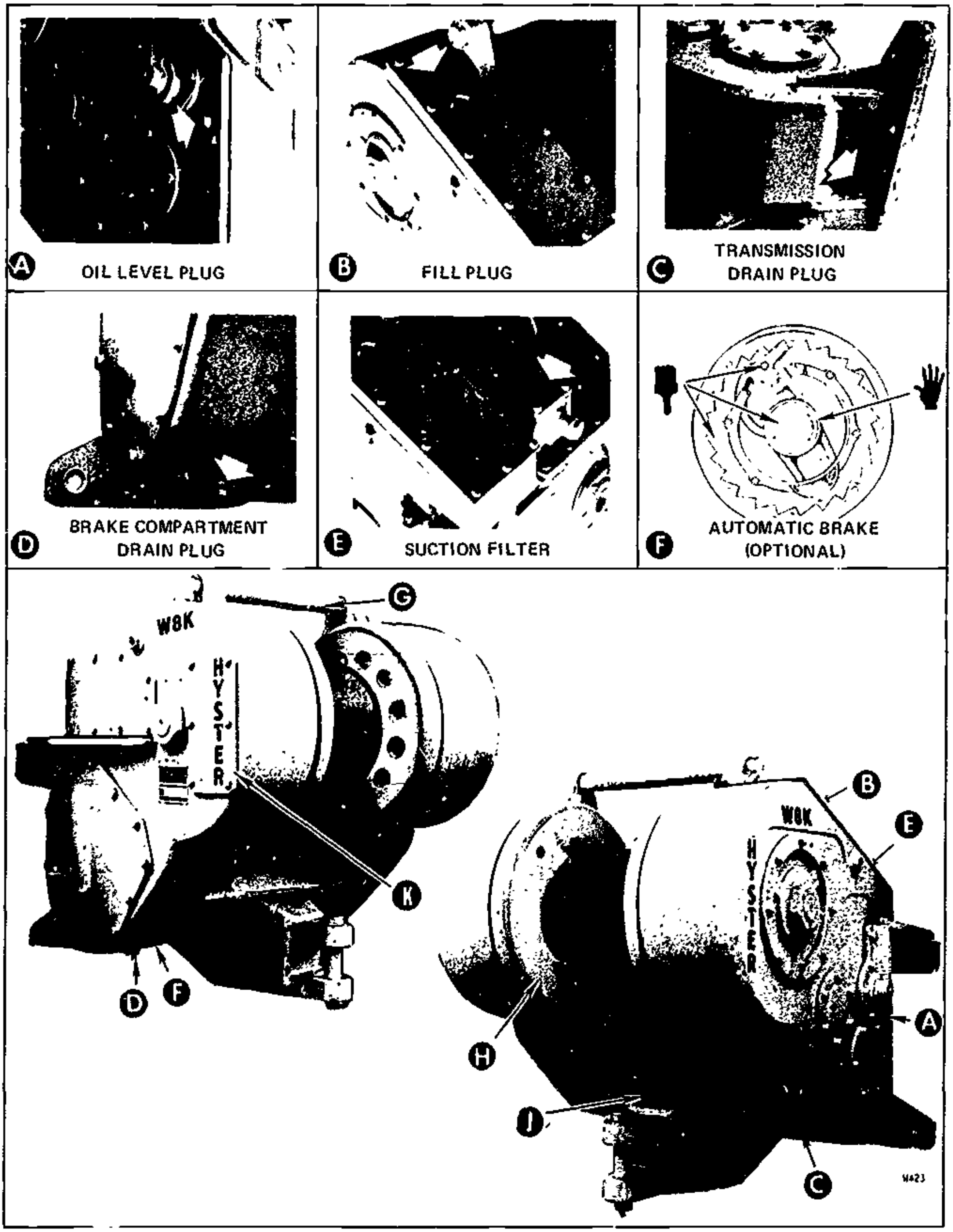
ITEM	SCHEDULE (Hour Period) 8/ dy	50/ wk	500/ 3 mo	1000/ 6 mo	2000/ 1 yr	QUAN	TYPE	PROCEDURE
Automatic Brake (Optional Direct Drive Only) (Cont)				S E R V I C E			Mobil Oil (Mobil-temp Grease #1) Shell Oil (Darina Grease 1) Standard Oil (Chevron Industrial Grease) Texaco (Thermatex EP #1) Union Oil (Strona HT-1) Sun Oil (Sunaplex 991 EP) BP Australia (Energrease HTB2)	high temperature grease on ratchet ring, pawl assembly, and hub DO NOT completely fill automatic brake assembly with grease or attempt to grease brake through the vent plug. CAUTION Always install oil seals so that lips of both seals are pointing inward
Cable Guide Rolls (Optional)	√						Multi-purpose Grease	Lubricate two grease fittings G.
Fairlead (Optional)	√						Multi-purpose Grease	Lubricate six grease fittings H.
Swiveling Drawbar (Optional)	√						Multi-purpose Grease	Lubricate one grease fitting J.
Pressure Filter (Power Controlled Only)			C H A N G E			One	Refer to Parts Manual	Replace with Hyster approved filter element K. Coat O-ring and backup ring with multi-purpose grease to ensure a leak proof seal between filter and case
Bevel Gear Shaft Locknut					√		Refer to Parts Manual if necessary to replace lockwasher	Pry lockwasher tangs away from locknut flats and retighten locknut to 200 ft-lbs torque Bend lockwasher tangs over locknut flats transmission

SAFEGUARD MAINTENANCE AND SERVICE INSPECTION SCHEDULE

ITEM	SCHEDULE (Hour/Period) 8/ dy	50 wk	500/ 3 mo	1000 6 mo	2000/ 1 yr	QUAN	TYPE	PROCEDURE
Brake and Transmission Compartments (Direct Drive) (Cont.)								compartment Tighten plug Ⓒ when oil appears.
Handling Gear	√					Few drops	SAE 30	Lubricate fulcrum pin connections and other moving parts at end of each eight hour shift
Suction Filter (Power Controlled Only)			SERVICE			One	Refer to Parts Manual	Remove suction filter Ⓔ, clean thoroughly, and reinstall. CAUTION If winch is new or overhauled, remove suction filter Ⓔ after first 50 hours of operation, clean thoroughly and reinstall. CAUTION Suction manifold cover gasket must be in good condition to prevent air leaks. Replace with Hyster approved gasket
Suction Hose Clamps (Power Controlled Only)		√						Check both ends of suction hose to see that hose clamps are TIGHT. Retighten hose clamps as necessary
Control Cables		√						Check both ends of each cable housing to see that they are securely anchored. Retighten set screw U-bolt, or bracket bolt as applicable. Check winch end of power control cable for condition of roll pin anchor
Automatic Brake (Optional Direct Drive Only)				SERVICE			High temperature grease as follows: Atlantic Richfield (Thermogrease)	Remove automatic brake assembly Ⓕ. Disassemble and clean automatic brake assembly components. Pack the two bearings with a high temperature grease

Service Instructions

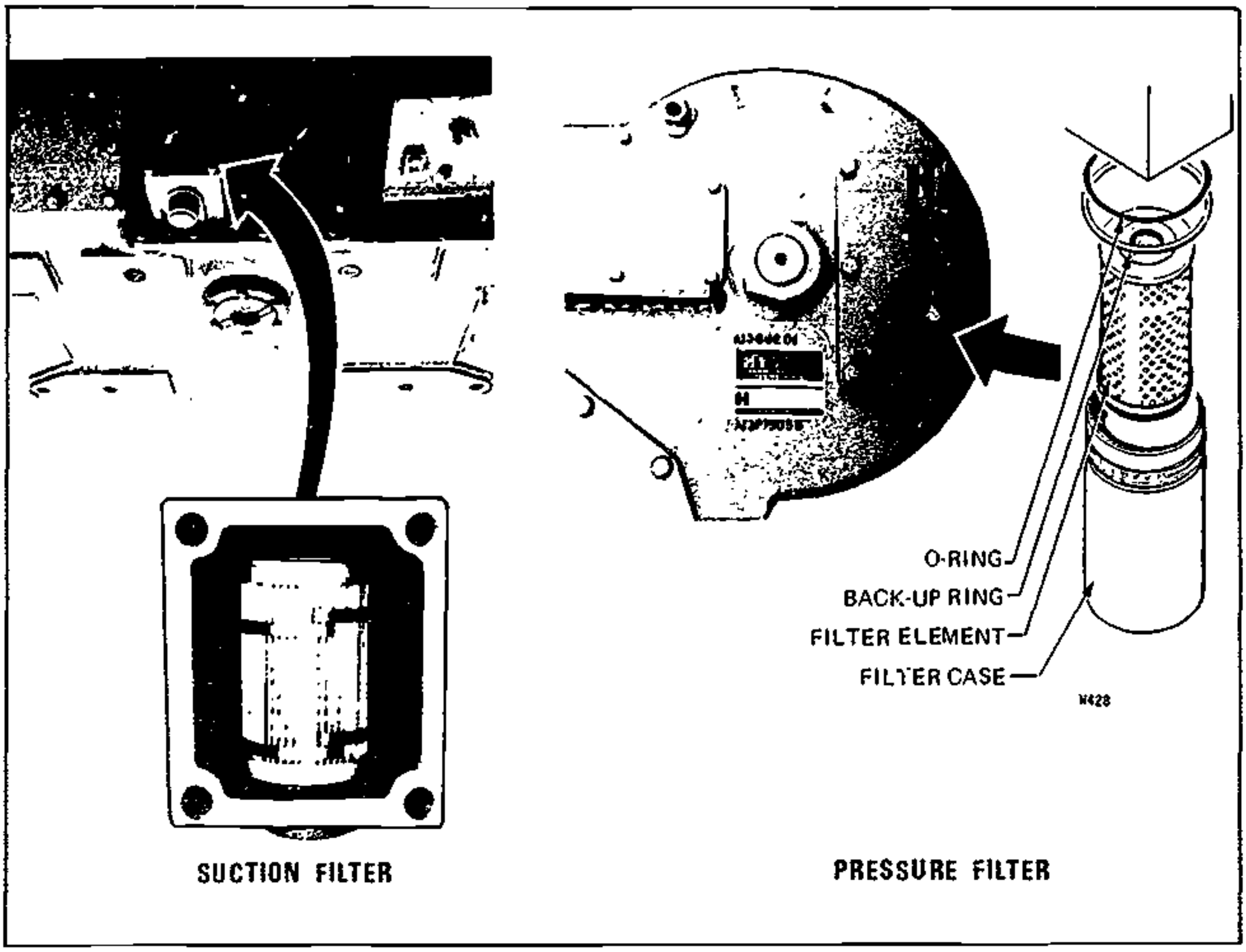
(9-23)



Courtesy of Hyster Company

Figure (9-24) shows the two filters and their locations on one model of winch. When replacing filters, be sure to clean the housings thoroughly and install new seal rings Also check for leaks after start up

Service Instructions



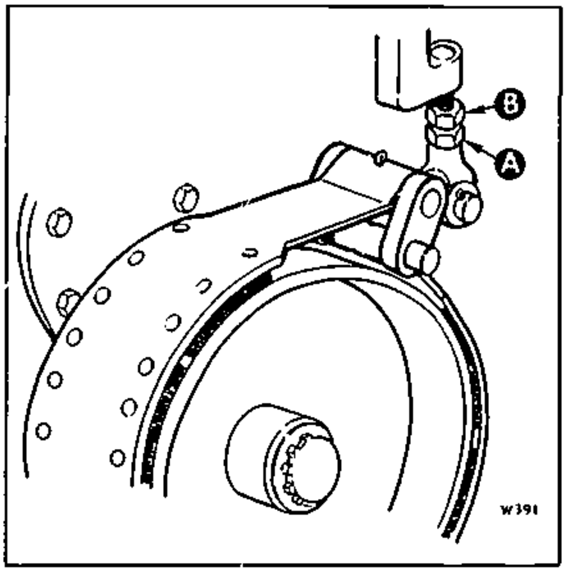
(9-24) SUCTION AND PRESSURE FILTERS, POWER CONTROLLED WINCH

Courtesy of Hyster Company

WINCH ADJUSTMENTS

DIRECT DRIVE WINCHES

Direct drive winches require periodic (1) tightening of the brake to compensale for normal running wear, and (2) minor adjustments to the control linkages These adjustments can be made quickly Below are examples of typical brake and linkage adjustment procedures



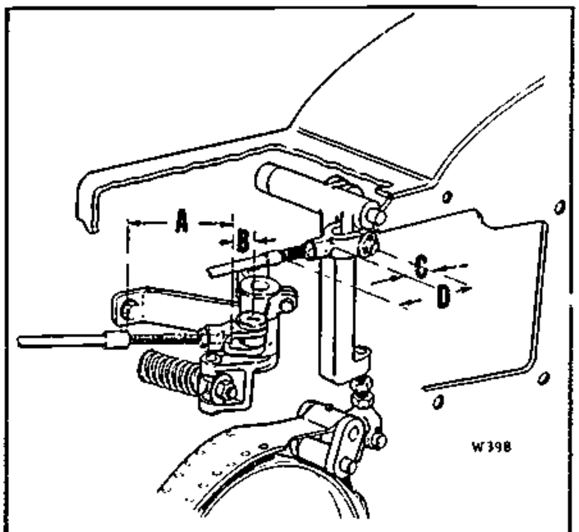
(9-25) BRAKE BAND ADJUSTMENT DIAGRAM DIRECT DRIVE WINCH
Courtesy of Hyster Company

To adjust the brake band, proceed as follows (Figure 9-25)

1 Remove the small brake cover from the left-hand side of the winch
2 Push the brake handlever to its full release position
3 Loosen jam nut A
4 Turn adjusting link B until there is approximately 1 32-inch clearance between the brake band and brake wheel or until there is just enough clearance to prevent 'brake drag'
5 Tighten jam nut A
6 Replace the brake cover

To adjust the positioning of the Brake Handlever, proceed as follows (Figure 9-26)

1 Adjust the brake band.
2 Loosen cable rod-end jam nut
3 Adjust the control cable at the winch control housing-end until dimension C is obtained (distance between the cable-end and the centerline of the rod-end pin).
4 Tighten the jam nut
5 Push the Brake Handlever to the full release position.
6 Adjust the push-pull cable at the Brake Handlever end until dimension D is obtained Tighten jam nut.



A=2-5/8" B=15/16" C=1-1/8" D=4-3/4"

(9-26) ADJUSTMENT OF BRAKE LINKAGE DIRECT DRIVE WINCH
Courtesy of Hyster Company

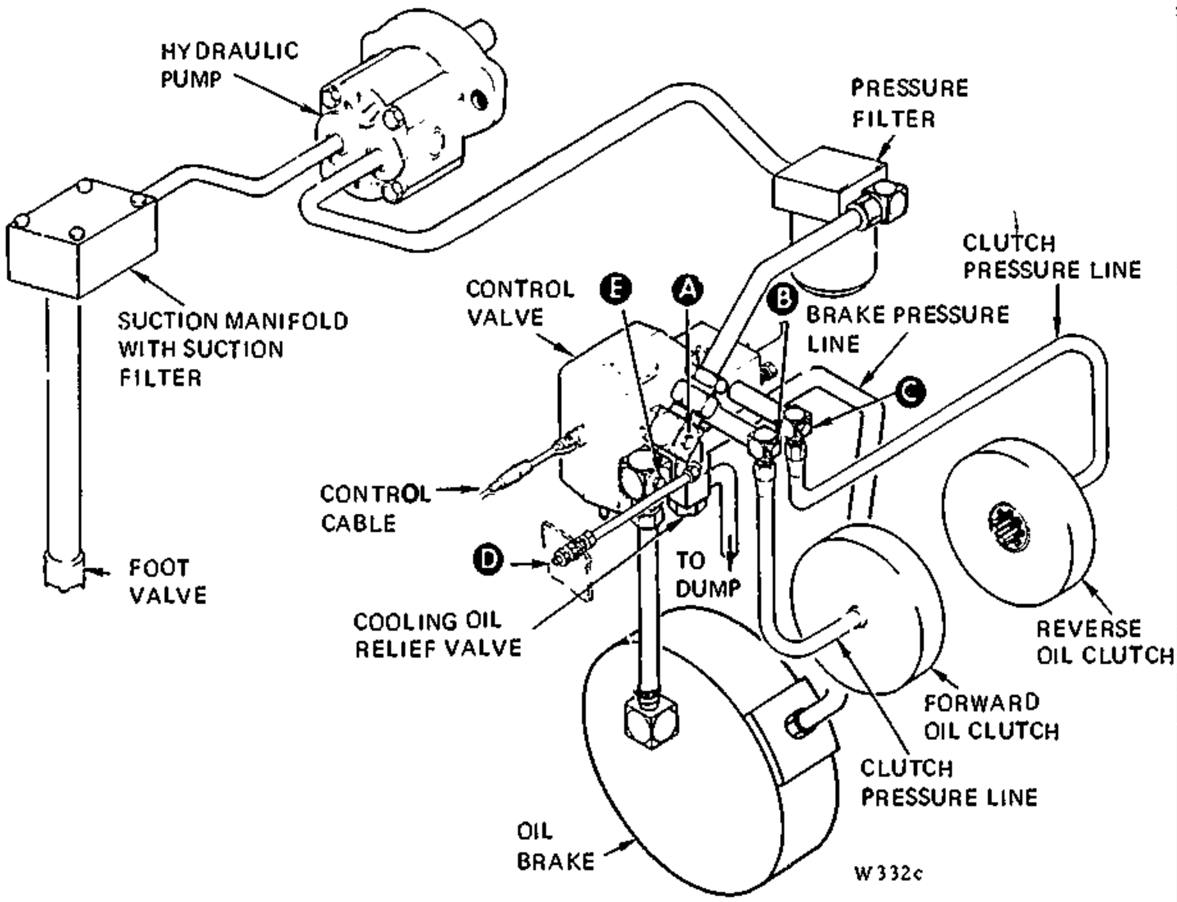
POWER SHIFT WINCH ADJUSTMENT

Power controlled winches require (1) adjustments on mechanical parts such as band brakes (note multi-disc oil controlled brakes don't need adjusting) and (2) pressure checks and adjustments on the hydraulic system Check service manuals for checks and adjustments on individual powershift winches

Figure 9-27 gives an example of the pressure checks called for by one manufacturer. These checks would be done with the hydraulic test box described earlier to test crawler brake and clutch hydraulic controls. If the pressure at any point is not within the allowable limits, the service manual will list the likely causes and state what service repairs would have to be done to correct the problem. Always make these pressure tests to locate the probelm before removing a winch. It's quite likely the winch may not have to come off.

Service instructions

PRESSURE PORT	PRESSURE, PSI FORWARD	NEUTRAL	REVERSE	BRAKE OFF
A	220 (± 10)	35 MAX.	220 (± 10)	220 (± 5)
B	220 (± 10)	2-5	2-5	2-5
C	2-5	2-5	220 (± 10)	2-5
D	220 (± 10)	2-5	220 (± 10)	220 (± 10)
E	15-30	10-13	15-30	15-30



(9-27) HYDRAULIC SYSTEM PRESSURE CHECKS *Courtesy of Hyster Company*

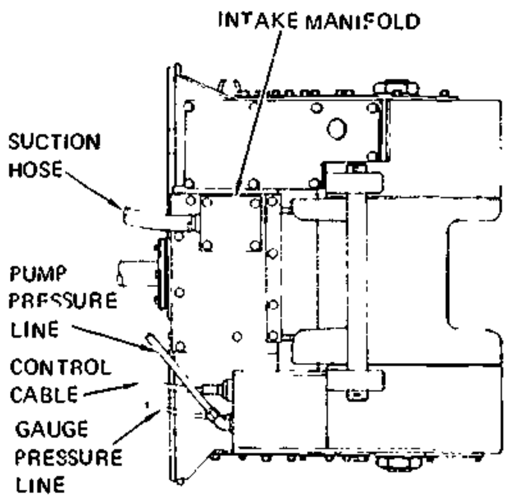
REMOVAL AND INSTALLATION OF TRACTOR MOUNTED WINCHES

To remove a tractor mounted winch follow the step by step procedures outlined in the service manual. Because of their weight, safety is a main concern when removing winches. The average winch will require a lifting device with a minimum capacity of 3000 lbs. (1360.8 kg) Cleanliness is also an important concern in winch removal. for example. before unbolting the winch clean the winch and the rear of the tractor to prevent dirt from entering the winch housing or the tractor transmission case Another clean work practice is to cover the opening in the rear of the tractor after removing the winch and P T O shaft Typical removal procedures for a Powershift Winch are given in Figure 9-28.

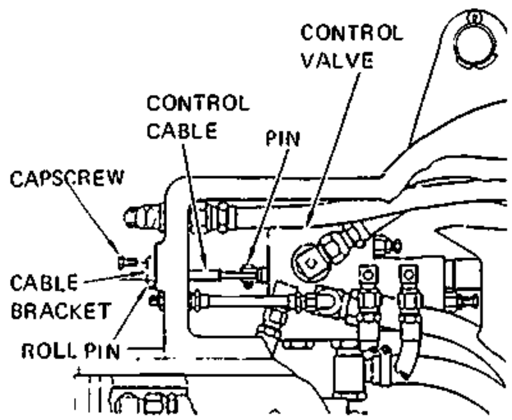
Note that removal of the winch's pump from the tractor requires a separate set of procedures that will be found in the service manual

Warning: If winch is to be disassembled the cable must be removed. Use extreme care when removing the cable-end ferrule from the drum When the cable lock is removed, the cable may spring out with extreme force.

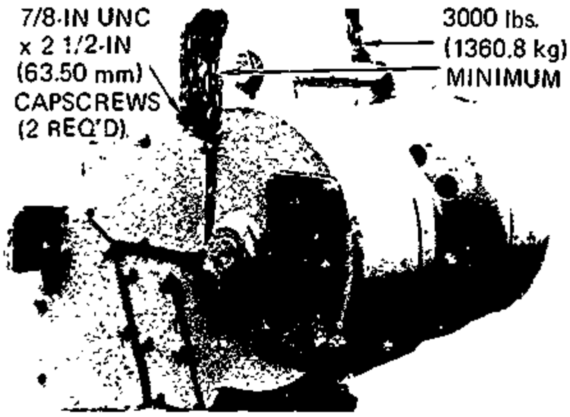
VIEW FROM TOP OF WINCH



STEP 1 Remove suction hose from intake manifold Disconnect pump pressure line Disconnect gauge pressure line

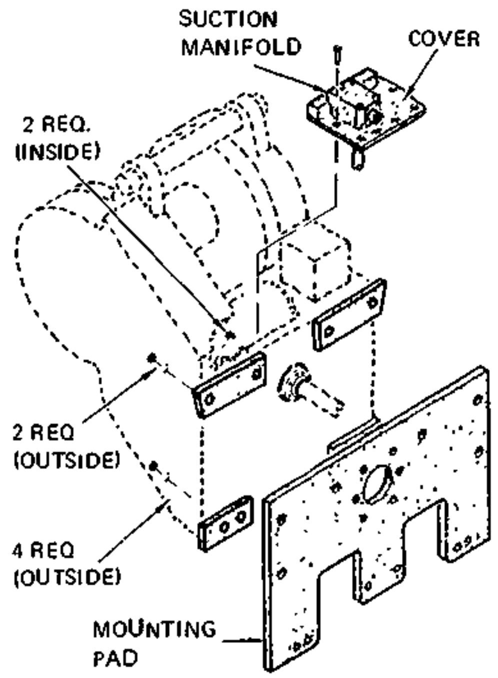


STEP 2 Remove access cover plate Remove cotter pin and detach blade end of control cable from control valve spool clevis. Remove capscrew holding cable bracket to housing, and pull out control cable If necessary to remove cable bracket, remove roll pin.



STEP 3. Connect lifting device to winch. Winch will be balanced when connected as shown.

STEP 4. Drain the oil from the winch.



STEP 5. Remove suction manifold and cover Remove the eight nuts and lockwashers attaching winch to mounting pad.

NOTE: When removing the eight nuts, loosen all nuts slightly, then pry winch away from mounting pad. Loosen all nuts again and pry winch again. Continue this sequence until winch can be removed.

Courtesy of Hyster Company

QUESTIONS — MAINTENANCE AND REPAIR OF TRACTOR MOUNTED WINCHES

1 True or False? Because of the heavy weight of winches, safety is a main concern when removing them.

2 What is the main source of oil contamination on tractor mounted winches?

3 If a winch is operated for less than eight hours a day, what maintenance schedule is recommended?

(a) Hourly maintenance schedule

(b) Daily, weekly, monthly schedule

(c) Once a year checks are enough

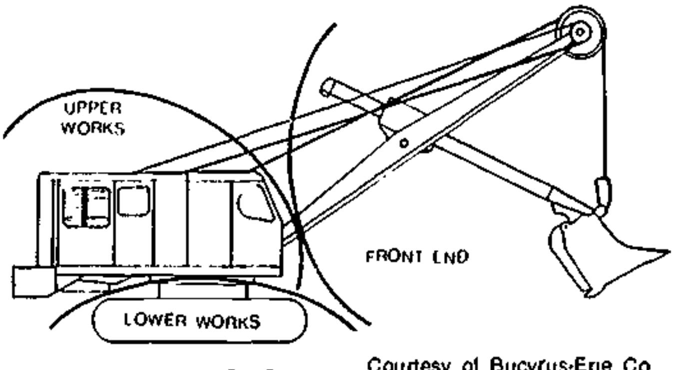
(d) Maintenance only when required

4 Referring to the section taken from a service manual on winch maintenance, find the interval at which the suction filter should be serviced

5 True or False? Winch band brakes require no periodic adjustments.

6 True or False? Multi-disc brakes require no periodic adjustment.

7 What instrument is used to test the hydraulic controls on a power shift winch?



(9-29) Courtesy of Bucyrus-Erie Co of Canada Ltd

Winch installation procedures will be found in the service manual. Having installed the winch and reconnected all the fittings, check the following prior to operating the winch.

1 No leakage.

2 Proper oil levels.

3 All mounting nuts are tightened to specifications.

4 All covers are securely installed.

5 All hydraulic hoses are properly routed to prevent chafing.

6 The hydraulic pump is primed The pump should have been primed during installation by filling the suction hose with hydraulic oil.

HOIST WINCHES FOR CRANES, EXCAVATORS AND YARDERS

The history of cable operated machines goes back a long time. Steam driven, partial swing shovels were made over 140 years ago. During the years steam changed to diesel or electric, the partial swing became a full 360 swing, and new versions of cable machines appeared such as a dragline, a clamshell, a hoe.

Until about 1950 nearly all excavator shovels powered their buckets by cable winding on and off drums Today cable-drum systems on excavators have all but disappeared having been replaced by hydraulically operated buckets Cable operation, however, is still widely used for cranes, draglines, clamshells (Figure 9-30) logging yarders and loaders, and large electric mine shovels Cable machines are divided into three main sections (Figure 9-29)

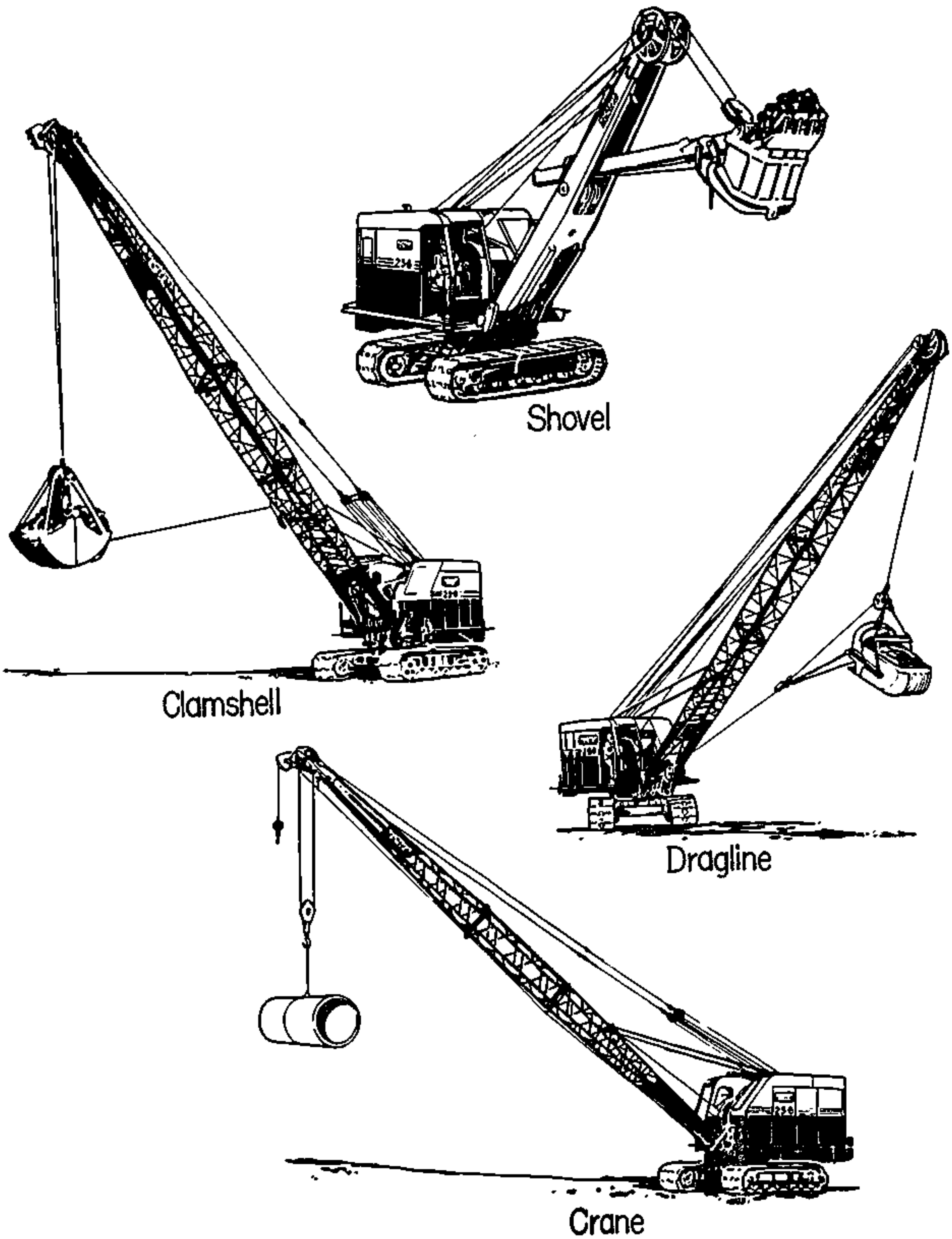
1 lower works (can be crawler mounted or truck mounted)

2 upper works (the revolving unit)

3 front end (the attachments)

An even simpler division is to speak of (1) the basic machine and (2) the convertibility The basic machine is the lower and upper works. The convertibility is the front end and is so named because front ends are convertible depending on the type of work it is to do a basic machine can have a crane, a clamshell, a shovel a dragline mounted to it Note that not all cable machines are convertible Large mining shovels, for example, are made for only one job and have a permanently mounted front end

Crawler Machine

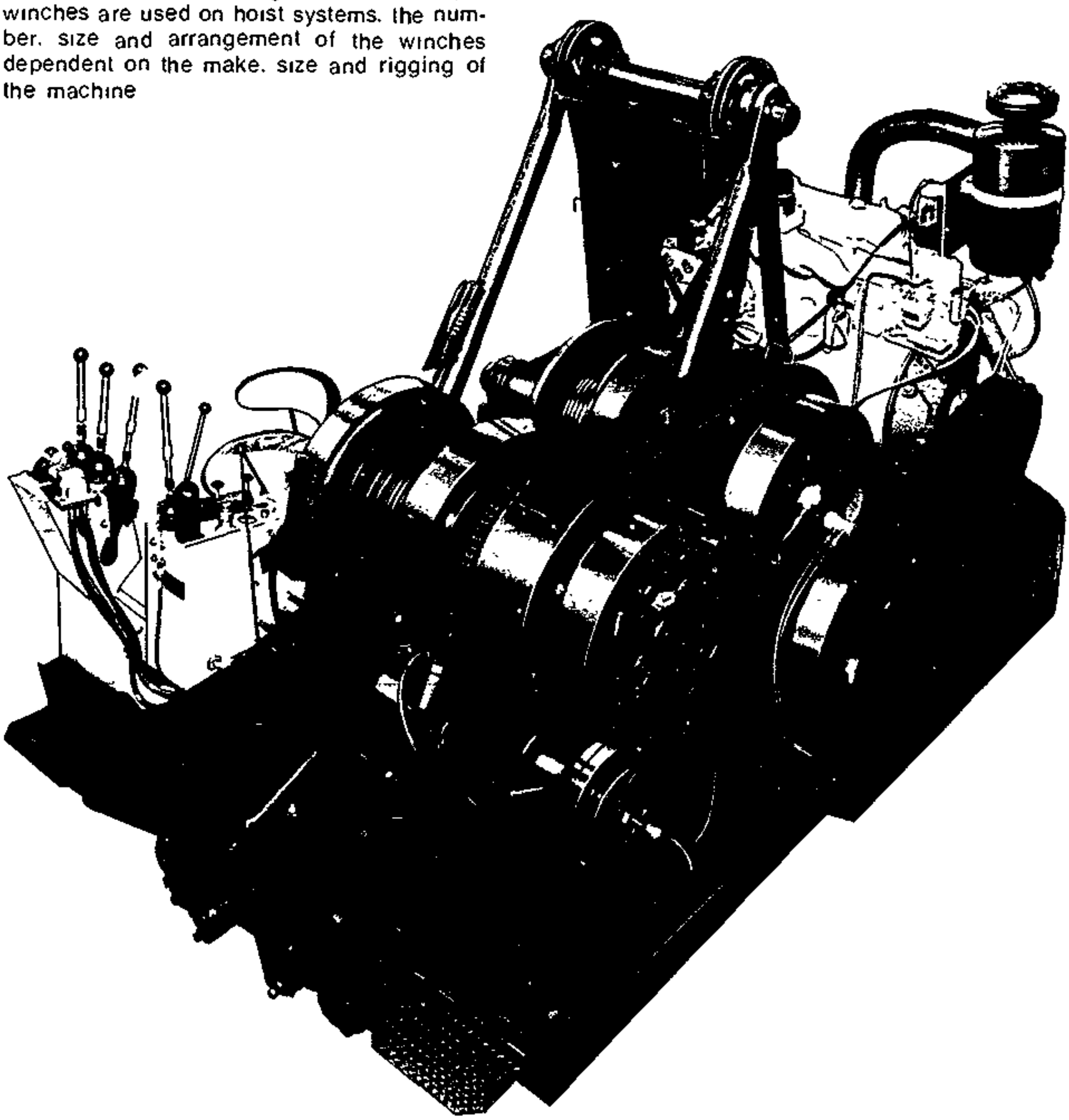


(9-30)

Courtesy of Bucyrus-Erie Co of Canada Ltd

HOIST WINCHES

Tractor mounted winches, as discussed earlier, run independently of the main tractor operations, a single drum is mounted at the back of the tractor and is used when needed. On the other hand, hoist winches for cranes, excavators and yarders are an integral part of the machine's working machinery. They are mounted on the upper works and are used to operate the machines digging, lifting, shoveling implement (Figure 9-31). Multiple winches are used on hoist systems, the number, size and arrangement of the winches dependent on the make, size and rigging of the machine



(9-31)

Courtesy of Bucyrus-Erie Co. of Canada Ltd.

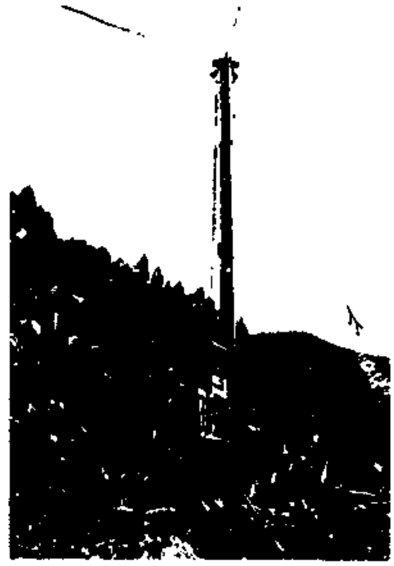
CABLE OPERATION

There are a number of cable circuits on a hoist winch system and the cable in each circuit is always tight In any given circuit one end of cable is attached to a drum, while the other end is threaded or reeved over a number of sheaves and then is either (1) fastened to a part of the working implement (2) returned to the drum and fastened at a different location of the drum or (3) fastened to a fixed point on the machine. Through the actions of clutches and brakes, cable is reeled on and off the drums to control the movement of the bucket, boom, load, etc.

CABLE OPERATIONS ON LOGGING YARDERS

Earlier, it was said that cable was always tight in hoist winch systems. One exception to this rule is a logging yarder (Figure 9-32) Yarders use much larger drums and considerably more cable than shovels or cranes, and the cable runs a lot looser.

There are numerous ways yarders can be rigged, one way is shown in Figure 9-33. Apart from all the guy lines, this yarder cable system basically consists of three lines: (1) a stationary line (skyline) on which the carriage runs (2) a haul-in line (main line) and (3) a haul-back line The haul-back line runs on sheave blocks that are attached to stumps The main line and the haul-back lines each have their own drums and are attached at the carriage. The main line drum is larger because it does the heavy work. Logs are attached to the carriage by choker cables, and the main line pulls in the logs on the skyline. The logs are released at their desired location near the yarder, and the haul back line pulls the carriage back out again on the skyline to pick up more logs.



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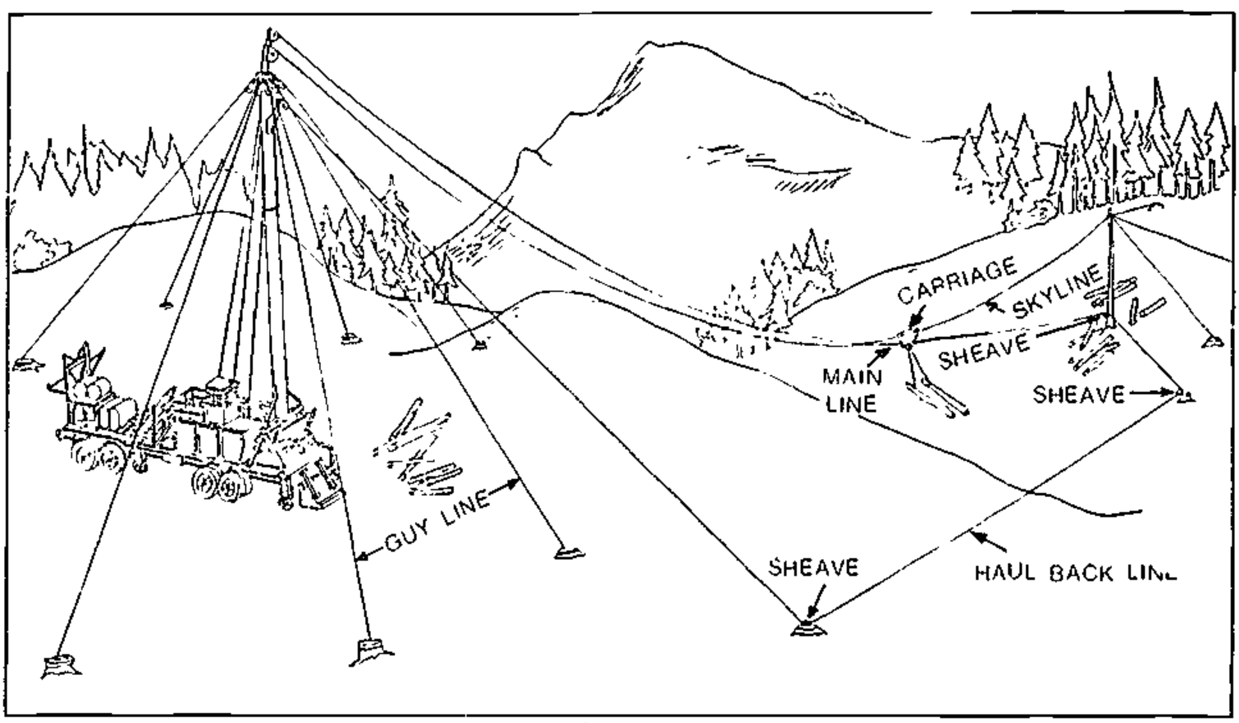
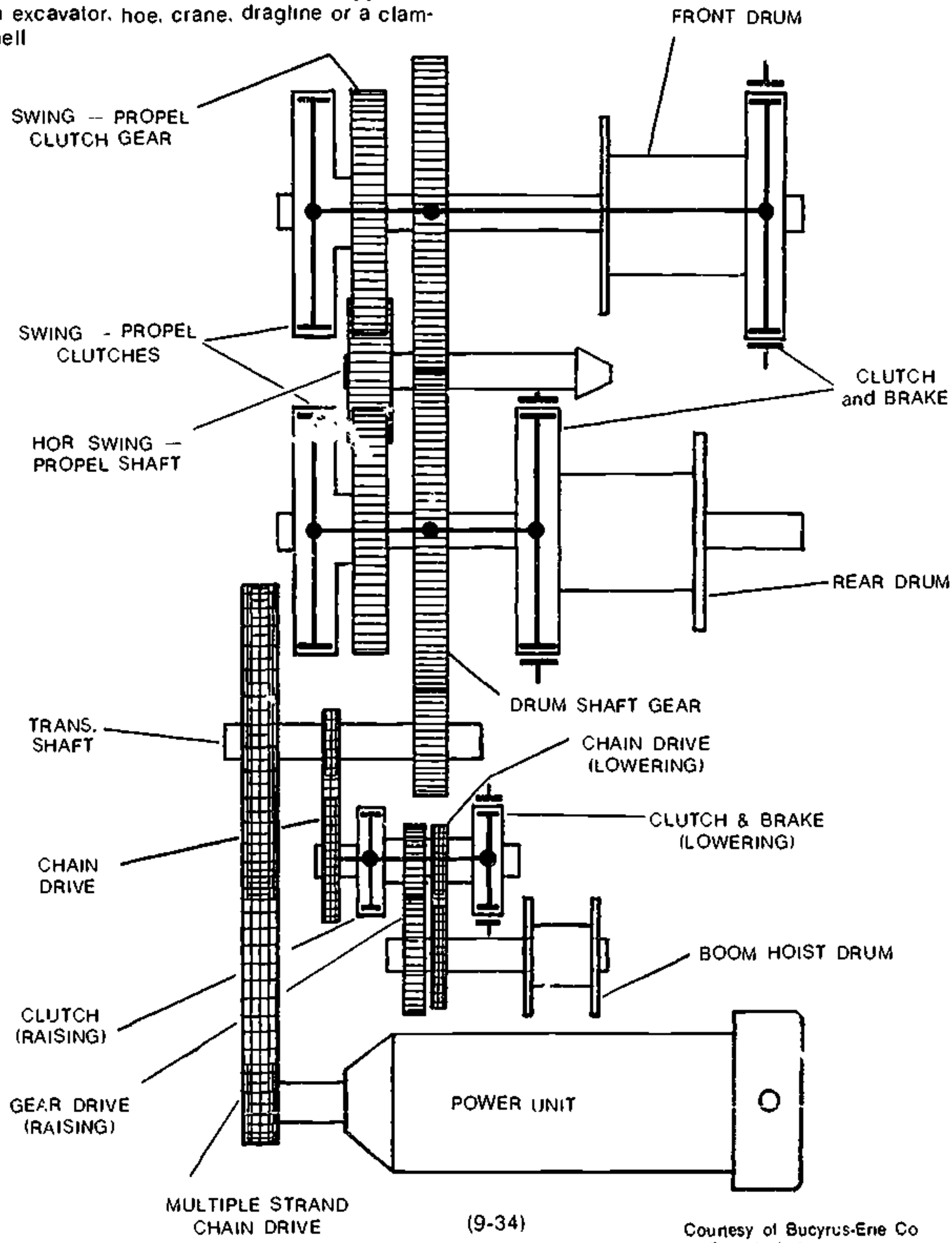


(9-33)

BASIC WINCH ASSEMBLY

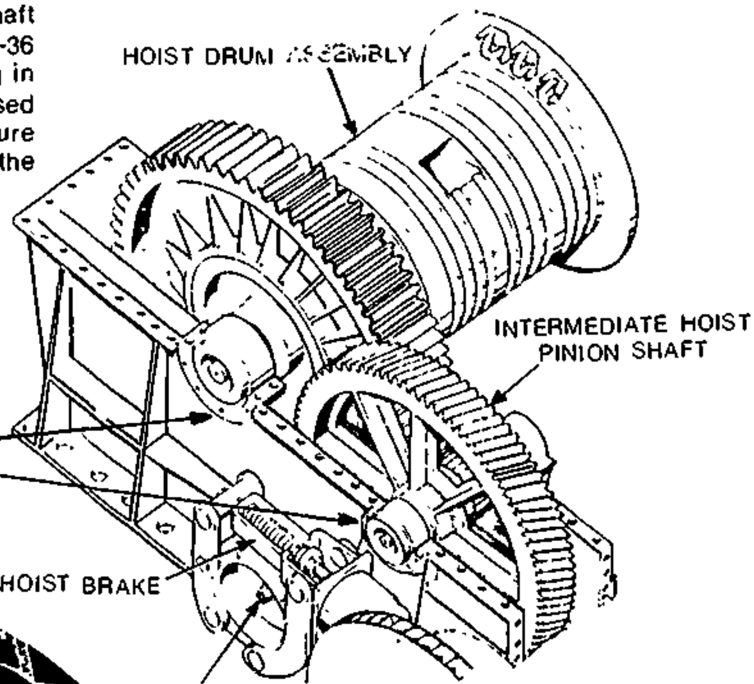
There are a number of differences in hoist winches such as size, ways of mounting and activating mechanisms. A common hoist winch arrangement is shown in Figure 9-34; this winch is convertible and can be rigged for an excavator, hoe, crane, dragline or a clamshell



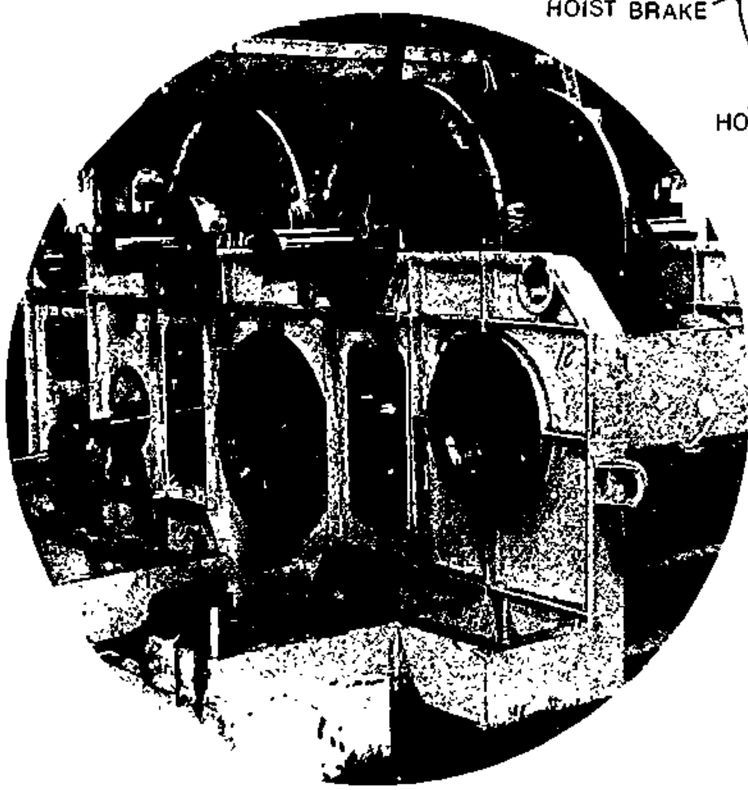
(9-34)

Courtesy of Bucyrus-Erie Co of Canada Ltd

This basic hoist winch arrangement consists of two main drum shaft units, one front and one rear, plus a small hoist drum further to the rear. The drums are not in line but are parallel. Mounted crossways near the centre of the revolving platform, the drums are positioned to give balance to the whole assembly. The main drum shaft units are supported by bearings that rest in precision bored supports in the machinery deck. Older machines used bronze or babbitt bearings but modern machines use anti-friction bearings. The bearings and supports ensure perfect shaft alignment and gear fit. Figures 9-35 and 9-36 show two examples of drum shafts resting in bearing saddles. In Figure 9-35 caps are used to retain the shaft assembly in place; in Figure 9-36 the upper half of the gear case forms the bearing cap



Courtesy of S. Madill Ltd (9-35)

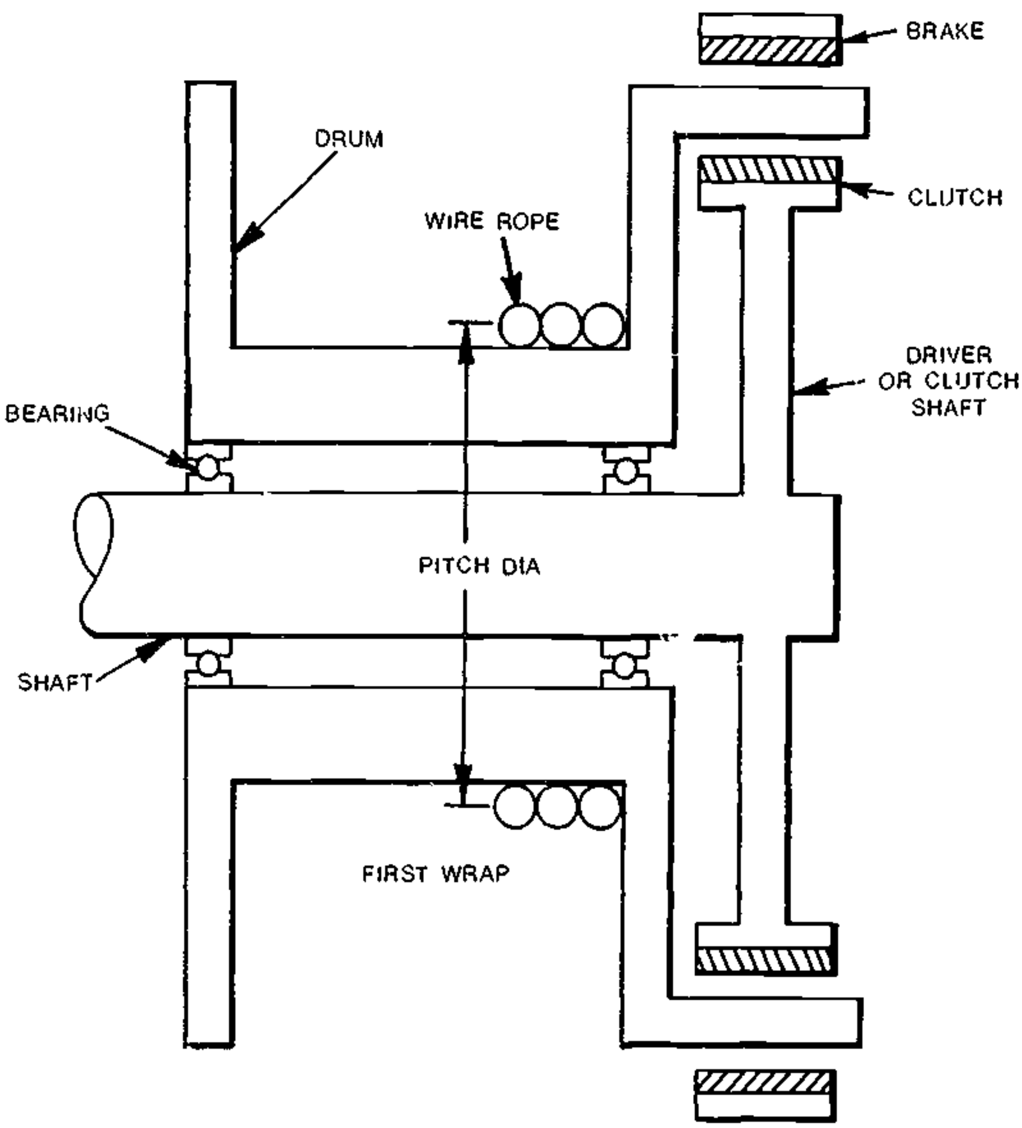


(9-36)

Courtesy of Harnischfeger Corporation P&H

DRUM OPERATION

As is seen in Figure 9-37, drums are mounted on bearings over the drum shafts, and thus a drum shaft can rotate without turning the drum. The internal expanding clutch assembly is attached by a clutch shaft to the drum shaft. When the clutch is engaged, the drum shaft drives the drum; when the clutch is disengaged the drum shaft and clutch rotate freely inside the drum An external contracting band brake encircles the drum.



(9-37)

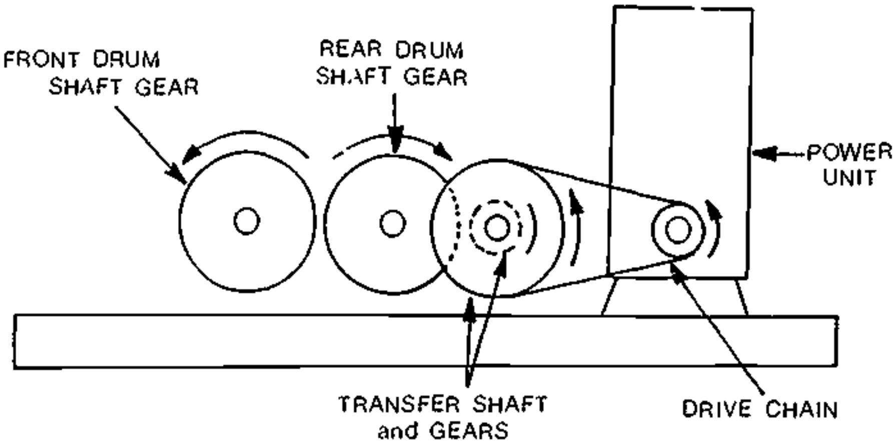
Courtesy of Bucyrus-Erie Co of Canada Ltd.

WINCH POWER TRAIN

Figure 9-38 illustrates a winch power train The power unit drives the transfer shaft and gears by a drive chain (multiple strand) The small gear on the transfer shaft (dotted lines behind the large transfer gear) is meshed with the large gear on the rear drum shaft which in turn is meshed with the large gear on the front drum shaft When the power unit is running, all the parts shown are turning Note that with this gear arrangement, the front and rear drum shaft rotations are opoosite

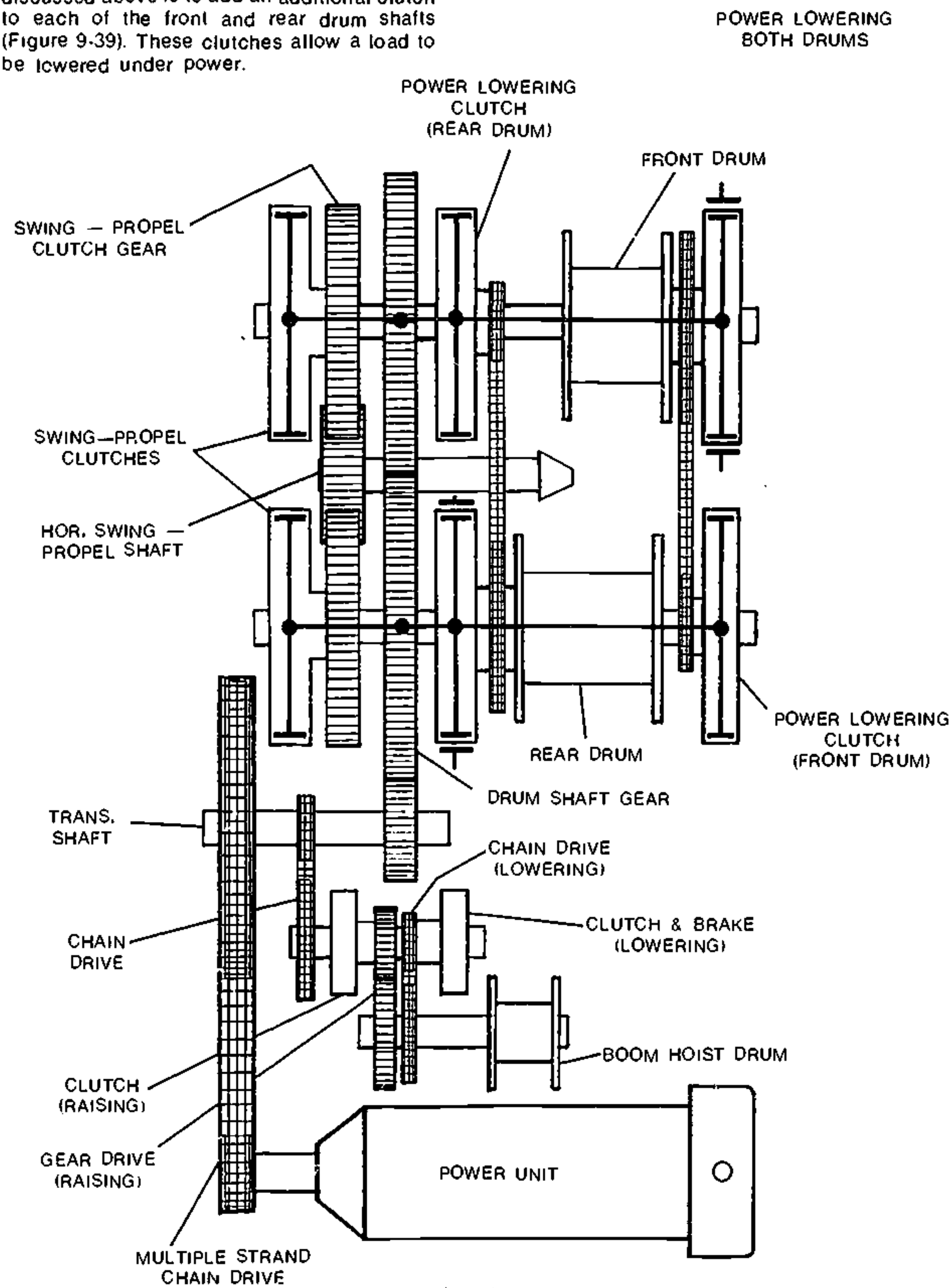
Engaging a drum clutch will cause the shaft and drum to turn as a unit, thereby reeling in the cable attached to the drum Releasing the clutch puts the drum in a free state and any pull on the cable will turn the drum and cable will be reeled out. The cable and drum can be stopped and held by the band brake

The brake just mentioned works independent of the clutch Some winch brakes on the other hand, operate in conjunction with the clutch When the clutch is engaged the brake automatically releases and, vice versa, when the clutch is disengaged the brake is applied



(9-38)

A variation on the basic hoist winch assembly discussed above is to add an additional clutch to each of the front and rear drum shafts (Figure 9-39). These clutches allow a load to be lowered under power.



(9-39)

Courtesy of Bucyrus-Erie Co of Canada Ltd

Each of the power lowering clutches has a sprocket attached to it. This sprocket is connected by a drive chain to a sprocket on the opposite hoist drum. Notice what happens when a load is lowered under power from the front drum:

1 Remember from the description on winch power flow that the two drum shafts turn in opposite directions.

2 When the load is to be lowered from the front drum, the drum's main clutch is disengaged, leaving the drum free to rotate in either direction. Of course, the drum will be braked until everything is set for the load to be lowered.

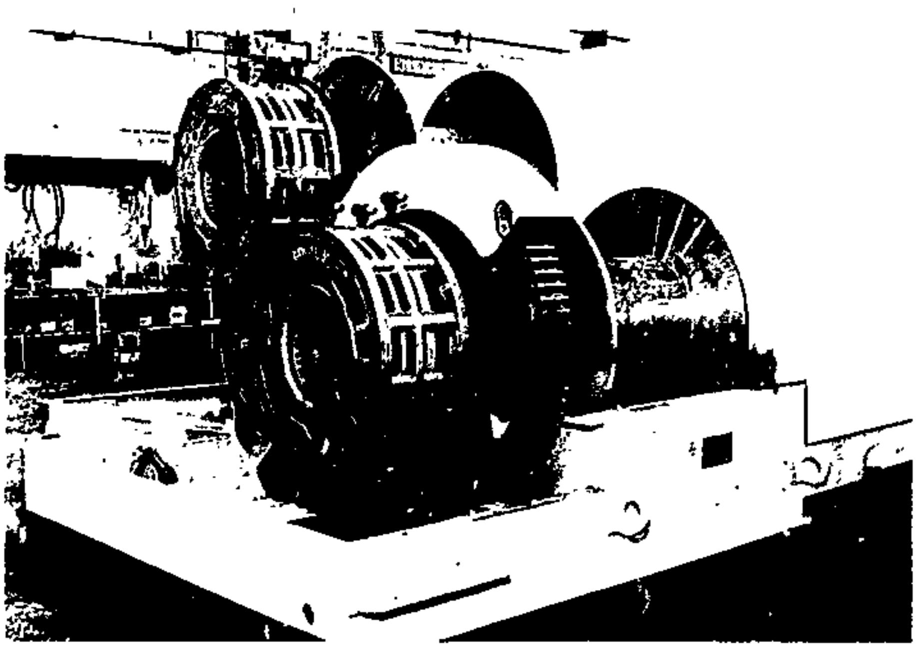
3 Attached to the rear drum shaft, the power lower clutch for the front drum is engaged, thus engaging the drive chain and causing the rear drum shaft to drive the front drum

4. Since the rear drum shaft turns in a direction opposite to the front, the front drum will unwind or lower the load under power.

This procedure would work in reverse to lower a load from the rear drum.

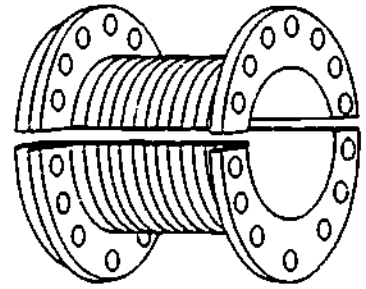
DRUMS AND DRUM LAGGING

Drums are made in various diameters, line capacities, and shapes to suit the work a machine must do A yarder drum (Figure 9-40) for example, has a high capacity drum because it uses a lot of cable

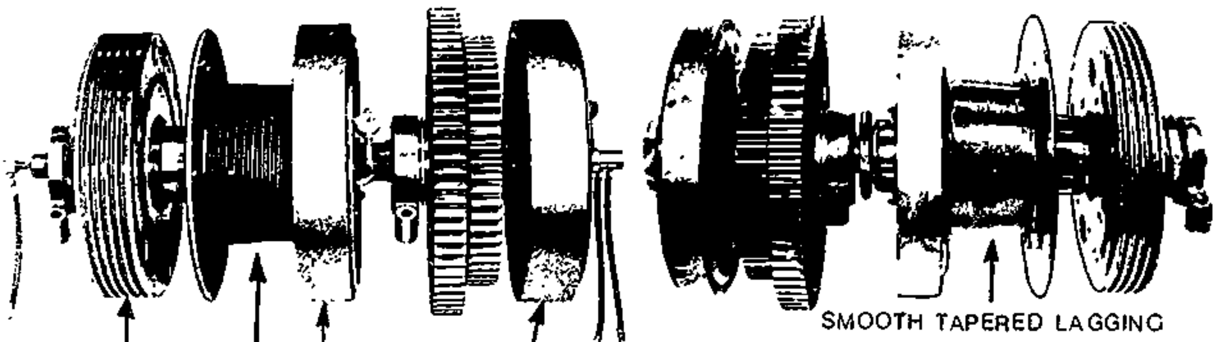


(9-40) YARDER DRUM Courtesy of S Madill Ltd

The drum working surface or the surface on which the cable winds is called the drum lagging. Lagging is made in split halves which are bolted to the drum frame. There are two main types of lagging, grooved lagging and smooth tapered lagging. Thickness is an important characteristic in lagging. Because it increases the drum diameter, a thicker lagging will give faster line speed but the line will run with less power. On the other hand, a thinner lagging will give more line power but slower line speed. Since lagging is bolted on, it is convertible, the type of lagging and its thickness may be changed to suit the particular front-end attachment mounted to the machine. Figure 9-41 illustrates types of lagging.



SPLIT LAGGING WITH GROOVES
(9-41)



(9-41)

Courtesy of Bucyrus-Erie Co. of Canada Ltd

Grooved lagging guides the cable into place and prevents the cable from flattening. Smooth tapered lagging works in the following way: the cable is anchored to the small diameter end. As the cable is reeled in each wrap slides on the smooth surface towards the narrow diameter end until snug against the previous wrap. Thus the cable winds evenly on the drum. The types of lagging by different front ends are listed below.

Magnet Work:

Hoisting – Grooved Lagging
Pull In – Smooth Lagging

Dragline:

Hoisting – Grooved Lagging
Pull In – Grooved Lagging

Hook and Clamshell:

Holding – Smooth Lagging
Closing – Smooth Lagging

Controlled Load Lowering:

Hoisting – Smooth Lagging
Lowering – Smooth Lagging

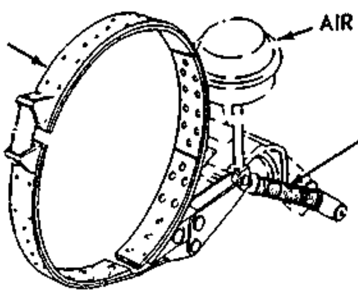
Following are instructions for installing lagging. Lagging installation is relatively simple provided you observe the following items.

1. Clean the bolted surfaces of both the drum and the lagging to remove burrs, rust and paint. If the mating surfaces are not quite flat, tightening the bolts will result in warping the drum slightly. This will produce unequal braking and brake lining wear.
2. Be sure to line up the lagging with the lubrication fittings so the drum bearings may be serviced easily when necessary.
3. Torque the bolts in a cross pattern.

HOIST WINCH CLUTCHES BRAKES AND CONTROLS

BASIC HOIST WINCH BRAKE

The external contracting band brake has been used for many years on hoist winches and is still used today. The band is wrapped around the outside of the brake drum (like a steering clutch brake) and has lining riveted to its inside face Smaller bands are one piece; generally, larger bands are two or more sections bolted together to form the circle. The sections make the large bands easier to remove and install. The ends of the bands have eyes to connect the bands to their actuating mechanism The complete band brake and control assembly is attached to the main frame on the machine. The band brake in Figure 9-42 is spring-applied and air-released.



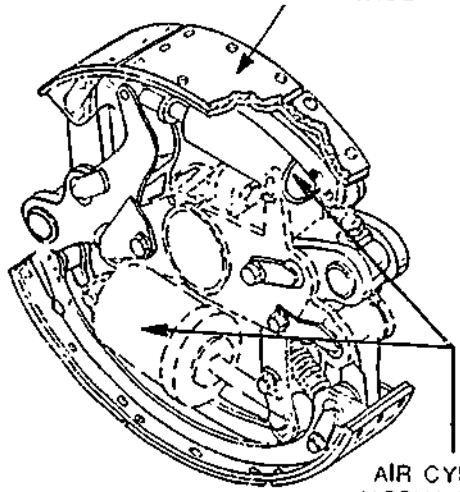
(9-42)

Courtesy of Bucyrus-Erie Co of Canada Ltd

Various types of controls have been used with band brakes - manual linkage, hydraulic, spring apply — air release,* and full air Air controlled is most common today.

BASIC HOIST WINCH CLUTCH

Like the band brake, the expanding shoe clutch (Figure 9-43) has been used for many years on hoist winches This clutch works similar to the wheel brake principle of a shoe contacting a drum The difference, though, is that with a brake the shoe must stop the drum, whereas with a clutch the shoe must join itself by friction to the drum to drive it



(9-43)

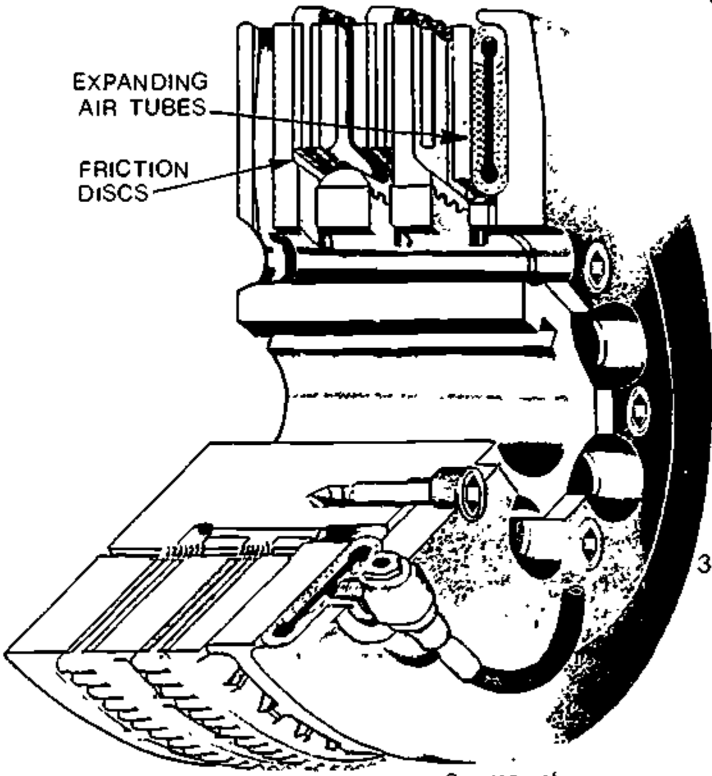
Courtesy of Bucyrus-Erie Co of Canada Ltd

In a hoist winch the clutch shoes and actuating mechanism are mounted to the clutch assembly. The clutch assembly is splined or keyed to the drum shaft and revolves with it. The friction surface that the clutch acts against is the inside of the brake drum. Clutch shoes have lining material riveted to their outer surface. The shoes are mounted on the clutch assembly so that they pivot at one end and move toward the friction surface at the other end. Actuation for the shoes is by hydraulic or air cylinders. Once the cylinders have expanded the shoes the clutch joins the drum shaft with the cable drum and the two rotate together

Besides expanding shoe clutches, hoist winches use external contracting band clutches Contracting band clutches are applied where the winch band brake would normally be positioned and so the brake has to be moved to another location These clutches are hydraulic or air actuated

Demands for clutches and brakes which will withstand heavier loads and will require less maintenance have brought advances in the basic band brake and expanding or contracting shoe clutch Three examples of these new clutches are·

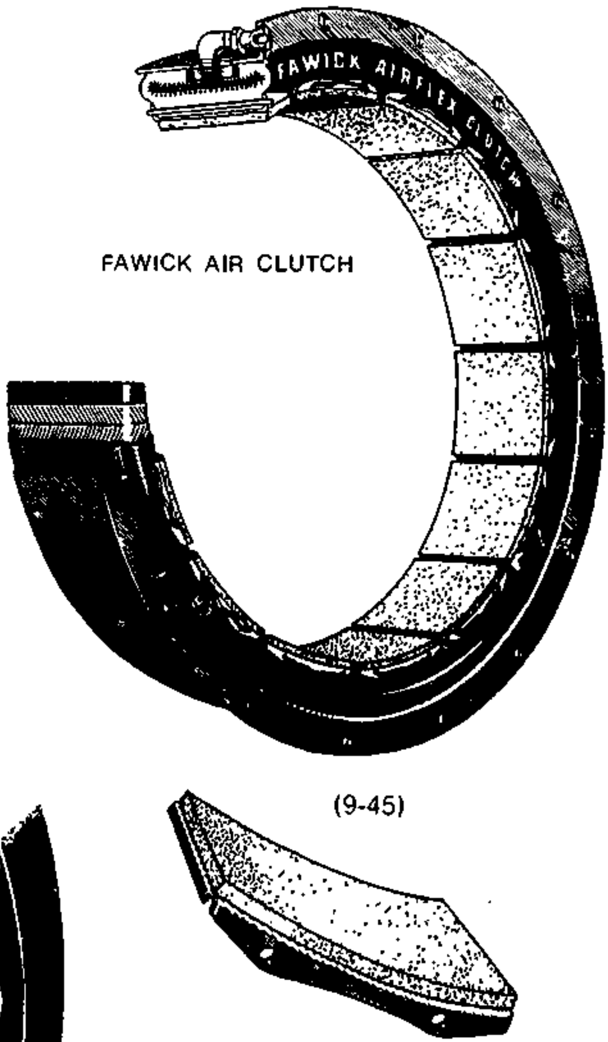
1 **Expanding air tube, multi-disc clutches.** Witchita Clutches (Figure 9-44) as one common type of these clutches is called, are frequently used on logging yarders. When air is applied to the air tube the discs and pressure plates are squeezed together to provide the drive. Not shown in Figure 9-44 is the drum which surrounds the clutch assembly. The drum is the driven member and the hub which is keyed to a shaft is the drive. A witchita clutch setup is similar to a steering clutch used on a crawler.



(9-44) WITCHITA AIR CLUTCH Courtesy of Witchita Company

Expanding air tube brakes are also made. Instead of the one or two discs on air clutches, expanding air tube brakes have a number of discs

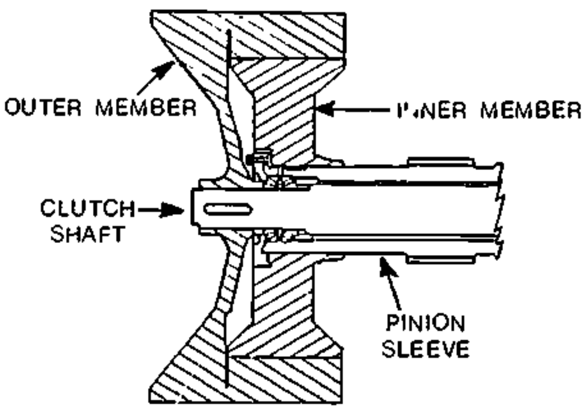
2 **Air tube clutches** used in conjunction with a contracting band clutch. The air tube and band assembly surround the drum When air is applied to the air tubes, the band shoes are forced towards the drum, joining the two and providing a drive.



(9-45)

Courtesy of Fawick Co

3. **Magnetic clutches** are used where electric power is available such as on an electric mining shovel They are called Magnetorque Clutches (Figure 9-46).



(9-46) A SIMPLIFIED VIEW OF THE 'MAGNETORQUE

Courtesy of Harnischfeger Corporation P&H

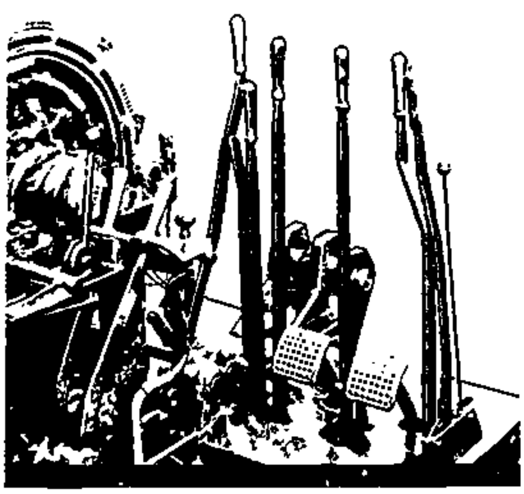
The clutch shaft and outer magnetorque member are driven by the main motor. Since the inner magnetorque member is separated from the outer member by bearings, the driven outer magnetorque can turn without causing the inner member to rotate. Only when the inner and outer members of the magnetorque are coupled together magnetically, do both members turn. When the operator places the hoist controller in the ON position, the outer driven member coils are energized, thus creating a strong magnetic field which couples the driven outer member to the inner member. When the inner magnetorque unit turns, the pinion sleeve drives the hoist drum

Magnetorque characteristics are such that a slight slip between the inner and outer members will cause a large increase in the amount of torque delivered by the magnetorque.

The repair of a magnetorque unit requires, in most cases, that the entire unit and clutch shaft be removed

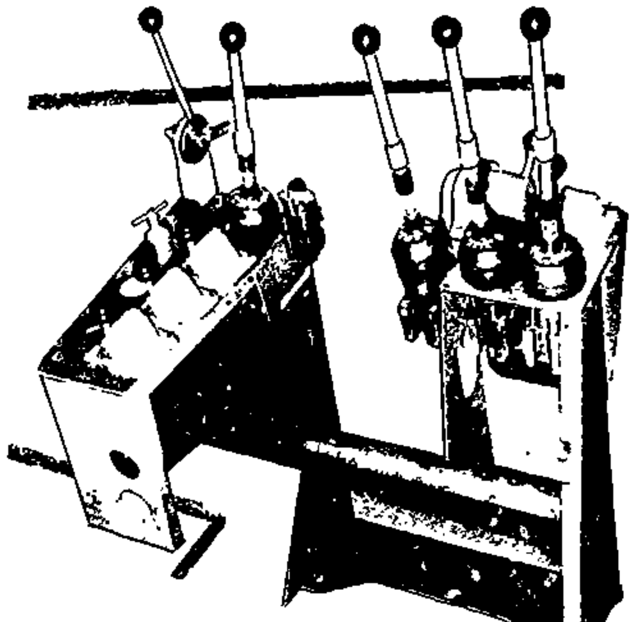
CAB CONTROLS FOR CLUTCHES AND BRAKES

Examples of mechanical and air cab controls for hoist winch clutches and brakes are shown in Figure 9.47



(9-47) MECHANICAL CONTROLS

Courtesy of Bucyrus-Erie Co of Canada Ltd



(9-47) AIR CONTROLS

Courtesy of Bucyrus-Erie Co. of Canada Ltd.

Two types of valves are used on air controls. Graduated valves are used where variable touch control is desired and poppet valves where the response must be fast and immediate

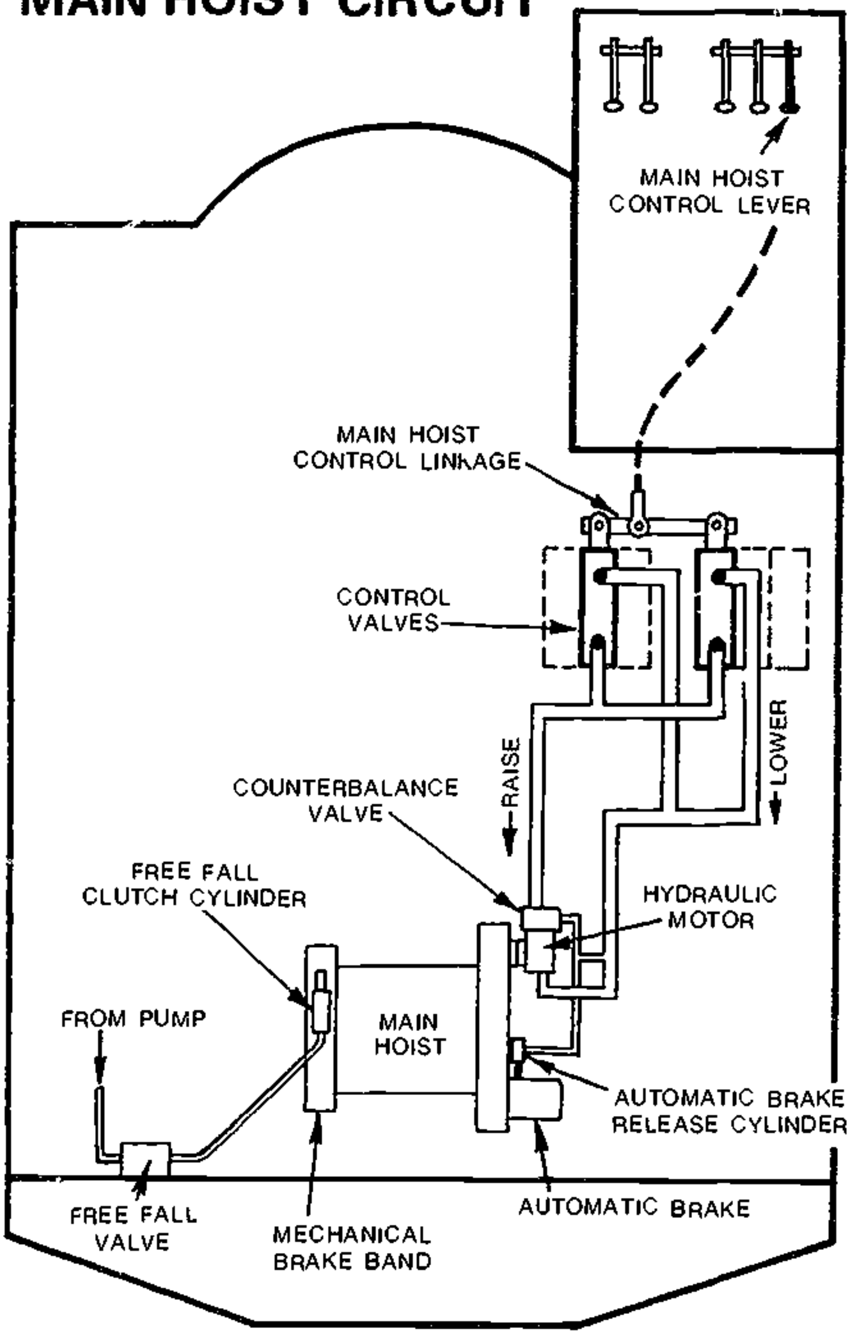
HOIST WINCHES ON HYDRAULIC CRANES

Hydraulic hoist winches are used on modern hydraulic cranes. The power train to operate the winches is as follows: the crane engine drives hydraulic pump(s), the pumps generate the flow and pressure to operate hydraulic motor(s), and the motors drive the hoist winches. By eliminating the mechanical gear train, drive and control mechanisms these hydraulic winches have greatly simplified the winch assemblies and deck machinery of mechanical hoist winches. Hydraulic winches take less space, have simpler controls, and require fewer adjustments.

Depending on the manufacturer, hydraulic hoist winch controls may be direct control or pilot control. However, the trend on hydraulic cranes and on other hydraulic machines is towards pilot controlled valving.

Figure 9-48 shows a simplified view of the main hoist drum on a hydraulic crane Not shown, but also usually found on the crane, are auxiliary winches (1 or more) for supplementary hoisting

MAIN HOIST CIRCUIT



(9-48)

Courtesy of Bucyrus-Erie Co of Canada Ltd

QUESTIONS — HOIST WINCHES

1 Referring to a cable machine, briefly state what is meant by

(a) the basic machine

(b) the convertibility

2 In contrast with tractor mounted winches, the cables on shovel hoist winches

(a) are smaller

(b) run tight at all times.

(c) run within a number of closed circuits

(d) are larger

(e) both (b) and (c) are right.

3 Compared to a cable on a shovel or a crane, logging yarder cable is

(a) shorter and runs tighter

(b) longer and runs looser.

(c) shorter and runs looser.

(d) longer and runs tighter

4 List three basic ways in which hoist winches differ

5 Power to drive a hoist drum is transmitted from the drum shaft to the drum by

(a) a clutch.

(b) a brake

(c) a combination clutch and brake.

(d) gears

6 What prevents a drum from free wheeling when the drive is disconnected?

(a) clutch brake

(b) clutch

(c) brake

(d) mechanical lock

7 When power lowering is desired for a front hoist drum, the power lowering clutch would be mounted on the

(a) rear drum shaft.

(b) front drum shaft

(c) main drive shaft.

(d) horizontal propel shaft

8. How would the drums on a logging yarder differ from those used on a crane or shovel?

9. What are the two common types of drum lagging?

10. Increasing the thickness of the lagging increases the drum diameter and causes the line speed to

(a) decrease.

(b) increase.

(c) stay the same.

11. True or False? In controlled load raising and lowering, smooth drum lagging is used

12. What is the advantage of making large brake bands in multiple pieces rather than in one piece?

13. The most common method for applying hoist winch brakes on today's machines is by ______________.

14 Give two methods used to apply shoe or band clutches on winches

15. What advantage do multi-disc expanding air tube clutches and brakes have over the older designed expanding shoe and contracting band ones.

16 The drive and driven members on a machine using magnatorque clutches are coupled together by

(a) friction.

(b) heat.

(c) mechanical force.

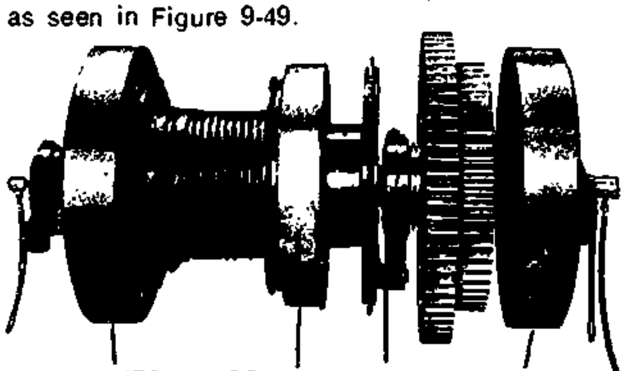
(d) magnetic field

17. True or False? Magnetorque clutch characteristics are such that a slight increase in slip between the drive and driven members will cause a large decrease in the torque delivered by the magnetorque.

18. What are the advantages of a hydraulically driven hoist winch over a mechanical hoist winch?

REMOVAL AND INSTALLATION OF CRANE EXCAVATOR AND YARDER HOIST WINCHES

Removal and installation of a hoist winch is a relatively straight forward job. On most machines the winch is generally mounted so that drum shaft assemblies come out as a unit, as seen in Figure 9-49.



DRAG CLUTCH AND BRAKE BOOM HOIST BRAKE SWING CLUTCH

(9-49)

Courtesy of Bucyrus-Erie Co of Canada Ltd.

SOME POINTS WHEN REMOVING AND INSTALLING HOIST WINCH COMPONENTS

1 Before attempting to remove a drum shaft assembly, place the working implement controlled by the drum shaft in a safely lowered position and remove the cable from the drum

2 Tag all hydraulic or air lines that are removed

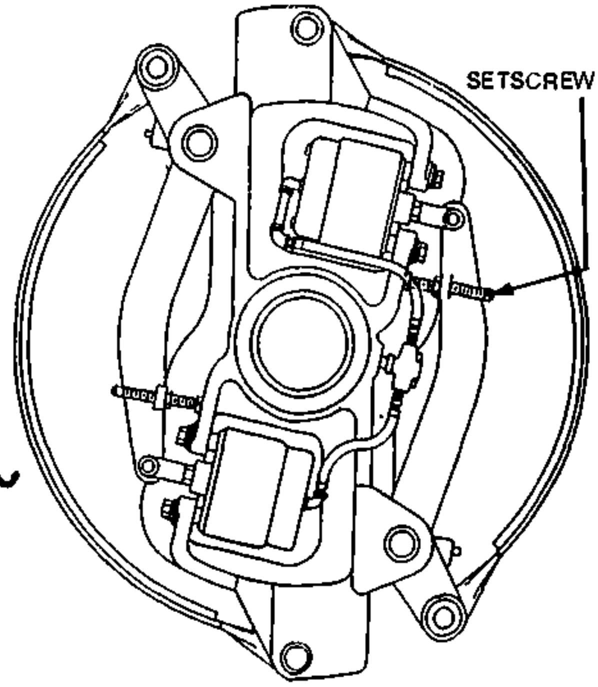
3 When the bearing caps and related accessories have been removed, attach slings so that they provide a safe, even and balanced lift to the shaft assembly.

SCHEDULED MAINTENANCE CHECKS, ADJUSTMENTS AND LUBRICATION ON HOIST WINCHES

Like most clutches and brakes, hoist winch clutches and brakes require periodic adjustment to compensate for normal running wear A clutch slipping under load or a brake not holding the drum indicates that adjustments are needed. Tremendous strain is applied to these clutches and brakes and allowing slippage to go unchecked will soon lead to the parts failing.

Typical adjusting procedures are given below, one for a contracting band clutch and one for a contracting band brake Always refer to the service or operator's manual for the adjusting procedures on specific machines.

ADJUSTMENT ON CONTRACTING BAND CLUTCH



(9-50)

Adjustment of contracting band clutches is recommended for smoother application and less maintenance to the air chamber assembly. To make the adjustment, disengage the clutch so that no air is left in the chambers. Then adjust the setscrew (Figure 9-50) to obtain a 1/32" clearance, all around, between the clutch surface and the lining.

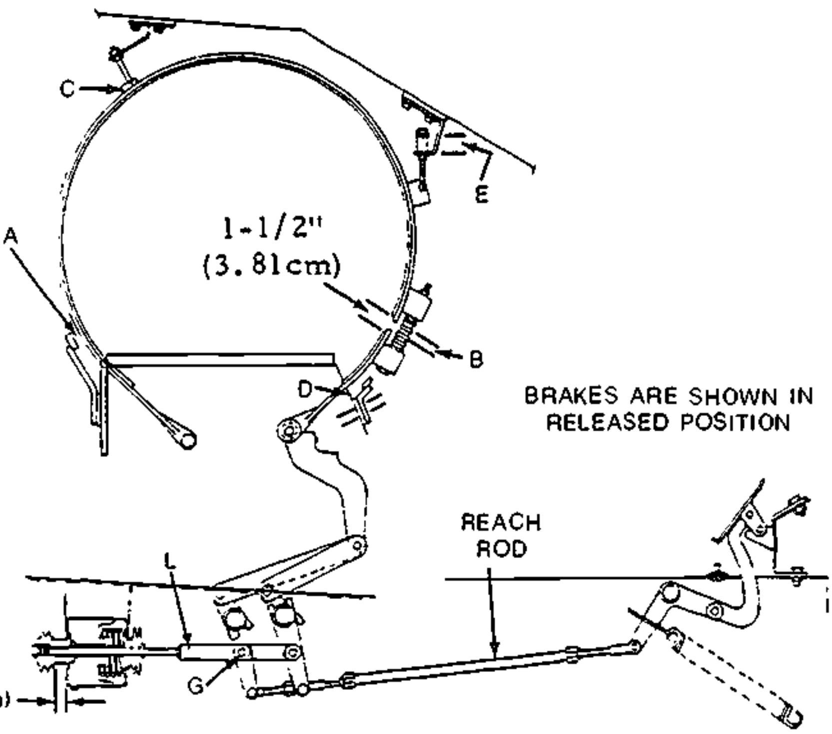
CLUTCH BAND LINERS

Clutch band liners wear more rapidly on the fixed end than on the moving end. "AMERICAN" clutch bands are made with both ends alike so that after a period of operation in one position, they may be reversed to give additional service life.

The clutch band liners should be examined periodically for wear, and they should be renewed before they become thin enough to permit the rivets to contact the clutch surface and cause scoring. When linings have to be renewed, care must be exercised in their installation to ensure that they are tightly and smoothly riveted to the band, and that the bands are not bent out of shape. After replacing the bands, they must be checked for "out-of-round" and if necessary, hammered back to shape to secure good contact at all points.

EXAMPLE
ADJUSTMENT OF CONTRACTING BAND BRAKE
(American Hoist and Derrick Co.)

MAIN HOIST BRAKE ADJUSTMENT



(9-51) Courtesy of American Hoist and Derrick Co

1 With new or newly relined band set gap on metal portion of band at point "B" to 1-1/2" (3 81 cm)

2 Disconnect spring loaded air brakes by removing pin "G" from clevis "L"

3 Adjust pedal to operators preference by extending or retracting reach rod. General setting is so the full line pull may be held in the last notch of the pedal latch

4 Set lifter "A" at dead end with brake set 030" (762 mm) clearance.

5 Make sure that guide "C" is free of both band and guide bars on band.

6 Set lifter "D" at live end with brake set to 060" (1 524 mm) clearance.

7 Adjust lifter spring "E" so that it has ample lifting force to disengage band when brake is released, but be very careful that the spring is not tightened to the point where there is no recoil left in it.

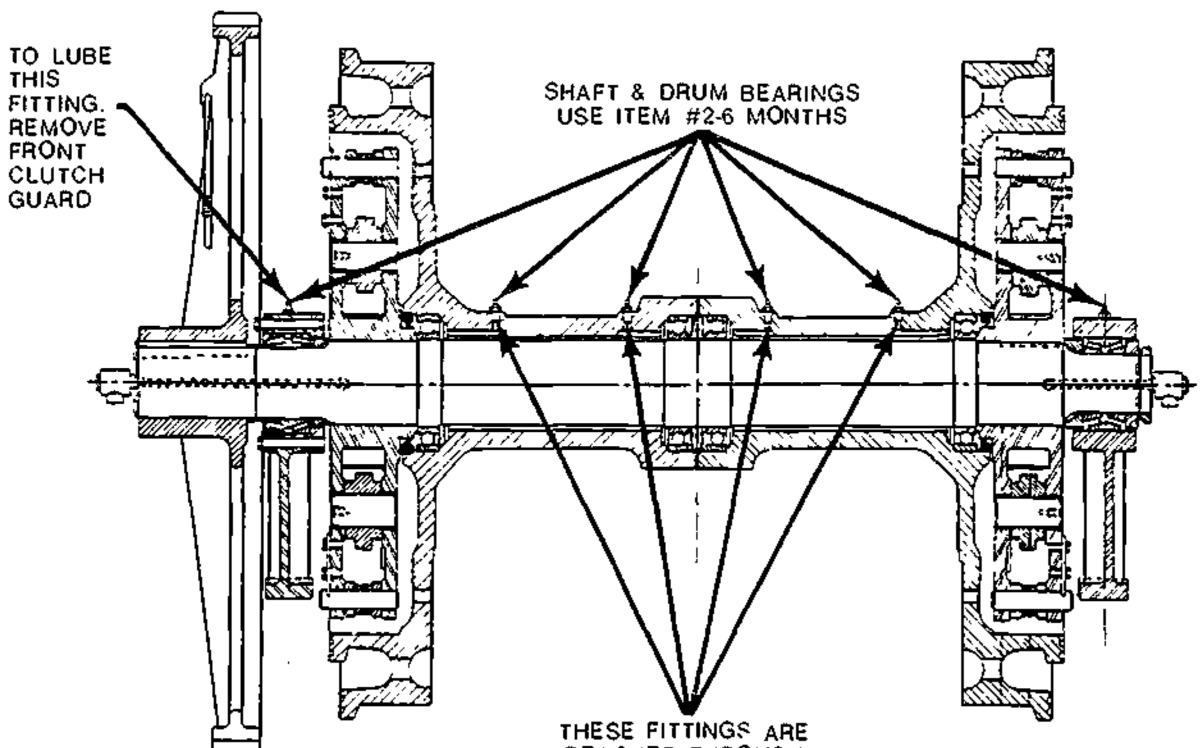
8. Test with load and make final and all future adjustments at split "B".

9 Adjust the clevises "L" on the brake chamber rods until they can be connected to the brake pedal linkage. The hoist brake pedal and brake valve (on lever stand) must be released (air in brake). Allow 1/8" (3 18 mm) clearance between the back of brake chamber and the nut and washers on the brake chamber rod.

LUBRICATION FOR HOIST WINCHES

Lubrication for hoist winches will be found in service manuals. The more mechanical the hoist machinery the more lubrication points it will have Most of the bearings for deck machinery, operating levers, shafts, bell cranks, etc., have grease fittings tapped directly into the bearings Location of these fittings as well as other points on the deck machinery that require lubrication will be shown in the manual on lube charts. A chart may show individual drum shafts or it may show a complete deck plan. Some charts also include the type of lubricant and lubrication interval Examples of lube charts are shown in Figure 9-52 and 9-53

MAIN & AUXILIARY HOIST DRUM ASSEMBLY

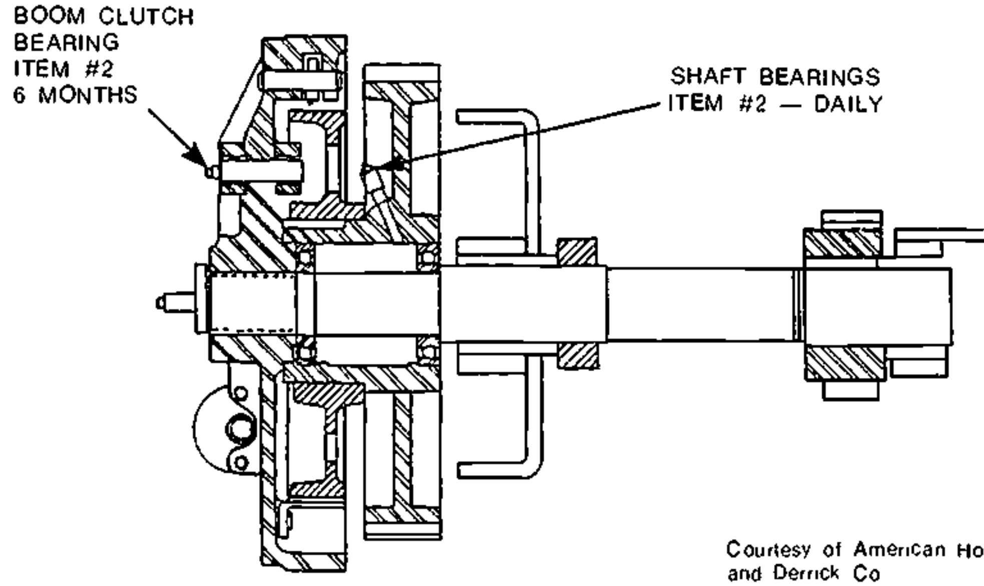


(9-52)

Courtesy of American Hoist and Derrick Co

BOOM HOIST CLUTCH SHAFT ASSEMBLY

LUBRICATION

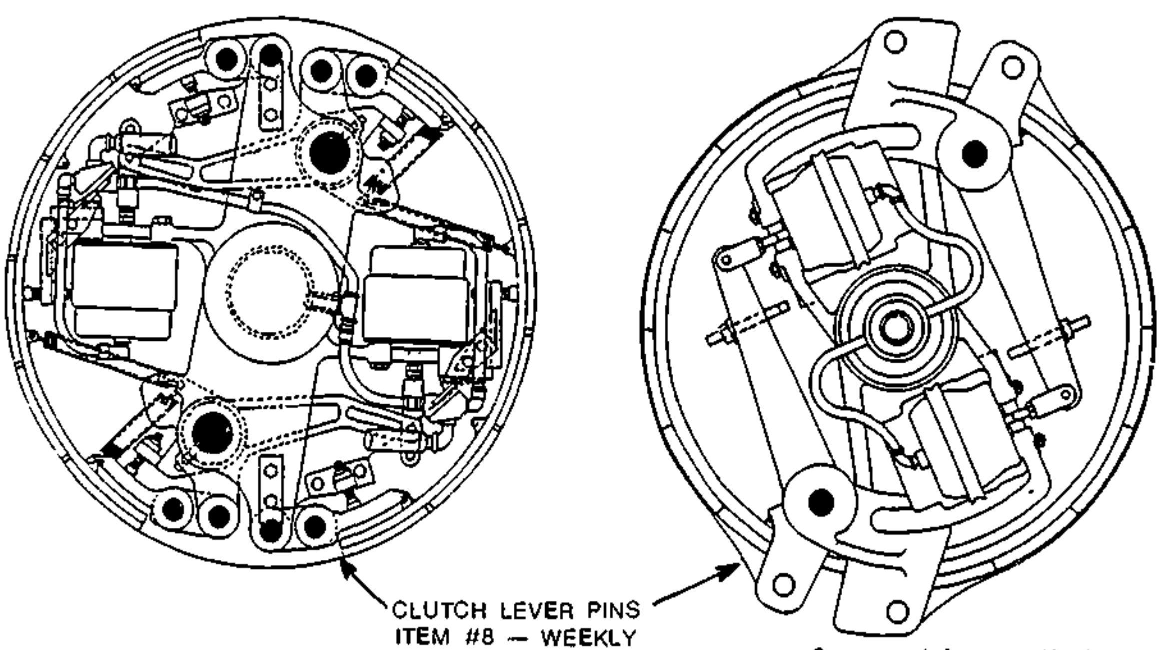


Courtesy of American Hoist and Derrick Co

(9-52)

MAIN HOIST CLUTCH ASSEMBLY

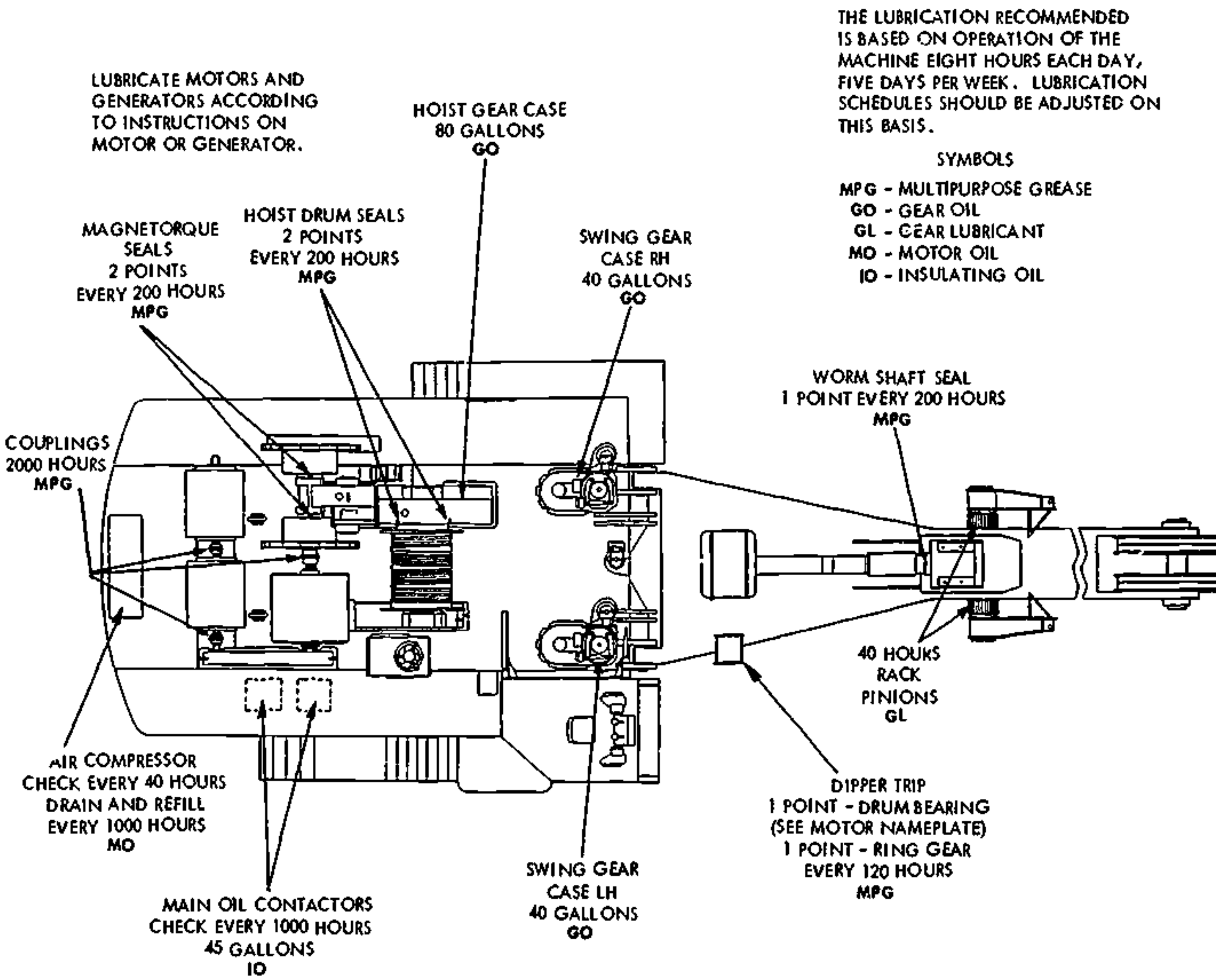
THIRD DRUM CLUTCH ASSEMBLY



Courtesy of American Hoist and Derrick Co

(9-52)

EXCAVATOR LUBRICATION (HOIST MACHINERY LUBE POINTS ARE STARRED (*))



(9 53)

Courtesy of Harnischfeger Corporation P&H

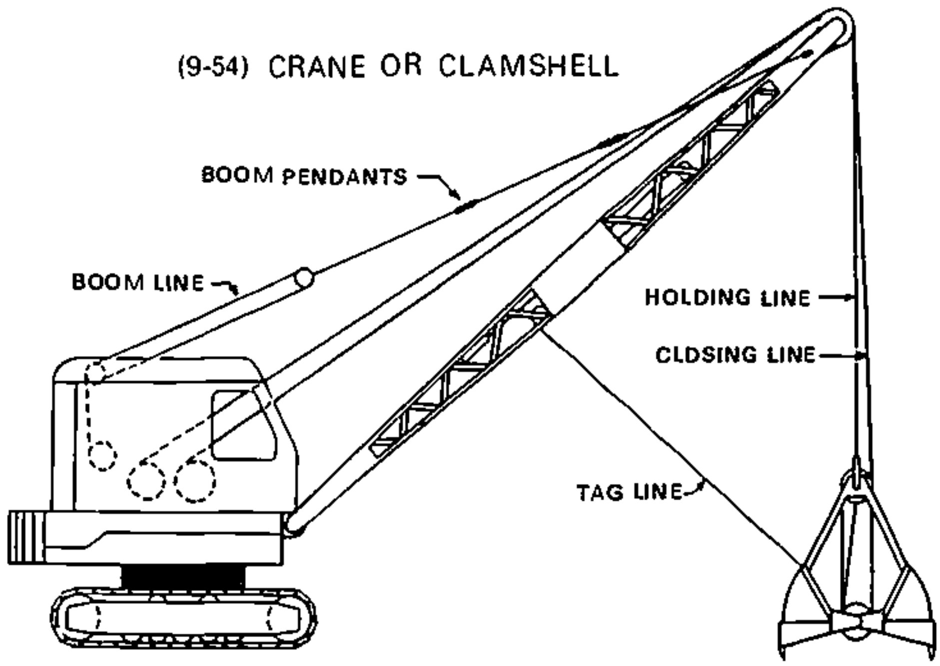
QUESTIONS — MAINTENANCE OF HOIST WINCHES

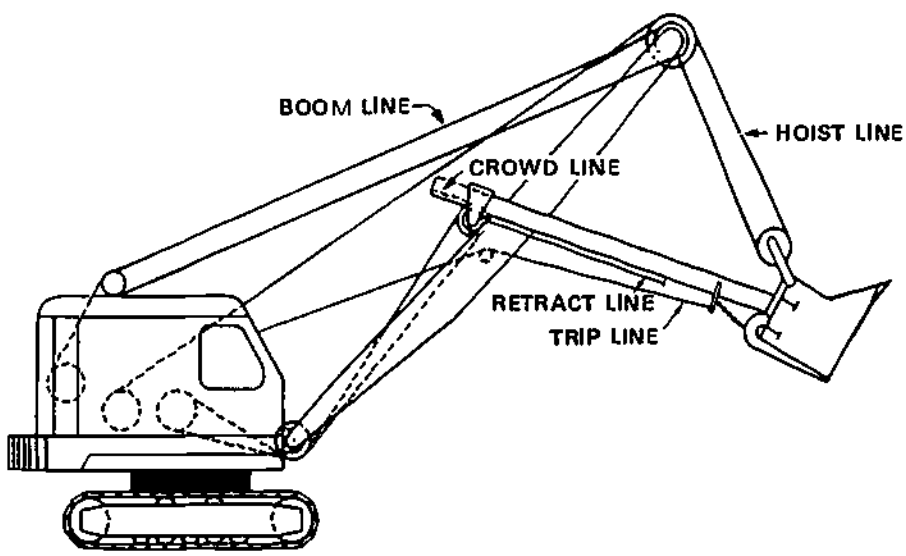
1. What is the first step that must be done before removing a hoist winch drum and shaft assembly?
2. An indication that adjustments to the clutch and brakes on a hoist winch are required is that the winch
   (a) operates slowly.
   (b) applies and releases with difficulty.
   (c) will not release
   (d) slips under load.
3. A typical adjustment procedure for a shoe clutch requires that the adjustment be made so that the clearance between the shoes and the drum is approximately:
   (a) 1/4"
   (b) 1/32"
   (c) 1/64"
   (d) 1/8"
4. True or False? Hoist winch assemblies should be lubricated on a "whenever required" basis
5. Referring to the excavator lubrication chart (Figure 9-53), find at what interval the hoist drum seals are greased and what type of grease is used.

WIRE ROPE

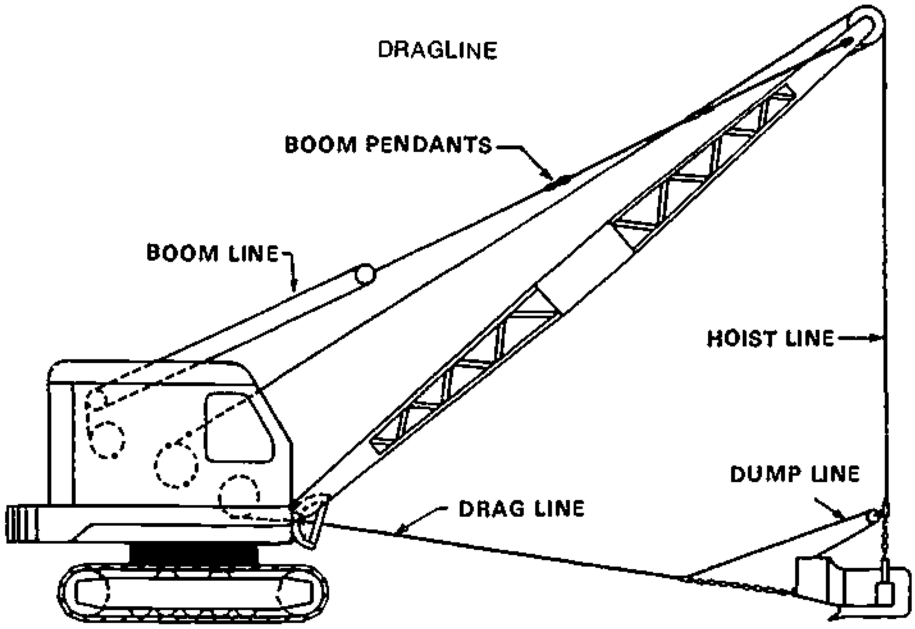
Wire rope comes in a number of diameters. cross sectional constructions and strengths It has many uses in the heavy duty mechanical field. a few of which are shown in Figure 9-54 and 9-55.

(9-54) CRANE OR CLAMSHELL





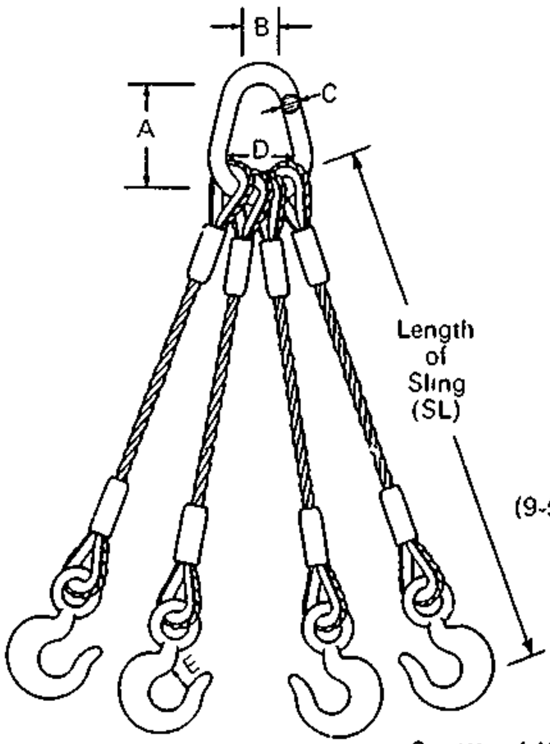
(9-54) POWER SHOVEL (EXCAVATOR)

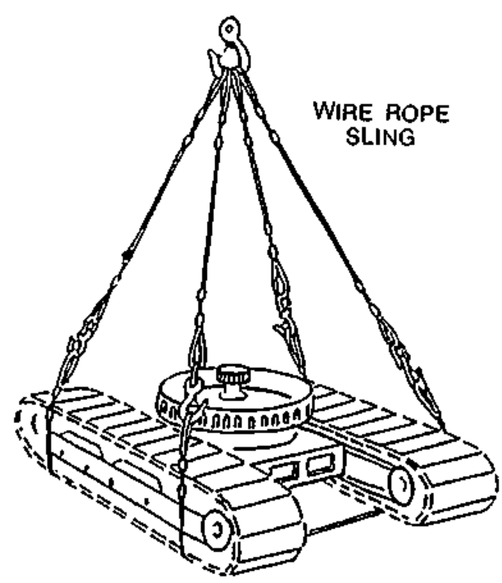


(9-54)

Courtesy of Martin and Black Wire Ropes Ltd

4 PART BRIDLE SLING

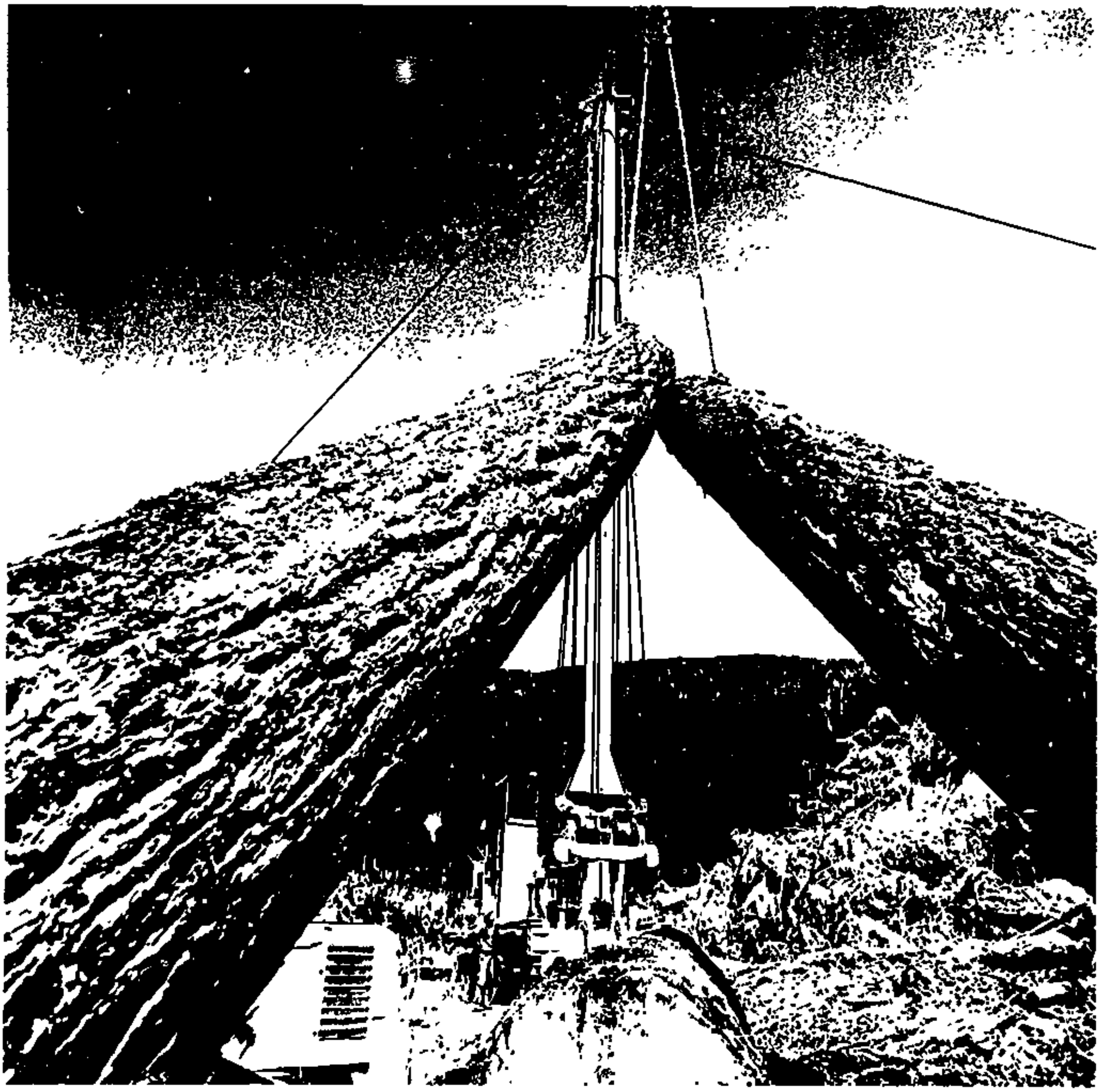




(9-54)

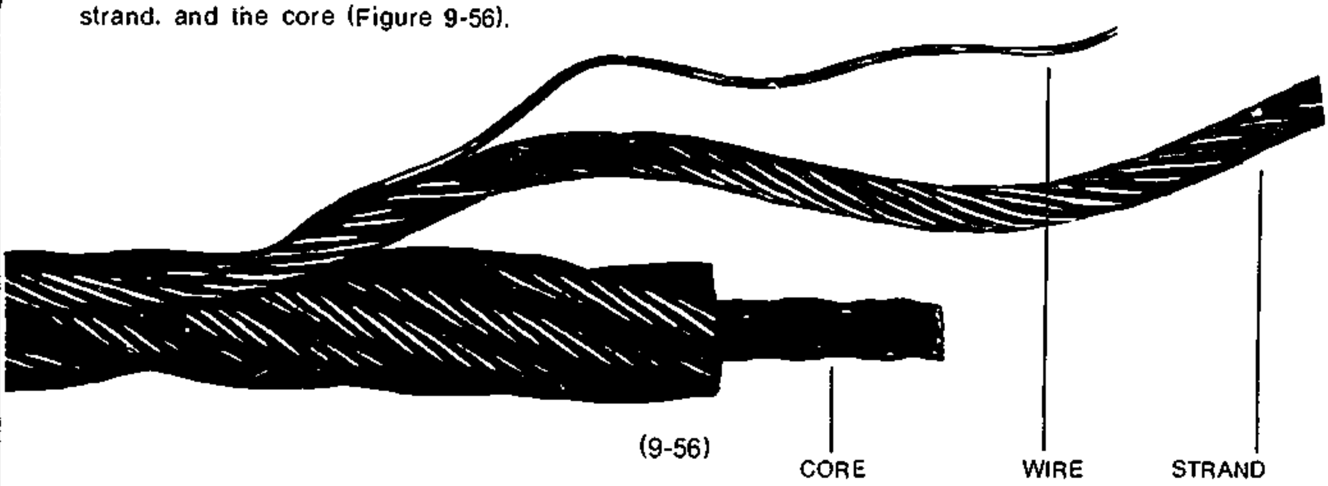
Courtesy of Martin and Black Wire Ropes Ltd

LOGGING



(9-55) Courtesy of S Madill Ltd

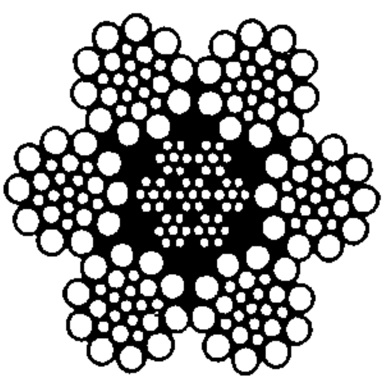
The parts of a wire rope are the wire, the strand, and the core (Figure 9-56).



(9-56)

Courtesy of Martin and Black Wire Ropes Ltd

The cross section of a common six strand wire rope is shown in Figure 9-57.

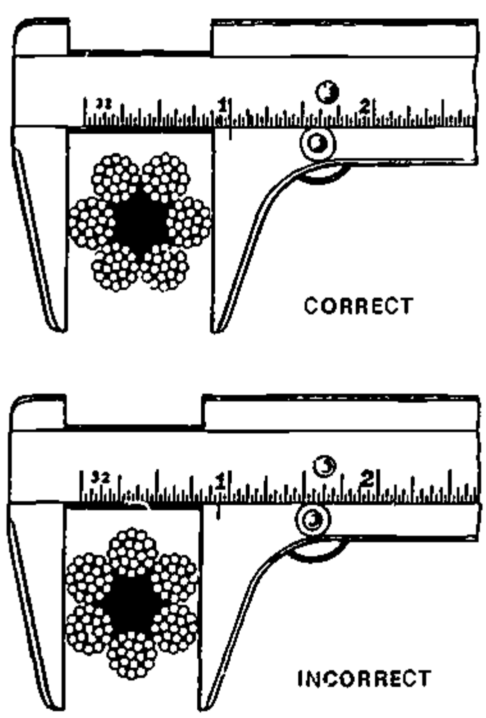


(9-57) Courtesy of Martin and Black Wire Ropes Ltd

MEASURING A WIRE ROPE

The diameter of a wire rope is identical to that of a circle which would surround the rope. To gauge a rope be sure that the faces of the calipers are in contact with the crowns of two opposite strands and not in contact with four strands (Figure 9-58). To be certain that the calipers are in the correct position rotate them around the rope: the greatest measurement is the correct size.

Note: After a rope has been in use it is sometimes possible to get two "correct" readings of its size that vary considerably. Different readings can occur when the rope has lost its shape due to crushing or when there is corrosion or core damage at intermittent points along the rope.



(9-58)

Courtesy of Martin and Black Wire Ropes Ltd

CORES

The core in a wire rope is the central section around which the strands are laid. Cores can be made of fiber or steel.

1. **Fiber Core**

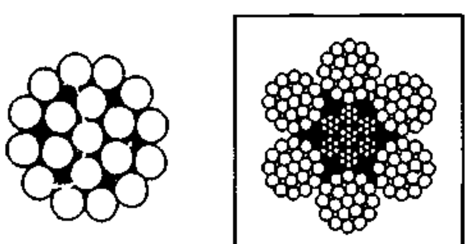
   Fiber cores can be made of vegetable fibers such as manila, jute or sisal, although increasing use is being made of manmade fibers. Polypropylene, for example, offers the advantage of better resistance to rotting, drying out and other forms of deterioration than natural fibers.

   The main function of a fiber core is to cushion the steel strands during operation. Also because the core is usually impregnated with lubricant before manufacture, it acts as an internal lubricator during the operation of the rope. Fiber core are the most flexible wire ropes.

2. **Steel Cores**

   A steel core is usually a small separate or independent wire rope referred to as an IWRC. An IWRC normally has a core and six strands (Figure 9-59). A wire strand can also be used as a steel core on fairly non flexible rope, such as guy wires (Figure 9-59)

   A steel core adds strength (7½% minimum) and provides resistance to crushing. Additional strength is not the only reason for specifying a steel core. Where a steel core is required excessive heat in the operation of a rope could cause charring of the fiber. An IWRC is also essential for maximum performance on such applications as shovel hoist lines, draglines, etc.



19 wire strand

6 x 25 IWRC

(9-59)

Courtesy of Martin and Black Wire Ropes Ltd

WIRES

Wire in a wire rope varies in its diameter and the type of steel it is made of. The steel will range from having great strength to having less strength but more durability or resistance to fatigue. Note that it is wrong to think that the rope with the strongest steel is necessarily going to be the best for every job. For example on a given job, a rope made with a ductile flexible steel may out perform and out last a rope made of a steel with a higher breaking strength.

When corrosive conditions warrant rope protection over and above normal lubrication, wire is galvanized.

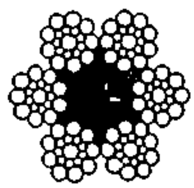
STRANDS

CHARACTERISTICS OF STRANDS

1. Strands are classified by the number of strands on a rope and the number of wires per strand

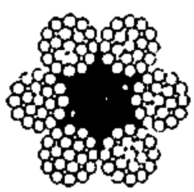
CLASSIFICATION	NO. OF STRANDS	WIRES PER STRAND
6 · 7	6	7
6 · 19	6	15 to 26
6 · 37	6	27 to 49
8 · 19	8	15 to 26

2 The wires on a strand have different cross sectional patterns. three of the most common are shown in Figure 9-60.



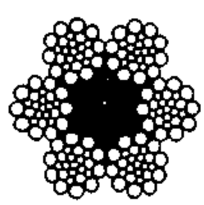
SEALE CONSTRUCTION

One layer of wires is laid over an equal number of smaller wires. with the same length and direction of lay. The wires in the outer layer are supported in the valleys between the wires of the inner layers



FILLER CONSTRUCTION

In this construction. the outer wires are supported by half their number of main inner wires with an equal number of small filler wires.



WARRINGTON SEALE

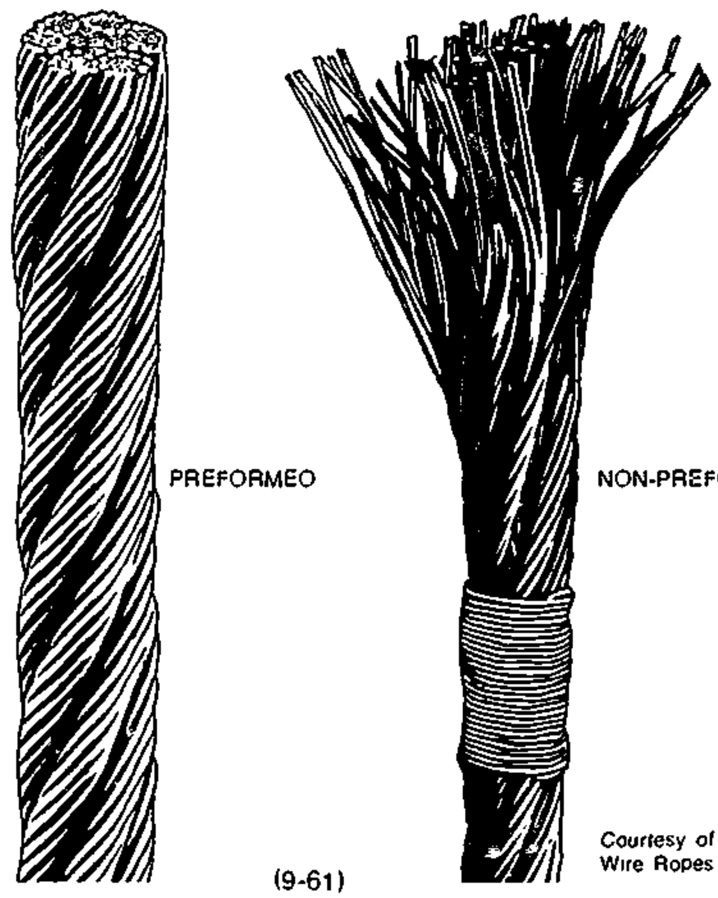
A strand construction in which one layer of wires is composed of alternating large and small wires. The length of lay and number of wires in each layer. are equal.

In larger size wire ropes, more than one of the above basic constructions may be integrated in a single strand.

(9-60)

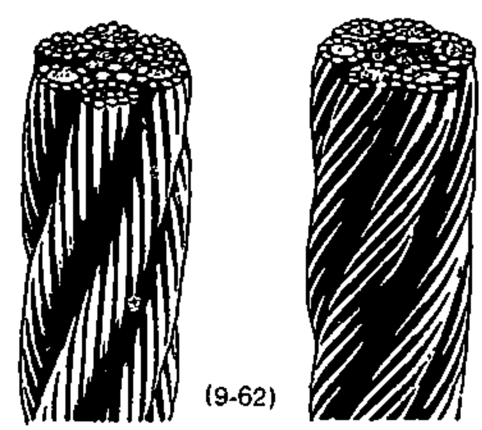
Courtesy of Martin and Black Wire Ropes Ltd

3 Most wire rope today is preformed. that is. each wire and strand is preset to the exact helical shape it will take in the finished rope A preformed rope won't unravel when cut Preformed wire rope is more flexible. lasts longer. and is easier to splice (Fig. 9-61)



(9-61)

Courtesy of Martin and Black Wire Ropes Ltd



(9-62)

REGULAR LAY LANGS LAY

Courtesy of Martin and Black Wire Ropes Ltd

4. **Lays of Wire Rope**

(Martin and Black Manual). The term "lay" has two meanings in reference to wire rope.

(a) When used to describe the direction of rotation of wires the term is usually applied to two basic lays:

Regular Lay is applied where the wires turn in the opposite direction to that of the strands in the rope. The outer wires of the strands are parallel to the rope axis (Figure 9-62).

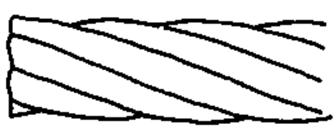
In **Langs Lay**, the wires in each strand are laid in the same direction as the strands of the rope (Figure 9-62) The outer wires of the strands are at an angle to the rope axis and much longer lengths of the individual wires are exposed

The advantages and disadvantages are.

Regular Lay: Greater resistance to crushing on drums than Langs Lay; it should always be used on a single part line, or when one end is free to rotate.

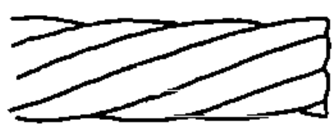
Langs Lay: More flexible and offers greater resistance to abrasion than Regular Lay ropes. Only applications where both ends are fixed are suitable for Langs Lay rope, it should not be used with a swivel terminal. Langs Lay cable is used on power shovels and draglines and for mine hoisting.

Right or left lay is determined by the direction in which the strands are laid in the rope The strands in a left lay rope (Figure 9-63) run to the left from the top to the bottom (which ever way you look at the rope). Strands in a right lay rope (Figure 9-63) run to the right from top to bottom The vast majority of ropes are right-regular lay.



Right Lay

(9-63)



Left Lay

(b) The term lay is also used as a rope measurement. One rope lay is the length along the rope which one strand takes to make one complete spiral around the core.

(9-63) Courtesy of Leschen Wire Rope Co

WIRE ROPE INSPECTION

Eventually all wire rope deteriorates to a point where it is no longer serviceable or safe. Regular inspections, therefore, are necessary to ensure that the rope is in acceptable working condition. Besides being good maintenance policy, periodic inspection of all wire rope in critical lifting service is required by government regulations, and records of the inspection must be kept. Wire rope should be replaced when a qualified inspector feels it can no longer safely do the job it was intended to do.

Points on Inspecting Wire Rope

(a) When checking wire rope, the rope should not be in motion or should not be supporting a load: it should have no stress on it.

(b) All rope used in vertical lifting service should be checked and each rope must be considered separately.

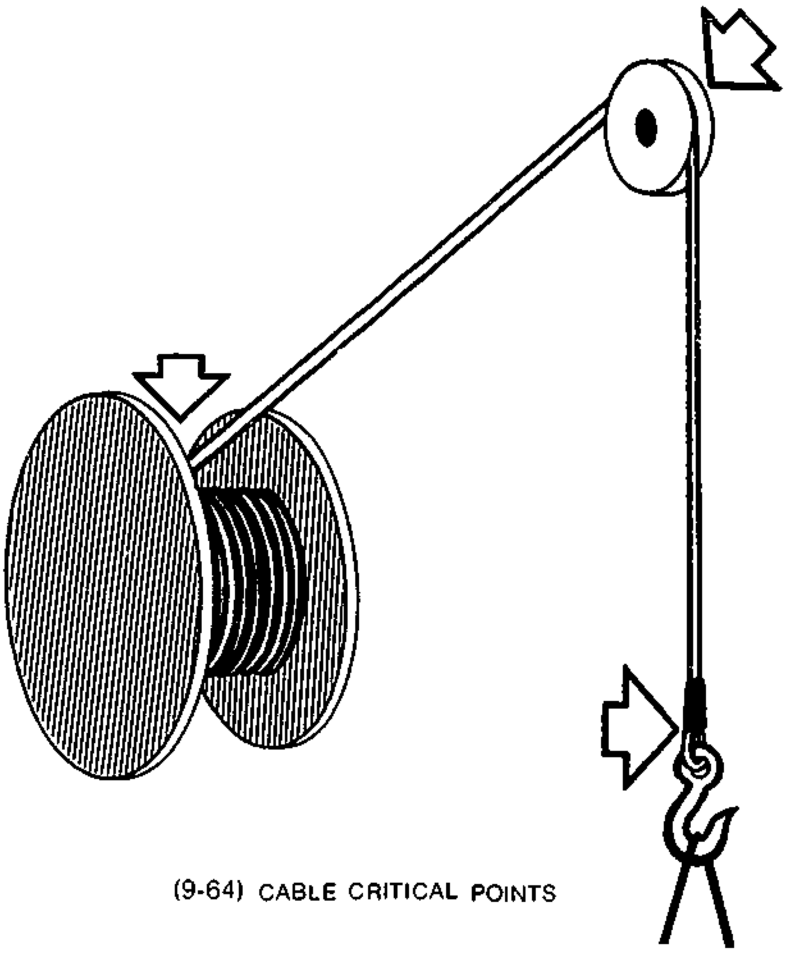
(c) Inspections should be done weekly.

(d) There are certain points along any given rope which should receive more attention than others, since some areas will usually be subjected to greater internal stresses, or to greater external forces and hazards. Although different types of cable applications will have different critical points (Figure 9-64) some common ones are:

Pick-up Points — These are sections of rope which are repeatedly placed under stress when the intitial load is applied. Examples are the sections of rope in contact with sheaves.

End Attachments — At each end of the rope, two things must be inspected, the fitting that is attached to the rope, or to which the rope is attached, and the condition of the rope itself where it enters the attachment.

Abuse Points — Frequently, ropes are subjected to abnormal scuffing and scraping such as where the rope contacts cross-members of a boom. Look for bright or shiny spots on the rope.

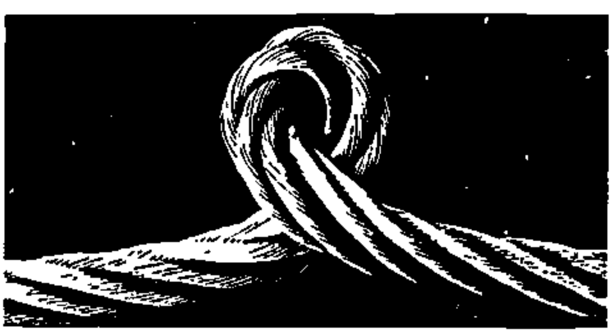


(9-64) CABLE CRITICAL POINTS

5 An inspection of wire rope should include checks for the conditions below (Figure 9-65). If any of these conditions are found. the strength of the rope is in question and the possibility of replacing it should be considered.

EXTERNAL ROPE DAMAGE OR ABUSE

Rope Abuse — Kinking. drum crushing, bird caged and trapped rope are shown in Figure 9-65.



An "OPEN KINK

An "OPEN KINK" after straightening (note misplaced wires and strands)

(9-65)

Courtesy of Martin and Black Wire Ropes Ltd

A rope with snagged wires resulting from "DRUM CRUSHING"

(9-65)

A BIRD CAGE which has been forced through a tight sheave

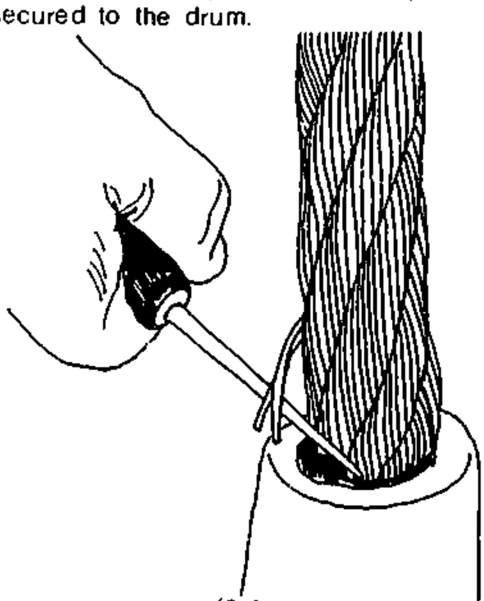
(9-65)

Courtesy of Martin and Black Wire Rope Ltd

A rope that has been "TRAPPED", after jumping off a sheave

Corrosion — look for serious corrosion in the rope

End Point of Cable — Check (1) for broken wires where the rope is attached to the fixture (Figure 9-66) and (2) that the fixture is firmly attached to the rope or that the rope is firmly secured to the drum.

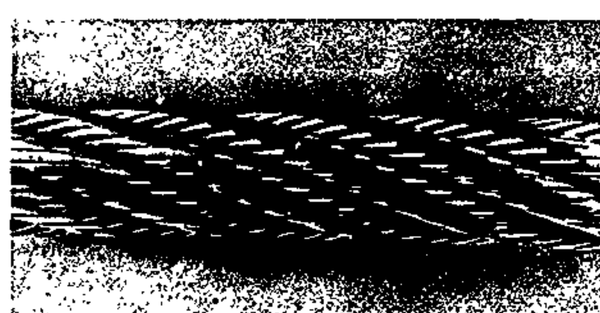


(9-66)

One manufacturer recommends that any broken wires at the dead end of a cable should be cause for cutting off a section, preferrably at least three feet beyond the broken wires Refasten or re-socket the rope.

Also check for:

1. The core showing through more than one pair of strands.
2. Evidence of improper lubrication of the rope Evidence of the rope overheating or coming in contact with an electrical circuit.
3. The amount of wear on outer wires. The Operating Engineer's Manual recommends that wire rope should be replaced when the wires in the crown of the strand are worn to less than 60% of their original diameter (Figure 9-67).



(9-67) Rope which has been worn due to ABRASION (Note even wear around the strands).

Courtesy of Martin and Black Wire Ropes Ltd

DIAMETER MEASUREMENT AND BROKEN WIRE COUNT

Reduction In Rope Diameter: Measure the rope diameter and compare the reading with the original diameter. A marked decrease can indicate a serious weakening of the rope

Broken Wire Count: Broken wires are probably the most common sign of rope deterioration because it's normal for running rope to break wires near the end of its serviceable life. Two broken wire counts are made over one lay length of rope:

1 Count the number of broken wires in one rope lay length on the worst section of rope It is important that the worst section be used for the count because that is the weakest section of rope Note that this count totals the broken wires in all the strands in the one lay length.

2 Count the number of broken wires in one strand in the lay length. Again. the worst strand or the strand with the most broken wires should be counted.

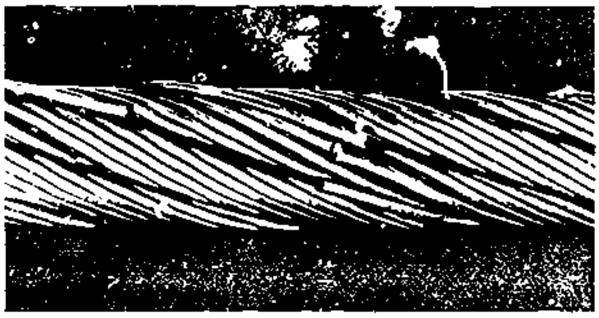
The number of broken wires permitted per lay or per strand per lay is specified according to the rope size. For example. the Operating Engineer's Manual. using a count for total broken strands per lay. recommends that rope should be replaced when

(a) three broken wires are found in one lay of 6 × 7 wire rope

(b) six broken wires are found in one lay of 6 × 19 wire rope.

LOOKING FOR BROKEN WIRES

A close search should be made for broken wires (Figure 9-68) With a sharp awl. pick and probe between wires and strands lifting any wires which appear loose or move excessively.



(9-68) BROKEN WIRES

Courtesy of Martin and Black Wire Ropes Ltd

Note that flexing a rope can often reveal broken wires that may not be visible when the rope is straight (Figure 9-69)

(9-69)

Courtesy of Martin and Black Wire Ropes Ltd

Records of inspections, as mentioned earlier, must be kept. An example of a Rope Inspection record sheet is given below. Diameter Loss and the number of wire breaks would be recorded and compared to allowable tolerances.

			Rope Condition					
Rope description (hoist, swing line, etc.)	Date of Installation	Date of Inspection & Inspector's Initials	Nom dia, in. (when new) Col 1	Current dia, in.	Loss of dia, in. Col 2	No. of wire breaks in one rope lay Col 3	No. of wire breaks in one strand of one lay Col 4	Date of Removal

INSPEC. DRUMS AND SHEAVES

The general condition of drums and sheaves should also be checked. A thorough checking of sheaves involves checking each sheave with a groove gauge. The drum should be observed in operation to check the drum wind.

In summary a recommended order of procedures for carrying out a wire rope inspection is

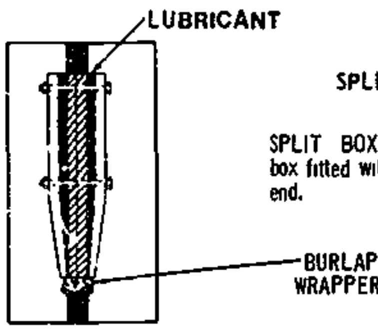
1. Measure diameter. Record.
2. Count broken wires (a) in one lay, (b) in one strand in one lay. Record.
3. Check rope end points.
4. Inspect the rope end to end for external damage and abuse. Try to find the cause of damage and see if it can be prevented from happening again.
5. Inspect the sheaves and drums.

LUBRICATING WIRE ROPE

Wire rope has moving parts. Each time a rope bends over a sheave or straightens from a slack position, many strands move or slide against each other. Therefore to prevent rope wires from wearing lubrication is necessary. An equally important reason for lubricating rope is to prevent the wires from corroding. Wire rope should not be allowed to rust: rusty rope is dangerous as there is no known method of inspecting it to determine its remaining strength.

No set rule can be given concerning the frequency of lubrication. The frequency will depend on the conditions to which the rope is subjected. The severity of the duty and the degree of corrosiveness will have to serve as an index in determining the need for lubrication. Proper lubricant should be used. The lubricant should be thin enough to penetrate the strands to the core, but not so thin that it will run off the rope. The best lubricant is a fairly thick, semi-plastic type, which is applied hot, in a thinned condition. This type of lubricant will penetrate while hot and then cool to form a plastic filler and coating, which will resist the penetration of water.

Three methods of applying lubricant to wire rope are illustrated in Figure 9-70. Each has its advantages, and no single method is recommended in preference to the others. The most convenient method should be used.

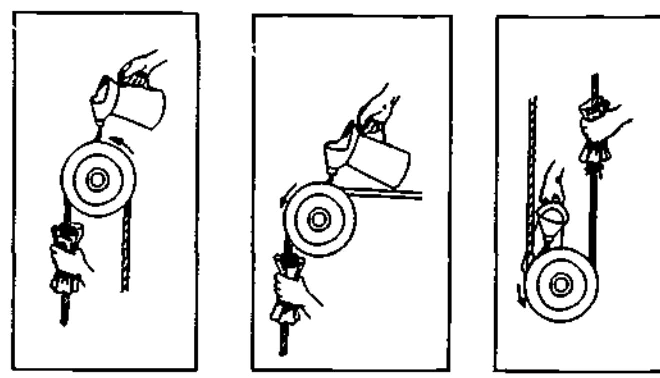


(9-70)

SPLIT BOX METHOD

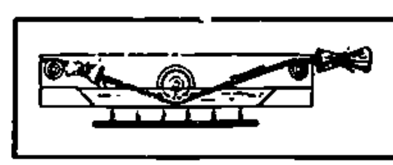
SPLIT BOX METHOD–funnel shaped box fitted with burlap or wiper at outlet end.

Courtesy of Harnishfeger Corporation P&H



POUR-ON METHOD

THE POUR-ON METHOD–oil should be hot, yet adhesive. Always hold the wiping swab behind the sheave.

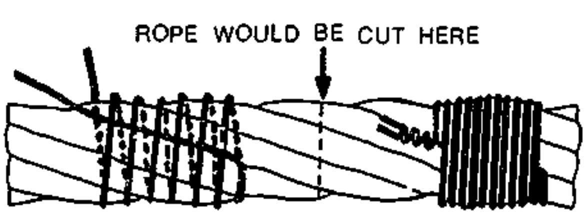


BATH METHOD

BATH METHOD–for applying heavier-bodied lubricant at high temperature. Gas burners or steam heat may be used to maintain temperature of lubricant. Rope should run through slowly.

CUTTING WIRE ROPE

When wire rope is to be cut, seizings should be placed on each side of the cut line to prevent underlaying of the strands. A seizing is shown in Figure 9-71. The seizing on the left is loose to show how it's wrapped. On the right is the tightened seizing.



(9-71)

On preformed wire rope, one seizing on each side of the cut is usually considered to be sufficient. On non-preformed wire ropes less than 7/8 inch in diameter, two seizings on each side are recommended. On non-preformed wire ropes over 7/8 inch in diameter, three seizings are recommended.

Three basic methods are recommended for cutting wire rope:

1. Abrasive cutting tools. A suitable abrasive cutting machine will cut cable.
2. Shearing tools. Wire cutters can be used to cut through smaller ropes, while special blade-action tools and a hammer are used for larger sizes.
3. Flame. Welding equipment can be used to burn cuts through wire rope. Flame cutting isn't recommended if the wire strands need to be free after the cut as the torch tends to weld the strands together.

STORING WIRE ROPE REELS

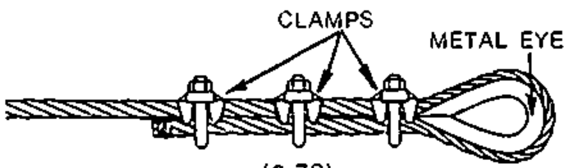
Wire rope reels should be stored in a covered area if possible and on pallets or timbers

CLAMPS AND SHEAVES

WIRE ROPE CLAMPS

Clamps are used to

1 Form a loop in a rope in order to attach the rope to a fixture (Figure 9-72).

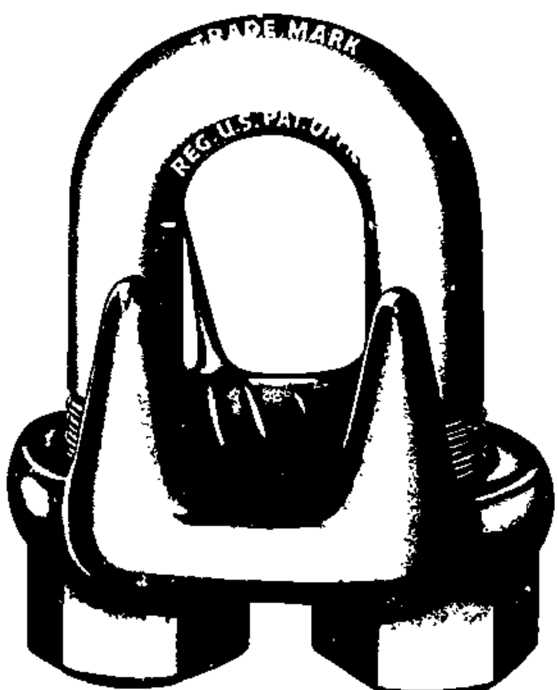


(9-72)

Courtesy of Martin and Black Wire Ropes Ltd

2. Form loops to attach two ropes together. The metal eyes are connected together.

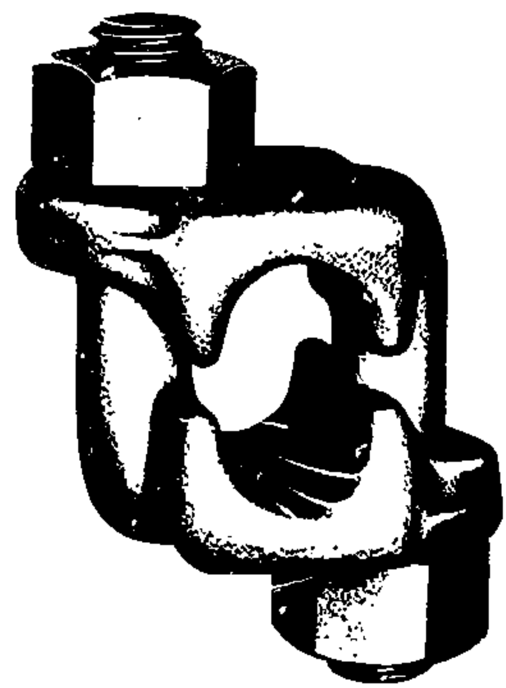
The U-Bolt in Figure 9-73 is a very common type of clamp used with wire rope. Properly attached U-Bolts are fairly efficient clamps: improperly attached they are unsafe.



(9-73) U-BOLT

Courtesy of Crosby Group
Division of American Hoist and Derrick

Another type of clamp is the Double Saddle or Fist Grip clamp (Figure 9-74). These clamps are better than U-bolts because they can't be installed incorrectly (i.e., they are the same on both ends) and they cause less damage to the wire rope. Also, a fist grip loop requires less rope turnback than a U-bolt loop and consequently fewer clamps are needed. In spite of the advantages of Double Saddle clamps, U-bolts still seem to be the most common clamp used, perhaps because they are cheaper and more readily available.

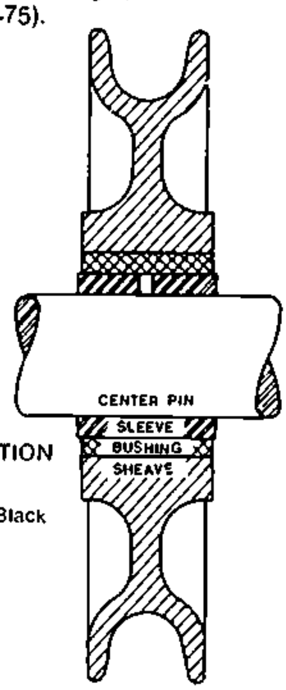


(9-74) DOUBLE SADDLE CLAMP

Courtesy of Crosby Group
Division of American Hoist and Derrick Co

SHEAVES

A sheave (pronounced shiv) is a wheel with a grooved circumference around which a rope turns A clothesline pulley is a sheave. Sheaves used on heavy duty machines are made of steel and either turn on or with an axle These sheaves have either a bronze sleeve bearing or anti-friction bearings and generally have grease fitting(s) that must be lubricated (Figure 9-75).



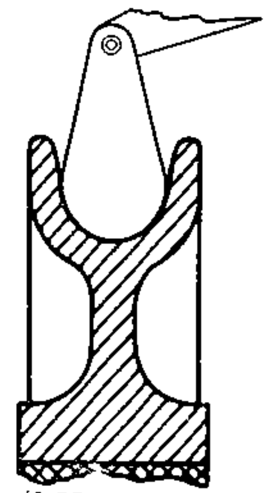
(9-75)

SHEAVE CROSS SECTION

Courtesy of Martin and Black Wire Rope Ltd

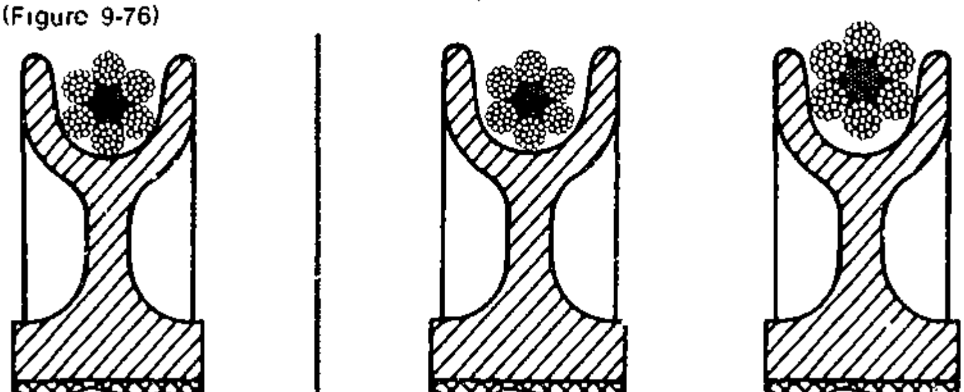
The groove on a sheave is made to fit a particular size rope One of the major causes of premature rope failure is having sheaves and ropes incorrectly matched. A groove that is too small will pinch and distort a rope, wearing or damaging one or both rope sides Too large a groove gives the rope no lateral support which can cause the rope to flatten and the wires and strands to be displaced (Figure 9-76)

If you need to match a sheave to a rope first measure the sheave with a groove gauge (Figure 9-77) Knowing the sheave size you can check with a rope manufacturing company the rope size suitable for it.



(9-77) GROOVE GAUGE

Courtesy of Martin and Black Wire Ropes Ltd



GROOVE CORRECT

GROOVE TOO LARGE

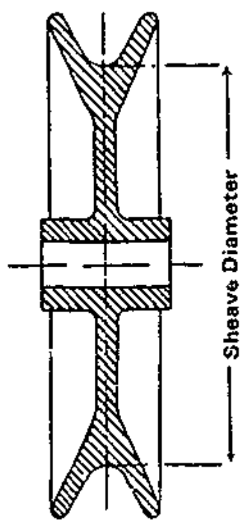
GROOVE TOO SMALL

(9-76)

Courtesy of Martin and Black Wire Ropes Ltd

Bending over sheaves is a factor that affects wire rope life. As the rope bends over a sheave or winds on and off a winch drum, especially under load, it is subjected to added stress. The less bend the rope is forced to make the less strain imposed on the rope. The "Diameter" of the sheave, therefore, is also important to rope operation. Wire rope life increases as the ratio of sheave diameter to rope diameter increases. A chart is given in Figure 9-78 showing the minimum sheave diameter size to rope diameter size

(9-78)



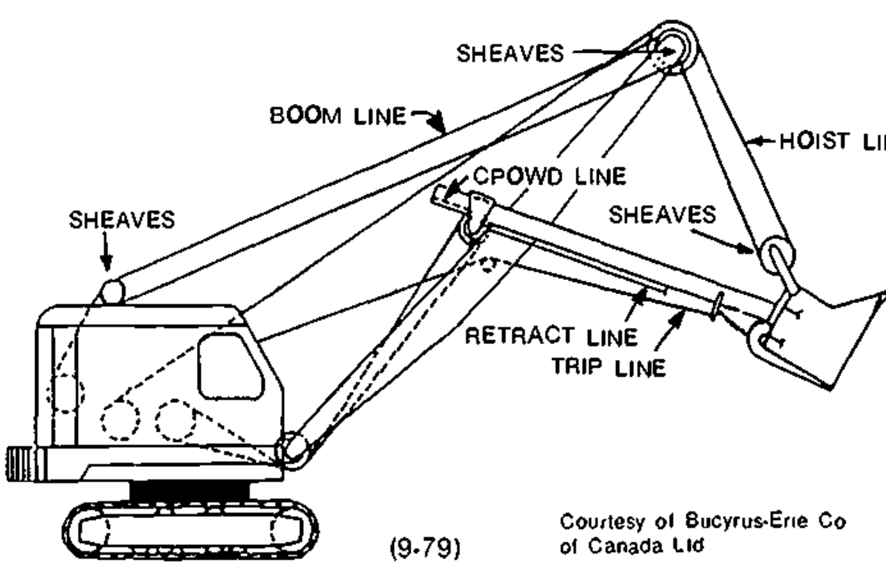
MINIMUM DIAMETERS:

A Sheave or Drum of too small diameter will hasten "fatigue" in any wire rope. The following table gives recommended *minimum* sheave tread diameters:

For 6 x 7 construction	42 x rope diameter
For 6 x 25 Flattened Strand construction	36 x rope diameter
For 18 x 7 construction	34 x rope diameter
For 6 x 19 Seale... "	30 x rope diameter
For 6 x 21 Filler... "	28 x rope diameter
For 6 x 25 Filler.... "	25 x rope diameter
For 6 x 26 construction	26 x rope diameter
For 6 x 31 construction	24 x rope diameter
For 6 x 36 construction	22 x rope diameter
For 8 x 19 Seale.. "	21 x rope diameter
For 6 x 41 construction	20 x rope diameter
For 6 x 43 ...... "	21 x rope diameter
For 8 x 25 ...... "	18 x rope diameter

Courtesy of Martin and Black Wire Ropes Ltd

Figure 9-79 illustrates sheave applications on a power shovel.



(9-79)

Courtesy of Bucyrus-Erie Co of Canada Ltd

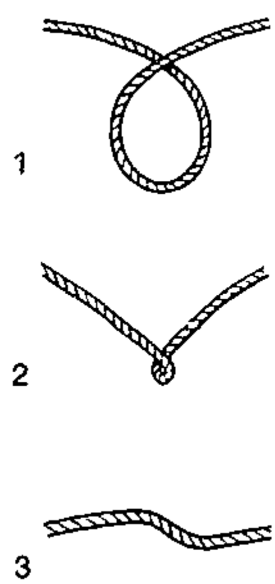
Multiple sheaves are used on some machines to gain mechanical advantage Increasing the number of lines and sheaves reduces the speed of the load being lifted but increases the amount of load that can be lifted. The shovel in Figure 9-30 has a two part line to the bucket giving it a mechanical advantage of two In other words, the bucket can lift twice as much as it could with one line to it

REMOVING AND INSTALLING WIRE ROPE

TAKING WIRE FROM A COIL

When unreeling wire rope, it is important that the coil or reel rotate as the rope unwinds. If the coil or reel does not rotate, the wire will be twisted as it is uncoiled, and kinking will result

Kinking is caused by the rope taking a spiral shape as the result of unnatural twist in the rope Figure 9-80 shows the progressive stages of a kink, and the end result



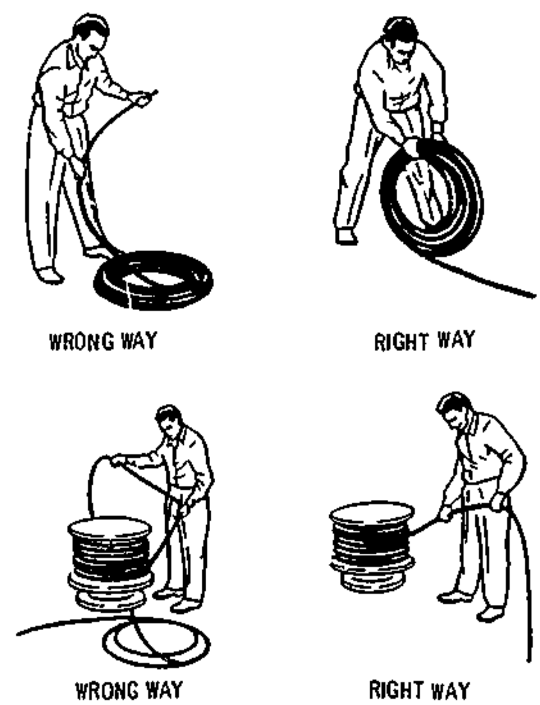
(9-80) KINKING OF WIRE ROPE

Part 1 of the illustration shows the beginning of a kink At this stage, no harm will be done if the loop is immediately thrown out to prevent further kinking.

Part 2 of the illustration shows the effect of the application of a load to a kinked line. The rope has been seriously strained and is no longer safe for maximum service.

Part 3 shows the condition of the rope after the kink has been straightened out. Strands and wires are out of position. This creates unequal tension and strain and will cause excessive additional wear on the damaged areas.

Figure 9-81 shows the correct methods for unreeling ropes from coils or reels.



WHEN UNREELING OR UNCOILING WIRE ROPE — DO NOT ALLOW ROPE TO FORM A LOOP IF LOOPS ARE FORMED KINKING WILL RESULT

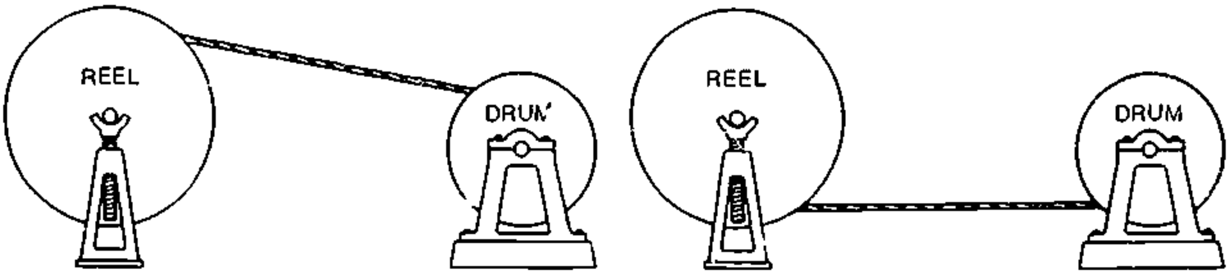
(9-81) UNREELING WIRE ROPE

Courtesy of Harnischfeger Corporation P&H

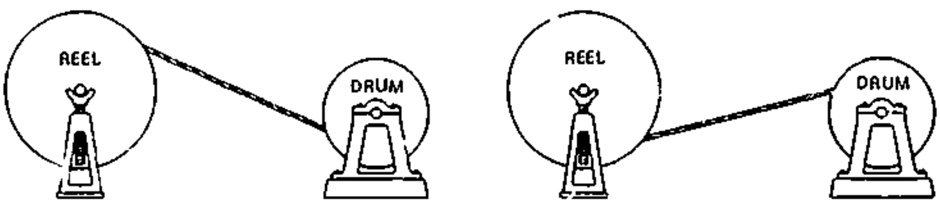
Another acceptable method of reeling rope off a reel is to place a shaft through the center of the reel and support the shaft so the reel can revolve as the rope is pulled off. If this method is used, the reel should not be allowed to revolve so rapidly that it throws rope off reel the rope off slowly.

REWINDING ROPE

When unwinding rope from its storage reel to another reel or a drum, the rope must be reeved from the top of one reel to the top of the other. It is also acceptable for an underwind to reel from the bottom of one reel to the bottom of the other reel or drum. By following either of these procedures, you will avoid twisting the rope (Figure 9-82).



RIGHT



WRONG

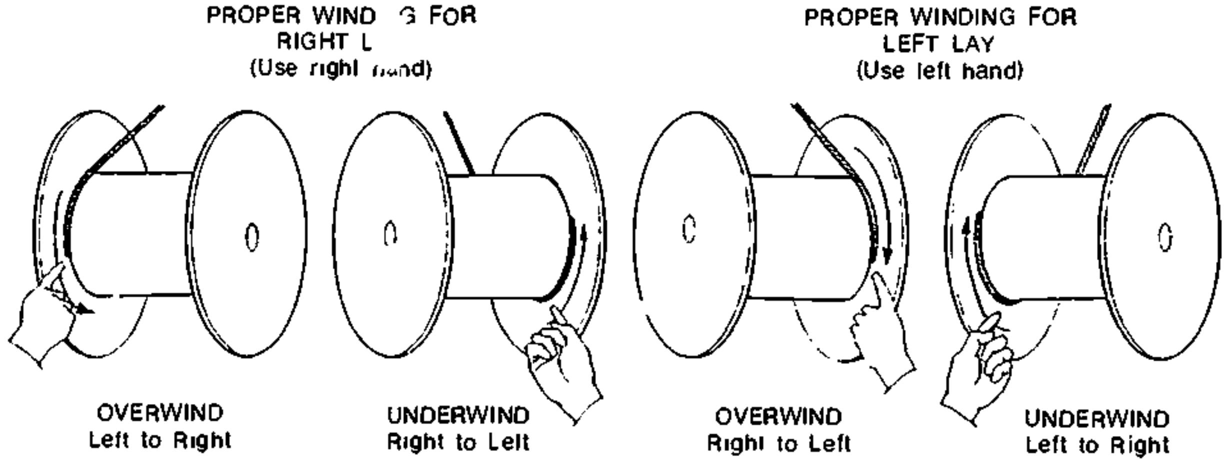
Courtesy of Martin and Black Wire Ropes Ltd

(9-82)

WINDING ROPE ON A DRUM

On grooved drums the cable will be laid in the correct position by the grooves, but on smooth faced drums, such as on a tractor mounted winch, attention must be given to getting an even lay on the first layer. When installing a new line on a tractor mounted winch, attach the line to the drum in the overwind or underwind position, whichever the winch is set up for (most mounted winches are set for overwind). Then attach the other end to a firm tail-hold and winch the machine backwards to load the drum. Watch that the first layer winds tight and snug. If the first layer is wound correctly, the rest of the cable should wind evenly on the drum. Caution: Keep hands clear of winding cable.

Figure 9-83 illustrates the correct way to attach left and right lay rope to a drum that has provision for attaching the cable to either side and that can be overwound or underwound. Note the point of view is from behind the drum.

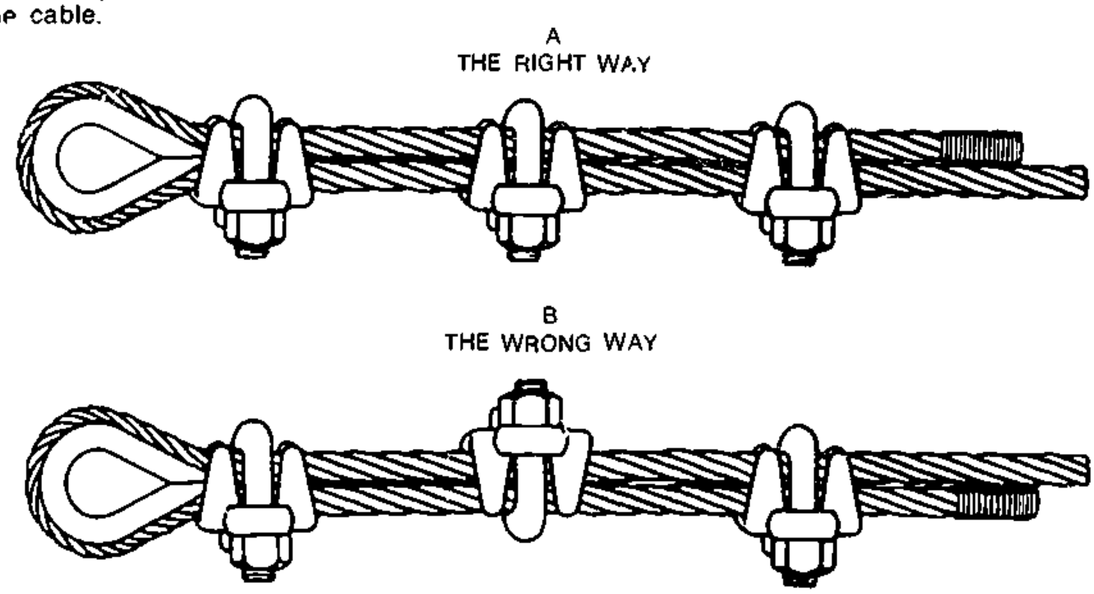


(9-83)

Courtesy of Martin and Black Wire Ropes Ltd

ATTACHING U-BOLTS

U-Bolts must be attached in the right numbers and in the right sequence to the correct side of the cable.



(9-84)

Courtesy of Martin and Black Wire Ropes Ltd

In Figure 9-84. A the right way, the saddle of all the clips bears on the live part of the rope and the U-bolt bears on the dead part. When the U-bolt bears on the live side as in Figure 9-84. B **the wrong way**, there is a possibility of the rope being kinked or deformed

The table in Figure 9-85 shows the correct number of clips to be used for each size of rope with the proper spacing between them.

DIAMETER OF ROPE	NUMBER OF CLIPS	SPACING CENTER TO CENTER
1/4"	2	2½"
5/16"	2	2¾"
3/8"	2	3"
7/16"	2	3½"
1/2"	3	3½"
9/16"	3	4"
5/8"	3	4"
3/4"	4	4½"
7/8"	4	5½"
1"	4	6"
1 1/8"	5	7"
1 1/4"	5	7½"
1 3/8"	6	8"
1 1/2"	6	9"
1 5/8"	6	9½"
1 3/4"	6	10½"
2"	7	12"

After the load is applied to the rope, lessen the tension and retighten the clips This will compensate for the natural diameter reduction of the rope under load

(9-85) Courtesy of Martin and Black Wire Ropes Ltd

The cable clamps should be put on in a set sequence After selecting the number of clamps according to the rope size and figuring out how long the dead end of the rope must be to give correct spacing between the clamps, attach the clamps in the following order (Figure 9-85)

Step 1 Attach the clip that is farthest from the eye Tighten it to the recommended torque.

Step 2 Attach the clip that is closest to the eye Firm it, but do not tighten.

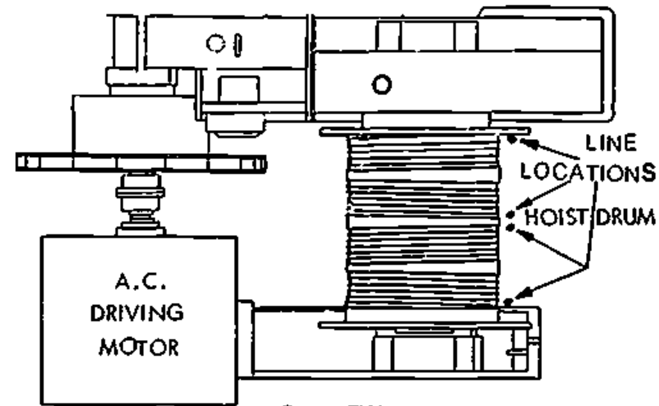
Step 3 Attach all other clips, equally spaced, between the first two clips. Firm, but do not tighten them.

Step 4 Apply tension to the rope at the eye and tighten all clips that haven't been tightened. The torque on the clips should be checked after the rope has been operated

(9-85) Courtesy of Martin and Black Wire Ropes Ltd

ATTACHING DOUBLE SADDLE CLIPS (FIST GRIP CLIPS)

Since double saddle clips are the same on both ends they can't be put on incorrectly. Fewer of these clips are needed than U-bolts; check the manufacturer's recommendation for the number of bolts per cable size. The sequence of attaching the clips would be the same as for U-bolts.



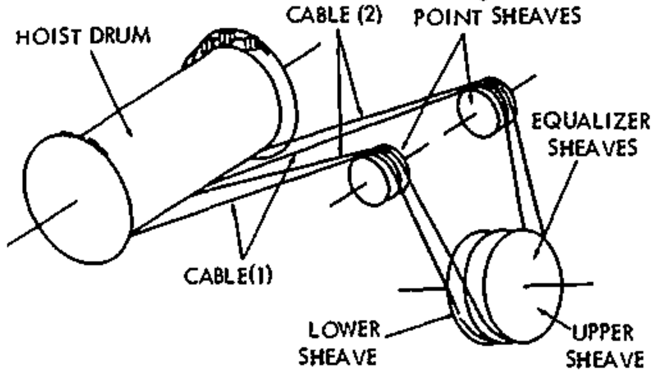
TOP VIEW

(9-87)

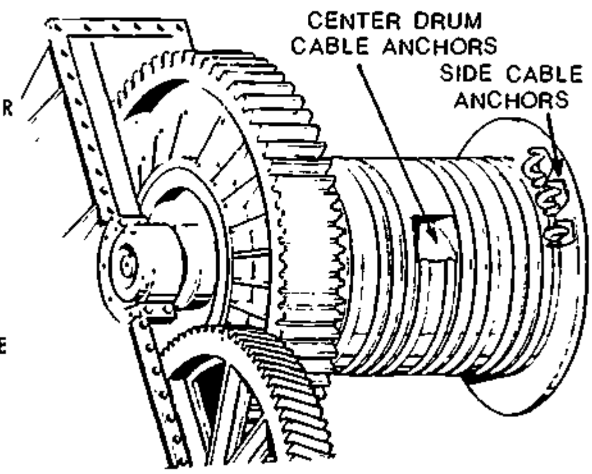
REEVING WIRE ROPE

Reeving means installing or rigging wire rope to a machine — attaching the rope to the drum, passing rope over sheaves, and generally arranging the cable into its operating circuit. Figure 9-86 shows the reeving on a large mining shovel. Since this particular machine has a fixed boom angle and a power operated crowd, it has only the hoist drum circuit to reeve.

Courtesy of Harnischfeger Corporation P&H



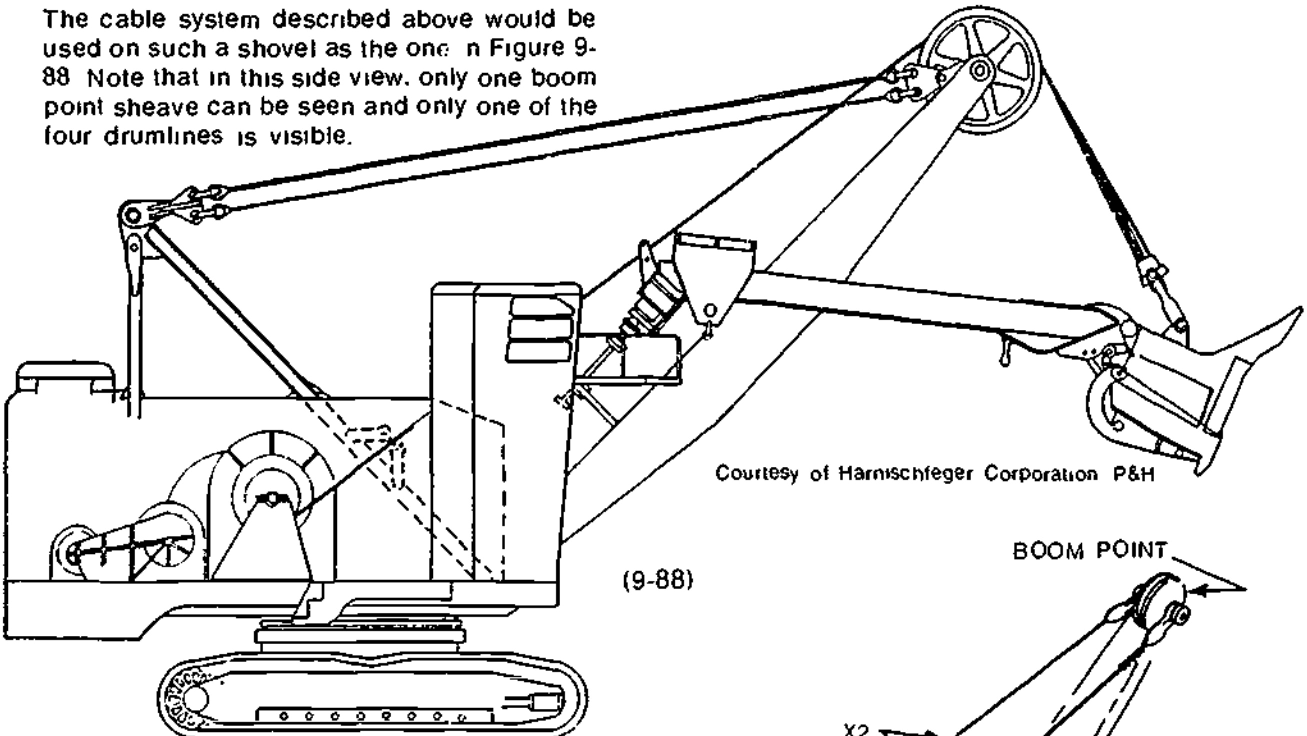
(9-86) HOIST REEVING DIAGRAM



(9-87)

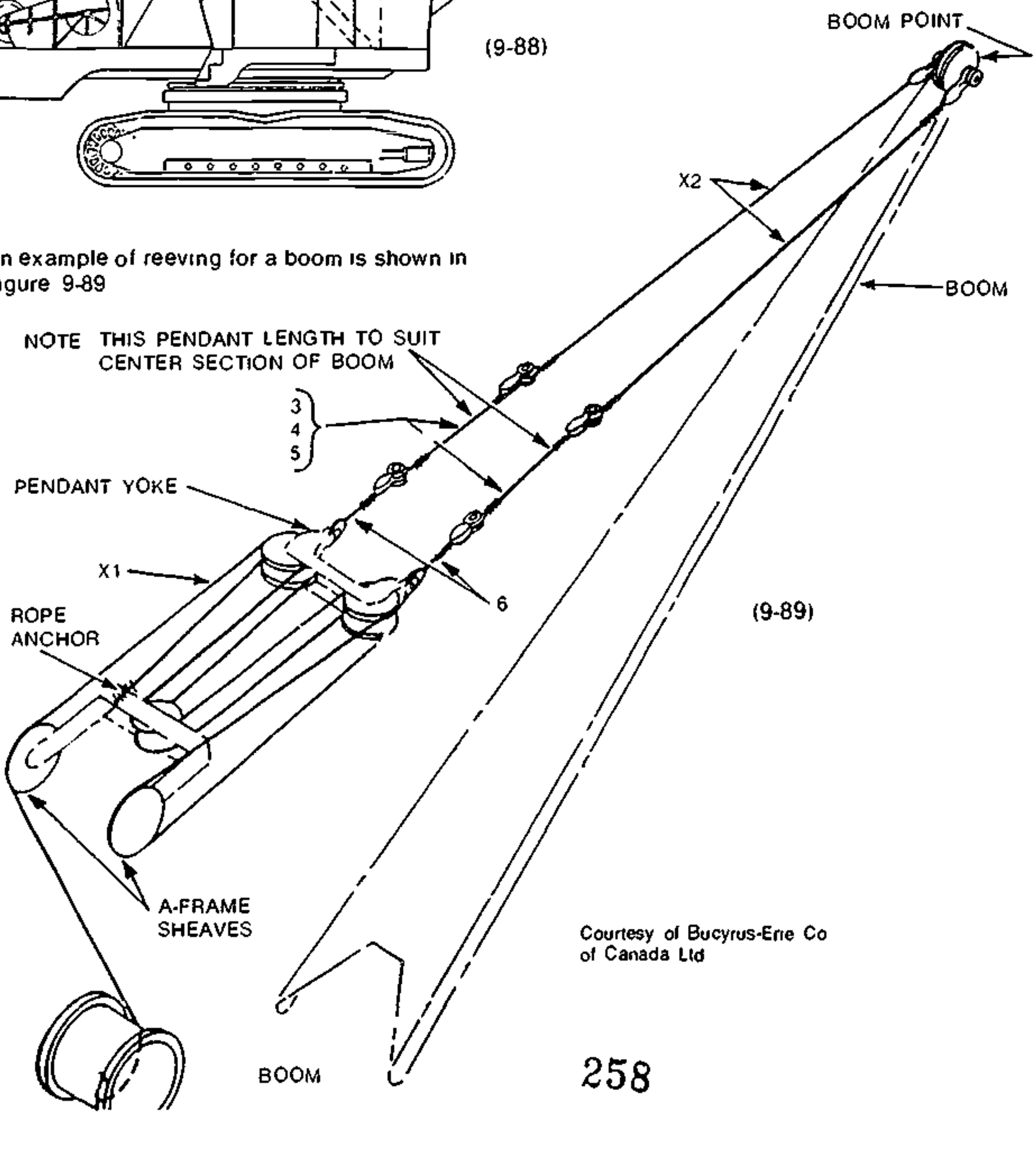
This cable system uses two cables of identical length and size The cables are attached one to either side of the drum. Each cable is passed over the boom point sheaves, down around the lower or bucket sheave, back over another boom point sheave, returning to the hoist drum near its center. Cable is therefore attached in four places to the drum, and when the line is winding, the two cables can appear to be four Figure 9-87 shows the locations where the cable is attached to the drum, and the anchors by which it is attached. Note the four sets of grooves the line runs in: the two cables on the outside wind towards the inside whereas the two central lines wind towards the outside.

The cable system described above would be used on such a shovel as the one in Figure 9-88 Note that in this side view, only one boom point sheave can be seen and only one of the four drumlines is visible.



(9-88)

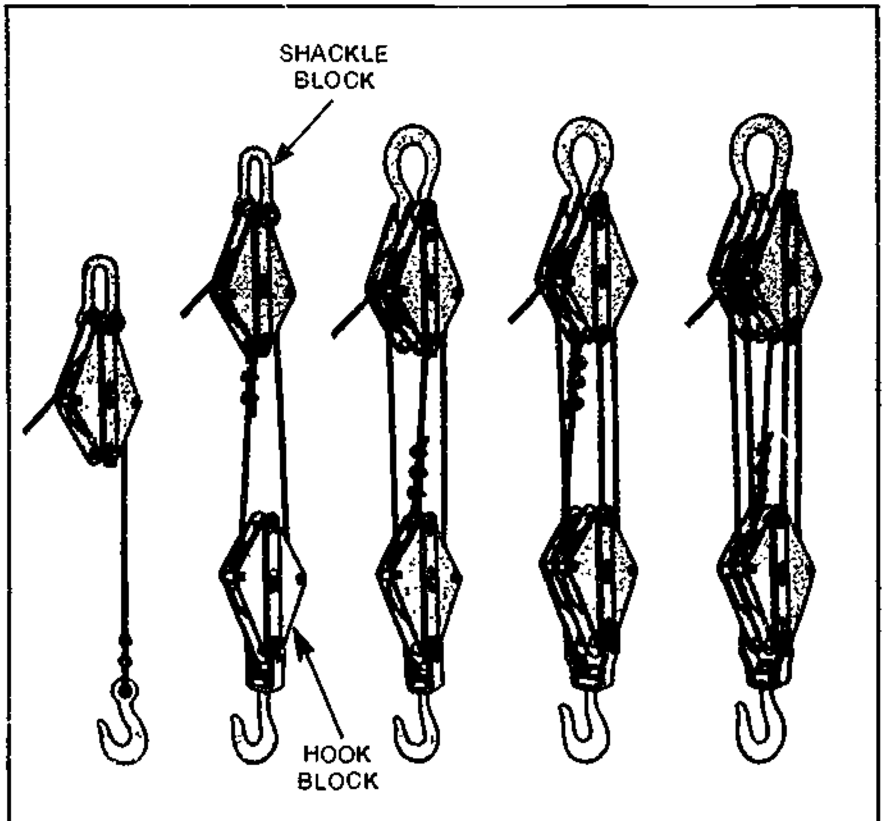
An example of reeving for a boom is shown in Figure 9-89



(9-89)

THE REEVING OF TACKLE BLOCKS

Tackle blocks give mechanical advantage: the more lines the blocks have the greater the load that can be lifted with the same pulling force. Note the reeving patterns on the sets of tackle blocks in Figure 9-90.



(9-90) Courtesy of Martin and Black Wire Ropes Ltd

It is good practice to use a shackle block as the upper one of a pair and a hook block as the lower one. A shackle is much stronger than a hook of the same size and the strain on the upper block is much greater than the lower one. The lower block supports only the load whereas the upper block carries the load as well as the hoisting strain. Also a hook is more convenient on the lower block because it can more readily be attached to or detached from the load. Note that when reeving a set of blocks where the rope leads from a block that has more than two sheaves, attach the rope to one of the center sheaves so that the hoisting strain is placed on the center of the block.

SELECTING TACKLE BLOCKS

A problem can arise in the shop or field in deciding what number of line Tackle Block to use When you know the weight of the load to be lifted and the line pull of the winch or hoist drum that will do the pulling. the following chart (Figure 9-91) will give you the number of line parts of the Tackle Block to use:

Number of Parts of Line	Ratio for Bronze Bushed Sheaves	Ratio for Anti-Friction Bearing Sheaves
1	.96	.98
2	1.87	1.94
3	2.75	2.88
4	3.59	3.81
5	4.39	4.71
6	5.16	5.60
7	5.90	6.47
8	6.60	7.32
9	7.27	8.16
10	7.91	8.98
11	8.52	9.79
12	9.11	10.6
13	9.68	11.4
14	10.2	12.1
15	10.7	12.9
16	11.2	13.6
17	11.7	14.3
18	12.2	15.0
19	12.6	15.7
20	13.0	16.4
21	13.4	17.0
22	13.8	17.7
23	14.2	18.3
24	14.5	18.9

(9-91)

Courtesy of Martin and Black Wire Ropes Ltd

EXAMPLE PROBLEM

The load you want to lift is 72.480 lbs. and the single line pull of the hoist-drum is 8000 lbs. The tackle sheaves you will use have bronze bushings.

Step 1: Find the ratio of load weight to line pull

$$\frac{\text{load weight}}{\text{line pull}} = \frac{72480}{8000} = 9.06 \text{ ratio}$$

Step 2: Look up the ratio. or the one closest to it. either in the Bronze Bushed Sheave column or the anti-friction bearing sheave column. When you find the ratio, look over on the same line to the first column which gives you the Number of Parts of line to use. In this case the 9.06 is closest to the 9.11. and so a tackle block with 12 line parts is needed.

QUESTIONS — WIRE ROPE

1 Wire rope is made of three basic parts What are they?

2 When measuring the diameter of wire rope, is the caliper placed on the crowns of two opposite strands or in contact with four opposite strands?

3 As cable gets thicker, less of it can be wound on a drum. Using the table on page 2 find the difference in feet between the amount of 5/8" cable that can be wound on a F-50 Hi-cap drum and the amount of 1" cable.

4 Give two functions that a fiber core will provide in a wire rope

5 What are the advantages of steel core in a wire rope?

6 True or False? The rope with the strongest steel is the best for every job Briefly support your answer

7 The figure 6 × 7 used to classify strands in a wire rope means

(a) there are 42 wires per strand.

(b) there are 6 wires per strand and 7 strands in the rope.

(c) there are 6 strands in the rope and 7 wires per strand.

(d) there are 42 wires in the complete rope including the core

8 When wire rope is preformed, it means that each wire and strand is preset to an exact ____________ shape

9 List at least two advantages of preformed wire rope

10 In one of its meanings the term "lay" describes the direction of rotation of wires in a rope What are the two basic lays and briefly describe the difference between them Give an example where each is used

11 The term "lay" also applies to the direction of rotation of the strands in a rope Which is the most common, left lay or right lay?

What is the most common sign of wire rope deterioration?

True or False? When inspecting a wire rope, it should be supporting a load?

14 Wire rope inspections should be done:

(a) daily.

(b) weekly.

(c) monthly

(d) yearly.

The frequency of lubrication of wire rope depends on

(a) its size.

(b) length.

(c) severity of duty and corrosive conditions.

(d) weather conditions.

16. What are cable clamps used for?

17. True or False? A sheave groove that is too large is better than one that is too small.

18 Briefly explain how the diameter of a sheave affects wire rope life.

19 When installing a new line on a tractor winch drum.

(a) hold onto the line and guide it onto the drum when operating the winch.

(b) use your foot to guide the line onto the drum when operating the winch.

(c) tail hold the line to a stump or tree and wind the line onto the drum while pulling the tractor backwards.

(d) the line will spool automatically when it is wound on.

20 Correctly installed cable clamps should be arranged so that the:

(a) clamp saddles are all on the live end of the line.

(b) clamp saddles are all on the dead end of the line.

(c) clamp saddles are alternated between the live and dead ends of the line.

(d) it doesn't matter.

21. When forming an eye on the end of a 1/2" piece of cable, the minimum number of U-bolt clamps that can be used is:

    (a) 2
    (b) 3
    (c) 4
    (d) 5

22. When reeving tackle blocks, increasing the number of line parts over sheaves:

    (a) increases the mechanical advantage.
    (b) decreases the mechanical advantage
    (c) no change in mechanical advantage; just decreases the lifting speed
    (d) no change in mechanical advantage; just increases the lifting speed.

ANSWERS — TRACTOR MOUNTED WINCHES

1 Live P.T.O. from a torque converter.

Live P.T.O. through a manual transmission.

Hydraulic motor.

2 (d) Overwind or underwind

3 True.

4 Overwind

5 (d) (a), (b) and (c) are all correct.

6 Sliding gear

Power shift.

Hydraulic

7 (b) Tractor's master clutch must be disengaged

8 By hydraulically applied clutch packs

9 Splash.

10 A hydraulic winch can be mounted in most cases, in whatever location it's required, provided that hydraulic lines can be connected to power it.

11 (c) Band and multi-disc

12 (c) Spring applied and hydraulic released

13 (a) Reel in

14 The housing acts as a cooler to cool the hydraulic oil

15 Provides a guide for the cable, allowing the cable to be reeled in at an angle without being damaged.

16 A hydraulic pump and a hydraulic motor.

ANSWERS — MAINTENANCE AND REPAIR OF TRACTOR MOUNTED WINCHES

1. True.
2. Condensation.
3. (b) Daily, weekly, monthly schedule.
4. 500 hours or 3 months
5. False.
6. True.
7. Hydraulic test box.

ANSWERS — HOIST WINCHES

1. The **basic machine** refers to the lower and upper works.

   The **convertibility** refers to various removable front ends which enable the machine to do different types of work.

2. (e) Both (b) and (c) are right.

3. (b) Longer and runs looser.

4. (1) Size.

   (2) Ways of mounting.

   (3) Activating mechanisms

5. (a) A clutch

6. Brake

7. (a) Rear drum shaft.

8. The yarder drums have much larger capacity.

9. (1) Grooved.

   (2) Smooth tapered.

10. (b) Increase

11. True

12. The multiple pieces are easier to remove and install.

13. Air

14. (1) Hydraulic

    (2) Air

15. They are stronger clutches and brakes and can withstand heavier loads and higher heat under increased machine horsepower

16. Magnetic field.

17. False

18. The hydraulic winch.

    (1) takes less space.

    (2) has simpler controls.

    (3) requires fewer adjustments.

ANSWERS — MAINTENANCE OF HOIST WINCHES

1. Ensure that the working implement controlled by the drum shaft is in a safely lowered position and tension is off the cable.

2. (d) Slips under load.

3. (b) 1/32″

4. False. They require regular, scheduled lubrication.

5. Every 200 hours with multi-purpose grease.

ANSWERS — WIRE ROPE

1 (a) wire
(b) strand
(c) core

2 On the crowns of two opposite strands

3 600 ft for the 5/8" cable and 215 ft. for the 1" cable; so the difference is 600 − 215 = 385 ft

4 A fiber core:

(1) provides a cushion for the steel strands

(2) Acts as an internal lubricator.

5 A steel core:

(1) Adds strength.

(2) Provides resistance to crushing.

(3) Gives heat protection

6 False. A rope with a ductile, flexible steel may out-last a rope made of a steel with a higher breaking strength

7. (c) There are 6 strands in the rope and 7 wires per strand.

8 Helical.

9. Preformed wire rope

(1) Won't unravel when cut.

(2) Is more flexible.

(3) Lasts longer.

(4) Is easier to splice.

10 Regular Lay — wires in the strands lay parallel to the rope.

Lang's lay — wires in each strand lay in the same direction as the strands of the rope.

Regular lay — general purpose rope.

Lang's lay — applications where both ends are fixed such as a hoist cable on a shovel

11 Right lay.

12. Broken wires.

13 False

14. (b) Weekly.

15 (c) Severity of duty and corrosive conditions.

16 To form a loop in a wire rope in order to attach the rope to a fixture.

17 False

18 The less bend the wire rope is forced to make the less strain will be imposed on the rope. With less strain a rope will last longer

19 (c) Tail hold the line to a stump or tree and wind the line onto the drum while pulling the tractor backwards.

20 (a) Clamp saddles are all on the live end of the line

21 (b) 3.

22 (a) Increases the mechanical advantage.

TASKS — WINCHES, HOISTS AND CABLES

TRACTOR MOUNTED WINCHES

SCHEDULED MAINTENANCE

1. Change the oil and filters and do minor adjustments as outlined in the service manual

SERVICE REPAIR

1. Remove and install a crawler winch assembly using the correct tools, lifting equipment, rigging equipment and safety procedures outlined in the service manual

CRANE AND SHOVEL HOIST WINCHES

SCHEDULED MAINTENANCE

1. Consulting the service manual, lubricate, do minor clutch and/or brake adjustments, inspect air lines or hydraulic lines and make any minor repairs or replace any damaged lines

SERVICE REPAIR

1. Remove and install a hoist winch from a shovel or crane using the correct tools, lifting equipment, rigging and safety practices outlined in the service manual. Reinstall the cable when complete.

CABLES, CLAMPS AND SHEAVES

SCHEDULED MAINTENANCE

1. Under the assistance of a journeyman, make a cable inspection on both standing and running cable such as would be found on a shovel or crane. Write a report to include the measurements necessary to check the cable and note any signs of failure (See sec 54 18 W.C.B. Regulations Paragraph 23 Wire Rope Rejection criteria)

SERVICE REPAIR

1. Demonstrate correct care, handling and storage of cable
2. Install a new drum cable on a crawler mounted winch:
   (a) Select the correct cable size and length.
   (b) Attach the cable to the correct side of the drum for either an over or an under wind.
   (c) Attach the other end of the cable to a secure tail hold and load the drum by winching the crawler backwards.
3. Make an eye on a piece of 1/2" (12 mm) cable, using a thimble and wire rope cable clamps of correct size, number and placement to meet W.C.B. safety standards.