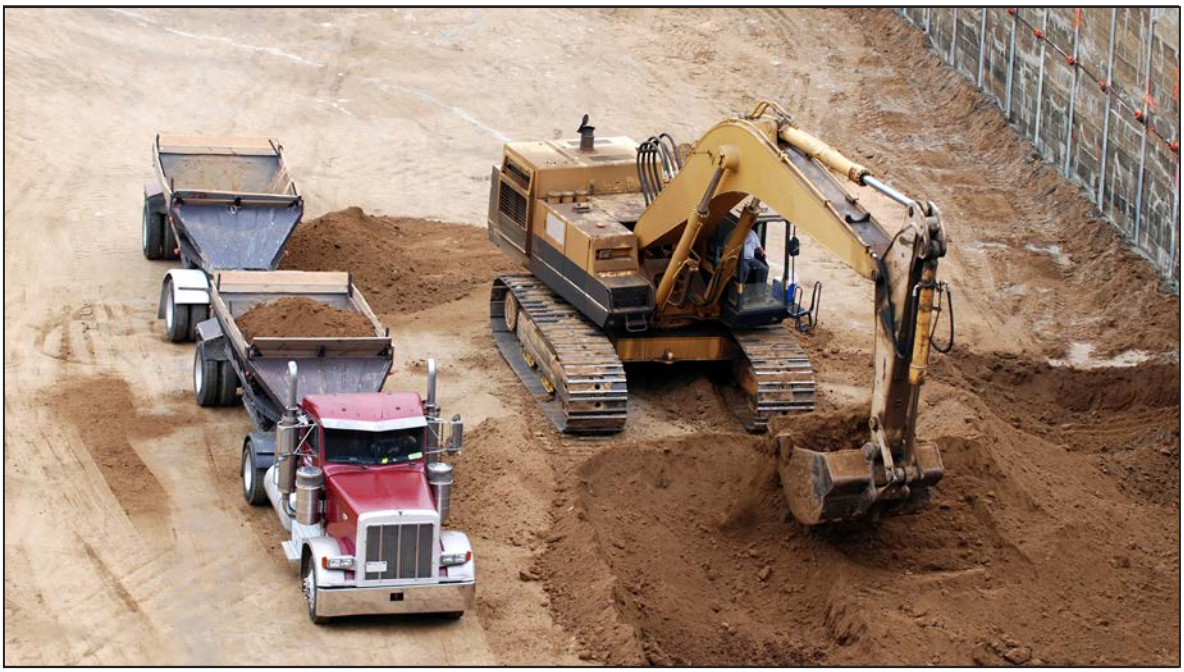
HEAVY MECHANICAL TRADES

FOUNDATION / LEVEL 1



Line A: Common Occupational Skills
Competencies A-7 to A-13

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Version 2, September 2016

Line A: Common Occupational Skills

Competencies A-7 to A-13

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COMPETENCY A-7
OPERATE EQUIPMENT



HEAVY MECHANICAL TRADES:
LINE A—COMMON OCCUPATIONAL SKILLS

Goals

When you have completed the Learning Tasks in this Competency, you will be able to:

- describe pre-start inspections for trucks and heavy-duty equipment
- describe the pre-start checklist
- identify starting aids used on diesel engines
- describe start-up procedures
- describe emergency shut-down procedures
- start, operate, and shut-down trucks and equipment
- lock out trucks and heavy-duty equipment prior to service
- operate a forklift.

LEARNING TASK 1

Describe Pre-start and Walk-around Inspections

Notes

Starting, moving, and stopping equipment and trucks is part of a mechanic's job. You must know:

- what to check prior to starting a piece of equipment or truck (pre-start checks)
- how to start a piece of equipment or truck under varying climatic conditions
- how to safely move equipment and trucks
- how to shut-down a piece of equipment or truck, for both overnight and extended periods

Equipment Pre-start Checklist

If the equipment has been in storage for a long period of time, preparation for starting is an elaborate procedure that is better covered under repair procedures. When conducting an out-of-storage pre-start inspection, every fluid compartment must be checked, wheel nuts or track pad bolts re-torqued, cab components checked, and fan belts re-tightened.

The goal of any pre-start inspection is to ensure that the unit can be operated safely so that no injury or damage occurs to any person, property, or to the unit itself.

Pre-start Inspection

Before beginning a pre-start inspection, ensure that the equipment is in the service position:

- Ensure that all attachments are on the ground and all hydraulic controls are in neutral.
- Ensure the parking brake is applied and the transmission neutral safety lock is engaged.
- Remove the ignition key from the ignition switch and open or disconnect the master switch.
- Ensure the equipment has been locked and a "do not start" tag has been placed in a conspicuous location.
- Install a safety bar on machines with articulated steering.
- Prevent the wheels from rolling by blocking the tires (if applicable).

When performing a pre-start inspection, refer to the operator's manual.

NOTES

Although pre-start inspections vary from equipment to equipment, there are some points common to most equipment:

- record the service hours or kilometres, whichever is applicable
- check and top up all fluid levels including coolant, fuel, battery electrolyte, lube oil, and keep records of fluid additions
- drain a small amount of fuel from the tank to remove any water and sediment
- check the condition and tension of drive belts
- check the air reservoir drains to make sure that they're closed
- do a walk-around inspection to review the machine's general condition
- visually inspect the undercarriage, frame, and suspension for loose bolts and missing parts
- check to see that mountings of components are tight
- check for fluid leaks
- examine pipes, hoses, and gasket joints for damage or leaks
- check tire condition and wheel studs
- check the condition of working attachments
- do minor repairs and make recommendations for major repairs

When completing an equipment check-off list, mark any non-applicable lines with "N/A." If there is additional information you need to note, most forms will have an area for this at the bottom.

Prestart Web Services

DOZER DAILY LOG

MR

Phone (111) 111-1111 Fax (111) 111-1112
13 Address Road City PR P0S 1C2
prestart@webaddress.com
TIP: Use the return key to go to the next line!

Operator: ..... Site Area: .....

Hours Start: ..... Hours Finish: ..... Date: / /12

Fluid Levels	Pass	Fail	Fluid Levels	Pass	Fail
Fuel Level			Radiator Level		
Engine Oil Level			Transmission Level		
Oil Level			Fluid Leaks		

Fluid Levels	Pass	Fail	Comments
Air Conditioning			
Cleaning Products			
Cutting Edges			
Damage Report			
Equaliser Bar			
Fire Extinguisher			
First Aid Kit			
Grease / Auto Greaser			
Hand Rails / Door Handles			
Horn			
Hydraulic Hoses (check for rubbings)			
Instruments			
Lights			
Mirrors			
Radiator / Hoses / Belts			
Rippers			
Roller / Idlers / Sprockets			
Seat Belts			
Tracks			
Two Way Radio			
Windows / Wipers			

Additional Notes: .....
.....
.....

PRESTART CHECKS CARRIED OUT BY: .....

Note: It is the operator's responsibility to notify their supervisor should they feel that the plant is unsafe or in need of urgent repair.

(Operators Signature)

Figure 1. Sample Pre-start Inspection Checklist

NOTES

NOTES

For maintenance, safety, and maximum service life, conduct a walk-around inspection before each work shift, or performing lubrication or maintenance. Inspect under and around the equipment for items such as loose or missing bolts; trash build-up; oil, fuel, or coolant leaks; and the condition of bucket, teeth, and tracks (Figure 2).

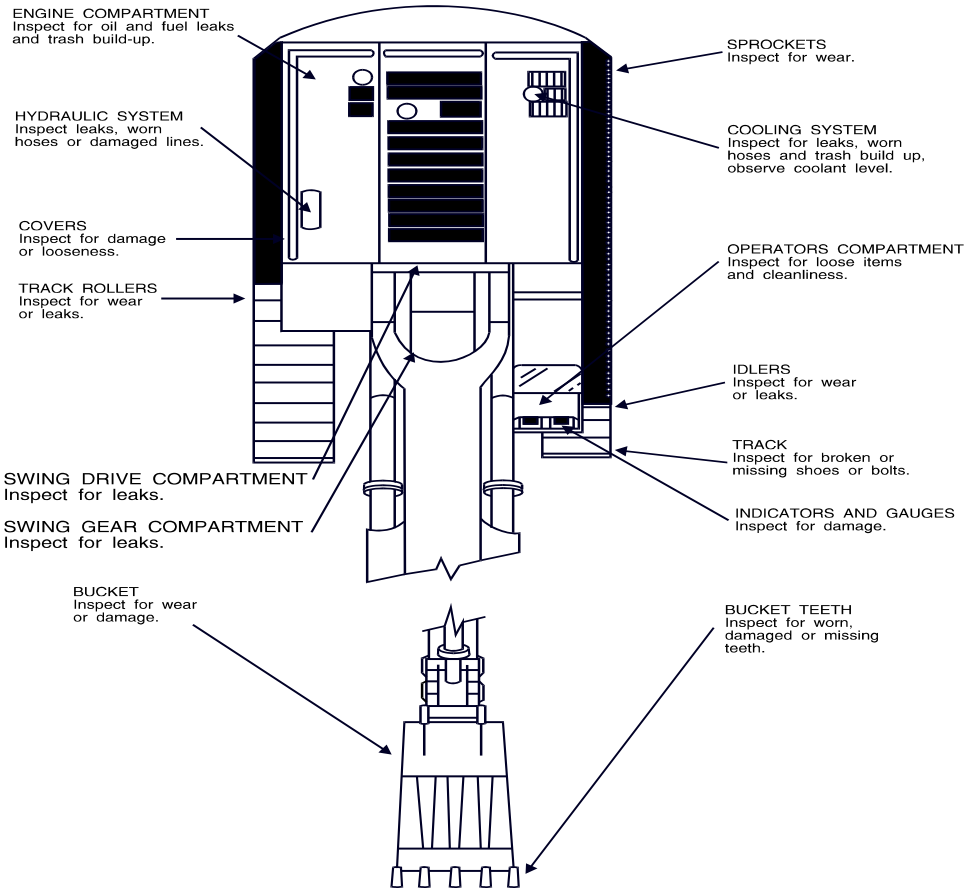
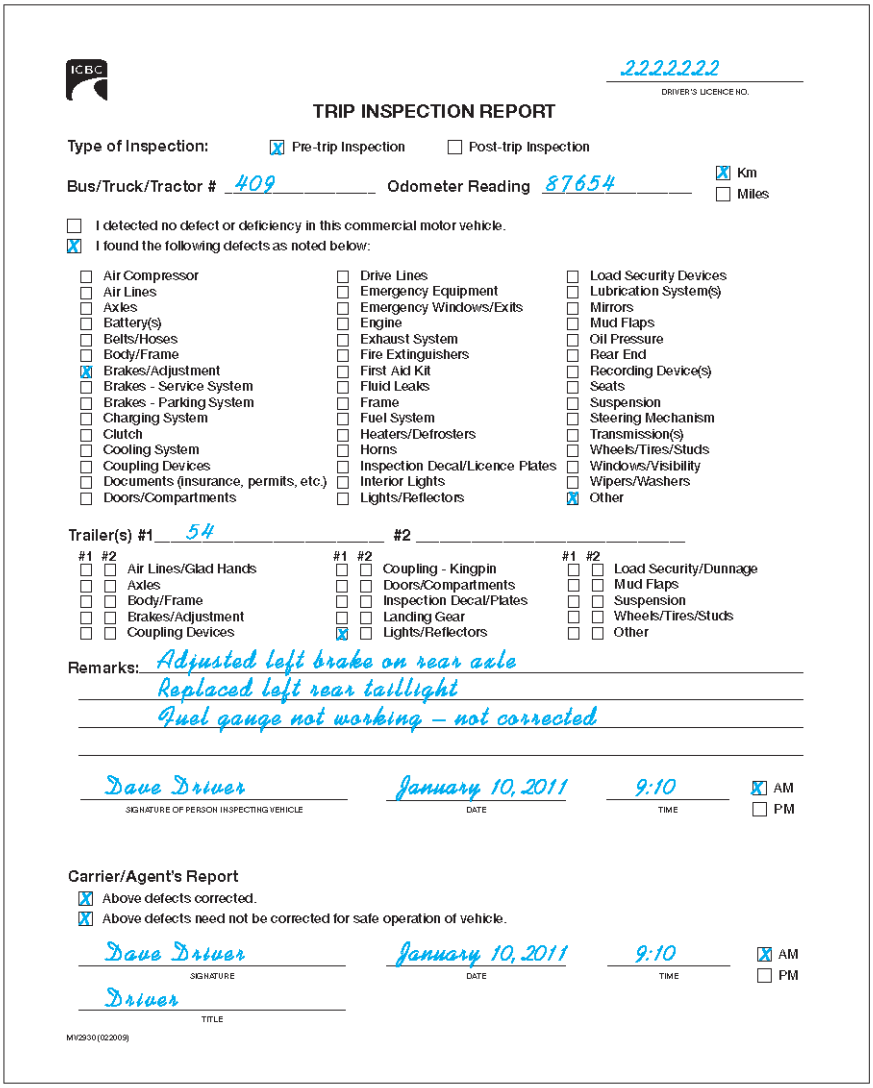


Figure 2. Areas for Inspection

Truck Pre-start Checklist

It's important to complete a systematic check of key items when putting a unit into service that you are unfamiliar with or has been out of use for a short period. An appropriate check list will make this task easier and more thorough. A sample pre-start inspection checklist is shown in Figure 3.

NOTES



2222222
DRIVER'S LICENCE NO.

TRIP INSPECTION REPORT

Type of Inspection: [X] Pre-trip Inspection [ ] Post-trip Inspection

Bus/Truck/Tractor # 409 Odometer Reading 87654 [X] Km [ ] Miles

[ ] I detected no defect or deficiency in this commercial motor vehicle.
[X] I found the following defects as noted below:

[ ] Air Compressor	[ ] Drive Lines	[ ] Load Security Devices
[ ] Air Lines	[ ] Emergency Equipment	[ ] Lubrication System(s)
[ ] Axles	[ ] Emergency Windows/Exits	[ ] Mirrors
[ ] Battery(s)	[ ] Engine	[ ] Mud Flaps
[ ] Belts/Hoses	[ ] Exhaust System	[ ] Oil Pressure
[ ] Body/Frame	[ ] Fire Extinguishers	[ ] Rear End
[X] Brakes/Adjustment	[ ] First Aid Kit	[ ] Recording Device(s)
[ ] Brakes - Service System	[ ] Fluid Leaks	[ ] Seats
[ ] Brakes - Parking System	[ ] Frame	[ ] Suspension
[ ] Charging System	[ ] Fuel System	[ ] Steering Mechanism
[ ] Clutch	[ ] Heaters/Defrosters	[ ] Transmission(s)
[ ] Cooling System	[ ] Horns	[ ] Wheels/Tires/Studs
[ ] Coupling Devices	[ ] Inspection Decal/Licence Plates	[ ] Windows/Visibility
[ ] Documents (insurance, permits, etc.)	[ ] Interior Lights	[ ] Wipers/Washers
[ ] Doors/Compartments	[ ] Lights/Reflectors	[X] Other

Trailer(s) #1 54 #2

#1	#2		#1	#2		#1	#2	
[ ]	[ ]	Air Lines/Glad Hands	[ ]	[ ]	Coupling - Kingpin	[ ]	[ ]	Load Security/Dunnage
[ ]	[ ]	Axles	[ ]	[ ]	Doors/Compartments	[ ]	[ ]	Mud Flaps
[ ]	[ ]	Body/Frame	[ ]	[ ]	Inspection Decal/Plates	[ ]	[ ]	Suspension
[ ]	[ ]	Brakes/Adjustment	[ ]	[ ]	Landing Gear	[ ]	[ ]	Wheels/Tires/Studs
[ ]	[ ]	Coupling Devices	[X]	[ ]	Lights/Reflectors	[ ]	[ ]	Other

Remarks: Adjusted left brake on rear axle
Replaced left rear taillight
Fuel gauge not working – not corrected

Dave Driver (SIGNATURE OF PERSON INSPECTING VEHICLE) January 10, 2011 (DATE) 9:10 (TIME) [X] AM [ ] PM

Carrier/Agent's Report
[X] Above defects corrected.
[X] Above defects need not be corrected for safe operation of vehicle.

Dave Driver (SIGNATURE) January 10, 2011 (DATE) 9:10 (TIME) [X] AM [ ] PM

Driver (TITLE)

MV2930 (022009)

Figure 3. Sample Truck Pre-start Inspection Checklist

Safety Circle Inspection

Fleet operators will require that you perform a safety circle inspection before starting a vehicle. This entails walking around the vehicle noting the general condition of tires, mirrors, and body as well as noting any bystanders, curbs, lampposts, or other potential hazards. You will also be able to clean headlights, taillights, and check tire pressures.

A traffic cone placement program is a good example of a safety circle procedure. Orange traffic cones are placed in front of and behind the vehicle every time it's parked. You're then required to pick up the cones and walk around the vehicle before driving away. This procedure reduces the number of accidents caused by backing into obstructions.

SELF TEST 1

1. What is the best resource for the proper procedure for pre-start, inspecting equipment/trucks?

   a. the equipment/truck parts manual
   b. the equipment/truck service manual
   c. the equipment/truck troubleshooting manual
   d. the equipment/truck operator's manual

2. What is the major reason for a pre-start inspection?

   a. machine can be safely started and moved
   b. machine can be moved in all speed ranges
   c. machine will function under heavy load
   d. confirm the operator is qualified

3. What must the operator do when finding a fluid compartment overfull?

   a. nothing as there is enough oil in the compartment to start the machine
   b. lower the fluid compartment to the proper level and proceed to start the machine
   c. lower the fluid level, document the amount of displaced oil, and notify supervisor
   d. drain the oil completely and refill to the full line

LEARNING TASK 2

Describe Starting Aids

Notes

Diesel engines use the heat of compression to ignite fuel. When the outside temperature drops below 10°C (50°F), compression alone may not be able to create a high enough temperature to do so. In this situation, cold starting aids are required. The most common types are:

- pre-heaters
- starting fluids
- block/circulating heaters
- battery warmers

Pre-heaters

Glow Plugs

Glow plugs (Figure 1) are often used in diesel engines that have pre-combustion chambers, but are also used with direct injection engines as well. A pre-combustion chamber is a small combustion chamber located in the cylinder head in which the injection nozzle and glow plug are installed. Glow plugs heat the pre-combustion chamber and this heat helps provide the heat necessary for combustion and the subsequent starting of the engine. Each cylinder will have its own glow plug.



Figure 1. Glow Plug

NOTES

Intake Manifold Heater

An intake manifold heater is an electrical element that heats incoming air. The element heats up as electrical current passes through the coil which then heats the air in the intake manifold.



Figure 2. Grid Heater

Starting Fluid

Starting fluid is a mixture of volatile hydrocarbons (heptane, butane, or propane), diethyl ether, and carbon dioxide (as a propellant). It is very volatile and readily combustible. The most common method of using starting fluid is to spray a small amount into the air cleaner intake while the engine is turning over or cranking.



Figure 3. An Example of a Starting Fluid

Starting fluid should be sprayed into the air cleaner intake only while cranking the engine. Doing so before the engine is cranking may cause an explosion. Caution must be employed when using starting fluid as excessive amounts can cause engine damage.

Never handle starting fluid near an open flame. Starting fluid must **never** be used when a glow plug or intake manifold heater is operating as it will prematurely ignite and cause damage.

Excessive amounts of starting fluid will remove oil from the cylinder walls resulting in low compression and failure to start the engine.

Some engines have manual or automatic ether injectors that prevent overloading the intake with starting fluid. These injectors are powered while the engine is turning over and will only give one small shot of ether for each cranking cycle.

Engines with computer controls do not require starting fluids.

Block/Circulating Heaters

There are many types of coolant heaters. The block heater type is an electric element installed in a core/frost plug hole, or threaded into the engine block (Figure 4).

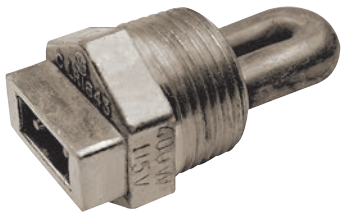


Figure 4. Block Heater

Coolant circulating heaters heat coolant which then circulates throughout the engine (Figure 5). Heavy-duty models are available—climate and type of equipment will determine if they are needed.

NOTES

Notes



Figure 5. Coolant Circulating Heater

Some coolant heaters are diesel-, fuel-, or propane-fired. They're used where electricity is unavailable. The heater is diesel-fired and is hooked into the heater hoses which heats both the engine and the cab.

Oil pan heaters are located near the bottom of an oil pan and heat with an electric coil. They may be attached internally or externally. Maintaining oil at a constant temperature aids starting, lubrication, and damage prevention.



Figure 6. Oil Pan Immersion Heater

Battery Warmers

Battery warmers are used to maintain battery efficiency in cold temperatures. The efficiency of a battery diminishes as the temperature drops, reducing cranking power resulting in difficulty starting the engine. Two types of battery warmers are available: pad and blanket (Figure 7).

A battery warmer is often used with a coolant heater to provide greater success starting an engine.

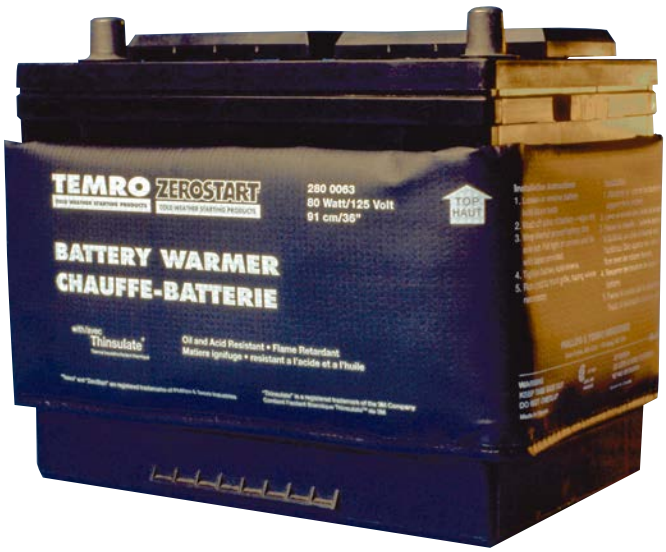


Figure 7. Blanket Style Battery Heater

NOTES

SELF TEST 2

1. When should starting fluid be injected or sprayed into the intake system?

    a. stationary before cranking
    b. while the engine is being cranked
    c. cranking with pre-heaters on
    d. engine shut down

2. Where are the glow plugs located?

    a. the water jacket
    b. the exhaust manifold
    c. pre-combustion chamber
    d. the intake manifold

3. Why are battery warmers used?

    a. maintain charging efficiency
    b. maintain engine efficiency
    c. maintain battery efficiency
    d. maintain starter efficiency

LEARNING TASK 3

Describe Start-up Procedures

Notes

Controls

You must know all the controls on a vehicle/machine. An operator's manual will help when starting a truck/equipment for the first time.

The major controls are:

- engine controls
- transmission controls
- attachment/hydraulic controls
- steering lock controls
- parking brake controls

Engine Controls

Diesel engines do not have spark ignition and so control of the fuel supply is used to control the engine. Before starting a diesel engine, you must know how to shut it off.

There are a number of ways that fuel is controlled in diesel engines. On modern engines, the fuel is controlled electronically—simply turning off the ignition switch turns off the engine. Turning it on typically requires that certain conditions are met such as the controls being in neutral, drive system in neutral, and the parking brake engaged. Older systems use mechanical governors that have a variety of internal mechanisms to shut-down or deliver fuel to the injectors.

Electronic Fuel On/Off Controls

Engines with electronic controls are programmed to control the fuel pump or the fuel injectors. When you turn on the ignition, the Engine Control Module (ECM) wakes from sleep mode and enters monitoring mode. The ECM checks the following items before allowing the engine to start:

- cranking speed
- battery cranking voltage
- fuel pump pressure

NOTES

Some vehicles are equipped with a yellow "check engine" light and a red "stop engine" light. When you turn the key to the run position, the lights will briefly come on and then go out after a few seconds. If either light stays on, you must inspect the vehicle to determine the cause.

High-pressure Fuel Injection Pump with Manual On/Off Control

Older machines control whether the engine is on or off by moving the throttle past the idle position until a click is felt. Rubber-tired machines have the throttle on the floor, but track-type machines often have the throttle on the dash.

Some vehicles have a cable mounted on the dash for on/off control. Pulling the cable shuts the engine off and pushing the cable allows the engine to be started.

High-pressure Fuel Injection Pump with Electric On/Off Control

Electronic controls use an electric solenoid mounted on the fuel injection pump. The wire on this solenoid is powered when the ignition is turned to the run position. You can identify this type of injection control by looking for a wire or solenoid on the injection pump.

Low-pressure Fuel Injection Pump with Electric On/Off Control

Older pre-emission engines used electric controls with a low-pressure fuel system. This system does not have fuel injector lines from the pump. There's only a single fuel line to the cylinder head. You control the shut-off valve with the ignition key.

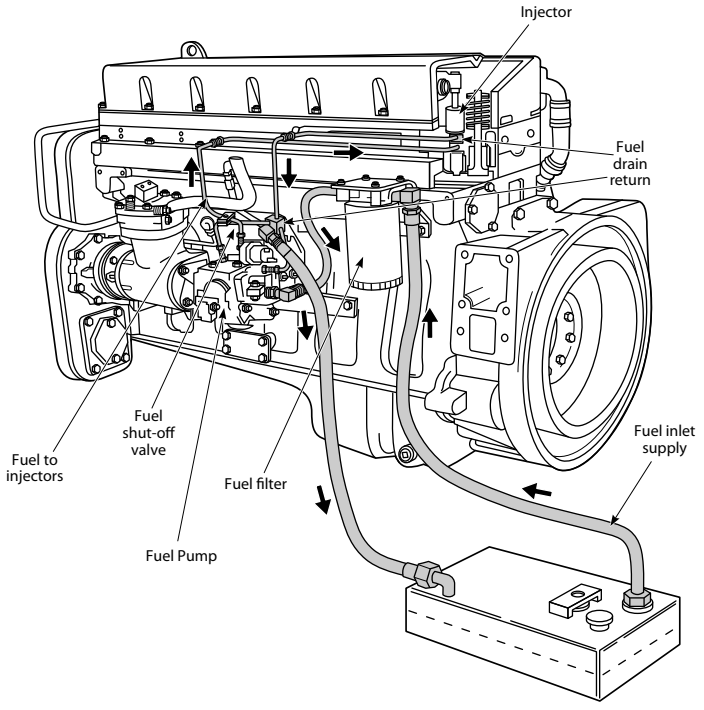


Figure 1. Low-pressure Fuel System Control

Transmission Controls

Manual Transmission Controls

Manual transmissions must be left in neutral when starting a vehicle. To prevent it from moving, a spring-type parking brake is used. Some equipment has a neutral safety switch that will not allow the starter to work unless the transmission is in neutral. Some vehicles require that you depress the clutch before starting the engine.

Automatic Transmission Controls

Automatic transmissions are left in park or neutral when starting the vehicle. Many larger vehicles do not have a park position so must be left in neutral with the parking brake applied.

Powershift Transmission Controls

Only heavy-duty equipment has a powershift transmission. Powershift transmissions do not have park position but do have neutral, speed, and direction control. For rubber tired machines, the parking brake must be applied, tires blocked, and attachments must be resting on the ground. Tracked machines require that the parking brake be applied and attachments be resting on the ground.

Attachment/Hydraulic Controls

Equipment attachments include the blades, rippers, buckets, etc. You must ensure that all attachments are resting on the ground and the control levers are in the float or hold position before starting the engine (Figure 2).



Figure 2. Excavator Bucket on the Ground

NOTES

NOTES

Parking Brake Controls

Most equipment/vehicles use spring-applied parking brakes and air or hydraulic means to release them. This prevents the equipment/vehicle from moving until the parking brake has been released.

Some small vehicles and forklifts have a hand-operated parking brake. While sufficient to keep the vehicle from rolling, these brakes are not strong enough to prevent it from moving under its own power and are therefore not as safe as a spring-applied parking brake.

Some equipment must have the engine running before the parking brake can be released as an extra safety precaution.

Cranking

Manufacturers have specific procedures for starting their engines. These procedures include directions and precautions on:

- maximum cranking time to avoid damage to the starter and its components
- desirable RPM during start-up to give lube oil a chance to reach all the vital areas
- cold starting aids

In winter weather, lighter engine oil or oil with lower viscosity should be used. Lighter oil allows the engine to turn over more easily. Manufacturer's recommendations should be followed for engine oil and fuels for summer and winter use.

The most important preparation for cold weather starting is to make sure the battery is fully charged. Not only is it more difficult for a battery to start an engine in cold weather, but the battery itself operates less efficiently when cold. In addition to keeping the battery fully charged, you should keep the terminals clean and the connections tight. Dirty or loose connections have high resistance to electric current. Battery connections and conditions are important for the proper starting and operation of all engines, but are vital for all electronically-controlled engines.

Once you've completed the pre-start inspection and understand how to start and stop the engine, the engine can be started. You must always follow the operator's manual when doing so. The engine may employ glow plugs, an intake heater, ether, or a block heater as a starting aid. Crank the engine and observe the oil pressure, cranking speed, and exhaust smoke. If the engine is cold, the oil pressure may not increase until the engine has started. If the engine turns too slowly, then you'll need to check the batteries and possibly warm the engine.

Never crank the engine for more than 30 seconds and allow a minimum of 2 minutes between attempts to allow the starter to cool down.

NOTES

Monitoring

Once the engine starts, check the oil pressure gauge. If no pressure is indicated within 15 seconds, shut down the engine and determine the cause. Also, watch for warning lights and fault indicators on electronically-controlled engines. Do not operate the equipment if the indicators show a fault until you have reported and clarified the warning (Figure 3).

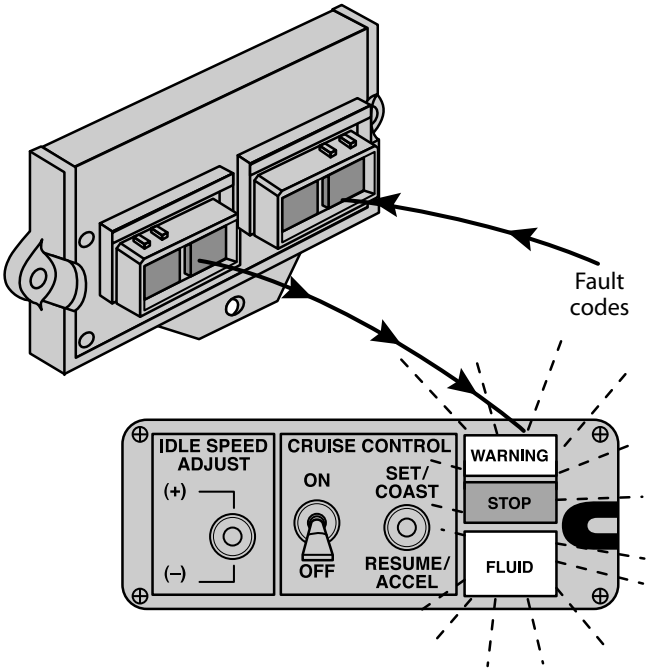


Figure 3. Check/Stop and Engine Maintenance Lights

You should hold the RPM to an idle and monitor the engine for noises, exhaust smoke, engine oil pressure, and coolant temperature.

Machines or vehicles with computer-controlled engines may monitor:

- engine oil pressure
- engine fuel pressure
- turbo boost pressure
- atmospheric pressure
- intake air humidity
- coolant temperature
- coolant level
- engine RPM
- road speed
- throttle position
- fuel consumed
- all the dash switch positions, e.g., Jake and cruise control

NOTES

The red stop engine light only comes on if:

- the engine has low oil pressure
- the engine has high oil temperature
- the engine has low coolant level
- the engine has high coolant temperature

The engine may be programmed to shut-down if any of these conditions are present. This is important when trouble-shooting premature engine shut-down.

In colder areas where the temperature is often below 0°C (32°F), the warm-up period for turbo-charged engines is especially important. The chilled external oil lines leading to the turbo-charger will slow oil flow which reduces oil available for bearings.

After two minutes of idling at 600 RPM, increase engine speed to 900 or 1000 RPM and continue warm-up. This procedure allows the oil to warm and flow freely while the pistons, liners, shafts, and bearings expand slowly and evenly.

Continue the warm-up until temperature reaches at least 54°C (130°F), when part throttle operation is permissible. Do not operate at full throttle until temperature is at least 71°C (160°F).

Jump-starting

Jump-starting is the process of adding extra electrical power to existing batteries prior to starting the engine. This can be done several ways:

- use jumper cables and the battery from another vehicle
- use a battery booster cart



Figure 4. Jumper Cables

Notes

Before connecting jumper cables or a booster cart, be sure all the electrical accessories such as lights, radio, and wipers are off. Observe all other specific warnings that are given by the battery and vehicle manufacturer regarding jump-starting.

Observe battery voltage when connecting the cables. Always jump-start a discharged battery with one of the same voltage, e.g., a 12 volt battery with another 12 volt battery. This is important because of the danger of arcing when connecting the jumper cables, which could cause a battery to explode.

Most equipment/vehicles will be either 12 Volt or 24 Volt systems. You can identify the system by:

- battery configuration
- identification stamp on the alternator
- identification stamp on the starter
- measuring the voltage at the starter



Some heavy-duty starting systems use multiple batteries (e.g., in order to provide 24 V for cranking, two 12 V batteries, or four 6 V batteries might be connected in series). In these cases, special precautions must be observed to avoid damage to electrical components. Check manufacturer's recommendations before attempting to jump-start any vehicle with this system. You will require two sets of jumper cables and two 12 V batteries or a battery cart configured with 24 V.



Shut off the engine with the good batteries before making any connections. Failure to do so may cause computer damage.

Identify polarity before connecting jumper cables. Connect the jumper cables negative-to-negative and positive-to-positive as follows:

1. Connect the first cable to the positive terminal of the dead battery.
2. Connect the other end of the first cable to the positive terminal of the booster battery.
3. Connect the second cable to the negative terminal of the booster battery.

NOTES

4. Connect the other end of the second cable to the engine block of the vehicle with the dead battery. On larger vehicles and equipment, this last connection should be made to the negative terminal on the starter instead of the engine block as there may not be a sufficient ground provided between the starter and the engine block. (Do not make the last connection to the dead battery as it may cause an explosion.)

When removing the cables, reverse the procedure for connecting them and keep the clamps separated until they are disconnected from the source to prevent arcing.

See Figures 5, 6, and 7 for different battery configurations.

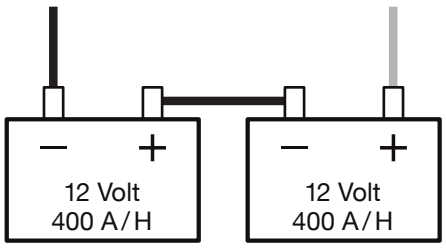


Figure 5. Series Connection

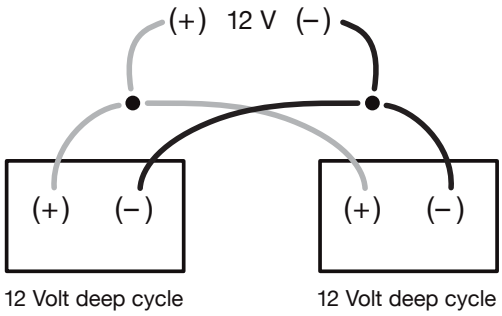


Figure 6. Parallel Connections

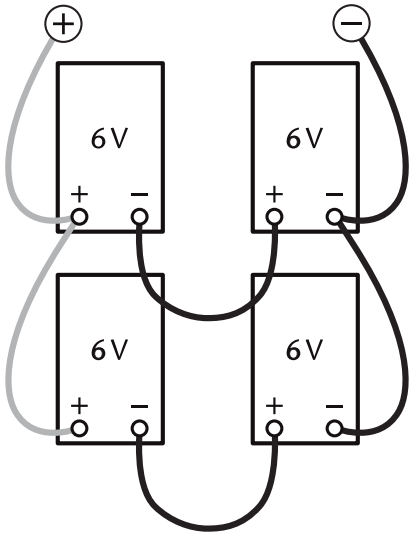


Figure 7. Series Parallel Connections

Battery carts can be either 12 V or 24 V and are a much safer and quicker method of starting equipment or vehicles (Figure 8).

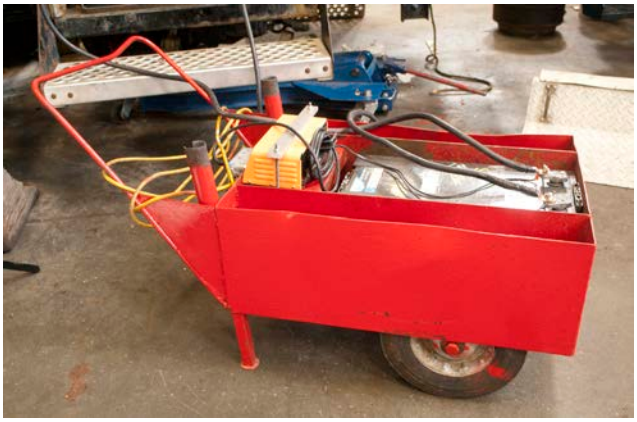


Figure 8. 24 V Battery Booster Cart

Maintenance-free batteries have jumping procedures that differ from a conventional battery. Check the manufacturer's recommendations.

Always use the shortest cables possible. Maintain good clamps on the cables to ensure the best possible connection. The cables should be heavy gauge to ensure they can handle the starting current.

If the battery being jumped is completely dead, connect the jumper cables and then start the vehicle that has the good battery. Without removing the jumper cables, leave the vehicle running for a few minutes before attempting to start the second vehicle. This will partially charge and stabilize the dead battery. Once the dead battery is partially charged, shut off the vehicle (leaving the jumper cables attached) and attempt to start the vehicle that has the dead battery.

NOTES

SELF TEST 3

1. To avoid damaging an electric starting motor, what is the maximum cranking time?

   a. 45 seconds
   b. 15 seconds
   c. 60 seconds
   d. 30 seconds

2. What should the operator do if the yellow check engine light comes on, after starting?

   a. notify a technician to have the problem located
   b. bring the engine RPM up to 1000 for engine warm-up
   c. ignore the light as it is not serious
   d. shut the engine down immediately to prevent engine damage

3. What should the operator do if the red engine light comes on, after starting?

   a. notify a technician to have the problem located
   b. bring the engine RPM up to 1000 for engine warm-up
   c. ignore the light as it is not serious
   d. shut the engine down immediately to prevent engine damage

4. What is the most important thing to know before starting an engine?

   a. the oil is up to the full mark on the dip stick
   b. the condition of the batteries
   c. the do-not-start tag is in place
   d. how to stop the engine

LEARNING TASK 4

Describe Emergency Shut-down Procedures

Notes

Once the pre-start checks have been completed, the engine can be started. Before you start a vehicle or equipment, you must know how to stop it. For a gasoline engine, this is as simple as turning off the ignition switch. The engine is fired by spark ignition and the ignition switch controls the spark, so turning off the switch stops the engine. This is also true for modern electronically-controlled engines because the injectors are also electronically controlled. Once the power supply is switched off, they will not inject. If there is an electronic malfunction, and the engine does not shut off, the only way it can be stopped is by shutting off the fuel or cutting off the air.

The speed of a diesel engine is controlled by the amount of fuel delivered to the cylinders. Older, pre-emission era diesel engines have a governor that senses engine RPM. It prevents the engine from over-speeding by controlling the amount of fuel delivered to the cylinders. Throttle position controls the RPM within the allowable governor settings.

For normal engine shut-down, either the throttle is moved to the No-Fuel position or an electric solenoid control valve shuts off the fuel. In either case, there should be no problem stopping the engine. A fuel system malfunction can cause an uncontrolled speed increase called runaway. Such an RPM increase can happen in seconds and if emergency procedures are not taken immediately, engine destruction is a possibility. If it's not possible to cut off the fuel supply, the other alternative is to cut off the air supply. Some older engines are equipped with a decompression control that can be used to stop the engine.

Shutting off the Fuel

Diesel engine sentinel systems are signal devices that automatically cut off the fuel supply or move the fuel control to the no-fuel position if:

- the engine overheats
- the oil pressure becomes low
- the engine over-speeds

These systems are on non-electronic, stand-alone engines (generators). Generators normally run for hundreds of hours without supervision. If the engine starts to runaway, the sentinel system simply shuts off the fuel and the engine stops. Such systems are unsafe for vehicles travelling at highway speeds.

NOTES

If an engine starts to runaway, you may be tempted to open the fuel lines. This is difficult and very dangerous. It is not a recommended method for emergency shut-down as the possibility of injury is high.

Shutting off the Air

Some engines have an emergency shut-down device that cuts off the air supply to the engine. An emergency shut-down valve is located in the air inlet of the engine and is operated by electrical power. Pushing the control powers up a solenoid and closes the valve, shutting off the air supply. If the engine has reached a runaway speed, the valve may not stop the engine but will slow it to a speed at which you can safely get near and disconnect the fuel line. This type of shut-off works well with both electronic and non-electronic engines.

Older machines with mechanical type unit injectors are most likely to suffer runaways. As such, many are fitted with intake air shut-offs. Note that the emergency shut-down valve is to be used for emergencies only and not for normal shut-down. Indiscriminate use could cause the blower shaft oil seals to fail; this could in turn cause engine oil to be drawn into the air intake which can result in a runaway engine.

If the manually operated air shut-off has been activated, the spring loaded damper door will have to be reset before the engine can be started. You will have to force the damper door open and reset the latch that holds the door open.



Figure 1. Damper Door and Latch in the Set Position

Most engines manufactured today do not have intake air shut-off devices as electronic-controlled engines monitor RPM and can shut-off the power to the injectors at any time. This will instantly cause the engine to shut-off.

Decompression

Some older engines use a decompression device mounted in the cylinder head to allow the engine to turn over in cold weather. This warms the cylinder walls aiding in engine starting. If an engine starts to runaway, you can activate the decompression lever and the engine will stop. This system is not used on newer engines.

NOTES

SELF TEST 4

1. What should a technician do to safely stop a runaway engine?

   a. loosen fuel lines
   b. turn the ignition key to off
   c. shut-off intake air
   d. nothing, the engine will control itself

2. What should a technician do to prepare for a possible runaway engine?

   a. have wrenches handy to loosen fuel lines
   b. have a piece of plywood handy to shut-off the air
   c. have the operator ready to turn off the key
   d. nothing, the engine will control itself

LEARNING TASK 5

Start, Operate, and Shut-down Selected Equipment

Notes

Pre-start and Walk-around Inspections

You should follow a set procedure each time you perform pre-start and walk-around inspections. This minimizes the chance of missing items:

- Make sure you have the correct machine. Compare the machine unit number and serial number with the work order information.
- Make sure the equipment/vehicle is in the service position:
  - equipment electrical locked-out
  - equipment attachments are on the ground and control levers are in hold
  - parking brakes applied
  - wheels blocked
- Perform the walk-around watching for anything out of the ordinary, e.g., loose, broken, or missing components. Document these items. Check the fluid levels at this time and top-up any that are low. Document the amount of oils added and any visual oil leaks.
- Turn on the electrical lockout and check all the electrical accessories in the cab. Document any that are not functioning properly.
- Identify if the machine has a functioning starting aid.

Use of Starting Aids/Starting

If a machine has a starting aid, you should first attempt to start it without the use of the aid.



Sound the horn as a warning to others before you start the equipment.

Watch for smoke at the exhaust to confirm that the engine is getting fuel. Remember: No smoke equals no fuel.



Exhaust fumes can be deadly. Do not operate equipment if the fumes cannot be vented.

If the engine does not start, then follow the manufacturer's recommendations to start the engine using a starting aid. Refer to Learning Task 2 for general starting aid information.

NOTES

Once the engine has been started, observe the oil pressure gauge and allow the engine to warm-up before activating the hydraulics or moving the machine. This allows time to check the engine and transmission oils which is normally done with the engine running.

Once the engine has warmed, the hydraulics should be cycled to check for operation and leaks. Document your findings.

Moving the Vehicle/Equipment

Before moving any vehicle/equipment, you must know how to stop it. Make sure there is no one in your path. Ensure that lights, back-up alarms, emergency brake, and other safety equipment all work before you move the vehicle/equipment. Never allow anyone to ride outside the cab.



Always use a spotter while moving vehicles/equipment—this helps prevent damage to equipment and injury to people.

Keep your vision unobstructed when moving equipment. This includes keeping attachments low. A load carried high not only obstructs your line-of-sight, but makes the machine top-heavy and unstable. If your vision is limited, sound your horn to warn bystanders.

Be aware of other equipment working around you and give loaded equipment the right-of-way.

If you are driving on a public road, be sure all required warning lights and flags are attached and operating.



Never swing a blade or bucket over workers. If you must work under a suspended attachment, be sure to properly block the attachment. Never leave a machine unattended with its engine running. Always use low gear and partial throttle to move vehicles/equipment in congested areas.

Securing and Shutting Down

NOTES

There are certain times when shut-down procedures must be followed:

- starting an engine after an overhaul
- starting an engine after a tune-up
- starting an engine after fuel pump or injector repairs
- starting an engine after a lengthy storage

When equipment and vehicles are being parked, it's best practice to:

- park on level ground
- park away from heavily trafficked areas
- set parking brakes
- shift the transmission into neutral/park
- engage the transmission lock if equipped
- lower all attachments to the ground or block them securely
- shut-down the engine before leaving the cab (make sure the engine has cooled) and remove the keys
- mark your equipment with flags or flares if it has been disabled or parked in an area where there is even a slight possibility of it being hit by traffic
- block wheels
- turn off the power disconnect switch
- place a "do not start" tag on the steering wheel if you are about to perform any service work

General Shut-down Procedures

It's important that the engine be idled for two to five minutes before shutting it down to allow the lubricating oil and water to carry heat away from the turbo, combustion chambers, cylinder head, bearings, and shafts. Residual heat left after the engine stops can damage many parts from valves to fuel pumps. Idling allows the turbocharger to slow down, preventing turbo bearing damage.

Physical stresses from heat expansion and contraction can cause distortion, permanent warping, and gasket failures. It's a good practice to idle any engine long enough to gradually reduce extreme operating temperatures.

Some electronically-controlled engines have an idle shut-down procedure programmed into the system that will automatically shut the engine down after a pre-set time to prevent extended idling. This can be changed in the computer to match the two to five minute cool-down period. Always remember that when the computer shuts off the engine, the key is still on and drawing power. Be sure to shut off the key at this time.

SELF TEST 5

1. What may cause an electronic controlled engine to shut down after 3 minutes of idling?

   a. the engine computer is programmed for 3 minute idle shut-down
   b. the engine is low on engine oil and the computer shuts the engine down
   c. there is an electrical problem in the computer wiring
   d. the machine/truck is low on fuel

2. Why is it important to provide a cool down period before shutting off the engine?

   a. prevent water pump damage
   b. prevent starter damage
   c. prevent turbo charger damage
   d. prevent piston damage

LEARNING TASK 6

Lock Out Heavy-duty Equipment Prior to Service

Notes

It's important to place the machine in the proper service position. This includes level ground, attachments on the ground, hydraulics de-pressurised, parking brakes applied, electrical power neutralized, a lockout device placed on the machine, and a "do not start" sign placed at the cab controls before service work is started (Figure 1).



Figure 1. Lockout Kit

WorkSafeBC Requirements

General Requirement

Prior to working on or around equipment and vehicles, you should be familiar with WorkSafeBC (www.worksafebc.ca) requirements. The unexpected release of an energy source such as hydraulic, pneumatic, electrical, or raised attachments could cause injury. These energy sources must be identified, isolated, and effectively controlled otherwise death or injury could result.

NOTES

When is a Lockout Required?

Generally, a lockout is required any time a piece of equipment is shut down for maintenance or repair. The purpose of locking out a machine is to prevent its inadvertent moving or starting while you are working on or around it. At times, you may need to work on a machine while it is operating. If so, do not install a lockout.

Lockout Procedure

In areas where maintenance is being carried out on powered machinery, lockout procedures are essential to prevent the unexpected operation of a machine. Lockout must involve more than merely disconnecting the power source. Workers have been killed by machinery that is dead electrically but whose hydraulic systems were still functioning. The machines must be assessed thoroughly and all energy sources (including electrical, pneumatic, hydraulic, or gravitational) must be made inoperative, a state called "zero mechanical state."

Each maintenance worker must have their own lock and key (combination locks are not allowed) and only these locks should be used to lock out energy sources. The machine operator should be informed of maintenance plans and the lock should be tagged to identify who has locked out the machinery.

Only the maintenance worker who placed the lock and tag can remove it. Operators and other workers are strictly forbidden to remove either the tag or the lock.

These procedures apply to stationary industrial equipment and mobile equipment, including passenger cars, trucks, and heavy construction equipment.

Whether working with others or alone, you need to be familiar with WorkSafeBC rules and regulations. Refer to the WorkSafeBC web site and reference *OHS Section 10*. Document the subsection number and summarize the Group Lockout Procedures.

NOTES

Electrical Isolation (Night) Switch

Most machines use a battery disconnect switch to isolate the batteries from the battery cables (Figure 2). The disconnect switch is normally located close to the batteries and is often wired into the ground circuit.

Isolation switches prevent the batteries from draining over time while the machine is shut-off. They also allow you to cut-off the power while working on it. Some isolation switches can be locked-out to prevent accidental starting while working on the machine.



Figure 2. Isolation Switch

Tagging the Machine

You should keep several "do not start" tags in your tool box so that you can apply more than one if necessary. This tag designates equipment as being out of service and also identifies the person who installed it on the machine (Figure 3). The person who applied the tag must remove it before the machine can be started or moved.

Key in Pocket

For additional security and preventing of accidental start-up, a technician should remove the ignition key and carry it in their pocket while servicing equipment.

NOTES



Figure 3. "Do Not Start" Tag

Steering Lock Controls

Articulated steering is found on skidders, graders, and wheel loaders. These machines have fixed axles and a frame that hinges in the middle in order to steer.

Equipment with articulated steering presents a particular safety concern. When the equipment hinges or articulates to turn, the two frame sections squeeze together. It is extremely dangerous for a person to be within this "pivot area" while the vehicle is running. Most articulated machines have area warning decals on each side of the frame (Figure 4). You must be absolutely sure that no one is in the pivot area while the vehicle is running.

WARNING

NO ROOM FOR A PERSON IN THIS AREA
WHEN EQUIPMENT IS TURNED.

DO NOT STAND OR WORK IN THIS AREA
WHEN ENGINE IS RUNNING.

USE SAFETY LINKS WHEN SERVICING EQUIPMENT.

Figure 4. Warning Decal

Articulated machines are equipped with a safety bar that locks the two sections in either a straight-ahead or full-turn position. Never check or service articulated equipment without first installing this safety bar. Before installing a safety bar, shut off the engine, relieve the hydraulic pressure, and attach a "do not operate" tag on the steering wheel. The safety bar is stored alongside the frame.

To lock the frames in a straight-ahead position, remove the safety bar from storage and attach it to the front frame with the pin provided.

To lock the frames in a full-turn position, some equipment will use the safety bar, but others simply insert a pin between the two frames.

Note: The frames should be locked in a straight-ahead position when transporting the vehicle.

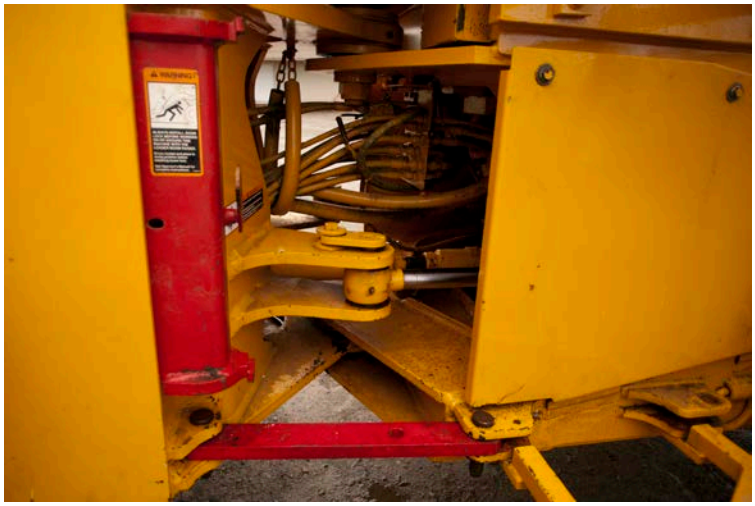


Figure 5. Safety Bar

NOTES

SELF TEST 6

1. Why is it important to lock-out the machine?

    a. prevent engine starting
    b. prevent machine/truck movement
    c. notify supervisor
    d. identify who is working on the machine

2. Why do we use a do-not-start tag?

    a. identify who is working on the machine
    b. prevent engine starting
    c. notify workers that the machine/truck is unsafe to start
    d. prevent machine movement

3. What is the purpose for the isolation switch?

    a. prevents the transmission from going into gear
    b. prevents the starter from being engaged
    c. isolates the ignition switch
    d. prevents the batteries from draining

LEARNING TASK 7

Operate a Forklift

Notes

Forklift Training

No person shall operate a forklift without training. All training must be provided in accordance with the requirements of *CSA Standard B335-94, Industrial Lift Truck Training*.

Motorized Forklifts

One of the most common types of material handling equipment is the motorized forklift. They are used for lifting and transporting materials that can be stacked or placed on pallets. Since forklifts steer with their rear wheels, the back of the forklift swings wide when turning. You must keep the front wheels close to the inside of a turn when operating in a confined area.

The main identifying features of the forklift are the two horizontal arms that protrude from the vertical mast (Figure 1). The mast can be tilted forward between 10–25°.

The load-lifting capacity of a forklift depends on the spacing of the forks, the height and tilt of the mast, and the floor or ground surface. Lifting capacities can range from 900–32 000 kg (2000–70 000 lbs.).



Figure 1. Forklift

NOTES

Occupational Health and Safety Regulations

The following sections of the *WCB Occupational Health and Safety Regulation* apply specifically to lift truck operators:

16.4 (1) A person must not operate mobile equipment unless the person:
(a) has received adequate instruction in the safe use of the equipment
(b) has demonstrated to a qualified supervisor or instructor competency in operating the equipment
(c) is familiar with the operating instructions for the equipment

Note *16.4 (1)(a)* does not apply if a trainee operates the equipment under the supervision of a qualified instructor, or a supervisor.

Note Lift truck operator training must meet the requirements of *Canadian Standards Association (CSA) standard B335-94*. Employers must become familiar with this CSA standard for training forklift operators.

Maintenance and Maintenance Records

Maintenance inspections occur at various intervals:

- pre-start
- daily
- 250-hour service
- 500-hour service
- 1000-hour service

Pre-start

Pre-start inspections must be performed to ensure that the forklift is safe to use. There will be many pre-start inspections of a single forklift each day.

Daily

Daily inspections are done at the beginning of the shift and should be documented on a daily service record form located on the forklift.

Manufacturer Service Intervals

250-, 500-, and 1000-hour service intervals are set by the manufacturer and require more extensive work such as oil and filter changes, greasing, carriage and mast adjustments, and brake adjustments. The lubrication and maintenance manual will specify the items to be serviced. This information is recorded in the machine service logbook.

Operator Controls

The hydraulic controls control the working attachment. A foot-operated brake is used for slowing and stopping, while a hand brake is used to prevent wheel movement once parked. Some forklifts feature a special "dead man" switch. The forklift will not operate unless you are standing on this switch.

NOTES

Hydraulics Controls

The hydraulic controls are on the right side of the steering wheel (Figure 2). There may be one, two, three, or four control levers:

- lift
- tilt
- carriage side shift
- fork side shift

To raise the forks, pull back on the lift lever. To lower the forks, push the lift lever forward.

To tilt the load towards the forklift, pull back on the tilt lever. To tilt the load away from the forklift, push the tilt lever forward.

Some forklifts have a lever that controls the side-shifting fork assembly. Pushing or pulling this lever will move the load to the left or right.



Figure 2. Hydraulic Controls

You must be familiar with each control and their sensitivity. Remember that lift and tilt must be controlled to within a few millimeters to prevent damaging the load.

NOTES

Transmission Controls

There are several different transmission controls:

- manual transmission
- powershift transmission with controls on the steering column
- powershift transmission with controls on the floor
- hydrostatic transmission with controls on the floor

Each transmission has its own inching characteristics. You must be able to control the machine to within a few millimeters.

Steering Controls

Forklifts have rear wheel steering (Figure 3). This gives very good turning radius at slow speeds but poor control at high speeds. Each time you turn the wheel while going forward, the rear of the forklift swings out from the centerline. This is very dangerous in tight areas.



Figure 3. Rear Steering Wheels

Stability Triangle

You must be familiar with the stability triangle for safe operation of the forklift. The higher the load, the less stable the forklift becomes. Always carry the load as close to the ground as possible (Figure 4).

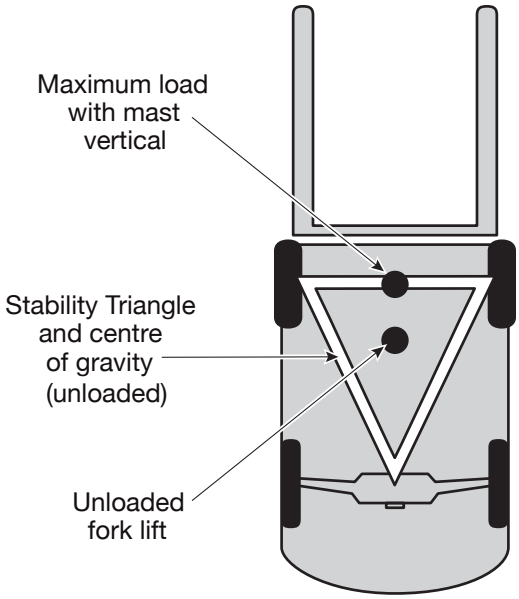


Figure 4. Stability Triangles

Safe Operation of Motorized Forklifts

Special training is required before you're able to operate a forklift. Here are some tips when using a forklift:

- Transport loads as low as possible.
- Loose loads must not project above the fork carriage.
- Single-unit loads must not project more than half their height above the fork carriage.
- Wide, high loads which block your view should be transported with the load trailing.
- Position all loads as near the fork carriage as possible.
- Transport loads with the load tilted back (towards the forklift).
- When you are moving a load up or down a ramp, the load must always face the top of the ramp.
- All turns must be made on level surfaces. Never turn a forklift on a sloping surface. You risk tipping the load, the forklift, or both.
- Avoid quick or jerky starts and stops.
- Slow down for all turns.
- When parking the forklift, park away from heavily travelled areas. Set the parking brake and lower the forks to the ground before leaving the machine.
- Never lift or carry personnel on a forklift.
- Ensure that all loads are secure.

NOTES

NOTES

Uphill Versus Downhill

It's very important to keep the load on the high side of the forklift while going up or down inclines. The load may cause the forklift to tip forward if the load is on the low side.

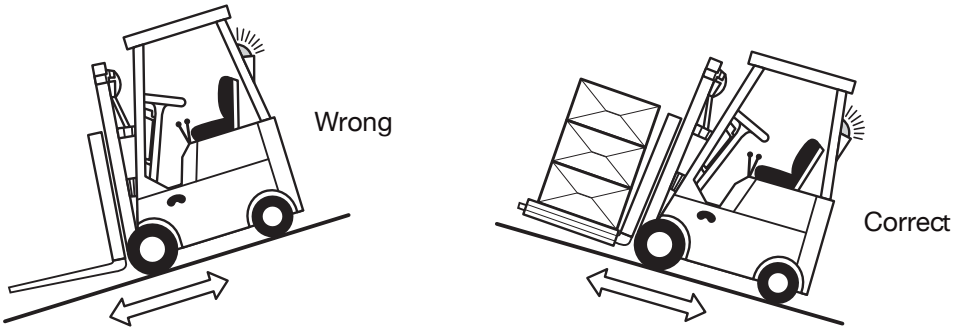


Figure 5. Direction of Forklift

Vision

Multi-piece loads should be no more than 1.5 times the height of the forks. Any higher and the load becomes unstable. If you need to carry a large load which will block your vision, you must tie the load down and drive backwards to the unloading location. If it's not possible to drive backwards, you must use spotters while transporting the load.

SELF TEST 7

1. What is the purpose for the stabilization triangle?

   a. identify the use of the forklift on uneven ground
   b. identify the area around the forklift
   c. identify stabilization as the forks are lifted
   d. identify stabilization as the speeds are increased

2. How often should a walk-around inspection be done?

   a. first thing in the morning
   b. at the end of each shift
   c. every time an operator climbs onto the machine
   d. once a week

3. How high should the load be carried?

   a. waist high
   b. as close to the ground as possible
   c. it does not matter
   d. it depends on the direction of the machine

COMPETENCY A-8

USE SHOP RESOURCES AND RECORD KEEPING PRACTICES



HEAVY MECHANICAL TRADES: LINE A—COMMON OCCUPATIONAL SKILLS

Goals

With the advance in computer business applications, record-keeping has become simplified for most companies. You will be required use computers and written media to locate service and maintenance information as well as to communicate with others using forms and reports. Although some shops still use manual or written forms for record keeping, it's expected that most will be moving to a computer operated system. You'll use these systems to manage day-to-day operations as well as time sheets, parts requisitions, parts inventory, and cost control. Some shops have gone completely electronic in every aspect of their operations.

When you have completed the Learning Tasks in this Competency, you will be able to:

- recognize the correct form to be used for each purpose
- know where and how to obtain the necessary information that must be entered on each form
- know how to list this information correctly

LEARNING TASK 1

Describe Methods of Record-keeping

Notes

The successful running of any business depends on effective record-keeping. Records must be kept of each business transaction, the hours worked by the various employees, and the jobs that each has performed. Forms such as memos and time sheets are relatively straightforward to complete. Others, such as invoice sheets and work orders, contain more detail. Depending on the work site, this could be computerized requiring only that you enter your time, date, and work performed.

There are two basic types of forms:

- business forms
- record-keeping forms

Business Forms

Business forms include work orders, parts requisitions, and purchase orders. These are used to authorize and initiate specific work projects that your company is about to undertake.

Work Orders

If you work for a dealership or repair service company, you'll be required to fill out a work order. This is often the case in private or fleet companies as well. Work orders are necessary to:

- authorize the start of work
- identify the nature of the work to be done
- provide a time frame for scheduling and completion of the work
- record the actual time, work steps, and material used in completing the work
- have the work order signed (in the case of repair service companies)

Work orders are essential for maintaining accurate records. They provide the information for necessary follow-up work and for possible warranty claims and guarantees.

NOTES

The time you spend with a customer filling out a work order may be the only time anyone in your company has any direct communication with that particular client, so it's important that you use this contact time productively:

- Ask the customer to outline the exact nature of the problem and give them sufficient time to explain.
- Make sure you have the customer's complete name, address, and a telephone number at which they can be reached in case a problem arises.
- Ensure that the customer signs the work order, as this constitutes formal authorization that the customer understands and approves the work to be done.
- Determine whether any portion of the work is to be covered by warranty.
- Determine whether or not the customer wishes to be contacted if unforeseen problems are discovered that could result in additional costs.
- Keep in communication with the customer as to what is occurring with the repair.

Make sure that you fill out the work order both legibly and accurately. Pay particular attention to the spelling of the customer's name, as an incorrect spelling can easily lead to confusion. (Note that the work order is not legally binding if the name is spelled incorrectly.)

Figure 1 shows a sample work order form.

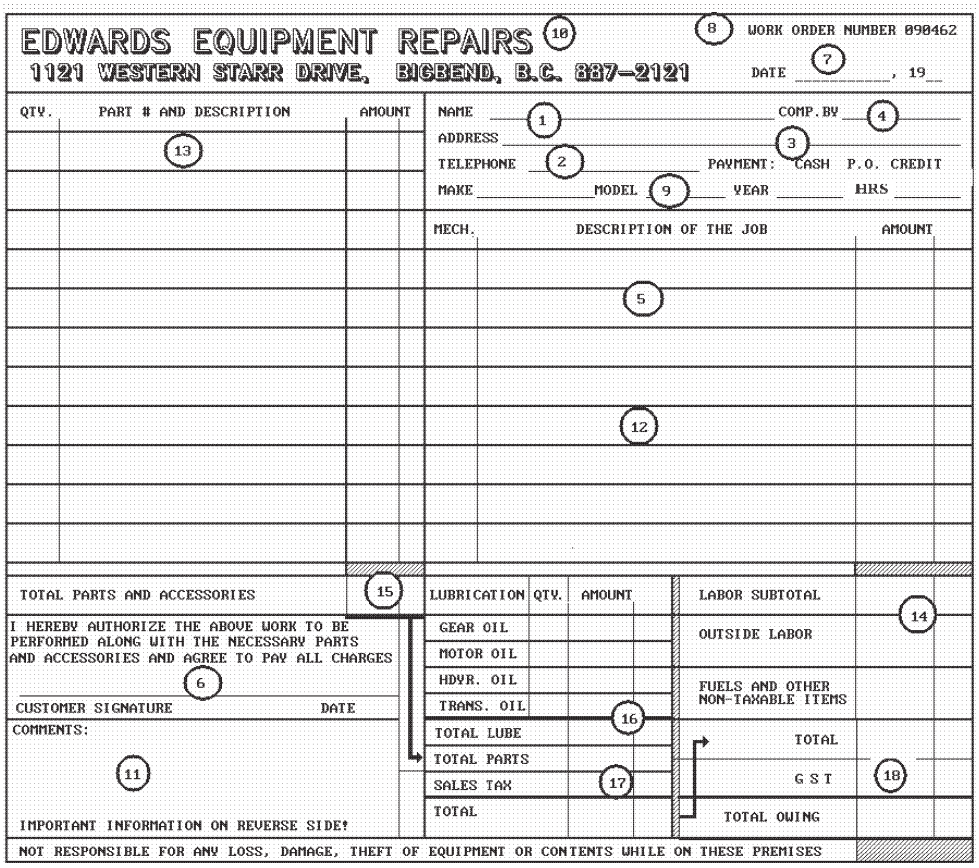


Figure 1. Sample Work Order

Customer Information

This is information that you will get from the customer at the time the work order is being completed:

1. name and address
2. telephone number
3. method of payment
4. time customer requests completion
5. specific problems customer wants fixed
6. customer signature (This is needed in order to authorize work.)

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Factual Information
It's extremely important that you note each of these details accurately:

7. date
8. work order number (usually pre-printed on the form)
9. model, serial number, license, and mileage
10. dealer name and address (usually pre-printed on the form)

Service Information
The technician working on the job will fill in these facts:

11. technician's comments
12. maintenance done
13. parts or accessories replaced

Billing Information
Although the office staff will usually fill in this information after the work has been completed, you should be familiar with these parts of the work order so that you can supply appropriate information if needed:

14. labour charges
15. parts and accessories charges
16. charges for lubricants and oils
17. provincial sales tax applied to parts, accessories, lubricants, and oils
18. applicable taxes applied to total parts and labour

Some shops add a percentage to cover the cost of buying supplies for the shop.

Parts Requisition

The parts requisition is a company internal parts purchasing form. It's a form that you will have to fill out whenever you have to order supplies or parts for a job you're doing.

A sample parts requisition is shown in Figure 2.

EDWARDS EQUIPMENT REPAIRS 887–2121
1121 WESTERN STARR DRIVE, BIGBEND, B.C.
REQUISITION #17062 (17)

CUSTOMER NAME AND ADDRESS (1)	REGION	WORK ORDER # (5)	MECH. CODE (6)
	ACCOUNT CODE	DEALER NAME AND ADDRESS (4)	
MACHINE MODEL/TYPE (3)	CODE		
SERIAL #	OFFICE USE ONLY	SPECIAL INFORMATION (7)	
ENGINE #			
ATTACH #			
WARRANTY NUMBER EXPIRY DATE		ORDER DATE (2)	

LOCATION (8)	QTY. (9)	PART NUMBER (10)	DESCRIPTION (11)	QTY. ISSUED (12)	QTY. B/O (13)	UNIT PRICE (14)	TOTAL PRICE (15)	CHARGED
						TOTAL PRICE	16	

Figure 2. Sample Parts Requisition

1. Customer's name and address. (This is not always included, but if it is, make sure it's accurate—note that your company may be the customer.)
2. Date of the order.
3. Vehicle/equipment model and type. (You may need to include a Vehicle Identification Number [VIN] or equipment serial number.)
4. Dealer's name and address.
5. Work order number. (Make sure that you copy it correctly and that it refers to the right customer.)
6. Technician code or the name of the technician performing the work.
7. Special information. (This is usually used to indicate who will pay for the work: customer, insurance company, warranty, etc.)
8. Location. (Indicates where the part is located.)
9. Quantity ordered.
10. Part number.
11. Description of the part. (Since the part number often means nothing to the customer or even to other employees, a brief description should be included.)

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12. Quantity issued. (This number may not be the same as the quantity ordered.)
13. Quantity back-ordered. (Where applicable, this figure will be the difference between the quantity ordered and the quantity issued.)
14. Unit price.
15. Total price. (This is the total cost for that item and is an extension of the unit price. For example, if two filters are purchased at $3.00 each, the unit price will be $3.00, and the total price will be $6.00.)
16. Total. (This column represents the total dollar value of the entire parts requisition. Taxes are not included since they will be included on the work order.)
17. Requisition number. (Parts requisitions are pre-numbered and if a requisition has to be cancelled for some reason, do not destroy it, just write "Cancel" across the face of the requisition and file it with the others.)

Purchase Order

A purchase order (PO or P/O) is usually used in conjunction with the parts requisition. Like a parts requisition, a purchase order is used for ordering supplies, parts, or labour. However, unlike a parts requisition, a purchase order is used for external ordering. The company sends it out to other companies for the parts, supplies, or services that are required.

The following points are important when completing a purchase order:

- Someone in authority in your company must sign each purchase order.
- Each purchase order has a number. The purchase order number is the record of the transaction. It will be noted both on the bill for the supplies or services ordered and on the cheque issued to pay that bill. It's very important that you note this purchase order number correctly.
- Some organizations use the same form for both internal and external ordering, but most will use different forms for parts requisitions and purchase orders. For this reason, it's important that you be familiar with both.
- Some companies have direct connections to other companies' parts departments. This allows purchase orders to be completed entirely electronically, saving time and paper work for both.

Figure 3 shows a sample purchase order form:

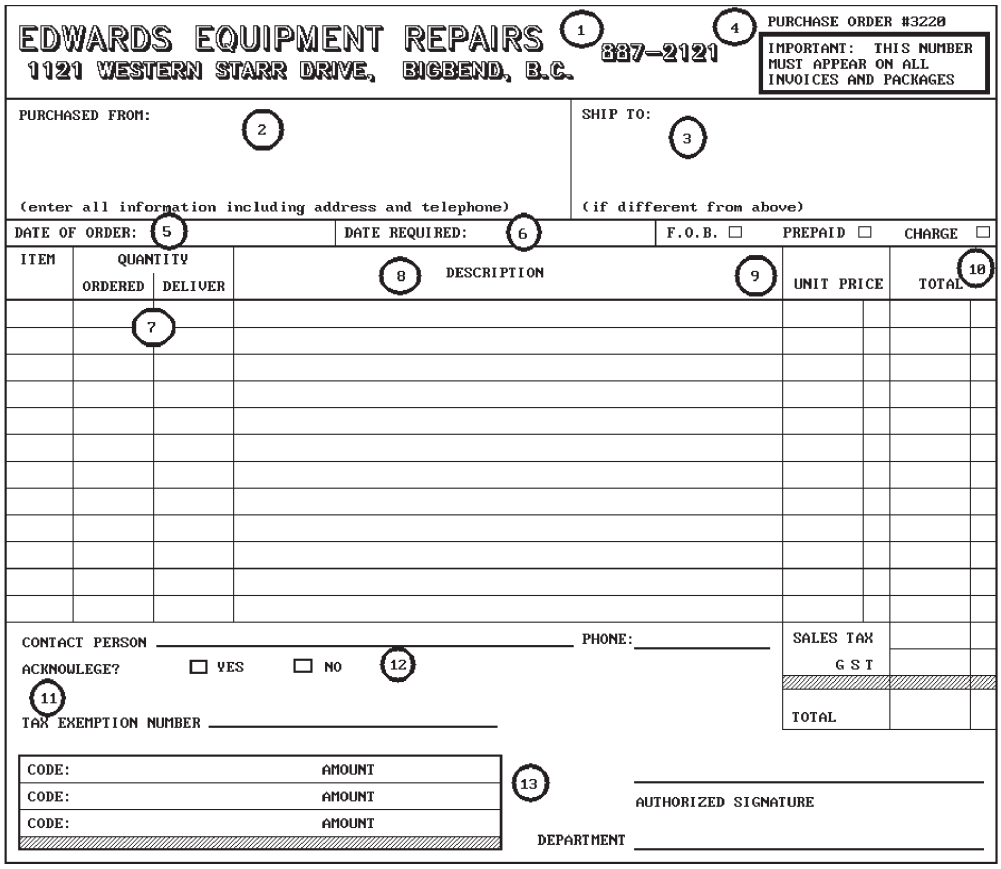
EDWARDS EQUIPMENT REPAIRS (1) 887–2121 (4) PURCHASE ORDER #3220
1121 WESTERN STARR DRIVE, BIGBEND, B.C.
IMPORTANT: THIS NUMBER MUST APPEAR ON ALL INVOICES AND PACKAGES
PURCHASED FROM: (2)
(enter all information including address and telephone)
SHIP TO: (3)
(if different from above)
DATE OF ORDER: (5) DATE REQUIRED: (6) F.O.B. ☐ PREPAID ☐ CHARGE ☐
ITEM | QUANTITY ORDERED | DELIVER | (8) DESCRIPTION | (9) UNIT PRICE | TOTAL (10)
(7)
CONTACT PERSON _____ PHONE: _____
ACKNOWLEGE? ☐ YES ☐ NO (12)
(11)
TAX EXEMPTION NUMBER _____
SALES TAX
G S T
TOTAL
CODE: AMOUNT
CODE: AMOUNT
CODE: AMOUNT
(13)
AUTHORIZED SIGNATURE
DEPARTMENT _____

Figure 3. Sample Purchase Order

1. Your company name.
2. Name and address of the company from which you're purchasing.
3. Ship to. (Indicates to what area of your organization you wish the goods to be delivered.)
4. Purchase order number. (Numbers are filed numerically, so it's important that they be used in sequence.)
5. Date of order.
6. Date required. (Note that you should always enter an actual date rather than terms such as "ASAP" or "RUSH".)
7. Quantity ordered and delivered. (Make note of any discrepancy between the quantity ordered and the quantity actually received.)
8. Description. (Describe the items you're purchasing including a part number where possible.)
9. Unit price.
10. Total price.
11. Tax exempt certification. (Refers to the tax structure for this particular purchase.)

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12. Direct inquiries to. (Purchase orders must be signed by the person ordering the goods or services and your signature on a purchase order indicates that you in fact ordered the goods and that you, as a representative of your company, promise to pay for them.)
13. Account code. (This may not appear on all purchase orders but is used to show which department within the company is to be charged for the purchase.)

Record-keeping Forms

You will need to keep a record of your own activities within your company and a list of the hours you have worked. In many companies, you'll be required to fill in a weekly time card. You may also be required to keep a record of what percentage of those hours were worked on each particular job.

In each of these cases, you'll have to fill out one of the following forms:

- time sheet
- daily time card
- vehicle/equipment log
- maintenance log
- maintenance schedule
- personal log

Time Sheets

A time sheet is usually filled out daily and covers either a one-week or a two-week time period. It records the number of hours you've worked each day. At the end of each pay period, your time sheet is sent to payroll, where your pay-cheque is made up based on the hours you've worked.

A sample time sheet is shown in Figure 4. Be sure to use the 24-hour clock when listing your hours. For example: 0800, 1330, and 2300 rather than 8 a.m., 1:30 p.m., and 11 p.m.

EDWARDS EQUIPMENT REPAIRS
1121 WESTERN STARR DRIVE, BIGBEND, B.C.

EMPLOYEE TIME SHEET FORM #2167

NAME
ADDRESS (1)
SOCIAL INSURANCE NUMBER

DATE: (2)
FOR TIME WORKED FROM: (3) TO:

DATE	TIME WORKED FROM	TO	TOTAL	(4)

(5) EMPLOYEE SIGNATURE
(6) SUPERVISOR SIGNATURE

PAYROLL USE ONLY

Figure 4. Sample Time Sheet

The following information is required on your time sheet:

1. name, address, and social insurance number
2. current date
3. time period covered by this time sheet
4. a brief description of the job
5. your signature
6. your supervisor's signature

Daily Time Card

In some shops, you may find that you're required to keep track of the amount of time spent on each particular task. Some shops still use a time clock in which you punch in and out of each job. It may also be used to give an accurate accounting of the cost for every piece of equipment in the fleet. This is done with a daily time card (Figure 5).

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EDWARDS EQUIPMENT REPAIRS
1121 WESTERN STARR DRIVE, BIGBEND, B.C.

Daily Time Card

DATE (1) _____

NAME (2) _____

JOB # (3)	DESCRIPTION (4)	TIME (5) START / (6) STOP
		START
		STOP
		START
		STOP
		START
		STOP
		START
		STOP
		START
		STOP
		START
		STOP
		START
		STOP
		START
		STOP
		START
		STOP

EMPLOYEE SIGNATURE _____

Figure 5. Sample Daily Time Card

The following information is required on a daily time card:

1. the date
2. your name
3. the order number for each job you have performed
4. a brief description of that job or operation
5. the time at which you started that particular job
6. the time at which you completed that particular job

Vehicle/Equipment Log

Equipment and vehicles may have a logbook with pages similar to the one shown in Figure 6. These books are kept with the unit at all times and are used to record any problems or defects as well as noting any repairs that are made. They may also include daily pre-operational and post-operational information.

Rugged Construction
1997 Hardtop Avenue, Bigbend B.C.

THIS LOG MUST REMAIN IN THE EQUIPMENT AT ALL TIMES. REPORT ALL DEFECTS IN OPERATION IMMEDIATELY.

EQUIPMENT TYPE (3)	MAKE

DATE (1)	OPERATOR (2)	DESCRIPTION OF DEFECT (4)	REPAIR # (5)

Figure 6. Sample Equipment Log

This information is requested on equipment logs:

1. date the report is being made
2. driver's name
3. vehicle fleet number
4. description of the defects or problems that have been encountered
5. work done to correct these problems

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Maintenance Log (Maintenance Performance Record)

Not only will proper operation and maintenance increase the efficiency of vehicles and equipment, but it will also ensure optimum safety for the operator. Scheduling of maintenance, the specific servicing done, and the results of servicing must be recorded.

The form used for recording this information is a maintenance log or maintenance performance record, similar to the one shown in Figure 7.

Rugged Construction (2)
1997 Hardtop Avenue, Bigbend, B.C.

EQUIPMENT MAINTENANCE RECORD
REPAIRER: INHOUSE ☐
OTHER: (5)

EQUIPMENT MAKE (1)	MODEL/TYPE	PURCHASE DATE
EQUIPMENT SERIAL #	ENGINE #	WARRANTY #

MINOR SERVICE AND MAINTENANCE				MAJOR SERVICE AND REPAIR				WARRANTY REPAIRS				
DATE	HOURS	SERVICE	R/O	DATE	HOURS	SERVICE	R/O	DATE	HOURS	MILEAGE	R/O#	✓
(4)		(3)		(4)		(3)		(4)		(3)		(6)

Figure 7. Sample Maintenance Log

The maintenance log should include the following information:

1. serial number, engine model, and make of the vehicle
2. owner's name
3. kilometres or time interval (operating hours) between maintenance checks
4. date at which each maintenance check was made
5. name of the dealer or shop performing that maintenance
6. authorized signature

Maintenance Schedule

The maintenance log is usually accompanied by a maintenance schedule (Figure 8). The difference between the two forms is that the maintenance log is a long-term record, listing maintenance operations that have been performed over a period of time. The maintenance schedule, on the other hand, details the maintenance operation for only one occasion.

Rugged Construction
1997 Hardtop Avenue, Bigbend, B.C.

EQUIPMENT # _____
MAKE: _____
MODEL: _____ YEAR: _____

DAILY INSPECTION ☐	MAINTENANCE SCHEDULE A ☐	MAINTENANCE SCHEDULE B ☐
CHECK FOR LEAKS ☐	CHANGE ENGINE OIL ☐	CLEAN ENGINE ☐
CHECK ENGINE OIL ☐	CHANGE FILTER ELEMENTS ☐	CLEAN UNDERCARRIAGE ☐
CHECK COOLANT ☐	SERVICE AIR FILTERS ☐	CHECK CHARGING SYSTEM ☐
CHECK AIR CLEANERS ☐	CHECK OIL PRESSURE ☐	ADJUST FUEL SYSTEM ☐
CHECK DRIVELINE ☐	CHANGE FUEL FILTERS ☐	ADJUST VALVES ☐
CHECK TRACKS ☐	CLEAN CRANKCASE BREATHER ☐	INSPECT VIBRATION DAMPER ☐
CHECK ATTACHMENTS ☐	LUBRICATE ☐	CHECK FUEL PRESSURE ☐
CHECK TRANS FLUID ☐	CHECK AIR SYSTEM ☐	CHECK EXHAUST BACKPRESSURE ☐
CHECK HYDRAULIC FLUID ☐	ADJUST BELT TENSION ☐	CHANGE HYDRAULIC FLUID ☐
CHECK OPERATOR REPORT ☐	INSPECT TRANS FLUID ☐	CHANGE TRANSMISSION FLUID ☐
CHECK TIRE PRESSURES ☐	CHECK TIRE CONDITION ☐	INSPECT WATER PUMP ☐
	CHECK ATTACHMENT WEAR ☐	CHECK TURBOCHARGER ☐
	INSPECT HYRAULIC FITTINGS ☐	PERFORM SCHEDULE A ☐
	PERFORM DAILY MAINTENANCE ☐	

ENGINE SERVICE INTERVALS			
V-6, V-8	MILES (Km)	6,000 (10,000)	30,000 (48,000)
	HOURS	200	1000
	CALENDAR	3 MONTHS	1 YEAR

ENGINE SERIAL NUMBER	ENGINE LUBRICANT USED	QTY.
TRANSMISSION SERIAL NUMBER	HYDRAULIC FLUID USED	QTY.
EQUIPMENT SERIAL NUMBER	TRANSMISSION FLUID USED	QTY.
SERVICE DATE	PARTS ORDER NUMBER	
REPAIR ORDER NUMBER	MECHANIC NAME & NUMBER	

Figure 8. Sample Maintenance Schedule

Personal Log

A daily personal record of repairs you conducted can provide valuable information. It gives you a record of what you did on a machine, and should also include what you didn't do or were instructed not to do. In the case of an accident or equipment failure, it may be used to help determine "who did what." Some companies require that you keep a personal record of all repairs and work you perform. This information can be used as a cross-reference for service reports. It can also be used as evidence of skill development or competency in particular types of work.

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There is no standard personal log, but you should consider including:

- date
- equipment make, model, and serial number
- hour meter reading (or mileage)
- work performed
- time to complete work
- comments on what was not completed or other key information

Warranty Forms

Companies use warranty forms to record the details and circumstances of a warranty claim. Warranty claims are divided into two types:

- factory warranty (new equipment/truck warranty)
- internal warranty (service warranty)

Factory Warranty

New trucks or equipment are often covered by a factory warranty that pays for parts and labour for needed repairs. It's important that factory warranty forms be properly completed in order to ensure coverage. Factory warranty forms usually require the following information:

- machine/truck model, serial number (VIN number), and application number
- the number of hours on the machine or kilometres on the truck
- the work order number
- list of part/parts that caused the failure
- list of other parts that were affected by the failure
- description as to how the failure occurred
- any factory bulletin information that relates to the failure
- technician employee information and signatures

Internal Warranty

An internal warranty is one offered by a company to guarantee service work performed on used equipment. Internal warranty forms usually require the following information:

- machine/truck model, serial number (VIN number), and application number
- the number of hours on the machine or kilometres on the truck
- the work order number from the current and previous job
- previous service report information
- list of part/parts or circumstances that caused the failure
- list of other parts that were affected by the failure
- description as to how the failure occurred
- technician employee information and signatures

SELF TEST 1

1. What two basic categories of forms are used by most companies?

   a. business forms and work order forms
   b. business forms and record keeping forms
   c. record keeping forms and time sheet forms
   d. record keeping forms and work order forms

2. In what form do we find the information authorizing the start of work?

   a. purchase order
   b. parts requisition
   c. business
   d. work order

3. What company form is used to order parts from one department to another?

   a. parts requisition
   b. purchase order
   c. customer order
   d. work order

4. What information identifies the customer on a parts requisition form?

   a. customers personal name
   b. customers company name
   c. work order number
   d. parts requisition number

5. What company form is used to order parts or services from another company?

   a. parts requisition
   b. work order
   c. service order
   d. purchase order

6. When are daily time cards usually filled out?

   a. hourly
   b. change of job
   c. daily
   d. beginning and end of day

7. What is the purpose for time sheets?

   a. record keeping for your pay cheque
   b. record keeping for the work order
   c. record keeping for your diary
   d. record keeping for company billing

8. What is the purpose for the equipment/truck logbook?

   a. record the hours/kilometres
   b. record the fuel consumed
   c. record the service information
   d. record the job information

9. What is the purpose for the maintenance schedule?

   a. details the maintenance for one occasion
   b. details the maintenance for all occasions
   c. details short term maintenance
   d. details long term maintenance

LEARNING TASK 2

Describe the Requirements for Report Writing

NOTES

To work safely and effectively, you need to communicate with those who work with you, give directions, ask questions, give information, and explain procedures. Much of this communication will be done orally, but some will be done with forms or written reports.

When you have completed this Learning Task, you will be able to:

- identify, select, and organize facts for a brief written report
- write a brief report on a work-related matter

Situations Requiring Reports

In almost all working situations, there will be occasions when a written report of some kind is needed. Here are some typical situations, each requiring its own, different kind of report:

- You've completed your shift and need to leave precise information for the person who will be taking over the work you've been doing.
- You've completed work on a vehicle and must summarize what has been done for your shop supervisor.
- You've been asked to write clear instructions for a colleague who has to install a component in a piece of equipment.
- You're repairing a vehicle and you run into a major unforeseen problem. Due to the cost implications, you need to spell out the repair options.
- Your shop is considering the purchase of a parts washer and you've been given the task of writing a description of the supplies needed to connect the new unit.
- You're injured on the job and are sent to a doctor. You must fill in a detailed accident report for WorkSafeBC.

Organizing Your Report

Good written communication usually contains three sections:

- **introduction**—saying **why** you're writing
- **body**—giving the details of **what** you're writing about
- **conclusion**—restating your **purpose** in writing and including your recommendations

NOTES

The best way to create effective reports is to follow a similar three-part structure.

Introduction

Keep it short and simple. Before you start, make sure in your own mind why you're preparing this report. Most often there is an originating incident for a report. Be prepared to state that incident at the start, clearly and directly.

Body

The body of the report is the place where you develop all the important details. These details should lead your readers to the conclusions you wish them to draw or provide them with the information you wish them to have. The most important thing to remember before you start to write is that you have to organize what you want to say. This is the most crucial part of the whole process.

This organization consists of two distinct steps:

- Look at the facts, details, or information you have collected to make sure that they are correct and complete.
- Decide on the best order or sequence for them in your report.

You have choices about the order in which to record the details in a report. Sometimes, these details should be presented in their natural sequence, in the order in which they occurred. This order would be used if you were preparing a service report on a vehicle brought in for repair.

This way of ordering the details in their natural sequence is also generally the best to use in giving instructions for the use or installation of an unfamiliar piece of equipment.

Sometimes, the purpose of your report will demand that you select a slightly more complex order or progression for your material. This may be especially useful when you have to write a report in which you need to discuss several alternatives, particularly if each of those alternatives has certain advantages and disadvantages.

Conclusion

This is the final section of your report and, like your introduction, it should be short and simple. Often the most useful thing is to restate the reason for your report and, if necessary, add your recommendations.

Clear, accurate, concise reports have the following qualities:

- **improve** the flow of information between workers
- **reduce** or **eliminate** misunderstandings among fellow workers
- **reduce** possible risks to safety
- **provide** necessary documented information when claiming warranty replacement parts or materials
- **protect** both you and your employer in the case of customer dispute

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Kinds of Reports

There are seven basic kinds of reports that you may have to prepare:

- shift-end reports
- service reports
- instructional reports
- problem-solving reports
- letters of inquiry
- accident reports
- safety reports

Shift-end Reports

Shift-end reports must:

- detail the work that you have completed in that shift
- describe any work actually in progress
- outline the work remaining to be done
- note any parts or equipment that might be required

Service Reports

Service reports are written on the completion of almost every job. These reports state:

- the complaint
- the cause
- the cure

Here is an example of a **poorly written** service report:

> *The valves are worn and could use a valve grind. I adjusted them. The camshaft is worn and should be replaced. The points were closed, so I set them. The spark plugs were badly carboned so I cleaned them. I replaced the worn vacuum hose. I replaced three bulbs in the running lights, two in the front and one on the rear.*

NOTES

Here is an example of a **well-written** service report:

> *On Monday June 10, 2011, Mr. Henry Colt brought in a 2006 Kenworth for an engine problem. At the customer's request the motor was disassembled and inspected. It was found that the camshaft was worn and needed replacement and that the cam followers were showing accelerated wear. The customer agreed to the replacement of the cam followers, but decided to postpone the replacement of the camshaft, as this would save about $1400 in the total bill.*
>
> *The job was done according to the customer's request and completed on June 15, 2011. Total cost to the customer was $2823.47.*

The service report written by this mechanic is complete, accurate, and clear, which are the three key qualities for any report.

Even though the report is quite short, its importance is illustrated by the fact that the customer returned two months later complaining that the work on the engine had been faulty and incomplete and insisting that it be fixed at no cost to him. When the engine was inspected a second time, the problem was found to be a worn camshaft. The clear written report of the original job provided details of the work done and a record of the customer's choice not to replace the worn camshaft.

A service report of this kind can be particularly important if the vehicle concerned should subsequently be involved in an accident. Often, the service report is used as evidence in court. It's very important that the report be complete and accurate.

Organized, written records of this kind can:

- identify details of work requested
- identify details of work completed
- record information to back-up warranty claims
- help protect your company against legal action
- help protect you against claims that you have not completed requested work or have done work that was not requested
- act as a permanent record made when your memory was fresh and accurate
- keep you out of situations in which it's a matter of your word against someone else's

Instructional Reports

Instructional reports can often be given either face-to-face or over the telephone. However, other workers may be unfamiliar with a certain type of vehicle and require detailed instructions to take to the job site.

In these cases, it's essential that you give these instructions properly in written form. Your instructions must be accurate, complete, and provide step-by-step details that cannot be misunderstood.

A technician who has been asked to install an unfamiliar component might require such a report. For example, if a customer purchases an after-market air conditioner, the technician tasked with installing it might ask you to provide installation instructions (if you are familiar with the equipment).

Problem-solving Reports

You might need to prepare a written report when a problem arises. These are called problem-solving reports. They should include information about the safety precautions that must be taken, the approximate completion time, the estimated number of workers needed, and the equipment that will be necessary.

Letters of Inquiry

You will need to know how to prepare a written report when you're required to write a letter that requests or provides information. Requests for and notices of information are not usually backed up by telephone. This makes it especially important for you to put together information that is clear, complete, and readily understood.

Accident Reports

Accidents or illnesses that occur on the job require the preparation of a detailed written report.

If this accident or illness is minor and can be attended to by your company first aid attendant, then you'll only have to provide verbal information and the nurse or medical officer will write the details in the company medical record book. If the accident or illness is more serious and requires professional treatment (e.g., from a doctor, a chiropractor, or a burn treatment centre), it will be necessary for you, or the person who treats you, to fill in a detailed report for WorkSafeBC.

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It's particularly important that such a report be accurate and specific. For example, in the case of a hand injury, it's essential that you state whether it's the right hand or the left. Otherwise, you may find that you cannot claim additional benefits should this injury cause further problems at some later date.

Here is an example of an injury report written by a worker who was using an electric drill to make a new metal bracket:

> *At 0900 hours on Thursday, June 15th, I was drilling through a small piece of metal in order to make a new bracket to replace a broken one. A vise was not available at that time to hold the piece of metal, so I was holding it with my left hand. The bit jammed and the piece of metal spun around, cutting my left hand across the palm near the base of the thumb. The cut was deep and bled profusely. The company medical officer sent me to the outpatient department at Royal Inland Hospital, where I received 16 stitches to close the wound.*

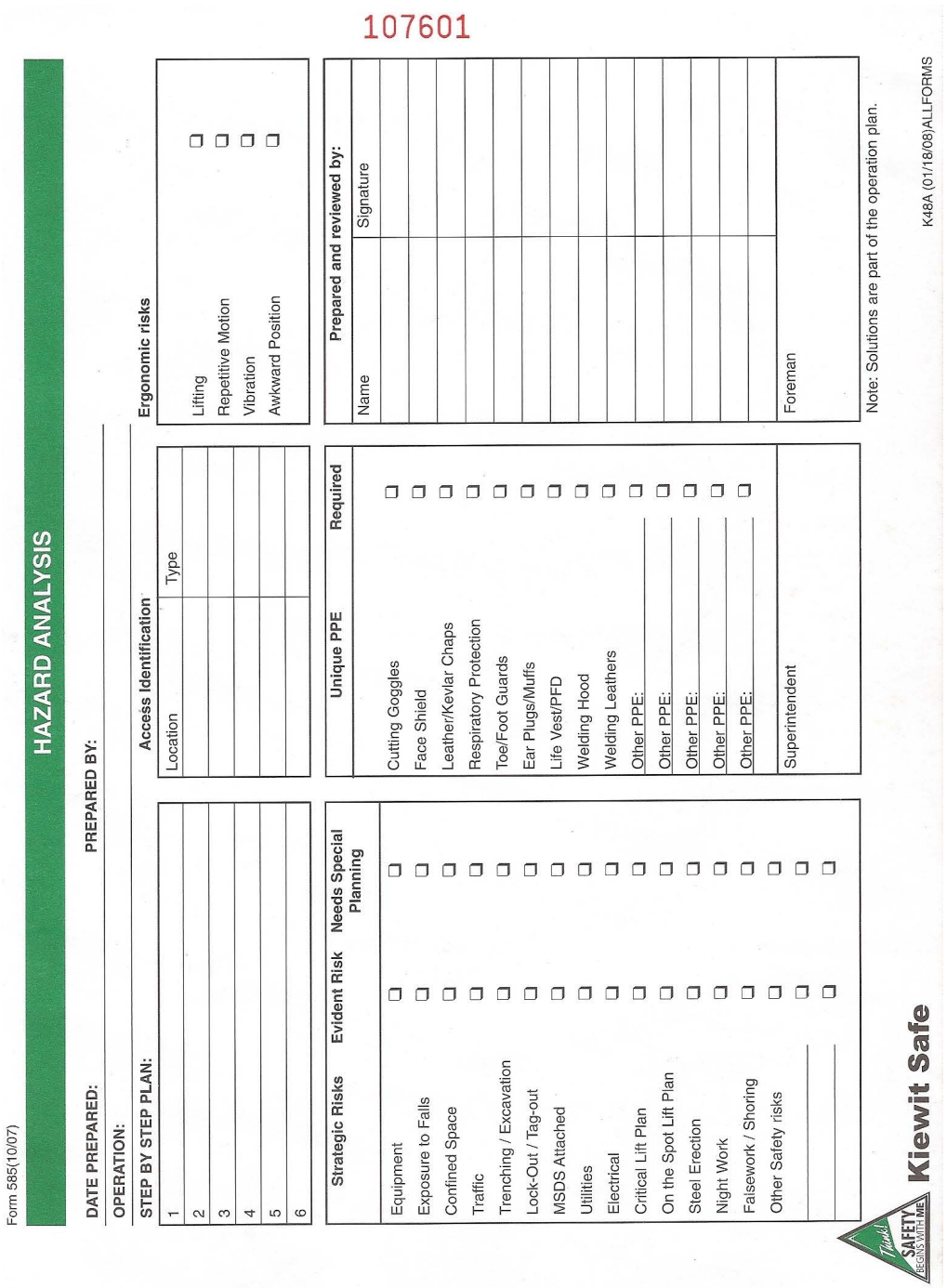
Safety Reports

These reports are conducted prior to any work being started. They identify potential hazards and safety concerns and include solutions to minimize or eliminate them.

A safety report will have a check-off area to be completed before the job is started and a check-off area to be completed when the job is finished.

Items that may be on the check-off sheet include:

- work order information
- lock-out information
- employee information and signature
- list of safety items such as:
  - oil reservoir checks
  - blocking needed and inspected
  - components to be removed including procedures
  - evacuation procedures
  - spill clean-up procedures



Form 585(10/07)

HAZARD ANALYSIS

107601

DATE PREPARED: PREPARED BY:

OPERATION:

STEP BY STEP PLAN:

1	
2	
3	
4	
5	
6	

Access Identification

Location	Type

Ergonomic risks

Lifting	☐
Repetitive Motion	☐
Vibration	☐
Awkward Position	☐

Strategic Risks	Evident Risk	Needs Special Planning
Equipment	☐	☐
Exposure to Falls	☐	☐
Confined Space	☐	☐
Traffic	☐	☐
Trenching / Excavation	☐	☐
Lock-Out / Tag-out	☐	☐
MSDS Attached	☐	☐
Utilities	☐	☐
Electrical	☐	☐
Critical Lift Plan	☐	☐
On the Spot Lift Plan	☐	☐
Steel Erection	☐	☐
Night Work	☐	☐
Falsework / Shoring	☐	☐
Other Safety risks	☐	☐
	☐	☐
	☐	☐

Unique PPE	Required
Cutting Goggles	☐
Face Shield	☐
Leather/Kevlar Chaps	☐
Respiratory Protection	☐
Toe/Foot Guards	☐
Ear Plugs/Muffs	☐
Life Vest/PFD	☐
Welding Hood	☐
Welding Leathers	☐
Other PPE:	☐
Other PPE:	☐
Other PPE:	☐
Other PPE:	☐
Other PPE:	☐
Superintendent	

Prepared and reviewed by:	
Name	Signature
Foreman	

Note: Solutions are part of the operation plan.

Think! SAFETY BEGINS WITH ME!

Kiewit Safe

K48A (01/18/08)/ALLFORMS

Figure 9. Safety Report (Page 1)

NOTES

NOTES

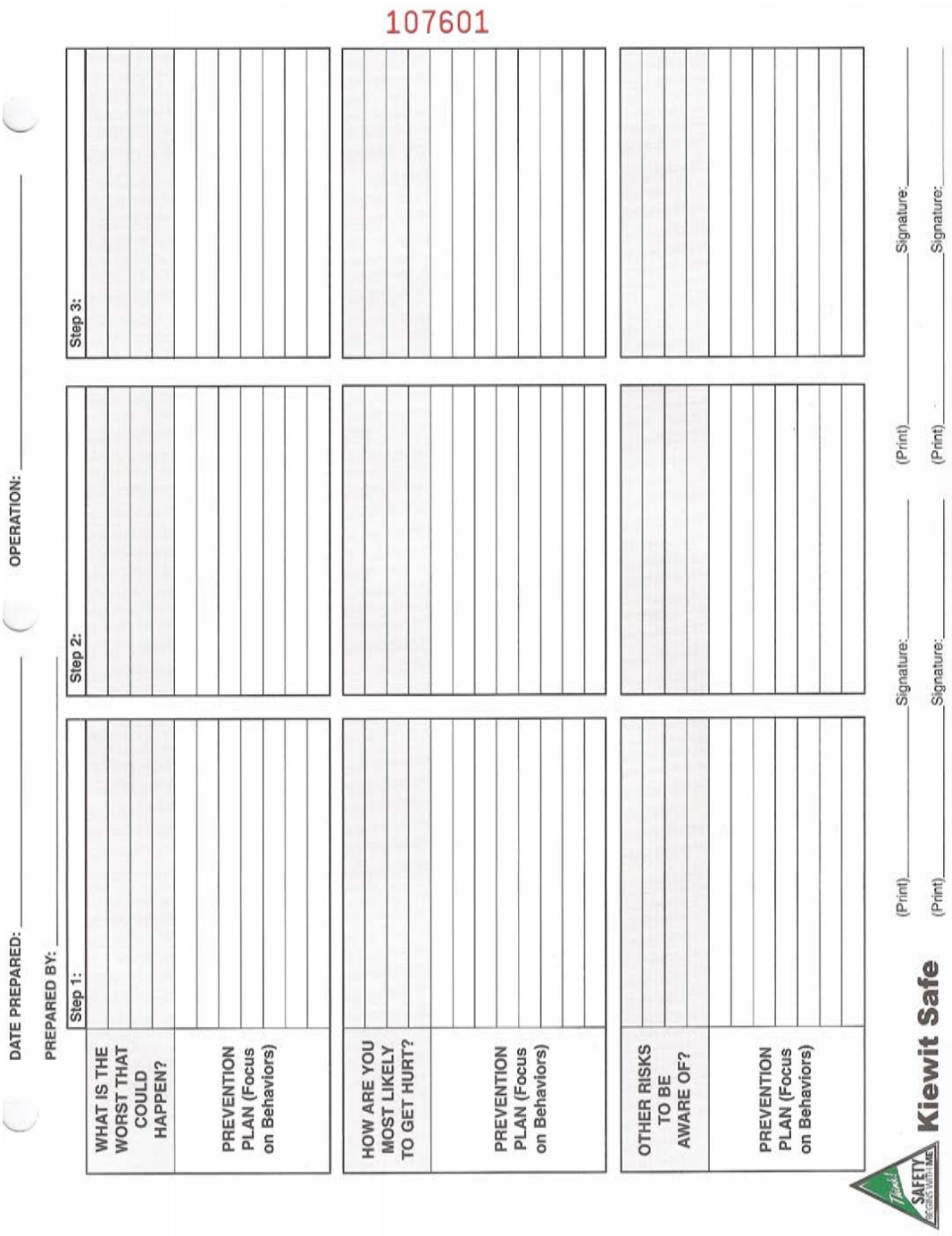


Figure 10. Safety Report (Page 2)

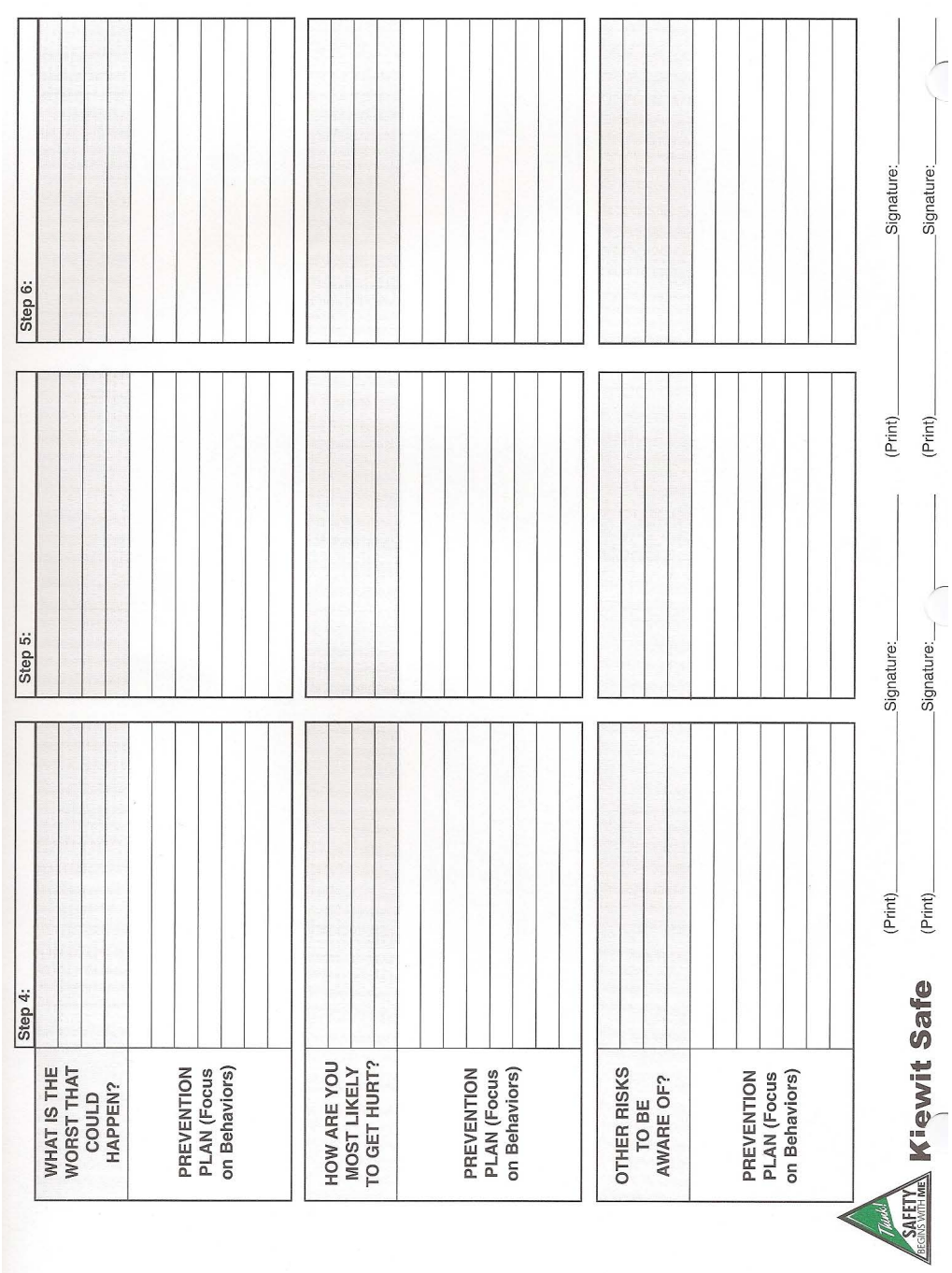


Figure 11. Safety Report (Page 3)

Digital Media

It's becoming increasingly common to use electronic methods when writing a report. Pre-existing templates may be used that show all necessary headings requiring only that you fill in the details. Computerization also greatly aids the organization of reports as well as making it easy to send them to the appropriate personnel.

NOTES

SELF TEST 2

1. What are the three sections of a written report?

   a. beginning, middle, end
   b. first, second, last
   c. introduction, body, conclusion
   d. preamble, main, post amble

2. What kind of report covers what work needs to be completed on a job?

   a. service
   b. shift-end
   c. cross over
   d. safety

3. What kind of report has a complaint, cause and cure?

   a. service
   b. instructional
   c. accident
   d. problem-solving

4. When is a safety report conducted?

   a. after the job is completed
   b. before the job is started
   c. at the end of your shift
   d. part way through the shift

LEARNING TASK 3

Use of Manuals

Notes

The design and construction of heavy equipment, trucks, and buses are subject to continuous technological advances. It's important that you keep up-to-date with these advances. Manufacturers provide service and information documents used in the repair and reconditioning of their equipment. Additionally, there are other, third-party sources that can provide you with the information you need to perform a specific task.

All told, there are a great many sources of information that you should be familiar with:

- repair manuals
- electrical manuals
- wiring diagrams
- service bulletins
- parts manuals
- system manuals
- lubrication manuals
- operator manuals
- computer databases
- electronic manuals
- service manuals
- internet
- repair forums
- social media sites
- blog sites

Remember that the journeyperson you're working with is also a source of valuable information.

Technical Manuals

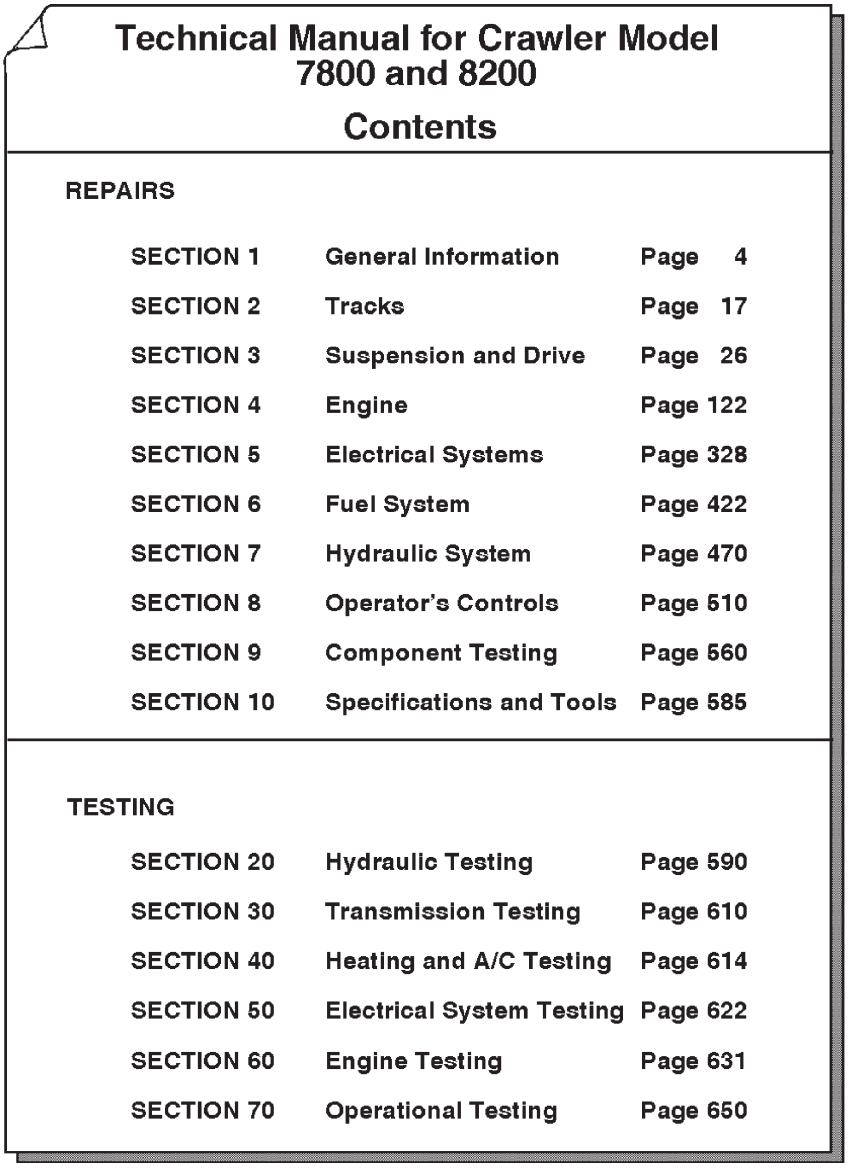
Technical manuals, whether they are repair or service (depending on manufacturer's terminology), contain detailed information concerning the operation, testing, removal, repair, and replacement of parts. In many cases, this might be the only information you require.

NOTES

Repair or service manuals usually contain the following information:

- a table of contents listing specific sections by title
- safety rules and special information
- specifications and capacities (oil and coolant)
- sections for specific information
- lists of special tools
- information about performing testing and repair
- electronic trouble-shooting and repair

For example, a service information manual (often called a technical manual) might have a table of contents as shown in Figure 1.



Technical Manual for Crawler Model 7800 and 8200

Contents

REPAIRS

SECTION 1	General Information	Page 4
SECTION 2	Tracks	Page 17
SECTION 3	Suspension and Drive	Page 26
SECTION 4	Engine	Page 122
SECTION 5	Electrical Systems	Page 328
SECTION 6	Fuel System	Page 422
SECTION 7	Hydraulic System	Page 470
SECTION 8	Operator's Controls	Page 510
SECTION 9	Component Testing	Page 560
SECTION 10	Specifications and Tools	Page 585

TESTING

SECTION 20	Hydraulic Testing	Page 590
SECTION 30	Transmission Testing	Page 610
SECTION 40	Heating and A/C Testing	Page 614
SECTION 50	Electrical System Testing	Page 622
SECTION 60	Engine Testing	Page 631
SECTION 70	Operational Testing	Page 650

Figure 1. Technical Manual Table of Contents

NOTES

At the beginning of most repair or service manuals, there is normally a section outlining safety on the job and specific precautions. This information will include information concerning:

- general shop safety
- protective clothing
- hazards of high-pressure fluids
- protection against noise
- operation safety
- jacking and blocking precautions
- safety checks on machinery
- explosion and fire safety
- battery safety
- preparing machinery for repairs
- shop ventilation and clean-up

This information is very important as it identifies hazard areas that have been noted by the manufacturer. This section identifies symbols that will alert you to hazards or specific special information that is vital to the operation and to your safety (Figure 2).



Figure 2. Warning Symbols

NOTES

Specifications and Capacities

This includes such information as:

- type of vehicle
- measurements of components
- weight of vehicle
- capacities of liquids, such as oil, coolant, etc.
- lifting capacities
- torque specifications
- fuel specifications
- oil specifications
- coolant specifications
- lubrication requirements

This information is vital for repair and servicing procedures. For instance, failure to use the correct engine oil in the right quantities could result in damage or destruction of the engine or some of its operating parts.

Specific System Repair

Most service manuals are sub-divided into sections that refer to specific portions of the machine. This lessens the possibility of confusion by the user. A typical division of information might be as shown for an excavator/loader in Figure 3.

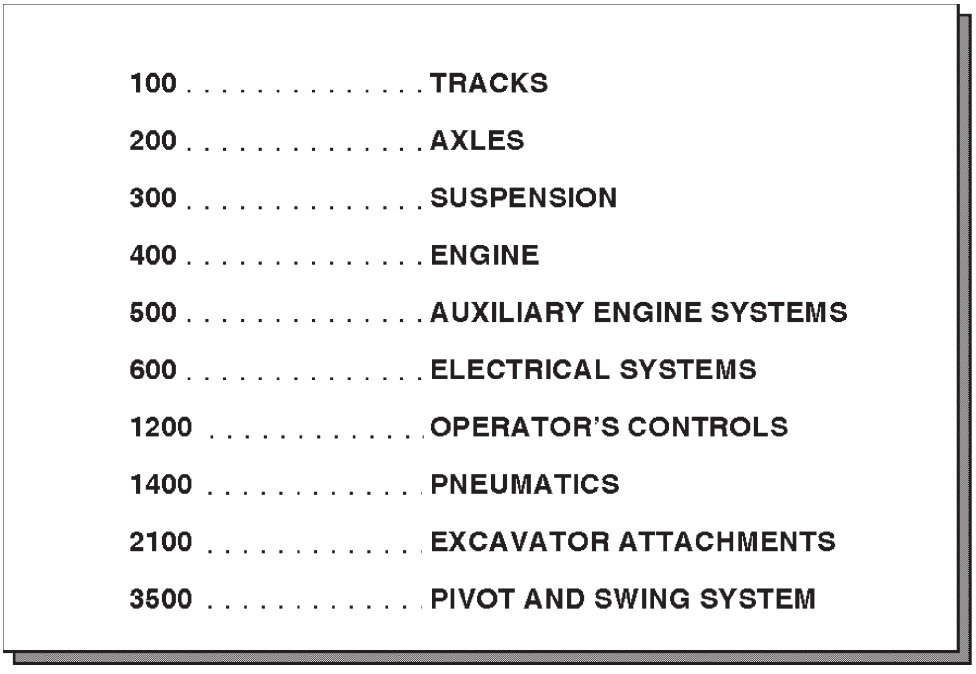


Figure 3. Section Titles for Specific Systems

Each of these sections will include information about:

- inspection
- disassembly/assembly
- repair
- trouble-shooting

NOTES

Inspection

The inspection portion will include all of the specifications and measurements for that particular item.

Track system specifications, cont.

Description	Specifications	
Inner flange roller width	new	42 mm
	service	41 mm
	limit	40 mm
Grouser shoe height	new	80 mm
	service	75 mm
	limit	70 mm
Track pitch/link	new	80 mm
	service	85 mm
	limit	90 mm
Track pin diameter	new	65 mm
	service	64 mm
	limit	63 mm

Figure 4. Undercarriage Specifications

FRONT AXLE SPECIFICATIONS							
Model	**Track**	**Wheel Disc.**	**Wheel Offset**	**King-pin Intersection**	**King-pin Inclination**	**Camber**	**Toe-in**
Rockwell FF-931	79 3/8	0.31	6.50	69	5 1/2° in at top	L/H + 3/4° – R/H + 1/4°	1/16 ± 1/16
Rockwell FE-970(1)	74 5/16			73 1/2	1° out at top		1/16 ± 1/16
Rockwell FL-931(2)	77 27/32	0.56	7.69	68 1/2	5 1/2° in at top	+1°	1/16 ± 1/16
Rockwell FL-931(3)	79 23/32	0.50	5.06	68 1/4	5 1/2° in at top	+1°	1/16 ± 1/16
Shuler FC-SERIES	82 1/2			76	1° in at top	+1°	1/8 ± 1/16

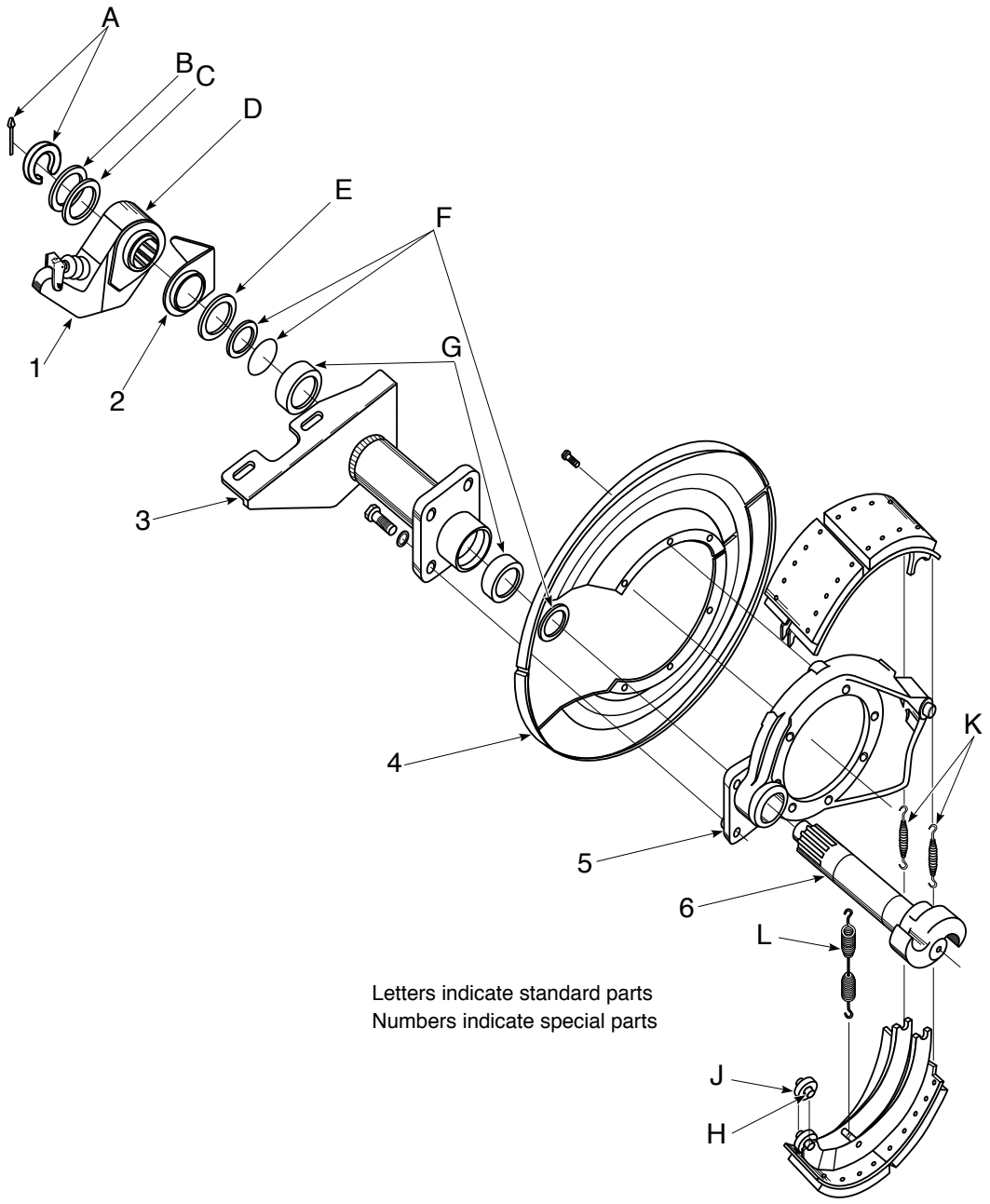
(courtesy of Peterbilt Motors Co., Peterbilt Trucks Pacific Inc.)

Figure 5. Truck Front Axle Specifications

Disassembly/Assembly

Disassembly, repair, and assembly instructions are usually provided in detail and outline exactly what must be done to correct any defects or faults in the system being repaired.

This information will also include exploded diagrams or special diagrams showing the location of parts in relation to each other. These are provided to avoid confusion when disassembling or assembling the unit. The assembly in Figure 6 shows an exploded diagram.



(courtesy of Peterbilt Motors Co., Peterbilt Trucks Pacific Inc.)

Figure 6. Exploded Diagram

Most service manuals will also list special tools that are required to perform the repair.

Repair

Repairs of equipment/trucks will require thorough knowledge of all systems and subsystems, as well as extensive experience performing overhauls of individual components on these systems.

NOTES

Repairs may involve:

- cleaning equipment/tucks and their component parts
- inspecting each component visually
- following manuals for repairs
- measuring components for wear and clearances
- following replacement procedures
- performing gas and electric welding for brackets and guards

Trouble-shooting

In addition to the information about the repair, there will also be information on how to test the entire system to isolate the cause of the problem. This trouble-shooting information is very important and can help you to avoid spending a long time hunting for a problem. Using the manufacturer's information and charts can help you to quickly and accurately diagnose problems. A typical trouble-shooting chart for a battery is shown in Figure 7.

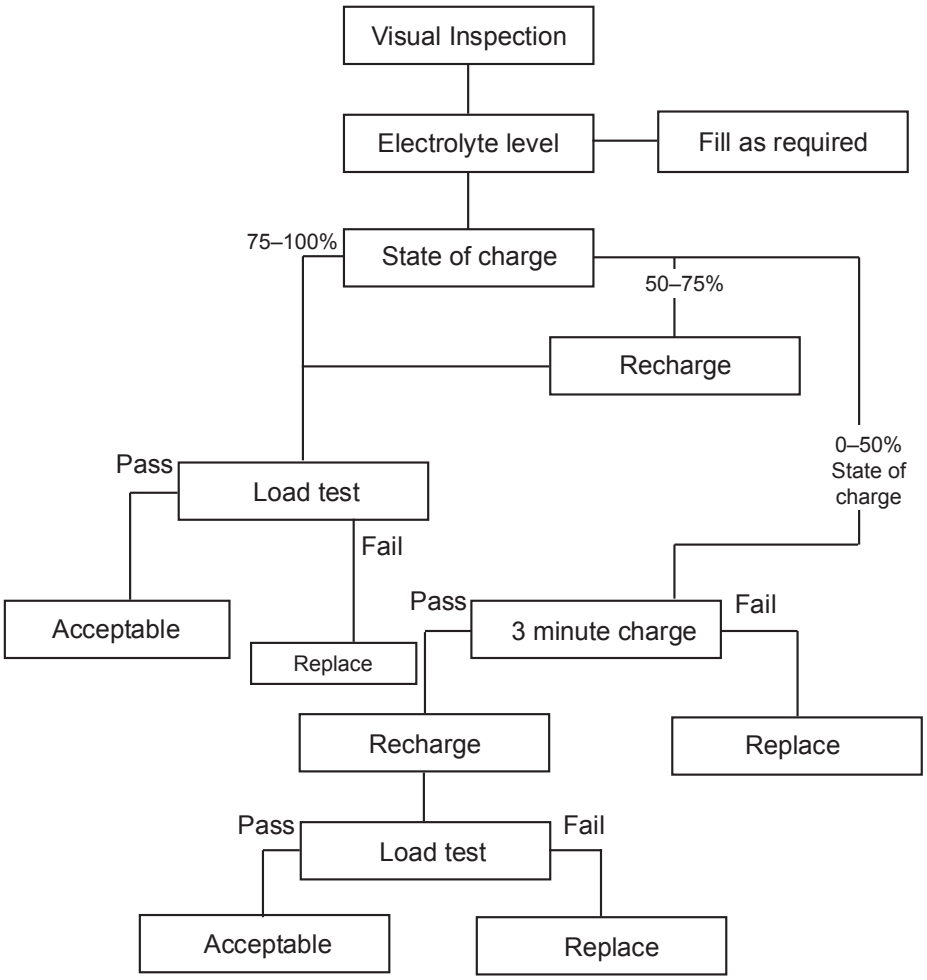
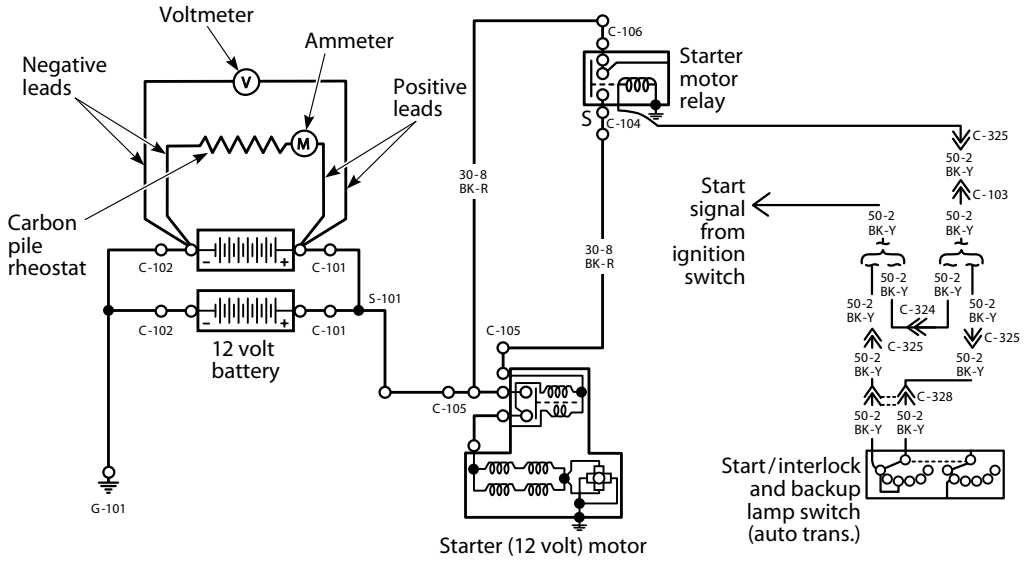


Figure 7. Battery Trouble-shooting Chart

Schematic Diagrams

In order to show how systems fit together, the manufacturer will provide schematic diagrams, such as those for hydraulics or wiring. Note that these schematics do not necessarily show the physical location of components. Rather they are intended to show how the components are arranged in relation to each other. For example, electrical diagrams do not provide any information about the location of connectors or grounds or how the systems operate or are constructed. They're designed to allow you to trace current flow and see how the components are connected (Figure 8).



(courtesy Ford Motor Co. of Canada)

Figure 8. Wiring Diagram

Service Bulletins and Updates

Service bulletins provide up-to-date information about changes in procedures, specifications, and operation of systems and devices in the vehicle. These bulletins reflect changes that the manufacturer has made to the equipment or vehicle to make it safer, operate more efficiently, or meet government regulations.

Service bulletins are made available to the dealer by the manufacturer. These bulletins are usually transmitted electronically and available to you online.

NOTES

NOTES

Bulletin 9010-46
Modified Radiator Airflow Test

Specifications

Minimum combined voltage reading	2.75 volts
Engine speed	slow idle plus100 RPM

Service Tools Required

92550 Air flow meter
28650 DVOM
Tachometer

Procedure

1. Open hood to full position
2. Move air conditioning condensor away from radiator (if equipped)
3. Inspect condensor for debris and clean if necessary
4. Straighten any bent fins in the radiator and oil cooler
5. Divide radiator into 16 equal squares
6. Connect air flow meter to voltmeter, set meter on AC volts
7. Start and run engine at slow idle plus 100 RPM
8. Put air flow meter against radiator with meter centered in square, air flow arrow on meter must point towards radiator
9. Record voltage reading for each square
10. The combined total of the readings must be greater than specifications

If readings are less than specifications, clean external surfaces of oil cooler and radiator and repeat test	NOTE: do not remove the panel from in front of the radiator

Figure 9. Bulletin for Radiator Air Flow Test

Parts Manuals

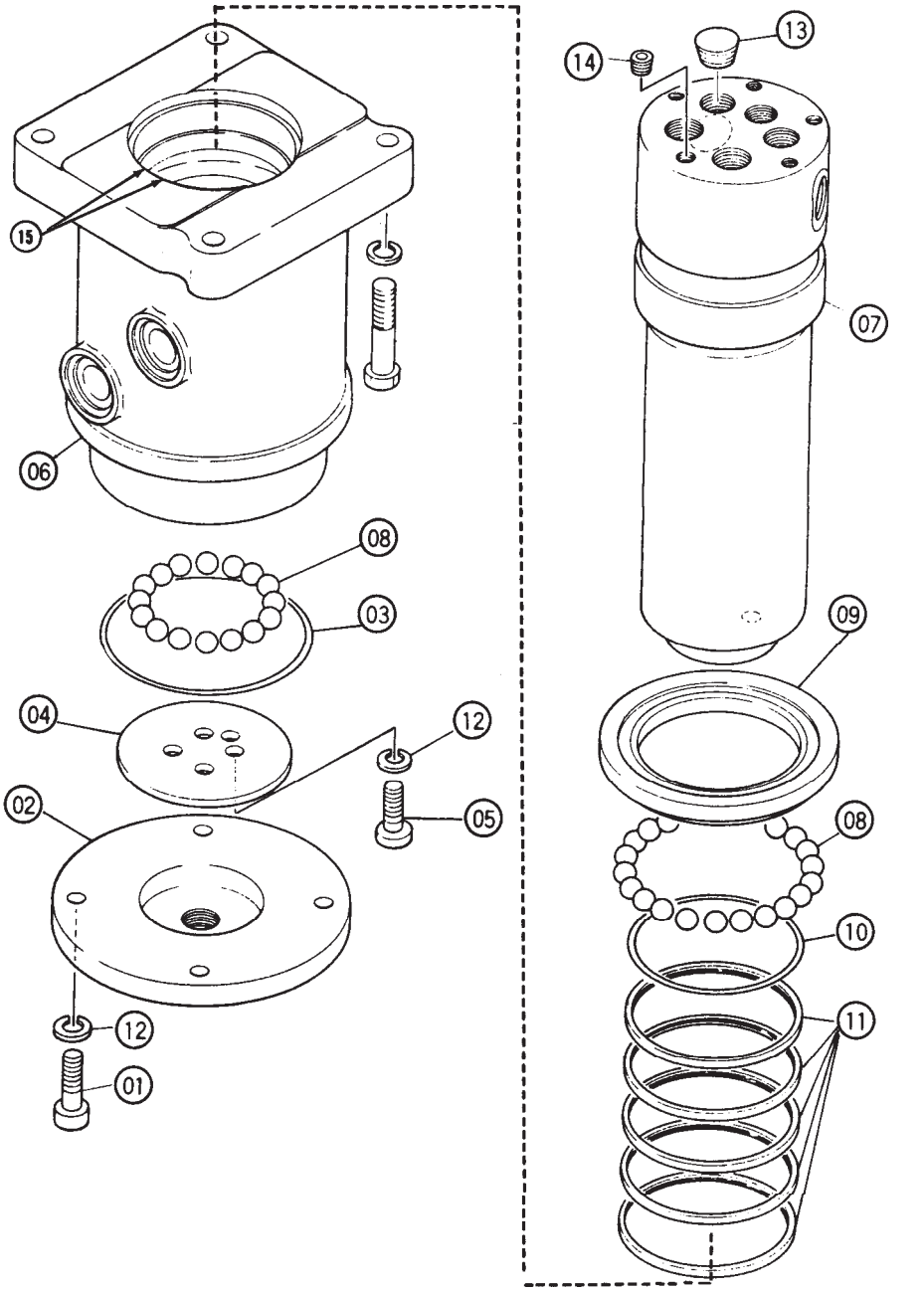
Information about specific parts is often required for ordering or to determine whether the replacement part is correct. Electronic parts manuals are widely available for most equipment and vehicles. Many of the electronic parts manuals will show exploded diagrams and/or parts lists that are tailored for a specific job. With a computerized parts operation, there is tighter control over inventory and re-ordering.

Some companies still use written parts manuals. They provide an exploded diagram with reference to a chart showing the number of the part or assembly. Information found in a parts manual may include:

- make/model
- serial number ranges
- exploded or cut-a-way diagram
- diagram name
- list of individual parts by key number
- an extension line from the key number to the part
- list of the key numbers at the bottom with description and part number
- number of items required

NOTES

NOTES



01	CKV1014	Bolt
02	P89802	Cover
03	1293394	O-ring
04	8577575	Thrust
05	FF8410	Bolt
06	LML2323	Body
07	8930220	Spindle
08	89U890	Ball (38)

09	CVR1001	Plate
10	9U9K08	O-ring
11	23239	Seal (5)
12	T54546	Washer (8)
13	FF8410	Plug (2)
14	39939	Plug (1)
15		Grooves

Figure 10. Parts Information

Systems Manuals

Trucks, buses, and heavy equipment are composed of systems designed and constructed by different manufacturers and assembled to form one unit. The manufacturer usually provides a manual which will be broken down into sub-systems. This allows you to find the specific area in the manual for repairs.

For example, a truck may have its engine, transmission, and drive axles produced by three different manufacturers. You will require three different manuals for the three different components. Most of these will be combined into a single service manual.

Not all manuals cover what is needed for equipment repair, so a supplementary manual is sometimes needed to support the main manual.

This type of manual is also available in electronic format depending on the manufacturer.

Operator Manuals

Operators' manuals are sold with equipment. The operators' manuals are designed to direct the owner, operator, service person, and technician to the main operating/service points of this machine. Many operators' manuals also include lubrication information. Information commonly found in an operator's manual includes:

- cold weather starting
- battery boosting directions
- starting procedures
- warm-up procedures
- dash and operator controls
- lubrication points
- service periods
- oil types
- safety precautions
- lock-out procedures

NOTES

NOTES

Digital Media

Digital media has become the norm for service and parts information. Desktop computers are common in shop environments whereas laptop computers are more prevalent on job sites.

You'll use a computer to reference specific service, repair, and trouble-shooting procedures. Parts are often ordered using online resources. In some situations, computers can be directly connected to equipment to diagnose problems in engines, hydraulics, transmissions, and cab components.

SELF TEST 3

1. What type of manuals cover information about operation, testing, removal and repair of equipment?

   a. parts
   b. technical
   c. operation
   d. electrical

2. What are used to show how a hydraulic system is connected together?

   a. maintenance log book
   b. service bulletin
   c. schematic diagrams
   d. operators manual

3. What contains information about changes and upgrades of systems or devices from the manufacturer?

   a. safety campaign
   b. service bulletins
   c. operating instruction
   d. repair manual

4. What manual contains information about the service, maintenance and warm up procedures?

   a. operation
   b. parts
   c. wiring
   d. service

COMPETENCY A-9

SERVICE WINCH WIRE ROPE



HEAVY MECHANICAL TRADES:
LINE A—COMMON OCCUPATIONAL SKILLS

Goals

The heavy mechanical trades make extensive use of wire rope winches, so it's important that you understand their composition and use as well as know how to inspect and service them.

When you have completed the Learning Tasks in this Competency, you will be able to:

- describe wire rope
- inspect wire rope
- service wire rope.

LEARNING TASK 1

Describe Wire Rope

Notes

Wire rope is used with a winch (usually pulls) or hoist (usually lifts).The winches may be mounted on a dozer or skidder, while hoists may be mounted to cranes. The winch or hoist has a rotating drum that can be driven clockwise or counter-clockwise, or released to rotate freely and is usually mechanically or hydraulically driven. Wire rope is attached to and wound around this drum. The operator will attach the wire rope to whatever is being pulled or hoisted. The operator will then engage the winch to spool in, which will pull or hoist the load. The rotating drum must be able to store all the wire rope when it is spooled in. The wire rope has to be able to handle the load it is pulling or hoisting. It's critical that the wire rope be maintained and inspected regularly and replaced if there is any defect. When working on equipment with a winch or hoist, you will be inspecting and servicing the wire rope. At times you may be asked to install wire rope on the rotating drum.



Figure 1. Winch with Wire Rope

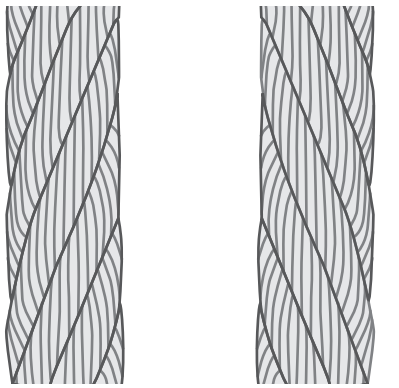
NOTES

Types

"Lay" is the direction the wires and the strands are wound. Both regular and Lang lay (described below) are available in right or left styles. Right lay has the strands wound in a clockwise direction along the length of the rope, while left lay has the strands wound in a counter-clockwise direction. There is also rope called "non-rotational" or "anti-rotational." This wire rope has an outer layer of strands wound in one direction and an inner layer wound in the opposite direction. Non-rotational wire rope is designed so it will not spin when a load is applied to it.

Regular Lay

Regular lay rope has the wires wound in one direction while the strands are wound in the opposite direction (Figure 2).

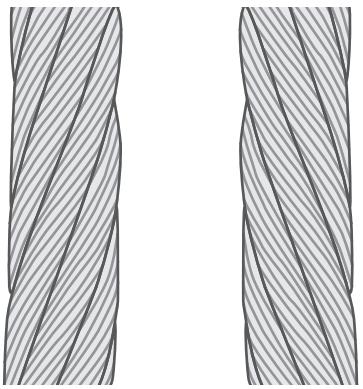


Right regular lay Left regular lay

Figure 2. Regular Lay

Lang Lay

Lang lay rope has both the wires and the strands wound in the same direction (Figure 3).



Right lang lay Left lang lay

Figure 3. Lang Lay

Construction

Wire rope can be constructed differently depending on application and each is designed for a specific use. The construction of the wire rope affects its strength, flexibility, and resistance to abrasion or crushing.

New wire rope's qualities as can be identified by a tag found on the storage reel or attached to the rope. This information should include the rope's:

- composition
- pattern
- length
- diameter
- formation
- grade
- core type

Composition

Wire rope composition is determined by three characteristics:

- number of strands
- number of wires in each strand
- pattern of the wires in the strand

The composition of the rope shown in Figure 4 is expressed as 6 × 19.

The number 6 indicates the number of strands. Most wire ropes are made with six strands but some are available with more.

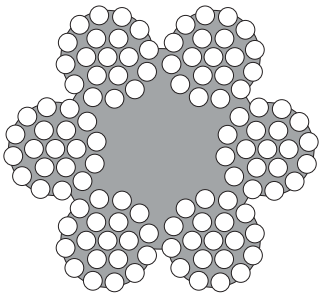


Figure 4. Rope Composition

The number 19 is the number of wires in each strand. The greater the number of wires in each strand, the more flexible the wire (compared to wires of the same diameter). Increasing flexibility decreases abrasion resistance.

NOTES

NOTES

Pattern

There are four standard patterns:

- Ordinary
- Seale
- Warrington
- Filler

Ordinary

All the wires in each strand have the same diameter (Figure 5).

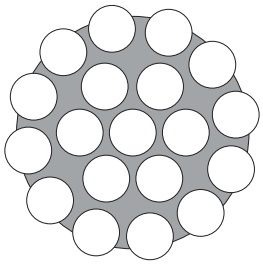


Figure 5. Ordinary Wire Pattern

Seale

Wires on the outside of the strand are thicker than those on the inside of the strand (Figure 6). The Seale pattern provides greater resistance to abrasion than does the ordinary pattern. The thinner wires on the inside increase the strand's flexibility.

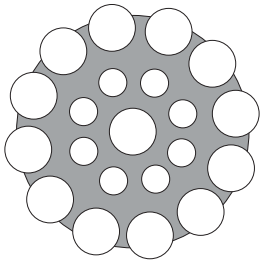


Figure 6. Seale Wire Pattern

Warrington

Thick and thin wires alternate (Figure 7). This provides greater flexibility as well as greater resistance to abrasion.

NOTES

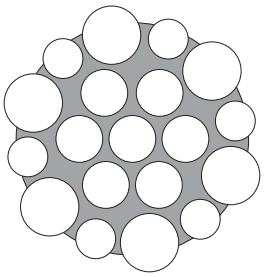


Figure 7. Warrington Wire Pattern

Filler

Very thin wires are used to fill the voids between the thicker wires (Figure 8). The filler wires prevent the outer wires from crowding into the valleys of the inner wires, making the rope resistant to crushing.

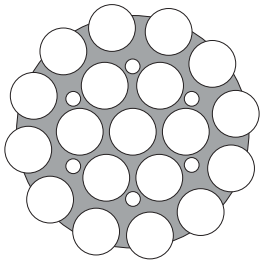


Figure 8. Filler Wire Pattern

Diameter

Wire rope diameter is given in metric or imperial units. Always measure wire rope diameter at its thickest point (Figure 9).



Correct Incorrect

Figure 9. Measuring Wire Rope

NOTES

Formation

Wire rope may be pre-formed. Each wire and strand in pre-formed wire rope is bent or molded to match its final shape in the completed rope (Figure 10). As a result, pre-formed rope will not untwist when cut. Also broken wires tend to remain in position rather than stick out from the rope.



Figure 10. Pre-formed Wire Rope

Non-pre-formed wire rope is made from wire as it comes from the spool. Wires are twisted to form strands, which in turn are twisted to form rope. Both strands and wire have a tendency to return to their straight form (Figure 11).



Figure 11. Non-pre-formed Wire Rope

Grade

The wires used to make wire rope are available in different grades. The grade indicates the wire rope's breaking strength. The lowest grade of steel used for making wire rope is called "100/110 plow steel." The next grade up is "110/120 improved plow steel." The top grade is "120/130 extra improved plow steel." It is used where maximum rope strength is required. Note that the wire rope will be less resistant to repeated bending the stronger the grade of steel.

Core

The central core of a wire rope will be either fibre or independent wire rope.

Fibre Core

Fibre cores are made of fibre rope. Most fibre cores are either sisal or manila, but they can also be made of synthetic fibres such as polypropylene or nylon. Fibre cores give wire rope more flexibility than other cores, but are more easily crushed.

Independent Wire Rope Core (IWRC)

The wire rope core is actually a small wire rope. It produces good flexibility and resistance to crushing.

Application

Different wire rope is selected depending on application (Figure 12).

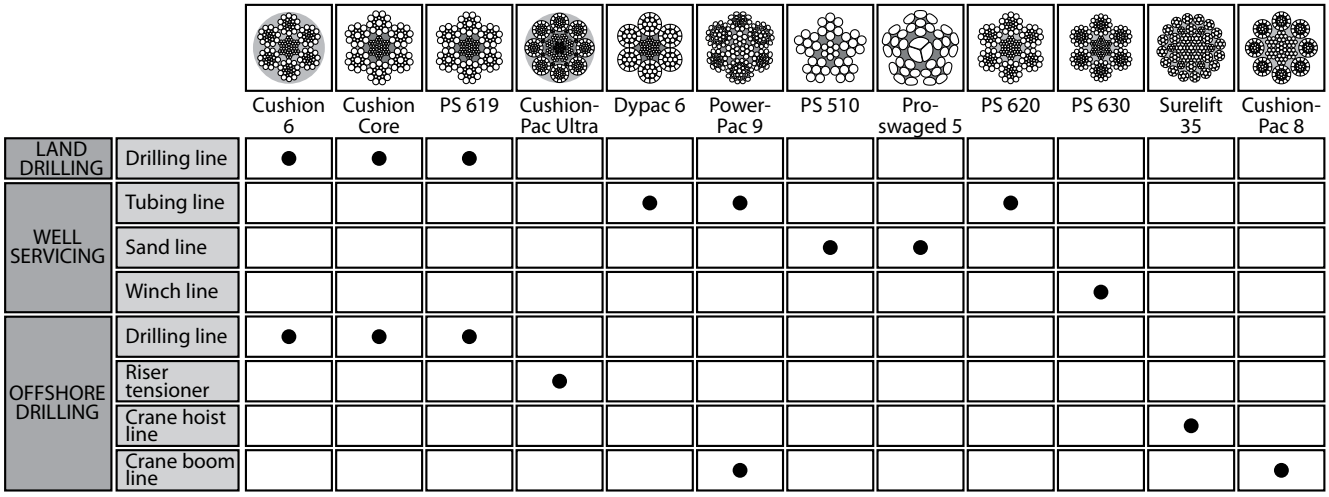


Figure 12. Wire Rope Selection Chart

NOTES

Safe Working Load

Before lifting technicians must know and not exceed the safe working load (referred to as working load limit-WLL)

Working Load Limit for Wire Rope

The working load limit (WLL) is a rating given to all rigging hardware and wire rope. The wire rope type and diameter are the basis for calculating the working load limit. Working load limits for wire ropes are calculated by dividing the wire rope's breaking strength by the design factor set by WorkSafeBC. The design factor for any rigging assembly used to hoist or support workers must be at least 10 (*OHS Regulation, Part 15.6.3*).

For example:

WLL = breaking strength (given by manufacturer) ÷
design factor (given by Worksafe for application)

= 4000 kg ÷ 10

= 400 kg

Inspect Wire Rope

Wire rope should be inspected for wear and damage. Wear could be hours in service or just time on the drum. Damage could be from use or just from sitting.

Frequency

Frequency of inspection can depend on many factors including government requirements, hours in use, hours on drum, environmental conditions, etc.

Some wire rope needs to be inspected before each lift, daily, monthly, bi-annually, annually, etc.

Inspection could be performed in house or someone comes in to inspect. Heavy Mechanical technicians should inspect wire rope they are using for hoisting or pulling before each use including verifying the WLL on the hoist or winch to make sure it is not exceeded.

Wear

Most wire rope will contain broken individual wires. In most cases, this will not require replacement, as long as the breaks are at well-spaced intervals. You should note the area and watch carefully for further wire breaks. Remove the broken wire ends as soon as possible by bending them backward and forward with a pair of pliers. In this way, the broken end is more likely to break off inside the wire rope, leaving the ends left tucked away between the strands where

they will do no harm. Ripping the broken ends off with pliers is likely to leave jagged ends that can cut and wear unbroken wires. Wear can be worn and Abraded wires, fatigue fracture, and corrosion.

NOTES

A wire rope used for hoisting must be replaced if there are six or more randomly distributed broken wires in one rope lay or three or more broken wires in one strand in one rope lay. (A rope lay is the length along the rope in which one strand makes a complete revolution around the rope.)

A wire rope must also be replaced if there are one or more broken wires near an attached fitting. Breaks that occur near attached fittings are usually the result of fatigue stresses concentrated in these localized sections. If you find wire breaks of this type, replace the wire rope or redo the attachment to remove the locally fatigued area.

Once broken wires appear in a wire rope operating under normal conditions, many more will show up within a relatively short period. Using a wire rope with more than the allowable number of broken wires is a hazard.

Worn and Abraded Wires

When new, each individual wire in a rope is circular in cross section. Wear caused by friction on sheaves, rollers, and drums will eventually cause the outer wires to become flat on their outer edge. As this flattening increases, the thickness of the wire will decrease.

These worn areas lose their lubrication and are characterized by their bright appearance. Close examination will reveal that these wires are much flatter than the surrounding wires. This is part of normal service deterioration and, in most installations where operating conditions are not particularly severe, abrasion on the outer wires will be relatively even.

Fatigue Fracture

When a wire breaks with square ends and shows little surface wear, the usual cause of the failure is fatigue. Such fractures can occur on the crown of the strands or in the valleys between the strands where there is contact with adjacent strands. In most cases, these failures are related to bending stresses or vibration.

Corrosion

Corrosion, while difficult to evaluate, is a more serious cause of wear than abrasion. Usually, it points to a lack of lubrication. Corrosion will often occur internally before there is any visible evidence on the rope surface. Machines that sit exposed to the weather for an extended period on time increase the chance

NOTES

of corrosion. Working near the ocean can increase corrosion of exposed winch wire rope. Remove the rope from service immediately if you see pitting in the wires.

Slight discoloration due to rust indicates that the rope needs lubrication. Severe rusting, on the other hand, leads to premature fatigue failures in the wires and the rope must be immediately removed from service. To slow down deterioration from corrosion, keep the rope well-lubricated. In situations where extreme corrosive action can occur, it may be necessary to use galvanized wire rope.

Damage

Damage can be caused in use or just sitting on the drum. Some forms of damage are peening, scrubbing, and damaged strands.

Peening

When wire rope strikes a structural part of the machine or beats against a roller or itself, the wires and strands become flattened, distorted, and brittle. This continuous pounding is called "peening." Often, this can be avoided by placing protectors between the rope and the object it's striking. Another common cause of peening is continuous working, under high loads, over a sheave or drum.

Where peening action cannot be controlled, you must inspect the wire rope often and replace it more frequently.

Scrubbing

"Scrubbing" is the displacement of wires and strands caused by wire rope rubbing against itself or another object. This rubbing causes wear and displacement of wires and strands along one side of the rope. You should take corrective measures as soon as you notice this condition.

Damaged Strands

Replace wire rope if the strands are crushed, flattened, or jammed. These conditions usually occur when there are multiple layers on drums. To prevent crushing, use independent steel wire-cored ropes. Crushing can also occur if the hoist rope becomes slack and cross-coiled on the drum or trapped in the machinery. Halt all further operations until the wire rope has been laid out, examined for possible damage and correctly re-spooled.

If the wire rope displays high stranding or unlaying, replace the wire rope or renew the end connection to reset the rope lay. In cases such as this, excessive wear and crushing take place and the other strands become overloaded.

"Bird caging" is caused by sudden stops, the wire rope being pulled through tight sheaves, or winding on too small a drum (Figure 13). If you cannot remove the affected section, replace the wire rope.

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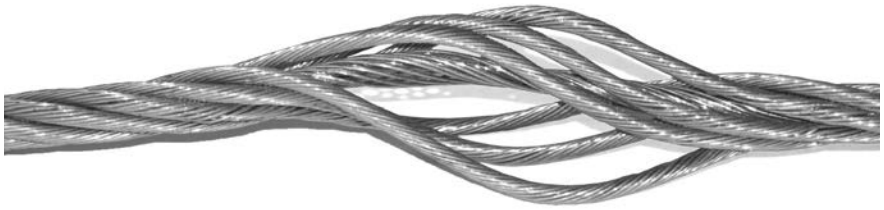

Figure 13. Bird Caging

Kinks are usually caused by faulty handling. The strands become dog-legged and, where running on sheaves, are subject to excessive wear at the kink.

Bulging indicates that there is core slippage or "turns" are being put into or taken out of the rope. Replace the wire rope, especially if it is of rotation- resistant construction.

Localized Conditions

Pay attention to wear at the equalizing sheaves. During normal operations, this wear is not visible. Excessive vibration or whip can also cause abrasion and/or fatigue.

Heat Damage

After a fire or exposure to elevated temperatures, there may be metal discoloration, an apparent loss of internal lubrication, or damage to fibre cores. Replace the wire rope if you see any of these conditions.

Electric Arc

Wire rope that has been in contact with a live power line or has been used as "ground" in an electric welding circuit will have wires that are fused, discoloured, and/or annealed. Remove such wire rope from service.

Deciding If Wire Rope is Safe

Deciding whether a wire rope is safe is not always a simple matter. When used on a winch, the wire rope is subjected to very harsh conditions. The wire rope can be dragged through mud and rocks, or wrapped around several trees. The wire rope can also be exposed to severe loads when pulling and hoisting. You must evaluate a number of different considerations. It's dangerous to declare a wire rope safe for service because its diameter has not reached the minimum value if other factors lead to an opposite conclusion.

NOTES

If you are not sure that a rope is safe for pulling or hoisting, it must be replaced. Any hoisting equipment that uses wire rope should be inspected regularly by an authorized inspector. Usually outside certification must be done at least once a year minimum.

Service Wire Rope

Inspecting Wire Rope and Drums and Sheaves

Winch wire rope can be subjected to severe conditions, cold and hot climates, dirt, rocks, and tree trunks. The operator of a machine winch can subject the wire rope to abuse. Overloading the wire rope, improper hook-up, and incorrect procedures can all damage the wire rope. Most of the time, a mechanic is called in to repair the damaged or snapped winch wire rope. Good operators will inspect their own wire rope and have the mechanic repair or replace it.

A regular inspection of the wire rope will include many of the items explained in the previous learning task. Wire rope and any attachments should be inspected for damage. Check the wire rope clamps, ferrule, and Flemish eye. Make sure they are installed correctly and are not damaged. Inspect for broken wire strands near the ferrule or Flemish eye. Cut off damaged wire rope, or replace the rope

if it's showing damage along the entire length. Inspect the end of the wire rope, make sure it has the proper end fitting and is not tied in a knot.

Regularly check the drum and sheave surfaces for damage. If there is evidence of wear, check the rope to make sure that it's the correct lay and type. Inspect the sheave for wear. A sheave that is too small will pinch and distort the wire rope.

This will cause the wire rope to wear on the rope sides as well as the sheave. A sheave that is too large will cause the wire rope to flatten out and displace some of the strands which leads to premature failure (Figure 14). You can use a gauge to measure the size and condition of the sheave groove. The diameter of the sheave also affects wire rope life. Wire rope bends a greater amount as it rolls over a small diameter sheave than it does over a larger diameter sheave. As a sheave wears, the diameter will decrease, which will reduce wire rope life.

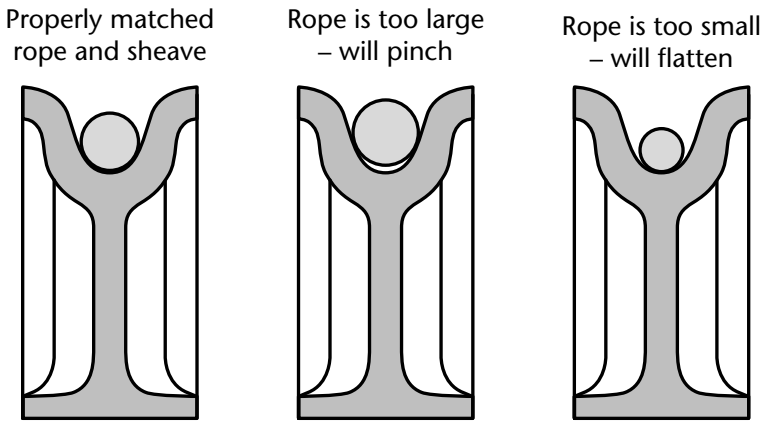

Figure 14. Correct Wire Rope Placement in Sheave

NOTES

Removal of Wire Rope

Always wear leather gloves when handling wire rope as the wires can be frayed and cut your hands or pieces strands can pierce the skin.

To remove wire rope from a winch you either pull manually or power feed the rope off the drum.

Reeving is the process of installing wire rope onto hoisting drums and pulleys. Reeving affects head room, lifting speed and capacity by increasing the hoist's mechanical advantage. Therefore it is very important that the rope is installed correctly.

Repair or Replace

If a wire rope needs replacing or you are installing a wire rope on a new winch, there are some critical steps to follow. Before removing the wire rope, check to see whether it is over- or under-wound and whether it is right-hand or left-hand wound. This will ensure that the rope is installed in the same manner as it was removed. After the old wire rope is removed, check the condition of the drum and sheave. If there is any damage, they must be repaired or replaced.

NOTES

New wire will be on a shipping roll or rolled up in a coil (Figure 15). When installing the rope onto the drum, you must ensure that the rope doesn't twist. Twisting may result in a kink that cannot be repaired, requiring immediate replacement.

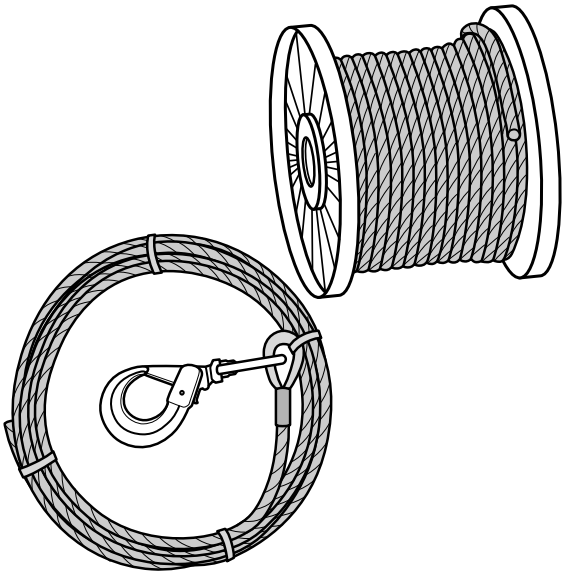

Figure 15. Coiled and Rolled Wire Ropes

Winding Methods

Winches can have the wire rope installed over- or under-wound. Over-winding means that the cable will wind from the top of the drum, while under-winding means that the cable will wind from the bottom of the drum. There are advantages and disadvantages to both types of winding on tractor mounted winches.

Over-winding will raise the load and prevent it from digging in, but may cause the tractor to tilt (or rear up) if the load is too heavy (Figure 16A).

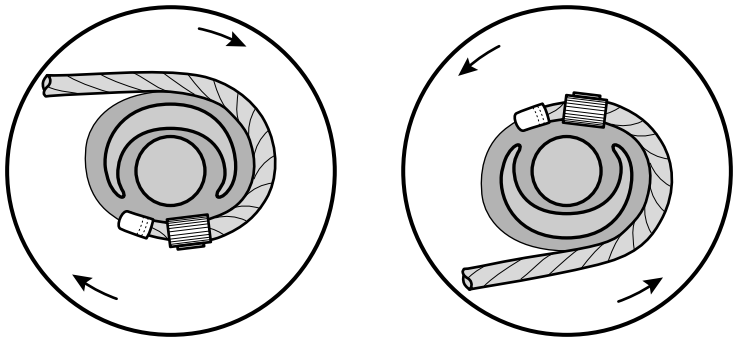

Figure 16. Wound Wire Rope

Notes

Under-winding will provide a straight pull that eliminates rearing, but may cause the load to dig in (Figure 16B).

Unless under-wind is requested, winches are normally assembled at the factory for over-wind. Changing a winch from over-wind to under-wind is a major operation requiring disassembly of the winch, changing the gearing, and changing the rope position. Additionally, the type of rope must also be changed:

- over-wind right to left requires left lay rope
- over-wind left to right requires right lay rope
- under-wind right to left requires right lay rope
- under-wind left to right requires left lay rope

When unwinding an over-wind rope, it must be transferred from the top of the storage reel to the top of the drum. It's also acceptable for an under-wind rope to reel from the bottom of one reel to the bottom of the drum. By following either of these procedures, you will avoid twisting the rope (Figure 17).

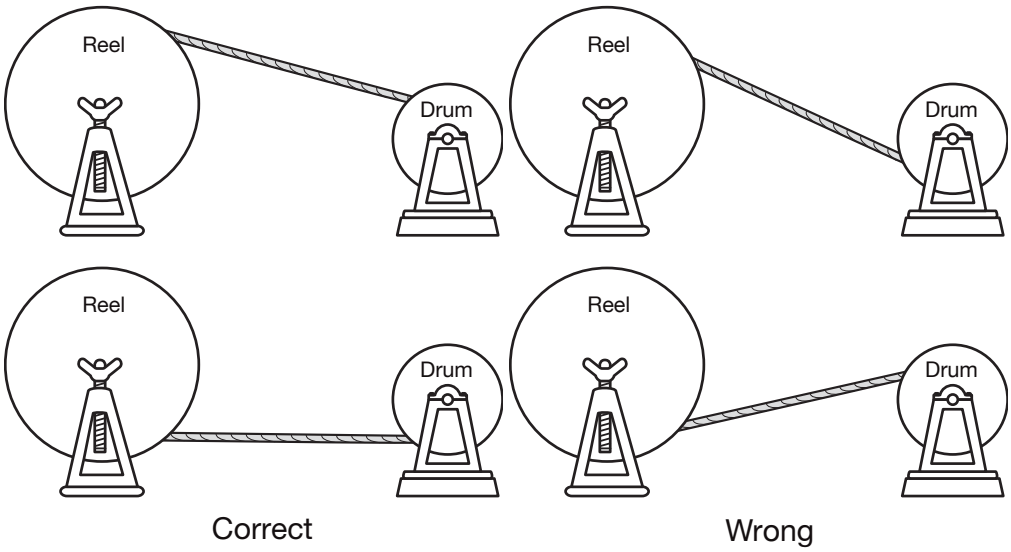

Figure 17. Transferring Wire Rope from Storage Reel to Drum

On grooved drums, the cable will be laid in the correct position by the grooves (lagging), 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 over-wind or under-wind position, whichever the winch is set up for (most mounted winches are set for over-wind). 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. If it's a smooth-faced drum, you may need to use a soft-faced hammer to lightly tap the wire rope in place. Caution: Keep hands clear of winding cable.

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Figure 18 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 over-wound or under-wound. Note the point of view is from behind the drum.

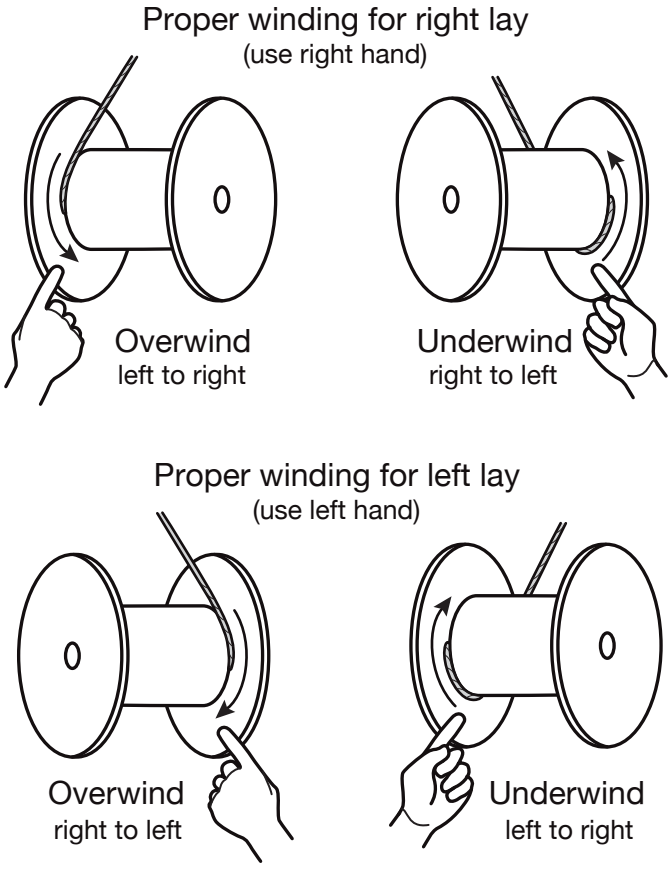

Figure 18. Attaching Wire Rope to Drum

It's a good practise to break in the new wire rope:

- Fully spool out the wire rope and apply a light load for a few minutes.
- Cycle from full out to full in several times, slowly increasing the load each time.

This break-in procedure will allow the wire rope to conform to the drum and sheave slowly with less shock load.

If you are storing wire rope, make sure it is wound back onto a drum or rolled up in a manner that does not produce twists (Figure 19).

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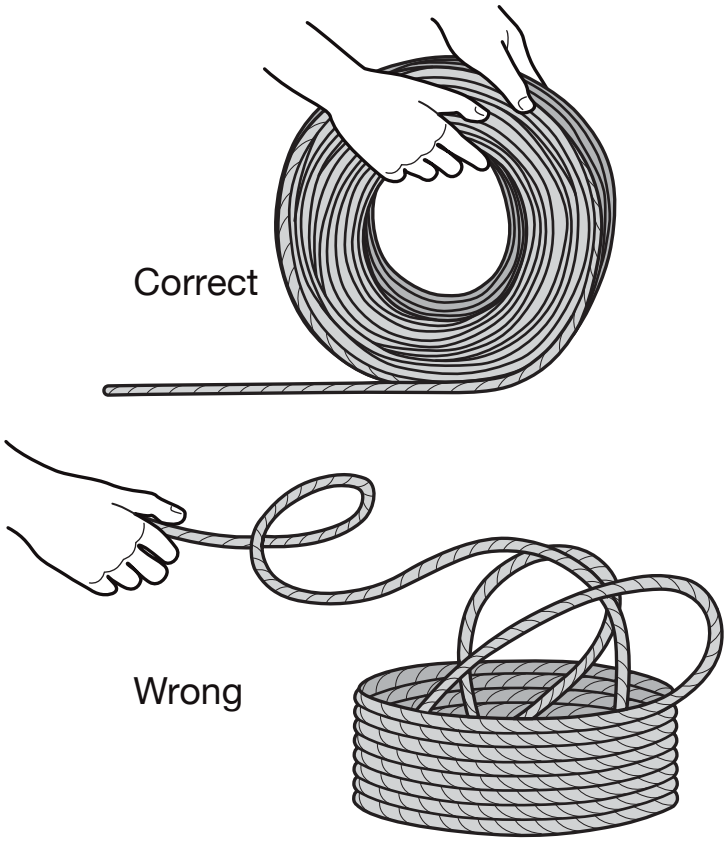

Figure 19. Storing Wire Rope

Lubrication

Wire rope lubricants have two principal functions:

- To reduce friction as the individual wires move over each other.
- To provide corrosion protection and lubrication in the core and inside wires and on the exterior surfaces.

Lubricating wire rope can be difficult. Ropes with fibre cores are easier to lubricate than those made exclusively from steel. All wire rope is initially lubricated, but over time will require re-lubrication as it has moving parts. Each time a rope bends over a sheave or straightens from a slack position, its strands move or slide against each other. The outside of a cable accumulates dirt and contaminants from sheaves and drums causing abrasion to the outer wires and strands. Abrasive wear usually reduces rope diameter and can result in core failure and internal wire breakage.

Lubricating rope also prevents the wires from corroding. Wire rope should not be allowed to rust. Corrosion can decrease rope life due to metal loss, pitting, and stress risers from pitting. A rusty rope is dangerous as there is no method of determining its remaining strength.

NOTES

The frequency of lubrication can not be pre-determined as it will depend on the conditions to which the rope is subjected. The severity of the duty and the degree of corrosiveness will serve as a guide when deciding the need for lubrication.

Proper lubricant must 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 water penetration. It's important to consider the issue of field re-lubrication when selecting rope.

There are two types of wire rope lubricants: penetrating and coating. Penetrating lubricants contain a petroleum solvent that carries the lubricant into the core of the wire rope then evaporates, leaving behind a heavy lubricating film to protect and lubricate each strand. Coating lubricants penetrate slightly, sealing the outside of the cable from moisture and reducing wear and preventing corrosion. Figure 20 shows different methods of applying wire rope lubricants.

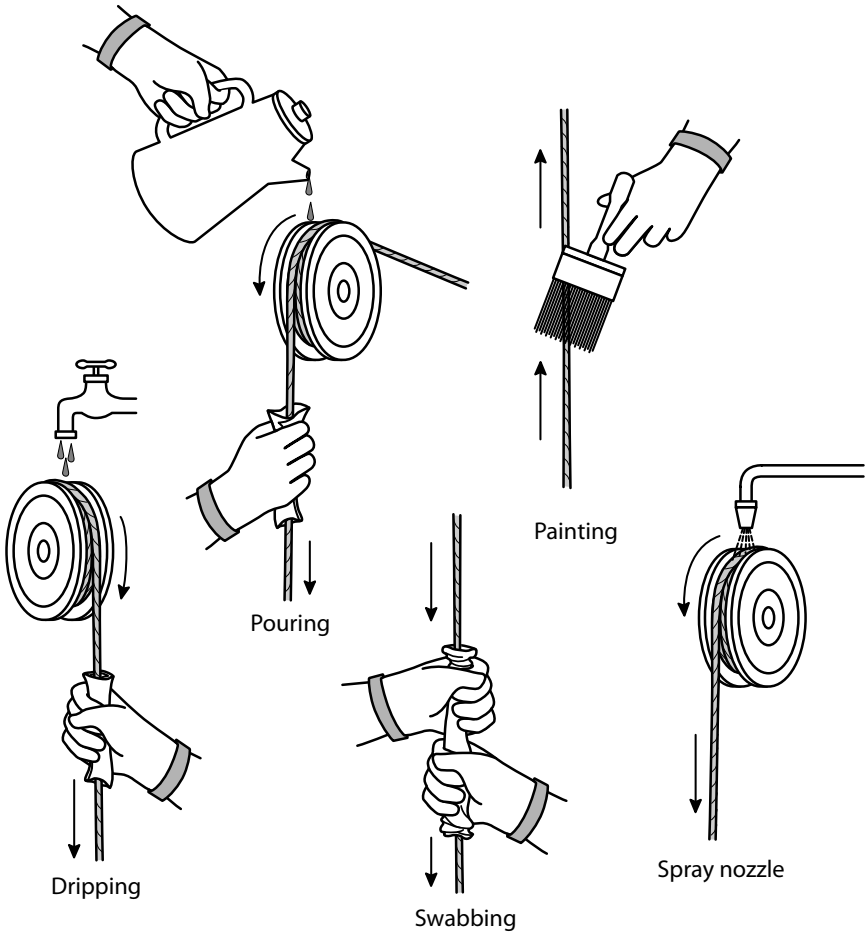

Figure 20. Applying Lubricant to Wire Rope

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Both types of wire rope lubricants are widely used but since most wire ropes fail from the inside, it's important to make sure that the core receives sufficient lubricant. A combination approach is recommended in which a penetrating lubricant is used to saturate the core, followed with a coating lubricant to seal and protect the outer surface. Wire rope lubricants can be petrolatum, asphaltic, grease, petroleum oils, or vegetable oil-based.

Various types of greases are used for wire rope lubrication. These coatings penetrate partially but do not saturate the rope core. Common grease thickeners include sodium, lithium, lithium complex, and aluminum complex soaps. Greases used for this application generally have a soft, semi-fluid consistency. They coat and achieve partial penetration when applied with pressure lubricators.

Scheduled Maintenance

Winch and hoist wire rope must be inspected and lubricated as part of a regular preventative maintenance schedule. Scheduled maintenance can be based of time or hours are a combination of both. The table in Figure 21 shows a sample wire rope maintenance shedule.

Wire Rope Inspection and Maintenance			
Frequency	Details	Performed by	Documentation
Each shift	Visual inspection of hoist/winch must begin performed prior to each shift- see sheet 1	Certified HMT mechanic	Not required
Monthly	Visual inspection and lubrication must be performed as outlined. See sheet 2	Certified HMT mechanic	Required. Must be sign by person who inspected
Annually	Outside complete hoist inspection and re-certification See sheet 3	Qualified person	Required. Must be signed by person who conducted inspection and retained for 12 months

Figure 21. Wire Rope Inspection and Lubrication Schedule

NOTES

SELF TEST 1

1. What kind of a machine would have a winch?

   a. packer
   b. dozer
   c. excavator
   d. grader

2. What are two methods of driving a winch?

   a. mechanical and hydraulic
   b. belt and air
   c. hydraulically and air
   d. mechanical and cable

3. What is the wire rope attached to on the winch?

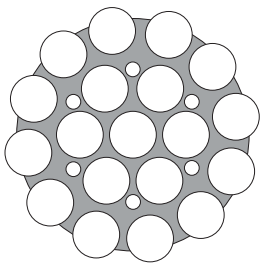
   a. spool
   b. sheave
   c. drum
   d. case

4. What does the number "8" refer to if the wire rope has composition of "8 × 20"?

   a. number of wires in each strand
   b. number of strands in the wire rope
   c. length of wire rope
   d. number of wires per foot

5. What type of wire rope composition is this figure?

   a. ordinary
   b. semi ordinary
   c. seale
   d. filler



6. What is "Warrington" when referring to wire rope?

   a. pattern
   b. lay
   c. grade
   d. lang type

7. What is the type of lay of the wire rope in this figure?



   a. right hand regular
   b. right lang
   c. left hand regular
   d. left lang

8. What does "WLL" stand for?

   a. weight lifting load
   b. working load limit
   c. work limited lay
   d. weighted load lift

9. How is a broken wire end removed from a wire rope?

   a. cut is off with side cutters
   b. burn it off with a torch
   c. bend it back and forth
   d. cut it off with a saw

10. What is the cause of a wire rope peening?

   a. repeated beating of the rope
   b. excessive straight pulls
   c. lack of lubrication
   d. excessive heat

11. What is the cause of a "kinked" wire rope?

   a. overloading
   b. excessive whipping
   c. faulty handling
   d. worn sheave

12. What is the cause of "bird caging" in a wire rope?

    a. snapping
    b. overloading
    c. sudden stops
    d. excessive speed

13. What will happen if the sheave grove is too large for the wire rope?

    a. pinch the rope
    b. seize the sheave
    c. overheat the sheave
    d. flatten the rope

14. When replacing the winch wire rope, what should be noted before removing the wire rope from the drum?

    a. direction it is wound
    b. drum condition
    c. sheave condition
    d. number of wraps

15. While installing a new winch rope what will a twist in the rope cause?

    a. over heating
    b. kink
    c. cracks
    d. splitting

16. What is the procedure to break in a new winch wire rope?

    a. cycle in and out and slowly increase load
    b. spool all the way out and apply maximum load
    c. spool all the way in while applying maximum load
    d. cycle in and out with no load

17. Where are two functions of wire rope lubricants?

    a. reduce noise and dirt build up
    b. increase heat and protective film
    c. reduce friction and corrosion
    d. increase wire strength and flexibility

COMPETENCY A-10

IDENTIFY LUBRICANTS



HEAVY MECHANICAL TRADES:
LINE A—COMMON OCCUPATIONAL SKILLS

Goals

You must know the theory of lubrication, the uses of a variety of specific lubricants, and details regarding the safe handling, storage, and disposal of lubricants. You must understand the causes of friction, the results of unrestrained friction in vehicles and equipment, the three different kinds of friction, and how lubrication can help counteract their effects.

When you have completed the Learning Tasks in this Competency, you will be able to:

- describe the theory of lubrication
- identify specific properties and uses of engine oils, power train fluids, hydraulic fluids, and lubricating greases
- use the API, SAE, MIL, ISO, ILSAC, OEM classifications for lubricants
- describe safe handling, storage, and disposal procedures for lubricants

LEARNING TASK 1

Describe the Theory of Lubrication

Notes

All vehicles and equipment require lubrication and lubricants in order to function efficiently. The major reason that lubrication is required is to overcome the effects of friction.

Friction

Friction may be defined as the resistance to movement between any two objects when placed in contact with each other. The amount of friction depends on the:

- type of material
- amount of pressure holding the objects together
- surface finish
- amount of movement between the objects

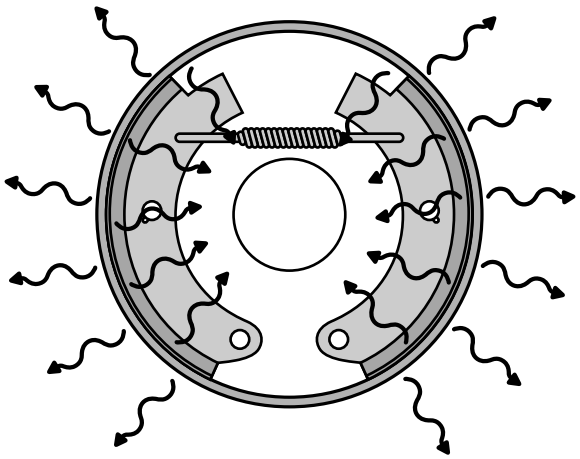


Figure 1. Material, Pressure, Surface, and Movement Determine the Amount of Friction

A closer look at the surface of any two objects will help you understand how friction occurs. If you were to examine the contact surfaces of two blocks of steel under a microscope (regardless of how smoothly they appeared to be polished) you would find a series of sharp points and grooves. When the two blocks contact each other, these jagged surfaces are forced together. As soon as one of the objects is forced to move while in contact with the other, the jagged edges will partially engage each other and impede movement.

NOTES

If, in addition to movement, there is also considerable pressure holding the two blocks together (as in engine bearings where pressures are very high), two things happen:

- Rapid wear will take place since the two blocks will literally tear tiny pieces from each other as they move together.
- The friction between these two moving objects will generate heat.

This heat is the conversion of the kinetic energy (required to move the objects) into heat energy. In vehicles and equipment, this heat energy can be tremendous, causing destruction or even melting of metal bearings and other components. It's impossible to completely eliminate friction between moving parts. All that can be done is reduce it to a minimum.

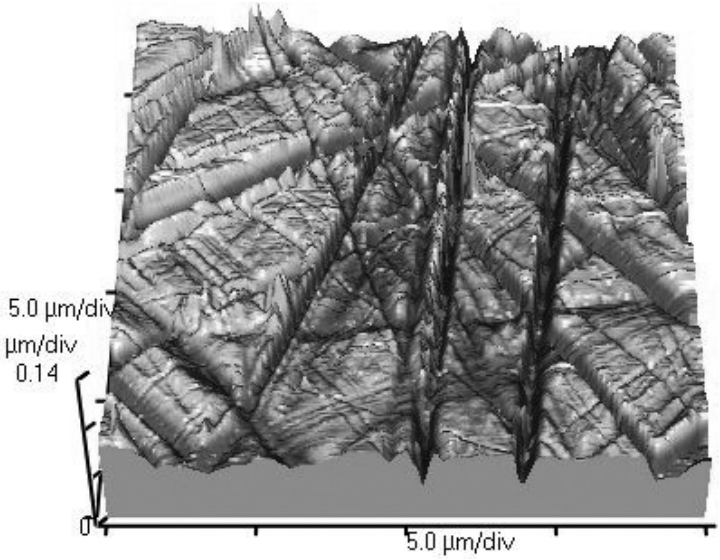


Figure 2. Topographical Scan of a Glass Surface
The micro and nano-scale features of the glass can be observed, portraying the roughness of the material.

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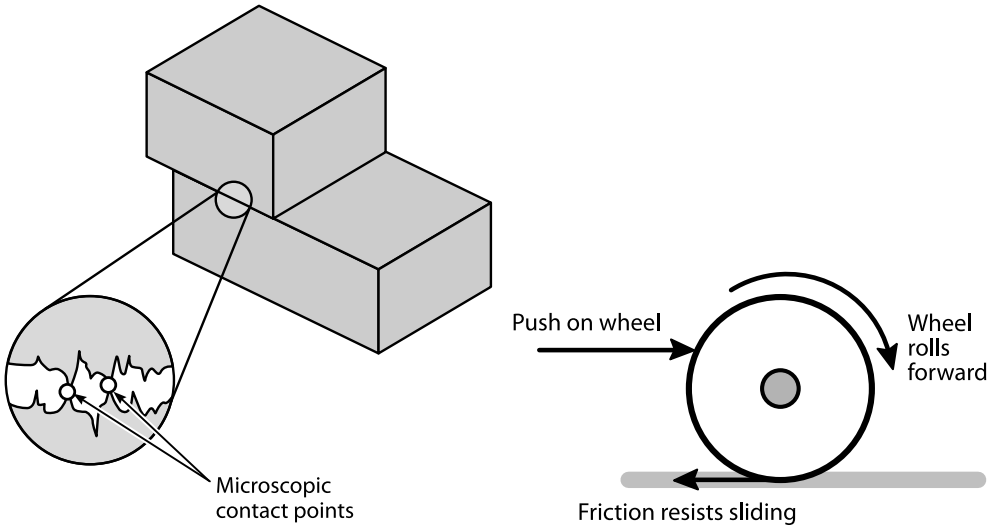

Figure 3. The Effect of a Rough Surface, Static Friction, and Kinetic Friction

Types of Friction

There are three types of friction:

- dry
- greasy
- viscous

Dry Friction

Dry friction is the resistance to motion between two dry objects, such as dry clutches, brakes, pulleys, and tires on a dry road surface. These are examples of dry friction operating to the benefit of a mechanical system.

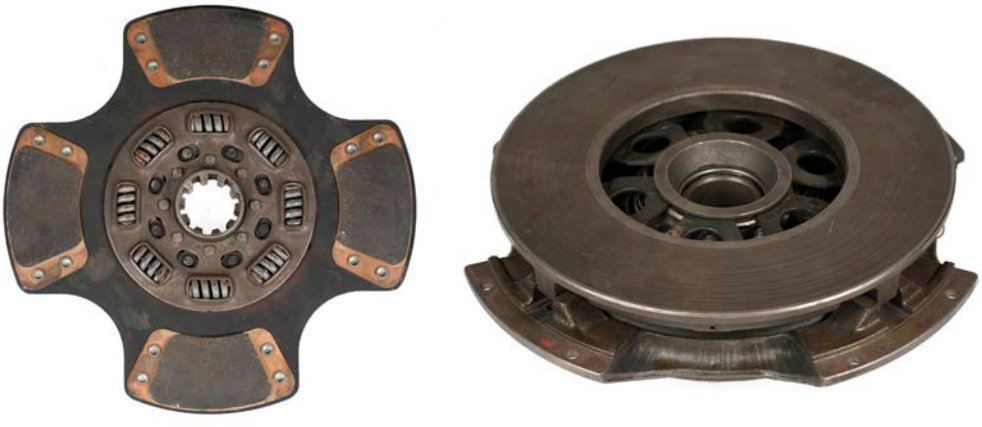

Figure 4. Dry Friction Clutch

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Greasy Friction

Greasy friction is the friction between two objects thinly coated with oil, grease, or a dry lubricant such as graphite or silicone. Greasy friction may occur in an engine on first starting. At this point, most of the lubricating oil may have drained away from the bearing surfaces, cylinder walls, and piston rings leaving only minimal lubrication. When the engine is first started, only this small amount of oil remaining on the surfaces protects them from undue wear. The lubricating system quickly supplies additional oil, but before this happens, greasy friction will exist on the moving surfaces.

The grease shown in Figure 5 will spread over the fifth wheel when it slides under the trailer. The grease is designed to leave a boundary layer on the fifth wheel. This allows the truck and trailer to turn independently and protects the fifth wheel from wear through greasy friction.



Figure 5. Greasy Friction

Viscous Friction

Viscosity is a term that refers to the tendency of liquids, such as oil, to resist flowing. Heavy oil is more viscous than light oil and flows more slowly because it has a higher viscosity or higher resistance to flowing. Viscous friction is the friction or resistance to motion between layers of liquid.

Hydraulics experience high degrees of viscous friction due to the high flow rates and the high pressures. This generates great heat that can cause damage.

Hydrodynamic Lubrication

In an oiled engine bearing, layers of oil (boundary layer) adhere to the bearing and shaft surfaces. The rotating shaft carries around the layers of oil clinging to the shaft and they wedge between the shaft and the bearing (Figure 6). The wedging action lifts the shaft so that the oil supports the shaft.

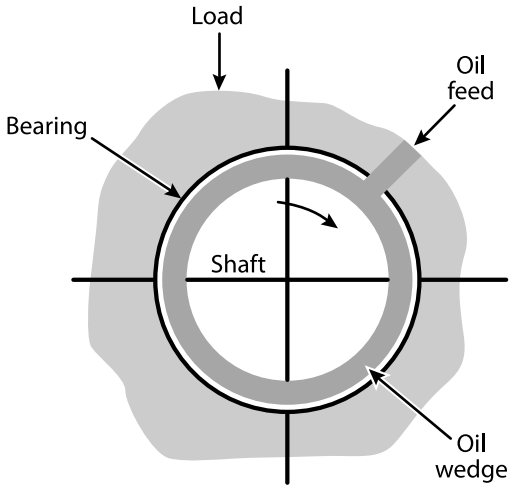

Figure 6. Hydrodynamic Lubrication

Since the shaft is supported on layers of oil, there is no metal-to-metal contact. However, the layers of oil must move over one another and although there is a great deal less resistance to movement, viscous friction does occur. This ideal lubrication process is called hydrodynamic lubrication. Since the components are never in contact, wear is virtually eliminated. Effective hydrodynamic lubrication requires the use of a pressure feed system for the lubricant, such as in an engine.

NOTES

SELF TEST 1

1. What is the major reason for the use of a lubricant between two moving parts?

   a. reduce friction
   b. reduce speed
   c. reduce pressure
   d. reduce movement

2. What type of friction is created by pushing a chair across the floor?

   a. dry heat
   b. static friction
   c. dry friction
   d. greasy heat

3. What term describes the friction between the layers of a liquid?

   a. greasy friction
   b. liquid friction
   c. viscous friction
   d. oily friction

4. What lubrication completely surrounds and supports a moving part so that it floats?

   a. hydrostatic
   b. viscostatic
   c. kinetic
   d. hydrodynamic

5. What will be produced if two blocks of steel are rubbed together without the benefit of lubrication?

   a. cold
   b. heat
   c. resistance
   d. an alloy

LEARNING TASK 2

Describe the Properties of Lubricants

NOTES

Viscosity

Oil viscosity refers to the thickness or fluidity of the oil. It's a measure of the ability of oil to resist flowing.

Viscosity Index

Viscosity index (VI) is the measure of the rate of change of viscosity with temperature change. When oil is heated, it tends to thin out or develop a lower viscosity. When oil is cooled, it tends to thicken or increase in viscosity. If oil is thin at cold temperatures and, when heated, does not thin out much more, it's said to have a high VI. However, if the heating produces a great change in viscosity, the oil will have a low VI. Viscosity index is a measure of the ability of oil to resist changes in viscosity when heated.

Oil Additives

Oils are manufactured from base stocks and are fortified with additives to perform all the necessary functions. Some of the additives found in oils are:

- **Anti-oxidants**—prevent oil oxidation, sludge, and acid formation.
- **Corrosion inhibitors**—prevent bearing corrosion.
- **Detergent/dispersant additives**—clean parts and disperse sludge and other solid contaminants. These detergents remove deposits and retain the deposits as fine particles suspended in the oil. Detergents may become depleted and after prolonged service they may not be able to keep the contaminants in suspension.
- **Rust inhibitors**—prevent rusting of parts, particularly those areas subjected to high moisture content.
- **Pour-point depressants**—provide free-flowing qualities at low temperatures.
- **Viscosity index improver**—the viscosity index is a measurement of the change in the viscosity as the temperature changes. This additive reduces the rate at which the oil thins out with increasing temperature.

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- **Anti-wear agents**—prevent galling and scoring of heavily loaded parts. A widely used material is an agent combining zinc, sulphur, and phosphorus called ZDDP. This additive uses the principle that dirty metal will not weld easily. At certain temperatures the additive will begin to burn and will "dirty" the metal surfaces preventing the welding of the metals together. This reduces scuffing and scoring in areas such as gear train, cylinder walls, and pistons.
- **Reserve alkalinity**—is a basic property of new engine oils, which are alkaline (or basic) in composition in order to neutralize the acids formed by the combustion process.
- **Foam suppressers**—do not prevent foam from forming, but they de-stabilize the foam so that it settles quickly.
- **Friction modifiers**—some oil contains friction-modifying chemicals, which can reduce the fuel consumption of an engine. These chemicals form a chemical or physically bonded film that reduces the friction between the moving parts or the oil flow.

While there may seem to be a great many additives used in 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 oil may have as much as 12% detergents present. The quantity of the additive is not necessarily an indication of the quality or the strength of oil.

Society of Automotive Engineering Rating (SAE)

Oil viscosity refers to the thickness or fluidity of the oil. It's a measure of the ability of oil to resist flowing. The Society of Automotive Engineers (SAE) has set low (-18°C/0°F) and high (100°C/212°F) temperature requirements for oil. Oil that meets low-temperature requirements has the letter "W" following the viscosity rating, which indicates suitability for low temperature and winter use, such as SAE 10W. Oil that meets the high-temperature requirements has no letter, but is designated by number only, such as SAE 30. Oil that meets either the low-temperature or the high-temperature ratings, but not both, is known as single-viscosity grade oil.

Table 1 shows the single-viscosity grades that are available.

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SAE 5W
SAE 10W
SAE 15W
SAE 20W
SAE 20
SAE 30
SAE 40
SAE 50

Table 1. SAE Single Viscosity Grades for Engine Oil

Along with the single-viscosity rated oil indicated in Table 1, there are also multi-viscosity oils, which are even more common.

Multi-viscosity oil meets SAE specifications for both the low-temperature requirements of light oil and the high-temperature requirements of heavy oil. It meets the viscosity and performance requirements of two or more SAE grades and is marked as shown in Table 2.

SAE 0W-30 Semi-synthetic
SAE 5W-20
SAE 5W-30
SAE 10W-30
SAE 10W-40
SAE 15W-40
SAE 20W-40
SAE 20W-50

Table 2. SAE Multi-Viscosity Grade Oil

API Service Classification

In 1970, the American Petroleum Institute, the American Society for Testing and Materials, and the Society of Automotive Engineers cooperated in establishing an entirely new API Engine Service Classification System. This system enables engine oil to be defined and selected on the basis of performance characteristics and the type of service.

It should be emphasized that the API Engine Service Classification System has no connection with SAE Engine Oil Viscosity Classification System. The latter is used to indicate only the SAE viscosity of oil. Both are necessary to adequately define engine oil characteristics.

NOTES

All engine oils distributed by reputable refiners and manufacturers are labelled to identify the SAE Viscosity and API Service Classification. The API Engine Service Classification System has several classes of service which are summarized in Tables 3 and 4:

Letter Designation	API Service	Oil Description
SA	Utility gasoline and diesel engine service. (obsolete)	Oil without additive.
SB	Minimum-duty gasoline engine service. (obsolete)	Some antioxidant and anti-scuff properties.
SC	1964 gasoline engine warranty requirements. (obsolete)	Meets 1964–1967 requirements of automotive manufacturers.
SD	1968 gasoline engine warranty requirements. (obsolete)	Meets 1968–1971 requirements of automotive manufacturers.
SE	1972 gasoline engine warranty requirements. (obsolete)	Meets 1972–1980 requirements of automotive manufacturers.
SF	1980 gasoline engine warranty requirements. (obsolete)	Meets 1980–1988 requirements of automotive manufacturers.
SG	1989 gasoline engine warranty requirements. (obsolete)	Meets 1989–1993 requirements of automotive manufacturers.
SH	1994 gasoline engine warranty requirements.	Meets 1994 onwards requirements of automotive manufacturers.
SJ	1996 gasoline engine warranty requirements.	Meets 1996 onwards requirements of automotive manufacturers.
SL	2001 gasoline engine warranty requirements.	Meets 2001 onwards requirements of automotive manufacturers.
SM	2004 gasoline engine warranty requirements	Meets 2004 onwards requirements of automotive manufacturers.
SN	2011 gasoline engine warranty requirements	Meets 2011 onwards requirements of automotive manufacturers.

Table 3. Spark Ignition API Ratings

Letter Designation	API Service	Oil Description
CA	Light-duty service on high-quality fuels. (obsolete)	Meets Military requirement MIL-L-2104A (1954).
CB	Moderate-duty service on lower quality fuels. (obsolete)	Meets Military requirement MIL-L-2104A, but test run on high-sulphur fuel. (Suppl. 1)
CC	Moderate- to severe-duty diesel and gasoline service. (obsolete)	Meets Military requirement MIL-L-2104B (1964).
CD	Severe-duty diesel service. (obsolete)	Provides moderately super-charged diesel performance. Meets requirements of MIL-L-2104C and Caterpillar Series 3® lubricants.
CD-II	Severe-duty 2-stroke cycle diesel engine service. (obsolete)	Meets requirements for API CD service, plus Detroit Diesel 6V53T® approval.
CE	Turbo-charged and Super-charged heavy-duty diesel engines, manufactured since 1983. (obsolete)	Meets the requirements for API CD service, plus those for Mack EO-K/2® and Cummins NTC-400® approvals.
CF	Off-road indirect injected diesel engines and other diesel engines using a broad range of fuel types including high-sulphur (>0.5%) fuel. (obsolete)	Provides effective control of piston deposits, wear, and corrosion in naturally aspirated turbo-charged or super-charged diesel engines. Can be used to replace CD oils.
CF-2	Severe-duty 2-stroke cycle diesel engine service.	Service typical of 1994 severe-duty two-stroke cycle diesel engines requiring highly effective control over deposits and wear. Can be used to replace CD-II oils.
CF-4	Severe-duty turbocharged 4-stroke cycle diesel engines, especially late model (since 1988) lower emission engines.	Meets requirements of Caterpillar 1-K® spec., plus those for Mack EO-K/2® and Cummins NTC-400® approvals.
CG-4	Severe-duty service in 4-stroke cycle diesel engines designed to meet 1994 emission standards using low-sulphur fuel (<0.5%).	Provides effective control over high temperature piston deposits, wear, corrosion, foaming, oxidation stability, and soot accumulation. Can be used to replace CD, CE, and CF-4 oils.

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CH-4	Severe-duty service in 4-stroke cycle diesel engines designed to meet 1998 emission standards using low-sulphur fuel (up to 0.05%).	Can replace those rated CD, CE, CF-4, and CG-4.
CI-4	Severe-duty service in 4-stroke cycle diesel engines designed to meet 2002 emission standards using low-sulphur fuel (up to 0.05%).	Maintain engine durability with EGR systems. Can replace those rated CE, CF-4, CG-4, and CH-4.
CJ-4	Severe-duty service in 4-stroke cycle diesel engines designed to meet 2006 emission standards using low-sulphur fuel (up to 0.05%).	CJ-4 is required with exhaust after treatment such as catalytic converters and carbon particular filters. Can replace CF-4, CG-4, and CH-4.

Table 4. Compression Ignition API Ratings

The following are more detailed descriptions of the API Service Classification. The classifications are a guide to the proper selection of engine oil, based on warranty and climate control conditions.

SH—1994 Gasoline Engine
Service typical of gasoline engines in passenger cars, vans, and light trucks beginning with the 1994 model year operating under manufacturers' recommended maintenance procedures. Oil developed for this service provides improved control of engine deposits, oxidation, and engine wear relative to oil developed for previous categories. Oil meeting API Service Classification SH may be used where API Service Categories SG, SG/CC, SF, SF/CC, and SE are recommended.

SJ—1996 Gasoline Engine Service
SJ oils provide improved performance in compatibility for catalytic converters, volatility, high-temperature deposits, and low-temperature pumpability.

SL—2001 Gasoline Engine Service
SL oils are for use in service typical of gasoline engines in present and earlier passenger cars, sport utility vehicles, vans, and light trucks operating under vehicle manufacturers' recommended maintenance procedures.

SM—2004 Gasoline Engine Service
SM oils are designed to provide improved oxidation resistance, improved deposit protection, better wear protection, and better low-temperature performance over the life of the oil.

Notes

SN—2011 Gasoline Engine Service

Oils that meet the SN motor oil ratings are designed to improve fuel economy, improve the life of emission components (such as the catalytic converter and oxygen sensors), and improve sludge, deposit, and oxidation control. The oils also have better low-temperature viscosity, high- and low-temperature corrosion protection, better turbocharger protection, and improved filter clogging protection.

CF-2—1994 Severe-duty Two-stroke Cycle Diesel Engine

API Service Category CF-2 denotes service typical of two-stroke cycle engines requiring highly effective control over cylinder and ring-face scuffing and deposits. Oil designated for this service has been in existence since 1994 and may also be used when API Service Category CD-II is recommended. This oil does not necessarily meet the requirements of CF or CF-4 unless the oil has specifically met the performance requirements of these categories.

CF-4—1991 Diesel Engine

Service typical of severe-duty turbo-charged, four-stroke cycle diesel engines, and particularly later models designed to give lower emissions. These engines are usually found in on-highway, heavy-duty truck applications. API CF-4 oils exceed the requirements of CE category oil and can be used in place of earlier CC, CD, and CE oil.

The CF-4 classification meets Caterpillar's 1K engine requirements, as well as the earlier Mack Trucks' (T-6, T-7) and Cummins' (NTC-400) multi-cylinder engine test criteria.

CG-4—1994 Severe Duty Diesel Engine

API Service Category CG-4 describes oils for use in high-speed four-stroke cycle diesel engines used in highway and off-road applications where the fuel sulphur may vary from less than 0.5% by weight. CG-4 oil provides effective control over high-temperature piston deposits, wear, corrosion, foaming, oxidation stability, and soot accumulation. This oil is especially effective in engines designed to meet 1994 emissions standards and may also be used in engines requiring API Service Categories CD, CE, and CF-4. Oil designated for this service has been in existence since 1995.

CH-4—1998 Reduced Emission Diesel Engine Service

CH-4 oils are specifically compounded for use with diesel fuels containing up to 0.5% sulfur. They can also be used in gasoline engines when combined with the appropriate "S" category when the vehicle or engine manufacturer recommends.

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CI-4—2002 Severe-duty Diesel Engine Service
These oils are compounded for use in all applications with diesel fuels ranging in sulfur content up to 0.05% by weight. These oils are especially effective at sustaining engine durability where Exhaust Gas Recirculation (EGR) and other exhaust emission components may be used.

CJ-4—2006 Heavy-duty Diesel Engine Service; Exhaust After-treatment
CJ-4 oils are compounded for use in all applications with diesel fuels ranging in sulfur content up to 500 ppm (0.05% by weight). CJ-4 oils are effective at sustaining emission control system durability where particulate filters and other advanced after-treatment systems are used. Optimum protection is provided for control of catalyst poisoning, particulate filter blocking, engine wear, piston deposits, low- and high-temperature stability, soot handling properties, oxidative thickening, foaming, and viscosity loss due to shear.

API Service Classification Symbol

API's lubricants subcommittee established the symbol in Figure 1 to provide uniform identification of appropriate engine oil according to the manufacturer's recommendation. The symbol is used to display the appropriate API service category or categories (upper part of the symbol), the SAE viscosity grade (centre of the symbol) and, if applicable, energy-conserving features of an oil (bottom part of the symbol). Energy-conserving is not applicable for heavy-duty diesel engines.



Figure 1. API Service Classification Symbol

Energy-conserving Oil Classification

This is a supplementary classification for engine oil that has energy-conserving (fuel-saving) properties. There are presently two energy-conserving oil categories:

- Energy-conserving
- Energy-conserving II

Engine oil categorized as Energy-conserving is formulated to improve fuel economy. Energy-conserving oil has produced a fuel economy improvement of 1.5% or greater over a standard reference oil. Engine oil categorized as Energy-conserving II has produced a fuel economy improvement of 2.7% or greater over a standard reference oil. Oil meeting this requirement displays the Energy-conserving II label in the lower portion of the API service symbol.

Other Oil Classifications

Some manufacturers have oil requirements that are not completely covered by API classifications. Always check the manufacturer's service manuals or operating manuals for the recommended lubricant.

- ISO standards
- MIL standards
- ILSAC standards
- OEM standards

International Organization of Standardization (ISO)

ISO is a standard-setting body made up of representatives from national standards bodies.

For the world's largest developer of standards, the principal activity is development of technical and economical standards and the ISO standards cover a wide variety of items ranging from medical equipment to shipbuilding:

- mechanical
- machinery
- chemistry
- coatings
- construction
- metals
- aerospace
- fuels
- energy
- transportation
- information

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- image technology
- quality
- measurements
- safety
- environment
- medical
- consumer goods

The heavy-duty industry uses SAE and ISO standards for hydraulic oils. Table 5 shows the ISO hydraulic oil comparisons to SAE oil viscosities. The two most common hydraulic oils used today are ISO 32 and ISO 46.

ISO Grade	Equivalent SAE Grade	Viscosity			
		Centistokes		*10–6 reyns (lbs/in²)*	
		40°C	*100°C*	*104°F*	*212°F*
32	10W	32	5.4	4	0.6
46	20	46	6.8	5.7	0.8
68	20W	68	8.7	8.5	1.1
100	30	100	11.4	12.6	1.4
150	40	150	15	19	1.8
220	50	220	19.4	27.7	2.4

Table 5. ISO and SAE Grade Equivalents

MIL Standards

A United States defense standard, often called a military standard, "MIL-STD," "MIL-SPEC," or (informally) "MilSpecs," is used to help achieve standardization objectives by the U.S. Department of Defense.

Equipment manufactured in the USA usually has some MIL specifications for the oils used in their equipment. You will find this information in the equipment lubrication manuals.

An example of the MIL specification is:

API rated CJ-4 lubricants. **MIL-L-21260E, GRADE 15W-40**

ILSAC Standards

The International Lubricant Standardization and Approval Committee (ILSAC) developed by the Japanese automotive association, Ford, Chrysler, and General Motors, also have standards for motor oil. Introduced in 2004, GF-4 applies to SAE 0W-20, 5W-20, 0W-30, 5W-30, and 10W-30 viscosity grade oils. In general, ILSAC works with API in creating the newest gasoline oil specification, with ILSAC adding an extra requirement of fuel economy testing to their specification. For GF-5 (SN), a Sequence VID Fuel Economy Test (ASTM D7589) is required that is not required in API service category SM.

Fuel Efficiency Increase (FEI), Sequence VID, ASTM D7589

SAE XW-20 viscosity grade:

- FEI SUM 2.6% minimum
- FEI 2 1.2% minimum after 100 hours aging

SAE XW-30 viscosity grade:

- FEI SUM 1.9% minimum
- FEI 2 0.9% minimum after 100 hours aging

SAE 10W-30 and all other viscosity grades not listed above:

- FEI SUM 1.5% minimum
- FEI 2 0.6% minimum after 100 hours aging

For oil to have the GF-5 (SN) rating, the oil listed above must pass the Fuel Efficiency Increase (FEI) minimum test.

A new set of specifications, GF-5, took effect in October, 2010. The industry has one year to convert their oils to GF-5 and in September, 2011, ILSAC no longer offers licensing for GF-4.

OEM Standards

By the early 1990s, many of the original equipment manufacturers (OEM) resigned on the direction of the American API oil standards, as it did not perform to the needs of oils to be used on OEM equipment. As a result, many leading manufacturers created and developed their own "OEM" oil standards, which were no longer directly compatible with the API. You can purchase these oils from the dealer of the manufactured equipment.

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The oils listed below are a sample of API CJ-4 classification:

- Volvo VDS-4
- Cummins CES 20081
- Caterpillar ECF-1, ECF-2, ECF-3, 20077, 20076
- Mack EO-O Premium Plus 07
- Mack EO-N Premium Plus 03
- Mercedes Benz 228.3
- DDC/MTU Series 2000/4000 category 1 and 2 engine performance
- DDC Power Guard Oil Specification 93K218

Oil Types

Each of the following oils/fluids comes with its own specifications and uses. You must check the lubrication manual for each machine/truck for proper selection and use.

- engine oils
- automatic transmission oils
- powershift transmission oils
- hydraulic oils
- steering oils
- differential oils
- final drive oils
- undercarriage oils
- air conditioning oils
- brake fluids

Engine Oils

The proper choice of engine oils will provide easy starting in cold climate and proper protection in hot climates. The engine oil must be pumped through the system at a rate that will feed all the necessary components no matter what the engine RPM, engine temperature, or loads on the engine. Referring to the engine lubrication manual normally guides selection of engine oils. The API, SAE, OEM, and ILSAC ratings will help with this selection.

Automatic Transmissions

Automatic transmission fluid must:

- transmit power within the torque converter
- lubricate gears, clutch plates, and bearings
- transfer heat away from the internal components

Notes

Inside an automatic or powershift transmission, the fluid must perform specific functions under severe conditions. These are:

- protect heavily loaded gears with an oil film
- perform as a non-foaming fluid in transmitting power
- operate as a hydraulic fluid between -40–150°C (-40–300°F)
- act as a wet clutch and transmission lubricant to provide smooth, silent engagement, without slipping
- resist oxidation under conditions of heat and aeration, while at the same time remaining compatible to all metals, rubber seals, gaskets, adhesives, facings, and liners in the system

As with engine oil, a variety of additives are required in automatic transmission fluid. The most commonly used additives are:

- oxidation inhibitors
- rust inhibitors
- dispersants
- corrosion inhibitors
- metal deactivators
- foam inhibitors
- viscosity index improvers
- seal swellers
- anti-wear agents
- friction modifiers

Automatic Transmission Fluid Types

There are a number of automatic transmission fluids:

- Dexron VI
- Mercon LV
- ATF+4®
- Synthetic

The only way to be sure that you select the correct fluid is to check the manufacturer's specifications.

Dexron VI

Dexron VI is a friction-modified fluid. It's formulated using treated base oil plus a high-quality additive package. The result is a fluid which demonstrates outstanding oxidation and thermal stability, providing extremely long service life under the most severe operating conditions. Dexron VI was introduced in 2007 as a direct replacement for Dexron III. Dexron III should not be used with newer transmissions.

NOTES

Mercon LV
Motorcraft® Mercon® LV is manufactured with high-viscosity index, premium-quality, hydroprocessed base oils, and specially designed performance additives, which provide excellent shifting characteristics at high and low ambient temperatures and guards against transmission shudder. This fluid has excellent thermal, oxidation, and shear stability and good low-temperature fluidity. It provides wear protection and inhibits the formation of gum, sludge, lacquer, and foam. It also prevents against rust and corrosion. It's dyed red for ease of leak detection.

ATF+4®
ATF+4® is manufactured with high shear stability, increased oxidation stability, and enhanced friction additives for transmissions.

ATF+4® Also offers extra wear protection and anti-shudder characteristics with enhanced low-temperature oil flow.

ATF+4® is back-serviceable (compatible for previous years) in transmissions where ATF+3® fluids or earlier versions are recommended.

Synthetic Automatic Transmission Fluid
Synthetic ATF is available on aftermarket brands, offering better performance and service life for certain applications (such as frequent trailer towing). Synthetic ATF helps to protect against thermal breakdown at high operating temperatures, while still providing outstanding performance at ambient temperatures as low as -54°C. Further, it helps to improve overall transmission durability and cleanliness.

Powershift Transmission Oils

Powershift transmissions are located in heavy equipment, such as crawlers dozers, and loaders. Oil in the powershift transmissions must perform the same functions as the automatic transmission. These transmissions will take oils that are rated by SAE, API, OEM, and MIL.

Most heavy equipment will require SAE and API rated oils. You will need to refer to the lubrication manual for the specific equipment.

Hydraulic Oils

The heavy-duty industry uses SAE and ISO standards for hydraulic oils. Viscosity of hydraulic oil follows the same regulations as for engine oil. The Society of Automotive Engineers establishes the viscosity ratings for hydraulic oil.

Notes

Winter viscosity ratings, such as 5W, 10W, and 20W, are determined by testing at -18°C (0°F). Summer ratings, such as 20, 30, 40, and 50, are determined at 100°C (212°F). Hydraulic oil must be able to withstand high temperatures without thinning out and leaking past seals. When cold, it cannot be so thick that it will not flow. Hydraulic oil must have a high viscosity index. The viscosity index of an oil will determine how much the oil changes with temperature. Low viscosity index oil will be very thick when cold and very thin when hot. High viscosity index oil will not vary considerably in resistance to flow from cold to hot.

The American Petroleum Institute provides a rating for all oil according to application. Many manufacturers use special hydraulic oil in the power steering, rather than using automatic transmission fluid. Although transmission fluid and even engine oil may be acceptable as a hydraulic oil, it's important that you always check the manufacturer's recommendations to make sure that the system is not damaged by using an incompatible fluid.

While petroleum-based oil is still widely used in hydraulic systems, many other types of fluids are used for different characteristics. Fluids are designed that are fire-resistant, environmentally neutral, or have better lubrication or wear characteristics. These fluids include:

- water glycol
- water-oil emulsion
- synthetic
- environmentally friendly

Fire Resistant Hydraulic Oils

For hydraulic applications where fire hazards or the threat of fire-inducing conditions are a concern, fire resistant hydraulic oil products like ACT Water Glycol and Quaker Quintolubric® may be employed.

Synthetic Hydraulic Oils

Synthetic Hydraulic Oils: ISO 15, 22, 32, 46, and 68. (AW) Protects hydraulic systems when working in a stress of high-pressure and high-loads. Synthetic oils maintain fluid flow in cold temperatures for immediate cold-weather lubrication. Anti-wear additives and rust inhibitors provide maximum protection to expensive hydraulic components.

EFL Products

EFL (Environmentally Friendly Liquids) are fluids that do not harm the environment if they're spilled.

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The most numerous EFL products are hydraulic fluids. Most of these products are based on rapeseed oil (RO), also known in the food industry as canola. (The rape plant is a member of the mustard family.) Other crop oils, synthetic esters (SEs), and polyglycols (PGs) are also being marketed. Most have excellent lubricating properties—in some cases, superior to mineral oils—making them candidates for use not only as hydraulic fluids, but also for lubricating oils and greases.

EFLs would be ideal if they had properties identical to the currently used mineral-based products, but such is not the case. Costs are higher, and compatibility with existing mineral-based products, moisture, and seal materials must be considered. EFLs typically have flatter viscosity curves but may also have more restrictive low- and high-temperature limits.

As with any harmful liquids, hydraulic fluid should be disposed of in an approved manner only. Do not pour hydraulic fluid into drains or outdoors as it can contaminate the environment.

Steering Oils

Steering oils must perform the same functions as hydraulic oils. Because of this, some machines will use the hydraulic tank as the steering reservoir. Truck power steering gears will have their own reservoir, but the fluids are rated for hydraulic systems. They use SAE, API rating systems. Some power steering gears will use Dexron/ATF oils.

Be sure to check the lubrication manual for steering oils.

Gear Oils

Gear oil must contain special anti-friction and anti-weld agents for gears that are subjected to high loads. Oils containing these additives are known as extreme pressure or hypoid lubricants.

To perform satisfactorily, most gear oils should have the following properties:

- extreme pressure properties
- oxidation stability
- corrosion resistance
- foam resistance
- high viscosity index
- low pour-point
- low channel temperature

Extreme Pressure Properties (EP)
Extreme pressure properties are required in gear systems which use hypoid, heavily loaded spiral-bevel, and worm gear combination. Spur gears and moderately loaded gears do not require this property.

Oxidation Stability
Gear oil must be chemically stable to resist oxidation and sludge formation because it's subjected to sustained heat, violent agitation, and air foaming.

Corrosion Resistance
Gear oil must provide effective resistance to corrosion because most extreme pressure agents are chemically active and protect gear teeth by coating them. However, discolouration of gears and internal parts frequently occurs. This does not indicate abnormal corrosion.

Foam Resistance
Foam resistance is mandatory in gear oil because of the violent agitation of the oil. Most gear oil contains foam suppressants.

Viscosity Index
Because of the wide variation in both ambient and gear-case temperatures, a higher viscosity index is desirable in gear oil.

Pour-point
This rating indicates the lowest temperature at which lubricating oil will pour. The pour-point must be low enough to provide lubrication at the lowest anticipated temperature. Low viscosity gear oil normally has a pour-point as low as -46°C (-50°F).

Channel Temperature
When the temperature of gear oil drops below its "channel temperature," the gear oil is no longer fluid and gears will cut a groove or channel in the oil, preventing proper lubrication and causing premature failure. Gear oil must be fluid enough at the lowest operating temperature to flow and cover moving parts. Channel temperature may be as much as 9°C (15°F) colder than the specified pour-point of the lubricant. The oil must be able to slump back into the channel for the gears to get adequate lubrication. Channel temperature is always lower than the pour-point temperature.

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SAE Gear Classification

Society of Automotive Engineers gear oil classification is based on viscosity alone and is not an indication of quality or service. While the SAE numbers of gear oil is higher than the SAE numbers of engine crankcase oil, gear oil is not necessarily that much higher in viscosity. Higher numbers are assigned to gear oil to avoid confusion. For example, SAE 85W gear oil actually has about the same viscosity as SAE 40 engine oil. Multi-grade gear oil is available from suppliers in grades of SAE 80-90 and SAE 85-140.

API Gear Oil Classification

The type of service the gear oil can be expected to perform defines gear oil performance. The API service designations were developed to assist manufacturers and end-users selecting gear lubricants for a variety of operating conditions.

The API service designation ranges from GL-1 to GL-5 and describe gear oil in terms of general type, severity of service, and application. Table 6 lists these designations. Note that GL-6 is now obsolete.

With the possible exception of API GL-1, each class is formulated using performance additives. These additives are chemicals that impart new, supplemental, or different properties to a fluid. The performance required for a particular service designation determines the type and amount of additive.

The most common gear oil is API GL-5. In some cases, API GL-4 oil is used as frequently as API GL-5. Each manufacturer has a set of unique test requirements for rear axle factory-fill. API GL-5 oil generally satisfies the majority of these requirements and is often recommended for service-fill. The API GL-5 specification is not acceptable for limited slip applications. Factory-fill (OEM) formulations for limited slip differentials are based on performance through testing at the factory. No standard, industry-wide test is available for evaluation of a lubricant's ability to prevent chatter in a limited slip differential.

Classifications	Type	Typical Applications
GL-1	Straight mineral oil	Automotive manual transmissions (tractors and trucks)
GL-2	Usually contains fatty materials	Worm gear drives, industrial gear oils
GL-3	Contains mild EP additive	Manual transmissions and spiral bevel final drives
GL-4	Equivalent to obsolete MIL-L-2105 Specification. Usually satisfied by 50% GL-5 additive level.	Manual transmissions, spiral bevel, and hypoid gears where moderate service prevails
GL-5	Equivalent to present MIL-L-2105D Specification. Primary field service recommendation of most passenger cars and truck builders worldwide.	Used for moderate and severe service in hypoid and all other types of gears. Also may be used in manual transmissions.
GL-6	Obsolete	Severe service involving high-offset hypoid gears.

Table 6. Gear Oil Classifications

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Undercarriage Oils

The undercarriages on crawler machines have idlers and rollers to guide the track. These rollers require internal lubrication. The oils must take extreme pounding pressures and temperatures. SAE and API rate the oils. These oils are normally SAE 10 to SAE 20 and have the highest API rating for the time of installation. Some manufacturers use a hydraulic oil for this purpose.

Air Conditioning Oils

A/C oils are installed in the compressor and charged into the closed system with the refrigerant. A/C systems require a certified A/C technician to install oil and charge the system. Each refrigerant requires a special oil to protect the compressor and flow with the refrigerant. These oils are SAE, ISO, and API rated. The three common oils are mineral, PAG, and Ester.

Mineral Oil

Mineral oil was used in the old R12 (Freon) systems. Mineral oil was the only recommended lubricant for all R12 applications. R12 has a high affinity for mineral oil, meaning it mixes well with R12 and flows through the system. Mineral oil does not mix with R134a and therefore not usable.

NOTES

PAG Oil (Polyalkylene Glycol Oil)

PAG oil is used by OEM (Original Equipment Manufacturers) in their R134a A/C systems. PAG oils soften paint, which can be a problem with spillage. PAG oils may cause o-ring and seal damage. PAG oils may cause skin irritations. It's recommended that you always wear hand and eye protection while handling or servicing a system with PAG oil. PAG oil is hydroscopic (absorbs moisture from the air) and must be kept in closed metal containers. PAG oils exposed to air will become water-saturated; this will cause A/C system failure if used.

You'll find three common viscosities when choosing PAG oil.

- PAG (ISO) 46—Thin
- PAG (ISO) 100—Medium
- PAG (ISO) 150—Thick

Polyol Ester Oil

Polyol Ester oil (Ester for short), or retrofit oil as it's sometimes called, is the preferred oil when performing a retrofit. Ester oil is recommended by most after-market manufacturers and rebuilders. Ester oil is compatible with mineral oil. Ester oil can be used with R12 and R134a refrigerants. Ester oil is more compatible to most seals and is less damaging to paints compared to PAG oils. This oil comes in, or is supplied with, the aftermarket compressor manufacturers.

NOTE: the latest changes to A/C are going to be phasing out R134a and introduce high-pressure carbon dioxide systems.

Greases

Grease is a lubricating substance designed to stay in place once it's applied. This is different from oil, which either drains away or circulates through a system. Grease is normally a blend of mineral oil to provide lubrication and a metallic soap to make the oil adhere when applied.

The soap used to make grease is a combination of fat, fatty acid, and a metallic substance. Among the metals used for this purpose are calcium, sodium, aluminium, lithium, lead, zinc, and barium. The different combinations produce differences in texture, dropping point (the point at which a grease liquefies), resistance to moisture, resistance to mechanical breakdown, and ease of pumping.

Grease is used for lubricating axle bearings, suspension and steering components, and universal joints.

NOTES

Grease Additive

Some special grease contains non-soap thickeners such as talc and asbestos fibre. Fillers are also sometimes added to grease to add bulk and to harden the grease. Many additives in grease are similar to those in oil, such as oxidation and corrosion inhibitors and anti-scuff agents. Other additives, which are only found in grease, include chemical stabilizers and additives, which increase the dropping point.

High-temperature Grease

High-temperature grease is formulated so that it will resist heat and will not liquefy. Special thickeners are used in place of the conventional soap to achieve this resistance.

Extreme-pressure Grease

Extreme-pressure (EP) grease has the ability to maintain a film on metal surfaces to prevent wear under high sliding loads or slow motion in a mechanism. Molybdenum disulfide or lead naphthenate are the most common additives.

Multi-purpose Grease

The development of multi-purpose grease has made it possible for a machine operator to use one grease for almost all fittings and bearings. Multi-purpose grease is water-resistant, will withstand high temperature, protects against rust, and is long-lasting. It may also have some of the qualities of extreme-pressure grease. The most popular multi-purpose grease is the lithium base type.

Dry Lubricants

Dry lubricants or solid lubricants are materials which, despite being in the solid phase, are able to reduce friction between two surfaces sliding against each other.

Such lubricants, including materials such as graphite, hexagonal boron nitride, molybdenum disulfide, and tungsten disulfide, are also able to operate at temperatures higher than liquid- or oil-based lubricants. These lubricants are often found in applications such as locks or dry lubricated bearings. Such materials can operate up to 350°C in oxidizing environments and even higher in non-oxidizing environments. For example, molybdenum disulfide can operate at up to 1100°C.

NOTES

Synthetic Lubrication Oil

Combining two or more dissimilar materials through a chemical reaction to form a new compound produces synthetic oil. Using this process, research chemists have been successful in developing new lubricants that have uniform molecular and physical properties.

Synthetic engine oil is based on a group of chemicals called "dibasic acid esters," shortened to "di-ester oil." These esters are formed by the reaction of combining an acid and alcohol occurring in both natural and synthesized forms, from simple fats to complicated polymers.

Through laboratory tests of hundreds of combinations of acid and alcohol, researchers were able to determine which combination would produce the desired qualities of engine oil. These qualities include long-term stability under extreme temperature conditions and the ability to blend easily with additives.

Petroleum based engine oil is composed of a high percentage of unsaturated molecules, referred to as having open or loose ends. Because of this, oil tends to readily absorb oxygen, especially under high operating temperatures. This causes the oil to undergo a chemical change called oxidation, causing the formation of contaminants, sludge, and acid. This oxidation rate will double for every 8°C (18°F) increase in temperature above 82°C (180°F). Synthetic oil has a base composed of saturated molecules with closed ends. As a result, there is no deterioration through oxidation.

Synthetic oils follow the SAE and API ratings.

Synthetic oil has several advantages over conventional oil:

- excellent low-temperature fluidity
- low pour-point
- high natural viscosity index
- excellent oxidation stability
- high flash, fire, and auto-ignition points
- low volatility
- non-corrosive and non-toxic

Synthetic oil is beginning to replace conventional petroleum oil in many applications. Despite higher cost, synthetics may offer operating advantages that can make them more economical, such as:

- reduced oil consumption
- longer oil life
- improved fuel economy
- easier starting at low temperatures

One disadvantage of synthetic oils is that the engine is more prone to leaks because there's very little swelling of the seals as there is with petroleum-based oil.

NOTES

Brake Fluids

Brake fluids must meet the requirements of the hydraulic brake system. The Society of Automotive Engineers (SAE) establishes the standards for hydraulic brake fluids. Brake fluids are graded on the following qualities:

- compressibility
- boiling point
- viscosity and viscosity index
- water tolerance
- corrosion resistance
- evaporation resistance
- lubrication

Compressibility

Brake fluids must resist compression to be able to transmit the forces applied.

Boiling Point

Brake fluid must have a high boiling point. Most of the heat generated in the brakes is dissipated to the surrounding air. Some of the heat is absorbed through the wheel cylinders and calipers and transmitted through the fluid. If the fluid absorbs too much heat, it will boil and become a vapour in the lines. Since vapour is compressible, it will affect braking.

The Department of Transport (DOT) establishes the regulations for boiling points of brake fluid. These regulations state the wet and dry boiling points. The dry boiling point is based on new, uncontaminated fluid without any absorbed water. As fluid is in service, it's occasionally exposed to air. This exposure will result in some moisture being absorbed by the fluid, affecting the boiling point.

Viscosity and Viscosity Index

Viscosity is resistance to flow. The viscosity index of a fluid is the measure of the stability of the viscosity over a wide temperature range. Brake fluid must maintain a consistent viscosity at low temperatures and at high temperatures. Brake fluid contaminated with water will thicken and freeze more readily than clean fluid.

NOTES

Water Tolerance

Water absorbed by brake fluid will affect more than the boiling and freezing point of the liquid. If water is allowed to collect in large concentrations, it will corrode lines and cause damage.

Brake fluid must distribute water equally throughout the fluid so that it resists accumulation that could cause damage.

Corrosion Resistance

Brake fluids are designed to limit their corrosive action by setting the levels of acidity during manufacture. In addition, brake fluid resists oxidation by resisting the combination of absorbed water and acids in the fluid.

Evaporation Resistance

Evaporation will occur with any fluid. Brake fluid must be designed to resist evaporation. When evaporation occurs, the fluid must minimize deposits left behind that might clog passages or interfere with the operation of the system.

Lubrication

Brake fluid must provide lubrication for moving parts, such as master cylinder pistons, sealing cups, and valves.

Types of Brake Fluid

Brake fluids are different in composition and qualities because of different system requirements. Types of brake fluids include:

- polyglycol
- silicone
- hydraulic system mineral oil (HSMO)

Polyglycol

- Polyglycol fluids are the most common and least expensive of the fluids. They cause a slight swelling of rubber parts to assist sealing, but not enough to cause deterioration.
- Polyglycol DOT-3 fluids are amber or clear in colour and the minimum boiling point is 205°C (400°F).
- Polyglycol DOT-4 fluids are amber or clear in colour and the minimum boiling point is 230°C (446°F).
- Polyglycol fluids react with metals and rubber in the brake system to form deposits that eventually gum up cylinders and pistons. They are also hygroscopic, which means that they will readily absorb moisture. This will change the characteristics of the fluid, reducing the boiling point and increasing corrosion.

- Polyglycol fluid must be stored in a tightly sealed container to prevent moisture absorption.
- Polyglycol fluids are strong solvents. They will corrode the finish on vehicles. Avoid skin contact with polyglycol fluids.

NOTES

Silicone

The lubrication qualities of silicone are excellent. Silicone brake fluid is purple and is rated as DOT-5. Minimum wet boiling point is 180°C (356°F). Silicone fluid is not hygroscopic. Metal corrosion and rubber deterioration is greatly reduced. Silicone brake fluid should not be used with ABS brakes as the corrosion can cause valve problems.

Silicone fluids have some disadvantages. They are almost chemically inactive and lack conductivity. While chemical inactivity is desirable to prevent damage to painted surfaces and metal components, the fluid will not conduct electricity. This prevents fluid level sensors and other electrical components in the brake system from functioning. Silicone fluids will not provide any swelling of rubber parts and does not assist in sealing.

Silicone fluids are not compatible with Polyglycol fluids. Never mix DOT-3 or DOT-4 fluid with DOT-5 fluid.

Hydraulic System Mineral Oil

This fluid (HSMO) is used in large heavy equipment, such as mining trucks. It's manufactured from petroleum oil with additives. It's not hygroscopic, has an extremely high boiling point of 265°C (509°F), and naturally inhibits rust and corrosion. It's coloured green to distinguish it from other fluids.

Mineral oil is not compatible with any other type of fluid. Mineral oil will corrode and damage rubber components and hoses.

SELF TEST 2

1. Who establishes the standards for engine oil viscosity?

   a. American Petroleum Institute
   b. National Oil Foundation
   c. Society of Automotive Engineers
   d. Society of Lubrication Engineers

2. Which of the following oil would be best suited for low-temperature operation?

   a. 10W-30
   b. 5W-30
   c. 20
   d. 30

3. What does the term API refers to?

   a. American Petroleum Institute
   b. American Pipeline Institute
   c. Alberta Petroleum Institute
   d. Alberta Pipeline Institute

4. SAE has set low- and high-temperature requirements for oil. The low temperature is -18°C (0°F). What is the high temperature?

   a. 10°C (50°F)
   b. 100°C (212°F)
   c. 112°C (234°F)
   d. 212°C (414°F)

5. What does SAE 10W-30 rating refer to?

   a. two-viscosity
   b. dual-viscosity
   c. multi-viscosity
   d. many viscosity

6. What is the measure of the rate of change of viscosity with temperature change?

   a. temperature index
   b. viscosity change
   c. viscosity index
   d. oil index

7. What is the API service classification oil required to meet 2006 emission standards?

   a. CJ-4
   b. CH-4
   c. CL-4
   d. CI-4

8. What term is used to describe the point when grease liquefies?

   a. liquefying point
   b. dropping point
   c. dripping point
   d. slump point

9. What component uses ATF+4®?

   a. differentials
   b. engines
   c. automatic transmissions
   d. brakes

10. Why are some fluids made from rapeseed oil?

    a. make them synthetic
    b. make them an environmentally friendly oil
    c. make them function as a low-temperature oil
    d. make them function as a brake fluid

LEARNING TASK 3

Describe the Use of Lubricants

Notes

Applications

Lubricants are used in a wide variety of applications:

- engine
- automatic transmissions
- powershift transmissions
- hydraulics
- steering
- differentials
- final drives
- undercarriage components
- air conditioning
- brake systems
- working attachments

Oils

The most commonly used lubricants are:

- engine oil
- gear oil
- hydraulic oil

Engine Oil Functions and Uses

Engine oil must perform a difficult task. It must continue to lubricate despite the high oxidizing conditions, extreme temperatures, and large amounts of contaminants found in internal combustion engines. High-output engines with reduced crankcase capacities and extended drain intervals all contribute to the severe conditions under which oil must perform.

NOTES

Engine oil performs many different functions in order to extend the operational life of the engine and prevent damage. These functions include:

- wear prevention
- engine cooling
- engine cleaning
- cylinder sealing
- control of combustion chamber deposits
- control rust
- control corrosion

Wear Prevention

Wear is caused by metal-to metal contact of moving parts, as well as from acid corrosion, rusting, and from the abrasive action of contaminants carried in the oil. To prevent metal-to-metal contact, engine oil must maintain sufficient viscosity to provide a full fluid film between moving parts under all operating temperatures. The viscosity must not be so high that starting the engine becomes difficult due to the viscous friction caused by thick oil. Note that lower temperatures will make this problem worse as the oil will become even more viscous.

Engine Cooling

Engine 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. Heat is also transferred from the underside of the piston, crown, and skirt to the crankcase. Oil must have good heat conductivity, but at the same time it must also have adequate thermal stability when subjected to high temperatures in order to resist decomposition when in contact with these hot surfaces. This means that it must not evaporate or boil easily.

Engine Cleaning

Over time, oil starts to deteriorate and oxidize. The oxidation causes the formation of harmful contaminants such as acids, varnish, and carbon. The result of this deterioration and oxidation is the formation of sludge; a thick, creamy, black substance that collects in the crankcase. Engine oil must minimize the formation of these contaminants, but when they inevitably form, the oil must keep the contaminants in suspension so that they do not settle inside the engine.

Oil must also act as a cleaning agent, carrying abrasive contaminants to the oil filter.

NOTES

Cylinder Sealing

Cylinder pressures of 1000 kPa (145 psi) in a gasoline engine and 3102 kPa (450 psi) in a diesel engine during cranking are not unusual. Combustion pressures may reach 6206 kPa (900 psi) or higher. Piston rings alone cannot seal off this pressure—they need the help of the oil film between the rings and the cylinder wall.

Control of Combustion Chamber Deposits

The formation of oil deposits in the combustion chamber must be minimal. These deposits decrease the volume of the chamber and increase the compression ratio. This changes the requirement for fuels, since it has effectively changed the combustion process. The deposits may also become "hot spots" that can glow and cause pre-ignition.

Control Rust

Extended periods of engine idling or short trip, stop-and-go driving allow moisture to accumulate in the oil. Also, condensation on engine parts can occur overnight when the engine is not running. An essential function of engine oil is to provide a protective film on engine parts to prevent rusting when the engine is not operating.

Control Corrosion

Products of combustion include corrosive materials (such as acids) that 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.

Gear Oil Functions and Uses

Gear oil is used in enclosed gearboxes to lubricate mechanical transmissions, differentials, final drives, and manual steering gears. In small, simple gear units where tooth pressures are relatively light, mineral gear oil is often adequate.

Gearboxes use splash or a combination of splash and circulating oil pump to help the oil perform its functions.

Wear Prevention

High-speed, high-torque power trains produce high loads on the gear teeth and harder rubbing between mating gears, making lubrication more critical. Unless a good film of fluid is maintained between the mating gear teeth, they will wear and score. Special gear arrangements such as hypoid and worm gears wear very rapidly without the correct gear oil.

NOTES

Component Cooling
Transmissions, differentials, and final drives can get very hot when under constant load. The gear oil must transfer the heat from the gears and bearings to the case and coolers to prevent gear and bearing failures.

Component Cleaning
Gears and bearings will experience some wear over time. This metal must be cleaned from the gears and bearings to prevent further damage.

Sealing
Gearboxes have dynamic seals to hold in the oil and lock out the dirt. The gear oil must lubricate the seal to help provide a leak-proof surface.

Hydraulic Oil Functions and Uses

Hydraulic fluids must:

- transmit power within the actuators
- lubricate pumps and actuators
- transfer heat away from the internal components

Hydraulic oils, used in vehicles and equipment to help lift heavy objects, also help open and close braking mechanisms as well as serving as a medium for heat transfer and lubrication. These hydraulic oil functions happen in boom lifting systems, blade lifting systems, brake systems, automatic transmissions, and steering systems.

Hydraulic oil operates under extreme circumstances so the following properties are essential:

- resistance to oxidation to prevent the formation of acids and sludge
- resistance to absorption of water
- resistance to foaming, since air in the fluid will cause sluggish operation and overheating
- good lubrication qualities to prevent rust and corrosion

To achieve these results, the oil must have additives that will effectively protect the system. These additives include:

- viscosity index improvers to maintain a consistent viscosity over a large temperature range
- oxidation inhibitors to decrease the tendency of the oil to react with oxygen in the air
- extreme pressure additives to improve the ability of the oil to lubricate under high heat and pressure
- corrosion inhibitors to neutralize the acids that form in the oil
- anti-wear (AW) additives to protect the components

Grease Functions and Uses

NOTES

There are several properties that are desirable in a grease:

- It must give impact and sliding protection under a wide range of temperatures.
- It must be able to be pumped at a low temperature to flow into the joints.
- It must be able to stick to metal parts and not flow out of the joints when heated.

The three basic types of greases are:

- high-temperature
- extreme-pressure
- multi-purpose

Uses for High-temperature Greases

High-temperature grease has excellent rust and oxidation inhibiting characteristics, very good water resistance, and good mechanical and shear stability. Furthermore, its adhesive properties prevent it from washing out, pounding out, splattering, or being squeezed out even under the heaviest loads and vibrations.

High-temperature greases work well with bearings that are in high-temperature compartments such as wheel bearings and universal joint bearings.

Uses for Extreme-pressure Greases

Extreme-pressure greases include the extreme pressure protection of molybdenum disulfide. They're well-suited in applications where metal is subject to sliding motion such as hinge pins, boom pins, blade pins, or fifth wheels.

Extreme-pressure grease is used in the mining, logging, and construction industries.

Uses for Multi-purpose Greases

It's common for shops to use a multi-purpose grease to simplify their stock. This minimizes the chance of using the wrong grease. Multi-purpose greases can be used on wheel bearings, steering linkages, chassis, suspension, and universal joints. You must check with the grease's manufacturer to confirm its intended uses.

NOTES

Dry Lubricant Functions and Uses

The three most commonly used solid lubricants are:

- **Graphite**. Used in air compressors, foodstuff industries, railway track joints, open gear, ball bearings, machine-shop works, etc. It's also very common for lubricating locks, since a liquid lubricant allows particles to get stuck in the lock, worsening the problem.
- **Molybdenum disulfide**. Used in CV joints.
- **Tungsten disulfide**. Similar usage as molybdenum disulfide, but due to the high cost, only found in some dry lubricated bearings.

Synthetic Lubricant Functions and Uses

Most manufacturers include synthetic oils in their list of recommended lubricants. Most shops in the northern climate are using some degree of synthetic oils as they offer superior protection for initial start-up and high operating temperatures.

Use of synthetic oil in engines, transmissions, and drive axles can increase component life and the warranty period over that of petroleum-based oil.

There's a whole range of synthetic lubricants available for use in engines, transmissions (standard and automatic), drives axles, hydraulics, and other applications. When selecting a product, ensure that it meets the (OEM) manufacturers' specifications for the vehicle.

Brake Fluid Functions and Uses

Polyglycol Fluids

DOT-3 fluids can be used on drum brakes.

DOT-4 fluids are specifically designed for disc brake systems due to the higher heat developed in the disc brake. DOT-3 and DOT-4 fluids are compatible, but DOT-3 fluid should not be added to a disc brake system.

The heavy-duty and the commercial transport fields prefer a heavy-duty brake fluid such as DOT-4.

Silicone

Because of its high boiling point, silicone brake fluid works well in racing applications as the disc brakes operate at a much higher temperature. In racing applications, the brake fluid is regularly flushed to make sure there's no air or water present. However, silicone brake fluid is not recommended for vehicles with ABS brakes.

Silicone brake fluid should never be mixed with DOT-3 or DOT-4 brake fluids.

Hydraulic System Mineral Oil

Hydraulic system mineral oil (HSMO) is used in large, heavy equipment, such as mining trucks. It's manufactured from petroleum oil with additives. Be sure to check the manufacturer's specification before adding any brake fluid to equipment or vehicles.

Mineral oil is not compatible with any other type of fluid. Mineral oil will corrode and damage rubber components and hoses.

Manufacturer's Specifications and Procedures

When managing a fleet, maintenance is very important. Procedures, schedules, and records are critical. Failing to follow an organized schedule for maintenance will result in increased down time and increased operating expense. Before any maintenance is performed, you should consult the owner's manual, maintenance record, and service manual.

The owner's manual will contain information about oil specifications, recommendations for other fluids, and specifications for replacement parts.

The maintenance manual will provide information about the scheduling of maintenance, which items must be inspected or replaced, and variations for different driving conditions.

Service manuals provide more detailed information about the fluid capacities of various components, such as the capacity of the engine crankcase, as well as recommendations for lifting and towing. In addition, most manuals will detail the procedures for each aspect of maintenance.

NOTES

NOTES

Manufacturer's specifications and procedures can be in electronic or paper form. Electronic form is the preferred method as it's constantly being updated for both new and old equipment. This information includes:

- records of previous maintenance including samples
- oil change procedures
- sampling procedures
- oil and filter change periods
- reservoir capacities
- location of drain plugs
- location of level indicators
- location of filters
- table showing the preferred SAE oil for the given starting temperatures
- table showing the preferred API oil for the given operating conditions

Minimum Requirements

It's important that you understand the minimum requirement for any lubricant on a machine or truck. This information is found in the service/lubrication manuals.

When choosing a new lubricant, you may have to locate a fact sheet. This ensures that the new lubricant meets all the minimum standards, especially the OEM standard. The choice of lubricant will affect all warranty claims.

You may have to contact a manufacturer's representative to confirm the use of any new lubricant.

Warranty Issues

Every manufacturer provides the owner with a maintenance record either as part of the owner's manual or as a separate book. These maintenance records must be completed according to the schedule set out by the manufacturer to maintain warranty requirements and to establish a record of service for each machine. Most companies also establish procedures for service.

Each manufacturer will have a list of steps and documentation that needs to be taken to validate warranty on a machine or truck. Such documentation may include:

- hours on the machine
- hours on the drained oil
- kilometres on the truck
- kilometres on the drained oil
- current oil sample result
- previous oil sample result
- part numbers of any components changed in the system
- the dealer code for identification
- your employee number to validate level of competency

It's important that you locate other information that may affect the warranty or maintenance schedule by checking for updates or technical bulletins issued by the manufacturer. In many cases, these will detail changes to procedures or selection of parts and lubricants.

NOTES

SELF TEST 3

1. What type of oil is most commonly used in equipment final drives?

   a. ATF oil
   b. gear oil
   c. transmission oil
   d. hydraulic oil

2. What type of dry lubricant is commonly use in open gear applications?

   a. molybdenum disulfide
   b. graphite
   c. tungsten disulfide
   d. polyglycol

3. What information may be required to validate warranty issues when dealing with lubricants?

   a. current oil sample result
   b. proposed kilometers on new oil
   c. daily hours of work
   d. operator or driver information

LEARNING TASK 4

Handle Lubricants

Handling and Storage

One of the main functions of a lubricant is to reduce friction and, as a result, reduce wear. If dirt or other contaminants are allowed to contact the lubricant during handling, you're defeating the basic purpose of the lubricant.

Lubricating oil or fluid is usually purchased in sealed containers in sizes ranging from 0.5 litre (1 pint) to 205 litre (45 gallon) drums. These sealed containers can be stored for long periods of time without any danger of contamination. Wherever possible, they should be stored indoors in clean, closed, fire-protected cabinets or rooms.

If drums of oil must be kept outdoors, take special precautions. Seal them tightly and store them horizontally. If they cannot be stored horizontally, tilt them slightly with a block of wood and turn the barrel so that the bungs are positioned at the 3 and 9 o'clock positions away from water, which may collect on the lid.

Make sure that can-openers, pour spouts, funnels, containers, pails, and any other equipment are clean. When adding oil to a crankcase or reservoir, clean all dirt from around the filler cap or plug before it's removed. Do not allow dirt or other contaminants to mix with lubricant.

Vehicles and equipment will have an oil reservoir for each component that requires oil, such as the engine oil pan. You must select the correct oil from the lubrication manual and prepare the method to add oil to the chosen reservoir.

You must always remember that dirty oil will cause damage to the internal parts of any system. Most hydraulic systems require clean oil. Particles must be smaller than 15 microns. Note that the smallest object a human eye can see is approximately 40 microns. This means that you will not always be able to see the contaminants in dirty oil.

The same precautions apply to handling and using grease, especially when they're stored in larger quantities, such as pails or drums. Every time you open the grease container, there's an opportunity for dirt or dust to contaminate the grease.

NOTES

NOTES

Once contaminated, the grease cannot be used and must be disposed of according to regulations. There is no way to filter or remove contaminants from lubricating grease. It's often more efficient to purchase small quantities of grease in sealed cartridges since there's less chance of the grease becoming dirty or contaminated.

Disposal

Lubricants should be disposed of in the same way as cleaning solvents and other liquids. Most municipalities have provisions for the pickup of used or waste oil. Oil must never be drained into sewage systems or dumped on the ground. Oily rags must be disposed of in metal, fireproof waste containers.

When storing waste oils, the shop should have specific waste tanks that hold common types of fluids. For example:

- mineral based oils in one tank
- brake fluids in a separate tank
- anti-freezes in a separate tank

If you're unsure of the disposal procedures for any oil, you need to check the MSDS information sheet for that product and discuss this with the shop authorities.

In addition to lubricants, there are many other hazardous materials that may have their own specific disposal procedures:

- fuels
- anti-freeze
- brake fluid
- refrigerants
- solvent and paint products (and many more)

Use only proper procedures and follow local, provincial, and federal regulations for disposal. The WorkSafeBC Regulation will help with this.

Personal Protection

Personal protection is important when handling lubricants because of the many hazards they present:

- hot oils when draining
- contaminated lubricants
- lubricants may be under pressure
- lubricants may be caustic
- lubricants may give off a dangerous gas

In order to protect yourself from these dangers, you must use appropriate protection for your face, hands, and lungs. Note that some contaminated lubricants may contain chemicals that are cancer causing. Putting your hands into this fluid will expose you to those chemicals. Use proper nitrile gloves when handling any used oils or solvents.

The best way to be sure you're using the correct personal protection is to refer to the MSDS information available in the shop area and discuss this with the shop authorities.

NOTES

SELF TEST 4

1. How should you dispose of used oil?

   a. burn it
   b. pour it down the drain
   c. have it picked up for recycling purposes
   d. re-use it for lubricating less-sophisticated equipment

2. What should you do if you see dirt in a tube of grease?

   a. filter it and re-use it
   b. dig out as much dirt as possible and continue to use the grease
   c. dispose of the entire tube of grease
   d. add more grease to reduce the proportion of dirt to grease

LEARNING TASK 5

Perform Fluid Analysis

Notes

Oil sampling is an important part of any servicing procedure. It helps determine if the service intervals are correct and identifies any foreign materials or fluids in the oil. Oil sampling is a service that provides diagnosis of a lubricant by spectrometer testing.

The spectrometer indicates the amount and identity of microscopic metal particles in the oil. Since these fragments come from specific parts of the equipment or engine, wear patterns of components can be detected and those parts that are near failure can be identified. Such analysis is invaluable in reducing costly equipment breakdown and in setting up preventive maintenance programs.

Used oil analysis can spot wear and contaminants and monitor oil condition in gasoline, diesel, propane, and natural gas powered engines, transmissions, final drives, industrial gearboxes, and hydraulic circulating oil systems. Used oil analysis cuts maintenance costs and increases operating efficiency:

- **Inspects For Wear Without Removing A Bolt**. Used oil analysis conducts spectrometric and physical/chemical tests on customer samples of engine oil, transmission fluid, hypoid gear-lube, hydraulic fluid, industrial gear oil, or circulatory system oil to determine if wear rates in the equipment are excessive.
- **Gets Right Into The Equipment**. Used oil analysis detects tiny amounts of sub-microscopic metal particles. It also identifies the metal (e.g., iron, copper, nickel, aluminum, etc.) from their computer-stored knowledge of similar equipment. Oil analysts are able to signal a problem by relating the amount of metal in the oil to the equipment manufacturer's norms.
- **Extends Service Intervals**. Contamination from fuel, coolant, moisture, and dirt; thickening due to oxidation; and the depletion of additives determine the useful service life of oil. Analysis identifies contaminants and determines the degree of oil deterioration. By constantly monitoring these analyses, you may be able to extend an oil change interval.
- **Reduces Downtime**. Results of analyses can pinpoint many types of trouble early. Abnormal wear in roller-bearings, ball-bearings, sleeve-bearings, piston rings, crank-shafts, and pumps; filter failure; poor engine combustion; and water or anti-freeze leaks can be identified before catastrophic failure occurs.

NOTES

In the spectrometer, an oil sample is burned and the colour of the flame is analyzed. Each element present in the burning oil emits a specific colour and frequency. The spectrometer translates the intensity of this rainbow of colours into a computerized readout. These figures are interpreted to assess wear levels in the equipment.

Seventeen elements are detected and measured in the spectrometer and analyzed by a computer. To simplify the test report, nine major wear metals are reported for industrial oil and twelve wear metals for automotive oil (Table 1).

Other elements indicate contaminants that have entered the lubrication system from the outside, such as sand or glycol. A comparison of metal content in the oil sample with clean oil allows the computer to track wear trends in equipment. Analysis can determine which parts are wearing excessively and can suggest remedial action.

No technical knowledge is required by the customer to use an oil analysis test.

NOTES

Element	Source of Contamination
Aluminum (Al)	bearings, bushes, blocks, pistons, blowers, pumps, clutches, washers, ingested dirt
Barium (Ba)	detergent/dispersant additive
Boron (B)	coolant additive, EP additive
Cadmium (Cd)	coatings on metals
Calcium (Ca)	detergent/dispersant additive, salt water, road salt
Chromium (Cr)	bearings, rings, rollers, liners, exhaust valves, seals, shafts, coolant treatment
Copper (Cu)	bearings, bushes, washers, pumps, gears, AW additive
Iron (Fe)	blocks, bearings, cylinders, pumps, liners, gears, pistons, rings, discs, shafts, valves, screws
Lead (Pb)	bearings, additives
Magnesium (Mg)	hard water, detergent/dispersant additive
Manganese (Mn)	detergent additive
Molybdenum (Mo)	rings, friction modifier, AW additive
Nickel (Ni)	bearings, valves, shafts
Phosphorus (P)	AW additive
Silicon (Si)	seals, gaskets, ingested dirt, coolant additive, antifoaming additive
Silver (Ag)	bearings, bushings, solder
Sodium (Na)	coolant additive, road salt, detergent additive
Tin (Sn)	bearings, bushings, pistons
Titanium (T)	turbine blades, compressor discs, bearing hubs
Vanadium (V)	valves, coating on metals
Zinc (Zn)	AW/inhibitor additive

Table 1. Oil Contaminants

A used oil analysis service is important in any preventive maintenance program. The benefits of used oil analysis include:

- reduction of major repairs by detecting problems early, providing ample time for the convenient scheduling of required maintenance before significant damage or component failure occurs
- elimination of premature oil replacement by establishing the correct service intervals under all operating and environmental conditions, resulting in reduction of service cost

NOTES

- reduction of expensive, unscheduled down-time caused by unexpected component breakdown, allowing for better utilization of equipment, maintenance resources and personnel
- increased equipment trade-in value by knowing when to dispose of existing equipment
- evaluation of used equipment sale or purchase, since oil sample records will indicate internal condition
- accurate tracking of warranty problems, since data can be provided in support of warranty claims
- evaluates new products and can play a key role in assessing the performance of lubricants, air cleaners, or oil filters

Procedure

The oil sample must be taken in a manner that will prevent sample contamination. Oil samples are usually taken over several oil changes, and you'll observe patterns and watch for sudden changes in particular elements. The spectrometer will measure in parts per million (ppm) and a high count could be a false reading and indicate a false problem.

The procedure for taking an oil sample as follows:

1. Oils should be up to operating temperature.

2. Decide on a method to sample:

   Method 1: drain the hot reservoir oil and scoop a mid stream sample in the bottle.

   Method 2: Use a suction gun and draw a hot sample from the reservoir.

   Method 3: Use a sample quick-connector-kit located in a pressure port and allow a sample of hot oil to flow into the bottle with the engine running. (This is the preferred method as there is less chance oil contamination.)

3. Once the oil is in the bottle, it must be sealed and the sample information sheet filled out. The information sheet and oil sample is sent to the lab for testing.

Never take oil samples from filters, filter housings, or the bottom of reservoirs as this oil is contaminated.

Safety

Safety is always a concern when working around equipment. You should always follow the proper lockout procedures before performing an oil sampling. You should always wear face and hand protection while sampling hot/caustic oil.

Reports

A used oil analysis kit usually contains a bottle, wrapper, mailing carton, and an information sheet to be filled out by the customer. A 50 ml sample of oil is mailed to the testing laboratory. The test report is either mailed within 24 hours, or the customer is called immediately if an emergency situation is detected from the tests. Some of the tests performed are shown in Table 2.

You should review the oil additives on the sample report as this is an indication for oil change periods. The report should indicate that the additives are still in the oil. You should also review the section on the report that lists the element count and compare the numbers to the machine's specifications.

Tests	Conditions Detected							
Basic	**Abnormal Wear**	**Fuel Dilution**	**Dirt**	**Water**	**Coolant**	**Incorrect Oil**	**Oxidation**	**Additive Depletion**
Glycol Test[2]					•			
Viscosity		•				•		
Appearance/ Odour[4]		•	•	•	•		•	
Spectrometric Analysis[3]	•		•		•	•		
Secondary[1]								
Alkaline Reserve (TBN)						•		•
Blotter Spot Test			•	•			•	
Water Content				•				
Distillation		•						
Flash Point		•						

Notes

[1] Carried out only as necessary, dependent on base test results.
[2] Carried out on engine oils only.
[3] Up to thirteen (13) trace elements reported.
[4] Gross contamination detected visually. Damaging levels of dirt can be suspended in the oil without altering its appearance. Spectrometric analysis required to detect such levels.

Table 2. Materials Found in an Oil Sample

Oil Analysis Results

Shop Job Number: _____

Segment Number: _____

Customer P.O. Number: _____

Sample Label Number: 364191

Sample Data

Sample Number	Taken Data	Process Date	Label Number	Comp hr.	Oil hr.	Overall Eval.
290505072	01/01/01	01/01/01	364191	1000		NAR

Overall Evaluation Codes:

AR = Action Required
MC = Monitor Compartment
NAR = No Action Required
NC = No Comment

Wear Elements (Parts Per Million)

Si	Fe	Al	Cr	Ni	Cu	Pb	Sn	Ag	Mg	Mo	Na	B	Zn	Ca	Ba	K
9	20	4	4	1	65	26	9	0	615	1	34	102	1162	870	1	8

Oil Data

Sample Number	Oil Brand	Oil Weight	Oil Added	Oil Change
290505072	XXXX	5W30		Yes

Oil Condition/Contaminants

OXI	NIT	V100
18	18	8.2

Evaluations & Recommendations

290505072: For Normal Oil Service: Copper reading only slightly elevated above the acceptable range. Inspect oil filter(s) for evidence of larger visible debris. Other readings appear to be normal. Check operation.

LEGEND

Si – Silicon	Cr – Chrome	Pb – Lead	Mg – Magnesium	B – Boron	W – Water	ST – Soot
Fe – Iron	Ni – Nickel	Sn – Tin	Mo – Moly	Zn – Zinc	F – Fuel	Oxi – Oxidation
Al – Aluminum	Cu – Copper	Ag – Silver	Na – Sodium	Ca – Calcium	A – Antifreeze	Sul – Sulphation
						Nit – Nitration

V100 – Viscosity at 100°C V40 – Viscosity at 40°C

Figure 1. Engine Oil Sample Report

Analysis Guide

Combinations of Classic Wear Elements

	Primary Element	Secondary Element	Potential Wear	Probable Problem Area/ Causes
Engines – Top End	Silicon (Dirt)	Iron, Chrome, Aluminum	Liners, Rings, Pistons	Air induction System/ Filter Dirt Contamination
	Iron	Chrome, Aluminum	Liners, Rings, Pistons	Abnormal Operating Temps., Oil Degradation, Fuel and/or Coolant Contamination, Stuck/ Broken Rings
	Chrome	Molybdenum, Aluminum	Rings, Pistons	Blowby, Oil Consumption, Oil Degradation
	Iron		Liners, Gears, Valve Train, Crankshaft	Abnormal Operating Temperature, Lack of Lubrication, Contamination, Storage (Rust)
Engines – Bottom End	Silicon (Dirt)	Lead, Aluminum	Bearings	Dirt Contamination
	Lead	Aluminum	Bearings	Lack of Lubrication, Coolant Contamination, Fuel Contamination

Oil Additives Used to Identify Oil Type			Coolant Additives	
Zinc	Calcium	Boron	Sodium	Boron
Barium	Magnesium		Potassium	

Suggested Safe Wear Levels (expressed in parts per million)

Diesel Engines	Silicon (Dirt)	5–20	Copper	10–30
	Iron	10–80	Sodium	10–50
	Chromium	2–10	Lead	5–30

Note: These charts are for general use only and do not indicate definite limits of wear metals for any specific make or model. Wear patterns are best established after evaluation of three samples taken at the same oil change intervals. Make, model, application, age, makeup oil added, time of use of recent repairs can cause the values to vary greatly from those shown. Values are given in parts per million (PPM).

Figure 2. Analysis Guide

SELF TEST 5

1. What is the preferred method to capture an oil sample?

   a. scoop a mid stream sample
   b. suction gun through dip stick tube
   c. quick connector kit and sample with engine running
   d. drain filter housing

2. What basic test will report 13 trace elements?

   a. Appearance/odor test
   b. Spectrometric analysis test
   c. Blotter spot test
   d. Viscosity test

COMPETENCY A-11
SERVICE BEARINGS AND SEALS



HEAVY MECHANICAL TRADES:
LINE A—COMMON OCCUPATIONAL SKILLS

Goals

When you have completed the Learning Tasks in this Competency, you will be able to:

- describe bearings
- describe types of loads
- describe removal procedures for bearings
- describe inspection procedures for bearings
- describe bearing storage
- describe installation procedures for bearings
- describe bearing adjustments
- service bearings
- identify seals
- describe the function of seals
- describe the procedures for seal service
- describe the analysis of seal failure
- describe removal and installation procedures
- describe the use of speedi-sleeves
- service seals

LEARNING TASK 1

Describe Bearings

Notes

Bearings are used extensively in equipment and machinery and are constructed differently depending on their application, from supporting transmission shafts and gears to supporting wheels and engine components. In all cases, bearings provide support to moving components and reduce friction.

Purpose for Bearings

Without bearings, friction would reduce efficiency, create high heat, and cause damage. Bearings must:

- support loads
- align and guide shafts
- reduce friction
- reduce wear
- provide a replaceable wear surface

Types of Loads

Bearings support loads imposed on moving parts by carrying the forces which act on the moving parts. These loads can be radial, axial, or angular. Each of these loads will require a different type of bearing to support the shaft or device properly.

Radial load occurs when the force occurs at right angles to the shaft (Figure 1). This type of load pushes down on the bearing. A load that is parallel to the shaft is called an axial load (thrust) and pushes sideways on the bearing (Figure 1).

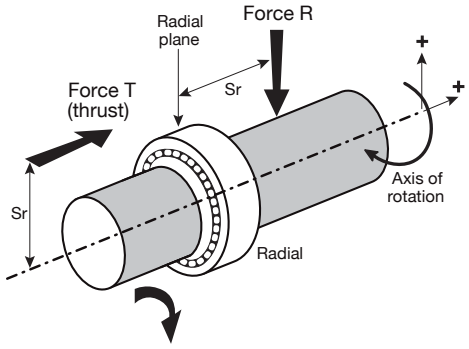


Figure 1. Radial and Axial Loads

NOTES

If the load combines an axial load and a radial load, it is called an angular load and will exert force on the bearing as shown in Figure 2. This load is diagonal to the shaft.

La = Load axial
Lr = Load radial
L = Load diagonal
R = load diagonal

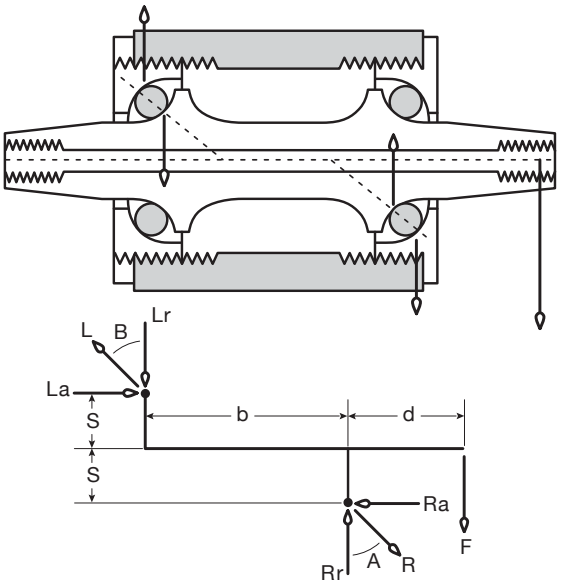


Figure 2. Axial, Radial, and Diagonal Loads

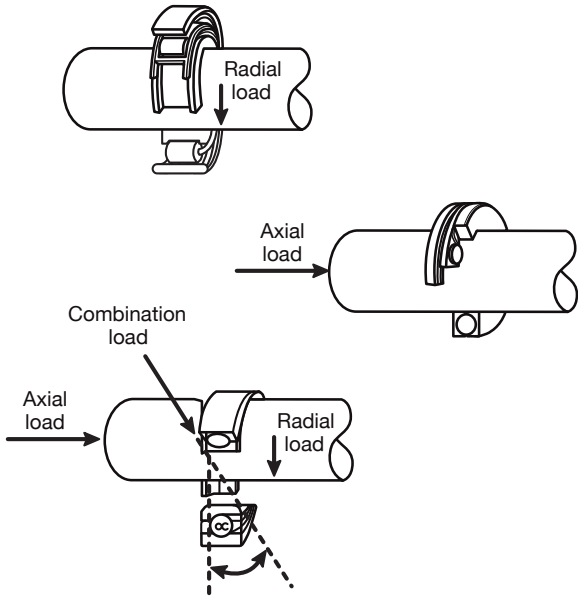


Figure 3. Axial and Radial Loads

NOTES

Types of Bearings

Bearings must support a variety of different loads in different situations, so there are also variations in the construction of bearings. There are two different bearing designs:

- friction (bushings)
- anti-friction (rolling elements)

Friction bearings provide a sliding contact between the bushing and shaft while anti-friction bearings contain rolling elements to reduce friction.

Friction Bearings

Friction bearings are divided into two main categories:

- full round
- two-piece

Friction bearings work well in high-impact locations such as undercarriage components. Friction bearings are primarily designed for radial loads (Figure 4).



Full Round Bushing

Two-piece Bushing

Figure 4. Friction Bearings

Anti-friction Bearings

Anti-friction bearings are constructed with different characteristics because of the wide variety of applications and load-carrying requirements. Bearings are categorized according to their construction. The three types of anti-friction bearings are:

- ball bearings
- roller bearings
- needle bearings

NOTES



Ball Bearing



Roller Bearing



Needle Bearing

Figure 5. Anti-friction Bearings

Any bearing which has moving parts is called an anti-friction bearing, since it is the most efficient at reducing friction. Anti-friction bearings all have the same basic parts:

- the outer race
- the inner race
- the rolling elements (balls, rollers or needles)
- the separator (or cage)

NOTES

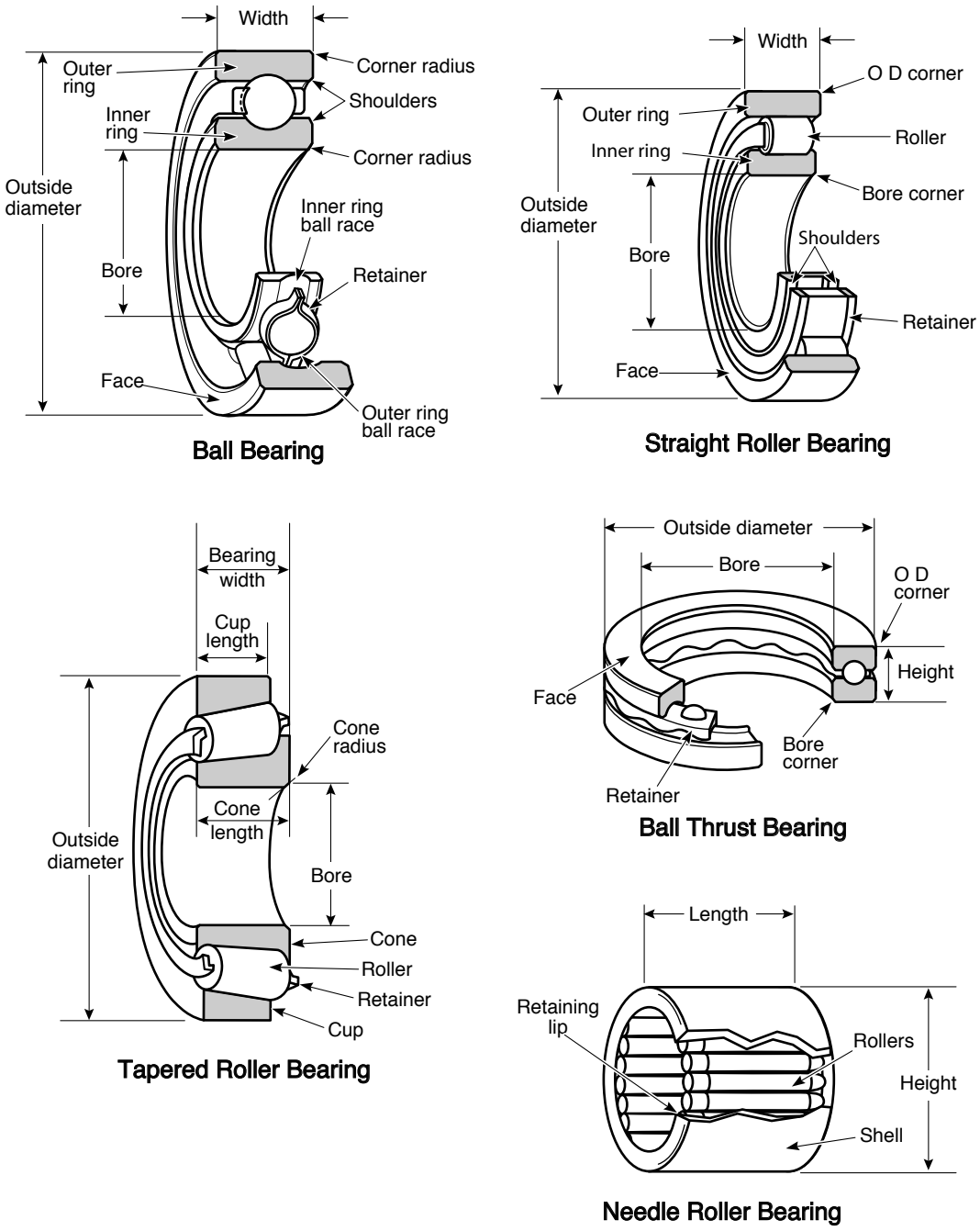


Figure 6. Rolling Bearing Features and Terminology

NOTES

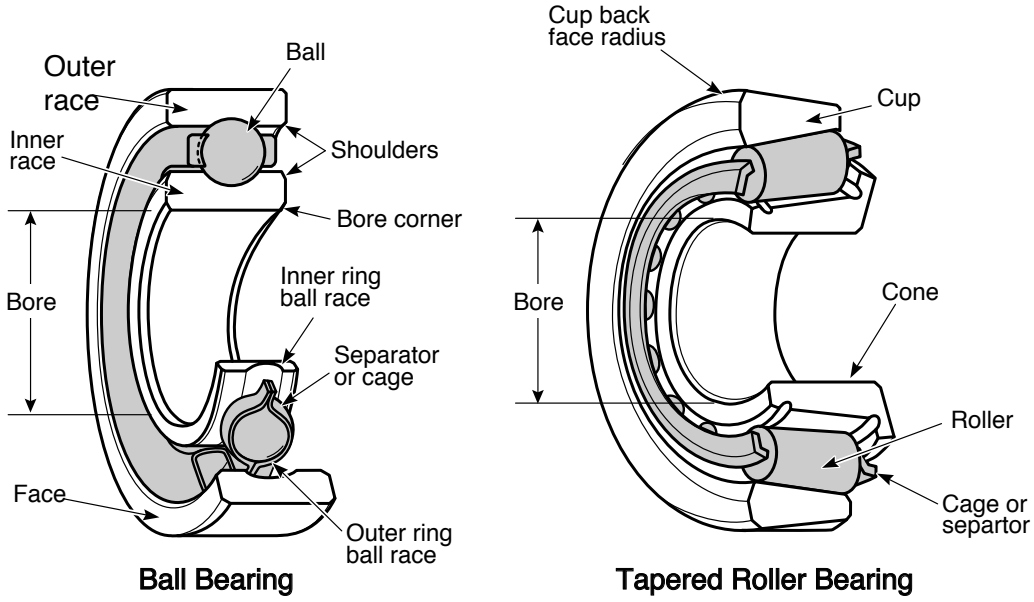


Figure 7. Bearing Parts

Bearing Parts

The inner race sits directly on the shaft and provides a surface for the rolling elements to rotate on. The inner race may be slightly larger than the shaft to provide a push/slip (non-interference) fit or may be slightly smaller than the shaft to provide a press (interference) fit.

Bearing races that are press fit will rotate with the shaft, while bearings that have a push/slip fit may creep slightly as the shaft rotates. If the bearing is too loose, it will creep too much and cause damage to the shaft and inner race. Wheel bearings normally use a slip fit to the spindle to accommodate bearing creep.

The outer race may be press fit or push fit and provides another surface on which the bearing elements can rotate. These two surfaces, the inner and outer race, provide the support for the rolling elements.

The rolling elements must have sufficient clearance to allow rotation without heat build-up, which can occur if they are too tight. The space between the elements will determine how much the inner and outer races will move in relation to each other. This movement is the clearance in the bearing. Ball bearings do not need much clearance for operation.

Bearings may also have snap rings in a groove around the outer race to properly locate them in a housing, a shield to cover the rolling elements to prevent dirt and contamination from entering, or a seal to keep in lubricants (Figure 8).

NOTES



Snap Ring Groove Shielded Sealed

Figure 8. Snap Ring, Shielded, and Sealed Bearings

Ball Bearings

Ball bearings are designed to support loads through the areas that contact the races. As each of the balls takes the load and releases it, they tend to create their own internal friction, causing heat and wear. Because of this internal friction, proper lubrication is very important to reduce rolling friction to a minimum and reduce distortion. The four basic ball bearing race designs are:

- Conrad®
- full bearing
- split race
- angular contact

Conrad Bearings

Conrad bearings have a relatively small number of balls held in place at even intervals by a cage (Figure 9). It's assembled by placing the inner race into an off-center position relative to the outer race, with the two races in contact at one point, resulting in a large gap opposite the point of contact. The balls are inserted via this gap and then evenly distributed around the bearing assembly, causing the races to become centered. A cage is then fitted which maintains the balls' relative positions. Without the cage, the balls would eventually drift out of [illegible]e bearing to fail. The cage carries no load and serves only to maintain ball position.

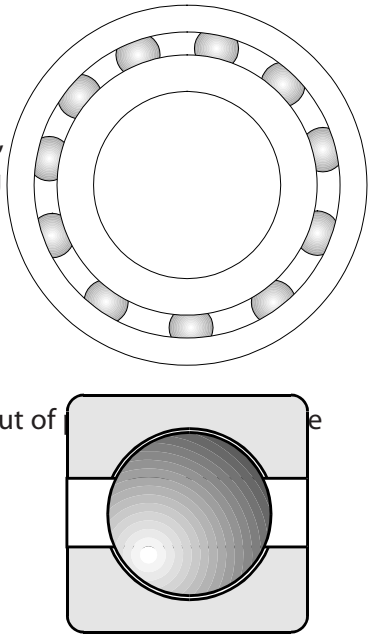


Figure 9. Conrad Bearings

NOTES

Conrad bearings have the advantage that they are able to withstand both radial and axial loads, but have the disadvantage of lower load capacity due to the limited number of balls that can be loaded into the bearing assembly. Probably the most familiar industrial ball bearing is the deep-groove Conrad style. The bearing is used in most mechanical industries.

Full Bearings

Full bearings feature a loading slot that allows the balls to be inserted between the races (Figure 10). They're only used for radial loads because the loading slot reduces the ability to carry axial loads.

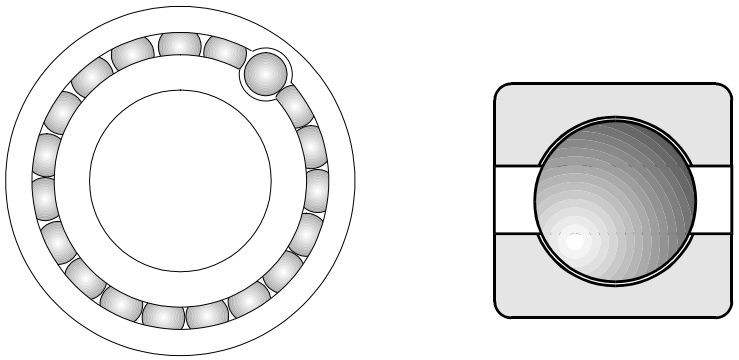


Figure 10. Full Bearings

Split Race Bearings

These bearings can take high axial loads due to the high shoulders on the races and because they can carry more rolling elements. This allows for ease of assembly.

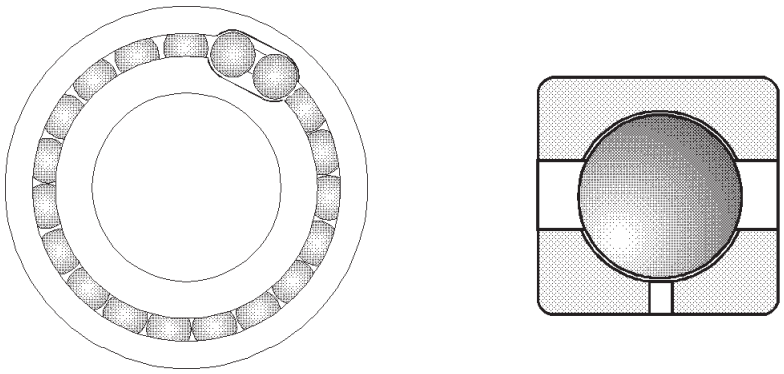


Figure 11. Split Race Bearings

NOTES

Angular Contact Bearings

These can accept both axial and radial loads, and will take axial loads in both directions (Figure 12).

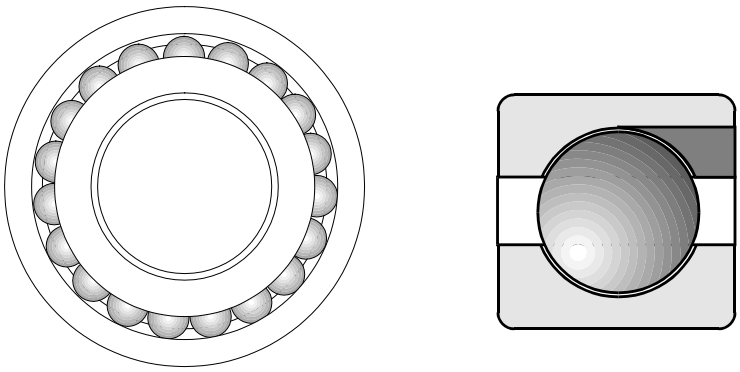


Figure 12. Angular Contact Bearings

Roller Bearings

Roller bearings support loads differently than ball bearings. These bearings can be separated into three basic categories:

- straight rolling elements
- spherical rolling elements
- tapered rolling elements

Straight Roller

Straight rolling elements are cylinders with the sides parallel to each other (Figure 13). Cylindrical roller bearings are used exclusively for radial loads and are not capable of handling axial or angular loads without damage.



Figure 13. Straight Rolling Elements

NOTES

Spherical Roller

Spherical roller bearings use rollers that are thicker in the middle and thinner at the ends; the race is shaped to match. Spherical roller bearings can adjust to support misaligned loads. However, spherical rollers are difficult to produce and expensive. They also have greater friction than a comparable ball bearing since different parts of the spherical rollers run at different speeds on the rounded race (Figure 14). These bearings are designed to handle radial loads with minimal axial loading.



Figure 14. Spherical Bearing

Tapered Roller

Tapered roller bearings can handle radial and axial loads in any combination. The bearing shape allows the elements to align perfectly between the two races without requiring any control from a cage and is held in place by a rib on the inner race (Figure 15).

Because of the shape of the rollers and the angle of the races, the bearings all share the load equally, providing excellent load support.



Figure 15. Tapered Roller Bearing

Tapered bearings must always be used in conjunction with another tapered bearing facing in the other direction so that thrust loads can be carried in both directions.

The inner and outer races of the bearing are normally separated as two separate components, with the rolling elements held in place on the inner race by a loose cage that will contain them when the bearing is apart, but will not interfere with the operation when the bearing is in motion.

The inner race and roller assemble is called the cone. The outer race is called the cup (Figure 16).

Tapered bearings are used in wheel hubs, on axle shafts, in transmissions, and in differentials. They're available in single and double row styles.



Figure 16. Cup and Cone

NOTES

Needle Bearings

Needle bearings are basically roller bearings with very small diameter rollers (Figure 17A). Needle bearings can be used in tight places because they're very compact. This type of bearing is capable of carrying large loads. In some applications, a hardened shaft or housing bore may be used as the needle bearing's inner or outer race. Needle bearings are divided into two types, thrust bearings and radial bearings. The axial needle bearing shown in Figure 17B has two hardened steel races on which the needle bearings rotate. These axial needle bearings work well between gears and housings. This protects the housings from the gears rubbing against them.



A. Radial B. Axial

Figure 17. Needle Bearings

Bearing Applications

It's important that you understand the various types of bearings and their applications. You must know how to handle, store, remove, inspect, install, adjust, and lubricate the many different types. Common applications include:

- Engines—full and split bushings, ball bearings.
- Clutches—ball bearings.
- Transmissions—ball bearings, needle bearings, straight roller bearings, tapered roller bearings.
- Drive shafts—ball bearings, needle bearings.
- Differentials—ball bearings, tapered roller bearings.
- Final Drives—ball bearings, straight roller bearings, tapered roller bearings.
- Wheel—ball bearings, tapered roller bearings.
- Hydraulics—bushings, ball bearings, roller bearings, needle bearings.
- Undercarriage—bushings, ball bearings, tapered roller bearings.
- Attachments—bushings, ball bearings, tapered roller bearings.
- Linkages and controls—bushings, needle bearings.

SELF TEST 1

1. How will bearing races with a press fit behave?

   a. rotate with the shaft
   b. creep on the shaft
   c. provide a higher load capability
   d. eliminate the need for a cage

2. What loads are full ball bearings mainly designed to support?

   a. radial load
   b. axial load
   c. angular load
   d. transverse load

3. What is one feature of tapered roller bearings?

   a. the races are sealed together
   b. the races have a different taper from the rolling elements
   c. they can only handle radial loads effectively
   d. the inner and outer races can be separated

4. What is the best ball bearing for supporting radial and axial loads?

   a. full type
   b. conrad type
   c. split race type
   d. angular contact type

5. What type of bearing would be used on an engine crankshaft?

   a. needle
   b. anti-friction
   c. friction
   d. ball

LEARNING TASK 2

Select and Service Bearings

NOTES

Bearing Removal

Bearings must be removed carefully to prevent damage. Correct removal procedures use an arbor press, hydraulic press, or puller. It's important to select a tool that will provide the right support for the bearing race. This is determined by the location of the bearing, how much force will be needed to remove it, and how well the bearing can be gripped.

When using a press, never apply force to the unsupported race or rolling elements. For instance, if a bearing is pressed on a shaft, you must support the bearing on the inner race, since it is the pressed-on race (Figure 1). Force can be applied smoothly and steadily to the shaft to remove the bearing.

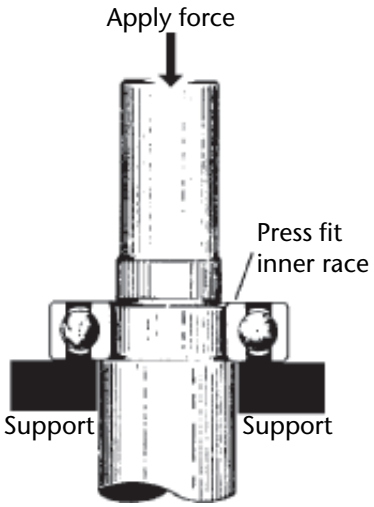


Figure 1. Guillotine Supporting the Inner Race

NOTES



Figure 2. Portable Pullers for Bearing Removal

You must never pry, heat, or directly hammer on the bearing as you may damage the component, shaft, or the bearing itself.

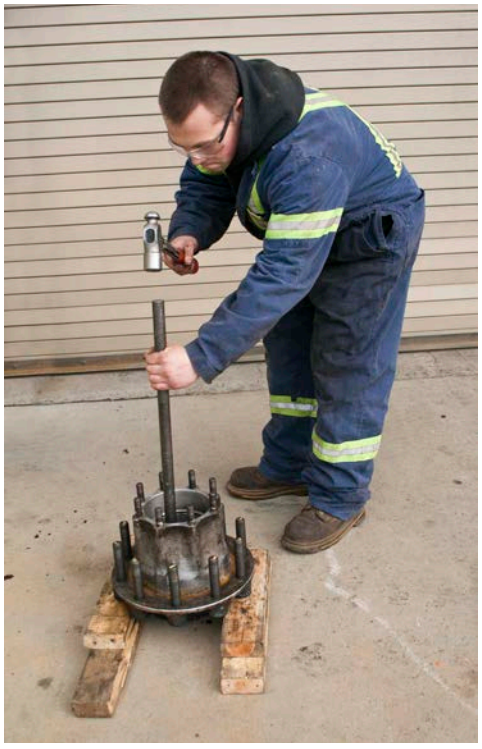


Figure 3. Mild Steel Punch for Bearing Removal

A mild steel punch may be used for bearing removal as shown in Figure 3. The mild steel punch will not damage the bearing as the mild steel is softer than the bearing race. Never use a hard steel punch for bearing removal or installation,

as it will chip the bearing race. You must always be very careful not to damage the bearing cage or the housing holding the bearing when using a punch and hammer.

Do not use a brass punch to install bearings as the brass may chip, potentially contaminating the bearing.

NOTES

Cleaning Bearings

Bearings must be cleaned in solvent and brushed clean with a non-metallic brush. Do not allow bearings to rest on the bottom of solvent containers. Filings and debris may have settled which can contaminate the bearing.

Bearings with a shield on one side can be cleaned in the same manner as open bearings. However, if the bearing has a seal on both sides, it should never be washed in solvent. Wipe off the outside of the bearing and rotate it carefully while feeling and listening for possible internal problems.

When the bearings have been washed, they should be rinsed in clean solvent to remove any remaining contaminants. Solvent should be dried from the bearing, including all internal rolling components. Natural air-drying is preferred, but clean, dry, compressed air can be used to blow out the solvent and contaminants.



Never spin the bearings with compressed air, as they can seize or disintegrate at high speed, sending parts flying in all directions. When you use compressed air, always wear approved safety equipment.

Bearing Inspection

Bearings should be checked carefully for damage. Look for damage such as:

- brinelling
- seizing
- contamination
- electric arc
- peeling
- corrosion
- misalignment
- spalling
- galling (discolouration)

Any of these are an indication of overload, poor lubrication, incorrect adjustment, contamination damage, or premature failure.

NOTES

Brinelling

Brinelling occurs as a direct result of hammering on the bearing. This hammering (shock loading) can be a result of improper adjustment, allowing the outer race to strike the rolling elements. The result is an indentation in the races that may be difficult to see and will result in corresponding indentations in the rollers (Figure 4). If left in operation, the bearing will produce deeper cuts and will eventually fail.



Figure 4. Brinelling

Seizing

Seizing is caused primarily by incorrect lubrication. When the bearing is first installed and placed in operation, any failure of the elements to rotate will result in high heat and friction. This seizing often seriously damages or destroys the bearing and may result in damage to the corresponding shaft (Figure 5).



Figure 5. Bearing Seizure

NOTES

Contamination

The races and rolling elements of the bearing will be scratched, pitted, or scored as a result of hard contaminants in the lubricant. Defective dust shields and seals allow dirt and other particles to enter the bearing. As the rolling elements move on the races, the particles are pressed into the metal, causing damage. Improper cleaning procedures can also cause damage from contamination. Fine particles of dirt will give the bearing surface a frosted appearance.

Electric Arc

Any electric current passing through a bearing will cause immediate damage. Even small amounts of current can cause pitting, burning, and grooving. Improper welding techniques (including a poor ground location) are the most common causes of arc damage (Figure 6).

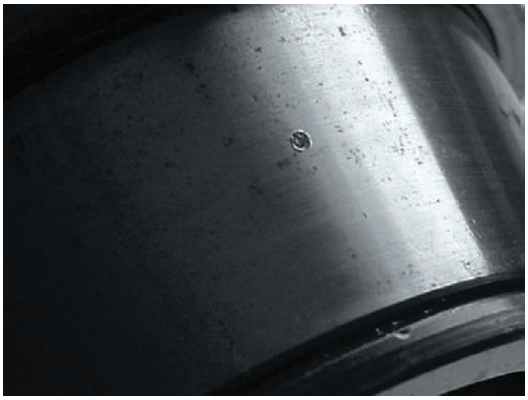


Figure 6. Electric Arc Damage

Peeling

Some peeling of the bearing surface during operation is normal. This peeling is usually superficial and does no damage to the bearing. Excessive peeling can be caused by improper lubrication or poor alignment of the shaft and bearing. Excessive peeling will scrape away the surface of the bearing and race resulting in damage to the bearing and rapid failure.

NOTES

Corrosion

Corrosion damage is normally caused by seal failure resulting in water entering the bearing cavity. Note the rust marks on the spindle in Figure 7.



Figure 7. Bearing Corrosion

Misalignment

Misalignment results in improper loading of the rolling elements and a concentration of the load on a narrow portion of the bearing. This load distribution will result in rapid failure of the bearing due to excess friction that spalls the rolling elements. Note the uneven pattern on the inner race in Figure 8.

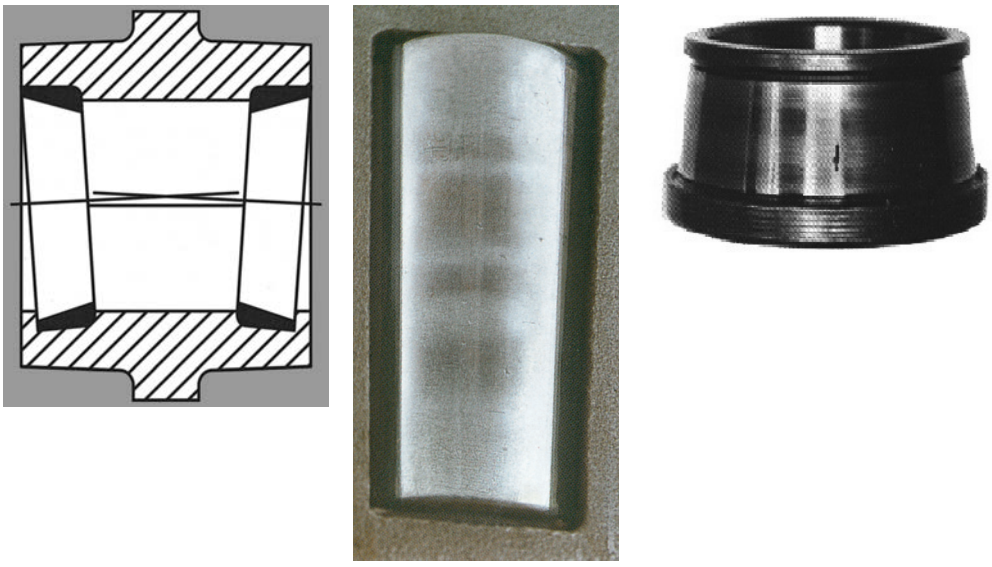


Figure 8. Misalignment

NOTES

Spalling

Spalling can be caused by normal wear or by abnormal wear problems such as brinelling, fretting, misalignment, or excessive loads. The problem begins as small fractures in the surface of the races and rolling elements. This results in metal flaking away, leaving rough, pitted surfaces. The end result is rapid bearing failure accompanied by vibration and noise. Note the rough surface in Figure 9.



Figure 9. Spalling

Galling (Discolouration)

Galling is caused by a lack of lubrication. The bearing starts to turn blue from concentrated heat and eventually experiences a complete meltdown (Figure 10).



Figure 10. Galling

Bearing Storage and Lubrication

When bearings have been cleaned, dried, and inspected, they must be correctly stored to prevent rust, contamination, and damage. You must select the correct lubricant as indicated by the manufacturer for the particular type of equipment. For example, a wheel bearing must be packed with the recommended wheel bearing grease, while a transmission bearing might be lubricated with gear oil.

NOTES

When packing bearings with grease, you must make sure that the grease is forced between the rolling elements, the cage, and the races so that all areas are filled with the lubricant. Bearings can be packed by hand by forcing the grease past the rolling element until it appears on the opposite side. Automated packers can be used to force grease into the bearing, but the job should always be checked carefully to make sure that all areas have been filled.



Figure 11. Packing a Bearing by Hand



Figure 12. F Automated Bearing Packer

Never mix gear oils with motor oils or use motor oil as a lubricant in place of gear oils. Motor lubricants do not have the extreme pressure capabilities of quality gear oil.

Never apply excessive amounts of grease into housings or bearings. More is not better, as excess grease can be forced out during operation and damage seals or other components that are not compatible with the grease.

If the bearing is not to be used immediately, you should wrap it in waterproof paper and store it in a clean, dry place until it's required. If the bearing is new, never wash the protective grease from it until you are ready to use it, as the lubricant prevents rusting and corrosion. Always store bearings so that they are lying flat.

NOTES

Bearing Installation

Bearing installation must be done carefully to avoid any damage to housings, shafts, or to the rolling elements and races. In addition, seals can be damaged or cut and this damage may not become evident until lubricants begin to flow past them.

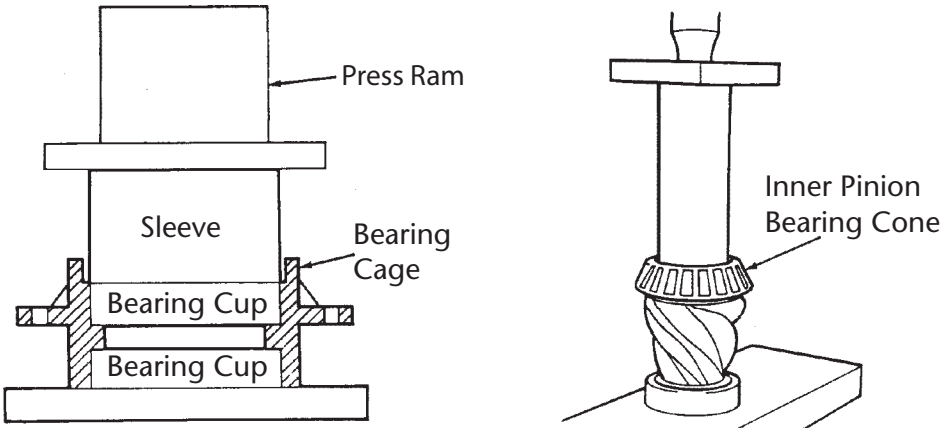
There are three basic types of bearing fits:

- **Interference Fit**: The shaft is larger than the bearing by approximately 0.304 mm (0.012 inch). This requires pressing tools to install the bearings on the shaft.
- **Tap Fit**: The shaft or housing is the same size as the bearing. The bearing can be tapped onto the shaft or into the housing with a rubber mallet.
- **Slip Fit**: The shaft is smaller than the bearing and the technician can slip the bearing onto the shaft with his hands. This will accommodate bearing creep.

Arbor presses, hydraulic presses, or a portable press can be used to install press fit bearings. You must press only on the race that makes contact with the shaft or housing. Make sure that the shaft or housing is correctly supported to prevent damage. Make sure that the bearing is pressed solidly against any locating shoulders in housings or on shafts and that the shaft or housing is clear of nicks, cuts, and damage prior to installation.

NOTES

The use of hammer and hard punch is not recommended as the bearings will dent and there is a risk of hitting the bearing cage. If a hammer and punch are your only option for installation, use a piece of round stock mild steel. Never use a brass punch to install bearings, as the brass can flake off into the bearings. Note the sleeve being used with the press in Figure 13.



(courtesy Ford Motor Company of Canada)

Figure 13. Hydraulic Press and Sleeve

To assist with bearing installation, you can heat the bearing in an approved heating device, or you can cool the shaft so that the bearing is easier to install. Never heat a bearing directly with a torch or other heater as this will damage the rolling elements and the race surfaces. Bearings may be heated with:

- induction heaters
- oil bath heaters
- oven heaters

NOTES



Figure 14. Induction

Do not exceed 121°C (250°F) when heating bearings or damage will occur.

Bearing Adjustments

Bearing adjustment must be made according to the recommendations of the manufacturer of the equipment on which the bearings are being used. Incorrect adjustment can cause premature bearing failure, which can also lead to expensive damage to other components.

All tapered roller bearings and some split race ball bearings require adjustments.

The three primary ways to make these adjustments are:

- changing shims on the shaft or covers
- changing spacers on shafts
- tightening an adjusting nut

It's important to know that an adjustment is correct. The primary methods to confirm adjustments are:

- Using a torque wrench to measure the rotating effort.
- Using a spring scale to measure the rotating effort.
- Using a dial indicator to measure the amount of movement.

Manufacturers' recommended bearing adjustments may be anything from a slight pre-load to a slight endplay or clearance. It's important to use the service manual to ensure the bearing adjustment is not too tight nor too loose.

NOTES

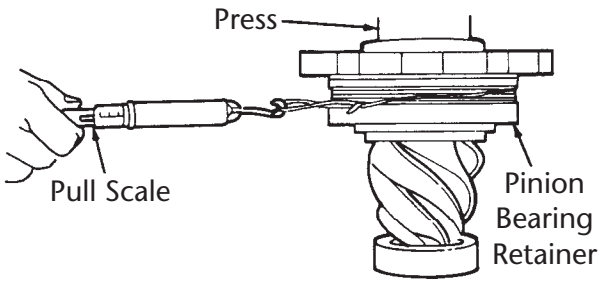
Bearing Pre-load

Pre-load means the bearing rolling elements are squeezed between their races. This puts a small load on the rolling elements before the machine is put to work. This is required in some areas to hold shafts and gears in perfect alignment.

Bearings can be adjusted to have no pre-load, but also no shaft or gear movement (i.e., no endplay). This setting is usually used when setting up proper bearing adjustments.

Bearings can be adjusted to have no pre-load, but also have endplay in the shaft and gears. This adjustment may prevent the bearings from overload when they start working.

One method of bearing pre-load adjustment uses a pull-type spring scale to measure the amount of force required to roll a bearing loaded in a press (Figure 15). In this instance, bearing pre-load is adjusted with spacers between the bearings.



(courtesy Ford Motor Company of Canada)

Figure 15. Measuring the Pinion Bearing Pre-load

Wheel Bearing Adjustment

Wheel bearing adjustments must be done according to the manufacturer's specifications. This will ensure long bearing and seal life. Bearings must be lubricated with the correct lubricant before adjustment and lubricant level must be kept within specifications.

For example, front and rear wheel bearing adjustments might be as follows:

Front wheel bearing adjustment specifications: 0.0254–0.127 mm (.001" to .005") endplay after adjustment. The following steps obtain this clearance:

1. Torque the front wheel bearing adjustment nut to 136 N•m (100 lb ft) while rotating the wheel to seat the bearings.

2. Back off the adjusting nut 1 turn.

3. Re-torque to 27 N•m (20 lb ft) while rotating the wheel.

4. Back off adjusting nut ⅓ of a turn.

5. Install and torque jam nut.

    i. Jam nuts less than 2⅝ in. (6.66 cm): torque to 271–407 N•m (200–300 lb ft).
    ii. Jam nuts more than 2⅝ in. (6.66 cm): torque to 339–542 N•m (250–400 lb ft).

    Note: Different styles of lock nuts may require different torque specs.

6. Measure endplay with a dial indicator.

Rear wheel bearing adjustment specifications: 0.0254–0.127 mm (.001" to .005") endplay after adjustment. The following steps obtain this clearance:

1. Torque the rear wheel bearing adjustment nut to 136 N•m (100 lb ft) while rotating the wheel to seat the bearings.

2. Back off the adjusting nut 1 turn.

3. Torque adjusting nut to 68 N•m (50 lb ft) while rotating the wheel.

4. Back off adjusting nut ⅓ of a turn.

5. Install and torque jam nut.

NOTES

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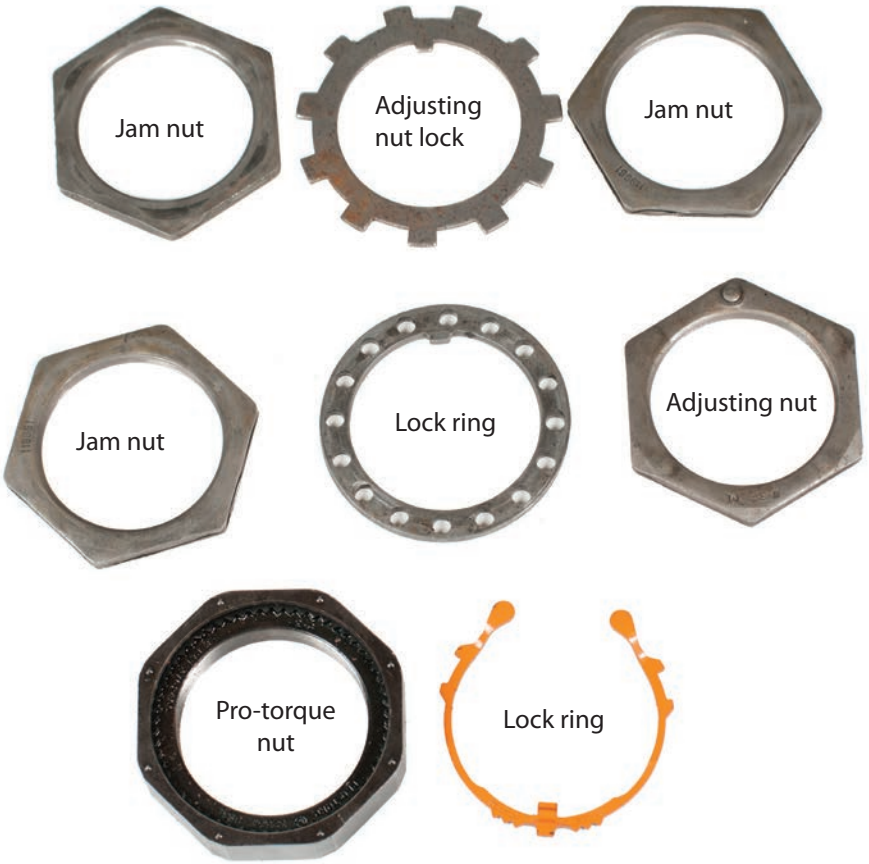

Figure 16. Adjusting Nut Configurations



Figure 17. Torquing Wheel Bearing Adjusting Nuts

SELF TEST 2

1. Which tool is used to check shaft endplay?

   a. feeler gauges
   b. dial indicator
   c. feel by hand
   d. micrometer

2. A technician is measuring preload on a pinion bearing.

   He measures 5 pounds on the spring scale, and 10-inch diameter on the hub.

   What is the preload setting?

   a. 50 inch pounds
   b. 10 inch pounds
   c. 15 inch pounds
   d. 25 inch pounds

3. What condition causes spalling?

   a. overload
   b. lack of lubrication
   c. assembly
   d. electric current

4. What condition causes brinelling?

   a. overload
   b. lack of lubrication
   c. assembly
   d. electric current

LEARNING TASK 3

Describe Seals

Notes

Seals are used to:

- retain lubricants
- exclude contaminants
- hold pressure
- hold vacuum
- isolate two fluids
- protect seals and shafts

Types of Seals

Seals retain fluids, exclude contaminants, or perform a combination of these tasks depending on how they are constructed and installed. Seals are designed for two different applications:

- static
- dynamic

Static Seals

Static seals are used in areas where there is no motion involved. Static seals include:

- gaskets—head gaskets, oil pan gaskets, etc.
- O-rings—hydraulic lines, turbo charger air intake piping, etc.
- sealing compounds—silicone, RTV, etc.

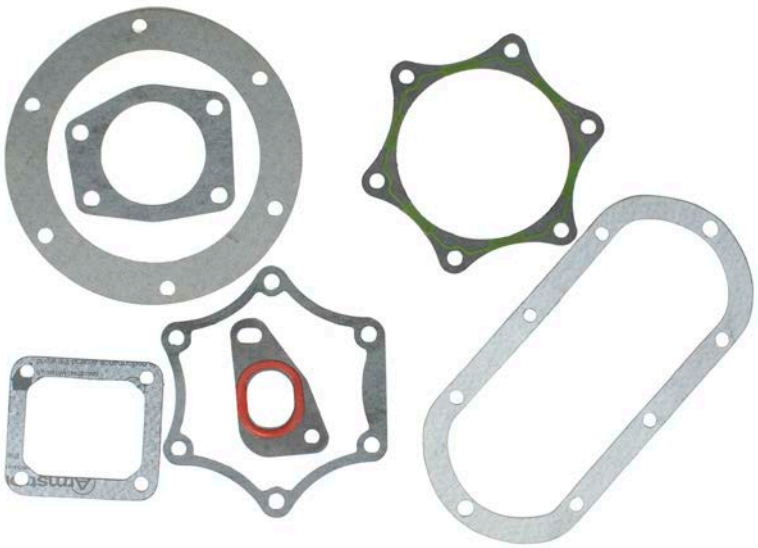

Figure 1. Static Seals/Gaskets

NOTES

Dynamic Seals

Dynamic seals are used in areas where rotary or linear motion is involved. They must be able to seal while in motion without being damaged by friction. Some types of seal work better for different applications. Dynamic seals include:

- radial lip
- exclusion seals
- face seals
- compression packings
- molded packings
- ring seals

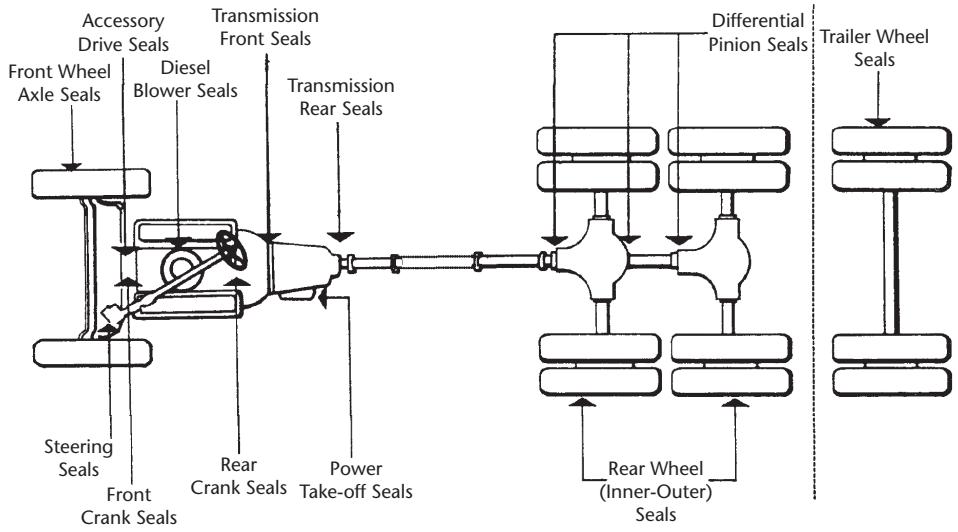

Figure 2. Common Dynamic Seal Locations

Lip Seal Design

Lip seals are designed to be used on shafts where the part to be sealed is rotating. These can be found in transmissions, front and rear wheels, differentials, and in many other locations. The basic seal consists of the following components:

- outer shell
- inner shell
- sealing element

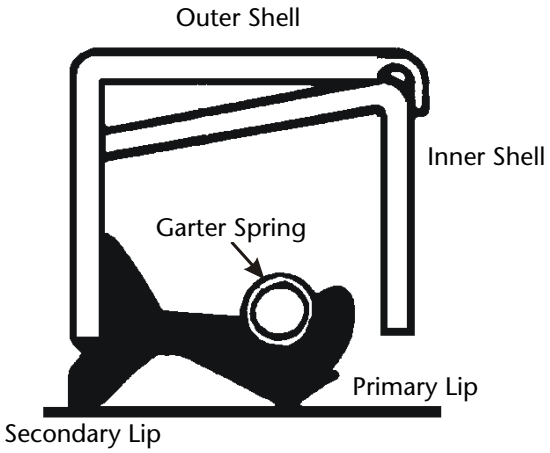

Figure 3. Seal Components

Outer Shell

The outer shell provides protection and support for the seal elements and provides a method of mounting in a housing bore. The outer shell also provides a contact surface for the removal and installation tools.

Inner Shell

The inner shell (which is attached to the outer shell) provides additional support and can also act as a shield or spring retainer.

Sealing Element

The sealing element performs the sealing operation by contacting the moving shaft. It may contain one or two sealing lips that press against the shaft and exclude or retain. On two lip seals, the primary lip will retain fluids and lubricants while the secondary lip excludes contaminants. The garter spring assists in sealing by providing additional force to the element.

Lip Seal Operation

Seals perform the required task by placing the lip of the seal in the path of the lubricant or contaminant. Retention seals hold lubricants in by having the lip face toward the lubricants (Figure 4). These seals do not have good exclusion capabilities and are rarely used where they would be exposed to high levels of contamination.

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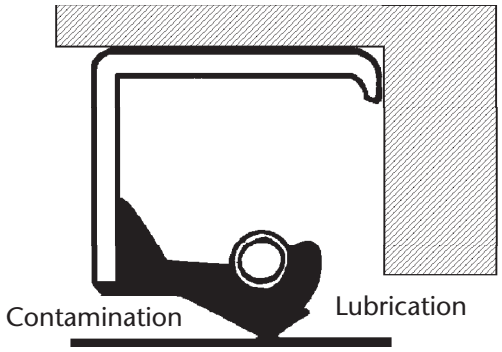


Figure 4. Retention Seal

Exclusion seals are placed so that the lip keeps dirt and contamination out of the shaft and bearing (Figure 5). They are often used in areas where they can be purged or cleaned out by applying grease through a fitting that will force the contaminants out past the lip with the clean grease, e.g., air brake S-cam outer seal.

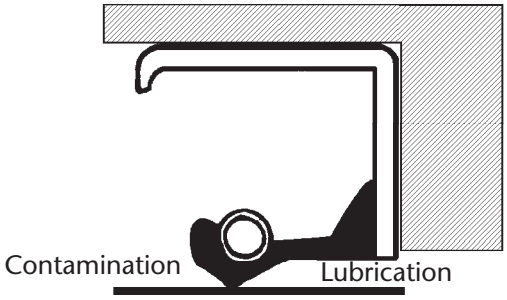


Figure 5. Exclusion Seal

A combination dual lip seal uses a garter spring on the primary lip to hold in the fluid and a smaller secondary lip to hold out dirt (Figure 6).

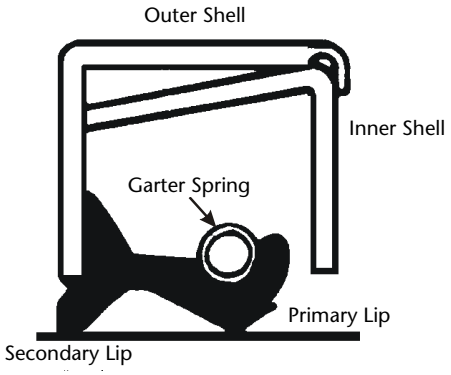


Figure 6. Dual Lip Retention/Exclusion Seal

In many cases, two seals will be used back-to-back to perform both tasks. A retention seal will be installed first, with the exclusion seal placed in last to keep the dirt out. Unfortunately, there is no way to purge the exclusion seal if they are installed this way. The failure rate due to lack of lubrication and a build-up of contamination is high. The cavity between the two seals must be packed with lubricant to extend the life of the exclusion seals.

NOTES

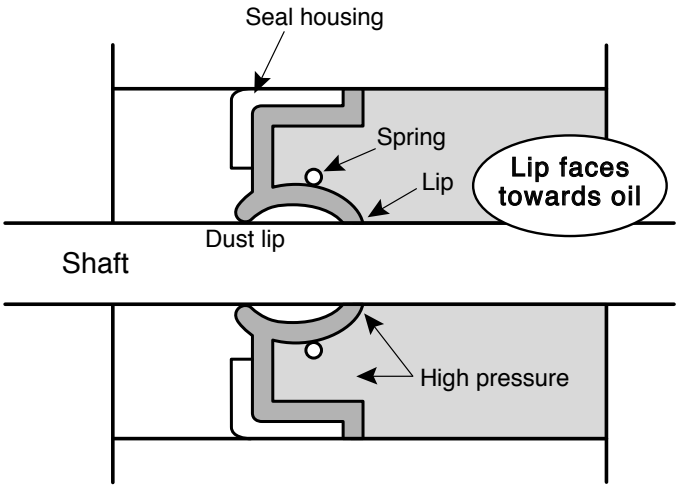


Figure 7. Direction the Lip of the Seal Should Face



Figure 8. Single Lip Seal

Face Seal

During the late 1950s, manufacturers of equipment needed a new type of seal to improve lubricant retention on final drives and undercarriage components. Elastomeric rubber shaft seals quickly wore out due to abrasive and corrosive environments. Two new seal designs were created which permanently sealed the final drives and undercarriage components. These are referred to as "Metal Face Seals."

Metal face seals provide lubricant retention and exclude contaminates in all working conditions. There are two basic types of metal face seals: DuoCone and HDDF (Heavy Duty Dual Face). Both seal designs use elastomeric rubber rings to provide loading for the metal component. Both designs use the contact area between the metal sealing rings to create a static and dynamic seal.

The difference between the seal designs lies primarily in the shape of the elastomeric rubber rings. DuoCone seals incorporate round rubber toric rings while HDDF seals use a rubber Belleville Washer.

NOTES



Figure 9. Steel Face Seal

Compression Packings

Compression packings are a reliable method to seal in oil under pressure on hydraulic cylinders as the cylinder rod extends and retracts. The packing squeezes against the housing and against the moving rod to seal the oil in the cylinder.

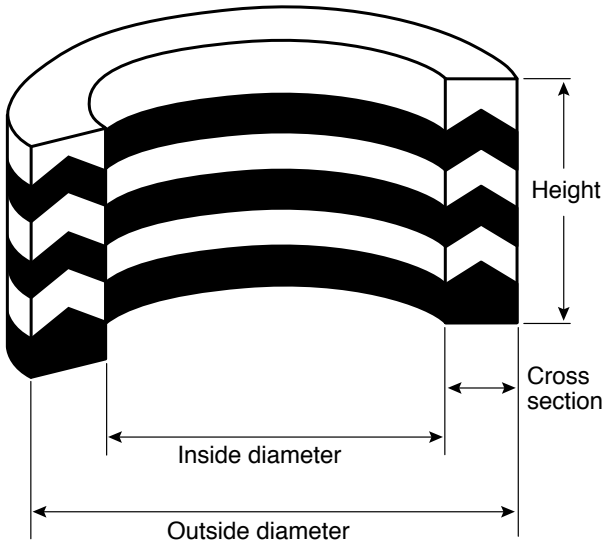


Figure 10. Hydraulic Cylinder V-Packing

V-packing works well with hydraulic cylinders as shims can be removed and the V-packing will squeeze tighter on the rod or shaft. The V-packing is also used on boats to seal the propeller drive shaft from water.

NOTES

Ring Seals

Steel ring seals can be either a single ring (piston ring) or a laminar type ring (spiral wound). A laminar seal ring is a seal consisting of two or three steel overlapping rings in a single groove. This arrangement and orientation of rings is dictated by the application and the severity of the environment.

- seals internal components from contamination
- sealing surface produced from metal materials instead of rubber
- withstands high temperatures and corrosive environments



Figure 11. Steel Piston Rings



Figure 12. Hook Ring Seals

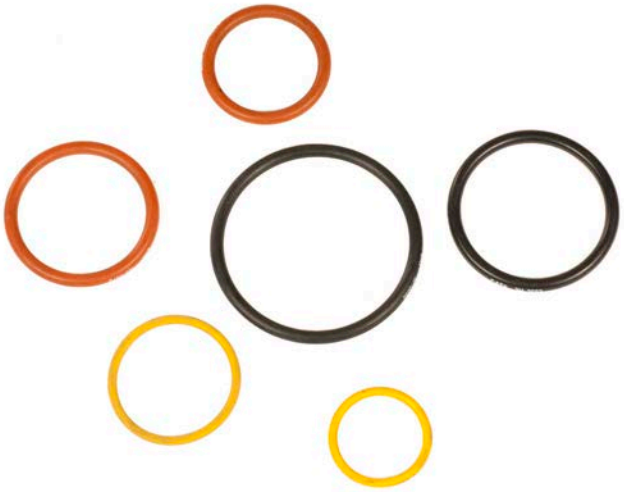


Figure 13. O-rings

Sealing Materials

Different types of seal materials are required for different applications. Operating temperatures, conditions of operation, and compatibility with fluids and lubricants are all factors in choosing the appropriate type.

NOTES

While rubber, felt, and leather seals can still be found, they're rare on modern equipment and machines. Synthetic seals are the most common and are made from different materials, each with advantages and disadvantages:

- nitrile
- polyacrylate
- silicone
- fluoroelastomers
- polyteflonfluoroelastomers (PTFE)

Nitrile

Nitrile seals are the most popular and provide good compatibility with lubricating greases and oils. They have good abrasion resistance, good low-temperature characteristics, and are relatively low-cost. They're not compatible with synthetic fluids or extreme-pressure greases and do not operate well at high temperatures. Some blends of nitrile are recommended for extreme abrasion situations where sand and dirt may be present in large quantities. The uses of nitrile rubber include non-latex gloves, automotive transmission belts, hoses, O-rings, gaskets, oil seals, V-belts, synthetic leather, and as cable jacketing. Nitrile seals are usually dark grey or black.

Polyacrylate

Polyacrylates are used where temperatures are high and extreme pressure lubricants are used. They have high resistance to oxidation but have poor compatibility with water and certain industrial fluids. These seals are found in power steering and hydraulic applications where temperatures are high. Polyacrylate seals are usually dark grey or black.

Silicone

Silicone seals absorb lubricants and can be used in high friction areas and applications where temperature ranges are extreme. They have a tendency to tear and cut easily during installation, are not compatible with most extreme pressure lubricants, and are expensive. They should not be used in areas that have high abrasion or contamination levels.

Silicone grease is typically used as a lubricant for brake components since it is stable at high temperatures, is not water-soluble, and is far less likely than other lubricants to foul. Spark plug wires are constructed of multiple layers of silicone to prevent sparks from jumping to adjacent wires. Silicone tubing is sometimes used in intake systems (especially for engines with turbo charged forced induction). Sheet silicone is used to manufacture gaskets used in engines, transmissions, and other applications. Silicone seals are red, orange, light grey, or blue.

NOTES

Fluoroelastomers

Fluoroelastomer seals are used with special fluids and lubricants, in temperature ranges that may be too extreme for other types of seal materials. These seals are very expensive and are normally brown, blue, or green.



Exposure to high temperatures will reduce the material in these seals to a black, sticky substance that is extremely caustic and corrosive. Never touch this material or allow it to contact clothing or other surfaces, as it will result in severe burns and serious injury.

With its lower density, Fluoroelastomer material is an excellent choice for low friction hydraulic seals and standard O-rings, but special shapes can easily be manufactured to typical dimensional tolerances.

Polyteflonfluoroelastomers (PTFE)

Seals made from PTFE compounds run with no lubricant between the seal surface and the shaft or metal sealing surface. The seal transfers some of the material to the shaft, increasing sealing and reducing friction. These seals have very low friction and will seal most oils and lubricants.

Another name for Polyteflonfluoroelastomers (PTFE) is Teflon. A good example of this is the Teflon tape used for pipe sealant.



Figure 14. Polyteflonfluoroelastomer Teflon Pipe Tape

Steel Wear Sleeves

Some applications include the use of a wear sleeve. These are installed during manufacture and can be replaced if worn. These steel wear sleeves may come with the original seal or may be purchased separately. Wear sleeves may have a back deflector ring which helps in excluding dirt and grit from the seal (Figure 15).

NOTES

Some seals come with an installed sleeve which should not be removed. The seal and sleeve must be installed together.



Figure 15. Wear Sleeve

Seal Variations

Some applications require special sealing characteristics to withstand temperatures, abrasion, and contamination.

Ceramic Water Pump Seals

Many engine water pumps use a spring-loaded ceramic face-type water seal. This type of seal must be treated carefully during overhaul to prevent damage to the brittle ceramic parts (Figure 16).



Figure 16. Water Pump Ceramic Seal

Directional Lip Type Seals

Directional seals are designed to seal with the rotating parts moving in one direction only. The seal is marked with the correct direction of rotation and must be installed to operate only in one direction. If installed incorrectly, leaks will occur. These seals may also be marked "input-output" (Figure 17).

NOTES



Figure 17. JD Front Crankshaft Seal

Wheel Seals

Wheel seals, which come with a wear sleeve, are called two-piece seals (Figure 18). Wear sleeves come in different styles for wheel seals. The standard sleeve is a flat band pressed onto the spindle. A more elaborate sleeve, still pressed on the spindle, is formed to wrap part way around the seal to help exclude dirt.

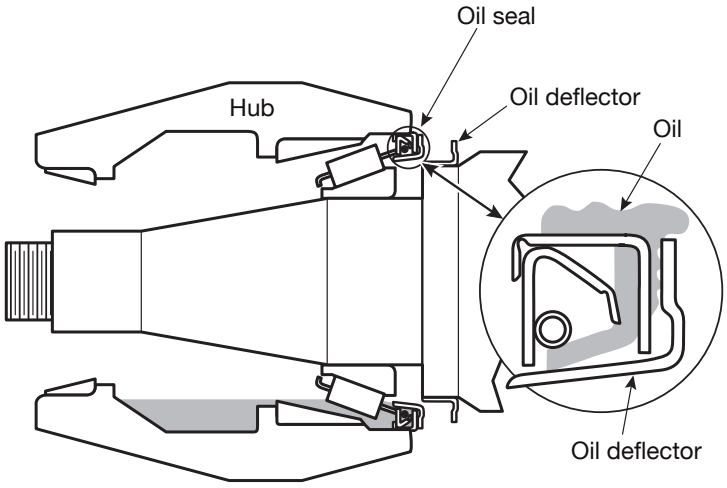


Figure 18. Two-piece Wheel Seal

Unitized type oil seals are designed specifically for use in oil bath wheel bearing systems (Figure 19). By using oil instead of grease in wheel bearings, the operating temperature and friction can be reduced, providing longer life and better fuel economy.

This unitized type of seal includes all of the necessary sealing components: both stationary and rotating members. It is designed so that the seal rotates within itself, rather than rubbing on the shaft, this eliminates wear to shaft surfaces. When the seal is replaced, all of the wearing surfaces are also replaced.

NOTES

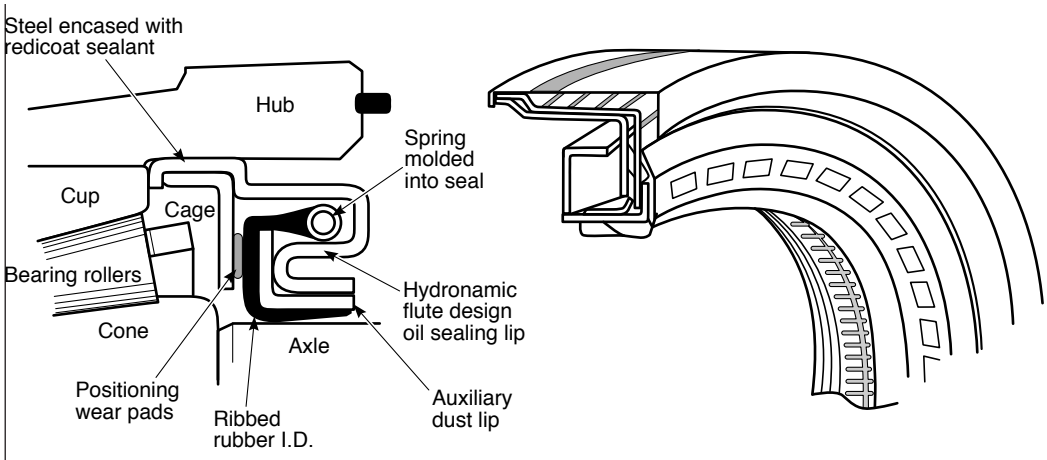


Figure 19. Unitized Type Wheel Seal

Some unitized wheel seals are designed with the outer housing pressed into the rotating wheel hub and may use sealant-coated steel or a rubber outer surface that helps hold and seal. The stationary inner seal area is pressed on the stationary spindle as the wheel is installed and is held and sealed with a rubber inner surface. Other seals are installed opposite to this, with the inner diameter of the seal pressed onto the spindle and the outer diameter pressed into the hub as the wheel is installed. Inside the unitized seal, the manufacturer may use a radial lip or lay down lip type seal.

Seal Requirements

Seals must be selected correctly for the application. This means considering temperatures, fluid compatibility, operating conditions, and specific application requirements. In most cases, the replacement is done by comparison of part number with a manufacturer's catalogue to determine if the correct replacement seal is used. All seals contain a part number stamped into the outer shell for identification. In addition to making sure that the part numbers are correct, always compare the measurements of the seals to make sure that they're the correct size.

Seal Size

Seal sizes are determined by measuring the width, outside diameter, and inside diameter (or shaft size). Seal outside diameter is normally slightly larger than the bore that they will fit in to ensure that they are not forced out during operation.

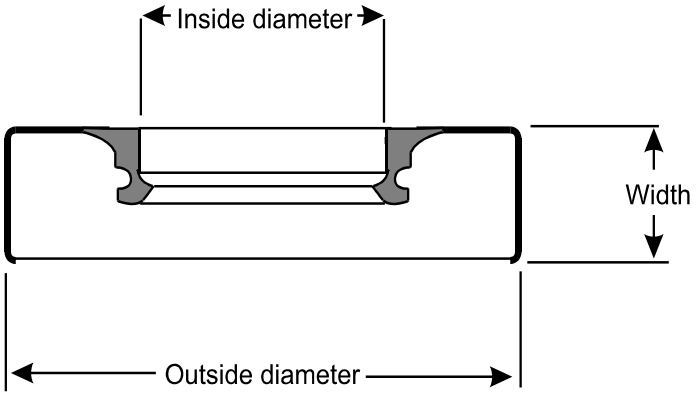


Figure 20. Measuring the Seal

Seal surface conditions will determine the life expectancy of the seal and the life of the component and bearings. The shaft must be smooth, round, and properly aligned. The bore that the seal fits into must be the right size, free from burrs and wear, and round. Shaft run-out or an oval shape will prevent the seal from operating properly, allowing lubricants out, and letting dirt and contamination in.

NOTES

SELF TEST 3

1. What are two jobs that seals must do?

   a. retain fluids and exclude contaminants
   b. slide smoothly and fit tightly
   c. reciprocate and rotate equally well
   d. eliminate friction and provide lubrication

2. What are two basic types of seals?

   a. metal and composite
   b. synthetic and natural
   c. static and dynamic
   d. potential and kinetic

3. Why is silicone a useful sealing material?

   a. low cost
   b. absorbs lubricant
   c. durable during installation
   d. good in high-abrasion applications

4. What components use metal face seals?

   a. crankshafts
   b. transmissions
   c. cylinder heads
   d. undercarriage rollers

5. What component uses a spring loaded ceramic face seal?

   a. track rollers
   b. water pump
   c. engine crankshaft
   d. cylinder head

LEARNING TASK 4

Select and Service Seals

Notes

Proper seal service is important to provide leak-free service and extend the life of bearings and components. Using the correct tools and procedures will ensure that the seal is removed and installed without damaging the housing seal or seal bore.

Proper seal service tools include:

- an arbor press
- a soft face hammer
- seal installation/removal tools

Installation tools can be obtained in a variety of shapes and sizes. The preferred tool is one that is custom made for the installation of seals. Other tools include a general seal driver that will fit a variety of seals.

The most important considerations are:

- never hammer directly on the seal face
- never use a drift or a punch to seat seals
- never strike steel to steel
- never use a screw driver or chisel
- always start the seal straight, not cocked
- always apply force at the mounting edge, not the seal edge

Seal Removal

Seals should always be removed using a slide hammer puller to pull the seal from the bore, or with a sleeve tool designed to push the seal. Remember that you may need the used seal in good condition for examination and warranty purposes.

Never remove a seal using pry bars or screwdrivers—you may damage the bearing, the seal, or the housing.

Remove wear sleeves according to the manufacturer's recommended procedures. One method that is commonly used is to gently strike the sleeve, on the seal surface, with a hammer and cold chisel. This will stretch the sleeve and allow you to slide the sleeve off the shaft by hand. Do not cut the sleeve as this can damage the shaft.

NOTES



Figure 1. Seal Removal Tool

Seal Inspection and Diagnosis

The most common indication that a seal has failed is lubricant leakage. It's not difficult to diagnose the problem and provide a solution. You should always follow an organized procedure to diagnose problems.

Examine the service history of the equipment to determine if the seal has been replaced regularly. Check to see if the seal is the correct type for the application. Often the wrong seal is installed repeatedly without attempting to determine the reason for failure.

Determine whether the leak is around the inner seal or the outer shell. You may have to clean the area thoroughly to locate the leak accurately.

High-pressure cleaning equipment can damage the seal, and can also force contaminants past the sealing element and into the bearing.

Inspect the sealing surfaces to determine if the seal has worn a groove into the shaft. Check the lip of the seal for damage, cuts, abrasion, and cracking. If the sealing surface is damaged, it must be repaired. The surface can be re-machined or the component can be replaced.

A common method of repairing damaged surfaces is by using a thin metal sleeve that is press fitted over the damaged area, providing a new surface for the seal to operate on. These are commonly called "Speedi-sleeves®" and are available in a variety of sizes for different applications.



Figure 2. Speedi-sleeve and Installation Cup

Check the manufacturer's recommendations before using this type of sleeve, as not all manufacturers will accept this type of repair and use of a Speedi-sleeve® may void the warranty.

Notes

Ensure that the seal was not cocked during installation as this will damage the seal shell resulting in leaks. If the seal was damaged due to cocked installation, it must be replaced. A bent seal cannot be straightened.

Determine if the seal has been subjected to temperature high enough to damage its surface. If so, determine why the temperature was so high.

Check that the lubrication level is correct and that the right lubricant is being used.

Check for incorrect directional rotation installation.

Seal Installation

The most important factor in correct seal installation is to always refer to the manufacturer's service procedures for correct installation methods and specifications. This will extend the serviceable life of the seal, bearings, and other components.



Figure 3. Seal Installation Tool and Seal

Safety Precautions for Seal Installation

Follow the list below anytime a seal or sleeve is installed:

- Confirm that you're installing the correct type of seal.
- Confirm that the seal is facing the correct way to seal or exclude.
- Use the recommended sealant on the outer portion of the seal.
- When installing a directional seal, check shaft rotation.
- Inspect the bore and shaft for nicks and scores which can cause a leak.
- If a wear sleeve is used, install it carefully with the correct tools.
- Install the seal straight into the bore using the correct tools.
- Do not damage the seal when sliding components into or over an installed seal.

NOTES

- Make sure that the seal spring is not been damaged and has not dropped out of the seal.
- Check bearing adjustment to ensure the new seal is not damaged by loose bearings.
- Radial lip seals—pre-lubricate the seal with the same lubricant that the seal will retain.
- Lay down lip seal Polyteflonfluoroelastomers (PTFE) installation—install with the shaft and seal lip clean and dry of lubricants and contaminants.
- Unitized wheel seal installation—remove any old wear sleeves on the axle hub before installing a unitized type seal. It is recommended that a new unitized seal be used whenever the wheel hub is removed.

SELF TEST 4

1. What is the preferred tool to remove seals?

   a. pry bar
   b. hammer
   c. slide hammer puller
   d. brass drift

2. What should you do if you cock a seal during installation?

   a. remove it and try again
   b. seat it firmly so it will straighten in the bore
   c. take it out and straighten it in an arbor press
   d. replace the seal

3. What lubricant should you use to pre-lubricate a seal (if required)?

   a. an acceptable EP type grease only
   b. used engine oil, or old gear oil
   c. the lubricant that it will retain
   d. any synthetic lubricant except silicone based

4. What is the purpose for a steel sleeve (speedi-sleeve)?

   a. repair the seal
   b. repair the gear
   c. repair the housing
   d. repair the rotating surface

COMPETENCY A-12
APPLY MATH AND SCIENCE



HEAVY MECHANICAL TRADES:
LINE A—COMMON OCCUPATIONAL SKILLS

Goals

Working in the Heavy Mechanical Trades requires a multitude of skills and abilities. One skill often overlooked is basic math. You should be competent at solving math problems that involve whole numbers, fractions, numbers using decimals, metric and imperial measurements, ratios, numerical equations, formulas, perimeters, areas, volume, and geometry.

This competency is meant as a review of basic math skills. It's assumed that you will have already learned these concepts and that this will serve merely as a refresher.

LEARNING TASK 1

Identify Words Indicating Mathematical Operations

Notes

Mathematical Operations

Solving problems involving numbers, fractions, and angles requires an understanding of the terms commonly used in mathematical calculations.

Addition

Addition is the process of combining a number of objects together into a larger collection. For example, adding 5 bolts to a box of 100 bolts results in a box containing 105 bolts.

The symbol for addition is: +

e.g., 5 + 100 = 105

The terms "sum", "summation", and "aggregate" have the same meaning as "addition".

Subtraction

Subtraction is the process of removing a number of objects from a collection. This decreases the number of objects in the collection. For example, if you need 15 bolts and take them from a box containing 105 bolts, there will be 90 bolts left in the box.

The symbol for subtraction is: –

e.g., 105 – 15 = 90

Subtraction can also be used to figure out the difference between two amounts. For example, taking the highway to work is 20 kilometres, but taking city streets is only 15 kilometres. Driving through the city is 5 kilometres shorter than taking the highway (20 – 15 = 5).

NOTES

Multiplication

Multiplication is a mathematical process that speeds up the addition of groups with an equal number of objects in them. For example, a truck has 5 wheel nuts on each of its 4 wheels. To find the total number of truck wheel nuts, you could add them together (5 + 5 + 5 + 5 = 20), or you could multiply the number of nuts per wheel by the number of wheels ($5 \times 4 = 20$).

There are several different ways to indicate multiplication:

The symbol: $\times$

e.g., $5 \times 4 = 20$
$A = L \times W$ (Area = Length × Width)

The symbol: $\cdot$

e.g., $5 \cdot 4 = 20$
$A = L \cdot W$

Parentheses can be used around terms:

e.g., $5(4) = 20$
$A = (L)(W)$

Terms can be placed directly next to each other:

e.g., $3z = 9$
$A = LW$

Note this method is not used when both terms are numbers. That is, you would never write "5 multiplied by 4" as "54" (for obvious reasons).

Division (Level 3)

Division is the fourth basic mathematical operation. Division is the process of separating a collection of objects into a number of equal groups. For example, consider a box containing 30 wheel nuts. If a truck uses 5 nuts per wheel, then 6 wheels can have their nuts replaced ($30 \div 5 = 6$).

There are two symbols commonly used for division: / and ÷

e.g., $10 \div 5 = 2$
$20/4 = 5$

Notes

Note that division can also be expressed as a ratio, with one number written over another or used with a colon symbol (:).

e.g., $\frac{21}{7} = 3{:}1$

Exponents (Level 3)

Exponents are used when you are multiplying the same number multiple times (e.g., 5×5). Exponents are written as a superscript number indicating the number of times the value is multiplied by itself.

e.g., $4^2 = 4 \times 4$
$6^3 = 6 \times 6 \times 6$

Order of Operations

You may be presented with an equation that includes several operations. It's important that you do the calculations in the correct order. The term "BEDMAS" can help you to remember the correct order:

B – brackets

E – exponents

DM – division and multiplication

AS – addition and subtraction

This means that you do anything in brackets first, then any exponents, then any division and multiplication, and finally any addition or subtraction.

If there are several of the same class of operation (e.g., multiplication and division), you do them in order from left to right.

e.g.,	$y = (8 - 2) \cdot 2^2 + 20 \div 5$	Brackets
	$y = (6) \cdot 2^2 + 20 \div 5$	Exponents
	$y = 6 \cdot 4 + 20 \div 5$	Division and Multiplication (left-to-right)
	$y = 24 + 20 \div 5$	Division and Multiplication (left-to-right)
	$y = 24 + 4$	Addition and Subtraction
	$y = 28$	

SELF TEST 1

1. Which of the following expressions gives an answer of 65?
   a. 20 + 55
   b. 30 + 25
   c. 25 + 45
   d. 20 + 45

2. You had a box of 75 bolts and used 13 on a job. How many are left in the box?
   a. 63
   b. 88
   c. 62
   d. 52

3. A truck and trailer combination has a total of 12 wheel ends with 10 studs on each. How many nuts are required to mount the wheels?
   a. 60
   b. 90
   c. 100
   d. 120

4. A box of grader cutting edge bolts contains 96 bolts. How many cutting edges can be installed if 8 bolts are required for each edge?
   a. 6
   b. 10
   c. 12
   d. 14

5. $9 \times 9 \times 9 \times 9 \times 9$ could also be written as:
   a. 9^5
   b. 9^3
   c. 9^6
   d. 9^7

6. Solve the following equation: $x = (16 + 8) \times 3^3 + 24$
   a. $x = 625$
   b. $x = 651$
   c. $x = 672$
   d. $x = 595$

LEARNING TASK 2

Solve Word Problems Involving Whole Numbers

NOTES

Process for Solving Word Problems

Complicated mathematical problems can be simplified and solved by following a systematic approach. Focusing on one part of a problem will produce the solution more easily and with less chance of error. The following process for solving word problems has four steps:

Step 1

What are you trying to determine? There may be several questions within a given problem, so you have to determine which answer will correctly solve the problem.

Step 2

What numbers are important to solving the problem? Figuring out which numbers or measurements are going to help find the solution is as important as determining which ones are not.

Step 3

What mathematical operation is needed to solve the problem? More than one operation may be needed to get to the final result. Numbers may have to be added together (addition) before they are separated into equal groups (division). The possible operations are addition, subtraction, multiplication, and division.

Step 4

Arrange the given numbers into an equation or number sentence which will result in the final answer. Your equation should have all the known values on one side of the equal sign, and the unknown value standing alone on the other side.

e.g., $8 + 12 = ?$

$4 \times 5 = ?$

NOTES

You may wish to do one equation at a time building to the final answer, or combine equations so that one calculation will result in the final answer.

The following example demonstrates how to use the four steps for solving a word problem.

A heavy duty mechanic requires 112 hours to complete a job. The mechanic works 8 hours each day. How many days will be required to complete the job?

Step 1: What are you trying to determine?

Number of days needed to complete the job.

Step 2: What numbers are important?

112 hours for the total job, mechanic works 8 hours per day.

Step 3: Which mathematical operation is needed to find the answer?

Division is required to find out how many days to complete the job.

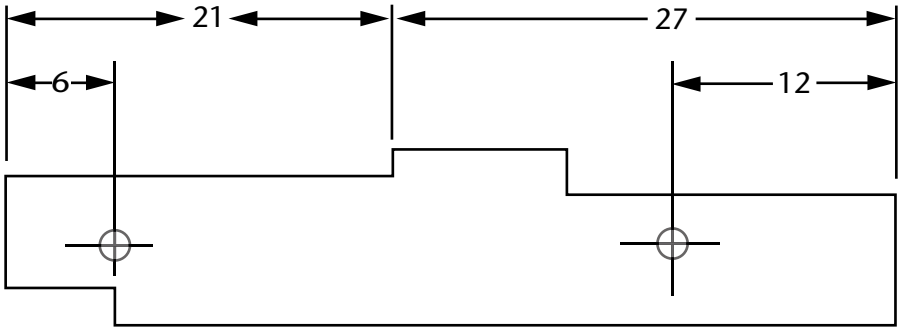
Step 4: What is your equation?

$112 \div 8 = ?$

Completing the calculation tells us that the answer is 14 days.

SELF TEST 2

1. What is the distance between the centres of the two holes in the following diagram? All dimensions are in centimetres.



   a. 27

   b. 48

   c. 18

   d. 30

2. You used 688 rods to weld some brackets. If each bracket required 8 rods, how many brackets did you weld?

   a. 96

   b. 86

   c. 76

   d. 106

3. A box of 8 mm washers contains 87 washers. How many washers are there in 12 boxes?

   a. 696

   b. 96

   c. 1096

   d. 1044

4. You're assembling a machine that has four parts. Each part requires 18, 26, 14, and 36 nuts respectively. You have 564 nuts. How many machines can you assemble?

   a. 14

   b. 6

   c. 8

   d. 12

LEARNING TASK 3

Describe Key Terms and Concepts for Working with Fractions

NOTES

Concepts and Terms Involved with Fractions

The prevalence of the metric system has reduced the use of fractions in the mechanical repair trade, but there are still many areas where fractions are common. Hose sizes, gear ratios, fastener sizes, drill bit sizes, and electrical resistance calculations are just a few examples where fractions are used every day.

Fractions are used to indicate the portion of a whole and are written as a whole number over a whole number. If it takes four hours to get half ($\frac{1}{2}$) way through a job, it will take another four hours to complete it. If a quarter ($\frac{1}{4}$) of a cake is eaten, then three quarters ($\frac{3}{4}$) of the cake remain.

Following are terms associated with fractions:

Numerator

The numerator is the number above the fraction line and indicates how many equal parts are present. In the fraction, $\frac{3}{8}$, the 3 is the numerator and indicates you have three equal parts of the whole unit.

Denominator

The denominator is the number below the fraction line and indicates how many equal parts make up a complete unit. In the fraction, $\frac{3}{8}$, the 8 represents how many equal parts the whole unit has been divided into.

Terms

The numerator and denominator are called the "terms" of the fraction.

NOTES

Proper Fraction

A proper fraction has a numerator that is smaller than the denominator. $\frac{1}{2}$, $\frac{15}{16}$, and $\frac{31}{64}$ are examples of proper fractions.

Improper Fraction

An improper fraction has a numerator as large or larger than the denominator. $\frac{6}{4}$, $\frac{8}{8}$, and $\frac{35}{32}$ are examples of improper fractions.

Mixed Number

A mixed number consists of a whole number (e.g., 1, 3, 12, 54) and a proper fraction (e.g., $\frac{1}{2}$, $\frac{5}{8}$, $\frac{2}{3}$). Examples are $1\frac{1}{2}$, $3\frac{1}{4}$, and $2\frac{5}{8}$.

Improper fractions are commonly written as a mixed number. For example, it's more common to write $2\frac{3}{4}$ than $\frac{11}{4}$ even though they are equivalent.

An improper fraction can be converted to a mixed number by dividing the numerator by the denominator with the remainder becoming the new numerator.

e.g., $\frac{17}{4}$

= 4 with a remainder of 1

= $4\frac{1}{4}$

Common Factor

A common factor is a number that will divide into both the numerator and the denominator resulting in smaller terms. Consider the fraction $\frac{4}{6}$. Since both 4 and 6 are divisible by 2, we can reduce the fraction to $\frac{2}{3}$. Both fractions have the same value, but $\frac{2}{3}$ uses the lowest possible terms which is the preferred way to express fractions.

Note that in addition to reducing a fraction to lowest possible terms, we can also increase a fraction to larger terms. For example, given the fraction $\frac{4}{5}$, we could multiply both terms by 3 to get $\frac{12}{15}$. Both fractions have the same value, but $\frac{12}{15}$ uses higher terms. The most common reason for doing this is when finding the "lowest common denominator" (see next page).

Reciprocal

The reciprocal of a fraction is found by switching the values of the numerator and the denominator. The reciprocal of $\frac{2}{3}$ is $\frac{3}{2}$. The reciprocal of $\frac{5}{4}$ is $\frac{4}{5}$. The reciprocal of $\frac{1}{4}$ is $\frac{4}{1}$ (which is usually written as just 4). The reciprocal is also called the "inverse" of the original fraction. Reciprocals are often used when dividing by fractions.

Lowest Common Denominator

The term "lowest common denominator" (LCD) applies to a group of fractions that are to be added or subtracted from each other. These fractions need to be expressed in higher terms to get a denominator that is common to all. For example, adding or subtracting $\frac{2}{5}$ and $\frac{1}{3}$ requires that both fractions be expressed with the lowest common denominator. The lowest common denominator of 5 and 3 is 15 so, in this case, you would convert $\frac{2}{5}$ to $\frac{6}{15}$, and $\frac{1}{3}$ to $\frac{5}{15}$. With the denominators the same, you can now use them in an equation involving addition or subtraction.

The more fractions involved, the harder it is to find the lowest common denominator. For example, the lowest common denominator of 2, 4, and 5 is 20. Note that the lowest common denominator might be one of the numbers itself. For example, the lowest common denominator of 2, 3, and 6 is 6.

NOTES

SELF TEST 3

1. Reduce $\frac{24}{64}$ to lowest terms.

2. Which fraction is larger, $\frac{3}{8}$ or $\frac{11}{32}$?

3. Express $\frac{83}{16}$ as a mixed number.

4. What is the reciprocal of $\frac{15}{16}$?

5. Express the following group of fractions with their lowest common denominator: $\frac{1}{4}$, $\frac{5}{6}$, $\frac{3}{8}$, and $\frac{9}{12}$.

LEARNING TASK 4

Add and Subtract Fractions

NOTES

Conditions for Adding and Subtracting Fractions

Only fractions with the same denominator (sometimes called "like" fractions) can be added or subtracted with each other. Fractions with different denominators (sometimes called "unlike" fractions) must be changed to higher terms to find the lowest common denominator.

Adding Fractions

When adding like fractions, simply add all the numerators together and place that number over the common denominator.

e.g., $\frac{1}{5}+\frac{2}{5}+\frac{3}{5}$

$=\frac{6}{5}$

Converting $\frac{6}{5}$ to a mixed number gives the final answer of:

$=1\frac{1}{5}$

In order to add unlike fractions, you must first find the lowest common denominator, convert each fraction to use the LCD, and then add the numerators together.

e.g., $\frac{2}{3}+\frac{1}{4}+\frac{1}{6}$

The lowest common denominator of 3, 4, and 6 is 12, so convert the fractions to:

$\frac{8}{12}+\frac{3}{12}+\frac{2}{12}$

Now add the numerators together to get:

$=\frac{13}{12}$

Converting 13/12 to a mixed number give the final answer of:

$=1\frac{1}{12}$

NOTES

When adding mixed numbers, you can do so in two steps: first add the fractions together, and then add the whole numbers (including any whole number portion that results when adding the fractions). Combine the results to get the final answer.

e.g., $2\frac{3}{4} + 4\frac{13}{16}$

First we add the fractions only:

$$\frac{3}{4} + \frac{13}{16}$$
$$= \frac{12}{16} + \frac{13}{16}$$
$$= \frac{25}{16}$$
$$= 1\frac{9}{16}$$

Now we add the whole numbers together (including the whole number 1 from our result above):

$$2 + 4 + 1$$
$$= 7$$

Finally we add the whole number portion (7) with the fractional portion ($\frac{9}{16}$) to get the final answer:

$$= 7\frac{9}{16}$$

Subtracting Fractions

When subtracting like fractions, simply subtract the numerators and place that number over the common denominator.

e.g., $\frac{3}{4} - \frac{1}{4} = \frac{1}{2}$

In order to subtract unlike fractions, you must first find the lowest common denominator, convert each fraction to use the LCD, and then subtract the numerators.

e.g., $\frac{7}{8} - \frac{5}{12}$

The lowest common denominator of 8 and 12 is 24, so convert the fractions to:

$$\frac{21}{24} - \frac{10}{24}$$

Now subtract the numerators to get the final answer:

$$= \frac{11}{24}$$

In order to subtract mixed numbers, it's easiest if you first convert to the lowest common denominator, and then convert each mixed number to an improper fraction.

e.g. $4\frac{1}{4} - 2\frac{1}{2}$

Convert to the lowest common denominator:

$$= 4\frac{1}{4} - 2\frac{2}{4}$$

Convert each mixed number to an improper fraction:

$$= \frac{17}{4} - \frac{10}{4}$$

Subtract the numerators:

$$= \frac{7}{4}$$

Finally, convert the improper fraction into a mixed number:

$$= 1\frac{3}{4}$$

NOTES

SELF TEST 4

1. $\frac{5}{8}+\frac{1}{16}=?$

2. $1\frac{2}{3}+3\frac{1}{4}=?$

3. $\frac{1}{2}-\frac{3}{16}=?$

4. $3\frac{1}{8}-1\frac{3}{4}=?$

LEARNING TASK 5

Multiply and Divide Fractions

NOTES

Multiply and Divide Fractions

Fractions can be multiplied or divided without having to find common denominators. The procedure for each process is outlined below.

Multiply Proper and Improper Fractions

Multiplying fractions is done by multiplying all the numerators and then multiplying all the denominators.

e.g., $\frac{1}{8} \times \frac{2}{3}$

Multiplying the numerators (1×2), and the denominators (8×3) gives us:

$= \frac{2}{24}$

Which can be reduced to the final answer of:

$= \frac{1}{12}$

e.g., $\frac{5}{8} \times \frac{4}{3}$

Multiplying the numerators (5×4), and the denominators (8×3) gives us:

$= \frac{20}{24}$

Which can be reduced to the final answer of:

$= \frac{5}{6}$

NOTES

Multiply Mixed Numbers

In order to multiply mixed numbers, you must first convert to improper fractions and then perform the steps described above.

e.g., $1\frac{1}{4} \times 2\frac{3}{8}$

Converting both mixed numbers to improper fractions:

$$= \frac{5}{4} \times \frac{19}{8}$$

Multiplying the numerators (5×19), and the denominators (4×8) gives us:

$$= \frac{95}{32}$$

Converting back to a mixed number gives us:

$$= 2\frac{31}{32}$$

Divide Proper and Improper Fractions

Dividing a number by a fraction is the same as multiplying by the reciprocal of the fraction. For example, 5 divided by $\frac{2}{3}$ is the same as 5 multiplied by $\frac{3}{2}$.

e.g., $\frac{1}{4} \div \frac{2}{5}$

The reciprocal of $\frac{2}{5}$ is $\frac{5}{2}$, so we can re-write this equation as:

$$= \frac{1}{4} \times \frac{5}{2}$$

Using the procedure for multiplying fractions results in a final answer of:

$$= \frac{5}{8}$$

e.g., $\frac{11}{4} \div \frac{1}{2}$

The reciprocal of $\frac{1}{2}$ is $\frac{2}{1}$, so we can re-write this equation as:

$= \frac{11}{4} \times \frac{2}{1}$

Using the procedure for multiplying fractions gives us:

$= \frac{22}{4}$

Converting to a mixed number results in:

$= 5\frac{2}{4}$

Which when reduced to lowest terms, gives us a final answer of:

$= 5\frac{1}{2}$

Divide Mixed Numbers

In order to divide mixed numbers, you must first convert to improper fractions and then perform the steps described above.

e.g., $5\frac{1}{3} \div 2\frac{4}{9}$

Converting to improper fractions gives us:

$= \frac{16}{3} \div \frac{22}{9}$

The reciprocal of 22/9 is 9/22, so we can re-write this equation as:

$= \frac{16}{3} \times \frac{9}{22}$

Using the procedure for multiplying fractions gives us:

$= \frac{144}{66}$

Converting to a mixed number results in:

$= 2\frac{12}{66}$

Which when reduced to lowest terms, gives us a final answer of:

$= 2\frac{2}{11}$

SELF TEST 5

1. $\frac{9}{10} \times \frac{5}{6} = ?$

2. $3\frac{3}{8} \times 2\frac{3}{4} = ?$

3. $\frac{5}{8} \div \frac{1}{2} = ?$

4. $12\frac{5}{8} \div 1\frac{1}{4} = ?$

LEARNING TASK 6

Solve Word Problems Involving Fractions

Word Problem Involving Fractions

To solve word problems involving fractions, follow the four-step strategy outlined in Learning Task 2:

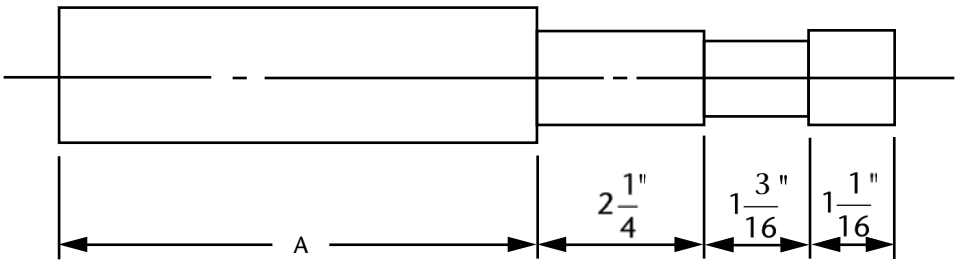
1. What are you trying to determine?
2. What numbers are important to solve the problem?
3. What mathematical operation is needed to solve the problem?
4. Create an equation that will result in the solution.

NOTES

SELF TEST 6

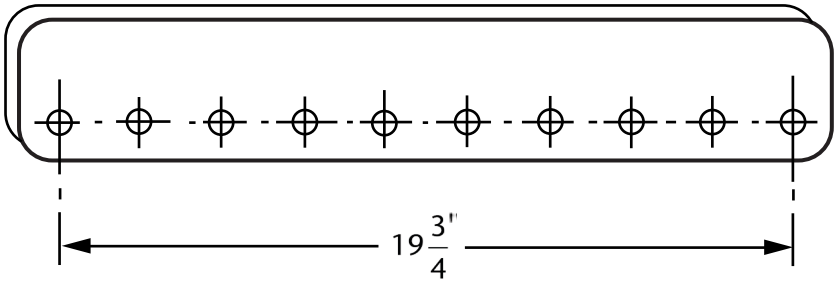
1. What length of bolt is required to go through a $\frac{5}{8}$ in. thick steel plate, a washer $\frac{1}{16}$ in. thick, and a nut $\frac{1}{4}$ in. thick?

2. Calculate the missing dimension "A" if the total shaft length is $10\frac{7}{8}$ in.



3. If a large gear rotates at $5\frac{1}{4}$ revolutions per minute (rpm), how many revolutions will it complete in $15\frac{1}{2}$ minutes?

4. Find the centre-to-centre distance between the evenly spaced holes in the steel bar below.



5. From a length of steel round stock $16\frac{7}{8}$ in. long, how many washers $\frac{3}{32}$ in. thick can be cut? Allow $\frac{1}{16}$ in. waste for each cut.

LEARNING TASK 7

Describe Key Terms and Concepts for Working with Decimals

NOTES

Concepts and Terms Involved with Decimals

Since the metric system is now the preferred system of measure, working with decimals has become more common than working with fractions. Even when using the Imperial system (which commonly uses fractions), you'll work with decimals for many types of measurements. You will need to understand the terms associated with decimals and have the ability to process mathematical equations.

Place Value

Place Value is the value of each digit in a decimal. Consider the number 0.3. The 3 is in the "tenths" position or place and has a value of $\frac{3}{10}$ of a complete unit.

As an example, the number 1.246835 can be broken down into its place values as follows:

1	2	4	6	8	3	5
Whole Numbers	Tenths	Hundredths	Thousandths	Ten Thousandths	Hundred Thousandths	Millionths

The "2" is in the tenths place and has a value of $\frac{2}{10}$ of a complete unit. The "4" is the hundredths place and has a value of $\frac{4}{100}$ and so on. With the "5" in the millionths place, this number is accurate to the millionth of one complete unit.

When there is no whole number in the value, include a leading zero for clarity.

NOTES

(That is, write 0.3579 rather than .3579 so that it's obvious what you mean.)

Significant Digits

Significant digits are the digits that represent portions of a unit that have actual value. For example, 0.035 mm has two significant digits: the "3" and the "5." The zeroes have no value but position the $\frac{35}{1000}$ of a mm in the correct place within the decimal.

Non-zero digits are always significant digits. Zero digits can be non-significant or significant depending on their position within the number. The following rules apply to zeroes positioned within a number:

- Zeroes placed before other digits are not significant; 0.035 has two significant digits.
- Zeroes placed between other digits are always significant; 30.04 kg has four significant digits.
- Zeroes placed after other digits but behind a decimal point are significant; 8.60 has three significant digits.

Adding zeroes after a decimal digit indicates the degree of accuracy of the number. If you measured a shaft with a ruler and found it to be 3 cm in diameter, you should record your reading as "3 cm." If you measure the same shaft with a micrometer and found it to have a 3.00 cm diameter then you should record your reading as "3.00 cm" to indicate the accuracy of your reading. The ruler has an accuracy of one significant digit and the micrometer has an accuracy of three significant digits.

Rounding

Rounding is the process of reducing the number of significant digits in a value which will also reduce the accuracy of the value. A measurement may be too accurate to be practical therefore it needs to be rounded up to be useful. For example, measuring a bolt across the threads with a micrometer might produce a reading of 7.88 mm. Requesting a "7.88 mm bolt" will result in confusion as bolt classifications are not this accurate. Your measurement should be rounded to 8 mm which is the list size of the bolt.

Rounding is accomplished by looking at the last digit and using its value to round up or round down. If the final digit is "4" or less, you simply drop that digit. If the final digit is "5" or more, you drop the digit and add one to the preceding digit. For example, 0.874 would be rounded down to 0.87, whereas 0.876 would be rounded up to 0.88.

You can also round up or down more than one place value at a time. To do this, you consider only the digit one greater than the place value you are interested in, and perform the rounding as described above. For example, if you want to round 3.72453 mm to the nearest hundredths of a millimetre, you consider the digit in the thousandths position. Since the thousandths digit is a 4, you round down by simply dropping it (and all subsequent digits) to get 3.72 mm.

Repeating Decimals

A repeating decimal is a number where a sequence of digits is endlessly repeated. A bar may be used over the digit(s) to indicate a repeating sequence.

e.g., $0.6666666 = 0.\overline{6}$

e.g., $0.54545454 = 0.\overline{54}$

SELF TEST 7

1. Write $\frac{75}{1000}$ as a number with decimals.

2. Change four thousandths to a number with decimals.

3. Express twenty-one ten thousandths in decimal form.

4. Round 67.1275 to the nearest:
   a. thousandth

   b. hundredth

   c. tenth

5. Round to the nearest thousandths:
   a. 0.05072

   b. 4.00009

   c. $1.\overline{6}$

LEARNING TASK 8

Convert Between Decimals and Fractions

NOTES

Converting Between Decimals and Fractions

Converting a fraction to a decimal is a simple task whereas converting a decimal to a fraction takes more work.

Fraction to Decimal

Converting a fraction to decimal is accomplished by dividing the numerator by the denominator. This works with both proper and improper fractions. Converting a mixed number requires that you convert only the fraction portion of the mixed number.

e.g., $\frac{3}{5}$

$= 3 \div 5$

$= 0.6$

e.g., $\frac{15}{16}$

$= 15 \div 16$

$= 0.9375$

e.g., $2\frac{9}{11}$

$= 2 + (9 \div 11)$

$= 2.\overline{81}$

Decimal to Fraction

To change a decimal to a fraction, you need to look at the place value of the last digit. Rewrite the digits above this place value then reduce the fraction to its lowest terms. If the decimal is repeating then write it over the place value minus 1 (this only works if all the digits are repeating).

e.g., 0.5

$= \frac{5}{10}$

$= \frac{1}{2}$

NOTES

e.g., 0.125

$$= \frac{125}{1000}$$

$$= \frac{25}{200}$$

$$= \frac{1}{8}$$

e.g., $0.\overline{45}$

$$= \frac{45}{99}$$

$$= \frac{15}{33}$$

$$= \frac{5}{11}$$

SELF TEST 8

1. Change $\frac{5}{8}$ to a decimal.

2. Convert $\frac{13}{16}$ to a decimal.

3. Express $2\frac{11}{64}$ as a decimal. Round to the thousandth place.

4. Change 0.06 to a fraction.

5. What is 0.875 as a fraction?

6. Convert $0.\overline{72}$ to a fraction.

LEARNING TASK 9

Add, Subtract, Multiply, and Divide Decimals

NOTES

Using any of the four basic mathematical operations on decimals is the same process as used with whole numbers. With a calculator, you simply plug in the numbers and select the math operation you wish to perform. If you're doing the calculations on paper, make sure to keep the place values aligned for all the numbers.

Adding Decimals

e.g., Add 3.75, 67.005, 892.2, 326, and 0.5325.

Align the decimal points to keep all the place values aligned, then add each column from right to left.

$$\begin{array}{r} 3.7500 \\ 67.0050 \\ 892.2000 \\ 326.0000 \\ 0.5325 \\ \hline 1289.4875 \end{array}$$

Subtracting Decimals

e.g., Subtract 0.0125 from 3.25.

Align the decimal points again and add zeroes to make it easier to move units of 10 from one place value to a lower place value.

$$\begin{array}{r} 3.2500 \\ -0.0125 \\ \hline 3.2375 \end{array}$$

Multiply Decimals

When multiplying decimals, first count the total number of decimal places in both numbers. Then multiply the numbers as though they are whole numbers (that is, ignore the decimal places entirely). Once you have an answer, place the decimal point the same number of places as the total of your original numbers.

NOTES

e.g., Multiply 8.08 × 0.625.

8.08 has **two** decimal places, and 0.625 has **three** decimal places for a total of **five** decimal places.

Multiply 808 × 0625:

$$\begin{array}{r} 0625 \\ \times\ 808 \\ \hline 5000 \\ 50000 \\ \hline 505000 \end{array}$$

Place the decimal point so that there are **five** decimal places (the same as the total in the original numbers):

5.05000

Trailing zeroes can be dropped to give a final answer of:

5.05

Divide Decimals

When dividing decimals, move the decimal point of both numbers an equal number of spaces to the right until both are whole numbers. (If the numbers do not have the same number of decimal places, add as many zeroes as needed.)

e.g., Divide 481.92 by 0.024

Move the decimal point of both numbers three places to the right:

481.92 becomes 481920, and 0.024 becomes 24.

Divide as would be done with whole numbers:

$$24\overline{)481920}\ 20080$$

Note that you do not move the decimal places "back" after completing the division, so the final answer is:

20080

Repeating Decimals

Calculations involving repeating decimals are more accurate if you use as many of the repeating decimals as possible. For example, consider the equation $0.\overline{6} \times 57$. The actual answer is 38. If you approximate $0.\overline{6}$ with 0.66, you get:

0.66×57
$= 37.62$

However, if you approximate $0.\overline{6}$ with 0.6666666, you get:

0.6666666×57
$= 37.999996$

Word Problems Involving Decimals

Once again, the four-step procedure applies to these types of problems too. Special attention must be paid to the decimal positioning during calculations as has been outlined.

NOTES

SELF TEST 9

1. Complete the calculations as indicated:

   a. 477.075 + 64 + 709.999 + 0.0025

   b. 37.2 – 36.864

   c. 0.25×0.375

   d. $0.17 \div 0.0034$

2. A nut advances 0.65 mm for each complete turn of the bolt. How far will the nut move if the bolt is rotated 23 complete turns?

3. 45 resistors have a mass of 116.6 grams. What is the mass of each resistor? Express your answer to the nearest tenth of a gram.

4. A steel bar is sheared into five pieces. If the pieces are 35.62 cm, 49.225 cm, 23.5 cm, 78.43 cm, and 55.1 cm long, what was the original length of the bar?

LEARNING TASK 10

Describe Metric Measurements

Notes

Metric Measuring System

The metric system has taken over as the most commonly used system for measuring in the Heavy Mechanical Trades. Not many manufacturer's still use the Imperial system for specifications, dimensions, fasteners, or parts and the few that do are based in North America.

There are some older vehicles and machines that were built when the Imperial system was popular but they are steadily being replaced with new machines that are all metric. Looking at the head of a bolt and quickly estimating that a 14 mm wrench will be needed is a skill that can't be understated. Understanding metric units of measure can even be a safety consideration. For example, is a pressure reading of 3500 kPa in a power steering system too high?

Metric Units

The metric system has specific units of measure for a number of dimensions. Length (metre), mass (gram), and volume (litre) are the most common basic units. The table below outlines some of the more common metric units of measure encountered in the mechanical repair industry:

Dimension Measured	Base Unit	Symbol
Length	metre	m
Mass	gram	g
Volume	litre	ℓ *or* L
Area	square metre	m^2
Time	second	s
Temperature	degrees Celsius	°C
Force	newton	N
Pressure	pascal	Pa
Energy	joule	J
Power	watt	W

NOTES

Metric Prefix

The metric system is based on the number 10. Each level is ten times greater than the level before it (10, 100, 1000, etc.) or ten times smaller than the level above it ($\frac{1}{10}$, $\frac{1}{100}$, $\frac{1}{1000}$). Each level away from the base unit is assigned a prefix for verbal or written use. The most common prefixes are listed in the table below:

Prefix	Symbol	Value
mega	M	1 000 000
kilo	k	1000
centi	c	0.01 or $\frac{1}{100}$
milli	m	0.001 or $\frac{1}{1000}$
micro	μ	0.000 001 or $\frac{1}{1\,000\,000}$

So, for example, a kilogram (kg) is 1000 grams. A centimetre (cm) is 1/100 of a metre.

Some common metric measurements don't follow the prefix system above. For example, a "tonne" is a mass measurement equal to 1000 kg and its symbol is "t." A "bar" is a pressure measurement equal to 100 kPa and its symbol is "bar."

Converting Within the Metric System

As the quantity of a dimension increases or decreases, we add the appropriate prefix and change the number by moving its decimal place.
For example:

1000 grams = 1 kilogram = 1 kg = 1000 g

0.001 litres = 1 millilitre = 1 mL = 0.001 L

0.01 metres = 1 centimetre = 1 cm = 0.01 m

With some measurements, you're able to convert between base units:

1 millilitre = 1 cubic centimetre = 1 cm^3 = 1 mL

1 kilogram = 9.8 newtons = 9.8 N = 1 kg

SELF TEST 10

1. Fill in the chart:

Name	Symbol	Value in Base Units
	mg	
	km	1000 metres
	μm	
millilitre		
	t	
		0.01 litres

2. Complete the following conversions:

a. 0.003 L = _____ mL

b. 47 mm = _____ m

c. 167 mL = _____ cm^3

d. 0.78 kg = _____ mg

e. 3.7 m = _____ μm

f. 64.5 cg = _____ kg

g. 80 kg = _____ N

h. 3500 kPa = _____ bar

LEARNING TASK 11

Convert Between the Metric and Imperial Systems of Measurement

NOTES

Converting Between Metric and Imperial Measurements

Although most of the equipment you will work on is metric, you're going to come across some that have Imperial-based measurements. Length, weight, capacity, temperature, torque, and pressure readings are the most common measurements that you may need to convert. Charts, calculators, or the Internet can provide you with tools to convert between the two systems.

Note that there are differences between U.S. and Imperial measuring systems even though they may use the same units. For example, 1 U.S. gallon is 3.785 L, whereas 1 Imperial gallon is 4.546 L.

The conversion chart below is using Imperial measurements, not U.S measurements. Memorizing conversion charts is not practical, but you should be able to use them.

Metric/Imperial Conversion Factors

Dimension	Metric to Imperial		Imperial to Metric	
Length	1 km	= 0.621 mi.	1 mi.	= 1.609 km
	1 m	= 1.094 yd.	1 yd.	= 0.914 m
	1 m	= 3.28 ft.	1 ft.	= 0.305 m
	1 cm	= 0.394 in.	1 in.	= 2.54 cm
	1 mm	= 0.039 in.	1 in.	= 25.4 mm
Mass	1 kg	= 2.205 lbs.	1 oz.	= 28.350 g
	1 g	= 0.035 oz.	1 lb.	= 0.454 kg
	1 t	= 2204.6 lbs.	1 ton	= 0.908 t
Capacity	1 L	= 1.760 pt.	1 pt.	= 0.568 L
	1 L	= 0.880 qt.	1 qt.	= 1.137 L
	1 L	= 0.220 gal.	1 gal.	= 4.546 L
Temperature	$\frac{9}{5}$ °C + 32 = F°		$\frac{5}{9}$ (°F – 32) = C°	
Torque	1 N•m	= 0.738 lb ft	1 lb•ft	= 1.356 N•m
Pressure	1 kPa	= 0.145 psi	1 psi	= 6.895 kPa
	1 bar	= 14.50 psi	1 psi	= 0.0689 bar

NOTES

Conversion Process

Whether converting metric to Imperial or vice versa, the process is the same. Multiply the measurement you have by the appropriate conversion factor. Realize your answer will only be as accurate as the accuracy of the initial value and the conversion factor.

e.g., Convert 38 mm to inches:

$38 \times 0.039 = 1.482$
$= 1.5$ inches

e.g., Convert 123 miles to kilometres:

$123 \times 1.609 = 197.907$
$= 198$ km

e.g., Convert 12 pounds to kilograms:

$12 \times 0.454 = 5.448$
$= 5.4$ kg

e.g., Convert 15 grams to ounces:

$15 \times 0.035 = 0.525$
$= 0.53$ oz.

e.g., Convert 8 gallons to litres:

$8 \times 4.546 = 36.368$
$= 36$ L

SELF TEST 11

Perform the following conversions:

1. 25.2 m = _____ yd

2. 25.0 in. = _____ cm

3. 50.5 kg = _____ lbs

4. 8.1 oz = _____ kg

5. 120 L = _____ qt

6. 26 gal = _____ L

LEARNING TASK 12

Describe Key Terms and Concepts for Equations and Formulas

NOTES

Mathematical Equations and Formulas

Using simple equations and formulas to solve problems is a useful skill for all trades. You have already started to develop this skill when converting metres to feet. You will encounter more equations and formulas as your training unfolds. Formulas such as Pascal's Law (hydraulics) and Ohm's Law (electricity) will become second nature to you. Learning to manipulate equations to determine an unknown quantity takes practice but is essential when solving mathematical problems.

Some key terms are explained below.

Equation

An equation is a statement of equality between two quantities as indicated by the equal sign (=). All equations must be true. An equation will usually have at most one unknown quantity.

e.g., $5 + 3 = 4 \times 2$

e.g., $x^2 = 64$

Formula

A formula is a mathematical law or rule expressed as an equation. For example, the formula for the area of a rectangle is the length times the width. This formula would be written as:

$A = lw$

where A = area, l = length, and w = width.

A formula will have two or more unknown quantities.

NOTES

Constant

A constant is a numerical value that forms part of an equation or formula. In the equation for finding the perimeter of a square, P = 4*l*, the number "4" is considered a constant because it does not change no matter how large the square.

The formula for the area of a circle is:

$$A = \pi r^2$$

π (pronounced "pi") is a constant even though it's not written as a number. It has a fixed numerical value which does not change no matter how large the circle.

Variable

A variable in a formula or equation is a symbol that represents an unknown or non-constant quantity. In the equation, $x^2 = 64$, the symbol "*x*" stands for an unknown quantity that can be found by calculation. In the formula, $A = lw$, the symbols "*A*", "*l*", and "*w*" represent variables that can be measured or calculated (if the value of two variables is known, the third variable can be calculated). Usually letters of the English alphabet are used to represent variables.

Solution

A "solution" is a value for an unknown quantity that will make an equation true. For example, in the equation, $x + 12 = 15$, the solution is $x = 3$.

SELF TEST 12

1. Indicate which of the following mathematical statements are equations and which are formulas:

   a. $I = \frac{E}{R}$

   b. $200x^2 = 5$

   c. $29.6 = 3\pi^2$

   d. $F = P\pi r^2$

2. Indicate the constant(s) and the variable(s) in the following equations and formulas:

   a. $P = 4S$

   b. $10 + U = 24h$

   c. $V = \pi r^2 h$

   d. $x = \frac{100y}{2}$

3. Solve for the unknown quantity:

   a. $\frac{5}{8} = N + \frac{1}{4}$

b. $3 \times 8 = Q \div 16$

c. $13 + 3 = 3 \times W$

d. $r^2 = \frac{45}{3.14}$

LEARNING TASK 13

Solve Problems Involving Formulas

NOTES

Using Formulas

When you encounter a word problem involving a formula, insert the known values so that you have an equation. Isolate the unknown value by itself on the left side of the equation, then perform the calculation.

e.g., The formula for torque is:

$T = FD$

where T is torque in newton-metres, F is the force in newtons, and D is the distance in metres.

What is the torque value if a force of 112.5 newtons is applied to the handle of a torque wrench that is 0.46 metres long?

$T = FD$
$T = (112.5)(0.46)$
$T = 51.75$

The answer is 51.75 N•m.

e.g., The formula for Ohm's Law is:

$E = IR$

where E is the electromotive force in volts, I is the current in amperes (amps), and R is the resistance on ohms.

How much current will flow through a 6 ohm resistor if 12 volts are connected to it?

$$E = IR$$
$$12 = I(6)$$
$$\frac{12}{6} = \frac{I(6)}{6}$$
$$2 = I$$

The answer is 2 amperes.

SELF TEST 13

1. Pascal's Law is:

   $F = PA$

   where F is force in newtons (N), P is pressure in pascals (Pa), and A is area in square metres (m^2).

   How much force needs to be applied to a 0.03 m^2 piston to generate a pressure of 250 000 Pa?

2. The formula for converting temperature readings is:

   $$C = \frac{5}{9} (F - 32)$$

   where C is degrees Celsius, and F is degrees Fahrenheit.

   a. What is a temperature reading of 77°F in °C?

   b. What is 30°C in °F?

3. The formula for calculating the time needed to move a distance down a rotating object is:

   $$t = \frac{L}{F_s V}$$

   where t is the time in minutes, L is the length travelled in centimeters, F_s is the feed speed in centimetres per revolution, and V is the rotational speed in revolutions per minutes (rpm).

   How long will it take a lathe to cut a groove in an 18 cm long shaft if the feed speed is 0.08 cm per revolution and the lathe is rotating at 250 rpm?

LEARNING TASK 14

Describe Key Terms and Concepts for Working with Ratio and Proportion

NOTES

Terms and Concepts Involved with Ratios and Proportions

Ratio and proportion specifications are used throughout the Heavy Mechanical Trades. Common ratio specifications include engine compression ratio, drive axle ratio, transmission or gear ratios, pulley ratio, and many more. Understanding the concepts behind ratios is key to understanding how we achieve mechanical, hydraulic, and electrical advantage in the design of equipment.

Proportions are used in many different ways, such as with mechanical drawings, when oil is mixed with gasoline for two-stroke cycle engines, and when antifreeze is mixed with water to form coolant.

Ratio

Ratio is a comparison between two related quantities. Most ratios used in the mechanical trade use quantities that have the same unit of measure (e.g., litres to litres; gear tooth number to gear tooth number). If a pulley drives another pulley with a belt, then the ratio between them is calculated using their diameters.

Ratios can be expressed in several ways:

- 1 to 2
- $\frac{1}{2}$
- 1:2
- $1 \div 2$

To avoid confusion, you need to clearly state how you're comparing the two quantities. For example, two pulleys have a diameter of 1 cm and 2 cm. Their ratio could be 1:2 or 2:1 depending on their relationship to each other. There are predetermined ways of calculating ratios in certain applications. Two common ones are listed on the next page.

NOTES

$$\text{Gear or pulley ratio} = \frac{\text{output gear/pulley}}{\text{input gear/pulley}}$$

$$\text{Compression ratio} = \frac{\text{total cylinder volume}}{\text{clearance volume}}$$

It's common to express ratios using the form:

#:1 (where # is replaced with an appropriate value)

e.g., 3:1
5:1
4.2:1

Note that, unlike fractions, we are not limited to using only whole numbers for the first term (as shown in the example above.) If you are given a ratio and need to express it in the form above, simply divide the first term by the second:

e.g., Given the ratio 7:2, we divide 7 by 2 (which equals 3.5) to get a ratio of 3.5:1

Proportion

Ratios are "proportionate" when they are equal to each other. For example, the ratios ½ and $^{2}/_{4}$ are equal, so they are said to be proportionate or "in proportion" to each other.

You can determine if two ratios are proportionate by using cross-multiplication.

e.g., Are the ratios 2:1 and 6:3 proportionate?

First, write the ratios as fractions:

$$\frac{2}{1} \qquad \frac{6}{3}$$

Now, we cross-multiply to get the following two equations:

$$2 \times 3 = 6$$

$$1 \times 6 = 6$$

Since the value of both equations is the same, the ratios are in proportion to each other.

You can use this principle to determine an unknown value if you're given the other three values:

Notes

e.g., A mechanical drawing has a scale (or ratio) of 1:100 (that is, 1 cm on the drawing is equal to 100 cm in real life). You measure a shaft on the drawing and it is 0.75 cm long. How long is the shaft in real life?

The two ratios are:

$$\frac{1}{100} \quad \frac{0.75}{s}$$ (where s is the length of the shaft in real life.)

Using cross-multiplication, we get the following equation:

$$1 \times s = 100 \times 0.75$$

Therefore $s = 75$ and the shaft is 75 cm long in real life.

e.g., In a two-stroke engine, oil is mixed with gasoline at a 50:1 ratio (50 parts gasoline to 1 part oil). How much oil should be added to 5 litres of gasoline?

The two ratios are:

$$\frac{50}{1} \quad \frac{5}{g}$$ (where g is the volume of oil needed.)

Using cross-multiplication, you get the following equation:

$$50 \times g = 1 \times 5$$

Therefore $g = 0.1$ and so 0.1 L of oil are required.

SELF TEST 14

1. Express the following ratios in the form of #:1.

   a. 63:9

   b. 6:1.5

   c. 3:4

   d. 14:27

   e. 2.4:0.8

2. A journeyman mechanic makes $32.00 an hour. A second year apprentice in the same shop makes $24.00 an hour. What is the ratio in lowest terms of the journeyman's wage to the apprentice's wage?

3. A gear with 10 teeth is driving (input) a gear with 15 teeth (output). What is the gear ratio?

4. One cylinder in an engine has 2 L of total volume and a clearance volume of 125 mL. What is its compression ratio?

5. A pulley with a diameter of 10 cm is driving a pulley that has 6 cm diameter. What is their ratio?

LEARNING TASK 15

Solve Word Problems Involving Ratio and Proportion

NOTES

Word Problems Involving Ratio and Proportion

Mathematical problems involving ratios or proportions are often presented with a written description of the situation. It's very important that you understand the problem so that you can set up an appropriate equation correctly.

Steps to Solving Word Problems Involving Ratio and Proportion

Use the same four-step procedure as before: determine what you're to find out, what information you're given, which mathematical operation to use, and create an equation that will result in a solution.

In the previous Learning Task, you used cross-multiplication to determine an unknown quantity. Another useful technique involves manipulating the equation to isolate the unknown value.

e.g., The ratio between two gears in mesh is 3:1. If the output gear has 24 teeth, how many teeth does the input gear have?

$$\text{Gear ratio} = \frac{\text{output}}{\text{input}}$$

Therefore the equation is:

$$\frac{3}{1} = \frac{24}{x}$$

and you need to determine the value of x.

If you multiply both sides by x, you get:

$$3x = 24$$

Now divide both sides by 3 to get:

$$x = 8$$

The input gear has 8 teeth.

SELF TEST 15

1. A starter gear (input) has 12 teeth and a flywheel ring gear (output) has 102 teeth. What is their gear ratio in lowest terms? What is their gear ratio in #:1 terms?

2. A gear set inside a transmission has a gear ratio of 3.5:1. If the input gear has 14 teeth, how many teeth are on the output gear?

3. An eight cylinder gasoline engine has a compression ratio of 8:1. If the total volume of one cylinder is 0.65 L, what is its clearance volume?

4. A steel pipe has a mass of 0.425 kg for every 0.33 m. What is the mass of 3.6 m of this pipe?

5. You're mixing boat gasoline and oil at a ratio of 50:1. You need 30 litres of fuel for the day's fishing trip. How much oil are you going to add to the 30 litres of gasoline?

LEARNING TASK 16

Solve Problems Involving Perimeters

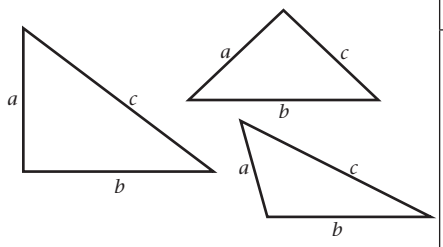
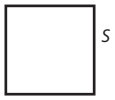
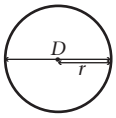
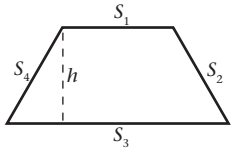
NOTES

Calculating Perimeters

Calculating the perimeter (the distance around an object) involves a formula which is dependent on the shape of the object.

Perimeter Formula

The formulas related to common objects are listed in the following chart. If you have a complex shape that doesn't match the standard shapes, you can divide it into smaller shapes that do.

Figure	Perimeter
Rectangle 	$P = 2L + 2W$ or $P = 2(L + W)$
	Where L = length W = width
Triangle 	P = $a + b + c$
	Where a = the length of a side b = the length of a side c = the length of a side
Square 	$P = 4S$
	Where S = the length of a side
Circle 	$C = \pi D$ or $C = 2\pi r$
	Where C = circumference (perimeter) D = diameter r = radius $\pi = 3.1416$
Trapezoid 	$P = S_1 + S_2 + S_3 + S_4$
	Where S = the length of a side

NOTES

e.g., A square has 25 cm sides. What is its perimeter?

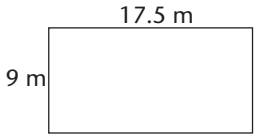
$P = 4S$
$P = (4)(25)$
$P = 100$ cm

e.g., What is the circumference (perimeter) of a circle with a diameter of 55 mm?

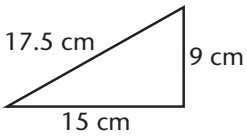
$C = \pi D$
$C = \pi(55)$
$C = 172.7$ mm

SELF TEST 16

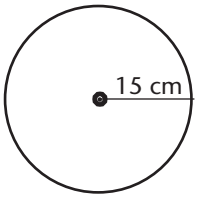
1. Find the perimeter of the rectangle below:



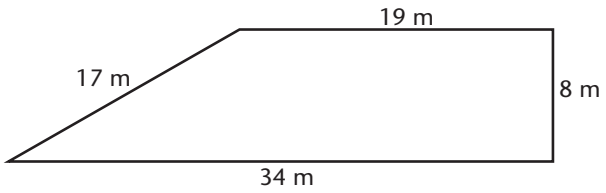
2. What is the perimeter of the following triangle?



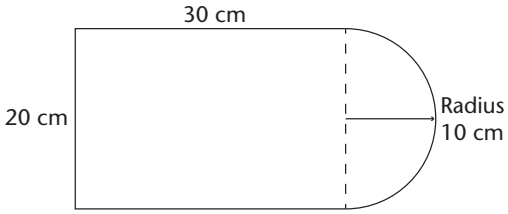
3. Find the circumference of the circle below:



4. What is the perimeter of the trapezoid pictured below?



5. What is the perimeter of the complex shape below?



LEARNING TASK 17

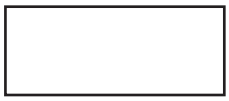
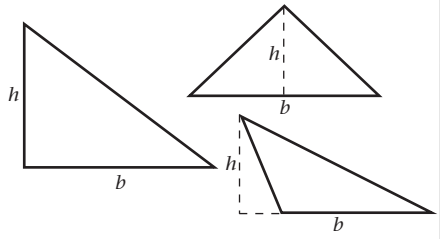
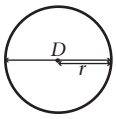
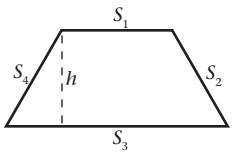
Solve Problems Involving Area

NOTES

Calculating Areas

Calculating the area of an object involves specific formulas based on its shape. The area of complex shapes can be calculated by dividing the shape into simpler forms, calculating their areas, and then adding to get the grand total.

Area Formula

Figure	Area
Rectangle 	$A = LW$ Where L = length W = width
Triangle 	$A = \frac{1}{2}bh$ Where b = base h = height
Square 	$A = S^2$ Where S = the length of a side
Circle 	$A = \pi r^2$ or $A = 0.79\ D^2$ Where D = diameter r = radius $\pi = 3.1416$
Trapezoid 	$A = h\ \frac{S_1 + S_3}{2}$ Where h = height or altitude Where S = the length of a side

NOTES

e.g., A square has 25 cm sides. What is its area?

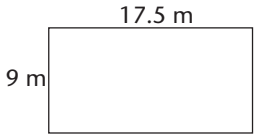
$A = S^2$
$A = S^2$
$A = 625\ cm^2$

e.g., What is the area of a circle with a diameter of 55 mm?

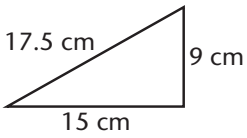
$A = 0.79D^2$
$A = (0.79)(55)^2$
$A = 2390\ mm^2$

SELF TEST 17

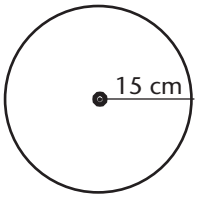
1. Find the area of the rectangle below:



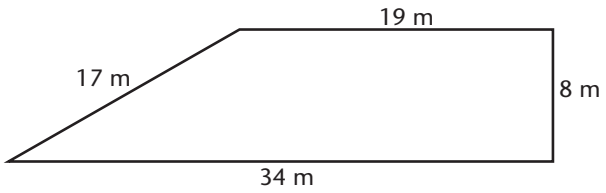
2. What is the area of the following triangle?



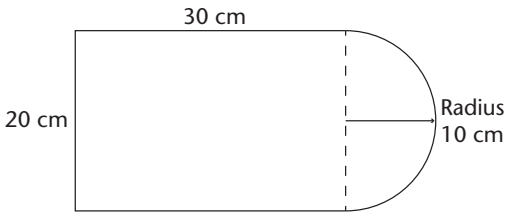
3. Find the area of the circle below:



4. What is the area of the trapezoid pictured below?



5. What is the area of the complex shape below?



LEARNING TASK 18

Solve Problems Involving Volume

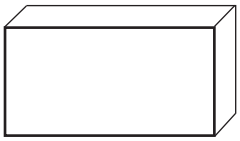
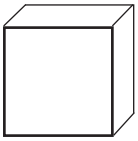
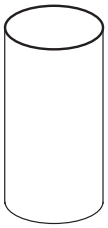
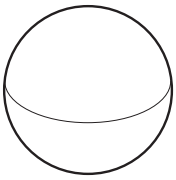
Notes

Calculating Volume

Volume is defined as the amount of space occupied by an object. The term "volume" is often used to mean "capacity" or the number of cubic units enclosed within a container such as a bin or tank.

Volume Formula

The formula for finding the volume of common objects is listed in the chart below:

Figure	Volume
Rectanglular Solid 	$V = LWH$ Where L = length W = width H = height
Cube 	$V = S^3$ Where S = the length of a side
Cylinder 	$V = \pi r^2 h$ Where h = height r = radius $\pi = 3.1416$
Sphere 	$V = \frac{4}{3} r^3$ Where r = radius

NOTES

e.g., A rectangular water tank measures 1200 cm long by 500 cm wide by 750 cm high. How much water can the tank hold if it's completely full?

$V = LWH$
$V = (1200)(500)(750)$
$V = 450\ 000\ 000\ cm^3$

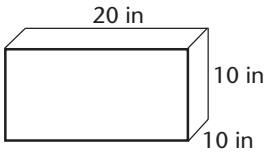
e.g., A hydraulic cylinder is 15 cm long and holds 3000 cm^3 of oil when it's fully extended. What is the diameter of this cylinder?

$V = \pi r^2 h$
$3000 = \pi r^2 15$
$200 = \pi r^2$
$63.7 = r^2$
$7.98 = r$

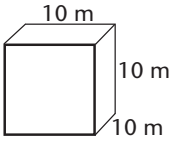
Diameter is equal to twice the radius so the final answer is
$2 \times (7.98) = 15.96$ cm

SELF TEST 18

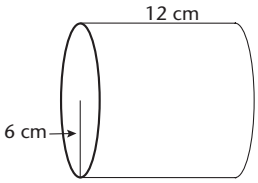
1. Find the capacity of the rectangular tank below:



2. What is the volume of the cube pictured below?



3. Find the volume of the cylinder:



4. A cylindrical fuel tank is 25 m long and 3 m in diameter. The tank is located inside a containment field that measures 30 m long by 5 m wide by 1 m high. If the tank develops a leak, is there enough volume in the containment field to hold the full tank capacity?

LEARNING TASK 19

Describe Key Terms and Concepts Associated with Using Angles

Notes

Terms and Concepts Involved with Angles

An angle is a measure of the size of the opening between two intersecting lines. It can also be thought of as the degrees of rotation a line sweeps through from a fixed point.

Understanding the terms and concepts associated with angles will allow you to better understand how equipment is supposed to function.

Degree

Degree is the common unit of measure of angles and its symbol is: °.

A complete rotation consists of 360°. An angle that is ¼ of a complete rotation is a 90° angle (and commonly called a "right angle").

Vertex

The vertex is the point about which a line rotates to form an angle. In the angle ABC below, B is the vertex.

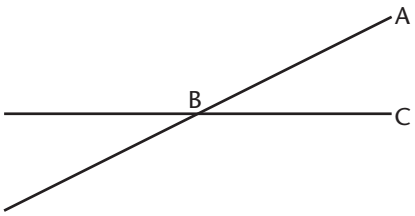


Figure 1. Vertex

NOTES

Angle Types

Angles are classified by their magnitude (that is, how wide or narrow they are).

Right Angle

An angle that forms exactly 90° is known as a right angle. Right angles are often identified by a square symbol place at the vertex.



Figure 2. Right Angle

Acute Angle

An angle less than 90° is known as an acute angle.

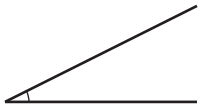


Figure 3. Acute Angle

Obtuse Angle

Obtuse angles have a measurement of greater than 90° but less than 180°. Sometimes an arc is placed at the vertex to indicate which angle is being measured.



Figure 4. Obtuse Angle

Straight Angle

An angle that that is exactly 180° is known as a straight angle.



Figure 5. Straight Angle

NOTES

Reflex Angle

Reflex angles are between 180° and 360°.

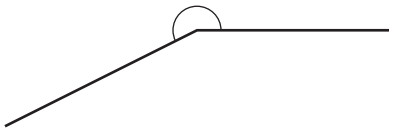


Figure 6. Reflex Angle

Complementary Angles

Complementary angles are two angles which together contain 90°.

e.g., angles ABC and CBD are complementary.

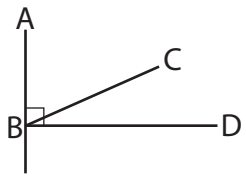


Figure 7. Complementary Angles

Supplementary Angles

Two angles that combine to make 180° are known as supplementary angles.

e.g., angles ABC and ABD are supplementary.

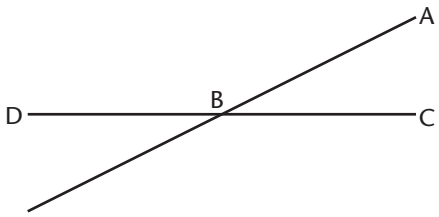


Figure 8. Supplementary Angles

Opposite Angles

Two intersecting lines will form four separate angles.

e.g., angles A, B, C, and D are formed.

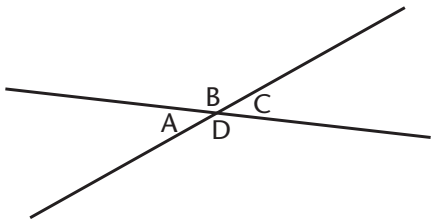


Figure 9. Opposite Angles

Angles A and C are opposite as are angles B and D. Opposite angles have the same magnitude.

NOTES

Triangle

A triangle is a geometric figure formed by the lines joining three angles. The three angles in a triangle always add up to 180°.

There are a number of special triangles that are given the following names:

Right Triangle

A triangle containing a right angle (90°) is known as a right triangle.

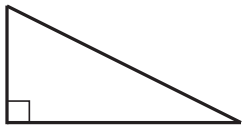


Figure 10. Right Triangle

Equilateral Triangle

If all three sides of a triangle are the same length, then it's an equilateral triangle. Each of the angles in an equilateral triangle is 60°.

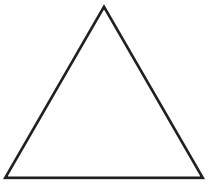


Figure 11. Equilateral Triangle

Isosceles Triangle

An isosceles triangle is one where two sides are equal in length but the third is not.

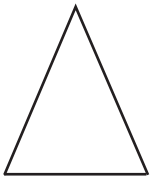


Figure 12. Isosceles Triangle

Similar Triangle

Two triangles which have angles of the same magnitude but different length sides are known as similar triangles.

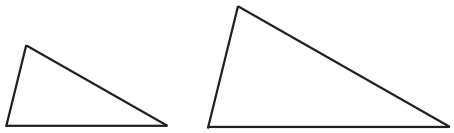


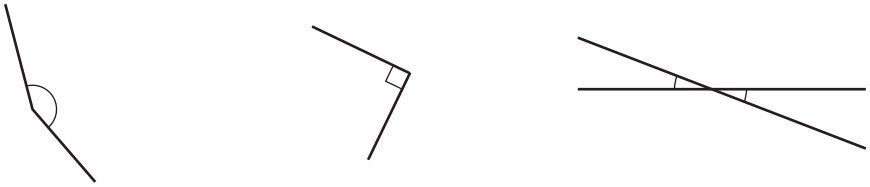
Figure 13. Similar Triangle

NOTES

SELF TEST 19

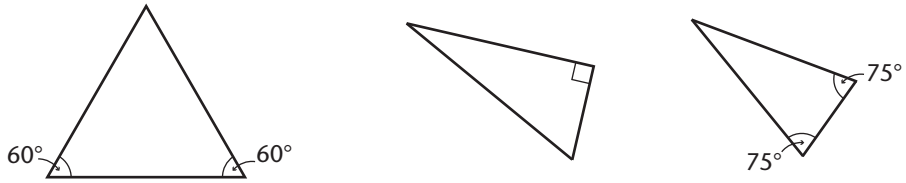
1. Identify the following angles.

a. b. c.



2. Identify the following triangles.

a. b. c.



LEARNING TASK 20

Use Angles

Notes

Use Angles

You'll often have to measure angles in the Heavy Mechanical Trades. Checking drive shaft angles or measuring a vehicle's frame for damage are just two examples.

Protractors

A protractor (Figure 1) is used to measure degrees in an angle. Notice that it has two scales: one on the outside and one on the inside. Both of them range from 0° to 180° but they do so in opposite directions. Use the one that is easiest to read when measuring an angle. Keep in mind that a straight line is 180° and a complete rotation is 360°.

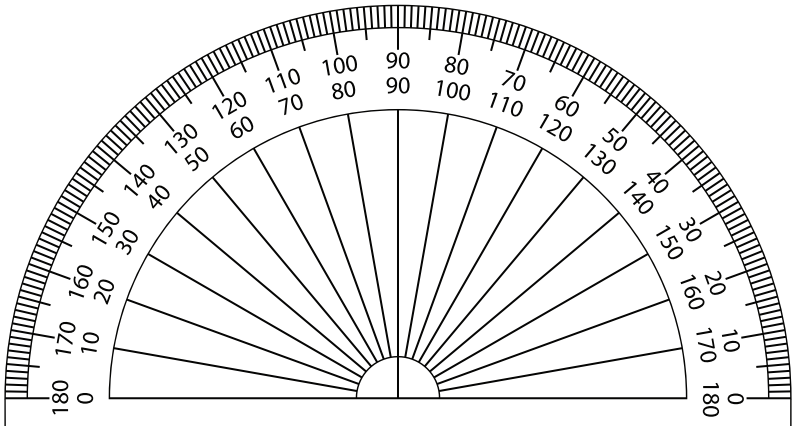


Figure 1. Protractor

To use a protractor to measure an angle, place the centre of the protractor on the vertex of the angle. Align the straightedge with one of the lines of the angle. Read the scale (inner or outer) that starts at 0° at the straightedge line. For example, using the protractor to measure the angle UVW shown in Figure 2 you would use the outer scale to get a reading of 50°.

NOTES

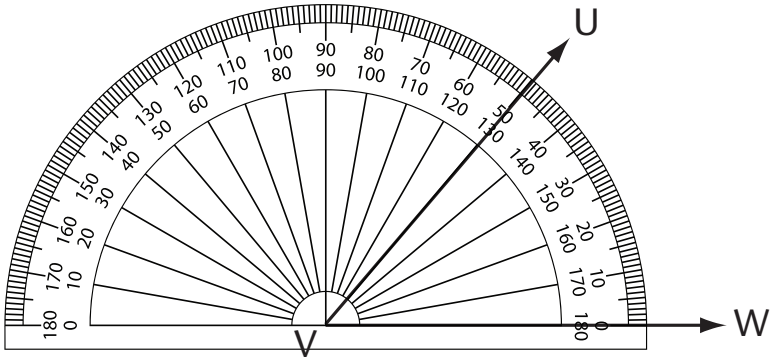


Figure 2. Measuring an Angle

Inclinometer

Another useful tool for measuring angles away from true horizontal or vertical is the inclinometer or digital protractor. These measuring tools are available in mechanical scales or electronic read-out (Figure 3).



Figure 3. Inclinometers

Angles and Parallel Lines

Two straight lines are parallel when they run in exactly the same direction. Floor joists are usually laid out to run parallel, as are studs and rafters.

Figure 4 shows a stud wall with a diagonal brace. Three of the many angles formed are labelled.

NOTES

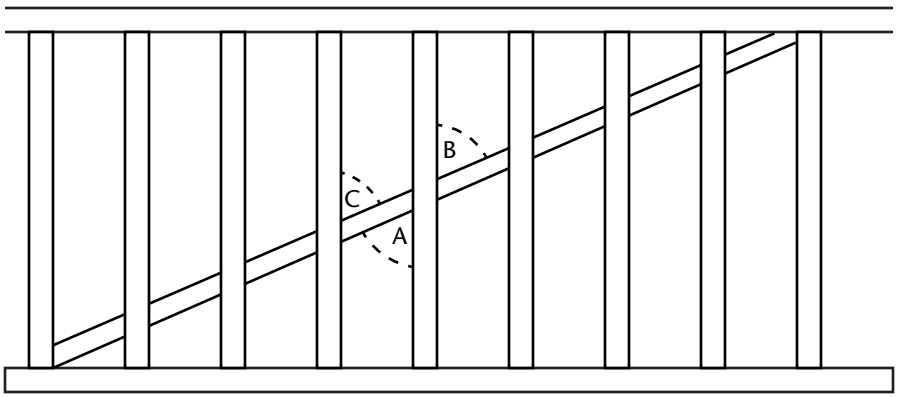


Figure 4. Stud Wall with Diagonal Brace

Angles A and B are opposite, so you know that they're equal. Angles B and C are equal as they are formed by the same straight line intersecting parallel lines.

Units of Angle Measurement

A complete rotation contains 360°. Each degree is further divided into 60 minutes, and each minute is further divided into 60 seconds. (The terms "minutes" and "seconds" have nothing to do with time despite their names.)

The symbol for minutes is: ′

e.g., 4°30′ (4 degrees, 30 minutes)

The symbol for seconds is: ″

e.g., 10°40′20″ (10 degrees, 40 minutes, 20 seconds)

The 3:4:5 Triangle

Sometimes a right triangle (a triangle that has a 90° angle) is called a 3:4:5 triangle. This is due to the fact that a triangle that has sides of length 3, 4, and 5 must form a right triangle. The side opposite the right angle is called the hypotenuse.

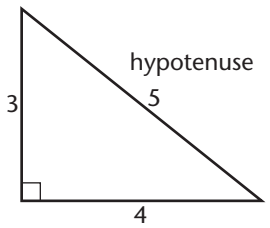


Figure 5. 3:4:5 Triangle

NOTES

The 3:4:5 triangle can be used to check that components are at right angles to each other:

1. Create a mark 3 units along one component. (The units can be any measure you choose: centimetres, inches, feet, metres, etc.)

2. Create a mark 4 units along the other component.

3. If the distance between the two marks is 5 units, then the components are at right angles to each other.

Pythagorean Theorem

The Pythagorean theorem states that in a right triangle, the square of the hypotenuse is equal to the sum of the square of the other two sides. Written as a formula it's:

$c^2 = a^2 + b^2$

You can use this theorem to prove that the 3:4:5 triangle is a right triangle:

$$c^2 = a^2 + b^2$$
$$c^2 = 3^2 + 4^2$$
$$c^2 = 9 + 16$$
$$c^2 = 25$$
$$c = 5$$

e.g., Find "*a*" in the following right triangle:

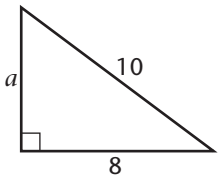


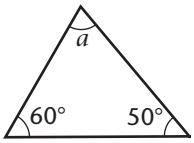
Figure 6.

$$c^2 = a^2 + b^2$$
$$10^2 = a^2 + 8^2$$
$$10^2 - 8^2 = a^2$$
$$100 - 64 = a^2$$
$$36 = a^2$$
$$6 = a$$

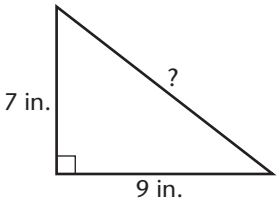
SELF TEST 20

Calculate the missing measurements in the following triangles.

1.



2.



COMPETENCY A-13
USE ELECTRONIC MEDIA



HEAVY MECHANICAL TRADES:
LINE A—COMMON OCCUPATIONAL SKILLS

Goals

When you have completed the Learning Tasks in this Competency, you will be able to:

- use computers to create documents and conduct research
- use electronic cameras

LEARNING TASK 1

Use Computers

Notes

Personal computers (PCs) have become common devices in both the home and office. In the Heavy Mechanical Trades, they have become an essential tool that you'll use on a regular basis. Some of the many tasks you'll use a computer for include:

- locating service information
- recording information on equipment service and maintenance
- writing reports and business forms
- ordering parts
- locating information on the Internet

Hardware

Computer hardware is the physical components that make up the computer. These items include:

- central processing unit (CPU)
- keyboard
- monitor
- mouse
- peripheral drives (memory sticks, external hard drives, etc.)
- printer
- modem/router

There are two main varieties of personal computers: desktops and laptops.

NOTES

Desktop computers are non-portable and usually consist of several separate components: the computer itself (sometimes called a "tower"), a monitor, mouse, and a keyboard (Figure 1).



Figure 1. Desktop Computer

Laptop computers (also called "notebooks") contain the computer, monitor, mouse, and keyboard in one self-contained unit. Laptops are becoming more popular due to their portability, but care must be employed as they are more vulnerable to damage from mishandling.

Both varieties can have other external devices (such as a printer) attached to them.

Central Processing Unit

The Central Processing Unit (CPU) is the "brain" of the computer—it's what does all the actual calculations and work of running the computer. The CPU is a large chip attached to circuit board (called the "motherboard") into which all other devices are attached. In a desktop computer, the CPU and motherboard are located in the tower.

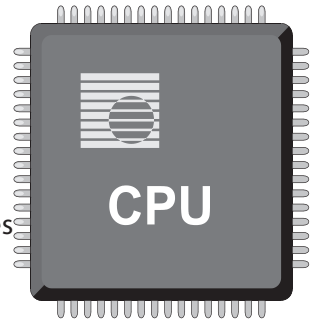


Figure 2. Central Processing Unit

NOTES

Monitors

The monitor (or screen) is the device that the computer uses to display information for you. Monitors for desktop computers will usually have their own separate power switch and may have separate controls for brightness and contrast. Although most monitors are used simply to display information, some have "touch screens" that can be used for input as well. Rather than using a keyboard or mouse, you'll touch the screen directly to enter information.



Figure 3. Monitor

Keyboard

The keyboard is the primary way that you'll enter detailed information into a computer, whether it's filling out a report, writing an email, or searching for information on the Internet. Traditional keyboards with individual keys are most common, but touch screens are becoming more and more popular (Figure 4). This is especially true on job sites as they are less susceptible to damage from dust or dirt.



Touch Screen Keyboard

It's important that you learn at least rudimentary keyboard skills as you'll be using them throughout your career in the Heavy Mechanical Trades.

NOTES

Mouse

A mouse is a small hand-held device used to control a cursor (or arrow) on the screen (Figure 5). It will also have one or more buttons used to select options and perform various functions. Most laptop computers have a "touchpad" or "trackpad" that acts in a similar way to a mouse (Figure 6).



Figure 4. Wireless Mouse



Figure 5. Laptop Trackpad

Storage

A computer needs to store information such as its operating system, applications, and your personal files (you'll learn more about these below) and it usually does so on an internal hard disk drive (Figure 7). You can think of a hard drive as a filing cabinet—a place that the computer stores all the information it will need to operate. Disk drives are identified by a letter followed by a colon and for most computers, the main drive will be the "C:" drive. Additional drives will usually be labelled alphabetically (i.e., D:, E:, F:, etc.).



Figure 6. Built-in Hard Disk Drive (HDD)

NOTES

There are also external disk drives or memory sticks that you can attach to a computer (Figures 8 and 9). These are also identified by a letter followed by a colon. (The specific letter will depend on the computer they are attached to. When you plug in an external storage device, it will be assigned the next available letter.) Normally, you will only store personal files, but not operating systems or applications, on external devices. This is so that you can share those files with other computers or to make back-ups. Currently, the most common way to attach external drives to a desktop tower or laptop, is through a USB (universal serial bus) plug.



Figure 7. External USB Hard Drive



Figure 8. USB Memory Stick

Most computers will also include a drive that reads CDs and DVDs. Unlike hard drives, external drives, or memory sticks, CDs and DVDs can only be written to once. Because of this, they are most often used when purchasing off-the-shelf software such as an operating system or application. You will then use the CD to install the software on your hard drive. CDs are not usually used for storing your personal files (except as a back-up).

Some businesses also use large computers called servers. These computers link many other computers together so that applications and files can be shared.

Storage Space

Hard drives, external drives, memory sticks, and CDs all have a specific capacity—a indication of how much they can store. The capacity is measured in "bytes"—a very small unit of information. Think of a byte as a single letter or number (e.g., a, b, 5, x, etc.) Because a byte is so small, they're organized it into larger and larger groups:

- a kilobyte (kB) is 1000 bytes
- a megabyte (MB) is 1 000 000 bytes (or 1000 kB)
- a gigabyte (GB) is 1 000 000 000 bytes (or 1000 MB)
- a terabyte (TB) is 1 000 000 000 000 bytes (or 1000 GB)

Storage capacity is increasing at a very fast rate. 20 years ago, a 20MB hard drive would have been considered large. Today, 2TB hard drives are not uncommon. That's an increase of 100 000 times!

NOTES

Printers/Scanners

Printers are one of the most common peripherals used with personal computers (Figure 10). They're used to print paper copies of reports and files. There are many types of printers, from low-cost "inkjet" printers to high-quality "laser" printers.

Scanners are used to make an electronic copy of a paper document and work in a similar fashion to a photocopier.

It's quite common for printers and scanners to be combined into a single machine (along with other features such as a photocopier and fax machine).



Figure 9. Printer

Software

Where hardware is the physical components that make up a computer, software is the instructions that tell the computer what to do. There are three major classes of software:

- operating system
- applications
- personal files

Operating System

The operating system (OS) is the main software that runs a computer. It does all the "behind the scenes" work that allows the computer to access peripherals, files, and devices. By far the most popular operating system is Microsoft Windows. Linux and Apple's Mac OSX are other popular operating systems, but they are far less common.

When you first turn on a computer (called "booting the system"), the OS will:

- run system tests
- check for new hardware
- start the main operating system

The operating system is what you use to configure the computer for use. However, you will mostly use it to start applications and store/move personal files.

Applications

An application (or app) is software designed to perform a specific task such as writing a report, sending an email, or exploring the Internet. The most common applications are:

- word processors
- spreadsheets
- presentation software
- web browsers
- email

NOTES

NOTES

Word Processors

A word processor is an application designed to create letters, reports, resumes, and all manner of written documents. They have built-in spell checkers and grammar checkers which help you create attractive, correctly-written documents. Most word processors include templates—existing files that are already arranged and formatted so that you need enter only specific information.

You will need to develop a cover letter and a resume at some point in your career and you'll use a word processor to do so.

The most popular word processor for Windows is Microsoft Word.

Spreadsheet

Spreadsheet applications are normally used to track mathematical information such as budgets or inventory. A spreadsheet is a group of cells arranged into columns and rows. Each cell will be identified by a letter (for its column) and a number (for its row). (e.g., C5, D13, H9) Into any cell, you can enter either a label, a number, or a formula. Formulas can include any sort of mathematical operation and can reference any other cell. This allows you to sum up a column of numbers, or average a group of entries, for example.

You could build a spreadsheet to keep track of your overall grade average. Each time you enter a mark in one of the subject cells, the spreadsheet will automatically calculate your new grade average.

Microsoft Excel is the most common spreadsheet application.

Presentation Software

Presentation software is used to create slideshows. These slideshows can incorporate text, spreadsheets, graphics, and animation. Slideshows are normally used when making presentations to a group. Your teacher may be using presentation software as part of his instruction.

Microsoft PowerPoint is the most common presentation software for Windows.

Web Browser

A web browser allows you to explore ("surf") the Internet—a global, interconnected collection of computer networks. The Internet has become an essential resource for many fields and the Heavy Mechanical Trades are no exception. You will use it to find service bulletins, order parts, and update your skills.

There are many browsers but the most popular ones are Internet Explorer, Firefox, and Chrome.

NOTES

Websites

The World Wide Web (WWW), the portion of the Internet you use with a web browser, is made up of billions of individual websites. In order to visit a particular website, you'll type its URL (Uniform Resource Locator) into your browser's address bar. A URL looks something like this:

e.g., http://www.apple.com

Since you won't always know the URL of a website you want to visit, you'll need to make use of an Internet search engine. The most popular one is Google:

http://www.google.com

Type in the terms you wish to search for (e.g., "transmission repair 1965 mustang"), and you will get a list of relevant websites.

Other popular websites include:

Google Maps	http://maps.google.com	An online map useful for finding locations or directions.
YouTube	http://www.youtube.com	A collection of videos. Many useful repair tutorials are available on YouTube, including ones from manufacturers.
Wikipedia	http://wikipedia.org	An online encyclopedia.

Email

Email stands for "electronic mail" and is an essential communication tool. It's primarily used to send written messages between individuals but has the capability of sending pictures, documents, and videos as well. In order to send or receive email, you'll need an email address (e.g., mechanic@gmail.com). There are many ways of acquiring an address, but you may also be assigned one by the shop you're working for.

There are many numerous applications used to read e-mail, some of which are online websites that you must visit with a web browser.

NOTES

Personal Files

The most important software on your computer will be the personal files you create. For example, when using a word processor, the individual document you create will be a personal file.

A typical personal file might be:

C:\employees\JohnSmith\resume.doc

There are several bits of important information in this full filename:

C:	This indicates which hard drive the file is stored on. C: is the default hard drive for most computers. Other drives (such as external drives or memory sticks) might be named D:, E:, etc.
employees	This is a folder (or directory). It is not a file itself, but merely a location to place files. Folders are used to organize files in a logical manner. (Such as placing all employee files in one common area.)
JohnSmith	This is a subfolder (of C:\employees). Again, it is not a file itself, but merely a location in which to place files. (In this case, files specific to John Smith.)
resume.doc	This is an actual file. Its name consists of two parts, separated by a dot. The first part ("resume") is the filename that you will provide when you first save the file. The second part ("doc") is the extension which describes what type of file it is. (In this case, it's a Word document.) The extension will be automatically set by the application when you save the file.

When working in a shop, there will likely be set procedures for where files should be saved. Normally, the hard drive (e.g., "C:") and folders (e.g., "employees\JohnSmith") will already be created for you. It's very important that you maintain a logical, organized method when saving personal files. This is so that you (and others) will be able to access these files at a later date, as well as being able to back-up files for safe-keeping.

When naming files, you should be as descriptive as possible so that the file can more easily be identified. It will be difficult to recall what "letter.doc" contains, whereas it's clear what "2008_Ford_Explorer_Repair_Manual.doc" is.

Normally, the extension of a filename will be set by the application that was used to create the file. This will tell you what type of file it is. Some of the more common extensions include:

- .doc Word document
- .ppt PowerPoint presentation
- .xls Excel spreadsheet
- .pdf Adobe Portable Document Format (A PDF is similar to a word processing document but is not editable. It is commonly used by manufacturers when sending service bulletins and updates.)
- .jpg A photograph

NOTES

SELF TEST 1

1. What are the three main components of a laptop computer?

   a. monitor, keyboard, and cassette player/recorder
   b. monitor, keyboard, and central processing unit
   c. printer, central processing unit, and keyboard
   d. disk drive, printer, and central processing unit

2. What is the main purpose for the USB port external hard drive?

   a. store e-mail information
   b. store CPU information
   c. store personal information
   d. store the computer operating system

3. How many characters can be stored in 1 kilobyte of memory space?

   a. 800 characters
   b. 1000 characters
   c. 8000 characters
   d. 10 000 characters

4. What might be the best method to send a signed resume to an employer?

   a. type your name in the signature spot and attach the resume to the e-mail message
   b. attach the resume to the e-mail with no signature and send with the e-mail
   c. scan the signed resume and attach to the e-mail message
   d. send the e-mail with a message that you will mail the signed resume

5. What software performs checks for new hardware?

   a. operating system software
   b. word document software
   c. file managing software
   d. applications software

6. What is the purpose for Bing and Google?

   a. operating system
   b. file managing software
   c. applications software
   d. internet search engine

LEARNING TASK 2

Use Electronic Media

Notes

Digital Camera

Digital cameras have become very common now that most cell phones include one. This presents many opportunities in the Heavy Mechanical Trades to improve service and efficiency. By taking pictures of damaged components or needed parts, you can document the repair process. This is especially handy when working in the field and you need to communicate with workers at other locations. It is also useful for providing feedback to customers such as showing them disassembled equipment or the progress of repairs.

Digital Video

In some situations, digital video can be even more useful than digital pictures. You can record a repair, damaged components, and disassembled parts and send the video to your shop for record-keeping purposes. The video can also be used by shop staff to order parts for you. Even more critically, it can be used to help you complete a repair in the field by allowing those at another location to see what you're seeing and offering assistance.

There is no Self Test for this learning task.

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Competency A-7: Operate Equipment

Self Test 1

1. d. the equipment/truck operator's manual
2. a. machine can be safely started and moved
3. c. lower the fluid level, document the amount of displaced oil, and notify supervisor

Self Test 2

1. b. while the engine is being cranked
2. c. pre-combustion chamber
3. c. maintain battery efficiency

Self Test 3

1. d. 30 seconds
2. a. notify a technician to have the problem located
3. d. shut the engine down immediately to prevent engine damage
4. d. how to stop the engine

Self Test 4

1. c. shut-off intake air
2. b. have a piece of plywood handy to shut-off the air

Self Test 5

1. a. the engine computer is programmed for 3 minute idle shut-down
2. c. prevent turbo charger damage

Self Test 6

1. a. prevent engine starting
2. c. notify workers that the machine/truck is unsafe to start
3. b. prevents the starter from being engaged

Self Test 7

1. c. identify stabilization as the forks are lifted
2. c. every time an operator climbs onto the machine
3. b. as close to the ground as possible

Competency A-8: Use Shop Resources and Record Keeping

Self Test 1

1. b. business forms and record keeping forms
2. d. work order
3. a. parts requisition
4. c. work order number
5. d. purchase order

6. b. change of job
7. a. record keeping for your pay cheque
8. c. record the service information
9. a. details the maintenance for one occasion

Self Test 2

1. c. introduction, body, conclusion
2. b. shift-end
3. a. service
4. b. before the job is started

Self Test 3

1. b. technical
2. c. schematic diagrams
3. b. service bulletins
4. a. operation

Competency A-9: Service Winch Wire Rope

Self Test 1

1. b. dozer
2. a. mechanical and hydraulic
3. c. drum
4. b. number of strands in the wire rope
5. d. filler
6. a. pattern
7. b. right lang
8. b. working load limit
9. c. bend it back and forth
10. a. repeated beating of the rope
11. c. faulty handling
12. c. sudden stops
13. d. flatten the rope
14. a. direction it is wound
15. b. kink
16. a. cycle in and out and slowly increase load
17. c. reduce friction and corrosion

Competency A-10: Identify Lubricants

Self Test 1

1. a. reduce friction
2. c. dry friction
3. c. viscous friction
4. d. hydrodynamic
5. b. heat

Self Test 2

1. c. Society of Automotive Engineers
2. b. 5W-30
3. a. American Petroleum Institute
4. b. 100°C (212°F)
5. c. multi-viscosity
6. c. viscosity index
7. a. CJ-4
8. b. dropping point
9. c. automatic transmissions
10. b. make them an environmentally friendly oil

Self Test 3

1. b. gear oil
2. b. graphite
3. a. current oil sample result

Self Test 4

1. c. have it picked up for recycling purposes
2. c. dispose of the entire tube of grease

Self Test 5

1. c. quick connector kit and sample with engine running
2. b. Spectrometric analysis test

Competency A-11: Service Bearings and Seals

Self Test 1

1. a. rotate with the shaft
2. a. radial load
3. d. the inner and outer races can be separated
4. b. conrad type
5. c. friction

Self Test 2

1. b. dial indicator
2. d. 25 inch pounds
3. a. overload
4. c. assembly

Self Test 3

1. a. retain fluids and exclude contaminants
2. c. static and dynamic
3. b. absorbs lubricant
4. d. undercarriage rollers
5. b. water pump

Self Test 4

1. c. slide hammer puller
2. d. replace the seal
3. c. the lubricant that it will retain
4. d. repair the rotating surface

Competency A-12: Apply Math and Science

Self Test 1

1. d. 20 + 45
2. c. 62
3. d. 120
4. c. 12
5. a. 9^5
6. c. $x = 672$

Self Test 2

1. d. 30
2. b. 86
3. d. 1044
4. b. 6

Self Test 3

1. Divide both terms by 8 so $\frac{24}{64}$ becomes $\frac{3}{8}$.
2. Find common denominator to compare fractions. $\frac{3}{8}$ becomes $\frac{12}{32}$ so it's larger than $\frac{11}{32}$.

3. To find the whole numbers, divide 83 by 16. The result is 5 and 3 remainder. $\frac{83}{16}$ can be expressed as $5\frac{3}{16}$.

4. The reciprocal is $\frac{16}{15}$ or $1\frac{1}{15}$.

5. The group becomes $\frac{6}{24}$, $\frac{20}{24}$, $\frac{9}{24}$, and $\frac{18}{24}$.

Self Test 4

1. $\frac{5}{8}+\frac{1}{16}$
$=\frac{10}{16}+\frac{1}{16}$
$=\frac{11}{16}$

2. $1\frac{2}{3}+3\frac{1}{4}$
$=1\frac{8}{12}+3\frac{3}{12}$
$=1+3+\frac{11}{12}$
$=4\frac{11}{12}$

3. $\frac{1}{2}-\frac{3}{16}$
$=\frac{8}{16}-\frac{3}{16}$
$=\frac{5}{16}$

4. $3\frac{1}{8}-1\frac{3}{4}$
$=3\frac{1}{8}-1\frac{6}{8}$
$=2\frac{9}{8}-1\frac{6}{8}$
$=2\frac{3}{8}-1$
$=1\frac{3}{8}$

Self Test 5

1. $\frac{9\times5}{10\times6}=\frac{45}{60}=\frac{3}{4}$

2. $3\frac{3}{8}\times2\frac{3}{4}=\frac{27\times11}{8\times4}=\frac{297}{32}=9\frac{9}{32}$

3. $\frac{5}{8}\div\frac{1}{2}=\frac{5}{8}\times\frac{2}{1}=\frac{10}{8}=\frac{5}{4}=1\frac{1}{4}$

4. $12\frac{5}{8}\div1\frac{1}{4}=\frac{101}{8}\div\frac{5}{4}=\frac{101}{8}\times\frac{4}{5}=\frac{404}{40}=\frac{101}{10}=10\frac{1}{10}$

Self Test 6

1. $\frac{5}{8}+\frac{1}{16}+\frac{1}{4}$
$=\frac{10}{16}+\frac{1}{16}+\frac{4}{16}$
$=\frac{15}{16}$

Answer: The bolt needs to be $\frac{15}{16}$ *in. long.*

2. $2\frac{1}{4}+1\frac{3}{16}+1\frac{1}{16}$
$=2\frac{4}{16}+1\frac{3}{16}+1\frac{1}{16}$
$=4\frac{8}{16}$
$=5\frac{1}{2}$

$10\frac{7}{8}-5\frac{1}{2}$
$=5\frac{3}{8}$

Answer: Dimension "A" is $5\frac{3}{8}$ *in.*

3. $5\frac{1}{4}\times 15\frac{1}{2}$
$=\frac{21}{4}\times\frac{31}{2}$
$=\frac{651}{8}$
$=81\frac{3}{8}$

Answer: $81\frac{3}{8}$ *revolutions in* $15\frac{1}{2}$ *minutes.*

4. $19\frac{3}{4}\div 9$
$=\frac{79}{4}\div\frac{9}{1}$
$=\frac{79}{4}\times\frac{1}{9}$
$=\frac{79}{36}$
$=2\frac{7}{36}$

Answer: *There is* $2\frac{7}{36}$ *in. between holes*.

5. $\frac{1}{16}+\frac{3}{32}$

$=\frac{2}{32}+\frac{3}{32}$

$=\frac{5}{32}$

$16\frac{7}{8}\div\frac{5}{32}$

$=\frac{135}{8}\div\frac{5}{32}$

$=\frac{135}{8}\times\frac{32}{5}$

$=\frac{4320}{40}$

$=108$

Answer: *108 washers can be made from the round stock*.

Self Test 7

1. 0.075
2. 0.004
3. 0.0021
4. a. 67.128
   b. 67.13
   c. 67.1
5. a. 0.051
   b. 4.000
   c. 1.667

Self Test 8

1. $5 \div 8 = 0.625$
2. $13 \div 16 = 0.8125$
3. $2 + (11 \div 64)$
   $= 2.171875$
   $= 2.172$
4. $\frac{6}{100} = \frac{3}{50}$
5. $\frac{875}{1000} = \frac{35}{40} = \frac{7}{8}$
6. $=\frac{72}{99}$

   $=\frac{24}{33}$

   $=\frac{8}{11}$

Self Test 9

1. a. 1251.0765

   b. 0.336

   c. 0.09375

   d. 50

2. 23 × 0.65 mm = 14.95 mm
3. 116.6 ÷ 45 = 2.6 grams
4. 241.875 cm

Self Test 10

1.

Name	Symbol	Value in Base Units
milligram	mg	$\frac{1}{1000}$ gram
kilometre	k	1000 metres
micrometre	µm	$\frac{1}{1\ 000\ 000}$ metre
millilitre	mL	$\frac{1}{1000}$ litre
tonne	t	1000 kilograms or 1 000 000 grams
centilitre	cL	0.01 litres

2. a. 3 mL
   b. 0.047 m
   c. 167 cm^3
   d. 780 000 mg
   e. 3 700 000 μm
   f. 0.000645 kg
   g. 784 N
   h. 35 bar

Self Test 11

1. 27.6 yd
2. 63.5 cm
3. 111.4 lbs
4. 0.23 kg
5. 106 qt
6. 118 L

Self Test 12

1. a. formula
   b. equation
   c. equation
   d. formula

2.

		Constant(s)	Variable(s)
a.	$P = 4S$	4	P, S
b.	$10 + U = 24h$	10, 24	U, h
c.	$V = \pi r^2 h$	π	V, r, h
d.	$x = \frac{100y}{2}$	100, 2	x, y

3. a. $$N = \frac{5}{8} - \frac{1}{4}$$
$$= \frac{5}{8} - \frac{2}{8}$$
$$= \frac{3}{8}$$

   b. $Q = 3 \times 8 \times 16 = 384$

   c. $W = 16 \div 3 = 5.\overline{3}$

   d. $$r = \sqrt{\frac{45}{3.14}}$$
$$= \sqrt{14.33}$$
$$= 3.79$$

Self Test 13

1. $F = PA$
   $F = (250\ 000)(0.03)$
   $F = 7500$

   Answer: 7500 N

2. a. $C = \frac{5}{9}(F - 32)$

   $C = \frac{5}{9}(77 - 32)$

   $C = \frac{5}{9}(45)$

   $C = \frac{225}{9} = 25$

   Answer: 25°C

   b. $C = \frac{5}{9}(F - 32)$

   $30 = \frac{5}{9}(F - 32)$

   $30\left(\frac{9}{5}\right) = (F - 32)$

   $54 = (F - 32)$

   $86 = F$

   Answer: 86°F

3. $t = \frac{L}{F_s V}$

   $t = \frac{18}{(0.08)(250)}$

   $t = \frac{18}{20} = 0.9$

   Answer: It will take 0.9 minutes to cut the groove.

Self Test 14

1. a. 7:1
   b. 4:1
   c. 0.75:1
   d. 0.52:1
   e. 3:1

2. Wage ratio $= \frac{\text{journeyman wage}}{\text{apprentice wage}} = \frac{32}{24} = \frac{4}{3}$

3. Gear ratio = $\frac{\text{output}}{\text{input}} = \frac{15}{10} = \frac{1.5}{1}$ or 1.5 : 1

4. Compression ratio = $\frac{\text{total cylinder volume}}{\text{clearance volume}} = \frac{2}{0.125} = \frac{16}{1}$ or 16 : 1

5. Pulley ratio = $\frac{\text{output pulley}}{\text{input pulley}} = \frac{6}{10} = \frac{0.6}{1}$ or 0.6 : 1

Self Test 15

1. Gear ratio = $\frac{\text{output}}{\text{input}} = \frac{102}{12} = \frac{17}{2}$

Answer in lowest terms is 17:2. Gear ratio is 8.5:1

2. $$\frac{3.5}{1} = \frac{x}{14}$$
$$3.5(14) = x$$
$$49 = x$$

Answer: The output gear has 49 teeth.

3. $$\frac{8}{1} = \frac{0.65}{x}$$
$$8x = 0.65$$
$$x = \frac{0.65}{8}$$
$$x = 0.08125$$

Answer: The clearance volume is 0.081 L (or 81 mL).

4. $$\frac{0.425}{0.33} = \frac{x}{3.6}$$
$$(0.425)\frac{(3.6)}{0.33} = x$$
$$4.\overline{63} = x$$

Answer: The mass is 4.6 kg.

5. $$\frac{50}{1} = \frac{30}{x}$$
$$50x = 30$$
$$x = \frac{30}{50}$$
$$x = 0.6$$

Answer: You need to add 0.6 L of oil.

Self Test 16

1. $P = 2(L + W)$
   $P = 2(9 + 17.5)$
   $P = 2(26.5)$
   $P = 53$ m

2. $P = a + b + c$
   $P = 15 + 17.5 + 9$
   $P = 41.5$ cm

3. $C = 2\pi r$
   $C = 2\pi(15)$
   $C = 94.2$ cm

4. $P = S_1 + S_2 + S_3 + S$
   $P = 19 + 8 + 34 + 17$
   $P = 78$ m

5. In order to calculate the perimeter of this complex shape, divide it into a rectangle and a circle.

   The rectangle has a perimeter of:

   $P_{rectangle} = 2L + 2W$
   $P_{rectangle} = 2(30) + 2(20)$
   $P_{rectangle} = 100$ cm

   However, since the right edge of the rectangle is not part of the perimeter of the complex shape, subtract 20 cm from the perimeter:

   $P_{rectangle} = 80$ cm

   The circle has a perimeter of:

   $P_{circle} = 2\pi r$
   $P_{circle} = 2\pi 10$
   $P_{circle} = 62.8$ cm

   However, since we only want the perimeter of the half-circle that makes up part of the complex shape, we divide the perimeter in half:

   $P_{circle} = 31.4$ cm

   The total perimeter of the complex shape is:

   $P = P_{rectangle} + P_{circle}$
   $P = 80 + 31.4$
   $P = 111.4$ cm

Self Test 17

1. $A = LW$
   $A = (9)(17.5)$
   $A = 157.5\ m^2$

2. $A = \frac{1}{2}bh$
   $A = (\frac{1}{2})(15)(9)$
   $A = 78.75\ cm^2$

3. $A = \pi r^2$
   $A = \pi(15)^2$
   $A = \pi(225)$
   $A = 706.9\ cm^2$

4. $$A = \frac{h(S_1 + S_3)}{2}$$
   $$A = \frac{8(19 + 34)}{2}$$
   $$A = 8(26.5)$$
   $$A = 212\ m^2$$

5. In order to calculate the area of this complex shape, divide it into a rectangle and a half-circle.

   The area of the rectangle is:
   $A_{rectangle} = LW$
   $A_{rectangle} = (20)(30)$
   $A_{rectangle} = 600\ cm^2$

   The area of the circle is:
   $A_{circle} = \pi r^2$
   $A_{circle} = \pi(10)^2$
   $A_{circle} = 314\ cm^2$

   However, since we only want the area of the half-circle that makes up part of the complex shape, we divide the area in half:

   $A_{circle} = 157\ cm^2$

   The total area of the complex shape is:
   $A = A_{rectangle} + A_{circle}$
   $A = 600 + 157$
   $A = 757\ cm^2$

Self Test 18

1. $V = LWH$
   $V = (20)(10)(10)$
   $V = 2000 \text{ in}^3$

2. $V = S^3$
   $V = 10^3$
   $V = 1000 \text{ m}^3$

3. $V = \pi r^2 h$
   $V = \pi(6)^2(12)$
   $V = (3.14)(36)(12)$
   $V = 1356.5 \text{ cm}^3$

4. $V_{cyl} = \pi r^2 h$
   $V_{cyl} = \pi(\frac{3}{2})^2(25)$
   $V_{cyl} = \pi(1.5)^2(25)$
   $V_{cyl} = (3.14)(2.25)(25)$
   $V_{cyl} = 176.6 \text{ m}^3$

   $V_{CF} = LWH$
   $V_{CF} = (30)(5)(1)$
   $V_{CF} = 150 \text{ m}^3$

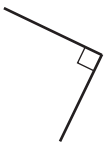
   There is not enough volume in the containment field to hold the full tank if it leaks.

Self Test 19

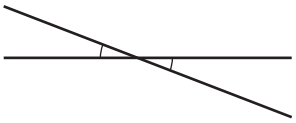
1. a. obtuse angle



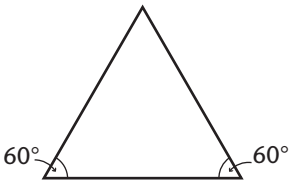
f. right angle



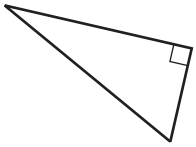
g. opposite angles



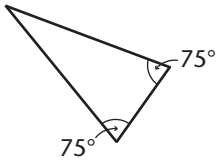
2. a. equilateral triangle



b. right triangle



c. isosceles triangle



Self Test 20

1. 70°
2. 11.4 in.

Competency A-13: Use Electronic Media

Self Test 1

1. b. monitor, keyboard, and central processing unit
2. c. store personal information
3. b. 1000 bytes
4. c. scan the signed resume and attach to the e-mail message
5. a. operating system software
6. d. internet search engine

Heavy Duty Mechanical Lines and Competencies

Line A Common Occupational Skills
- A-1 Use Safe Work Practices
- A-2 Apply Occupational Health and Safety
- A-3 Use Environmental Practices
- A-4 Use Hand Tools, Power Tools, and Shop Equipment
- A-5 Use Fasteners and Fittings
- A-6 Lift and Support Loads
- A-7 Operate Equipment
- A-8 Use Shop Resources and Record Keeping Practices
- A-9 Service Winch Wire Rope
- A-10 Identify Lubricants
- A-11 Service Bearings and Seals
- A-12 Apply Math and Science
- A-13 Use Electronic Media
- A-14 Use Cutting and Welding Equipment
- A-15 Prepare Job Action
- A-16 Describe Diagnostic Procedures
- A-17 Prepare for Employment

Line B Brakes
- B-1 Service and Repair Hydraulic Brakes
- B-2 Service and Repair Hydraulic Power Brakes
- B-3 Service and Repair Air Brakes
- B-4 Diagose and Repair Advanced Brake Systems

Line C Hydraulics
- C-1 Describe Hydraulic Systems
- C-2 Service Hydraulic Components
- C-3 Diagnose and Repair Advanced Hydraulic Systems

Line D Electrical
- D-1 Describe Electricity
- D-2 Use Electrical Testing Instruments
- D-3 Service and Diagnose Batteries
- D-4 Service Charging Systems
- D-5 Diagnose and Repair Charging Systems
- D-6 Service Starting Systems
- D-7 Diagnose and Repair Starting Systems
- D-8 Service Electrical and Electronic Circuits
- D-9 Diagnose and Repair Electrical Components and Systems
- D-10 Diagrnose and Repair Electronic Compoments and Systems
- D-11 Diagrnose and Repair Vehicle Management Systems
- D-12 Service, Diagnose, and Repair Hybrid Systems
- D-13 Service, Diagnose, and Repair Electric Drive Systems

Line E Suspension and Steering
- E-1 Service and Diagnose Tires, Wheels, and Hubs
- E-2 Service Steering Systems
- E-3 Diagnose and Repair Truck Hydraulic Assisted Steering Systems
- E-4 Service, Diagnose, and Repair Machine Suspension Systems
- E-5 Remove and Install Undercarriage
- E-6 Diagnose and Repair Frames
- E-7 Align Vehicle
- E-8 Diagnose and Repair Wheeled Equipment Steering
- E-9 Diagnose and Repair Track Machine Steering
- E-10 Diagnose and Repair Undercarriage

Line F Trailer
- F-1 Service Landing Gear and Trailer Accessories
- F-2 Service and Repair Coupling Systems
- F-3 Service, Diagnose, and Repair Trailer Body Components
- F-4 Service, Diagnose, and Repair Trailer Heating and Refrigeration Systems

Line G Heating, Ventilation and Air
- G-1 Describe Heating and Air Conditioning Fundamentals
- G-2 Diagnose and Repair Heating and Air Conditioning Systems

Line H Engines and Supporting Systems
- H-1 Describe Engine Fundamentals
- H-2 Service Engine Support Systems
- H-3 Diagnose and Repair Engine Support Systems
- H-4 Service Diesel Fuel Supply Systems
- H-5 Diagnose and Repair Diesel Supply Systems
- H-6 Service Gasoline Fuel Systems
- H-7 Describe Alternative Fuel Systems
- H-8 Diagnose Engines and Components
- H-9 Remove and Install Diesel Engines
- H-10 Repair Engines and Components
- H-11 Describe Diesel Fuel Injection Fundamentals
- H-12 Diagnose and Repair Mechanical Fuel Injection Systems
- H-13 Diagnose and Repair Electronic Diesel Fuel Systems
- H-14 Diagnose and Repair Diesel Emission Systems
- H-15 Diagnose and Repair Engine Brakes
- H-16 Service, Diagnose, and Repair Electronic Ignition Systems

Line I Powertrain
- I-1 Describe Power Transfer Systems
- I-2 Service Clutches
- I-3 Diagnose and Repair Clutches
- I-4 Service Manual Transmissions
- I-5 Diagnose and Repair Manual Transmissions
- I-6 Diagnose and Repair Automated Transmissions
- I-7 Service Torque Converters and Dividers
- I-8 Service Powershift and Automatic Transmission
- I-9 Diagnose and Repair Automatic Transmissions and Torque Converters
- I-10 Diagnose and Repair Powershift Transmissions
- I-11 Service Drivelines
- I-12 Diagnose and Repair Drivelines
- I-13 Service Drive Axles
- I-14 Diagnose and Repair Drive Axles
- I-15 Service Final Drives
- I-16 Diagnose and Repair Final Drives
- I-17 Diagnose and Repair Driveline Retarders
- I-18 Diagnose and Repair Winches
- I-19 Diagnose and Repair Power Takeoffs and Transfer Cases
- I-20 Remove and Install Transmissions
- I-21 Remove and Install Driveline and Differentials
- I-22 Remove and Install Final Drives

Line J Structural Components and Accessories
- J-1 Indentify Protective Structures
- J-2 Service Cab Structures
- J-3 Repair Advanced Cab and Body Structures
- J-4 Diagnose and Repair Working Attachments
- J-5 Diagnose and Repair Pnuematic System