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Lesson Plan

Hydraulics

LESSON ID: NCOM -D01

ENGINEER EQUIPMENT MECHANIC NCO

A16ACU1

REVISED 05/05/2014

APPROVED BY ________________________________ **DATE** ________________

INTRODUCTION **(10 MIN)**

INSTRUCTOR NOTE
Study guides for all lessons are issued to the students at the beginning of the course.

(ON SLIDE #1)

1. **GAIN ATTENTION**. You-tube video of mini excavator climbing a tower. Discuss the versatility of modern hydraulics and what is able to be accomplished with modern hydraulics.

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(ON SLIDE #2)

2. **OVERVIEW**. Good morning/afternoon Marines, my name is _________. The purpose of this class is to provide you with the knowledge necessary to service, troubleshoot, and repair hydraulic systems.

3. LEARNING OBJECTIVES.

(ON SLIDE #3)

a. **TERMINAL LEARNING OBJECTIVE**. Provided a service request, a malfunctioning hydraulic system, appropriate tools, and references, conduct advanced repair to equipment hydraulic system to restore proper function. (1341-MANT-2007)

b. **ENABLING LEARNING OBJECTIVE**.

(1) Without the aid of references, identify the characteristics of a hydraulic system per the FOS-1006NC. (1341-MANT-2007a)

(2) Provided a hydraulic shop (HHR), and the references, fabricate hydraulic hose/tubing per the TM 12059A-OI/7, TM 12059A-OI/5 and TM 12059A-OI/12. (1341-MANT-2007b)

(3) Provided engineer equipment, tools, and references, repair hydraulic components per the appropriate technical manuals. (1341-MANT-2007c)

(4) Provided references, hydraulic schematics, and hydraulic training boards, trace the oil flow through a hydraulic system per the FOS-1006NC, and the vickers board instruction manual. (1341-MANT-2007d)

(ON SLIDE #4)

4. **METHOD/MEDIA**. This lesson will be taught utilizing the lecture, demonstration and practical application methods. Media used will be computer generated graphics, student outline and actual item objects.

INSTRUCTOR NOTE
Explain Instructional Rating Forms.

(ON SLIDE #5)

5. **EVALUATION**. You will be evaluated on this period of instruction. You will be evaluated with a fifty question multiple choice exam and a performance exam.

6. **SAFETY/CEASE TRAINING**. If at any time you the student see anything unsafe or are told by an instructor to stop. Stop immediately. Safety at this course is paramount.

(ON SLIDE #6)

TRANSITION: Are there any questions on anything that has been covered to this point? If not then we will move on to the principles of hydraulics.

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BODY **(50 HRS 35 MIN)**

1. **THE PRINCIPLES OF HYDRAULICS. (30 min)**

(ON SLIDE #7)

a. Liquids have no shape of their own. They acquire the shape of any container. Because of this, oil in a hydraulic system will flow in any direction and into a passage of any size or shape.

(ON SLIDE #8)

b. Liquids are practically incompressible.

(1) Liquids will compress slightly under pressure, but from a practical point the amount is negligible.

(ON SLIDE #9)

c. Liquids under pressure follow the path of least resistance.

(ON SLIDE #10)

d. Liquids transmit applied pressure in all directions. Inside a hydraulic circuit all internal areas are under the same amount of pressure.

e. Pressure can be created only by resistance to flow.

(ON SLIDE #11)

f. Energy put into a hydraulic system in the form of flow under pressure will result in either work or heat. Hydraulic energy is neither created nor destroyed, only converted to another form. All hydraulic energy must come out as work (gain) or heat (loss).

(ON SLIDE #12)

g. Hydraulic power is generated from mechanical power. There has to be a driving force for the hydraulic pump.

h. Oil is pushed into a pump by atmospheric pressure or charge pump, not drawn into it.

(ON SLIDE #13)

i. Flow across an orifice results in a pressure drop.

(ON SLIDE #14)

TRANSITION: Are there any questions over principles of hydraulics? If not, let's take a 10 min break.
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(BREAK-10 MIN)

(ON SLIDE #15)

TRANSITION: During the break did anyone come up with any questions? If not I have some for you. **Q:** Pressure can only be created by resistance to what? **A:** Flow. Now let's talk about hydraulic terms.

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2. **HYDRAULIC TERMS**. **(30 min)**

(ON SLIDE #16)

a. **Hydraulics**. The use of liquids under controlled pressure to do work.

(ON SLIDE #17)

b. **Force**. A dynamic influence that changes a body from a state of rest to one of motion or changes its rate of motion.

(ON SLIDE #18)

c. **Pressure**. The amount of force exerted on a unit of area.

d. **Flow**. Is the movement of fluid. It is measured in gallons per minute (GPM).

(ON SLIDE #19)

e. **Hydrodynamics**. The use of fluids at high speeds (on impact) to supply power.

(ON SLIDE #20)

f. **Hydrostatics**. The use of fluids at relatively low speeds but at high pressure to supply power.

(ON SLIDE #21)

g. **Displacement**. The volume of oil displaced by one complete stroke or revolution of a pump, motor or cylinder.

(ON SLIDE #22)

h. **Actuator**. A device which converts hydraulic power into mechanical force or motion. Examples: Cylinder and motors.

(ON SLIDE #23)

i. **Pump**. A device that converts mechanical force into hydraulic fluid power.

j. **Motor**. A device that converts fluid energy into rotary mechanical force and motion.

(ON SLIDE #24)

k. **Valve**. A device that controls the pressure, direction or the flow of fluid.

(ON SLIDE #25)

l. **Viscosity**. Viscosity is a measurement of a fluid resistance to flow. It is a fluid's "thickness" at a given temperature. All petroleum oils tend to become thicker as temperature falls and thinner as it rises.

(ON SLIDE #26)

TRANSITION: We just got done with hydraulic terms. Do you have any questions? If not then I have a couple for you. **Q:** What is the difference between hydrostatics and hydrodynamics? **A:** Hydrostatics is low speed high pressure, hydrodynamics is high speed impact use of fluids. If there are no more questions then let's talk about filters.

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3. FILTERS. (30 min)

(ON SLIDE #27)

a. **Why we use them**. Contaminated oil can score or completely freeze a precisely fitted valve spool. Dirty oil can ruin the close tolerance of finely finished surfaces and a grain of sand in a tiny orifice can put a whole machine out of operation.

(ON SLIDE #28)

b. **How they are used**. Full-flow system and bypass systems.

(ON SLIDE #29)

(1) Full-Flow System: A full-flow system filters the entire supply of oil as it circulates in the system. Filters in a full-flow system are usually located in the return line from the hydraulic functions.

(ON SLIDE #30)

(2) Bypass Systems: A bypass system has the filter teed into a line so that only a small portion of the oil is diverted through the filter. The rest of the oil goes unfiltered to the system or to the reservoir.

(ON SLIDE #31)

(a) In both systems there will be a slight pressure drop across the filter. As the filter gets dirtier the pressure will increase. When the filter becomes completely plugged no oil will flow through it.

(b) Because dirty oil is better than no oil at all or a ruptured filter, a bypass or relief valve is usually incorporated into the filter assembly.

(ON SLIDE #32)

INSTRUCTOR NOTE
Picture of by-pass valve.

(ON SLIDE #33)

c. **Two main types of filters**: Surface and depth filters.

(ON SLIDE #34)

(1) Surface Filters. Have a single surface that catches and removes dirt particles larger than the holes in the filter. Normally made of wire mesh and used on inlet (suction side) lines.

(ON SLIDE #35)

(2) Depth Filters. Uses a thicker filtering area. The filter material makes the oil move in many different directions before getting through. Normally made of pleated paper material.

d. **Filter Rating**.

(ON SLIDE #36)

(1) Micron Rating. Is a measure of the opening (hole) size of the filter. It would therefore be an indication of the size particle the filter would allow to pass through.

(ON SLIDE #37)

INSTRUCTOR NOTE
Picture of micron breakdown.

(ON SLIDE #38)

e. **Contamination**. What is contamination and how does it get into the hydraulic system?

(ON SLIDE #39)

(1) Air. A prime source of contamination. It may contain moisture and particles from the atmosphere, as well as road or field dust. These particles can enter through a variety of different means. (Seals, gaskets or when opened for maintenance)

(ON SLIDE #40)

(2) The Machine Itself. The piece of gear can be a significant source of contamination. Wear on the internal parts of the machine will cause metal and other abrasive contaminants.

(ON SLIDE #41)

(3) Hydraulic Oil. The hydraulic oil can become contaminated during service or maintenance. Clean containers and tools should always be used.

(ON SLIDE #42)

(4) Water. Even in small amounts can rust polished metal surfaces. Water will plug depth filters, mixed with oil will cause foam in the system.

(ON SLIDE #43)

TRANSITION: Are there any questions over hydraulic filters? If not, let's take a 10 min break.

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(BREAK-10 MIN)

(ON SLIDE #44)

TRANSITION: During the break did anyone come up with any questions? If not I have one for you. **Q:** What are the two types of filters we covered? **A:** Surface and depth filters. Let's talk about hydraulic reservoirs and coolers.

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4. **RESERVIORS AND COOLERS**. **(30 min)**

(ON SLIDE #45)

a. **RESERVIORS**. Every hydraulic system must have a reservoir. The reservoir not only stores the oil, it also helps keep the oil clean, free of air and cools the oil.

(ON SLIDE #46)

(1) Types. There are two types of reservoirs, pressurized and vented.

(ON SLIDE #47)

(2) Capacity. A reservoir should be compact, yet large enough to:

(ON SLIDE #48)

(a) Hold all of the oil and not overflow when all the cylinders in the system are retracted.

(b) Maintain the oil level enough above the suction line so that air is not drawn into the pump intake when all the cylinders are extended.

(ON SLIDE #49)

(c) Dissipate heat during normal operation.

(d) Allow air and foreign material to separate from the oil.

(ON SLIDE #50)

b. **COOLERS**. Friction in a hydraulic system creates a lot of heat. Modern hydraulic systems require additional cooling other than normal dissipation. Two types are used, air to oil and water to oil.

(ON SLIDE #51)

(1) Air to oil. Uses moving air to dissipate heat from the oil. Normally mounted in front of or next to the radiator.

(ON SLIDE #52)

(2) Water to oil. Uses moving water to carry off heat from the oil. The water flows through many tubes and the oil circulates around the tubes. The engine coolant is used to circulate through the cooler.

(ON SLIDE #53)

TRANSITION: We just completed reservoirs and coolers. Do you have any questions? If not let's take a break.

(BREAK-10 MIN)

(ON SLIDE #54)

TRANSITION: Are there any questions before moving on? If not I have a couple for you. **Q**: Name one thing a reservoir does other than hold the hydraulic oil. **A**: Maintain oil level when all cylinders are extended, dissipate heat and allow air and foreign material to separate from oil. If there are no more questions then let's talk about hoses, lines and seals.

5. **HOSES, LINES AND SEALS**. **(1 hr)**

(ON SLIDE #55)

a. **Hoses**. Provide flexible oil conduits between hydraulic components. Hoses permit some movement and absorb vibration and pressure surges.

(ON SLIDE #56)

(1) Always replace damaged hoses with the kind specified in the technical manual or parts manual. If you are building a hose to replace a damaged one than make sure you consider the following tolerances.

(ON SLIDE #57)

(a) Inside Diameter

(ON SLIDE #58)

(b) Outside Diameter

(ON SLIDE #59)

(c) Maximum Operating Pressure

(d) Temperature Limits

(ON SLIDE #60)

(2) Hose size is determined by the amount of flow needed. If the hose is too small, it will restrict flow, slow operation and generate heat. If a hose is too large, hydraulic pressure may rupture because of the greater inner wall area.

(ON SLIDE #61)

(3) When inspecting hoses carefully check for:

(ON SLIDE #62)

(a) Cracks and Splits

(b) Pinhole Leaks

(c) Incorrect Hose Length

(d) Improper Installation

(e) Wrong Type Hose

(f) Wrong Fitting

(ON SLIDE #63)

b. **Tubes**. Tubing is used where flexibility is not needed. Correctly sized, shaped and installed it adds to reliability.

(ON SLIDE #64)

(1) Replace tubes only with replacement parts ordered from the parts manual. Even if ordered in bulk, ensure the material is correct before replacing.

(2) Bends in replacement tubing should be the same as the original.

(ON SLIDE #65)

(3) Straight-line tubes should not be used. It does not allow for proper length.

(ON SLIDE #66)

c. **Seals**. No hydraulic circuit can operate without the proper seals to hold the fluid in the system. Seals also keep grime and dirt out of the system.

(1) Two Uses.

(ON SLIDE #67)

(a) Static Seal. Used to seal fixed parts. Static seals can be gaskets, o-rings or packings.

(ON SLIDE #68)

(b) Dynamic Seal. Used to seal moving parts. Dynamic seals include shaft and rod seals.

(ON SLIDE #69)

(2) Types.

(ON SLIDE #70)

(a) O-rings. The most common seal in industrial hydraulics. Usually made from synthetic rubber, it is used in both static and dynamic applications.

(ON SLIDE #71)

(b) U and V Packings. Dynamic seals for pistons, rod guides of cylinder and pump shafts. Designed to be installed with the open side (lip side) toward the highest pressure. The pressure will force the lip against the mating surface.

(ON SLIDE #72)

(c) Spring-Loaded Lip Seals. A refinement of a U or V type packing. The rubber lip is ringed by a spring that gives the sealing lip tension. It is most often used to seal rotary shafts.

(ON SLIDE #73)

(e) Metallic Seals. Used on pistons and piston rods, very similar to the piston rings used in engines. Used as a dynamic seal, usually made of steel. The ends overlap or push together to form an endless seal.

(ON SLIDE #74)

(f) Metal Face Seal. Used only as a dynamic seal. Sealing is done at the highly polished surfaces of two identical steel sealing rings.

(ON SLIDE #75)

(g) Compression Gasket. Suitable only for static uses. Gaskets seal by molding into the imperfections of the mating surfaces. This seal depends on a very tight seal at all points.

(ON SLIDE #76)

INTERIM TRANSITION: Are there any questions over hoses, lines and seals? If not, let’s take a break and then we will move into the demonstration.
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(BREAK-10 MIN)

<u>INTERIM TRANSITION</u>: Are there any more questions before the demonstration.

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INSTRUCTOR NOTE:
Perform the following demonstration. **<u>Allow students to take breaks as required or as instructed.</u>**

<u>DEMONSTRATION</u>. (2 hrs) Demonstration will be conducted in the HHR class room. The purpose of this demonstration is to show the students the proper procedures to fabricate Hydraulic hoses and tubes. Before moving to the HHR the students will watch a 45 min video on the HHR. After the video the instructor will have one hydraulic hose cut, 1 tube cut and fitting prepared. One Instructor is required.

Supplies: (1) 1 15” hose 1 15” Metal Tube
(2) 1 hydraulic hose fitting.
(3) 1 HHR.

STUDENT ROLE: Students should sit around the demonstration desk where they can observe. Students should ask questions throughout the demonstration if they have any.

INSTRUCTOR(S) ROLE: The instructor will show students how to determine what size fitting is required and how to adjust hydraulic hose press to conform to fitting. After demonstration of hose fabrication Instructor will demonstrate tube bending and flaring using the HHR.

1. Safety Brief: N/A
2. Supervision and Guidance: The Instructor will demonstrate using the HHR using the conversion chart and Parker books provided in the HHR. Answer any and all questions. Talk in detail about all procedures during the process. Ask questions of the students throughout the process.
3. Debrief: Allow students the opportunity to comment on what they experienced and/or observed. Provide overall feedback, guidance on any misconceptions, and review the learning points of the demonstration.

INTERIM TRANSITION: Are there any questions over the demonstration? If not, let's move into the practical application.

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INSTRUCTOR NOTE:
Perform the following practical application. **Allow students to take breaks as required or as instructed.**

PRACTICAL APPLICATION. **(6 hrs)** Practical application will be conducted in the HHR. The purpose of this practical application is to allow the students to fabricate a hydraulic hose and tube.

PRACTICE: Using the knowledge obtained during the demonstration and lecture portion of the course the students will safely fabricate hydraulic hoses and tubes. Students will also have the TM step by step fabrication instructions.

PROVIDE HELP: The instructor will ensure the students have all TM's, PPE, tools, hazmat products and anything else needed to perform the task.

1. Safety Brief: Ensure the students have all appropriate PPE and materials before starting the practical exercise.
2. Supervision and Guidance: Instructor is moving around the bay, assisting students and answering questions as they arise.
3. Debrief: N/A

TRANSITION: We just finished with the fabrication of hydraulic hoses and tubes. Do you have any questions? If not let's take a break.

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(BREAK-10 MIN)

(ON SLIDE #77)

TRANSITION: During the break did anyone come up with any questions? I have a few for you. **Q:** True or False. Straight in-line tubes should be used? **A:** False, it does not allow for proper length. **Q:** Name the two uses of seals. **A:** Static and Dynamic. If there are no more questions then let's talk about cylinders.

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6. **CYLINDERS**. **(1 hr)**

(ON SLIDE #78)

a. The cylinder does the work of the hydraulic system. It converts fluid power from the pump into linear mechanical power.

(ON SLIDE #79)

b. **Piston Type Cylinders**. There are two types of piston cylinders. Single acting and double acting. In both types a movable piston and rod slides in a cylinder housing or barrel in response to pressurized oil admitted to the cylinder.

(ON SLIDE #80)

(1) Single Acting Cylinder. Pressurized oil is sent to only one side of the piston. The piston and rod are forced out of the housing. When the oil is released, mechanical force from another cylinder, the weight of the load or a spring devise retracts the cylinder.

(ON SLIDE #81)

(2) Double Acting Cylinder. Provide force in both directions. Pressurized oil enters at one end of the cylinder to extend it, at the other end to retract it.

(ON SLIDE #82)

(a) Balanced Double Acting. Piston rod extends through the piston head on both ends. Equal pressure/force in both directions.

(ON SLIDE #83)

INSTRUCTOR NOTE
Picture of balanced double acting cylinder.

(ON SLIDE #84)

(b) Unbalanced Double Acting. Piston rod extends out one end of the piston head only. Less pressure/force when it retracts because there is less surface area for the oil to act upon due to the rod. It will have a more powerful extend stroke than when it retracts.

(ON SLIDE #85)

INSTRUCTOR NOTE
Picture of unbalanced double acting cylinder.

(ON SLIDE #86)

c. **Extra Features of Piston Type Cylinders**.

(ON SLIDE #87)

(1) Stroke Control Devices. Hydraulic stop cylinders can be adjusted to stop at a precise position every time the cylinder is retracted. Enables the operator to lower an implement to the same level every time.

(ON SLIDE #88)

(2) Cushion Stops. A cushion is built into some cylinders to slow them down gradually at the end of their strokes.

(ON SLIDE #89)

INSTRUCTOR NOTE
Picture of orifice type cushion stop.

(ON SLIDE #90)

d. **Vane Type**. Provides limited rotary motion.

(1) Consists of a barrel, shaft and two vanes. Oil entering the right vane rotates the shaft counter-clockwise. Oil entered into the left vane causes the shaft to rotate clockwise.

(ON SLIDE #91)

e. **Telescoping Cylinders**. Used mainly on forklifts and cranes. Because the area on which the pressure acts changes as the cylinder extends, the lift specifications are greater for the first part of the travel.

(ON SLIDE #92)

INTERIM TRANSITION: Are there any questions over hydraulic cylinders? If not, let's take a 10 min break and then you will be given a quiz.

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(BREAK-10 MIN)

INSTRUCTOR NOTE

Hand out quiz prior to demonstration. Allow 30 minutes for completion. Students should work from memory. Explain that this is also a good study guide for the test.

INTERIM TRANSITION: Are there any more questions? If not let's move into a demonstration.

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INSTRUCTOR NOTE:

Perform the following demonstration. **Allow students to take breaks as required or as instructed.**

DEMONSTRATION. **(1 hr)** Demonstration will be conducted in the classroom. The purpose of this demonstration is to show the students the proper procedures to disassemble, inspect and reassemble a hydraulic cylinder. Before the demo the instructor will have one hydraulic cylinder prepared and in the classroom with a seal removal tool. One Instructor is required.

*All five cylinders have been rebuilt prior and reassembled without the head being tightened. No tool will be required to remove the cylinder head.

Supplies: (1) One of five 420E cylinders located in the big shed.
(2) Rebuild kit, located in the office closet.
(3) Cylinder seal removal tool.

STUDENT ROLE: Students should sit around the demonstration desk where they can observe. Students should ask questions throughout the demonstration if they have any.

INSTRUCTOR(S) ROLE: The instructor will completely disassemble, inspect and reassemble the hydraulic cylinder. During the course of the demonstration show the proper tooling and procedures.

1. Safety Brief: N/A
2. Supervision and Guidance: The Instructor will demonstrate using the 420E TM disassembly and assembly sections as reference.

Answer any and all questions. Talk in detail about all procedures during the process. Ask questions of the students throughout the process.
3. Debrief: Allow students the opportunity to comment on what they experienced and/or observed. Provide overall feedback, guidance on any misconceptions, and review the learning points of the demonstration.

INTERIM TRANSITION: Are there any questions over the demonstration? If not, let's move into the practical application.

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INSTRUCTOR NOTE:
Perform the following practical application. **Allow students to take breaks as required or as instructed.**

PRACTICAL APPLICATION. **(6 hrs)** Practical application will be conducted in the work bay. The purpose of this practical application is to allow the students to completely disassemble, inspect and reassemble working hydraulic cylinders off of a 420E backhoe.

PRACTICE: Using the knowledge obtained during the demonstration and lecture portion of the course the students will safely disassemble, inspect and reassemble the hydraulic cylinders on the 420E. Students will also have the TM step by step removal and installation steps.

PROVIDE HELP: The instructor will ensure the students have all TM's, PPE, tools, hazmat products and anything else needed to perform the task.

1. Safety Brief: Ensure the students have all appropriate PPE and materials before starting the practical exercise.
2. Supervision and Guidance: Instructor is moving around the bay, assisting students and answering questions as they arise.
3. Debrief: N/A

(ON SLIDE #93)

TRANSITION: We just finished with cylinders, do you have any questions? I have one for you. **Q:** What are the two types of cylinders we talked about? **A:** Piston type and vane type. If there are no more questions then let's take a break and then we will talk about accumulators.
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(BREAK-10 MIN)

TRANSITION If there are no more questions then let's talk about accumulators.
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7. **ACCUMULATORS**. **(1 hr)**

(ON SLIDE #94)

a. **Four Major Uses**. Hydraulic accumulators have four major uses. Most accumulators can do many of these things, they are usually placed in a system to do only one.

(ON SLIDE #95)

(1) Store Energy

(a) Used to store oil under pressure for systems with fixed displacement pumps and closed center valves. Stores pressurized oil during non use periods and feeds it back to supplement the pump during periods of usage. Often used to protect against oil supply failure, traps enough for emergency uses. Example: Emergency steering and braking.

(ON SLIDE #96)

(2) Absorb Shocks

(a) Takes in excess oil during peak pressures and lets it out again after the “surge” is past. When a shock load occurs in the system, there is an extra amount of oil with nowhere to go. Without an accumulator that volume must be made up by line expansion and leakage.

(ON SLIDE #97)

(3) Build Pressure Gradually

(a) Used to “soften” the working stroke of a piston against a fixed load. Example: A hydraulic press. Not used on mobile equipment.

(ON SLIDE #98)

(4) Maintain Constant Pressure

(a) Always a weight loaded type which place a fixed force on the oil in a closed circuit. Not used on mobile equipment.

(ON SLIDE #99)

b. **<u>Types</u>**.

(ON SLIDE #100)

(1) <u>Pneumatic</u>.

(a) Uses inert gas as a way of “charging” a load of oil or providing a “cushion” against shocks. In these accumulators, gas and oil occupy the same container. When the oil pressure rises, incoming oil compresses the gas. When oil pressure drops, the gas expands, forcing out oil. In most cases, the gas is separated from the oil by a piston, a bladder or a diaphragm.

(ON SLIDE #101)

1 Removal and Charging. Never remove a pneumatic accumulator without reading the proper TM for correct removal procedures! Never charge with anything other than an inert gas, normally dry nitrogen is used.

(ON SLIDE #102)

(2) Weight-Loaded.

(1) The earliest form of accumulators is the weight-loaded type. Supplies constant pressure but is always large and bulky which is why it has no function on mobile machinery.

(ON SLIDE #103)

INSTRUCTOR NOTE
Picture of weight-loaded type accumulator.

(ON SLIDE #104)

(3) Spring-Loaded.

(1) Very similar to the pneumatic except it is a spring doing the loading. The operation of a spring-loaded accumulator can be varied by changing: 1) the strength of the spring, 2) the length of the spring, 3) the preload of the spring, 4) the size of the piston or 5) the length of the piston stroke. These types are very large if they are to be used for high pressure systems, therefore have no use on mobile machinery.

(ON SLIDE #105)

INSTRUCTOR NOTE
Picture spring-loaded type accumulator.

(ON SLIDE #106)

TRANSITION: We just finished with accumulators, do you have any questions? If not let’s take a break.

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(BREAK-10 MIN)

(ON SLIDE #107)

TRANSITION: We just finished with accumulators, do you have any questions? I have a one for you. **Q:** What should be done before removing an accumulator? **A:** Read the TM for proper procedures. If there are no more questions then let's talk about pumps.

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8. **PUMPS**. **(2 hrs)**

(ON SLIDE #108)

a. The heart of the hydraulic system. It creates the flow of fluid that supplies the whole circuit. Pumps draw in fluid and forces it out converting mechanical energy into fluid (hydraulic) energy. All pumps create flow, however, they are divided into two categories.

(ON SLIDE #109)

(1) Pump Output. All pump outputs are measured in flow. GPM (gallons per minute) is the standard measurement.

(ON SLIDE #110-111)

(2) Non-Positive Displacement Pumps. The output flow of the pump will vary or even stop depending on restriction to flow. Engine water pump is an example of a non-positive displacement pump. Non-displacement pumps have no viable use on modern hydraulic systems.

(ON SLIDE #112)

INSTRUCTOR NOTE
Picture non-positive displacement pumps.

(ON SLIDE #113)

(3) Positive Displacement Pumps. Positive displacement pumps fall under two categories.

(ON SLIDE #114)

(a) Fixed Displacement. Moves the same amount of oil with every cycle. This volume is only changed when the speed of the pump is changed.

(ON SLIDE #115)

(b) Variable Displacement. Can vary the volume of oil they move with each cycle, even at the same speed. These pumps have an internal mechanism, which varies the displacement and thus the output.

(ON SLIDE #116)

b. **Types of Positive Displacement Pumps**. Most pumps on today's machines use three kinds of pumps.

(ON SLIDE #117)

(1) Gear Pumps. Widely used because they are simple and economical. Fixed displacement only but able to provide for most fixed displacement systems. They are often used as charge pumps for large circuits or for pilot operated systems to supply pilot pressure.

(ON SLIDE #118)

(a) External Gear Pumps. Two gears in mesh, closely fitted inside a housing. Drive shaft drives one gear, which turns the idle gear. Shaft bushings and machined surfaces or wear plates seal the working gears. Operation is quite simple. The gears rotate and come out of mesh, inlet oil fills the cavity between the gear teeth. The oil is then carries in the tooth cavity to the outlet chamber. Oil is pushed out in a continuous even flow as the gears rotate. Only the speed that the gears rotate will adjust the flow of the pump.

(ON SLIDE #119)

(b) Internal Gear Pumps. Also uses two gears, but now a spur gear is mounted inside a larger gear. Both gears are divided on the other side by a crescent shaped separator. The drive shaft drives the spur gear, which drives the larger gear.

Operation is basically the same as the external gear pump. The major difference is that both gears rotate in the same direction. Low efficiency, used on low pressure systems such as transmissions and charge pumps.

(ON SLIDE #120)

(c) Advantages. Easiest to manufacture, produces large volume for its size, tolerant to dirt and inexpensive to manufacture.

(d) Disadvantages. Noisier than other pumps and fixed displacement only.

(ON SLIDE #121)

(2) Vane Pumps. The shaft drives a slotted rotor, the rotor is fitted with blades that can move in and out of the slots. Offset mounted in a circular ring, end caps seal the vanes, rotor and cam. As the assembly rotates, the cavity formed by the cam, rotor and vanes will get increasingly larger on the inlet side. Oil from the inlet will fill this void. Oil is carried to the outlet side where the cavity gets increasingly smaller. This forces the oil out the outlet passage.

(ON SLIDE #122)

(a) Balanced Vane Pumps. Most modern equipment uses balanced vane pumps. Using two inlet passages and two outlet passages keeps the pressure balanced internally in the pumps. Minimizing wear and load on the bearings. Creates a full pumping cycle every 180 degrees of rotation.

(ON SLIDE #123)

(b) Unbalanced Vane Pumps. Inlet passage is located on only one side of the pump. Pressure from only one side creates very high shaft bearing loads. For this reason these pumps are not common on most modern hydraulic systems.

(ON SLIDE #124)

(c) Advantages. The vane pumps is quite and self compensating for wear.

(d) Disadvantages. Not as tolerable for dirt and contamination as gear pumps. Low volume and pressure output.

(ON SLIDE #125)

INTERIM TRANSITION: Are there any questions over hydraulic pumps? If not, let's take a 10 min break.

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(BREAK-10 MIN)

INTERIM TRANSITION: During the break did anyone come up with any questions? If not let's continue with hydraulic terms.

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(ON SLIDE #126)

(3) Piston Pumps. Among the most sophisticated of all pumps. They are capable of high pressures, high volume, high speeds and variable displacement.

(ON SLIDE #127)

(a) Radial Piston Pumps. It has a rotating cylinder block which contains the pistons. The cylinder block is offset from the pumps circular housing. Can be made variable displacement by adjusting the relation of the cylinder block to the outlet housing. Radial piston pumps are used where space is not limited. Not normally found on mobile systems.

(ON SLIDE #128)

(b) Axial Piston Pumps. The most common pump found on modern hydraulic systems. The pistons are mounted in lines parallel with the pump's "axis". Operate using pistons that pump oil by moving back and forth in cylinder bores.

(ON SLIDE #129)

1 Inline Axial Piston Pumps. Has the pistons operating in line with the input shaft. Contains a cylinder block assembly (rotating group) and swashplate on which the pistons ride. The cylinder block is splined into the drive shaft which turns it. The swashplate can be fixed to the housing for fixed displacement or connected to a servo (hydraulic cylinder) to allow for the angle to change for variable displacement. The servo cylinder when pressurized can move the swashplate against

the bias spring to lower the angle of the swashplate. As the cylinder block rotates the pistons are riding on the swashplate. The pistons being pushed out of the block draw oil into them, pistons being pushed into the block force oil out.

(ON SLIDE #130)

INSTRUCTOR NOTE
Play the inline axial piston pump video.

(ON SLIDE #131)

INSTRUCTOR NOTE
Picture of inline axial pumps.

(ON SLIDE #132)

2 Bent-Axis Axial Piston Pumps. The housing is slanted in relation to the drive shaft. The pistons are connected to the drive member. Both the cylinder block and drive member are driven by the drive shaft. Without a servo cylinder the pump is will be fixed displacement.

(ON SLIDE #133)

(c) Pressure Compensating Pumps.

1 Modern equipment is currently utilizing pressure compensating systems.

INSTRUCTOR NOTE
Play the pressure compensating pump videos on slides #134-135-136, and 137.

2 A variable displacement axial piston pump that must use closed center valves. With the valve in neutral the pump will hold a standby pressure. The standby pressure will be the maximum operating pressure for the system. While in standby the servo cylinder and swashplate will be at minimum angle to simply maintain the pressure. When the valves open the pressure will drop allowing the bias spring to push the swashplate to a higher angle thus allowing the pump to supply more pressure. Once the valve is closed again the system pressure will return the swashplate to standby.

3 When a valve is actuated flow will begin. This will cause a drop in system pressure. The pump senses this drop and goes into stroke instead of standby mode. Pumping enough oil to try and maintain standby (system) pressure. Return oil is directed by the valve back to the reservoir. When the valve is returned to neutral position or the cylinder reaches the end of its travel, pressure builds to standby pressure and the pump stops pumping.

(ON SLIDE #138)

(d) Advantages. Capable of variable displacement. Able to withstand high pressures, high volume and high speeds over a long lifespan.

(e) Disadvantages. Very low tolerance to contamination, more difficult to manufacture and more expensive to manufacture.

(ON SLIDE #139)

INTERIM TRANSITION: Are there any questions over hydraulic pumps? If not, let's take a 10 min break.

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(BREAK-10 MIN)

INTERIM TRANSITION: During the break did anyone come up with any questions? If not let's move into the demonstration.

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INSTRUCTOR NOTE:
Perform the following demonstration. **Allow students to take breaks as required or as instructed.**

DEMONSTRATION. **(1 hr)** Demonstration will be conducted in the classroom. The purpose of this demonstration is to show the students the proper procedures to disassemble, inspect and reassemble a hydraulic pumps.

STUDENT ROLE: Students should sit around the demonstration desk where they can observe. Students should ask questions throughout the demonstration if they have any.

INSTRUCTOR(S) ROLE: The instructor will completely disassemble, inspect and reassemble the hydraulic pump. During the course of the demonstration show the proper tooling and procedures.

Supplies: (1) One of five hydraulic pumps located in the big shed.
(2) General Mechanics tool box.

1. Safety Brief: N/A
2. Supervision and Guidance: Answer any and all questions. Talk in detail about all procedures during the process. Ask questions of the students throughout the process.
3. Debrief: N/A

INTERIM TRANSITION: Are there any questions over the demonstration? If not, let's move into the practical application.

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INSTRUCTOR NOTE:
Perform the following practical application. **Allow students to take breaks as required or as instructed.**

PRACTICAL APPLICATION. (7 hrs) Practical application will be conducted in the work bay. The purpose of this practical application is to allow the students to completely disassemble, inspect and reassemble a hydraulic pump.

PRACTICE: Using the knowledge obtained during the demonstration and lecture portion of the course the students will safely remove, disassemble, inspect, reassemble and reinstall the hydraulic pump.

PROVIDE HELP: The instructor will ensure the students have all TM's, PPE, tools, hazmat products and anything else needed to perform the task.

1. Safety Brief: Ensure the students have all appropriate PPE and materials before starting the practical exercise.

2. Supervision and Guidance: Instructor is moving around the bay, assisting students and answering questions as they arise.
3. Debrief: N/A

(ON SLIDE #140)

TRANSITION: We just finished with hydraulic pumps, do you have any questions? I have one for you. **Q:** What are the two types of vanes pumps? **A:** Balanced and unbalanced. If there are no more questions then let's take a break and then we will talk about valves.

____

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(BREAK-10 MIN)

TRANSITION: Do you have any more questions? If not let's take a talk about valves.

____

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9. **MOTORS**. **(30 min)**

(ON SLIDE #141)

a. Hydraulic motors work in reverse when compared to pumps. Pumps drive fluid while motors are driven by fluid. Fluid is forced in and exhausted out converting fluid (hydraulic) energy back into mechanical energy. The motor design is much like the pump. Both use the same basic types; gear, vane and piston. Often their parts are identical. Motors can be fixed or variable displacement just like their counterpart the pump.

(ON SLIDE #142)

(1) Reversing Motors. To reverse a motors direction you must simply reverse the direction of flow. This is done with the use of a control valve. Reversible motors require a check valve between inlet and outlet ports, for this reason a pump cannot be used as a motor or vice versa.

(ON SLIDE #143)

(2) Motor Output. All motor output is measured in torque. Standard U.S. measurement is "pounds-feet", which is one pound acting on the end of a one foot long lever.

(ON SLIDE #144)

INTERIM TRANSITION: We just finished with motors, does anyone have any questions? If not let's take a break.

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(BREAK-10 MIN)

(ON SLIDE #145)

TRANSITION: We just finished with hydraulic motors, do you have any questions? I have one for you. **Q:** Hydraulic motors convert _________ energy to ________ energy? **A:** Fluid energy to mechanical energy. If there are no more questions then let's talk about valves.

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10. **VALVES**. **(50 min)**

(ON SLIDE #146)

a. Valves are the controls of the hydraulic systems. They regulate the pressure, direction and volume of oil flow in the hydraulic circuit. Valves can be divided into three major types.

(ON SLIDE #147)

(1) Pressure Control Valves. Used to limit or reduce system pressure, unload a pump or set the pressure for oil entering a circuit.

(ON SLIDE #148)

(a) Relief Valves. Each hydraulic system is designed to operate in a certain pressure range. Higher pressures can damage components and cause safety concerns. Relief valves remedy this danger, they are safety valves that release the excess oil when pressures get to high. Two types of relief valves are used; direct acting and pilot operated.

(ON SLIDE #149)

1 Direct Acting Relief Valves. Simple open-closed valves, the pressure acts directly on the valve. When closed the spring tension is greater than the force of the inlet oil pressure, holding the valve on its seat. When the inlet oil pressure exceeds the spring tension it will unseat the valve allowing excess oil to flow back to the reservoir. Some are adjustable, normally there is a screw installed behind the spring to adjust tension. Direct acting relief valves have a fast response, making them ideal for relieving shock pressures.

(ON SLIDE #150)

INSTRUCTOR NOTE
Play the direct acting relief valve video.

(ON SLIDE #151)

2 Pilot Operated Relief Valves. Used to handle large volumes of oil. Does not start to open until approximately 90% pressure is in the system compared to approximately 50% in a direct acting. Instead of direct contact, a orifice in the poppet causes lower pressure on the other side. Once pressure over takes the pilot valve spring (relief setting) the poppet valve with the light spring moves up out of the way. When pressure on the back side lowers the pilot spring closes. This valve has better control then direct acting relief valves. Because it opens less often it creates less heat.

(ON SLIDE #152)

INSTRUCTOR NOTE
Play the pilot operated relief valve video.

(ON SLIDE #153)

(b) Pressure Reducing Valves. Used to control the pressure in one branch of the circuit. The pressure in that branch will always be at or below the main circuit. Operates by sensing fluid pressure after it has passed through the valve. As pressure downstream equals the setting of the valve, the spool begins to close causing a restricted flow path.

(ON SLIDE #154)

INSTRUCTOR NOTE
Play the pressure reducing valve video.

(ON SLIDE #155)

(c) Pressure Sequence Valves. Used to control the sequence of flow to various branches of a circuit. Allow flow to a second function only after the first has been fully satisfied. One use is to sequence two separate cylinders, second cylinder will start its stroke only after the first has completed its own.

(ON SLIDE #156-157)

INSTRUCTOR NOTE
Picture of pressure sequence valve.

(ON SLIDE #158)

(d) Unloading Valves. Directs pump outlet oil back to the reservoir at low pressure after the system pressure has been reached. Can be used as an independent system used for brakes or differentials locks on very large machines.

(ON SLIDE #159)

INSTRUCTOR NOTE
Play the unloading valve video.

(ON SLIDE #160)

(2) Directional Control Valves. Direct the flow of oil in a hydraulic system.

(ON SLIDE #161)

(a) Check Valves. Simple one way valves that can be separate component, but usually are part of another complex valve. They open to allow flow in one direction, but close to prevent flow in the opposite direction.

(ON SLIDE #162)

INSTRUCTOR NOTE
Picture of check valve.

(ON SLIDE #163)

(b) Spool Directional Valves. The sliding spool valve is the most common used on modern hydraulic systems. Two or more valves can be contained in a single assembly.

(ON SLIDE #164)

INSTRUCTOR NOTE
Picture of spool directional valve.

(ON SLIDE #165)

1 Open Center Spool Valve. Open center spool valves allow pump oil to flow through the valve during neutral and return to the reservoir.

(ON SLIDE #166)

INSTRUCTOR NOTE
Picture of open center spool valve schematic.

(ON SLIDE #167)

2 Closed Center Spool Valve. Closed center spool valves stop (dead end) the flow of oil from the pump during neutral.

(ON SLIDE #168)

INSTRUCTOR NOTE
Picture of closed center spool valve schematic.

(ON SLIDE #169)

3 Controls for Spool Valves. There are three ways to operate a spool valve. Mechanically, using hydraulic pilot lines or using electric solenoids.

(ON SLIDE #170)

a Mechanical Linkage. Consists of a handle or lever being directly linked to the valve spool.

(ON SLIDE #171)

INSTRUCTOR NOTE
Picture of mechanical spool valve schematic.

(ON SLIDE #172)

b Pilot Operated. Pilot pressure is used to push the spool against the centering spring. When the activating oil is removed the centering spring returns the spool to neutral.

(ON SLIDE #173-174)

INSTRUCTOR NOTE
Picture of pilot operated spool valve schematic and pilot control valve.

(ON SLIDE #175)

c Electro-Hydraulic Valve Control. Actuated by an electric solenoid. Electric signal is sent by a switch or by a microprocessor. If sent by switch than it can only be fully open or neutral. If sent by a microprocessor than the force exerted by the solenoid is proportional to the current winding signal sent to the microprocessor.

(ON SLIDE #176)

INSTRUCTOR NOTE
Picture of electro-hydraulic control valve.

(ON SLIDE #177)

(3) Volume Control Valves. Controls valves that regulate oil flow rate to a hydraulic circuit. There are two types of volume control valves, flow control and flow divider valves.

(ON SLIDE #178)

(a) Needle Valves. One type of flow control, a non compensated valve that restricts flow in or out of a component. Because it is a set orifice it will not change or compensate for varying pressures.

(ON SLIDE #179)

INSTRUCTOR NOTE
Picture of a needle valve.

(ON SLIDE #180)

(b) Flow Control Valve or Bypass Regulator. Another flow control type volume control valve. Very similar in function to the pressure sequence valve from the pressure control portion of this lesson, for this we are talking about flow not pressure. Once the flow is great enough to overtake the spring tension it will divert the remaining flow to another circuit or back to the reservoir.

(ON SLIDE #181)

INSTRUCTOR NOTE
Play flow control valve video.

(ON SLIDE #182)

(c) Flow Divider. Divides flow evenly or at a set percentage rate depending on needs of the system. Can regulate flow ratio from 50/50 to 90/10.

(ON SLIDE #183)

INSTRUCTOR NOTE
Picture of flow divider valve.

(ON SLIDE #184)

INTERIM TRANSITION: We just finished with valves, are there any questions? If not let's take a break and then you will have a quiz.

____

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(BREAK-10 MIN)

INSTRUCTOR NOTE
Hand out quiz prior to demonstration. Allow 30 minutes for completion. Students should work from memory but student outlines are authorized. Explain that this is also a good study guide for the test.

INTERIM TRANSITION: During the quiz did anyone come up with any questions? If not let's move into the demonstration.
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INSTRUCTOR NOTE:
Perform the following demonstration. **Allow students to take breaks as required or as instructed.**

DEMONSTRATION. (1 hr) Demonstration will be conducted in the classroom. The purpose of this demonstration is to show the students the proper procedures to disassemble, inspect and reassemble a hydraulic spool valve.

STUDENT ROLE: Students should sit around the demonstration desk where they can observe. Students should ask questions throughout the demonstration if they have any.

INSTRUCTOR(S) ROLE: The instructor will completely disassemble, inspect and reassemble the hydraulic spool valve. During the course of the demonstration show the proper tooling and procedures.

Supplies: (1) One of ten hydraulic spool valves located in the big shed.
(2) General Mechanics tool box.

1. **Safety Brief: N/A**
2. **Supervision and Guidance:** Answer any and all questions. Talk in detail about all procedures during the process. Ask questions of the students throughout the process.
3. **Debrief: N/A**

INTERIM TRANSITION: Are there any questions over the demonstration? If not, let's move into the practical application.

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INSTRUCTOR NOTE:
Perform the following practical application. **Allow students to take breaks as required or as instructed.**

PRACTICAL APPLICATION. **(7 hrs)** Practical application will be conducted in the work bay. The purpose of this practical application is to allow the students to completely disassemble, inspect and reassemble hydraulic spool valves.

PRACTICE: Using the knowledge obtained during the demonstration and lecture portion of the course the students will safely remove, disassemble, inspect, reassemble and reinstall the hydraulic spool valves.

PROVIDE HELP: The instructor will ensure the students have all TM's, PPE, tools, hazmat products and anything else needed to perform the task.

1. Safety Brief: Ensure the students have all appropriate PPE and materials before starting the practical exercise.
2. Supervision and Guidance: Instructor is moving around the bay, assisting students and answering questions as they arise.
3. Debrief: N/A

(ON SLIDE #185)

TRANSITION: We just finished with hydraulic valves, do you have any questions? I have a one for you. **Q:** What are the three types of hydraulic valves? **A:** Pressure control, directional control and volume control valves. If there are no more questions then let's take a break and then we will talk about troubleshooting.

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(BREAK-10 MIN)

TRANSITION: Any more questions before we go into troubleshooting.

____
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11. **Troubleshooting**. **(30 min)**

(ON SLIDE #186)

a. Modern hydraulic systems have become increasingly more difficult to diagnosis and test. Simply guessing what is wrong and changing parts until the problem is found is not acceptable. Parts are far more expensive to replace and more time consuming to repair. Instead, an informed, knowledgeable approach to identifying the problem is essential. There is a seven step process used to properly troubleshoot.

(ON SLIDE #187)

(1) Know the system. Study the machine technical manuals, know how the system works. Understand the limitations of the system, don’t try to fix a system that is operating normally.

(ON SLIDE #188)

(2) Ask the operator. The operator can tell you how the machine acted, when it started to fail and what was unusual about it. Find out what was being done when the machine failed. Was it sudden or did it happen gradually? Also find out when it was last brought in for maintenance and what for. Many problems can be traced to poor maintenance or abuse of the machine.

(ON SLIDE #189)

(3) Operate the machine. Operate the machine at normal operating temperature to verify the operator’s statement. Try to answer the following questions:

(a) How is the performance? Is the action slow or erratic?

(b) Do the controls feel correct? Do they seem to be sticking or are they working at all?

(c) Are the gauges reading normal?

(d) Any signs of smoke?

(e) Any unusual sounds? Where from and at what speeds?

(ON SLIDE #190)

(4) Inspect the machine. Use a LTI sheet (NAVMC 10560) to inspect every possible hydraulic component. Make sure you check the simple things, open the reservoir and look at the oil to make sure it's not foamy.

(ON SLIDE #191)

(5) List the possible causes. Make a list of all the problems you found during your inspection, what are the likely causes for those problems? Remember that the cause of a problem can be much different than the result of that problem. Look for the root cause and then worry about fixing everything that it damaged, after you find the main problem then it will be easier to determine everything that it affected.

(ON SLIDE #192)

(6) Reach a conclusion. Look over your list of possible causes and decide which are most likely and which are easiest to verify.

(7) Test your conclusion. Before you start repairing the system, test your conclusions to see if they are correct. Analyze the information you already have.

(a) Were all the functions bad? Then probably the failure is in a component that is common to all parts of the system. Examples: pump, filters and relief valves.

(b) Was only one circuit bad? Then you can eliminate the system components and concentrate on the parts of one circuit.

(ON SLIDE #193)

b. **Types of Systems**. There is no substitute for understanding the general principles of hydraulics when troubleshooting. It is also necessary to know and understand the hydraulic system on the machine.

(ON SLIDE #194)

(1) Open-Center Systems. In the simpler open-center system, the pump produces a continuous flow that must be returned to the reservoir when the cylinder or other actuator is not in operation. During the stand-by condition, flow is high but pressure is low. When flow is diverted by the control valve to the cylinder or other actuator, flow remains constant and the pressure increases to the level necessary to move the load or to the relief valve setting, whichever is lower. When the control valve is returned to neutral, fluid trapped in the cylinder supports the load, and pump output returns to the reservoir at low pressure. For the operation of one function this arrangement is satisfactory. All the components in the system must be large enough to handle the full flow of the pump. Where it is necessary to decrease pump flow to any function or divide the flow to two or more functions, the system becomes very inefficient.

(2) Closed-Center Systems. In a typical closed-center system, a central source of hydraulic power supplied by one pump is used to power multiple functions. Pump displacement, and thus flow, changes to meet the demands of the system. When no functions are in use, oil flow is blocked at the valve. The pump is at minimum flow but pressure is maintained to the valves at a preselected maximum pressure. In a closed-center system, each actuator circuit can be designed individually. The size of the cylinder, valves and connecting lines are selected to provide the flow rate required to produce the required actuator speed.

(ON SLIDE #195)

TRANSITION: Are there any questions over hydraulic troubleshooting? If not, let's take a 10 min break.

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(BREAK-10 MIN)

(ON SLIDE #196)

TRANSITION: We just finished with troubleshooting, do you have any questions? I have a one for you. **Q:** What NAVMC should you use when inspecting the machine during your troubleshooting process? **A:** NAVMC 10560, Limited Technical Inspection sheet.

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12. **Schematic Symbols**. **(30 min)**

(ON SLIDE #197)

a. It is important to understand the basic schematic symbols. Different companies' schematics will have slightly different symbols. The basic format comes from the ISO (International Organization for Standardization) chapter 1219-1, which has been approved by the ANSI (American National Standards Institute).

(ON SLIDE #198)

(1) Filter. A diamond with a dotted line through the center.

(ON SLIDE #199)

(2) Reservoirs. A enclosed box or oval for pressurized reservoirs and a upside down T for a vented reservoir.

(ON SLIDE #200)

(3) Lines. Bisecting lines with dots or tees are connections. Bisecting lines that jump each other or have no dots are not connections.

(ON SLIDE #201)

(4) Cylinders. A rectangle represents a cylinder.

(ON SLIDE #202)

(5) Accumulators. A vertical oval, depending on what symbol is inside determines the type of accumulator.

(ON SLIDE #203)

(6) Pumps and Motors. A circle represents both, internal arrows and which direction they point decides between the two. A bisecting arrow at a forty five degree angle tells you it is variable displacement.

(ON SLIDE #204)

(7) Spool Valves. A rectangle represents the valve, every square within the rectangle is a different position for that valve

(ON SLIDE #205-206)

INTERIM TRANSITION: Are there any questions over schematic symbols? If not, let's move into the demonstration.

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INSTRUCTOR NOTE:
Perform the following demonstration. **Allow students to take breaks as required or as instructed.**

DEMONSTRATION. **(1 hr)** Demonstration will be conducted in the work bay. The purpose of this demonstration is to show the students the proper procedures to read/interpret schematics and assemble hydraulic simple circuits on the hydraulics training boards.

STUDENT ROLE: Students should stand around the demonstration area where they can observe. Students should ask questions throughout the demonstration if they have any.

INSTRUCTOR(S) ROLE: The instructor will familiarize students with hydraulics boards. Will show students proper procedures for assembly of simple circuits on hydraulic boards.

Supplies: (1) Student handbook and printed schematics.
(2) Hampden hydraulic training boards.

1. Safety Brief: Insure all personnel are wearing safety glasses.
2. Supervision and Guidance: Answer any and all questions. Talk in detail about all procedures during the process. Ask questions of the students throughout the process.
3. Debrief: N/A

INTERIM TRANSITION: Are there any questions over the demonstration? If not, let's move into the practical application.

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INSTRUCTOR NOTE:
Perform the following practical application. **Allow students to take breaks as required or as instructed.**

PRACTICAL APPLICATION. **(7 hrs)** Practical application will be conducted in the work bay. The purpose of this practical application is to allow the students to practice interpreting schematics and assembling simple hydraulic circuits.

PRACTICE: Using the knowledge obtained during the demonstration and lecture portion of the course the students will read/interpret the schematics and build the circuits on the training boards.

PROVIDE HELP: The instructor will ensure the students have all TM's, PPE, tools, hazmat products and anything else needed to perform the task.

1. Safety Brief: Ensure the students have all appropriate PPE and materials before starting the practical exercise.
2. Supervision and Guidance: Instructor is moving around the bay, assisting students and answering questions as they arise.
3. Debrief: N/A

TRANSITION: We just finished with Schematic Symbols and assembling the hydraulic boards, do you have any questions? I have a one for you. **Q:** The basic format for hydraulic schematic symbols comes from what Organization? **A:** ISO (International Organization for Standardization).

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(ON SLIDE #207)

SUMMARY. **(5 min)**

Over the course of this lesson we have covered principles of hydraulics, hydraulic terms, filters, reservoirs and coolers, hoses, lines, seals, cylinders, accumulators, pumps, motors, valves, troubleshooting and schematics. I am confident that after having this class you will be a more efficient technician. At this time any Marines with IRF's please fill them out to completion, everyone else take a 15 min break.

(BREAK 10 min)

REFERENCES:

TM 12059A-OI/7 Parker Exactol 400 Series Tube Benders

TM 12059A-OI/5 CC30 Hydraulic Crimper Operators Manual

TM 12059A-OI/12 Parker Hydra-Tool Hydraulic Flaring and Presetting Tool

TM 10996B-OI/1 Backhoe Loader, Caterpillar Model 420E IT

FOS-1006NC John Deere Hydraulics

FPT-2 second edition Vickers board instruction manual