Practical Hydraulics Workshop for Mobile and Industrial Systems

Fluid Power Training Institute™
2170 South 3140 West
Salt Lake City, UTAH 84119
United States of America

http://www.fpti.org
1-888-222-3421

Practical Hydraulics Workshop – 40 hours

The Practical Hydraulics Workshop for Mobile and Industrial Hydraulics covers the following topics:

1. Safety
2. Hydraulic Symbols
3. Basic Hydraulic Laws and Principles
4. Pressure Control Valves
5. Hydraulic Pumps and Closed-loop (hydrostatic) Systems
6. Check Valves, Accumulators, and Actuators
7. Reservoirs, Coolers, Hoses, and Connectors
8. Directional Control Valves
9. Flow Control Valves
10. Flow Dividers
11. Proactive Maintenance
12. Filtration

The workshop includes extensive simulator activities as outlined in the Student Simulator Activities Book.

Practical Hydraulics Workshop
Course Syllabus

1 - Safety
(approximately 5-hours)

1. Describe at least six typical accidents associated with hydraulics. Describe how and why they occur, and, describe what steps must be taken to prevent them.
2. Describe why exhausting high-pressure oil to atmosphere can lead to severe injury, death, or substantial property damage.
3. Describe what conditions can lead to a high-pressure injection injury.
4. Describe what steps to take in the event of suffering a high-pressure injection injury.
5. Explain what steps must be taken to make a hydraulic system safe to work on.
6. Describe OSHA's/MSHA's six-step lockout and tagout procedure.
7. Describe how to safely bleed air from a hydraulic system.
8. Explain how a flowmeter, pressure gauge, and temperature gauge can be used to prevent accidents.
9. Explain how to safely tighten a leaking connector.
10. Explain the potential consequences of tightening a leaking connector while it is under pressure.
11. Explain how to safely de-energize a hydraulic system.
12. Explain the potential consequences of de-energizing a hydraulic system to atmosphere.
13. Explain why it is dangerous to attempt to stall the output shaft of a hydraulic motor.
14. Describe what steps to take before using a high-pressure porta-power.
15. Describe why only trained, authorized personnel should be permitted to service, repair, and charge an accumulator.
16. Describe why only trained, authorized personnel should be permitted to make high-pressure hose assemblies.
17. Describe why using compressed air to disassemble a hydraulic cylinder can lead to severe injury, death, or substantial property damage.
18. Describe the correct technique for removing a stubborn gland when disassembling a hydraulic cylinder.
19. Describe at least five design features that will make a hydraulic system safe to service, repair, and troubleshoot.

2 - Hydraulic Symbols

(approximately 2-hours)

1. Correctly describe the meanings of:
    a. a complete graphic symbol
    b. a simplified graphic symbol
    c. pictorial symbol.
    d. cutaway symbol
    e. graphic symbol
2. Correctly describe the six elements of the scope of the symbol standard.
3. Correctly describe the four elements of the purpose of the symbol standard.
4. Correctly describe the three symbol rules.
5. Correctly describe the five shapes that are used to make fluid power symbols.
6. Correctly describe what the following shapes represent:
    a. Circles
    b. Squares
    c. Diamonds
    d. Rectangles
7. Correctly describe what the four basic types of lines represent.
8. Correctly describe what the acronyms ISO and ANSI mean.
9. Identify on a schematic, and correctly interpret, the following groups of symbols:
    a. Pumps
    b. Pressure control valves
    c. Directional control valves
    d. Accumulators
    e. Flow control valves
    f. Check valves
    g. Fluid conditioners
    h. Actuators
    i. Measuring instruments
10. Use the ANSI and/or ISO symbol reference manual to look-up a symbol.

3 - Basic Hydraulic Laws and Principles

(approximately 6-hours – includes simulator time)

1. Describe Pascal's Law and explain how it revolutionized the fluid power industry.
2. Explain what "hydraulic power" is.
3. Give at least six advantages of using hydraulics as opposed to other means of power transmission.
4. Describe the effect pressure and flow have on hydraulic horsepower.
5. List the six primary components in a hydraulic system and describe their respective purposes.
6. Describe the primary difference between a positive and non-positive displacement pump.
7. Explain the meaning of "positive displacement."
8. Explain the two methods used to describe pump volume.
9. Describe what factors must be known to calculate pump flow.
10. Describe how to calculate pump flow when displacement and speed are known.
11. Explain the difference between theoretical pump flow and actual pump flow.
12. Explain what pump "volumetric efficiency" means.
13. Recite the volumetric efficiencies (by rule-of-thumb), of the following pumps:
    a. Piston
    b. Vane
    c. Gear
14. Recite three diagnostic instruments needed to safely and accurately determine pump flow.
15. Describe how a "regeneration" circuit works.
16. Describe what occurs when oil is flowing in parallel flow paths.
17. Explain why a hydraulic cylinder can be compared to a 3-speed mechanical transmission.
18. Describe what components determine maximum force/torque output of a hydraulic system.
19. Describe, using a diagram, the primary components which make up a hydraulic cylinder.
20. Explain what causes pressure in a hydraulic system.
21. Describe the two "sources" of pressure in a hydraulic system.
22. Explain how to determine if oil is flowing using pressure gauges.
23. Explain the point-to-point resistance which a pressure gauge can read.
24. Describe the difference between system-generated pressure and load-generated pressure.
25. Describe the difference between flow and velocity.
26. Describe Pascal's Law and explain how it applies to a hydraulic system.

4 - Pressure Control Valves

(approximately 6-hours – includes simulator time)

1. List the five types pressure control valves.
2. Describe the basic operation of a pressure control valve.
3. Describe the two components which determine the pressure setting of a pressure relief valve.
4. Explain the difference between an unguided poppet-type and a guided poppet-type relief valve.
5. Describe the differences between parallel and series circuits.
6. Describe what occurs when two or more pressure relief valves are connected in series.
7. Describe the meaning of “power-beyond.”
8. Explain what a “power-beyond” option achieves in a directional control valve.
9. Skill Drill – Correctly set a pressure relief valve at a pressure specified by a system designer.
10. Describe the single most important safety consideration when installing a pressure relief valve in a circuit.
11. Explain what will happen if a pressure relief valve is incorrectly installed (ports reversed) in a circuit.
12. Describe the correct safety procedures for setting a pressure relief valve.
13. Explain what must be done to safely create the resistance necessary to set a pressure relief valve.
14. Select the correct pressure gauge, know where to install it in the circuit, and know how to use it to correctly set a pressure relief valve.
15. Recognize the symbol for a pressure relief valve from a “line-up” of pressure control valve symbols.
16. Describe the primary purpose of a sequence valve.
17. Describe the main difference between a pressure relief valve and a sequence valve.
18. Describe why a sequence valve must be externally drained.
19. Recite the three basic rules for setting pressure control valves when there are two or more in a circuit.
20. Describe the basic steps you must follow to safely and correctly set a sequence valve.
21. Describe the primary purpose of a counterbalance valve.
22. Describe the basic operation of a counterbalance valve.
23. Explain the two primary applications of a counterbalance valve.
24. Describe at least four purposes of a counterbalance valve.
25. Describe the main differences between a pressure relief valve, a sequence valve and a counterbalance valve.
26. Describe the basic steps you must follow to safely and correctly set a counterbal-

ance valve.

27. Recognize the symbol for a counterbalance valve from a “line-up” of pressure control valve symbols.
28. Describe the primary purpose of an unloading valve.
29. Describe the basic operation of an unloading valve.
30. Explain the two primary applications of an unloading valve.
31. Describe the main differences between a pressure relief valve, a sequence valve, a counterbalance valve, and, an unloading valve.
32. Describe the basic steps you must follow to safely and correctly set an unloading valve.
33. Recognize the symbol for an unloading valve from a “line-up” of pressure control valve symbols.
34. Describe the primary purpose of a pressure reducing valve.
35. Describe the basic operation of a pressure reducing valve.
36. Explain what the term “step-level pressure control means.”
37. Describe the main differences between a pressure relief valve, a sequence valve, a counterbalance valve, an unloading valve, and, a pressure reducing valve.
38. Describe the basic steps you must follow to safely and correctly set a pressure reducing valve.
39. Recognize the symbol for a pressure reducing valve from a “line-up” of pressure control valve symbols.
40. Describe the basic operation of a pilot-operated relief valve.
41. Explain what is meant by the term “override” as it applies to a direct-operated relief valve.
42. Explain what the term “cracking pressure” means.
43. Explain what causes a direct-operated pressure relief valve to open before its pressure setting is reached.
44. Explain what will happen if a direct-operated pressure relief valve is set to its recommended pressure with a porta-power.
45. Explain what will happen if the pilot orifice in a pilot-operated relief valve becomes plugged.
46. Describe the basic difference in operation between a direct-operated relief valve and a pilot-operated relief valve.
47. Describe two application advantages of a pilot-operated relief valve.

5 – Pumps and Closed-Loop Systems

(approximately 6-hours – includes simulator time)

1. Describe how the inlet side of a hydraulic pump works.
2. Explain what cavitation is and how it effects the operation of a hydraulic pump.
3. Explain what “pump volumetric efficiency” means.
4. Explain from which end a hydraulic pump shaft rotation is determined.
5. Explain the difference between an internal drain pump and an external drain pump.
6. Describe the difference between an internal gear pump and an external gear pump.
7. Explain why an external gear pump is “unbalanced.”
8. Explain why it is critical to perform a “phased pressure” start-up on an external gear pump.
9. Describe how an external gear pump works.
10. Describe how an internal gear pump works.
11. Describe how an unbalanced vane pump works.
12. Describe how a balanced vane pump works.
13. Describe how a radial piston pump works.
14. Describe how an axial piston pump works.
15. Describe how a bent-axis piston pump works.
16. Give at least three applications in which a fixed-displacement pump would not be suitable.
17. Explain what is meant by the term “variable volume.”
18. Explain the concept of ”pressure compensation.”
19. Give at least two advantages of a pressure-compensated pump.
20. Describe how to make the flow adjustment on a pressure-compensated pump.
21. Describe how to make the pressure adjustment on a pressure-compensated pump.
22. Describe the steps which must be followed to safely and accurately set a pressure-compensated pump when it has a pressure relief valve.
23. Explain what the term “load-sensing” means.
24. Explain the primary purpose of a load-sensing system.
25. Give at least three advantages of a load-sensing system.
26. Explain how a load-sensing system works.
27. Describe the difference between an “open-loop” and a “closed-loop” hydraulic system.
28. Give at least three advantages of a closed-loop system.
29. Explain what the term “over-center” means.
30. Give at least four purposes of a charge pump.
31. Explain how to set a charge pressure relief valve for neutral.
32. Describe the purpose of the cooling and filtering system in closed-loop system.
33. Explain how to set the forward and reverse charge pressure relief valve in a closed-loop system.
34. Describe the function of a “towing bypass valve” in a closed-loop system.

35. Explain what will happen if the towing speed and distance are exceeded in a closed-loop system.
36. Explain why the inherent braking in a closed-loop system must never replace the primary braking system on a propelled vehicle.
37. Explain what steps must be taken if a hydraulically propelled vehicle experiences a “runaway” condition.
38. Describe what typically causes a closed-loop system to experience a freewheel condition.
39. Describe why it is critical that the case drain line of a pump or motor must terminate below the oil level in the reservoir.
40. Explain what happens when the case pressure in a pump or motor exceeds the maximum case pressure recommended by the manufacturer.
41. Using a schematic explain how a closed-loop system works in the following modes:
    a. Start-up
    b. Forward motion
    c. Reverse motion
    d. Overload.
42. Explain what steps must be taken before starting an external drain pump.

6 – Check Valves, Accumulators, and Actuators

(approximately 2-hours)

6-1 CHECK VALVES

1. Describe how a check valve works.
2. Give at least three typical circuit applications for check valves.
3. Describe how a pilot-to-open check valve works.
4. Give the distinct advantage of a pilot-to-open check valve.
5. Describe how a pilot-to-close check valve works.
6. Give a typical application of a pilot-to-close check valve
7. Describe what “thermal expansion” means.
8. Describe how a rectifier valve works.
9. Give a typical application for a rectifier valve.
10. Describe how a velocity fuse works.
11. Give a typical application for a velocity fuse.

6-2 ACCUMULATORS

1. List the three most common types of accumulators.
2. Describe why nitrogen, rather than air or oxygen, is used as the pre-charge medium in an accumulator.
3. Describe the rule-of-thumb for the pre-charge pressure for an accumulator.
4. Describe the instrument used to pre-charge an accumulator with nitrogen.
5. Give at least three safety rules for pre-charging and accumulator.
6. Give at least three causes of premature accumulator failure.
7. Describe the correct method for installing an accumulator.
8. Explain how to pre-charge an accumulator with nitrogen.
9. Give at least three typical circuit applications for an accumulator.
10. Describe what safety steps must be followed when installing a new (or rebuilt) accumulator in a hydraulic system.
11. Explain how low nitrogen charge pressure effects the operation of a hydraulic system.
12. Describe what can happen if an accumulator valve core is depressed with a finger.
13. Explain why it is critical that an accumulator be charged, repaired, and serviced by trained authorized personnel only.
14. Describe what steps must be taken when transporting a pressurized accumulator.
15. Describe the steps that must be followed to safely de-energize a hydraulic system.
16. Explain how an accumulator works.

6-3 ACTUATORS

1. Explain the purpose of a hydraulic cylinder.
2. Explain the purpose of a hydraulic motor.
3. Explain what items determine the maximum force output of a hydraulic cylinder.

4. Explain what items determine the torque output of a hydraulic motor.
5. Recite the definition of torque.
6. Describe at least four types of hydraulic cylinders.
7. Explain the leading cause of cylinder failure in the industry.
8. Describe how to safely remove trapped air from a hydraulic cylinder.
9. Explain why cycling a cylinder rod while the rod clevis is not attached is extremely hazardous.
10. Describe what the term “pressure intensification” means as it relates to a hydraulic cylinder.
11. Describe what the term “flow intensification” means as it relates to a hydraulic cylinder.
12. Explain what a cylinder cushion is and how it works.
13. Explain how a cam-wave motor works.
14. Explain what steps must be taken before starting a new or rebuilt external drain motor.
15. Explain what is achieved when the displacement of a hydraulic motor is variable.

7 – Reservoirs, Coolers, Hoses, and Connectors

(approximately 2-hour)

7-1 RESERVOIRS

1. Give at least four purposes of a hydraulic reservoir.
2. Describe the "rule-of-thumb" for sizing a hydraulic reservoir.
3. Explain the purpose of the baffle in a hydraulic reservoir.
4. Describe the service interval for a hydraulic reservoir.
5. Give at least two advantages of pressurizing a hydraulic reservoir.

7-2 COOLERS

1. Describe the purpose of an oil cooler.
2. Describe why the oil in a hydraulic system gets hot.
3. List at least three problems associated with excessive oil temperature.
4. Describe the two types of coolers used in the industry.
5. Describe the typical operating temperature of hydraulic oil.
6. Describe what effect heat has on hydraulic oil.
7. Describe how an air/oil cooler works.
8. Describe how a water/oil air cooler works.
9. Describe how to correctly install an oil cooler in relationship to the inlet and outlet ports.
10. Explain what critical schedules service must be performed on an oil cooler.
11. Explain how heat affects the operation and life of a hydraulic system.
12. Explain what the "enemy" of a water/oil cooler is.
13. Describe what the relationship of scale is to the transfer of heat through iron.
14. Explain what the ratio of water flow is to oil flow as it applies to a water/oil cooler.
15. Explain what effect excessive back-pressure can have on an oil cooler.
16. Explain why it is necessary to "by-pass" an oil cooler when oil is cold.
17. Describe what steps must be taken to clean an air/oil cooler.
18. Explain what the purpose of the shroud is on an air/oil cooler.
19. Explain what will happen to cooling efficiency if a hydraulic system is operating and the shroud is removed.
20. Explain what technique to use to check the effectiveness of an oil cooler.
21. Explain what is the most suitable time to check the effectiveness of a cooler.

7-3 HOSES AND CONNECTORS

1. Describe the three basic elements of a hydraulic hose.
2. Explain what "static bond" means as it is applied to a hydraulic hose.
3. Describe what factors determine how often hydraulic hose should be inspected.
4. Describe six areas of a hose which should be inspected on a regular basis.
5. Explain why a person should never use his/her hands to check for leakage from a hydraulic hose.

6. Explain what could happen if a hose is lifted from a single point with the sides hanging down.
7. Explain by what maximum percentage the outside diameter of a hose can be reduced to the degree it is unfit for service.
8. Describe the most effective technique for cleaning the inside of a hydraulic hose.
9. Describe why steam-cleaning a hydraulic hose is not recommended.
10. Explain the difference between rated working pressure and the safety factor of a hydraulic hose.
11. Explain why it is an unsafe practice to crimp one manufacturer's connector onto the end of another manufacturer's hose, and/or use another manufacturer's crimping machine to make the assembly.
12. Explain why it is unwise to exceed the bend radius of a given size hose.
13. Explain what happens when a hose chafes against a solid object or another hose.
14. Describe what the specifications written on the side of a hydraulic hose mean.
15. Explain why it is undesirable to use thread sealing tape on a hydraulic connector.
16. Explain why hose assemblies should be made by trained, authorized persons only.
17. Explain what can happen if an untrained person makes a hose assembly.
18. Explain the difference between a SAE code 61 connector and a SAE code 62 connector.
19. Explain what procedure or process is used to prevent the inadvertent connection of a SAE code 61 to a SAE code 62 and vice-versa.
20. Explain how to correctly torque a SAE 37 JIC swivel connector.
21. Use the International Connector Identification kit and determine the following:
    a. Use a caliper to determine inside or outside dimensions.
    b. Use a thread gauge to determine thread dimensions.
    c. Use an angle gauge to determine seat angle.
    d. Use these dimensions to determine what type of connector it is from the information in the guide.
22. Explain what the dash numbers associated with connector sizes mean.
23. Explain why it is unwise to use low-pressure hydraulic hose in a suction line application.
24. Explain what will occur if a small diameter hydraulic hose is substituted with a larger diameter hose.
25. Explain what will occur if a large diameter hydraulic hose is substituted with a smaller diameter hose.
26. Explain what happens when a hose assembly is twisted while it is being installed between two immovable components.
27. Explain what happens to the length of a hydraulic hose when it is subjected to pressure.
28. Explain what could happen if a hose length is just sufficient to span the distance between to immovable components.

8 – Directional Control Valves

(approximately 4-hours – includes simulator time)

1. List at five purposes of a directional control valve.
2. Describe how the symbol shows how many “positions” are in a directional control valve.
3. Describe how the symbol shows how many “ways” the oil can flow in a directional control valve.
4. Name the four standard “center configurations” for directional control valves in the industry.
5. Describe a typical application for a tandem-center directional control valve.
6. Describe a typical application for a open-center directional control valve.
7. Describe a typical application for a closed-center directional control valve.
8. Describe a typical application for a float-center directional control valve.
9. Describe a directional control valve application that will cause a double-acting, single-rod cylinder to creep.
10. Explain what can be done to prevent a rod from creeping.
11. Explain how “silting” can cause the spool in a directional control valve to seize.
12. Explain what the most probable cause for spool seizure is.
13. Describe the purpose of radial grooves on the land of a directional control valve.
14. Explain what the term “explosive decompression” is as it relates to a directional control valve.
15. Describe how it is controlled in the design of a directional control valve.
16. Give at least three reasons why a directional control valve spool will seize.
17. Explain what is meant by the terms, “open-center crossover” and “closed-center crossover” as it applies to a directional control valve.
18. Describe how a “detent positioner” works.
19. Describe what the “International Directional Control Valve Interface Size Cross Reference” means.
20. Describe what steps must be taken to correctly install an 03 size valve on its subplate.
21. Describe what steps must be taken to correctly install an 05 size valve on its subplate.
22. Describe what steps must be taken to correctly install an 08 size valve on its subplate.
23. Describe what steps must be taken to correctly install a D10 size valve on its subplate.
24. Describe how a “choke control” works in a two-stage valve.
25. Describe how a “back-pressure” check valve works in a two-stage valve.
26. Explain why a two-stage directional control valve, in certain applications, needs to be externally drained.
27. Explain why a two-stage directional control valve, in certain applications, needs to

be externally piloted.

28. Demonstrate how to convert an internal drain two-stage valve to an external drain.
29. Demonstrate how to convert an internal pilot two-stage valve to an external pilot.
30. Explain what a “circuit module” is.
31. Give at least two advantages of circuit modules.
32. Name the typical components which make up a mobile directional control valve.
33. Describe the purpose of a “load-check” valve in a mobile directional control valve.
34. Describe the purpose of a “cylinder port” relief valve in a mobile directional control valve.
35. Describe the purpose of an “anti-cavitation” valve in a mobile directional control valve.
36. Describe how a “power-beyond” circuit works.
37. Describe how a “power logic” valve works.
38. Give at least three advantages of a power logic valve.

9 – Flow Control Valves

(approximately 2-hours – includes simulator time)

1. Name two categories of flow control valves.
2. Describe what is meant by the term “non-pressure-compensated” flow control valve.
3. Describe what is meant by the term “pressure-compensated” flow control valve.
4. Explain how pressure difference effects flow through an orifice.
5. Explain how this effects the operation of a hydraulic system.
6. Describe the four variables that effect flow through an orifice.
7. Name three types of flow control valves.
8. Give two suitable applications for a non-compensated flow control valve.
9. Describe how a fixed orifice works.
10. Describe how a needle valve works.
11. Describe how a one-way flow control valve works.
12. Describe how a pressure-compensated flow control valve works.
13. Give a typical application for a pressure-compensated flow control valve.
14. Describe what the term “temperature compensation” means.
15. Describe how a temperature-compensated flow control valve works.
16. Describe how a bimetallic or metal rod is used to compensate for oil temperature changes.
17. Describe how a sharp edge orifice works.
18. Describe how a “meter-in” flow control circuit works.
19. Give at least two advantages of a meter-in flow control circuit.
20. Give at least two disadvantages of a meter-in flow control circuit.
21. Describe how a “meter-out” flow control circuit works.
22. Give at least two advantages of a meter-out flow control circuit.
23. Give at least two disadvantages of a meter-out flow control circuit.
24. Describe how a “bleed-off” flow control circuit works.
25. Give at least two advantages of a bleed-off flow control circuit.
26. Give at least two disadvantages of a bleed-off flow control circuit.

10 – Flow Dividers

(approximately 2-hours – includes simulator time)

1. Explain what a flow divider is.
2. Give at least two advantages of a flow divider.
3. Give at least two classifications of flow dividers.
4. Give at least three applications of flow dividers.
5. Explain how a by-pass type pressure-compensated flow control valve, also known as a priority flow divider, works.
6. Describe a typical application for a by-pass type pressure-compensated flow control valve.
7. Explain how a flow divider-combiner valve works.
8. Give a typical application for a flow divider-combiner valve.
9. Explain how a gear-type flow divider works.
10. Give a typical application for a gear type flow divider.

11 – Proactive Maintenance

(approximately 1-hour)

1. Describe the meaning of “proactive” maintenance.
2. Identify the two primary “enemies” of a hydraulic system.
3. Describe, according to rule-of-thumb, the normal operating temperature of a hydraulic system.
4. Describe what happens when hydraulic components have internal wear.
5. Explain why it is critical to observe oil temperature on a daily basis.
6. Describe why it is critical to observe pump inlet restriction on a daily basis.
7. Describe what will happen if pump inlet restriction is higher than normal.
8. Describe what will happen if accumulator pre-charge pressure is not monitored on a monthly basis.
9. Describe why it is critical to monitor the temperature drop across a heat exchanger on a monthly basis.
10. Describe when a hydraulic filter should be changed.
11. Describe why it is important to monitor engine speed on a monthly basis.
12. Describe why it is critical to monitor pump flow on a regular basis.
13. Explain why it is critical to take oil samples on a monthly basis.
14. Describe the best location in a hydraulic system from which to draw an oil sample.
15. Describe at least four primary functions of a hydraulic reservoir.
16. Explain why it is necessary to clean a hydraulic reservoir out on a scheduled maintenance basis.
17. List the diagnostic instrumentation needed to safely and effectively perform scheduled maintenance on a hydraulic system.

12 - Filtration

(approximately 2-hours)

1. Explain what is meant by “filtration objective” for a hydraulic system.
2. Give at least two reasons why filters don’t adequately condition the oil in a hydraulic system.
3. Describe the three modes of failure in a hydraulic system.
4. Describe the four basic steps which define a “system approach” to contamination control.
5. Describe the four purposes of hydraulic oil.
6. Describe the average clearance in hydraulic components.
7. Describe the four primary sources through which contaminants enter a hydraulic system.
8. Give at least four reasons how contamination is generated within a hydraulic system.
9. Describe how cavitation generates contamination in a hydraulic system.
10. Explain what an ISO range code is.
11. Describe the four steps which must be followed to set a target cleanliness level for a hydraulic system.
12. Explain what a range code number is.
13. Explain how a range code number is determined.
14. Explain what a multi-pass filter performance test is.
15. Explain what “filtration ratio beta” means.


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