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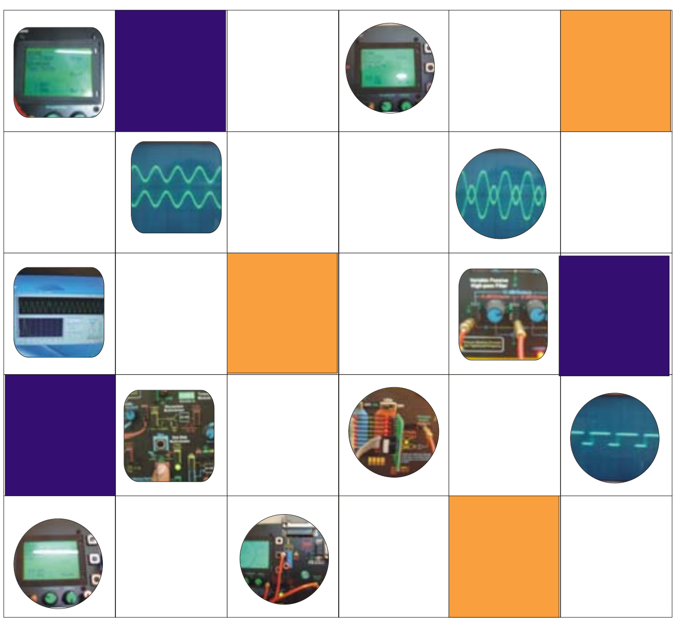
DEV-2757

Industrial Hydraulic Trainer

Operations Manual

PART NO. 2757-00-301



COMPREHENSIVE & ILLUSTRATED
EASY EXPERIMENTS STARTUP
LAB MANUAL

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HYDRAULIC SAFETY

HYDRAULIC PRESSURES AND OILS CAN BE HAZARDOUS AND LIFE THREATENING. PLEASE DONOT USE THE TRAINER WITH UNDERSTANDING THE SYSTEM OPERATION. DONOT (REPEAT) CLOSE THE BY PASS VALVE OF HYDRAULIC SYSTEM WITH THE POWER PACK

Mechanical devices, especially fast acting, powered mechanical devices can b dangerous Hydraulic systems are powerful and fast acting. It is possible to avoid injuries by recognizing and identifying dangerous conditions. The first rule of hydraulic safety is: Always wear safety glasses when working with hydraulics. In this lesson, participants will learn to recognize particular hazards associated with the speed and forces generated by hydraulic systems. Participating students will also identify safe practices when working with and around hydraulic systems.

Objectives

- Estimate and calculate velocities of moving objects.
- Describe and demonstrate the potential for injury from hydraulic powered devices and systems with respect to the velocities and forces they generate.

- Describe safe practices to follow when working with and around hydraulic components.

Terms	Materials
Force	Computer
Pressure	Calculator
Velocity	Dial Callipers
HRT	Ruler
Kilogram (kg)	Pens
Pounds (lbs)	Internet Access
Newton	Note Book
	Hydraulic Storage Reservoir
	Tubing
	On-Off Valve
	Pressure Regulator
	Solenoid Valve
	Hydraulic Cylinder
	12Volt Battery
	Test Leads

Hydraulics Are Potentially Dangerous Because They Are Fast

Pressurized gases are capable of storing significant amounts of energy, and releasing this stored energy very quickly. hydraulic oil systems are capable of generating significant forces that power fast moving mechanisms. When things move fast and with great force, they become very dangerous. Hydraulically powered mechanisms can move at speeds that are too fast for humans to safely react to.

When Dealing With Hydraulic Components Keep These Habits In Mind.

1. Always wear safety glasses.

2. Read and obey all hydraulic safety rules

3. hydraulic oil should never be directed towards or applied to any part of the human body. Never direct a hydraulic oil stream at your face or anyone else's.

4. Use the on/off /relieving valve supplied in the kit in every hydraulic circuit you design or build. This valve will depressurize downstream components.
5. Vent and depressurize all circuits and components when you are finished using them.

6. Never connect, or activate a pressurized system without direct supervision of a qualified person, and or express permission from a supervising instructor.

7. Never place yourself, another person or any part of a person in the line of action of a hydraulic actuator, or system component. This means that you never point moving parts toward anyone, ever. Treat hydraulic components like loaded guns.

8. When activating a hydraulic system, be certain that you have examined all the components and you have predicted what will happen when the system is energized.

9. Check and secure all of the mountings, fittings, piping, tubing, connectors and connections before connecting any hydraulic components or systems to a hydraulic oil supply.

10. Disconnect battery leads and vent hydraulic oil supplies BEFORE any adjustments, maintenance or dismantling of a hydraulic circuit is begun.

11. Allow only one person near the hydraulic system while it is being activated or deactivated.

12. Never heat the pressure storage tank.

13. Always use a regulator and pressure gauges in your system to monitor systems conditions.

14. Never over pressurize cylinders, storage tanks, directional valves or other system components. Never exceed the pressure rating of a hydraulic component; this is a recipe for disaster.

15. Use only the tubing valves, cylinders and regulators supplied.

16. Maximum allowable pressures of all products must be strictly observed. Most commonly available hydraulic components are designed to operate in the 100 psi range. Identify and remember the published design and pressure specifications of the hydraulic components supplied in the trainer. Never design or build a hydraulic circuit or cause the pressure within a hydraulic component, to exceed the specified design pressures!

2

Hydraulic System Components

Regulator

A device that adjusts and maintains a pre-determined pressure within a hydraulic circuit. The regulator maintains pressure in the downstream components as long as there is a pressure differential between the reservoir and the "Required" operating pressure. The reading on the regulator mounted gauge indicates the regulated or circuit pressure.

Speed Control Or Flow Control Valves

A device that controls the flow of pressurized hydraulic oil in a hydraulic circuit. Speed control valves are used to adjust the rate of hydraulic oilflow into or out of a hydraulic circuit or component. The rate of flow through a circuit or component affects the speed of the component. The higher the flow rate, the faster the component will operate. Note: Controlling hydraulic oil flow out of the cylinder is the preferred choice for accurate and smooth control of slower moving actuators.

Hydraulic Cylinders

Linear actuators that is available in thousands of different configurations. Cylinders refer to devices with pistons of various diameters and strokes of various lengths. They are most commonly specified as single acting (powered in one direction) or double acting (powered in both directions). Single acting spring return cylinders are more economical with respect to hydraulic oil consumption. The hydraulic cylinders supplied in the TRAINER are single acting, spring return valves.

Solenoid Valves

Solenoid valves are electrically operated valves that control the direction and flow of pressurized hydraulic oil to and from hydraulic actuators. Solenoid valves can be either monostable, (they spring return to a preferred or default condition either on or off) or Biteable, (having no preferred or default condition thus remaining where it was last positioned either on or off) Hydraulic valves can be hand, (mechanical) electrically (solenoid) or hydraulic oil (pilot) operated. For the purpose of electronically controlled machines we will only consider solenoid controlled directional sliding valves. The kit includes a 3 port, 2 position electrically operated solenoid valve.

Never Exceed The Pressure Ratings Of Hydraulic Components

Hydraulic power system components control and transmit energy stored in pressurized gas. The TRAINER hydraulic components are rated for at least 100psi (100 pounds per square inch). This is a working pressure commonly associated with high performance bicycle tires.

Always Use A Regulator

Use a bicycle pump to fill the hydraulic reservoir. Do not pressurize the storage reservoir to more than 150psi, and never construct or use a hydraulic circuit without a regulator. This will greatly reduce the chances of over pressurizing the system. It is not necessary to generate storage tank pressures greater than 150 psi.

3

INTRODUCTION TO CONSTRUCTING HYDRAULIC CIRCUITS

This unit provides students and teachers with the information and skills they need to use the hydraulic components. Students who understand the fundamental principles involved in the operation of hydraulic components can safely design and build working hydraulic modules. Students can then integrate these modules into machines and mechanisms they design. Built machines and mechanisms can be used in engineering contests played at the classroom, school, district, state or national level.

Objectives

1. Describe the use and function of each component in the TRAINER hydraulic circuit.
2. Assemble a working hydraulic circuit
3. Perform basic hydraulic experiments.
4. Use hydraulic components safely.

Terms	**Materials**
1/8 inch NPT Thread	150 psi Bicycle Pump
3 Way Shut Off Valve	1 Hydraulic Reservoir
Bicycle Pump	1 3 Way Shut Off Valve
Bore	1 Regulator
Breadboard	1 Solenoid Valve
Check Valve	1 Hydraulic Cylinder or Linear Actuator
One Touch Fittings	Tubing cutter or sharp razor knife
Hydraulic Cylinder	1 TRAINER kit
Hydraulic Reservoir	

Hydraulic Symbols Ports Pressure Regulator Schrader Valve Solenoid Valve Stroke Sub Assembly Volume Work	

Introduction to Constructing Hydraulic Circuits

The purpose of this lesson is to provide students and teachers with the knowledge necessary to use the hydraulic components correctly and safely. It is advisable to build and test the operation of hydraulic modules and sub assemblies before attempting to integrate the components into a working mechanism.
It is advisable that students and teachers become familiar with the feel, function and placement of the hydraulic components used in the basic circuit. This is best accomplished by building working mechanisms and developing a database of hydraulic experience. Understanding and using hydraulics correctly, safely and creatively requires time and practice.

Note: Never build a hydraulic circuit WITHOUT A REGULATOR. The hydraulic solenoid and cylinder are rated for working pressures below that of the reservoir. Passing unregulated pressurized hydraulic oil from the reservoir directly to the solenoid or cylinder can damage the components and result in personal injury. ALWAYS WEAR SAFETY GLASSES WHEN WORKING WITH HYDRAULIC COMPONENTS

These components are:

1. The Bicycle Pump

2. The Hydraulic Reservoir

3. The 3 Way Shut Off Valve

4. The Regulator

5. The Solenoid Valve

6. The Hydraulic Cylinder or Linear Actuator

7. The quick disconnects

8. The Speed Controls

Hydraulic components are designed to accomplish one or more of the following tasks; store, condition, direct, control or utilize hydraulic oil to perform useful work.

Work

Work is defined as the result of force acting through a distance.
WORK = FORCE x DISTANCE

Example: When the piston of a hydraulic cylinder exerts a force of 10lbs through a 1 inch stroke, the amount of work = 10 inch pounds.

It all Starts with a Pump and Ends With an Actuator

Work is performed by a pump to compress and store atmospheric hydraulic oil in the reservoir.

The pressurized hydraulic oil is routed from the reservoir to the 3 way shut off valve. This valve controls the flow of hydraulic oil to the circuit.

From the 3 way shut off valve the hydraulic oil is directed to the regulator which controls the pressure of the hydraulic oil in the circuit.

Pressure adjusted hydraulic oil is fed to the solenoid valve. This valve controls the direction and flow of hydraulic oil to the actuator.

The actuator extracts work from the hydraulic oil by allowing it to expand within a confined space (cylinder) and against a moving surface (piston).

Note: Speed control valves affixed to the hydraulic cylinder (actuator) control the FLOW of hydraulic oil into or out of the cylinder. These valves DO NOT control HYDRAULIC OIL PRESSURE.

Once the work has been extracted, the hydraulic oil is exhausted back through the solenoid valve and into the atmosphere.

Note: Hydraulic circuits like the one used in the TRAINER kit are commonly open circuits. In an open circuit atmospheric hydraulic oil is pressurized, used in the hydraulic circuit and then exhausted back out into the atmosphere. This is one way that hydraulic circuits differ from hydraulic circuits. Hydraulic circuits are closed circuits. The same fluid is continually re-circulated within the circuit

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Introduction to Hydraulic Components

The hydraulic components are described in the order in which they are connected in a working hydraulic circuit.

The Bicycle Pump

Hold this component in your hands as you read the following description.

Bicycle Pump Specifications

Pump Bore is approximately 1.180 inches or 30mm

Pump Stroke is approximately 17.3/4 inches or 450mm

Hose Bore is approximately 1/4 inch or 6mm

Hose Length is approximately 44 inches or 1117 mm

A bicycle pump is comprised of a cylinder, piston and piston rod. A handle is fixed to the Piston rod. When the handle is depressed, the piston travels the length of the cylinder, reducing the interior volume of the pump cylinder and increasing the interior hydraulic oil pressure. This increase in hydraulic oil pressure is proportional to the decrease in volume. The length of the piston travel is called the stroke, and the inside diameter of the cylinder is called the bore.

Conversely, as the pump handle is extended, the piston rises and the volume inside the pump cylinder increases.

The increase in volume causes the pressure inside the pump cylinder to drop below the surrounding (atmospheric) pressure. The result is that atmospheric hydraulic oil is drawn into the pump through a flapper valve built into the piston. When the pump handle comes to rest at full extension the interior pump volume is at maximum and the hydraulic oil pressure within the pump is at normal atmospheric pressure.

Boyles Law describes the relationship between pressure and volume in a closed system like the pump. Gas laws developed by physicists and chemists are covered in depth in other lessons
Charles Law describes the relationship between pressure, volume and temperature of a gas in closed system. If you pump the hydraulic oil into the reservoir with rapid pump strokes, the temperature of the pressurized hydraulic oil will increase. You will be able to feel this temperature increase if you hold the reservoir while a partner operates the pump.

The hydraulic oil capacity of the pump is described in terms of standard atmospheric pressure and volume.

Solving for Volume we get approximately 19 cubic inches at ambient hydraulic oil pressure and temperature.

As the pump handle is depressed, the interior volume of the pump cylinder decreases and the pressure and temperature of the hydraulic oil inside the pump increases. When the pump is connected to the reservoir, the hydraulic oil inside the pump is forced through the pump hose, through the Schrader valve and into the reservoir. The Schrader valve is a one-way (check) valve that allows higher-pressure hydraulic oil to enter an area of relatively lower pressure. The Schrader valve used on the reservoir is the same valve used on bicycle tires and operates in exactly the same way.

Caution: ***The hydraulic circuit is powered by the energy of hydraulic oil stored in the hydraulic reservoir. To prevent accidental overpressure, the***

reservoir should only be filled using a bicycle pump. In addition to adding an extra margin of safety, pressurizing a hydraulic circuit with a hand pump is a great way to appreciate and understand the amount of work (energy) necessary to store hydraulic oil in the reservoir.

Always use Safety glasses when working with pressurized hydraulic circuits

The Hydraulic oil Reservoir or Storage Tank

Hold this component in your hands as you read the following description.

Reservoir Specifications

Reservoir Bore is approximately 1-1/2 inches or 38mm

Interior Cylinder Length is approximately 5-1/4 inches or 133mm

Recommended Operating Pressure for the reservoir is 150 psi. Do not exceed this operating pressure or the regulator will be damaged

The bicycle pump transforms work into the (Potential) energy of pressurized hydraulic oil. This pressurized hydraulic oil is stored in the reservoir. The potential energy captured or stored in the reservoir comes from the energy (Work) you expended pumping the hydraulic oil into the cylinder. In other words, some of the work of pumping the hydraulic oil is now stored and ready for use within the reservoir.

The reservoir is comprised of a Stainless Steel tube with 2 aluminium end caps. The end caps are identical, and each has a 1/4 inch NPT, ***National Pipe Thread***, threaded port and threaded mounting bosses.

A Schrader valve is threaded into one end of the reservoir. The end of the bicycle pump hose locks onto the Schrader valve during filling. The locking feature allows a single person to fill the reservoir.

A One Touch, quick connect fitting is threaded into the other 1/8 inch NPT (National Pipe thread) port. These fittings provide an easy means of quickly assembling and disassembling hydraulic circuit components by allowing hoses and tubes to be easily and quickly disconnected and reconnected.

3 Way Shut Off Valve

Hold this component in your hands as you read the following description.

The 3 way shut off valve is referred to as a 3/2 manual valve.

The 3 way shut off valve is connected between the hydraulic reservoir and the regulator. This hand operated valve has 3 ports and 2 states or operating positions.

3 Ports

The **P** port is connected to the pressurized hydraulic oil supply or reservoir.

The **A** port is connected to the circuit and supplies the circuit with pressurized hydraulic oil when the valve is turned on.

The **E** or exhaust port vents the circuit when the vale is closed, and serves to depressurize or de-energize the circuit.

Off Position: In this position the valve handle is perpendicular to the flow of hydraulic oil through the valve. As the valve handle is turned to the off position the valve will vent the circuit pressure.

On Position: In this position the valve handle is parallel to the flow of hydraulic oil through the valve.

Venting the circuit during shut down is a hydraulic safety feature. Venting or depressurizing the hydraulic circuit and components prevents the possibility of inadvertent operation of the system or any system components.

Note: The 3 Way Valve is a directional valve. Be certain to align the flow of hydraulic oil through the valve with respect to the directional arrows embossed on the valve housing. Connecting the valve in reverse will vent the reservoir when the valve is turned on.

The Regulator

Hold this component in your hands as you read the following description.

Note: Maximum Regulator Operating Pressure is 145 psi or 1Mpa

The regulator controls the pressure within the hydraulic circuit. The pressure within the hydraulic circuit determines the force generated by the actuator. Higher hydraulic oil pressures requires more hydraulic oil to be forced into a given volume, therefore higher pressures affect the rate at which the stored pressurized gases are consumed.

As the pressure of a gas increases, the density or amount of gas per unit volume increases. The reservoir contains a finite amount of hydraulic oil at any given pressure. When the hydraulic circuit pressure is increased, stored hydraulic oil is consumed at a proportionally higher rate. The result is that increasing the pressure results in greater actuator force, but fewer actuator operations. The regulator allows the hydraulic oil pressure within the circuit to be adjusted to meet the performance requirements of the hydraulic system.

It is not always necessary for student engineers to operate the hydraulic systems at maximum pressure in order to ensure maximum performance. Well-engineered machines are optimized with respect to required force and hydraulic oil reserves. This is an engineering design challenge. Higher pressure means fewer cycles from the hydraulic cylinder.

One conclusion that might be drawn from this knowledge is: Do not set the regulator to maintain a pressure higher than what is necessary for the design function of a given mechanism. To do otherwise would result in an unnecessary depletion of stored hydraulic oil reserves.

Regulator Operation

The regulator controls and maintains the hydraulic circuit pressure. The regulator prevents both under pressure and overpressure situations. As pressurized hydraulic oil is consumed by the actuator, pressure on the downstream (circuit) side of the regulator drops. This drop in pressure creates an imbalance of forces acting between a tensioned spring and a pressurized diaphragm valve within the regulator. The imbalance causes the spring to open a valve connecting the circuit to the (higher pressure) hydraulic oil stored in the reservoir. As the higher pressure hydraulic oil flows from the reservoir, through the regulator and into the circuit, the circuit pressure increases. This increased pressure acts to re-establish the balance of forces between the spring and diaphragm within the regulator, and closes the valve connecting the reservoir to the circuit.

3/2 Solenoid Valve

Hold this component in your hands as you read the following description.

Solenoid Specifications

Voltage 12 volts

Power Consumption 1 Watt @ 42mA

Cv .008

This valve is a 3/2 (Read Three, Two) normally closed solenoid valve used to operate single acting hydraulic cylinders.

The designation, 3/2 refers to the number of ports (3) and the number of positions (2) or States of Operation of a hydraulic valve.

The first number (3) refers to the number of ports through which hydraulic oil can enter or leave the valve. Counting the ports or holes in the valve body is an easy way to determine the number of ports in a valve. The solenoid valve in the TRAINER kit has three holes, or ports. These ports are labelled as follows:

P1 This is the Pressure Port. This is the connection port from the solenoid valve to the regulator or pressure line.

A2 This is the actuator port. This is the connection port from the valve to the hydraulic cylinder or actuator.

E This is the exhaust port. This is where the spent hydraulic oil is exhausted from the hydraulic cylinder or actuator to atmosphere.

The second Number (2) refers to the number of possible operational states or modes. The solenoid valve used in the TRAINER kit has 2 modes:

OFF

This is the default mode in which the A2 actuator port is normally closed (NC) and the exhaust port is normally open. When the solenoid valve is not energized, it defaults to this mode or position. (NO).

ON

In this position solenoid is energized by an electrical current and a poppet valve within the solenoid body is opened. This closes the E (exhaust) port and opens the A2 (Actuator) port. The ON condition is maintained as long as the solenoid valve is energized. When power to the circuit is disrupted or shut off, the internal valve spring closes the A2 (Actuator) port and opens the E (Exhaust) port. This returns the valve to the default or NC state.

The solenoid valve is electrically actuated. When the valve is energized, a 12 volt 42mA (low amperage) current passes through a coil of wire within the valve. The electrical energy passing through the coil induces a magnetic field around the coil. This magnetic field draws an iron core into the center of the coil and actuates a poppet valve within the body of the solenoid valve. The poppet valve opens a path from the pressure port (P1) on the regulator side of the valve, to the actuator port (A2) on the hydraulic Cylinder or actuator side of the valve.

When the coil is not energized (The current to the coil is turned off), the poppet valve returns to a default position closing the connection between the pressure port (P1) and the actuator port (A2), and opening the connection between the actuator (A2) and the exhaust port (E). The pressurized hydraulic oil within the actuator passes back through the solenoid valve, and is exhausted into the atmosphere.

The solenoid valve can open or close a circuit pressurized to .8 MPa (116psi) within 3.5 ms. This is more than 10 times the stimulus response time of the average person.

There is little wonder why fast, effective industrial automation systems are the result of hydraulics coupled with microprocessors.

The Hydraulic Cylinder (Actuator)

Hold this component in your hands as you read the following description.

- Bore 5/8" or 16mm
- Stroke 1" or 25.4mm
- Single Acting Spring Return

The hydraulic cylinder contains the same components as the bicycle pump. These components are:

Cylinder

Piston

Piston Rod

Single acting cylinders are powered by pressurized hydraulic oil in one direction only. They are returned to their default position by the force of an internal spring.

The hydraulic cylinder supplied in the TRAINER kit is referred to as a Single Acting Cylinder with a Spring Return. This means that the cylinder is hydraulically powered in only 1 direction (extended). Single acting cylinders are also manufactured as a Single Acting Cylinder with a Spring Extend.

Double acting cylinders are often used when it is necessary to hydraulically power a mechanical action through extension and retraction.
The hydraulic cylinder or actuator is a mechanical device that transforms the energy of pressurized hydraulic oil into useful work.

The hydraulic cylinder or actuator operates in a manner that is similar but opposite to the bicycle pump. The bicycle pump transform work done on the piston and piston rod, into the potential mechanical energy of hydraulic oil, while the hydraulic cylinder accomplishes the reverse of this. The hydraulic actuator is used to extract the stored mechanical energy of hydraulic oil in order to accomplish useful work.

Examine the bicycle pump and the hydraulic cylinder closely. Even though you cannot See inside these components, it is clear that they share strong similarities.

The pump is an efficient mechanism for compressing hydraulic oil and thereby transforming work into the stored potential energy of hydraulic oil. Conversely the actuator uses the same components, piston, piston rod and cylinder to extract the stored (potential) energy of the hydraulic oil to perform useful work.

Force Generated by a Hydraulic Cylinder or Actuator

The theoretical pushing or pulling force created by a hydraulic cylinder can be mathematically determined. The actual forces must be measured directly. There is often a wide discrepancy between theoretical force calculations and measured forces. Actual cylinder force is diminished due to interferences and frictional losses in the mechanical assemblies and pressure drops that occur on the circuit as the cylinder fills with pressurized hydraulic oil. Hydraulic oil has mass, and is slowed by frictional forces between hydraulic oil molecules and the interior surfaces and bends of the hydraulic circuit components.

The theoretical force generated by a hydraulic cylinder is the product of the piston area and the internal pressure of the cylinder.

Theoretical Piston Force = Piston Surface Area x Internal Pressure

The piston area is calculated using the cylinder bore, and the pressure is approximated from the regulator gage reading.

Hydraulic Cylinder Speed Control

The hydraulic cylinder assembly includes a speed controller installed in the cylinder port. The speed controller is a combination needle valve and check valve used to control the maximum speed of the piston in either one direction or the other. The speed controller allows free flow of hydraulic oil in one direction and restricts the flow of hydraulic oil in the opposite direction. Changing the size of the orifice through which the hydraulic oil moves restricts the hydraulic oilflow into or out of the cylinder. This restriction is accomplished using a needle valve and seat assembly.

One Touch Quick Connects

These handy fittings allow builders to quickly assemble and disassemble circuits and components. Connections are made by fully depressing the (orange) plastic spring loaded collar before inserting or removing the tubing. Caution, be certain to fully depress the fitting before attempting to remove or insert the tubing. Attempting to extract the tubing from a quick connect fitting without fully depressing the fitting collar will damage the connector.

To ensure an hydraulic oiltight fit, prepare the tubing by cutting the ends square. Use a curved jaw tubing cutter and check that the tubing ends are square and free of burrs or rough edges.

Speed Controllers

A speed controller is attached to the input/output port of the single acting hydraulic cylinder. The flow of hydraulic oil into and out of the hydraulic cylinder is controlled by a metering system inside the speed controller. The metering system is essentially a threaded needle valve used to change the cross section of the orifice through which the hydraulic oil flows into or out of the cylinder. The hydraulic oil is allowed to flow through the speed controller freely in one direction, while being metered in the opposite direction. Speed controllers that meter either input hydraulic oil or output hydraulic oil are available.

It is important to understand the distinction between speed control valves and regulators. Speed control valves control the FLOW or hydraulic oil while regulators control the PRESSURE of the hydraulic oil within the circuit.

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DEV-2757-00-301

Product Title: Industrial Hydraulic Trainer
Document Code: DEV2757-00-301
Revision 2.0.1 dated 27 January 2007

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