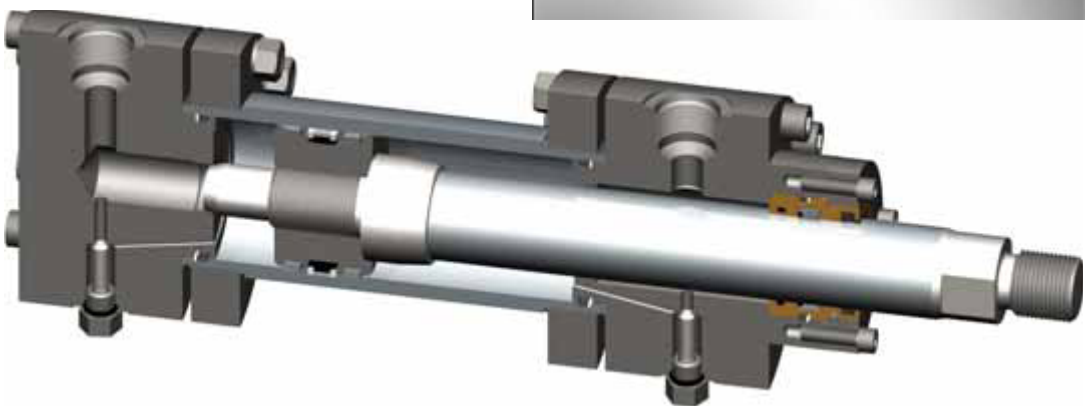
Hydraulic and Pneumatic Basics - 1
Student Manual



Section I - Hydraulic / Pneumatic Fundamentals

This Module provides a general introduction to the world of hydraulics / pneumatics and the physics involved with it. It also looks at various hydraulic / pneumatic mediums and their characteristics.

Objectives

Upon completion of this Section you will be able to understand hydraulic / pneumatic fundamentals and the basic physics involved. You will be able to identify and describe how hydraulic / pneumatic force and energy is transmitted and what types of mediums are used to accomplish that.

What you will learn

- What is Hydraulic - Pneumatic
- Force - Pressure - Work and Power
- Transmission of Hydraulic - Pneumatic Force and Energy
- Mediums Used to Transmit Hydraulic - Pneumatic Force and Energy

What is Hydraulic – Pneumatic

The following unit will provide you with a brief introduction to hydraulics and pneumatics.

Objectives

Upon completion of this unit you will be able to identify the purpose of and difference between hydraulic and pneumatic systems.

What you will learn

- Hydraulics
- Pneumatics

Hydraulics

Hydraulics has been defined as a study of the physical behavior of water at rest and in motion. This term has broadened in meaning to include the physical behavior of all liquids. This includes the oils used in present day hydraulic systems.

Hydraulics is also referred to as "Power Hydraulics" or "Fluid Power".

Fluid power is used in practically every industrial sector. It is also found in everyday uses such as machine tools, cars, airplanes, satellites, or a bread making machine. The reason for this widespread use is that a fluid is one of the most versatile means of transmitting power and modifying motions.

The definition of a fluid is a substance that will flow and will take the shape of its container. Liquids and gases are both considered fluids. Gases will be discussed in the next lesson, however liquid fluids can:

• Readily change shape
• be divided into parts to do work in different locations
• move rapidly in one place and slow in another
• transmit a force equally in any or all directions

A liquid fluid is infinitely flexible, yet as unyielding as steel. A liquid is virtually non-compressible. No other medium combines the same degree of positive, accurate, flexible control with the ability to transmit a maximum of power in a minimum of bulk and weight. Unlike mechanical power, fluid power eliminates cams, levers, gears and other drive mechanisms that lose energy through friction.

A 25 mm line of fluid will transmit energy as easily as a 300 mm pipeline of fluid.

Pneumatics

Pneumatics is similar to hydraulics. The difference is that pneumatics refers to pressurized air (compressed air) or other gases, instead of liquids, as in hydraulics. The main difference between a fluid and a gas is the fact that a gas is compressible and a liquid is considered to be virtually non-compressible.

By definition a fluid is a substance that will flow and conform to the shape of its container. This means that liquids and gases are considered fluids. Any reference in this curriculum to fluids could include hydraulic liquid media or compressed air or gas.

Force - Pressure - Work and Power

The following unit will provide you with a quick snapshot of basic physics involved in hydraulic / pneumatic systems.

Objectives

Upon completion of this unit you will be able to identify basic laws of physics as they apply to hydraulic / pneumatic systems. You will be able to describe the physical characteristics of fluids.

What you will learn

- Some Basic Physics
- Physical Characteristics of Fluids

Some Basic Physics

Force is defined as any cause which tends to produce or modify motion. To move an object, force must be applied to the object. The amount of force required depends on the objects inertia.

[Inertia: a property of matter by which it remains at rest or in uniform motion in the same straight line unless acted upon by some external force.]

Force is expressed in any unit of weight measure. Kilograms (Kg) or Pounds (lbs.) are the most common measurements.

Pressure is force per unit of area and is usually expressed in terms of kilograms per square centimeter (Kg/cm2), pounds per square inch (psi) or "Bar" which is equal to 14.7 psi, the atmospheric pressure at sea level.

The relationship between Force, Pressure and Area is expressed mathematically by the following equation:

Force = Pressure x Area.
F (Kg) = P (kg/cm2) x A (square centimeters)
F (lbs.) = P (psi) x A (square inches)
F = P x A
Hydraulic pumps do not create pressure, they create flow. Air or gas compressors create pressure, however the pressure "flows" from high to low pressure areas.

Pressure is created when the flow meets with resistance. If the flow encounters slight or minimal resistance, then the pressure developed would be low or minimal. As the resistance force increases so does the pressure developed.
Force and pressure are the primary measures of effort. Work however is a measure of accomplishment. It describes the application of force moving through a distance and is commonly expressed in units of Newton-meters, inch-pounds or foot-pounds. If a force of

5,280 Newton’s (1200 lbs.) moves a ram 0.1 meters (4"), the work accomplished is 528 Newton meters or 528 Joules (4800 inch-lbs. or 400 foot-lbs.).
Note: Joule = Newton meter.

The mathematical equation for this is:

W (work) = F (force) x D (distance)

Work (Joules or Newton meters, Ft. lbs.) = Force (Newton’s or lbs.) x Distance (meters or Ft.)

This calculation makes no allowance for a time factor. Power is work per unit of time. Horsepower or Watts are the standard units of power measurement. One horsepower = 746 Watts or .746 kW

1 Horsepower = the amount of power necessary to raise 33,000 lbs. 1 foot in 1 minute or 550 lbs. (2,420 Newton’s) 1 foot (.305 meters) in 1 second.

- ***Pascal's Law - Pressure at any one point in a static liquid is the same in every direction and exerts equal force on equal areas. Pressure in a sealed vessel acts equally at right angles to all surfaces.***

First

Since liquid fluids are virtually non-compressible, mechanical force may be transmitted, multiplied, controlled and directed by means of fluids under pressure. When a force is applied to a confined liquid, the liquid exhibits substantially the same effect of rigidity as a solid. In all hydraulic/pneumatic applications, delivery force equals the pressure in the line, times the receiving area [see Figure below].

Note:

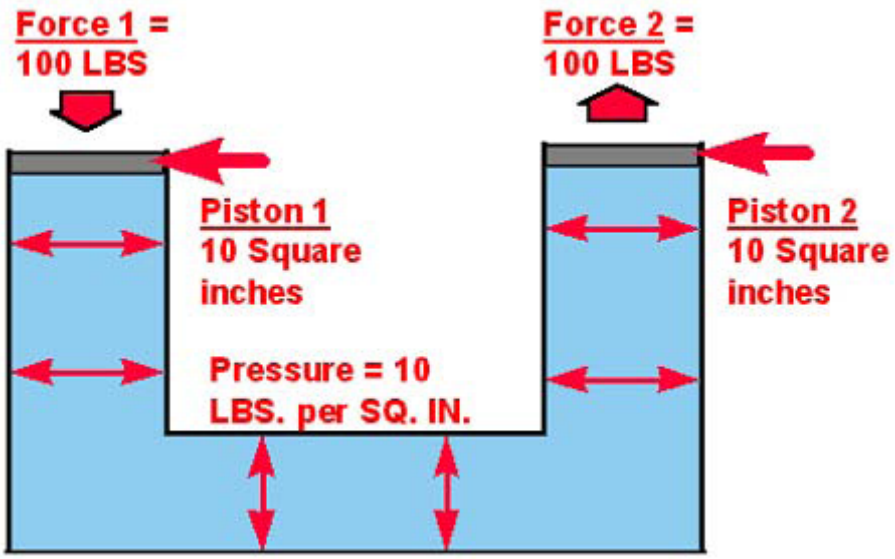
1 Kilogram (Kg or Kilo) = 2.2 pounds (lbs.)

1 square inch (in.2) = 6.45 square centimeters (cm2)

1 square centimeter (cm2) = 0.155 square inches (in.2)

1 Bar = 14.7 psi

1 Kilogram per square centimeter (Kg/cm2) = 14.2 psi

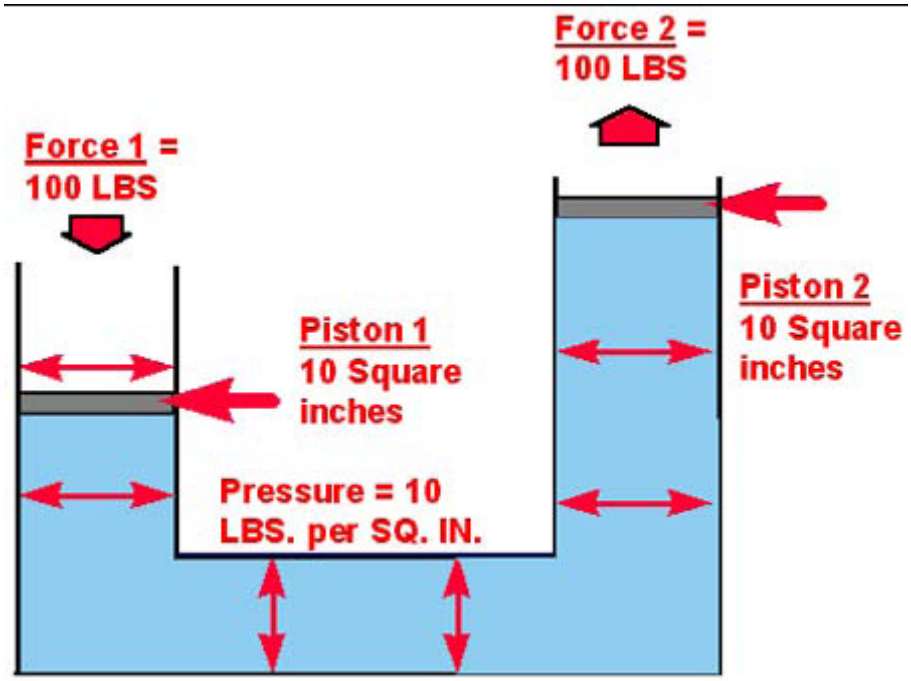


Input Force equals Output Force with same Piston Area

Second

If piston 1 were to move down 75 mm (three inches), then Piston 2, the receiving piston of the same size, would rise 75 mm (three inches) [See below].

This offers no advantage as the output force is the same as the input force. We must change the area of the receiving piston in order to increase the output force.



Input Force and Output Force are the same - No Advantage

A small force of 1 lb. (.45Kg.) on an area of 1 square inch (6.45 cm2) = 1 psi (.07 Kg/cm2). If this 1 psi (.07Kg/cm2) is applied to a container of fluid then the pressure in the fluid would be 1 psi (.07 Kg/cm2). Here is where the force is multiplied by the laws of physics and the "magic" occurs.

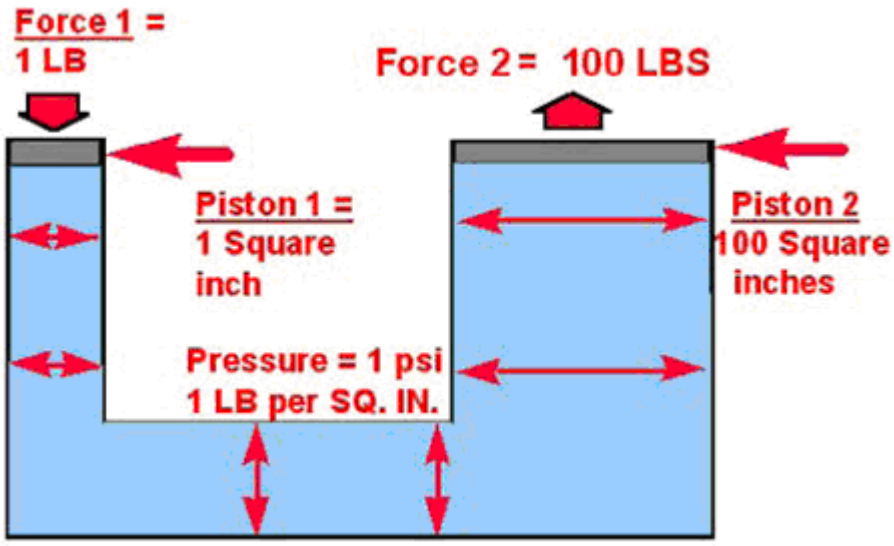
If we had a second moveable piston built into our container that had a surface area of 100 square inches (645 cm2), exposed to 1 psi (.07 Kg/cm2) of pressure, we would then have 1 psi (.07Kg/cm2) pressure acting on 100 square inches (645 cm2) of moveable surface area which would deliver 100 lbs. (45 Kg). of force to do work with.

F = P x A

F = 1 psi x 100 square inches. F = 100 lbs.

(F= .07 Kg/cm2 x 645 cm2. F= 45Kg.) With 1 lb. of force input, we were able to get 100 lbs. of force output [see Figure below].

The input force or energy in a hydraulic/pneumatic system comes from fluid flow. The flow meets with resistance and pressure is developed. The pressure acts over the surface area of a piston or ram and a force is created. When the force is greater than the resistance, the piston or ram will move.



With 1 lb. of Input Force we can get 100 lbs. of Output Force

Transmission of Hydraulic - Pneumatic Force and Energy

The following unit will introduce you to basic fluid flow characteristics and the importance of pressure drop - 2 important principals in the transmission of hydraulic / pneumatic force and energy.

Objectives

Upon completion of this unit you will be able to identify and describe fluid flow characteristics and the pressure drop principal.

What you will learn

- Fluid Flow Characteristics
- Pressure Drop

Fluid Flow Characteristics

When a fluid flows in a system, friction results and heat is produced. Some of the energy being transmitted is lost in the form of heat energy.

Friction cannot be eliminated in a system. It can be controlled. The four main areas of excessive friction and excessive energy loss and consumption are:

- Length of fluid travel. Shorter is better.
- Number of turns and fittings. Less is better.
- Undersized lines cause high fluid velocity. Larger lines are better.
- Fluid viscosity too high. Lower is better.

In a hydraulic or pneumatic system, fluid flowing through a pipe is traveling at a certain speed, or velocity, which is measured in feet per second (f/s) or meters per second (m/s).

The volume of fluid flowing through a pipe in a given period of time is flow rate, which is measured in gallons per minute (gpm) or liters per minute (lpm). To achieve equal flow rates through pipes of different diameters, fluid velocity would need to change. Flow through a small diameter pipe would have to travel at a higher velocity than it would through a larger diameter pipe to achieve the same flow rate. Remember, the amount or volume of fluid being delivered is flow rate. The speed it is traveling is velocity.

Pressure Drop

As fluids flow through pipes, energy is lost to friction producing a pressure drop or pressure differential. There must be a pressure drop (pressure differential) across an orifice or restriction to cause flow through it. If there is no flow there will be no pressure drop.

In a moving fluid, pressure drop tends to increase and pressure tends to decrease as the distance from the source of pressure (pump, accumulator, and compressor) increases. As a fluid flows it loses energy to friction and pressure losses due to restrictions and orifices. For these reasons, system designers specify oil of the proper viscosity, use correct size piping, and keep the number of bends and fittings to a minimum

Mediums Used to Transmit Hydraulic - Pneumatic Force and Energy

The following unit describes the mediums used to transmit force and energy in pneumatic and hydraulic systems. It identifies important characteristics and different types of mediums used in those systems.

Objectives

Upon completion of this unit you will be able to identify and describe pneumatic and hydraulic mediums used to transmit force and energy.

What you will learn

- Pneumatic Mediums
- Hydraulic Mediums

Pneumatic Mediums

In pneumatic systems, "shop" air or compressed air is the medium most often used. In some applications, inert gases such as nitrogen may be used. The air or gas is compressed and stored in a compressor for distribution throughout the pneumatic system via pipes or hoses. These components of the system will be discussed in later units.

Pneumatic System Maintenance

Pneumatic air systems should be dry, and clean. Moisture in the system causes corrosion to components such as the pipes, valves and actuators. This corrosion causes harmful contaminants to be introduced to the system. Contaminants in the system cause damage to moving components and plug small fittings and orifices.

Pneumatic systems rely on proper filtration and proper lubrication. The lack of lubrication creates excessive maintenance costs, production inefficiency and premature failure. Proper lubrication allows components to operate with a minimum of friction and corrosion, and it minimizes wear on the parts.

Hydraulic Mediums

In hydraulic systems a wide variety of liquid mediums are used. The fluid has an important effect on equipment performance and maintenance.

A clean, high quality fluid is the first step in long term reliable system operation. In addition to serving as a power transmission medium, the fluid must keep wear to a minimum by providing good lubrication. It must remain effective over a wide temperature range.

Important Characteristics of Hydraulic Mediums

• **Viscosity -** This is the most important property of a hydraulic fluid. It is the measure of a fluids resistance to flow. Think of it as the "thickness" or " thinness" of the liquid. Thick fluids, like molasses, flow slowly and would be a high viscosity fluid. Thin fluids, like water, flow easily and would be a low viscosity liquid. Some fluids like oil are a lower viscosity when hot and higher when cold. Low viscosity can increase leakage and wear of components and high viscosity can cause sluggish operation by increasing pressure drop through lines and valves.

• **Lubricity -** Hydraulic fluid must have good lubricity characteristics to prevent wear between closely fitted working parts. Direct metal to metal contact is avoided by the film strength of good quality fluids.

• **Oxidation Resistance -**This is a characteristic that determines the operating effectiveness and life of the fluid. The factors that promote oxidation are air, heat and contamination. Premium grade fluids usually contain oxidation inhibitors to slow the oxidation process and increase operating effectiveness and overall life of the fluid.

Types of Hydraulic Mediums

- **Petroleum Based Mediums -** Petroleum base mediums are the most widely used and the best choice for long reliable system life because of its lubricity and compatibility with elastomers in hoses, seals and gaskets.

- **Crude / Soluble / Animal / Vegetable Oils -** From a high pressure lubrication standpoint it is advisable to avoid the use of these as hydraulic fluid mediums. They do not possess all the properties of a good hydraulic fluid.

- **Water -** Although water is considered relatively inexpensive in cost, water is the worst of all fluids to use as a hydraulic medium. It has poor lubrication characteristics and causes corrosion of the metallic parts.

- **Fire-Resistant Fluids -** Some hydraulic systems are in hazardous environments. They can be located near high-temperature equipment or a source of ignition. In these situations, fire-resistant fluids are used. They can be classified according to the base fluid:

  - Water / Glycol - Water, mixed with glycol similar to that used as anti-freeze in automobile radiators. These mixtures are usually 40% - 60% water. Compatibility with hoses, seals and gaskets may be a problem.

  - Synthetic - Synthetic "oils" can be produced which are fire resistant (will not sustain a flame) or totally non-flammable (will not ignite). However, they may be expensive and may attack hoses, seals and gaskets.

  - Water-oil emulsions - These are usually petroleum oil mixed with water and an emulsifier which suspends the oil in the water. These fluids can be as much as 95% water.

Manufacturers' recommendations should be closely followed in changing from a petroleum-base fluid to a fire-resistant fluid or from one fire-resistant fluid to another. The system must be thoroughly drained, cleaned, flushed and properly refilled. It may also be necessary to disassemble components and change seals and gaskets. Some of these fluids will attack elastomer materials and soften and remove paints used to coat the inside of some components.

Hydraulic System Maintenance

The frequency with which hydraulic fluid is changed depends on both the fluid and the operating conditions of the system. The importance of good draining and testing practice cannot be overemphasized.

Periodic laboratory analysis is the most accurate method for determining when or how often fluid should be changed. The fluid supplier often offers these tests.

Fluid should be changed when viscosity and acidity begin to increase and/or when contamination levels are high.