HYDRAULICS AND ELECTRICAL CONTROL OF HYDRAULIC SYSTEMS

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Open Oregon Educational Resources

CONTENTS

UNIT 1: INTRODUCTION

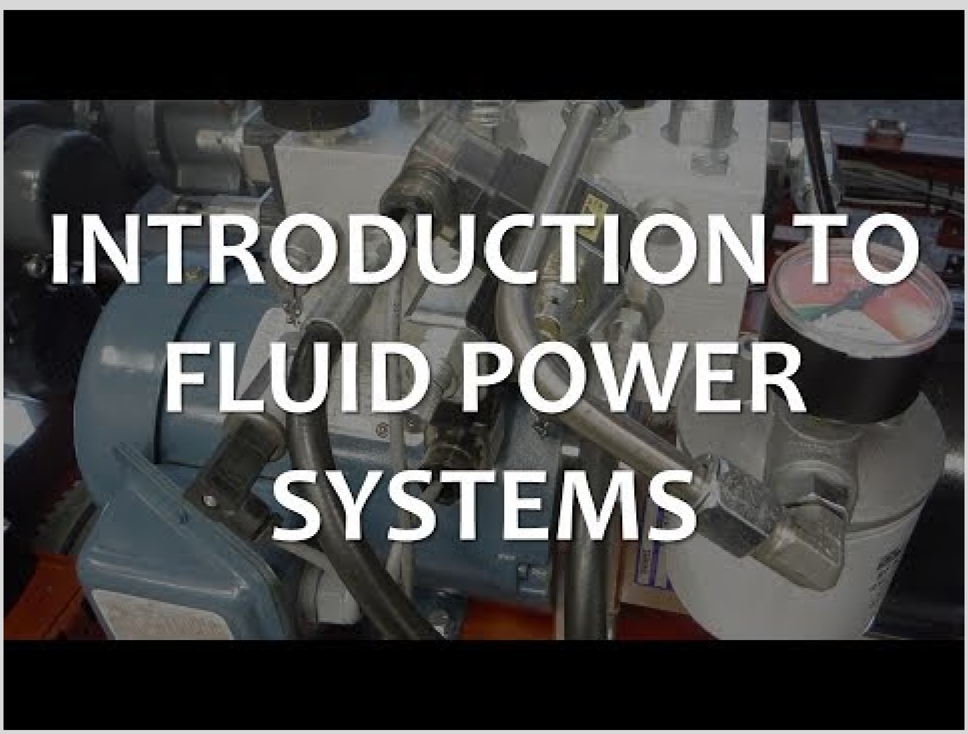
1.1 INTRODUCTION TO FLUID POWER SYSTEMS

Describe the purpose of a fluid power system

Differentiate between fluid power systems and mechanical or electrical systems

Differentiate between hydraulic and pneumatic systems with respect to the fluid medium employed, characteristics, capacity, performance, and cleanliness

Describe a basic fluid power system in terms of power conversion.



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Describe the role of a prime mover like a motor or internal combustion engine in a fluid power system.

Draw the schematic symbol for a motor and internal combustion engine.

Describe the role of a pump in a fluid power system. Draw the schematic symbol for a pump and reservoir.

Describe what properties pressure, flow rate, and valve position influence in a fluid power system.

Describe Pascal's Law and the formula used to relate force, pressure, and area.

Describe the role of an actuator in a fluid power system. Draw the schematic symbol for a cylinder and hydraulic motor.

Comment on the drawbacks of systems composed of numerous stages

Comment on the advantages and disadvantages of fluid power systems

Identify safety concerns associated with fluid power systems.

Comment on sources of inefficiency within a fluid power system

Identify five different types of pressure control valves

Draw the schematic symbol for a pressure gauge, pressure switch, and pressure transducer

List the devices that control flow rate

Draw the schematic symbol for a flow control valve and comment on how they are employed in fluid power systems.

Draw the schematic symbol for flow meters and comment on how they are employed in fluid power systems.

Draw the schematic symbol for a check valve. Differentiate between free flow and blocked direction.

Describe the purpose of a directional control valve in a fluid power system.

Draw the schematic symbol for a 3 position, spring centered, manually actuated directional control valve with a closed center, a straight through position, and a cross connect position

Discuss how the above valve's position influences a double acting cylinder's actuation direction when the cap end port is hooked to actuator port A and rod end port is hooked to actuator port B.

Discuss how the above valve's position influences a double acting cylinder's actuation direction when the actuator ports are swapped (rod end port is hooked to actuator port A and cap end port is hooked to actuator port B).

Discuss how a double acting cylinder's actuation direction is influenced when one port is blocked.

Describe the purpose of mechanical limit switches, magnetic proximity switches, and position transducers in a fluid power system.

Differentiate between energy and power and give examples of common energy and power units.

Determine the energy requirement in ft*lbf to move a 500lbf object 12ft.

Determine the power requirement in ft*lbf/s, hp, and W to move a 500lbf object 12ft in 2.3s.

Given a 72% efficient system determine the input power in W necessary to produce 5.6hp output
Given a 79% efficient system determine the output power in hp if 3.2kW was input

1.2 HYDRAULICS MATH

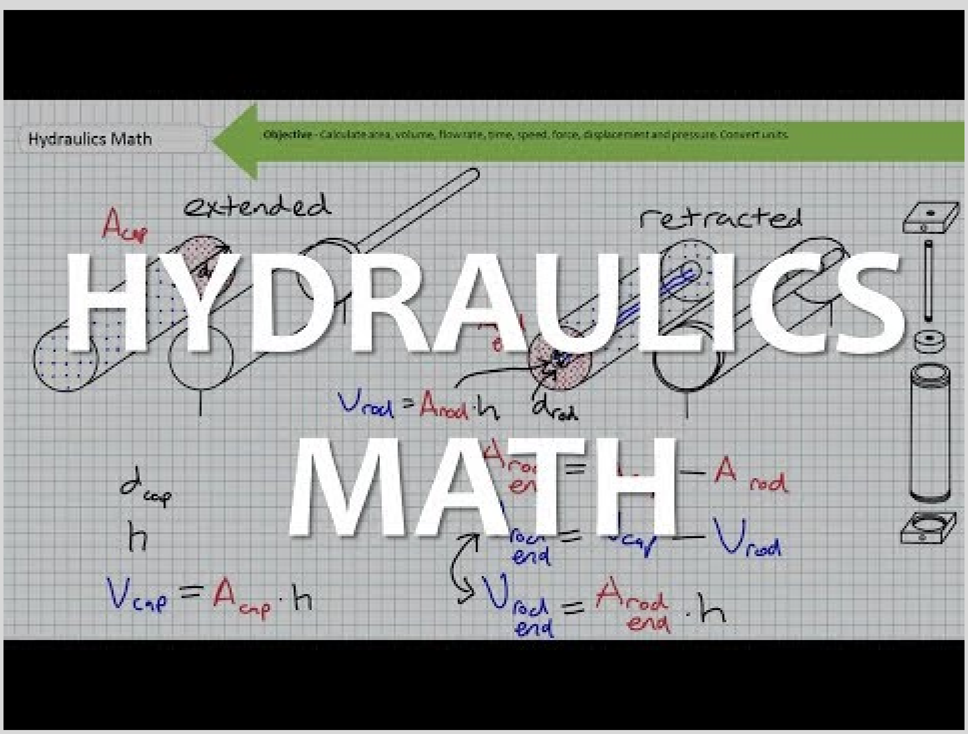
Given F=pA, solve for p in terms of F and A.

Given F=pA, solve for A in terms of F and p.

Given Q = V/t, solve for V in terms of Q and t

Given Q = V/t, solve for t in terms of v and Q

Comment on pressure and flow rate and how they influence the force and speed of a hydraulic actuator.



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List units commonly employed to measure hydraulic quantities

	US	SI/metric
length		
area		
volume		
pressure		
force		
flow rate		
time		

Determine equivalencies for the following values:

1 in =>	cm		
1 lbf =>	N		
1 l =>	cm^3		
1 gallon =>	in^3		
14.5 psi =>	bar=>		kPa
1 gallon =>	l		

Convert a volume of 0.45 gallon to in3

Convert a volume of 40 in^3 to gallons

Convert 650kPa to psi and bar

Convert 18 bar to psi and kPa

Convert 490psi to bar and kPa

Differentiate between the terms cap end, rod, and rod end with respect to area and volume. Draw a picture.

Which volume must be filled to extend a cylinder, the cap end, the rod, or the rod end?

Which volume must be filled to retract a cylinder, the cap end, the rod, or the rod end?

Write the formula used to determine the surface area of a circle.

Write the formula used to determine the surface area of a ring.

Write the formula used to determine the volume of a cylinder.

Write the formula used to determine the volume of a tube (a cylinder with a cylinder removed).

Given cylinder X with the following dimensions calculate the desired quantities:
d_{cap} = 2 ¾ in
d_{rod} = ¾ in
travel length = 12 in

A_{cap} =
A_{rod} =
$A_{rod\ end}$ =
V_{cap} =
V_{rod} =
$V_{rod\ end}$ =

Given a fixed flow rate of 0.75 gpm calculate the desired quantities for cylinder X:
t_{extend} (s) =
$t_{retract}$ (s) =
$speed_{extend}$ (in/s) =
$speed_{retract}$ (in/s) =

Given a pump with a fixed displacement of 0.4 in^3/rev is rotated at 1800rpm calculate the flow rate in units of gpm.

Given a motor with fixed speed describe how flow rate can be varied.

Given a pump with fixed displacement describe how flow rate can be varied.

Given cylinder X calculate the desired quantities given the applied load is 2300lbf.
p_{extend} =
$p_{retract}$ =

Given cylinder X calculate the desired quantities given maximum pressure is limited to 670psi.
F_{extend} MAX =
$F_{retract}$ MAX =

1.3 HYDRAULIC CYLINDERS

Define the term actuator and give examples of a rotational electrical actuator and a linear hydraulic actuator.

Draw a pictorial diagram of a double acting hydraulic cylinder. Identify the barrel, piston, rod, cap end plate, rod end plate, rod wiper, cap end port, and rod end port. NOTE: the rod end is often called the "head" end and the cap end is often called the "blind" end.

Draw the schematic symbol for a double acting hydraulic cylinder.

Differentiate between the cap end and rod end. Which has more functional area?

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Describe the act of extending and retracting a double acting cylinder in terms of which volumes are filled and which volumes are emptied. Comment on observed differences between extension and retraction speeds given constant flow rate.

Comment on how blocked ports affect extension and retraction of double acting hydraulic cylinders.

Differentiate between static and dynamic seals. Point out static and dynamic seals in a double acting hydraulic cylinder.

Comment on how a gasket is used to form a static seal. Comment on gasket composition and fluid compatibility.

Comment on how O-rings, piston rings and oil form a dynamic seal.

Comment on why oil is used in hydraulic systems.

Describe the cross sections of other dynamic seals.

Comment on the purpose of the rod wiper. Comment on storage of hydraulic equipment and the role of fabric bellows.

Comment on the purpose of a stop tube.

Describe a double rod cylinder and draw its schematic symbol.

Describe a tandem cylinder. Describe a duplex cylinder. Draw the schematic symbols.

Describe how a cushion works. Draw the schematic symbol for a cushion on extension. Draw the schematic symbol for a cushion on retraction. Draw the symbol for a variable cushion.

Draw lug, flange, flush, and tie rod mounted cylinders. Describe the purpose of fixed mounting methods.

Draw trunnion and clevis mounted cylinders. Describe the purpose of pivoting mounts. NOTE: Pivoting mounts are often specified by the location of the pivot point (example: head trunnion vs. center mounted barrel trunnion)

Describe and draw the schematic symbol for a single acting cylinder. Describe the means a single acting cylinder uses to retract.

Describe a ram. Describe how the descent of a lifted object can be controlled.

Describe a telescoping cylinder.

Describe how a spring can be used to apply or remove a brake in the event of pressure loss. Comment on how a spring is a source of hazardous energy.

1.4 GENERAL INDUSTRIAL SAFETY

Comment on elements essential to emergency preparedness.

Enroll in a First Aid/CPR/AED class if you are not already certified

Define the purpose of a lock out and tag out program.

Describe lock out devices used for plugs, switches, and valve handles.

Describe how a hasp is utilized with a group of workers and their individual lock and tag.

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Define lock out, define tag out, and differentiate between the two terms.

Describe the general procedure to conduct service on a system.

Comment on the purpose of inspecting Personal Protective Equipment (PPE) prior to use.

Differentiate between types and classes of hard hats.

Describe the features and types of eye protection and prescription eyewear.

Describe the purpose of eye wash stations and emergency showers.

Differentiate between ear plugs and ear muffs.

Describe how the NRR of a hearing protection device affects environmental noise.

Describe the time weighted average requirement

Comment on protective clothing and hand protection utilized for specialized industrial tasks (ie: electrical, abrasion resistance, chemicals, etc.).

Comment on machine guards.

Comment on the purpose of protective toes and oil resistant soles.

Comment on when fall arrest systems must be utilized.

Comment on the purpose of a harness and shock absorbing lanyard.

Describe the purpose and function of a ladder climber.

Describe the purpose of suspension trauma mitigation straps.

Describe the purpose of a work positioning lanyard. Describe other uses of a work positioning lanyard.

Describe the purpose of a rescue, retrieval and evacuation device.

Describe how a pre-roped pulley assembly, additional pulleys, slings, and carabiners complement a rescue kit.

Describe the purpose of an exclusion zone and tethering.

Describe the 3 features of a confined space and how environmental testing, attendants, communication, and rescue equipment mitigate the problems associated with confined spaces.

Describe some of the unique safety concerns associated with fluid power systems and best practices to mitigate these hazards.

Describe the purpose of OSHA.

Describe the purpose of ANSI.

Describe the purpose of the NEC.

Describe the purpose of NRTLs and give examples.

Describe the purpose of the NEMA and the IEC and differentiate between them.

Show up to your assigned lab period wearing long pants and closed toed shoes.

UNIT 2: PASCAL'S LAW AND HYDRAULIC COMPONENTS

2.1 PASCAL'S LAW

Describe Pascal's Law and the formula used to relate force, pressure, and area. Solve for F in terms of p and A. Solve for p in terms of F and A. Solve for A in terms of F and p.

List common units of force, pressure, and area.

Determine equivalency for psi, Pa, and bar.

If area is kept constant determine how changes in pressure affect force.

If pressure is kept constant determine how changes in area affect force.

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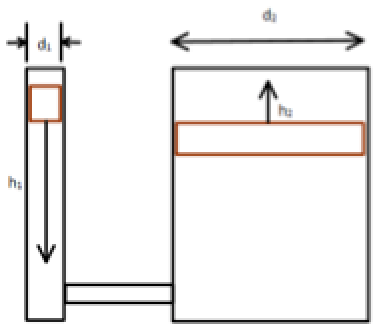
If area is kept constant determine how changes in force affect pressure.

If force is kept constant determine how changes in area affect pressure.



Given a force multiplication system with the following dimensions:
d_1 = 3/4 in
F_1 = 120 lbf
h_1 = 4 in
d_2 = 1 ¼ in
Calculate A_1, p, V_1, A_2, F_2, h_2, $energy_{in}$, $energy_{out}$

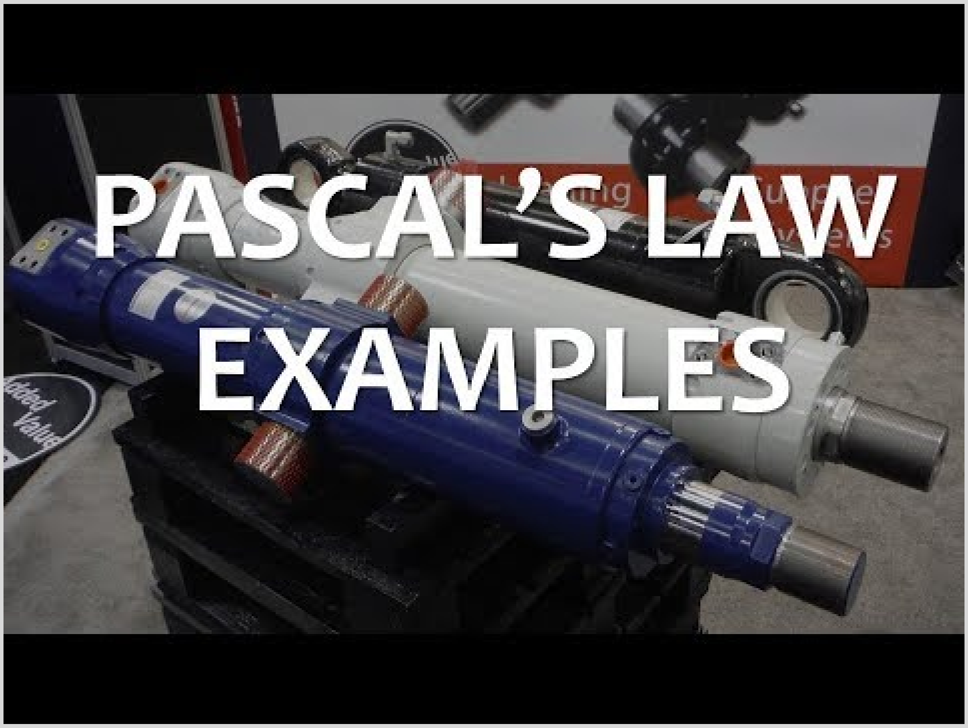
Comment on the differences between the cap end and rod end of a double acting cylinder with respect to functional area.

Explain why the pressure necessary to retract is greater than the pressure necessary to extend with the same force for a double acting cylinder.

Explain why the force of extension is greater than the force of retraction given the same pressure limit for a double acting cylinder.

Given cylinder X with the following dimensions:
d_{cap} = 2 7/8 in
d_{rod} = 7/8 in
Calculate p_{ext} and p_{ret} for cylinder X given the system is tasked with moving a 1350lbf object.
Calculate F_{extMAX} and F_{retMAX} for cylinder X given the system is limited to 640psi.

2.2 PASCAL'S LAW EXAMPLES



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2.3 PRESSURE AND PRESSURE MEASUREMENT

List common units of pressure. Equate psi, bar, and Pa.

Convert 230psi to bar and kPa.

Convert 7.3 bar to psi and kPa.

Convert 440kPa to bar and psi.

Determine the minimum of height of a water tower necessary to ensure at least 30 psi

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Describe atmospheric pressure and the sources of variance.

Convert 550psi to psia

Convert 900psia to psig

Define a vacuum

Describe the function of a pressure gauge and draw its schematic symbol.

Differentiate between analog (needle) and digital pressure gauges.

Differentiate between bourdon tube and spring loaded piston (Schrader) gauges and describe the basic operation and constituent parts of both.

Differentiate between pressure switches and pressure sensors (transducers).
Describe set, reset, and span (hysteresis) for a pressure switch.

2.4 CHECK VALVES

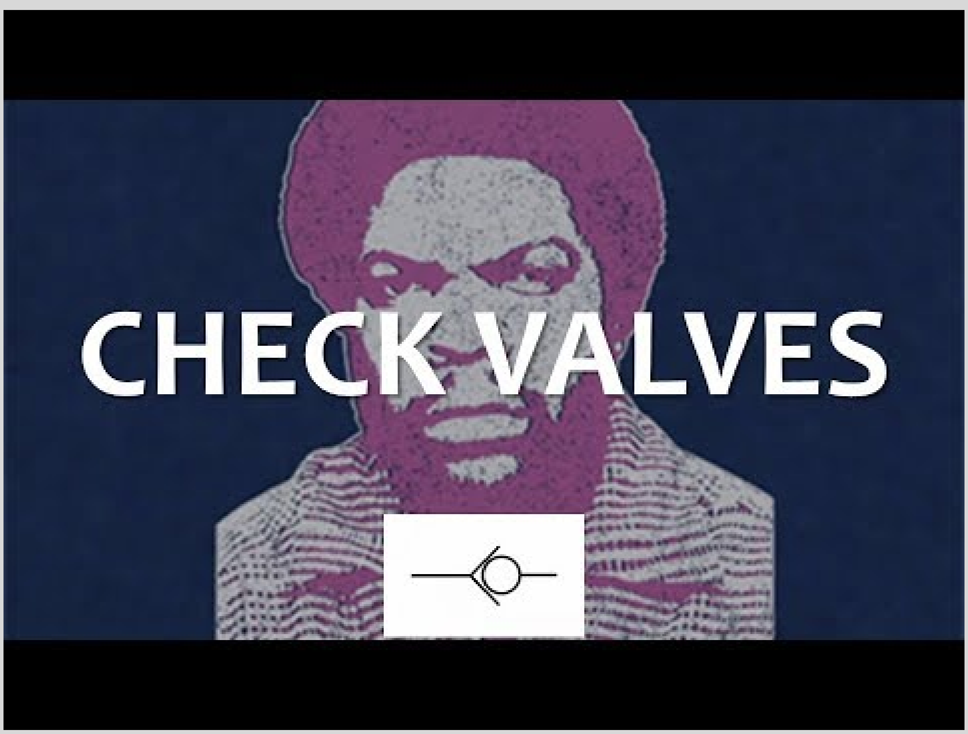
Describe the basic purposes of valves in fluid power systems.

Define the terms: body, ports/ways, spool, poppet, seal, springs, actuation/adjustment methods

Describe the different valve mounting methods: inline, subplate, manifold, cartridge, stack

Draw the schematic symbol and cutaway view of a basic poppet style check valve. Identify direction of free flow. Identify direction of blocked flow.

Describe how a primitive pressure relief valve can be created with a check valve.



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Define cracking and full open pressure.

Discuss the main disadvantage of a basic poppet style check valve in the free flow direction and how a right angle check valve overcomes this disadvantage. Draw a cutaway view of a right angle check valve.

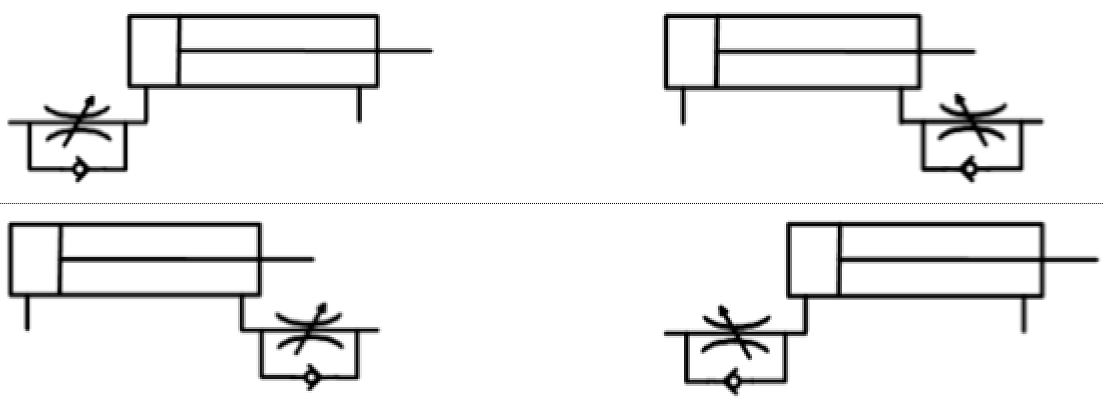
Draw the schematic symbol and cutaway view of a restriction (orifice) style check valve. Identify direction of free flow. Identify direction of restricted flow. Describe how a restriction (orifice) style check valve works.

Draw the schematic symbol and cutaway view of a pilot to open check valve. Describe how a pilot to open check valve works in the absence and presence of pilot pressure.

Draw the schematic symbol and cutaway view of a pilot to close check valve. Describe how a pilot to close check valve works in the absence and presence of pilot pressure.

Describe how check valves are employed in the following applications: foot valves, manual pumps, filters in bidirectional systems, quick disconnects, valve bypasses, clogged filter bypasses

Determine how these 4 flow control valves with check valve bypasses influence speed of extension or retraction.



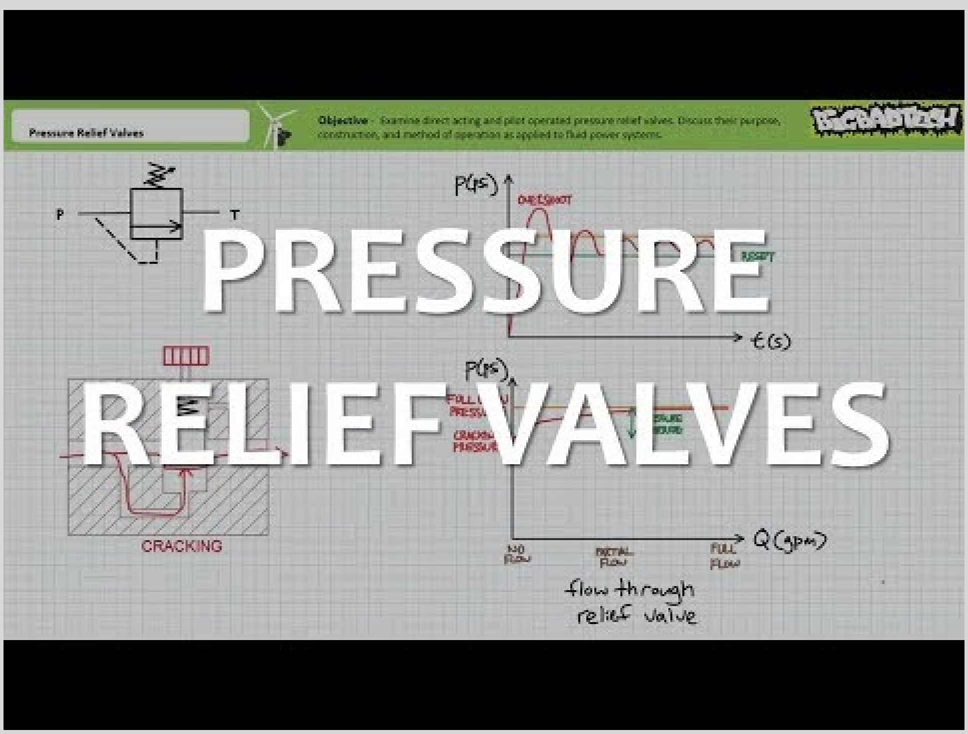
2.5 PRESSURE RELIEF VALVES

Describe the purpose of a pressure relief valve

Describe scenarios that call for pressure relief

Draw the schematic symbol for a rupture/burst disc and discuss its purpose and method of operation.

Draw the schematic symbol for a pressure relief valve and describe the purpose of the individual elements.



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Describe how a check valve and heavy bias spring can be used to create a primitive pressure relief valve.

Draw a cutaway view of a spool type direct acting pressure relief valve. Describe its operation.

Describe the terms overshoot, set, reset, and span (hysteresis)

Define cracking pressure and pressure override. Discuss the influence of pressure override for actuators operating near the set point.

Differentiate between the terms pilot (control) and primary (power)

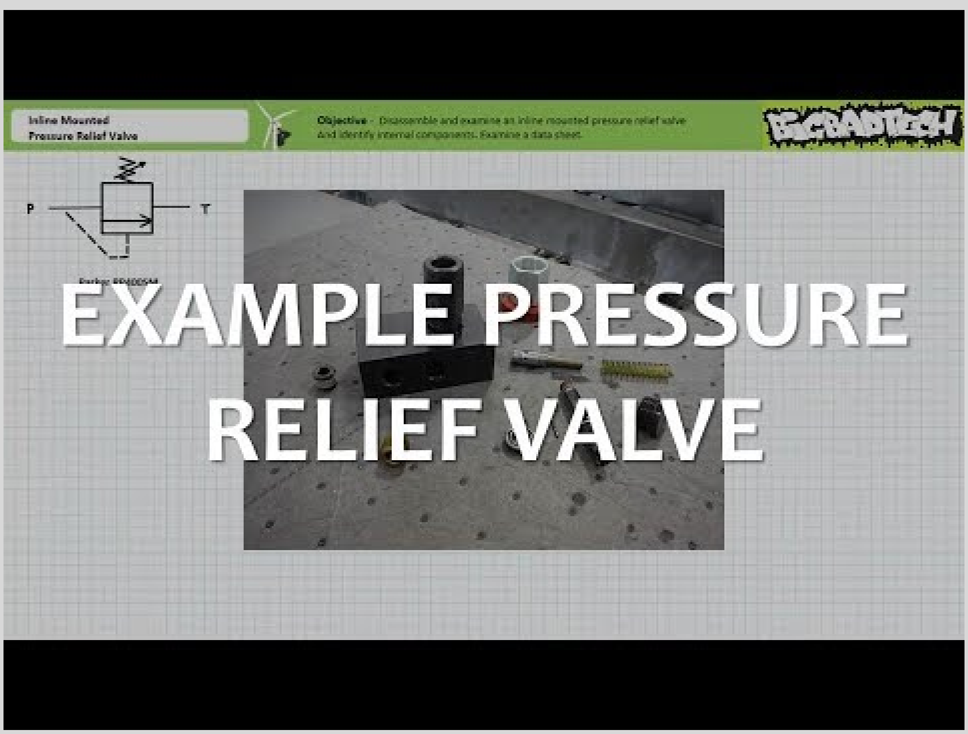
Draw a cutaway view of a balanced piston type pilot operated pressure relief valve. Describe its operation.

Describe the principle advantage of pilot operated pressure relief valves over direct acting pressure relief valves

Comment on observed properties of systems with malfunctioning, improperly set, or improperly connected pressure relief valves.

Comment on the efficiency of systems that actuate the pressure relief valve frequently.
Comment on alternate methods to prevent overpressure events without the necessity of actuating the pressure relief valve.

2.6 EXAMPLE PILOT OPERATED PRESSURE RELIEF VALVE



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2.7 DIRECTIONAL CONTROL VALVES

Describe the purpose of a valve in a fluid power system

Describe the purpose of a directional control valve in a fluid power system

Define the following features of directional control valves: positions, ports/ways, return springs, actuation method, deactivated state

Draw the schematic symbol for a 2 position, 2 way, solenoid actuated, spring offset, NC directional control valve. Describe its behavior and use in a fluid power system.

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Draw the schematic symbol for a 2 position, 2 way, solenoid actuated, spring offset, NO directional control valve. Describe its behavior and use in a fluid power system.

Draw the schematic symbol for a manual override and discuss its purpose

Draw the schematic symbol for a 2 position, 3 way, manually actuated directional control valve spring offset to a deactivated position that blocks flow at 2 and allows flow from 1 to 3. In its activated state it allows flow from 2 to 3 and blocks flow at 1. Draw three different configurations of this valve.

1. selector valve – 1 A, 2 P, 3 B
2. spring retracted, hydraulically extended single acting cylinder – 1 T, 2 A, 3 P
3. spring retracted, hydraulically extended single acting cylinder – 1 P, 2 A, 3 T

Draw the schematic symbol for a 2 position, 3 way, solenoid actuated directional control valve, spring offset to a position that dumps A to T and when activated routes P to A, describe how this can be used in a failsafe braking application

Draw the schematic symbol for a purposely blocked or plugged port, describe how blocked ports can be used to change the functionality of a directional control valve.

Draw the schematic symbol for a 2 position, 4 way, manually actuated directional control valve used to control a double acting cylinder. Describe the cross connect position. Describe the straight through position.

Describe detents used to position a valve. Describe how an automatic detent with kickout works. Describe the operation of a double solenoid 2 position valve with detents.

Draw the schematic symbol for a 3 position, 4 way, manually actuated directional control valve used to control a double acting cylinder. Describe the closed center position and how it affects the actuator and pressure relief valve.

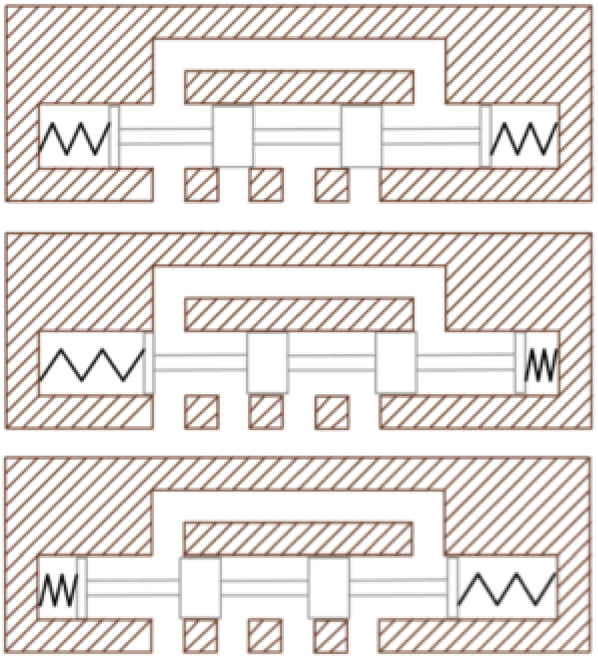
Describe the tandem center position and how it affects the actuator and pressure relief valve.

Describe the float center position and how it affects the actuator and pressure relief valve.

Describe the open center position and how it affects the actuator and pressure relief valve.

Describe the behavior of a double acting cylinder with both cap and rod end at the same pressure.

Use these cutaway diagrams to describe how the spool affects the position of a directional control valve. Label each position given ports are assigned: A, P, B, T



Describe how flow control restrictions are implemented in a directional control valve and their purpose.

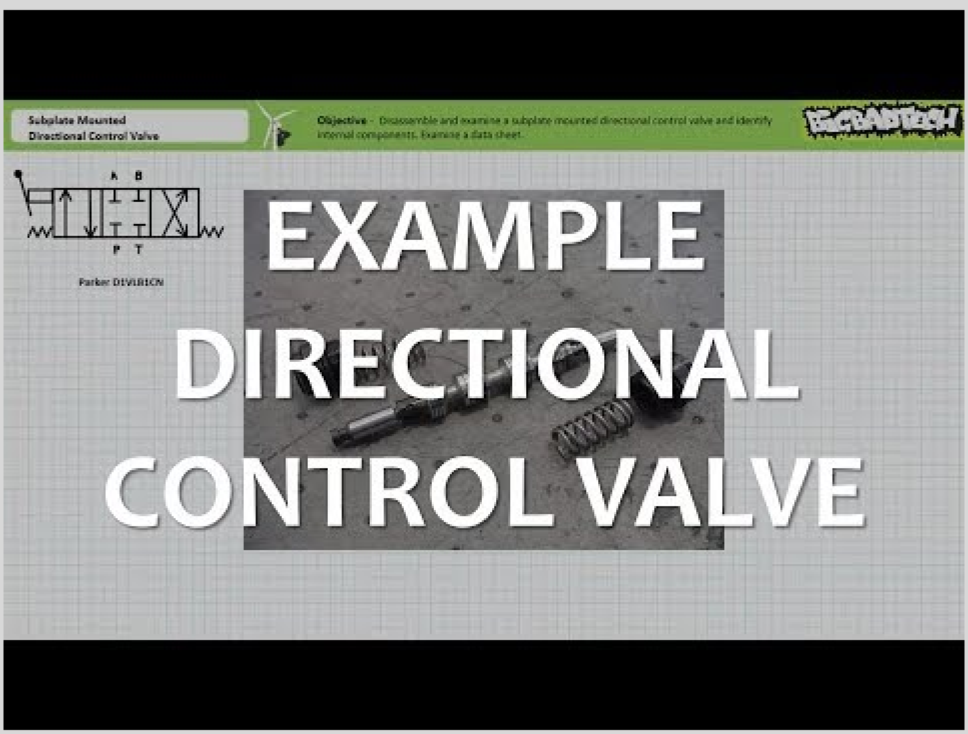
Describe what check valves in a directional control valve position box imply

Describe the shape of the pressure drop for different flow rates performance curve and how to read it

Describe the shape of the operating limits performance curve and how to read it

Identify common entries found on a directional control valve data sheet (Bul 2531-M11 D1VL Data Sheet)

2.8 EXAMPLE DIRECTIONAL CONTROL VALVE



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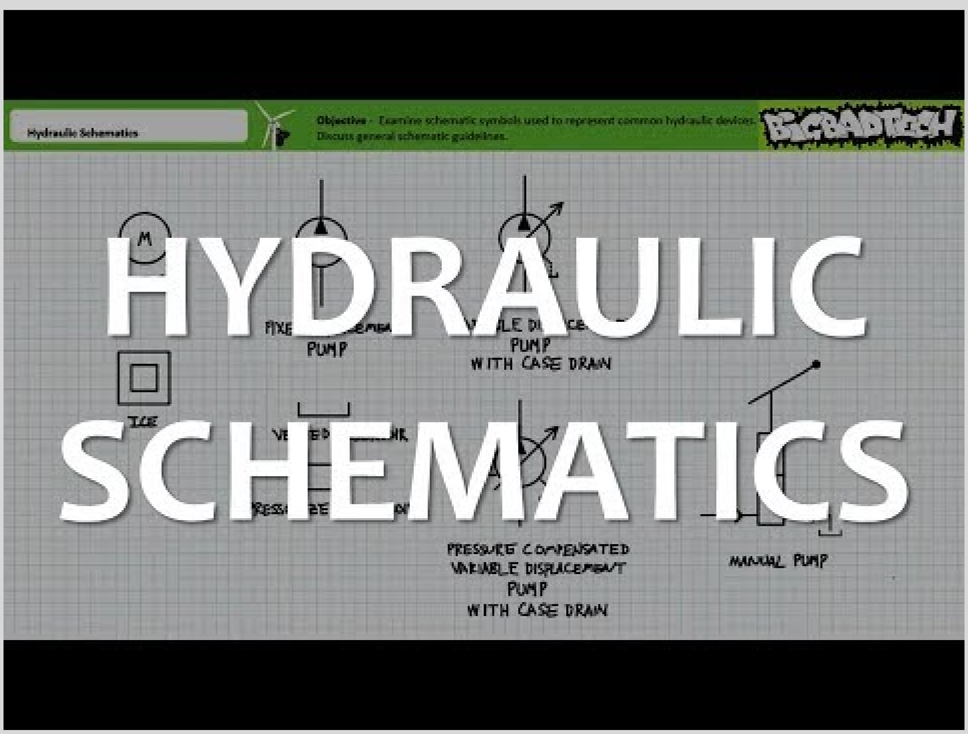
2.9 HYDRAULIC SCHEMATICS

Discuss the advantages and disadvantages of representing hydraulic components using pictorial, cutaway, and schematic symbols

Differentiate between working, pilot, and drain lines and show how these lines are depicted schematically

Differentiate between schematically connected and unconnected fluid conductors

Describe an enclosure and how enclosures are depicted schematically.



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Describe which fluid(s) these colors represent in a hydraulic schematic

Red
Blue
Yellow
Orange (2)
Green (2)
Purple

Define the purpose of these general shapes in a hydraulic schematic:

Circle
Square
Diamond
Slanting Arrow

Define a prime mover. Draw the schematic symbol for a motor and internal combustion engine.

Define a pump. Draw the schematic symbol for a fixed displacement pump, variable displacement pump, pressure compensated variable displacement pump, and manual pump. Differentiate between these types of pumps.

Define the purpose of a case drain and draw the schematic symbol.

Define a coupling. Draw the schematic symbol for a shaft linking a prime mover and pump.

Define a reservoir. Draw the schematic symbol for an atmospheric/vented reservoir and pressurized reservoir.

Define a hydraulic motor. Draw the schematic symbol.

Define a hydraulic cylinder. Draw the schematic symbol for a double acting hydraulic cylinder, a hydraulically extended spring retracted single acting cylinder, a spring extended hydraulically retracted single acting cylinder, and single acting ram. Discuss how these cylinders extend and retract. Describe the purpose of a vent port on a single acting cylinder.

Draw the schematic symbol for a double rod cylinder, a tandem/duplex cylinder, a telescoping cylinder, and an intensifier.

Draw the schematic symbol for a double acting cylinders with a fixed cushion on extension, a fixed cushion on retraction, and a fixed cushion on extension and retraction. Do the same for variable cushions.

Identify the purpose of a pressure relief valve and draw the schematic symbol.

Identify the purpose of a burst/rupture disc and draw the schematic symbol. (see the pressure relief valve lecture)

Identify the purpose of a directional control valve. Draw the schematic symbol for the following directional control valves and discuss the uses of these valves:

2 position, 2 way, solenoid actuated directional control valve spring offset into the NC position featuring a manual override

2 position, 3 way, manually actuated directional control valve spring offset into a position that dumps A to T

2 position, 4 way, solenoid actuated directional control valve with detents featuring a cross connect and straight through position

3 position, 4 way, manually actuated directional control valve, spring centered into a closed center position featuring a straight through and cross connect position

Differentiate between closed, tandem, float, and open center positions. Draw the schematic symbols.

Identify the purpose of a check valve, pilot to open check valve, pilot to close check valve, restriction/orifice type check valve, and manual shutoff valve. Draw the schematic symbol for these devices and discuss how these valves operate.

Identify the purpose of a flow control valve and draw the schematic symbol for the following devices: fixed flow control valve, variable flow control valve, variable flow control valve with check valve bypass, pressure compensated variable flow control valve with check valve bypass, pressure and temperature compensated variable flow control valve with check valve bypass. For flow control valves with check valve bypass identify direction of free flow and controlled flow.

Identify the purpose of a pressure control valve and draw the schematic symbol for the following devices: pressure relief valve, sequence valve, pressure reducing valve, counter balance valve, unloading valve.

Discuss how the following characteristics assist in identifying pressure control valves:

Pilot line

Deactivated state

Check valve bypass

Internal vs external drain

Location and perceived function

Identify the purpose and general operation principle of an accumulator and draw the schematic symbol for a gas charged accumulator, spring loaded accumulator, and weighted accumulator. Discuss any safety precautions regarding accumulators.

Identify the purpose and draw the schematic symbol for the following devices: pressure gauge/manometer, quick disconnect inspection ports, pressure switch (hydraulic and electric), pressure sensor, flow meter, limit switch, magnetic proximity switch (hydraulic and electric)

Identify the purpose and draw the schematic symbol for the following devices: filter, filter with check valve bypass, heater, cooler, cooler with liquid heat transfer fluid, cooler with gas heat transfer fluid. Discuss the purpose of counter flow in heat exchangers.

Define a hydraulic power unit (HPU). Identify devices commonly found in an HPU.
Identify the purpose and draw the schematic symbol for a rotary hydraulic coupling.

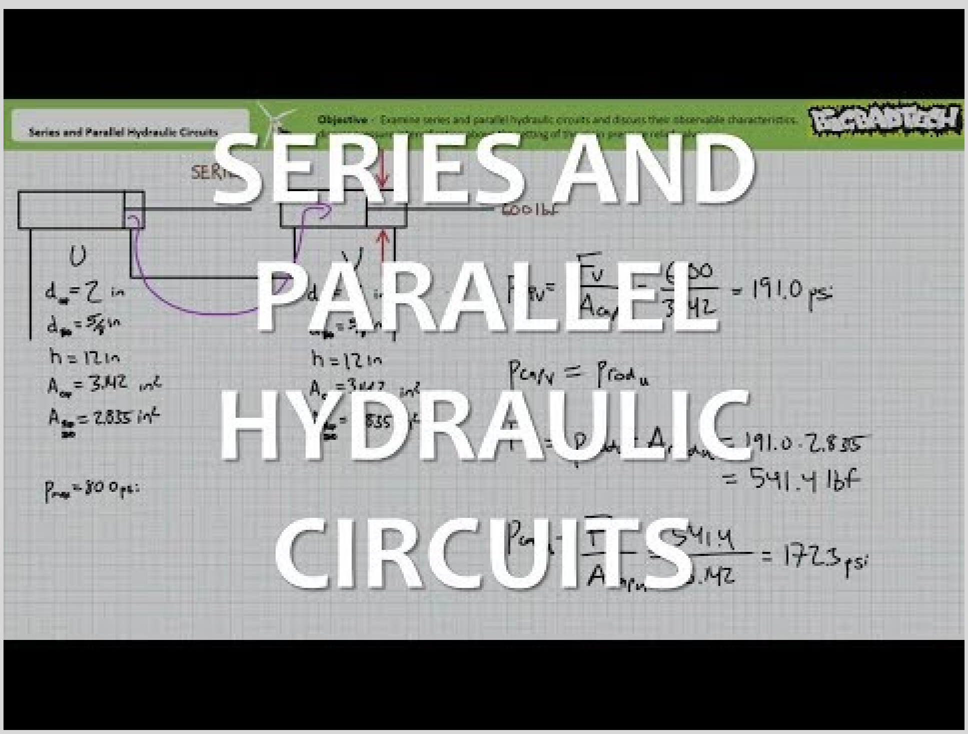
UNIT 3: HYDRAULIC APPLICATIONS

3.1 SERIES AND PARALLEL HYDRAULIC CIRCUITS

Describe flow paths in basic series hydraulic circuits

Describe the actuation sequence of actuators in a series relationship.

Discuss the source of differences in travel length and speed for series hydraulic circuits.



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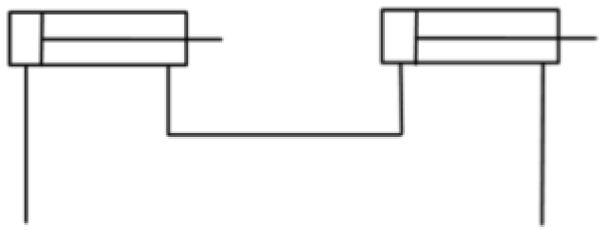


Given two cylinders with the following dimensions in a series relationship, calculate the extension distance of the downstream cylinder given the upstream cylinder fully extends

cap = 1 3/4”
rod = 5/8
travel = 6”

Given the dimensions of the upstream cylinder are to remain fixed, determine the diameter of the downstream cylinder such that it fully extends 6” when the upstream cylinder reaches the limits of travel.

Given two cylinders with the following dimensions in a series relationship, calculate the maximum extension force the system is capable of exerting with the downstream cylinder given input to the upstream cylinder’s cap in limited to 490psi.

cap = 1 3/4”
rod = 5/8
travel = 6”

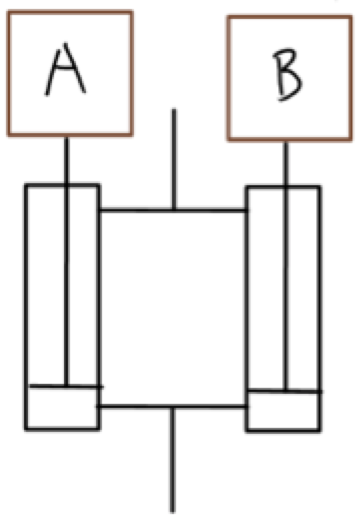
Given the downstream cylinder is loaded with an 800lbf object determine the pressure in the cap end of the downstream cylinder, the force exerted by the upstream cylinder, and the pressure in the cap end of the upstream cylinder.

Comment on advantages and disadvantages of pressure intensification for series hydraulic circuits.

Given an intensifier with the following dimensions, calculate the output pressure given an input pressure of 80psi.

d_{in} = 3”
d_{out}= 3/4”

Describe flow paths in basic parallel hydraulic circuits.



Given two cylinders in a parallel relationship with the following dimensions determine the extension sequence if cylinder A is loaded with a 500lbf load and cylinder B is loaded with a 600lbf load. Calculate the extension pressure necessary to move A. Calculate the extension pressure necessary to move B.

cap = 1 3/4”
rod = 5/8
travel = 6”

Given two cylinders in a parallel relationship with the following dimensions calculate the extension sequence if the cylinders are both loaded with 800lbf loads. Calculate the extension pressure necessary to move A. Calculate the extension pressure necessary to move B.

A cap = 1 3/4”
A rod = 5/8
A travel = 6”

B cap = 2”
B rod = 5/8
B travel = 6”

Discuss the purpose of a mechanical yoke, balanced loads, and flow control valves in a parallel relationship.

Given two cylinders in a parallel relationship with the following dimensions mechanically yoked together calculate the extension pressure necessary to move a perfectly balanced 960lbf object.

cap = 1 3/4”
rod = 5/8
travel = 6”

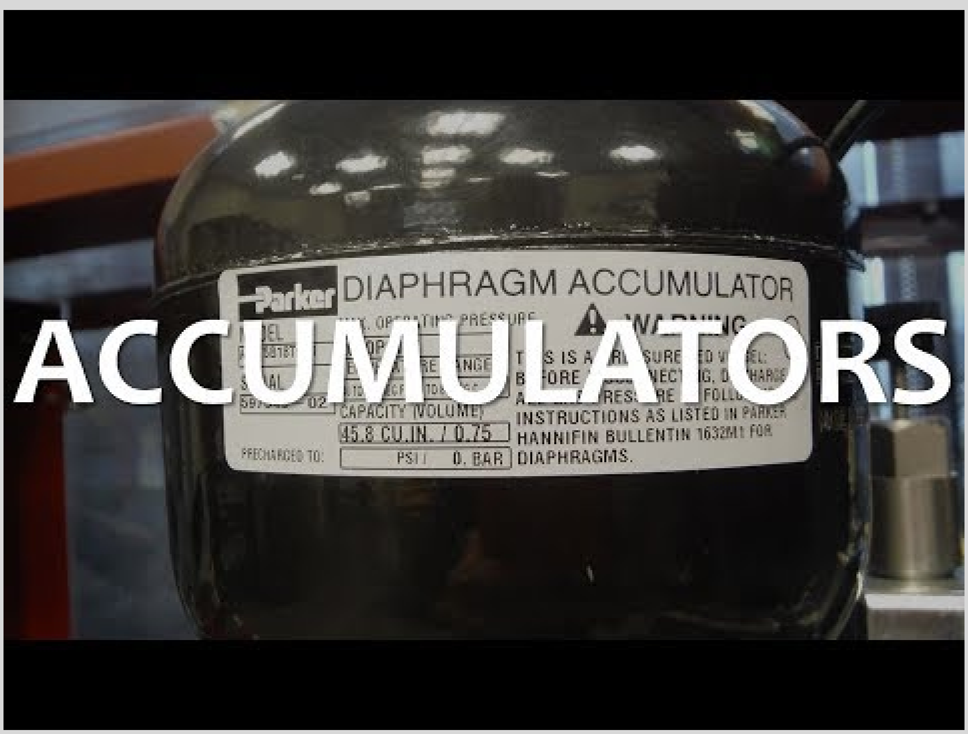
3.2 ACCUMULATORS

List common functions of accumulators in a hydraulic system

List the two general classes of accumulators.

List the two types of mechanical accumulators. Describe each one. Draw the schematic symbol.

List the three types of hydro-pneumatic accumulators. Draw the schematic symbol. Describe each one. Draw the cutaway view of each type.



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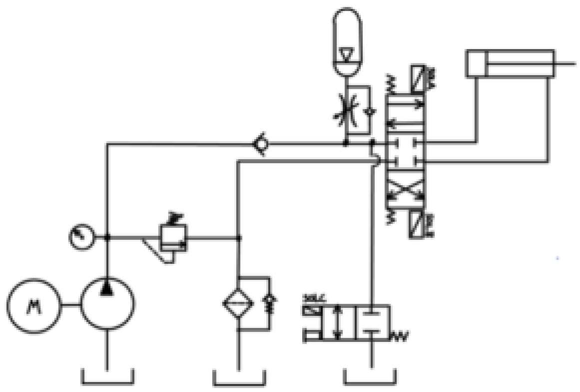
Draw the cutaway view of a bladder type hydro-pneumatic accumulator in various states of charge. Identify various components and their function.

Define precharge.

Describe why dry nitrogen or another inert gas is used to precharge accumulators.

Use this schematic to describe how an accumulator influences a hydraulic circuit. Describe the purpose of the flow control valve with check valve bypass on the accumulator. Describe how a technician would release the stored energy in the accumulator.



Differentiate between the terms adiabatic and isothermal with respect to charging and discharging an accumulator

List which data is required to properly size a Parker A series piston accumulator. Given an application with a minimum pressure of 500psi determine the recommended precharge for a Parker A series piston accumulator. (Parker A Series Piston Accumulator datasheet)

Draw a cutaway view of a piston style hydro-pneumatic accumulator. Identify the internal components.
Differentiate between failure modes and loss of precharge for piston, diaphragm, and piston style hydro-pneumatic accumulators

3.3 FLUID PROPERTIES

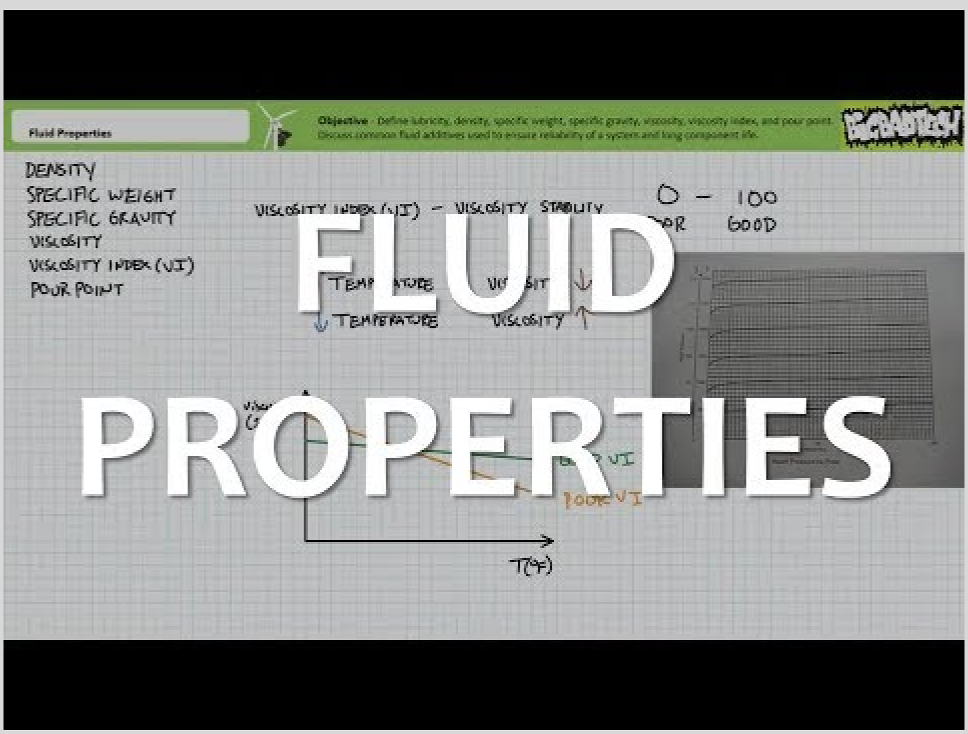
List the purposes of fluid in a fluid power system

Define lubricity and the factors that influence lubricity

Describe why petroleum based oil is the liquid of choice for most hydraulic systems

Comment on the observed compressibility of liquids under pressure.

Define density.



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Define specific weight, differentiate between it and density. Look up the specific weight of oil, water, and other common substances.

Define specific gravity. Look up the specific gravity of oil and other common substances.

Name the tool used to measure specific gravity of a liquid. Describe why a discharged battery has an SG reading closer to 1. Comment on properties that influence density, specific weight, and specific gravity.

Define viscosity.

Describe how viscosity is measured using a Saybolt viscometer.

Comment on the viscosity measurement of a thick fluid using units of SSU. Comment on the viscosity measurement of a thin fluid using units of SSU. Look up the viscosity of common liquids.

Comment on the advantages and disadvantages of liquids with high viscosity measurements.

Comment on the advantages and disadvantages of liquids with low viscosity measurements.

List another common viscosity unit.

Define viscosity index (VI). Comment on how temperature ordinarily affects viscosity. Comment on VI for liquids exhibiting excellent and poor viscosity stability.

Comment on manufacturers specifying viscosity measurements for data sheets.

Define pour point. Comment on the magnitude of a liquid's pour point an application that must work in an extremely cold environment.

List common additives in a hydraulic system.
Comment on additive compatibility

3.4 FILTRATION AND CONDITIONING

Describe the purpose of fluid in a fluid power system.

Define contaminant. Identify sources of contaminants and give examples.

Describe how oil can become a contaminant.

Describe the negative effects of contaminants in a fluid power system.

Describe the unit commonly used to measure contaminants.

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Describe methods of reducing contaminant entry into a system.

Define a filter and describe a filter's construction.

Define and differentiate between the terms nominal and absolute rating for a filter.

Define a strainer and differentiate between strainers and filters. Describe common strainer locations. Describe mesh count.

Describe a clogged filter bypass and indicator

Define beta ratio.

Calculate the beta ratio for a filter that has 1000 particles greater than 10μm upstream and 10 particles greater than 10μm downstream.

List different filter locations. Discuss the pressure requirements and describe their operation.

Describe why filters are ordinarily unidirectional. Draw an arrangement of check valves that ensures unidirectional flow through a filter given a bidirectional flow path.

Describe the additional function of a kidney loop/offline filter with respect to viscosity.

List the 3 particle sizes of concern for the ISO Standard 4406:1999.

Determine the particle count for an oil with an 18/16/13 cleanliness rating

Discuss why cleanliness standards must be considered for different applications.
Describe conditioning and differentiate between it and filtration.

Describe tube in shell and baffle heat exchangers employing liquid heat transfer fluids and comment on the purpose of counter flow.
Comment on the purpose of a reservoir and how it is used to passively condition fluid.

Range Code	Particles per mL	
	from	up to
24	80000	160000
23	40000	80000
22	20000	40000
21	10000	20000
20	5000	10000
19	2500	5000
18	1300	2500
17	640	1300

16	320	640
15	160	320
14	80	160
13	40	80
12	20	40
11	10	20
10	5	10
9	2.5	5
8	1.3	2.5
7	0.64	1.3
6	0.32	0.64

3.5 REGENERATIVE EXTENSION

Given volume (V) and time (t) solve for flow rate (Q).

Given time (t) and flow rate (Q) solve for volume (V).

Given flow rate (Q) and time (t) solve for volume (V).

Given a cylinder with the following dimensions:

d_{cap} =2 ½ in

d_{rod} = 1 in

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$travel = 24$ in

Calculate the time to fully extend the cylinder and the time to fully retract the cylinder in units of seconds given a constant flow rate of 2.3 gpm. Additionally, calculate maximum extension and retraction force given maximum pressure of 400psi.

Determine the response of a double acting cylinder given equal pressure on the cap and rod end. Use Pascal's Law to explain your answer.

Determine the force and functional area imbalance between cap and rod end of the above cylinder given equal pressure on the cap and rod end.

Describe flow patterns within a double acting cylinder in regenerative extension mode.

Identify the volume differential between the cap end at full extension and the rod end at full retraction.

Compare the extension force and speed for a cylinder in regenerative extension mode with one in normal extension mode.

Given the above example cylinder calculate the extension speed in units of seconds while in regenerative extension mode.

Given a cylinder with the following dimensions and a system with the following parameters:

$d_{cap} = 3$ in

$d_{rod} = 1\frac{1}{4}$ in

$travel = 16$ in

$Q = 1.8$gpm

$P_{max} = 500$psi

Calculate the time to fully extend the cylinder the cylinder in units of seconds and maximum extension force in normal extension mode:

Calculate the time to fully extend the cylinder the cylinder in units of seconds and maximum extension force in regenerative extension mode:

Describe applications for regenerative extension.

Describe the physical characteristics of a 2:1 cylinder and its application in a system that routes pressurized flow to both cap and rod end serving to extend the cylinder and a cross connect position serving to retract the cylinder.

Given a 2:1 cylinder with the following dimensions:

$d_{cap} = 1\frac{1}{2}$ in

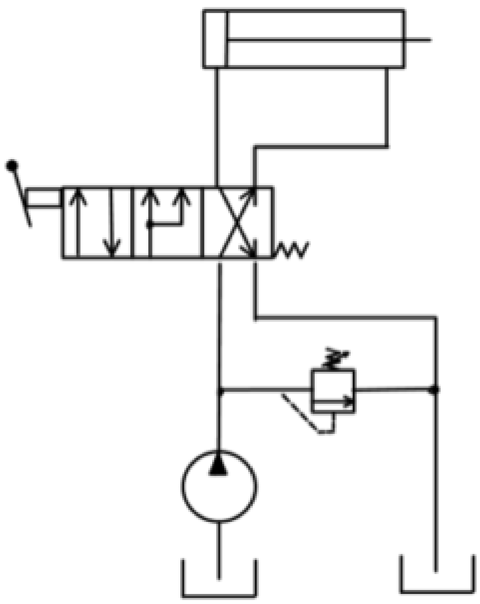
$d_{rod} = 1.06066017178$ in

$travel = 12$ in

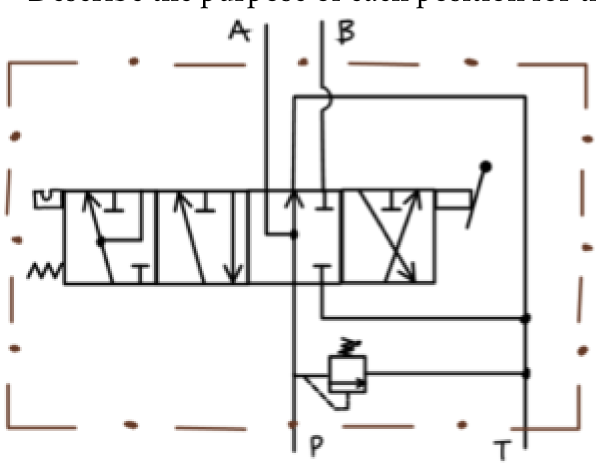
$Q = 0.9gpm$
$P_{max} = 700psi$

Calculate the extension and retraction force and the time to fully extend and retract given extension in regenerative mode.

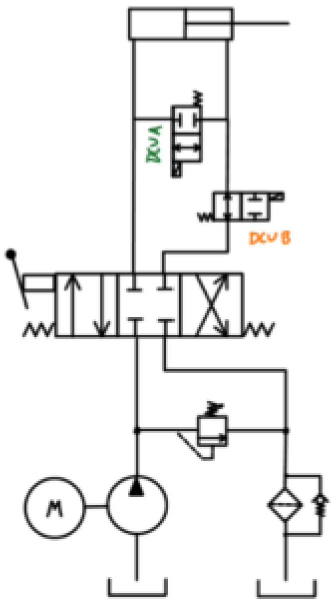
Describe the operation of this system employing a manually actuated 3 position directional control valve spring offset into the cross connect position with a soft and hard stop.



Describe the purpose of each position for this directional control valve.



Describe the operation of this system employing additional directional control valves.


DCV A
DCV B
M

UNIT 4: PUMPS AND FLOW CONTROL

4.1 HYDRAULIC PUMPS

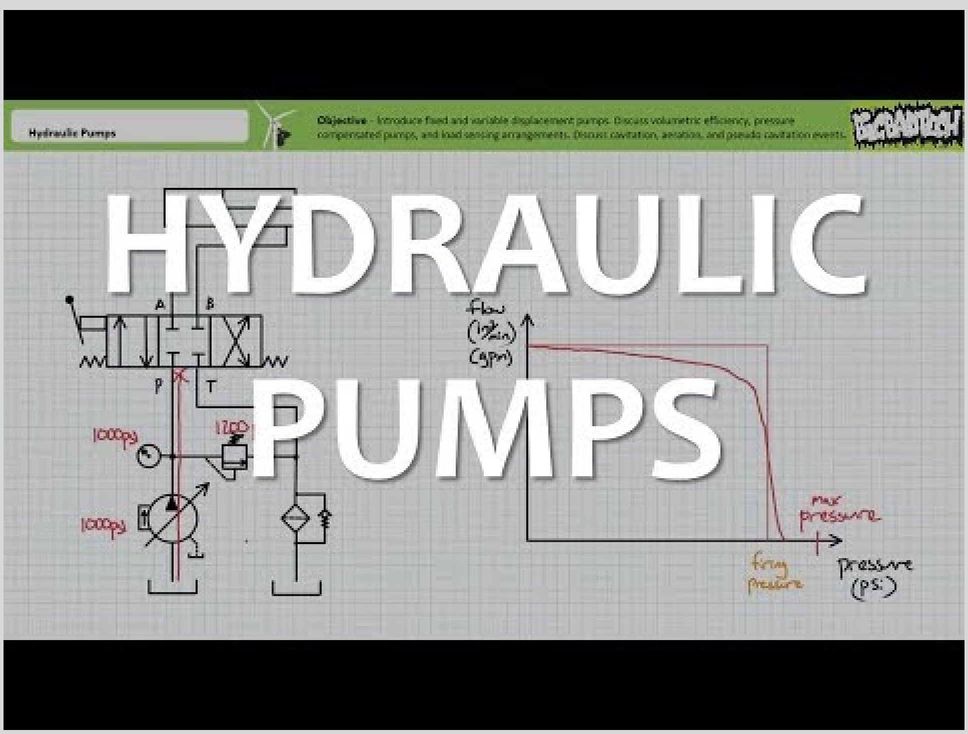
Describe the role of pumps in a hydraulic system.

Describe the role of prime movers in a hydraulic system.

Define flow rate. List the formulas used to calculate flow rate.

Define displacement.

Discuss two methods the prime mover and pump combination can directly influence flow rate.



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Discuss how a system can control flow rate given a fixed displacement pumps operated at a fixed rotational speed.

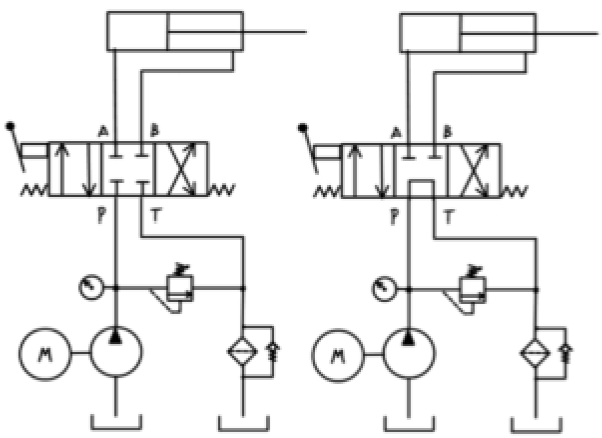
Discuss the purpose of the check valve bypass for a flow control valve.

List the characteristics of a positive displacement pump. Compare and contrast this with a non-positive displacement pump.

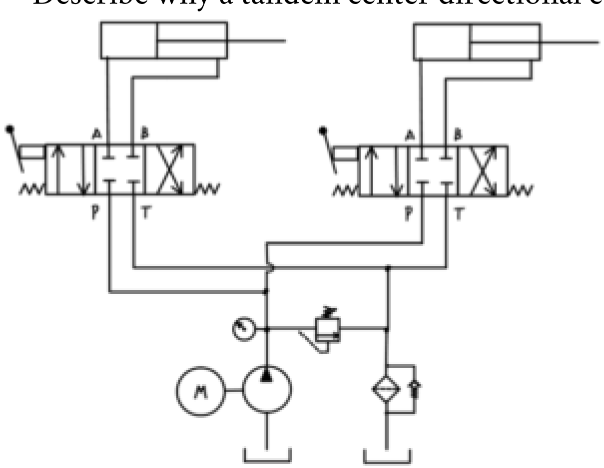
List the sequence of operation of a positive displacement pump.

Comment on viscosity requirements, conditioning needs, and cleanliness standards for positive displacement pumps.

Describe the pressure requirements for these two different system given the following scenarios: moving unloaded actuator, moving loaded actuator, actuator stalled at the limits of travel, centered directional control valve



Describe why a tandem center directional control valve would not work for this circuit.

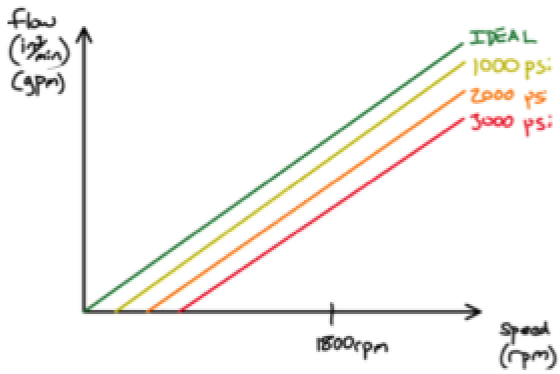


Describe why displacement ordinarily decreases at higher pressures.

Describe why rotational speed ordinarily decreases at higher pressures.

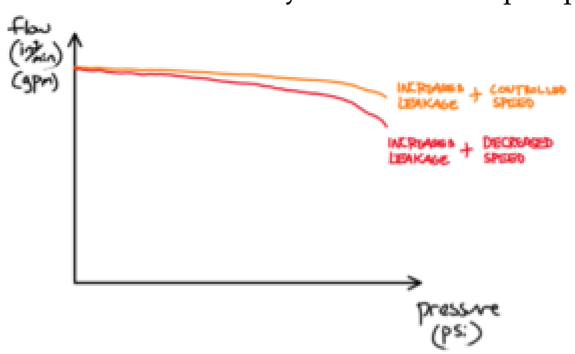
Describe why flow rate ordinarily decreases at higher pressures.

Describe this family of curves.



Given a pump with a fixed displacement of .35CIR at ideal conditions, calculate flow rate in gpm if the pump was driven at exactly 1800 rpm.

Describe this family of curves for a pump rotated at a nominal speed.



Comment on how actuator speed is influenced by increased pressure requirements.

Define volumetric efficiency.

Given a pump with a fixed displacement of .35CIR at ideal conditions decreased to .33CIR at 1000psi, calculate the volumetric efficiency at 1000psi.

Describe why pump manufacturers specify drive speed, fluid properties, and pressure ranges.

Define pump overall efficiency and the formula used to calculate pump overall efficiency

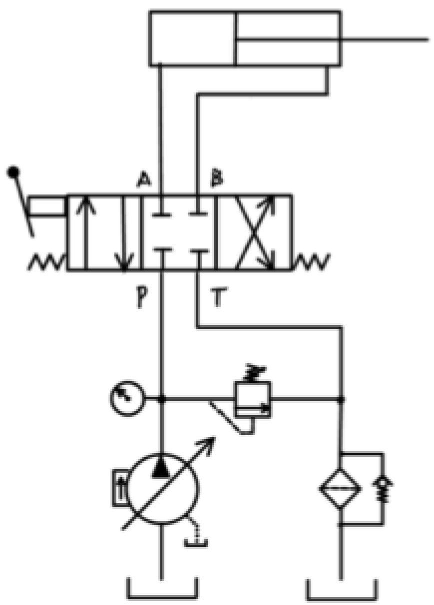
Write the formula used to calculate hydraulic power when pressure is expressed in units of psi, flow rate is expressed in units of gpm, and power is expressed in units of hp.

Given a pressure of 1500psi and a flow of 2gpm, calculate the hydraulic power output of the pump. Given this output necessitated the prime mover supply 2.4hp of mechanical power, determine the overall efficiency of the pump.

List three common positive displacement pumps employed in hydraulic systems. Comment whether the pumps are fixed or variable displacement.

Differentiate between fixed and variable displacement pumps. Discuss the advantages and disadvantages of variable displacement pumps.

Describe how the pressure compensated variable displacement pump prevents the main pressure relief valve from actuating in this circuit when the actuator reaches the limits of travel or when the valve is placed in the center position.



Define firing pressure. Describe why the main pressure relief valve must be above the compensator setting. Explain high pressure standby.

Describe the advantages and applications for circuits using pressure compensated variable displacement pumps.

Describe how a shuttle (OR) valve works. Draw the schematic symbol.

Describe a load sensing operation making use of a pressure compensated variable displacement pump.

Define cavitation and identify possible sources of cavitation.

Define aeration and identify possible sources of aeration.

Define pseudo-cavitation and identify possible sources of pseudo cavitation.

Differentiate between cavitation, aeration, and pseudo cavitation.

Comment on the observable effects of systems encountering cavitation, aeration, and pseudo-cavitation problems

4.2 GEAR PUMPS

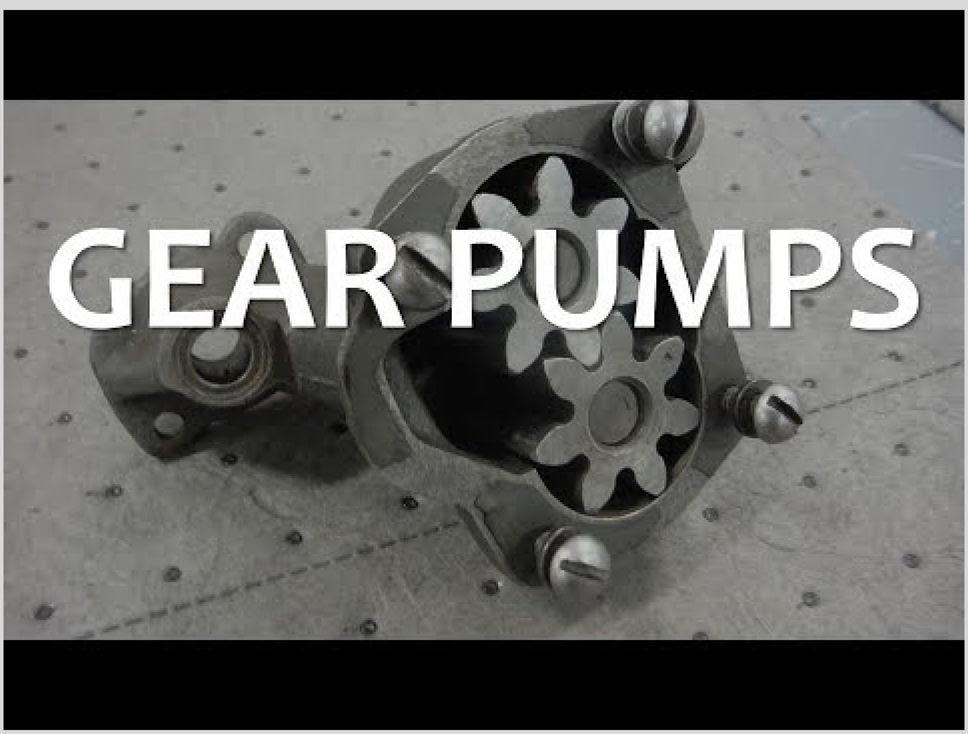
Describe the sequences of a positive displacement pump.

Differentiate between fixed and variable displacement pumps.

Classify and describe the three types of positive displacement pumps commonly employed in hydraulic systems.

Describe how fixed displacement pumps vary flow rate.

List the four types of gear pumps and identify the most common type.



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Identify parts in an external gear pump and draw a diagram of an external gear pump.

Describe how a gear pump executes the phases of a positive displacement pump.

Describe where dynamic and static seals can be found in a gear pump.

Take apart a gear pump. Identity internal components.

Find the data sheet for a gear pump. Identify displacement, drive speed range, viscosity range, fluid cleanliness requirements, and other pertinent specifications. Explain flow rate as a function of pressure, flow rate as a function of drive speed, and other pertinent charts. (Prince SP25A Gear Pump Datasheet)
Briefly describe lobe, internal, and gerotor type gear pumps.

4.3 VANE PUMPS

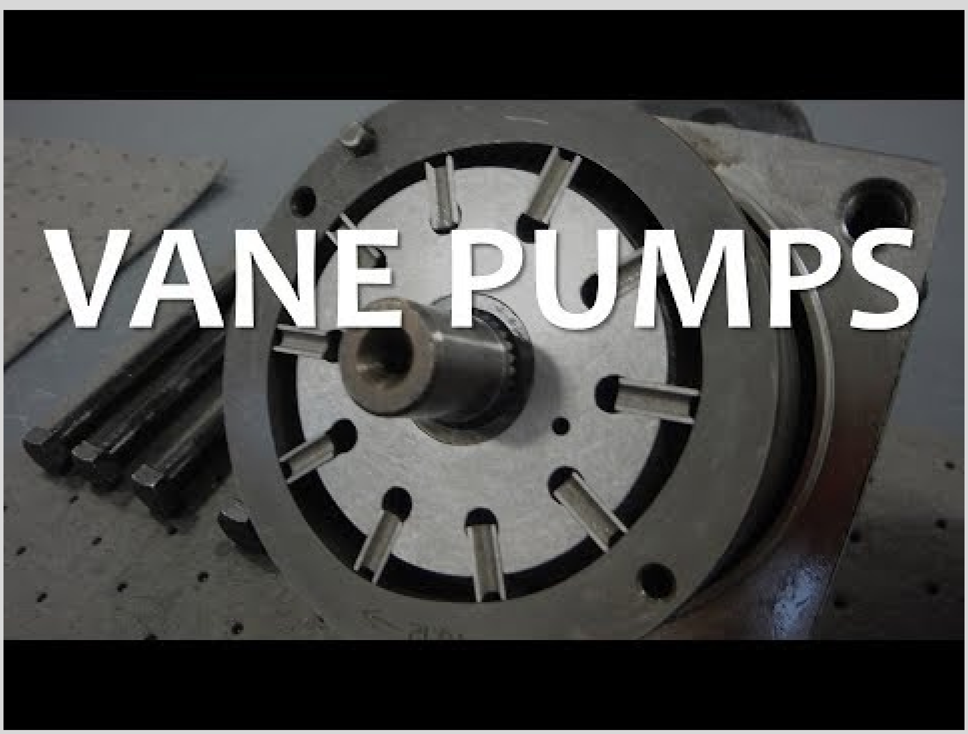
Describe the sequences of a positive displacement pump.

Differentiate between fixed and variable displacement pumps.

Classify and describe the three types of positive displacement pumps commonly employed in hydraulic systems.

Describe how a variable displacement pump can vary flow rate.

List the two main types of vane pumps



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Identify parts in an unbalanced vane pump and draw a diagram.

Describe how an unbalanced vane pump executes the phases of a positive displacement pump.

Describe how a variable displacement unbalanced vane pump works.

Define eccentricity and concentricity. Identify which positions produce max/min flow rate.

Describe the main disadvantage of unbalanced vane pumps and how balanced vane pumps solve this issue.

Identify parts in balanced vane pump and draw a diagram.

Describe how a balanced vane pump executes the phases of a positive displacement pump.

Take apart a fixed displacement unbalanced vane pump. Identity internal components.

Take apart a variable displacement unbalanced vane pump. Identity internal components. (NOT SHOWN IN LECTURE)

Take apart a fixed displacement balanced vane pump. Identity internal components.

Define the term cartridge. Identify advantages of cartridges when repairing vane pumps.
Find the data sheet for a vane pump. Identify displacement, drive speed range, viscosity range, fluid cleanliness requirements, and other pertinent specifications. Explain flow rate as a function of pressure, flow rate as a function of drive speed, and other pertinent charts. (Vane Pump Data Sheet Parker T6C Balance Vane Pump Datasheet)

4.4 PISTON PUMPS

List the four main types of piston pumps.

Define the terms axial and radial.

Identify parts in an axial piston pump and draw a diagram.

Pronounce the term "swash plate" correctly. Have your instructor verify correct pronunciation.

Describe how an axial piston pump executes the phases of a positive displacement pump.

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Describe how a variable displacement axial piston pump works.

Identify which swash plate positions produce max/min flow rate.

Describe a bent axis piston pump.

Describe a radial piston pump.

Describe a rotating cam radial piston pump.

Take apart a piston pump. Identity internal components.

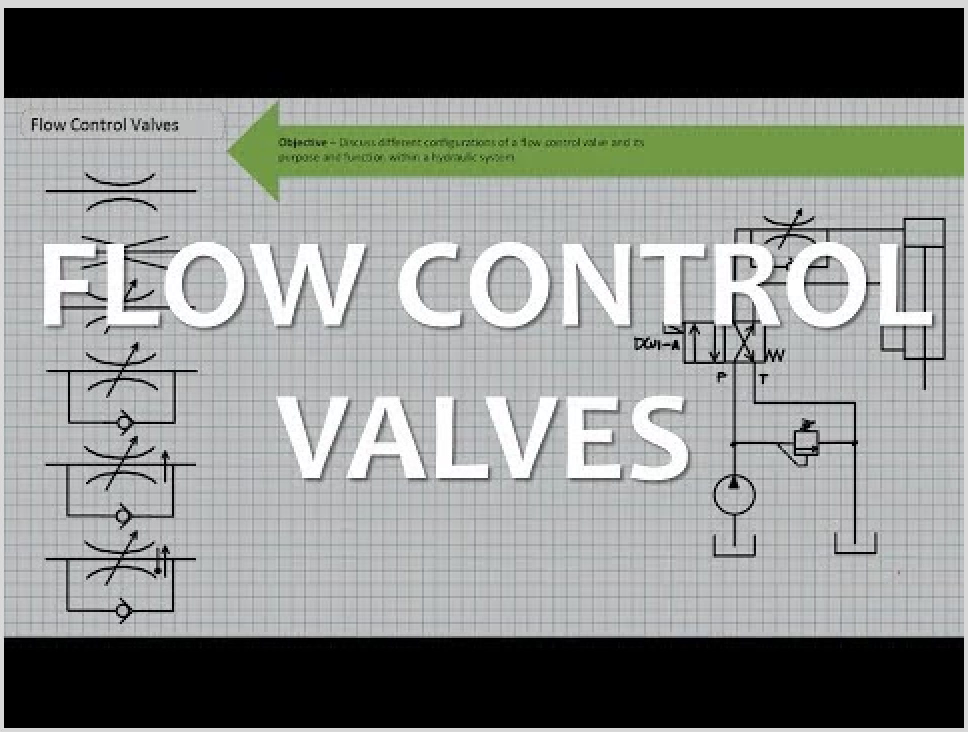
Find the data sheet for a piston pump. Identify displacement, drive speed range, viscosity range, fluid cleanliness requirements, and other pertinent specifications. Explain flow rate as a function of pressure, flow rate as a function of drive speed, input power requirements as a function of pressure, case drain flow as a function of pressure, and other pertinent charts. (Piston Pump Data Sheet Parker PV Axial Piston Pump Datasheet)

4.5 FLOW CONTROL VALVES

Describe how restriction style flow control valves control flow in a hydraulic system making use of a fixed displacement pump and a pressure relief valve.

Draw the schematic symbols for the following devices:

- fixed flow control valve
- adjustable flow control valve
- adjustable flow control valve with check valve bypass
- pressure compensated adjustable flow control valve with check valve bypass
- temperature and pressure compensated adjustable flow control valve with check valve bypass



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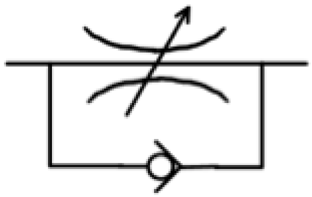
Given the orientation of this adjustable flow control valve with check valve bypass determine the direction of free flow and the direction of controlled flow.



Draw a cutaway view of an adjustable flow control valve with check valve bypass and discuss how it functions.

Describe how an adjustable flow control valve with check valve bypass responds to these scenarios:
input pressure increases and load stays the same
input pressure decreases and load stays the same
input pressure stays the same and load decreases
input pressure stays the same and load increases
input pressure and load return to initial conditions

Draw a cutaway view of a pressure compensated adjustable flow control valve with check valve bypass and discuss how it functions.

Describe how a pressure compensated adjustable flow control valve with check valve bypass responds to these scenarios:
input pressure increases and load stays the same
input pressure decreases and load stays the same
input pressure stays the same and load decreases
input pressure stays the same and load increases
input pressure and load return to initial conditions

Discuss how a temperature and pressure compensated adjustable flow control valve with check valve bypass functions.

Describe how a pressure compensated adjustable flow control valve with check valve bypass enhances the performance of multi actuator systems.

Discuss how a bypass type flow control valve works and differentiate between it and a restriction style flow control valve.

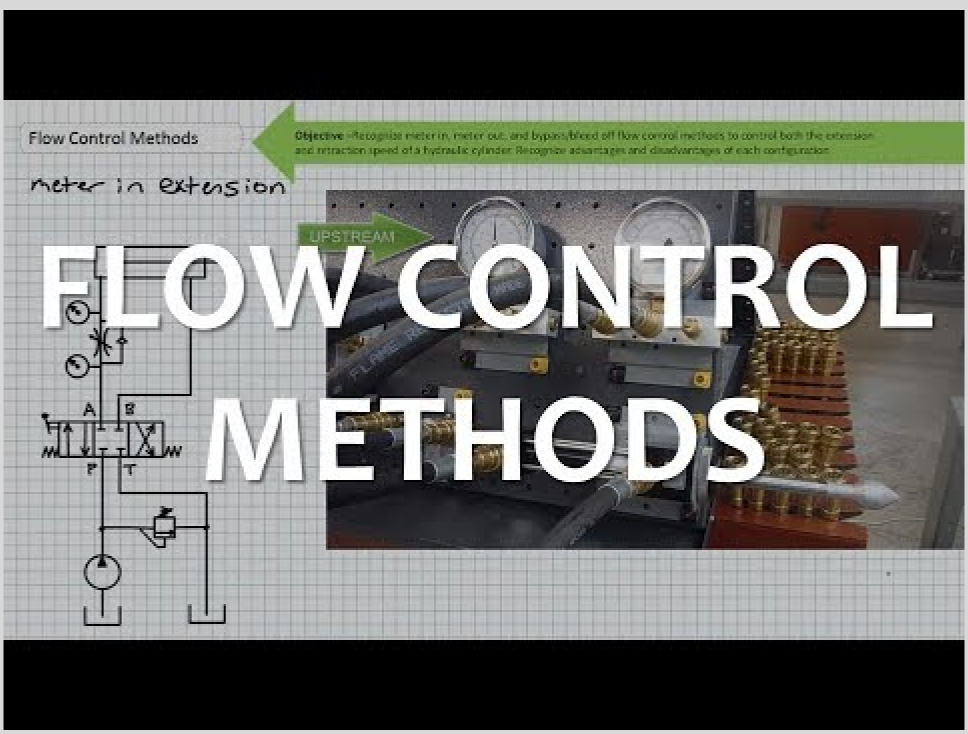
Discuss means other than manually changing flow rate.
Describe lunge control.

4.6 FLOW CONTROL METHODS

Draw a meter in extension arrangement using an adjustable flow control valve with check valve bypass.

Draw a meter in retraction arrangement using an adjustable flow control valve with check valve bypass.

Describe why meter in configurations are not used to control the descent of a lifted object or negative or overrunning loads.



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Draw a meter out retraction arrangement using an adjustable flow control valve with check valve bypass.

Draw a meter out extension arrangement using an adjustable flow control valve with check valve bypass.

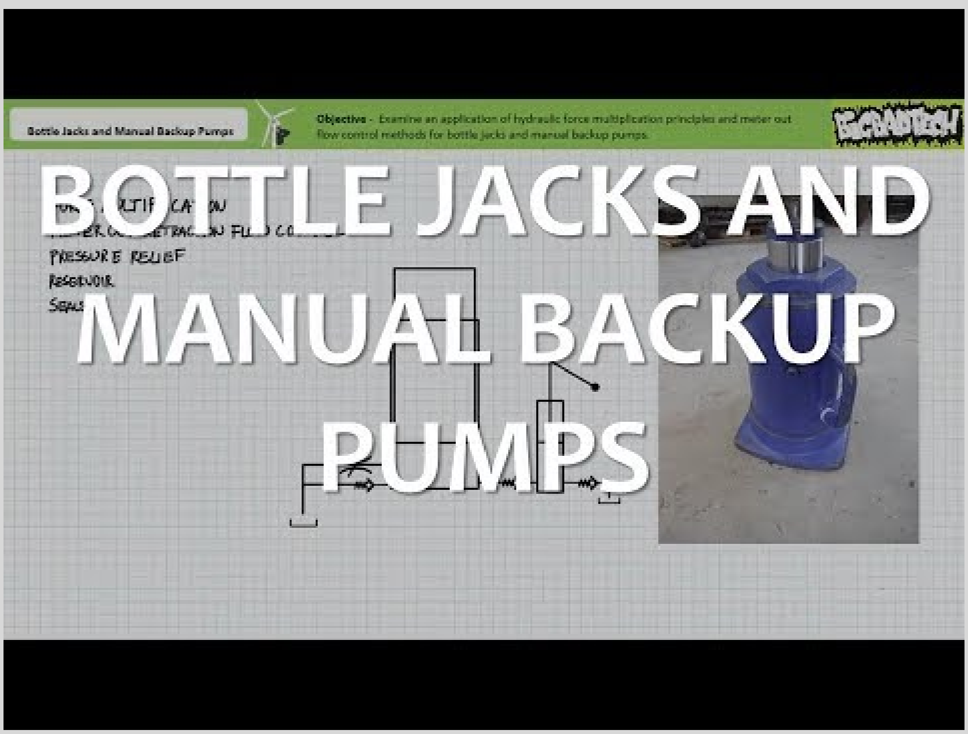
Discuss pressure intensification.

Discuss how a meter out flow control arrangement can control the descent of a lifted object or a negative or overrunning load.

Draw a bypass arrangement using an adjustable flow control valve.

4.7 BOTTLE JACKS AND MANUAL BACKUP PUMPS

Describe the operation of a bottle jack using this diagram. Discuss pumping action, force multiplication, meter out flow control, and pressure relief.



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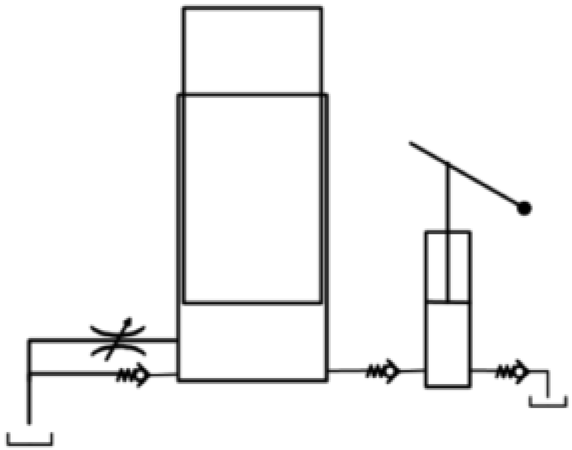
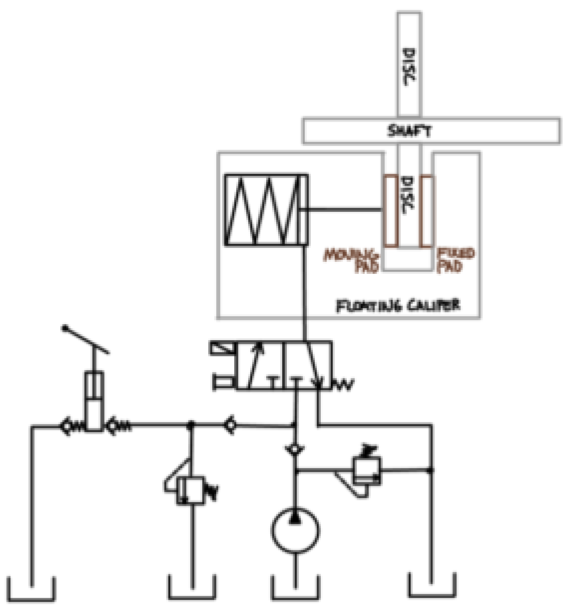


Comment on inspection and troubleshooting procedures for “broken” bottle jacks.

Describe the regular and override operation of this fail safe braking system making use of a manual backup pump.



UNIT 5: PRESSURE CONTROL

5.1 VENTED AND REMOTE CONTROLLED PRESSURE RELIEF VALVES

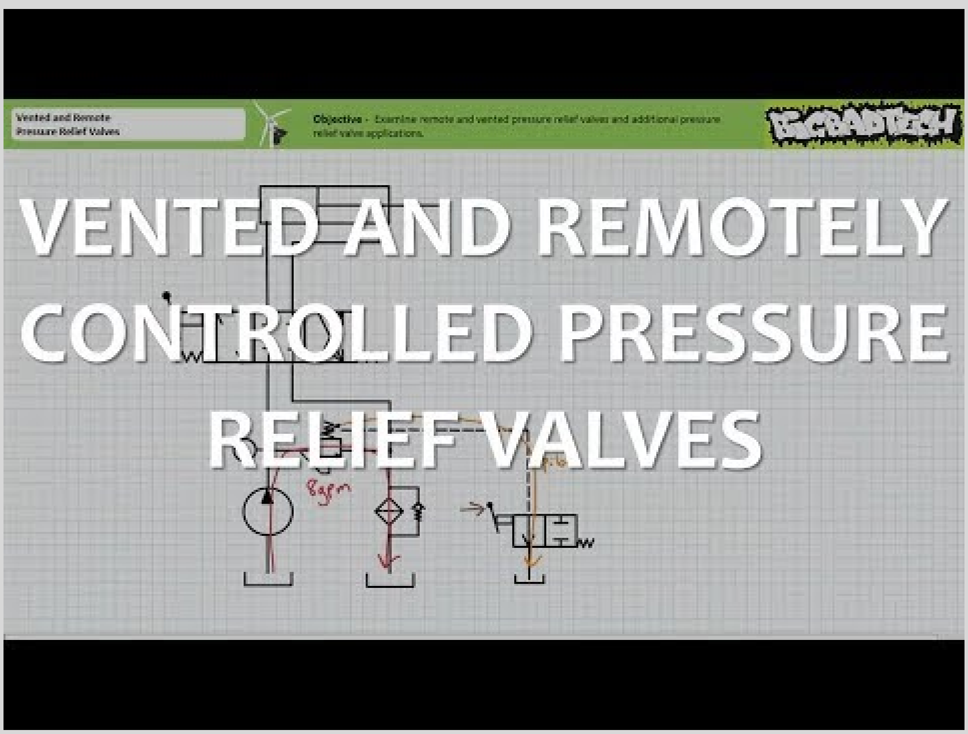
List the 5 main types of pressure control valves. Draw their associated schematic symbols.

Identify the 5 main characteristics used to classify pressure control valves.

Describe the purpose of a pilot line. Describe the schematic symbol for a pilot line.

Identify pressure control valves that make use of internal pilot lines on their primary, or input, port.

Identify pressure control valves that make use of internal pilot lines on their secondary, or output, port.



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Identify pressure control valves that make use of external/remote pilot lines.

Identify pressure control valves that have a NC deactivated state.

Identify pressure control valves that have a NO deactivated state.

Identify pressure control valves that have a check valve bypass. Identify why a check valve bypass is necessary.

Identify pressure control valves that do not have a check valve bypass. Identify why a check valve bypass is not necessary.

Identify pressure control valves that have an internal drain. Identify why an external drain is not necessary.

Identify pressure control valves that have an external drain. Identify why an external drain is necessary. Describe the schematic symbol for an external drain.

Identify customary locations for the 5 main pressure control valves.

Describe a pressure relief valve using the 5 main characteristics used to classify pressure control valves.

Draw the cutaway diagram of a pilot operated pressure relief valve with a vent port.

Describe the basic operation of a balanced piston style pilot operated pressure relief valve.
Describe the main purpose of the vent port.

5.2 SEQUENCE VALVES

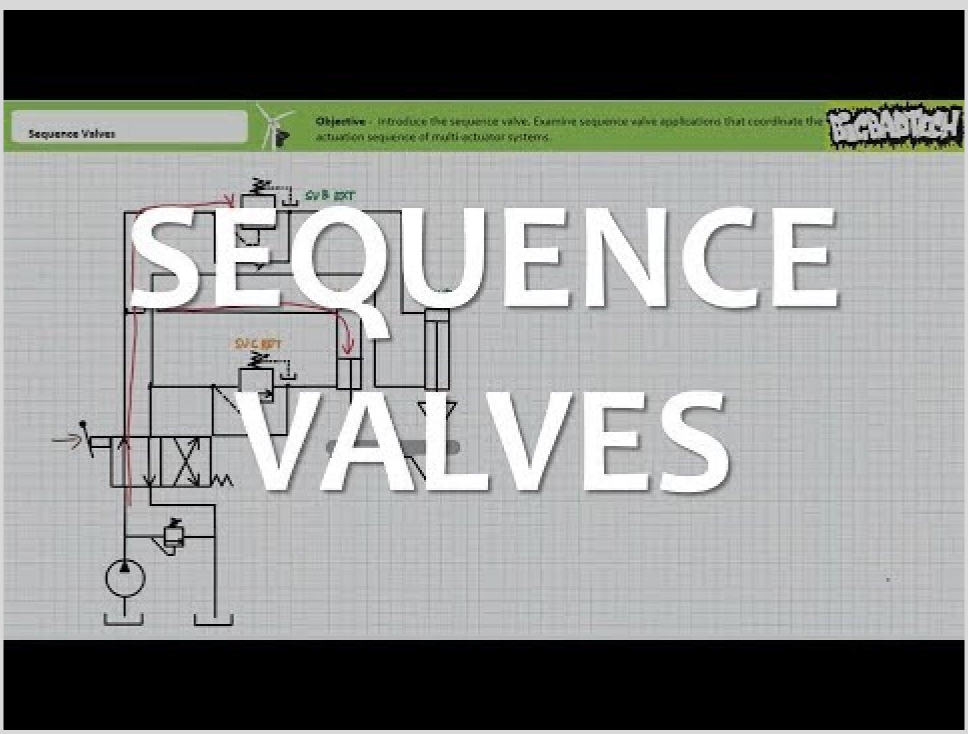
NOTE: first 13 entries are REVIEW of pressure control valve family

List the 5 main types of pressure control valves. Draw their associated schematic symbols.

Identify the 5 main characteristics used to classify pressure control valves.

Describe the purpose of a pilot line. Describe the schematic symbol.

Identify pressure control valves that make use of internal pilot lines on their primary, or input, port.



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Identify pressure control valves that make use of internal pilot lines on their secondary, or output, port.

Identify pressure control valves that make use of external pilot lines.

Identify pressure control valves that have a NC deactivated state.

Identify pressure control valves that have a NO deactivated state.

Identify pressure control valves that have a check valve bypass. Identify why a check valve bypass is necessary.

Identify pressure control valves that do not have a check valve bypass. Identify why a check valve bypass is not necessary.

Identify pressure control valves that have an internal drain. Identify why an external drain is not necessary.

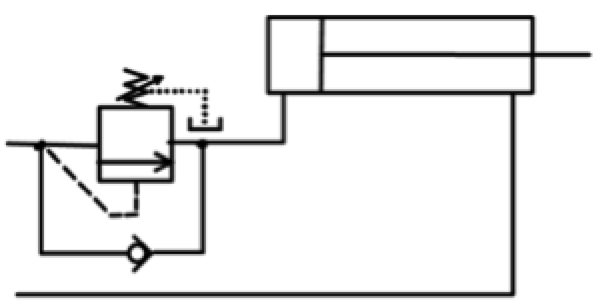
Identify pressure control valves that have an external drain. Identify why an external drain is necessary. Describe the schematic symbol for an external drain.

Identify customary locations for the 5 main pressure control valves.

Describe a sequence valve using the 5 main characteristics used to classify pressure control valves.

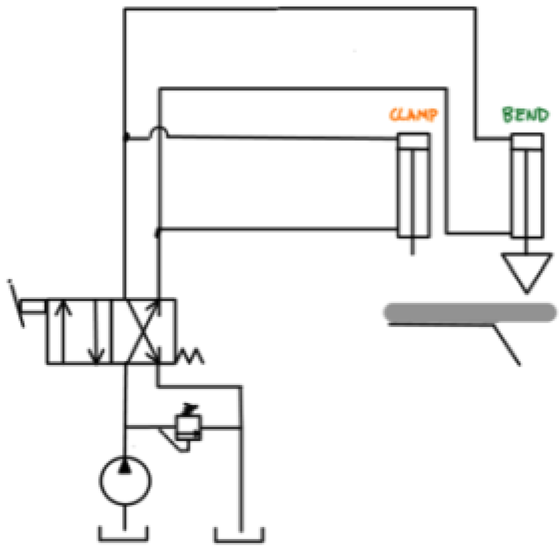
Identify functions of the P, S, D, and X ports for a sequence valve

Describe how the orientation of the check valve bypass influences this actuator's action.

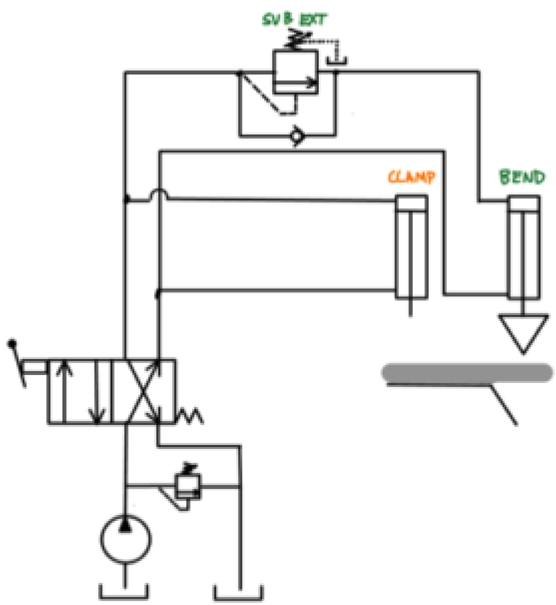


Describe the basic operation of a sequence valve.

Describe operation of this multi actuator clamp and bend hydraulic circuit.

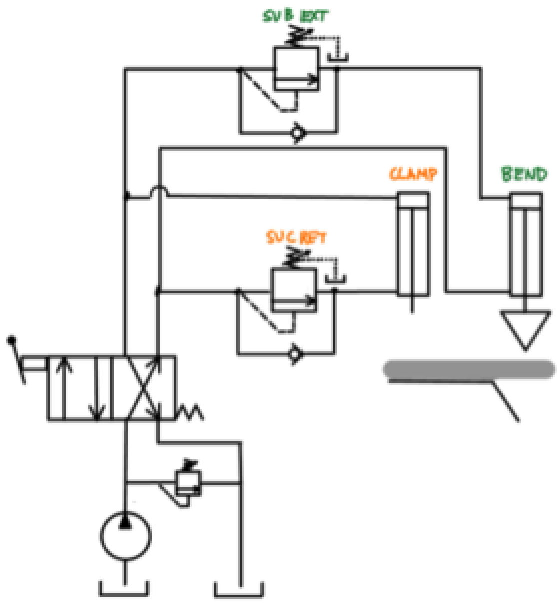


Describe the operation of this multi actuator hydraulic circuit making use of a sequence valve on the cap end of the bend cylinder. Assume the set value of the sequence valve is 400psi and the main pressure relief valve is set to 800psi.

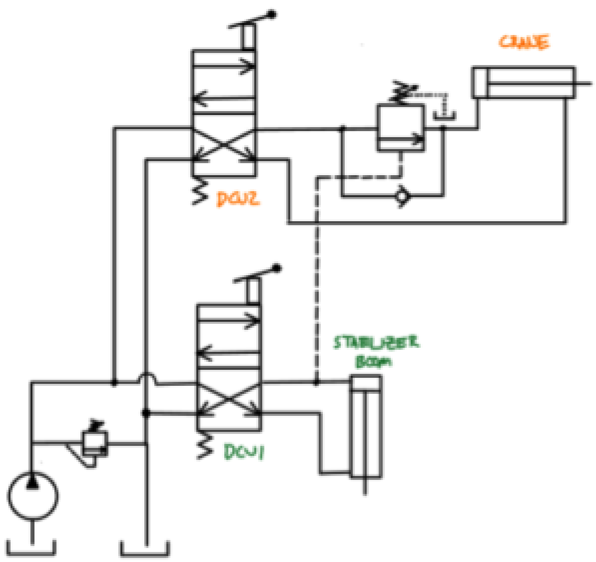


Identify potential disadvantages of coordinating actuation sequence using solely pressure input.

Describe the operation of this multi actuator hydraulic circuit making use of a sequence valve on the cap end of the bend cylinder and another sequence valve on the rod end of clamp cylinder.

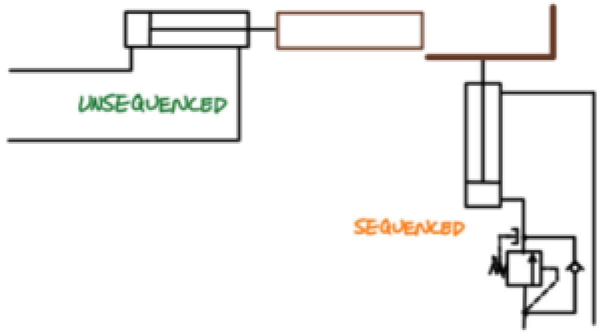


Describe the operation of this hydraulic circuit making use of a sequence valve with an external remote pilot used to coordinate two separate actuators (stabilizer boom and crane) using two independent directional control valves.

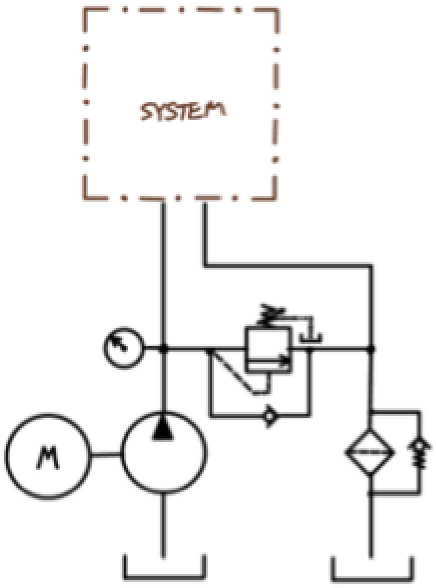


Differentiate between the operation of a normal versus a kick down style sequence valve.

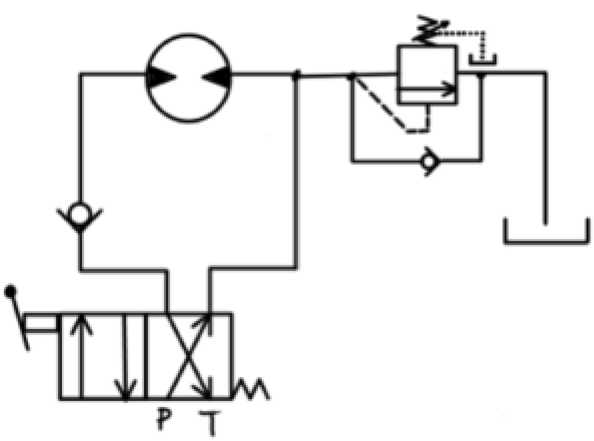
Describe the operation and advantages of this multi actuator hydraulic circuit making use of a kick down style sequence valve.



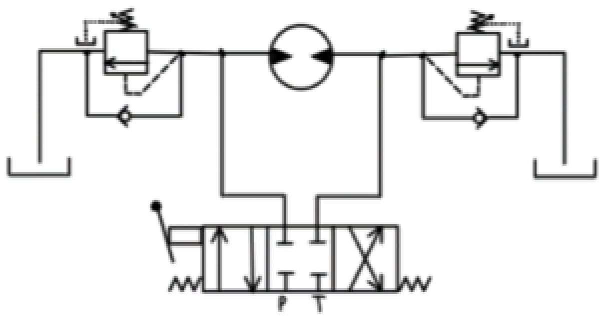
Describe how a sequence valve can present an advantage when used as a pressure relief valve in this hydraulic circuit.



Describe how this sequence valve and check valve can be used to brake a unidirectional hydraulic motor.



Describe how these two sequence valves can be used to brake a bidirectional hydraulic motor.



Describe how the set value of the above sequence valves influences the deceleration rate of the hydraulic motor.

Identify the purpose of a makeup check valve.

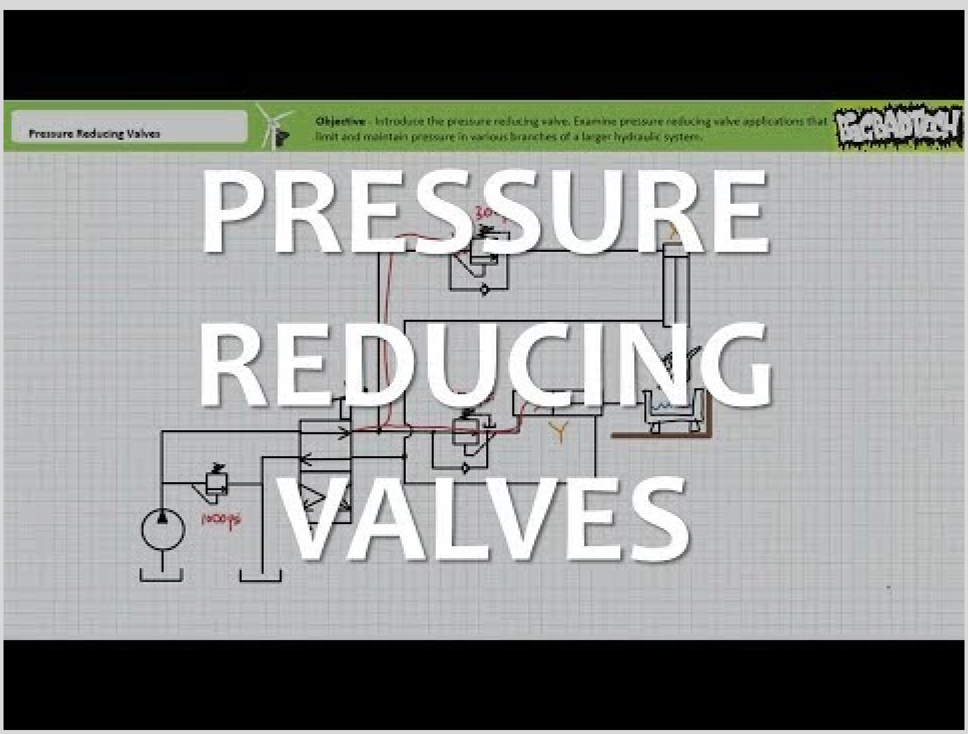
5.3 PRESSURE REDUCING VALVES

NOTE: first 13 entries are REVIEW of pressure control valve family

List the 5 main types of pressure control valves. Draw their associated schematic symbols. Identify the 5 main characteristics used to classify pressure control valves.

Describe the purpose of a pilot line. Describe the schematic symbol.

Identify pressure control valves that make use of internal pilot lines on their primary, or input, port.



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Identify pressure control valves that make use of internal pilot lines on their secondary, or output, port.

Identify pressure control valves that make use of external pilot lines.

Identify pressure control valves that have a NC deactivated state.

Identify pressure control valves that have a NO deactivated state.

Identify pressure control valves that have a check valve bypass. Identify why a check valve bypass is necessary.

Identify pressure control valves that do not have a check valve bypass. Identify why a check valve bypass is not necessary.

Identify pressure control valves that have an internal drain. Identify why an external drain is not necessary.

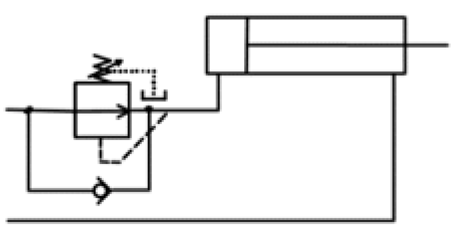
Identify pressure control valves that have an external drain. Identify why an external drain is necessary. Describe the schematic symbol for an external drain.

Identify customary locations for the 5 main pressure control valves.

Describe a pressure reducing valve using the 5 main characteristics used to classify pressure control valves.

Describe the basic operation of a pressure reducing valve.

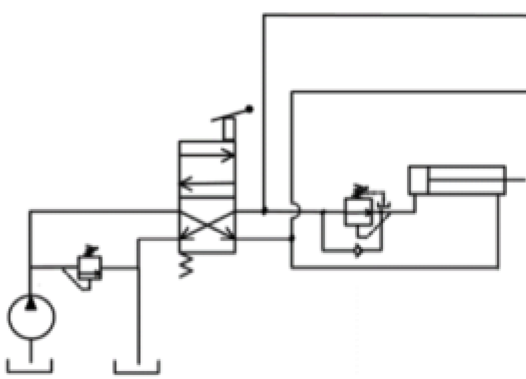
Describe how the orientation of the check valve bypass influences this actuator's action.



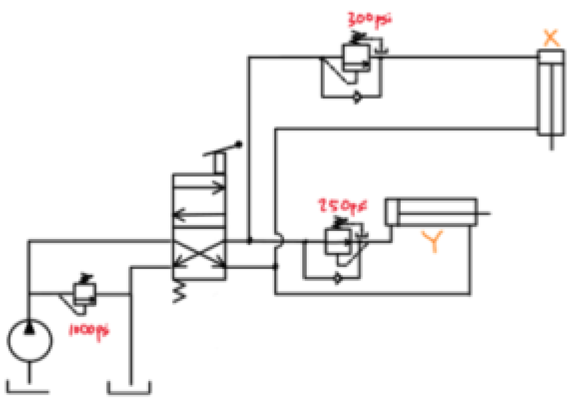
Identify functions of the P, R, and D ports for a pressure reducing valve

Differentiate between constant pressure type pressure reducing valves and constant reduction type pressure reducing valves.

Describe operation of this multi actuator hydraulic circuit making use of a pressure reducing valve.



Describe operation of this multi actuator hydraulic circuit making use of both a pressure reducing valve and a sequence valve.



Discuss how set values of the pressure reducing valve, sequence valve, and main pressure relief valve influence the proper functionality of the above system.

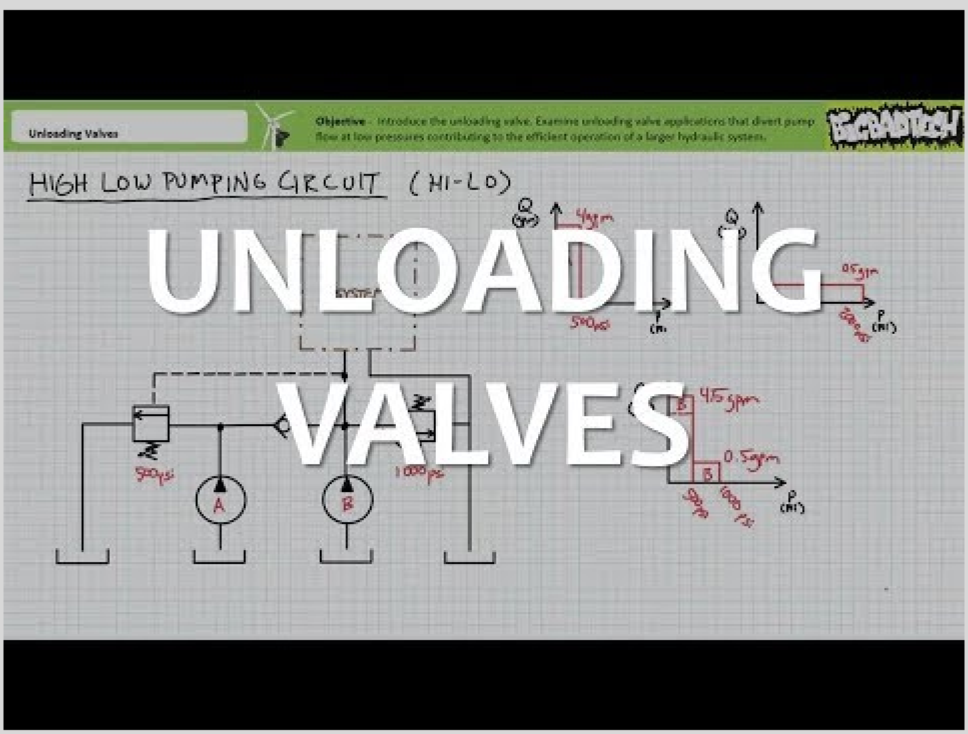
5.4 UNLOADING VALVES

NOTE: first 13 entries are REVIEW of pressure control valve family

List the 5 main types of pressure control valves. Draw their associated schematic symbols.
Identify the 5 main characteristics used to classify pressure control valves.

Describe the purpose of a pilot line. Describe the schematic symbol.

Identify pressure control valves that make use of internal pilot lines on their primary, or input, port.



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Identify pressure control valves that make use of internal pilot lines on their secondary, or output, port.

Identify pressure control valves that make use of external pilot lines.

Identify pressure control valves that have a NC deactivated state.

Identify pressure control valves that have a NO deactivated state.

Identify pressure control valves that have a check valve bypass. Identify why a check valve bypass is necessary.

Identify pressure control valves that do not have a check valve bypass. Identify why a check valve bypass is not necessary.

Identify pressure control valves that have an internal drain. Identify why an external drain is not necessary.

Identify pressure control valves that have an external drain. Identify why an external drain is necessary. Describe the schematic symbol for an external drain.

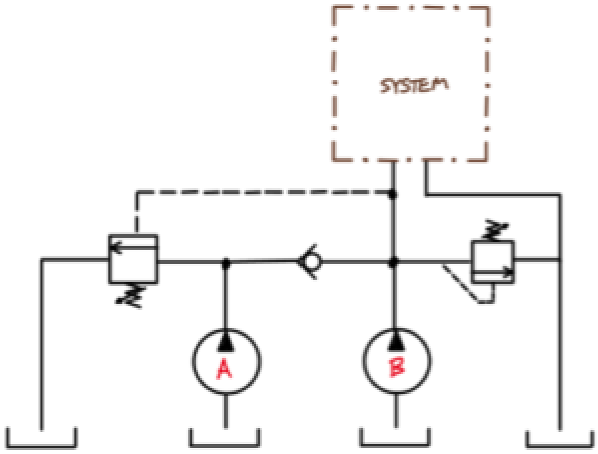
Identify customary locations for the 5 main pressure control valves.

Describe an unloading valve using the 5 main characteristics used to classify pressure control valves.

Describe the basic operation of an unloading valve.

Identify functions of the P, T, and X ports for an unloading valve

Describe operation of this high-low pumping circuit making use of an unloading valve. Assume pump A is high flow/low pressure and pump B is low flow/high pressure. Assume set value of unloading valve is half that of the main pressure relief valve. Identify the purpose of the check valve between pump A and B.

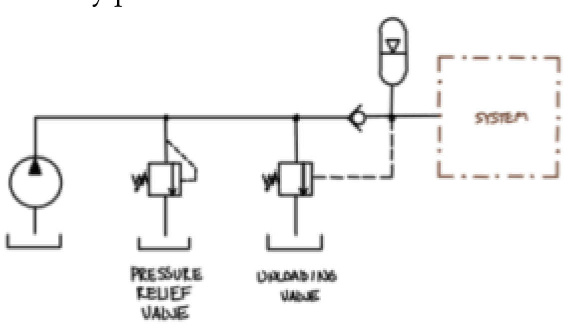


When pressure in the external pilot line reaches the set value of the unloading valve identify the magnitude of the pressure differential across the unloading valve when it opens.

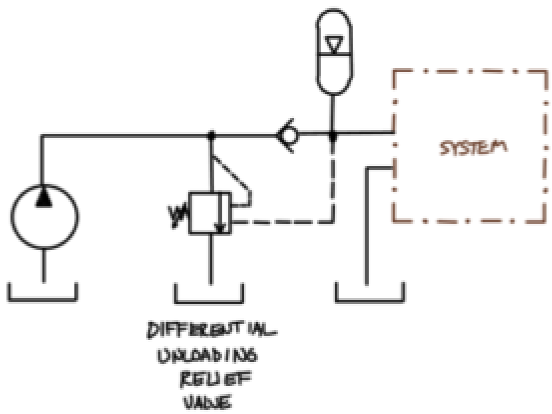
Identify 2 general applications of a high-low pumping circuit.

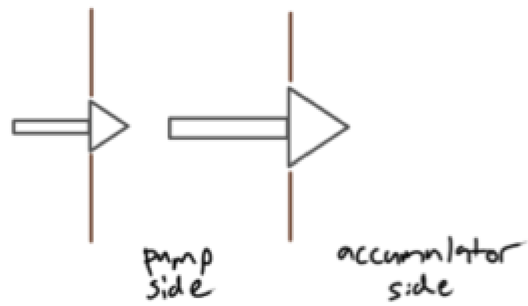
Compare and contrast regenerative extension with high-low pumping circuits making use of an unloading valve.

Describe operation of this hydraulic circuit making use of an unloading valve and an accumulator. Identify problems with this circuit when the unloading valve is pilot operated.

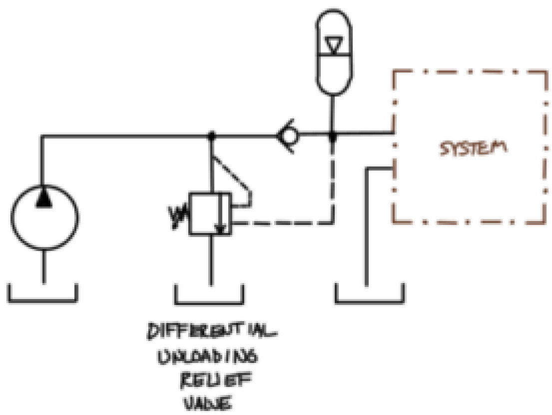


Use this hydraulic circuit and diagram of two pilot darts to describe the general operation of a differential unloading relief valve.



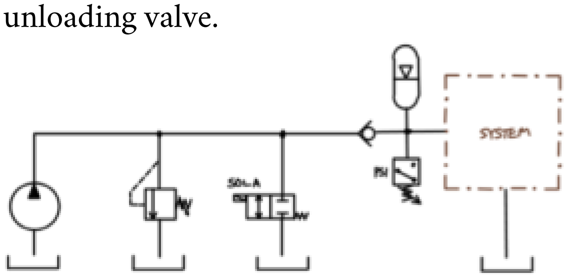


Describe the operation of this hydraulic circuit making use of a differential unloading relief valve and an accumulator.

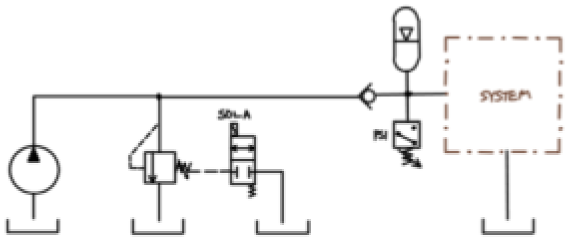


Identify the source of the differential range experienced during the operation of differential unloading relief valve

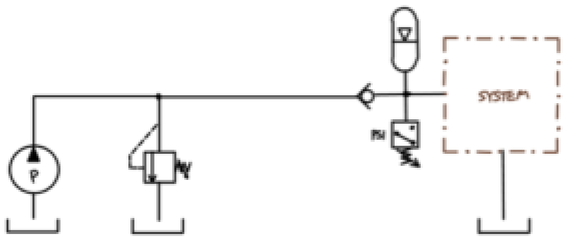
Describe how this hydraulic circuit making use of a pressure switch replicates the function of an unloading valve.



Describe how this hydraulic circuit making use of a pressure switch replicates the function of an unloading valve.



Describe how this hydraulic circuit making use of a pressure switch that turns off the prime mover when pressure is in excess of the set value contributes towards efficient operation.



5.5 COUNTER BALANCE VALVES

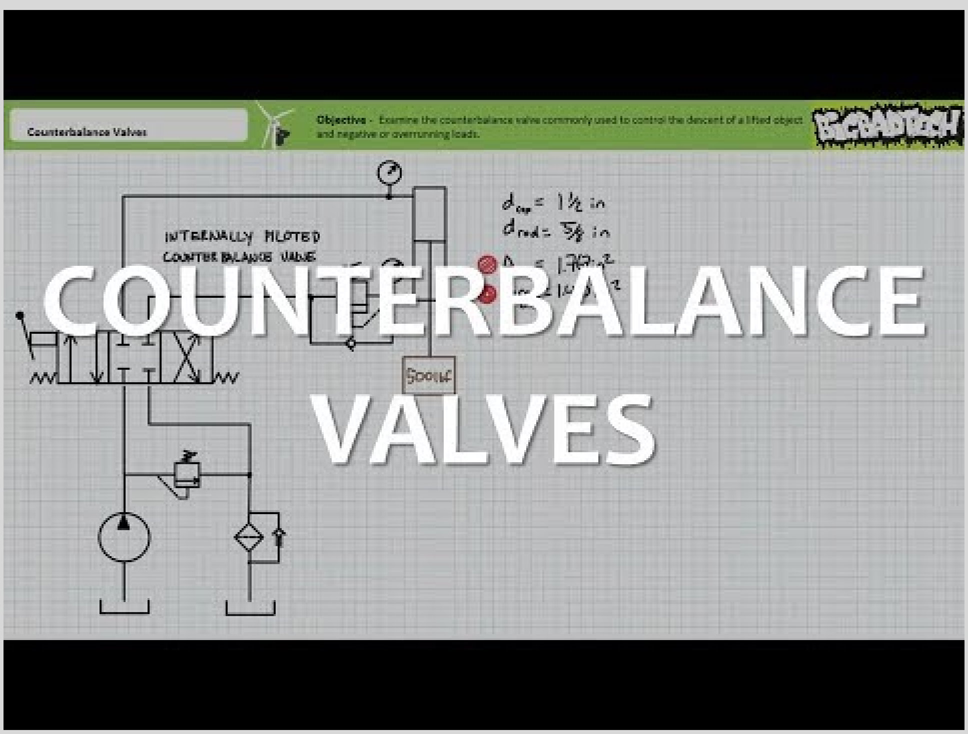
NOTE: first 13 entries are REVIEW of pressure control valve family

List the 5 main types of pressure control valves. Draw their associated schematic symbols.

Identify the 5 main characteristics used to classify pressure control valves.

Describe the purpose of a pilot line. Describe the schematic symbol.

Identify pressure control valves that make use of internal pilot lines on their primary, or input, port.



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Identify pressure control valves that make use of internal pilot lines on their secondary, or output, port.

Identify pressure control valves that make use of external pilot lines.

Identify pressure control valves that have a NC deactivated state.

Identify pressure control valves that have a NO deactivated state.

Identify pressure control valves that have a check valve bypass. Identify why a check valve bypass is necessary.

Identify pressure control valves that do not have a check valve bypass. Identify why a check valve bypass is not necessary.

Identify pressure control valves that have an internal drain. Identify why an external drain is not necessary.

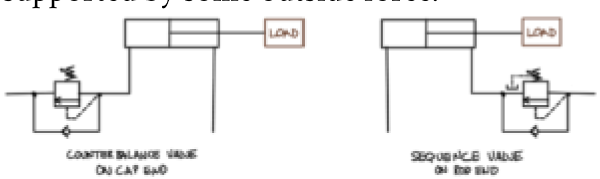
Identify pressure control valves that have an external drain. Identify why an external drain is necessary. Describe the schematic symbol for an external drain.

Identify customary locations for the 5 main pressure control valves.

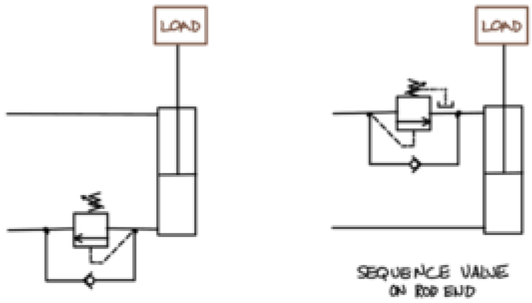
Describe a counterbalance valve using the 5 main characteristics used to classify pressure control valves.

Describe the basic operation of a counterbalance valve.

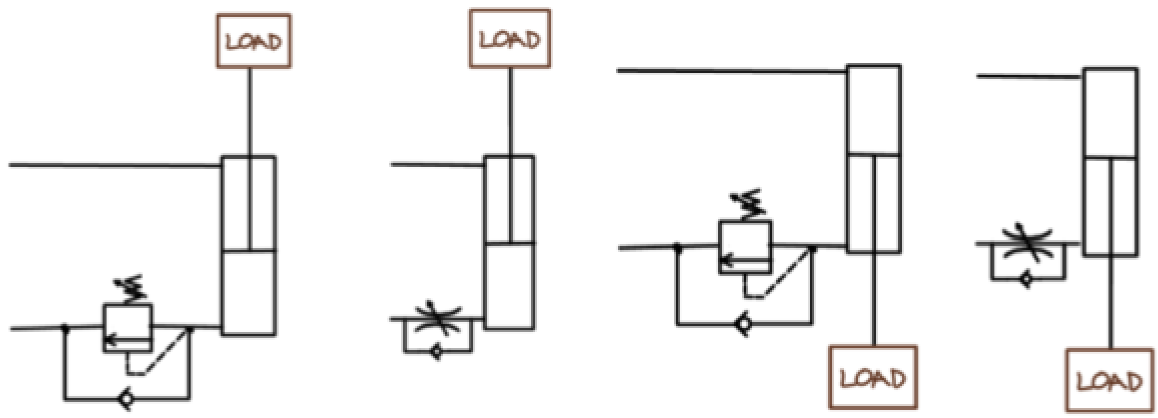
Compare the operation of these two hydraulic circuits when the laterally manipulated load is fully supported by some outside force.



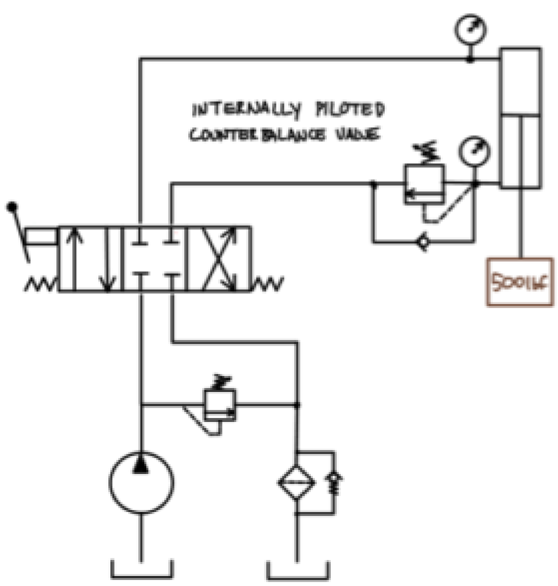
Compare the operation of these two hydraulic circuits when the vertically manipulated load is influenced by some outside force like gravity.



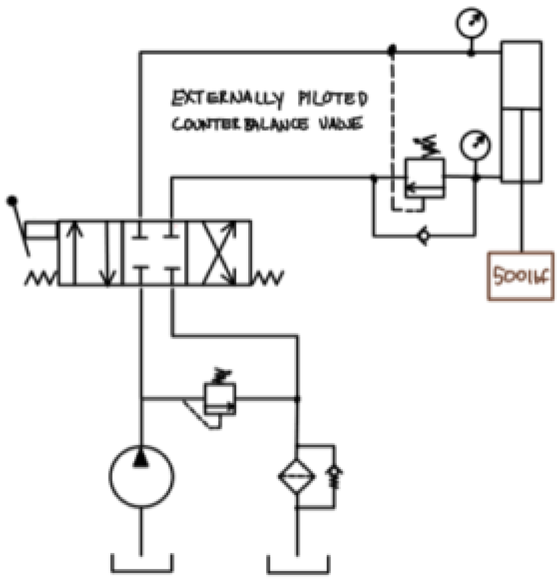
Compare and contrast these circuits making use of counterbalance valves and meter out flow control circuits.



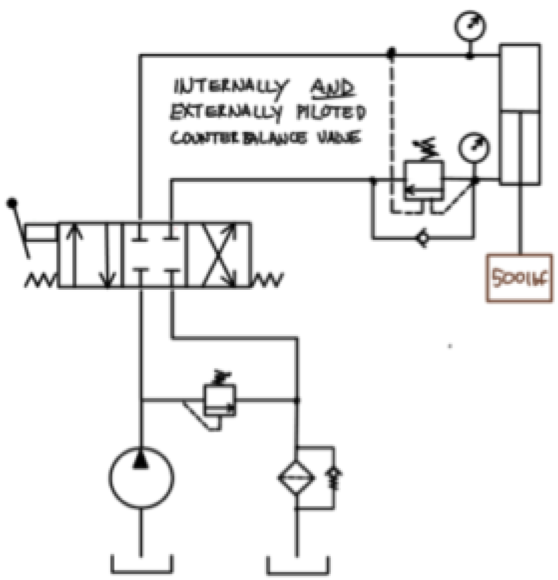
Describe the operation of this circuit making use of an internally piloted counterbalance valve. Comment on the maximum downwards force exerted by this system.



Describe the operation of this circuit making use of an externally piloted counterbalance valve used to lower a heaving mold, forming piece or platen. Comment on the behavior of this system during lowering and the maximum downwards force it is capable of generating.



Describe the operation of this circuit making use of an internally and externally piloted counterbalance valve used to lower a heaving mold, forming piece or platen. Comment on the behavior of this system during lowering and the maximum downwards force it is capable of generating.



Comment on observed behavior of hydraulic systems for different counterbalance valve set values and loads.

Compare and contrast the general behavior of internal, external, and internal and externally piloted counterbalance valves.

UNIT 6: ELECTRICALLY CONTROLLED HYDRAULIC SYSTEMS

6.1 INTRODUCTION TO ELECTRICALLY CONTROLLED SYSTEMS

List basic applications of electrically controlled systems.

Give examples of inputs, outputs, and internal components in an electrically controlled system

Give examples of potential faults in an electrically controlled system

Differentiate between control/pilot signal and power/primary signals

Describe the purpose of separating pilot and primary

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Describe the purpose of a control transformer

Describe the similarities and differences between a contactor and a solenoid operated valve

Describe ladder logic diagrams and indicate the advantages of ladder logic

List the general rules of ladder logic

Differentiate between switches and sensors

Describe the purpose of a transducer

Differentiate between manual and mechanical/automatic switches and give examples of each

Describe span/hysteresis/override

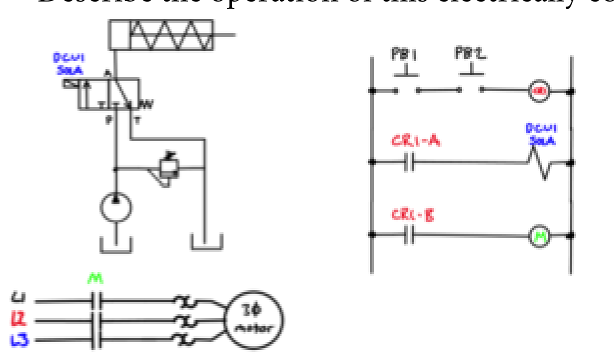
Differentiate between hard wired relay based ladder logic and PLCs and discuss the advantages of PLCs

Describe a control relay

Describe the AND function

Describe the OR function

Describe the operation of this electrically controlled system.



Discuss general troubleshooting procedures for electrically controlled systems.

6.2 CONTROL RELAYS

Describe a control relay and identify its purpose in an electrically controlled system
Describe the similarities and differences between a contactor and a control relay

Describe the keyed base associated with an ice cube relay and identify advantages of using keyed bases.

Draw the NEMA schematic symbol for a control relay with a coil, two NO SPST contacts, and two NC SPST contacts

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Draw the NEMA schematic symbol for a control relay with a coil and two SPDT C form/transfer contacts

Draw the IEC schematic symbol for a control relay with a coil and two SPDT C form/transfer contacts

Number the terminals of the above control relays

Describe a solenoid and discuss its function and purpose inside a control relay

Describe the components of a control relay and identify their purpose

Define and differentiate between rated voltage, pickup voltage, hold in voltage, and dropout voltage

Describe why a 120V AC coil cannot be used with 24V DC

Differentiate between inrush and sealed in current

Describe why a means of voltage spike suppression must be used for certain coils

Discuss points of inspection and maintenance procedures for control relays

Describe the purpose of bifurcated or split contacts in a control relay

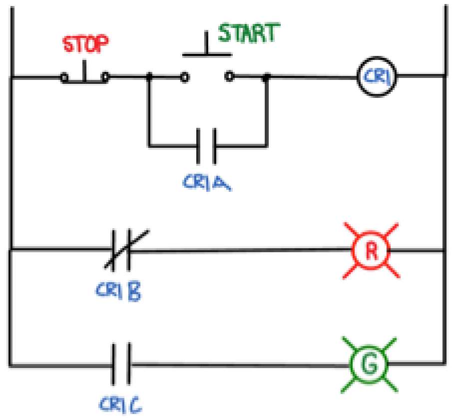
Differentiate between make, break, and continuous current carrying capacity

Describe a solid state relay in general terms

Discuss the PLC and its relation to the control relay (comment at 25:40)

BONUS: Describe the behavior of this ladder logic diagram making use of a control relay and its associated contacts for the following sequence of actions:

both STOP and START in their deactivated state
operator presses and releases START
operator presses and releases STOP


STOP
START
CR1
CR1A
R
CR1B
G
CR1C

6.3 SOLENOID OPERATED VALVES

Describe a solenoid operated valve and identify its purpose in an electrically controlled system

Describe the similarities and differences between a solenoid operated valve and a contactor

Differentiate between the terms NO and NC as applied to electrical switches and valves

Draw the hydraulic schematic symbol for a spring offset, 2 position, four way, solenoid operated valve with a cross connect in the deactivated state and a straight through in the activated state

Draw the electrical schematic symbol for the coil of a solenoid operated valve

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Describe a solenoid and discuss its function and purpose inside a solenoid operated valve

Describe the purpose of the drain port inside a solenoid operated hydraulic valve

Describe the purpose of a manual override for a solenoid operated valve and draw its schematic symbol

Differentiate between the applications of closed, tandem, float, and open center 3 position valves

Describe the problems associated with the simultaneous activation of both solenoids for a double solenoid valve and discuss the means of preventing this from occurring

Differentiate between electrically held and detented solenoid operated valves

Describe the components of a typical solenoid operated valve and identify their purpose

Define and differentiate between rated voltage, pickup voltage, hold in voltage, and dropout voltage

Describe why a 120V AC coil cannot be used with 24V DC

Differentiate between inrush and sealed in current

Describe why a means of voltage spike suppression must be used for certain coils

Discuss points of inspection and maintenance procedures for solenoid operated valves

Describe shift limit characteristics for solenoid operated valves

Define both "rated flow" and "maximum inlet pressure" for solenoid operated valves

Describe both the "pressure drop for different flow rates" and "operating limits" performance curve for solenoid operated valves

Describe leakage, fluid compatibility, and required filtration specifications for solenoid operated valves

Describe a variable solenoid operated valve and discuss its application for a hydraulic system

Describe a piggyback valve and discuss its application for a hydraulic system

6.4 SWITCHES IN ELECTRICALLY CONTROLLED SYSTEMS

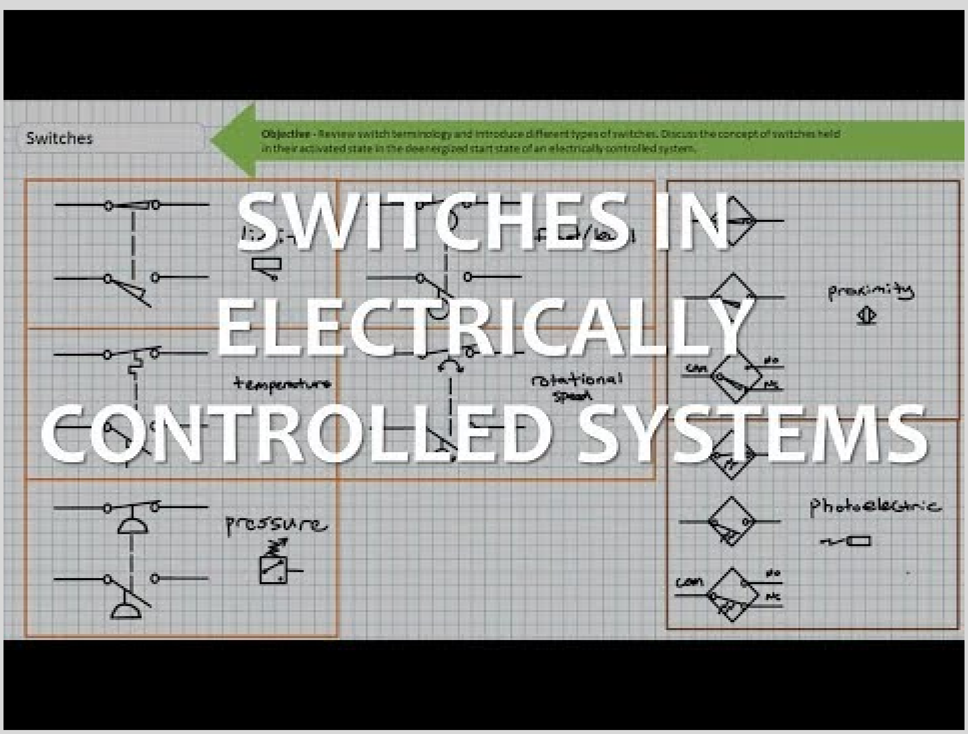
Compare and contrast switches and sensors/transducers.

Discuss observed properties of closed and open switches with respect to resistance and current.

Define the terms pole and throw.

Draw the schematic symbol for the following switches: SPST, SPDT, SPTT-CO, DPST, DPDT, 3PST

Define the term electrical isolation.



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Define the term actuation and differentiate between manually and mechanically/automatically actuated switches.

Define making and breaking.

Differentiate between the deactivated state and activated state of a switch.

Identify in which state switches are illustrated in schematics.

Differentiate between the deenergized state and energized state of a load.

Differentiate between NC and NO switches in their deactivated and activated states. Identify resistance and current carrying ability in both states.

Describe advantages of a double break switch over a single break switch.

Define a mechanical interlock.

Differentiate between momentary and maintained contact switches.
Draw the schematic symbol for a maintained contact ESTOP button.

Draw the schematic symbol for a momentary contact break-make pushbutton package consisting of a mechanically interlocked set of NC and NO contacts.

Identify the purpose of an auxiliary contact block.

Draw the schematic symbol for a maintained contact 3 position selector switch with two associated contacts A and B. Assume contact A is closed in position 1, both contacts are open in position 2, contact B is closed in position 3. Draw the target table/contact chart illustrating this functionality.

Draw the schematic symbol for a drum or cam switch used to reverse the rotational direction of an industrial 3 phase AC motor. Draw the target table/contact chart illustrating this functionality.

Draw the ladder logic representation of a limit switch consisting of a mechanically interlocked pair of NC and NO contacts. Draw the hydraulic schematic representation of a limit switch.

Describe the concept of switches being held in their activated state using both the gravity and arrow convention. Draw examples of each. Identify the preferred method.

Draw the schematic symbol for a temperature switch consisting of a mechanically interlocked pair of NC and NO contacts.

Draw the ladder logic representation of a pressure switch consisting of a mechanically interlocked pair of NC and NO contacts. Draw the hydraulic schematic representation of a pressure switch.

Differentiate between the set and reset value of a pressure switch. Identify why this is a desirable trait.

Draw the ladder logic representation of a float switch consisting of a mechanically interlocked pair of NC and NO contacts.

Draw the ladder logic representation of a rotational speed (plugging/anti-plugging) switch consisting of a mechanically interlocked pair of NC and NO contacts.

Differentiate between electromechanical and solid state switches, give examples of each.

Draw the ladder logic representation of a proximity switch consisting of a SPDT transfer contact. Draw the hydraulic schematic representation of a proximity switch.

Identify the advantages and disadvantages of proximity switches compared to limit switches.

Differentiate between inductive and capacitive proximity switches.

Define the terms operating point, release point, and hysteresis with respect to a proximity switch.

Draw the ladder logic representation of a photoelectric switch consisting of a SPDT transfer contact. Draw the hydraulic schematic representation of a photoelectric switch.

Differentiate between through beam scanners, retroreflective scanners, and diffuse scanners. Identify when a polarized retroreflective scanner would be used.

6.5 BASIC LADDER LOGIC

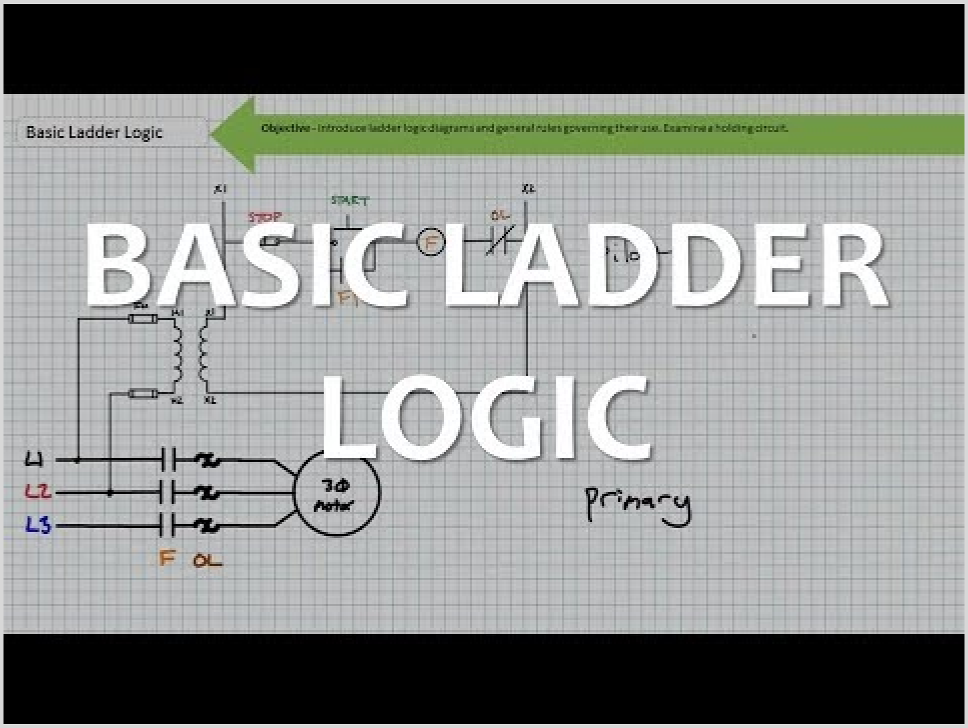
Describe ladder logic diagrams and indicate the advantages of ladder logic

Differentiate between control/pilot signal and power/primary signals

Describe the purpose of separating pilot and primary

List the 11 basic rules of ladder logic as discussed in this lecture

Describe the behavior of this system for all possible combinations of input conditions.



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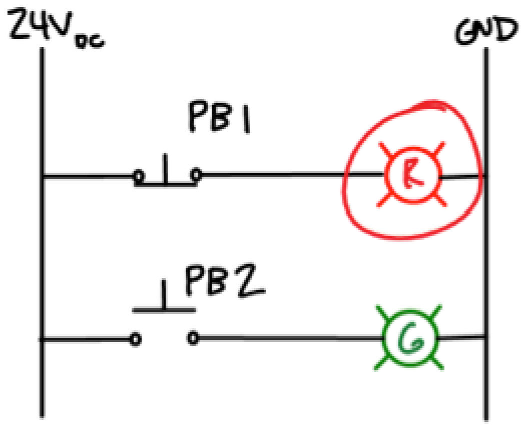
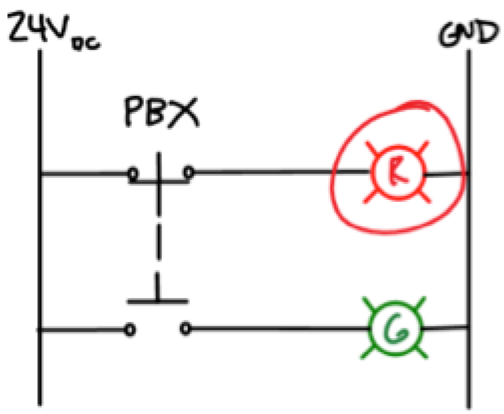
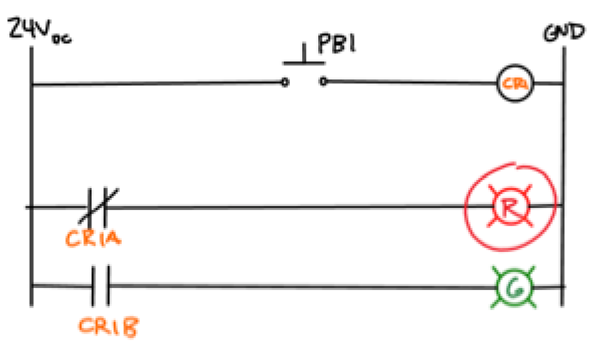


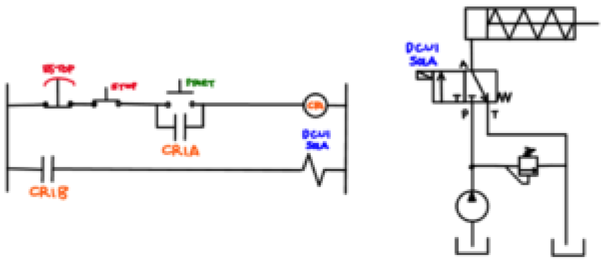
Describe the behavior of this system for all possible combinations of input conditions.



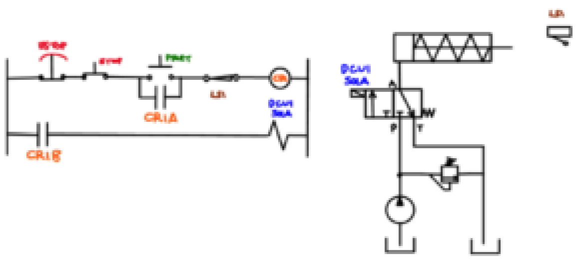
Describe the behavior of this system for all possible combinations of input conditions.



Describe the behavior of this electrically controlled hydraulic system. Define the purpose of the holding circuit.



Describe the behavior of this electrically controlled hydraulic system incorporating a limit switch.

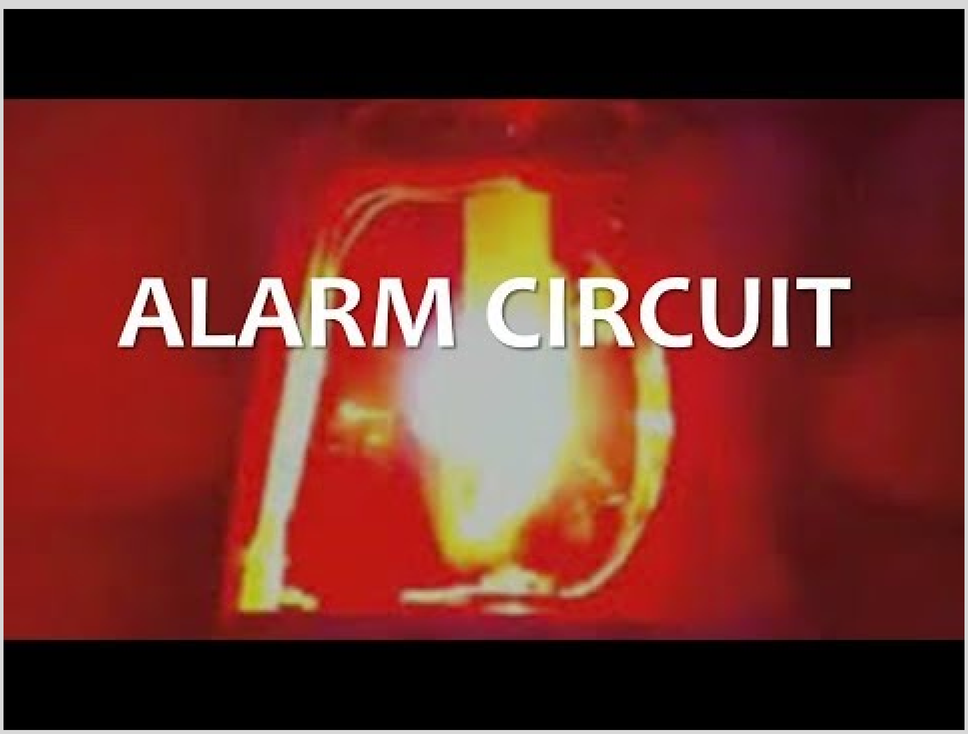


Compare and contrast hard wired relay based ladder logic with a programmable logic controller.

6.6 ALARM CIRCUIT

Discuss the significance of contacts being held in their activated state by a deenergized system.

Describe the behavior of this alarm system.



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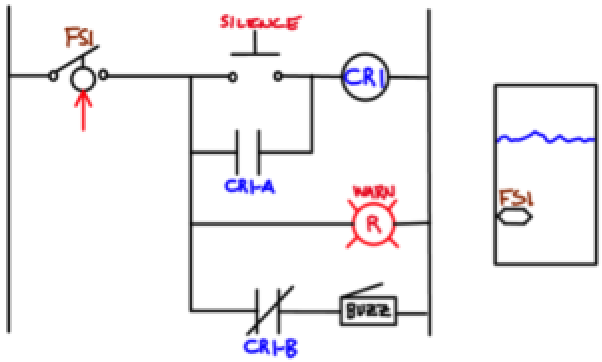


Describe the behavior of the above circuit if a NO pressure switch and a NO temperature switch are placed in parallel with the NC-HO FS1.

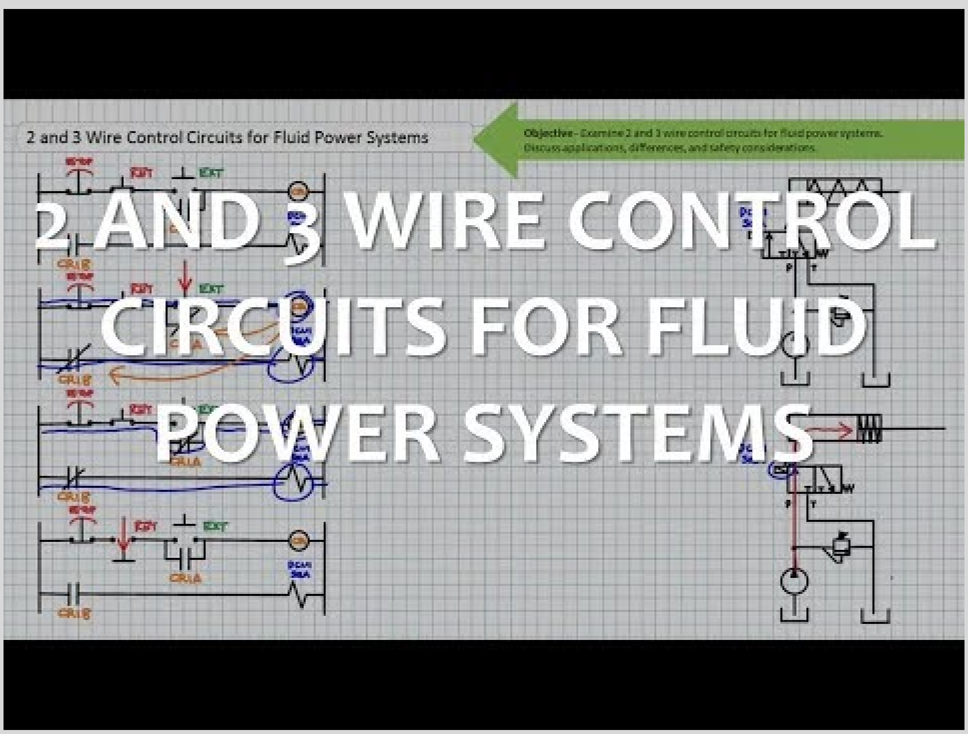
Describe the behavior of the above circuit if the NC-HO FS1 at the top of the tank is replaced with a NO FS1 at the bottom of a tank.

6.7 2 AND 3 WIRE CONTROL CIRCUITS FOR FLUID POWER SYSTEMS

Describe a 2 wire control circuit.

Describe a 3 wire control circuit.

Describe the behavior of this 2 wire control circuit.



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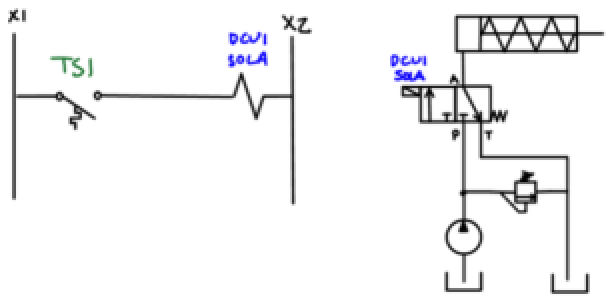
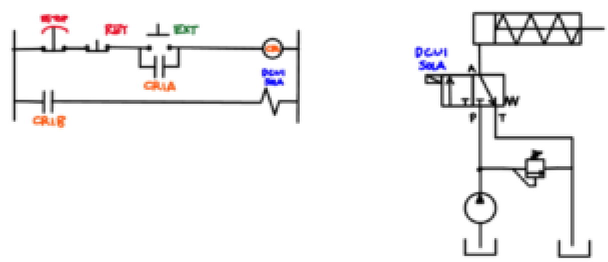


Describe the behavior of a 2 wire control circuit if it ever experienced sudden loss and restoration of pilot or primary power.

Describe the behavior of this 3 wire control circuit.



Describe the behavior of a 3 wire control circuit if it ever experienced sudden loss and restoration of pilot or primary power.

Differentiate between low or no voltage <u>release</u> circuits and low or no voltage <u>protection</u> circuits

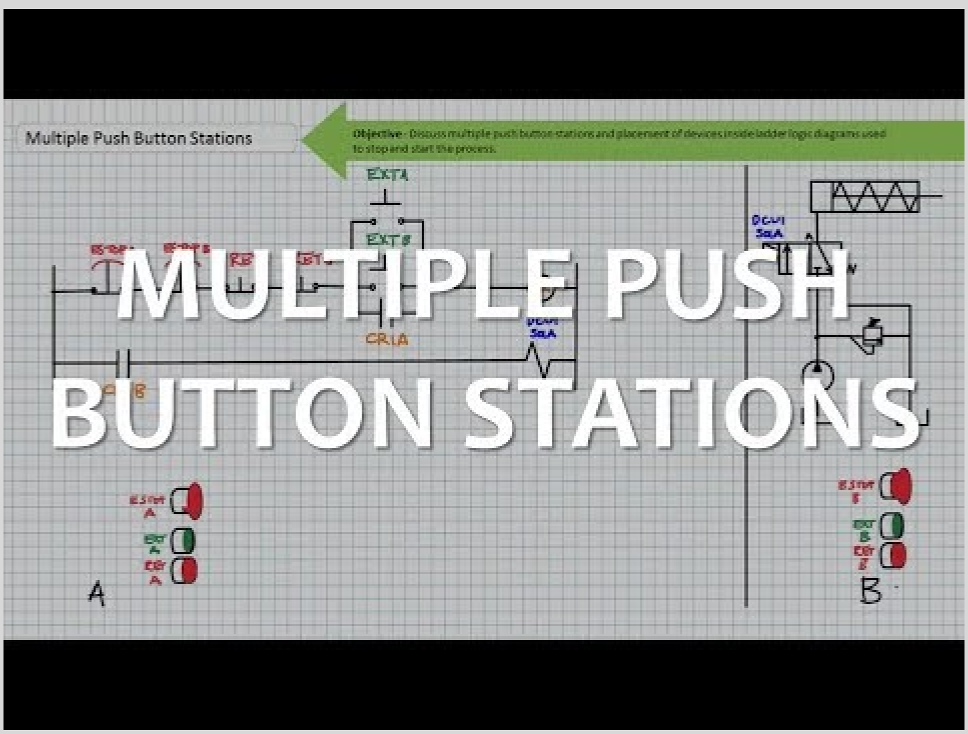
Comment on the utility of lock out and tag out procedures.

6.8 MULTIPLE PUSH BUTTON STATIONS

Identify the advantages of multiple push button stations.

Generalize the placement of input devices intended to stop the process and devices intended to start the process.

Describe the behavior of this electrically controlled hydraulic system making use of multiple pushbutton stations.



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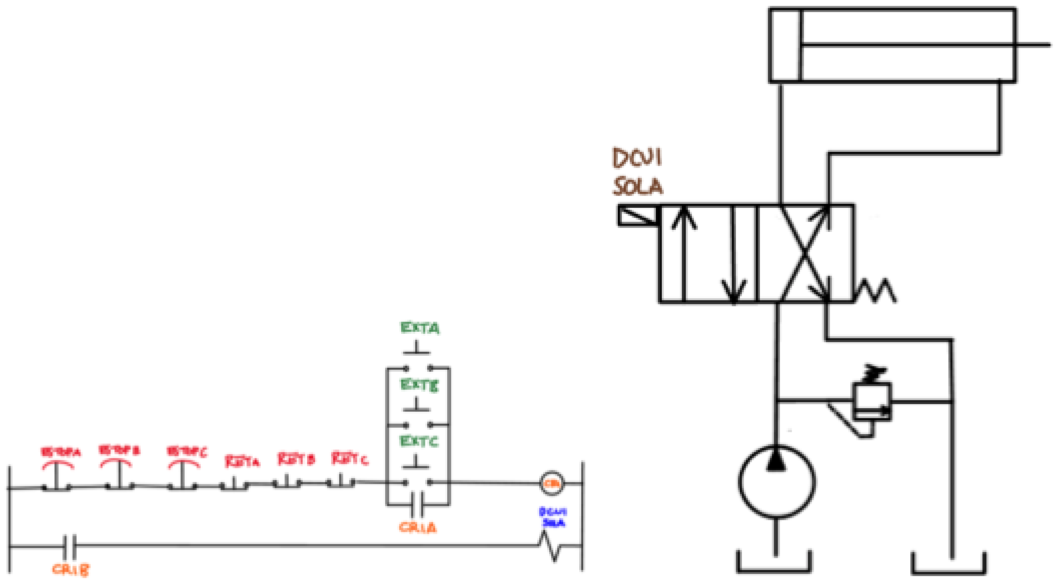
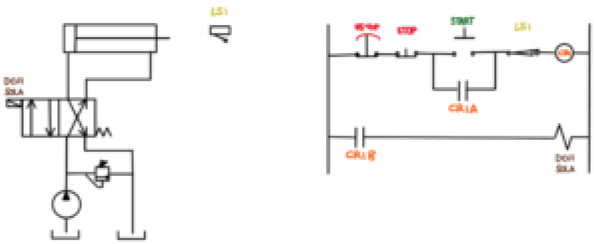


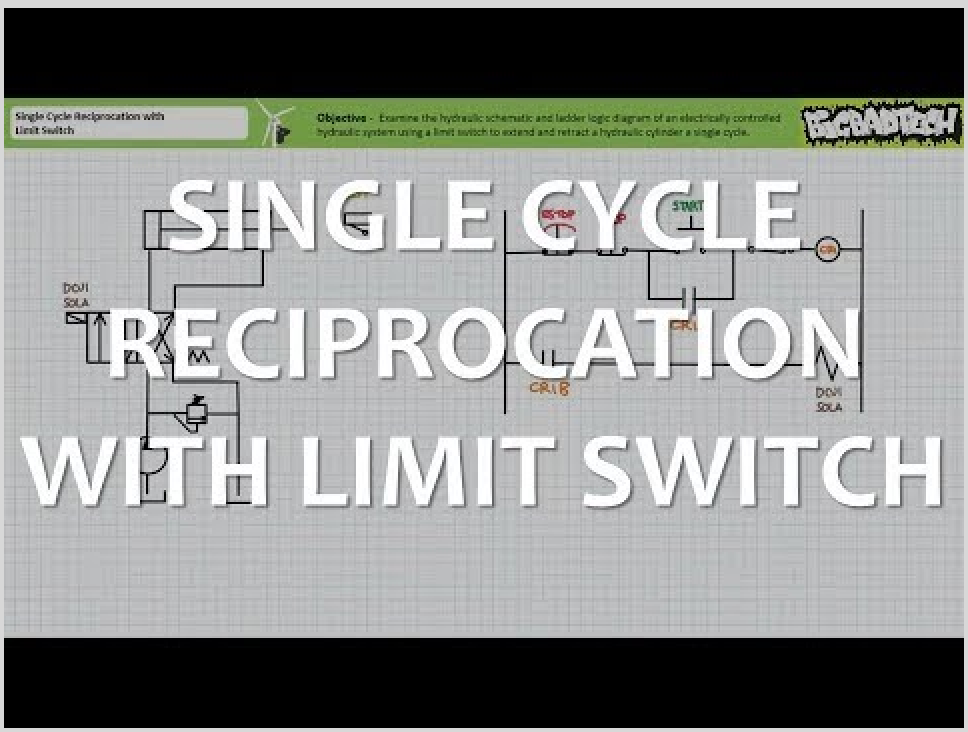
Comment on the observed behavior of a system making use of multiple push button stations if any one of the ESTOPs was accidentally triggered.

6.9 SINGLE CYCLE RECIPROCATION WITH LIMIT SWITCH

Define a single cycle reciprocation action.

Describe the behavior of this electrically controlled hydraulic circuit.





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Discuss the influences of inadvertent opens at various points in ladder logic diagram.

Discuss the influences of the loss of primary hydraulic power.

Comment on the influences of an improperly set pressure relief valve.

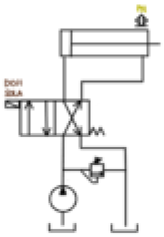
Discuss the influences of an activated ESTOP.

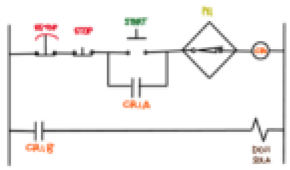
Discuss the influences of a limit switch inadvertently triggered by some errant object.

Discuss the influences of an improperly positioned limit switch that fails to activate.

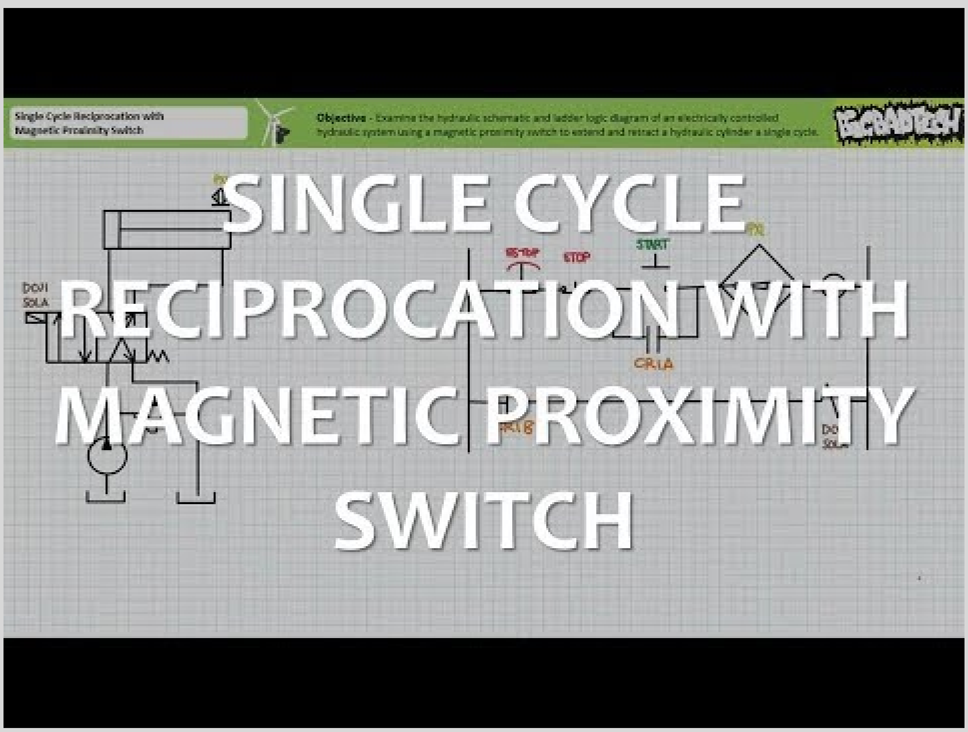
6.10 SINGLE CYCLE RECIPROCATION WITH MAGNETIC PROXIMITY SWITCH

Describe the behavior of this electrically controlled hydraulic circuit.





Discuss the influences of loss of power to magnetic proximity switch.



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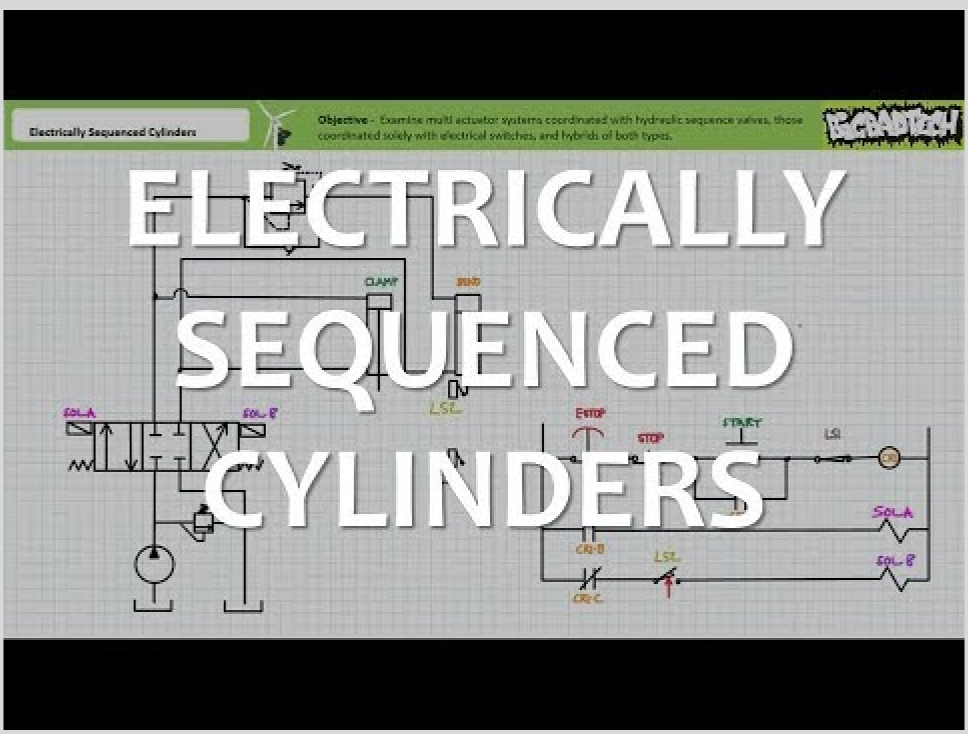
Discuss the influences of an errant metal object near the magnetic proximity switch.

6.11 ELECTRICALLY SEQUENCED HYDRAULIC CYLINDERS

Describe the operation of this manually sequenced clamp and bend hydraulic circuit. Discuss any disadvantages of this system.



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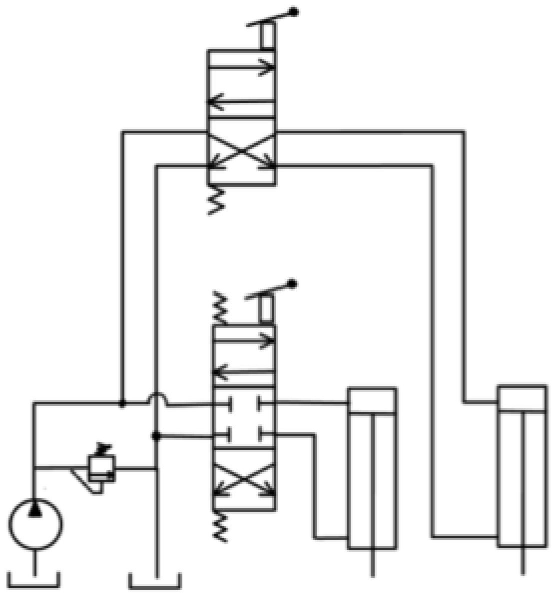
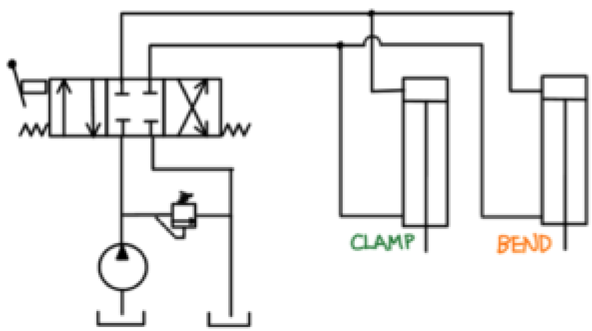
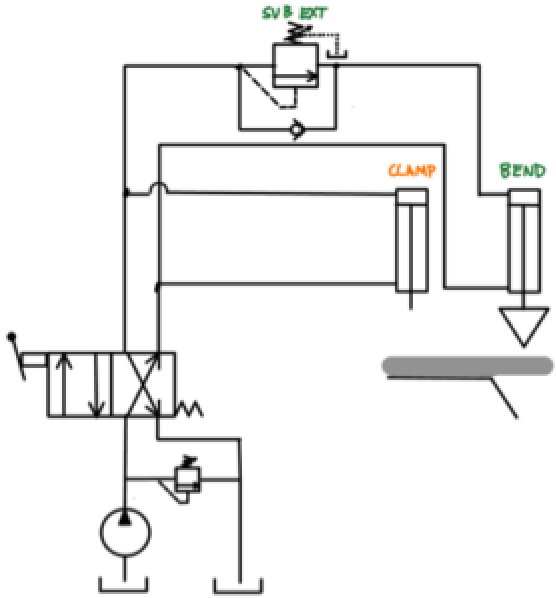


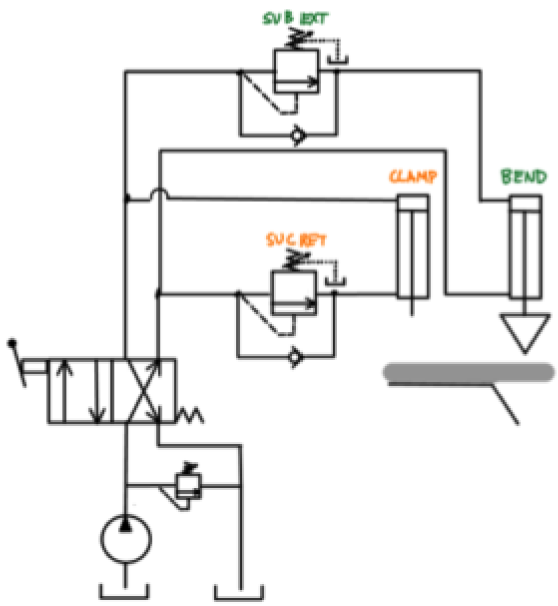
Describe the operation of this clamp and bend hydraulic circuit making use of a single directional control valve. Discuss any disadvantages of this system.



Describe the operation of this multi actuator hydraulic circuit making use of a sequence valve on the cap end of the bend cylinder. Assume the set value of the sequence valve is 400psi and the main pressure relief valve is set to 800psi.

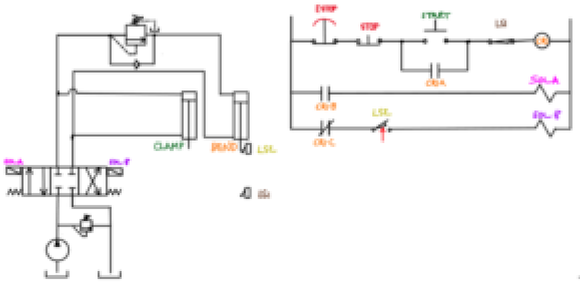


Describe the operation of this multi actuator hydraulic circuit making use of a sequence valve on the cap end of the bend cylinder and another sequence valve on the rod end of clamp cylinder.



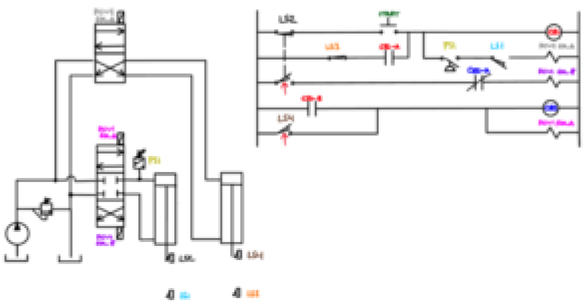
Identify potential disadvantages of coordinating actuation sequence using solely pressure input.

Describe the operation of this electrically controlled clamp and bend hydraulic system.



Describe what would occur if the clamp cylinder ever lagged significantly behind the bend cylinder during retraction.

Describe the operation of this electrically sequenced clamp and bend hydraulic system.



Discuss any advantages exhibited by the above purely electrically sequenced clamp and bend system compared to those making use of hydraulic sequence valves.