Example

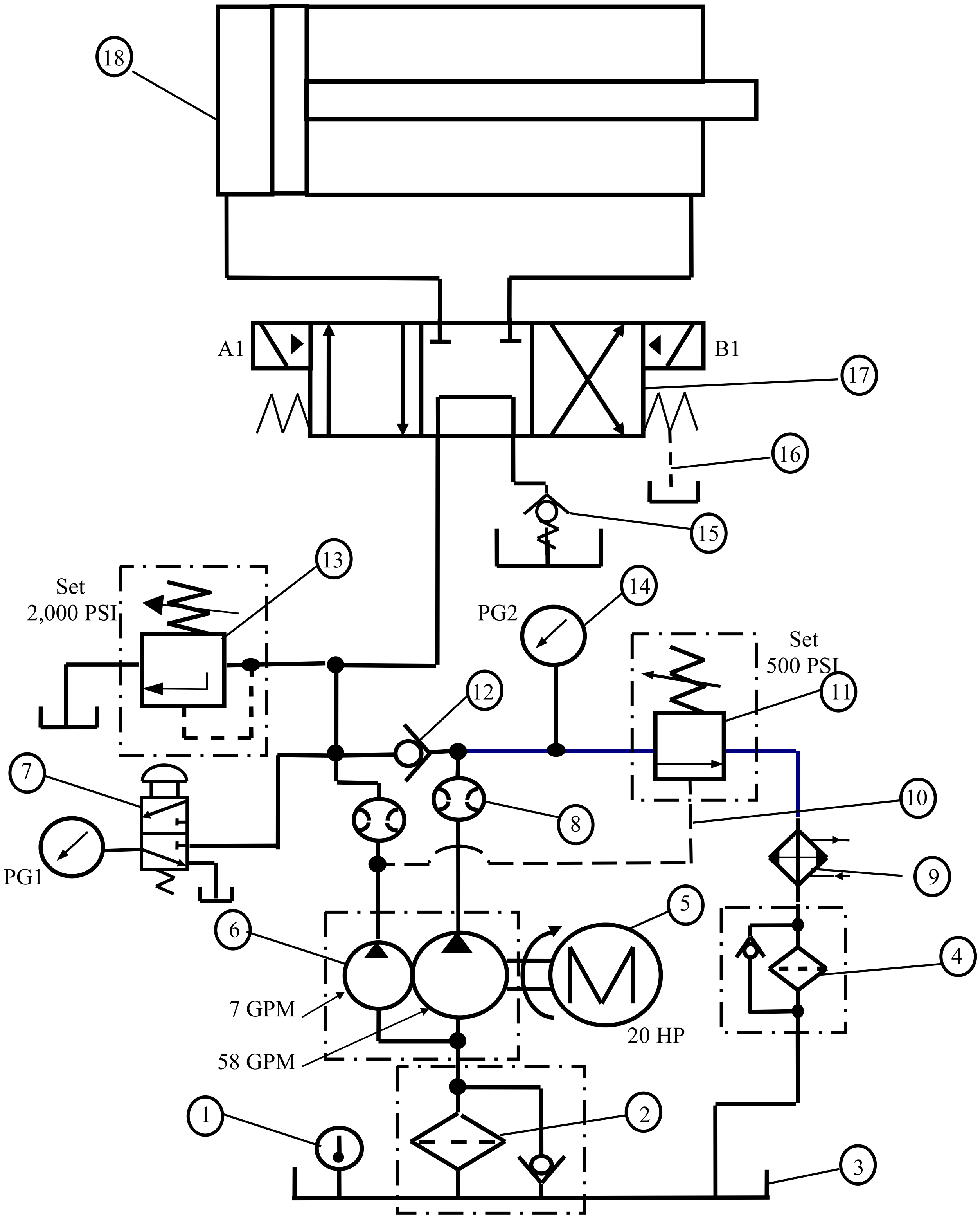
Fluid Power

Circuits

To Enhance Symbol Reading Skills
To Work On Circuit Reading Skills

With Answers

HI – LO Pump Circuit



Identify the Components

1. Temperature Gauge
2. Suction Strainer
3. Reservoir (Tank)
4. Return Filter
5. Electric Motor
6. Double Fixed Volume Pump
7. Gauge Isolator Valve
8. Flow Meter
9. Water Cooled Heat Exchanger
10. Pilot Line
11. Remote Piloted Unloading Valve
12. Isolation Check Valve
13. Pilot Operated Relief Valve
14. Pressure Gauge
15. Back Pressure Check Valve
16. Drain Line
17. 4-Way, Three Position, Double Solenoid Pilot Operated, Spring Centered, Tandem Center, Directional Control Valve
18. Double Acting, Single Rod End Cylinder

Circuit Operation

At rest both Pumps (6) send all flow through the Tandem Center directional control valve (17) and 75 PSI back pressure Check Valve (15) to Tank (3). Pressure at PG1 and PG2 reads 75-90 PSI giving ample pilot pressure to shift the Solenoid Pilot Operated Directional Control Valve (17). Both Flow Meters (8) show full pump flow if the pumps are good.

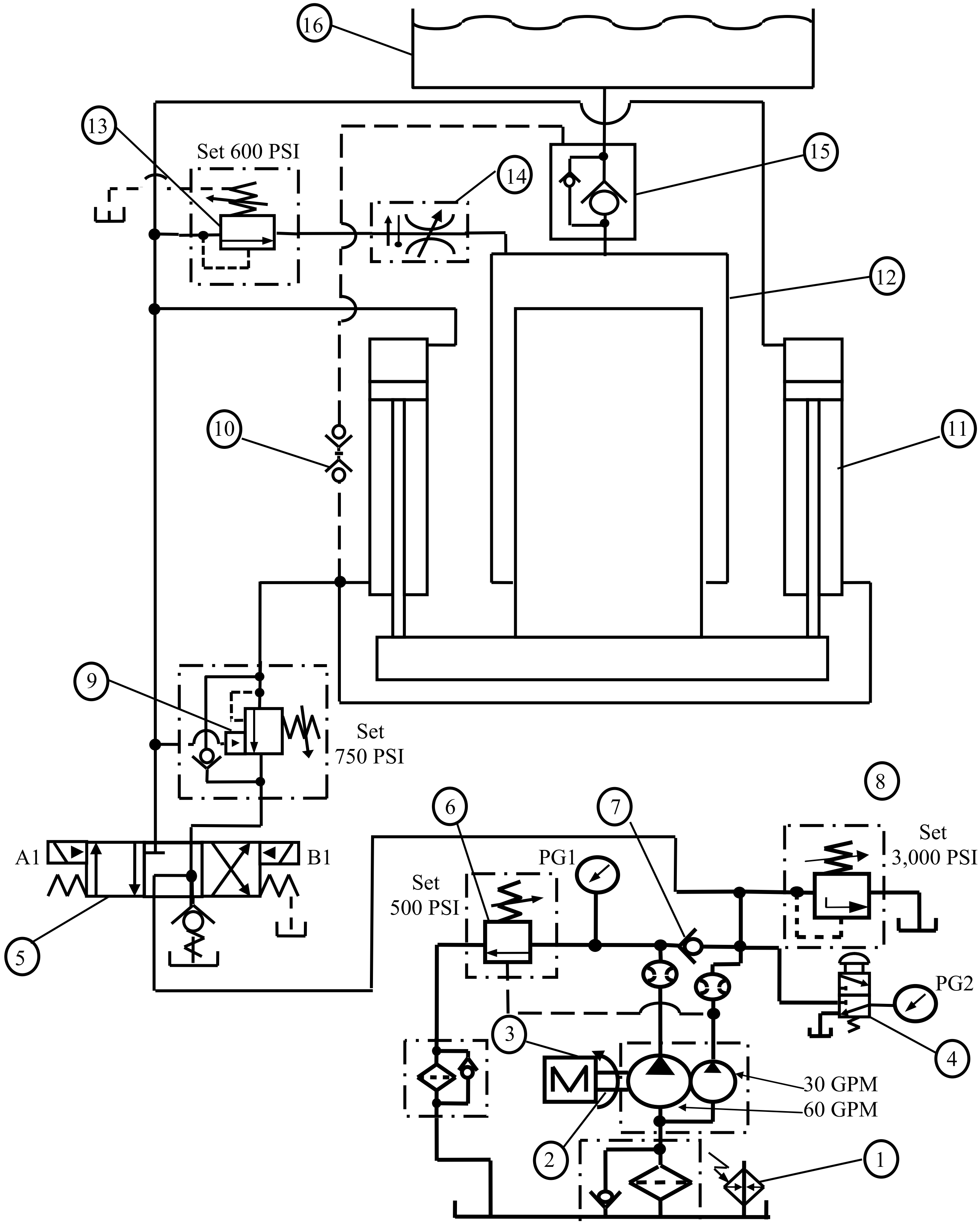
A start signal at Solenoid A1 shifts the Directional Control Valve (17) to send flow from both pumps to Cylinder (18) cap end and allow rod end fluid to go to Tank (3). Cylinder (18) extends rapidly at approximately 65 GPM flow at whatever (WE) pressure it takes to move it. Pressure at this time should be less than the 500 PSI set on Unloading Valve (11).

At work contact pressure builds and as it reaches and exceeds 500 PSI, Unloading Valve (11) is remotely piloted open from the low volume high pressure 7 GPM pump through Pilot Line (10). This allows the 58 GPM pump to send all fluid to tank at very low pressure and makes its horsepower requirement almost zero. Isolation Check Valve (12) keeps the high pressure pump from unloading to tank at this time. Now all Horsepower is available to take the 7 GPM pump to 2,000 PSI maximum to perform high force work at reduced speed.

When work is complete, Solenoid A1 is de-energized and Solenoid B1 is energized to send flow from both Pumps (6) at low pressure to Cylinder (18) rod end and allow oil from its cap end to go to Tank (3). The cylinder (18) now retracts rapidly at approximately 65 GPM and at whatever pressure it needs to move it. This should be below 500 PSI set on Unloading Valve (11).

When the Cylinder (18) fully retracts it contacts a limit switch that de-energizes Solenoid B1 and allows the Directional Control Valve (17) to return to center. The pumps again unload through the tandem center flow path while the operator unloads and reloads a new part.

Single Acting Ram Press Circuit



SFPC-4

Identify the Components

1. Electric Tank Heater
2. Mechanical Connection
3. Heat Engine (Non Electric Motor)
4. Gauge Isolator Valve
5. 4-Way, Three Position, Double Solenoid Pilot Operated, Spring Centered, Port "A" Blocked Pump "B" and Tank Connected Center, Directional Control Valve
6. Remote Piloted Unloading Valve
7. Isolation Check Valve
8. Pilot Operated Relief Valve
9. Internally and Externally Piloted Counter Balance Valve
10. Quick Disconnects (Connected)
11. Double Acting, Single Rod End Cylinders to control extend action and return Single Acting Ram
12. Single Acting Ram Actuator
13. Sequence Valve
14. Pressure and Temperature Compensated Flow Control Valve
15. Pre-fill Valve with Decompression Feature
16. Reservoir (Tank)

Circuit Operation

The pump circuit is the same HI – LO design as shown and explained in the previous schematic. The pump is driven by a Heat Engine (3) in this circuit and unloads in the at rest condition through a 4-Way, Three Position, Double Solenoid Pilot Operated, Spring Centered, Port "A" Blocked Pump "B" and Tank connected center, Directional Control Valve (5). This directional control valve allows the pump to unload while blocking fluid in the return cylinders cap end.

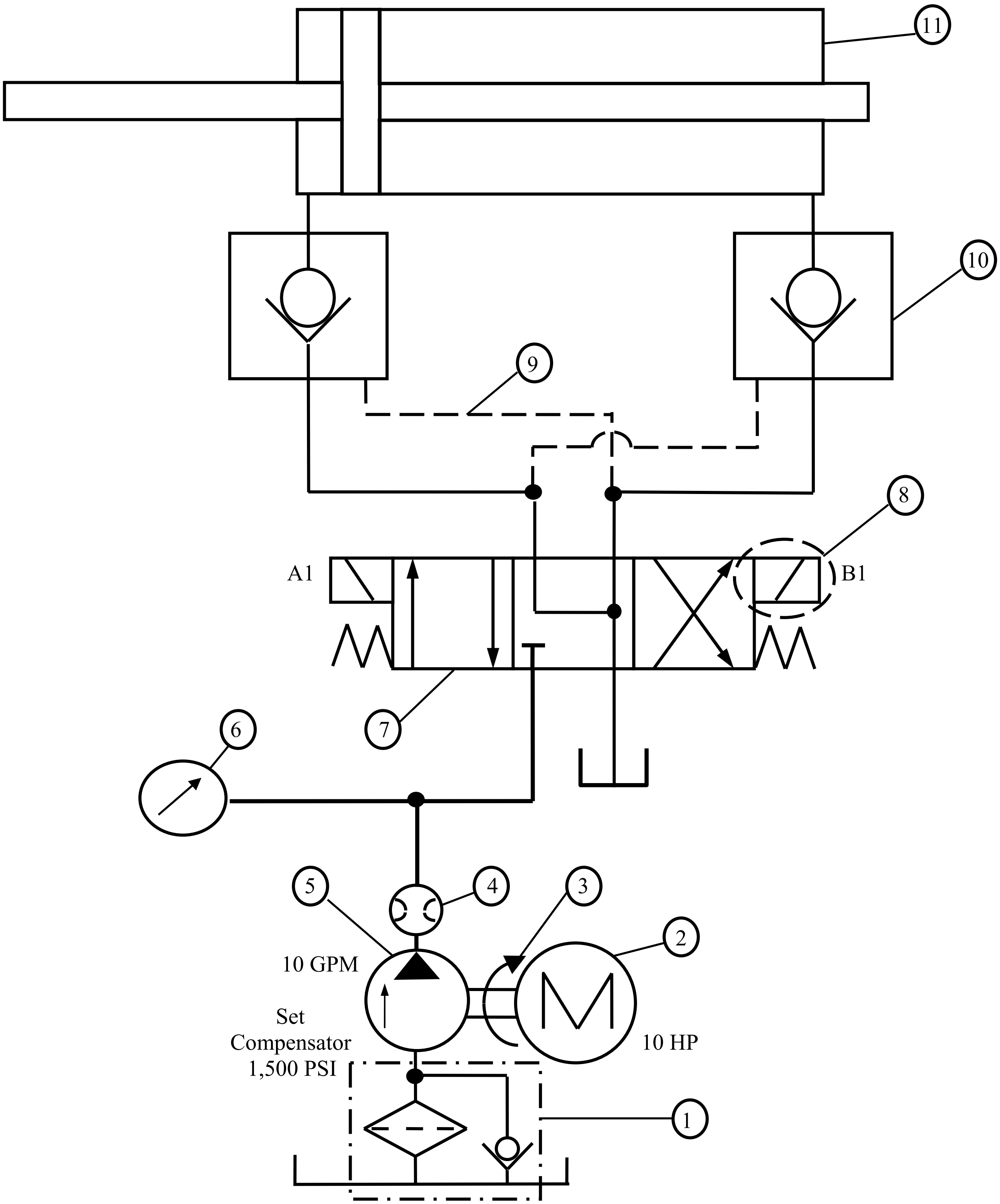
Energizing Solenoid A1 sends all pump flow to Double Acting, Single Rod End Cylinders (11) forcing them to extend by opening Counter Balance Valve (9) just enough to allow flow while still holding the press platen from running away. As the platen extends Pre-fill valve (15) opens by vacuum and lets oil flow into Single Acting Ram (12). The platen advances rapidly at low pressure and low force until it contacts work.

At work contact pressure quickly builds above 500 PSI and unloads the high volume pump to tank while the low volume pump continues sending fluid to Cylinders (11). Pressure continues to build on Cylinders (11) until it reaches the setting of Sequence Valve (13). At this point fluid is ported to the Cylinders (11) and Ram (12) to obtain full tonnage on the platen. Pre-fill Valve (15) closes blocking flow to tank during the high tonnage portion of the cycle. Counter Balance Valve (9) is piloted fully open as work pressure builds releasing all back pressure to Cylinders (11).

After work is complete Solenoid A1 on Directional Control Valve (5) is de-energized and Solenoid B1 is energized to start the retract cycle. Pump flow is ported to the rod ends of Cylinders (11) and a pilot signal is sent to Pre-fill Valve (15) to open it to tank. Pre-fill Valve (15) has a built in decompression feature indicated by the small and large check valves. Since high pressure is trapped in the main Ram (12) it is impossible to open the large poppet but the small one opens easily and lets the trapped high pressure fluid go to tank in a smooth non-shock flow. When pressure drops enough the large poppet opens and the return Cylinders (11) starts retracting the platen while Ram (12) fluid flows to tank through the open Pre-fill Valve (15). The platen retracts rapidly at low pressure using flow from both pumps

When the platen is retracted to a limit switch position the Directional Control Valve (5) centers and platen movement stops.

Dual Pilot Operated Check Valve Locking Circuit



Identify the Components

1. In Tank Suction Strainer
2. Electric Motor
3. Pump Rotation Arrow (Right Hand, Clockwise)
4. Flow Meter
5. Pressure Compensated Variable Volume Pump (Simplified Symbol)
6. Pressure Gauge
7. 4-Way, Three Position, Double Direct Solenoid Operated, Spring Centered, Float Center, Directional Control Valve.
8. Solenoid Operator
9. Pilot Line
10. Pilot to Open Check Valve
11. Double Acting, Double Rod End Cylinder, Non Cushioned

Circuit Operation

At rest the output of Pressure Compensated Pump (5) is blocked at the 4-Way, Three Position, Double Direct Solenoid Operated, Spring Centered, Float center, Directional Control Valve (7), pressure is at compensator setting and flow is zero. Double Rod End Cylinder (11) is blocked with Pilot Operated Check Valves (10) at each port. They are in the closed position since there pilot ports are connected to tank in the at rest condition. Anytime a pilot operated check valve is used for cylinder position holding always use a directional control valve with “A” and “B” ports connected to tank center condition. This makes sure the check valves can close when the cylinder is stopped.

Energizing Solenoid “A1” of Directional Control Valve (7) sends pump fluid free flow through the left hand Pilot Operated Check Valve (10) and on to Cylinder (11). Pressure buildup in this line pilots the right hand Pilot Operated Check Valve (10) open to allow oil to return to tank while the cylinder is extending. If Directional Control Valve (7) is de-energized while the cylinder is extending, the cylinder stops and is locked in place hydraulically.

If outside forces can try to move the actuator or fluid heating can occur while the cylinder is locked a suitable relief circuit must be installed to prevent component damage or a safety hazard from excessive pressure. The cylinder is free to move anytime the directional control valve shifts and is locked in place when it is in center condition.

After work is complete Solenoid A1 on Directional Control Valve (7) is de-energized and Solenoid B1 is energized to start the retract cycle. Energizing Solenoid “B1” of Directional Control Valve (7) sends pump fluid free flow through the right hand Pilot Operated Check Valve (10) and on to Cylinder (11). Pressure buildup in this line pilots the left hand Pilot Operated Check Valve (10) open to allow oil to return to tank while the cylinder is retracting. If Directional Control Valve (7) is de-energized while the cylinder is retracting, the cylinder stops and is locked in place hydraulically.

Proportional Throttle Valve Circuits

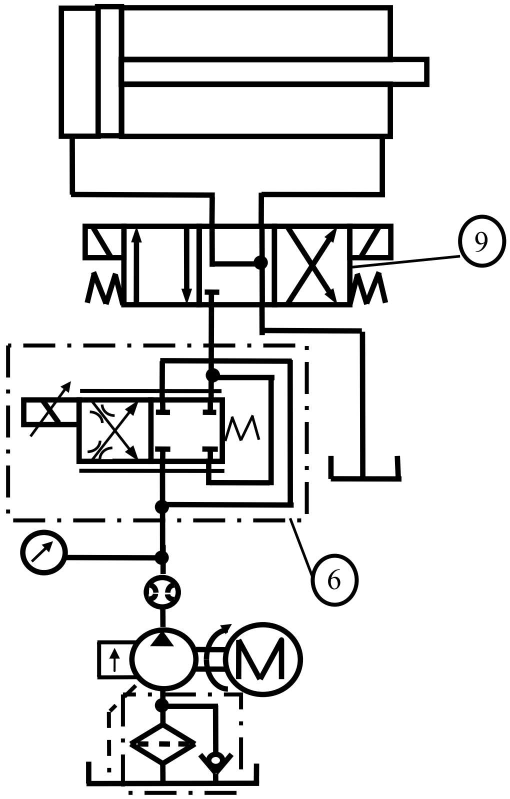


Fig. 1

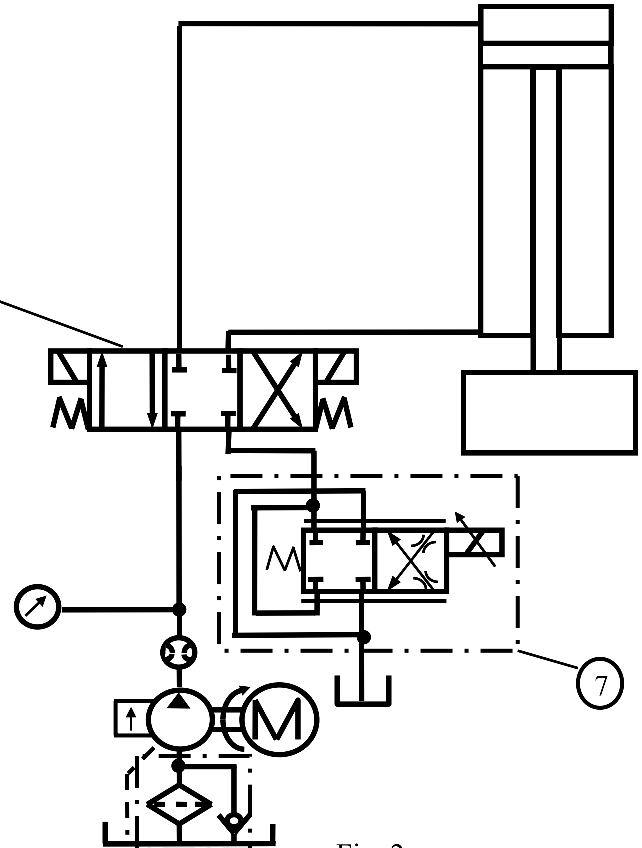


Fig. 2

Proportional Directional Control Valve Circuit

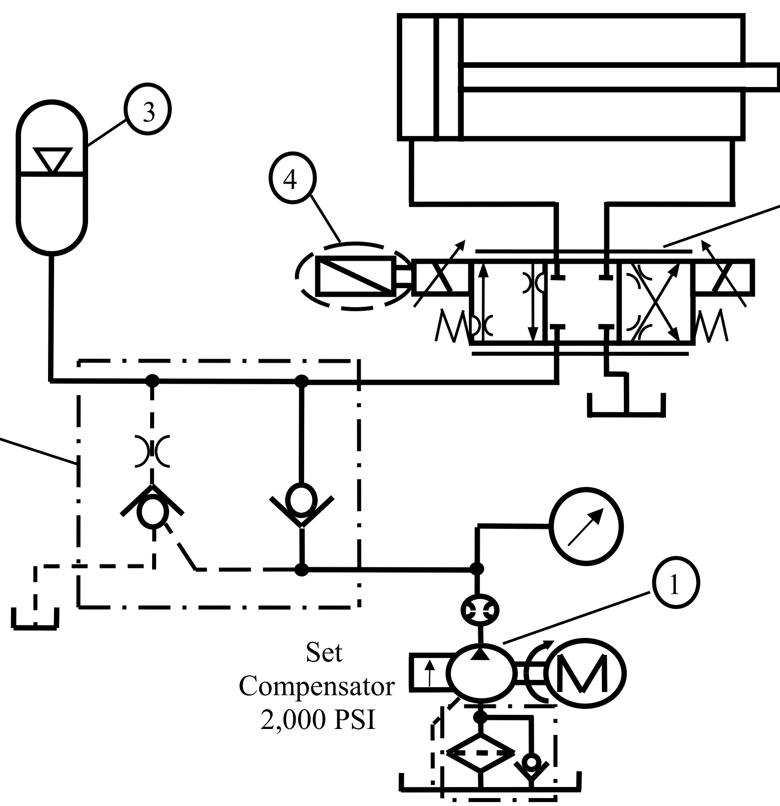


Fig. 3

Identify the Components

1. Pressure Compensated Pump (Complete Symbol)
2. Accumulator Isolation and Dump Valve
3. Gas Charged Accumulator
4. LVDT Feedback Transducer
5. 4-Way, Three Position, Direct Double Solenoid Operated, All Ports Blocked Center Condition, Proportional Directional Control Valve, Spring Centered, with Linear Variable Displacement Transducer Feedback
6. Meter in, 4-Way, Two Position, Spring Centered, Direct Single Solenoid Operated, All Ports Blocked Center Condition, Proportional Throttle Valve, Piped for Dual Flow
7. Meter out, 4-Way, Two Position, Spring Centered, Direct Single Solenoid Operated, All Ports Blocked Center Condition, Proportional Throttle Valve, Piped for Dual Flow
8. 4-Way, Three Position, Double Direct Solenoid Operated, Spring Centered, Float Center, Directional Control Valve
9. 4-Way, Three Position, Double Direct Solenoid Operated, Spring Centered, All Ports Blocked Center Condition, Directional Control Valve

Circuit Operation

Fig. 1

This circuit uses a 4-Way, Three Position, Direct Single Solenoid Operated, All Ports Blocked Center Condition, Proportional Throttle Valve, Piped for Dual Flow (6), metering in fluid to the Float Center Directional Control Valve (8). Directional Control Valve (8) shifts to make the cylinder extend or retract and the meter in Proportional Throttle Valve (6) controls fluid flow to give smooth acceleration and/or deceleration and/or infinitely variable speed control without system shock.

The Dual Flow Path arrangement allows a given size valve to handle twice its rated flow without high pressure drop. This is because directional control valves are rated to handle flow to and from an actuator so only one flow path is considered when determining pressure drop.

Fig. 2

This circuit uses a 4-Way, Three Position, Direct Single Solenoid Operated, All Ports Blocked Center Condition, Proportional Throttle Valve, Piped for Dual Flow (7), metering out fluid from an All Ports Blocked Directional Control Valve (9). Directional Control Valve (9) shifts to make the cylinder extend or retract and the meter out Proportional Throttle Valve (7) controls fluid flow to give smooth acceleration and/or deceleration and/or infinitely variable speed control without system shock. The meter out control keeps the cylinder from running away also.

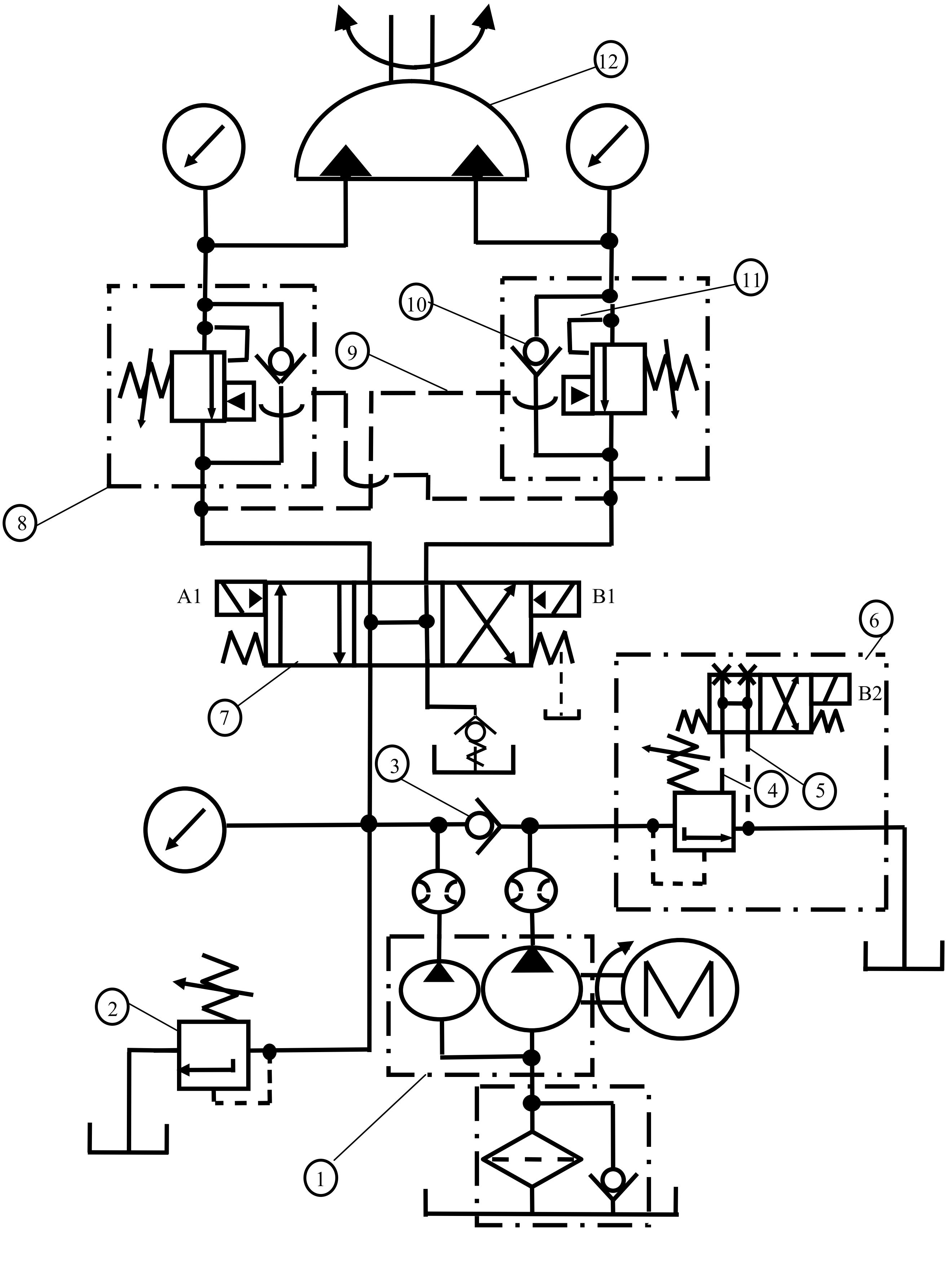
The Dual Flow Path arrangement allows a given size valve to handle twice its rated flow without high pressure drop. This is because directional control valves are rated to handle flow to and from an actuator so only one flow path is considered when determining pressure drop.

Fig. 3

This circuit shows a typical proportional valve setup for good response and minimum system shock. The Pressure Compensated Pump (1) supplies fluid at the rate required by the actuator from zero to full flow. The Accumulator (3) stores energy to give fast response when movement is needed and to reduce shock when flow is abruptly stopped. The Accumulator Isolation and Dump Valve (2) isolates the pump from Accumulator back flow and allows the Accumulator to discharge stored energy automatically at shutdown.

The 4-Way, Three Position, Direct Double Solenoid Operated, All Ports Blocked Center Condition, Proportional Directional Control Valve (5), with Linear Variable Displacement Transducer (LVDT) Feedback (4) controls cylinder direction, acceleration, deceleration and speed. The LVDT Feedback Transducer (4) reads directional valve spool position so a given signal always shifts the spool to a precise opening. Though this is not always the same flow it does give repeatable actuation at consistent pressure drop and viscosity.

Two Speed Rotary Actuator Circuit



Identify the Components

1. Double Fixed Volume Pump
2. Pilot Operated Relief Valve
3. Isolation Check Valve
4. Pilot Line
5. Drain Line
6. Normally Open Solenoid Operated Relief Valve
7. 4-Way, Three Position, Double Solenoid Pilot Operated, Spring Centered, All Ports Open Center Condition Directional Control Valve
8. Internally and Externally Piloted Counter Balance Valve (Brake Valve)
9. External Pilot Line
10. Bypass Check Valve
11. Internal Pilot Line
12. Hydraulic Rotary Actuator

Circuit Operation

This circuit uses a double pump with high and low volume sections and must have a separate Solenoid (B2) energized to force the high volume pump to go to the actuator. Solenoid (B2) is on a Solenoid Operated Relief Valve that is normally dumping fluid to tank at low pressure. It is set 150-200 PSI above system pressure. Isolation Check Valve (3) keeps the low volume pump from going to tank so it unloads through 4-Way, Three Position, Double Solenoid Pilot Operated, Spring Centered, All Ports Open center condition Directional Control Valve (7). Pilot Operated Relief Valve (2) sets maximum pressure for both pumps.

Internally and externally piloted Counter Balance Valves (8) keep the Rotary Actuator (12) from over running when the load tries to force it to move ahead. The External Pilot Line (9) opens the Counter Balance Valve fully to remove all back pressure when the load is resistive. This dual action makes over center loads controllable without wasting energy.

Energizing Solenoid A1 sends low volume pump flow to the Rotary Actuator (12) around the left Counter Balance Valve (8) and starts it turning clockwise. Fluid exiting the Rotary Actuator is retarded by right Counter Balance Valve by the Internal Pilot (11) if it is trying to flow faster than the pump supplies. If the load is resistive pressure buildup in the External Pilot Supply (9) forces the Counter Balance Valve open and relieves all back pressure from the Rotary Actuator.

Energizing Solenoid A1 and B2 at the same time increases speed of rotation for fast traverse between travel limits. De-energizing Solenoid B2 near the end of travel causes the Rotary Actuator to slow and travel home at reduced speed to eliminate shock. The reason it slows is the Counter Balance Valves hold back when flow decreases and retard movement until reaching low volume pump speed.

Energizing Solenoid B1 sends low volume pump flow to the Rotary Actuator (12) around the right Counter Balance Valve (8) and starts it turning counterclockwise. Fluid exiting the Rotary Actuator is retarded by left the Counter Balance Valve by the Internal Pilot (11) if it is trying to flow faster than the pump supplies. If the load is resistive pressure buildup in the External Pilot Supply (9) forces the Counter Balance Valve open and relieves all back pressure from the Rotary Actuator.

Energizing Solenoid B1 and B2 at the same time increases speed of rotation for fast traverse between travel limits. De-energizing Solenoid B2 near the end of travel causes the Rotary Actuator to slow and travel home at reduced speed to eliminate shock.

Pneumatic Sequence Circuit

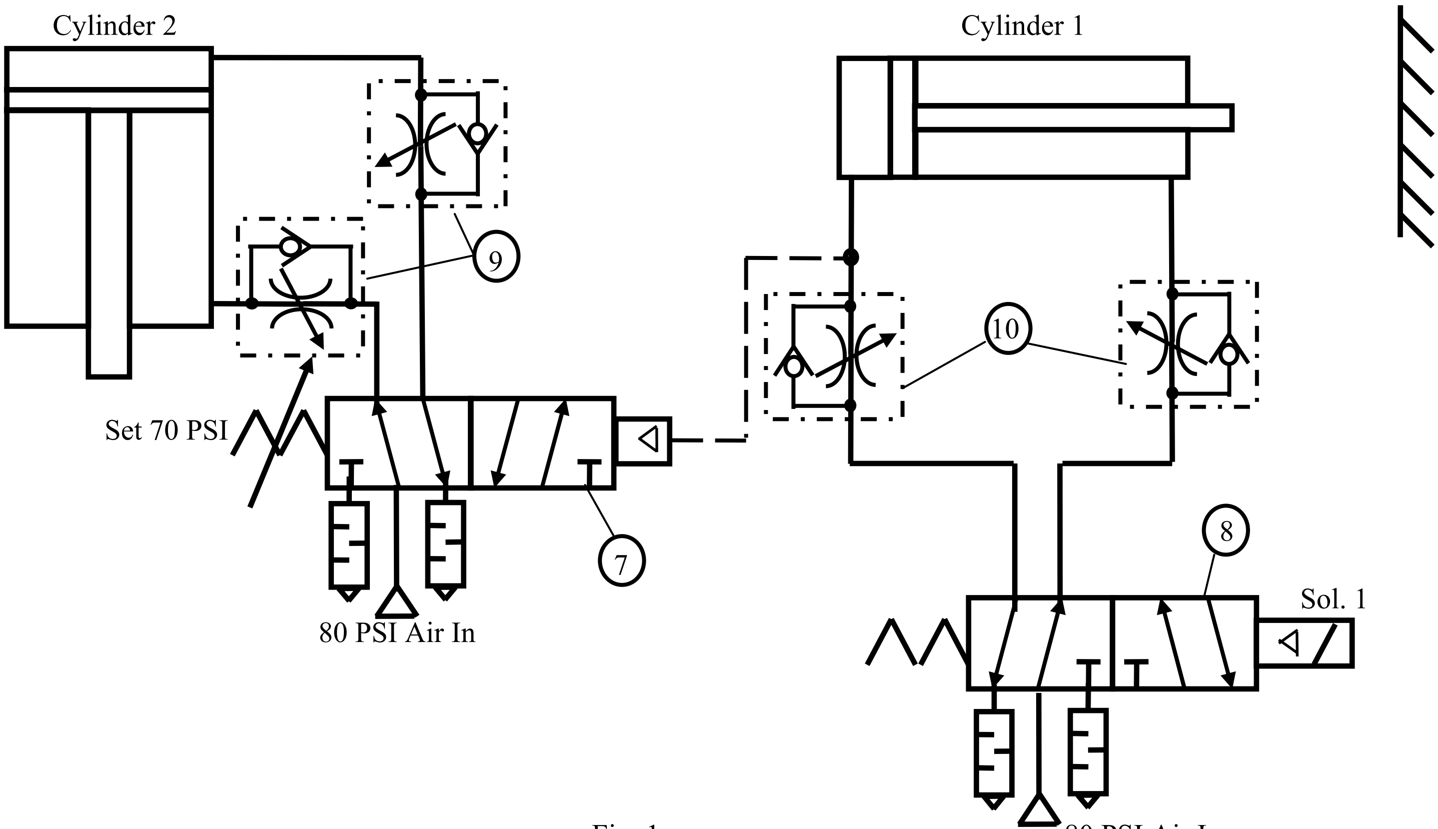


Fig. 1

Hydraulic Sequence CIRCUIT

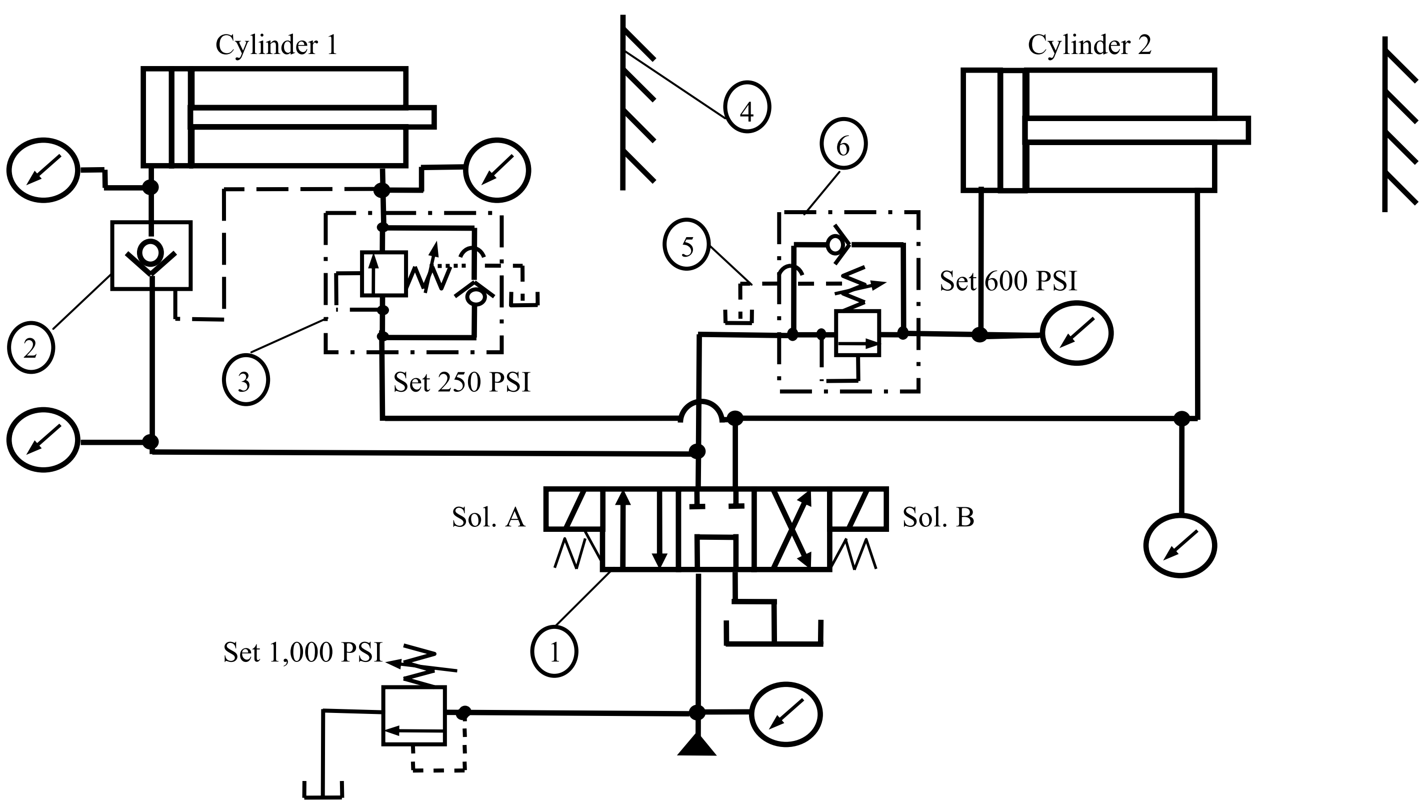


Fig. 2

Identify the Components

1. 4-Way, Three Position, Double Direct Solenoid Operated, Spring Centered, Tandem Center condition Directional Control Valve
2. Pilot Operated Check Valve
3. Internally Piloted Sequence Valve
4. Machine Member
5. Drain Line
6. Internally Piloted Sequence Valve
7. 5-Way Sequence Valve, Pneumatic
8. Single Solenoid Pilot, Spring Return, 5-Way Valve, Pneumatic
9. Meter Out Flow Controls
10. Meter In Flow Controls

Circuit Operation

Fig. 1

In this circuit, Cylinder 1 extends first and builds to a pressure of 70 PSI before Cylinder 2 can extend. This sequence of events should take place every cycle no matter part size or cylinder speed. NOTE: *"This sequence of events should take place"* means Cylinder 2 could start prematurely if Cylinder 1 is damaged and cannot move full stroke or if the machine member it is driving gets bound up and stalls it before reaching the part. "IMPORTANT" ANY SEQUENCE CIRCUIT MAY NOT MAKE A COMPLETE CYCLE SO THEY MUST NOT BE USED IF PART DAMAGE OR SAFETY IS AN ISSUE. ALWAYS USE LIMIT SWITCHES OR VALVES FOR POSITVE POSITIONING.

Energizing Sol.1 starts Cylinder 1 extending to the work. Pressure in the cap end of Cylinder 1 will be whatever (WE) it takes to move it since its extend speed is controlled by Meter In Flow Control (10). This means pressure at the 5-Way Sequence Valve (7) pilot port will be less than 70 PSI until work contact. At work contact pressure in the cap end of Cylinder 1 quickly builds to 70 PSI which shifts 5-Way Sequence Valve (7) and starts Cylinder 2 extending. Cylinder 2 has Meter Out Flow Controls (9) to keep it from running away and to make sure at least 70 PSI is available at Cylinder 1.

De-energizing Sol. 1 starts Cylinder 1 retracting and drops pilot pressure at 5-Way Sequence Valve (7) so Cylinder 2 also starts retracting. Both cylinders continue retracting until they bottom out.

Fig. 2

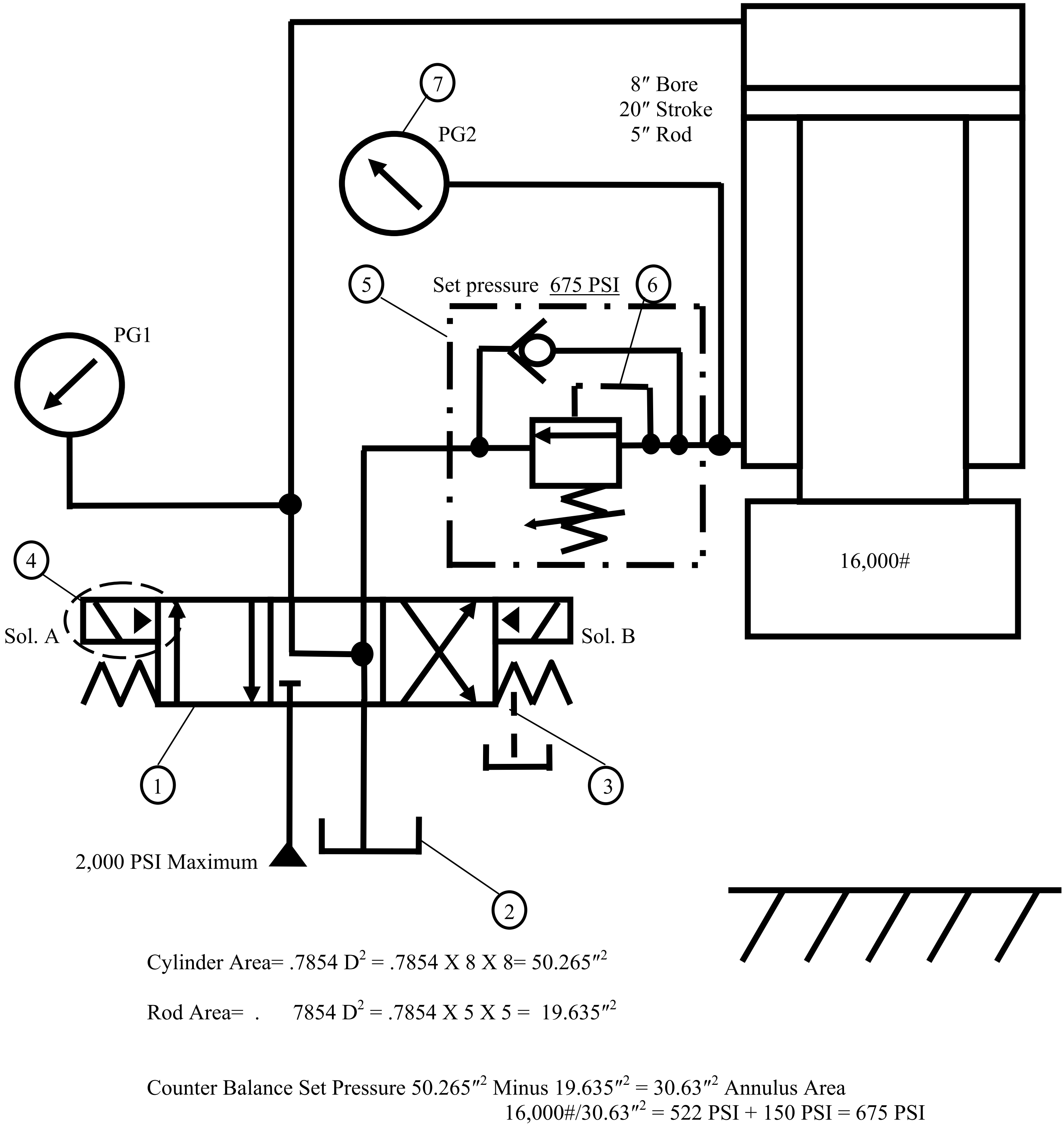
In this circuit, Cylinder 1 extends first and builds to a pressure of 600 PSI before Cylinder 2 can extend. (See NOTE and "IMPORTANT" above)

Energizing Sol. A sends pump flow to Cylinder 1 through a Pilot Operated Check Valve (2) to start it extending. Pressure in the circuit at this time is whatever it takes to move Cylinder 1. Oil from Cylinder 1 rod end returns to tank through Sequence Valve (3) bypass check valve. Cylinder 1 extends until it contacts the work no matter its speed or part size.

After Cylinder 1 is in contact with the work pressure builds to 600 PSI and Cylinder 2 starts extending. Pressure at Cylinder 1 never drops below 600 PSI no matter how low pressure is at Cylinder 2. Cylinder 2 continues extending until its work is complete.

After work is complete Sol. A is de-energized and Sol. B is energized. Pressure in the cap end of Cylinder 1 is trapped there by Pilot Operated Check Valve (2) so it remains clamped until Cylinder 2 fully retracts and pressure reaches 250 PSI. At this point Cylinder 1 retracts from Sequence valve (3) opening and piloting open Pilot Operated Check Valve (2). At the end of stroke of Cylinder 1 the directional control valve centers to complete the cycle.

Internal Pilot Counter Balance Valve Circuit



Cylinder Area= .7854 D^2 = .7854 X 8 X 8= 50.265″^{2}

Rod Area= . 7854 D^2 = .7854 X 5 X 5 = 19.635″^{2}

Counter Balance Set Pressure 50.265″^{2} Minus 19.635″^{2} = 30.63″^{2} Annulus Area
16,000#/30.63″^{2} = 522 PSI + 150 PSI = 675 PSI

When the Cylinder is against the work:
What is the maximum force applied to the work? __95,856#

Down Force Hydraulic= 50.265″^{2} X 2,000 PSI = 100,531#
Down Force Weight= 16,000#
Minus Up Force from counter balance valve= 30.63 X 675 PSI =20,675#
Total Down Force Maximum = 95,856#

Identify the Components

1. 4-Way, Three Position, Double Solenoid Pilot Operated, Spring Centered, Float Center Directional Control Valve
2. Reservoir (tank)
3. Drain Line
4. Solenoid Pilot Operator
5. Internal Pilot Operated Counter Balance Valve
6. Internal Pilot Line
7. Pressure Gauge

Circuit Operation

This circuit is designed to hold the 16,000# platen and tooling from falling in the At Rest condition and to keep it from running away when the directional control valve shifts to extend it. Notice the cylinder ports are connected to tank in the center condition to keep any pressure off them during the stop mode. Blocked cylinder ports could cause the cylinder to stop abruptly and pressure buildup from spool bypass could cause it to drift when at rest. The Counter Balance Valve (5) is always set 100-150 PSI higher than load balance to assure the cylinder stops and holds but does not waste energy when moving.

This circuit is using an Internally Piloted Counter Balance Valve (5) that is best for smooth action but wastes energy since it is always holding back against the annulus area of the cylinder.

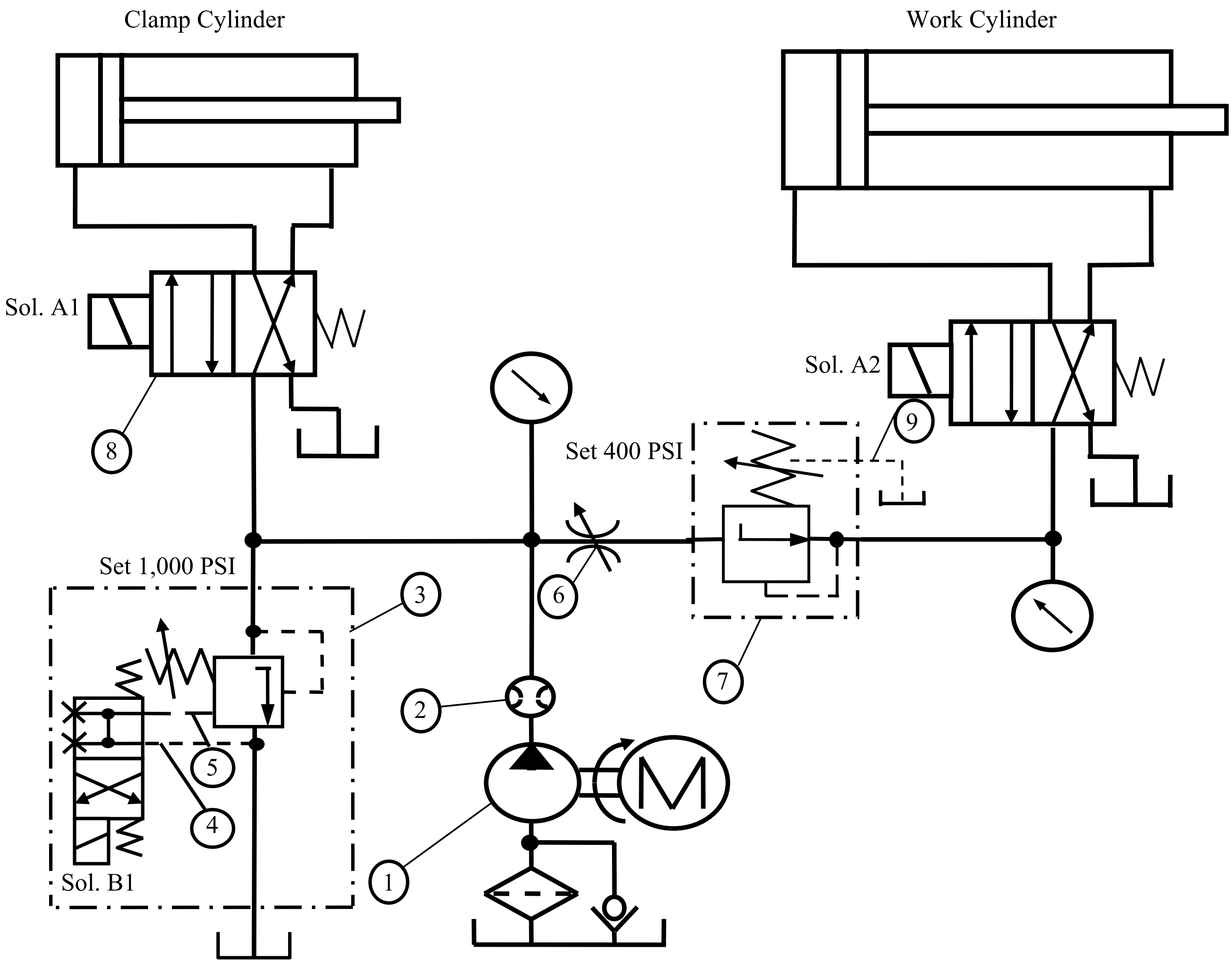
Shifting Sol. A on Directional Control Valve (1) sends pump flow to the cylinder cap end and pressure builds there and in the rod end also. When the cylinder cap end reaches approximately 93 PSI pressure in the rod end will be at or near 675 PSI. Load induced pressure of 522 PSI (16,000#/30.63$''^2$) plus 153 PSI hydraulic down force intensified (93 PSI X 1.64:1 intensification) equals 675 PSI to force the counter balance valve open. The Counter Balance Valve (5) only opens enough to let flow out as fast as the pump puts fluid in and maintains the 675 PSI drop across it. The cylinder will continue to extend smoothly and pressure at gauge PG2 (7) should read around 675 PSI during the extend stroke.

If the directional control valve goes to center any time during the cylinder extend travel the counter balance valve will smoothly stop it and hold it in place.

At work contact pressure in the cylinder cap end continues to build to perform work as required. Pressure in the cylinder rod end never drops below 650-675 PSI during the work stroke. This means the 16,000# platen and tooling weight is not doing work plus 125-150 PSI hydraulic force on the rod end pushing up must be overcome. Using an externally piloted or an internally/externally piloted counter balance valve eliminates this back pressure problem.

After work is complete Sol. A is de-energized and Sol. B is energized to send fluid to the cylinder rod end. The bypass check valve in Counter Balance Valve (5) allows fluid to reach the cylinder rod end. The cylinder continues to retract until contacting an upper limit switch and centering Directional Control Valve (1). This puts the circuit back to its start position ready for another cycle.

Pressure Reducing Valve Circuit



Identify the Components

1. Fixed Volume Pump
2. Flow Meter
3. Normally Open Solenoid Operated Relief Valve
4. Internal Drain Line
5. Internal Pilot Line
6. Needle Valve
7. Pressure Reducing Valve
8. 4-Way, Two Position, Single Solenoid, Spring Return Directional Control Valve
9. External Drain Line

Circuit Operation

This circuit uses a Fixed Volume Pump (1) that is sending all fluid to tank at 20-50 PSI through Normally Open Solenoid Operated Relief Valve (3). This type circuit reduces heat while using a fixed volume pump in a multiple cylinder circuit. Sol. B3 must be energized when the cylinders are cycling

The Clamp Cylinder needs up to 1,000 PSI while the Work Cylinder cannot go above 400 PSI. This is accomplished by using Reducing Valve (7) in the pump line going to the Work Cylinder directional control valve. Needle Valve (6) sets maximum flow to the Work Cylinder and maintains pressure at the Clamp Cylinder while the Work Cylinder advances to the work. This function could also be handled by a sequence valve.

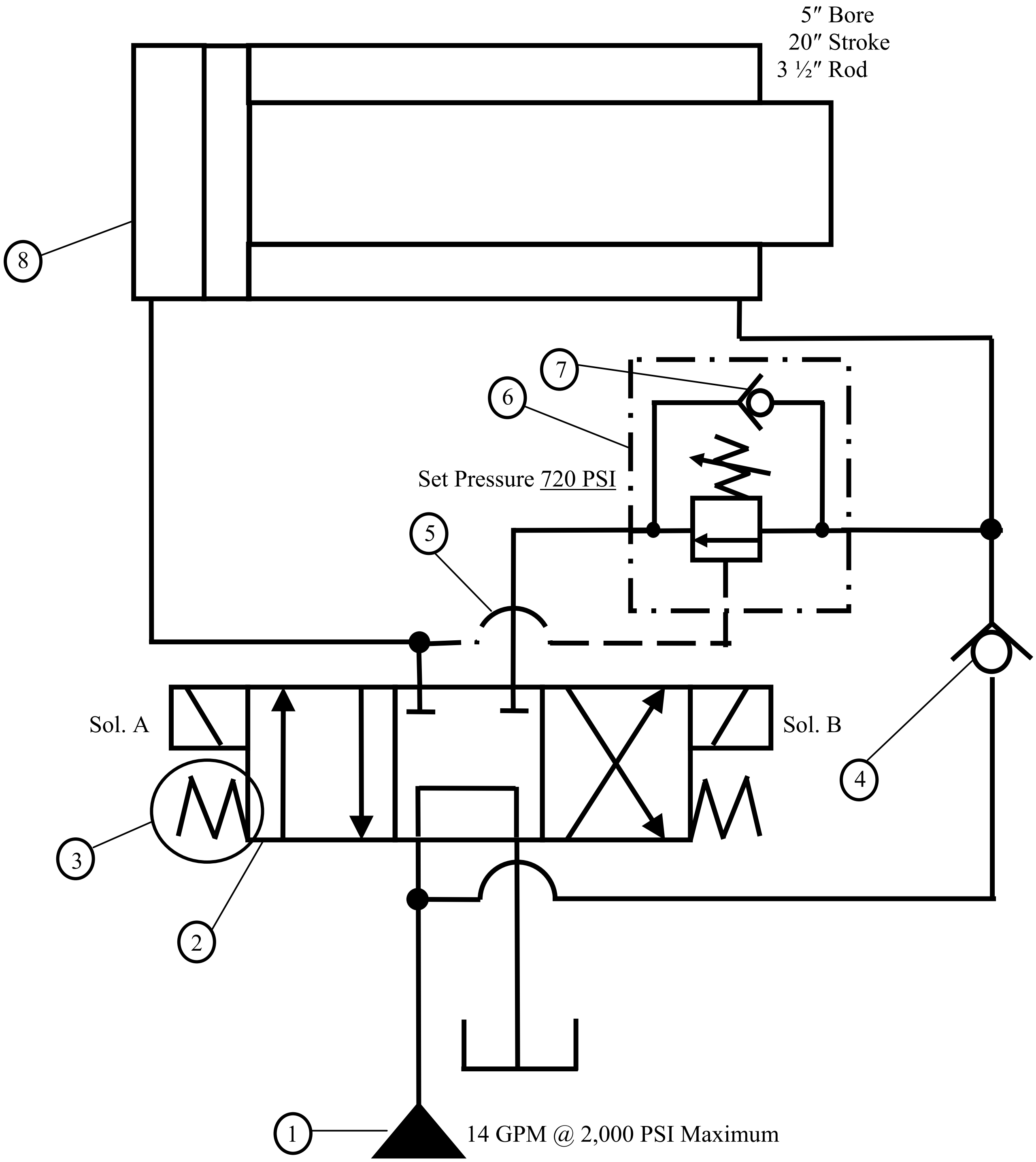
Energizing Sol. A1 and B1 causes the Clamp Cylinder to extend at full speed until it clamps the part. A limit switch or pressure switch could indicate the part is clamped to start the Work Cylinder.

Energizing Sol. A1, B1 and A2 causes the Work Cylinder to extend at almost full pump flow according to how Needle Valve (6) is set. Needle Valve (6) should be set so pressure at the Clamp Cylinder never drops below a predetermined minimum that will keep the part firmly in place. The work Cylinder continues to extend at low pressure until it contacts the part. At part contact the Work Cylinder performs its work as long as it requires 400 PSI or less. This maximum pressure could protect an expensive tool from being damaged when it gets dull or worn and requires excessive force to make it work.

Energizing Sol. A1 and B1 and de-energizing Sol.A2 allows the Work Cylinder to retract at almost full pump flow while still maintaining clamp force due to Needle Valve (6). A limit switch at the fully retracted position of the Work Cylinder would indicate it is in home position and start the Clamp Cylinder retracting.

Energizing Sol. B1 and de-energizing Sol. A1 allows the Clamp Cylinder to return to home position at full pump flow. A limit switch at the retract position of the Clamp Cylinder would de-energize Sol. B3 and unload the pump to tank. The circuit is now ready for another cycle.

Pressure Deactivated Regeneration Circuit



Cylinder Area= .7854D^2 = .7854 X 5 X 5 = 19.635″^{2}

Rod Area= .7854D^2 = .7854 X 3.5 X 3.5 = 9.621″^{2}

Fast Advance Thrust Required Minimum 5,500#

Sequence valve Set Pressure = 5,500 PSI/9.621″^{2} =+ 150 PSI =720 PSI

Identify the Components

1. Hydraulic Energy Triangle
2. 4-Way, Three Position, Direct Double Solenoid Operated, Tandem Center, Directional Control Valve
3. Centering Spring
4. Pump Isolation Check Valve
5. Line Crossing Jumper
6. Remotely Piloted Unloading Valve or Remotely Piloted Sequence Valve
7. Bypass Check Valve
8. 2:1 Area Ratio Single Rod End, Double Acting Hydraulic Cylinder (Standard cylinders never are exactly 2:1 ratio. They use standard bores and rods that are close to 2:1 but never over 2:1 except for a 7″ bore and 5″ rod.

Circuit Operation

This circuit gives a fast advance and return from a lower volume pump when work is only done at the end of stroke. It is called a Regeneration Circuit since the rod end oil is sent to the cap end during the fast approach. When the cylinder is advancing in regeneration mode the rod is the piston so extend force and speed is determined by rod diameter. On the retract stroke only the annulus area around the rod uses oil from the pump so speed is fast though force is low.

With the Unloading valve (6) set 100-150 PSI higher than it takes to regenerate the cylinder it will move fast until it meets work resistance. At this point pressure buildup in the cap end pilots Unloading Valve (6) open and sends rod oil directly to tank. With back pressure eliminated the cylinder has full tonnage at reduced speed to accomplish work. The unloading valve can be replaced by a directional control valve to open the rod end to tank at a limit switch position.

Energizing Sol. A. sends pump oil to the cylinder cap end and it starts extending. Since pressure is less than Unloading Valve (6) is set for rod oil goes through Check Valve (4) and mixes with pump flow at 4-Way, Three Position, Direct Double Solenoid Operated, Tandem Center, Directional Control Valve (2) inlet. This action increases flow to the cylinder cap end which increases flow from the rod end to the directional control valve and on to the cap end in what seems a never ending climb. However, since the only part leaving the cylinder is the over size rod, speed only increases to what the rod area is using. Force at this time is pressure times rod area. This is not usually a problem since no work is being done on the approach stroke.

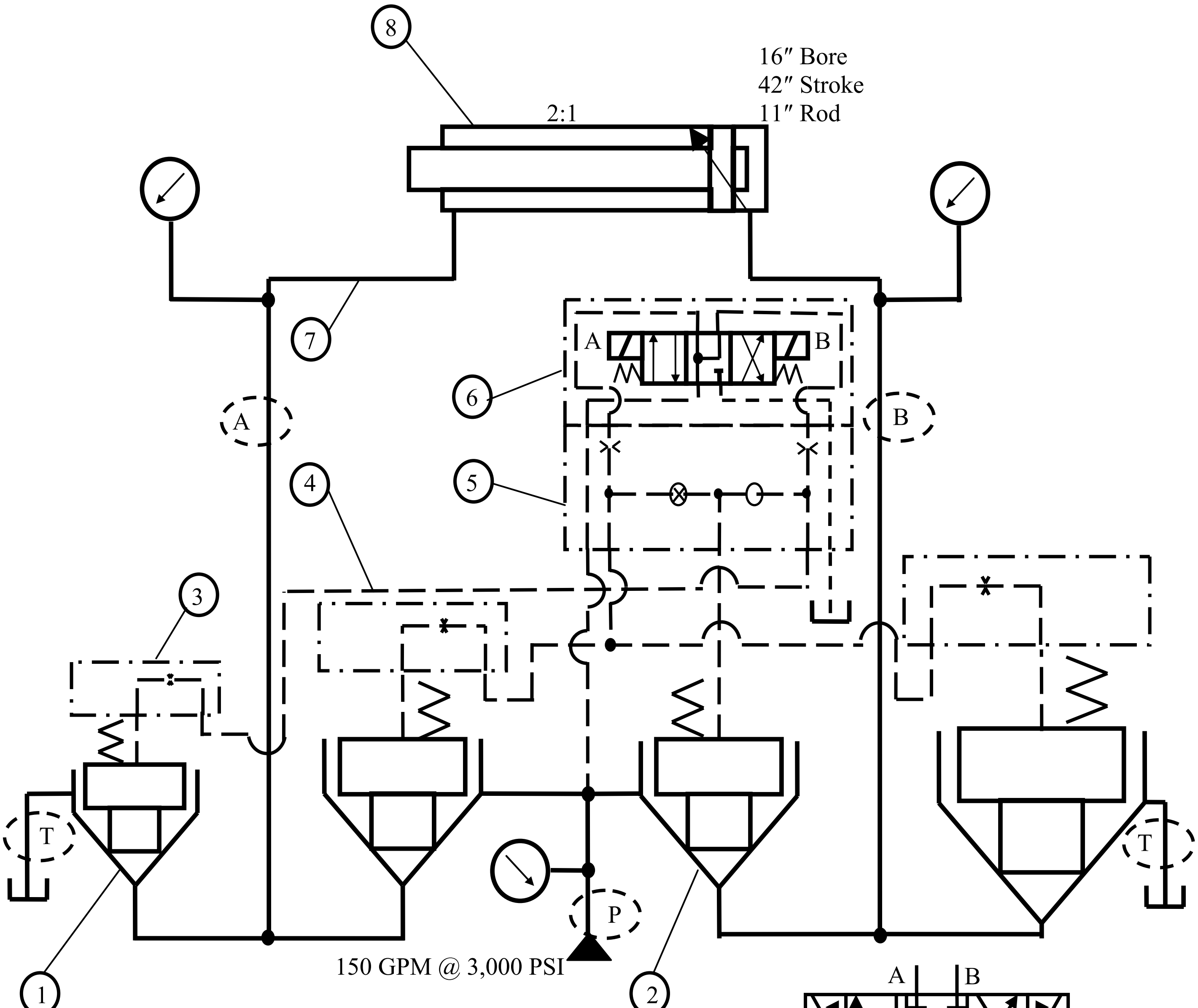
Note, the directional control valve must handle up to twice pump flow during this part of the cycle so it will have high pressure drop if it is sized to match pump flow. Also notice there is no oil going to tank at this time, the cylinder is moving the same as a single acting ram.

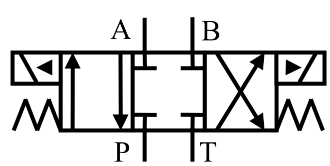
At work contact pressure builds in the cylinder cap end and remotely pilots Unloading Valve (6) open allowing rod flow to go to tank. Check Valve (4) closes in this part of the cycle to stop pump flow from going to tank also. During this part of the cycle cylinder speed is half or less than it was regenerating but force capabilities are up to double.

A limit switch or pressure switch would indicate work cycle complete and de-energize Sol. A and energize Sol. B to start the cylinder retracting. Pump flow goes around Unloading Valve (6) through Bypass Check Valve (7) and directly to the cylinder rod end. The cylinder starts retracting and cap end flow goes to tank through the directional control valve. Again the directional control valve sees up to twice pump flow and must be sized accordingly.

When the cylinder retracts fully a limit switch de-energizes Sol. B allowing 4-Way, Three Position, Direct Double Solenoid Operated, Tandem Center, Directional Control Valve (2) to center and end the cycle.

Slip-In Cartridge Valve Circuit





ISO Symbol

Cylinder Area= $.7854D^2$ = .7854 X 16 X 16 = $201.062''^2$

Rod Area= $.7854D^2$ = .7854 X 11 X 11 = $95.037''^2$

Net Rod End Area = 201.062 – 95.037 = 106.025

Area Ratio between Rod End and Cap End = 201.062/106.025 = 1.896:1

What is flow to tank extending? 150 GPM/1.896 = 79.11 GPM

What is flow to tank retracting? 150 GPM X 1.896 = 284.4 GPM

Identify the Components

1. Cartridge Valve Insert (Tank Return)
2. Cartridge Valve Insert (Pump Inlet)
3. Cartridge Valve Plain Cover
4. Pilot Line
5. Cartridge Valve Cover with Directional Control Valve Interface
6. 4-Way, Three Position, Spring Centered Direct Double Solenoid Operated, “P”, “A” and “B” connected, “T” Blocked Center Condition, Directional Control Valve
7. Working Flow Line
8. Single Rod End, Double Acting Hydraulic Cylinder with Adjustable Cushion on Cap End and a 2:1 Rod Area Ratio

Circuit Operation

This is a simple Slip-in Cartridge Valve circuit showing some of the features of this type control system. Slip-in Cartridge Valves are fast response since there is no overlap to move through at flow start. This means quicker actuator movement after receiving a start signal. Also, unlike a spool valve the poppet only shift’s as far as flow moves it so flow reduces flow immediately when it is signaled to close. Slip-in Cartridge Valves are sized for each flow path to keep pressure drop low and efficiency high and since they are a poppet design they have practically no leakage when closed.

Slip-in Cartridge Valves are very versatile and offer many advantages to circuit design. They are available in sizes from 15 to 6,000 GPM with low pressure drop. Notice in this circuit the left Tank poppet is small since it only has to handle 79 GPM. The Inlet and right Tank poppets are larger sizecto handle their respective flows of 150 and 284 GPM.

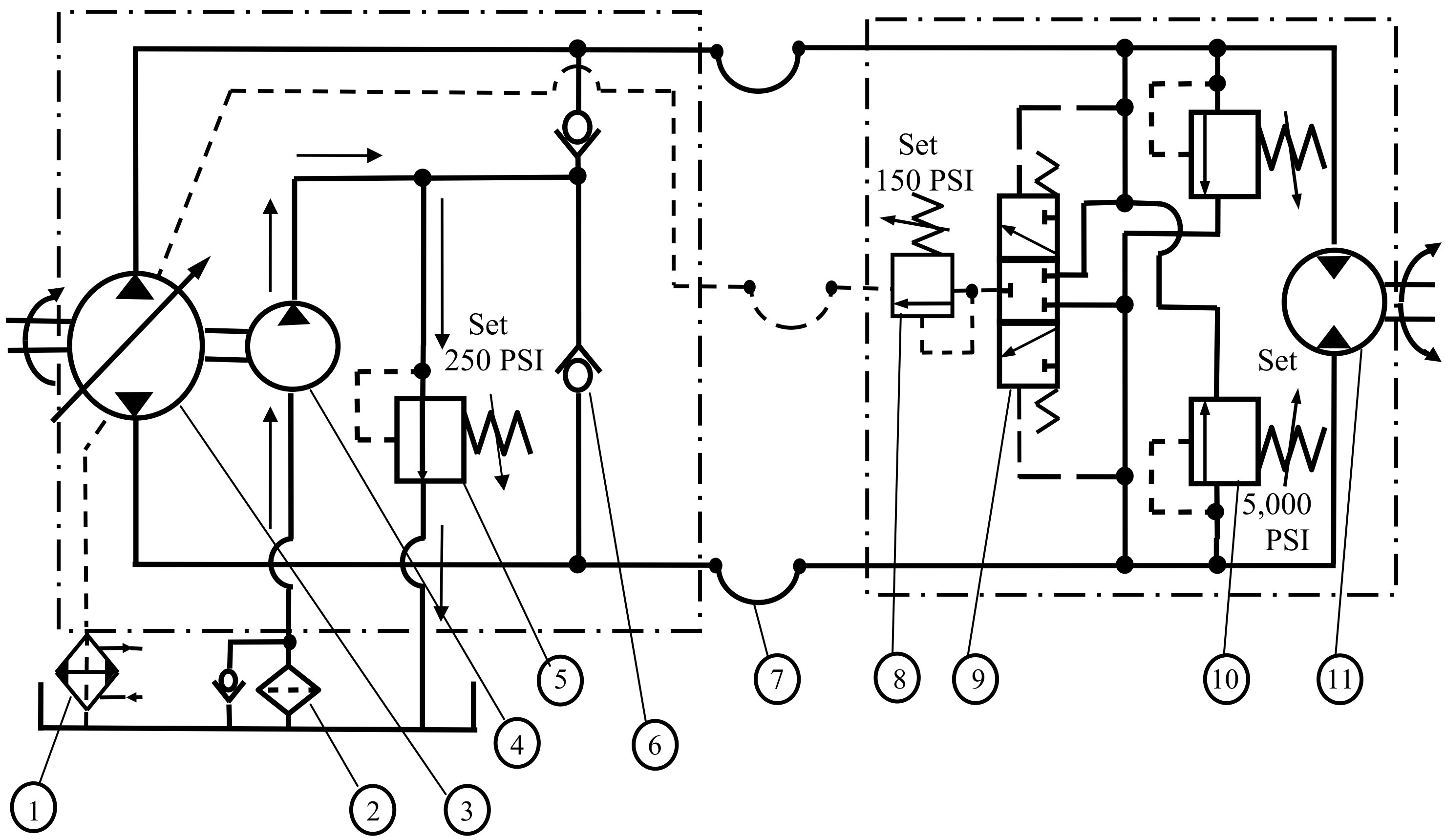
At rest the 4-Way, Three Position, Direct Double Solenoid Operated, “P”, “A” and “B” connected “T” Blocked Center Condition, Directional Control Valve (6) sends pilot pressure to hold all four poppets closed. Inlet pressure or load induced pressure may be trying to push the poppets open but in a well designed circuit there is always equal or greater pressure plus a spring holding it closed. Hence the ISO Symbol showing All Ports Blocked Center Condition and Pilot Energy Triangles pointing out.

Energizing Sol. A leaves pilot pressure on the left Inlet Poppet and the right Tank Poppet. At the same time pilot pressure is dropped to the left Tank Poppet (1) and right Inlet Poppet (2) so they are free to open. Pump flow is now directed to Cylinder (8) cap end and its rod end port is connected to tank. Cylinder (8) extends at full flow and is capable of full force for its full travel. De-energizing Sol. A stops cylinder movement and holds it in place.

De-energizing Sol. A and energizing Sol. B pilots the left Tank Poppet (1) and the right Inlet Poppet (2) closed and drops pilot pressure to the left Inlet Poppet and the Right Tank Poppet allowing them to be pushed open. The Cylinder (8) starts retracting at full speed and is capable of full force for the full stroke.

De-energizing Sol. B at a limit switch location stops cylinder movement at its home position.

Hydrostatic Drive Circuit



Identify the Components

1. Water Cooled Heat Exchanger
2. Suction Filter
3. Bi-directional Variable Volume Pump
4. Fixed Volume Charge Pump (Makeup Pump) (Replenishing Pump)
5. Charge Pump Relief Valve
6. Charge Circuit Isolation Check Valves
7. Flexible Connection
8. Hot Oil Bypass Relief Valve
9. Hot Oil Bypass Valve
10. Cross Port Relief Valve
11. Bi-directional Fixed Cubic Inch Displacement (CID) Hydraulic Motor

Circuit Operation

Hydrostatic transmissions are often used to propel mobile equipment but can be found in industrial applications that need direction control and infinitely variable speed. The Hydraulic Motor (11) can be fixed or variable displacement according to need. The Bi-directional Pump (3), used to drive these systems, can also power single or double rod end cylinders with some special considerations.

This is a Closed Loop Hydraulic Circuit so the same fluid appears to be used over and over. However, pump and motor leakage require makeup fluid and if the loop does not get enough new fluid heat buildup would soon cook the oil beyond use. A Charge Pump (4) provides makeup fluid and also flushes the loop through the Hot Oil Bypass circuit when the motor is turning. This Charge Pump can also power auxiliary equipment and/or control circuits.

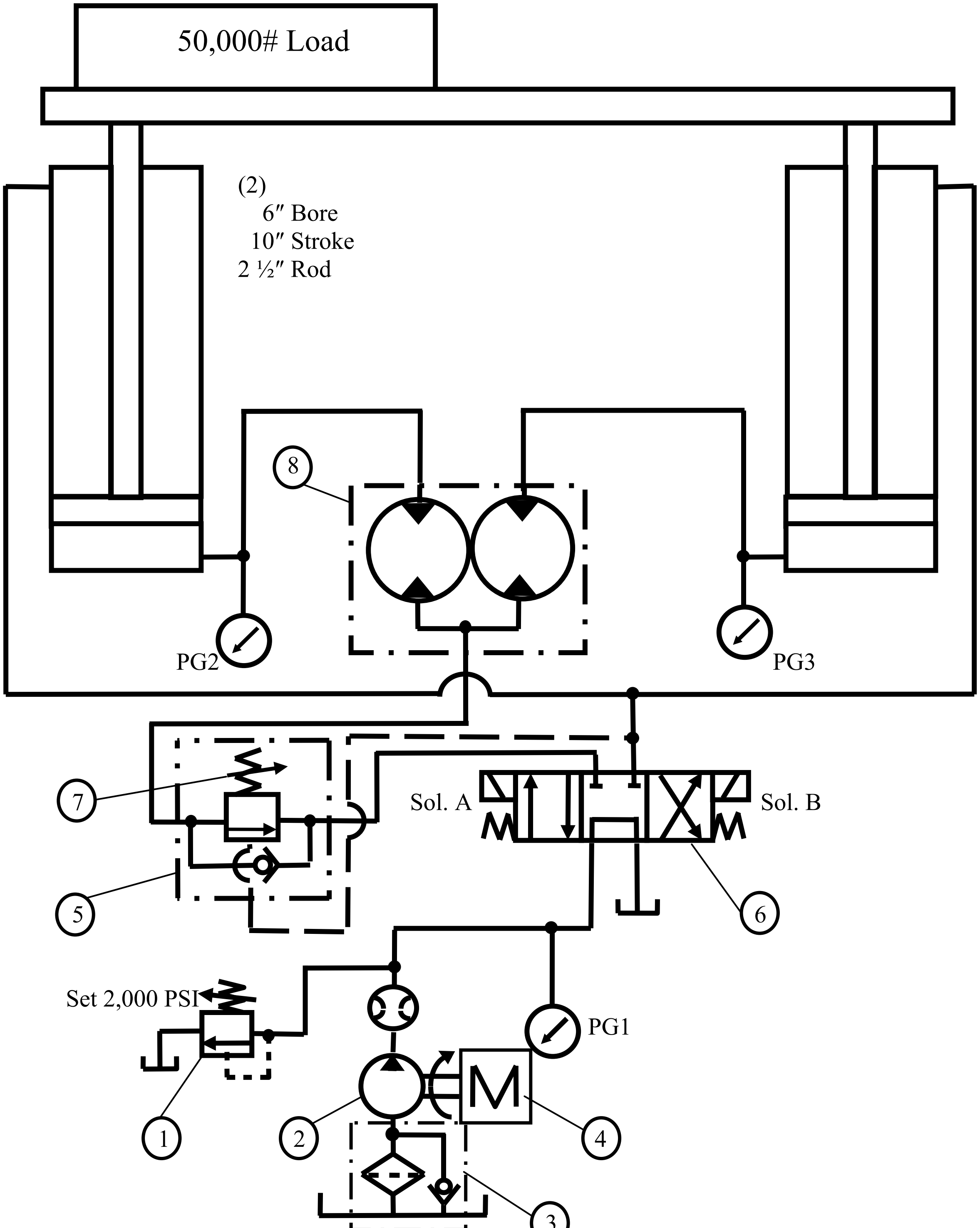
When the Bi-Directional Pump (3) first starts turning it is in center or no flow condition so the Hydraulic Motor (11) is not turning. The Charge Pump (4) is picking up and sending flow to both lines of the loop through the Charge Circuit Isolation Check Valves (6). Pressure at the Charge Pump (4) is 250 PSI and most output is going to tank through Relief Valve (5).

Shifting Bi-directional Pump (3) to flow out the top port sends oil to Hydraulic Motor (11) to turn it counter clockwise. This flow direction and motor speed is infinitely variable and is protected from over pressure by the upper Cross Port Relief Valve (10). Pressure in the pilot line to Hot Oil Bypass Valve (9) shifts it to connect the opposite closed loop flow line to Hot Oil Bypass Valve Relief Valve (8). Since this relief valve is set 100 PSI lower than the relief valve at the charge pump all charge pump flow is directed to tank through the hot oil bypass valve relief valve to tank. Clean cooled fluid is now filling the inlet to the pump and contaminated heated fluid is going to tank through the cases of both drive units and Heat Exchanger (1). This flushing circuit works in both directions of rotation anytime the motor is turning at any speed.

Shifting Bi-directional Pump (3) to flow out the bottom port sends oil to Hydraulic Motor (11) to turn it clockwise. The explanation in the previous paragraph works in this direction of rotation through the opposite side of the circuit.

Notice all pump inlet pump flow comes from the outlet of the hydraulic motor and the charge pump. Since a hydraulic motor has nearly the same flow out as in they work well. Using a single rod end cylinder poses some other problems and special pump considerations given in the chapter on pumps.

Motor Flow Divider Circuit



What is the pressure at PG1, PG2 and PG3 when the cylinders are extending?

PG1 884 PSI PG2 1,326 PSI PG3 442 PSI

Consider left hand cylinder is carrying 75% of load..

75% of 50,000#= 37,500# 25% of 50,000#= 12,500#

From Womack Data Book a 6″ Bore Cylinder has 28.274″^{2}

PG2= 37,500 PSI/28.274 = 1,326 PSI PG3= 12,500 PSI/28.274 = 442 PSI

PG1= 1,326 PSI + 442 PSI/2 = 884 PSI

Identify the Components

1. Direct Acting Relief Valve
2. Fixed Volume Pump
3. Suction Strainer
4. Non Electric Motor (Heat Engine, Gas Diesel, Steam)
5. Externally Piloted Counter Balance Valve
6. 4-Way, Three Position, Direct Double Solenoid Operated, Tandem Center, Directional Control Valve
7. Variable or Adjustable Arrow
8. Motor Type Flow Divider 50-50 Split

Circuit Operation

Motor Type Flow Dividers are often used to synchronize cylinder as shown here. The hydraulic motors in a flow divider are in a common housing with a common shaft and a common inlet so they must turn at the same rate and flow equal amounts out their separate outlets. Even when outlet pressures are different flow remains nearly the same though there is some difference in flow due to hydraulic motor bypass as outlet pressures vary. Motor type flow dividers also give some combining of fluid on the return stroke if the cylinders cannot be stopped by outside forces. For positive return synchronization use another motor flow divider on the rod side ports.

Motor flow dividers also transfer energy through the common shaft so they waste less energy when outlet pressures vary. The example here shows pump pressure at 884 PSI while the left cylinder requires 1,326 PSI and the right cylinder is using 442 PSI. The inlet pressure to a motor flow divider is always the average of the sum of the outlets.

Energizing Sol. A on the 4-Way, Three Position, Direct Double Solenoid Operated, Tandem Center, Directional Control Valve sends fluid to the cap end of both cylinders through Motor Flow Divider (8). As stated the Motor Flow Divider splits the flow equally less bypass and the cylinders extend simultaneously even though pressure required is different. The lightly loaded cylinder will stroke out first by an amount in relation to pressure differential and stroke length. Usually there is enough bypass in the flow divider to allow the lagging cylinder to stroke out quickly.

De-energizing Sol. A and energizing Sol. B starts the cylinders retracting in a synchronized manner as long as there is no mechanical binding that can stop or retard one cylinders movement.

If the cylinders must be stopped mid-stroke an externally drained pilot operated check valve is required at each cap end port to stop oil transfer between the cylinders.

Notes: