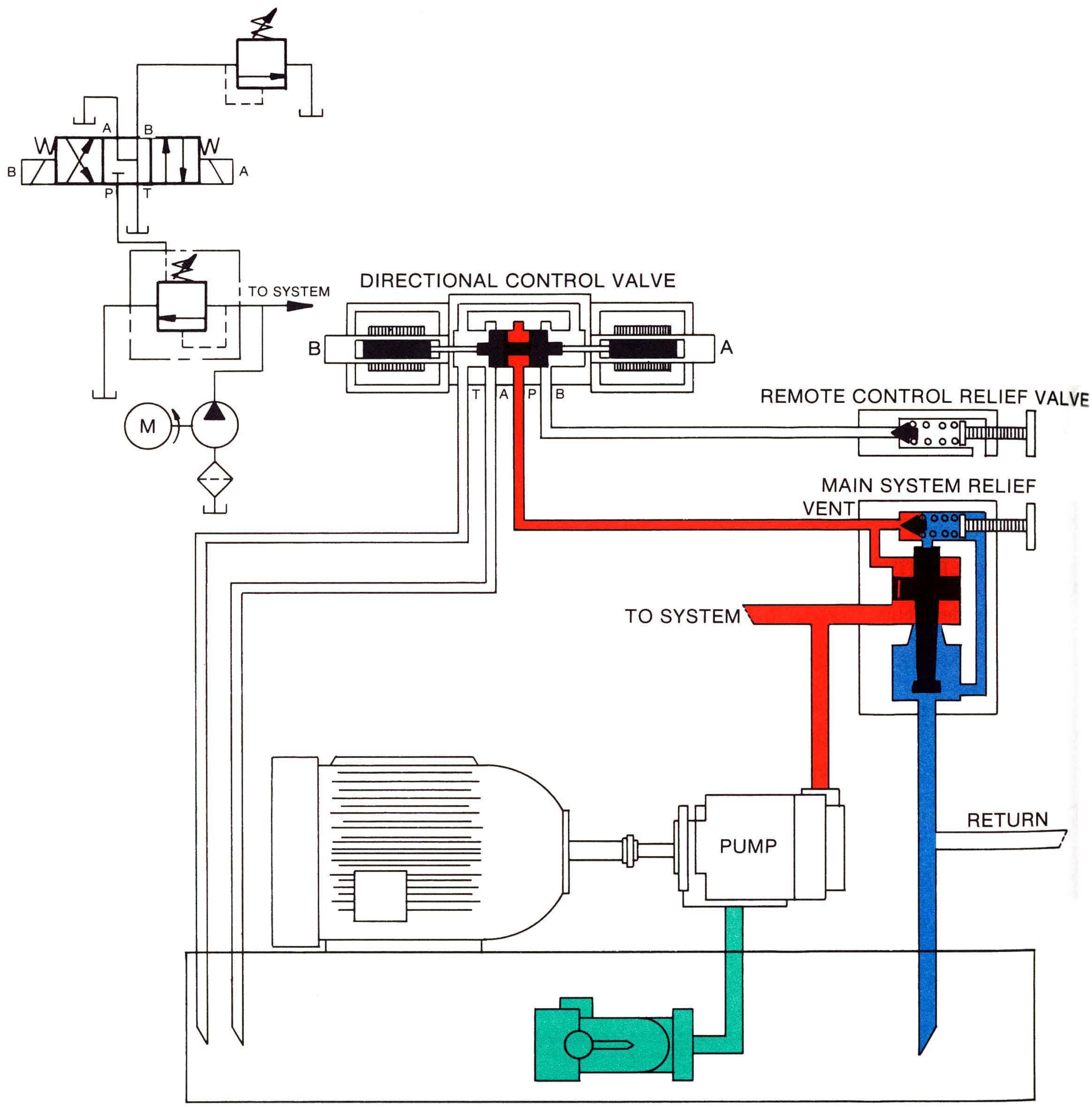
Appendix B
Basic Hydraulic Circuitry

The following legend will be used for the color coding of the drawings. It is as follows:

- Red — Operating or System Pressure
- Yellow — Reduced Flow or Reduced Pressure
- Orange — Intermediate Pressure Inside Flow Control
- Green — Intake or Drain
- Blue — Return Line Flow
- No Color — Inactive Fluid

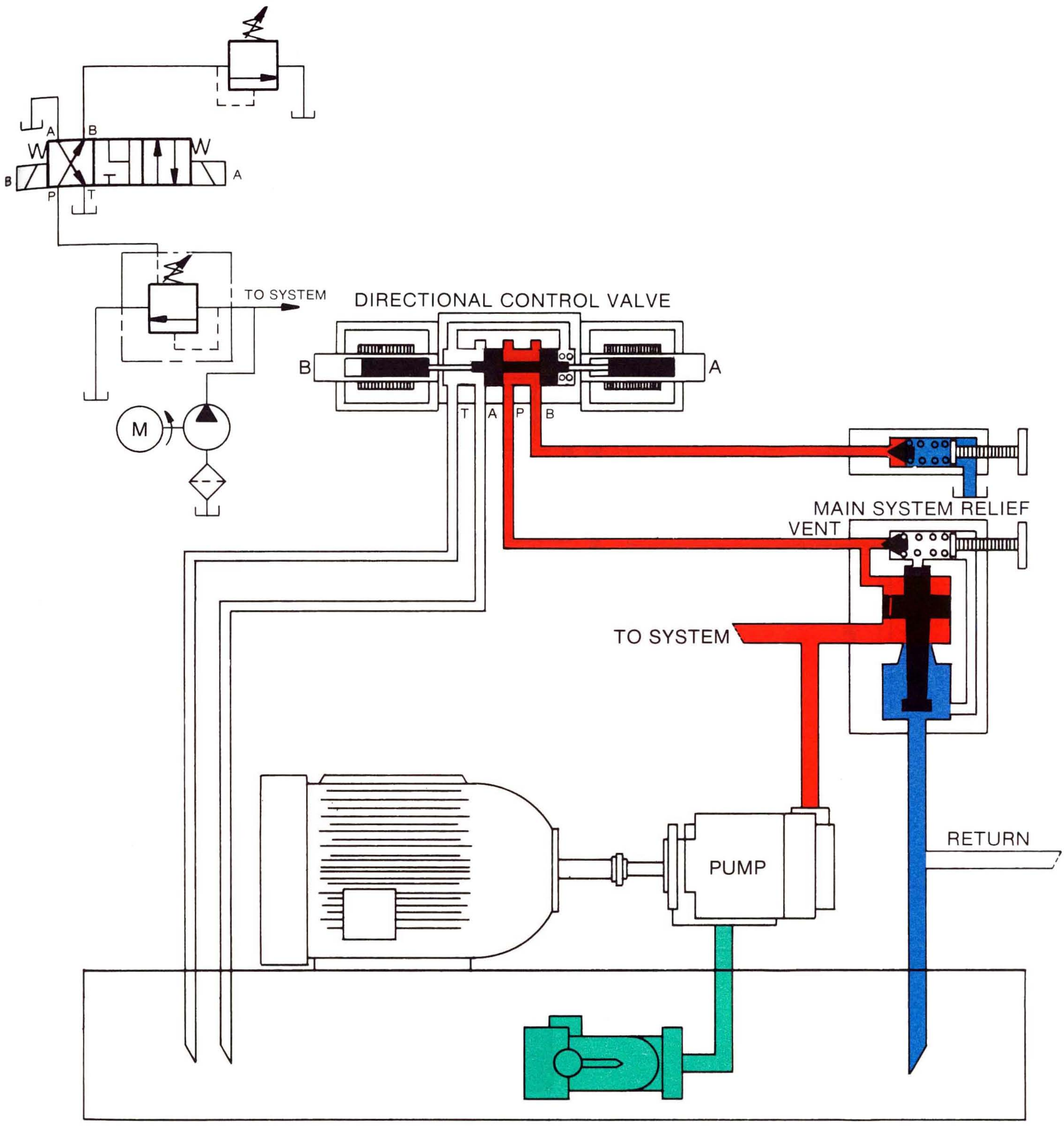
Solenoid Operated Relief Valve



HIGH MAXIMUM PRESSURE

Directional Control Valve is not energized causing vent line to be plugged. Pressure at pump is determined by relief valve setting.

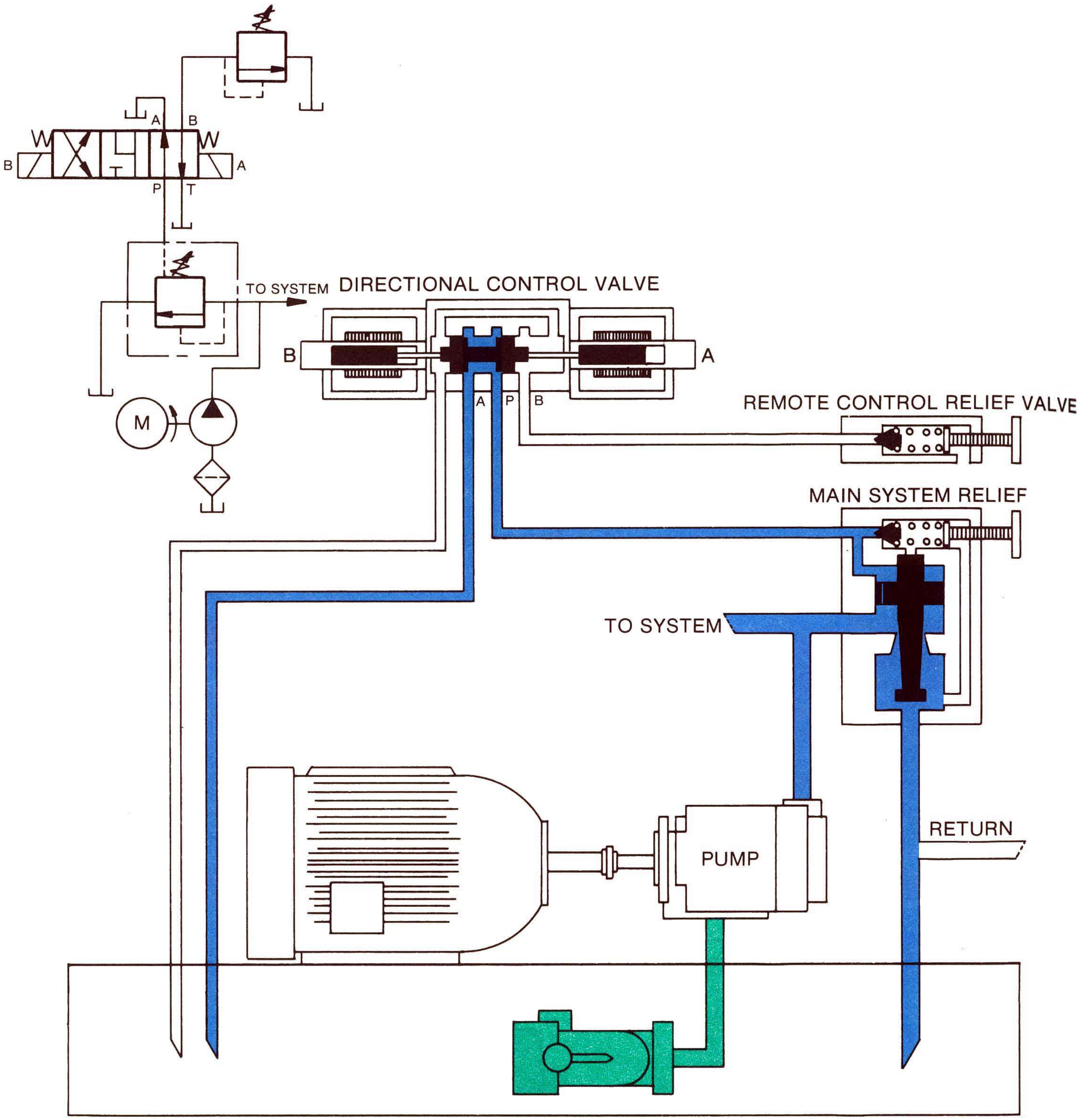
Solenoid Operated Relief Valve



INTERMEDIATE PRESSURE

Solenoid "B" of directional valve is held energized. The spool shift thereby connecting the vent of relief valve to pressure port of remote control relief valve. System pressure is limited by the remote control relief valve which remotely controls the main relief.

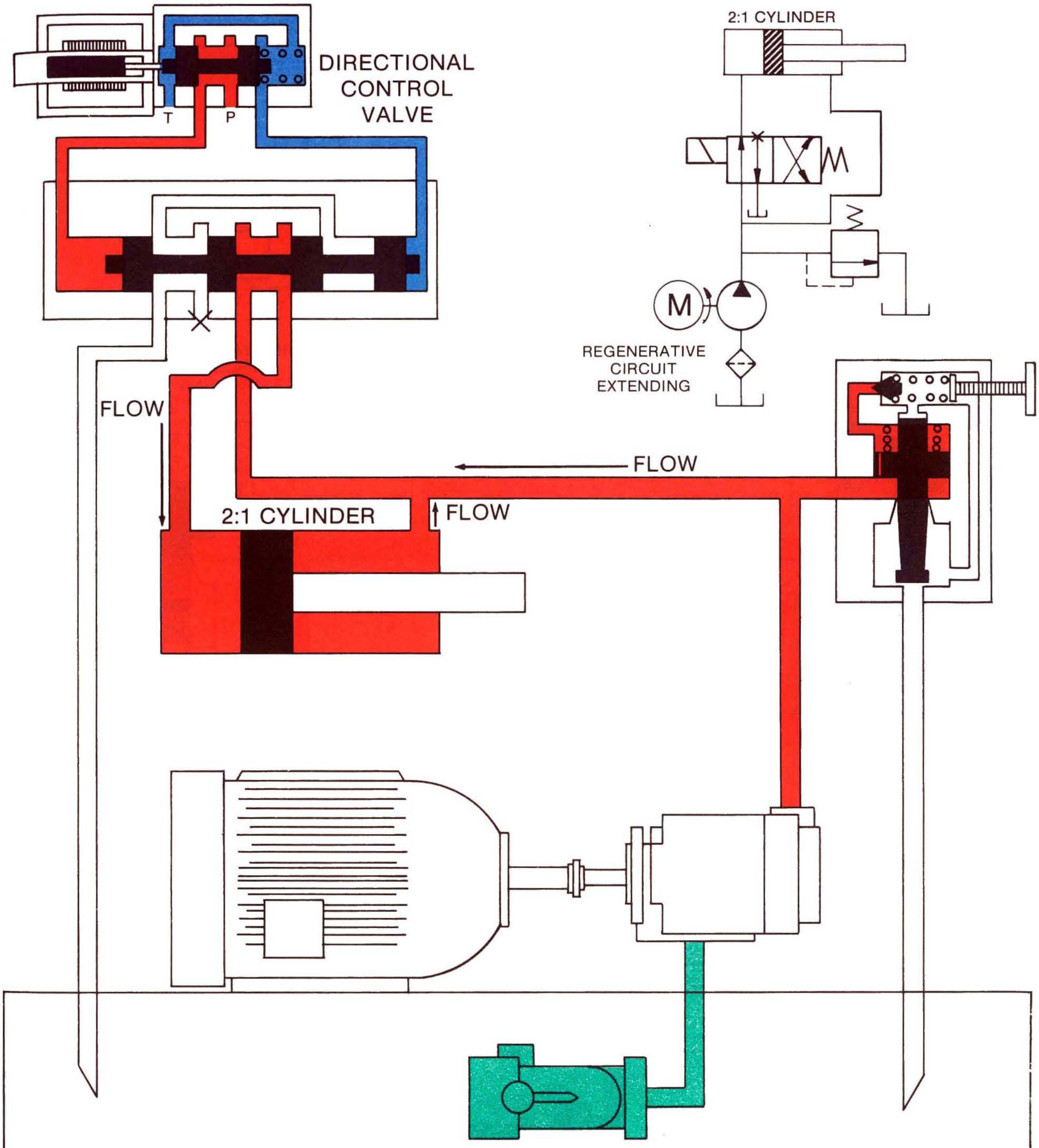
Solenoid Operated Relief Valve



VENTING

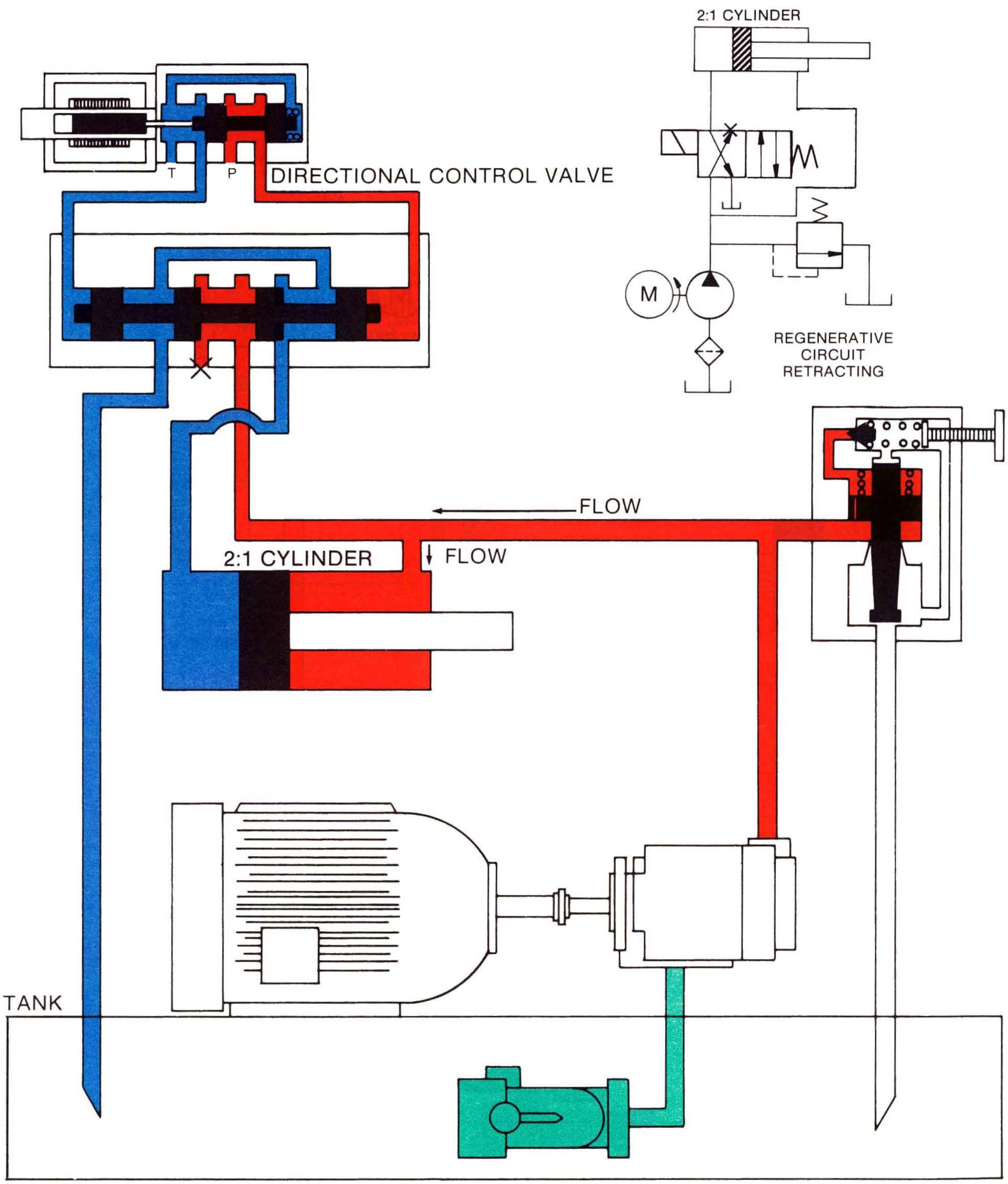
Solenoid A is energized connecting the vent port of the main relief to tank. By releasing this pilot pressure, the only pressure holding the spool closed is the relatively light pressure of the spring. This results in the pump applying a relatively low pressure to return its flow to tank.

Regenerative Circuit - Cylinder Extending



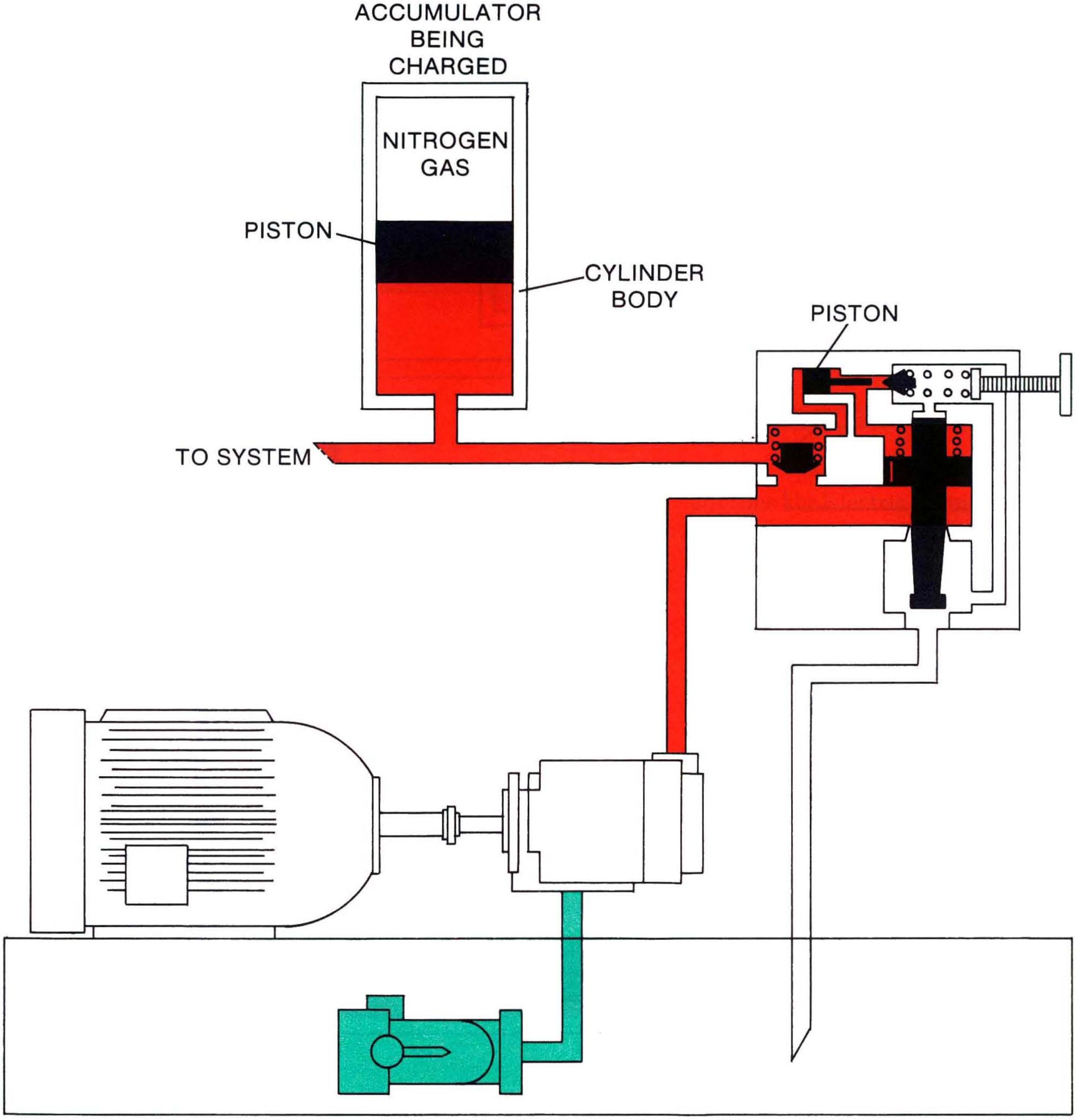
The regenerative circuit which is illustrated consists of a pump, relief valve, a directional valve with a blocked port, and a 2:1 cylinder. With the directional valve in the position shown, both sides of the cylinder piston are subjected to the same pressure. The unbalanced force which results extends the rod. Fluid discharging from the rod end is added to the pump's flow. Since in a 2:1 cylinder the discharge fluid from the rod end is always half the volume entering the cap end, the only volume which is filled by pump flow is the other half of the cap end volume. To calculate the rod speed of a 2:1 cylinder when it is regenerating, the cross-sectional area of the rod is used in the calculations.

Regenerative Circuit - Cylinder Retracting



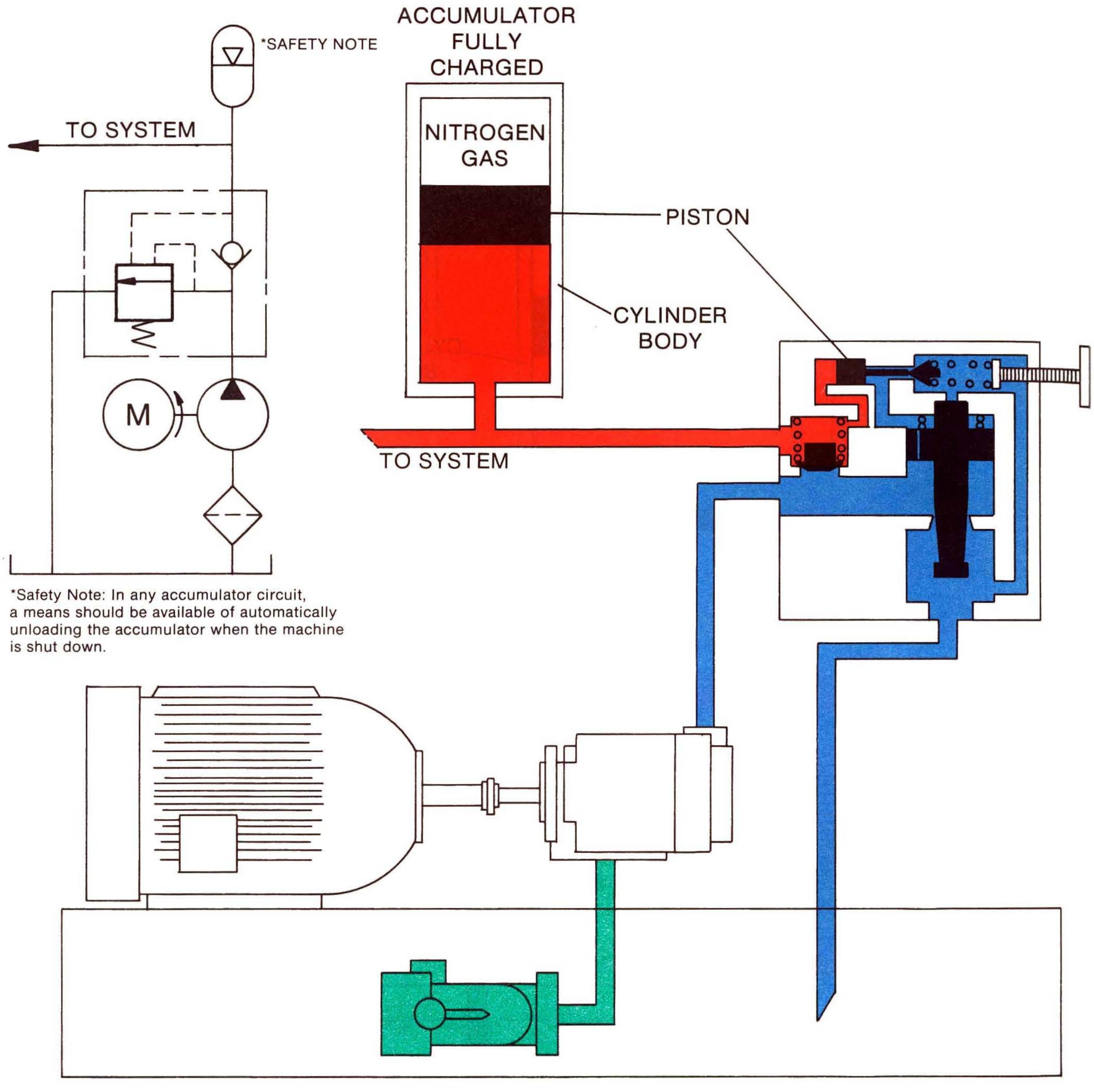
To retract the cylinder rod, the directional valve is shifted. The cap end of the cylinder is drained to tank. All pump flow and pressure is directed to the rod end side. Since the pump is filling the same volume as at the cap end side (half cap end volume), the rod retracts at the same speed.

Differential Unloading Relief Valve



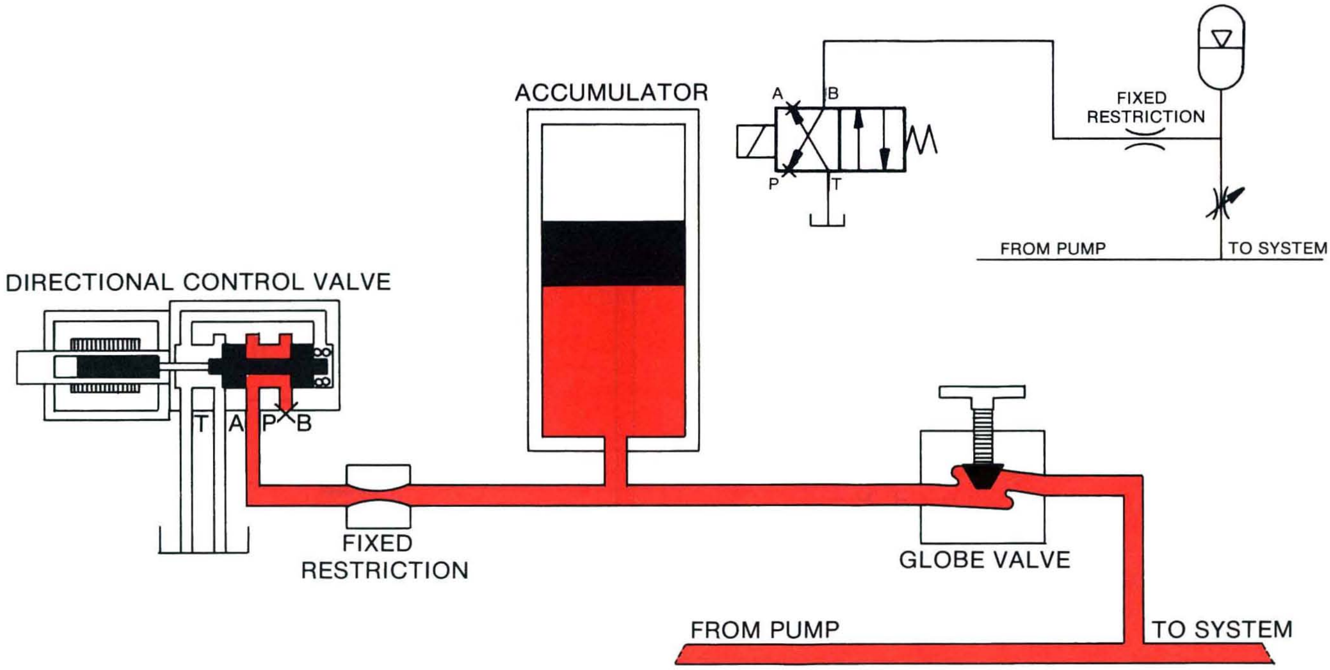
The differential piston fits in a bore opposite the pilot valve dart. At each end of the piston, the areas exposed to pressure are equal. During the time the accumulator is being charged, pressure at each end of the piston is equal.

Differential Unloading Relief Valve

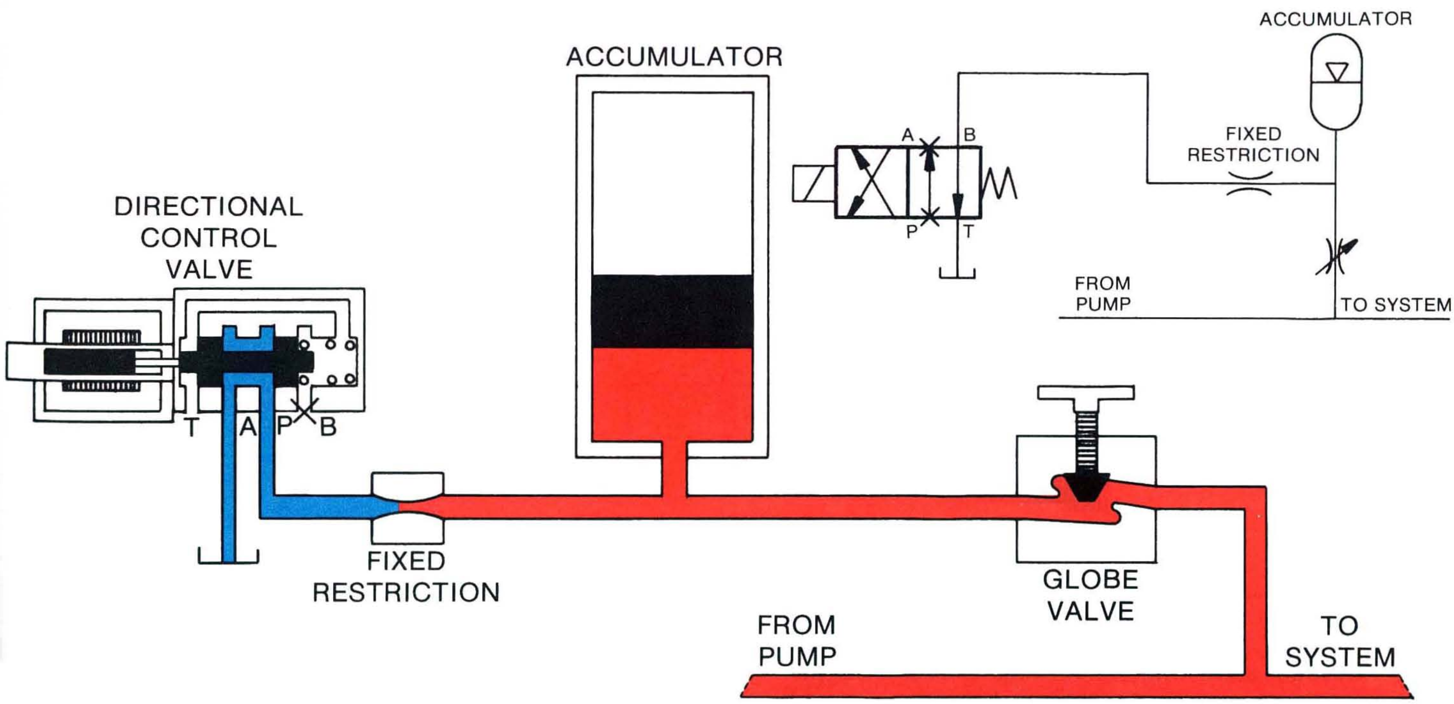


When the accumulator is charged, the piston is forced toward the pilot dart and forces the pilot dart completely off its seat. This in effect releases the main spool spring chamber of pilot pressure. The relief valve is vented. The spool moves up and allows flow to go to tank at a low pressure. At the same time the check valve closes so that the accumulator cannot discharge through the relief valve. At this point one pressure has been achieved — the accumulator's maximum pressure.

Accumulator Bleed Down Circuit



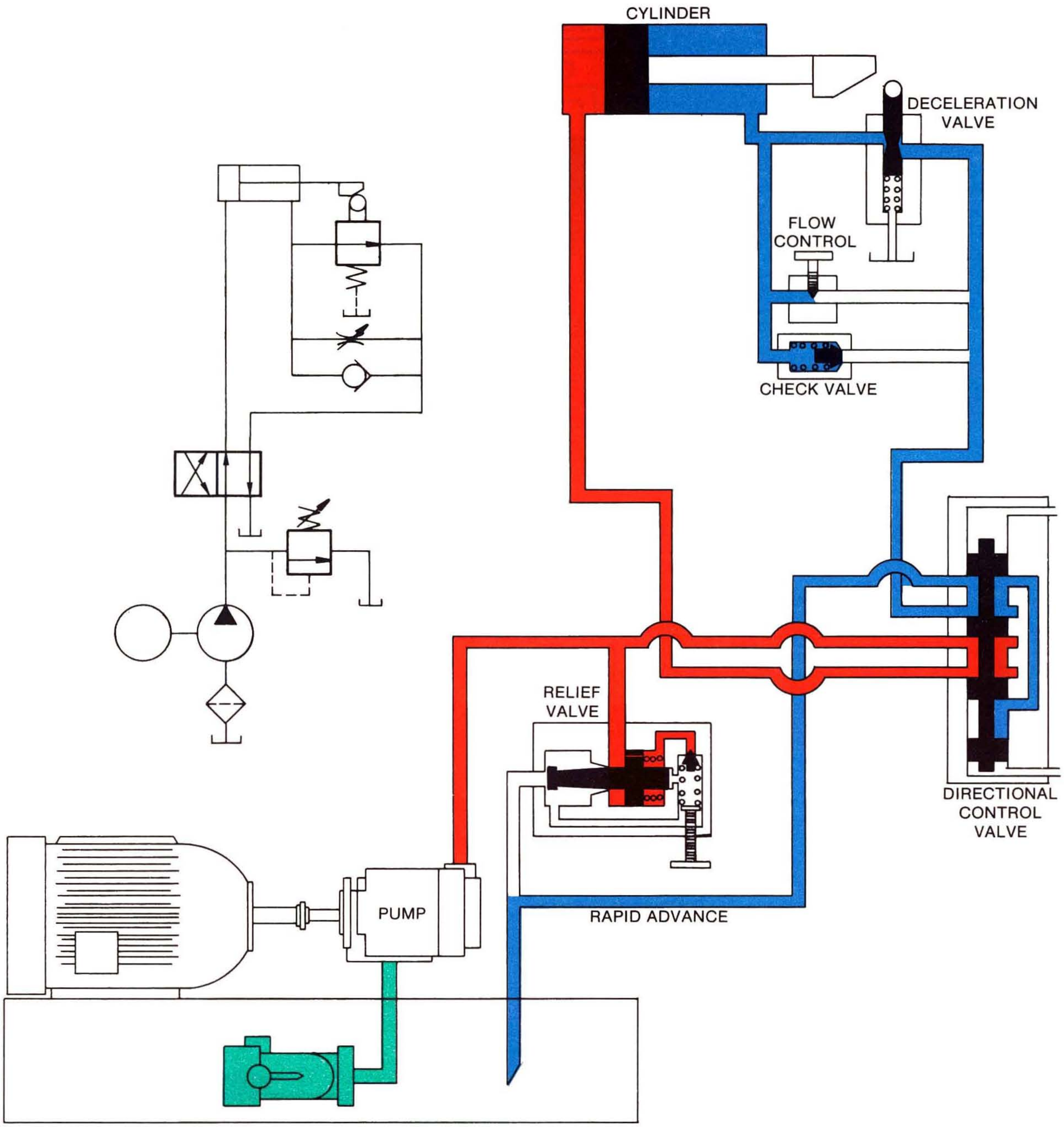
When the system is shut down, the solenoid is de-energized and the spring pushes the valve to its normally open position. The accumulator bleeds down safely through the needle valve. Therefore, anytime the electric motor is shut down, the accumulator automatically bleeds.



In any accumulator circuit, a means should be available of automatically unloading the accumulator when the system is shut down. This can be accomplished by using a spring offset, solenoid operated, 4-way valve, that has been converted into a normally open 2-way.

In the example circuit, the solenoid of the converted 2-way valve can be energized when the electric motor is started. This blocks the flow through the valve and allows the accumulator to charge.

Rapid Advance & Feed Type Circuit

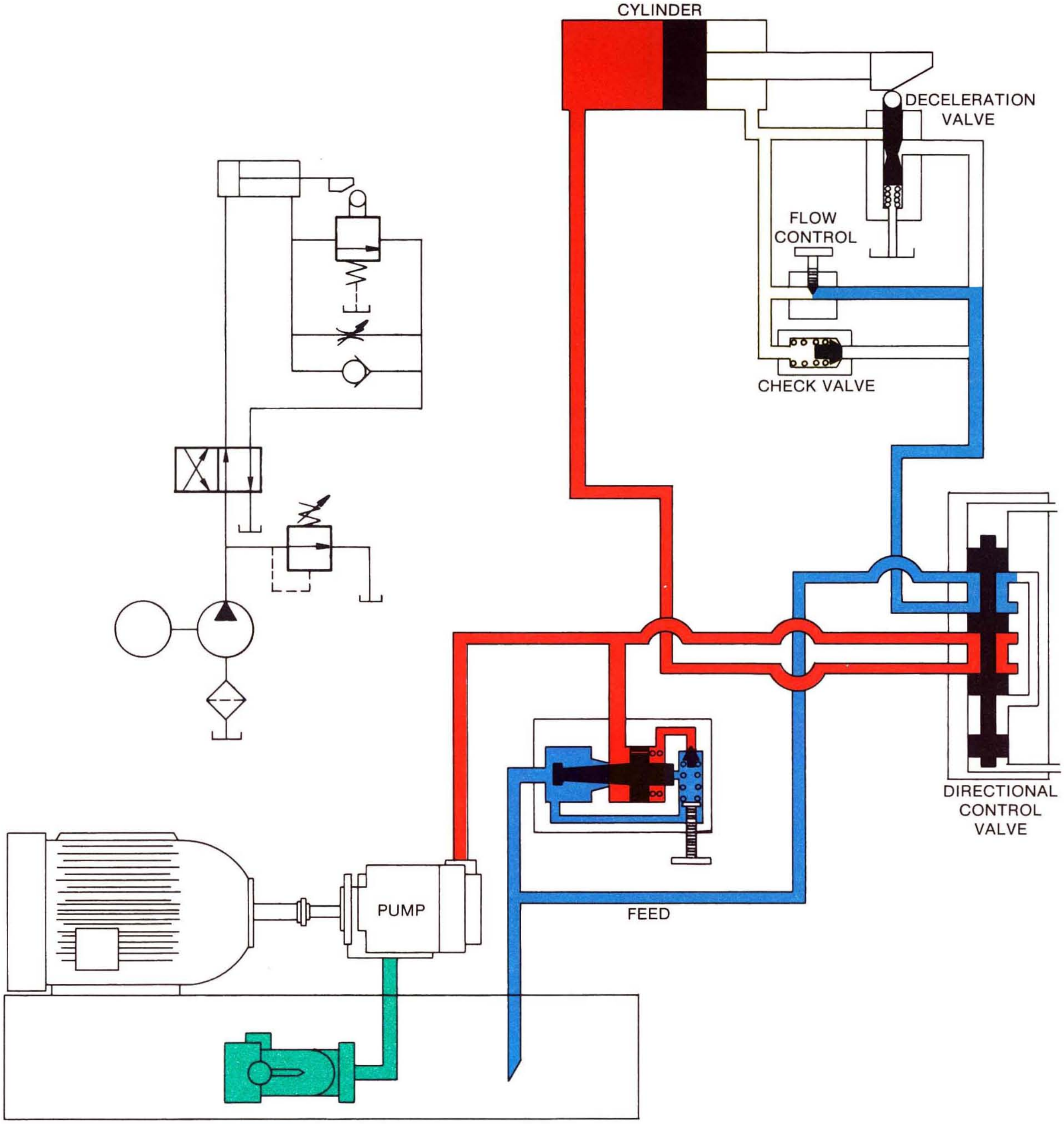


RAPID ADVANCE

In many Hydraulic Circuits, a rapid traverse is needed until the machining portion of the stroke is reached. This is known as rapid advance & feed type circuitry.

For this portion of the circuitry, the directional valve has been shifted and pump flow is directed to the cap end of the cylinder. Oil flow from the head is free to flow through the deceleration valve. The fluid will move through the directional control valve and back to tank.

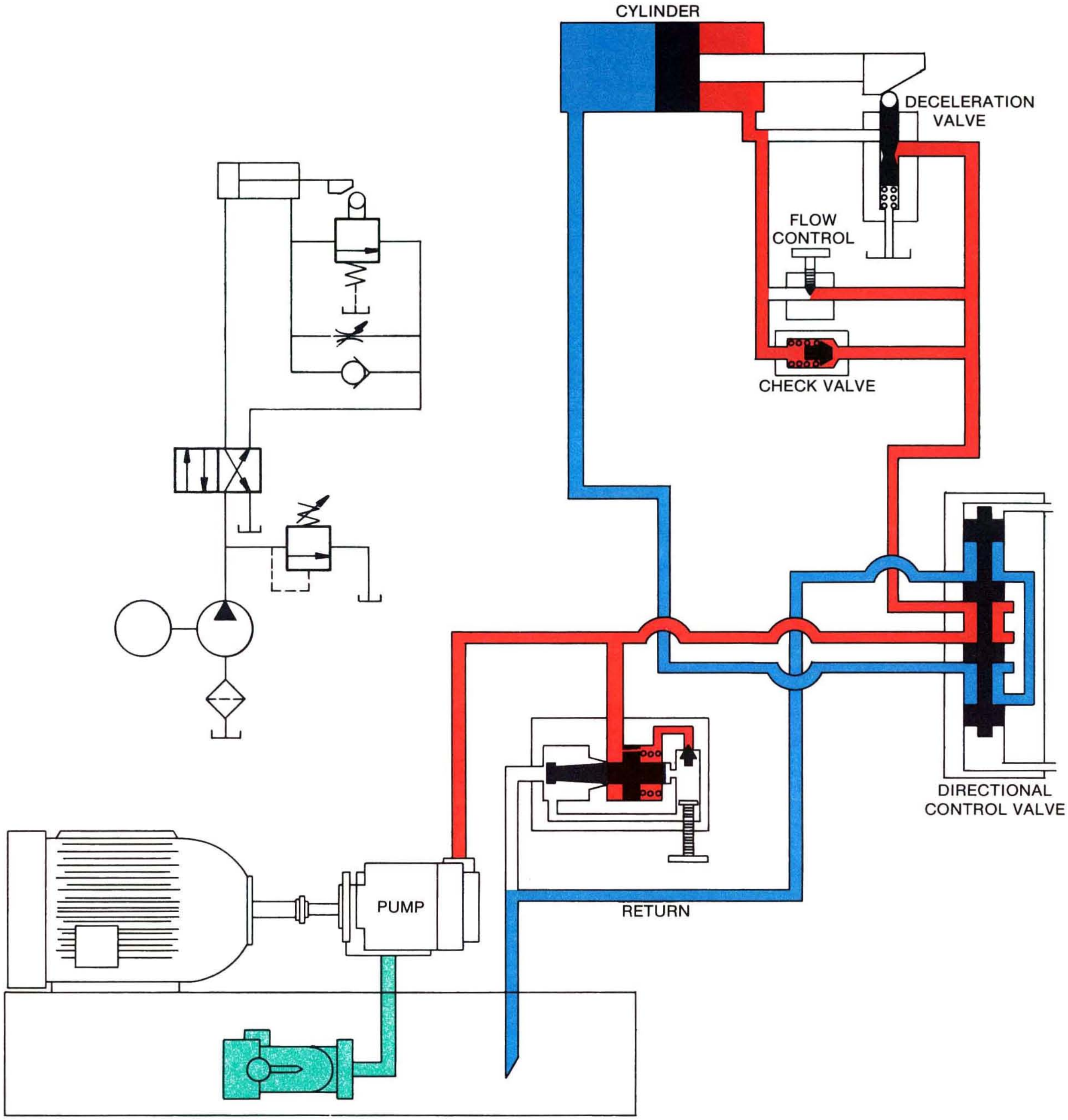
Rapid Advance & Feed Type Circuit



FEED

It is at this point in the circuitry, that the cam connected to the cylinder rod actuates the deceleration valve. As the cam depresses the plunger, flow through the valve is gradually cut off. This valve allows a load attached to the cylinder rod to be slowed down at any point of its stroke, where cylinder cushions are not in effect. For the remainder of the stroke, oil leaving the head end will pass through the flow control valve (set at the necessary feed rate) through the directional control and back to tank. It should be noted that the relief valve has opened because flow control has now become apparent to the circuitry.

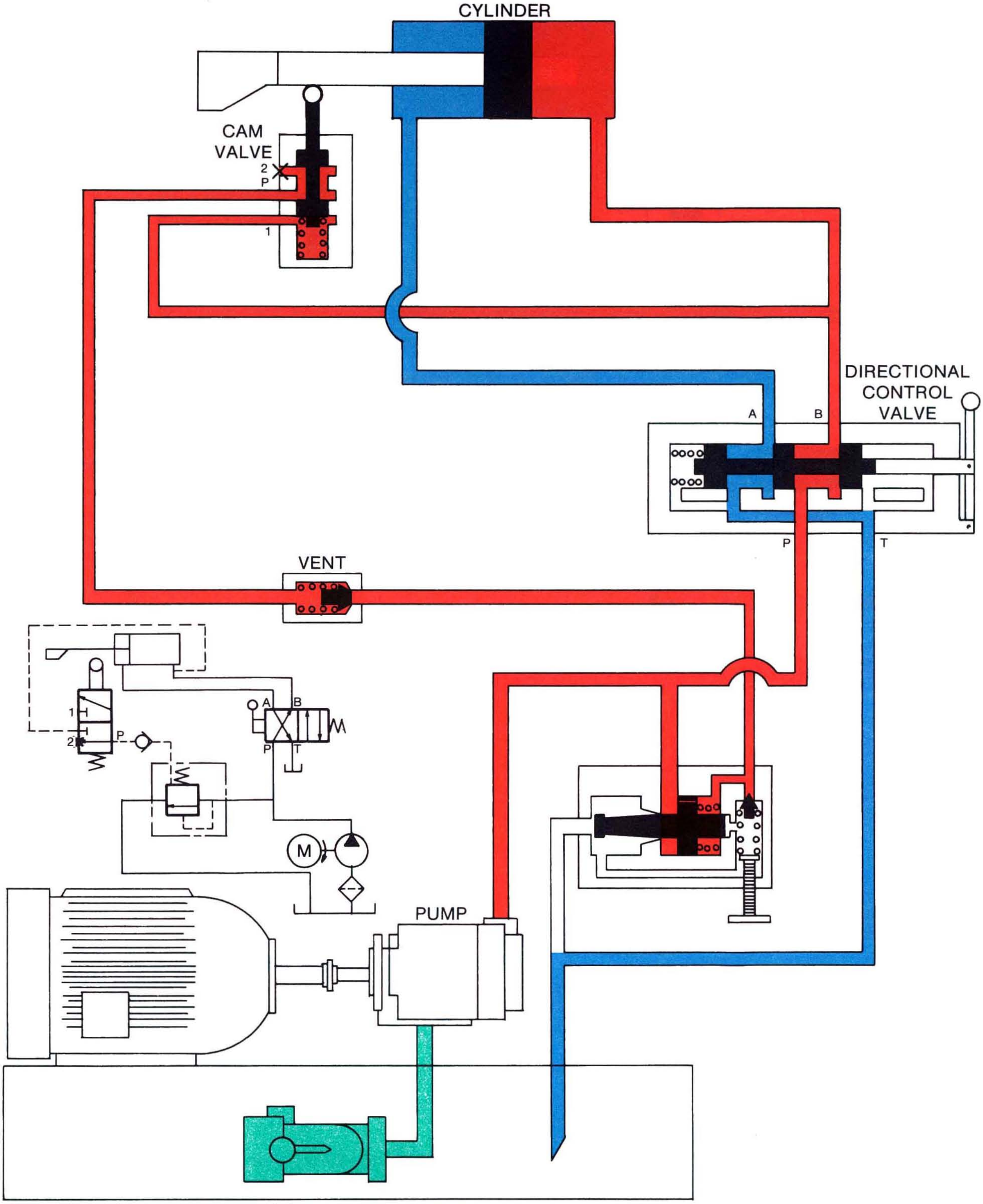
Rapid Advance & Feed Type Circuit



RETRACT

In this sketch, pump flow is directed through the directional control valve to the check valve, flow control, and deceleration valve. Since the check valve has the least resistance, most of the flow will pass through its path. Fluid exiting the cap end of the cylinder is directed through the directional control and back to tank.

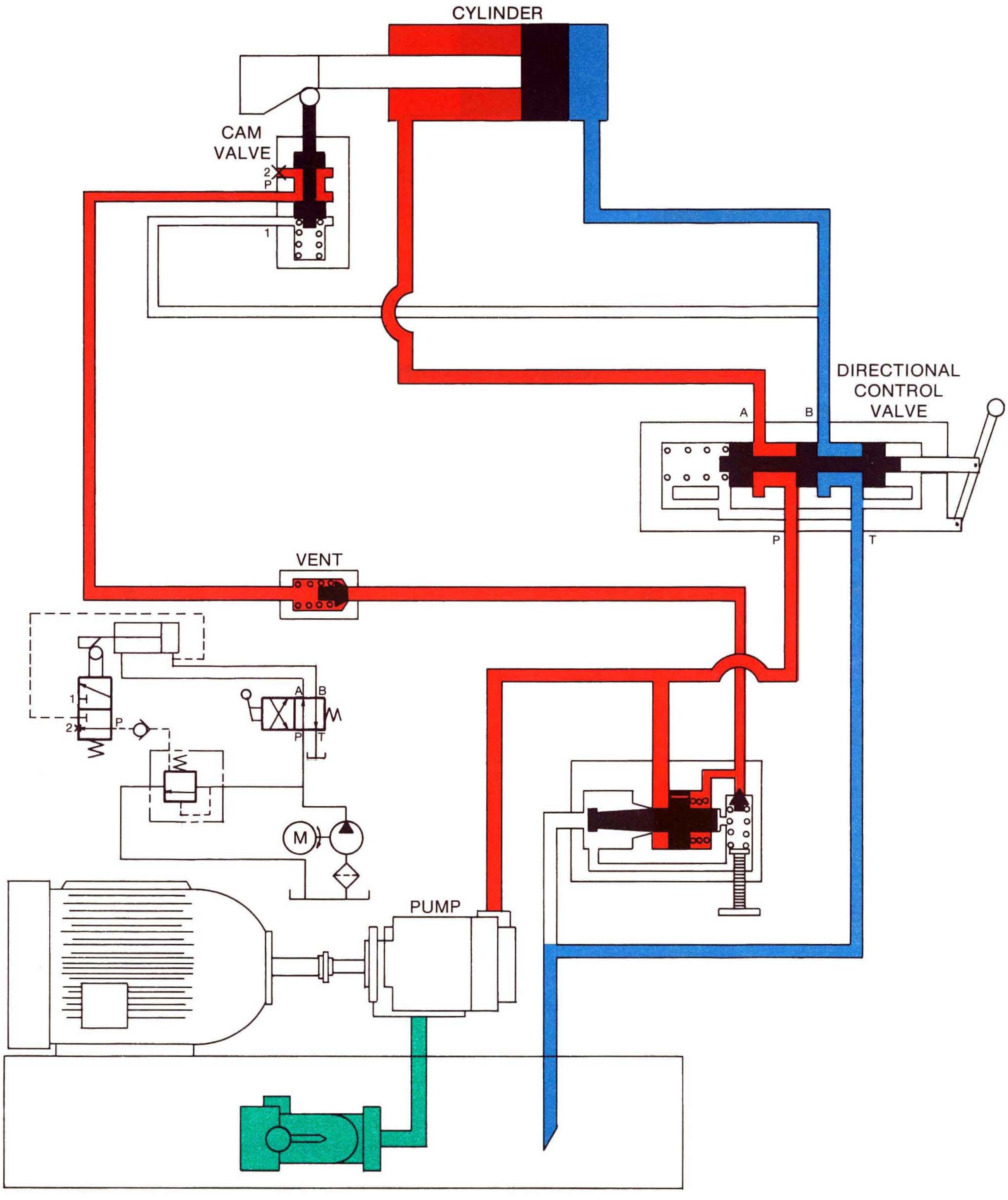
Automatic Pump Unloading



CYLINDER EXTENDING

To make the cylinder extend, the directional control valve is pushed. This directs the flow from the pump to the cap end of the cylinder, as well as closing the 5 psi check valve. By closing the check valve, pilot flow from vent port stops, and working pressure is obtainable.

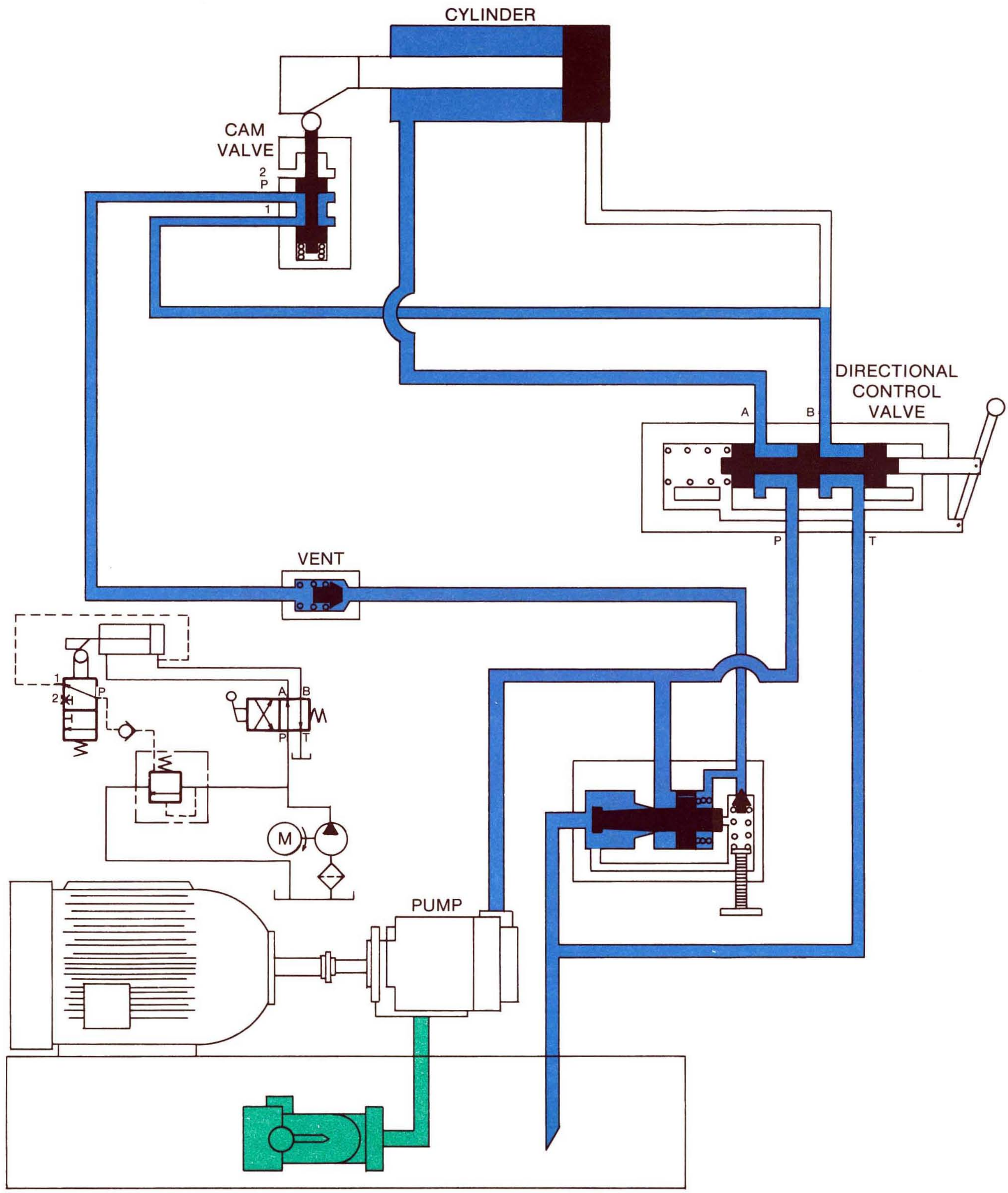
Automatic Pump Unloading



CYLINDER RETRACTING

For retraction the directional control valve handle is released. This directs pump flow to the head end of the cylinder. The vent line of the relief valve remains closed until the cylinder is fully retracted.

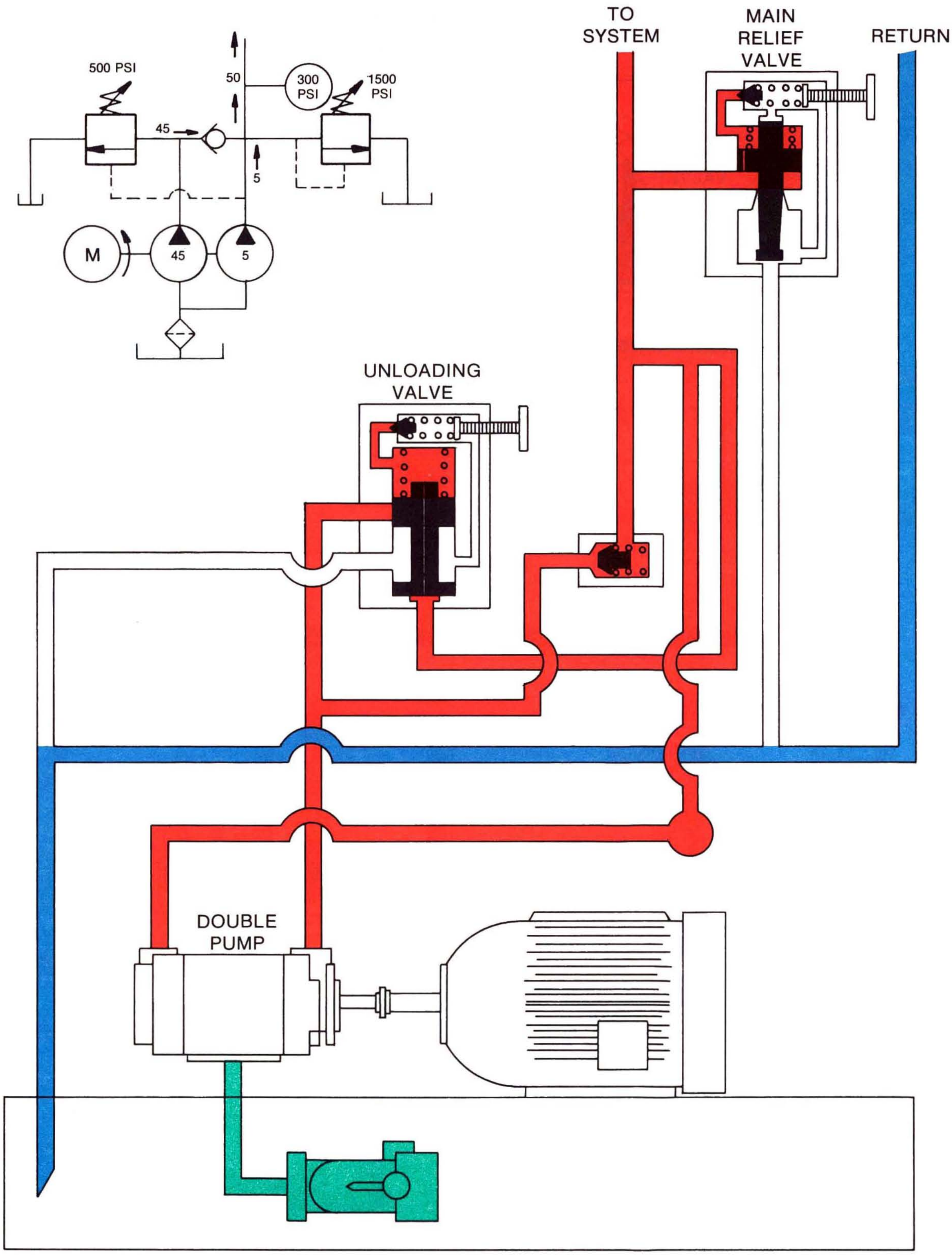
Automatic Pump Unloading



PUMP UNLOADED

At the end of the retraction stroke, the cam on the cylinder will depress the cam valve. This will allow the fluid from the vent port of the relief to return to tank. This in turn, will allow the main relief to open causing the pump to run at low pressure for efficient idle operation.

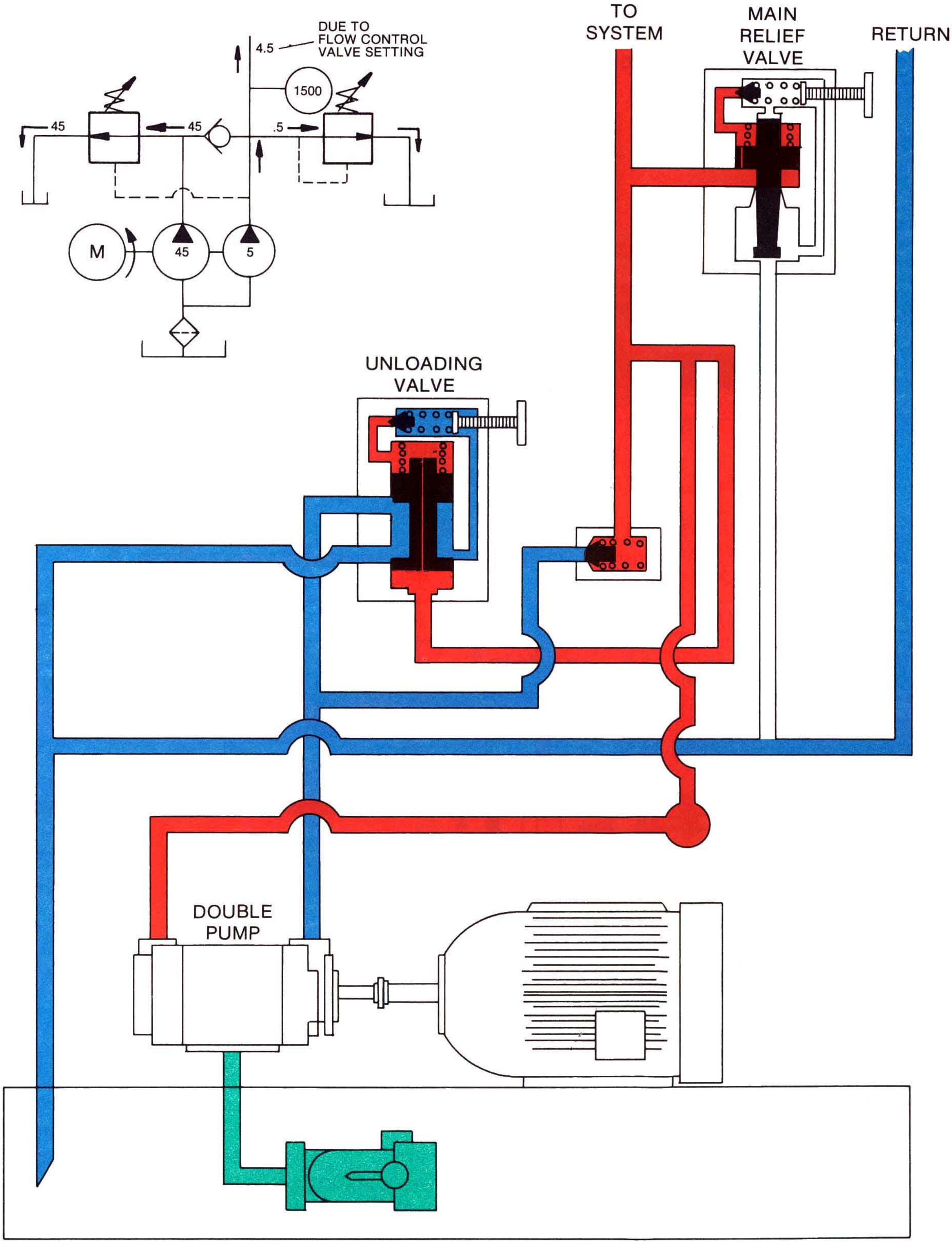
Hi-Lo System



LOW PRESSURE OPERATION

A hi-low system satisfies a system demand by combining a 45 GPM and 5 GPM pump flow. When the electric motor is turned on, the 45 GPM passes through the check valve adding to the 5 GPM flow; 50 GPM passes out into the system possibly extending a cylinder at a relatively low pressure.

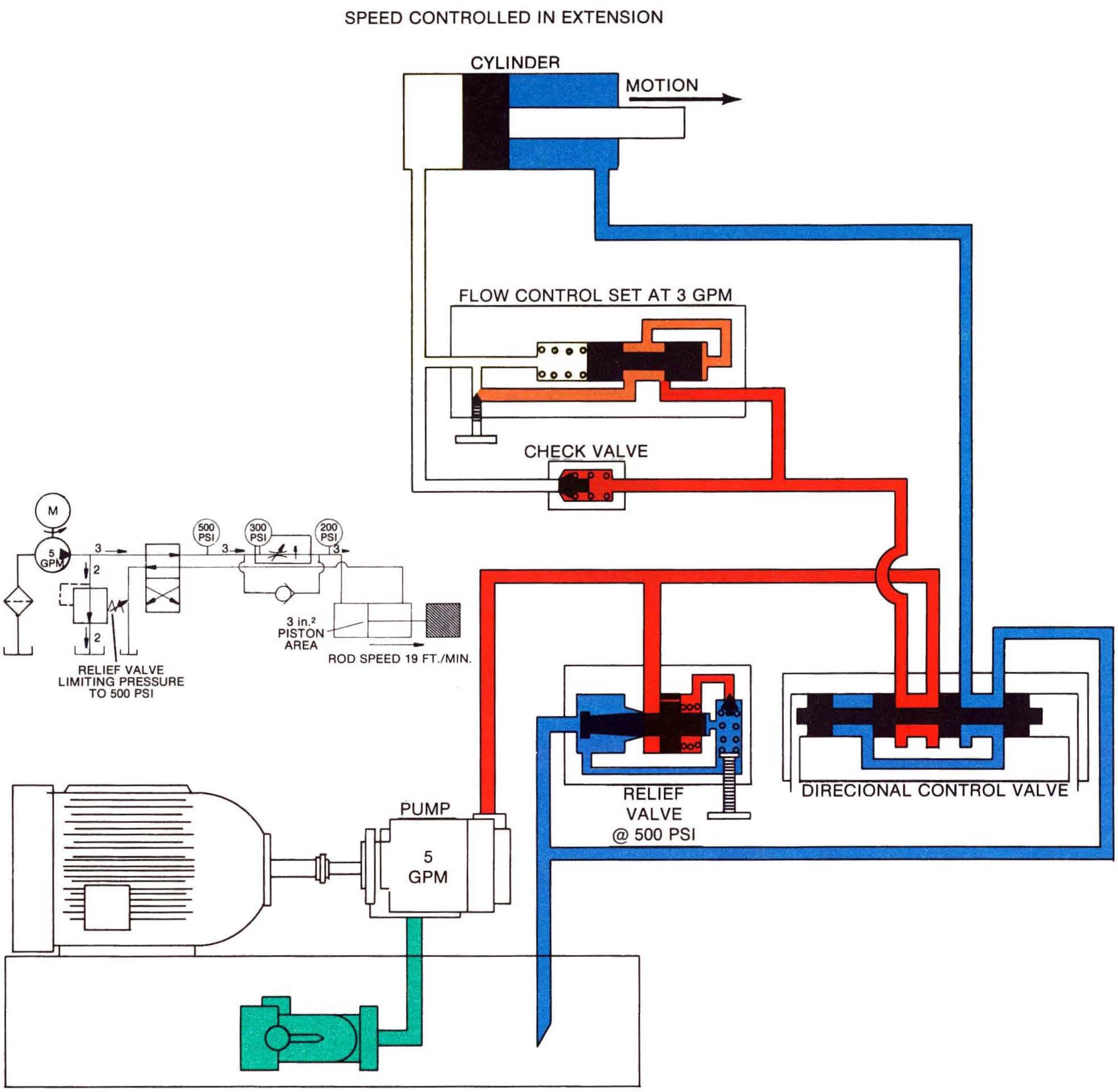
Hi-Lo System



HIGH PRESSURE OPERATION

When the work load is contacted and work pressure is desired, pump/electric motor pressure starts climbing toward the relief valve setting of 1500 PSI. As it passes through the 500 PSI pressure level, the normally closed unloading valve opens allowing the 45 GPM pump to unload while the 5 GPM pump continues to work. This action eliminates unnecessary power generation by the 45 GPM pump when it is not needed.

Meter In Circuitry

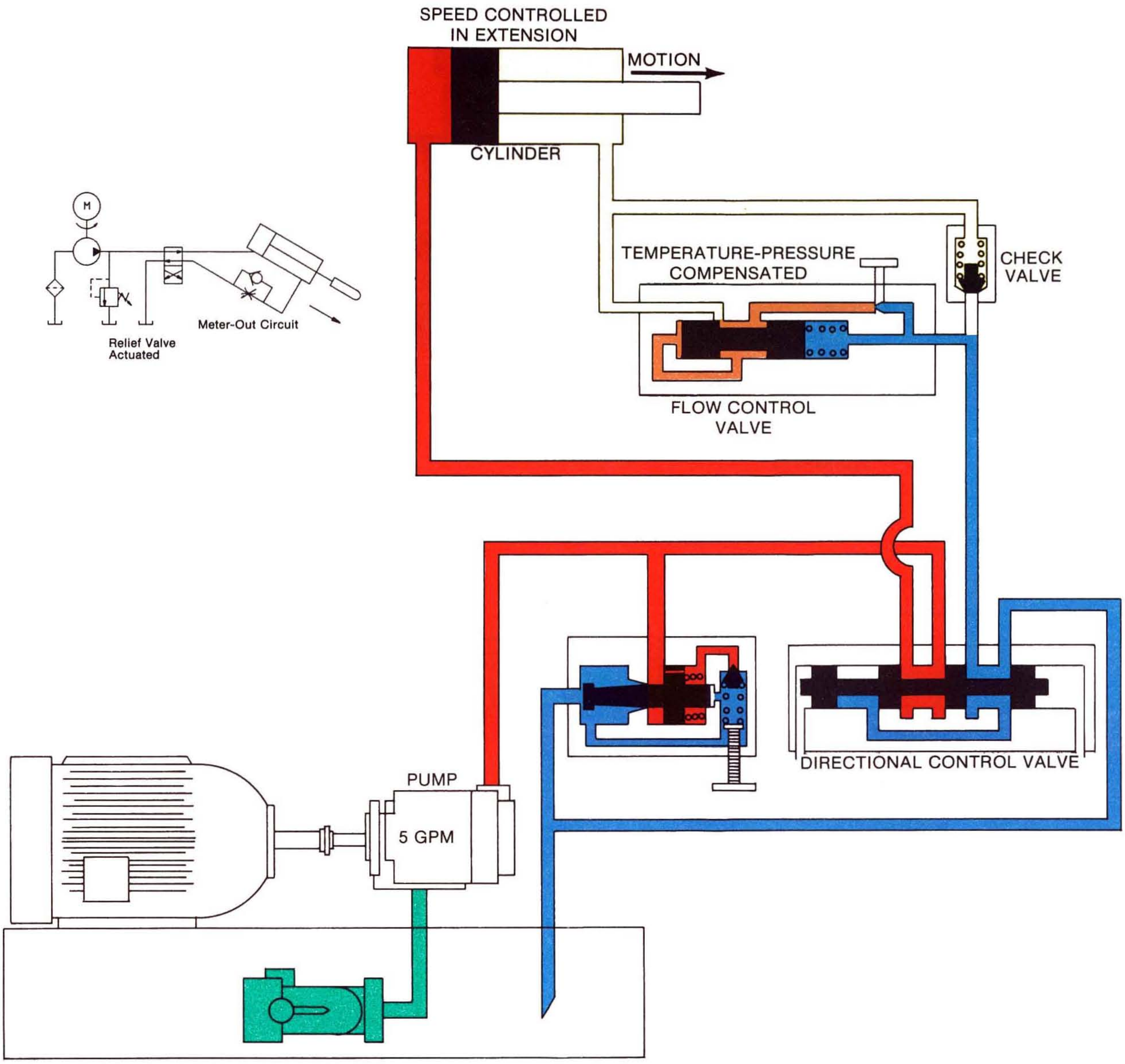


In the circuit illustrated, the restrictor type pressure compensated flow control valve is set for 3 GPM. Relief valve setting is 500 PSI. Work-load pressure is 200 PSI. The spring biasing the compensator spool has a value of 100 PSI.

During system operation, the work-load pressure of 200 PSI, plus the 100 PSI spring, bias the compensator spool.

The pump attempts to push its total flow of 5 GPM through the needle valve orifice. When pressure ahead of the needle valve reaches 300 PSI, the compensator spool moves and causes a restriction for the incoming fluid. The pressure at the flow control inlet rises to the relief valve setting of 500 PSI. As the fluid passes over the restriction made by the compensator spool, 200 PSI of the 500 PSI is transformed into heat. The pressure ahead of the needle valve is limited to 300 PSI. Of this 300 PSI, 200 PSI is used to overcome the resistance of the load; 100 PSI is used to develop a flow rate through the needle valve orifice. The flow rate in this case is 3 GPM. The remaining 2 GPM is dumped over the relief valve.

Meter Out Circuitry

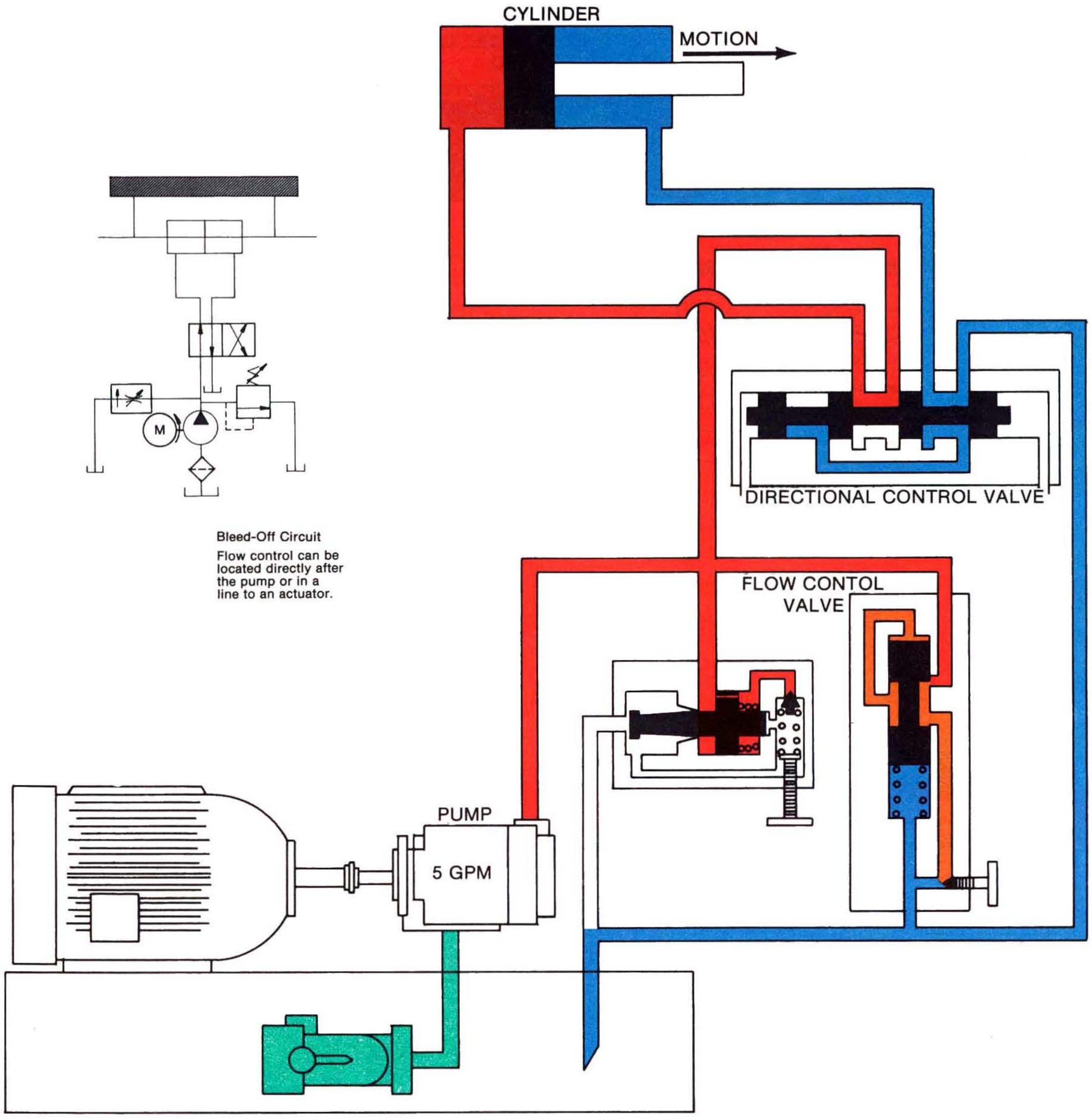


If the speed of an actuator must be precise through the workday, a temperature-pressure compensated flow control could be used.

In some cases, the work load changes direction (load passing over the center point of an arc) or the work load pressure suddenly changes from full to zero pressure (drill breaking through stock). This causes the load to run away.

A flow control valve placed at the outlet port of an actuator controls the rate of flow exiting the actuator. This is a meter-out circuit and gives positive speed control to actuators used in drilling, sawing, boring, and dumping operations. A meter-out circuit is a very popular industrial hydraulic flow control circuit.

Bleed Off Circuitry



Bleed-Off Circuit
Flow control can be located directly after the pump or in a line to an actuator.

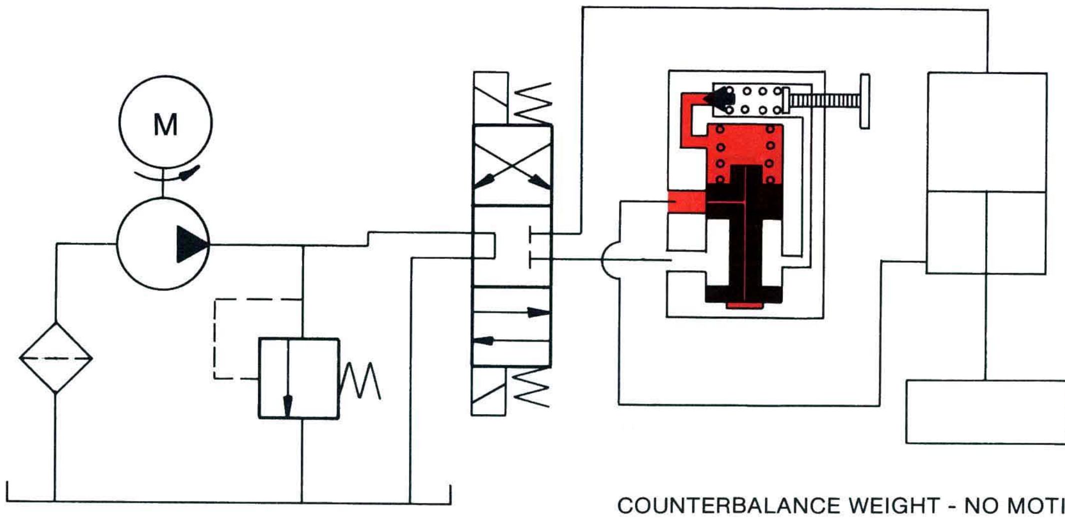
Another type of flow control circuit is the bleed-off circuit. In this circuit, the flow control valve does not cause an additional resistance for the pump. It operates by bleeding-off to tank a portion of the pump's flow at the existing system pressure.

Besides generating less heat, a bleed-off circuit can also be more economical than a meter-in or meter-out circuit. For instance, if a flow rate of 100 GPM had to be reduced to 90 GPM, a 90 GPM flow control valve would be needed in a meter-in circuit and, depending on the size of the cylinder, approximately a 70 GPM flow control in a meter-out circuit. Whereas in a bleed-off circuit, a 10 GPM flow control could be used.

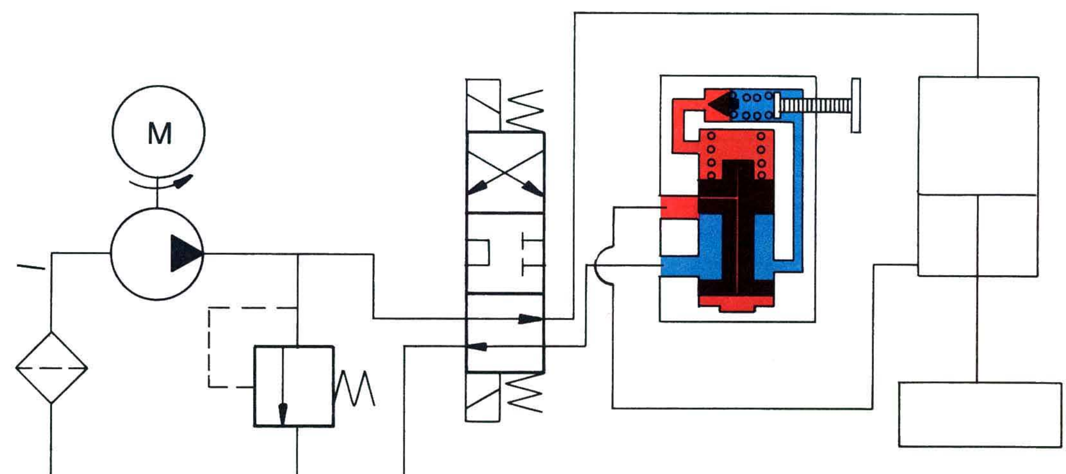
Even with these apparent advantages, a bleed-off circuit is not a very popular flow control circuit. This is because a flow control in a bleed-off arrangement only indirectly controls the speed of an actuator. It can precisely meter flow to the tank, but if leakage through various system components increases, actuator speed will decrease.

A bleed-off circuit can be used in any application where precision flow regulation is not required; and where the load offers a constant resistance as in reciprocating grinding tables, honing operations, and vertically lifting a load.

Counterbalance Valve



COUNTERBALANCE WEIGHT - NO MOTION



EXTEND (KEEP WEIGHT FROM FALLING)

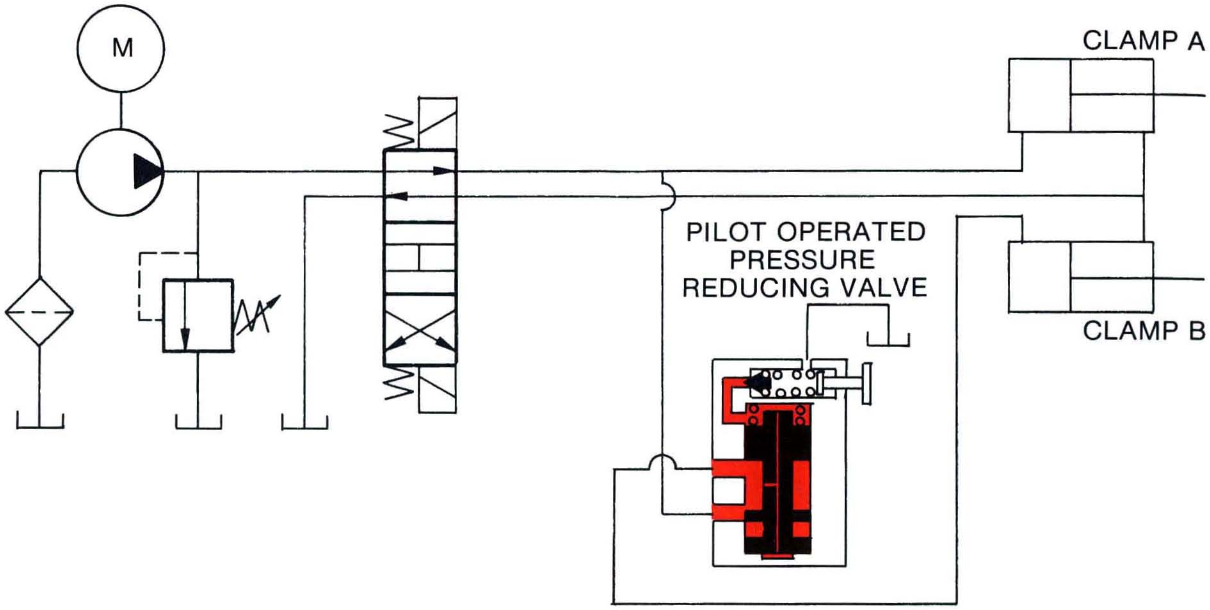
In a press circuit, when the directional valve directs flow to the cap end of the cylinder, the weight of the platen attached to the cylinder rod will fall uncontrollably. Pump flow will not be able to keep up.

To avoid this situation, a normally closed pressure valve is located downstream from the press cylinder. The spool in the valve will not connect primary and secondary passages until a pressure, which is sensed at the bottom of the spool, is greater than the pressure developed by the weight of the platen. (In other words, when fluid pressure is present at the cap end of the piston.) In this way the weight of the platen is counterbalanced throughout its downward stroke.

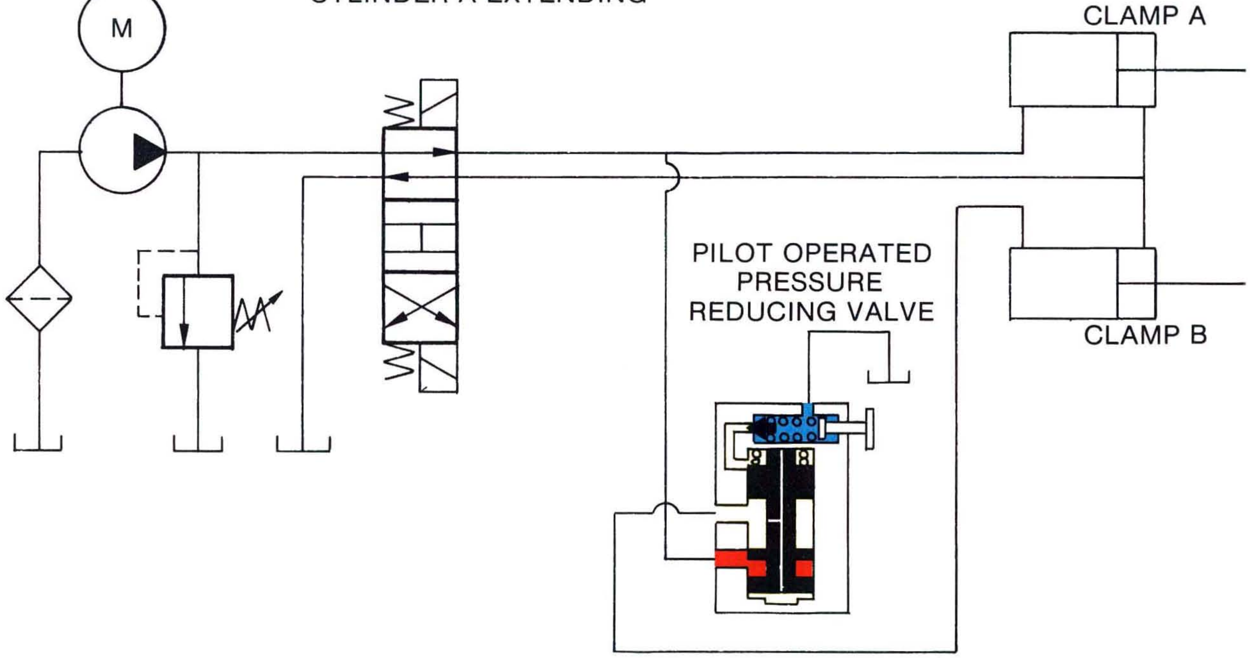
A normal requirement of the counter balance valve is that reverse flow must be able to pass through the valve.

Since normally closed pressure valves sense pressure from the primary passage, as soon as flow is reversed, pressure in the primary passage falls off. The spool is de-actuated. Primary and secondary passages are disconnected. Flow through the valve is blocked. Since we cannot go through the valve, we go around the valve by using a check valve. This check is typically built right in the valve. (It has not been shown in this case.)

Pressure Reducing Valve



CYLINDER A EXTENDING



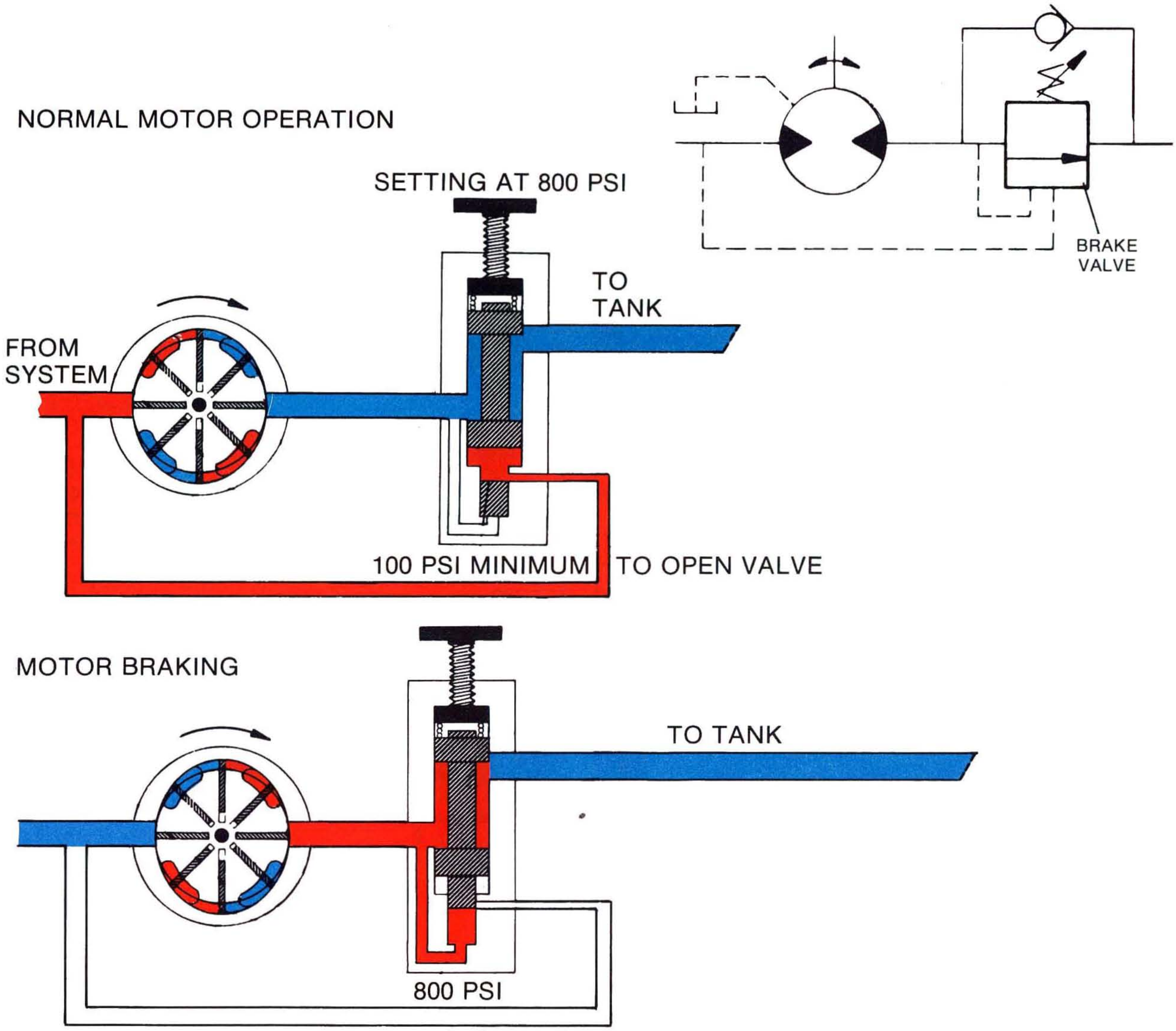
A pressure reducing valve is a normally open pressure control valve.

A pressure reducing valve operates by sensing fluid pressure after it has passed through the valve. As pressure downstream equals the setting of the valve, the spool is partially closed causing a restricted flow path. This restriction turns any excess pressure energy ahead of the valve into heat.

If pressure after the valve drops off, the spool will open and allow pressure to build once again.

The illustrated clamp circuit requires that clamp cylinder B apply a lesser force than clamp A. A pressure reducing valve placed just ahead of clamp cylinder B will allow flow to go to the cylinder until pressure reaches the setting of the valve. At this point, the valve spool is actuated causing a restriction to that leg of the circuit. Excess pressure ahead of the valve is turned into heat. Cylinder B clamps at a reduced pressure.

Brake Valve



A brake valve consists of a valve body with primary and secondary passages, internal and remote pilot passages, spool, piston, bias spring, and spring adjustment.

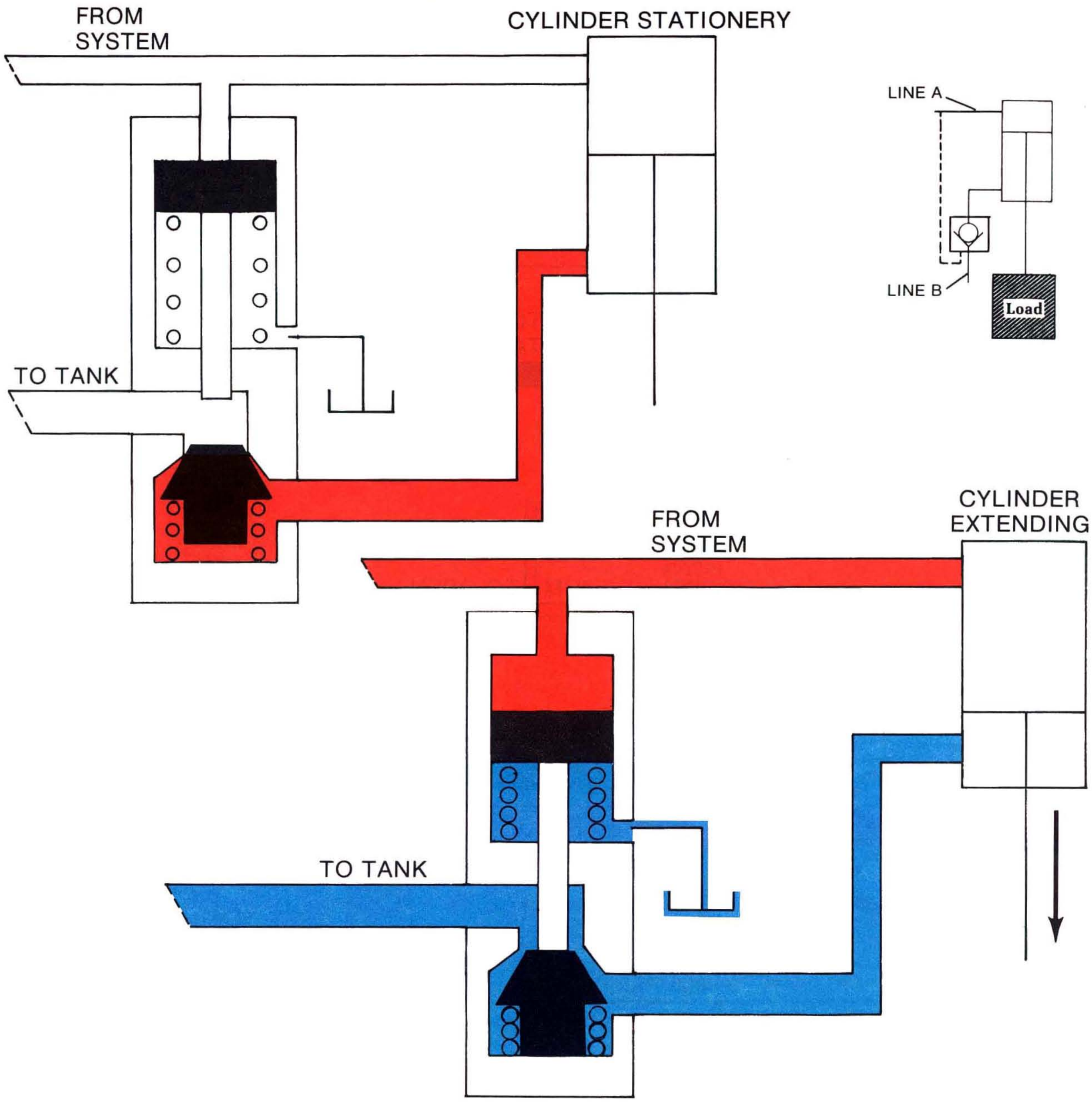
A brake valve is a normally closed valve. Assume that the spring biasing the spool is adjusted for 800 PSI direct operation. When pressure in the internal pilot passage reaches 800 PSI, the piston moves up pushing the spool and opening a passage through the valve. If pressure falls below 800 PSI the valve closes. This operates as the directly operated counter-balance valve which we saw earlier.

The piston on which the internal pilot pressure acts, has much less cross sectional area than the spool. The area ratio is frequently 8:1. With the remote pilot connected to the opposite motor line, a pressure of only 100 PSI is needed to open the valve since it acts on the bottom of the spool with eight times more area than the piston.

With a brake valve set for 800 PSI, the valve will be open when 100 PSI is present in the motor inlet line. Pressure at motor inlet will be whatever it takes to turn the load only (assuming that this pressure is above 100 PSI). If the load attempts to runaway, pressure drops off in the motor inlet line. The brake valve closes and does not reopen until a back pressure of 800 PSI is generated to slow down the load.

A brake valve is a normally closed pressure control valve whose operation is directly tied to the needs of a motor load.

Pilot Operated Check Valve



A pilot operated check valve allows free flow from its inlet port to its outlet port just as an ordinary check valve.

Fluid flow attempting to pass through the valve from outlet to inlet port will force the poppet on its seat. Flow through the valve is blocked.

When enough pilot pressure is sensed at the plunger piston, the plunger is moved and unseats the check valve poppet. Flow can pass through the valve from outlet to inlet as long as sufficient pilot pressure is acting on the plunger piston.

With a pilot operated check valve blocking flow out of cylinder line B, the load will stay suspended as long as the cylinder seals remain effective. When it is time to lower the load, system pressure is applied to the cylinder piston through line A.

Pilot pressure to operate the check valve is taken from this cylinder line. The check valve will remain open as long as enough pressure is available in line A.

To raise the load, fluid flow can easily pass through the valve since this is the valve's free flow direction.