Lancair 320/360 Hydraulics

6-18-2013 (rev C)

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Introduction

Figure 1, 108 Series Catalog

The Lancair 320/360 Hydraulic System is rather simple by hydraulics' standards. Even with a simple system when one component or adjustment is off, it can quickly become perplexing to diagnose. What follows is a look at the internal workings of the Lancair hydraulic system and some of the more common issues encountered.

The Lancair uses an Oildyne 108 series pump. These pumps can be assembled in a myriad of configurations. We use one of the more complex of these. It is reversible, locking with a back-pressure circuit. Early Lancair pumps did not have a back pressure circuit. The significance of this is addressed later, but first some definition of parts and terms.

Parts and their Function

The following section briefly describes key components within the pump.

Figure 2, Poppet

Poppet – The poppet Valve is a one way check valve that isolates the aircraft plumbing from the internal workings of the pump. When pressurized, it is held in place by system pressure. When not in pressurized a very light spring keeps in position to be able to lock under pressure. To release pressure, the poppet is pushed off its seat by the spool. The poppet has a hard rubber face that seals against the poppet valve body.

Spool – The spool can serve several different functions depending on the pump configuration. The spool unlocks a pressurized system by pushing the poppet valve open. Internal passages within the spool are used to relieve back pressure when more fluid is returning to the pump than is leaving.

Figure 3, Symmetric Spool

Figure 4, Asymmetric Spool

PRV – Pressure Relief Valve – The pressure relief valve is an adjustable valve that is set ~300 psi above the operating pressure of the hydraulic system. In the case of a run-away pump, system pressure will not exceed the relief valve setting. The PRV setting is user adjustable.

TRV – Thermal Relief Valve – Thermal relief valves are added to the circuit on the external side of the poppet valve to prevent damage if thermal influences cause pressure to rise excessively. The TRV setting is not intended to be user adjustable. See section 'Adjusting Thermal Relief Valves'

Back Pressure Circuit – This term can take on more than one meaning. Sometimes a back pressure circuit is used to relieve pressure and in other cases it is used to provide pressure. In the 'LB' pump design, the 'back pressure' circuit relieves pressure that builds up when more fluid is returning to the pump than is leaving. If no backpressure circuit is available, pressure builds until the relief valve opens. Excess fluid is then expelled through the PRV.
A back pressure circuit is also used in the return line to the pump. In this case, it adds about 100 psi to the return path to guarantee a minimum pressure on the face of the spool. This prevents the possibility of fluid porting directly to the reservoir through the passages within the spool once the pump direction is reversed.

Pressure Switches – Pressure switches control pump operation by measuring system pressure. When below the set-point the contacts are closed which allows the pump to be energized. Once the system is pressurized, the switch opens which in turn shuts down the pump. Lancair supplied pressure switches are adjustable.

LL circuit - Early pumps used kit production used the LL configuration. It is a reversible locking pump. The motor and pump are driven two directions to affect retraction and extension – as opposed to an external shuttle valve. Locking means that pressure is held in the hydraulic systems once the pump is shut down.

LB circuit - This is the configuration used through the end of production of the Lancair 320/360. The LB circuit incorporates a back pressure circuit. This provides a low resistance path back to the reservoir during gear retraction.

LD circuit - The LD circuit is the same as the LB circuit but with a symmetric spool

Configuration Numbering

The part number of the pump describes the configuration to a great extent. The numbering scheme was updated since the time most 320/360 pumps were manufactured. More detail was added to the to include pressure settings of the relief valves. A few other items are not specified directly, such as thermal relief valve settings. These must be specified separately or they will be set relative to expected operating pressures. The 320/360 pumps are supplied with the lowest available setting of 2,000 psi. The Legacy pump also offers an exception to the numbering scheme. It contains a "ZZ" which identifies it as a custom configuration that cannot be decoded using publicly available documentation. This pump will be described in more detail later, specifically the effects of using it in the 320/360 hydraulic system.

Most 320/360 pumps in service will have the following part number: 108AM19-CLB-3VT. Enough similarity with the current numbering scheme exists to tell this is a pump with 12V series wound motor, It is reversible, locking and has a back pressure circuit. What cannot be taken from the part number is that the PRVs were set at 550 and 1200 psi.

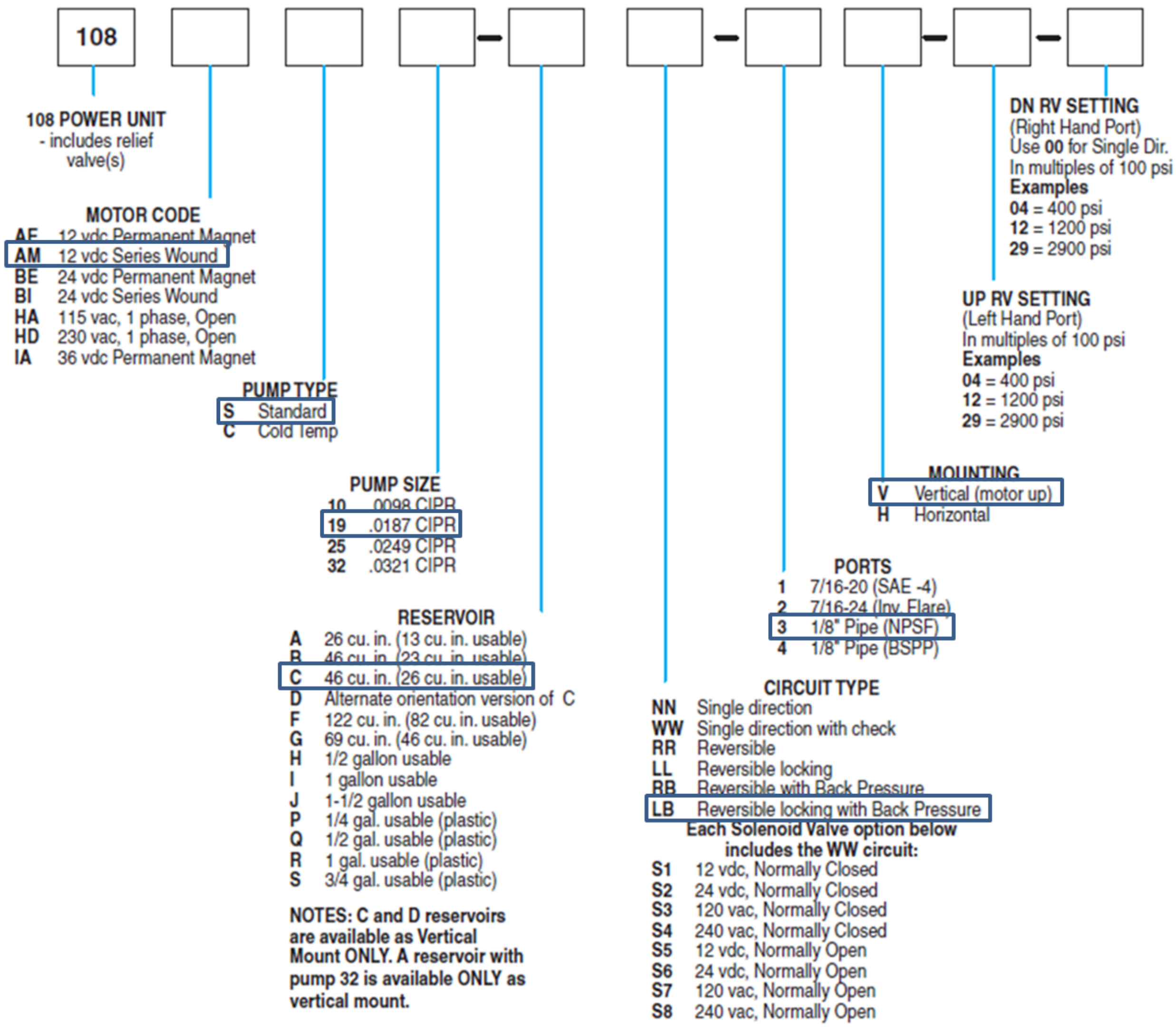

Figure 5, Part Number Decoding

The Hydraulic Circuit

The hydraulic schematic is not necessarily the easiest thing to read. On the left is the pump schematic found in Oildyne literature with minor modifications to show the 320/360 configuration. On the right is the graphical equivalent. The system is closed loop and reversible. That is, the pump direction is reversed when extending versus retracting the gear. The fluid will also reverse direction; however, there is some fluid exchange with the reservoir. During retraction hydraulic fluid equivalent to the volume taken up by the rods being pulled into the cylinders is expelled into the reservoir. Upon extension, the opposite occurs. The rod volume leaving the system must be replenished. Make-up fluid is pulled from the reservoir as needed through one-way check valves.

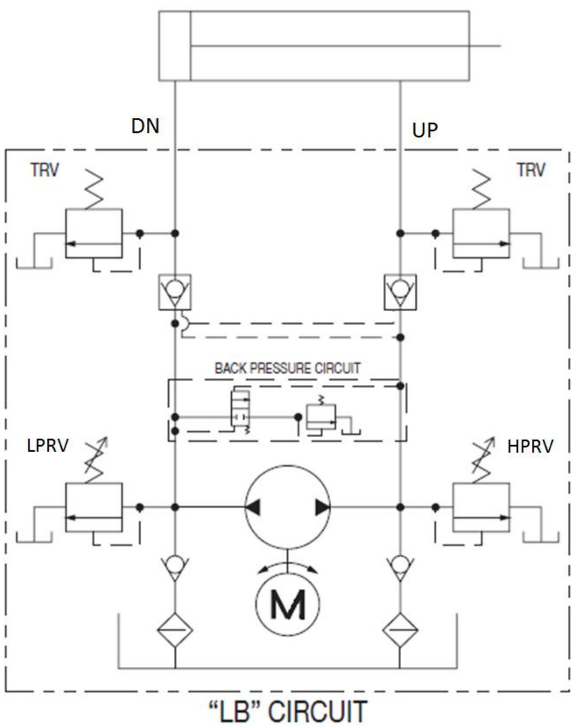

Figure 6 Pump Schematic

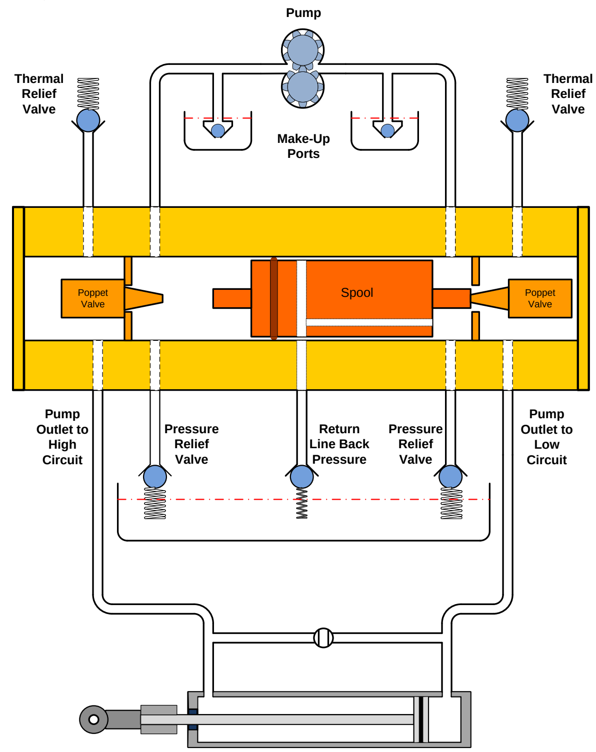

Figure 7, Pump Graphic

The gear pump itself only serves to move fluid when motor is powered. It has inherent leakage losses and cannot maintain pressure once it shuts down. For this reason, poppet valves are used to lock in pressure in the system. After pressurization, they seal off the external hydraulic system from the internal areas of the pump. The poppet valves have a hard rubber face that is pressed against the valve body. These are very robust. While it is rare, they can leak. They should not be overlooked when trouble shooting for leaks.

Normal Operation

Retraction

During retraction the spool is pushed against and unseats the low side poppet value. This allows fluid return from the cylinder to the pump. Since rod volume is being introduced to the cylinder, more fluid returns than is pumped out. The excess fluid follows a passage in the spool to the return line back to the reservoir. A small ball and spring apply about 100 psi back-pressure in the return line. This small back-pressure can be seen on the pressure gauge during retraction. It should be noted that a number of spools were installed backwards in the 1995 to 1997 time frame. When this is done, it disables the back pressure circuit essentially turning the pump into an “LL” configuration. In that case, the high side pressure must fight the full low-side relief valve pressure. The net working pressure is then High side minus Low side PRV setting. This is oftentimes not enough to fully retract the gear into the wells and some cycling will occur at the end of the retraction cycle. Pressure gauges show this very clearly.

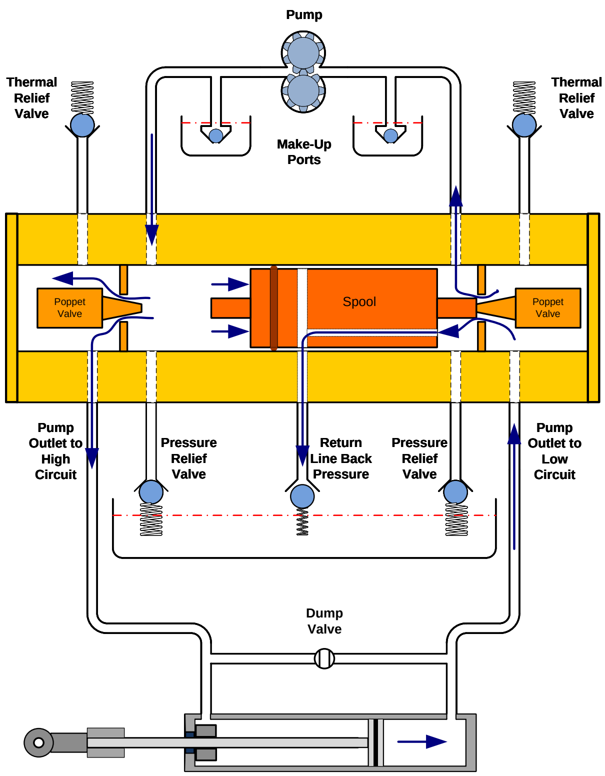

Figure 8, Retracting

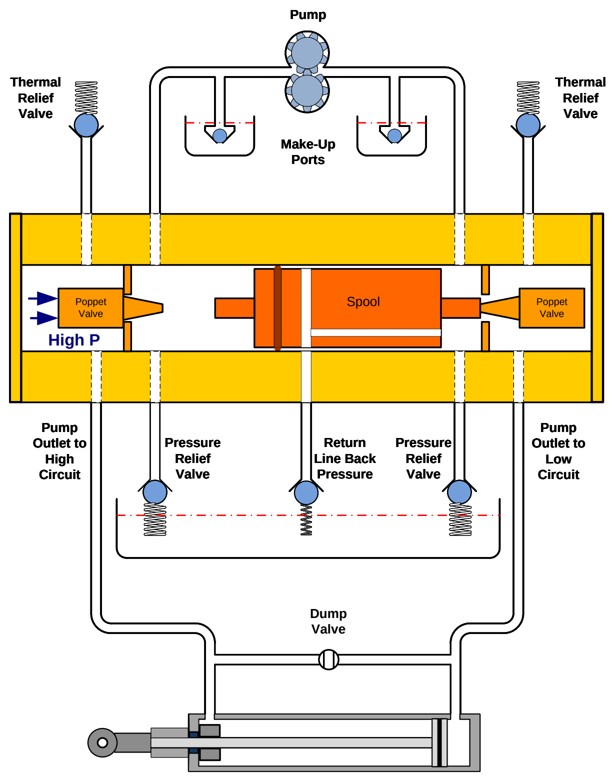

Figure 9, Retracted

Once fully retracted, the high side circuit will pressurize to the set-point of the pressure switch and the pump will shut down. Now the high side poppet seals against its seat and retains system pressure to keep the gear up. There will be some overshoot of the pressure setting once the set point is reached. The pump does not have a dynamic break. It will spin down fairly quickly, but during this time pressure increases above the set point. This is immediately followed of a brief period of pressure decline as the system relaxes or stretches under the pressure. Flexible hoses are the most compliant component. While they are very stiff, they will expand ever so slightly. It does not take much expansion to drop pressure measurably.

Extension

During extension the spool is pushed against the high side poppet. This releases the pressure in the high side circuit and allows fluid to return to the pump. During extension rod volume is removed from the cylinder. This lost volume is made up as hydraulic fluid is pulled from the reservoir via a one-way check valve.

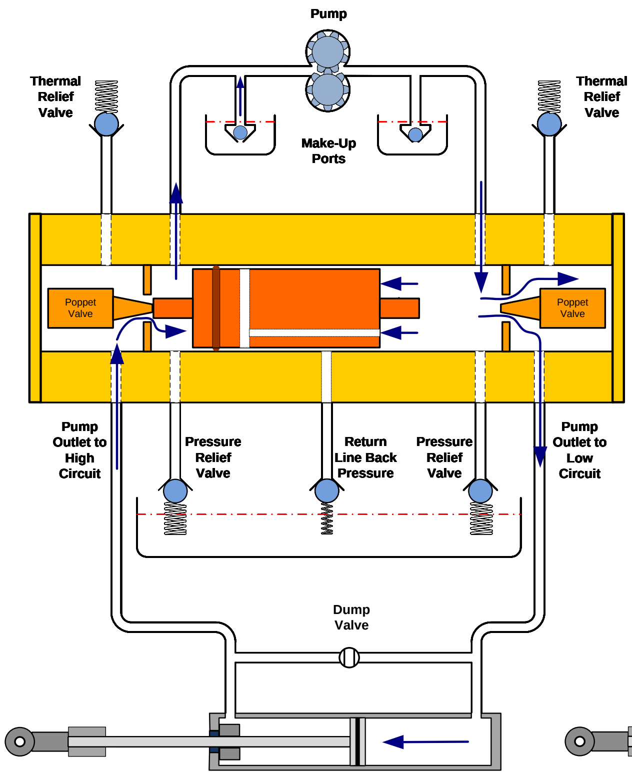

Figure 10, Extending

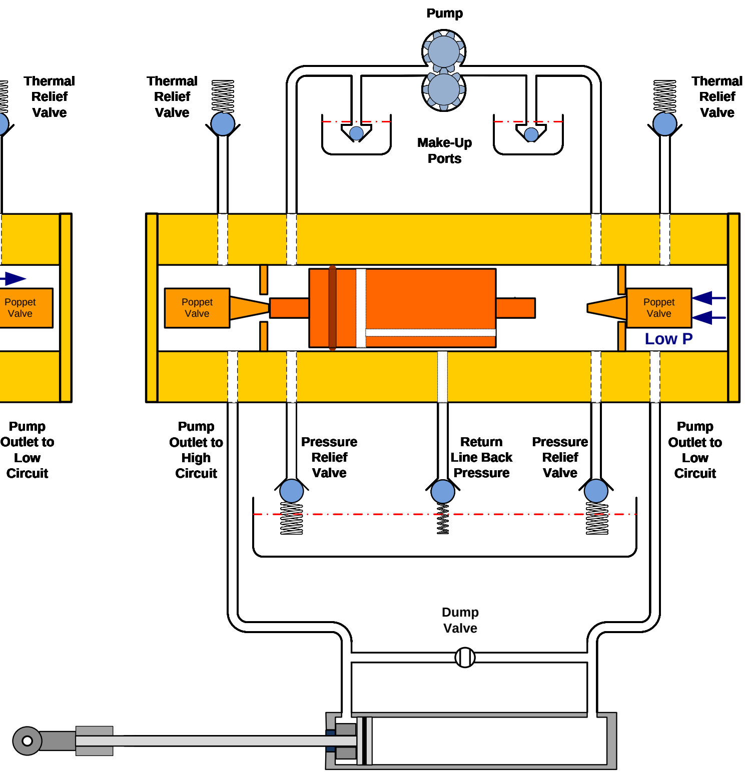

Figure 11, Extended

Free Fall, Emergency Extension

In the event of complete electrical failure, the gear is extended using gravity as the primary motive force. When the emergency dump valve is opened, high and low circuits are joined. As the gear falls, the rods are extracted and make up fluid is drawn from the reservoir. This is one area where the newer Legacy hydraulic system is different. In the Legacy, rods are retracted during emergency gear extension. Therefore, excess fluid must be expelled and returned to the reservoir. This required a different dump valve otherwise the only path to return fluid to the reservoir would have been through the PRV. Thus a three-way valve was introduced to provide a low-resistance path back to the reservoir. The 320/360 system only needs to join the high and low hydraulic circuits.

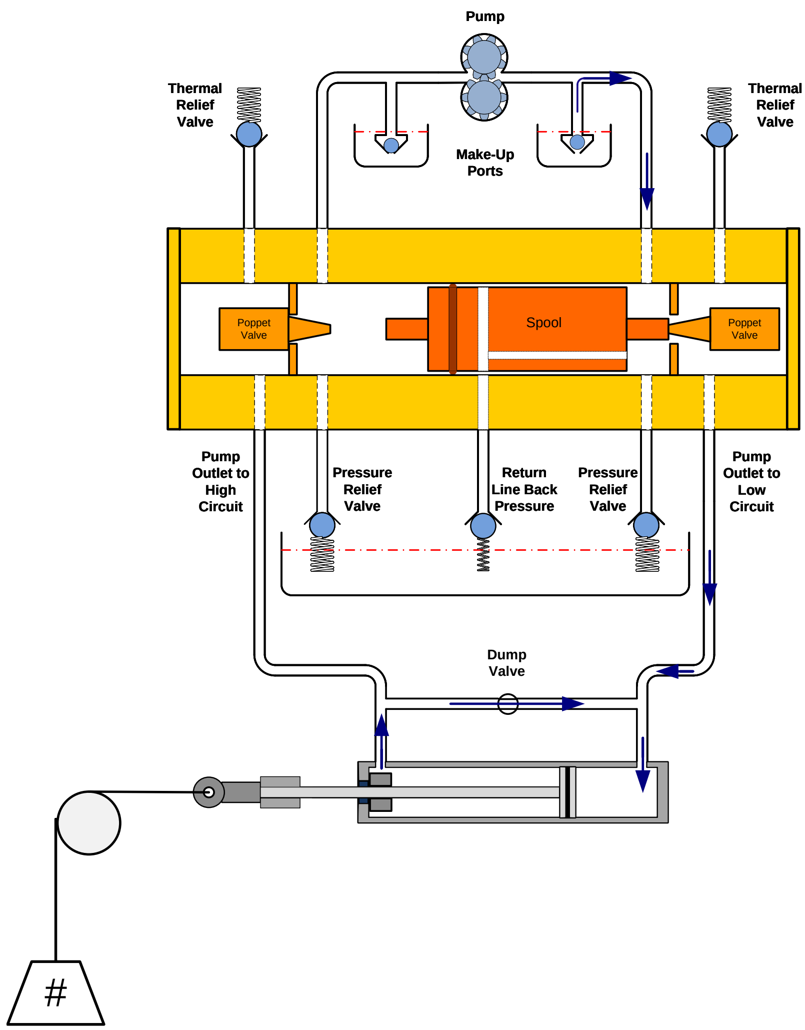

Figure 12, Emergency Extension, Free-Fall

Common Failure Modes and their Causes

Leaks

Leaks fall into two major categories: Internal and External. External leaks will, by definition, leave evidence making them easy to spot and track down. Typical sources are fittings and shaft seals. Internal leaks can be very difficult to isolate. There are six pistons, the dump valve and the two poppet valves that can all be a source of internal leaks. In general, the system should hold pressure for days. In fact, temperature changes should have a greater influence on systems pressure than leaks. During trouble shooting internal leaks, the cross dividers are a good place to isolate sections of the system.

Figure 13, Pressure Gauges

It is nearly impossible to investigate small leaks without pressure gauges. Pressure gauges will show a trend long before a pressure switch is tripped to recharge the system. Pressure gauges are highly recommended as permanent additions to the panel. Not only can adjustments to relief valves and pressure switches be properly set, but trouble can be spotted long before it grounds an aircraft.

Leaking seals are generally accompanied by scratches in the cylinder bore or on the shaft. Scratches need to be removed to prevent the replacement seals from suffering premature failure. The following link offers some suggestions with respect to rebuilding of cylinders including the removal of scratches. Link to Cylinder Rebuild
(http://www.n91cz.com/Hydraulics/Rebuilding_Lancair_Hydraulic_Cylinders.pdf)

Sticking Pressure Switches

Lancair previously supply pressure switches from VEP. These had a tendency to stick after long exposure to hydraulic fluid. In the mid to late 90's, Lancair switched to Suco switches which have proven much more reliable.

Reversed Spool Valve

For a few years back in the mid 90's, hydraulic pumps were being assembled and shipped with the spool valve installed incorrectly. The orientation was reversed. This effectively disabled the backpressure circuit that allows a low resistance path back to the reservoir. During retraction, when excess fluid needs to be expelled from the circuit, the passage through the spool is blocked. This builds backpressure until the PRV is forced open. The drawback is that the working pressure during retraction is: Working Pressure = High Side Pressure – Low Side PRV Setting. As a result the gear may not retract fully before the pump shuts down. Once pressure bleeds down the pump restarts and the gear continues which again builds back pressure. The cycle may continue a several times until the gear is fully retracted. In order to correct this condition, the spool needs to be removed and reversed. This is not very difficult. Two hex plugs are removed, followed by the poppets and some very light retaining springs. Then a drift is then used to push the spool against the opposite side poppet valve body. Once the poppet valve body and spool are removed, the spool is turned around the reinserted into the pump body.

Hydraulic Lock on the Ground

This can be caused by a failed pressure switch (see stuck VEP switches mentioned above) or by a hydraulic lock-up condition where the entire hydraulic system is pressurized above the pressure switch setting. This condition will occur if the spool valve does not keep the non-pressurized poppet off its seat so that the non-operating side remains depressurized. This is where the Lancair community has run into some configuration management issues. Back in about 2003, a change was made to the Legacy hydraulic pump, now sold as a replacement for the 320/360. Spool return springs were added. These are not compatible with the 320/360 hydraulic circuit. If the spool is centered and the hydraulic system is heated, such as on a hot ramp for example, both high and low circuit pressures will rise. If the high side circuit pressure rises above the pressure switch setting, one will not be able to raise the gear. The pressure switch will not allow the pump to run because the high-side circuit is already pressurized. When the spool remains at its last commanded position, the unpressurized side of the circuit cannot be pressurized due to thermal effects. It is essentially open to the reservoir.
The following video clip shows the effects of thermal effects, both heating and cooling. Note that with stock 320/360 hydraulic pump (108AM19-CLB-3VT) the non-operating side remains at zero pressure all the time. The Legacy pump, on the other hand allows both sides to pressurize.
Video Clip with proper 320/360 configuration – no lock-up
(http://www.n91cz.com/Hydraulics/Thermal%20Cycling%20IIII.wmv)
Video Clip of Legacy configuration exhibiting hydraulic lock-up
(http://www.n91cz.com/Hydraulics/NewPumpLockUp_0001.wmv)

The Legacy Hydraulic System and Pump, 108AMS32-CZZ-3V-14-08-Y

While this lock-up described above will occur on the Legacy, it has not been raised as a major concern since that system has a means of undoing the lock-up. The Legacy uses a three way dump valve that drains directly to the reservoir. The Legacy needs this type of dump valve because the cylinder orientation requires it to expel excess rod volume during extension (and emergency free-fall extension). On a Legacy demo flight back in 2006, I saw the factory Legacy experience such a hydraulic lock and the dump valve was needed to raise the gear. Unfortunately, the paper trail for the design changes made to the Legacy pump has been lost over time. The following sequence may explain how the potential hydraulic lock entered the design.

1. The Legacy needed a three-way dump valve for free-fall due to cylinder orientation
2. The return line was plumbed back to the pump using the return line port on the front of the pump.
3. In using the return line port, the 100 psi back-pressure circuit had to be removed since this would both interfere with free fall and the spring could no longer be retained after the pipe plug is removed.

Figure 14, Return Line Back-Pressure Circuit Ball and Spring

4. This now introduced a potential failure by opening up a direct path from gear pump to the reservoir when the symmetric spool is at either travel endpoint.
5. To eliminate the above failure, return springs were added, thus cutting off the direct path from pump to reservoir.
6. Now the potential for hydraulic lock-up has been introduced

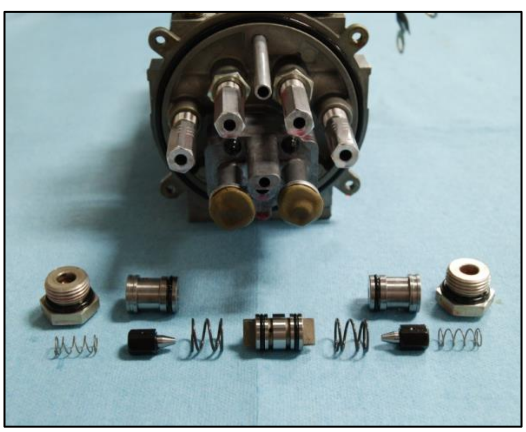

Figure 15, Internal Parts, Symmetric Spool and Legacy Pump Return Springs

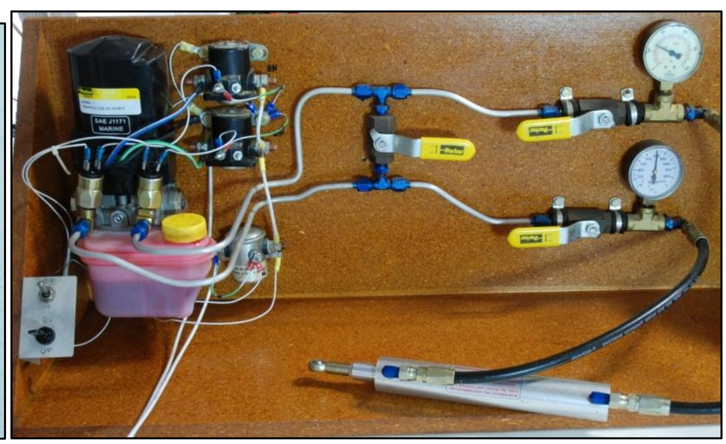

Figure 16, Legacy Pump experiencing Hydraulic Lock after heating (Note: both circuits pressurized)

There was little motivation to remove this potential failure mode in the Legacy since the three-way dump valve can be used to undo the lock-up once it occurs. The better hydraulic design would be to plumb the dump valve directly to the reservoir, leaving the 100 psi back-pressure circuit and not installing the return springs.

The centering springs serve no useful purpose on the 320/360 and instead introduce a debilitating failure mode that the stock system cannot undo. The following document shows how to remove the springs if one has a Legacy type pump in the 320/360.

Link to Reverting the Legacy pump to the 320/360 Configuration (http://www.n91cz.com/Hydraulics/Pump-Unlock.pdf)

Failure to Extend

When retracted, the landing gear stores a lot of potential energy. Gravity, and in the case of the Outback Gear, aerodynamics, are trying to pull the gear out of the wells. This stored energy becomes very significant during the extension cycle.

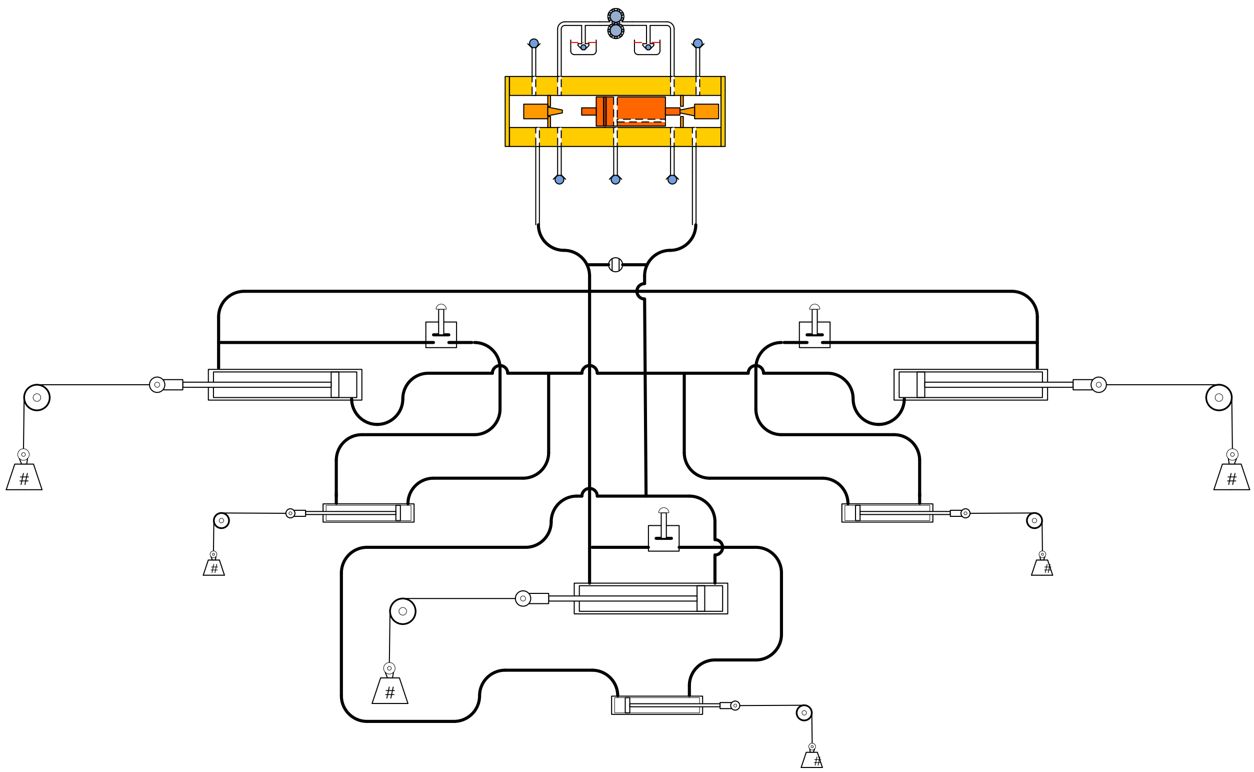

Figure 17, Potential Energy during Extension

When 'gear down' is selected, the pump pushes the spool against the up-side poppet to open the 'up' circuit. This unlocks the high side circuit and allows the gear to start down. Initially the gear isn't driven down by the pump. Instead it is pulled down by gravity. The initial volume flow rate generated by falling gear is more than the return side of the pump can absorb. This in-rush and backing up of fluid generates a pressure spike that impinges on the face of spool. If high enough, it will begin to push the spool back and start to close off the poppet valve. As this occurs, back pressure is transmitted though the high-side circuit, through the cylinders, all the way back to the low side circuit and corresponding pressure switch. If the pressure spike climbs to the low side pressure switch setting, the pump will shut down. This is a very fast and dynamic event. Several key factors come into play: The pressure generated by the inrush of fluid from the descending gear decays very quickly; the pump is transferring fluid at a near constant rate; the pressure spike takes a finite time to propagate; and finally the pump has inertia. Even if the pressure spike momentarily reaches the low side pressure switch setting and power is cut to the pump, the spool down of the motor combined with the rapidly decreasing push from the gear can enable the spike to drop back below the pressure switch setting. This can be heard as a hesitation in the pump shortly after gear down is selected. It can also be observed when monitoring system pressure during the event. If the spike is long enough in duration, the pump can be shut down completely with the system remaining in a stable condition. In that case:

1. Both high and low sides will be pressurized at a value higher than the low side pressure switch (550 psi in a nominal stock system)
2. The spool will be centered or nearly centered
3. The gear down pressure switch is open (pressure just above set-point)
4. The gear up pressure switch is closed (pressure between high and low set points)

In this state, the gear can still be retracted, but not further extended. The system is in a state where it thinks it is fully extended.

So how does one resolve the issue? The solution is actually quite simple: Increase the pressure setting of the low side pressure switch. As the pressure switch setting is increased, the pressure spike has less influence and the duration of the pump interruption decreases. Once the setting is higher than the pressure spike, there is no longer any interruption in pump operation and the gear always extends normally.

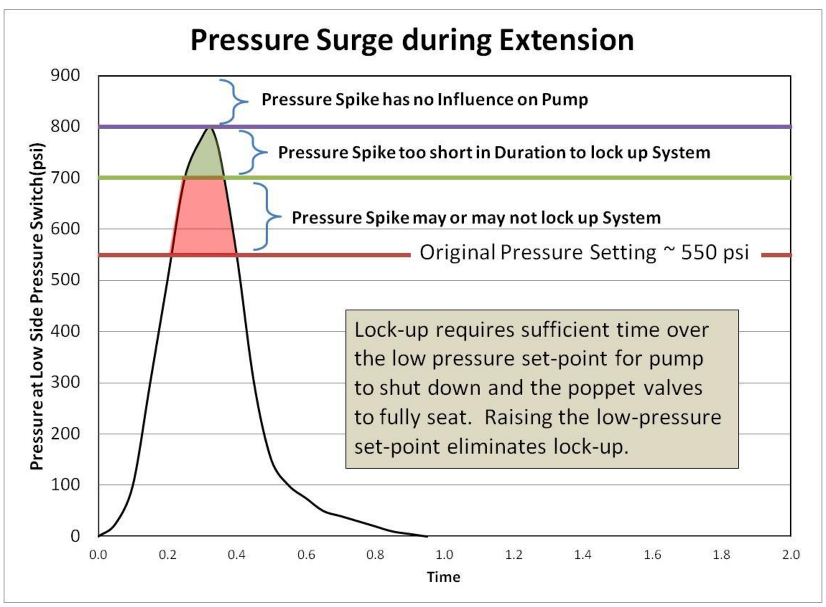

Figure 18, Extension Pressure Surge

Maintenance

Routine maintenance is quite minimal: Inspecting the entire exterior for signs of hydraulic leaks, chaffing, hose deterioration and verifying the fluid level in the hydraulic system. Maintenance, adjustment and troubleshooting activities are made immensely easier when pressure gauges are installed. When a hydraulic system is acting up, so much can be learned by observing the pressure readings on both the high and low sides of the system. There is no guessing, assuming or inferring the

system pressure. Rates of change and any interaction between high and low sides can be observed directly.
Also, trouble can be spotted long before it becomes a problem. The pressure switches have a lot of hysteresis. Very small leaks may go undetected on shorter flights.

Pressure Switch Settings

Original Nominal settings were: 550 psi down, 1,200 psi up.
These values need adjusting based on a few factors. If the aircraft has the larger Outback Gear, the hydraulic system must not only work to keep the gear up, but is also fighting a very high aerodynamic load. This is due to the camber added to the Outback Gear doors to reach around the larger wheels. 1,200 psi is the lower end of the pressure range than will keep the gear up. 1,300 or 1,400 psi adds a little margin.
To avoid the extension hang-up described earlier it is recommended that the low side pressure setting be raised to 700 or 800 psi.
The pressure switch has a small screw between the electrical tabs that allows pressure to be adjusted. The VEP switches had two screws that needed to be adjusted equally.

Adjusting Pressure Relief Valves

The pressure relief valves are also easily adjusted, but the pump must be removed from the aircraft. The valves work by applying spring pressure against a small steel ball. Adjusting the compression on the spring changes the pressure required to push the steel ball off its seat. Access to the relief valve is gained by removing the reservoir from the pump.   A large hex nut is loosened which then frees up the adjusting screw. Turing the screw (really a hex column) clockwise increases the pressure.

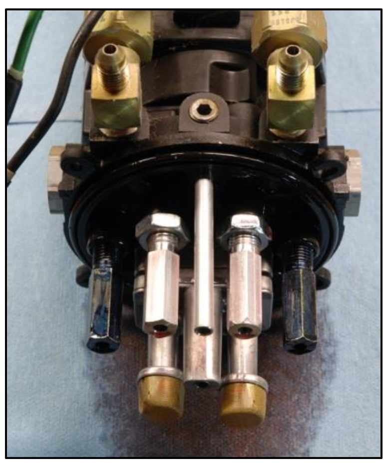

Figure 19, Pump, Reservoir Removed

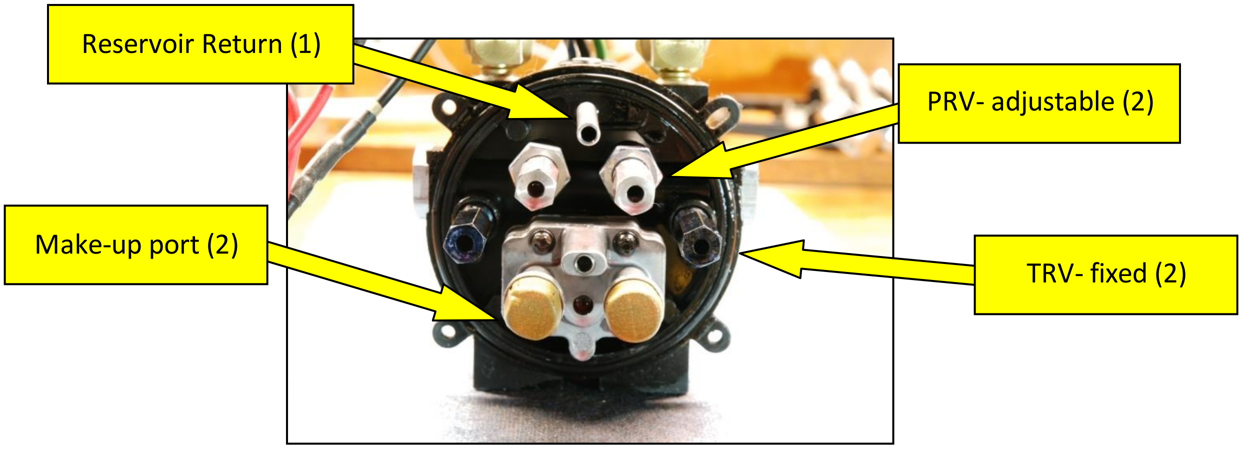

Figure 20, Pump, Bottom View

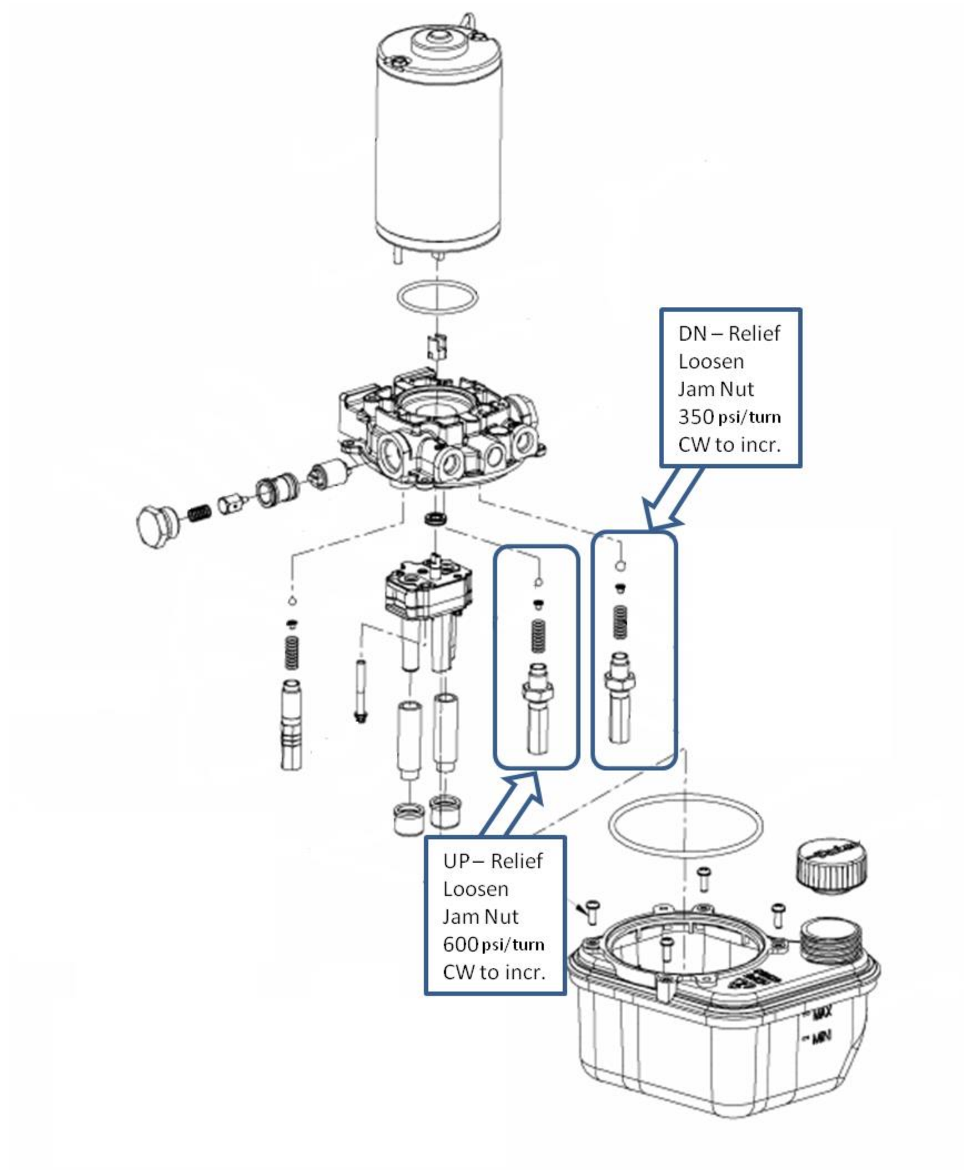

Figure 21, Pressure Relief Valves

Adjusting Thermal Relief Valves

The cracking pressure of the pressure relief valve on the 320/360 pump is nominally 2,500-3,000 psi. This is the lowest setting available, but is still quite high compared when compared with the operating pressures of the system.   The TRV was not intended to be user adjustable. The TRV can however be made user adjustable by the addition of a jam nut. In its original configuration the TRV body is fully bottomed out and tightened. With the use of a jam nut, the TRV can be backed off and tightened at less than full spring compression. This lowers the cracking pressure of the TRV.

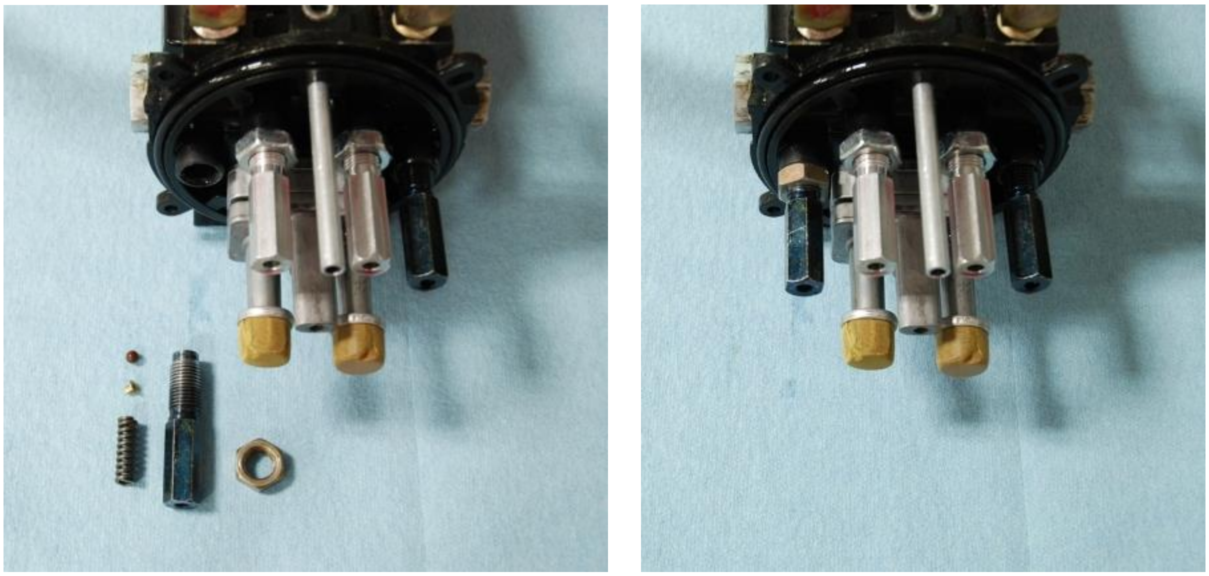

Figure 22, High Side Thermal Relief Valve made adjustable with the addition of a jam nut

Seal Kits

The Parker 108 series Seal Kit contains all the seals in the pump and reservoir. The kit covers all configurations so there are a lot of unused parts after seal replacement.

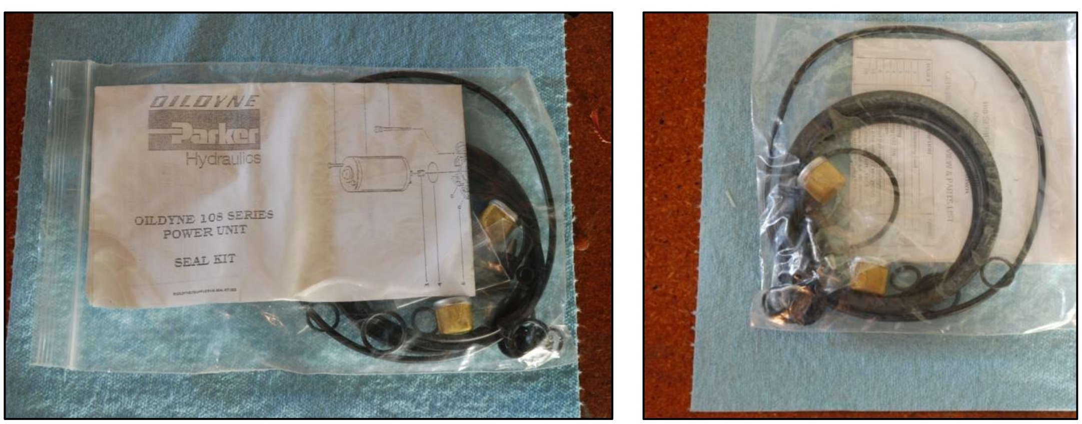

Figure 3, 108 Series Seal Kit, 634412

Some of the commonly encountered O-Rings used in the pump are:
013-90, Spool Seal
014-90, Check Valve Body seal
908-70, Hex Plug Seal
These are available at any industrial supply house. Note that the spool uses a 90 durometer O-ring. These are very stiff. Its purpose is not only to seal during pump operation, but also to hold the spool in place during non-operation. O-Rings generally don't need to be replaced on any regular basis if kept in service and exposed to hydraulic fluid. Parker is the only source for poppet valves.

Conclusion

The design of Lancair 320/360 hydraulic system has proven to be very robust and reliable. It does however require proper set-up and configuration. As with any mechanical system, it will require occasional maintenance. Above all, and this applies to any aircraft system, anomalous behavior should be investigated. Proper set-up and configuration are key to problem free landing gear operation.

Addendum for the Lancair Legacy

This addendum to "Lancair 320/360 Hydraulics" is intended to provide some additional detail regarding Lancair Legacy hydraulic system. While similar in many respects to the 320/360 system, a few small changes are very significant. A key difference between the 320/360 system and that of the Legacy is the reversal of gear cylinder orientation. Gear retraction occurs during cylinder extension rather than retraction. This drove the need for a three-way dump valve. Given the new cylinder orientation, the emergency free-fall requires that excess fluid be returned to the reservoir. This cannot be done through the pump adapter itself. It requires a more direct line.

Additionally, there was a pump configuration change about five years into kit production. When the Legacy was first unveiled in 1999, the Parker/Oildyne pump supplied with kits was identical to the pump previously supplied for the 320/360 kit. 108AM19-CLB-3VT. In the 2005/2006 time frame a new pump configuration was introduced specifically for the Legacy, the 108AMS32-CZZ-3V-14-08-Y. There are five primary changes:

1. The spool was made symmetric. This provides the ability for the pump to absorb more oil volume returning to the pump than is delivered by the pump in either operating directions without building up excess back pressure.
2. A higher volume gear pump was installed. .32 cipr vs .19 cipr
3. Spool centering springs were added
4. The 150 psi backpressure circuit in the return line was removed
5. The PRV set points were raised from 1200/550 psi to 1400/800 psi

The symmetric spool is a very good idea. During retraction or extension of the landing gear, half the hydraulic cylinders extend while the others retract. These two actions are segregated in time via sequencing. This means that both during retraction and extension there are times when make-up fluid is pulled from the reservoir and other periods when excess fluid needs to be returned to the reservoir. The symmetric spool provides back pressure relief when operating in either direction.

Spool return springs were added. It is unclear why this was done. Current staff at both Lancair and Oildyne could not recall why this was done nor locate documentation that could help explain the reasoning behind this change. Unfortunately the spool return springs brought with them the unintended consequence of a lock up potential when the system is subjected to thermal heating. Fortunately the three-way dump valve required on the Legacy can unlock the system. To eliminate the possibility of thermal lock-up, the spool return springs should be removed. It then becomes advisable to replace the back pressure circuit in the return line that was removed. This ball and spring ensure a minimum pressure on the back side of the spool regardless of starting position. The dump valve return line can still be routed to the center port which houses the back pressure ball and spring. The AN fitting installed in this port for the return line from the dump valve will compress the spring adequately.

Figure 1 shows the stock Legacy Pump (post 2005) which has a custom part number, **108AMS32-CZZ-3V-14-08-Y**. This configuration removed the 150 psi back pressure circuit in the return line, and added spool centering springs. Figures 2 through 5 show extension and retraction sequences.

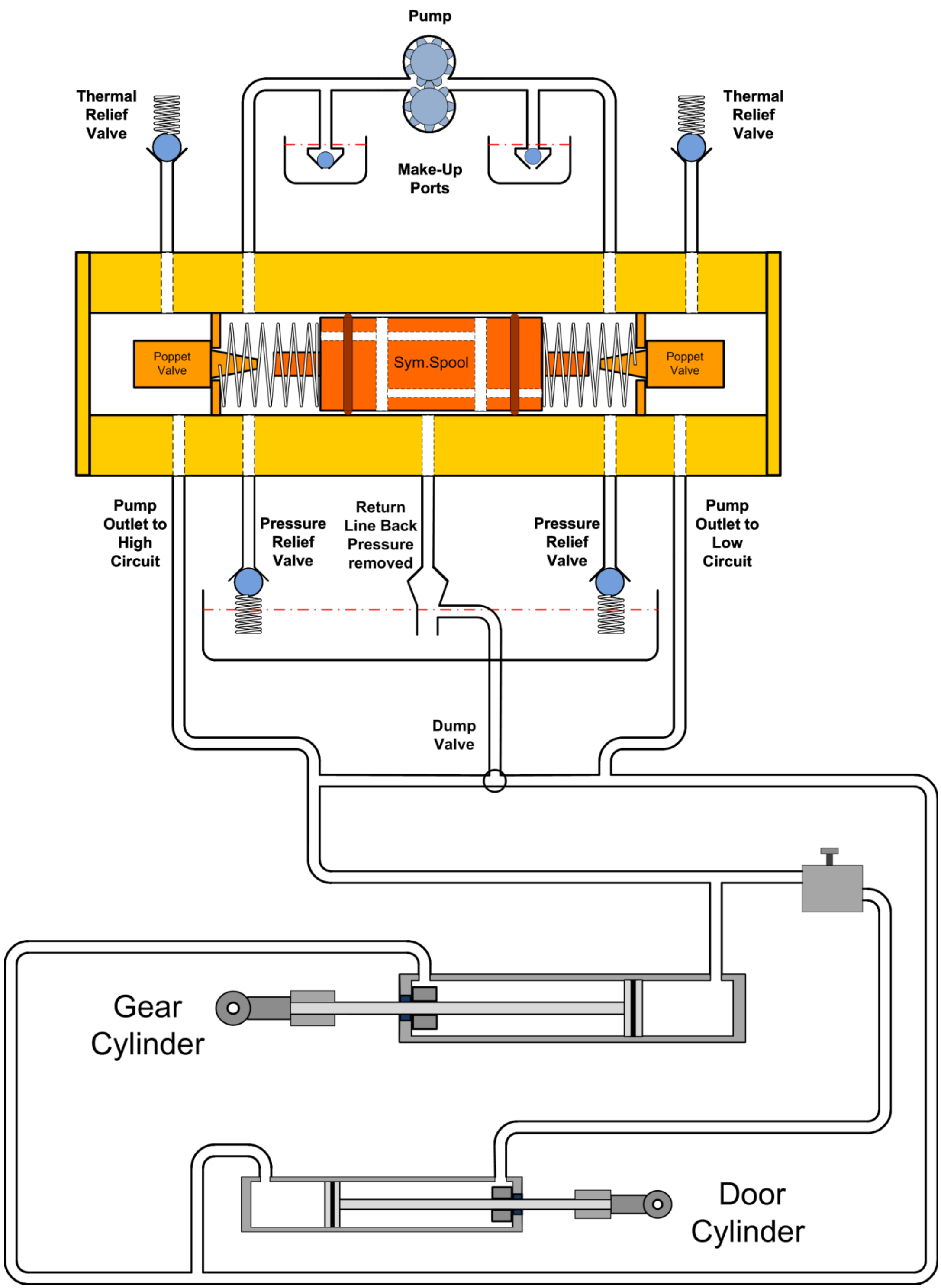

Figure 1, Lancair "Legacy" Pump, **108AMS32-CZZ-3V-14-08-Y**

Figure 2 shows operation during gear retraction. Make-up fluid is drawn from the reservoir to make up for the gear cylinder rod volume.

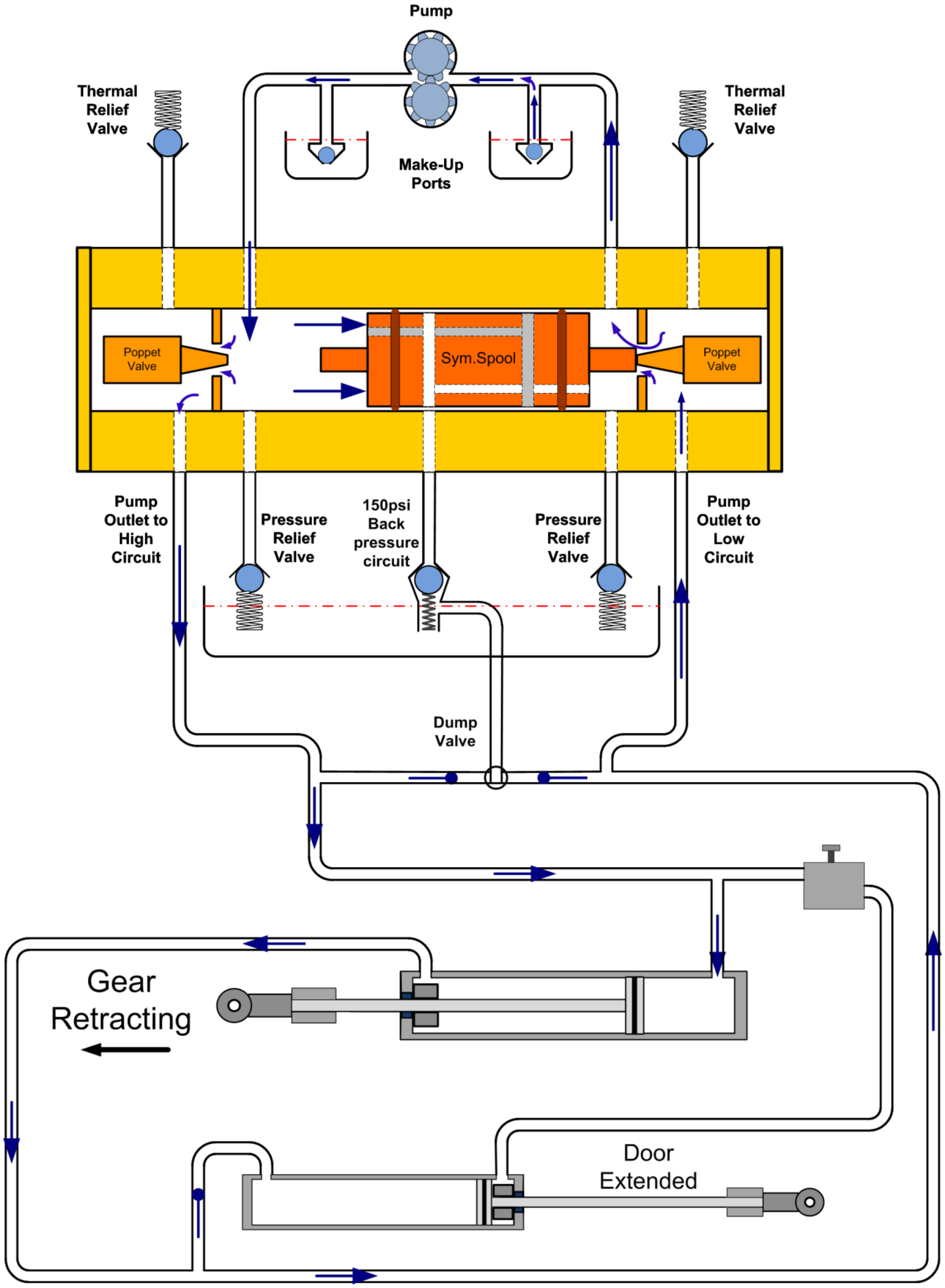

Figure 2, Legacy Gear Retracting, Pump with a Symmetric Spool, **108AMS19-CLD-3V-14-08**

Figure 3 continues the retraction sequence. The gear is fully retracted and has sequenced the gear door cylinder. The gear door cylinder must expel excess fluid back to the reservoir via the spool valve.

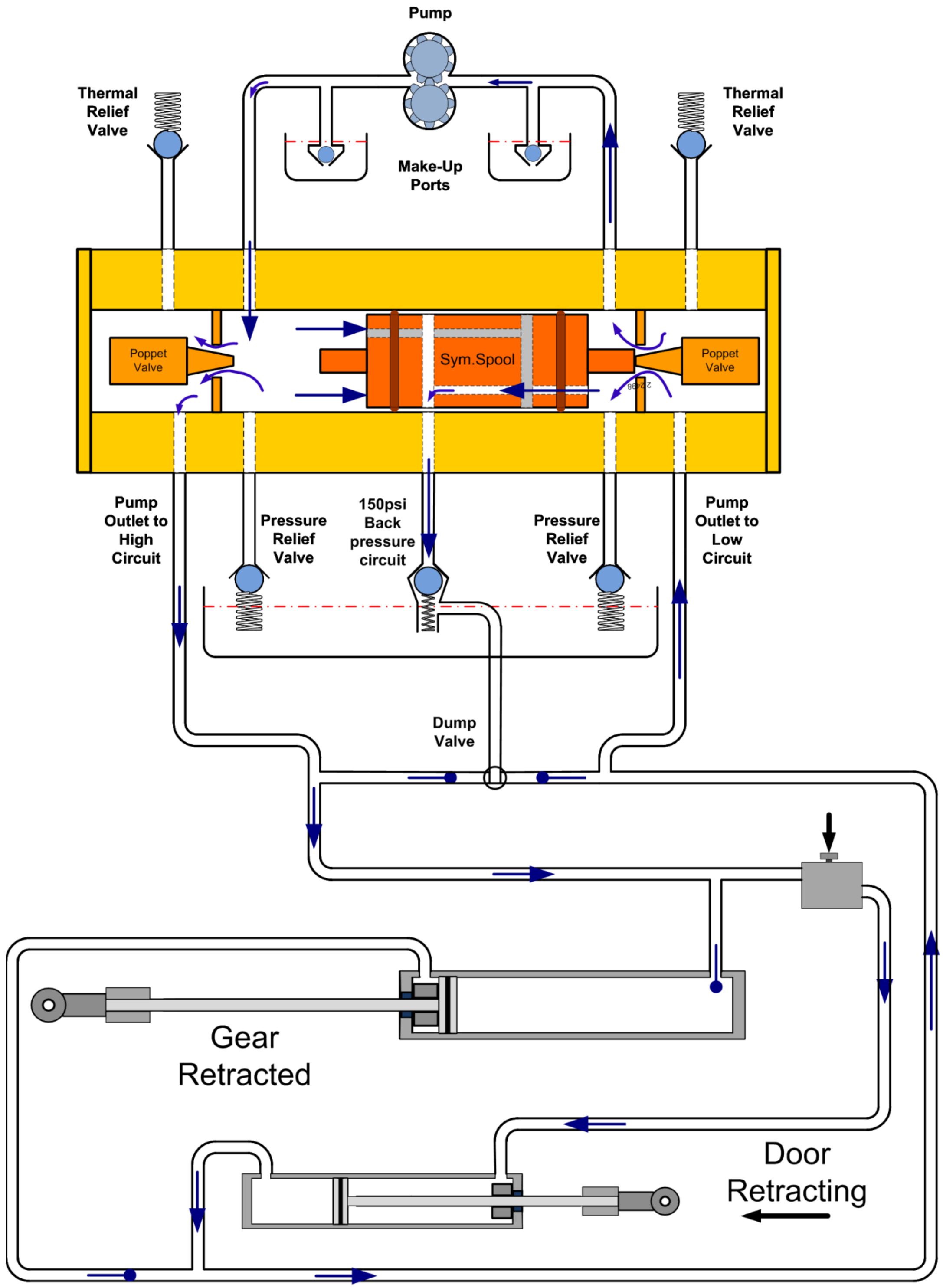

Figure 3, Legacy Doors Retracting, Pump with a Symmetric Spool, **108AMS19-CLD-3V-14-08**

Figure 4 depicts the extension cycle. Both cylinders begin extension simultaneously, however assisted by a spring, the gear doors will extend more quickly and finish its travel first.

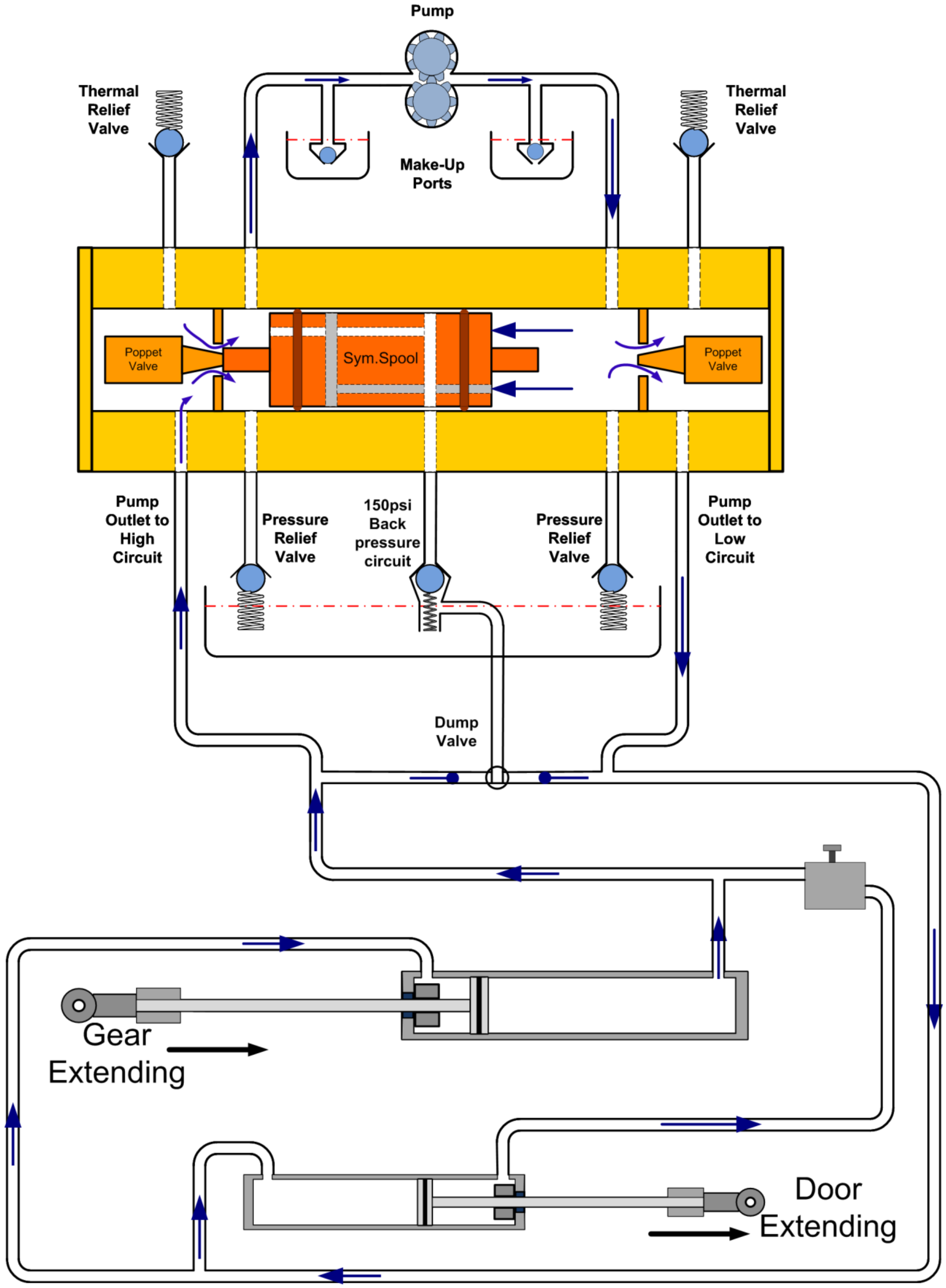

Figure 4, Legacy Doors Extending, Pump with a Symmetric Spool, **108AMS19-CLD-3V-14-08**

With gear doors fully extended, excess rod volume fluid is returned to the reservoir via the spool. Note that the symmetric spool is now relieving back pressure in the opposite direction as during retraction.

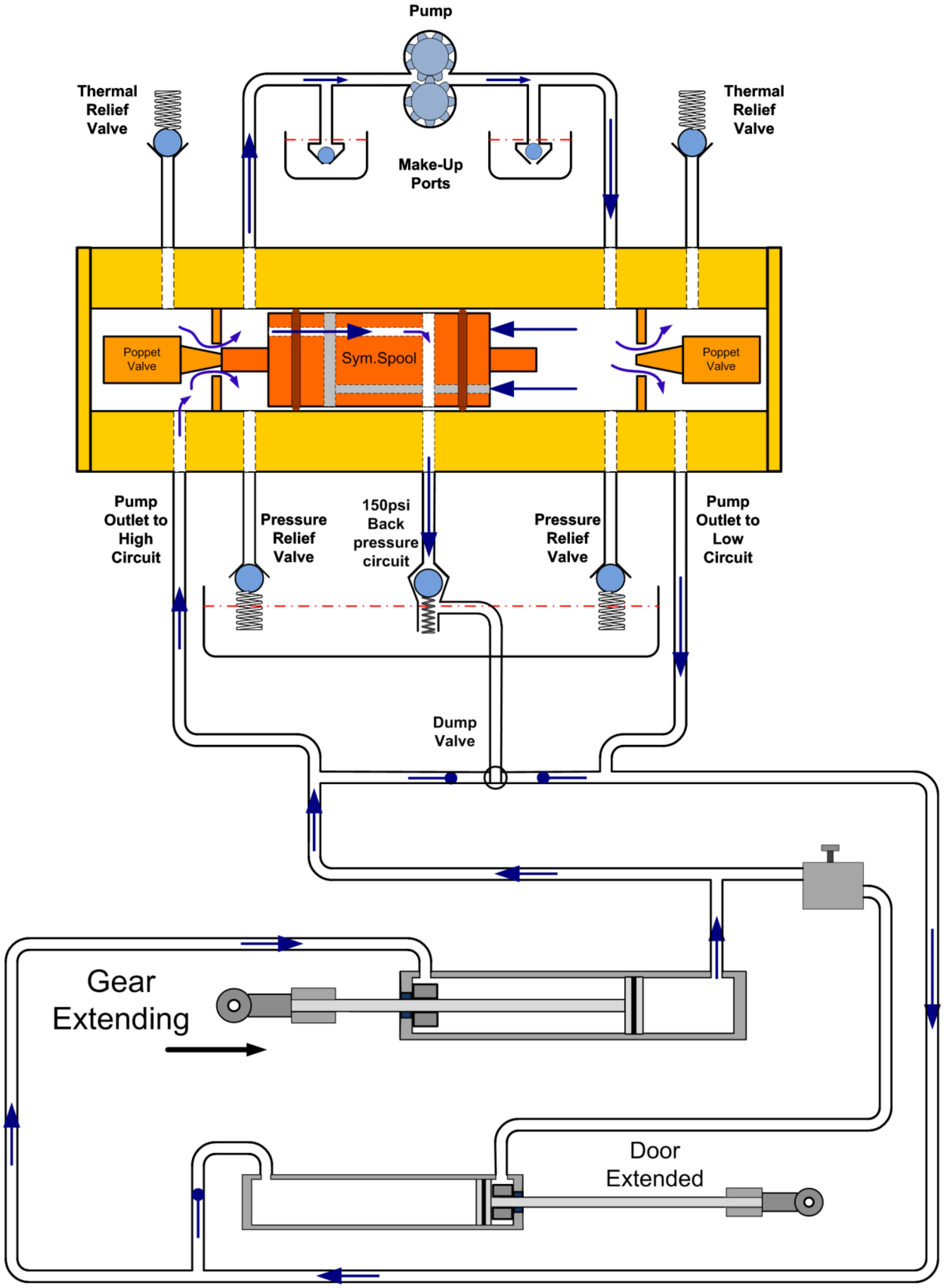

Figure 5, Legacy Gear Extending, Pump with a Symmetric Spool, **108AMS19-CLD-3V-14-08**