Change Order #5798

Installation and Operation Manual (IOM):
Lee Radial Piston Pump Module

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Revision Status

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All	A	02/20/2024	J. Glanzrock	B. Brelig	Initial Release
All	B	10/18/2024	J. Glanzrock	K. Russell	Added information regarding bonding, shielding, and operating specifications. Added reference electrical schematic. Added troubleshooting table. Various additional clarifications.
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1 PRODUCT DESCRIPTION

The Lee Radial Piston Pump Module is a pumping system which includes a positive displacement radial piston pump, brushless DC motor, and integrated motor controller. Because there may be differences in setup, construction, control, and other parameters between different pump modules, many specifics are found on the pump module's inspection drawing unique to the part number. Contact your Lee Company Sales Representative to obtain a copy of the inspection drawing for your pump module.

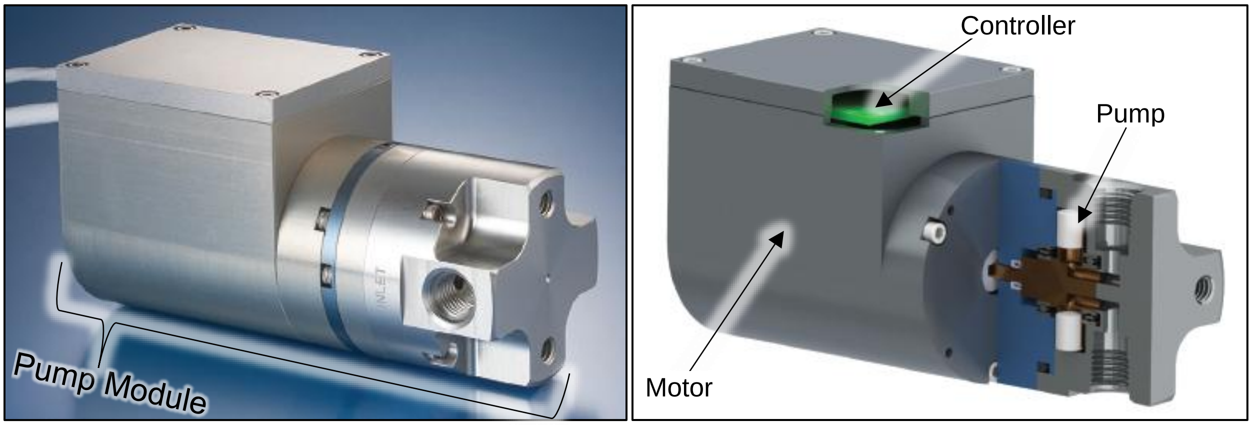

Figure 1 - Pump Module Construction

2 THEORY OF OPERATION

Positive displacement pumps generate a fixed volume of output flow for each revolution of the shaft. The pressure at the pump's outlet depends entirely on the hydraulic restriction of the discharge system. Positive displacement pumps make volumetric flow and pressure results. The following graph depicts the output flow of a pump vs. pump speed (revolutions per minute, or RPM). The actual flow and speed depend on the pump module's specification.

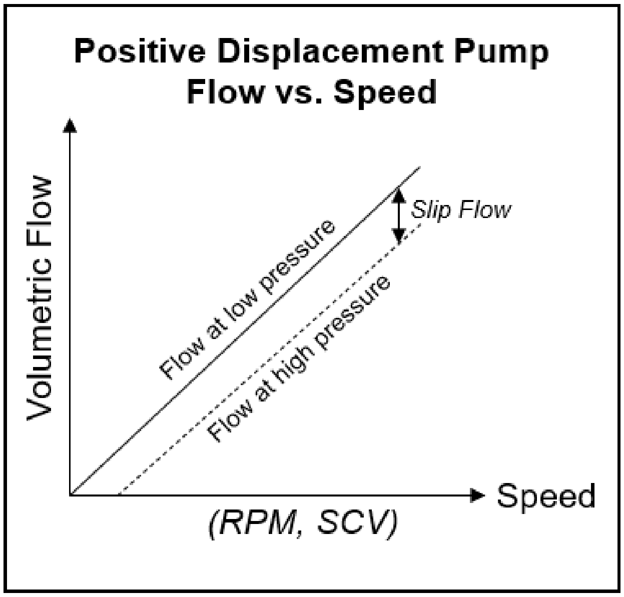

Figure 2 - Positive Displacement Pump Principle

For a pump module, the speed is set by a speed command that the user inputs to the pump. As an example, a pump with an analog input for Speed Command Voltage (SCV) of 950 RPM/V would reach approximately 5500 RPM at 5.79 VDC SCV.

Because the pump output flow is generally linear with pump speed, which is also linear with SCV, the SCV is essentially a volumetric flow command.

As the discharge pressure increases as a result of down-stream system restrictions for the given flow, some small internal leakage will exist within the pump - this is called slip flow, and is a minor inefficiency. Slip flow increases with increasing pressure rise. Slip flow also increases with fluids that have lower viscosity - this often occurs when increasing temperature, or changing to a thinner fluid.

Pump volumetric flow and slip flow is generally unchanged by fluid density. However, if the operating parameter of the customer system is mass flow (such as engines requiring fuel mass flow rates), then density will affect the output - recall that positive displacement pumps provide volumetric flow. The volume flow capacity will be unchanged but there will be more fluid weight in that fixed volume.

3 INSTALLATION

3.1 Mounting

3.1.1 Mounting screw locations are provided on the pump head, and are defined on the pump module inspection drawing. The pump module was qualified in vibration and shock when mounted only from these locations - they are the proper mounting location in all orientations.

- Supporting brackets may be connected to bonding surfaces. Reference Figure 7.

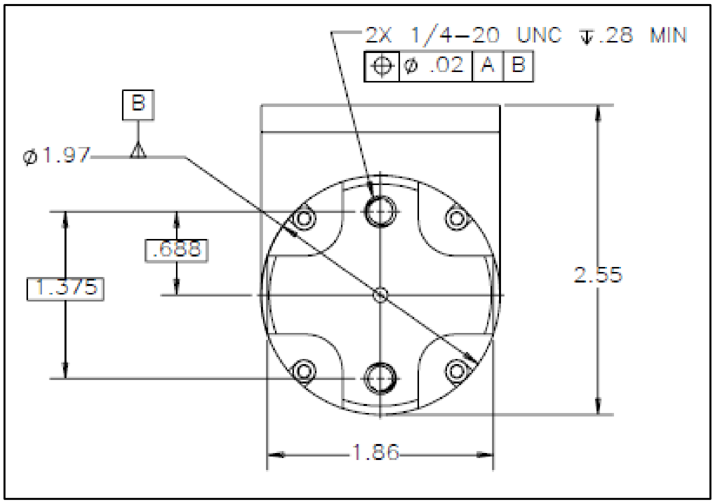

Figure 3 - Mounting Screw Hole Location Example

3.1.2 If the pump housing is aluminum, the torque setting for fasteners and fittings must be reduced when compared to steel. The target assembly torque for a screw or fitting depends on the fastener chosen and/or fitting material and thread engagement, and if any lubricants are used.

- For aluminum pump housings, use 55-65% of the recommended assembly torque (not including any further reductions for lubricants).

3.1.3 Do not mount the pump solely by rigid plumbing (supported only by tubing).

3.1.4 It is optimal to mount a pump module farther from heat sources or hot zones - added external heat increases thermal load on the motor and internal electronics.

3.2 Plumbing

3.2.1 Use the largest reasonable diameter tubing for inlet (suction-side) plumbing, and mount the pump as close to the fluid source as possible. Shorter line lengths and larger line diameters reduce the risk of cavitation. If assistance is needed to determine suction requirements, contact your Lee Company sales representative.

3.3 Electrical

3.3.1 Wiring

- Pump modules with two cables separate supply power from signals - refer to the pump inspection drawing to determine which cable is which. Carefully identify each wire according to the wiring table on the inspection drawing - many pump cable wires are by default white with a color stripe, and must be examined closely.

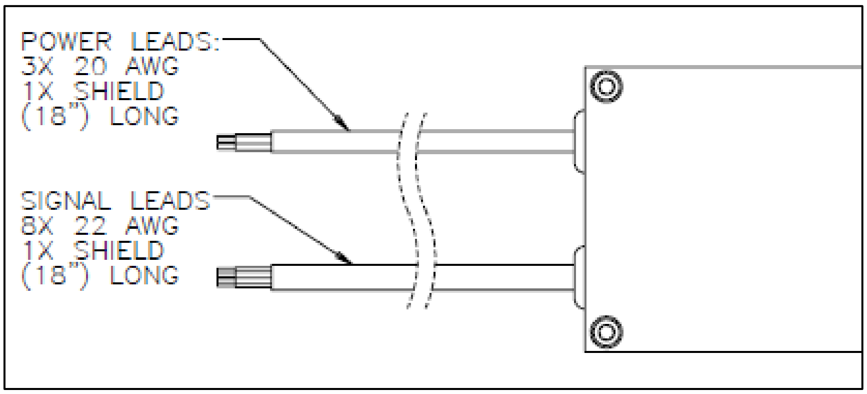

Figure 4 - Power and Signal Cable Identification Example

- Exact wiring is specific to the pump module part number. The inspection drawing includes a wiring table for the pump's cables or connector pins – an example is provided below. The input and output requirements are also defined on the inspection drawing.
- **WARNING:** Mistakenly applying Supply Voltage to any Signal I/O channel will result in damage to the pump module's integrated controller. Ensure all wiring is properly connected before applying power.

WIRING TABLE		
#	STRIPE	DESCRIPTION
POWER LEADS		
1	WHT	SUPPLY VOLTAGE +
2	BLU	SUPPLY VOLTAGE –
3	ORG	CASE
SIGNAL LEADS		
1	WHT	INHIBIT
2	BLU	SIGNAL GROUND
3	ORG	SPEED COMMAND +
4	GRN	SPEED COMMAND –
5	RED	CURRENT MONITOR
6	BLK	SPEED MONITOR – ANALOG
7	YEL	FAULT OUTPUT
8	VIO	SPEED MONITOR – SQ WAVE

Figure 5 - Wiring Table Example, Floating Shields

3.3.2 Shielding

- Refer to the pump's inspection drawing for specifics about shield terminations within the product.
- If a pump with shielded cables does not note any connections for the shield, then the cable shields are floating. This is the case for the example wiring table shown in Figure 5.
- Pumps that do indicate shield connections on the wiring table contain a (360°) termination of the shield to the pump's case. Reference Figure 6.

WIRING TABLE		
#	STRIPE	DESCRIPTION
POWER LEADS		
1	WHT	SUPPLY VOLTAGE +
2	BLU	SUPPLY VOLTAGE -
3	ORG	CASE
SHIELD	N/A	CASE
SIGNAL LEADS		
1	WHT	INHIBIT
2	BLU	SIGNAL GROUND
3	ORG	SPEED COMMAND +
4	GRN	SPEED COMMAND -
5	RED	CURRENT MONITOR
6	BLK	SPEED MONITOR - ANALOG
7	YEL	FAULT OUTPUT
8	VIO	SPEED MONITOR - SQ WAVE
SHIELD	N/A	CASE

Figure 6 - Wiring Table Example, Shield Terminations

- Pumps with integrated connector receptacles have the receptacle housing bonded to the pump case, unless otherwise noted on the inspection drawing.

3.3.3 Bonding

- If a pump has a dedicated bonding surface location, it will be identified on the inspection drawing. This is the appropriate location for connection of a bonding strap or additional mounting bracketry that also serves as a bonding path.

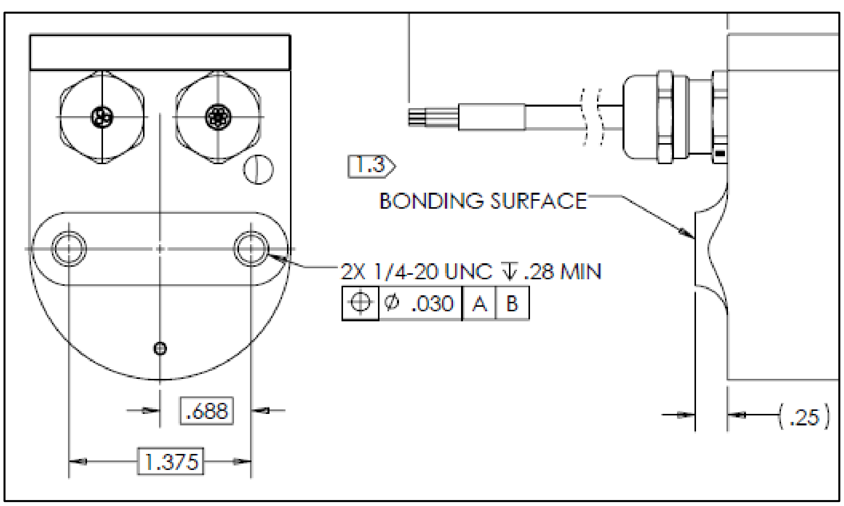

Figure 7 - Bonding Surface

3.3.4 Supply Power (Voltage and Current)

- The Supply Voltage range provided on the inspection drawing specifies the operational limits of the integrated controller. Providing a voltage below the minimum or above the maximum will result in a Fault.
- Achieving rated performance for the pump depends on providing appropriate Supply Power (both Voltage and Current) in accordance with the inspection drawing.
  - While the pump module's RPM is set by the SCV, the maximum achievable RPM (and therefore pump flow) is "capped" by the Supply Voltage.
  - While the pump module's outlet pressure is a result of the system restriction, the maximum achievable pressure is "capped" by the Supply Current.
- Supply and return current may be significant. Ensure that lead resistance is accounted for when setting up the Supply Voltage.

3.3.5 Output Signals

- Pump modules provide several output signals for monitoring the unit's status. The specifics for each output are found on the inspection drawing.
- **Note:** Power and Signal Ground are common at the pump module's integrated controller. A Signal Ground wire is provided as a reference for the various signal output channels. Failure to use Signal Ground as a reference will cause inaccurate monitoring due to the voltage drop across the power return.

3.3.6 Speed Monitor signals are an output that indicate the pump's RPM.

- Analog Speed Monitors are referenced to Signal Ground, and are specified as a nominal pump RPM per Volt feedback. The analog output is a reference value generated by the integrated controller.
- Square Wave Speed Monitors are a direct line into the motor hall sensors, and are specified on the inspection drawing as number of pulses per revolution (with a reference RPM/Hz value). As this is a direct measurement of hall sensor frequency, it is a very accurate indicator of pump RPM.
- **Note:** Square Wave Speed Monitors usually requires a minimum input impedance (specified on the inspection drawing) so as not to create too much demand on the hall sensor line. Violating this specification may cause unstable pump operation.

3.3.7 Current Monitor is a feedback generated by the integrated controller indicating the internal motor current. This is the current within the Pump Module, not the Supply Current.

3.3.8 Speed Command

- The Speed Command Voltage (SCV) input is a fully differential analog input.
- **Note:** The SCV low (negative) may be tied to Signal Ground if desired for convenience. However, there may be a voltage offset between the pump's Signal Ground and the application's control electronics ground due to the voltage drop across the power return.
- The SCV range listed in the pump module's Flow specification on the inspection drawing is the application range for the attached pump head, which considers mechanical and hydraulic limits of the pump for stable operation and long life.
- The full SCV range is 0-10 VDC unless otherwise specified on the inspection drawing.
- The over-current protection of the SCV line for 0-10 VDC products is 15 VDC max.

3.3.9 Inhibit

- A pump module will attempt to run at the speed given by the SCV whenever Supply Voltage is applied. To stop the pump while it is powered, short Inhibit to Signal Ground.
- Nominal current from the Inhibit pin while shorted to ground is 0.5 mA.

4 OPERATION

4.1 Operating Specifications

4.1.1 Operating Speed Limits

- While the SCV is a full analog input range, there may be additional limits for the pump and/or motor. A minimum and maximum operating speed range is specified on each inspection drawing. Operating outside of these ranges may cause unstable operation or excess wear.

4.1.2 Rated Operation

- The Rated Operation of each pump is defined on the inspection drawing as a minimum volumetric flow achieved at a minimum differential pressure applied, without exceeding a maximum allowable test speed (defined either as RPM or SCV). This is the Acceptance Test Procedure (ATP) test point, and ensures that the pump displacement is adequate and that slip flow is acceptable.
- Supply Voltage may have a large range over which the pump will function, but most pump inspection drawings define a minimum voltage required to achieve rated operation. Supply Voltage under this value will limit pump RPM and Rated Operation may not be achieved.
- Power Consumption is defined as the maximum electrical supply power input observed during ATP.

4.1.3 Maximum Pressure Rise

- The max allowable working pressure stated as a differential pressure from the inlet to the outlet. Exceeding this value may cause operational issues including but not limited to exceeding thermal limits of electronics due to high motor current, or premature wear-out of internal friction surfaces.

4.1.4 Proof Pressure

- The maximum casing pressure from the pump's internals to the environment tested during ATP.

4.1.5 Storage Temperature Range

- The limit rating of the materials of construction for long term storage.

4.1.6 Operating Temperature Range

- The limit range of the pump to achieve rated operation. Exceeding these values might cause operational issues including but not limited to thermal limiting of electronics at the high end, or excessive motor current at the low end.
- A note that operating temperature limits may depend on ambient and fluidic conditions refers to the pump module's internal thermal limit, described in 4.6.4.

4.1.7 Standby Current

- A nominal or maximum value for the current demanded by the pump while it is provided Supply Voltage, but not operating (Inhibited).
- A pump inspection drawing may specify a higher Standby Current for cold conditions below a reference temperature. If so, the pump contains an internal heater circuit to warm the electronics while powered in cold environments before start up. The heater circuit is only enabled below the reference cold temperature, and will disable automatically when the pump warms up either by self-heating during operation, changing ambient conditions, or a combination of both. The heater standby current is in addition to any operational supply current while the heater is active.

4.1.8 Performance Curves

- Inspection drawings may reference Technical Report number, which contains detailed typical performance information for the pump beyond the Rated Performance point.
- Performance Curve reports often contain graphs of flow vs. pressure, operating current, performance limits based on supply voltage, and specific details of pump construction such as piston count.

4.2 Setup

4.2.1 When removing the pump from its packaging, ensure shipping caps are removed before plumbing.

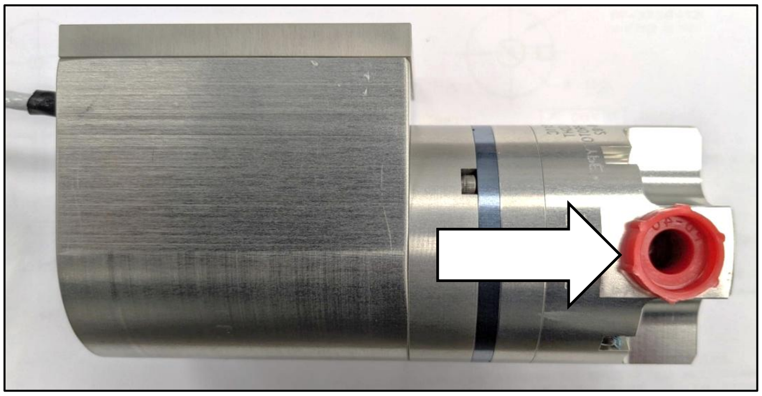

Figure 8 - Pump Module Shipping Caps

4.2.2 Identify the INLET and OULET ports as marked on the pump housing, and on the pump module inspection drawing. Use fittings and seals appropriate for the application.

- The Lee radial piston pump is designed for unidirectional flow. It is not designed to operate in reverse flow unless otherwise specified.
- The Lee radial piston pump module is not designed for submersion unless otherwise specified.

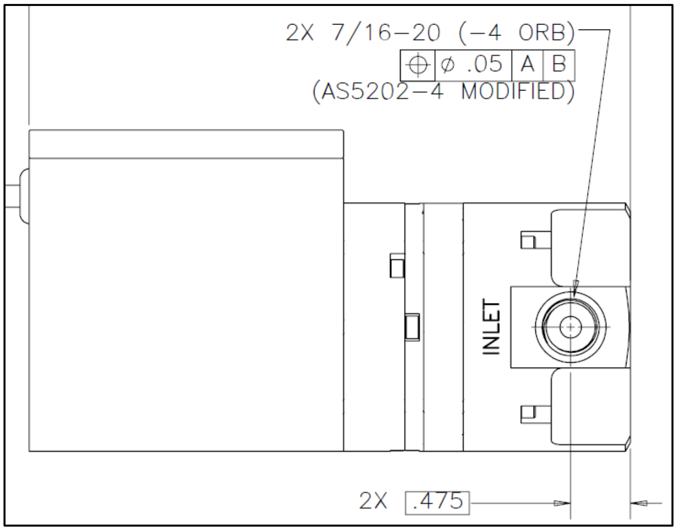

Figure 9 - Pump Module Porting

4.2.3 A light "rattling" noise may be heard if you shake the pump depending on the specific pump part number – this is normal. Certain pumps contain free floating components that are located against an internal surface with operating pressure.

4.2.4 Installing the pump such that the center line of the inlet port is below the liquid level in the source (also called flooded suction) will provide maximum performance and life. However, Lee radial piston pumps do not need to be manually primed unless otherwise specified – they will readily self-prime and clear air within the pump, even with a high fluid lift. Installing the pump above the liquid source level is acceptable (also called dry prime).

- The pump will operate during a dry prime without failure; however, it is not designed for continuous dry run operation. Operating the pump without fluid may cause premature wear-out of the internal friction surfaces.

- Minimize dry prime duration. Less than 5 seconds provides a long pump life over many starts. Dry prime longer than 10 seconds should be avoided (although it will not immediately cause failure).
- The maximum height above liquid level (max suction lift) will depend on available pressure at the inlet, and maximum dry prime time.

4.2.5 If the pump is to self-prime, use caution operating it against a closed outlet such as a pressure relief valve – the Lee radial piston pump is a liquid pump, and will not generate the same pressure when flowing air (gasses).

- While the pump will clear air from the suction tubing and the pump casing, it might not build enough pressure to open a pressure-operated valve.
- If a pressure-operated valve at the outlet is used, it is preferred to provide an air bleed. Otherwise, ensure there's appropriate volume after the pump to allow for self-prime.

4.3 Wiring Connections

4.3.1 Refer to the pump module inspection drawing for the wiring table and I/O requirements specific to the part number. Contact your Lee Company Sales Representative for assistance with wiring if necessary.

4.3.2 The minimum wiring required to operate the pump is Supply Voltage and the desired Speed Command Voltage.

4.3.3 **Do not connect the pump's wires or connector to an energized line** – apply power after connections are made. Failure to do so may cause damage to the pump's electronics.

4.4 Startup

4.4.1 **Ensure all system valves are open.** Do not operate the pump against a closed outlet (dead head) such as a closed valve – a positive displacement pump will build pressure well above that intended if operated against a dead head.

4.4.2 Apply Supply Voltage in accordance with the range on the inspection drawing.

4.4.3 Command the pump to start by opening the Inhibit line (no longer shorted to signal ground).

4.4.4 Apply the desired Speed Command Voltage.

4.4.5 When starting up, if self-priming, the pump may make some "sputtering" noises during the start of flow – this is the pump clearing air from within its own case, and a few air bubbles might be trapped even after initial priming. This is normal and will not damage the pump.

- If this noise does not stop, it could be cavitation or air leaks of the inlet system plumbing.

4.5 Running the Pump

4.5.1 Changing Speed

- The pump module's integrated controller will attempt to change pump speed (and pump flow) as fast as possible based on the applied Speed Command Voltage.
- A maximum Speed Command Voltage slew rate of 10 mV/mS is suggested. Change of speed faster than this may cause unstable operation.
- Pump response time for speed increases depends on system and application characteristics.
- There is no brake function (ex.: brake resistor) provided by the pump module – the integrated controller cannot "slow down" the pump electrically; it will momentarily reduce motor current while the hydraulic system slows the pump down. This happens quickly, but response time for falling speed will depend on system characteristics.

4.5.2 Adjusting the pump's speed will adjust the output flow, directly correlated with RPM as described in Section 2. The pressure developed at the pump's outlet depends only on the system restriction.

4.6 Operational Faults

4.6.1 The pump module inspection drawing describes the Fault signal output type.

4.6.2 Maximum Allowable Motor Current

- The maximum current rating of a pump module is significantly above what would be demanded by the pump operating at the maximum hydraulic pressure and flow conditions – it would only be experienced in an error state, or if the pump's operation limits are significantly exceeded.
- The pump module does not have an internal overcurrent limit function for maximum continuous operating current. It will attempt to run whatever current the load demands until the Thermal Limit is reached (described below). For the most reliable operation, monitor the Motor Current output signal during operation and take action in system error handling if it exceeds the maximum rating.

4.6.3 Peak Current

- The pump module's Peak Current rating is a hard limit at which the integrated controller will shut down. This current level should only be experienced during extreme fault conditions, such as a locked rotor or internal short circuit.

4.6.4 Thermal Limit

- The pump module contains an internal thermal switch which will shut off the pump if the thermal limit of the electronics is exceeded. The thermal limit is at a level above the maximum operating temperature listed on the pump module inspection drawing, and will be reached above the pump module's rated performance.
- Fault Output will go high during a thermal limit event.
- Higher operating power (pressure, flow, and fluid properties) can cause thermal shut down prior to the maximum listed operating temperature – not all performance limits can be achieved simultaneously in all applications.
- The thermal limit fault will automatically reset when the internal temperature of the unit has recovered to a level under the limit.

4.6.5 The Fault Output will also go high for over/voltage or motor short circuit.

4.6.6 Seal Leakage

- Some pumps have weep channels behind the shaft seal, as depicted below. If a seal leak occurs near the end of the pump's life, fluid emission may be visible.

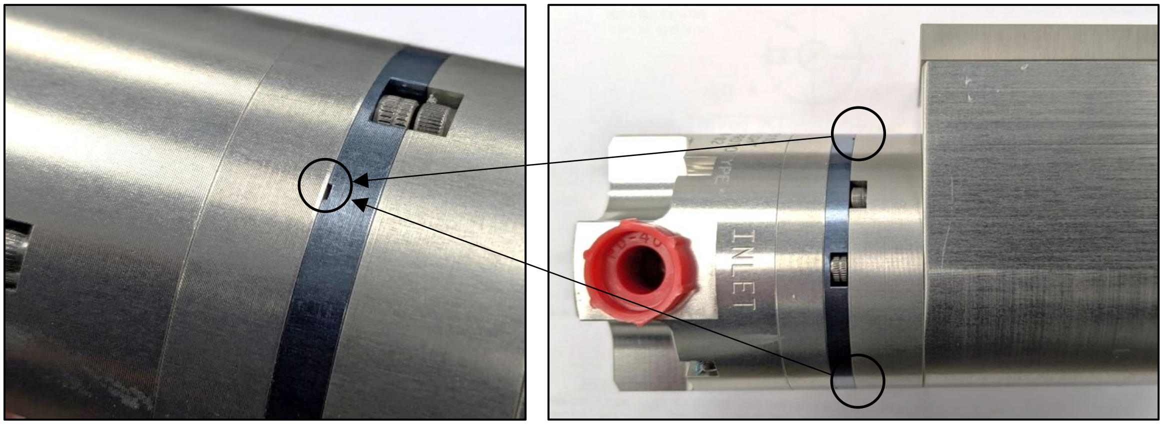

Figure 10 - Post-seal Weep Channels

5 TROUBLESHOOTING

5.1.1 Lee radial piston pump products are not serviceable. If problems occur during setup or operation, first reference the Troubleshooting table below. If no solution is identified, or if you need any further assistance, contact your Lee Company Sales Representative.

Problem:	**Might be:**	***Try this:***
Pump runs immediately when supply voltage is applied.	Inhibit line open	This is the intended design if the Inhibit line is actually open – the pump will try to run when it is powered unless it is Inhibited. Reference section 3.3.9. To check for problems with the system, directly short the Inhibit lead to Signal Ground to see if it stops the pump.
Pump is powered, but won't run when commanded to start	Inhibit shorted	Check the Inhibit line with a multimeter vs. signal ground, and look for 5V. If it is at ground voltage, there's a system problem, and the pump is still Inhibited.
	SCV is 0	The pump will attempt to run at << 1 RPM at 0 SCV. It might sit stagnant forever. Check that an appropriate speed command is applied.
	Open supply line	Inhibit the pump and check the line current. If current is less than the Standby Current on the print, there might be a disconnect in the supply voltage line. If there is no issue with the supply line but Standby Current is 0, contact your Lee Company Sales Representative.
	Pump jammed	The pump might have become jammed with debris. Signs of a jammed pump are high current at 0 RPM. Check the source tank for FOD. The pump is not field serviceable – you might need to contact your Lee Company Sales Representative for assistance.
	Fault on	Check if the Fault line is high. See section 4.6 for more information.
Pump is running, but there's no flow	Discharge blocked	Ensure that the pump outlet is open. The pump can build dangerously high pressures if operated against a dead head.
	Plumbed backwards	Check that the inlet and outlet lines are properly connected to the fluid source and the discharge system. The ports should be labeled on the pump body, or identified on the inspection drawing, or both.
	Incorrect SCV	Check that the SCV applied to the pump is in the range on the inspection drawing.
	SCV polarity is backwards	The SCV is a differential input, and if a negative value is provided, the pump will spin backwards. The pump is unidirectional, and will not operate properly in the incorrect direction. Try reversing the polarity to see if it fixes the problem.
	Pump is not primed	Even though the pump self-primes, system issues can cause prime failure. Check the following: 1) Waited long enough for pump to dry prime. 2) Liquid level is above source tank pickup. 3) No excessive leaks in suction plumbing.
Flow is lower than expected	Incorrect speed command	Check that the SCV applied to the pump is in line with expectations, and is appropriate with respect to the range on the inspection drawing.
	Excessive cavitation	Ensure that sufficient Net Positive Inlet Pressure Available (NPIPA) is present.
	Aeration	Check for air leaks on the suction side of the plumbing. Also, if there is a flow return to tank, ensure it returns below liquid level – dropping return flow into a tank can cause excessive fluid aeration.
	Supply voltage too low	Check the pump's RPM from one of the available speed feedback signals. If the supply voltage is too low, the pump's RPM might be capped, and it might be running slower than the commanded SCV would dictate.
	Pressure is too high	The Lee Radial Piston Pumps have exceptional volumetric efficiency. However, if pressure is much higher than anticipated, slip flow could be excessive, and internal leakage might be responsible for reduced flow.
Unstable operation	Loose connections	This can be especially true for the speed command voltage line. Check all electrical connections for mechanical integrity.
	Cavitation or Aeration	See above.
	Speed too low	Below a certain RPM, the motor will start to cog, or the pump may lope, or chatter. Ensure that the speed command voltage is above the minimum specified on the inspection drawing.
	Electrical noise	While unlikely, excessive noise can cause unstable operation, especially on the speed command line. Ensure all shields are connected as intended, and that sources of significant external EMI are mitigated appropriately.
Excessive pressure ripple	Long discharge line	The pump only produces a flow ripple – the pressure ripple is a result of how the system responds to the flow ripple. This is called Acceleration Head. It can be reduced with larger diameter lines and shorter lines. In rare instances, a harmonic may exist in the system plumbing.
	Small discharge line	
	Harmonics	

6 REFERENCE SCHEMATICS

6.1 Product References

6.1.1 The following generic schematic is a generic reference for the pump module's integrated controller.

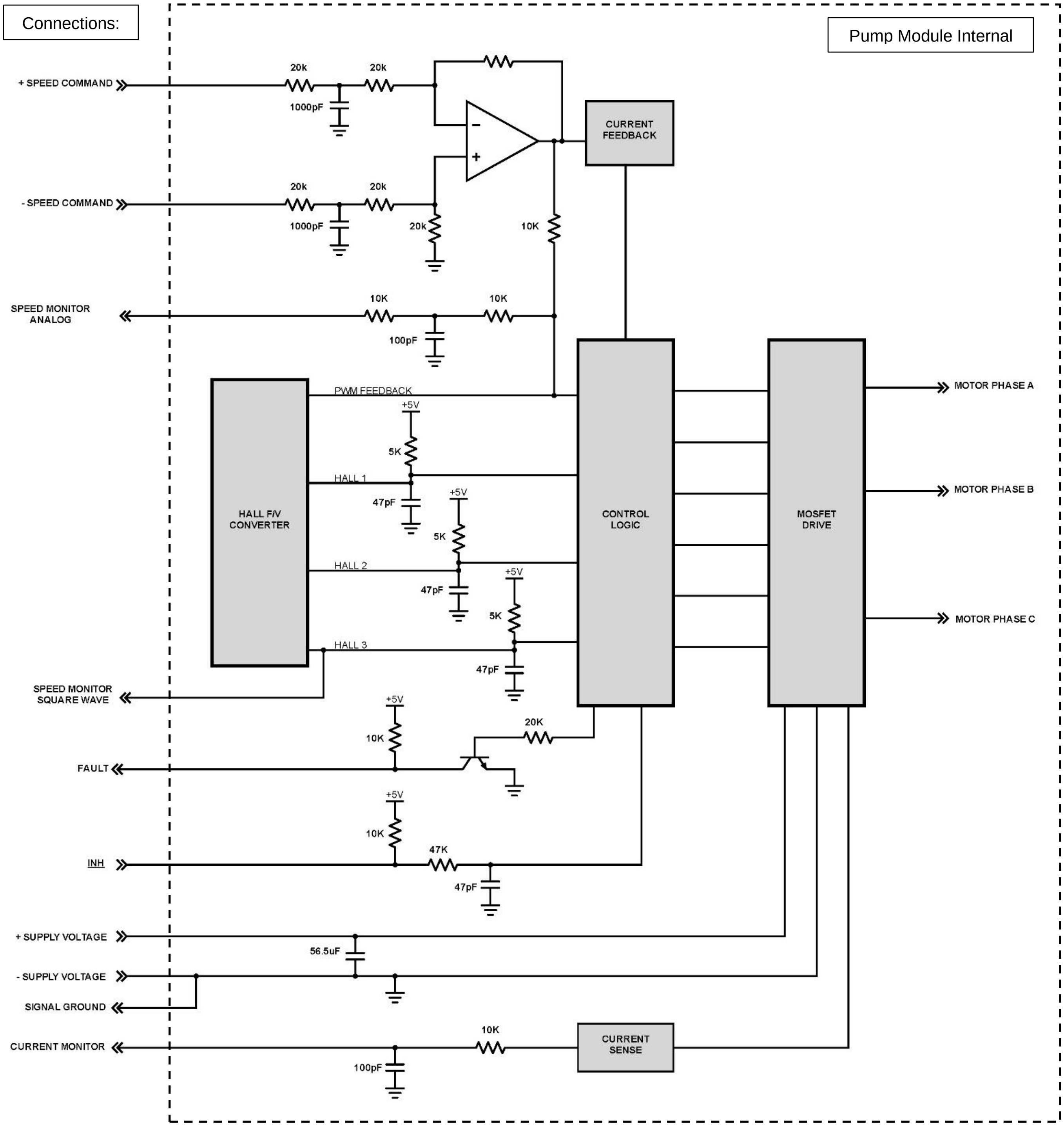

Figure 11 – Controller Reference Schematic