A pump is a volume output device only. It delivers oil flow directly related in polarity and amplitude to the command voltage input to the pump amplifier (EPC). Pressure at the pump output is determined by resistance put on pump flow by the machine process. Modification to the command signal relative to actual pressure (signal conditioning) is used to control the output volume and therefore the horsepower (HP). HP Limiting protects the electric motor driving the pump from overloading.

This example represents a system using a PVL250 pump (25 in³/rev) and 150 HP electric motor at 900 rpm. The HP Limit Factor of 50 is calculated automatically by the EPCXPCI software (see page 6). The breakpoint is 2500 PSI and HP Limit is 5000 PSI (see Figure 1).

The breakpoint is the level of pressure feedback (transducer) that begins to reduce full flow of the pump. The HP Limit Factor determines the HP curve. The KP (proportional gain) and KI (integral gain) of the HP Limiter sets the amount at which the flow is reduced once the Motor Overload Zone condition exists.

Figure 1: HP Limiting Example
The horsepower curve, for the example on the previous page, can be calculated using the following equations. All values are approximate.

\[
Q_m = \frac{D_{\text{max}} \times N}{231 \times n}
\]

\[
= \frac{25 \times 900}{231 \times .94}
\]

\[
= 100 \text{ GPM (Pump 100% Full Volume)}
\]

Where:

- \(Q_m\) is flow rate in GPM (Gallons Per Minute)
- \(D_{\text{max}}\) is maximum displacement of the pump in CIPR (Cubic Inches Per Revolution)
- \(N\) is speed in RPM (Revolutions Per Minute)
- \(n\) is efficiency
- 231 is cubic inches per gallon

\[
\text{Output HP} = \frac{Q_m \times P}{1714}
\]

Where:

- HP is horsepower
- P is pressure (PSI)
- 1714 is a constant value

Rearranged for Pressure

\[
P = \frac{\text{Output HP} \times 1714}{Q_m}
\]

\[
= \frac{150 \times 1714}{100}
\]

\[
= 2500 \text{ PSI (Breakpoint)}
\]

Rearranged for Flow Rate

\[
Q_m = \frac{\text{Output HP} \times 1714}{P}
\]

\[
= \frac{150 \times 1714}{5000}
\]

\[
= 50 \text{ GPM (Slope Final Volume)}
\]

The pump will put out 100 GPM at 100% flow with no pressure feedback. As the pressure feedback increases, the output HP increases. Once the pressure feedback reaches 2500 PSI (breakpoint), the flow will start to reduce to maintain a maximum 150 HP output. The flow will continue to reduce until the pressure reaches 5000 PSI at which the pump is delivering 50 GPM at 50% flow @ 150 HP.
The HP Limit Factor can be used to limit the power consumed by the hydraulic pump. To limit horsepower, a HP Limit Factor is determined which defines a PQ (Pressure-Flow) curve. This curve defines a certain horsepower.

The product of Pressure and Stroke is compared to the curve. If the product is greater than the HP Limit Factor, the feedback HP is greater than the allowed HP, and the command to the pump is adjusted.

The HP Limit Factor is configured as a percentage with 0% as the lowest controllable HP level and 100% as the highest controllable HP level. It is calculated as follows:

\[
\text{HP Factor} = \frac{(4 \times 10^7) \times \text{Power} \times n}{\text{DMAX} \times \text{PXDCR} \times N} \\
= \frac{(4 \times 10^7) \times (150)}{(25) \times (5000) \times (900)} \times 0.94 \\
= 50
\]

Where:
- \(\text{Power}\) is the motor rating in HP
- \(\text{DMAX}\) is maximum displacement of pump (CIPR)
- \(\text{PXDCR}\) is the maximum measured pressure (PSI)
- \(N\) is the speed (RPM)
- \(n\) is the pump efficiency
- \(4 \times 10^7\) is a constant value

The HP Limit Factor can be determined in two ways: Theoretically and Experimentally.

For the **Theoretical HP Limit Factor**, the user enters motor and pump information into the HP Limit Worksheet in the Advanced Diagnostics Form. For the motor, the user enters the **Power Rating** and **Speed**. For the pump, the user enters the **Displacement** and **Pump Efficiency**. Finally, the user enters the **Nominal Pressure** for the pressure feedback device (pressure value corresponding to a +10V command). The setup procedure is discussed in detail on page 6.

For the **Experimental HP Limit Factor**, the user builds up pressure and increases stroke until the motor draws the maximum rated current. Then, the user simply presses the experimental button, in the HP Limit Worksheet of the Advanced Diagnostics Form. The setup procedure is discussed in detail on page 8.
1. Setup the EPC with the pump for Flow Control as per Bulletin 836261.

2. Connect a **5000 PSI pressure transducer** (4-20mA) as shown (bold font) in the Connection Example below (Figure 2). A 500 ohm resistor is placed across Analog Input 2 for the current mode. The 24V power to the EPC should be turned off during this step.

3. Set the command to **0V** on Analog Input 1.

![Connection Example Diagram](image)
4. Click **Diagnostics** on the Menu Bar and then **Analog IO Configuration** or F7. See Figure 3 for Analog Input 2 signal conditioning setups.

- Set **Analog Input 2 Offset Voltage** (860) to -2.0V.
- Set **Analog Input 2 Gain** (861) to 1.250.
- Set **Analog Input 2 Polarity** (862) to (0) Normal.
- Set **Analog Input 2 Current Fault** (863) to (1) Enable.

![Analog Input 2 Configuration](image)

**Figure 3: Analog IO Configuration**

The 5000 PSI transducer is now offset and scaled for 0 to 10V as follows:

- Transducer: 0 to 5000 PSI
- Current Range: 4 to 20 mA
- Analog Input 2 with 500 Ohm Resister (Raw Value): 2 to 10 V
- Analog Input 2 (-2.0V Offset): 0 to 8 V
- Analog Input 2 (1.250 Gain): 0 to 10 V

Pressure can be converted into voltage as follows:

\[ V \text{ (Pressure)} = 0.002V/\text{PSI} \times \text{Pressure (PSI)} \]

Therefore for this example:

\[ V \text{ (5000 PSI)} = 0.002V/\text{PSI} \times 5000 \text{ PSI} \]
\[ = 10.0V \]

\[ V \text{ (2500 PSI)} = 0.002V/\text{PSI} \times 2500 \text{ PSI} \]
\[ = 5.0V \]

A 5000 PSI transducer should always be calibrated 0 to 10 V for the full range of 0 to 5000 PSI, even if the maximum system pressure is significantly less than 5000 PSI. All of the signal conditioning (offsetting and scaling) is done after Analog Input 2 voltage is converted by the ADC (Analog to Digital Converter). Therefore, the volts per bit does not change with signal conditioning. Thus, there is not a benefit to change the range.

When the current fault (863) is enabled, a fault is triggered when a line is broken (open connection). This only works with a 4 to 20mA signal on the Analog Input.
5. Click **Diagnostics** on the Menu Bar and then **Advanced Diagnostics** or press **F8**. See Figure 4 for Theoretical HP Limit Factor worksheet setup.

- Select **English Units**
- Set **Motor Power** to 150 HP
- Set **Nominal Pressure** to 5000 PSI
- Set **Displacement** to 25 cu. in/rev
- Set **Speed** to 900 RPM
- Set **Pump Efficiency** to 0.94
- Click on **HP Theory button**

The worksheet calculates the HP Limit Factor to 50.

![Figure 4: Theoretical HP Limit Worksheet](source_url)
6. Click on **Pump Controller** on the Menu Bar or press **F6**. See Figure 5 for Pump Controller setups.

- Set **HP Limit Factor** (810) to 50
- Set **Pressure Feedback Source** (811) to (2) Analog Input 2
- Set **Stroke Feedback** (800) to (4) LVDT
- Set **KP** (813) to 10
- Set **KI** (814) to 10

![Figure 5: Pump Controller](image)

7. Increase the **command** on Analog Input 1 to 10V and build pressure. The function of the HP limiter can be evaluated and adjusted for the specific application. An explanation of the pump controller is discussed below.

The Pressure Feedback Source is Analog Input 2 (program item 811=2) and the Stroke Feedback Source is LVDT (program item 800=4). The internal HP calculation based on these pressure and stroke signals results in a value of 5.23V. The HP Limit Factor of 50% results in a value of 4.99V, so the actual HP is greater than the allowed HP. The error signal is the difference of these calculated numbers is 4.99V - 5.23V = -0.24V. The HP Limit is made up of the Yi and Yp contributions computed from the HP Limiter PI controller (-3.60V + (-0.41V) = -4.01V).

The resulting Command with HP Limit is 10.00V - 4.01V = 5.99V. This command, along with the Stroke Feedback signal is passed to the Stroke Controller, where the error signal is 5.99V - 8.69V = -2.70V. This error signal is used for the Stroke Controller PI calculations, and the output is equal to the Yi and Yp contributions is 0.00V - 1.35V = -1.35V.

The stroke will reduce until actual HP is less than the HP Limit Factor. The amount reduced is determined by the KP and KI settings in the HP limiter. The larger the value, the greater the stroke is reduced.
General Notes:

1. The flow will not be affected until the product of the pressure feedback (transducer) and stroke is greater than the HP Limit Factor.
2. A KI gain is required for horsepower limiting.
3. The gain (KP and KI) should be set for the best response of the system.
4. Simulate the transducer pressure/current input to the EPC.
5. The settings on the previous page are for a typical hydraulic system. Every application is unique and slight adjustments are required to optimize the system’s performance. Adjustments should be in the field on actual system.
6. Use Online help as needed.

Optional Experimental HP Limit Factor Setup:

1. Connect the multimeter to read current (Amps) to one phase of the AC motor.
2. Choose a simple flow program from the General Configuration Form.
3. Choose a pressure and feedback source from the Pump Controller Form.
4. Set the HP Limit Factor to 100 in the Advanced Configuration Form.
5. Rig the hydraulic circuit to build maximum pressure.
6. Increase the command (stroke) until maximum pressure is achieved.
7. Slowly increase the command (stroke) while measuring the current to the AC motor. When maximum current is reached, press the HP Experimental command button from the Advanced Configuration Form. The HP Limit Factor is displayed in menu 810.

<table>
<thead>
<tr>
<th>HP Limit Worksheet (Theoretical)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SI Units: Motor Power (hp): 150.00</td>
</tr>
<tr>
<td>English Units: Nominal Pressure (PSI): 5000</td>
</tr>
<tr>
<td>Displacement (cu. in./rev): 25.00</td>
</tr>
<tr>
<td>HP Limit Worksheet (Experimental)</td>
</tr>
<tr>
<td>-----------------------------------</td>
</tr>
<tr>
<td>(1) Set HP Limit Factor to 100.</td>
</tr>
<tr>
<td>(2) Build Maximum Pressure.</td>
</tr>
<tr>
<td>(3) Measure Motor Current while increasing Stroke to Pump.</td>
</tr>
<tr>
<td>(4) When Maximum Motor Current is Achieved, Press the HP Experiment Button.</td>
</tr>
</tbody>
</table>

Figure 6: Experimental HP Limit Worksheet