

ENGINE OIL PUMP PERFORMANCE AND DURABILITY TEST PROCEDURES

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1. SCOPE

SAE/USCAR-46 defines test methods and outputs for engine oil pump bench testing. Performance and durability testing are the primary focus of this standard. This is written to specifically address testing of electronically controlled variable displacement pumps but can be adapted to mechanically controlled pumps and other pump technologies as needed. This standard outlines critical inputs and outputs in order to perform the testing and report results, but does not specifically set the acceptance standards or pass/fail criteria. Acceptance criteria must be set by the customer.

2. GENERAL TESTING AND REPORTING REQUIREMENTS

- The test procedures in this standard are stand-alone tests and may be used as such. However, they may also be used as part of a sequential test series. The requestor will outline the sequential test order and quantity of parts if desired. The general testing requirements are:
 - Part submitted for test conform to the dimensional characteristics specified on the applicable engineering drawing(s) of the part.
 - Any engineering development, prototype, or production part may be submitted for test, provided the design is documented.
 - The samples submitted for test must be identified by description, part number, and revision level where applicable. All test samples shall be serialized if they do not already include a serial number.
 - It is expected that summary reports include graphs as outlined in each procedure and that the raw data accompanies all reports in a universal format such as .CSV, tab delimited, or spreadsheet file. All data channels must be clearly labeled in the raw data file.
 - This standard is meant to aid in communication between the test requestor and the test lab, not replace that communication. Before start of test, please verify with the requestor all test setup parameters.
 - Many of the parameters described in this standard are template standards and may not be required for all tests. Verify all temperatures, speeds, and other test parameters with the requestor.
- This standard includes a list of tests that MAY be run as part of a development and validation plan. This does not mean that ALL tests must be run at every build phase of a program. Individual tests must be carefully selected by the requestor to support their required needs.
- Safety: Not defined in this procedure. Please follow your internal safety protocols. Please note that any example system circuits are provided for reference only and may not completely define the circuit with all safety protocols in place.
- All tests are expected to be run in accordance with ISO 17025, A2LA, or NIST traceable standards.
- Unless otherwise specified in a specific procedure, it is expected that the sampling rate will be at least ten times faster than the data recording rate and the signal should be averaged/smoothed/filtered. For example, if recording data at a 10 Hz rate, it is expected that the data will be sampled at 100 Hz minimum, and the value smoothed to get the 10 Hz recorded data. For all tests except for 3.4, the intention is to present averaged or filtered data for a smoother curve fit.

- Unless otherwise specified, the same oil type will be used for all tests. The requestor will be responsible for setting the exact oil viscosity. If not specified, use the latest API grade 0W-20.
- Aeration control and measurement is needed for some of the tests. The exact method of aeration generation, introduction, and measurement must be discussed and agreed upon with the test requestor.
 - Unless otherwise specified by the requestor, aeration should be defined as the ratio of volume of air to the total volume of the sample (air + oil). These values need to be compensated for pressure and temperature and are typically reported at standard temperature and pressure.
 - It is desired to be able to measure total aeration level with an accuracy of $\pm 1\%$ aeration with at least a 1 Hz frequency response, with fluid temperature from 60 to 140 °C, and operating pressure conditions up to 35 bar (i.e., aeration measurement to be made either at inlet or outlet side of the pump under test).
 - Test system should be able to create and control aeration level within $\pm 1\%$ aeration in the suction reservoir in closed-loop mode typically up to 20%, while maintaining temperature control stability within ± 3 °C.
- Please verify all restriction settings with the requestor. The examples shown are for reference only and the requestor should be aware of the detailed test setup.
- For fixed orifices, it is recommended that the test lab and requestor agree on orifice size in 0.1 mm increments. In the past, many requests may have used an orifice size such as 7.563 mm. In most cases equivalent test data could be generated using a 7.500 mm or 7.600 mm orifice. This will allow the usage of common orifices on multiple test setups, minimizing the amount of test fixture hardware required at each lab. This will also allow more sharing of test fixtures between various requestors.
- The diameter and length of each restrictor should be agreed with the test requestor. In general, the restrictors in this standard are assumed to be short orifices with a length to diameter ratio less than 2.

See Appendix A for a reference of sensors that should be used for each test. The test lab is responsible to verify the sensor selected can meet the measurement frequency and temperature range requirements.

3. PERFORMANCE TEST PROCEDURES

3.1 Revolutions Per Minute Sweep Against a Fixed Restriction

3.1.1 Purpose

This test shows the performance of an oil pump when pumping against a fixed restriction. Pump speed is varied while the restriction(s) are held constant to understand the oil pump pressure regulation performance at various speeds. The pressure regulation system of the pump is active during this test. Restrictor 1 simulates the restriction from pump outlet to the feedback. Restrictor 2 simulates the rest of the engine restriction.

3.1.2 Test Setup and Instrumentation

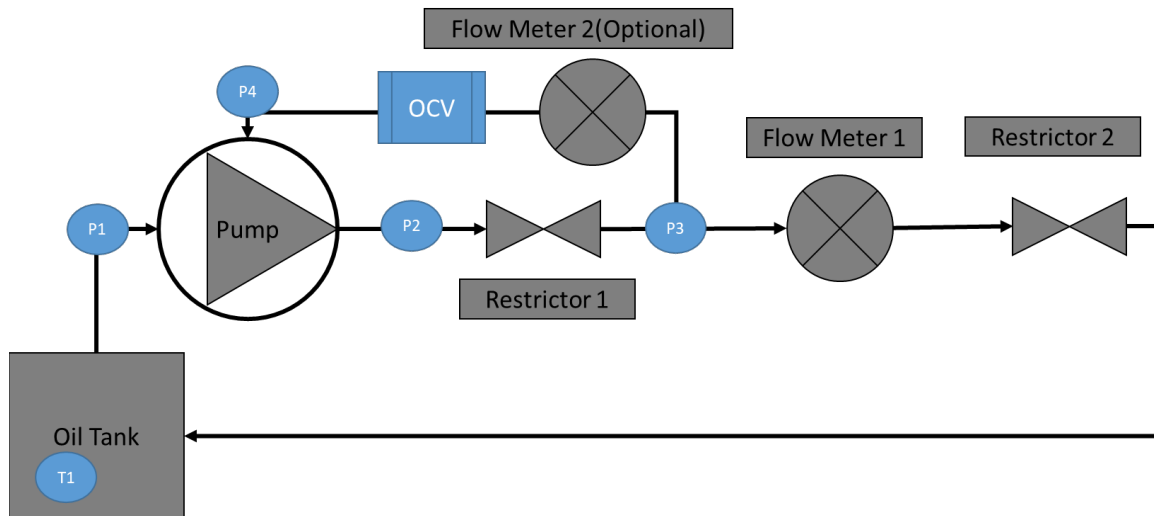


Figure 1 - Example hydraulic schematic for rpm sweep

- 3.1.2.1 The oil pump mounting should represent the engine mounting conditions and drive system and be agreed upon with the test requestor.
- 3.1.2.2 If desired, the flow meter can be placed before Restrictor 2 or after at the discretion of the test lab.
- 3.1.2.3 The suction side of the oil pump should use a representative suction pipe if possible. If this is not possible on the test stand, the suction pipe design must be approved by the requestor.
- 3.1.2.4 Height of pump above oil level and sump size should be defined and approved by requestor.
- 3.1.2.5 Air volume in suction side and pressurized side should be noted in the test report (for priming tests only).
- 3.1.2.6 Pressure drop of the stand in the unrestricted state should be noted. The target for a typical stand is $P2 < 150 \text{ kPa}$ at 100 LPM, 100 °C with 0W-20 oil.
- 3.1.2.7 Restrictors

The restrictors may be fixed restrictors, such as an orifice or variable restrictors such a manually controlled valve, or electrically controlled valve. Should be agreed with requestor. For long-term repeatability, some requestors prefer to use fixed orifices, so the bench restriction is very repeatable after multiple years of use.

- 3.1.2.8 Restrictors 1 and 2 should be defined by the requestor. If these are not defined geometry orifices, the requestor may give guidance on how to set the restriction of a valve.

3.1.3 Procedure

- 3.1.3.1 Before starting the stand, turn on the data recorder to record initial values of transducers. Save this data set as the stand tare data set for the start of test. At the end of the data collection, repeat this tare procedure to ensure sensors have not drifted during the course of the test. Bring the oil to the desired temperature. Once the oil has reached the desired temperature, start spinning the pump at the lowest rpm provided in the inputs to prime the pump. Ensure the proper restrictions are set and cannot change during the test.

- 3.1.3.2 Set the OCV voltage and duty cycle or current to the selected value. Please note the method for controlling the OCV in the test documentation.
- 3.1.3.3 Turn on the data recorder at **10 Hz** for the selected channels. Ramp the rpm from the minimum value to the maximum value in a continuous manner over **30** seconds (or longer), then decrease the rpm from the maximum value to the minimum value in a continuous manner over **30** seconds (or longer). Test stand equipment may change the optimum rate at which the rpm is increased and decreased in order to generate the best quality data. It is important that the data is smooth for the duration of the test and that the ramp rate has minimal impact on the pressure. Please review the underlined values with requestor to verify the data meets the requestor's needs.
- 3.1.3.4 Set the OCV to the next desired duty cycle or current value, then repeat step #3 until all OCV duty cycle or current settings are run.
- 3.1.3.5 Once all duty cycles have been run at a selected temperature, go to the next highest temperature setting and repeat steps #2 through #4.
- 3.1.3.6 Repeat the entire test procedure again at each aeration setting desired. Need to define aeration generation method and measurement method.
- 3.1.3.7 Default Test Conditions Table

Verify these with the requestor:

Temperature (°C)	OCV Duty Cycle	Aeration	rpm Range
20, 60, 100, 120, 140	0 - 100%, 10% increments	On/Off	500 - 7000 - 500

3.1.4 Minimum Required Recorded Data Channels

See Figure 2 for reference: P1, P2, P3, P4, T1, flow, torque, rpm, time, measured OCV duty cycle, voltage, and current, aeration.

3.1.5 Default Graphs and Output Formats

Plot pressure versus rpm, torque versus rpm, flow versus rpm, overall efficiency versus rpm.

Calculated signal: Overall Efficiency = Pressure*Flow / Torque * Speed.

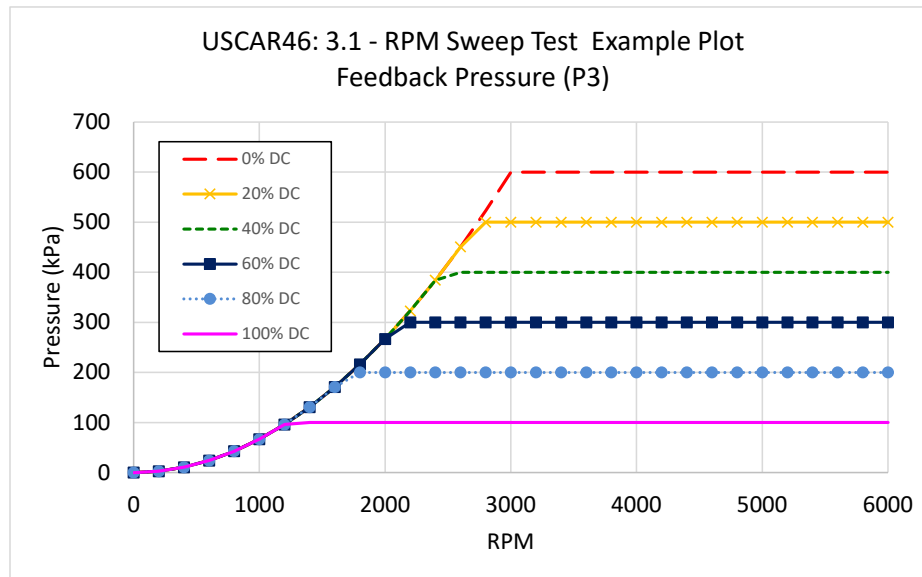


Figure 2 - Revolutions per minute sweep example plot

3.2 Flow Versus Pressure at a Fixed rpm (Waterfall/Performance Mapping)

3.2.1 Purpose

To understand the oil pump performance at various speeds, restrictions, and solenoid positions. Restrictor 1 simulates the restriction from pump outlet to the feedback, typically the oil cooler and filter. Restrictor 2 simulates the rest of the engine restriction and is variable from fully open to fully closed in this test to characterize the pump's response to various restrictions that may be encountered.

3.2.2 Test Setup and Instrumentation

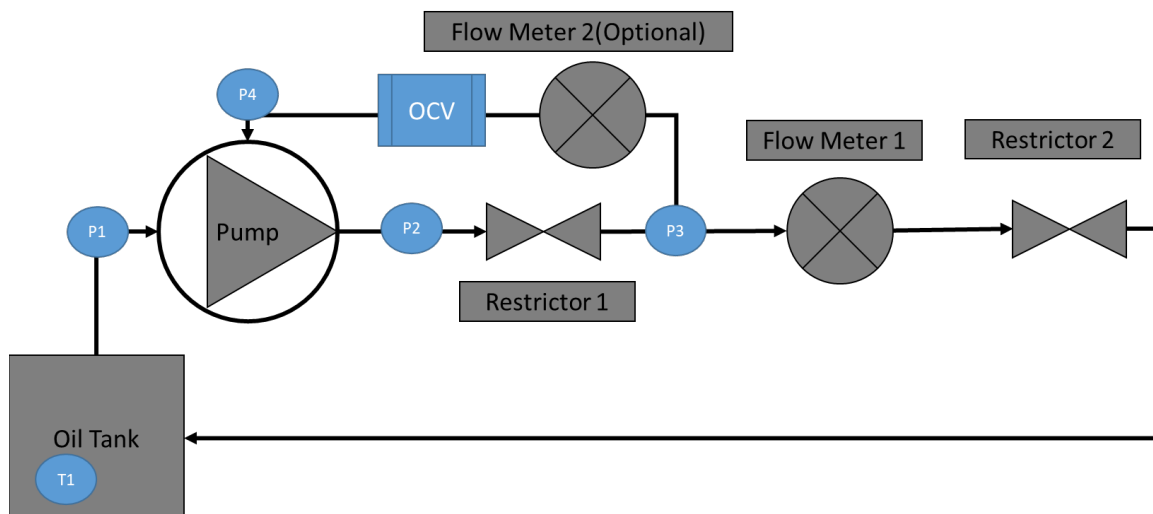


Figure 3 - Example hydraulic schematic for rpm sweep

3.2.2.1 If desired, the flow meter can be placed before Restrictor 2 or after at the discretion of the test lab.

- 3.2.2.2 The oil pump mounting should represent the engine mounting conditions and drive system or must be agreed upon with the test requestor.
- 3.2.2.3 The suction side of the oil pump should use a representative suction pipe if possible. If this is not possible on the test stand, the suction pipe design must be approved by the requestor.
- 3.2.2.4 Height of pump above oil level and sump size should be defined and approved by requestor.
- 3.2.2.5 Pressure drop of the stand in the unrestricted state should be noted. The target for a typical stand is <150 kPa at 100 LPM, 100 °C with 0W-20 oil.
- 3.2.2.6 Restrictors

It is assumed for this test that Restrictor 2 will be a controlled valve that can go from fully open to fully closed. A globe style valve may best be used to regulate the pressure. The valve should be equipped with a pneumatic actuator and an electronic positioner. The valve should have an equal percentage opening characteristic. The control valve flow coefficient should be chosen to match the pressure/flow characteristics of the pump under test. Through software, the valve can be controlled in open-loop mode, which will allow it to hold a fixed "percent open" position. Additionally, the valve can be controlled in closed-loop mode, using the signal from an external pressure transducer to create a closed-loop pressure control system. PID gains need to be adjustable for operation in closed-loop mode. The gains should be tuned to minimize overshoot as much as practically possible, to avoid damage to components due to pressure spikes.

- 3.2.2.7 Restrictor 1 may be a fixed orifice, manually controlled valve, or electrically controlled valve, and should be agreed upon with the requestor. If Restrictor 1 is not a defined geometry orifice, the requestor should define the restriction. Leave Restrictor 1 set to this value for the entire test. Check this restriction setting after the test to ensure it has not drifted.

3.2.3 Procedure

- 3.2.3.1 Before starting the stand, turn on the data recorder to record initial values of transducers at 10 Hz. Save this data set as the stand tare data set for the start of test. At the end of the data collection, repeat this tare procedure to ensure sensors have not drifted during the course of the test. Once the oil has reached the desired temperature, fully open the stand restriction. If using a two-restrictor setup, keep Restrictor 1 set as specified.
- 3.2.3.2 Set the OCV voltage and duty cycle or current to the selected value. Please note the method for controlling the OCV in the test documentation.
- 3.2.3.3 With the pump spinning at the lowest fixed rpm provided in the inputs. Close the stand restriction fully in a continuous manner over 180 seconds (or longer), then open the stand restriction fully in a continuous manner over 180 seconds (or longer). Test stand equipment may change the optimum rate at which the valve is closed in order to generate the best quality data. It is important that the data is smooth from the start of regulation to the deadhead condition. Please review with the requestor to verify the data meets the requestor's needs.
- 3.2.3.4 Set the OCV to the next desired duty cycle or current value, then repeat step #3 until all OCV duty cycle or current settings are run.
- 3.2.3.5 Stop recording data and go to the next highest rpm.
- 3.2.3.6 Repeat steps 3.2.3.2 through 3.2.3.4 for all rpms selected to be run.
- 3.2.3.7 Once all pump speeds have been run at a selected temperature, go to the next highest temperature setting and repeat steps 3.2.3.2 through 3.2.3.6.

3.2.3.8 Repeat the entire test procedure again at each aeration setting desired. Need to define aeration generation method and measurement method.

3.2.3.9 Default Test Conditions Table

Verify these with the requestor:

Temperature (°C)	OCV Duty Cycle	Aeration	rpm
20, 60, 100, 120, 140	0 - 100%, 10% increments	On/Off	500, 750, 1000, 1250, 1500, 2000, 3000, 4000, 5000, 6000

3.2.4 Minimum Required Recorded Data Channels

P1, P2, P3, P4, T1, flow, torque, rpm, time.

3.2.5 Default Graphs and Output Formats

Plot flow versus feedback pressure (P3), plot flow versus feedback pressure (P2), torque versus pressure (P3), torque versus pressure (P2), overall efficiency versus pressure (P2), overall efficiency versus pressure (P3).

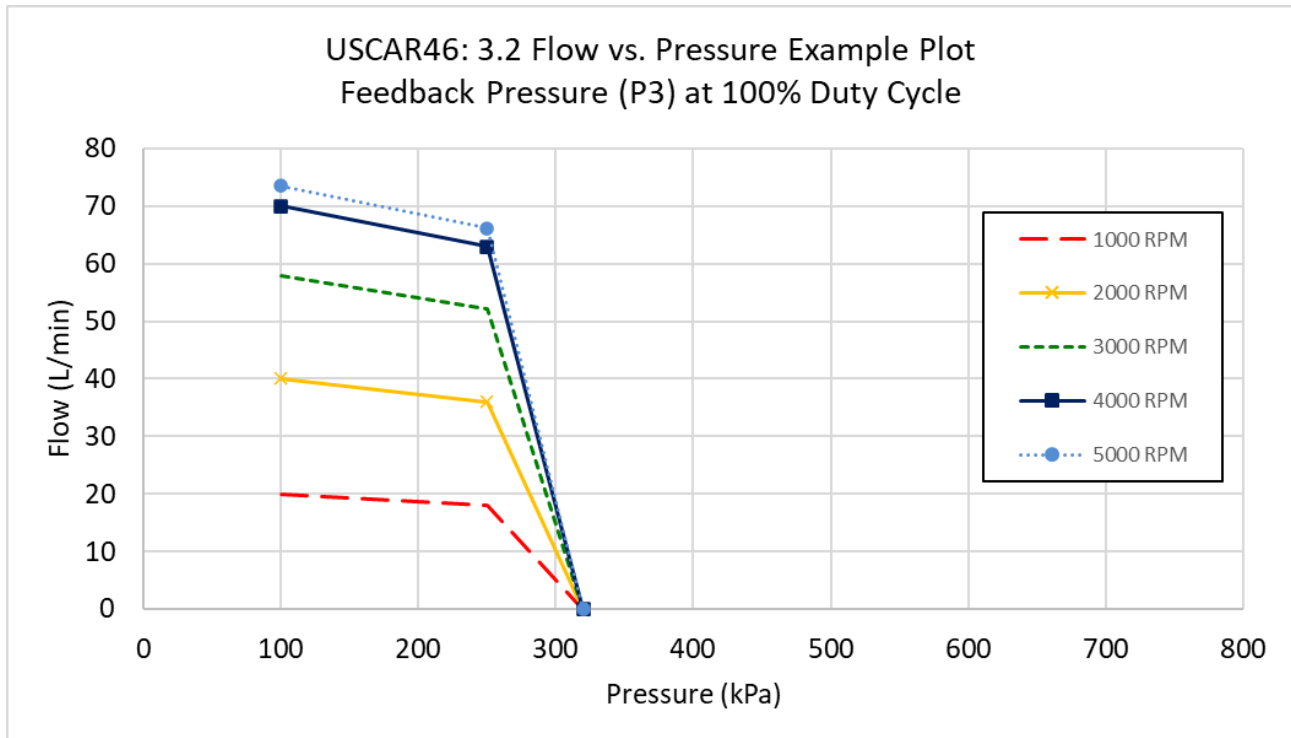


Figure 4 - Example flow versus pressure plot

3.3 High Speed Flow Limit/Cavitation

3.3.1 Purpose

This test shows the flow performance of an oil pump at fixed pump outlet pressures. Pump speed is varied while the pump outlet pressure is held open/as low as possible. The pressure regulation system of the pump is inactive during this test. In

the case of a variable displacement pump, this may be run at multiple different displacements, but in each case the pump is fixed at that displacement.

Because the pump is run at a fixed displacement, the efficiency (volumetric, mechanical, overall) of the pump can be easily calculated with this test procedure.

3.3.2 Test Setup and Instrumentation

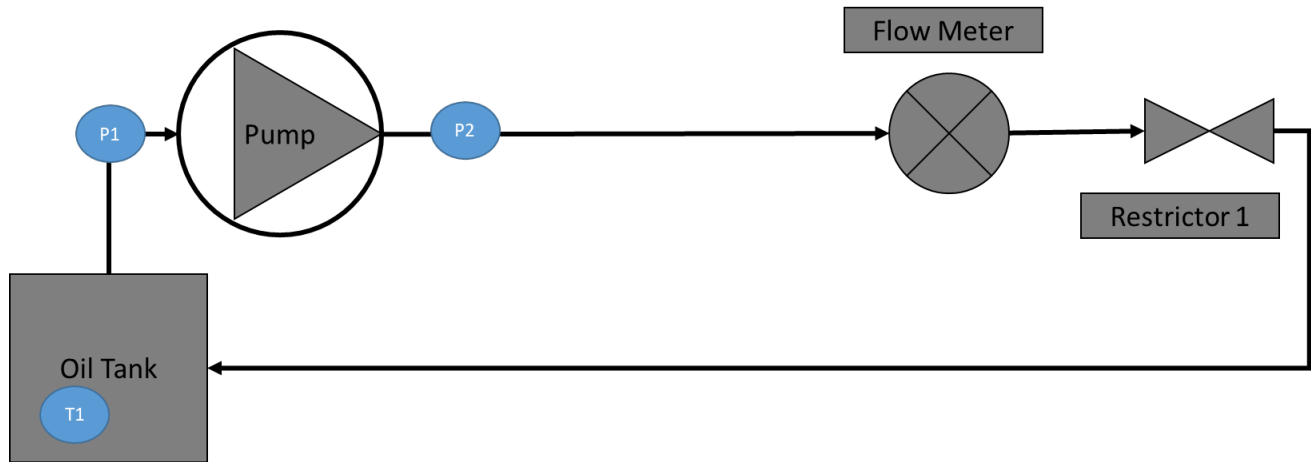


Figure 5 - Example hydraulic schematic for HSFL test

- 3.3.2.1 The oil pump mounting should represent the engine mounting conditions and drive system and be agreed upon with the test requestor.
- 3.3.2.2 If desired, the flow meter can be placed before the restrictor or after at the discretion of the test lab.
- 3.3.2.3 The suction side of the oil pump should use a representative suction pipe if possible. If this is not possible on the test stand, the suction pipe design must be approved by the requestor.
- 3.3.2.4 Height of pump above oil level and sump size should be defined and approved by requestor.
- 3.3.2.5 Pressure drop of the stand in the unrestricted state should be noted. The target for a typical stand is <150 kPa at 100 LPM, 100 °C with 0W-20 oil.
- 3.3.2.6 Restrictors

The stand restriction should be as open as possible to achieve the lowest back pressure for this test. No restrictors are needed, and any that cannot be removed should be as open as possible.

3.3.3 Procedure

- 3.3.3.1 Before starting the stand, turn on the data recorder to record initial values of transducers. Save this data set as the stand tare data set for the start of test. At the end of the data collection, repeat this tare procedure to ensure sensors have not drifted during the course of the test. Bring the oil to 90 °C (desired temperature). Once the oil has reached the desired temperature, start spinning the pump at the lowest rpm provided in the inputs to prime the pump. Ensure the proper restrictions are set.
- 3.3.3.2 Set the rpm to the minimum value.

- 3.3.3.3 Turn on the data recorder at 10 Hz for the selected channels. Ramp the rpm from the 500 rpm (minimum) to the 6000 rpm (maximum) in a continuous manner over 30 seconds (or longer), then decrease the rpm from 6000 rpm (maximum) to 500 rpm (minimum) in a continuous manner over 30 seconds (or longer). Test stand equipment may change the optimum rate at which the rpm is increased and decreased in order to generate the best quality data. It is important that the data is smooth for the duration of the test and that the ramp rate has minimal impact on the pressure. Please review with requestor to verify the data meets the requestor's needs.
- 3.3.3.4 If aeration is requested, re-run step 3.3.3.3 at the desired aeration level. Review aeration generation method and measurement method with requestor.
- 3.3.3.5 If multiple temperatures are requested, go to the next temperature set point and repeat steps 3.3.3.3 through 3.3.3.4.
- 3.3.3.6 If requested, repeat the entire test procedure again with the pump at each selected displacement. One hundred percent displacement is required; lower displacements are optional at the discretion of the requestor. Typical displacements will be 100%, 75%, 50%, and 25%. The pump must be physically locked at each displacement.

3.3.3.7 Default Test Conditions Table

Verify these with the requestor:

Temperature (°C)	Aeration	rpm Range	Displacement (%)
20, 100, 140	On/Off	500 - 7000 - 500	100%, 75%, 50%, 25%

3.3.4 Minimum Required Recorded Data Channels

P1, P2, T1, flow, torque, rpm, time.

3.3.5 Default Graphs and Output Formats

Plot flow versus rpm, pressure versus rpm, torque versus rpm.

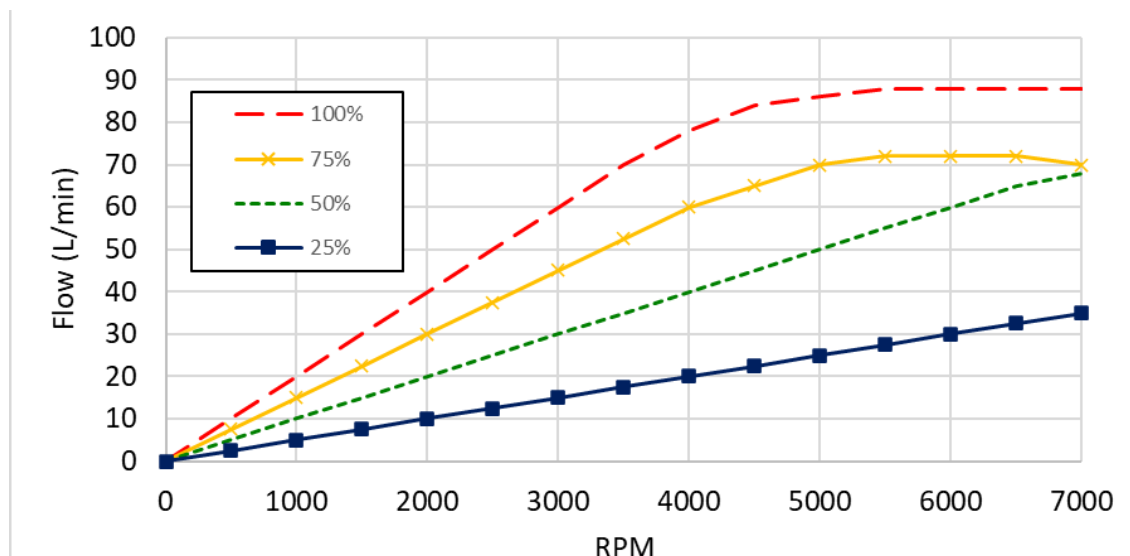


Figure 6 - Example flow versus speed plot