TECHNICAL BULLETIN

PROGRESSING CAVITY PUMPS | LS-TB-020

LIFTING SOLUTIONS

BULLETIN	TOPIC	ISSUE DATE	ISSUED BY
LSI-TB-020	**PC PUMP TESTING OVERVIEW**	**DECEMBER 22 2020**	**ENGINEERING**

BACKGROUND

Performance tests are done on Progressing Cavity (PC) pumps to quantify their hydraulic performance as part of the pump sizing process where a rotor/stator combination is matched for a specific application. Lifting Solutions (LS) Pump Sizing Methodology is described in Technical Bulleting LSI-TB-019. Pumps tests are also commonly done after pumps are pulled to compare to the original pump test and support the decision on whether to reuse.

PC pump testing has evolved significantly over the years in terms of equipment, process and reporting and as a result while there are many similarities, there are also differences between pump providers and even sometimes within a given provider due to differences in test equipment. The International Standard for PC Pump Systems ISO 15136-1 includes in Annex C.3 specifications for a Functional Hydraulic Test (F1) and associated reporting. LS uses this standard as a framework for its testing process and one of several different Test Report formats available complies with this standard.

This Technical Bulletin provides an overview of LS pump testing processes including critical test parameters as well as its results evaluation and reporting. It also describes how the LS test process compares to the ISO 15136-1 Annex C.3 requirements. Detailed work/operational instructions exist for the various LS Pump Test Equipment configurations, but they are all based off the LS Manufacturing Pump Testing Work Instructions MF-WI-CDA-PCP-021.

TEST PARAMETERS

Test parameters can be separated into those controlled to a constant value within a given test, those manipulated to multiple values during a test and those that respond and characterize the pump performance. These three categories and their specific parameters are described below in terms of their relevance, method of control/adjustment and measurement processes in the context of LS Pump Testing.

Controlled Variables

Fluid Composition: Water is the standard test fluid used at LS due to it being readily available and any leakage outside the test set-up being easy to clean-up. It can become slightly contaminated at the manufacturing facility due to the lubricating oil put on the rotor and at the operational bases due to produced fluids that remain after cleaning but is minimized through filters and absorbent pads. Periodically, depending on use and contamination, the fluid tanks are flushed and the water replaced. Water does not result in any elastomer swell or change to mechanical properties during the short test exposure period and because it evaporates under ambient conditions the water does not have any impact on the elastomer during pump storage. Because of its low viscosity it represents the worst-case scenario in terms of fluid slippage and volumetric efficiency relatives to oils that depending on their composition can have a variety of viscosities. Minimal changes in water viscosity with temperature also eliminates the impact of the viscosity variable when comparing test results at different temperatures. ISO 15136-1 Annex C.3 allows for water, oil or a mixture of the two provided the test fluid is benign to the pump during testing and storage.

Fluid Temperature: The fluid temperature is a critical controlled test parameter because it warms up the stator elastomer resulting in thermal expansion and at higher temperatures elastomer softening. The thermal expansion reduces the internal stator dimensions and tightens the rotor/stator fit resulting in increases in pump flow rate and associated volumetric efficiency that may be partially counteracted by elastomer softening. However, the warming of the stator is a slow process and in a standard pump testing scenario thermal equalization never fully occurs due to heat losses from the stator exterior that is exposed to ambient temperature. Accordingly, the standard test temperature used at LS is 30°C which given its proximity to ambient minimizes changes to the stator elastomer. For applications where the downhole temperatures are elevated the fluid temperature may be increased to provide a more representative test and in the case of loose pump sizing ensure the pump can move fluid against a differential pressure. Common elevated fluid temperature set-points are 40, 50 and 60°C and while higher values can be used, they are uncommon due to limited applications at those values and the complexities introduced in the pump testing process. Fluid temperatures are increased by tank heaters and when t need to be reduced by adding cold water. LS continually measures fluid temperatures within the tank and tests must start at a temperature within +-2°C of the set-point and not deviate beyond +-5°C of the set point during the test. Fluid temperature at the start and end of the test is recorded on the pump test report and when testing at elevated temperatures the stator tube external temperature is also measured at the intake and discharge ends of the pump at the start and end of testing and recorded on the pump test report. ISO 1516-1 Annex C.3 recommends fluid temperatures of 30, 40, 50 60 and 90°C and specifies a measurement accuracy of +-5% and a maximum allowable variation within a given test of less than +-5°C. ISO also requires that the fluid temperature be recorded on the pump test report along with the stator tube external temperature at the center of the pump at the start and end of the test.

Pump Speed: Pump speed is a critical controlled test parameter in that it determines the time for fluid slippage within the pump with higher speeds having lower slippage and higher flow rates and associated volumetric efficiency. The relationship between speed and flow rate/volumetric efficiency is highly predictable enabling pump curves to be estimated at other speeds based on a single test speed. LS uses 150 and 300 RPM as its standard test speeds with the selection being a function of the application and its typical speed range. Speeds are adjusted using a variable frequency drive which also continually measures and controls the speed with a high degree of precision. ISO 15136-1 Annex C recommends test speeds of 100, 150, 200, 250, 300 and 500 RPM and requires a measurement accuracy of +-3% and allowable variation of +-2% within a given test.

Pump Intake Pressure: Maintaining the pump intake pressure at an appropriate value and minimizing variability is important to ensure representative and repeatable pump tests. LS uses a charge pump to ensure the intake has sufficient fluid combined with a bypass valve to regulate the pressure to the targeted set-point of 20 psi +-10 psi. ISO 15136-1 Annex C requires that the intake pressure be monitored and variability within a given test is limited to +-10 psi.

Manipulated Variables

Pump Discharge Pressure: In a PC pump test the manipulated parameter is the discharge pressure which combined with a low controlled intake pressure determines the pump differential pressure. The pump rated pressure is the most important test pressure as it is normally the pump sizing target reference point. LS tests the pump at a minimum of five pressures including zero and rated pressure with the other points approximately evenly spaced between those two extremes. The exception is when the sizing target is 0% efficiency at a pressure below the pump pressure rating in which case the maximum pressure is determined in a deadhead pressure test. LS adjusts the discharge pressure using a manual control valve with values monitored with a pressure gauge or transducer. ISO 15136-1 Annex C recommends a minimum of five pressure points including a no-load condition not exceeding 50 psi and the rated pump pressure with pressure measurements having an accuracy of +-5%.

Responding Variables

Flow Rate: The primary result of interest in a PC pump test is the flow rate at the discrete operating pressure conditions. LS measures flow rates either directly using inline flow meters or indirectly through the measurement of fluid weight over a time increment which then is transformed into a fluid rate based on the specific gravity of the water. When flow meters are used there are several sizes that are selected depending on the flow rate to ensure measurement accuracy of +-5%. ISO 15136-1 Annex C does not mandate any specific type of flow rate measurement but requires that the accuracy be +-5% of the measured values.

Torque: The other critical pump test result is the torque at the operating pressure conditions. LS obtains the torque value directly from the variable speed drive which is calibrated to adjust for the belt and sheave reduction ratio. Torque accuracy is +-5% of the measured torque values. Torque is measured and displayed continuously with representative values being taken at the stabilized pressure conditions. ISO 16-136-1 Annex C does not mandate any specific method of measuring torque but requires that the accuracy be +-5% of the measured values.

TESTING PROCESS AND DATA COLLECTION

The test process begins with the installation of the rotor on the drive shaft of the test bench after which lubricating oil is lightly applied to the rotor surface. The rotor is then rotated into the stator and its discharge end attached to the flow tee at the drive end of the bench and its intake end attached to the fluid feed hose. In the case of pumps with a tight rotor/stator fit or aggressive geometry, water may be run through the stator prior to rotating the rotor into it.

The pump is then started with zero discharge pressure and the speed ramped up to the test speed. The pump is left operating at no load for five to ten minutes to warm-up. During this period, the target fluid temperature is confirmed and if required adjustments made. While the pump is warming up the pump serial number information along with the test speed are recorded on the physical or digital pump test sheet. After the warm-up period the control valve is slowly closed to adjust the discharge pressure normally to the pump rated pressure. If required adjustments to the intake bypass valve are made to maintain the target intake pressure. At this point the starting fluid temperature and intake pressure are recorded on the data sheet along with the stator external temperature in the case of elevated temperature tests. The pump is operated at rated pressure for several minutes (typically less than 2 minutes) until the flow rate and torque values stabilize after which the stabilized values are recorded onto the pump test sheet. The exception to this procedure is when the pump sizing target is 0% efficiency at a pressure less than rated in which case a deadhead pressure test is completed. In this deadhead scenario the maximum discharge pressure at zero flow is recorded five minutes after the control valve is choked off. Subsequently, in either the standard or deadhead test process, the control valve is opened to decrease the pressure to the next lowest target pressure on the test sheet. Once reaching the next target pressure the pump and associated measurements are allowed to stabilize for approximately thirty seconds after which the flow rate and torque values are recorded. The process is repeated working downward in pressure until the final no load/pressure condition (maximum 50 psi). At the conclusion of testing the final fluid temperature and intake pressure are recorded along with the stator external temperature for elevated temperature tests.

After completion of the pump testing and collection of all required data, the pump speed is slowly reduced and the test bench powered off. The pump test data is then processed as described in the following section to ensure there were no problems with the testing. Once the pump test is confirmed, the stator is removed from the test bench and the water drained by tilting it on an incline. Subsequently the rotor is wiped clean and dry and removed from the test bench.

RESULTS PROCESSING AND REPORTING

LS processes the pump test data in a consistent manner although basic and advanced pump test reports with different levels of detail can be generated in either metric, imperial or mixed units. The initial processing is the determination of the differential pressures by subtracting from the measured discharge pressures the average of the starting and ending intake pressure. Pump torques values are obtained from the measured torque values by subtracting the test bench system friction torque which has been determined for each bench and periodically remeasured and adjusted. The actual pump capacity is determined based on the flow rate at no load and the test speed. This actual capacity can vary slightly from the nominal capacity depending on the pump fit and fluid temperature with tighter fits and higher efficiencies resulting in lower values due to reductions in the cavities. At each differential pressure, the nominal volumetric efficiency is determined based on the measured flow rates, nominal pump capacity and pump speed. Similarly, actual volumetric efficiencies are determined in the same manner but using the calculated actual pump capacity. Pump hydraulic torques are calculated at each differential pressure based on the actual pump capacity and the differential pressure. Pump friction torques are calculated at each differential pressure by subtracting the hydraulic torque from the measured torque. Lastly mechanical pump efficiencies are calculated at each differential pressure as the ratio of the fluid power calculated based on the differential pressure and flow rates to the mechanical input power calculated based on the pump speed and measured pump torque. These parameters and associated calculations are all in compliance with the ISO 15136 Annex C data processing and reporting requirements.

The basic pump test report, an example of which is included in Figure 1, contains the tabular differential pressure, flow rate, nominal volumetric efficiency and pump torque data. It also contains a chart of nominal volumetric efficiency and pump torque as a function of differential pressure.

The advanced pump test report complies with ISO 15136 Annex C requirements by adding to the basic test report the actual pump capacity as well as in the table the hydraulic torque, friction torque and actual volumetric efficiency. The chart displays both nominal and actual volumetric efficiency, pump torque and the friction torque as a percentage of hydraulic torque all as a function of differential pressure.

In the case of a test of a new pump the data and charts are reviewed while the pump is still on the bench to ensure it meets the pump sizing targets as well as conforms with expected pump hydraulic performance. Normally the pump sizing targets are a nominal volumetric efficiency range at the pump rated pressure at a specified fluid temperature and pump speed. In the cases of loosely fit pumps to accommodate fluid swell or elevated temperature the target may be 0% efficiency at a specified pressure/lift lower than rated pressure. Given the sensitivity of fluid rate and associated volumetric efficiency to small changes in product dimensions or even test conditions, the target range is at a minimum 10% and ideally 20% within the lower efficiency range (<40%). Other considerations in reviewing the pump test include confirming that the actual capacity is within +-5% of the nominal capacity with the exception being pump tests at temperatures of 60°C or higher where the actual capacity may be more than 5% lower than nominal. The pump friction is also reviewed by looking at the torque at zero pressure or via the advanced report the percentage friction in the chart which should be relatively consistent across the test pressure range. The percentage friction torque varies by pump model and pump sizing, LS has guidelines for acceptance that are based on the initial model development process and historical pump testing. Lastly the profiles of the volumetric efficiency curves are examined to ensure they follow the characteristic shape. Deviations in shape are usually related to data entry errors in the test process in which case the test is rerun and data recollected while the pump is still to the bench.

For used pump tests there is more opportunity for variations in the performance results and the pump curves themselves. Normally used pumps are tested under the same fluid temperature and speed conditions as was done originally and the results compared to assess changes in characteristics. In the case of worn pumps, the rotor/stator fit will be looser and volumetric efficiencies will be lower with similar or slight lower torques. Pumps with elastomer swell will have tighter rotor/stator fits consequently higher efficiencies and usually slightly to significantly higher torques due to increased friction. In extreme cases of swell the actual pump capacity will be meaningfully reduced resulting in the nominal volumetric efficiency being well below 100% but relatively constant across the differential pressure range (i.e., flat line efficiency curve). Lower efficiencies can also occur due to pump damage that compromises the pressure capability of certain sections. Likewise, in addition to swell there are other modes of damage in a pump that can result in increases in torque. Accordingly, used pump tests should be interpreted in conjunction with the pump inspection to make a final determination of its condition and suitability for reuse.

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Progressing Cavity Pump Test Report

Pump Information	
Serial #	LSI 028-1200-HN1-S202898-R12828-L-300
Model	28
Rated Lift	1200 m
Rated Pressure	psi

Stator Information	
Serial #	S202898
Elastomer Type	HN1
Elastomer Length	171.0in (4343mm)
Intake Area	1.71in^2 (43.43mm^2)
Condition	New

Rotor Information	
Serial #	R12828
Rotor Length Code	L
Average Minor	1.531in (38.89mm)
Average Major	2.090in (53.09mm)
Condition	New

Test Information	
Pump Test ID	PTR-MED-00094
Tested	2020-01-14 by DDeng
Test Bench	MFG001
Test Temperature	30 °C
Test Speed	300

Lifting Solutions Information	
Entered	2020-01-21 by ASharma
Office Number	3067737714
Location	Medicine Hat

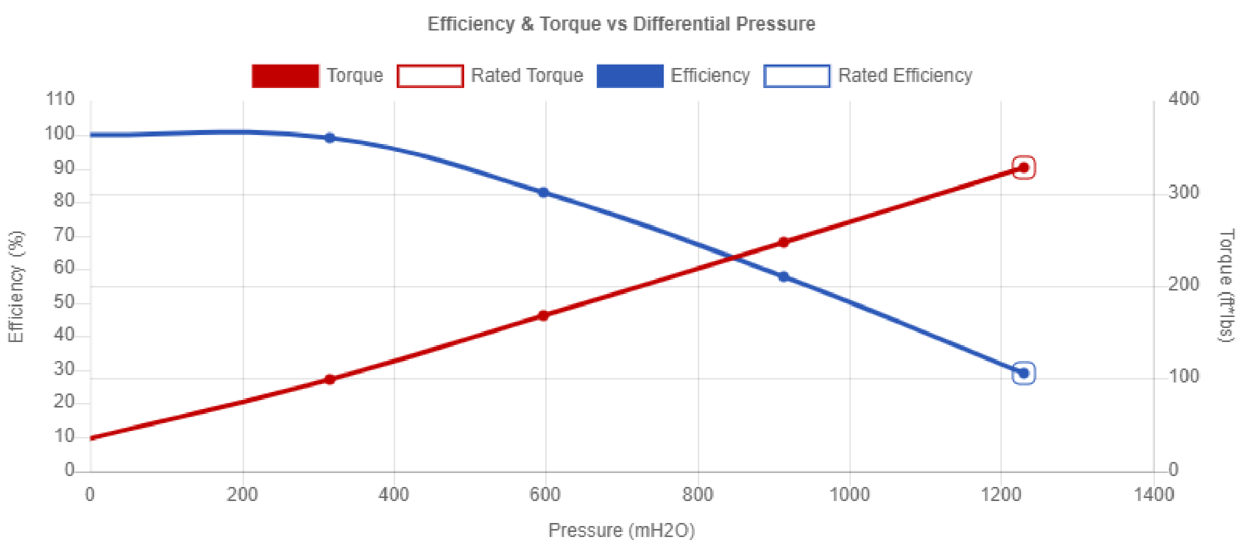
Installation Information	
Date	2020-06-27
Delivery #	SV008399
Customer	Canadian Natural Resources
Location	102/10-34-014-10W4/00

Pump Characteristics @ Rated Discharge Pressure

Pressure (mH2O)	Flow Rate (m^3/day)	Rated Efficiency (%)	Rated Torque (ft*lbs)
1230	23.9	29	328

Test Results:

Pressure (mH2O)	Flow Rate (m^3/day)	Test Efficiency (%)	Test Torque (ft*lbs)
0	83.8	100	35
316.4	83	99	98
597.6	69.9	83	168
914	49	58	247
1230.4	23.9	29	328



Comments:

Figure 1: LS PC Pump Basic Test Report (metric units)

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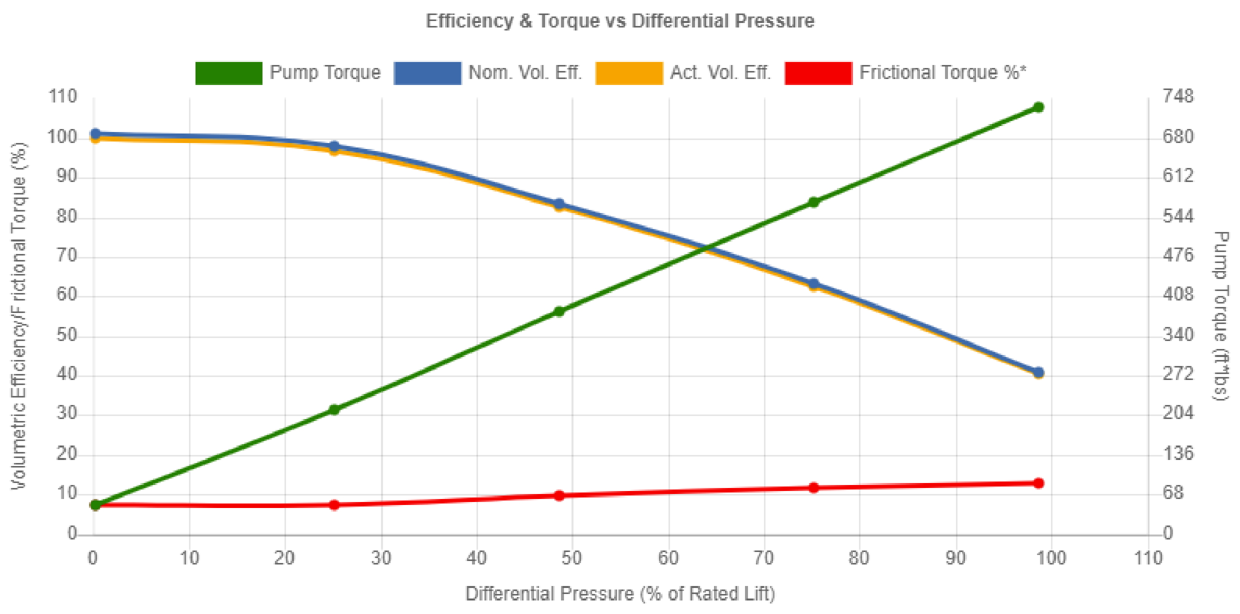
PC Pump Test Report

LSI 68-1200-HN1-S202942-R12872-L-300rpm & 86°F Test Report

Nominal Capacity (m³/d/100rpm)[1]	68	Rated Lift (m)	1200	Target Lift (%)	100	Elastomer	HN1

Test Information					
Rotor Serial Number	R12872	Rotor Major (in)	2.083	Test Speed (rpm)	300
Stator Serial Number	S202942	Rotor Minor (in)	1.534	Fluid Temp °F	86
Tested by	EGonkang	Test Date	2020-01-27	Actual Capacity (m³/d/100rpm)[2]	68.8

Differential Pressure	Differential Pressure	Pump Torque	Hydraulic Torque	Frictional Torque	Flow Rate	Nom. Vol. Eff.[3]	Act. Vol. Eff.[4]
psi	%	ft*lbs	ft*lbs	ft*lbs	m³/D	%	%
3	0	50	1	49	206	101	100
428	25	213	166	48	200	98	97
828	49	383	320	63	170	83	82
1278	75	570	494	76	129	63	63
1678	99	733	649	84	83	41	40



[1]Nominal Capacity is the "published" volumetric capability of this "pump model" when operating at 100rpm at no load (i.e. 0 differential pressure).
[2]Actual Capacity is the volumetric capability of this "specific pump" normalized at 100rpm based on "measured" flow rate at no load.
[3]Nominal Volumetric Efficiency (Nom. Vol. Eff.) is based on the Nominal Capacity.
[4]Actual Volumetric Efficiency (Act. Vol. Eff.) is based on the Actual Capacity.
*Frictional Torque % is the ratio of the frictional torque at each test point and hydraulic torque at rated lift.

Figure 2: LS PC Pump Advanced Test Report (mixed units).

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