Attachment 11

CDM Apvd RELEASED 2017/10/12

30441R00045
Revision B

REACTOR-BASED MOLYBDENUM-99 SUPPLY SYSTEM PROJECT

TARGET COOLING SYSTEM FLOW TEST REPORT

Prepared by General Atomics
for the U.S. Department of Energy/National Nuclear Security Administration and Nordion Canada Inc.

Cooperative Agreement DE-NA0002773

[redacted]

GA Project 30441
WBS 1252

GENERAL ATOMICS

MURR® Matters...

nordion

REVISION HISTORY

Revision	Date	Description of Changes
A	11OCT17	Initial Release
B	12OCT17	Revised with updated figures and references

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DESIGN CONTROL SYSTEM DESCRIPTION

	DISC	QA LEVEL	SYS
☐ R & D ☒ DV&S ☐ DESIGN ☐ T&E ☐ NA	N	II	N/A

[redacted]

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ACRONYMS

Acronym	Description
GA	General Atomics
GPM	Gallons Per Minute
HX	Heat Exchanger
LOPF	Loss of Pump Flow
Mo-99	Molybdenum 99
MURR	Missouri University Research Reactor
P&ID	Piping and Instrumentation Diagram
PSI	Pounds per Square Inch
PSIA	Pounds per Square Inch Absolute
PSID	Pounds per Square Inch Differential
PSIG	Pounds per Square Inch Gauge
TA	Target Assembly
TCS	Target Cooling System
TCSTL	Target Cooling System Test Loop

1 PURPOSE AND SCOPE

As with all nuclear fission assemblies, cooling must be provided to remove heat generated from fission reactions. Validating the analysis of the target system cooling water flow behavior is vital to ensuring proper function of the cooling system when it is installed in the MURR pool. The specific purpose of these tests was to confirm the analysis of the flow and pressure drop through the target assembly (TA), to measure and validate the bypass flow through the cartridge, and to measure the pump coast-down time during a simulated loss of pump flow (LOPF) event. This report describes these tests in detail and provides the results.

2 APPLICABLE DOCUMENTS

A list of applicable documents is provided below.

DOCUMENT NUMBER	DOCUMENT TITLE
30441P00026	Target Cooling System Flow Test Procedure
30441R00017	ANSYS Target Cartridge, Housing Structural Analysis Design Calculation Report
30441R00019	Target System Cooling Calculation Report
30441R00032	RELAP Accident Analysis and FRAPTRAN Target Rod Transient Analysis Design Calculation Report
30441R00038	Computational Fluid Dynamics Analysis of Target Housing Design Calculation Report
QAPD-30441-II	Quality Assurance Program Document QAPD-30441-II Reactor-Based Molybdenum 99 Supply System (RB-MSS)

3 FULL SCALE SYSTEM FLOW TESTING

The main objective of the target cooling system (TCS) flow testing was to validate the pressure drop through a target assembly, simulate a loss of pump flow (LOPF) event, and measure the bypass flow through the labyrinth seal.

3.1 Description of Test Rig

The TCS tests were conducted at the General Atomics (GA) Torrey Pines campus in Building G35. The target cooling system test loop (TCSTL) duplicates as best as possible the piping system, location of target assembly at proper water depth, key flow instrumentation, and primary parameters to be implemented at MURR. Table 1 shows a parameter comparison between the TCSTL at GA and the reactor system at MURR.

Table 1: GA Test Pool and MURR Pool Comparison

Parameters	GA Test Pool	MURR Pool
Diameter	6 feet	10 feet
Depth	27.5 feet	30 feet
Target Assembly Water Depth	Same as MURR	25.8 feet
Number of Target Assemblies	1 TA and 1 bypass valve	2
Pipe Size	Same as MURR	3 inches
Pump	Same as MURR	Model: 3796 MTi Size: 3x3-13
Heat Exchanger	Pressure drop simulated via valve (HV-305)	HX is part of cooling skid
Water Chemistry	5.5 nominal pH Conductivity ~ 2 µS/cm	5.5 nominal pH Conductivity < 2 µS/cm

The target assembly water depth (25.8 feet) was measured from the top of the operating water level at MURR to the bottom of the TA. An underwater pressure transducer (PT-335 with ± 0.1% accuracy), was attached to the target inlet which is approximately three feet above the bottom of the TA.

The process flow is detailed in Figure 1 with the piping and instrumentation diagram (P&ID). Figures 2 and 3 show the TCSTL setup. It is important to note that the suction line in the TCSTL has the same overall size and liquid volume as the layout at MURR required to ensure proper pump priming. The supply line from the pump to the TA is slightly shorter in length compared to the MURR design and does not contain the main heat exchanger (HX). As a result, a valve (HV-305) was added to simulate the highest system pressure drop. The water pH and conductivity were tested weekly to ensure the water chemistry standards were maintained. Appendix A specifies the equipment and instrumentation used for testing.

The test equipment in the TCSTL consists of:

- One fiberglass surrogate pool
- One target assembly (consisting of a cartridge, diffuser, target housing, and 11 stainless steel surrogate target rods)
- One surrogate bypass valve (HV-200 shown in Figure 1)
- One self-priming pump (refer to Appendix B for pump specifications and performance test from pump manufacturer)
- Target cooling system piping (PVC), support structures and valves designed to mimic the setup at MURR.

[redacted]

- Instrumentation (including flow meters, pressure gauges, and an underwater pressure transducer).
- Transparent graduated standpipe.

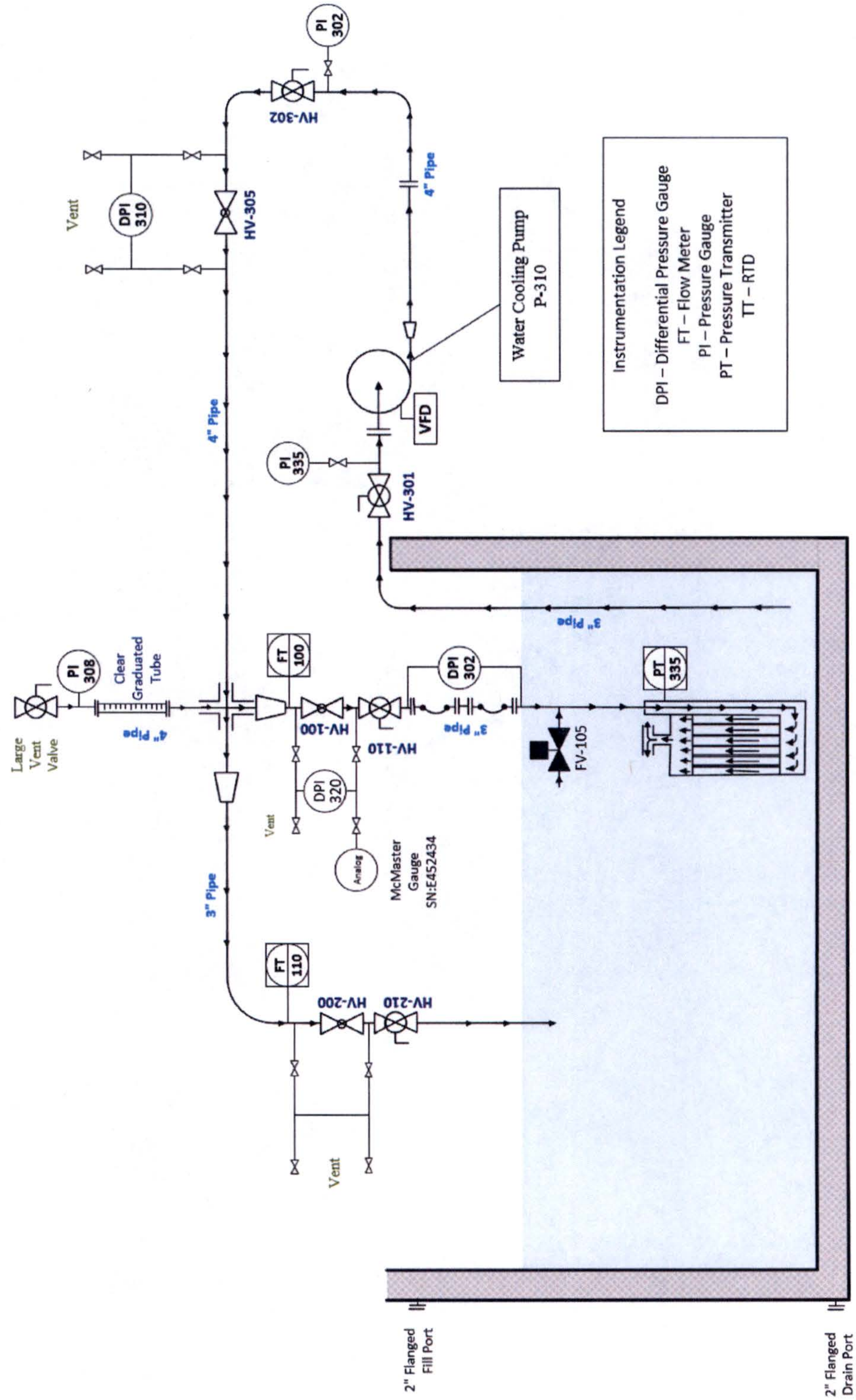


Figure 1 – Target Cooling System Test Loop P&ID

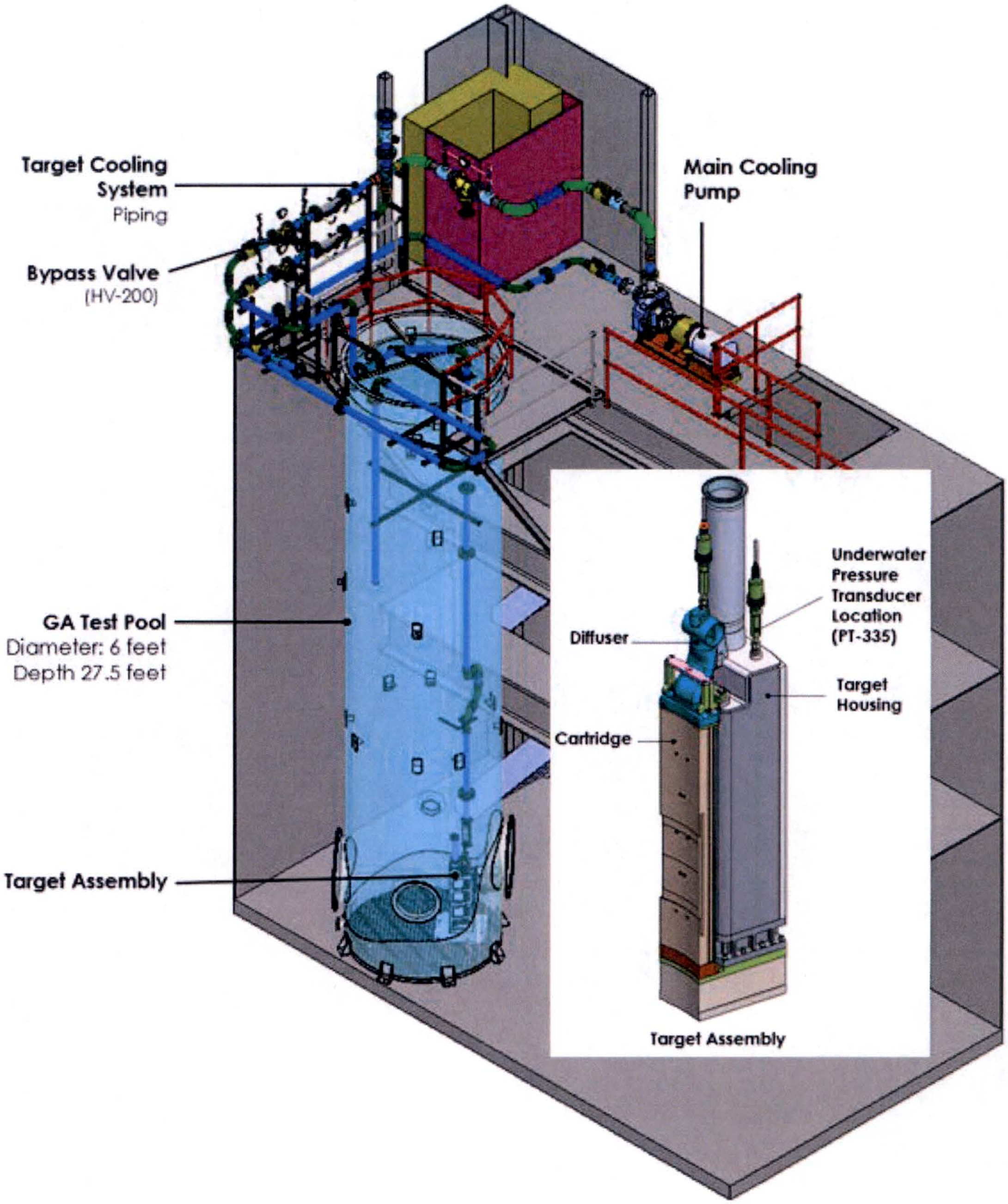


Figure 2 – 3D Model of the Target Cooling System Test Loop Design

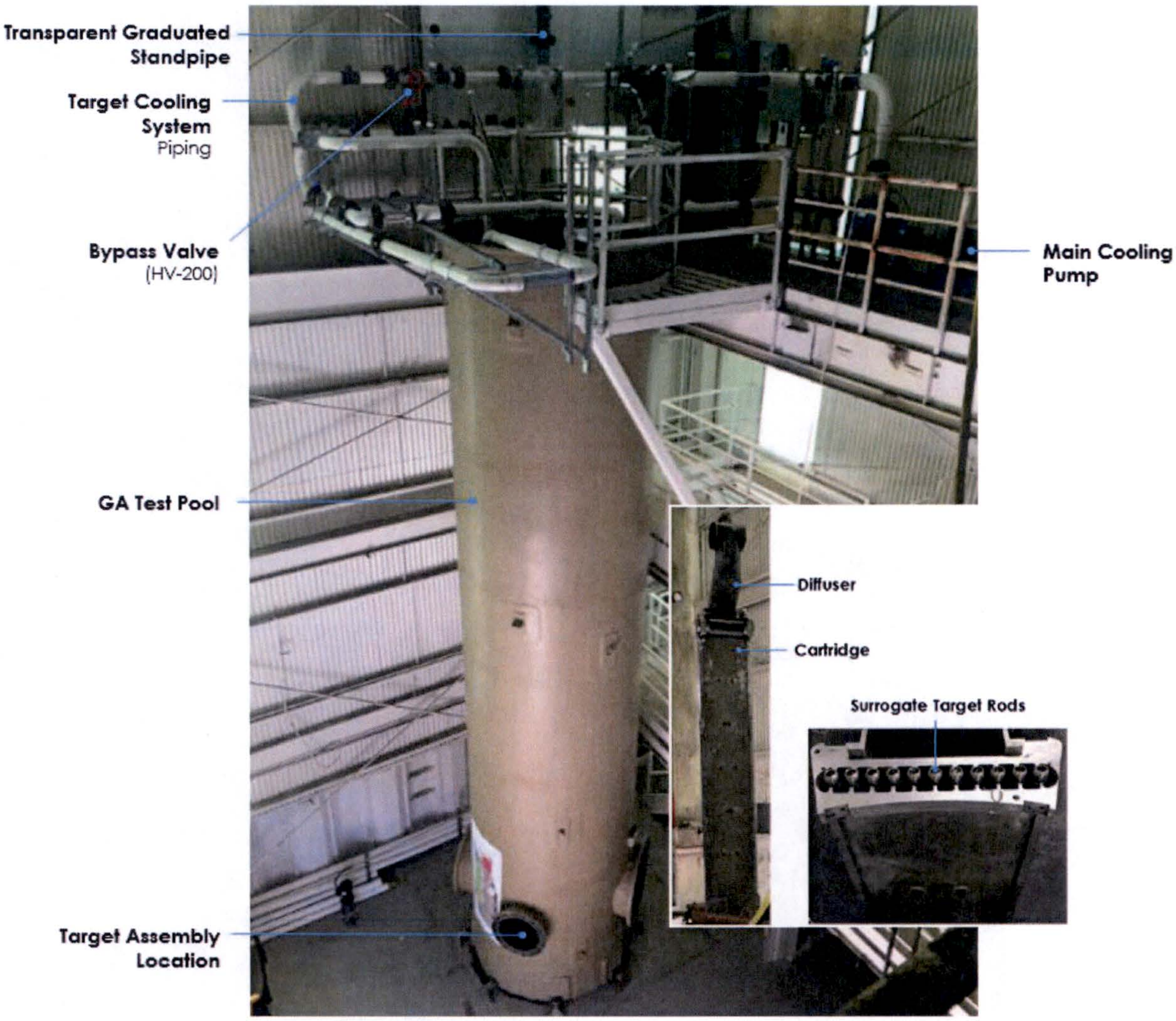


Figure 3 – GA Target Cooling System Test Loop Setup

3.2 Test Procedures

3.2.1 Target Assembly Pressure Drop Test

The objective of this test was to verify the pressure drop from the target inlet through the diffuser outlet as a function of flow rate. Test flows values were set to 85%, 100% and 115% of the nominal target assembly flow rate (107 GPM at 100%), which is the calculated nominal flow rate from analysis document 30441R00021. This flow rate was measured to within the ±0.5% accuracy of the flowmeter used for the tests. A gasket seal was placed on the TA upper and bottom cartridge flanges to ensure that accurate flow and pressure drop measurements were made by eliminating these as potential bypass paths. Figure 4 shows the upper and lower gasket seal locations. The diffuser outlet pressure was calculated by taking the measured absolute pressure reading from PT-335 and subtracting 14.7 psi (to convert the pressure from absolute to

[redacted]

gauge) and 9.9 psi (to account for the 22.8 feet of static water head above the transducer). The raw data from the pressure transducer were automatically recorded on a data logger and are summarized in Appendix C.

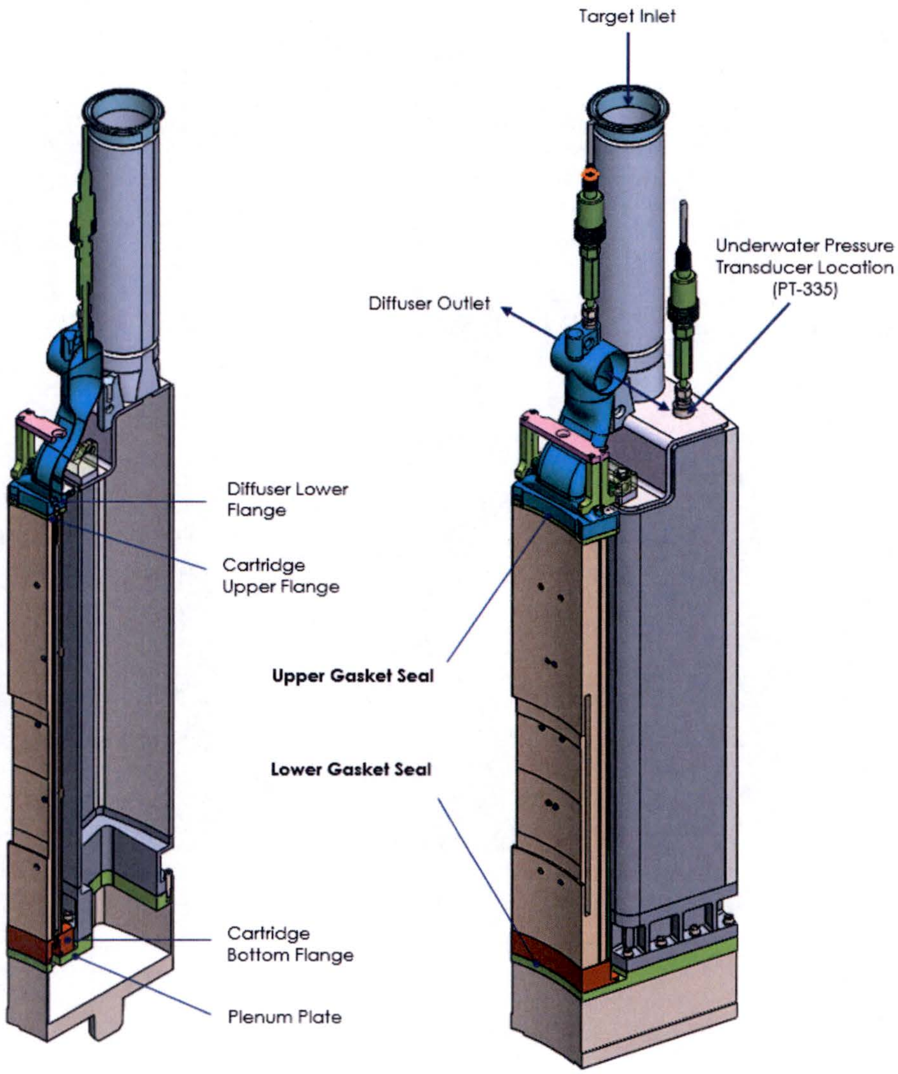


Figure 4 – Gasket Seal Location

<u>Procedure</u>:

1. Install the target assembly into the pool.
2. Check to see that the cartridge is secured in the housing and that the locking mechanism is engaged.
3. Check the fill level of the surrogate pool to the normal MURR operating pool level (water height = 25.8 feet).

4. Open system valves and control frequency of pump to 85% flow through the system.
5. Turn on pump.
6. Record start and stop times to calculate duration. Manually record system pressures, pressure drops, and temperature data from the instrumentation gauges every 5 mins. Pressure to the target assembly will be recorded electronically at 1 sec intervals. Run flow test for 15 min.
7. Turn off pump.
8. Control frequency of pump to increase the flow rate to 100% flow through the system.
9. Turn on pump.
10. Record start and stop times to calculate duration. Manually record system pressures, pressure drops, and temperature data from the instrumentation gauges every 5 mins. Pressure to the target assembly will be recorded electronically at 1 sec intervals. Run flow test for 15 min.
11. Turn off pump.
12. Control frequency of pump to increase the flow rate to 115% flow through the system.
13. Turn on pump.
14. Record start and stop times to calculate duration. Manually record system pressures, pressure drops, and temperature data from the instrumentation gauges every 5 mins. Pressure to the target assembly will be recorded electronically at 1 sec intervals. Run flow test for 15 min.
15. Turn off pump.
16. Secure all equipment.

3.2.2 Pump Coast-down Test

The objective of this test was to record the flow rate entering a target assembly as a function of time during a simulated loss of pump flow (LOPF) event at room temperature with the decay heat removal valves in the closed position. Valve HV-320 was adjusted in order to test for the worst case system pressure drop by analysis in document 30441R00019. This system pressure drop analysis has 25% margin built into it for the 85% and 100% flow cases and 13% margin for the 115% flow case. The margin on the 115% case was limited by pump performance. Table 2 provides a summary of the flow and pressure drop parameters used for this test. The decay heat removal valve (FV-105), in the test rig remained closed during this test to ensure all the flow went through the target assembly.

<u>Procedure:</u>

1. Install the target assembly into the pool.

2. Check to see that the cartridge is secured in the housing and that the locking mechanism is engaged.
3. Check the fill level of the surrogate pool to the normal MURR operating pool level (water height 25.8 feet).
4. Open all system valves and control frequency of pump to 85% flow through the target assembly.
5. Turn on pump.
6. Open all bleed valves to release any trapped air. Once all the air is released, close the bleed valves.
7. Adjust valves HV-100 and HV-200 to have equal flow for each flow meter.
8. Adjust valve HV-305 and increase the frequency of the pump to obtain the expected ΔP (see Table 2) across PI-335 and PI-302.
9. Manually record system pressure data from the instrumentation gauges (PI-335, PI-302, and DPI-310).
10. Ensure data loggers are connected to the flow meters.
11. Turn off power to the pump.
12. Record flow rate manually at 1 sec intervals until the flow reaches 0 GPM. Flow rate will also be recorded electronically at 1 sec intervals.
13. Turn on pump.
14. Repeat steps 7-12 for the 100% and 115% flow cases shown in Table 2.

Table 2 - Test Cases

Test Case Description	Expected ΔP (psid)	Source
85% Flow with 25% Margin on ΔP	[redacted]	30441R00019
100% Flow with 25% Margin on ΔP	[redacted]	30441R00019
115% Flow with 13% Margin on ΔP	[redacted]	Pump limit

5a, d, e, f

3.2.3 Labyrinth Seal Bypass Test

The objective of this test was to measure the bypass flow between the cartridge bottom flange and the target housing lower plenum. The full scale test was performed with the locking mechanism torqued to 30 in-lbs (each bolt). The lower gasket seal (Figure 4) was removed and the outlet of the diffuser was blocked such that the water volume lost was through the labyrinth seal and the pins in the cartridge. The expected bypass through the cartridge pins is small (much less than 1 GPM), as the internal pressure should help "self-seal" the leak path (Figure 5). The leak through the pins and the leak through the labyrinth seal were measured as a single leak.

[redacted]

5a, d, e, f

Figure 5 – Bypass Flow Paths for Labyrinth Path and Cartridge Pins

<u>Procedure</u>:

1. Remove the cartridge from the pool.
2. Block the diffuser outlets to prevent water flow.
3. Remove the lower gasket seal on the cartridge bottom flange.
4. Insert cartridge back into the housing inside of the pool.
5. Check to see that the cartridge is secured in the housing and that the locking mechanism is engaged. Torque down cartridge locking mechanism to 30 in-lbs.
6. Check the fill level of the surrogate pool to the normal MURR operating pool level (water height = 25.8 feet).
7. Torque down cartridge locking mechanism to 30 in-lbs.
8. Turn on pump.
9. Fill the pipe going to the target assembly with water. The transparent graduated standpipe should be filled to approximately 42 inches of water (Figure 9).
10. Turn off pump and close valves HV-200 and HV-302.
11. Pressurize the pipe going to the target assembly with compressed air to the value obtained for the pressure drop through the target assembly for the 115% flow case, which is the highest pressure and flow conditions the cartridge will ever see.
12. Measure and record the water drop in the transparent standpipe as a function of time ensuring static pressure stays above the required value.

13. Let system run for 30 sec.
14. Secure all equipment.

4 TEST RESULTS

4.1 Target Assembly Pressure Drop Test

The design analysis of the pressure drop from the target inlet through the diffuser outlet detailed in document 30441R00038 has been validated by agreement to within 2% of the expected range of the extrapolated test data. The tests were run at slightly higher volumetric flow rates when compared to the values used in the analysis. The polynomial equation shown in Figure 6 was obtained from the test data in Appendix C – Raw Pressure Drop Data Summary. The polynomial equation was used to determine the pressure drop at 20°C for each corresponding flow rate. The results are shown in Table 3. All tests at GA were run with an inlet temperature to the target of 20°C. During normal operation at MURR however, the target inlet temperature will be 29°C with a TA average temperature of 34°C, which was the temperature used in the ANSYS-FLUENT analysis. To account for the temperature difference between the operating conditions at MURR and the test conditions at GA, the calculation detailed in Appendix D was applied to extrapolate the test values to a system with an average temperature of 34°C. Table 3 lists the test values at 20°C, and both the extrapolated test values and the analysis prediction values at a TA average temperature of 34°C. The test data extrapolation resulted in a less than 2% decrease in the pressure drop values when adjusting the temperature from 20°C to 34°C.

The flow values used in the analysis did not include the bypass effect and assumed all the flow would go through the cartridge to cool the target rods. For 100% flow (107 GPM) at 34°C average TA temperature, ANSYS-FLUENT predicted [redacted] psi and the extrapolated test value at 34°C average TA temperature yielded [redacted] psi. The difference between the two values is 1.5%. Figure 6 shows the pressure drop through the TA as a function of flow rate for both the analysis and test values. It also shows that the pressure drop values are within the design limit of [redacted] psi for the target housing, which has built in margin (refer to Table 2 in document 30441R00017 for more details). For reference, the test data sheets have been provided in Appendix E – Target Assembly Pressure Drop Test Data Sheets.

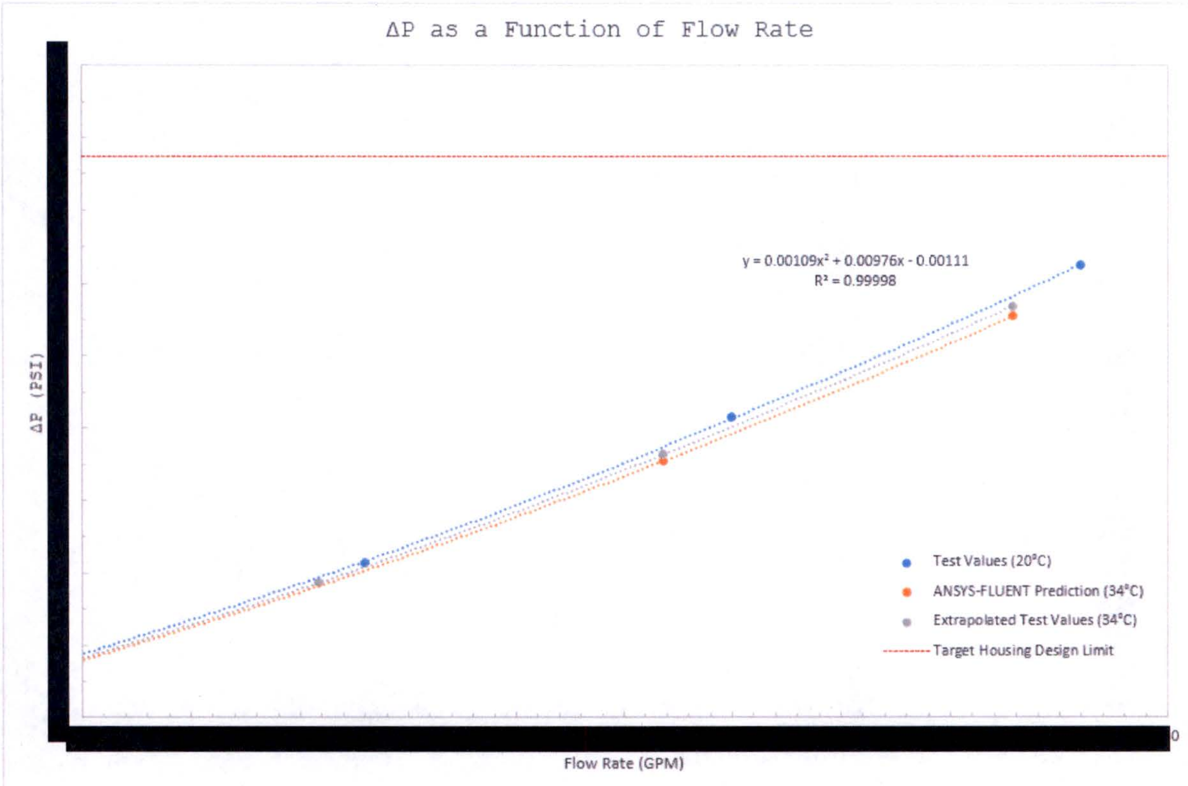
5a, d, e, f

Table 3 – Pressure Drop Data Summary

ΔP Source	ΔP at 91 GPM (psi)	ΔP at 107 GPM (psi)	ΔP 123 GPM (psi)
Test Values (20°C)	[redacted]	[redacted]	[redacted]
Test Values (Extrapolated to 34°C)	[redacted]	[redacted]	[redacted]
ANSYS-FLUENT Prediction (34°C)	[redacted]	[redacted]	[redacted]

5a, d, e, f

[redacted]



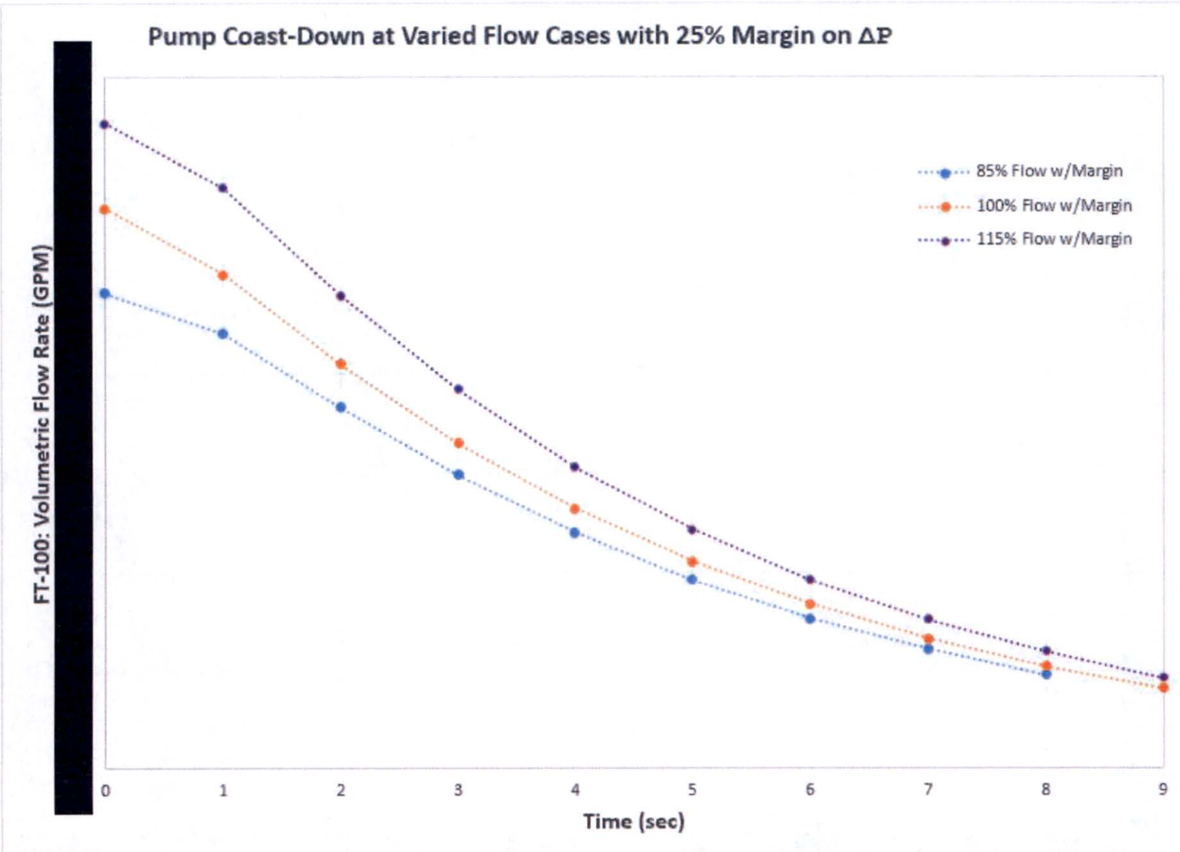
5a, d, e, f

Figure 6 - Target Assembly Pressure Drop Test Results

4.2 Pump Coast-down Test Results

A loss of pump flow (LOPF) event can be caused by loss of electrical power, pump failure, or system blockage. This test only covered the loss of electrical power event. The LOPF impacts both target assemblies and includes pump coast-down and fluid momentum to ease the transition from forced flow to natural circulation flow. Although the decay heat removal valves in the MURR system can be opened to improve the natural circulation cooling during LOPF, the butterfly valve (FV-105) remained closed during this test.

This test measured the amount of time it takes the pump to coast down to 15% flow when the pressure drop through the system is increased to the highest value by analysis which has 25% margin (see Table 2 for values). The pump coast-down times for three different flow cases are shown in Figure 7. It took approximately 9 seconds for the flow rate to decrease significantly from 100% flow (~112.8* GPM – see Table 4 for flow values with bypass flow included) to about 15% flow (16.2 GPM).



5a, d, e, f

Figure 7 – Pump Coast-down Results at Various Flows with 25% Margin on ΔP

4.3 Labyrinth Seal Bypass Test Results

A bench test was initially conducted to obtain the required torque value for the final system to produce an acceptable leak rate through the labyrinth seal. The results from the bench test demonstrated the labyrinth seal required a torque of 30 in-lbs to each bolt in the final system in order to operate below the maximum 5% total flow. An image of the bench test article can be seen in Figure 8. The torque value from the bench tests was then applied and used on the locking mechanism in the full scale test.

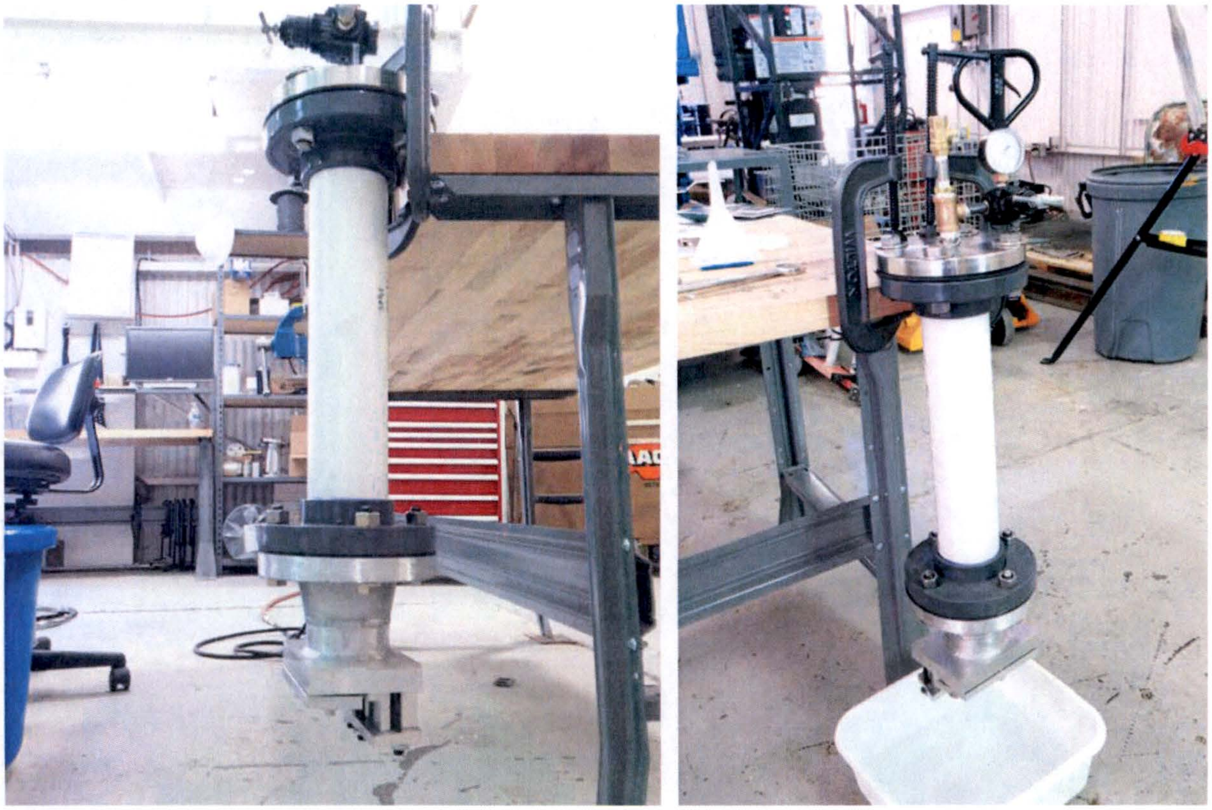


Figure 8 – Bench Bypass Test Article Setup

Figure 9 shows the setup for the full scale test. Similar to the bench test, a transparent standpipe was installed in the location shown in the P&ID. The standpipe is made from clear PVC to be able to measure the water that is going through labyrinth seal and the cartridge pins.

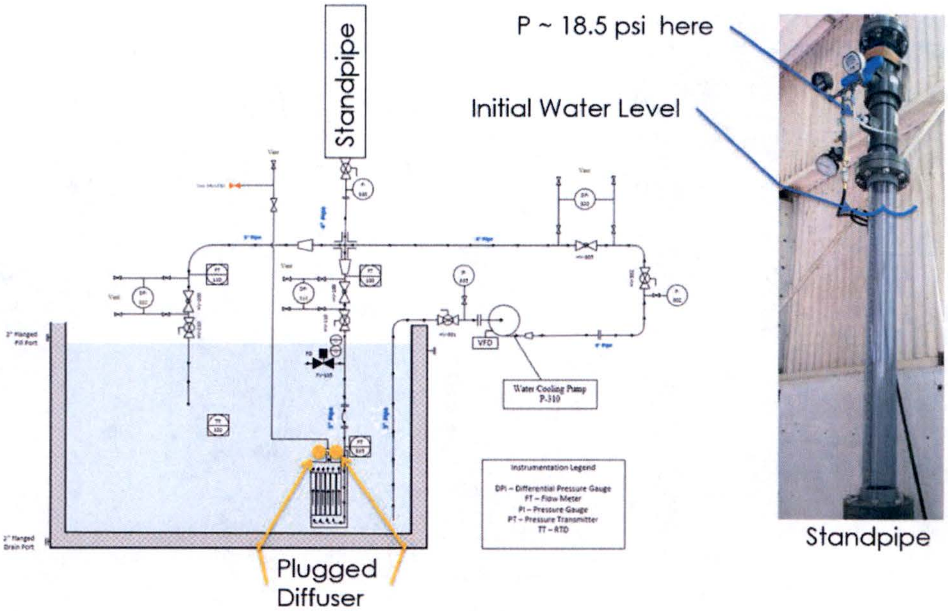


Figure 9 – Full Labyrinth Seal Bypass System Setup with Standpipe

The maximum allowed bypass for the three different flow cases and the pressure requirements for the labyrinth seal are summarized in Table 4. The tests were run at the worst case pressure condition which was derived from the 115% case shown in Table 4. The tests ensure that the pressure was always greater than 17.4 psi, for instance Run 1 was executed at 18.6 psi (Table 5). The cartridge was unlocked, lifted out of its seating position, re-seated and locked back down again to thirty in-lbs for each test to simulate and measure the consistency of the seal through several runs. Eleven cartridge lifting and re-seating operations were performed and results can be seen in Figure 10.

Table 4 - Bypass Test Loading Conditions and Requirements

Flow Case	Flow Rate (GPM)	5% Max Allowed Bypass (GPM)	Cartridge Pressure Report 30441R00017
85%	95.9*	4.8	[redacted]
100%	112.8*	5.6	[redacted]
115%	129.7*	6.5	[redacted]

5a, d, e, f

**Flow values include the 5% maximum bypass flow through the cartridge pins and labyrinth seal.*

Table 5 - Bypass Test Results

9/12/2017		9/14/2017			9/15/2017					9/17/17
Run 1 @ 18.6 psi back pressure	**Run 2 @ 18.8 psi back pressure**	**Run 3 @ 19.2 psi back pressure**	**Run 4 @ 19.0 psi back pressure**	**Run 5 @ 18.8 psi back pressure**	**Run 6 @ 19.0 psi back pressure**	**Run 7 @ 18.6 psi back pressure**	**Run 8 @ 18.9 psi back pressure**	**Run 9 @ 18.8 psi back pressure**	**Run 10 @ 18.7 psi back pressure**	**Run 11 @ 18.6 psi back pressure**
GPM	**GPM**	**GPM**	**GPM**	**GPM**	**GPM**	**GPM**	**GPM**	**GPM**	**GPM**	**GPM**
3.78	4.43	3.96	4.23	3.41	3.38	3.43	3.21	3.29	4.23	3.09

The tests confirm that the labyrinth path slows the amount of water bypassing the cartridge, satisfying the maximum design requirement of 5%. The allowed bypass at 115% flow case is 6.5 GPM and the highest bypass measured in the tests is less than 4.5 GPM, including the cartridge pins. The average of the eleven runs is 3.7 GPM providing margin to the design requirement.

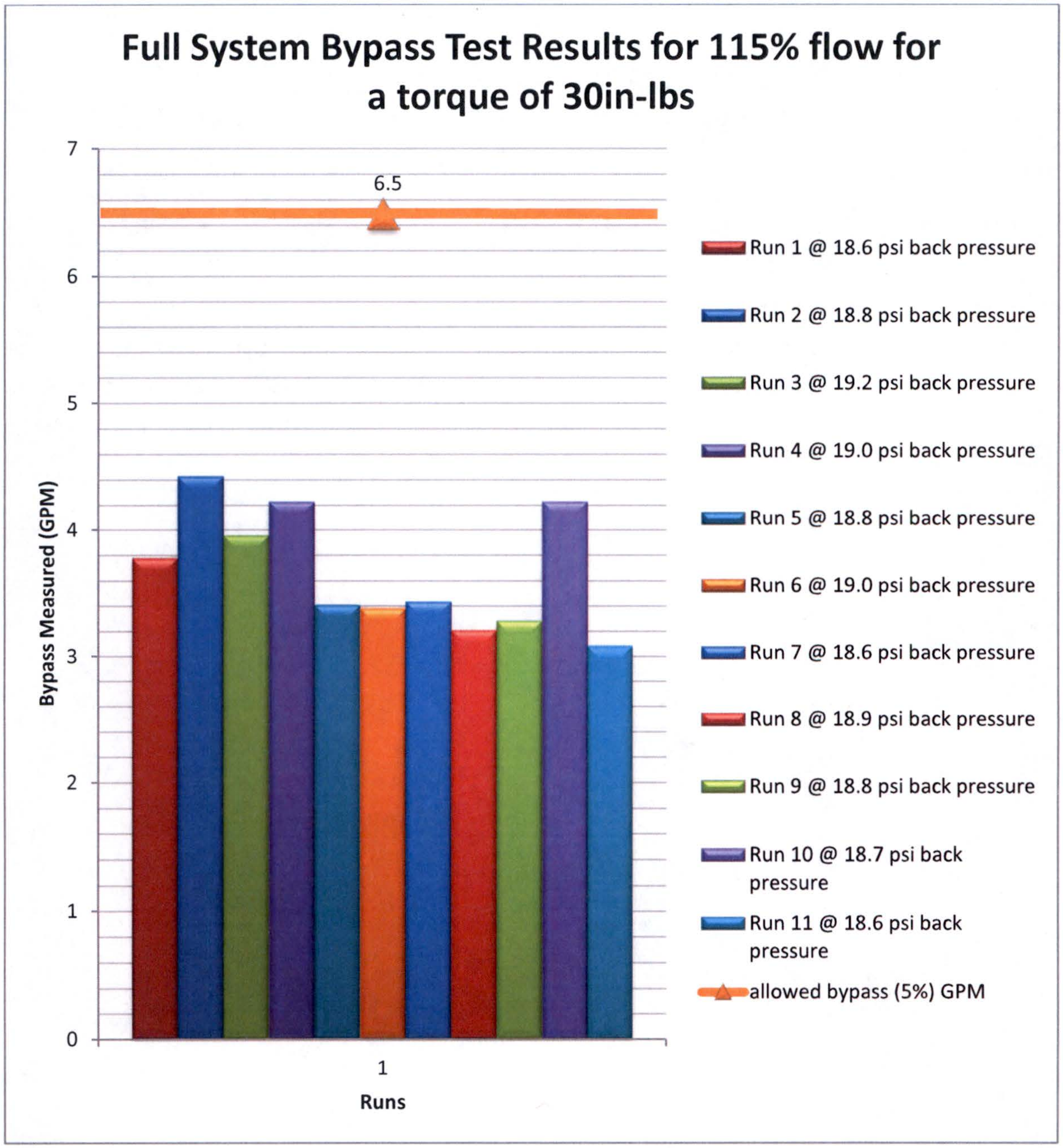


Figure 10 – Full System Bypass Test Results

APPENDIX A – Equipment and Instrumentation Used in Testing

Equipment / Instrument	Make / Model	Measuring Range
Pressure Gauge (PI-335)	OMEGA PN: DPG409-015CG	Pressure Range: ±15 psi Accuracy: ± 0.08%
Pressure Gauge (PI-302)	OMEGA PN: DPG1001B-60G	Pressure Range: 0 to 60 psi Accuracy: ± 0.10%
Pressure Gauge (PI-308)	OMEGA PN: DPG1001B-60G	Pressure Range: 0 to 60 psi Accuracy: ± 0.10%
Analog Pressure Gauge (E452434)	Ashcroft PN: 45 1082AS 02L XC4 30#	Pressure Range: 0 to 30 psi Accuracy: ± 0.25%
Differential Pressure Gauge (DPI-302)	OMEGA PN: DPG409-030DWU	Pressure Range: 0 to 30 psi Accuracy: ± 0.08%
Differential Pressure Gauge (DPI-310)	OMEGA PN: DPG409-030DWU	Pressure Range: 0 to 30 psi Accuracy: ± 0.08%
Differential Pressure Gauge (DPI-320)	OMEGA PN: DPG409-050DWU	Pressure Range: 0 to 50 psi Accuracy: ± 0.08%
Pressure Transmitter (PT-335), DL	Keller Preciseline PN: 0308.00301.051307.54	Pressure Range: 0 to 100 psi Accuracy: ± 0.1%
Flow Meter (FT-100), DL	McCrometer PN: VW03AE14AA	Flow Range: 100 GPM to 140 GPM Accuracy: ± 0.5%
Flow Meter (FT-110), DL	McCrometer PN: VW03AE14AA	Flow Range: 100 GPM to 140 GPM, Accuracy: ± 0.5%
Pump (P-310)	Goulds Pumps Model: 3796 MTi Pump Size: 3x3-13 Self-Priming Pump	Speed: 1770 RPM Flow: 250 GPM Head: 102 FT Efficiency: 48.0% Total Power: 13.5 HP NPSHr: 7.8 FT
VFD	Allen Bradley PowerFlex 525 AC Drive PN: 25B-D037N114	480 VAC, 3 Phase 25 HP, 18.5 kW Normal Duty 20 HP, 15 kW Heavy Duty

[redacted]

APPENDIX B – Goulds Pump Specification and Test Data

Model: 3796	Size: 3x3-13	Group: MTi	60Hz	RPM: 1770	Stages: 1

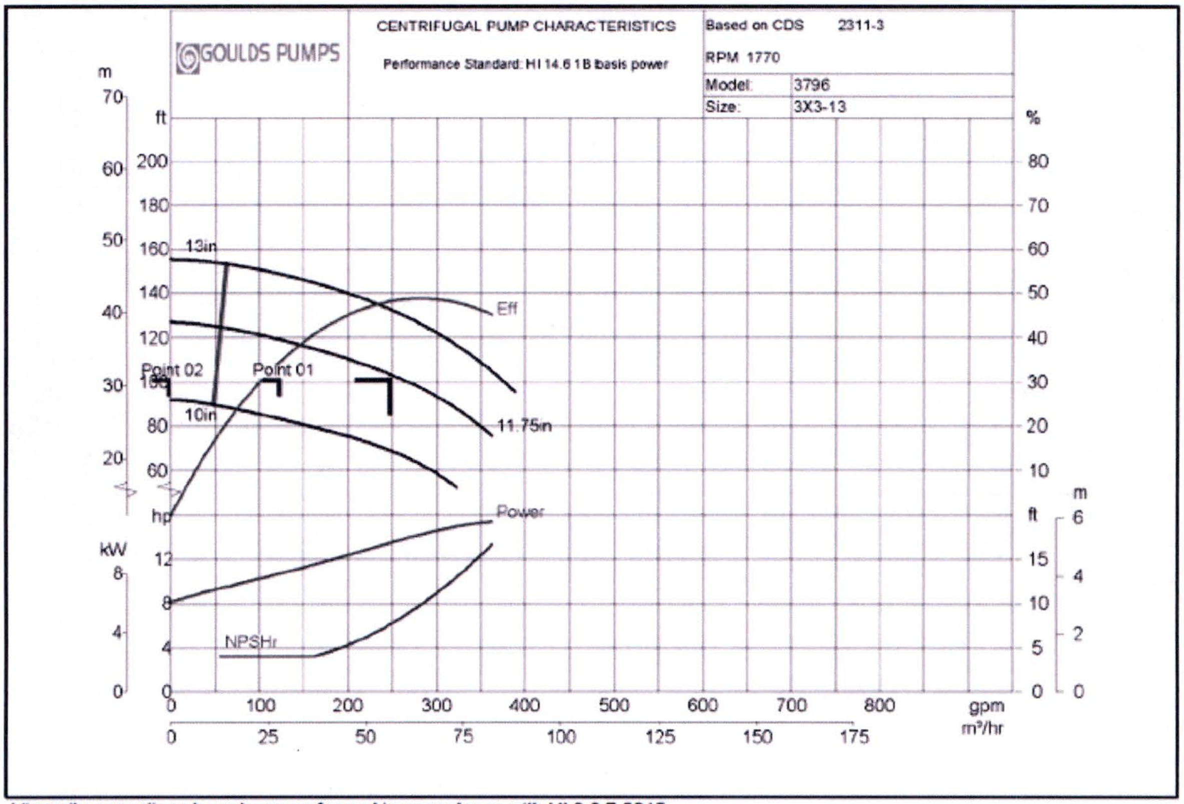
Job/Inq.No. :	Opti-Temp- HEX Feed Pumps				
Purchaser :	OPTI TEMP				
End User :	Opti-Temp	Issued by :	Brandon Bond	Rev. :	0
Item/Equip.No. :	ITEM 001 (Base Offer)	Quotation No. :	DF16-10-25 01	Date :	01/25/2017
Service :	Self Priming to HEX Skid				
Order No. :	6058869	Certified By :	Brandon Bond	SN/SO :	N736H003

Operating Conditions / **Pump Performance**

Liquid:	Water	Published Efficiency:	48.5 %	Suction Specific Speed:	5,018 gpm(US) ft
Temp.:	110.0 deg F	Rated Pump Efficiency:	48.0 %	Min. Hydraulic Flow:	56.9 gpm
S.G./Visc.:	1.000/1.000 cp	Rated Total Power:	13.5 hp	Min. Thermal Flow:	N/A
Flow:	250.0 gpm	Non-Overloading Power:	15.4 hp		
TDH:	102.0 ft	Imp. Dia. First 1 Stg(s):	11.7500 in		
NPSHa:		NPSHr:	7.8 ft	Shut off Head:	127.1 ft
Solid size:		Max. Solids Size:	0.3750 in	% Susp. Solids (by wtg):	

Vapor Press:

Notes: 1. Elevated temperature effects on performance are not included.



Viscosity corrections have been performed in accordance with HI 9.6.7-2015

PLAN 01 PARTS LIST - ARMORED TEFLON HOSE (RECIRCULATION FROM PUMP CASE TO SEAL)		
PART NAME	MATERIAL	DESCRIPTION
HOSE	316SS/ TEFLON	ARMORED TEFLON HOSE WITH SWIVEL FITTING
FITTINGS	A-20	-----

CONNECTIONS TABLE						
NO	SIZE	TYPE	QTY	PURPOSE	STATUS	FOR USE BY
TA	1-1/2	NPT	1	CASING FILLER	PLUGGED	CUSTOMER
TB	1-1/2	NPT	1	CASING DRAIN	PLUGGED	CUSTOMER
TC	1/2	NPT	1	CASING BYPASS	PLAN 01	GOULDS
TF	1/2	NPT	1	BEARING FRAME DRAIN	PLUGGED	CUSTOMER
TY	3/4	NPT	1	OIL FILL	PLUGGED	CUSTOMER

WEIGHTS	WEIGHTS ARE APPROXIMATE			
ITEM	WET		DRY	
	LBS	KG	LBS	KG
PUMP	472	214	415	188
COUPLING	2	1	2	1
DRIVER	270	122	270	122
BASEPLATE	150	68	150	68
TOTAL	894	405	837	379

COUPLING SPECIFICATIONS

MFR: T.B. WOODS SIZE: 7H
TYPE: SC
GUARD PROVIDED: YES [X] NO [ ]
MATERIAL: CARBON STEEL

MECHANICAL SEAL SPECIFICATIONS

MFR: JOHN CRANE
TYPE: SINGLE CARTRIDGE
GLAND TYPE: FLUSH QUENCH DRAIN

DRIVER SPECIFICATIONS

MFR.: WEG
POWER: 20 HP FRAME: 256T
PHASE: 3 RPM: 1800
HERTZ: 60 VOLTS: 460
ENCLOSURE: SEVERE DUTY/MILL AND CHEMICAL PREMIUM EFFICIENCY

MODEL: 3796 GROUP: MT1

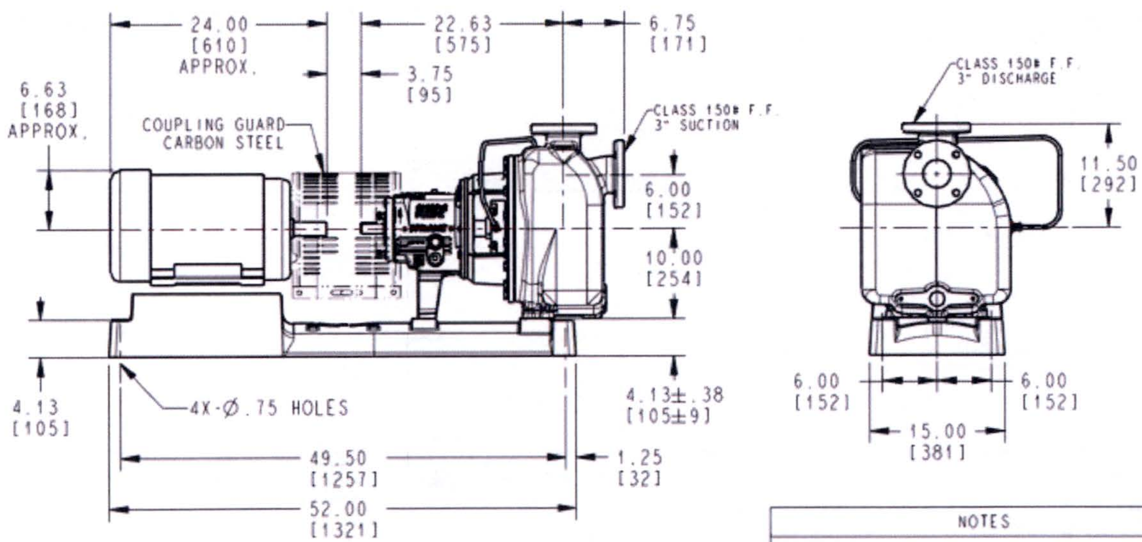
SIZE: 3X3-13
LUBRICATION: FLOOD OIL
BEARING ARRANGEMENT: BALL/BALL
BASEPLATE: CAST IRON

CERTIFIED FOR CONSTRUCTION ONLY WHEN SIGNED.

SIGNATURE: B.BOND DATE: 1/16/17

CUSTOMER DATA

Customer: PROFESSIONAL PUMP
Goulds Serial No: N736H003
Customer P.O. No: 6058869
Item No: ITEM 001
End User: Opti-Temp
Service: Self Priming to HEX Skid



NOTES

- FLANGES CONFORM TO ANSI STANDARDS. BOLT HOLES STRADDLE ℄. (B16.5 STEEL OR B16.1 IRON)
- ROTATION CCW VIEWED FROM COUPLING END.
- DIMENSIONAL TOLERANCE TO PIPED CONNECTIONS IS ±0.50 (13) EXCEPT FOR PUMP SUCTION AND DISCHARGE.
- ROUTING OF PIPELINES IS APPROXIMATE AND MAY VARY AFTER ASSEMBLY.
- REFER TO MECHANICAL SEAL DRAWING FOR GLAND DETAIL.

PUMP OUTLINE DRAWING
MODEL 3796

ITT GOULDS PUMPS

DRAWING SCALE: 0.090
DIMENSIONS IN INCHES(mm)

DRAWN	CHECKED	APPROVED	COPYRIGHT
BMB 1/16/17	BMB 1/16/17	BMB 1/16/17	2017

DRAWING B1-736H003 REV 0
SHEET 1 OF 1

Goulds Pumps
ITT
Engineered for life

INSPECTION AND TEST PLAN

Form EF-3170, Rev. 1
19-May-2006

DATE:	1/17/2017
REVISION:	0
ISSUED BY:	B. LUCCHESI

CUSTOMER	PROFESSIONAL PUMP
P.O. #	6068869
GOULDS S/N	N736H003
MODEL	3796 MTi
PUMP SIZE	3x3-13
EQUIPMENT TAG	
SERVICE	Self Priming to HEX Skid

REF. #	INSPECTION REQUIREMENTS	PROCEDURE	Acceptance Criteria	Character to be Checked	QC Form/Verifying Document	Inspection Test Codes GOULDS	Inspection Test Codes CUSTOMER	Notes
⇨	***QCP- REPRESENTS A GOULDS QUALITY CONTROLLED PROCEDURE. THE LATEST PROCEDURE/STD. REVISION WILL BE APPLICABLE IF NO SPECIFIC REVISION HAS BEEN APPROVED FOR THIS CONTRACT.***							
1	Configure order per customer specifications.	Purchase Order						
2	Casting inspection requirements	ITT Engineering Standard E-2373	MSS-SP-55					Responsibility of Casting Suppliers
3	**ASSEMBLY**							
4	Impeller Balance	QCP, 641 ISO 1940	ISO 1940 G6.3	Residual Unbalance	Report	I	R	
5	Assembled Hydrostatic Test	QCP 551	No Leakage	Integrity of assembled pump and seal installation	NA	I	NA	
6	Hydraulic Performance Test	QCP 550	Hydraulic Institute	Pump Head-Capacity-Power	Test Report	I	A	Performance Curve Approval Prior to Shipment
7	Blast and Coating Compliance	<u>Top of Baseplate and Pump Components:</u> Goulds standard ANSI paint system <u>Motor</u> WEG standard paint		Surface Preparation/ Paint Thickness	NA	I	R	
8	Documentation Review	NA	Customer Order	Accuracy/ Completeness of documents	NA	R	R	
9	Shipment Preparation	QCP-520	N/A	Adequacy of packaging and shipment preparation	NA			
10	Confirmation of Conformance to PO	CUSTOMER PO	Customer PO		Certificate of Conformance			
11	Release To Ship	CUSTOMER PO			Performance Curve Approval		A/H	

H = Hold Point
I = Inspection
W = Witness
V = Verify
S = Surveillance
R = Record/Review
A = Approval

Rev 0 - Initial submittal.

OPTITEMP

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CERTIFICATE OF CONFORMANCE

Date: **February 28, 2017**

Supplier:
Opti Temp Inc
1500 International Drive
Traverse City, MI 49686
PH: 231.946.2931

General Atomics Purchase Order: 4500066103
Part Number: (Below)

	Main Pump
1	MODEL 3796 MTi SIZE 3x3-13, Self Priming Pump w/ I-Alert
1	Drive (Motor) 480V/3ph/60Hz
1	25B-D037N114, PowerFlex 525 AC Drive, 480 VAC, 3 Phase, 25 HP, 18.5 kW Normal Duty, 20 HP, 15 kW Heavy Duty, Frame E, IP20 NEMA / Open Type, Filter
1	Crating
1	Testing

Serial Number- Motor: 1033917920, Pump: N736H003, Coupler: No Serial Number
Quantity: 1 Each Items Above

I hereby certify that all items furnished against your contract/purchase order 4500066103 are in conformance with the requirements, specifications, and drawings applicable to that order.

Signature	Title	Date
[signature]	Vice President, Engineering	2.28.2017

ITT — ITT/Goulds Pumps, Engineered Products Division — Performance Test Report ****HQ****

Customer:	Professional Pump			Test Type:	Non-Witness
Order Info.	Work Order No.: 5417	Model:	3796	Seal Desc:	Single Cart
	Serial No.: N736H003	Size:	3x3-13	Imp. Dia.:	11.750 in
	Item No.: 0	Pump Mat'l Construction:	316	Ord. Imp. Dia.	11.750 in
	Quantity: 1			Dwg. No.:	100-539
Test Info.	Test Location: ANSI-Stand2	Flow Meter:	4In Mag	Gauge Corr.:	0.00 ft
	Torque Shaft: TS3	Suct. Gauge:	ABS	Suct. I.D.:	3.068 in
	Rotation: cw	Disch. Gauge:	D1	Disch. I.D.:	3.068 in
Rating Info.	Rated Speed: 1770 rpm	Test Speed:	1770 rpm	Cust. Mtr. & Svc Factor:	20/1.25
	Rated Flow: 250 gpm	Test Flow:	250 gpm	Cust. S.G.:	1.00
	Rated Head: 102 ft	Test Head:	102 ft	Seal Type:	Single Cart
	Rated Eff.: 48 %	Atm. Press.:	33.03 ft	Torque Residual	9.00
	Rated Power: 13.50 bhp				
Remarks:				Acceptance Grade:	1B

**********Performance at Test Speed and Specific Gravity = 1.0**********

Pt. No.	Suct. Head (abs ft)	Spec Gravity	Vel. Head (ft)	Disch. Head (ft)	Total Head (ft)	Temp Deg F	Capacity (gpm)	Torque Correc (in-lbs)	Power (bhp)	Speed (rpm)	Eff (%)
1	56.1	0.9990	0.0	154.7	131.6	76.4	0	289	8.1	1765	0.1
2	55.9	0.9990	0.0	149.6	126.7	76.4	58	323	9.1	1765	20.5
3	55.5	0.9990	0.0	145.0	122.6	76.5	112	362	10.1	1765	34.3
4	55.0	0.9990	0.0	141.1	119.1	76.6	157	393	11.0	1765	42.8
5	54.2	0.9990	0.0	132.6	111.5	76.6	208	438	12.3	1765	47.8
6	53.2	0.9990	0.0	120.8	100.6	76.7	260	479	13.4	1764	49.2
7	52.5	0.9990	0.0	111.9	92.5	76.7	296	504	14.1	1764	49.0
8	51.5	0.9990	0.0	99.7	81.3	76.8	336	532	14.9	1763	46.4

As-Built Performance at Rated Spd = 1770 rpm
******** And Specific Gravity = 1.000 ********

Pt. No.	Capacity (gpm)	Total Head (ft)	Power (bhp)	Eff (%)
1	0.3	132.5	8.2	0.1
2	58.2	127.6	9.1	20.5
3	112.7	123.4	10.2	34.3
4	157.1	120.0	11.1	42.8
5	208.9	112.3	12.4	47.8
6	260.6	101.4	13.6	49.2
7	297.0	93.3	14.3	49.0
8	337.3	82.0	15.1	46.4

Notes
Eff = (Capacity X Total Head X Spec Grav)/(Power X 3960)

Tested By: Test Date: 2/9/17 Test Number:

Approved By: [signature] Witnessed By: ____________

Customer: OPTI TEMP
Serial No: N736H003
Customer P.O. No: 6058869
Item No: ITEM 001 (Base Offer)
End User: Opti-Temp
Service: Self Priming to HEX Skid

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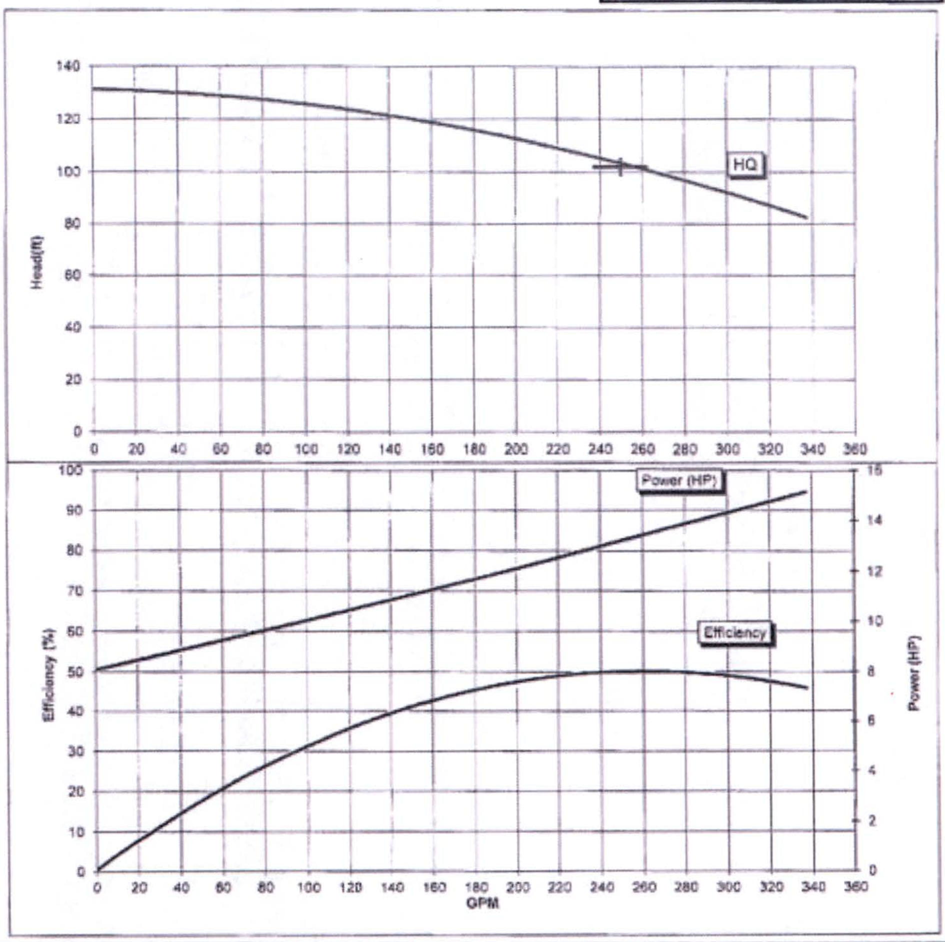
Pump Serial No.	N736H003	Impeller Diameter (in)	11.750	Flow (GPM)	250
Size	3x3-13	Temperature (oF)	76.4	Head (ft)	102
Type	3796	Acceptance Grade	1B	Rated Speed	1770
No. of Stages				Specific Gravity	1.00

ITT

Certified By

Name: [signature]

Date: 2/9/17



Customer: OPTI TEMP
Serial No: N736H003
Customer P.O. No: 6058869
Item No: ITEM 001 (Base Offer)
End User: Opti-Temp
Service: Self Priming to HEX Skid

Attachment 11

APPENDIX C – Raw Pressure Drop Data Summary

Time	Flow Rate (GPM)	PT-335 Absolute Pressure Reading (psia)	Absolute to Gauge Conversion (psig)	Static Water Head Adjustment (psig)
10:15:14 AM	0	[redacted]	[redacted]	[redacted]
10:15:16 AM	0	[redacted]	[redacted]	[redacted]
10:15:18 AM	0	[redacted]	[redacted]	[redacted]
10:15:20 AM	0	[redacted]	[redacted]	[redacted]
10:15:22 AM	0	[redacted]	[redacted]	[redacted]
10:15:24 AM	0	[redacted]	[redacted]	[redacted]
10:15:26 AM	0	[redacted]	[redacted]	[redacted]
10:28:06 AM	93	[redacted]	[redacted]	[redacted]
10:28:08 AM	93	[redacted]	[redacted]	[redacted]
10:28:10 AM	93	[redacted]	[redacted]	[redacted]
10:28:12 AM	93	[redacted]	[redacted]	[redacted]
10:28:14 AM	93	[redacted]	[redacted]	[redacted]
10:28:16 AM	93	[redacted]	[redacted]	[redacted]
10:28:18 AM	93	[redacted]	[redacted]	[redacted]
10:55:56 AM	110	[redacted]	[redacted]	[redacted]
10:55:58 AM	110	[redacted]	[redacted]	[redacted]
10:56:00 AM	110	[redacted]	[redacted]	[redacted]
10:56:02 AM	110	[redacted]	[redacted]	[redacted]
10:56:04 AM	110	[redacted]	[redacted]	[redacted]
10:56:06 AM	110	[redacted]	[redacted]	[redacted]
10:56:08 AM	110	[redacted]	[redacted]	[redacted]
11:13:20 AM	126	[redacted]	[redacted]	[redacted]
11:13:22 AM	126	[redacted]	[redacted]	[redacted]
11:13:24 AM	126	[redacted]	[redacted]	[redacted]
11:13:26 AM	126	[redacted]	[redacted]	[redacted]
11:13:28 AM	126	[redacted]	[redacted]	[redacted]
11:13:30 AM	126	[redacted]	[redacted]	[redacted]
11:13:32 AM	126	[redacted]	[redacted]	[redacted]

5a, d, e, f

[redacted]

APPENDIX D – Calculation for Extrapolating GA ΔP Test Values at 20°C (Constant) to ANSYS-FLUENT Prediction Values at 34°C (Target Assembly Average)

The pressure drop in a turbulent flowing fluid is governed by the equation:

$\Delta P = (f\ L/d + K)\ (\rho V^2/2)$

f is the friction factor and governs the frictional component of the flow,

The friction pressure drop is linearly a function of the density, ρ and the friction factor, f.

f, in turn, is approximately a function of the Reynolds number to the -0.25 power[1], and Re is a **function of ρ/μ.**

Thus, $(\Delta P_{friction})_{test} / (\Delta P_{friction})_{actual} = (f\rho)_{test} / (f\rho)_{actual} = f_{test} / f_{actual} * \rho_{test} / \rho_{actual} = (\rho_{test}/\mu_{test})^{-0.25} / (\rho_{actual}/\mu_{actual})^{-0.25} * \rho_{test} / \rho_{actual} =$

$$[(\rho_{test} / \rho_{actual}) / (\mu_{test}/\mu_{actual})]^{-0.25} * \rho_{test} / \rho_{actual}$$

K governs the momentum and area change component of the pressure drop.

Thus, the momentum pressure drop is linearly a function of the density, ρ.

So, $(\Delta P_{momentum})_{test} / (\Delta P_{momentum})_{actual} = \rho_{test} / \rho_{actual}$

Our test is basically carried out with water at 20°C, but the real flow through the target will be at an average temperature of 34°C, with the inlet at 29°C and the outlet at 39°C.

For the target flow at 2 atm:

	Test conditions	Actual conditions	Test/Actual
$\rho\ (kg/m3)_{avg}$	998.2536	994.4179	1.0039
$\rho\ (kg/m3)_{inlet}$	998.2536	995.9924	1.0023
$\rho\ (kg/m3)_{outlet}$	998.2536	992.6396	1.0057
$\mu\ (kg/m\ sec)_{avg}$	0.001002	0.000734	1.3651

[redacted]

In addition, it is noted from GA report 30441R00038 that of the total [redacted] psid target assembly pressure drop, [redacted] psid is the momentum pressure drop at the assembly inlet, [redacted] psid is frictional pressure drop along the target rods, and [redacted] psid is the momentum pressure drop at the assembly outlet. Thus [redacted] of the total pressure drop is inlet momentum drop, [redacted] is frictional pressure drop and [redacted]% is outlet momentum drop. Assuming the same pressure drop distribution through the test configuration would mean that 5a, d, e, f

$(\Delta P)_{test} / (\Delta P_{actual})$ = [redacted]*1.0023 +

[redacted]*$(1.0039 / 1.3651)^{-0.25}$ * 1.0039) +

[redacted]*1.0057

= [redacted] 1.0208

5a, d, e, f

Thus the measured pressure drops for the target assembly will be about 2.1% higher for the test than the actual system.

[1]Blasius, P. R. H. 1913. Das Aehnlichkeitsgesetz bei Reibungsvorgangen in Flüssigkeiten. Forschungsheft 131, 1-41.

APPENDIX E – Target Assembly Pressure Drop Test Data Sheets

DATA SHEET
Target Cooling System Flow Test (30441P00026_A)
Section 3.3.2 - Target Assembly Pressure Drop Test

35 **% Flow Case** Operator: [signature] Date: 7/6/17 Operator: [signature] Date: 7/6/17

VFD Frequency (Hz)	40

QA Review: [signature] Date: 7/6/17

Time	Time Elasped (min)	PI-335 (psig)	PI-302 (psig)	DPI-310 (psig)	PI-308 (psig)	FT-110 (GPM)	FT-100 (GPM)	DPI-320 (psig)	McMaster Gauge S/N: E452434 (psig)	DPI-302 (psig)	Data Recorded Electronically PT-335 (psig)	Thermocouple
10:29	0	-4.5	14.2	2.7	11.0	93	93	1.5	10.5	.7		
10:34	5	-4.5	14.2	2.7	11.0	93	93	1.5	10.5	.7		
10:39	10	-4.6	14.1	2.7	11.0	93	93	1.5	10.5	.7		Temp 74 °F
10:44	15	-4.6	14.1	2.7	11.0	93	93	1.5	10.5	.7		74 °F

All valves are fully opened

Turn on Pump @ 10:15 VFD @ 30 Hz to bleed system
Water 25' 10"
slightly closed HV-200 to [illegible] flow meters

DATA SHEET
Target Cooling System Flow Test (30441P00026_A)
Section 3.3.2 - Target Assembly Pressure Drop Test

100 **% Flow Case** Operator: [signature] Date: 7/6/17 Operator: [signature] Date: 7/6/17

VFD Frequency (Hz)	47

QA Review: [signature] Date: 7/6/17

Time	Time Elasped (min)	PI-335 (psig)	PI-302 (psig)	DPI-310 (psig)	PI-308 (psig)	FT-110 (GPM)	FT-100 (GPM)	DPI-320 (psig)	McMaster Gauge S/N: E452434 (psig)	DPI-302 (psig)	Data Recorded Electronically PT-335 (psig)	Thermocouple (°F)
10:47	0	-5.8	20.5	3.6	16.2	107	110	2.2	14.5	.8		74 °F
10:52	5	-5.8	20.5	3.7	16.2	106	110	2.2	14.5	.8		74
10:57	10	-5.8	20.5	3.6	16.4	106	110	2.2	14.5	.9		74
11:02	15	-5.6	20.4	3.7	16.2	106	110	2.3	14.5	.8		74

PI-308 + Air pocket

10:40 Temp OMEGA Data Logger EMZ-208
Calibration Due 9/20/18

DATA SHEET
Target Cooling System Flow Test (30441P00026_A)
Section 3.3.2 - Target Assembly Pressure Drop Test

115 **% Flow Case** Operator: [signature] Date: 7/6/17 Operator: [signature] Date: 7/6/17

VFD Frequency (Hz)	52.7

QA Review: [signature] Date: 7/6/17

Time	Time Elasped (min)	PI-335 (psig)	PI-302 (psig)	DPI-310 (psig)	PI-308 (psig)	FT-110 (GPM)	FT-100 (GPM)	DPI-320 (psig)	McMaster Gauge S/N: E452434 (psig)	DPI-302 (psig)	Data Recorded Electronically PT-335 (psig)	Temp
11:08	0	-6.9	27.0	4.3	21.7	112	126	3.0	19.0	1.1		74.2
11:13	5	-6.8	27.0	4.3	21.8	112	126	2.9	19.0	1.0		74.2
11:18	10	-6.7	26.9	4.3	21.7	112	126	2.9	19.0	1.0		74.2
11:23	15	-6.8	26.9	4.3	21.7	112	126	2.9	19.0	1.0		74.2

Air Temp 75°F

11:05 55 Hz

11:08 52.7 Hz

APPENDIX F – Measuring & Test Equipment (M&TE) List with Certificates of Calibration

M&TE Name	M&TE Asset No.	Calibration Due Date
Pressure Gauge (PI-335)	QC-15-240	9/29/2018
Pressure Gauge (PI-302)	QC-15-238	12/22/2018
Pressure Gauge (PI-308)	QC-15-239	12/22/2018
Differential Pressure Gauge (DPI-302)	QC-15-242	12/20/2018
Differential Pressure Gauge (DPI-310)	QC-15-243	12/12/2018
Differential Pressure Gauge (DPI-320)	QC-15-246	2/20/2019
Pressure Transmitter (PT-335)	QC-15-259	5/30/2019
Torque Wrench	QC-05-147	12/6/2017

[redacted]

APPENDIX G – Laboratory Notebook Reference

All test data were recorded in Lab Notebook No. 13569.

Test	Lab Notebook Page No.
Target Assembly Pressure Drop Test	Page 8
Pump Coast-down Test	Page 11
Labyrinth Seal Bypass Test	Page 14

[redacted]