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Salt Valve and Instrumentation Test Using the Nagle Long Shafted Pump: Final Report

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Prepared by
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Abstract

The Salt Valve and Instrumentation Test was done to provide data on equipment performance in high temperature environments similar to that expected in the next large scale application of that technology. The experiment tested three different valves: (1) a valve with the standard valve body and standard high temperature self-packing material; (2) a valve with the standard valve body and stainless steel O-rings; and (3) a magnetic valve that uses a high temperature coil and no packing material. The first valve, which was used at Solar Two, performed sufficiently throughout the test with only a small leak from the split-body, not the packing material, on the 6th day of testing on the long-term test. The second valve, with the stainless steel O-rings, developed a small leak on the last run of the third test at the bonnet (packing material), at which point it was noted to watch if it got worse and the test continued. By the 6th day of the long-term test, the leak was significant (up to 3 cups per day) and the test was terminated. The magnetic valve failed when exposed to a relatively low temperature of 500 °F. According to the manufacturer, it was expected to survive up to temperatures of 600 °F. Two different pressure transducers were tested and compared, Taylor and Dynisco. The Taylor pressure transducer was used and proven successful at Solar Two. However, they are no longer made. Therefore the experiment tested a new pressure transducer from Dynisco and compared the results to that of the Taylor. The Dynisco pressure transducer performed inaccurately from the beginning. The pressure transducer was affected by an increase in temperature when the pressure remained the same. Dynisco agreed to recalibrate the pressure transducer and/or send us a new one if the piece was faulty. However, in the process of removing the piece from the system, due to the high temperatures used, the piece had gulled with the stainless-steel piping and broke. Flared fittings versus Swagelock fittings were tested in the experiment as well. Both fittings showed no signs of any leakage when exposed to the high temperatures and corrosive environment. The existing test set-up for the Nagle Long Shafted Pump was used in this experiment and additional test hours were obtained on the pump bearings. However, only 132 hours (5 ½ days) of the 5000 hours (208 days) were performed due to a salt leak, which required removal of insulation. The experiment had to be terminated prior to removal of the insulation.

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Nexant Corporation
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Acronyms and Abbreviations

NSTTF: National Solar Thermal Test Facility

OP: Operation Procedure

SS: Stainless Steel

NEC: National Electric Code

P&ID: Piping and Instrument Drawing

SGS: Steam Generator System

R & D: Research and Development

T & E: Test and Evaluation

TC: Thermocouple

PT: Pressure Transducer

PT200: Dynisco Pressure Transducer

PT100: Taylor Pressure Transducer

FCV100: Masoneilan split-bodied globe valve (2")

FCV300: Milwaukee gate valve (SS-O-rings - 2")

HV400: Curtis Wright 2" pilot actuated globe valve with magnetic coil actuator

1.0 INTRODUCTION

1.1 Project Background

Solar Tres is a 50 MWe molten salt power tower project to be built in Spain. The Spanish government is very interested in generating electricity from renewable sources and is subsidizing solar-only power plants. Molten salt power towers are ideally suited for delivery of bulk electricity to a grid. These plants utilize nitrate salts (60 wt% $NaNO_3$, 40 wt% KNO_3) heated to their liquid state, as both the heat collection fluid and the thermal energy storage media. Molten salt power towers work by first pumping "cold" 554°F (290°C) molten nitrate salt, which is at a temperature just above melting so the salt is liquefied, from the cold salt storage tank to the receiver on top of a central tower. The salt is heated with concentrated sunlight to 1049°F (565°C) by solar energy reflected from a field of heliostats. The hot molten nitrate salt then flows by gravity to grade level and is stored (with efficiencies of nearly 99%)[1] in a hot tank. The molten nitrate salt is pumped as needed through a steam generator; producing high-pressure superheated steam (see Figure 1) that powers a turbine generator producing electric power.

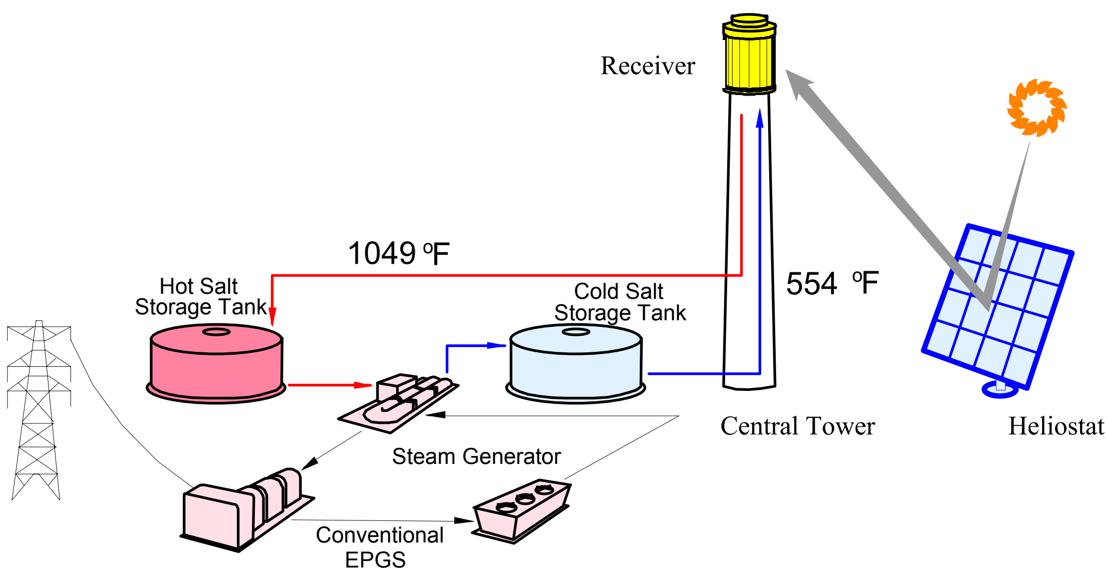

Figure 1. Schematic drawing of solar power tower

Molten salt power towers have thermal storage systems that allow electricity to be produced when it is needed (dispatched), decoupling it from solar collection. Nexant and

[1] http://www.energylan.sandia.gov/sunlab/Snapshot/solartes.html

Boeing prefer molten-salt power towers because they can be dispatchable. Energy storage allows the solar electricity to be dispatched to the utility grid when the power is needed most, which increases the economic value of solar energy.[2]

Solar Two was a collaborative, cost-shared project between eleven U.S. industries and utility partners and the U.S. Department of Energy to validate molten salt power tower technology. The Solar Two plant, located east of Barstow, CA, comprised of 1,926 heliostats, a receiver, a thermal storage system and a steam generation system (SGS). Solar Two operated from June 1996 to April 1999. Molten nitrate salt was used as the heat transfer fluid and storage media. The steam generator powered a 10 MWe, conventional Rankine cycle turbine[3]. The objectives of the Solar Two Test and Evaluation (T&E) program were gathering data and information, and performing analyses to achieve the following goals:

- Validate the technical characteristics (reliability, annual net electric performance, environmental impact, and capability for dispatch) of the nitrate salt receiver, storage system, and steam generator technologies.
- Improve the accuracy of economic projections for commercial projects by increasing the database of capital, operating, and maintenance costs.
- Distribute information to U.S. utilities and the solar industry to foster wider interest in the first commercial plants.[3]

Solar Two met most of these goals. The daily conversion of the thermal energy to electrical energy met design goals. The steady-state gross cycle efficiency matched design. And the start-up of the SGS and turbine routinely surpassed the project goals. Startup energy usage was as low as 6.6 MWht.

However, the design goal for the gross turbine output was not met for several reasons. One reason for not achieving this goal was cold salt bypassing the receiver and leaking past the isolation valves in the SGS. This resulted in a reduction of the inlet salt temperature to the steam generator. The highest salt temperature into the steam generator was approximately 1035 °F, when the desired temperature was 1050 °F. [Please see Sandia National Laboratories Lessons Learned from Solar Two for several other solutions and modifications of the receiver bypass loop piping and isolation valves in the SGS.] [4] Several other improvements in the valve selection were required as well:

- Ball-type valves were used for vent and drain valves. Experience at Solar Two indicated that these valves did not operate satisfactory in salt. Excessive friction

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[2] Pacheco, J.E., 2001, "Final Test and Evaluation Results from the Solar Two Project" Sandia National Laboratories Report

[3] Pacheco, J.E., Gilbert, R., 1999, "Overview of the Recent Results of the Solar Two Test and Evaluations Program" *Proceeding of the ASME International Solar Energy Conference: Renewable and Advanced Energy Systems for the 21st century,* Maui, HI.

[4] Litwin, R. Z., 2002, "Receiver System: Lessons Learned from Solar Two" Sandia National Laboratories SAND2002-0084 Report

between the ball and the seat and solid debris in the salt scratched the sealing surfaces and caused shear pin failure and loss of valve operation. The congested valve location and configuration made shear pin replacement very difficult. Replacing the ball-type valves with gate valves was identified as one way to eliminate this problem. Gate valves have less frictional resistance and are not as sensitive to solid debris in the salt.

- The compact drain valve configuration, although desirable in the receiver system layout, overheated the valve stem seal because of its close proximity to the valve body. Locating the stem seals further from the valve body was identified as a solution to maintain lower temperatures at the seals.

- During "hot" drain and in the event of leakage through the drain valves during receiver operation, some of the drain lines and the drain valves themselves were subjected to temperatures greater than normally acceptable for carbon steel material. Stainless-steel material will be used for these drain valves since it can withstand the high temperatures and corrosive environment of the salt. [5]

The Solar Tres power tower plant will utilize molten- salt technology. The plant will be rated at 50MWe, with 16 hours of full-power storage to allow 24-hour/day operations. Solar Tres represents a scale-up of the Solar Two plant while improving economic competitiveness by increasing plant rating and annual capacity factor. Solar Tres will incorporate a number of improvements and innovations identified at Solar Two and through continued development by industry and Sandia National Laboratories. These improvements include a more robust receiver and a dramatically simplified salt circuit design.

1.2 Test Objectives

The Salt Valve and Instrumentation Test was an experiment done at Nexant's request, (a subsidiary of Bechtel Corporation), and in preparation for Solar Tres. The main objectives of the Salt Valve and Instrumentation Test were to determine: 1) if suitable packing material and/or valves containing no packing material can be qualified to withstand the high temperature (up to 1050 °F), corrosive, and abrasive environment of molten nitrate salt; 2) to test a new type of pressure transducer against a previously used pressure transducer at Solar Two, which is no longer made; 3) to compare Flared fittings versus Swagelock fittings in a salt system; and 4) to run a long-term, 5000 hour test, designed to increase the hours tested on the Nagle Long Shafted Pump bearings.

[5] Litwin, R. Z., 2002, "Receiver System: Lessons Learned from Solar Two" Sandia National Laboratories SAND2002-0084 Report

Specifically tested were:

- A Masoneilan valve with the standard valve body and standard high temperature self-packing material;
- A Milwaukee valve with the standard valve body and stainless steel O-rings;
- A Curtis Wright magnetic control valve, which uses no packing material, instead a high temperature-heating coil.
- A Taylor pressure transducer previously used at Solar Two;
- A Dynisco pressure transducer;
- ½" stainless steel Swagelock fittings, and;
- ½" stainless steel Flared fittings.

The magnetic valve design was tested to see if such a device would withstand the high temperature, corrosive and abrasive environment of molten nitrate salt. The long shafted pump, which was designed and built by Nagle Pump Inc. of Chicago, Illinois and tested and operated at Solar 2, was used solely to increase the number of hours tested on the pump bearings.

1.3 Test Configuration

The set up for the Salt Valve and Instrumentation Test is located at an existing pump and valve site west of Building 9980- C and D at the National Solar Thermal Test Facility (NSTTF). The test used molten salt ranging in temperature between 500°F and 1050°F. The molten salt was stored in the sump located in a containment pit west of Building 9980-C and D. [The Operation Procedure document 058, Molten Salt Systems at the NSTTF, covers the operations involving molten salt.] This salt was kept at a predetermined temperature with electrical heat trace.

The piping, valve and other components of the system were also kept hot using electrical heat trace to prevent the salt from freezing. The usual set point for these items was 550°F. However, during operation they were at times higher (up to operating temperature) depending on the salt temperature. The electrical heat trace was installed per the National Electric Code (NEC).

The data and experimental control, such as temperature, pressures levels, etc., for this test were collected using a computer-based Lab VIEW program. The test engineer was able to download this data to a spreadsheet format for evaluation.

The Lab VIEW program provided controls for the system such as heat trace, start/stop, cooler operation, valve position, etc. The data and control were on one computer, which was located in the control room of Building 9980-C. Any computer tied to the network, which was allowed access to the local computer using a Lab View-based monitoring program, could monitor the experiments. Operation of the system was unattended and safeties were designed into the system to shut the pump down if abnormal conditions were detected. [A separate controls document explained these control system safeties, "Salt Valve Control System."]

The piping system was subjected to pressures of up to 135 psig requiring a pressure safety data package, ["Pressure Data Package for the Salt Valve Instrumentation Test,"] which was reviewed by the SNL pressure advisor prior to system start up.

All of the valves were on/off valves, and normally closed. A P&ID for the experiment is shown in Figure 2.

Table 1 contains all the specifications for the instrumentation and equipment used in the experiment.

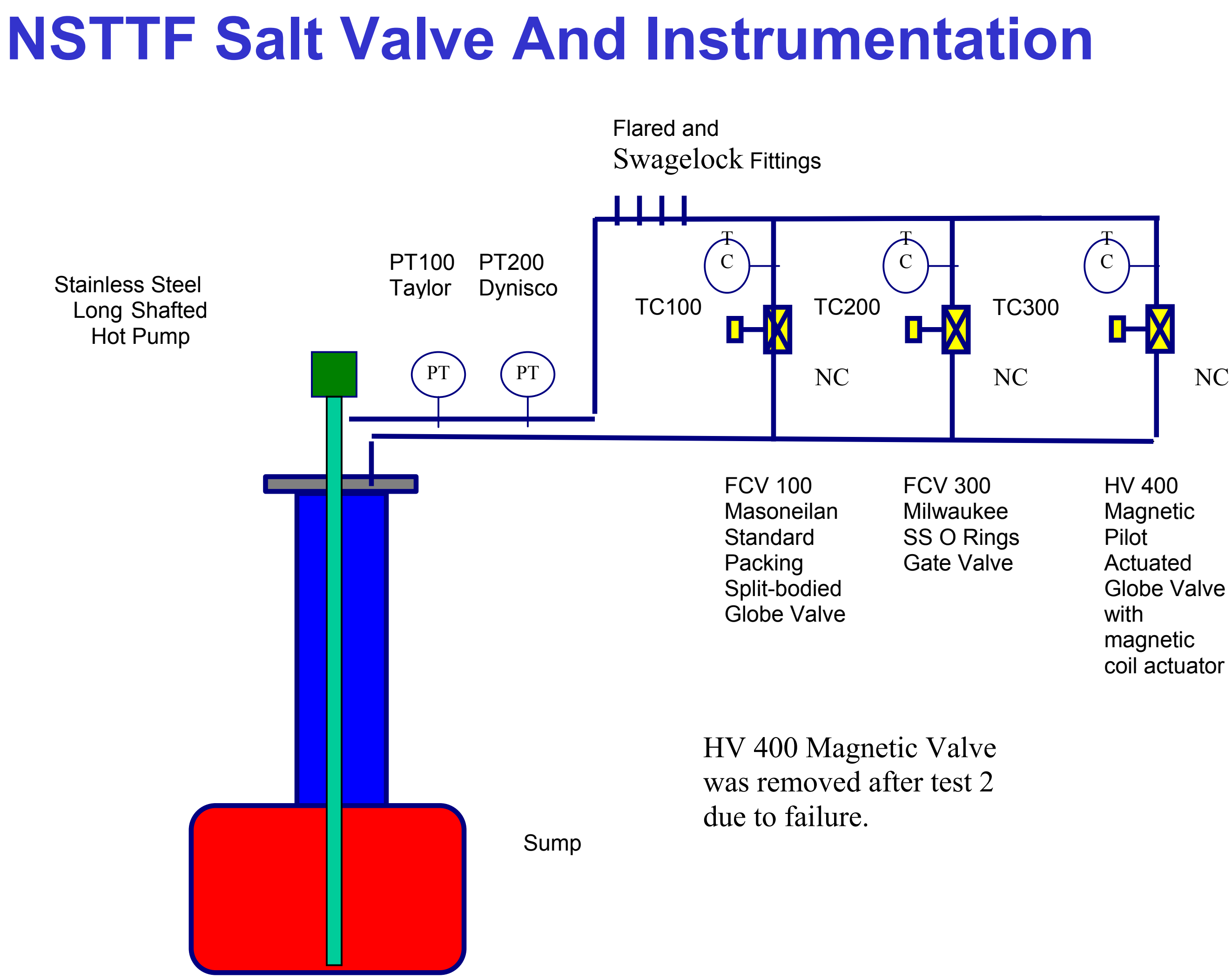


Figure 2. Salt valve piping and instrumentation drawing

Table 1. Component Specifications

Component	Material	Qty	Supplier	Model #	Pressure Rating
Piping	SS 316-L	80 ft	Redman	Sch. 40	350 psi @ 500F 335 psi @ 750F 320 psi @ 850F
Pipe Fittings	SS 304	200 ft	Redman	Sch. 40	435 psi @ 500F 400 psi @ 750F 325 psi @ 1000F
Pipe Fittings	SS 304L		Redman	Sch. 40	380 psi @ 500F 335 psi @ 750F 330 psi @ 800F
Pipe Fittings	SS 316		Redman	Sch. 40	480 psi @ 500F 425 psi @ 750F 365 psi @ 1000F
Pipe Fittings	SS 316L		Redman	Sch. 40	350 psi @ 500F 335 psi @ 750F 320 psi @ 850F
Molten Salt Tank	SS 304	1 ea	Continental Boiler Works		Atmospheric
½" fittings	Stainless Steel	2 ea	Nupro/ Swagelock	SS-8UW-HT	250 psi @ 1200°F
Pump	SS316	1 ea	Nagle Pumps	SN NP98-1168	128 psi max
Flanges (600 lb)	SS 304	2 ea			170 psi @ 500F 95 psi @ 750F 20 psi @ 1000F
2" Gate Valve	Carbon Steel	1 ea	Milwaukee Valve	Class 150 A216 WCB	170 psi @ 500F 95 psi @ 750F 20 psi @ 1000F
½ " flared fitting	SS 316	1 Ea	Parker	4310-A5	800 psi
2" Globe Valve/ Magnetic Valve, 600 lb	Carbon Steel	1 ea	Curtis Wright/ Target Rock	Model 120	1500 psig @ 600F
Pressure Transducer	SS 316	1 ea	Taylor	SPR 11237	2000 psi (data from PDP –6215-021
Pressure Transducer		1 ea	Dynisco	PT412-5C-12/18	500 psig
2" Globe Valve	Stainless Steel	1 ea	Masoneilan	Group 26	300 psig @ 550F

2.0 SUMMARY OF TEST PROCEDURES AND RESULTS

[Note: Detailed test procedures and results are contained in Appendix A and B.]

Pre-Test: - "WATER LEAK TEST"
Connected the Masoneilan valve, Milwaukee valve, and the Curtis Wright magnetic valve to the city water. Operated the valves from fully open to fully closed and all positions between. Preformed test several times. Measured the amount of water leaked, which was none.

Test 1: - "INITIAL START UP TEST "
Inspected the Masoneilan valve, Milwaukee valve, the magnetic valve and both the flared fittings and Swagelock fittings for leaks in the system and verified that they and the pressure transducers operated under low temperature conditions (500 ºF). The Masoneilan, Milwaukee, and magnetic valves operated from fully open to fully closed and all positions between. Refer to Appendix A for a table showing valve positions. The Masoneilan valve, which was used at Solar Two, and the Milwaukee valve with the SS O-rings opened and closed smoothly at this low temperature and corrosive environment of the molten salt. The outputs of the two pressure transducers, Taylor and Dynisco, were recorded and compared and showed no signs of leaks. Their pressures ranged from 27 - 44 psi and were within 2-4 psi of one another. Refer to Appendix B for a table showing the correlated pressures with valve positions. The solenoid power draw of the Curtis Wright magnetic valve was monitored and recorded. Unfortunately, the pilot actuated globe valve with the magnetic coil actuator failed within 30 seconds when it was brought up to a temperature of 500 °F. Due to the failure of the Curtis Wright magnetic valve, it was removed after the test was completed. The test lasted approximately two hours.

Test 2: "VALVE POSITIONING WITH SALT AT 500 °F"
This test was not performed due to failure of the Curtis Wright magnetic valve. The purpose of this test was to inspect the Masoneilan valve, the Milwaukee valve, the magnetic valve and the both the flared fittings and Swagelock fittings for leaks with the low salt temperature set to 500ºF for longer test cycles, as well as verify/compare pressure transducer operation under low temperature conditions. However, due to the failure of the Curtis Wright magnetic valve after the initial start up test at 500 ºF, this test was not performed.

Test 3: "VALVE POSITIONING WITH SALT AT 550 °F"
Inspected the Masoneilan valve, Milwaukee Valve, and both the flared fittings and Swagelock fittings for leaks when the salt was at 550 ºF, as well as verified the pressure transducers operated under low temperature conditions. Both valves operated from fully open to fully closed and all positions between. Please see Appendix A for a table showing valve positions. In the first 4 test runs, both valves operated adequately. In the fifth test run, a small amount of salt began to leak from the bonnet of the Milwaukee valve. Test coordinators decided to watch for an increase of salt leakage from the Milwaukee valve bonnet and continued the test. The outputs of the two pressure

transducers, Taylor and Dynisco, were recorded and compared and showed no signs of leaks. Their pressures ranged from 30-50 psi and were consistently within 10 psi of one another for the first three test runs. However, half way through the fourth test run, the Dynisco pressure transducer began to deviate (see Figure 3 & 4). Refer to Appendix B for a table showing the correlated pressures with valve positions. Test duration lasted approximately five hours. This test was performed five times to verify reproducibility and durability.

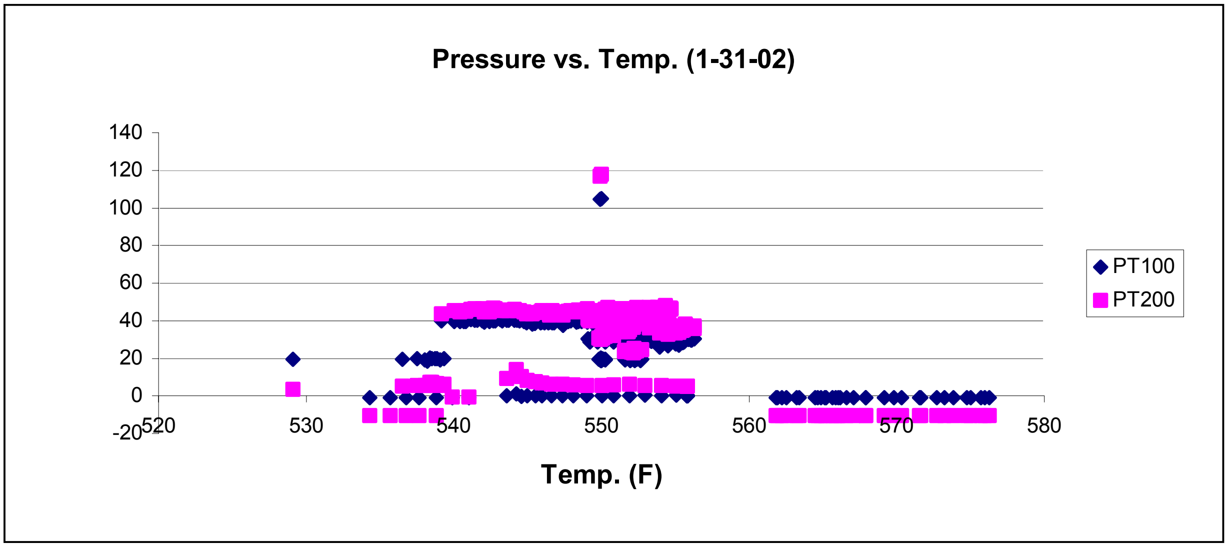
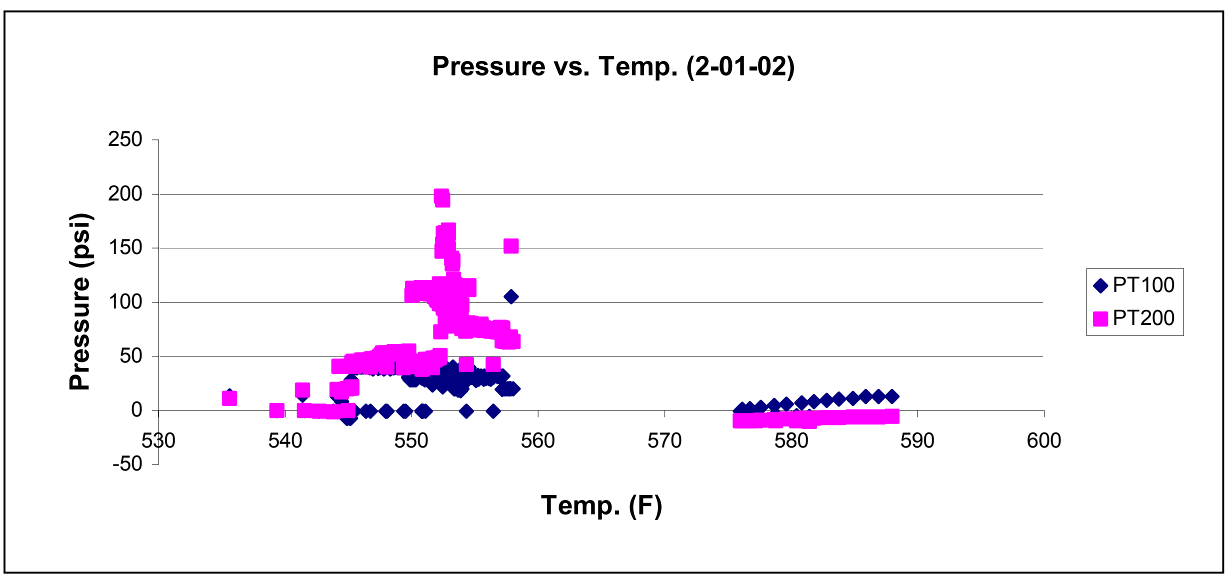


Figure 3. Pressure versus temperature for Taylor (PT100) and Dynisco (PT200) pressure transducers, before PT200 went bad



Test 4: “VALVE POSITIONING WITH SALT AT 750 °F”
Inspected the Masoneilan valve, Milwaukee valve, and both the flared fittings and Swagelock fittings for leaks when the salt was at 750 ºF, mid temperature conditions. Both valves operated from fully open to fully closed and all positions between. Please see Appendix A for a table showing valve positions. There were no signs of any new salt leakage from the Milwaukee valve bonnet in the first test run and both valves appeared to be working adequately in mid temperature conditions. However, there were signs of a small amount of salt leakage from the pump shaft, as seen in previous tests. The second test run showed no sign of any new salt leakage from the pump shaft, although there was again a small amount of new salt leakage from the Milwaukee valve bonnet. This leak appeared in the third test run as well, but not in the fourth or fifth test runs. Approximately 2 tbs of salt was brought up when the valve was opened at the end of the test; please see Appendix B for specific results. Both valves appeared to still work adequately. Test duration lasted approximately nine hours. This test was performed five times to verify reproducibility and durability.

Test 5: “VALVE POSITIONING WITH SALT AT 1050 °F”
Inspected the Masoneilan valve, Milwaukee valve, and both the flared fittings and Swagelock fittings for leaks when the salt was at 1050 ºF, high temperature conditions. Both valves operated from fully open to fully closed and all positions between. Please see Appendix A for a table showing valve positions. As the test runs were performed, the leak from the Milwaukee valve bonnet progressively got worse, from approximately 1 tbs to 3 tbs per test run, please see Appendix B for specific salt amounts leaked. However, both the Masoneilan and Milwaukee valves still operated smoothly in the high temperature environment. Test duration lasted approximately nine hours. This test was performed five times to verify reproducibility and durability.

Test 6: - “LONG-TERM TEST”
Observed the Masoneilan valve, Milwaukee valve, and both fittings for leaks over an extended period of time at high temperatures, 1050 ºF. Both valves operated from fully open to fully closed and all positions between. Please see Appendix A for a table showing valve positions and schedule. Test duration time was planned to be approximately 5000 hours. However, on the sixth day of testing, salt was leaking from numerous locations and the test was terminated.

One the first day, both valves operated smoothly. On the second day of testing, approximately 1 cup of salt had leaked from the Milwaukee valve bonnet and leaking appeared to start around the stem of the Dynisco Pressure Transducer. The pressure transducer was tightened a quarter turn and stopped leaking. Both valves still appeared to be operating smoothly at this point. Days three, four, and five showed progressively worse leaking from the Milwaukee valve bonnet and the valves were not operating as smoothly. By day six, the system should have completed twelve cycles. The computer showed eleven cycles, 1 hour, and 8 minutes of the 12^{th} cycle completed. This was due to the watchdog timer shutting off. At this point, there were approximately 3 cups of salt leaking from the Milwaukee valve bonnet, which was much worse than it had been before. At this point the system was shut down and the test was terminated. Please see Appendix B for specific results.

One week later the insulation was pulled off to identify the locations of all the salt leaks. In the process, we noticed that a small amount of salt appeared to be leaking from the split-body of the Masoneilan valve. The flared fittings were loose and tightened approximately ⅛th turn. The Swagelock fittings would not tighten. The pressure transducer from Dynisco was removed at this point. In the process of removing the pressure transducer, we noticed it had gulled with the stainless steel and therefore snapped off when we tried to remove it. It is to be sent back to the factory for repair and recalibration.

3.0 CONCLUSION

In conclusion, all of the components that were tested failed except the flared fittings and the Swagelock fittings and the Taylor pressure transducer, which is no longer made. The Curtis Wright 2" magnetic valve failed immediately when brought to a temperature of 500 °F. The magnetic coil actuator was the main failure in the magnetic valve. According to the manufacturers specifications, the magnetic valve was designed for use at temperatures up to 600 °F. Searches are being conducted now to find high temperature magnetic coil actuators to replace the one in the Curtis Wright 2" magnetic valve.

The Dynisco Pressure Transducer failed half way through the test performed at a temperature of 550°F. The Dynisco Pressure Transducer was being compared to a Taylor Pressure Transducer that was used at Solar Two and proved to perform accurately. The Taylor Pressure Transducers are no longer made and a new one needs to be found that can withstand the high temperature corrosive and abrasive environment of molten salt. Either the Dynisco Pressure Transducer was a defective component to begin with or it could not perform correctly at design temperatures. The Dynisco Pressure Transducer has been removed and will be sent back to the factory for recalibration.

The Milwaukee gate valve with the SS O-rings started leaking early on in the test. The leak was coming from the packing material and not the fittings. However, it seemed to perform adequately (open and close smoothly) until the long-term test, where it started leaking significant amounts (up to 3 cups per day) of salt. The purpose of the test was to certify packing materials that would withstand the high temperature and abrasive and corrosive environment of molten salt, and it did not.

The Masoneilan split-bodied globe valve performed well, with only a slight leak at the very end of the experiment from the split-body, not the packing material or the fittings. The Masoneilan split-bodied globe valve has performed satisfactorily at Solar Two in past years.

Appendix A

Test Plan for the Salt Valve and Instrumentation loop using Nagle Long Shafted Pump

Objective:

Test several valves using standard valve bodies with the standard high temperature salt packing, stainless steel O-rings, and a magnetic control valve. Also test flared fittings versus Swadglock fittings and test high temperature pressure transducers. (The long shafted pump will be used for this test to obtain additional hours on the bearings this pump was designed and built by Nagle Pump Inc. of Chicago, Ill. Sandia National Laboratories had a major role in determining the types of materials to be used for all components of the pump and in component layout.)

The main objective of the test is to determine if suitable packing material can be qualified that will withstand the high temperature, corrosive, and abrasive environment of the hot molten salt.

Tests:

There are several tests, which are described below.

TEST PROCEDURES

Pre-Test: - "WATER LEAK TEST"

- Connected both the Masoneilan and Milwaukee Valves containing the SS O-rings to the city water to verify no leaks. Operate the valves from fully open to fully closed and all positions between. Measure the amount of water leaked (if any) over time.

Test 1: - "INITIAL START UP TEST "
Inspect the valves and fittings for leaks and verify that the pressure transducers operated under low temperature conditions.

- Set salt temperature to: 500 ºF
- Valves were in position as shown below
- System control: Manual Stop/Start, Protection portion of controls were in automatic
- Test duration- Approximately 2 hours
- Monitor and recorded solenoid power draw
- Compare output of the 2 PT's (PT100 & PT200).
- Record: valve control status, valve positions (total of 3), pressure, and bearing temps (11total) as a function of time. Record data at 1 minute intervals
- Prior to starting, record pump hours

Valve Positions for Test-1

Time	FCV100	FCV300	HV400
10 Minutes	100% Open	100% Open	100% Open
Stop Pump	• Inspect valves, fitting, and PT's for leaks • Listen for magnetic valve operation • Verify operation of the Masoneilan, Milwaukee, and magnetic valves went smoothly		
10 Minutes	Closed	Open	Open
10 Minutes	Open	Closed	Open
10 Minutes	Open	Open	Closed
10 Minutes	Closed	Open	Open
10 Minutes	Open	Closed	Open
10 Minutes	Open	Open	Closed
10 Minutes	Closed	Open	Open
10 Minutes	Open	Closed	Open
10 Minutes	Open	Open	Closed
Stop Pump	• Inspect valves, fitting, and PT's for leaks • Listen for magnetic valve operation • Verify operation of the Masoneilan, Milwaukee, and magnetic valves went smoothly		

Test 2: "VALVE POSITIONING WITH SALT AT 500 °F"

Inspect the Masoneilan and Milwaukee Valve packing ring designs, magnetic valve and fittings for leaks when the salt is at 500ºF, and verify pressure transducer operation under low temperature conditions. Use the following table for the test conditions.

Test Conditions

- Salt temperature: 500ºF
- Valves in position as shown below
- System control: Manual Stop/Start, Protection portion of controls in automatic
- Test duration- Approximately 8 hours
- Record solenoid power draw
- Compare output of the 2 PT's (PT100 & PT200).
- Record, valve control status, valve positions (total of 3), pressure, and bearing temps (11total) as a function of time. Record data at 1-minute intervals
- Prior to starting record pump hours
- Perform test a total of 5 times

Valve Positions for Test-2

Time	FCV100	FCV300	HV400
10 Minutes	Open	Open	Open
Stop Pump	• Inspect valves, fitting, and PT's, look for leaks • Listen for magnetic valve operation • Verify operation of the Masoneilan, Milwaukee, and magnetic valves went smoothly		
60 Minutes	Open	Closed	Closed
60 Minutes	Closed	Open	Closed
60 Minutes	Closed	Closed	Open
10 Minutes	Open	Open	Open
60 Minutes	Open	Closed	Closed
60 Minutes	Closed	Open	Closed
60 Minutes	Closed	Closed	Open
10 Minutes	Open	Open	Open
Stop Pump	• Inspect valves, fitting, and PT's, look for leaks • Listen for magnetic valve operation • Verify operation of the Masoneilan, Milwaukee, and magnetic valves went smoothly		

Test 3: "VALVE POSITIONING WITH SALT AT 550 °F"

Inspect the Masoneilan and Milwaukee Valve packing ring design and fittings for leaks when the salt is at 550 ºF, and verify that the pressure transducers operate under low temperature conditions.

- Set salt temperature to: 550 ºF
- Valves in position as shown below
- System control: manual stop/start, protection portion of controls were in automatic
- Test duration- Approximately 5 hours
- Compare output of the 2 PT's (PT100 & PT200).
- Record: valve control status, valve positions (total of 3), pressure, and bearing temps (11total) as a function of time. Record data at 1 minute intervals
- Prior to starting, record pump hours
- Perform test a total of 5 times

Valve Positions for Test-3

Time	FCV100	FCV300
10 Minutes	Open	Open
Stop Pump	• Inspect valves, fitting, and PT's, look for leaks • Operate Masoneilan and Milwaukee valves, verify operates smoothly	
60 Minutes	Open	Closed
60 Minutes	Closed	Open
10 Minutes	Open	Open
60 Minutes	Open	Closed
60 Minutes	Closed	Open
10 Minutes	Open	Open
1 Minute	Closed	Closed
Stop Pump	• Inspect valves, fitting, and PT's, look for leaks • Operate Masoneilan and Milwaukee valves, verify operates smoothly	

Test 4: "VALVE POSITIONING WITH SALT AT 750 °F"

Inspect the Milwaukee Valve packing with 750 ºF salt, and verify that the pressure transducer operates under mid temperature conditions.

- Set salt temperature to: 750 ºF
- Heat trace on Milwaukee Valve: 550 ºF
- Valves in position as shown below
- System control: Manual Stop/Start, Protection portion of controls were in automatic
- Test duration- Approximately 9 hours
- Compare output of the 2 PT's (PT100 & PT200).
- Record: valve control status, valve positions (total of 3), pressure, and bearing temps (11total) as a function of time. Record data at 1 minute intervals
- Prior to starting, record pump hours
- Perform test a total of 5 times

Valve Positions for Test-4

Time	FCV100	FCV300
10 Minutes	Open	Open
Stop Pump	• Inspect valves, fitting, and PT's for leaks • Verify operation of the Masoneilan and Milwaukee Valves went smoothly	
60 Minutes	Open	Closed
60 Minutes	Closed	Open
60 Minutes	Open	Closed
60 Minutes	Closed	Open
1 Minutes	Closed	Closed
60 Minutes	Open	Closed
60 Minutes	Closed	Open
60 Minutes	Open	Closed
60 Minutes	Closed	Open
1 Minutes	Closed	Closed
Stop Pump	• Inspect valves, fitting, and PT's for leaks • Verify operation of the Masoneilan and Milwaukee Valves went smoothly	

Test 5: "VALVE POSITIONING WITH SALT AT 1050 °F"

Inspect the Milwaukee Valve packing with 1050 ºF salt, and verify that the pressure transducers operated under high temperature conditions.

- Set salt temperature to: 1050 ºF
- Heat trace on Milwaukee Valve: 550 ºF
- Valves were in position as shown below
- System control: Manual Stop/Start, Protection portion of controls were in automatic
- Test duration- Approximately 9 hours
- Compare output of the 2 PT's (PT100 & PT200).
- Record: valve control status, valve positions (total of 3), pressure, and bearing temps (11total) as a function of time. Record data at 1 minute intervals
- Prior to starting, recorded pump hours
- Perform test a total of 5 times

Valve Positions for Test-5

Time	FCV100	FCV300
10 Minutes	Open	Open
Stop Pump	• Inspect valves, fitting, and PT's for leaks • Verify operation of the Masoneilan and Milwaukee Valves went smoothly	
60 Minutes	Open	Closed
60 Minutes	Closed	Open
60 Minutes	Open	Closed
60 Minutes	Closed	Open
1 Minutes	Closed	Closed
60 Minutes	Open	Closed
60 Minutes	Closed	Open
60 Minutes	Open	Closed
60 Minutes	Closed	Open
1 Minutes	Closed	Closed
Stop Pump	• Inspect valves, fitting, and PT's for leaks • Verify operation of the Masoneilan and Milwaukee Valves went smoothly	

Test 6: - "LONG-TERM TEST"

Observe the valve and PT performance over an extended period of time (approximately 5000 hours). Inspect the fittings for leaks.

- Set salt temperature to: 1050ºF
- Heat trace on Milwaukee Valve: 550ºF
- Pump Start/Stops- Pump was on for 21 hours, then pump was off for 3 hour
- System control: Automatic Stop/Start and Protection portion of controls was in automatic
- Test duration- 5000 hours
- Record: valve control status, valve positions (total of 2), pressure, and bearing temps (11total) as a function of time. Record data at 10-minute intervals
- Inspect valves, fittings and PT's initially each work day for a week and then weekly after that.

SCHEDULE

Run Time	Idle Time	Time Per Cycle	Cycles Per Day
21 Hours	3 Hour	24 Hours	7-3 hr valves cycles with 1-3 hr pump off

Valve Position for Test-6

Pump Status	Time	FCV100	FCV 300
ON	10 Minutes	Open	Open
ON	25 Minutes	Closed	Open
ON	25 Minutes	Open	Closed
ON	10 Minutes	Open	Open
ON	25 Minutes	Closed	Open
ON	25 Minutes	Open	Closed
ON	10 Minutes	Open	Open
ON	25 Minutes	Closed	Open
ON	25 Minutes	Open	Closed

Repeat the above sequence 7 times for a total of 21 hours of pump run time

OFF	1 HOUR	Open	Open
OFF	1 HOUR	Closed	Closed
OFF	1 HOUR	Open	Open

Appendix B

RESULTS:

Pre-Test: - "WATER LEAK TEST"

1st Run - Inspected valves and fittings

- Fittings okay, no leaks
- FCV – 100 operated fine
- FCV – 300 binds in the up stroke (closed to open)
  - (From open to close works fine)

2nd Run – Inspected valves and fittings

- No leaks at valves, fittings, or PT's
- Valve 300 operated fine closing
  - 1st time opened the valve chattered
  - 2nd time operated smooth open and closed

Test 1: - "INITIAL START UP TEST "

- Started up pump (auto mode)
- Thrust Bearing Temp. 130.99 °F
- Pump stopped on auto, tested FCV100 and FCV300
- No signs of leaks, operated smoothly
- Recalibrated PT200
- Restarted Pump (auto mode)

FCV100	FCV300	Thrust Bearing Temp. (°F)	Pump Power (Amp)	PT100 (psi)	PT200 (psi)
Closed	Open	139.77	25 – 36	27 – 32	27 – 34
Open	Closed	148	36	39 – 40	43 – 44
Closed	Open		20 – 35	27 – 32	31 – 35
Open	Closed	150.6	Stable	Stable	Stable

- Pump stopped on auto (timed out for 1 minute)
- Opened and closed FCV100 and FCV300
- Smooth operation on both

Test 1: - "INITIAL START UP TEST "

(Page 2 of 2)

Figure 5. Pressure versus temperature for Taylor (PT100) and Dynisco (PT200) pressure transducers, during the initial start up test

Test 3: "VALVE POSITIONING WITH SALT AT 550 °F"
(Page 1 of 9)

Test 1:

- Started Pump (auto mode)
- Paused both valves, operated smoothly
- Recalibrated PT200
- Restarted Pump
- Thrust Bearing Temp. 97 °F

Hour	Sump Level	FCV100	FCV300	TB Temp. (°F)	Zone 2 (°F)	Zone 4 (°F)	PT100 (psi)	PT200 (psi)
1	39.44			108			Stable	Stable
				124				41 – 48
2		Closed	Open	124	510 - 490		29	40
Pump tripped on heat trace, low limit on Zone 2								
		Closed	Open	114			30	41
Pump tripped, low limit heat trace unknown								
				107	483 - 470			
10 min. Run		Open	Open	105		540	19	29
Zone 4 tripped on low limit, reset limits on both Zones to 450 °F								
3		Open	Closed	105.7	480	479		
					468	460		
				102			39	49
4			Open	99	434	440	27 – 32	36 - 42

- Auto Stop Pump
- Both valves opened and closed roughly
- Closed valves and they operated smoothly
- Test finished well! ☺

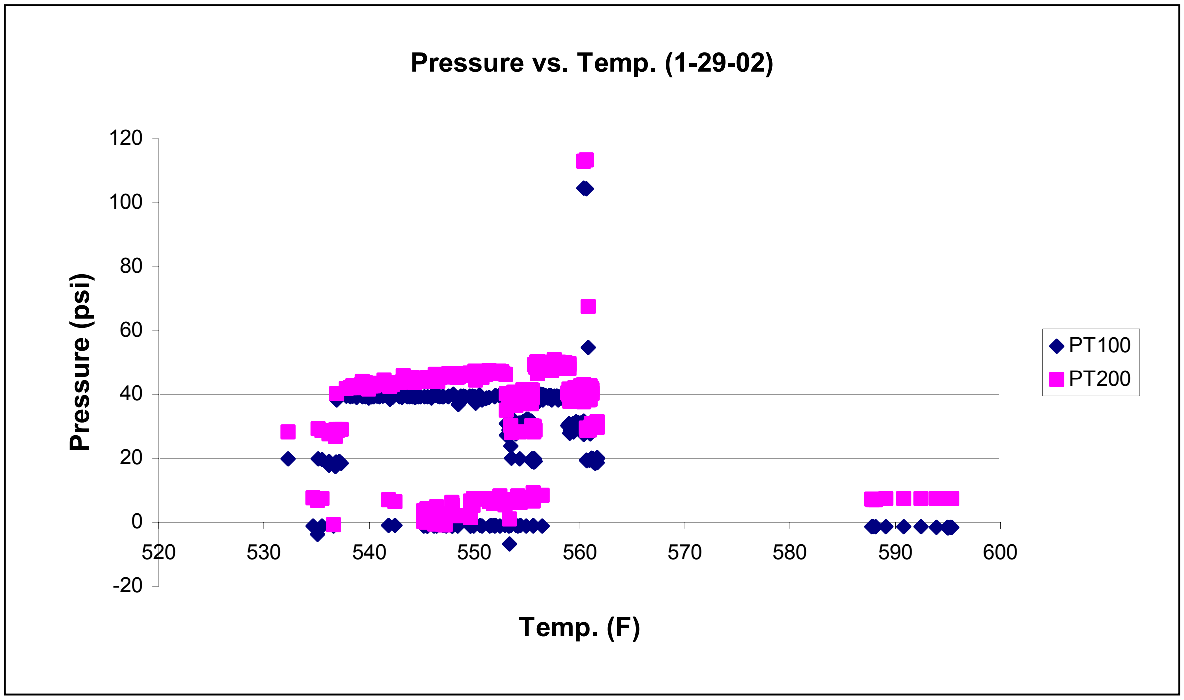


Figure 6. Pressure versus temperature for Taylor (PT100) and Dynisco (PT200) pressure transducers, during test 1 of the valve-positioning test at 550 °F

Test 2:

- Sump Level: 39.9
- Zone 1: 556 °F
- Zone 2: 653 °F - Low limit: 500°F
- Zone 4: 688 °F - Low limit: 500°F
- Thrust Bearing Temp. 80.3 °F
- Pump turns by hand
- 560 °F – Turned fan on
-

- Started Pump (auto mode)
- Thrust Bearing Temp. 94 °F
- TC100 - 57 °F – Leak Detection
- TC300 – 218 °F – Leak Detection
- Valves operate smoothly

TC100 (°F)	TC300 (°F)	Sump Level	FCV100	FCV300	TB Temp. (°F)	Zone 1 (°F)	Zone 2 (°F)	Zone 4 (°F)	PT100 (psi)	PT200 (psi)
57	218	39.6			94	545	606	602	19.9	17.58
60	182	39.6	Open	Closed	105	546	604	602	39	42 - 45
62	124	39.7			117	557	528	553	39	43 - 47
57	134	39.8	Closed	Open	114	558	519	553	27 - 31	32 - 37
64	119	39.7			109	551	496	553	28 - 31	32 - 37
			Open	Open					19	23 - 26
55	147	39.7	Open	Closed	106	553	492	530	39	45-47
Pump tripped on low temp. heat trace zones 2 and 4 – Z-2: 458 °F, Z-4: 470 °F										
52	138	39.8			94	554	443	420	39	43-46
51	194	39.7	Closed	Open	99	556	458	484	29-30	35-38
48	187	39.7			98	558	437	439	29-31	35-39
52	188	39.7	Open	Open	97	560	450	453	19	28

- Both valves operated smoothly
- No leaks

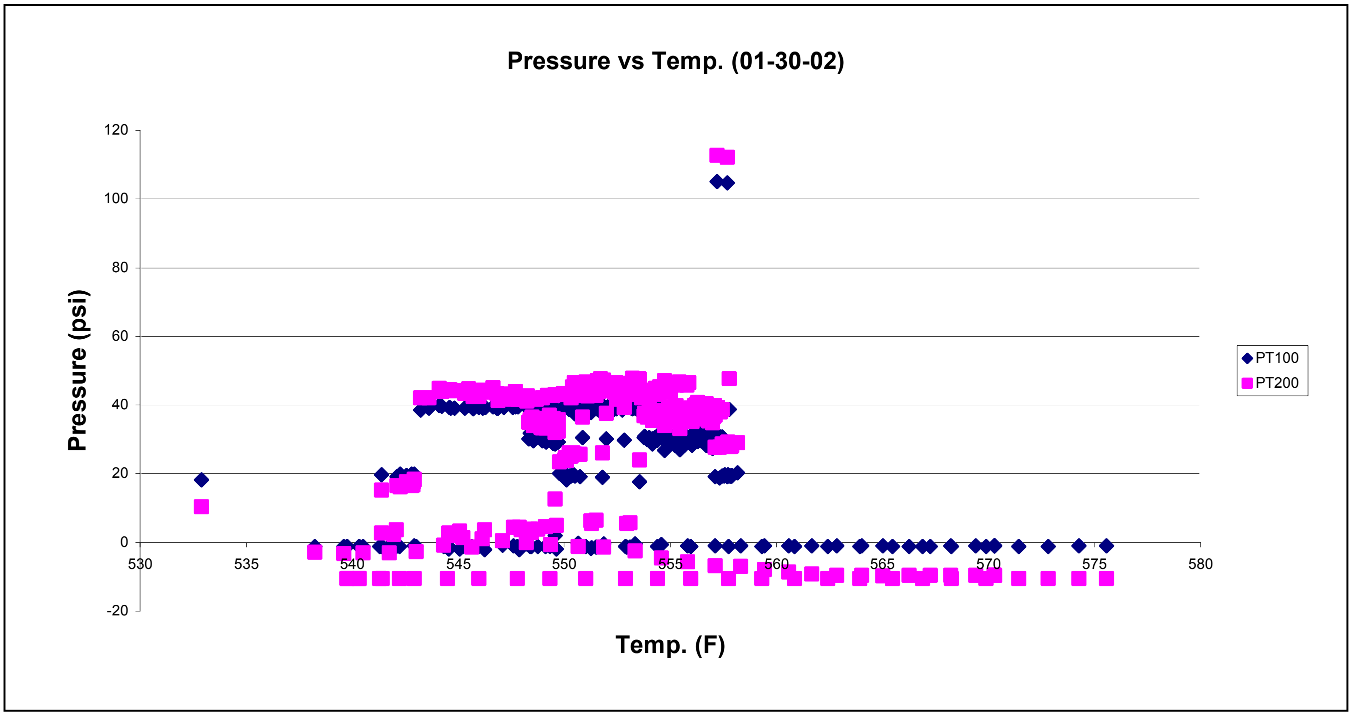


Figure 7. Pressure versus temperature for Taylor (PT100) and Dynisco (PT200) pressure transducers, during test 2 of the valve-positioning test at 550 °F

Test 3:

- Started Pump (auto mode)
- FCV100 – Open
- FCV300 - Open
- Sump Level: 39.4
- Zone 1: 541 °F
- Zone 2: 693 °F
- Zone 4: 667 °F
- Thrust Bearing Temp. 140 °F
- TC100 - 133 °F – Leak Detection
- TC300 – 112 °F – Leak Detection
- Auto Stop and Pause
- Valves operate smoothly
- No signs of salt leakage

TC100 (°F)	**TC300 (°F)**	**Sump Level**	**FCV100**	**FCV300**	**TB Temp. (°F)**	**Zone 1 (°F)**	**Zone 2 (°F)**	**Zone 4 (°F)**	**PT100 (psi)**	**PT200 (psi)**
144	150	39.5	Open	Closed	143	544	671	649		
113	99	39.5			148	550	637	611		
79	83	39.6	Closed	Open	151	557	610	598		
86	81	39.8			152	559	598	598	29	35
84	74	39.7	Open	Open	153	555	587	605	19	23
84	64	39.7	Open	Closed	153	555	585	603	39	44
102	112	39.8			152	558	579	605	39	46
97	160	39.8	Closed	Open	153	554	573	597	30	35
122	162	39.7			152	555	571	603	30	39
99	63	39.8	Open	Open	154	553	572	591	19	30
Auto Run did not work, tripped out pump. Had to run pump manually.										
			Closed	Closed	Both valves operated smoothly, No leaks					

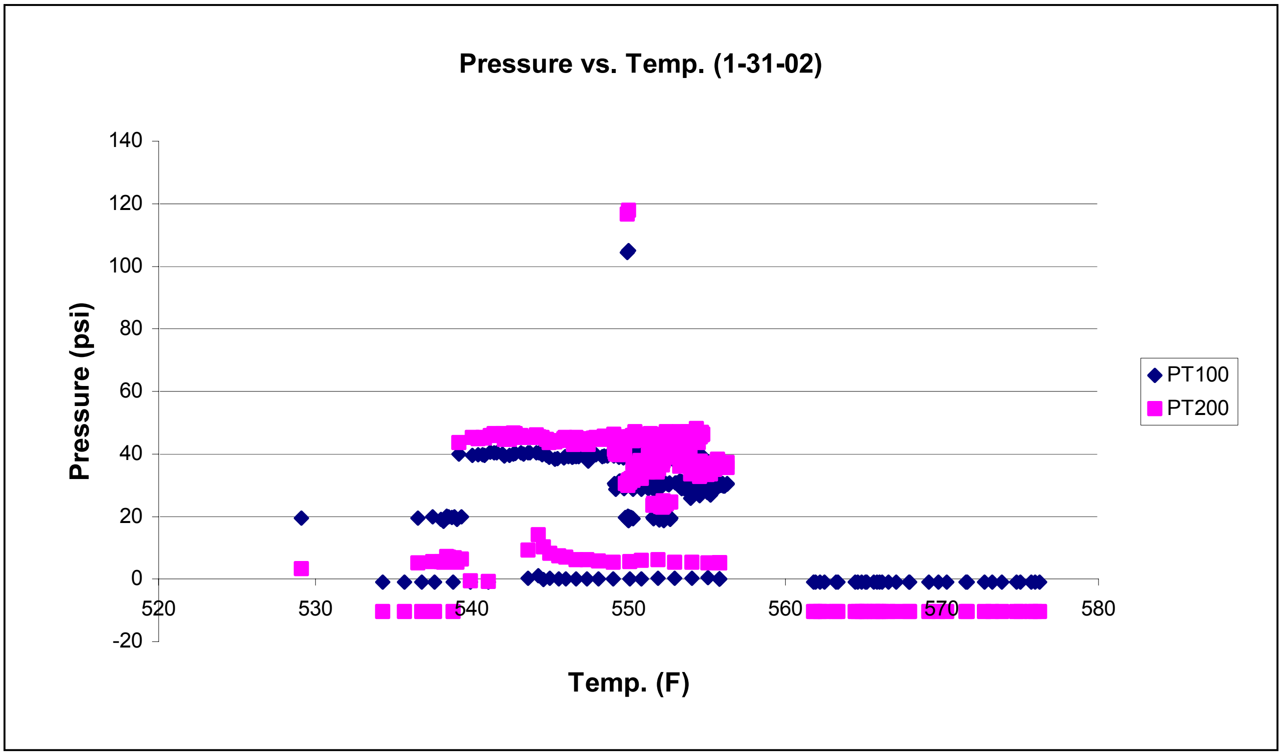


Figure 8. Pressure versus temperature for Taylor (PT100) and Dynisco (PT200) pressure transducers, during test 3 of the valve-positioning test at 550 °F

<u>Test 4:</u>

- Started Pump (auto mode)
- FCV100 – Open
- FCV300 - Open
- Sump Level: 39.3
- Zone 1: 552 °F
- Zone 2: 707 °F
- Zone 4: 699 °F
- Thrust Bearing Temp. 99 °F
-
- TC100 - 186 °F
- TC300 – 198 °F
- PT100 – 12 psi
- PT200 - 18 psi
- Auto Stop and Pause
- Valves operate smoothly
- No signs of salt leakage

TC100 (°F)	TC300 (°F)	Sump Level	FCV100	FCV300	TB Temp. (°F)	Zone 1 (°F)	Zone 2 (°F)	Zone 4 (°F)	PT100 (psi)	PT200 (psi)
190	169	39.3	Open	Closed	114	548	689	670	40	44
195	189	39.5			130	550	648	616	39	49
111	65	39.7	Closed	Open	144	552	621	597	30	44
201	238	39.75			148	554	611	606	30	45
PT200 has gone bad – PT200: 160psi										
106	100	39.8	Open	Open	152	556	603	597	19	119
90	94	39.78	Open	Closed		557	602	598	40	111
79	82	39.8			152	554	594	599	39	110
89	153	39.8	Closed	Open	151	555	585	600	30	85
67	80	39.8			147	558	576	604	30	77
98	103	39.8	Open	Open	143	558	570	596	19	64
Manually Started Pump; Closed FCV100 and FCV300										
Test completed. Valves operated smoothly, no salt leaks										

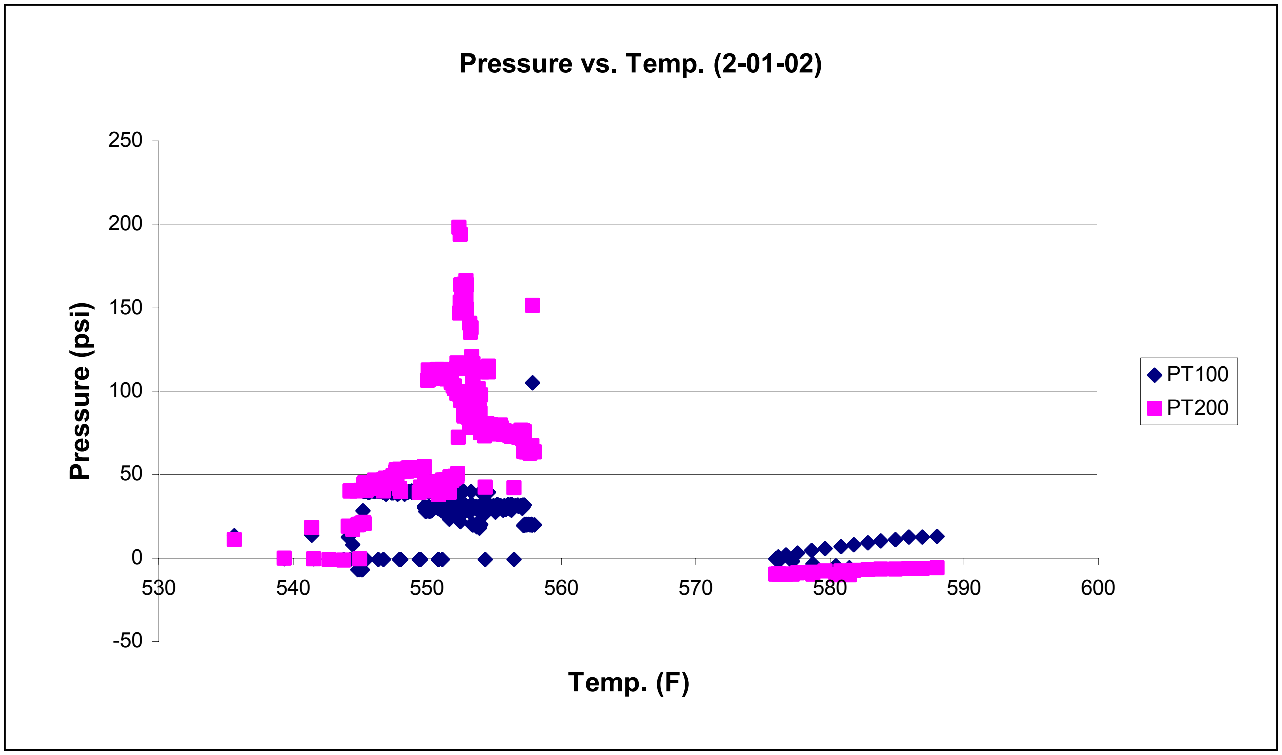


Figure 9. Pressure versus temperature for Taylor (PT100) and Dynisco (PT200) pressure transducers, during test 4 of the valve-positioning test at 550 °F PT200 has gone bad.

<u>Test 5:</u>

- Started Pump (auto mode)
- FCV100 – Open
- FCV300 – Open (Salt leak around stem of FCV300)
- Sump Level: 39.4
- Zone 1: 554 °F
- Zone 2: 669 °F
- Zone 4: 647 °F
- Thrust Bearing Temp. 87 °F
- TC100 - 109 °F
- TC300 – 169 °F
- PT100 – 18 psi
- PT200 - 30 psi
- Auto Stop and Pause
- Valves operate smoothly
- No signs of new salt leaking at FCV300

TC100 (°F)	TC300 (°F)	Sump Level	FCV100	FCV300	TB Temp. (°F)	Zone 1 (°F)	Zone 2 (°F)	Zone 4 (°F)	PT100 (psi)	PT200 (psi)
89	128	39.7	Closed	Open	87	560	506	589	30	40
174	114	39.8	Open	Closed	92	559	548	580	39	51
146	176	39.6	Closed	Open	95	547	550	596	30	39
158	173	39.65	Open	Open	125	550	557	598	19	33
Auto Stopped pump and paused FCV100 opened and closed smoothly FCV300 has signs of salt leaking around stem of valve, opened rough first time, smooth second time										
			Closed	Closed	Fittings look good; 1 minute run					

Note: Salt leaking around pump shaft just like initial 5000-hour test.

Test 4: "VALVE POSITIONING WITH SALT AT 750 °F"
(Page 1 of5)

Test 1:

- FCV 300 shows signs of salt leakage, ⅛" thick and ½" up shaft.
- FCV100 high temp limit rose to 750 °F, not to go higher than 750 °F

- Started Pump (auto mode)
- FCV100 – Open
- FCV300 – Open
- Sump Level: 40.5
- Zone 1: 718 °F
- Zone 2: 719 °F
- Zone 4: 705 °F
- Thrust Bearing Temp. 134 °F
- TC100 - 187 °F
-
- TC300 – 183 °F
- TC8 – 564 °F
- PT100 – 18 psi
- PT200 - 58 psi
- Auto Stop and Pause
- Valves operate smoothly
- No signs of new salt leaking at FCV300

TC100 (°F)	TC300 (°F)	Sump Level	FCV100	FCV300	TB Temp. (°F)	Zone 1 (°F)	Zone 2 (°F)	Zone 4 (°F)	PT100 (psi)	PT200 (psi)
88	73	40.7	Open	Closed	146	710	667	635		
Paused to recalibrate PT200; TC8: 548 °F, not to go over 750 °F										
81	46	40.8	Closed	Open	146	714	610	601	30	73
106	161	41	Open	Open	146	722	589	604	19	68
103	115	41	Open	Closed	146	724	586	596	39	83
90	84	41	Closed	Open	146	735	582	606	30	80
100	110	41	Open	Open	145	745	580	602	18	74
Auto stopped and paused FCV100 opened and closed smoothly FCV300 Closed and opened roughly, tried again and it closed and opened smoothly Signs of salt leak around pump shaft No sign of leaks at fittings										
1 minute run, FCV100 and FCV300 closed										

Test 2:

- Started Pump (auto mode)
- FCV100 – Open
- FCV300 – Open
- Sump Level: 40.8
- Zone 1: 728 °F
- Zone 2: 548 °F
- Zone 4: 598 °F
- Thrust Bearing Temp. ___°F
-
- TC100 - 155 °F
- TC300 – 233 °F
- Auto Stop and Pause
- Recalibrated PT200
- Valves operate smoothly
- Slight leak on stem at FCV300

TC100 (°F)	**TC300 (°F)**	**Sump Level**	**FCV100**	**FCV300**	**TB Temp. (°F)**	**Zone 1 (°F)**	**Zone 2 (°F)**	**Zone 4 (°F)**	**PT100 (psi)**	**PT200 (psi)**
201	110		Open	Closed	105	730	558	602	39	54
126	76	41.1	Closed	Open	133	740	577	603	29	61
153	87	41.3	Open	Closed	151	758	593	594	38	80
131	80	41.06	Closed	Open	154	758	594	604	29	76
100	141	41.11	Open	Open	157	752	592	600	18	64
Auto paused and stopped pump Both valves operated smoothly Slight salt leak at stem of FCV300										

Test 4: "VALVE POSITIONING WITH SALT AT 750 °F"
(Page 3 of 5)

Test 3:

- Started Pump (auto mode)
- FCV100 – Open
- FCV300 – Open
- Sump Level: 41
- Zone 1: 741 °F
- Zone 2: 522 °F
- Zone 4: 595 °F
- Thrust Bearing Temp. 81°F
- TC100 - 80 °F
- TC300 – 142 °F
- Auto Stop and Pause
- Recalibrated PT200
- Valves operate smoothly
- No sign of new salt leak at FCV300

TC100 (°F)	TC300 (°F)	Sump Level	FCV100	FCV300	TB Temp. (°F)	Zone 1 (°F)	Zone 2 (°F)	Zone 4 (°F)	PT100 (psi)	PT200 (psi)
103	173	41	Open	Closed	112	745	551	603	39	68
63	155	41.2	Closed	Open	122	756	542	589	29	66
65	114	41.3	Open	Open	104	558	516	576	19	55
64	137	41.2	Open	Closed	103	559	511	569	39	80
68	149	41.1	Closed	Open	97	753	511	558	29	67
75	130	41.2	Open	Open	10	753	497	530	19	60
Auto paused and stopped pump										
1 minute run; FCV 100 Closed, FCV300 Closed										
Both valves operated smoothly Slight leak on stem of FCV300; film of salt on stem No salt leaks at fittings										

Test 4: "VALVE POSITIONING WITH SALT AT 750 °F"
(Page 4 of 5)

Test 4:

- Started Pump (auto mode)
- FCV100 – Open
- FCV300 – Open
- Sump Level: 41
- Zone 1: 735 °F
- Zone 2: 542 °F
- Zone 4: 602 °F
- Thrust Bearing Temp. 92°F
- TC100 - 185 °F
- TC300 – 100 °F
- PT100 – 18psi
- PT200 – 22psi
- Auto Stop and Pause
- Recalibrated PT200
- Valves operate smoothly
- No sign of new salt leak at FCV300

TC100 (°F)	TC300 (°F)	Sump Level	FCV100	FCV300	TB Temp. (°F)	Zone 1 (°F)	Zone 2 (°F)	Zone 4 (°F)	PT100 (psi)	PT200 (psi)
180	125	40.8	Open	Closed	100	734	551	602	39	48
157	116	41	Closed	Open	138	744	576	597	29	58
68	106	41.2	Open	Open	149	755	557	605	18	62
62	98	41.1	Open	Closed	143	754	537	602	39	81
174	127	41.2	Closed	Open	145	755	568	595	29	75
86	129	41.1	Open	Open	137	755	550	595	18	69
Auto pause and stopped pump										
1 minute run; FCV 100 Closed, FCV300 Closed Manual start and stop of pump										
Pressure transducer offset PT200 with pump off 42 psi										

Shut down system. Field verified open FCV100 and FCV300.

FCV100 operates smoothly
FCV300 when opened, brought up with the shaft approximately 2tbs of salt. The salt ran off the shaft and froze on top of the hanging. Waited several minutes then closed the valve, which operated smoothly. Opened the valve again, when opened it brought molten salt up with it again, however, the amount was much less.

Test 5:

- Started Pump (auto mode)
- FCV100 – Open
- FCV300 – Open
- Sump Level: 41
- Zone 1: 734 °F
- Zone 2: 658 °F
- Zone 4: 652 °F
- Thrust Bearing Temp. 72°F
- TC100 - 162 °F
- TC300 – 48 °F

- PT100 – 18 psi
- PT200 – 14.61 psi
- Auto Stop and Pause
- Recalibrated PT200
- Valves operate smoothly
- No sign of new salt leak at FCV300

TC100 (°F)	**TC300 (°F)**	**Sump Level**	**FCV100**	**FCV300**	**TB Temp. (°F)**	**Zone 1 (°F)**	**Zone 2 (°F)**	**Zone 4 (°F)**	**PT100 (psi)**	**PT200 (psi)**
160	42	40.92	Open	Closed	79	736	635	631	38	51
133	89	41.2	Closed	Open	139	758	589	602	27	66
77	83	41.2	Open	Closed	141	762	568	597	40	89
122	150	41.2	Closed	Open	134	748	563	596	28	78
89	182	41.2	Open	Open	141	749	566	601	18	73
Auto paused and stopped pump Valves operated smoothly Slight amount of salt leaking at stem of FCV300										
1 minute run; both valves closed										

Both valve operated smoothly. New salt leak after we deadheaded the pump. No leaks at the fittings.

Test 5: "VALVE POSITIONING WITH SALT AT 1050 °F"
(Page 1 of 5)

Test 1:

- Started Pump (auto mode)
- FCV100 – Open
- FCV300 – Open
- Sump Level: 43.2
- Zone 1: 1021 °F
- Zone 2: 566 °F
- Zone 4: 596 °F
- Thrust Bearing Temp. 103°F
- TC100 - 204 °F
- TC300 – 83 °F
- PT100 – 17 psi
- PT200 – 130 psi
- Auto Stop and Pause
- Recalibrated PT200
- Valves operated smoothly
- No sign of new salt leak at FCV300

TC100 (°F)	TC300 (°F)	Sump Level	FCV100	FCV300	TB Temp. (°F)	Zone 1 (°F)	Zone 2 (°F)	Zone 4 (°F)	PT100 (psi)	PT200 (psi)
194	120	43.0	Open	Closed	109	1012	615	641	36	131
TC8 – 597 °F TC8 – 740 °F, TC100 – 160 °F Had to open FCV300 to cool down FCV100 was at 750 °F Went ahead and closed FCV100, TC8 – 745 °F with 7 minutes left in 1st hour run.										
149	102	43.3	Closed	Open	137	1019	735	704	28	123
TC8 – 733 °F										
97	78	43.4	Open	Open	159	1029	763	749	18	114
TC8 – 603 °F										
118	98	43.4	Open	Open	160	1030	766	747	37	137
TC8 – 649 °F										
136	157	43.4	Closed	Open	165	1038	793	748	26	129
TC8 – 729 °F, TC12 – 1008 °F										
91	84	43.4	Open	Open	165	1050	803	758		
Auto stopped and paused pump Valves operated smoothly Leakage at FCV300										
1 minute run, both valves closed Valves operated smoothly 1tbs of new salt at FCV300, salt on the shaft										

Note: Insulation is out gassing, smell is bad.

<u>Test 2:</u>

- Started Pump (auto mode)
- FCV100 – Open
- FCV300 – Open
- Sump Level: 43.2
- Zone 1: 1028 °F
- Zone 2: 579 °F
- Zone 4: 603 °F
- Thrust Bearing Temp. 110°F
- TC100 - 82 °F
- TC300 – 49 °F
- TC8 – 626 °F
- PT100 – 17 psi
- PT200 – 96 psi
- Auto Stop and Pause
- Recalibrated PT200
- Valves operated smoothly
- After valve FCV300 closed, it brought salt back up when it opened

TC100 (°F)	**TC300 (°F)**	**Sump Level**	**FCV100**	**FCV300**	**TB Temp. (°F)**	**Zone 1 (°F)**	**Zone 2 (°F)**	**Zone 4 (°F)**	**PT100 (psi)**	**PT200 (psi)**
104	52	43.2	Open	Closed	111	1028	615	635	36	119
TC8 – 664 °F										
78	43	43.3	Closed	Open	127	1042	741	725	27	107
TC8 – 585 °F										
67	41	43.3	Open	Closed	127	1044	745	731	37	115
TC8 – 598 °F										
720	42	43.3	Open	Open	131	1050	762	738	17	103
TC8 – 680 °F										
81	47	43.4	Closed	Open	132	1052	763	739	27	110
TC8 – 703 °F										
69	47	43.5	Open	Closed	129	1052	767	748	37	116
TC8 – 604 °F										
85	65	43.4	Open	Closed	133	1046	747	729	38	116
TC8 – 693 °F, 33.1 Amps										
79	62	43.4	Open	Open	138	1047	754	738	17	102
TC8 – 699 °F, 33.4 Amps										
Auto stop pump pause Both valves operated smoothly FCV300 had about 3tbs of salt leakage										
1 minute run, both valve closed Both valve operated smoothly FCV300 brought more salt about ½ tbs										
No salt leakage at fittings										

Test 5: "VALVE POSITIONING WITH SALT AT 1050 °F"
(Page 3 of 5)

Test 3:

- Started Pump (auto mode)
- FCV100 – Open
- FCV300 – Open
- Sump Level: 43.3
- Zone 1: 1039 °F
- Zone 2: 541 °F
- Zone 4: 593 °F
- Thrust Bearing Temp. 71 °F
- TC100 - 103 °F
- TC300 – 73 °F
- TC8 – 577 °F
- PT100 – 17 psi
- PT200 – 79 psi
- Auto Stop and Pause
- Recalibrated PT200
- Valves operated smoothly
- No new signs of salt leakage from FCV300

TC100 (°F)	TC300 (°F)	Sump Level	FCV100	FCV300	TB Temp. (°F)	Zone 1 (°F)	Zone 2 (°F)	Zone 4 (°F)	PT100 (psi)	PT200 (psi)
71	104	43.2	Open	Closed	80	1034	591	636	36	119
TC8 – 664 °F										
152	102	43.4	Closed	Open	133	1049	752	721	27	146
TC8 – 653 °F										
130	177	43.4	Open	Closed	136	1051	759	720	37	157
TC8 – 697 °F										
114	119	43.5	Open	Open	144	1054	781	739	17	138
TC8 – 741 °F										
121	123	43.4	Closed	Open	145	1054	784	784	27	123
TC8 – 682 °F										
91	92	43.4	Open	Closed	165	1048	809	764	38	146
TC8 – 708 °F										
100	91	43.4	Open	Closed	154	1045	787	751	37	147
TC8 – 718 °F										
133	168	43.4	Open	Open	155	1047	795	746	18	129
TC8 – 719 °F										
Auto stop pump and pause Both valves operated smoothly 2-3 tbs of salt leakage from FCV300										
1 minute run, both valves closed Both valves operated smoothly No salt leakage from valve or fittings										

<u>Test 4:</u>

- Started Pump (auto mode)
- FCV100 – Open
- FCV300 – Open
- Sump Level: 43.3
- Zone 1: 1036 °F
- Zone 2: 542 °F
- Zone 4: 589 °F
- Thrust Bearing Temp. 92 °F
- TC100 - 153 °F
- TC300 – 121 °F
- TC8 – 583 °F
- PT100 – 17 psi
- PT200 – 73 psi
- Auto Stop and Pause
- Recalibrated PT200
- Valves operated smoothly
- No new signs of salt leakage from FCV300

TC100 (°F)	TC300 (°F)	Sump Level	FCV100	FCV300	TB Temp. (°F)	Zone 1 (°F)	Zone 2 (°F)	Zone 4 (°F)	PT100 (psi)	PT200 (psi)
243	74	43.2	Open	Closed	107	1034	626	624	37	74
TC8 – 701 °F										
175	78	43.3	Closed	Open	99	1045	743	710	27	112
TC8 – 591 °F										
141	158	43.4	Open	Closed	127	1053	767	726	38	128
TC8 – 707 °F										
102	115	43.4	Open	Open	132	1055	772	739	17	114
TC8 – 706 °F										
113	104	43.4	Closed	Open	137	1054	778	738	27	125
TC8 – 719 °F The pump tripped, leak detection from FCV300, about 3tbs of salt										
102	144	43.3	Open	Closed	157	1053	787	755	38	128
TC8 – 720 °F										
110	199	43.4	Open	Open	160	1055	796	753	17	119
TC8 – 728 °F										
Auto stop pump and pause Both valves operated smoothly 3 tbs of salt leakage from FCV300, seems to be getting worse										
1 minute run, both valves closed Both valves operated smoothly FCV300 leaked, about 3tbs of salt during dead head										
No leakage from the fittings										

Test 5: “VALVE POSITIONING WITH SALT AT 1050 °F”

Test 5:

- Started Pump (auto mode)
- FCV100 – Open
- FCV300 – Open
- Sump Level: 43.3
- Zone 1: 1038 °F
- Zone 2: 536 °F
- Zone 4: 588 °F
- Thrust Bearing Temp. 82 °F
- TC100 - 57 °F
- TC300 – 139 °F
- TC8 – 580 °F
- PT100 – 17 psi
- PT200 – 75 psi on meter, 10 psi on the computer
- Auto Stop and Pause
- Recalibrated PT200
- Valves operated smoothly
- No new signs of salt leakage from FCV300

TC100 (°F)	TC300 (°F)	Sump Level	FCV100	FCV300	TB Temp. (°F)	Zone 1 (°F)	Zone 2 (°F)	Zone 4 (°F)	PT100 (psi)	PT200 (psi)
169	123	43.2	Open	Closed	96	1036	591	629	36	121
TC8 – 668 °F										
189	89	43.3	Closed	Open	144	1050	761	730	27	135
TC8 – 685 °F										
108	100	43.4	Open	Closed	147	1052	770	730	37	144
TC8 – 705 °F										
152	96	43.5	Open	Open	154	1054	797	754	17	
TC8 – 766 °F										
150	70	43.4	Closed	Open	156	1053	800	761	27	130
TC8 – 748 °F										
106	62	43.4	Open	Closed	167	1048	810	766	37	126
TC8 – 726 °F										
105	105	43.3	Open	Closed	165	1046	788	756	36	127
TC8 – 716 °F										
123	190	43.3	Open	Open	165	1048	793	750	17	113
TC8 – 697 °F										
Auto stop pump and pause Both valves operated smoothly 4 tbs of salt leakage from FCV300, still seems to be getting worse PT200 - 83 psi										
1 minute run, both valves closed Both valves operated smoothly FCV300 leaked, about 2tbs of salt										

Test 6: - "LONG-TERM TEST"
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Initial sump level: 43.37
Sump level trip: 42"

Day 1:
Pump tripped; TC8 was over 750 °F
FCV100 opened
FCV300 closed
Operated smoothly; tripped with 4 minutes left in first cycle

Continues to next step of test.
FCV100 opened
FCV300 opened
Allow FCV100 to cool down
Raised high limit pump trip to 800 °F on TC8

First cycle:

Sump level: 43.5
TC100: 121 °F
TC300: 72 °F

Day 2:
About 1 cup of salt leaked from FCV300
Both valves operated smoothly
Sump level: 43.53
Completed 3 cycles and part of first 60 minute run with pump off and both valves open
PT200 leaking, tightened ¼" turn
Fittings not leaking

Day 3:
About 1 cup of salt leaked at FCV300
Sump level: 43.59
Completed 1 cycle
Changes to program were made
PT200 stopped leaking
Fittings not leaking

Day 4:
Salt leak at FCV300 seems to be increasing, 1 cup +
Fittings and PT200 not leaking
Sump level: 43.6

Test 6: - "LONG-TERM TEST"
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Day 5:

Salt leak at FCV300 was slightly less than prior days, only about ½ cup
Sump level: 43.59
No leaks at fittings or PT200
FCV100 operated roughly
FCV300 operated smoothly

Day 6:

Should have completed 12 cycles, computer shows 11 cycles completed and 1 hour and 8 minutes of the 12th cycle. Timer may be off?

Sump level: 43.4
About 3 cups of salt leaked from FCV300 – much worse than before!
Salt is leaking out of hot to cold shim stock tower

1 Week Later:

Insulation removed to identify salt leak at PT200 or the 2 sets of fittings. Also took insulation off to remove PT200 to be sent back for calibration from Dynisco (this will not happen in FY02 due to funding). The 37 ° flared fittings were loose and needed to be tightened approximately ⅛th turn. The Swagelock did not tighten. There appeared to be a leak from FCV100 once all the insulation was removed.