CONTRACTOR REPORT

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UC–237

Construction of the Molten Salt Pump and Valve Loops

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CONSTRUCTION REPORT FOR MOLTEN SALT SUBSYSTEM/COMPONENT TEST EXPERIMENT UTILITY-SCALE MOLTEN SALT PUMPS AND VALVES FOR SOLAR CENTRAL RECEIVERS

Patricia A. Bator
and
Ralph L. Dowling
The Babcock & Wilcox Company
Nuclear Equipment Division
Sandia Contract 91-4687

ABSTRACT

The purpose of the molten salt pump and valve test loop is to demonstrate the performance, reliability, and lifetime of full-scale hot and cold salt pumps and valves for use in a commercial salt-in-tube receiver solar power plant. The test hardware consists of two pumped loops, one to simulate the hot side of the receiver at a temperature of 565°C (referred to as the hot loop) and one to simulate the receiver's cold side at 285° C (referred to as the cold loop). Each loop contains a pump and five representative valves sized for a 60-MW_e commercial solar power plant using molten salt heat transport fluid. The test loop is part of the Molten Salt Subsystem/Component Test Experiment, which is being conducted to reduce the technical risk of building and operating commercial solar central receiver plants. The project, managed by Sandia National Laboratories with Babcock and Wilcox as the prime contractor, is cost shared by the U.S. Department of Energy and six contractors.

FOREWORD

The research and development described in this document were conducted within the U. S. Department of Energy's Solar Thermal Technology Program. The goal of the Solar Thermal Technology Program is to advance the engineering and scientific understanding of solar thermal technology and to establish the technology base from which private industry can develop solar thermal power production options for introduction into the competitive energy market.

Solar thermal technology concentrates solar radiation by means of tracking mirrors or lenses onto a receiver where the solar energy is absorbed as heat and converted into electricity or incorporated into products as process heat. The two primary solar thermal technologies, central receivers and distributed receivers, employ various point and line-focus optics to concentrate sunlight. Current central receiver systems use fields of heliostats (two-axis tracking mirrors) to focus the sun's radiant energy onto a single tower-mounted receiver. Parabolic dishes up to 17 meters in diameter track the sun in two axes and use mirrors to focus radiant energy onto a receiver. Troughs and bowls are line-focus tracking reflectors that concentrate sunlight onto receiver tubes along their focal lines. Concentrating collector modules can be used alone or in a multi-module system. The concentrated radiant energy absorbed by the solar thermal receiver is transported to the conversion process by a circulating working fluid. Receiver temperatures range from 100°C in low-temperature troughs to over 1500°C in dish and central receiver systems.

The Solar Thermal Technology Program is directing efforts to advance and improve promising system concepts through the research and development of solar thermal materials, components, and subsystems, and the testing and performance evaluation of subsystems and systems. These efforts are carried out through the technical direction of the Department of Energy and its network of national laboratories, who work with private industry. Together they have established a comprehensive, goal-directed program to improve performance and provide technically proven options for eventual incorporation into the nation's energy supply.

To be successful in contributing to an adequate national energy supply at reasonable cost, solar thermal energy must eventually be economically competitive with a variety of other energy sources. Components and system-level performance targets have been developed as quantitative program goals. The performance targets are used in planning research and development activities, measuring progress, assessing alternative technology options, and making optimal component developments. These targets will be pursued vigorously to ensure a successful program.

The success of a molten salt solar power plant will depend not only on the development of new components, but also on the application of common components to the new service conditions dictated by molten salt. In particular, large plants will require the application of large pumps and large valves of types that had not previously been tested in molten salt service. Pumps for the required headflow capacity have been successfully designed and operated for other fluids, such as water, and this available technology, together with knowledge developed operating molten salt pumps of lower capacity, served as a basis for large-size molten salt pump designs. In addition, an increase in valve size required changes in the valve stem seal design, and increases in temperature required changes in the valve packing material. The performance and reliability of these components for use in the severe molten salt environment needed to be demonstrated. In order to gain experience with commercial-size pumps and valves, the two test loops were built.

The design and construction of the molten salt pump and valve test loops are described in this report.

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1.0 INTRODUCTION AND SUMMARY

This report provides description and results of the Pump and Valve Test (P&V) headed by the Babcock & Wilcox Company under contract to Sandia National Laboratories. The Pump & Valve Test was conducted as part of the Molten Salt Subsystem/Component Test Experiment (MSS/CTE) [1] to test utility scale pumps and valves. This test was designed to draw from commercial pump and valve technology, supplemented, in the case of the valves by the Bench Test subprogram [2], and establish designs for pumps and valves typical of the those required for the Saguaro molten salt solar power plant [3].

1.1 OBJECTIVES/PURPOSE

The objective of the Pump & Valve Test is to test commercial size pumps and valves in molten salt in order to verify their feasibility for use in a solar central receiver power plant. Due to the limited experience with pump and valve performance in molten salt it was necessary to provide a test environment for these components prior to their use in an intermediate commercial plant.

For the pumps, the objectives are to test each of two pumps over the range of plant operating conditions to:

- Verify pump performance
- Check for vibration and wear
- Check pump seals and bearings
- Evaluate pump maintainability, and
- Identify operating procedures which yield the best performance

For the valves, the objective is to test a variety of valve configurations typical of those a plant designer would use for various control and isolation applications in order to:

- Evaluate/compare valve seals at plant operating conditions
- Test valves for long-term cycling
- Verify valve seat/trim design and materials at conditions for control and shutoff
- Check for evidence of valve erosion, corrosion, and wear

1.0 INTRODUCTION AND SUMMARY

- Determine the drainability of the valve bodies, and
- Confirm the stability of the packing materials screened during the Bench Test in a dynamic environment.

1.2 PROJECT ORGANIZATION

The Pump & Valve Test is supported by a team comprising Arizona Public Service, Black & Veatch - Architects & Engineers, McDonnell Douglas, Olin Chemical, and Southern California Edison. The responsibilities of these members are summarized in Table 1.2-1.

Table 1.2-1 Project Responsibilities

Babcock & Wilcox	Project Management, Pump & Valve Test Test Plan and Scope & Objectives, control system design, test article procurement and fabrication.
Arizona Public Service	Input to Pump & Valve Test tests/designs, assist in test evaluation.
Black & Veatch	Test loop design, hardware specifications, construction specifications and drawings.
McDonnell Douglas	Control system design support.
Olin Chemical	Engineering support and corrosion evaluation.
Southern California Edison	Test design input and assist in test evaluation.

1.3 GENERAL DESCRIPTION

The design, material procurement and fabrication of the Pump & Valve Test loops took place between April of 1984 and February of 1987. The fabrication took place at Sandia National Laboratories Central Receiver Test Facility in Albuquerque, New Mexico. The Pump & Valve Test consists of two adjacent loops, designated hot and cold loops, which each contain one pump and seven control and isolation valves. The salt pumps are set in sump tanks which hold an inventory of molten nitrate salt. The piping is designed in parallel branch paths to allow functioning of valves with continuous operation. Each loop contains one bellows seal control valve and two standard packed control valves. An artists rendering of the Pump & Valve Test showing the overall arrangement of the system with its piping and components is shown in Figure 1.2-1.

A simplified flow schematic of the Pump & Valve Test loops is shown in Figures 1.2-2 and 1.2-3. The cold loop operates at 550°F and a pump discharge pressure of 1250 psig. The hot loop operates at 1050°F and 157 psig. In both loops the flow of molten salt is controlled by two flow control valves in parallel paths and one pressure control valve downstream to maintain operating pressures. General service isolation valves are located in one of the parallel loops and are designed for weekly evaluation of salt leak-by past the valve plug seal. Each valve is packed with an arrangement of Crane 1625gf braided graphite packing interspaced with glass reenforced teflon washers supplied by RM Industrial Products. The additional heat generated by the pumps is removed via salt cooler-heat exchangers to maintain operating temperatures.

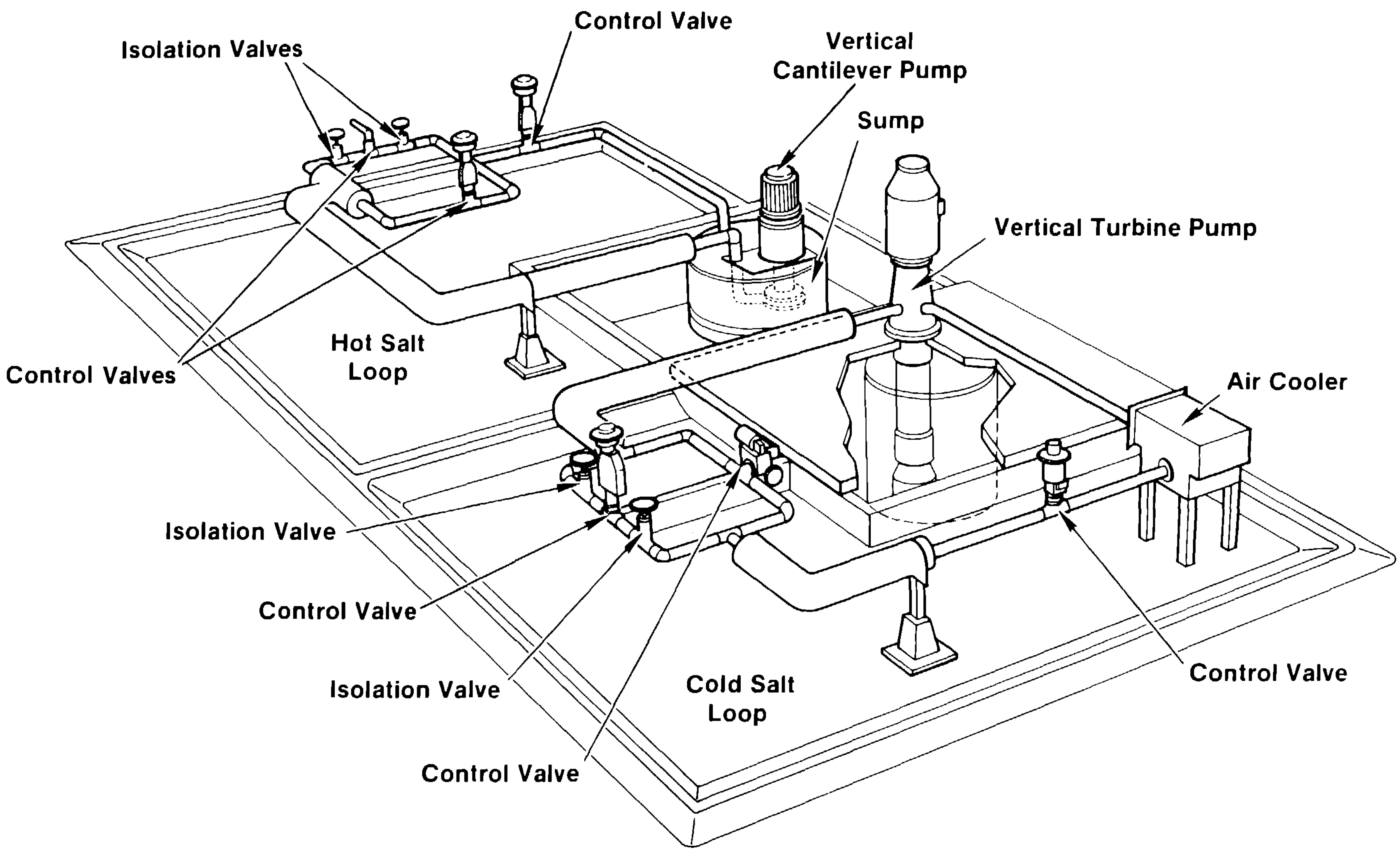


Figure 1.2-1. Artist Rendering of the Pump and Valve Test Loop.

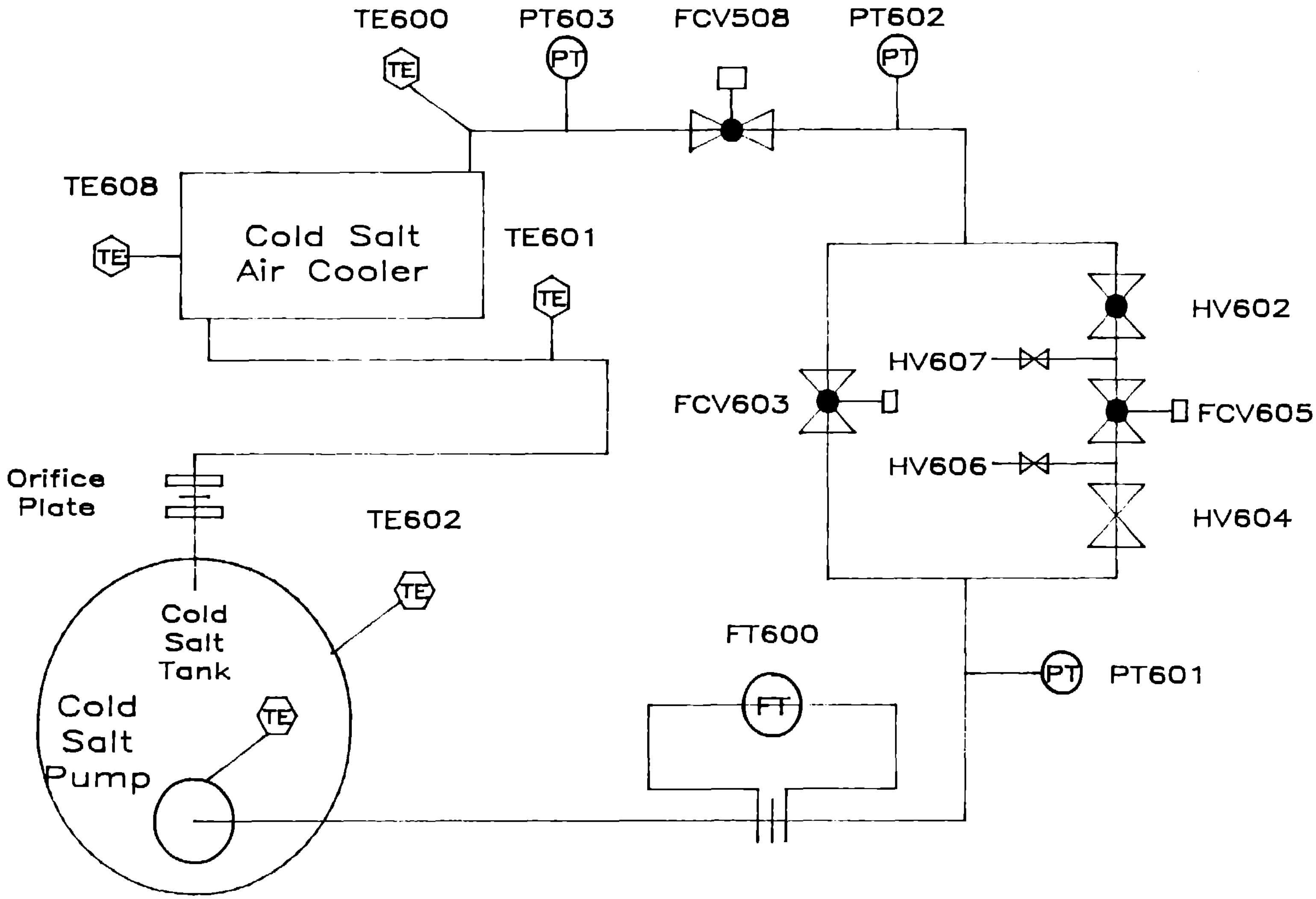


Figure 1.2-2. Cold Loop Schematic.

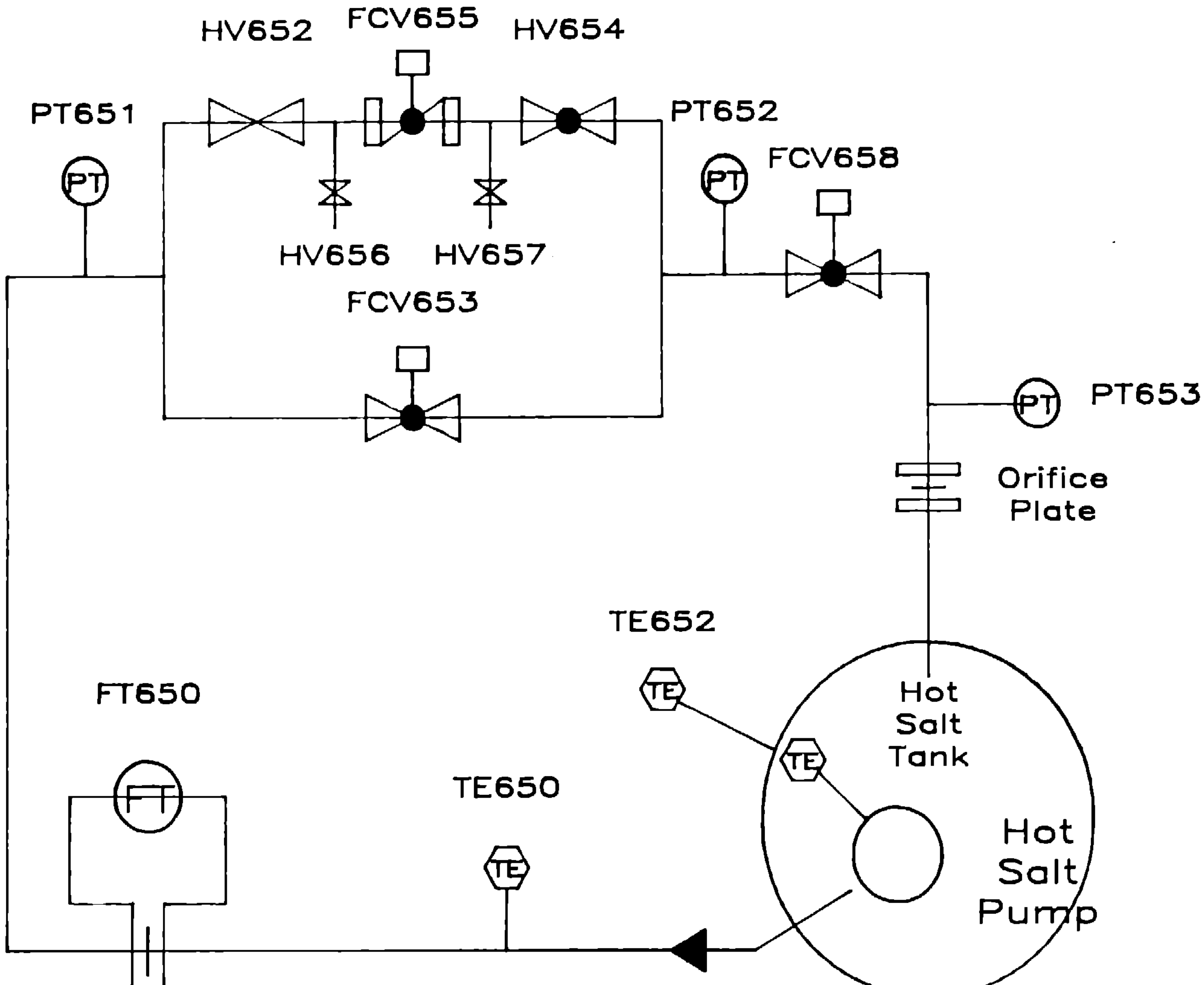


Figure 1.2-3. Hot Loop Schematic.

2.0 PUMP & VALVE TEST LOOP DESIGN

2.1 DESCRIPTION

The Pump and Valve Test was designed to simulate the conditions of the Saguaro molten salt solar power plant [3] as part of the Molten Salt Subsystem/Component Test Experiment (MSS/CTE) [1]. The system has the objectives of verifying the feasibility of full scale molten salt pumps and valves to be used as part of a solar central receiver power plant.

The Pump & Valve Test consists of one hot and one cold loop designed for the following conditions:

	T, °F	P, psig
Cold Loop	575	1650
Hot Loop	1075	200

The hot loop has a 350 horsepower vertical cantilever pump. The cold loop has a 2250 horsepower vertical turbine pump. Components in both loops include two 6 inch globe control valves, one 6 inch rotary control valve, a 10 inch globe isolation valve, a 10 inch gate isolation valve, two 3/4 inch isolation valves, salt cooler, associated 10 inch, and 6 inch piping, heat tracing, controls, and instrumentation. The loops are located within a earthen berm at the south end of CRTF. The general location plan is shown in Figure 2.1-1. The overall arrangement of the loops are shown on B&V Drawing M3001, Figure 2.1-2 and M3002, Figure 2.1-3. The Pump & Valve test is controlled by a Bailey Network 90 control system.

The molten salt is circulated by each pump over a flow range of 1000 to 2300 GPM. At each flow, the two flow control valves operate alternately in automatic control and manual sequencing to maintain flow, while the pressure control valve maintains the system pressure. This sequencing continues over the flow range of the pump during a two hour test cycle. Each cycle was designed for 1-1/2 hours of actual testing and 1/2 hour for pump cool down prior to restart of the pump. For maximum cycling and operation the loops are designed for continuous testing 24 hours/day, 7 days/week. Half a day every week is set aside for leak-by testing of the isolation valves in the parallel branch of each loop. This continuous sequencing allows for evaluation of performance of the pumps and valves in a molten salt environment.

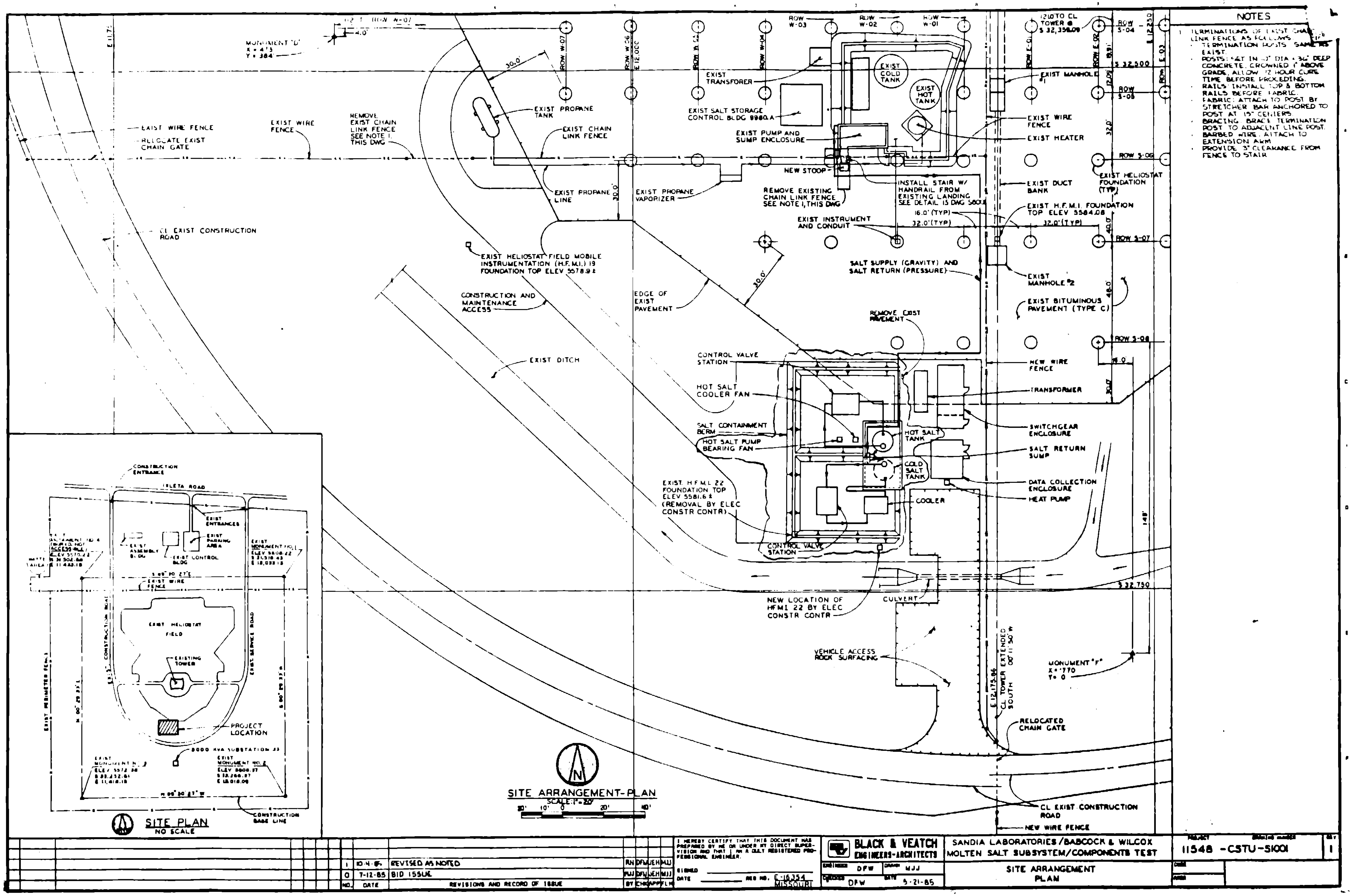


Figure 2.1-1. General Location Plan. B&V Drawing S1001.

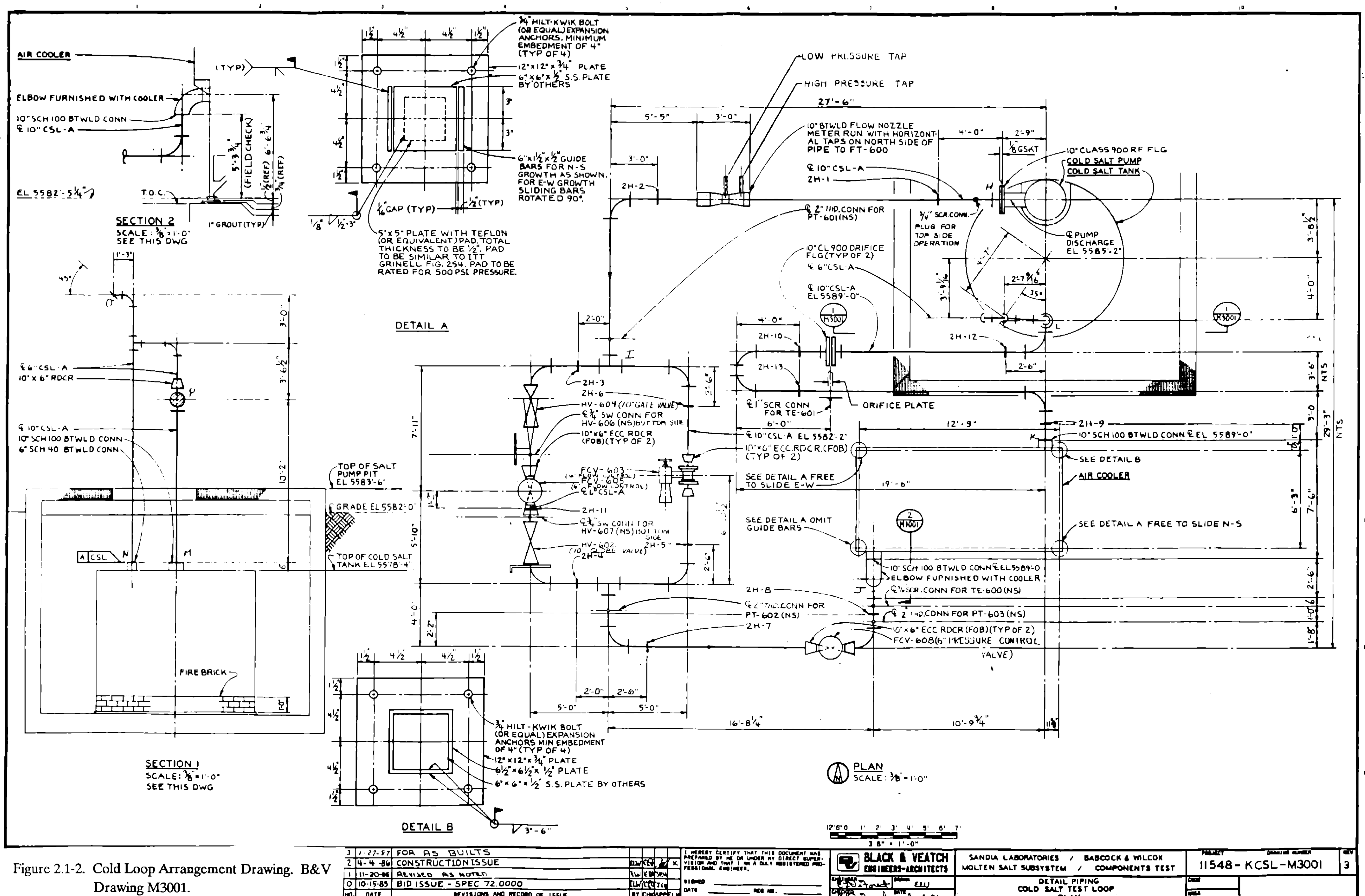


Figure 2.1-2. Cold Loop Arrangement Drawing. B&V Drawing M3001.

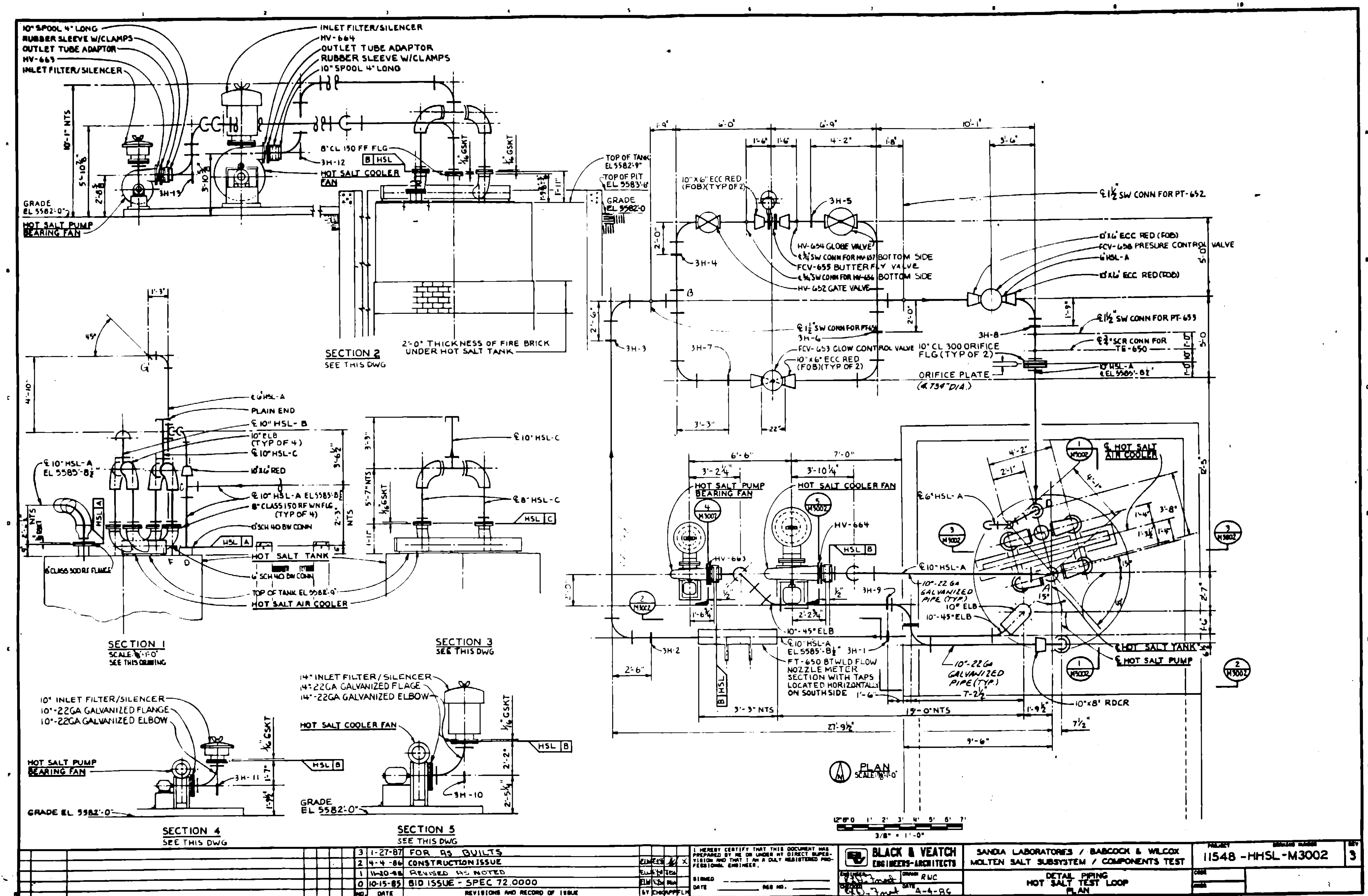


Figure 2.1-2. Hot Loop Arrangement Drawing. B&V Drawing M3002.

2.2 COLD PUMP

The cold salt pump is a 26x, seven stage, type FCDW vertical turbine pump manufactured by Byron-Jackson Pump Division (B-J). The vertical turbine pump was chosen for the cold salt application due to its ability to meet the high head and flow requirements of the Saguaro plant conditions. The cold salt pump was purchased by B&W based on design and manufacturing requirements developed by Black & Veatch (B&V) in Specification 11548.62.2614 for Pump & Valve Experiment Molten Salt Pumps [4]. The pump is shown in B-J drawing L000230, Figure 2.2-1.

The B-J pump is designed to deliver 2050 GPM at 1505 feet of head with a required NPSH of 22 feet. The cold salt pump is provided with a 2250 horsepower 4160 volt, 3 phase motor. The pump performance curves are shown in Figure 2.2-2. The pump is instrumented with axial displacement probes in two directions at both the upper and lower motor bearings for detection of abnormal shaft deflections. An electrical interlock will shut down the pump should the deflection exceed +/-.005 inches.

A thermocouple is located in each of the three windings of the motor to monitor motor temperatures. Thermocouples are also located in the upper and lower motor bearings and in the pump housing. These thermocouples are monitored by the control system for data acquisition and safe shutdown protection. The manufacturers winding temperature upper limit is 260°F and the manufacturers bearing upper limit is 180°F.

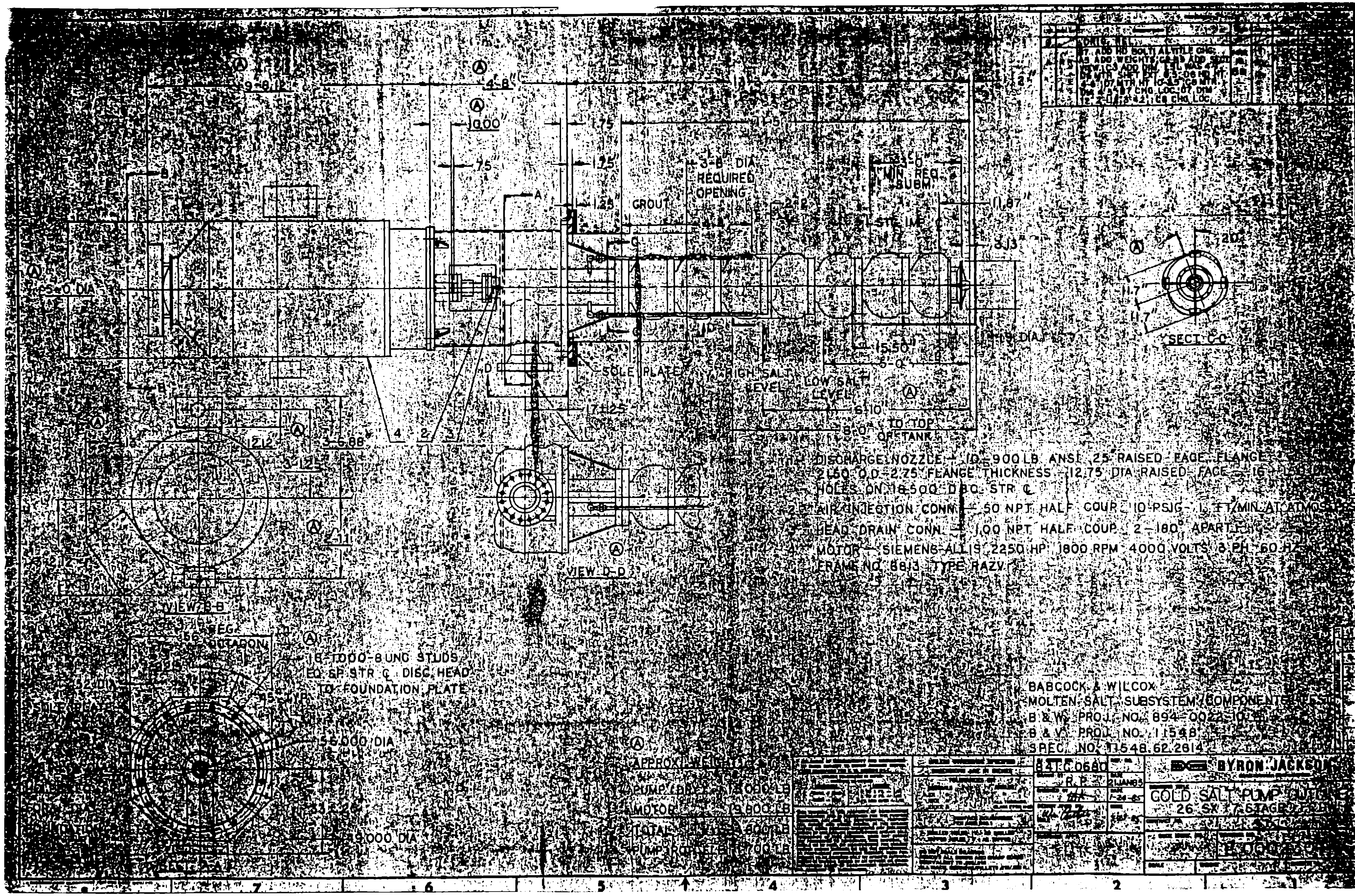


Figure 2.2-1. Cold Pump Outline Drawing. B-J Drawing L000230.

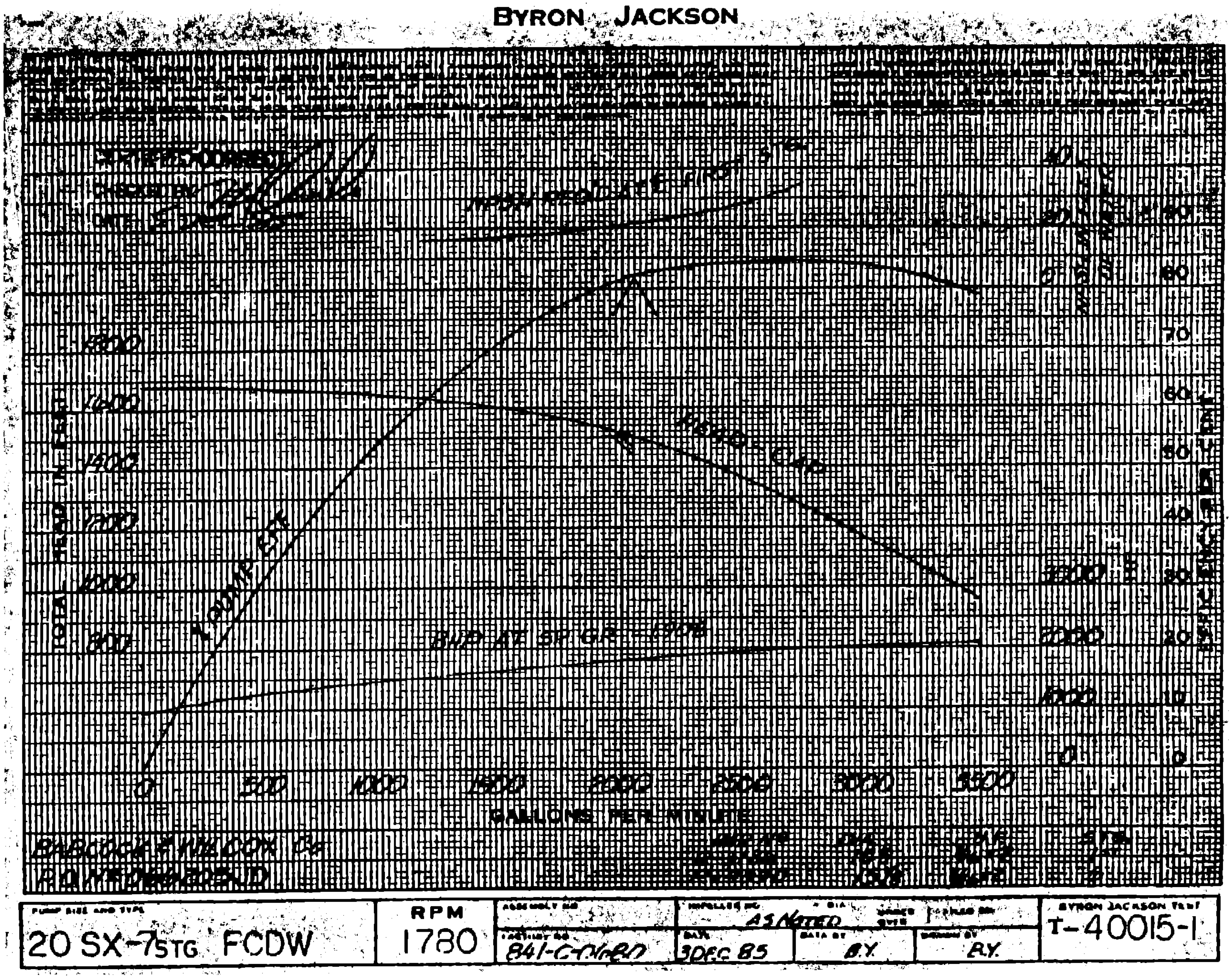


Figure 2.2-2. Cold Pump Performance Curves.

2.3 COLD VALVES

This section provides information and description of the cold salt valves purchased for the Pump and Valve Test cold loop. The valves and associated accessories were provided in accordance with ANSI B31.1 Code for Pressure Piping and constructed in accordance with ANSI B16.34. End-to-end dimensions conform to ANSI 16.10. The valves were designed in accordance with B&V Specification 11548.62.3809 for Pump and Valve Experiment Molten Salt Control Valves [5], and B&V Specification 11548.62.3805 for Pump and Valve Experiment General Service Valves [6]. All valves are completely heat traced, insulated, and instrumented to maintain temperatures above the salt freezing limit and prevent thermal shock during loop salt fill. The valves are packed with Crane 1625gf braided graphite rings with interspaced glass reenforced teflon washers supplied by RM Industrial Products. These materials were selected based on the results of the Bench Test. Due to the temperature limitations of the teflon washers careful monitoring of the heat trace is necessary to limit temperatures in the packing region to 500°F-550°F.

2.3.1 HV-602

HV-602 is a 10 inch - 1500 pound class manual Wye globe valve manufactured by the Atwood & Morrill Company (A&M) and is typical of general service isolation hand valves in a plant. The valve body and bonnet material are A216 WCB carbon steel with butt welded ends. The plug and stem are carbon steel with Alloy #21 hardsurfacing. The outline drawing of the valve is shown in A&M drawing 15444-01, Figure 2.3-1.

2.3.2 FCV-603

FCV-603 is a 6 inch 200 series 900 pound class Camflex rotary globe valve supplied by the Masoneilan Company. It is air actuated with a fail closed spring diaphragm actuator. The valve is typical of low pressure drop receiver inlet flow control valves and will be used for flow control. The body/bonnet assembly is A216 WCB carbon steel with the stellited wear surfaces. The outline drawing of the valve is shown in Masoneilan drawing 01-SK-495, Figure 2.3-2.

2.3.3 HV-604

HV-604 is a 10 inch 900 pound class No. 783 W.E.O.S. manually operated cold salt pressure seal gate valve. The valve is a general service isolation valve manufactured by The Crane Company. It is characteristic of receiver inlet isolation valves. The wear surfaces and plug/disc are carbon steel with stellite surfaces. The body and bonnet are A216 WCB carbon steel. Figure 2.3-3 shows Crane valve assembly drawing C-171371.

2.3.4 FCV-605

FCV-605 is a series D-100, 6 inch globe type control valve manufactured by the Copes-Vulcan Company (C-V). The valve is air actuated with a fail closed spring return actuator. The valve is typical of receiver inlet flow control valves. The valve body material is A216 WCB carbon steel with butt welded ends. The valve assembly is shown in C-V drawing E-277727, Figure 2.3-4.

2.3.5 FCV-608

FCV-608 is a series D-100, 6 inch globe type pressure control valve with a bellows stem seal design supplied by the Copes Vulcan Company. The valve is air actuated with a fail closed spring return actuator. It is designed to model high pressure drop pressure control valves such as pump recirculation and cold surge tank level control valves. C-V drawing E-277726, Figure 2.3-5 shows the valve assembly.

2.3.6 HV-606 & 607

HV-606 & 607 are manually operated model SS-12UW-TW-HT 3/4 inch bellows valves located in the drip legs on either side of FCV-603. The valves are isolation valves and are used during leak-by testing of the control and general service valves. The valves are supplied by the Nupro Company and are shown in Figure 2.3-6.

2.4 COLD PIPING

This section provides information on the cold salt loop piping for the Pump & Valve Test. All piping materials, fabrication, erection, testing, and application is in accordance with ANSI Code for Pressure Piping B31.1-1983 and Power Piping Code ANSI B31.1b-1984. The cold loop materials were purchased and the loop constructed in accordance with B&V Specification 11548.72.0000 Pump and Valve Experiment Mechanical Construction Specification [7].

The cold loop piping is designed for 1650 psig and 575°F. Operating pressure and temperature are 1250 psig and 550°F, respectively. All piping is ASTM A106 GrB carbon steel. Eight inch through 12 inch (nominal diameter) piping is Schedule 100; 2-1/2 inch through 6 inch is Schedule 80, with the exception of the 4 inch which is XXS; and 2 inch and smaller is also Schedule 80. These sizes and schedules conform to ANSI B36.10.

The piping is arranged as shown in B&V drawing M3001, Figure 2.1-2. The piping and components are heat traced and insulated for temperature maintenance and personnel protection.

The piping is supported at various location by pipe supports supplied by Pipe Shields, Inc. The supports include 9 inches of high density calcium silicate insulation, a protective jacket, and a pipe hanger.

2.5 COLD SALT COOLER

The Pump & Valve Test cold loop salt cooler is a forced draft, single bay cooler designed to remove excess heat generated by the cold pump work. The cooler is designed to B&V Specification 11548.62.1200 Pump and Valve Experiment Molten Salt Air Coolers [8] and was manufactured by the Happy Division of Therma Technology, Inc. The cooler is designed to a heat removal rate of 6.4×10^6 BTU/Hr based on an inlet cooler temperature of 559°F and an outlet temperature of 550°F. The tube side design flowrate is 2050 GPM at an inlet pressure of 1650 psig. The air side conditions to remove this heat are T_{in} = 105°F, and T_{out} = 265.1°F at 37017 SCFM of air.

The cooler tube bundle consists of 94 - 1 inch diameter, .110 min. wall tubes. The single pass heat exchanger is cooled by an 11.5 horsepower, model 12F24 CHECO fan located on the bottom of the bundle. The tube bundle is isolated from the fan by air operated adjustable louvers to control the air circulation. Directly beneath the tube bundle are four metal grids which are equipped with strip heaters to heat the cooler to an operating temperature of 550°F prior to introduction of salt to the system. The heaters are sized to maintain temperatures up to 550°F. The cooler is insulated with mineral fiber blanket and lagged with aluminum sheeting.

2.6 COLD SUMP TANK

The cold salt tank is a carbon steel tank designed and constructed in accordance with ASME Boiler and Pressure Vessel Code, Section VIII, Division 1. The tank, manufactured by Continental Boiler Works, Inc. (CBW), is 8 feet tall by 7 feet in diameter and is designed to B&V Specification 11548.62.3602 for Pump and Valve Experiment Molten Salt Tanks [9]. The tank holds a total of 56,000 pounds of molten salt which is required for operation of the cold salt loop. The sump includes four 1/2 inch internal baffle plates with 1/2 inch diameter staggered holes for flow distribution. The baffles are used for flow straightening to avoid vortex problems entering the cold salt pump. It is fully heat traced with mineral insulated cable with a primary heat input of 13kw and insulated for temperature maintenance and personnel protection. Thermocouples are located at six locations on the outside of the tank for use in monitoring and controlling salt temperature in the sump. The level of the salt is monitored by a bubbler level transmitter and is interlocked to the control system for low level indication.

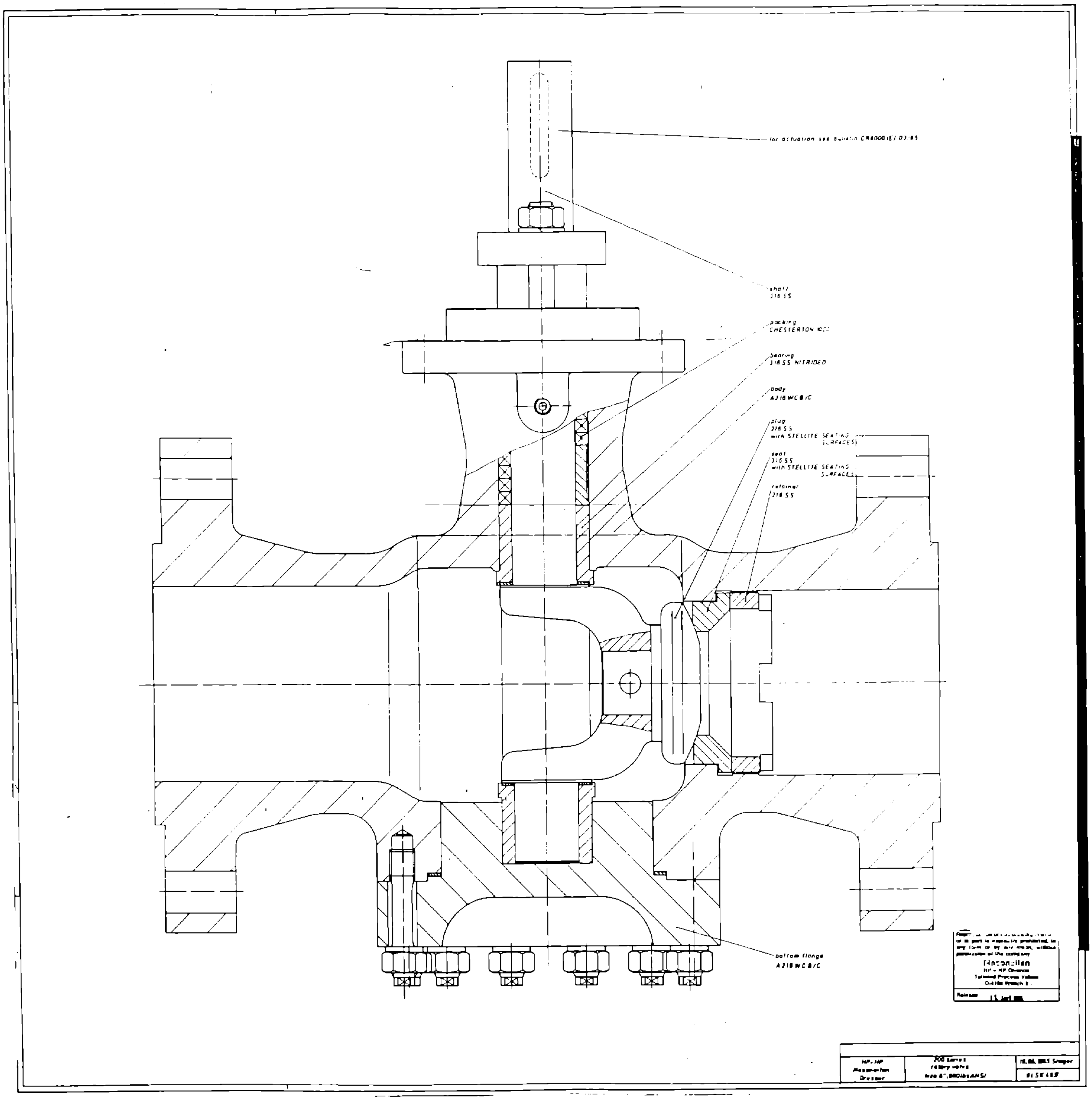


Figure 2.3-2. FCV-603. Masoneilan Drawing 01SK493.

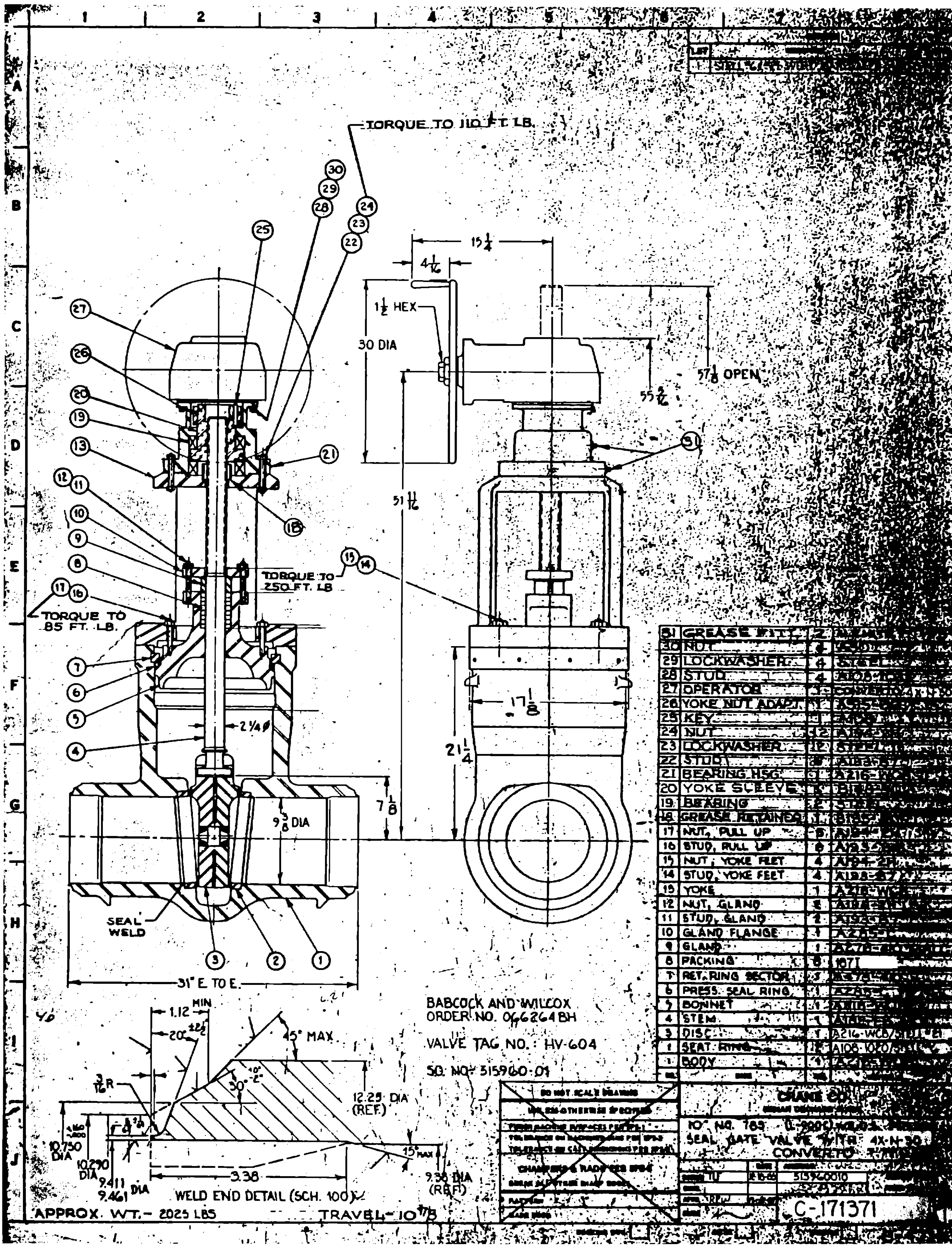
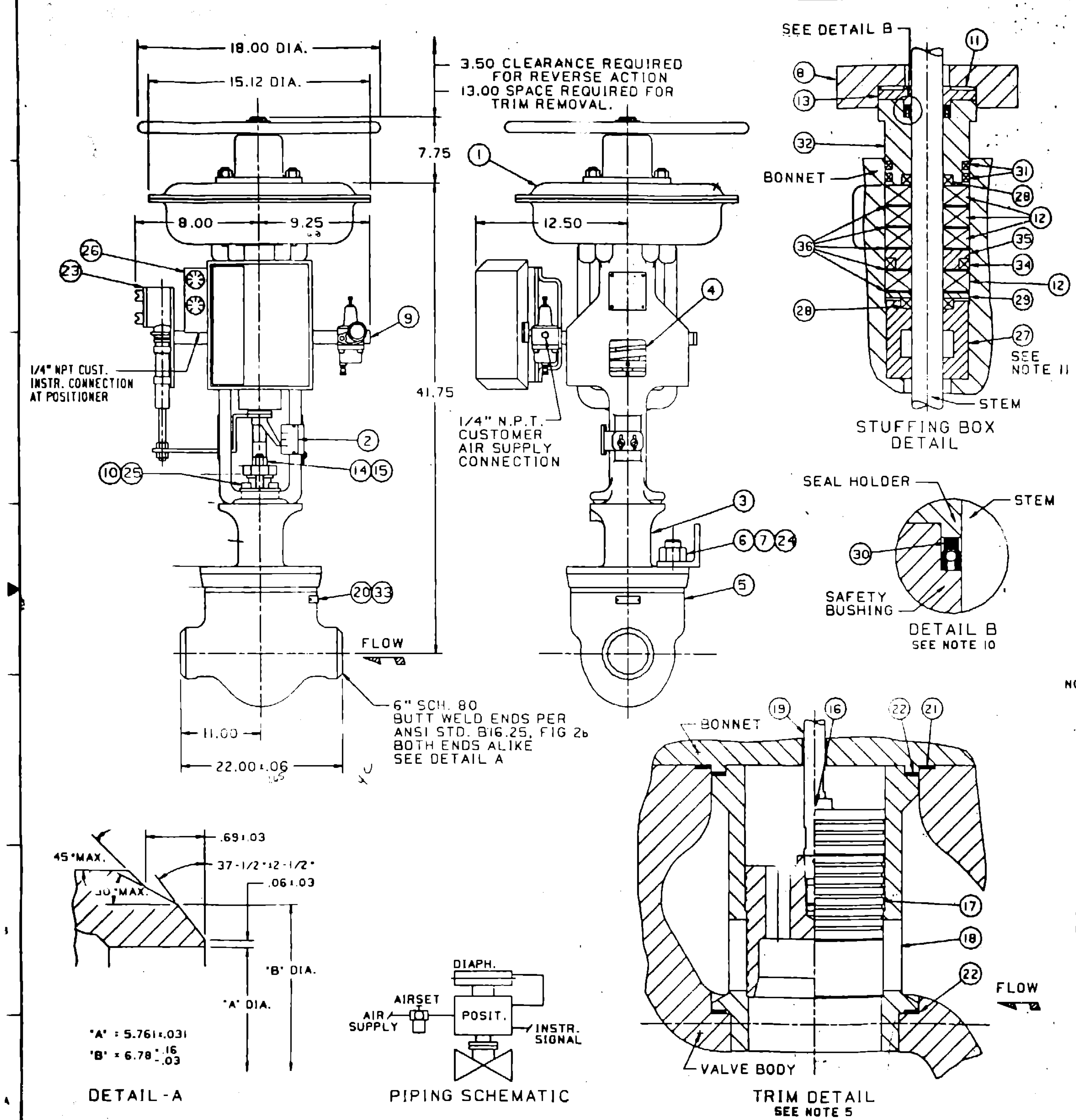


Figure 2.3-3. HV-604. Crane Drawing C-171371.



LIST OF MATERIALS

ITEM NO.	NO. REQ'D	PART NO.	DESCRIPTION	MAT'L	MAT'L SPECS.	DWG. NO.	REMARKS
1	1	193774	ACTUATOR ASSEMBLY			E-193775	
2	1	081640	INDICATOR PLATE	CRES	COM'L	M-81640	300 SERIES
3	1	285898	BONNET	STEEL	ASTM - A216	E-285898	GR. WCB
4	1	081652	SPRING	STEEL	COM'L	S-81652	1200#/IN
5	1	278640	VALVE BODY	STEEL	ASTM - A216	E-278639	GR. WCB
6	12	139648	STUD, BODY (1-3/8"-8UN)	STEEL	ASTM - A193	L-168285	GR. B7
7	12	090370	NUT, BODY (1-3/8"-8UN)	STEEL	ASTM - A194	M-170423	GR. 2H
8	1	275011	GLAND FOLLOWER	CRES	ASTM - A479	L-275011	TYPE 316L
9	1	279128	ACCESSORY KIT	FISHER 67FR AIRSET		(F)S-279128	
10	4	137776	SOC. HEAD CAP SCREW	STEEL	COM'L		
11	1	275016	DISC SPRING	STEEL	COM'L		
* 12	1	286520	PACKING SET (4 RINGS)	GRAFOIL	COM'L		JOHN CRANE 1625 GF
13	1	285893	SEAL HOLDER	CRES	ASTM - A479	M-285893	TYPE 316L
14	2	274645	STUD, PACK. (5/8"-11UNC)	CRES	ASTM - A479	S-274645	TYPE 410
15	2	148114	NUT, PACK. (5/8"-11UNC)	CRES	ASTM - A194		CL. 6
* 16	1	096227	ROLL PIN	CRES	COM'L		
* 17	1	285899	PLUG	CRES	ASTM - A182/479	E-285899	TYPE 304 STELLITED
* 18	1	285897	CAGE	CRES	ASTM - A182/479	E-285897	TYPE 304 STELLITED
* 19	1	170538	STEM	CRES	ASTM - A276	L-168282	TYPE 316 COND.
20	1	058917	INLET TAG	CRES	COM'L	S-58917	300 SERIES
* 21	1	194794	BODY GASKET	ASB-SST	COM'L		
* 22	2	177698	TRIM GASKET	ASB-SST	COM'L		
23	1	285721	ACCESSORY KIT	LVDT POSIT. TRANS.		E-285721	
24	2	149572	LIFTING LUG	STEEL	COM'L	M-149572	
25	2	137475	HOLD DOWN CLAMP	STEEL	SAE 1015-1020	S-137475	
26	1	272546	ACCESSORY KIT	BAILEY AP-4 POSITIONER		L-272546	
* 27	1	285894	BUSHING	CRES	ASTM - A564	M-285894	TYPE 17-4 PH GR. 63"
* 28	2	285902	WIPER RING	REINF. CARN. YARN	COM'L		CHESTERTON STYLE 1800
* 29	1	285895	PACKING WASHER	CRES	COM'L	M-285895	300 SERIES
* 30	1	285901	SAFETY SEAL		COM'L		ENERSEAL MK-I
* 31	2	275015	STATIC SEAL	REINF. CARN. YARN	COM'L		CHESTERTON STYLE 1800
* 32	1	285896	SAFETY BUSHING	CRES	ASTM - A479	M-285896	TYPE 316L
33	2	064341	DRIVE SCREW	STEEL	COM'L		
* 34	1	285937	STATIC SEAL	REINF. CARN. YARN	COM'L		CHESTERTON STYLE 1800
* 35	1	285936	PACKING SEAL RING	CRES	ASTM - A479	M-285936	TYPE 316L
* 36	5	286518	PACKING SPACER	TEFLON	COM'L		

NOTES:

1. FOR MAX. C_V 220 SET VALVE TRAVEL AT 1.25±.12 INCHES
2. ASSEMBLE VALVE PER CV PROC. 1.2.187.
3. RECOMMENDED SPARE PARTS ARE MARKED WITH AN ASTERISK (*) ON THE "LIST OF MATERIALS". A DIAPHRAGM (C.V. PART NO. 808111) IS ALSO RECOMMENDED.
4. ALL DIMENSIONS ARE IN INCHES AND ARE REFERENCE UNLESS OTHERWISE SPECIFIED.
5. TRIM TYPE IS DOUBLE SEAT BALANCED MODIFIED PARABOLIC.
6. DESIGN PRESSURE AND TEMPERATURE IS 1650 P.S.I.G. AT 600°F.
7. APPROXIMATE TOTAL VALVE WEIGHT IS 940 LBS.
8. REQUIRED AIR TO OPERATE 60 P.S.I.
9. AIR PRESSURE IN THE DIAPHRAGM CHAMBER MUST NOT EXCEED 100 P.S.I.G. TO PREVENT COMPONENT DAMAGE.
10. SAFETY-SEAL (ITEM 30) MUST BE INSTALLED AS SHOWN.
11. BUSHING (ITEM 27) IS TO BE A PRESS FIT.

CUSTOMER: BABCOCK & WILCOX CO.
BABCOCK & WILCOX P.O. NO.: 066252BH
BLACK & VEATCH SPEC.: 11548.62.3809
COPES-VULCAN JOB NO.: 8510-82204
VALVE TAG NO.: FCV-605
APPLICATION: MOLTEN SALT TEST VALVE

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One of the White Consolidated Industries
LAKE CITY (ERIE CO.) PA. U.S.A.

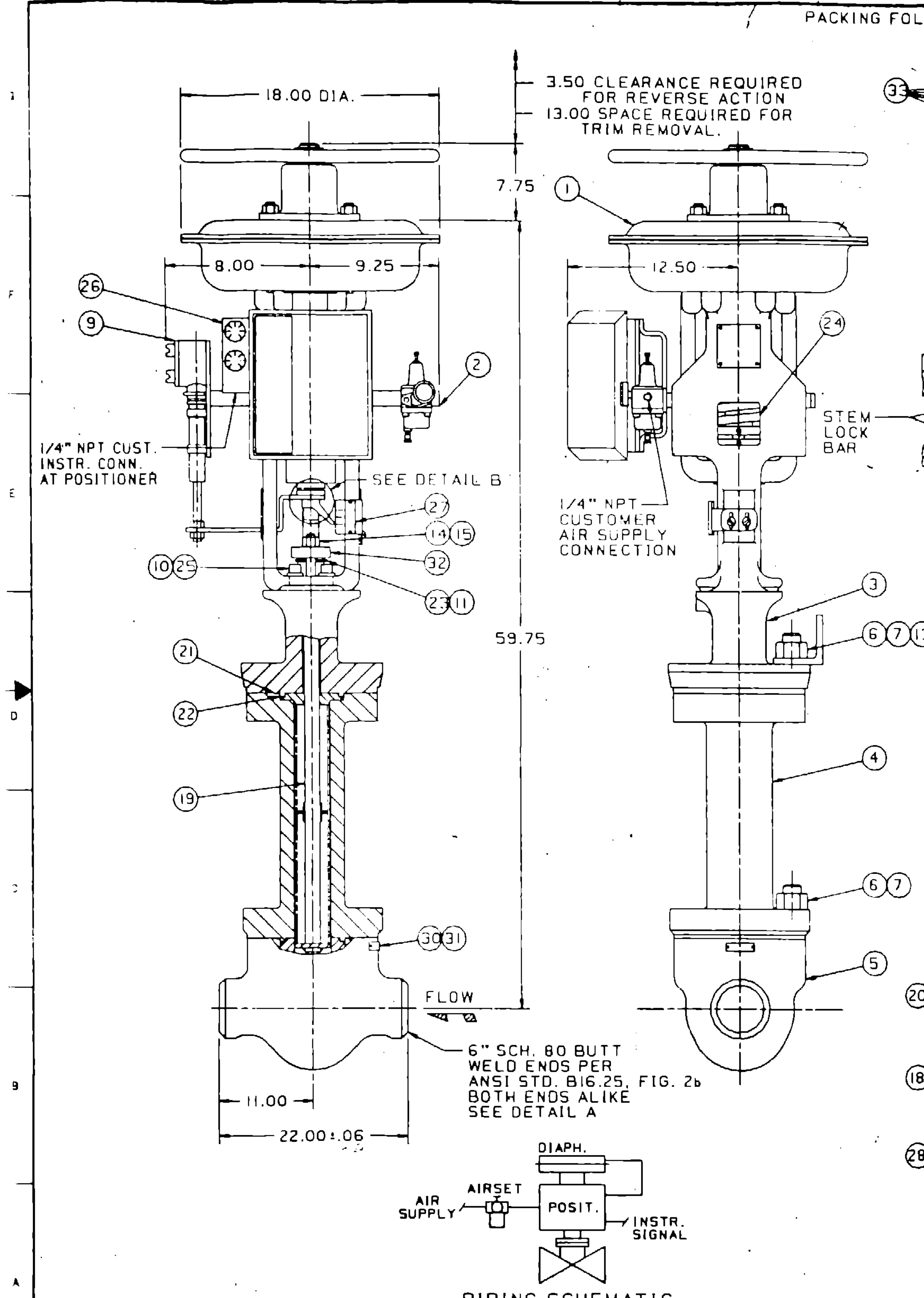
SERIES D-100 VALVE ASSEMBLY WITH D-100-100 RA ACTUATOR

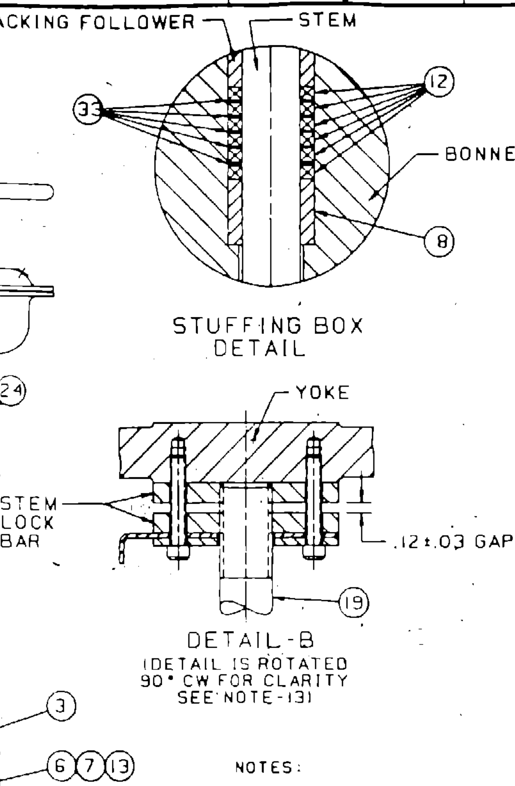
6" CLASS 1500

NO	DATE	REVISIONS	BY	CHK.
1	9-27-85	UPDATED & COMPLETED BOM. UPDATED STUFFING BOX, TRIM DETAIL AND NOTES.	K.H.	BCS
2	1-16-86	ADDED ITEM #36: ITEM #12 WAS P/N 285903	MD	BS

DRAWN JA DATE 7-1-85 | CHECKED BCS DATE 8-28-85 | APP'D. | ENGR. REJ DATE 9-1-85
SCALE NONE | DWG. NO. E-277727 | REV. 2

Figure 2.3-4. FCV-605. Copes Vulcan Drawing E-277727.





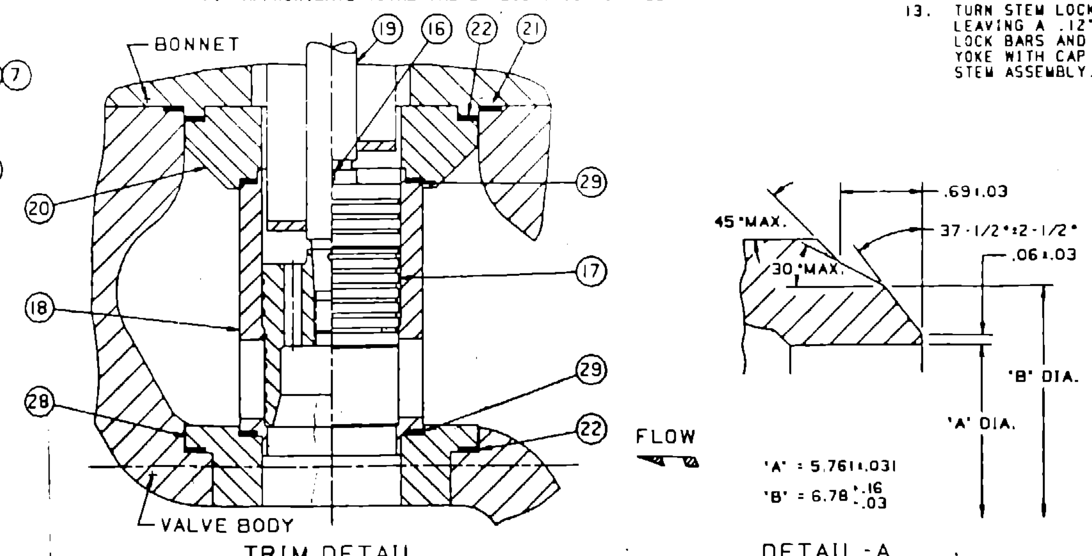
LIST OF MATERIALS

ITEM NO.	NO. REQ'D	PART NO.	DESCRIPTION	MAT'L	MAT'L SPECS.	DWG. NO.	REMARKS
1	1	285723	ACTUATOR ASSEMBLY			(F)E-285723	
2	1	279128	ACCESSORY KIT	FISHER 67FR AIRSET		(F)S-279128	
3	1	279414	BONNET	STEEL	ASTM - A216	E-279413	GR. WCB
4	1	285904	BONNET EXTENSION	STEEL	ASTM - A105	D-285904	
5	1	278640	VALVE BODY	STEEL	ASTM - A216	E-278639	GR. WCB
6	24	139648	STUD, BODY (1-3/8"-8UN)	STEEL	ASTM - A193	L-168285	GR. B7
7	24	090370	NUT, BODY (1-3/8"-8UN)	STEEL	ASTM - A194	M-170423	GR. 2H
* 8	1	169763G	GUIDE BUSHING	CRES	ASTM - A479	S-169763	TYPE 410
9	1	282591	ACCESSORY KIT	LVDT POSIT. TRANS.		E-282591	
10	4	137776	SOC. HEAD CAP SCREW	STEEL	COM'L		
11	1	137603	PACKING GLAND	CRES	ASTM - A479	S-137603	TYPE 410
* 12	1	286521	PACKING SET (6 RINGS)	GRAFOIL	COM'L		JOHN CRANE 1625 OF
13	2	149572	LIFTING LUG	STEEL	COM'L	M-149572	
14	2	137477	STUD, PACK. (5/8"-11UNC)	STEEL	SAE 4140	S-137477	
15	2	001923	NUT, PACK. (5/8"-11UNC)	STEEL	COM'L		
* 16	1	096227	ROLL PIN	CRES	COM'L		
* 17	1	285931	PLUG	CRES	ASTM - A182/A479	(F)E-285931	TYPE 304 STELLITED
* 18	1	285933	CAGE	CRES	ASTM - A182/A479	E-285933	TYPE 304 STELLITED
* 19	1	285939	STEM & BELLOWS ASS'Y	SEE NOTE 10		E-285939	
20	1	285929	UPPER REDUCER BUSHING	CRES	ASTM - A479	E-285929	TYPE 410
* 21	2	194794	BODY GASKET	ASB-SST	COM'L		
* 22	3	177698	TRIM GASKET, OUTER	ASB-SST	COM'L		
23	1	018263	SNAP RING	STEEL	COM'L		
24	1	268471	SPRING	STEEL	COM'L	S-268471	1800#/IN.
25	2	137475	HOLD DOWN CLAMP	STEEL	SAE 1015-1020	S-137475	
26	1	272546	ACCESSORY KIT	BAILEY AP-4 POSITIONER		E-272546	
27	1	081640	INDICATOR PLATE	CRES	COM'L	M-81640	300 SERIES
28	1	285930	LOWER REDUCER BUSHING	CRES	ASTM - A479	E-285930	TYPE 410
* 29	2	168253	TRIM GASKET, INNER	ASB-SST	COM'L		
30	1	058917	INLET TAG	CRES	COM'L	S-58917	300 SERIES
31	2	064341	DRIVE SCREW	STEEL	COM'L		
32	1	137236	GLAND FOLLOWER	STEEL	COM'L	M-137236	
* 33	5	286519	PACKING SPACER	TEFLON	COM'L		

NOTES:

1. FOR MAX. C_V 150 SET VALVE TRAVEL AT 2.00±.12 INCHES.
2. ASSEMBLE VALVE PER CV PROC. 1.2.187.
3. RECOMMENDED SPARE PARTS ARE MARKED WITH AN ASTERISK (*) ON THE "LIST OF MATERIALS". A DIAPHRAGM (C.V. PART NO. 80815) IS ALSO RECOMMENDED.
4. ALL DIMENSIONS ARE IN INCHES AND ARE REFERENCE UNLESS OTHERWISE SPECIFIED.
5. TRIM TYPE IS DOUBLE SEAT BALANCED MODIFIED PARABOLIC.
6. DESIGN PRESSURE AND TEMPERATURE IS 1650 P.S.I.G. AT 600°F.
7. APPROXIMATE TOTAL VALVE WEIGHT IS 1500 LBS.
8. REQUIRED AIR TO OPERATE IS 60 P.S.I.
9. AIR PRESSURE IN THE DIAPHRAGM CHAMBER MUST NOT EXCEED 100 P.S.I.G. TO PREVENT COMPONENT DAMAGE.
10. STEM MATERIAL: ASTM-A276, TYPE 316, CONDITION B
    BELLOWS SPACER: INCONEL 600, ASTM-B166
    ADAPTER & END FLANGE: INCONEL 600, ASTM-B166
    BELLOWS NESTING: INCONEL 718, AMS 5596
    SEALING FLANGE: CRES, AMS 5507, 316L SST.
11. STEM AND BELLOWS ASSEMBLY (ITEM 19) MUST BE REMOVED PRIOR TO HYDROSTAIC TESTING.
12. MAXIMUM ALLOWABLE PRESSURE 2500 P.S.I.G.
13. TURN STEM LOCK BARS ONTO THE STEM ASSEMBLY LEAVING A .12" GAP BETWEEN PLATES. SECURE LOCK BARS AND STEM ASSEMBLY TO THE ACTUATOR YOKE WITH CAP SCREWS. "DO NOT TURN THE STEM ASSEMBLY."

CUSTOMER: BABCOCK & WILCOX CO.
BABCOCK & WILCOX P.O. NO.: 066252BH
BLACK & VEATCH SPEC. 11548.62.3809
COPES-VULCAN JOB NO.: 8510-82204
VALVE TAG NO.: FCV-608
APPLICATION: MOLTEN SALT TEST VALVE



THIS DRAWING WAS PRODUCED BY ELECTRONIC METHODS. DO NOT REVISE MANUALLY.

COPES-VULCAN COMPUTER GRAPHICS VA.1.100.-TCBWB-.E-277726

COPES-VULCAN
LAKE CITY (ERIE CO.) PA. U.S.A.

SERIES D-100 VALVE ASSEMBLY WITH D-100-160 RA ACTUATOR

6" CLASS 1500

NO	DATE	REVISIONS	BY	CHK.
1	10-1-85	UPDATED & COMPLETED BOM: UPDATED TRIM & NOTES	KAH	BCS
2	11-27-85	ITEM #22 WAS 2 REQ'D., ADDED BODY GASKET ITEM #22 TO VIEW	MD	BCS
3	1-16-86	ADDED ITEM #33; ITEM #12 WAS P/N 137598	MD	BS

DFTSMN JA DATE 7-1-85 · CHECKED BCS DATE 8-23-85 · APP'D. · APPD ENG REJ DATE 9-1-85

SCALE NONE · DWG. NO. E-277726 · REV. 3

Figure 2.3-5. FCV-608. Copes Vulcan Drawing E-277726.

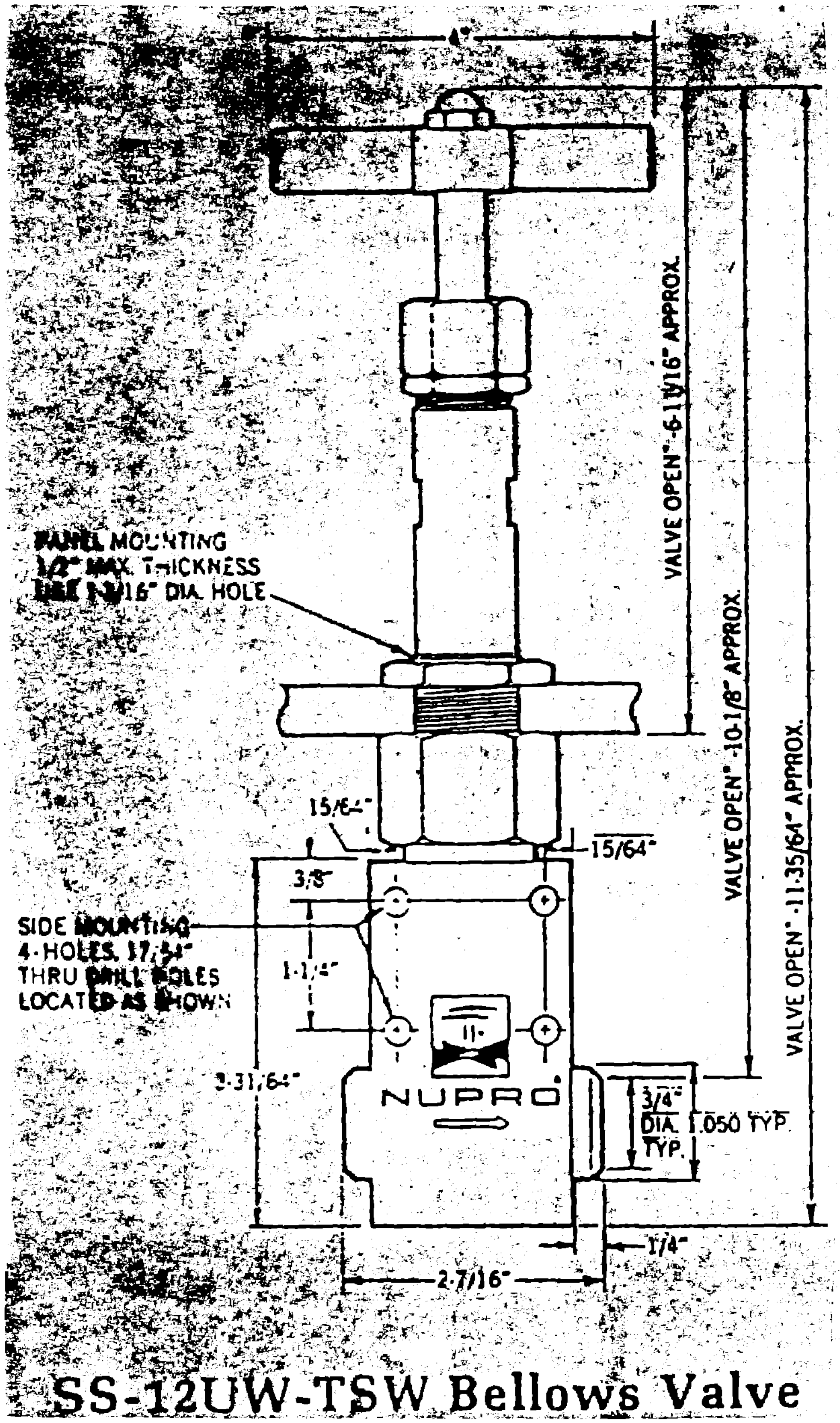


Figure 2.3-6. HV-606, 607, 656,, 657. Nupro Drawing.

2.7 HOT SALT PUMP

The hot salt pump is of a vertical cantilever design. The vertical cantilever pump configuration was chosen over the vertical turbine due to the high temperature requirements during service. The vertical cantilever design has no bearing surfaces in the salt which eliminating the erosion and corrosion concerns associated with molten salt at 1050°F. The pump, specified by B&V Specification 11548.62.2614 for Pump and Valve Experiment Molten Salt Pumps [4] is designed and manufactured by Lawrence Pump & Engine Company (LP&E). The pump is a 8 X 10 - 22 SCP Vertical Cantilever pump and is shown on the LP&E pump outline drawing 22433, Figure 2.7-1. The head and flow requirements meet those of the Saguaro design for hot pumps.

The LP&E pump is designed to deliver 1850 GPM at 210 feet of head with a required NPSH of 8 feet. The pump is run by a Siemans-Allis 350 horsepower motor and operates on 4160 vac, 3 phase, 60 hertz. The pump performance curves are shown in Figure 2.7-2. Due to the temperature limitations of the bearings, the pump is equipped with a 1.8 CFM, 5 psi oil mist system as well as the duct work for field attachment of an air blower. The blower is a type "TBA" turbo pressure blower purchased from Twin City Fan and Blower Company, and is used to maintain an internal pedestal temperature of 100°F. The fan delivers 1843 ACFM at 12.61 inches of pressure. The pump and pump motor are instrumented with thermocouples which are interlocked to the control system. The motor is equipped with a vibration switch for shutdown of the pump/motor on the detection of high deflection at the top of the motor.

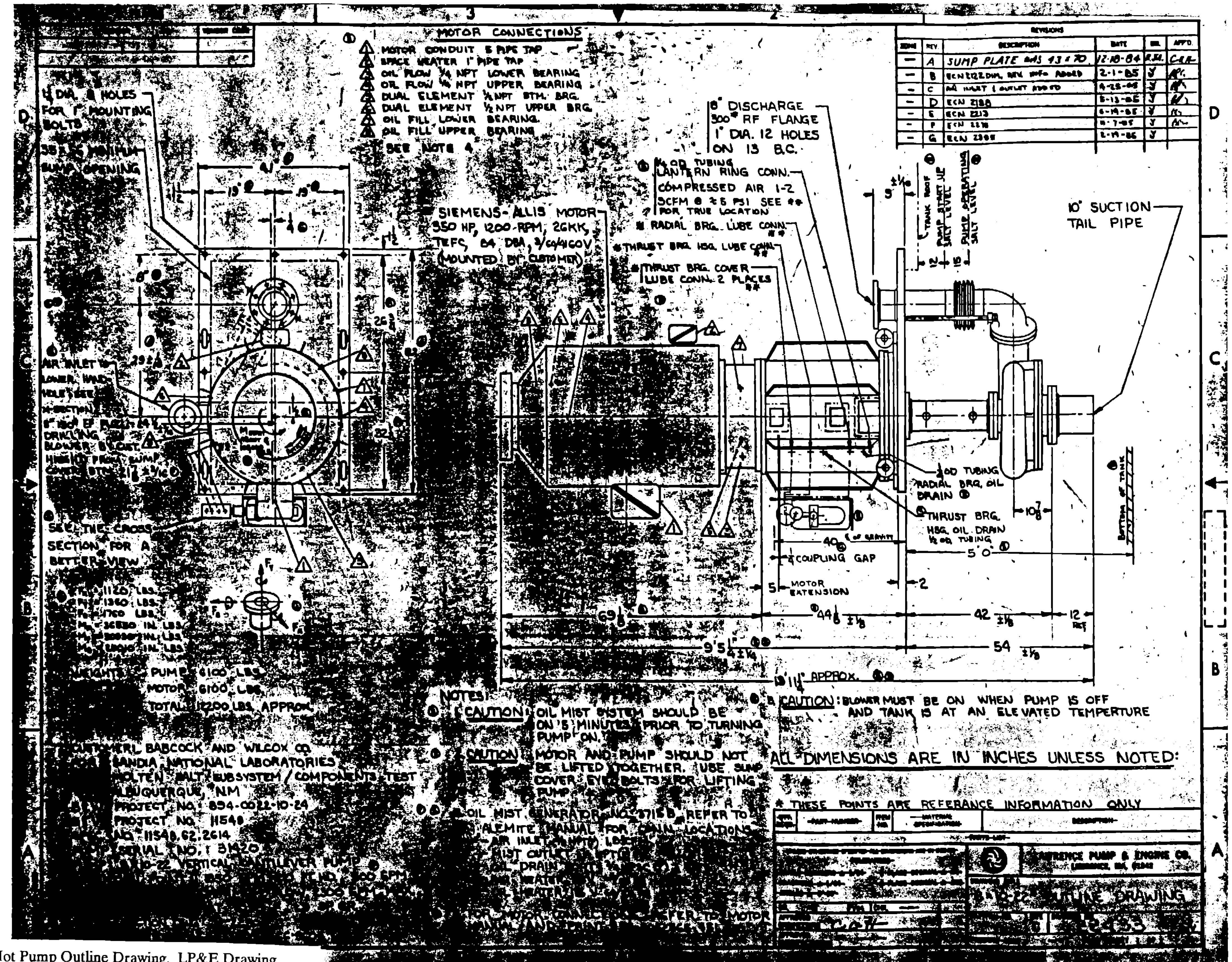


Figure 2.7-1. Hot Pump Outline Drawing. LP&E Drawing 22433.

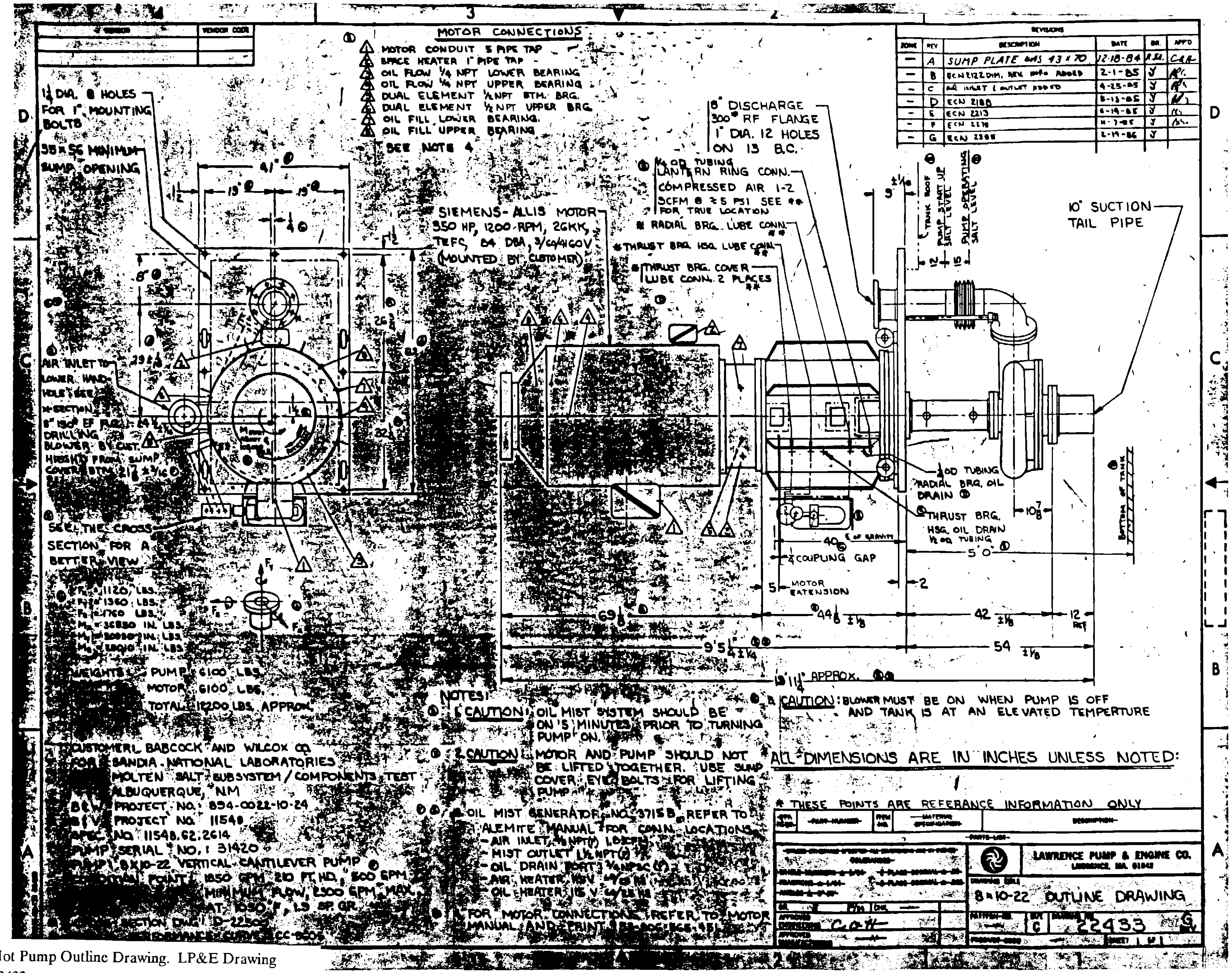


Figure 2.7-1. Hot Pump Outline Drawing. LP&E Drawing 22433.

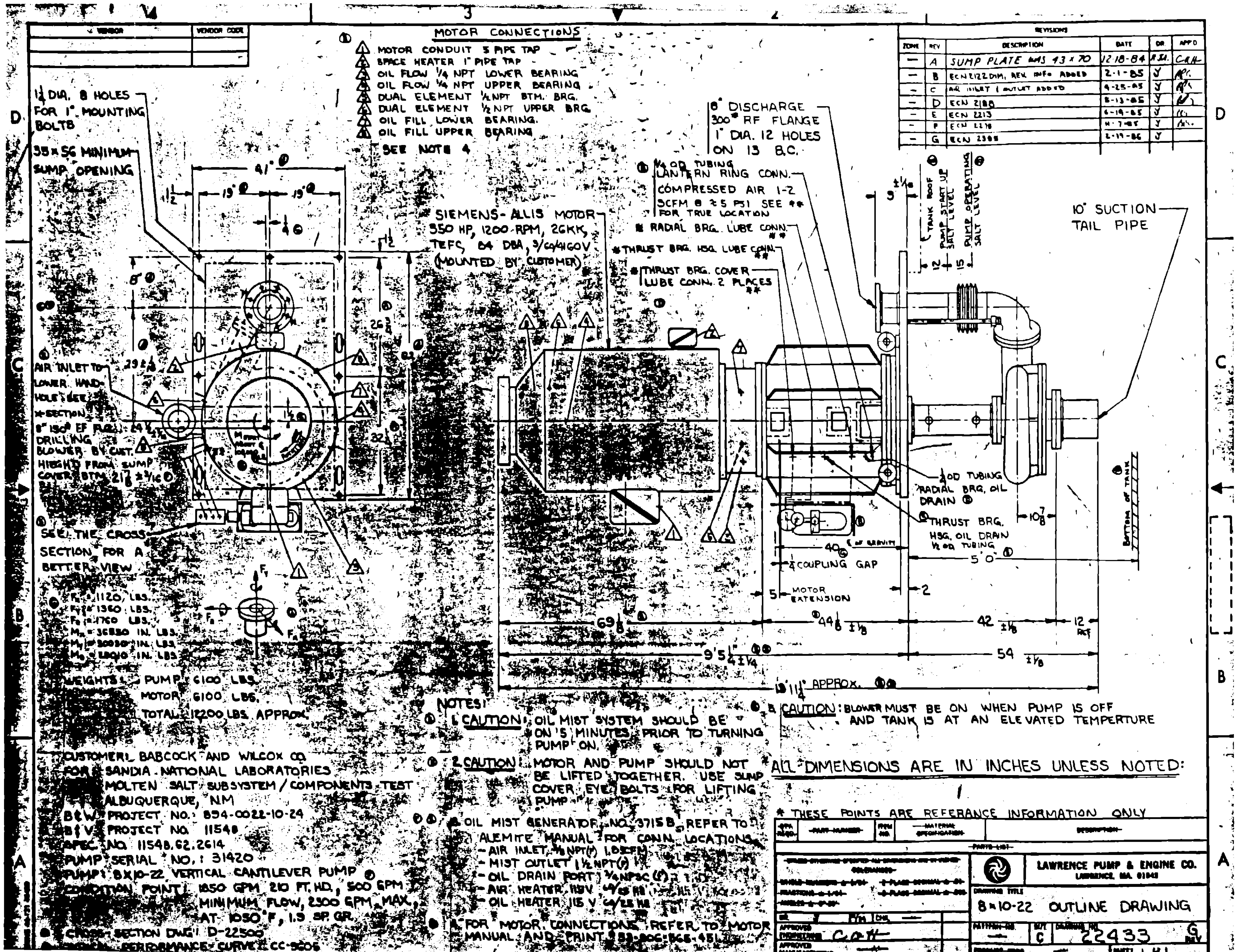


Figure 2.7-1. Hot Pump Outline Drawing. LP&E Drawing 22433.

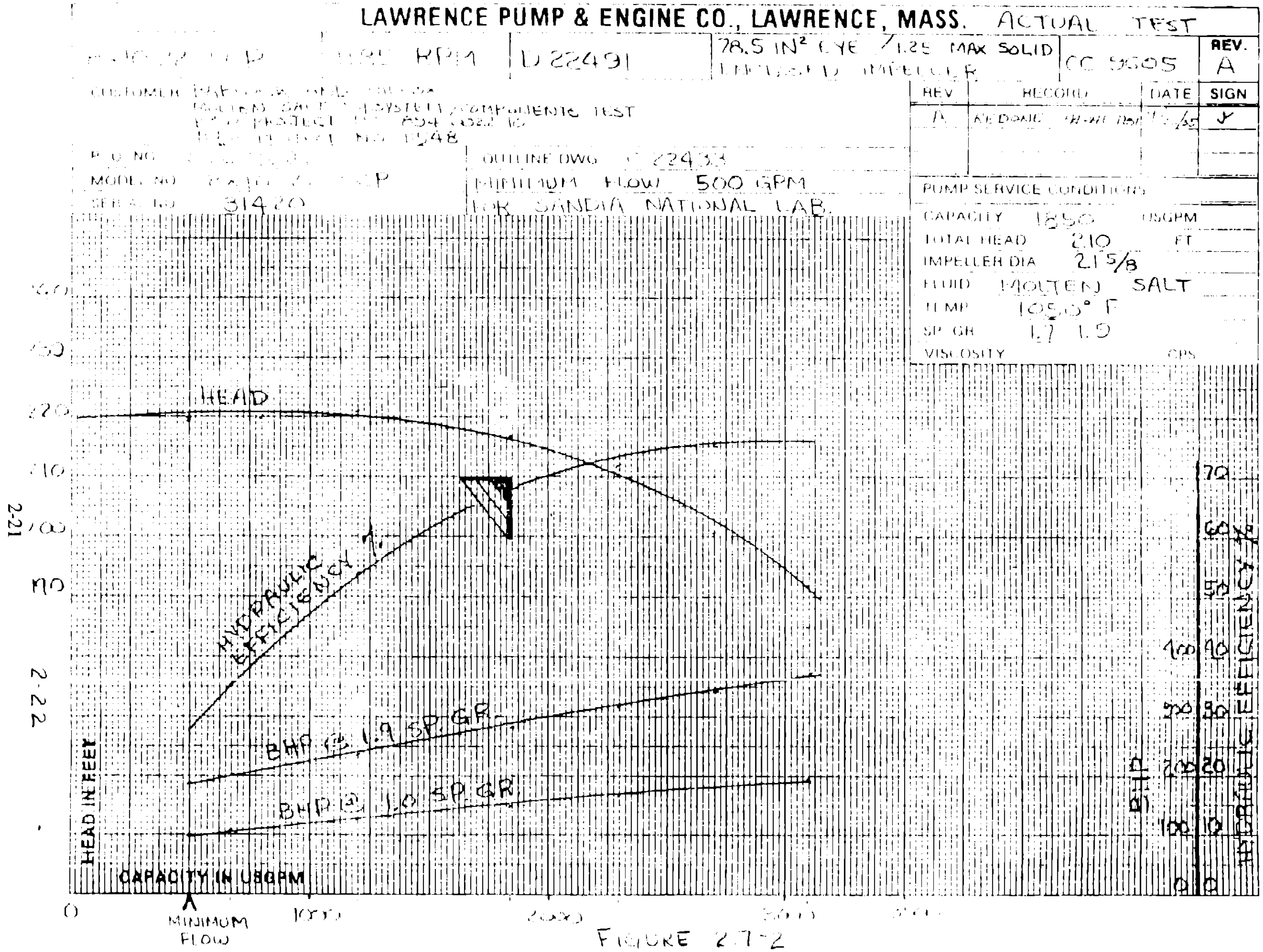


Figure 2.7-2. Hot Pump Performance Curves.

2.8 HOT VALVES

This section provides information and description of the hot salt valves purchased for the Pump and Valve Test hot loop. The valves and associated accessories are provided in accordance with ANSI B31.1 Code for Pressure Piping and are constructed in accordance with ANSI B16.34. End-to-end dimensions conform to ANSI 16.10. The valves were designed in accordance with B&V Specification 11548.62.3809 for Pump and Valve Experiment Molten Salt Control Valves [5] and B&V Specification 11548.62.3805 for Pump and Valve Experiment General Service Valves [6]. All valves are completely heat traced, insulated, and instrumented to maintain temperatures above the salt freezing limit and prevent thermal shock during loop salt fill. The valves are packed with Crane 1625gf braided graphite rings with interspaced glass reenforced teflon washers supplied by RM Industrial Products. These materials were selected based on the results of the Bench Test. Due to the temperature limitations of the teflon washers careful monitoring of the heat trace is necessary to limit temperatures in the packing region to 500°F-550°F. The hot loop valve bonnets have been extended to act as a cooling fin whereby allowing the salt temperature to cool from 1050°F to 550°F.

2.8.1 HV-652

HV-652 is a 10 inch - 33 1/2 LUF-SS gate valve manufactured by the Crane Company. It is a 300 pound class, ASTM A351 stainless steel manually operated valve designed to model general service isolation valves. The outline drawing of the valve is shown in Crane drawing D-171326 Figure 2.8-1.

2.8.2 FCV-653

FCV-653 is a 6 inch pneumatically operated globe valve. It is a 300 pound class, model 667-SS173 valve with a series 70 air operated actuator manufactured by the Fisher Controls Company. The valve is characteristic of low pressure drop receiver flow control valves and will be used for flow control. The body/bonnet assembly is A351 stainless steel. The outline drawing of the valve is shown in Fisher drawing 50B2000, Figure 2.8-2.

2.8.3 HV-654

HV-654 is a 300 pound class 10 inch manually operated globe valve to be used as a general service isolation. It is a model 151 1/2 LUF-SS, class 300 valve manufactured by the Crane Company. It is typical of receiver isolation valves. The body and bonnet are A351 stainless steel with stellited wear surfaces. Figure 2.8-3 shows the Crane valve assembly drawing D-171365.

2.8.4 FCV-655

FCV-655 is a 6 inch class 150 - 600 pound class Valdisk manufactured by Valtek. It is a rotary acting butterfly valve designed to model low pressure drop hot sump level control valves. The valve is air actuated with a fail closed spring return actuator. The valve body material is A351 stainless steel. The valve assembly is shown in Valtek drawing 39505-1, Figure 2.8-4.

2.8.5 FCV-658

FCV-658 is a series 667-SS173, 6 inch globe type pressure control valve supplied by the Fisher Control Company. It has a bellows stem seal design. The valve is air actuated with a fail closed spring return actuator. It is characteristic of high pressure drop hot salt valves such as hot pump recirculation valves. Fisher drawing 50B2001, Figure 2.8-5 shows the valve assembly.

2.8.6 HV-656 & 657

HV-656 & 657 are manually operated model SS-12UW-TW-HT 3/4 inch bellows valves located in the drip legs on either side of FCV-655. The valve are isolation valves and are used during leak-by testing of the control and general service valves. The valves are supplied by the Nupro Company and are shown in Figure 2.3-6.

2.9 HOT PIPING

The hot salt piping for the Pump & Valve Test was purchased, and fabricated in accordance with B&V Specification 11548.72.0000 Pump and Valve Experiment Mechanical Construction Specification [7]. The piping, fabrication, and testing are in accordance with ANSI Code for Pressure Piping B31.1-1983 and Power Piping Code ANSI B31.1b-1984.

The hot loop is designed to 200 psig and 1075°F, and operated at 157 psig and 1050°F. The piping is ASTM A312 type 304 stainless steel. All 2-1/2 inch diameter and larger piping is Schedule 40S with the exception of 4 inch which is XXS; 2 inch and smaller piping is also Schedule 40S. These sizes and schedules are in conform to ANSI B36.10. The hot loop piping is arranged as shown is B&V drawing M3002, Figure 2.1-3. The piping is heat traced and insulated for temperature maintenance and personnel protection.

The piping is supported at various location by pipe supports supplied by Pipe Shields, Inc. The supports include 9 inches of high density calcium silicate insulation, a protective jacket, and a pipe hanger.

2.10 HOT SUMP TANK

The hot salt tank is a type 304 stainless steel tank designed and constructed in accordance with ASME Boiler and Pressure Vessel Code, Section VIII, Division 2. The tank, manufactured by Continental Boiler Works (CBW), is 5 foot tall and 10 foot in diameter and is constructed in accordance with B&V Specification 11548.62.3602 for Pump and Valve Experiment Molten Salt Tanks [9]. The tank holds a total of 35,000 pounds of molten salt which is required for operation of the hot loop. The sump tank has a 1/2 inch plate roof designed to support the hot salt pump and the immersion cooler. It is fully heat traced with mineral insulated cable with a primary heat input of 15kw, insulated and instrumented for temperature control. Thermocouples are integral to the tank via thermowells inserted through the sump wall. Thermocouples located at six locations on the outside of the tank are used for temperature monitoring and controlling salt temperature in the sump tank. A bubbler level transmitter is used to measure salt level in the tank. Both the thermocouples and level transmitter are interlocked to the control system.

2.11 HOT IMMERSION COOLER

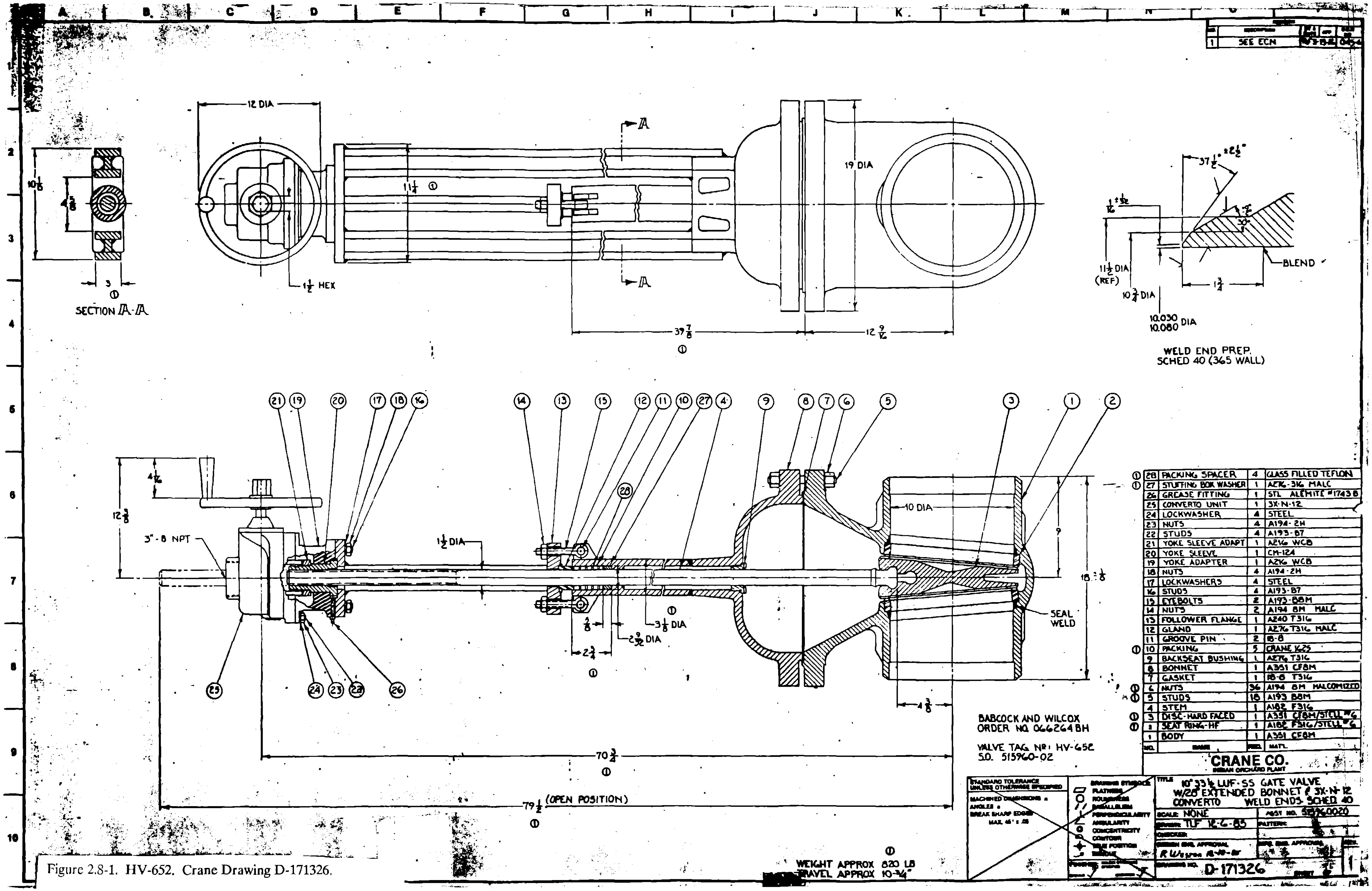
The hot loop immersion salt cooler in the hot sump tank is a U-tube salt to air heat exchanger designed to reject the heat generated in the test loop by the hot salt pump. The cooler is designed and manufactured to B&W specification RLD-894-0022-10-20 Pump and Valve Test Hot Loop Immersion Cooler [10] by Happy Division of Therma Technology, Inc. The cooler is designed, fabricated, tested, and code stamped in accordance with ASME Boiler and Pressure Vessel Code, Section VIII, Division 1.

The cooler is designed for a heat removal rate of 9.0 X 10^5 BTU/hr with a salt inlet temperature of 1052°F and an outlet temperature of 1050°F. The salt side design flow is 1850 GPM. The air side design conditions are; inlet temperature of 100°F, outlet temperature of 441°F with an air flow of 3000 ACFM. The cooler tube bundle consists of 49 - 1.5 inches diameter by .083 inches minimum wall by 10 feet long U-tubes. Air flow through the tubes is provided by a 25 horsepower Twin City model 20TBA25 Turbo Blower Assembly. The blower delivers the required flow to remove the excess heat.

2.12 IMMERSION HEATERS

Four immersion heaters are mounted in the top of the hot salt sump tank, the heaters are used for heat-up of the salt from 500°F to 1050°F and for maintenance of the salt temperature at 1050°F during non-testing of the hot salt pump and valve test loop. The immersion heaters are 25 KW flanged electrical heaters. The heaters were designed and fabricated in accordance with B&V Specification 11548.62.1205 Pump and Valve Experiment Immersion Heaters [11] and all applicable requirements of ASME, ASTM, ANSI, NEMA, IEEE, and OSHA. The heaters were fabricated by Wellman Thermal Systems.

The mounting flanges are 6" - 150# 304 stainless steel and the sheath material is Incoloy 800. The heaters are three phase, 480 vac and are weathertight for outdoor use. Two type K thermocouples are mounted on the heater sheath for monitoring and controlling hot salt sump temperature through the Network 90 control system. The heaters are controlled in two steps, Heaters 1 and 2 cycle between 1025°F and 1050°F while Heater 3 and 4 cycles between 1025°F and 1050°F.



28	PACKING SPACER	4	GLASS FILLED TEFLON
27	STUFFING BOX WASHER	1	A276-316 MALC
26	GREASE FITTING	1	STL ALEMITE #1743B
25	CONVERTO UNIT	1	3X-N-12
24	LOCKWASHER	4	STEEL
23	NUTS	4	A194-2H
22	STUDS	4	A193-B7
21	YOKE SLEEVE ADAPT	1	A216 WCB
20	YOKE SLEEVE	1	CM-124
19	YOKE ADAPTER	1	A216 WCB
18	NUTS	4	A194-2H
17	LOCKWASHERS	4	STEEL
16	STUDS	4	A193-B7
15	EYEBOLTS	2	A193-B8M
14	NUTS	2	A194 8M MALC
13	FOLLOWER FLANGE	1	A240 T316
12	GLAND	1	A276 T316 MALC
11	GROOVE PIN	2	18-8
10	PACKING	5	CRANE 1625
9	BACKSEAT BUSHING	1	A276 T316
8	BONNET	1	A351 CF8M
7	GASKET	1	18-8 T316
6	NUTS	36	A194 8M MALCOMIZED
5	STUDS	18	A193 B8M
4	STEM	1	A182 F316
3	DISC-HARD FACED	1	A351 CF8M/STELL #6
1	SEAT RING-HF	1	A182 F316/STELL #6
1	BODY	1	A351 CF8M

Figure 2.8-1. HV-652. Crane Drawing D-171326.

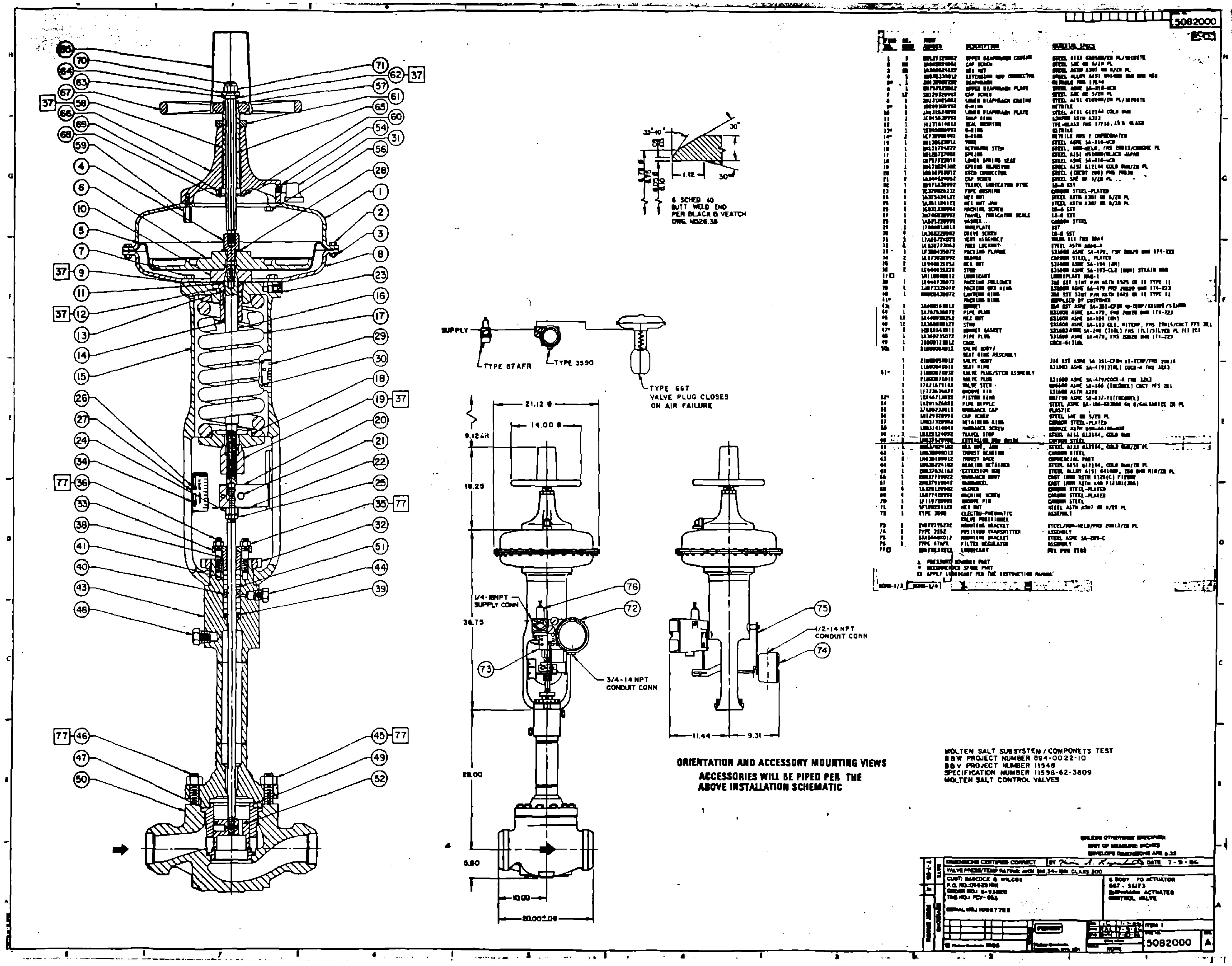
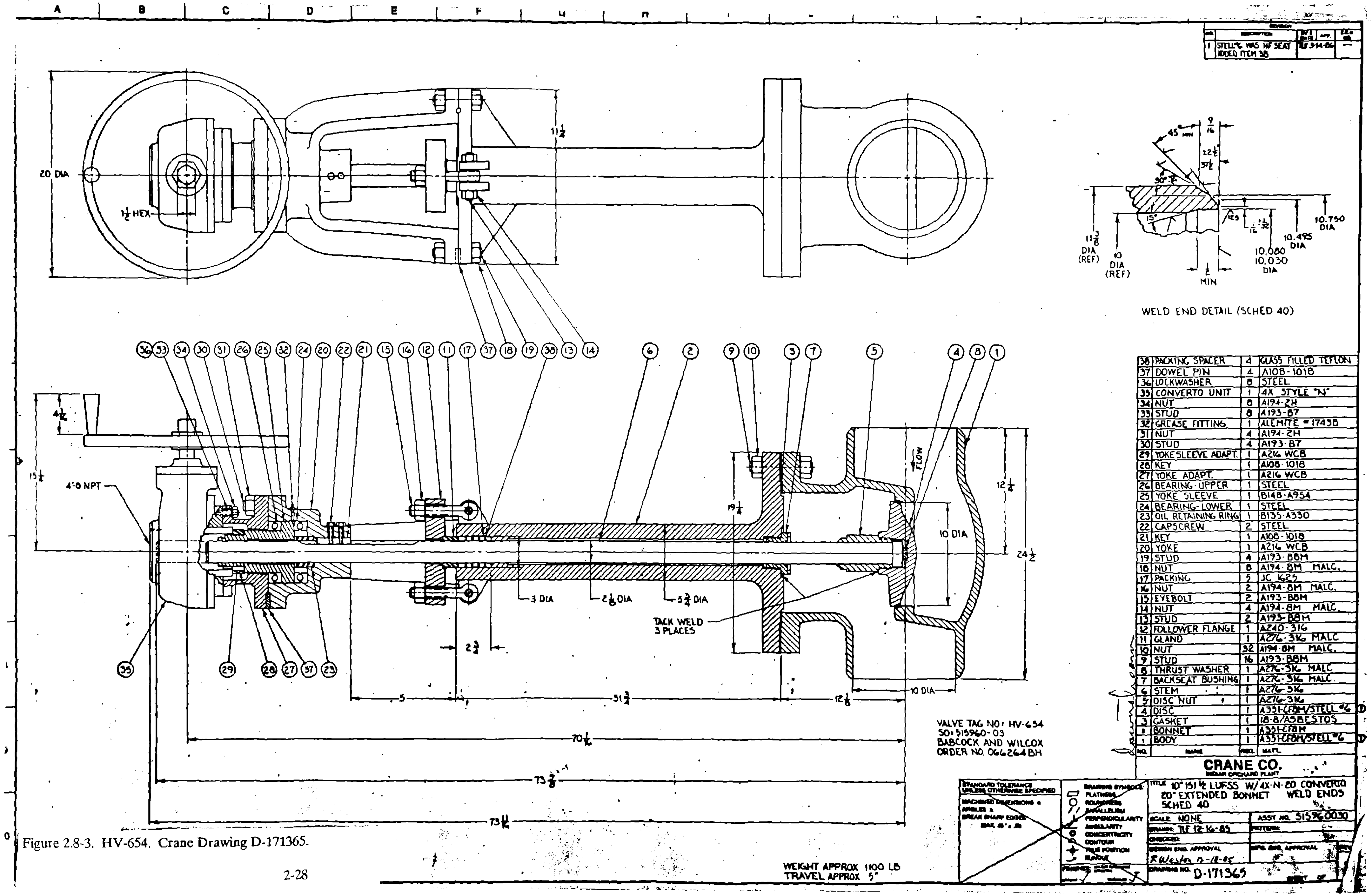
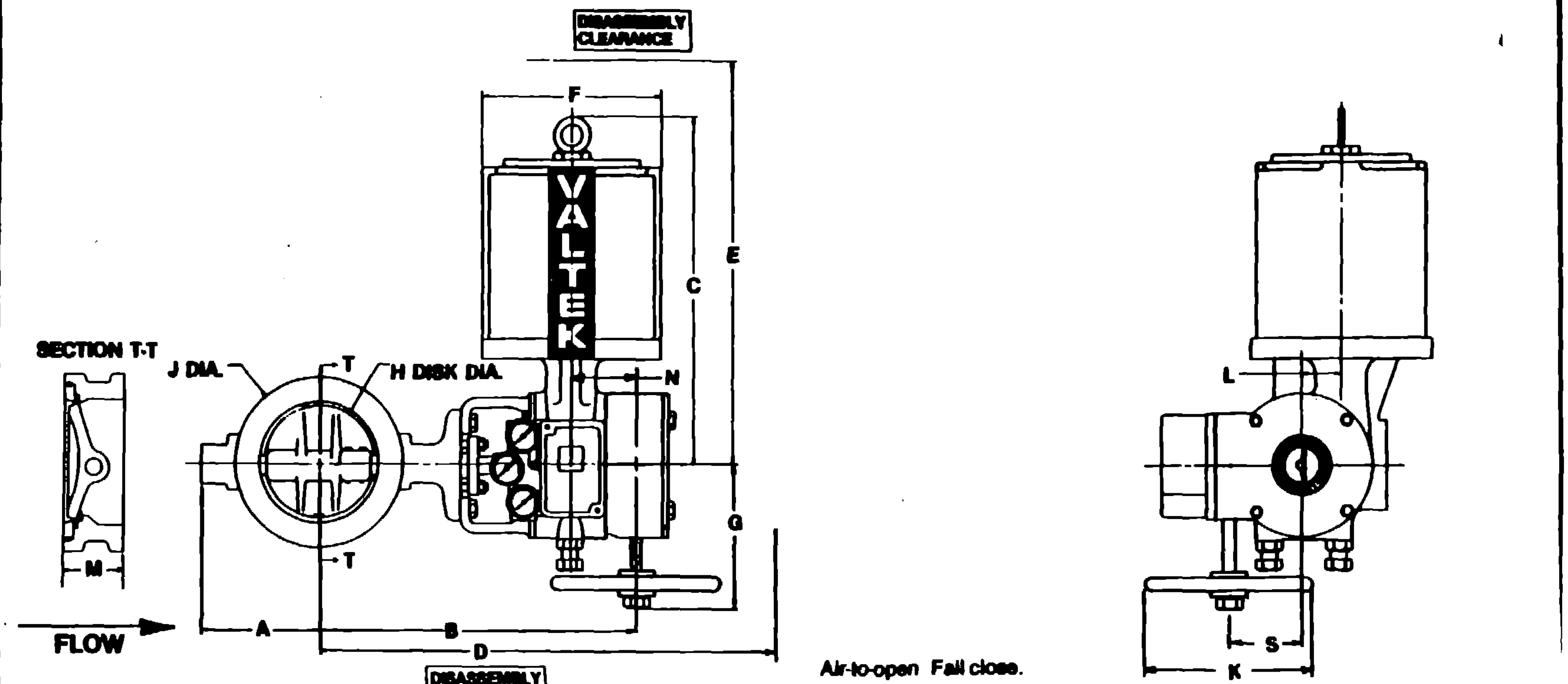


Figure 2.8-2. FCV-653. Fisher Drawing 50B2000.



NO.	NAME	REQ.	MATL.
38	PACKING SPACER	4	GLASS FILLED TEFLON
37	DOWEL PIN	4	A108-1018
36	LOCKWASHER	8	STEEL
35	CONVERTO UNIT	1	4X STYLE "N"
34	NUT	8	A194-2H
33	STUD	8	A193-B7
32	GREASE FITTING	1	ALEMITE #1743B
31	NUT	4	A194-2H
30	STUD	4	A193-B7
29	YOKE SLEEVE ADAPT.	1	A216 WCB
28	KEY	1	A108-1018
27	YOKE ADAPT.	1	A216 WCB
26	BEARING-UPPER	1	STEEL
25	YOKE SLEEVE	1	B148-A954
24	BEARING-LOWER	1	STEEL
23	OIL RETAINING RING	1	B135-A330
22	CAPSCREW	2	STEEL
21	KEY	1	A108-1018
20	YOKE	1	A216 WCB
19	STUD	4	A193-B8M
18	NUT	8	A194-8M MALC.
17	PACKING	5	JC 625
16	NUT	2	A194-8M MALC.
15	EYEBOLT	2	A193-B8M
14	NUT	4	A194-8M MALC.
13	STUD	2	A193-B8M
12	FOLLOWER FLANGE	1	A240-316
11	GLAND	1	A276-316 MALC
10	NUT	32	A194-8M MALC.
9	STUD	16	A193-B8M
8	THRUST WASHER	1	A276-316 MALC
7	BACKSEAT BUSHING	1	A276-316 MALC.
6	STEM	1	A276-316
5	DISC NUT	1	A276-316
4	DISC	1	A351-CF8M/STELL #6
3	GASKET	1	18-8/ASBESTOS
2	BONNET	1	A351-CF8M
1	BODY	1	A351-CF8M/STELL #6

Figure 2.8-3. HV-654. Crane Drawing D-171365.



Body Pressure Class ☐ 150 ■ 300 ☐ 600

VALVE SIZE	A	B	C	D	E	F	G	H	J	K	L	M	N	S
6 INCH	6.76"	17.4"	17.88"	34.9"	23.35"	9.19"	9.5"	5.5"	8.5"	12.0"	1.96"	2.25"	3.25"	3.5"

CUSTOMER	CERTIFIED DIMENSIONAL DRAWING		VALTEK
BABCOCK & WILCOX			
CUSTOMER ORDER NO	CERTIFIED BY [signature]	DATE	VALDISK DECLUTCHABLE SIDE-MOUNTED HANDWHEEL DIMENSIONAL DRAWING
06250 BH			
VALTEK SERIAL NO	TAG NO	ACCESSORIES MOUNTED BUT NOT SHOWN	
39505-1	FCV-655	4-20 POSITION TRANSMITTER	
ITEM NO		AIRFILTER	
1			
PAGE			DRAWING NO. 39505-1 / REV. 0
1			

Figure 2.8-4. FCV-655. Valtek Drawing 39505-1.

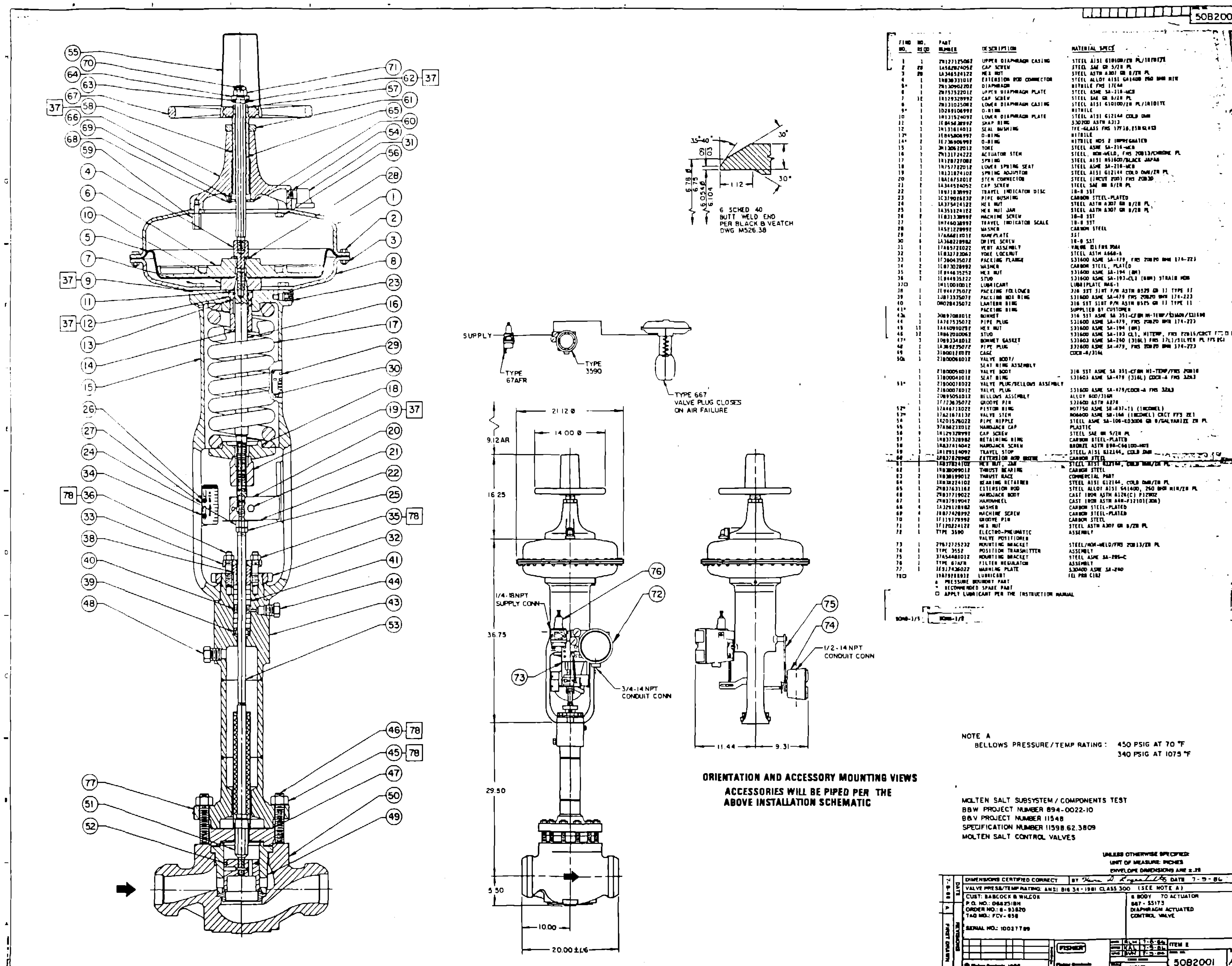


Figure 2.8-5. FCV-658. Fisher Drawing 50B2001.

2.13 INSTRUMENTATION/CONTROLS

2.13.1 OVERVIEW

The control and monitoring of the Pump & Valve Test loop is accomplished through a Bailey Control Company Network 90 (Net 90) system. The Net 90 sends and receives signals from all major components in the Pump & Valve Test. It also interfaces with an Acurex system. Both the Bailey and the Acurex are located in the data collection building on the Pump & Valve Test site. This section describes the transmitters, thermocouples and other equipment which provide signals to the Net 90 necessary for control and monitoring of the Pump & Valve Test.

2.13.2 TRANSMITTERS

The transmitters discussed below are located on the Pump & Valve Test hot and cold loops. These transmitters measure flows, pressures, and sump tank levels and transmit signals through the junction boxes to the Net 90. All signals to the Net 90 are 4-20 madc unless otherwise noted. The designations for each of the transmitters discussed below are taken from the Pump & Valve Test P&ID [12], Figure 2.13-1. These transmitters were purchased in accordance with references [13], [14], [15], and [16].

Cold Salt Loop Flow Transmitter FT-600

Transmitter

Manufacturer: Rosemount, Inc.

Model No.: 1151DP8E22S2B1

Flow Device

Manufacturer: Energy Flow Systems

Model: Type VTW Weld-in Venturi, 10 inch diameter

The transmitter senses the pressure drop across the flow venturi located downstream of the cold salt pump as show in Figure 2.13-1. Salt flowrate is a function of this pressure drop. The transmitter is mounted adjacent to the venturi by a mounting bracket. The transmitter assembly includes two remote seal elements and capillary tubes which are filled with Syltherm 800 silicon oil. The fill fluid in the capillary tubes transmits the salt pressure to the transmitter while providing a barrier between the salt and the transmitter.

Cold Loop Pressure Transmitter PT-601

Manufacturer: Taylor Instruments Co.
Model: X3445 TF 10229-02-05 (146) Model B

The transmitter senses the pressure of the molten salt in the cold loop upstream of the FCV-603/605 loop as show in Figure 2.13-1. The transmitter assembly includes a diaphragm seal element mounted on the piping and a capillary tube which is filled with NaK (Sodium/Potassium) fill fluid. The fill fluid in the capillary tube transmits the salt pressure to the transmitter while providing a barrier between the salt and the transmitter. The loop salt pressure is measured for the purpose of indicating and recording.

Downstream Cold Loop Pressure Transmitter PT-602

Manufacturer: Taylor Instruments Co.
Model: X3445 TF 10229-02-05 (146) Model B

The transmitter senses the pressure of the molten salt in the cold loop between FCV-603/605 loop and FCV-608 as show in Figure 2.13-1. The transmitter assembly includes a diaphragm seal element mounted on the piping and a capillary tube which is filled with NaK fill fluid. The fill fluid in the capillary tube transmits the salt pressure to the transmitter while providing a barrier between the salt and the transmitter. The loop salt pressure is measured for the purpose of controlling the loop pressure.

Salt Cooler Inlet Pressure Transmitter PT-603

Manufacturer: Taylor Instruments Co.

Model: X3445 TF 10229-02-05 (146) Model B

The transmitter senses the pressure of the molten salt at the inlet of the cold loop salt cooler downstream of FCV-608 as show in Figure 2.13-1. The transmitter assembly includes a diaphragm seal element mounted on the piping and a capillary tube which is filled with NaK fill fluid. The fill fluid in the capillary tube transmits the salt pressure to the transmitter while providing a barrier between the salt and the transmitter. The loop salt pressure is measured for indicating and recording purposes.

Cold Sump Tank Level Transmitter LT-600

Manufacturer: Computer Instrument Corp.

Model: 7600 Bubbler

This transmitter is a bubbler level transmitter which senses the level of the molten salt in the cold tank as shown in Figure 2.13-1.

Hot Salt Loop Flow Transmitter FT-650

Manufacturer: Taylor Instruments Co.

Model: 3478 TD 10203-02-05 (131)(146)

Flow Element Model: X1344LZ/SPR10538

The transmitter senses the pressure drop across the Taylor wedge flow element located downstream of the hot salt pump as show in Figure 2.13-1. Salt flowrate is a function of this pressure drop. The transmitter is mounted adjacent to the wedge device by a mounting bracket. The transmitter assembly includes two remote seal elements and capillary tubes which are filled with NaK fill fluid. The fill fluid in the capillary tubes transmits the salt pressure to the transmitter while providing a barrier between the salt and the transmitter.

Hot Loop Pressure Transmitter PT-651

Manufacturer: Taylor Instruments Co.
Model: X3443 TF 10226-02-05 (93)(146) Model B

The transmitter senses the pressure of the molten salt in the hot loop upstream of the FCV-653/655 loop as show in Figure 2.13-1. The transmitter assembly includes a diaphragm seal element mounted on the piping and a capillary tube which is filled with NaK fill fluid. The fill fluid in the capillary tube transmits the salt pressure to the transmitter while providing a barrier between the salt and the transmitter. The loop salt pressure is measured for the purpose of indicating and recording.

Downstream Cold Loop Pressure Transmitter PT-652

Manufacturer: Taylor Instruments Co.
Model: X3443 TF 10226-02-05 (93)(146) Model B

The transmitter senses the pressure of the molten salt in the hot loop between FCV-653/655 loop and FCV-658 as show in Figure 2.13-1. The transmitter assembly includes a diaphragm seal element mounted on the piping and a capillary tube which is filled with NaK fill fluid. The fill fluid in the capillary tube transmits the salt pressure to the transmitter while providing a barrier between the salt and the transmitter. The loop salt pressure is measured for the purpose of controlling the loop pressure.

FCV-658 Downstream Pressure Transmitter PT-653

Manufacturer: Taylor Instruments Co.
Model: X3443 TF 10226-02-05 (93)(146) Model B

The transmitter senses the pressure of the molten salt downstream of FCV-658 as show in Figure 2.13-1. The transmitter assembly includes a diaphragm seal element mounted on the piping and a capillary tube which is filled with NaK fill fluid. The fill fluid in the capillary tube transmits the salt pressure to the transmitter while providing a barrier between the salt and the transmitter. The loop salt pressure is measured for indicating and recording purposes.

Hot Sump Tank Level Transmitter LT-650

Manufacturer: Computer Instrument Corp.
Model: 7600 Bubbler

This transmitter is a bubbler level transmitter which senses the level of the molten salt in the hot tank as shown in Figure 2.13-1.

2.13.3 VALVE POSITIONERS, POSITION INDICATORS, LIMIT SWITCHES

Pneumatically operated valves in the Pump & Valve Test are positioned by the control system by a 4-20 madc signal to the valve positioner. The positioner converts this signal to an air pressure supplied to the valve diaphragm or piston to move the valve between 0% and 100% of full open. Valves used for control purposes have position indicators which transmit a 4-20 madc feedback signal to the control system to indicate 0% to 100% of full open valve position.

2.13.4 THERMOCOUPLES

The thermocouples installed as part of the Pump & Valve Test are grouped into three categories: control/indicating thermocouples, heat trace control thermocouples and informational thermocouples. All thermocouples were purchased in accordance with reference [17].

2.13.4.1 CONTROL/INDICATING THERMOCOUPLES

The thermocouples required for control of the Pump & Valve Test and for indicating and recording of various temperatures listed in Table 2.13.4.1. The thermocouples are immersion thermocouples which are installed in the fluid stream to approximately the centerline of the pipe and 10 inches into the sump tanks. These are located as indicated on B&W drawing 418351E [12], Figure 2.13-1. The thermocouples are Type K ungrounded, dual element with a waterproof head located outside the insulation. The signal from these thermocouples is sent to the Net 90.

2.13.4.2 HEAT TRACE CONTROL THERMOCOUPLE

The operation of the heat trace control zones is controlled by forty thermocouple signals transmitted to the Acurex Data Logger. The thermocouple are pad type thermocouples. The pads are mounted on the pipe and component outside surfaces at locations indicated in Table 2.13.4-2 & 3 and as shown on B&V Drawing R7512 [18] and R7513 [19], Figures 2.13-2 and 2.13-3. The thermocouples are ungrounded, type K dual element with waterproof head located outside the insulation.

2.13.4.3 INFORMATIONAL THERMOCOUPLES

Fifty thermocouples are installed at various location in the Pump & Valve Test loops to provide additional information on the operating characteristics of the system. The thermocouples are sheathed thermocouples located as indicated on the drawings listed in Table 2.13.4-4 & 5 and shown in Figures 2.13-2 and 2.13.3. The thermocouples are type K, ungrounded with a plug connector located outside the insulation.

2.13.5 NETWORK 90 SYSTEM EQUIPMENT

The Net 90 equipment includes an operator interface unit (OIU), a driver cabinet for the OIU, a process control unit (PCU) and a printer. The equipment is located in the data acquisition building. The OIU consists of a CRT console and keyboard for Pump & Valve Test operation overview, control, alarm indicating and tuning and configuration of the control system. The OIU driver cabinet contains the necessary electronics for OIU operation.

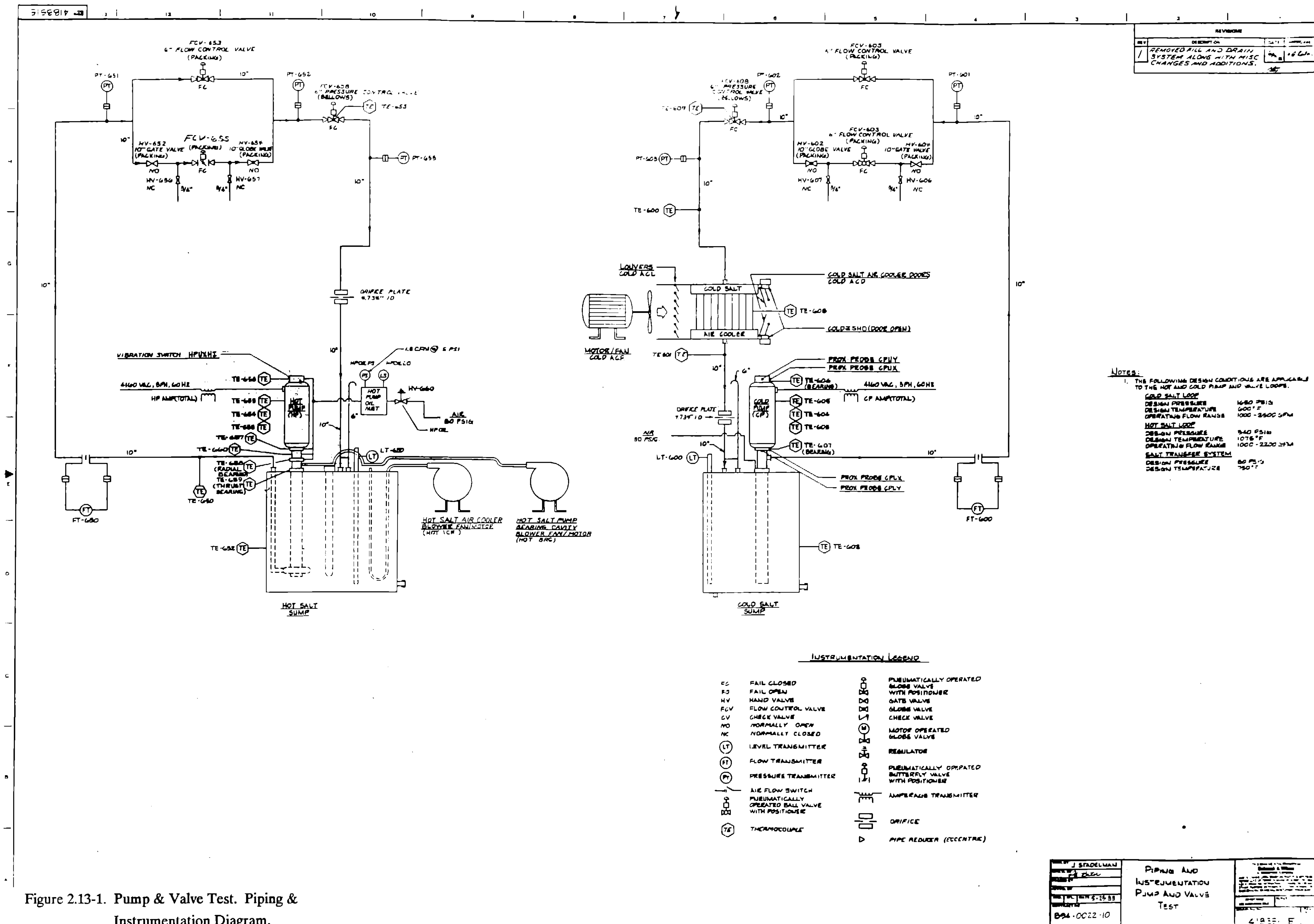


Figure 2.13-1. Pump & Valve Test. Piping & Instrumentation Diagram.

Table 2.13.4-1

Pump & Valve Test Loop Control Thermocouples

Thermocouple	Description	Drawing #
TE600	Cold Salt Cooler Inlet	B&W 418351
TE601	Cold Salt Cooler Outlet	B&W 418351
TE602	Cold Salt Sump	B&W 418351
TE603	Cold Salt Pump L1 Motor	B&W 418351
TE604	Cold Salt Pump L2 Motor	B&W 418351
TE605	Cold Salt Pump L3 Motor	B&W 418351
TE606	Cold Salt Pump Upper Bearing	B&W 418351
TE607	Cold Salt Pump Lower Bearing	B&W 418351
TE608	Cold Salt Air Cooler Temperature	B&W 418351
TE650	Hot Salt System Temperature	B&W 418351
TE652	Hot Salt Sump Temperature	B&W 418351
TE653	Hot Salt Pump L1 Motor	B&W 418351
TE654	Hot Salt Pump L2 Motor	B&W 418351
TE655	Hot Salt Pump L3 Motor	B&W 418351
TE656	Hot Salt Pump Upper Bearing	B&W 418351
TE657	Hot Salt Pump Lower Bearing	B&W 418351
TE658	Hot Salt Pump Radial Bearing	B&W 418351
TE659	Hot Salt Pump Thrust Bearing	B&W 418351
TE660	Hot Salt Pump Bearing Cavity	B&W 418351

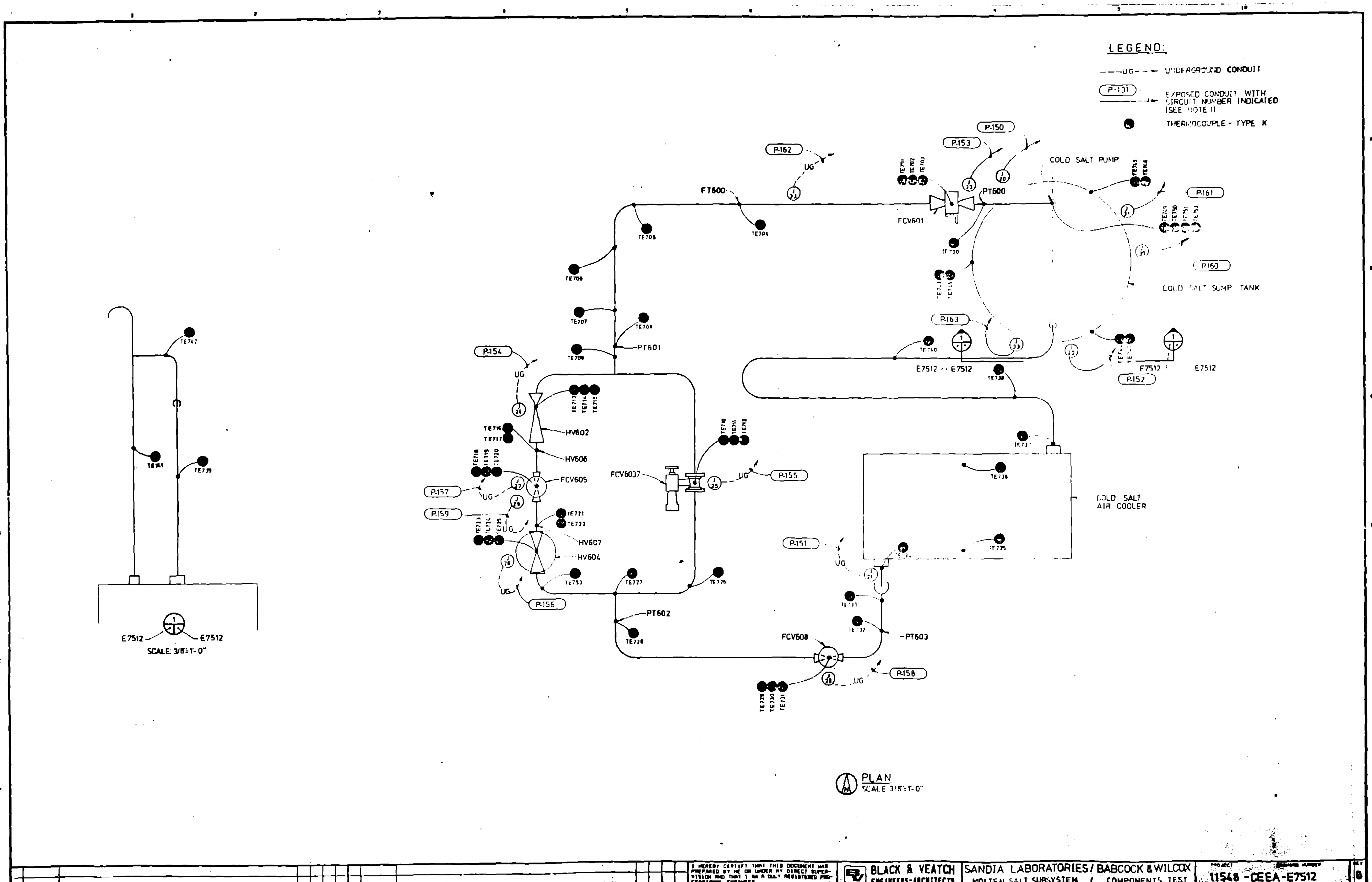


Figure 2.13-2. Cold Loop Thermocouples. B&V Drawing R7512.

Table 2.13.4-3

Heat Trace Control Thermocouples
Hot Loop

Thermocouple	Description	Drawing #
TE800	Hot Pump Discharge Pipe	B&V R7513
TE801	FT651 Diaphragm	B&V R7513
TE802	Hot Pump Discharge Pipe	B&V R7513
TE808	FCV653 Bonnet	B&V R7513
TE811	HV652 Bonnet	B&V R7513
TE813	HV656 Bonnet	B&V R7513
TE816	FCV655 Bonnet	B&V R7513
TE818	HV657 Bonnet	B&V R7513
TE821	HV654 Bonnet	B&V R7513
TE822	Control Valve Loop Elbow	B&V R7513
TE828	FCV658 Bonnet	B&V R7513
TE829	PT653 Diaphragm	B&V R7513
TE833	Hot Salt Sump Lower Side	B&V R7513
TE836	Hot Salt Sump Upper Side	B&V R7513
TE839	Hot Salt Sump Vent Pipe	B&V R7513
TE840	Hot Sump Heaters 1 and 2	B&V R7513
TE841	Hot Sump Heaters 3 and 4	B&V R7513

Table 2.13.4-2

Heat Trace Control Thermocouples
Cold Loop

Thermocouple	Description	Drawing #
TE700	Pump Discharge Pipe	B&V R7512
TE701	FT600 Diaphragm	B&V R7512
TE702	Pump Discharge Pipe Elbow	B&V R7512
TE708	FCV603 Bonnet	B&V R7512
TE711	HV602 Bonnet	B&V R7512
TE713	HV606 Bonnet	B&V R7512
TE716	FCV605 Bonnet	B&V R7512
TE718	HV607 Bonnet	B&V R7512
TE721	HV604 Bonnet	B&V R7512
TE722	Control Valve Loop Elbow	B&V R7512
TE728	FCV608 Bonnet	B&V R7512
TE729	PT603 Diaphragm	B&V R7512
TE730	Air Cooler Inlet Pipe	B&V R7512
TE732	Air Cooler Tube Bundle	B&V R7512
TE733	Air Cooler Tube Bundle	B&V R7512
TE735	Air Cooler Outlet Pipe	B&V R7512
TE738	Cold Sump Tank Inlet Pipe	B&V R7512
TE740	Cold Sump Side Lower	B&V R7512
TE743	Cold Sump Side Upper	B&V R7512
TE745	Cold Sump Pipe Riser	B&V R7512
TE746	Cold Sump Pipe Riser	B&V R7512
TE748	Cold Sump Vent Pipe	B&V R7512

Table 2.13.4-3

Heat Trace Control Thermocouples
Hot Loop

Thermocouple	Description	Drawing #
TE800	Hot Pump Discharge Pipe	B&V R7513
TE801	FT651 Diaphragm	B&V R7513
TE802	Hot Pump Discharge Pipe	B&V R7513
TE808	FCV653 Bonnet	B&V R7513
TE811	HV652 Bonnet	B&V R7513
TE813	HV656 Bonnet	B&V R7513
TE816	FCV655 Bonnet	B&V R7513
TE818	HV657 Bonnet	B&V R7513
TE821	HV654 Bonnet	B&V R7513
TE822	Control Valve Loop Elbow	B&V R7513
TE828	FCV658 Bonnet	B&V R7513
TE829	PT653 Diaphragm	B&V R7513
TE833	Hot Salt Sump Lower Side	B&V R7513
TE836	Hot Salt Sump Upper Side	B&V R7513
TE839	Hot Salt Sump Vent Pipe	B&V R7513
TE840	Hot Sump Heaters 1 and 2	B&V R7513
TE841	Hot Sump Heaters 3 and 4	B&V R7513

Table 2.13.4-4

Informational Thermocouples
Cold Loop

Thermocouple	Description	Drawing #
TE703	Pump Discharge Pipe	B&V R7512
TE704	PT601 Diaphragm	B&V R7512
TE705	Discharge Pipe Tee	B&V R7512
TE706	FCV603 Body	B&V R7512
TE707	FCV603 Bonnet	B&V R7512
TE709	HV602 Body	B&V R7512
TE710	HV602 Bonnet	B&V R7512
TE712	Cold Valve Loop Piping	B&V R7512
TE714	FCV605 Body	B&V R7512
TE715	FCV605 Bonnet	B&V R7512
TE717	Control Valve Loop Piping	B&V R7512
TE719	HV604 Body	B&V R7512
TE720	HV604 Bonnet	B&V R7512
TE723	Control Valve Loop Elbow	B&V R7512
TE724	PT602 Diaphragm	B&V R7512
TE725	Air Cooler Inlet Piping	B&V R7512
TE726	FCV608 Body	B&V R7512
TE727	FCV608 Bonnet	B&V R7512
TE731	Air Cooler Inlet Elbow	B&V R7512
TE734	Air Cooler Outlet Piping	B&V R7512
TE736	Air Cooler Outlet Piping	B&V R7512
TE737	Air Cooler Outlet Piping	B&V R7512
TE739	Cold Sump Upper Side	B&V R7512
TE741	Cold Sump Upper Side	B&V R7512
TE742	Cold Sump Lower Side	B&V R7512
TE744	Cold Sump Lower Side	B&V R7512
TE747	Sump Vent Elbow	B&V R7512

Table 2.13.4-5

Informational Thermocouples
Hot Loop

Thermocouple	Description	Drawing #
TE803	Hot Pump Discharge Pipe	B&V R7513
TE804	Hot Pump Discharge Elbow	B&V R7513
TE805	Hot Pump Discharge Tee	B&V R7513
TE806	FCV653 Body	B&V R7513
TE807	FCV653 Bonnet	B&V R7513
TE809	HV652 Body	B&V R7513
TE810	HV652 Bonnet	B&V R7513
TE812	Hot Valve Loop Piping	B&V R7513
TE814	FCV655 Body	B&V R7513
TE815	FCV655 Bonnet	B&V R7513
TE817	Hot Valve Loop Pipe	B&V R7513
TE819	HV654 Body	B&V R7513
TE820	HV654 Bonnet	B&V R7513
TE823	Hot Valve Loop Elbow	B&V R7513
TE824	Hot Sump Return Piping	B&V R7513
TE825	PT652 Diaphragm	B&V R7513
TE826	FCV658 Body	B&V R7513
TE827	FCV658 Bonnet	B&V R7513
TE830	Hot Sump Return Piping	B&V R7513
TE831	Hot Sump Return Piping	B&V R7513
TE832	Hot Sump Upper Side	B&V R7513
TE834	Hot Sump Upper Side	B&V R7513
TE835	Hot Sump Lower Side	B&V R7513
TE837	Hot Sump Lower Side	B&V R7513
TE838	Hot Sump Vent Elbow	B&V R7513

2.14 MOTOR CONTROL CENTER/SWITCHGEAR

4160-volt switchgear is provided in the pump and valve test loops for operation of the hot and cold salt pumps. The switchgear was purchased from Westinghouse Electric Corporation based upon Black & Veatch Specification 11548.63.3603 [20]. The switchgear is comprised of the following four sections.

Section 1 contains a 4160-volt, 3-phase, 600-amp load break switch for the operation of the 2250 horsepower cold salt pump motor. The current limiting fuses are rated for 450 amps. The switchgear is reduced voltage nonreversing with an auto-transformer. The switchgear included a current transformer for monitoring the amperages of the three phases of the motor. The amperage is displayed on the cabinet face on an analog dial and remotely by a 4 to 20 ma signal for input into the Network 90 control system. The motor is operated through the switchgear from a 24vdc signal from the Network 90 control system. The manual override capability of the switchgear has been removed so that operation of the motor can only be accomplished through the Network 90. A emergency kill switch is provided in the data collection enclosure which will terminate pump operation. The switch is manually operated by the test conductor. The switchgear is provided with a loss of phase relay.

Section 2 contains a 4160 Volt, 3 phase, 600 amp load break switch for the operation of the 350 horsepower hot salt pump motor. The current limiting fuses are rated at 100 amps. The switchgear is full voltage nonreversing. The switchgear included a current transformer for monitoring the amperages of the three phases of the motor. The amperage is displayed on the cabinet face on an analog dial and remotely by a 4 to 20 ma signal for input into the Network 90 control system. The motor is operated through the switchgear from a 24vdc signal from the Network 90 control system. The manual override capability of the switchgear has been removed so that operation of the motor can only be accomplished through the Network 90. A emergency kill switch is provided in the data collection enclosure which will terminate pump operation. The switch is manually operated by the test conductor. The switchgear is provided with a loss of phase relay.

Section 3 contains a 4160 Volt, 3 phase, 800 amp load break switch for main incoming power. The cabinet face contains an analog dial for monitoring system amperage of the three phases separately, incoming voltage of the three phases separately and the power factor.

Section 4 contains a 4160 Volt, 3 phase, 600 amperage load break switch which provides control of the 4160/480 Volt transformer for facility power. The cabinet face contains an amperage dial to monitor the amperage at the transformer.

2.15 HEAT TRACE

The Pump & Valve Test piping, valves, pumps, tanks and instrumentation are heat traced. The heat trace system allows the piping and components to be heated from ambient conditions to a temperature above the salt freezing point prior to salt fill into the Pump & Valve Test. The system also maintains the temperature above the freezing point during periods of shutdown.

The heat loss was calculated based on the following conditions.

- Power input based on 550°F temperature difference between salt system component and ambient temperature.
- 1" of Kaowool blanket insulation and 8" of Calcium-Silicate insulation on piping.
- 8" of Kaowool blanket on all other components.
- Conductivity for Kaowool is .057 BTU/hrftF; Conductivity for Calcium-Silicate is .054 BTU/hrftF.

The heat trace was designed and fabricated to meet B&V Specification 11548.63.1401 Pump and Valve Experiment Molten Salt Heat Tracing [21] by Pyrotenax, USA. There are 29 heat trace zones in the Pump & Valve Test. Zones 1 thru 14 are in the hot loop and zones 20 thru 34 are in the cold loop. The heat tracing information is summarized in Table 2.15-1. All of the heat trace is Incoloy sheath, mineral-insulated cable with single conductors of nichrome wire. Redundant heat trace cables are installed as back up on all piping and components.

Table 2.15-1

Heat Trace Zones
Hot Loop

Zone	Description	Drawing #
1	10 inch piping extending from point A to point B hot pump discharge to control valve station	B&V M3002
2	10 inch piping including valves FCV653, FCV655, FCV658, HV652 and HV654 from point B to point D hot tank return piping	B&V M3002
4	HV652 valve bonnet	B&V M3002
5	FCV653 valve bonnet	B&V M3002
6	HV654 valve bonnet	B&V M3002
7	FCV655 valve bonnet	B&V M3002
8	FCV658 valve bonnet	B&V M3002
9	HV656 and HV657 and drip leg piping	B&V M3002
10	Instrumentation	B&V M3002
11	Hot sump tank sides	B&V M3002
12	Hot sump vent piping points E, F and G	B&V M3002

Table 2.15-2

Heat Trace Zones
Cold Loop

Zone	Description	Drawing #
20	10 inch piping from cold pump discharge to control valve station point H to point I	B&V M3001
21	10 inch piping from point I including valves FCV603, FCV605, FCV608, HV602 and HV604 to air cooler inlet point J	B&V M3001
22	10 inch piping between points K and L, air cooler outlet to sump return line	B&V M3001
24	HV602 valve bonnet	B&V M3001
25	FCV604 valve bonnet	B&V M3001
26	HV604 valve bonnet	B&V M3001
27	FCV605 valve bonnet	B&V M3001
28	FCV608 valve bonnet	B&V M3001
29	HV606 and HV607 including drip leg piping	B&V M3001
30	Cold sump tank sides	B&V M3001
31	Cold salt pump discharge head	B&V M3001
32	Instrumentation	B&V M3001
33	Cold sump vent piping between points N and O including point P	B&V M3001

3.0 ERECTION

3.1 BACKGROUND

The MSSCTE pump and valve test loop was erected at Sandia National Laboratories Central Receiver Test Facility (CRTF) in Albuquerque, New Mexico. The major construction specifications were prepared by Black & Veatch Engineer-Architects and these specifications were used by Babcock & Wilcox to obtain quotations and award contracts with local contractors. The Black & Veatch specifications for erection were developed based upon standard commercial criteria which would be used for a solar central receiver power plant. All fabrication, erection, and quality assurance was under the management of Babcock & Wilcox personnel with aid from Black & Veatch as necessary. Babcock & Wilcox provided a full time construction manager at the site to coordinate the efforts of the contractors. Babcock & Wilcox purchased the major mechanical and electrical hardware and this was shipped to the CRTF for erection by the contractors.

The erection of the pump and valve test loop was contracted into five parts:

- General construction
- Mechanical construction
- Electrical construction
- Insulation
- Nondestructive testing

3.2 GENERAL CONSTRUCTION

The general construction was comprised of site excavation, sump pit foundation erection, building foundations and structural steel erection, pipe support foundation erection, and berm development. Black & Veatch specification 11548.71.0000 [22] was used as the contracting document for the general construction.

3.3 MECHANICAL CONSTRUCTION

The mechanical construction was comprised of piping fabrication and erection, pipe hanger support fabrication and erection, installation of major customer supplied hardware and hydrotesting of the pressure boundary components. Black & Veatch specification 11584.72.0000 [7] was used as the contracting document for the mechanical construction except that the insulated pipe hangers, insulation application, nondestructive testing and crane support were removed from the workscope and sublet separately by Babcock & Wilcox.

3.4 ELECTRICAL CONSTRUCTION

The electrical construction was comprised of the installation of all power and signal wiring and conduit, installation of the 4160 volt switchgear and transformer, installation and connection of heat trace, and electrical support during start-up of the system. Black & Veatch specification 11548.73.0000 [23] was used as the contracting document for the electrical construction.

3.5 INSULATION

The insulation contract was removed from the mechanical contractors workscope and Babcock & Wilcox prepared a separate inquiry for the material and labor associated with the application of insulation on the pump and valve test loops. The specifications for the application of insulation was prepared based upon commercial standards and are representative of the requirements which would be applied to a solar facility. The piping and sump tanks for both the hot and cold test loops included 1 inch of ceramic blanket insulation and 8 inches of calcium silicate insulation. The ceramic blanket insulation was applied over the piping and heat trace to eliminate custom cutting of the calcium silicate insulation to accommodate the heat trace cables. In addition, the ceramic blanket minimized the chimney effect which would exist if calcium silicate were applied directly over the pipe, resulting in gaps between the insulation and the pipe.

3.6 NON-DESTRUCTIVE TESTING

The non-destructive testing of the piping welds was removed from the mechanical contractors workscope and sublet inspection involved radiographic inspection of all the stainless steel piping welds as required by ANSI B31.1. All welds were radiographically inspected and accepted in accordance with the acceptance criteria of ANSI B31.1.

3.7 SCHEDULE

The erection of the pump and valve test loop was initiated by the general contractor on January 3, 1986 with the excavation of the sump pit. The mechanical and electrical contractors started work on their portions of the system in April, 1986. The erection of the final systems was completed in preparation for operation of the pump and valve in March, 1987. A summary of the erection schedule is shown in Figure 3.7-1.

In general, the erection of the pump and valve test loop proceeded well. The predicted erection span prior to the award of construction contracts was 9 months for the whole system. The actual span was 15 months. Major causes for the delay in the schedule were:

1. Delays in the delivery of the Fisher Control valves due to availability of material, and delays in the delivery of the Crane Company isolation valves due to a prolonged strike at the suppliers facilities.

2. Problems encountered by the mechanical contractor in welding the root pass of the 10 inch stainless steel pipe to stainless steel fittings and valves. The particular properties of the pipe caused suck-up or burn-thru to occur on the inside of the weld which resulted in x-ray rejects.

3. Underestimation of the efforts necessary to install the insulation on the piping, tanks and valves by the insulation contractor. This was due to the fact that the insulation necessary for molten salt loops demanded more attention to detail to minimize heat loss and insure proper sealing of penetrations for the heat trace and transmitters.

The contractors were able to fabricate and erect the equipment in accordance with the standard commercial specifications and encountered no undue hardship meeting the specification requirements.

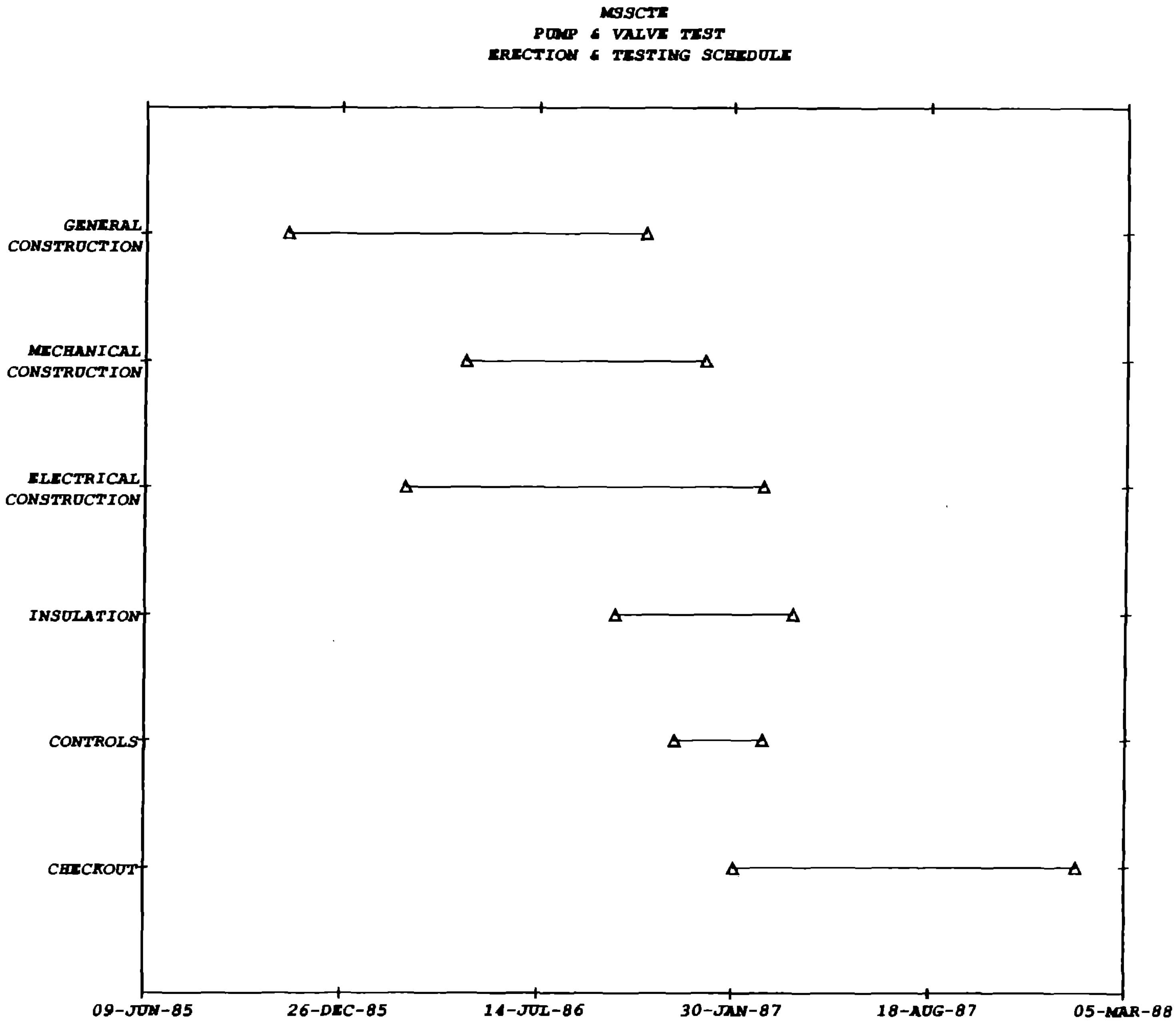


Figure 3.7-1. Pump and Valve Construction Schedule.

4.0 REFERENCES

[1] Bator, P. A., "Molten Salt Subsystem/Component Test Experiment Pump and Valve Test Test Plan", B&W Document PAB-894-0022-10-27, Babcock & Wilcox Co., July, 1987.

[2] Dowling, R. L., "Molten Salt subsystem/Component Test Experiment Valve Packing Bench Test Experiment-Final", B&W Document RLD-894-0022-20-45, Babcock & Wilcox Co., July, 1987.

[3] Weber, E. R., "Saguaro Power Plant Solar Repowering Project", DOE/SF10739-2, Arizona Public Service Co., Phoenix, Arizona, July, 1980.

[4] Black & Veatch Specification 11548.62.2614 for Pump & Valve Experiment Molten Salt Pumps, Black & Veatch - Engineers-Architects, Kansas City, Missouri, 1984.

[5] Black & Veatch Specification 11548.62.3809 for Pump & Valve Experiment Molten Salt Control Valves, Black & Veatch - Engineers-Architects, Kansas City, Missouri, 1984.

[6] Black & Veatch Specification 11548.62.3805 for Pump & Valve Experiment Molten Salt General Service Valves, Black & Veatch - Engineers-Architects, Kansas City, Missouri, 1984.

[7] Black & Veatch Specification 11548.72.0000 for Pump & Valve Experiment Mechanical Construction, Black & Veatch - Engineers-Architects, October, Kansas City, Missouri, 1985.

[8] Black & Veatch Specification 11548.62.1200 for Pump & Valve Experiment Molten Salt Air Coolers, Black & Veatch - Architects-Engineers, Kansas City, Missouri, October, 1984.

[9] Black & Veatch Specification 11548.62.3602 for Pump & Valve Experiment Molten Salt Tanks, Black & Veatch - Architects-Engineers, Kansas City, Missouri, 1985.

[10] B&W Specification for Hot Loop Immersion Cooler, B&W Document RLD-894-0022-10-20, March, 1985.

[11] Black & Veatch Specification 11548.62.1205 for Pump & Valve Experiment Molten Salt Immersion Heaters, Black & Veatch - Architects-Engineers, Kansas City, Missouri, October, 1986.

[12] B&W Drawing 418351E, "Pump and Valve Loop Piping and Instrumentation Diagram", May, 1985.

[13] B&W Specification for Pressure Transmitters, document JPS-894-0022-10/30-28, August, 1985.

[14] B&W Specification for Flow Transmitters, document JPS-894-0022-10/30-30, January, 1986.

[15] B&W Specification for Bubbler Level Transmitters, document JPS-894-0022-10/30-31, June, 1985.

[16] B&W Specification for Level Transmitters, document JPS-894-0022-10/30-32, August, 1985.

[17] B&W Specification for Thermocouples, document JPS-894-0022-10/30-16, January, 1986.

[18] B&V Drawing R7512, "Heat Tracing Cold Salt Test Loop Plan", October, 1985.

[19] B&V Drawing R7513, "Heat Tracing Hot Salt Test Loop Plan", October, 1985.

[20] B&V Specification 11548.63.3603 for 4160 Volt Switchgear, Black & Veatch - Engineers-Architects, Kansas City, Missouri, 1984.

[21] B&V Specification 11548.63.1401 for Molten Salt Heat Tracing, Black & Veatch - Engineers-Architects, Kansas City, Missouri, January, 1986.

[22] B&V Specification 1548.71.0000 for General Construction, Black & Veatch - Engineers-Architects, Kansas City, Missouri, July, 1985.

[23] B&V Specification 11548.73.0000 for Electrical Construction, Black & Veatch - Engineers-Architects, Kansas City, Missouri, October, 1985.

Appendix A

Pump & Valve Loop
Hardware Costs

5.0 Appendix A

Table A-1 contains a list of the costs associated with the major components for the Pump and Valve Test Loops. The components were purchased between 1984 and 1986, therefore, the costs are representative of 1984 to 1986 dollars.

Pump and valve prices are considered to be representative of the cost of actual plant components. The remaining items listed below are only representative of the cost required to build the test loops and not those of a plant.

Table A-1

Component	Cost
Mechanical Construction	$277,942.00
Byron-Jackson Cold Pump	$212,043.00
General Construction	$130,823.00
Electrical Construction	$119,281.00
LP&E Hot Pump	$ 76,770.00
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