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TITLE
SNAP 2 Primary System Test - Objectives, System Description, and Procedures

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PROGRAM
SNAP 2

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Primary Coolant Development

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STATEMENT OF PROBLEM
Fabricate a loop to simulate the SNAP 2 primary system, using prototype components and test operate to obtain objectives as outlined on pages 1 and 2.

ABSTRACT The SNAP 2 Primary System Test (PST) loop fabrication, with associated flight prototype components, has been completed. The following system components are integral to the loop.

1) Reactor core mockup (volume and Δ P simulator)
2) Boiler mockup (volume and Δ P simulator)
3) CRU-III NaK pump
4) Compact Heater
5) Expansion Compensator

A mobile loading system has been designed and fabricated with the capability of cleaning the NaK prior to final loop sealing.

Detailed loop descriptions, test objectives, and operating procedures are contained herein.

I. OBJECTIVES OF TEST

A. Construct the PST loop and perform an evaluation of fabrication and welding techniques where applicable to S-2-PSM-1.

B. Establish the coolant system loading and cleanup methods and procedures.

C. Experimental determination of system volume.

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D. Operation of CRU NaK pump to determine system pressure drop and flow characteristics

E. Compact heater performance in the S-2-PST loop

F. Determination of system heat losses

G. Expansion compensator performance check

H. Evaluation of APU piping configuration

II. DESCRIPTION OF EQUIPMENT

To accomplish the aforementioned objectives, a test system has been designed and fabricated.

A. General Description

1. Figure 1 is a schematic of the test loop.
2. Figures 2 and 3 are photographs of the PST.
3. Figure 4 is a close up view of the CRU NaK pump and motor drive assembly.
4. Figure 5 is a schematic of the NaK loading system.
5. Figures 6 and 7 are photographs showing the loading system as connected to the PST.

B. Detailed Component Description.

The system is constructed entirely of type 304 stainless steel.

1. Piping and Fittings - The PST loop is constructed of 1.25 in. OD, 0.035 in. wall seamless tubing. Fittings used are 1 in. schedule 10S as these are the thinnest walled available fittings having the same ID as the system tubing.

2. Reactor Mockup* - The reactor mockup is a tank fabricated of a section of 4-in. schedule 40 pipe into which an orifice plate has been fitted. This arrangement has been designed to provide the same NaK volume and pressure drop as the actual reactor, i.e.: 112 in^3 volume and 0.15 psi pressure drop at 12.5 gpm of NaK 78 at a mean temperature of 1100°F.

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*The reactor mockup, as well as the boiler mockup, has been hydraulically tested and found to produce the desired pressure drops within 10%.

3. **Boiler Mockup***- The boiler mockup is a tank constructed of a section of 10-in. schedule 40 pipe into which an orifice has been fitted. This design provides the same NaK volume (1100 in^3) and pressure drop (20 psi @ 12.6 gpm) as the TRW 7-tube boiler design.

4. **Compact Heater** - Consists of 14 high power density electrical cartridge heaters, positioned in an annulus, providing 65 kw of heat at full power. This unit weighs approximately 10 pounds. A detailed description is contained in reference (1). Power to the heater is controlled by a motor-driven variable power transformer as shown in Figure 8.

5. **CRU NaK Pump** - This pump, designed and fabricated by TRW, is of the rotating permanent magnet type. Velocity is imparted to the NaK in the annulus by the rotating permanent magnet rotor which is separated from the NaK by a 0.020-inch wall diaphragm. The rotor is positioned 0.030 inches from the diaphragm and operates up to 40,000 rpm. Reference (2) gives a detailed description of this pump assembly.

6. **Flowmeter** - The flowmeter consists of a horseshoe-type permanent magnet affixed to a straight run of tubing. Location and position of this flowmeter is shown in Figures 2 and 3. This flowmeter has been calibrated and has a signal output of approximately 0.4 millivolts per gallon per minute of NaK flow. This output is essentially independent of the NaK temperature.

7. **Expansion Compensator** - The expansion compensator is a device consisting of 52 discs which are welded together to form a 12-inch OD bellows configuration designed to contain

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*Refer to Page 2 footnote.

the expansion of 1.5 ft^3 of NaK-78 resulting from a 1100°F average temperature increase. Inert gas contained by the surrounding bellows shell permits control of the system pressure. A detailed discussion including design equations is contained in reference (3).

8. <u>NaK Loading, Cleanup and Vacuum System</u> - Figure 5 is a schematic of the loading system. Figures 6 and 7 show the loading system in relationship to the PST.

   The mobile NaK loading system consists of two 2.1 cubic foot capacity tanks. One tank is used for loading, the other for dumping.

   Cleanup is accomplished by cooling the NaK in the tanks and forcing the NaK through porous metal filters.

   Integral to this system are the high vacuum and refrigeration units. All valves in contact with the NaK are Fulton-Sylphon bellows valves.

   For ease of connection and removal, the loading system is connected to the PST with 1-inch tubing using stainless steel swagelock fittings.

C. Instrumentation

Figures 1, 2, and 3 also indicate the position of thermocouples and pressure transducers on the PST. Located near the CRU NaK pump motor drive unit is the photo electric pickup to measure rotor rpm. Figure 9 is a photograph of the console room which contains all of the instrumentation and readouts for the PST. The following table lists the type, position of the measuring device, and the readout instrumentation used.

TABLE I - PST INSTRUMENTATION

		Readout Instrument	Console No.
1.	Thermocouples		
	1 Heater, inlet	2 pen continuous recorder	2
	2 Heater, outlet		
	3 Boiler,mockup, inlet	2 pen continuous recorder	2
	4 Boiler mockup, outlet		
	5 Pump, inlet	Multipoint strip chart Temperature recorder	1
	6 Pump, outlet		
	7 Reactor Mockup, inlet	"	
	8 Reactor Mockup, outlet	"	
	9 Expansion Compensator	"	
	10 Expansion Compensator gas	"	
	11 Flowmeter	"	
	12 CRU NaK pump - front face	"	
	13 CRU NaK pump - back face	"	
	14 Fill Line	"	
	15 Immersion type thermocouple at tee below CRU NaK pump	"	
2.	Pressure Transducers	Manometer	2
3.	Rotor RPM	Tachometer	3
4.	Expansion Compensator gas pressure	Bourdon pressure gauge	2
5.	Flowmeter	Continuous pen recorder A pyrovane controller is tied to the flowmeter such as to shutdown the compact heater and the CRU pump motor drive in the event of loss of flow	1
6.	Heater Power (controlled by Powerstat remote control)	Continuous recording wattmeter	2
7.	CRU NaK pump motor control	Frequency converter	4
8.	CRU NaK pump power	Wattmeter	3
9.	PST vacuum gauges (Thermocouple and ionization)	NRC ionization gauge control	On top deck of loading system

III. PROCEDURES

A. Evaluation of Fabrication and Welding Techniques Where Applicable to S-2-PSM-1

This evaluation has been completed. It points out the critical necessity for high quality welding on thin-walled (0.035 in.) tubing. Extra care must be exercised to prevent drop-through and burning during the welding process. Tubing to be butt welded must be carefully matched with respect to degree of roundness and end conditions.

It should be pointed out that AI does not presently have the facilities for the adequate bending of 1.25 in. OD tubing with thin walls. All the tube bending was performed by outside vendors.

B. Initial Loading Procedure and System Checkout

1. Evacuate loop and supply tank No. 1.
   - a. 1×10^{-6} mm Hg for a NaK-free system (at diffusion pump)
   - b. 1×10^{-4}* mm Hg for a NaK-wetted system (at diffusion pump)

   To obtain as high a vacuum as possible, the PST loop will be heated during the pump-down operation to speed up the outgassing procedure.

2. NaK charging of supply tank

   A fireman is to be present during this operation. The volume of each loading tank is approximately 2.1 ft^3. Tank number 1 is loaded from a NaK supply drum which is positioned on a weight-scale. The level probe height vs NaK weight in the supply tank is plotted as the tank is loaded with NaK. Upon completion of loading, the tank is pressurized with argon.

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*1×10^{-4} was obtained from NaK vapor-pressure considerations

3. Cold trap the NaK in tank No. 1 (NaK at 30°F, cold finger at 10°F) for 24 hours.

4. Pressurize the supply tank with argon, open isolation valve, and load NaK into the PST through the filter. Maintain 2 psig constant pressure on the supply tank and 5 psig in the expansion compensator shell.

5. System is loaded when:
   a. glass standpipe tube at top of loop becomes full of NaK
   b. the argon gas pressure commences to increase on the charge tank.

   Approximately 48 pounds of NaK is required to fill the loop up to the loading tee at the pump outlet. A stainless steel sheathed immersion thermocouple at the loading tee will indicate the arrival of cold NaK at this point.

6. The glass standpipe at the top of the loop will be crimped and severed from the PST and this NaK sample will be shipped to Analytical Chemistry for determination of sodium oxide content.

7. Close PST isolation valve (under tee at pump outlet).

8. The PST loop has now been loaded with clean NaK* and is now ready for operation.

9. Start CRU NaK pump and operate at 15,000 rpm.

10. Energize Compact Heater - Operate at a power level so as to obtain a NaK temperature increase $\leq$ 300°F/hr. The pump body temperature must be maintained at a temperature differential no greater than 50°F compared with the NaK temperature in the pump. This is accomplished by controlling the power input to the flexible heater cable which has been affixed to the pump body.

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*Clean NaK is here taken to mean:
   a. Sodium oxide concentration of less than 20 ppm oxygen
   b. No particulate matter larger than 5 microns

11. Check out thermocouples and temperature readout instrumentation.

12. Before tubing oxidizes, check Δ T's between appropriate thermocouples. Then check Δ T's after the tubing oxidizes to determine an approximate change in emissivity of the tubing.

13. Check Expansion Compensator operation as the NaK temperature increases from ambient to operating temperature.

14. The PST is operated so that the pump inlet temperature $\leq$ 1000°F and the CRU NaK pump speed is maintained at $\sim$15,000 rpm.

15. Check out flow rate and system pressure drops at operating temperatures.

C. Experimental Determination of System Volume

The first step in the determination of the PST volume is the calibration of the NaK loading tanks. These tanks contain level probe units which enable determination of the volume of NaK in these tanks. Known quantities of NaK, as loaded from a NaK supply drum positioned on a weight scale, are transferred to charge tank No. 1. Level probe readings for known weight additions of NaK make it possible to calibrate the charge tanks.

An immersion thermocouple is installed at the tee below the CRU NaK pump outlet. When the system is being loaded the position of the cold ($\sim$30°F) NaK will be indicated as it reaches the immersion thermocouple. At this time a level probe measurement is taken on the charge tank. The system is then completely filled with NaK at which time another level probe reading is obtained. The difference between these two level probe readings will permit the determination of the weight of NaK introduced in the PST and subsequently the volume of the PST.

D. Operation of the CRU NaK Pump

After the PST has been loaded with NaK, the CRU NaK pump will be energized and operated at 15,000 - 40,000 rpm. Flow and system pressure drop will be noted during this test. Figure 10 is a plot of system Δ p vs flow based on analytical calculations.

E. System Heat Losses

The system tubing has been polished to a high lustre to produce a low emissivity surface (~ 0.3). Knowing the power input to the compact heater under equilibrium conditions, the heat losses from the uninsulated PST loop can then be calculated. The change in emissivity of the tubing as it becomes oxidized (due to operation at high temperatures) can be determine by comparing temperature differentials along a section of tubing before and after oxidizing.

A 6000 cfm exhaust fan has been installed above the PST loop to provide for hot air removal.

F. Expansion Compensator Performance

The expansion compensator will be checked out for its ability to absorb the necessary NaK expansion and also to provide void-free operation. Two vertical 1/4-inch OD standpipes at the top of the loop will enable the determination by x-ray, of any gas buildup in the system. After operation at temperature, various regions of the PST will be x-rayed for determination of voids or gas pockets.

G. Evaluation of APU Piping Configuration

Visual examination, operational characteristics and test results of the PST loop will determine the suitability of the present PST piping and component configuration.

H. Sealing of the NaK-Loaded PST Loop

Sealing of the NaK loaded PST consists of crimping closed the NaK loading tube and then welding the crimped area using a mobile resistance seam welder. Following this operation, the crimped and welded section will be cut in two and the loop side end of the flattened section will be heliarc welded to further ensure the seal.

IV. REFERENCES

1. TDR 5837, Logan, D., Compact Heater Design.

2. Thompson-Ramo-Wooldridge, CRU NaK Pump Drawing Numbers: 804105-804107, 804365-804370.

3. a) IOL, C. Burke to M. A. Perlow, dated 9/15/60 - Expansion Compensator for SNAP 2 Primary System Test.
   b) Magnilastic drawing number 8705500.

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CHECKED BY:

DATE:

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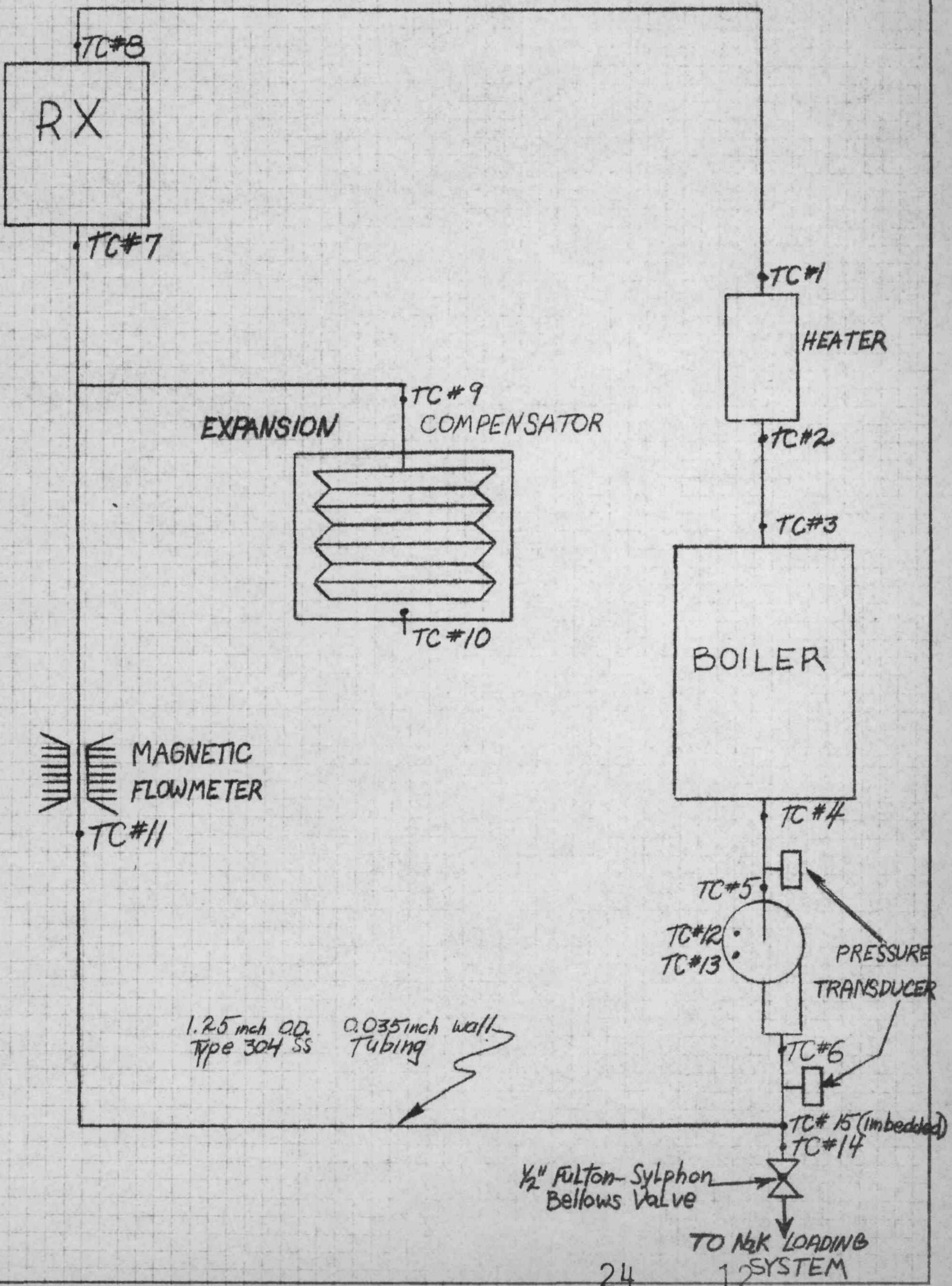
Fig.1 PST Schematic



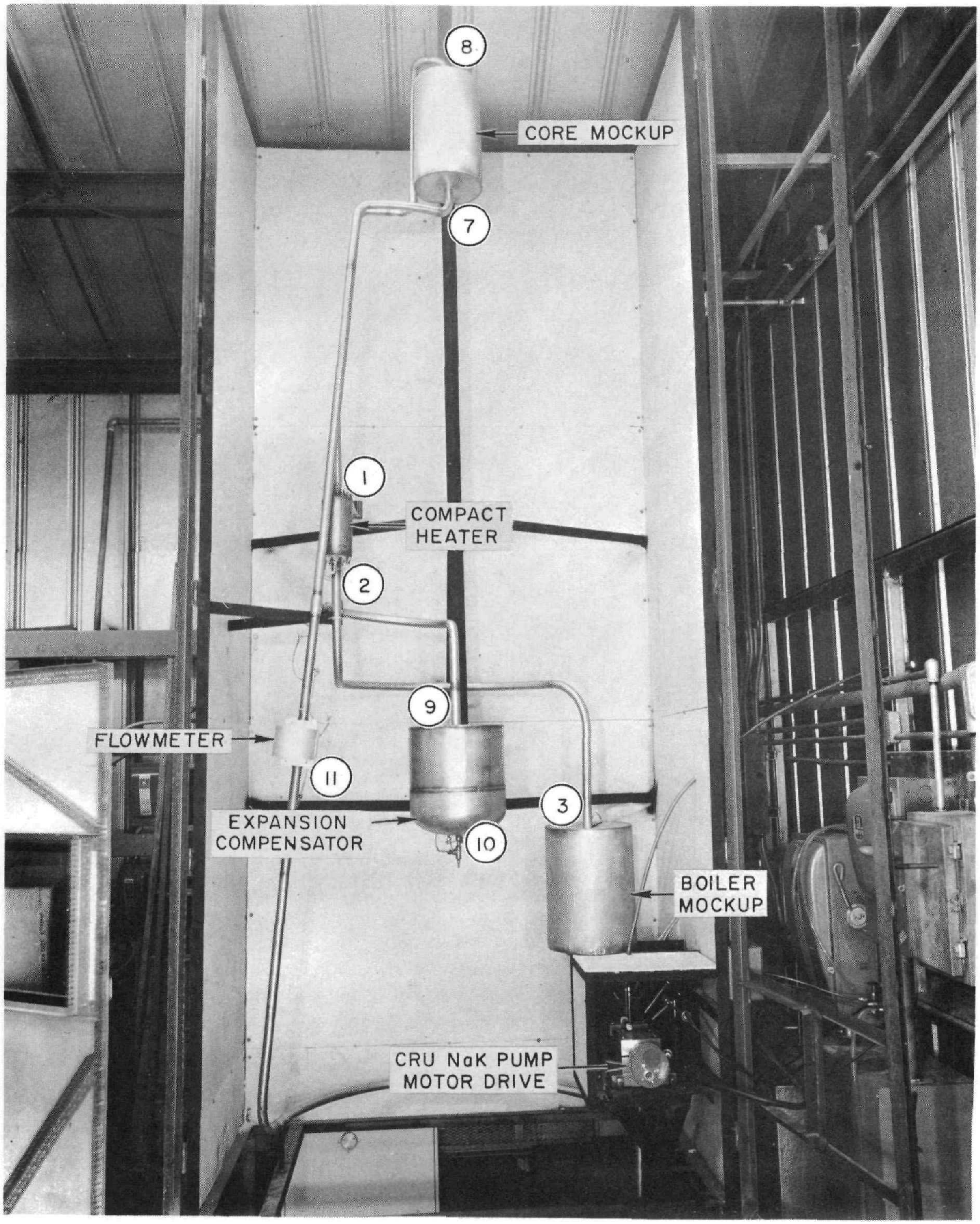


Figure 2 - PST Loop - Front View

note; circled numbers indicate thermocouple locations

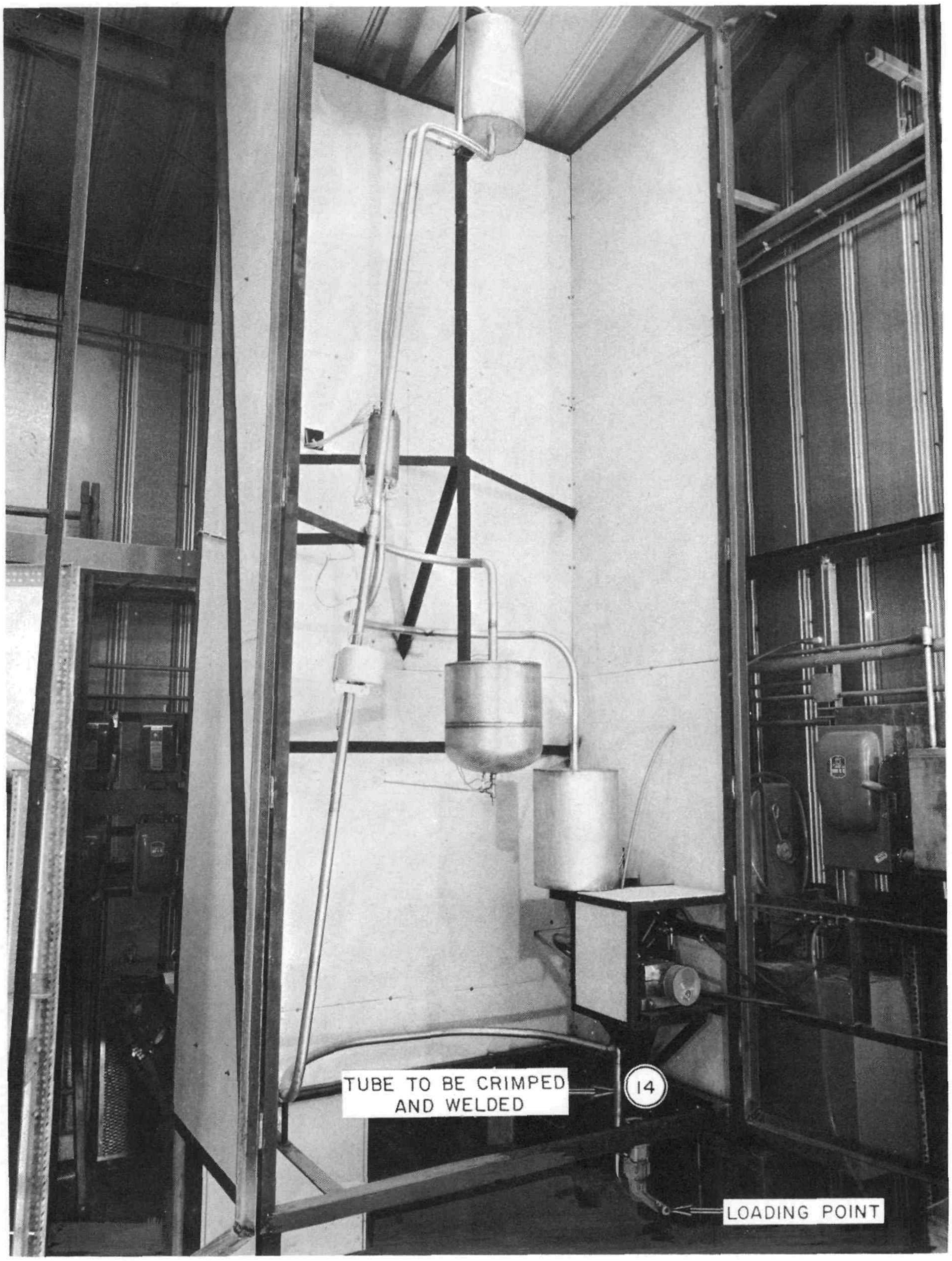


Figure 3 - PST Loop - ¾ View

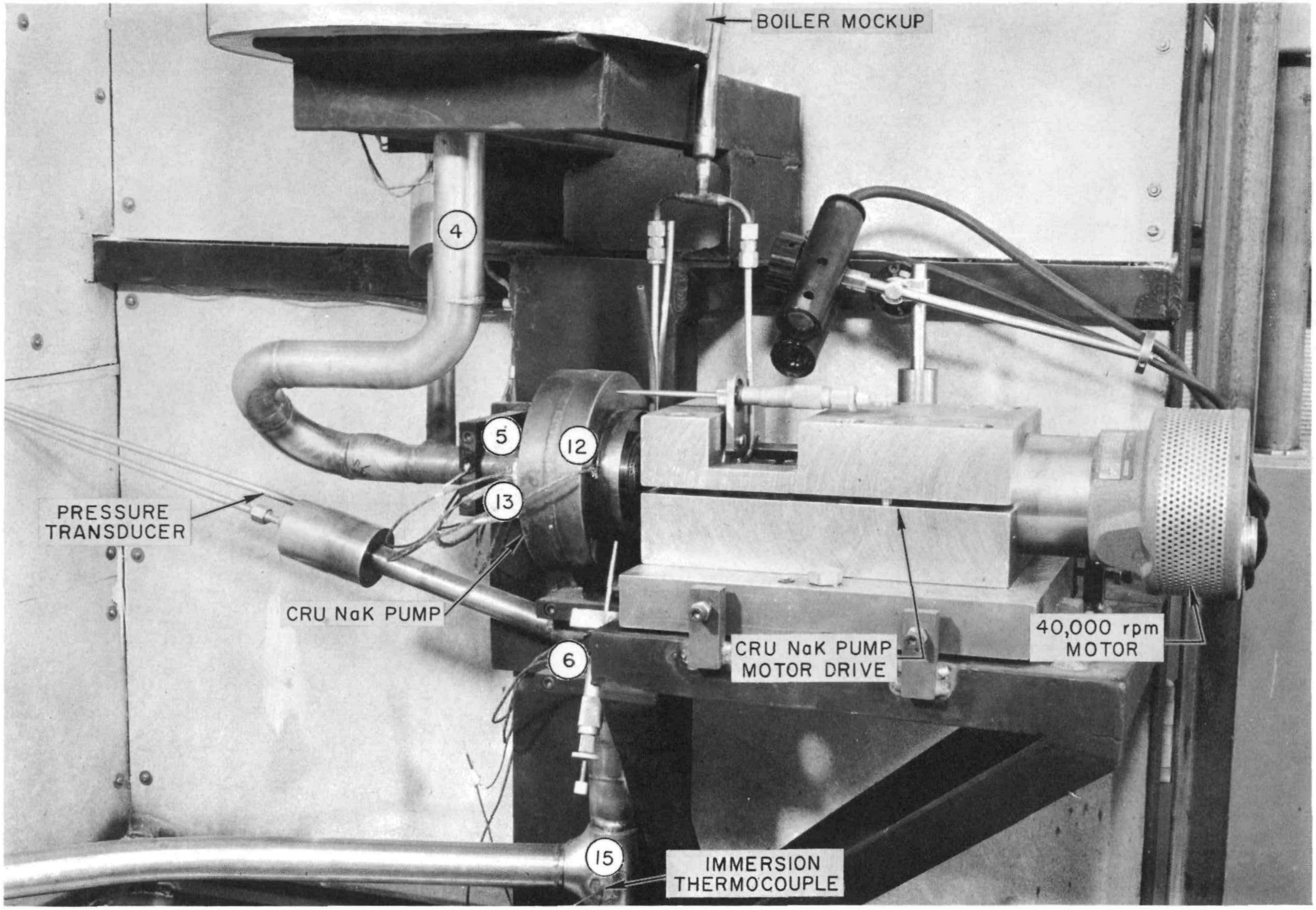


Figure 4 - CRU NaK Pump and Motor Drive Assembly

note: circled numbers indicate thermocouple locations

NaK LOADING SYSTEM

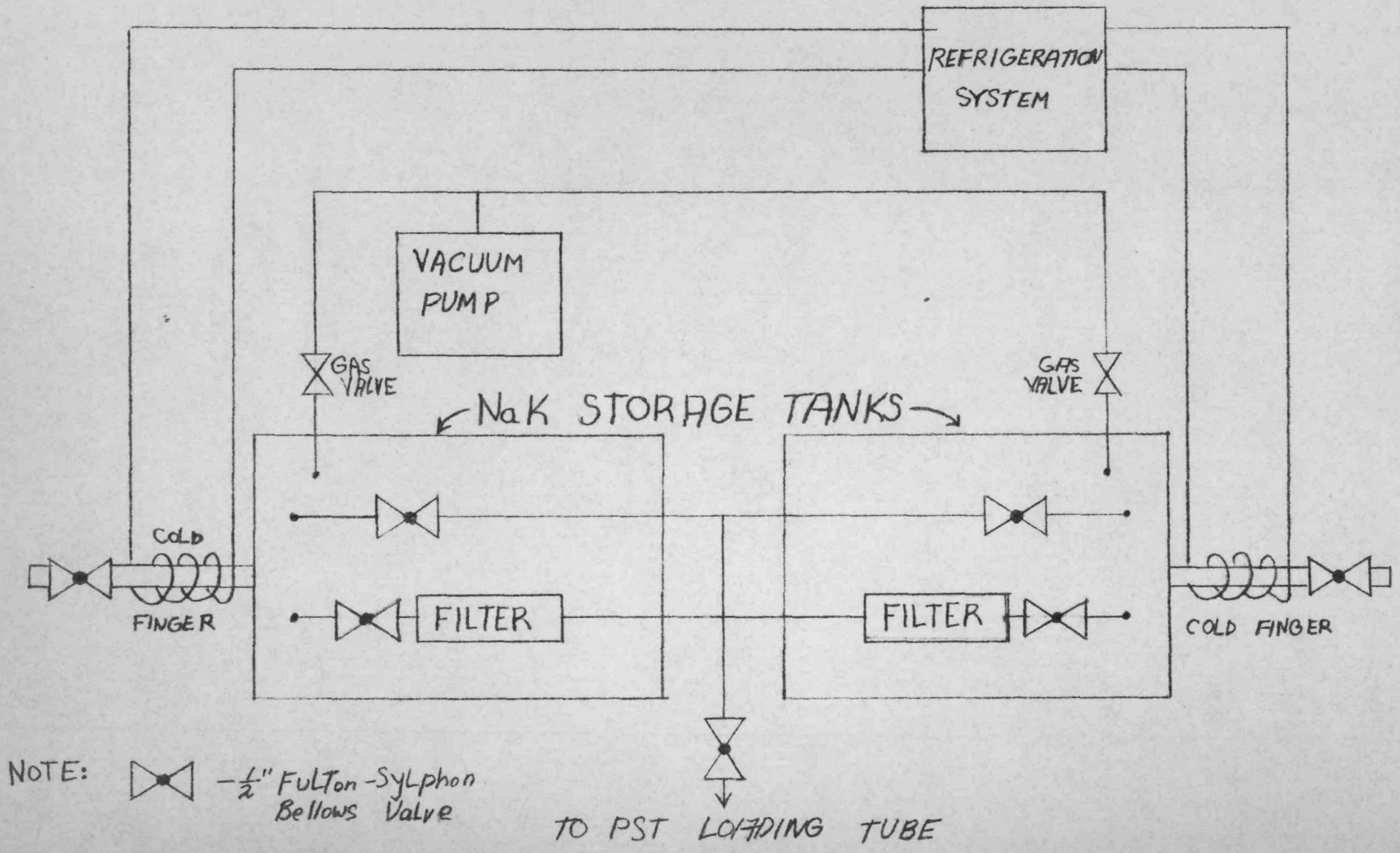


Fig 5 - NaK Loading System Schematic

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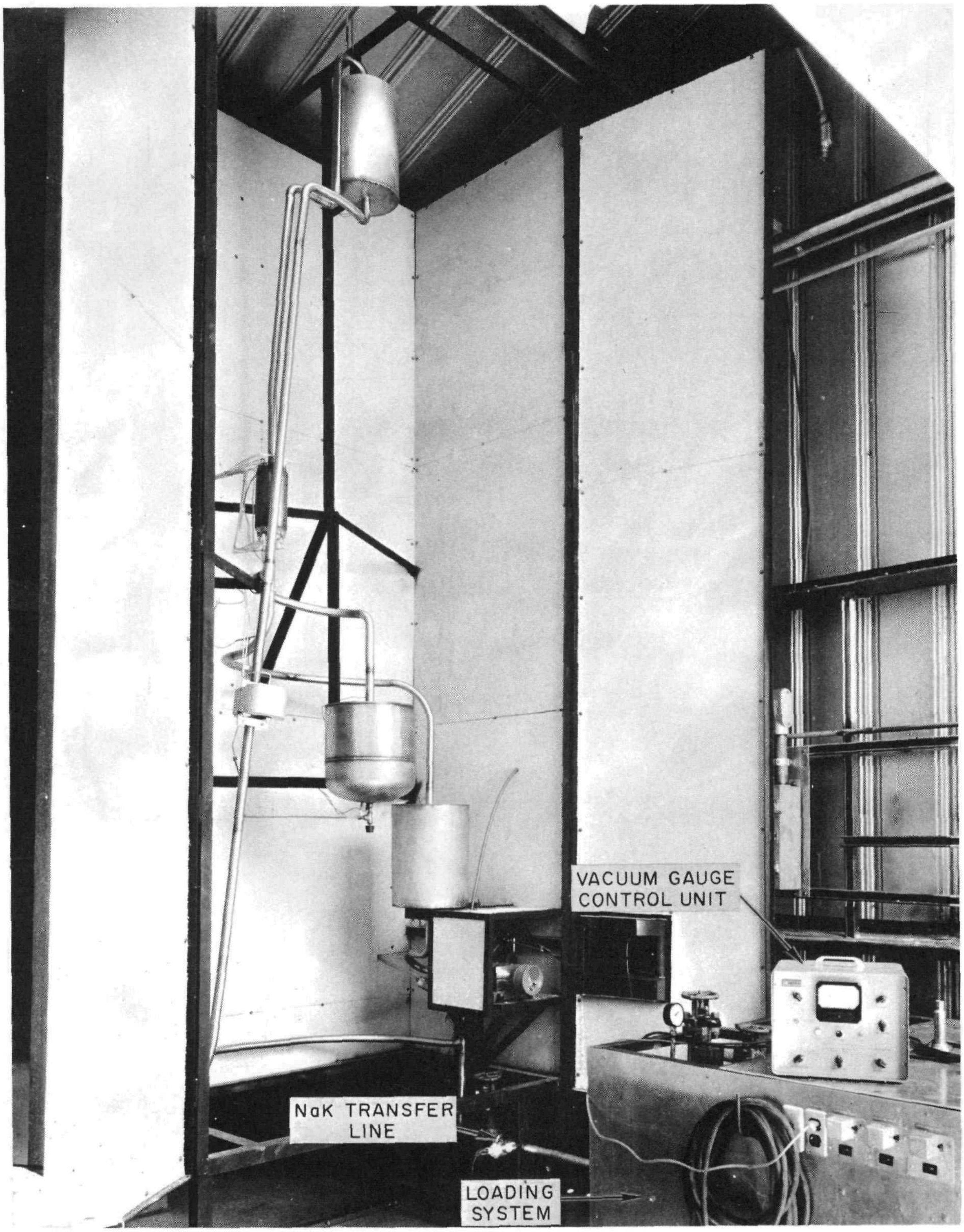

Figure 6 - PST and Loading System - ¾ View

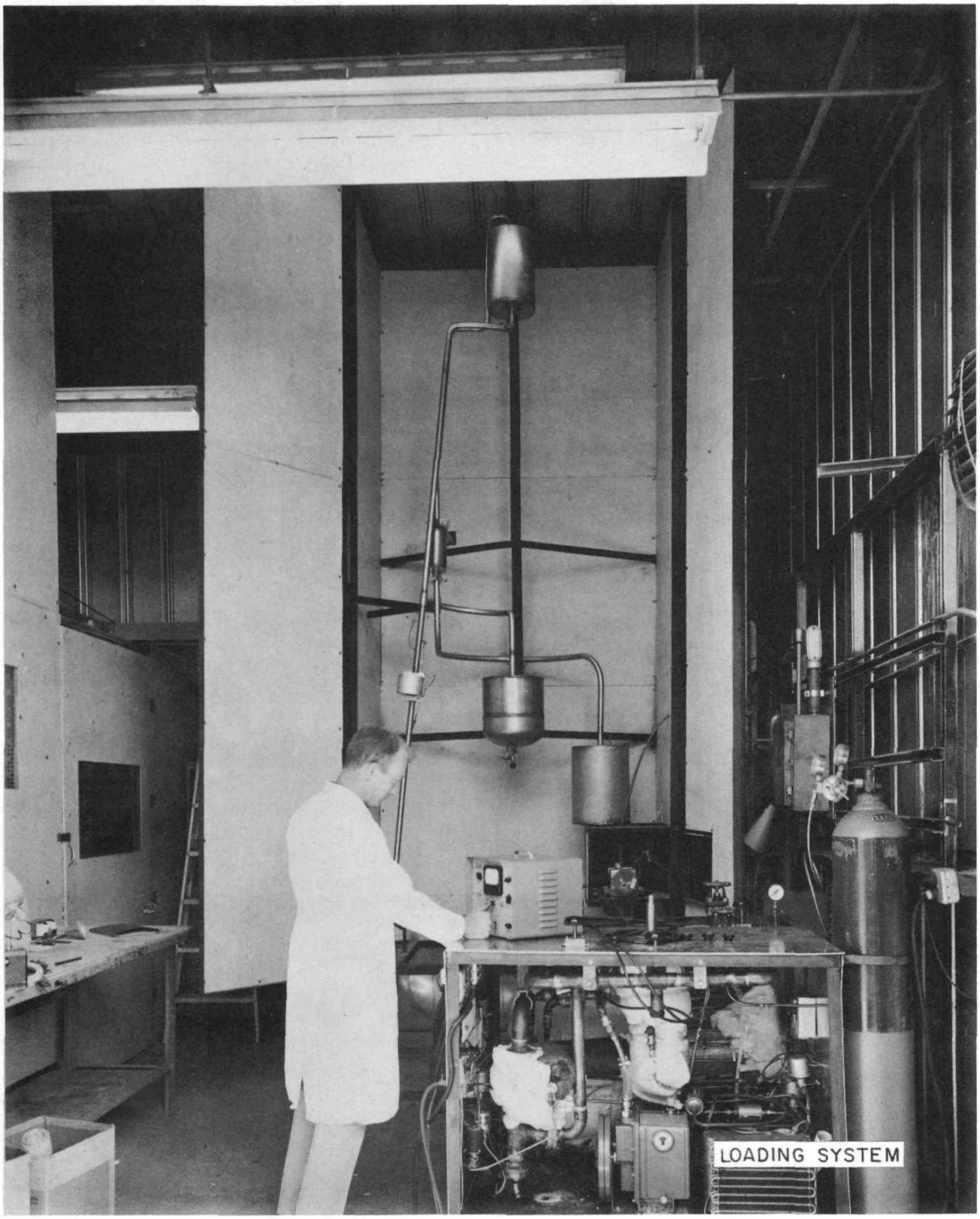

Figure 7 - Loading System and PST - Front View

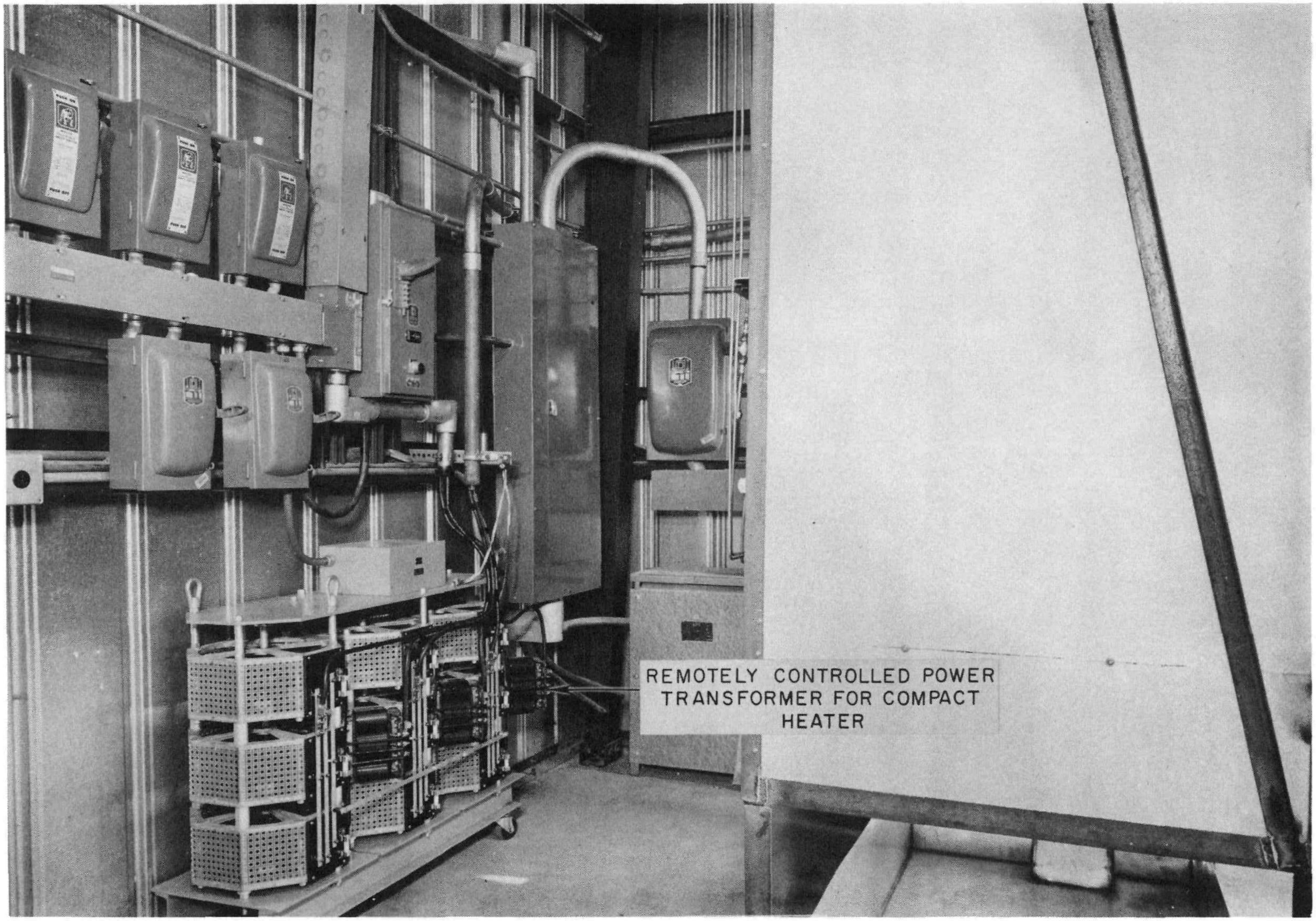

Figure 8 - Compact Heater Remotely Controlled Variable Transformer

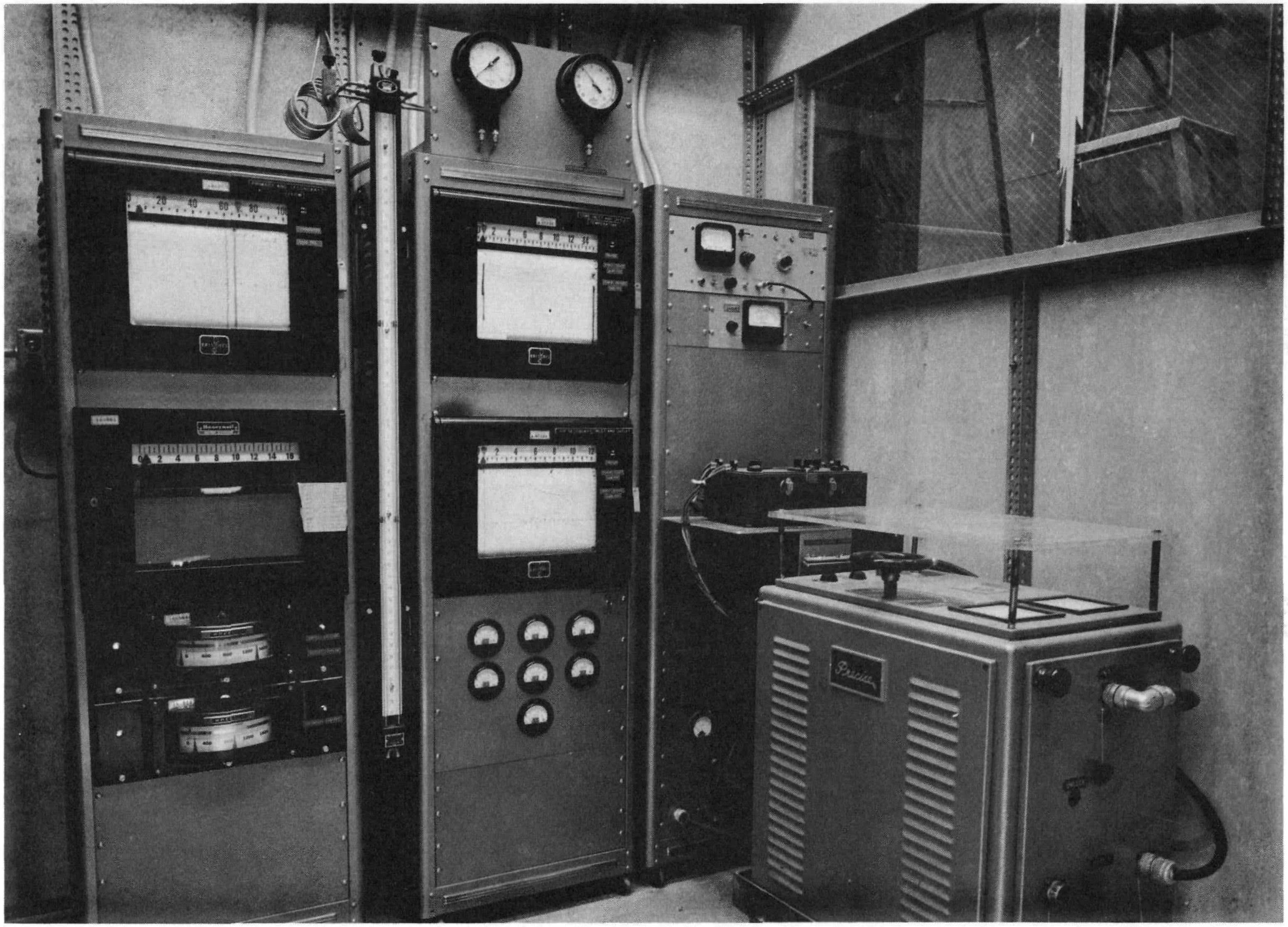

Figure 9 - PST Instrumentation and Control Room

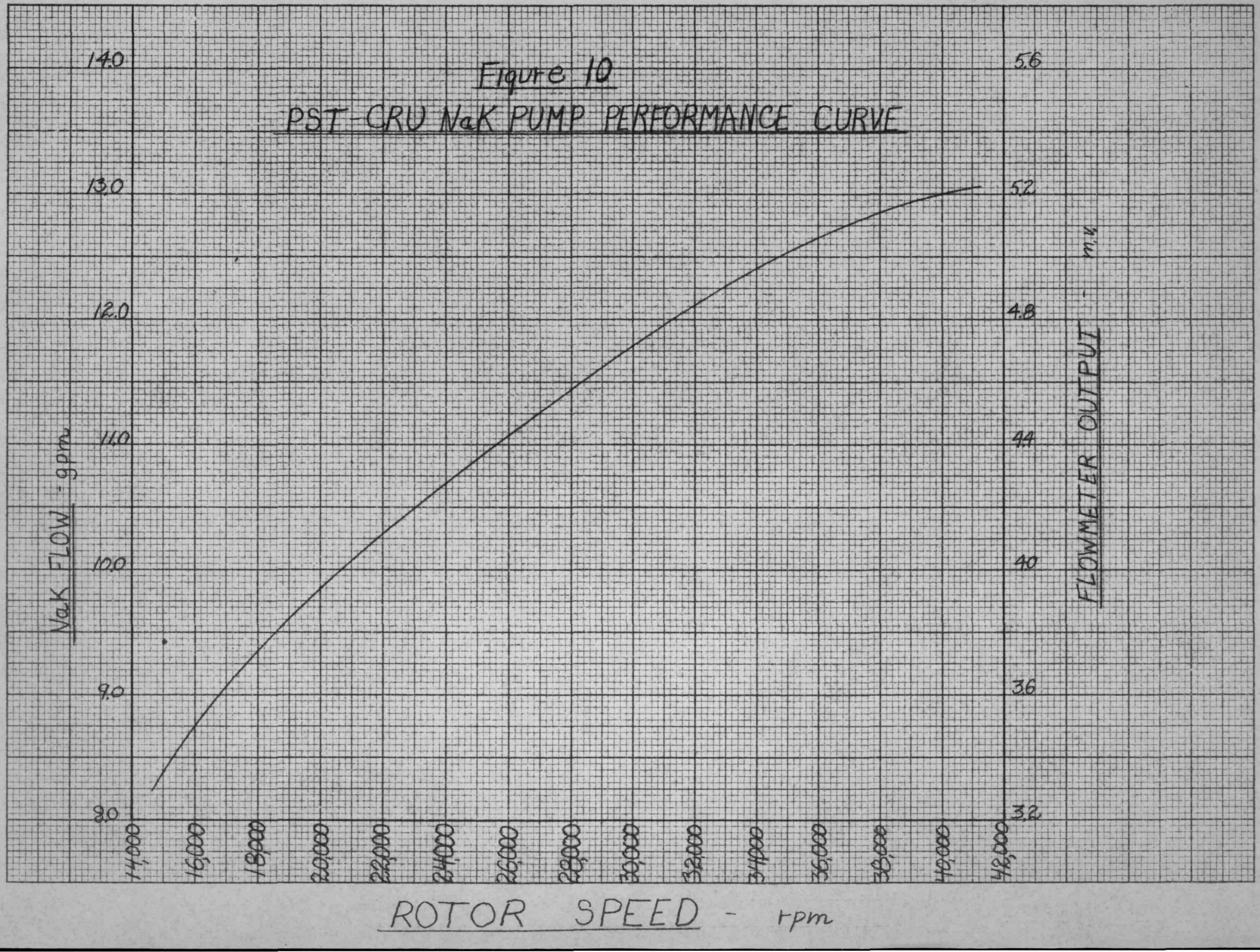

Figure 10

PST-CRU NaK PUMP PERFORMANCE CURVE