University of Minnesota
ST. ANTHONY FALLS HYDRAULIC LABORATORY

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MODEL STUDY OF DONALD C. COOK POWER PLANT CONDENSATE DRAIN SYSTEM

by

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CONDENSATE DRAIN SYSTEM

I. INTRODUCTION

The construction of the Donald C. Cook Power Plant on the southeast shore of Lake Michigan will result in a significant increase in the total generating capacity of the American Electric Power Service Corporation (AEP).

The design of the condensate drain system, which drains condensate from the cross-under piping connecting the high-pressure turbine exhaust to the Moisture Separator-Reheater (MSR) and from the MSR unit, is shown in AEP's Drawing No. MSK-82771. In a letter from Mr. Millard Cherry of AEP to Professor Edward Silberman of the St. Anthony Falls Hydraulic Laboratory, the need for this study is indicated as follows:

> We [American Electric Power Service Corporation] are presently involved in the design of a fluid system transporting a saturated liquid at 98 psia to a similar pressure level by gravity. We are dealing with two manufacturers with divergent opinions on how this system should be designed. For various reasons we have selected one manufacturer's design philosophy for both units. We are now anxious to prove by model testing that this design philosophy will work equally well with both manufacturers' equipment.
>
> The two systems are shown isometrically on the attached drawings MSK-62371 and MSK-82771. Both systems were designed using the criteria outlined in G. E. Interim Report No. 2 on Moisture Separator-Reheater Drain Systems dated March 1971.
>
> We are interested in a model of MSK-82771 to study the flow of drains in all lines under conditions of steady state and transient pressure reductions at the drains' sources.

In order to obtain the answers to the questions raised, the following problems were studied:

1. Condensate flow in all drain lines and surface level fluctuations in drain tank at steady state conditions for
    a. Normal flow without loop seals
    b. 1.32 times normal flow without loop seals
    c. Normal flow with loop seals
    d. 1.32 times normal flow with loop seals

2. Flow conditions in all drain lines subsequent to a rapid pressure reduction in the MSR unit. Pressure decreases from 98 psia to approximately 20 psia in 20 to 25 seconds in the prototype as a result of a significant load change or load rejection.

Based on the anticipated volume of condensate produced in the prototype system, the drain lines would not flow full at any time. For a flow in which a free surface at constant pressure exists, dynamic simulation is obtained when model-prototype relationships are determined by the Froude law of similarity. The following relationships for discharge and time in terms of the length scale ratio (L_r) are obtained:

$$\text{Prototype Time} = \text{Model Time times } L_r^{1/2}$$

$$\text{Prototype Flow} = \text{Model Flow times } L_r^{5/2}$$

A model of the right moisture separator drain system shown in Drawing No. MSK-82771 was constructed at a scale of 1:12. This scale was chosen so that the model would be large enough to provide meaningful data, but small enough to be reasonably economical to construct. The model was instrumented to provide temperature, flow rates, and continuous pressure recording via pressure transducers and chart recorders wherever appropriate throughout the system. Also, where possible, high-pressure glass tubing was incorporated in the model so the flow conditions could be observed.

Based on the test results, the drain system as shown in Drawing No. MSK-82771 functioned satisfactorily during all the tests. For all test conditions indicated in point 1 above, the water level fluctuation (maximum level minus minimum level) probably will not exceed 0.5 ft (±0.25 from mean level) except for very low or high (essentially empty or full) levels in the drain tank. Also, during rapid pressure drops the model tests indicated that no problems should occur in the prototype drain system.

II. DESCRIPTION OF THE MODEL

Based on similarity, it was decided that a model of either the right or the left drain system, as shown in AEP's Drawing No. MSK-82771, would be sufficient. A model of the right system was constructed at a scale of 1:12, as previously indicated. For a Froude model with a 1:12 scale, the condensate flow in the model is equal to

$$\frac{\text{Prototype flow}}{498} = \frac{677{,}000 \text{ lbs/hour}}{498} = 1360 \text{ lbs/hour}$$

and model time = $\frac{\text{Prototype time}}{3.46}$.

The flashing of the saturated liquid (98 psia and 326°F) during a rapid pressure reduction was the most important characteristic to be studied, and thus the model was operated at prototype pressures and temperatures.

Steam Supply: The boiler system used to heat the buildings on the University of Minnesota campus produces steam at approximately 130 psia and 350°F. A six-inch steam line passed directly beneath the area where the model was constructed. A two-inch line capable of supplying the model with 3000 lbs per hour of steam at 130 psia was tapped into the six-inch line. Appropriate controls were installed to regulate the flow and reduce the pressure to model operating conditions.

Inlet and Discharge Controls: Photos 1, 2, 3, and 5 show the inlet and discharge controls used to operate the model. Photos 1 and 2 show

1. The orifice meters and manometers used to measure the incoming flow of steam (left center in photos).
2. The inlet pressure regulators used to control the rate of steam flow and reduce the pressure to the proper operating level according to test conditions in the model (upper right in photos). The top pressure regulators on each inlet pipe supplying one of the cross-under pipes reduced the pressure from 130 psia to 98 psia during steady flow operation. They were also electrically controlled for rapid closure during a pressure reduction test. The lower regulators were set to reduce the pressure from 130 psia to approximately 20 psia to maintain a minimum constant pressure of 20 psia in the MSR unit during a rapid pressure reduction test.
3. The start of the cross-under piping.

Photo 3 is an overall view of the model. The MSR discharge valve is in the center of the photo. The valve (normally closed) was electrically controlled for rapid opening during a pressure reduction test. The valve pressure regulation system was set to reclose the valve automatically when the pressure in the MSR unit dropped to approximately 20 psia.

Photo 5 shows (1) a portion of the cross-under piping (top of photo); (2) the drain lines; (3) the drain tank (center of photo); and (4) the discharge control valves and rotometer used to measure the condensate flow leaving the drain tank (used primarily as a cross check on steam flow rate measured by orifice meters).

Instrumentation: The model was instrumented to measure the temperature at the ten points shown in Fig. 1. Temperature sensors were bonded to the piping and then the pipe and sensor were wrapped with asbestos cloth to retain the heat. Temperature sensors 1 and 3 were mounted so that they would measure the temperature at which the pressure transducers were operating; this monitoring was necessary because the transducers were temperature-sensitive. The remaining eight temperature sensors measured the incoming steam temperature (points 4, 5, 9, and 10) and the condensate temperature in the drain lines (points 2, 6, 7, and 8).

The average pressures throughout the model were measured by pressure gages at the points shown in Photos 2 and 3. The gages were accurate to ±1 psi.

One of the primary reasons for constructing the model was to enable study of the flow conditions during rapid pressure reductions. Two pressure transducers were constructed and mounted as shown in Photo 3 (right center on top of MSR unit) and Photo 7 (top left center on drain tank) to measure the instantaneous pressure in both the MSR unit and the drain tank as a function of time. Each transducer was connected to one channel of a two-channel Sanborn recorder. The two channels recorded pressure as a function of time as shown in Figs. 6a through 6f. Thus a continuous record was obtained of the pressure in the MSR unit and the drain tank as a function of the same instant in time.

The total steam and condensate flow (1360 lbs per hour for normal model flow) was measured as described earlier. It was not possible to measure the flow in the individual drain lines directly. Thus an estimate of the flow in each drain line was also made. The estimated individual flow rates are judged to be accurate to within ±5 per cent of the total flow rate.

III. TEST PROCEDURE

The steady state test procedure was as follows:

1. The entire model was checked for loose fittings, bolts, etc. Because of the large temperature cycle from cold to hot to cold during each day's testing, parts often worked loose from one day to the next.
2. The steam was turned on slowly to allow the model to heat up evenly in order to reduce differential expansion of the steel and glass components.
3. The large discharge valve on the MSR unit was opened to expel all air in the system, then closed.
4. The inflow rate of the steam was adjusted using a gate valve in the 2-inch supply line to either 1360 or 1800 (1.32 times normal flow) lbs per hour.
5. The flow rate of the cold water in the steam condenser (see right end of MSR unit in Photo 3) was adjusted to condense the incoming steam. Approximately one million BTU's per hour of heat had to be removed from the steam by the condenser to insure proper flow. The condenser was 3/4 the length of the MSR unit and extended past both inflow points from the cross-under piping. Steps 4 and 5 were actually done simultaneously to obtain proper flow balance.
6. The pressure regulators were checked to insure that the model was operating at the design pressure of 98 psia.
7. The discharge valve from the drain tank was adjusted to obtain the proper outflow as measured by the rotometer.
8. Temperature and pressure distributions throughout the system were observed.
9. The distribution of condensate flow in all drain lines was observed.

10. Water surface level fluctuation data were taken for various water levels in the drain tank.

The steam flow rate was then set at normal flow and the following pressure reduction test procedure was carried out:

1-9. Same as for steady state test.

10. After the Sanborn recorder had had sufficient time to warm up, it was balanced and its calibration was checked.

11. The discharge valve on the MSR unit was opened and the steam inflow control valves were closed. These operations were performed by electric solenoids to insure consistent, rapid operation.

12. The resulting flow conditions (steam flashing) were observed and the pressures were recorded on the time charts as shown in Figs. 6a through 6f.

13. The discharge valve was closed and the inlet valve opened, and the system was allowed to come to equilibrium. Steps 10 through 12 were then repeated until the desired number of tests had been conducted at a given condensate level.

14. The condensate level in the drain tank was adjusted and steps 10 through 13 were repeated.

IV. TEST RESULTS AND DISCUSSION

A. General Flow Conditions

After the flow conditions in the model reached equilibrium, the first observations that were made were usually of the temperature and pressure distributions throughout the system. The pressure regulators were carefully adjusted until the overall model pressure was 98 psia (±0.5 psia). Then the temperature distribution throughout the model was measured. The average operating temperatures are shown in Fig. 1. The temperature at point 2 was affected by the steam condenser in that end of the MSR unit, resulting in a temperature less than the 326°F for saturated water at 98 psia. The measured incoming steam temperature (points 9 and 10 in Fig. 1) was less than the expected 326°F. The exact reason for the lower temperature at this location is unknown, but it was probably due to a poor connection between the temperature sensors and the pipe. However, the temperatures at points 4 through 8 indicated that the model was operating at saturation temperatures.

The distribution of the flow in the drain lines was estimated by careful observation. It was not possible to measure these individual flows in the model. The flow in the small drain lines serving the internal portion of the cross-under piping (see Photo 6) was estimated to be between 30 and 35 per cent of the total flow. The flow in the drain lines which drained the cross-under pipes just before they discharged into the MSR unit was approximately 10 per cent each. The flow in the drain lines serving the MSR unit (see Photo 4, for example) was estimated to be 20 to 25 per cent each.

B. Steady Flow Tests

The primary objective of the steady flow tests was to determine the maximum probable fluctuations in the drain tank water level. The results are shown in Figs. 2 through 5. The fluctuations plotted in these figures are equal to the maximum level minus the minimum level plotted at the average elevations; e.g., in Fig. 2 the point at elevation 615 with a fluctuation of 0.2 ft would be for 615 ±0.1 ft.

The fluctuations for normal flow and 1.32 times normal flow without loop seals are shown in Figs. 2 and 3. The test results indicate that for the normal prototype drain tank operation level (614.5 to 615.5), the maximum fluctuation probably will not exceed ±0.25 ft (0.5 ft total fluctuation as plotted in the figures).

As the drain tank became essentially empty or full, the magnitude of the fluctuation increased significantly. This effect can be seen at the water surface levels near 614 and above 617 in Figs. 2 through 5.

Figures 4 and 5 show the fluctuations for normal flow and 1.32 times normal flow with loop seals (see Photo 8 for loop seal configuration). The fluctuations in Fig. 4 are similar to those in Figs. 2 and 3 without loop seals. However, at the higher flow rate, Fig. 5, the magnitude of the average fluctuation increased for elevations 614.5 to 615.5.

The configuration shown in Drawing No. MSK-82771 functioned satisfactorily in all respects during steady state operation. Based on the satisfactory overall performance of the model and the results in Fig. 5 compared to those in Figs. 2 and 3, it is recommended that the prototype be constructed without loop seals.

C. Pressure Reduction Tests

During the rapid pressure reduction tests, the pressure at which the saturated water in the drain lines and the drain tank flashed into vapor was approximately 75 psia. The flashing occurred very suddenly and lasted only a fraction of a second in the model. In the prototype the flashing would occur at a similar pressure, but the duration of the flash period would be somewhat longer--perhaps on the order of several seconds. During the flash period, reverse flow occurred in all the drain lines. However, the flow was a saturated vapor containing many small droplets (fog-like in appearance). The fineness of the water droplets in the drain would indicate that they probably vaporize completely as they pass through the MSR unit prior to reaching the discharge valve and pipe.

Typical time-pressure records obtained from the Sanborn recorder are shown in Figs. 6a through 6f. All tests started with the pressure at 98 psia (point 1 on the charts). During the first ten seconds (prototype) the pressure dropped rapidly from 98 psia to approximately 40 to 50 psia (see Figs. 6a-f and 7 and 8). Subsequently, the rate of pressure drop decreased until 23 to 25 psia was reached (point 2 in Figs. 6a-f). The test was then stopped.

The inlet and exhaust control valves were set to maintain a low pressure of approximately 20 to 22 psia. In some tests (see tests 1 and 12 for examples) the automatic valve controls oscillated, causing slight pressure cycling in the entire model. This happened only at the low 20 to 22 psia pressure level.

The deflection diaphragm in the pressure transducer mounted on the MSR unit cooled rapidly as the saturated liquid in the model continued to vaporize. This caused the diaphragm to stiffen. As a result, the pressure trace for the MSR unit shows an apparent increase in pressure (see test 2 after point 2, for example) while in fact the pressure remained constant or continued to decrease slightly as is shown for the drain tank.

Not all of the 12 tests shown in Figs. 6a through 6f were used in the final analysis. These charts were selected at random as typical examples from the many tests that were conducted. For example, tests 1, 6, and 9 were considered unacceptable for inclusion in Figs. 7 through 9.

Figures 7 and 8 show the pressure reduction in the MSR unit and the drain tank as a function of time for various water levels in the drain tank. In general, the pressure drop is more rapid with less liquid in the drain tank--i.e., with less liquid to vaporize and thus maintain pressure, the pressure drops more rapidly--although the scatter of the data is large.

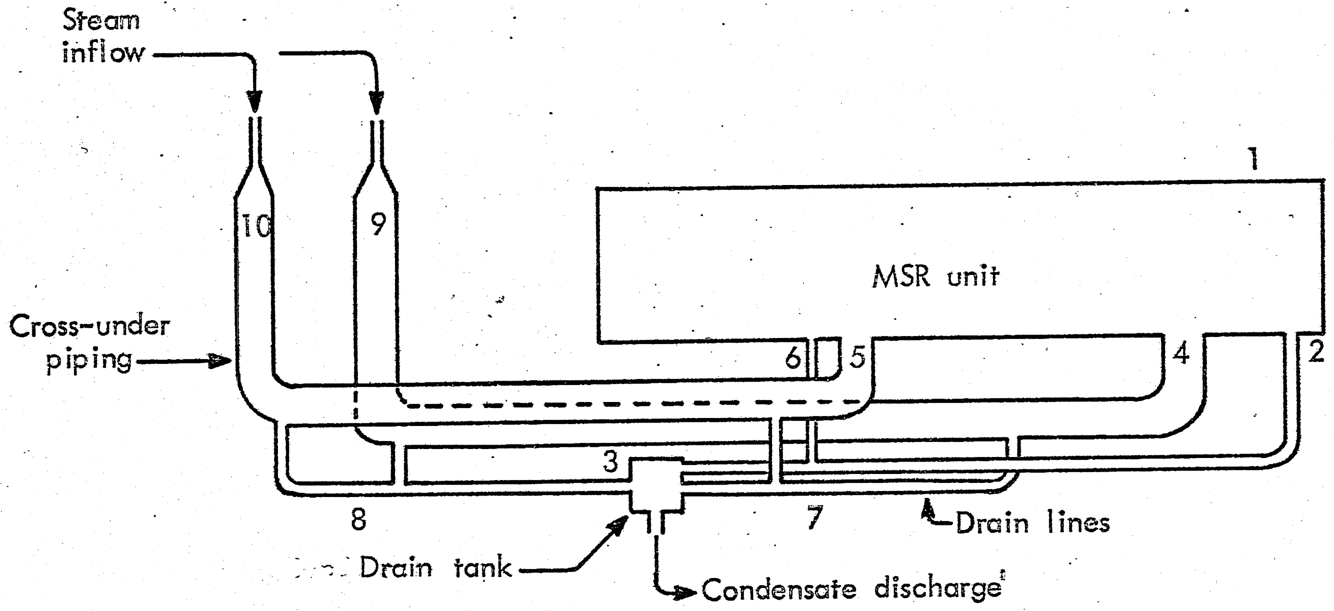
Figure 9 compares the pressure in the MSR unit with that in the drain tank for the same instant in time. The data show that the pressure in the MSR unit drops faster than that in the drain tank. This result was to be expected. If pressure differentials between the MSR unit and the drain tank will cause problems in the prototype system, a large vent pipe following the most direct, least restricted path should be installed.

The drain system functioned satisfactorily in all respects during rapid pressure reductions, excepting the possible problem discussed in the previous paragraph. Again, based on the satisfactory overall performance of the model, the configuration shown in AEP Drawing No. MSK-82771 should be satisfactory for operation of the prototype drain system.

V. RECOMMENDATIONS

1. The drain system shown in AEP's Drawing No. MSK-82771 functioned satisfactorily during both steady state and pressure reduction tests.
2. The system shown in Drawing No. MSK-82771 or a similar one based on the same design philosophy should be used for the prototype Donald C. Cook power plant.
3. If pressure differences (approximately 2 psi on the average) between the drain tank and the MSR unit are unacceptable, large vent lines should be provided.

LIST OF FIGURES



Location	1[2]	2	3[2]	4	5	6	7	8	9	10
Temperature in °F[1]	308	313	185	320	325	325	322	322	320	315

[1] Maximum probable error in reading ±5°F

[2] Temperature sensor located on pressure transducer, not tank

Fig. 1 - Temperature Distribution

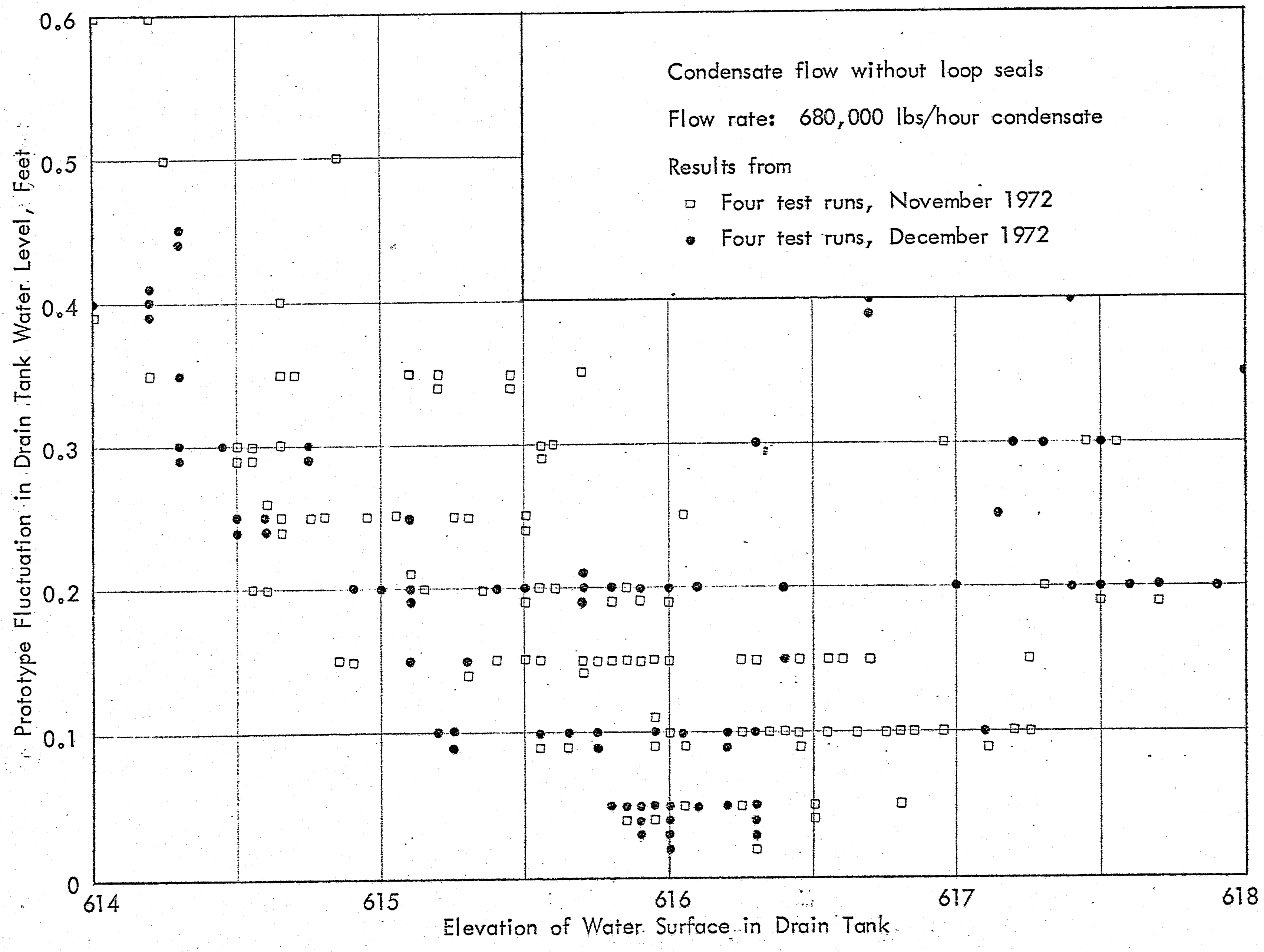


Fig. 2 - Drain Tank Level Fluctuations: Normal Flow

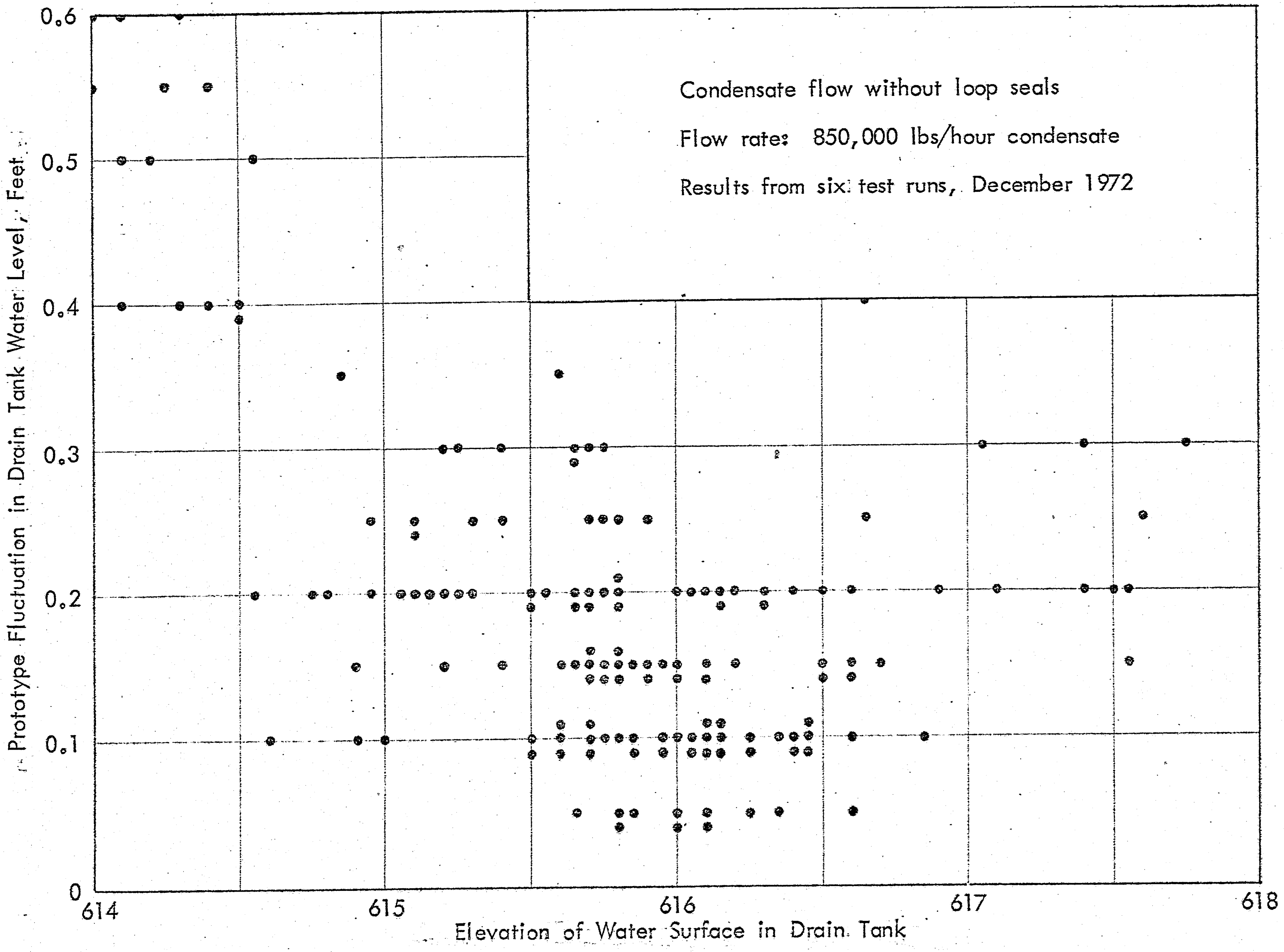


Fig. 3 - Drain Tank Level Fluctuations: 1.32 times Normal Flow

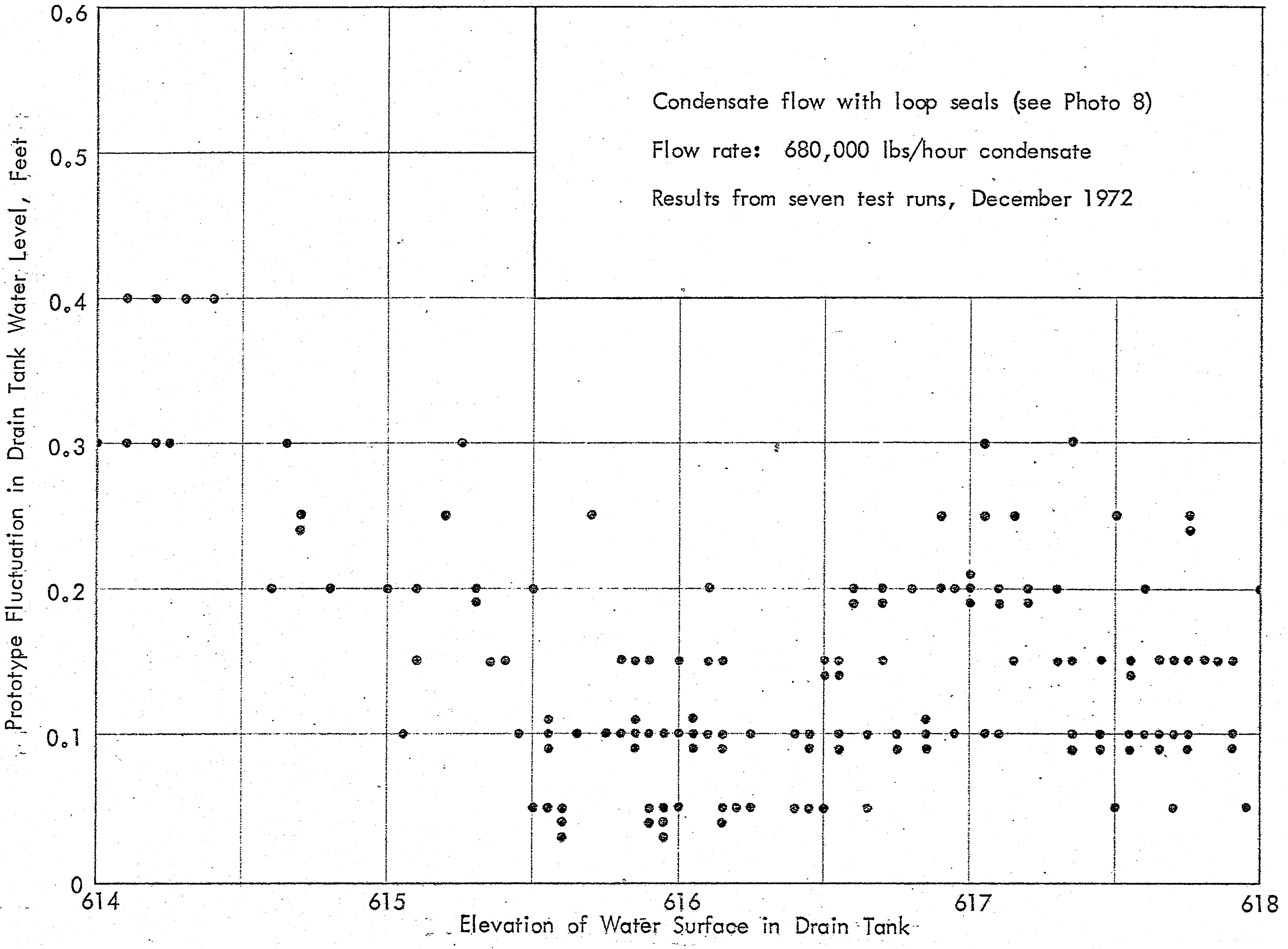


Fig. 4 - Drain Tank Level Fluctuations: Normal Flow Rate with Loop Seals

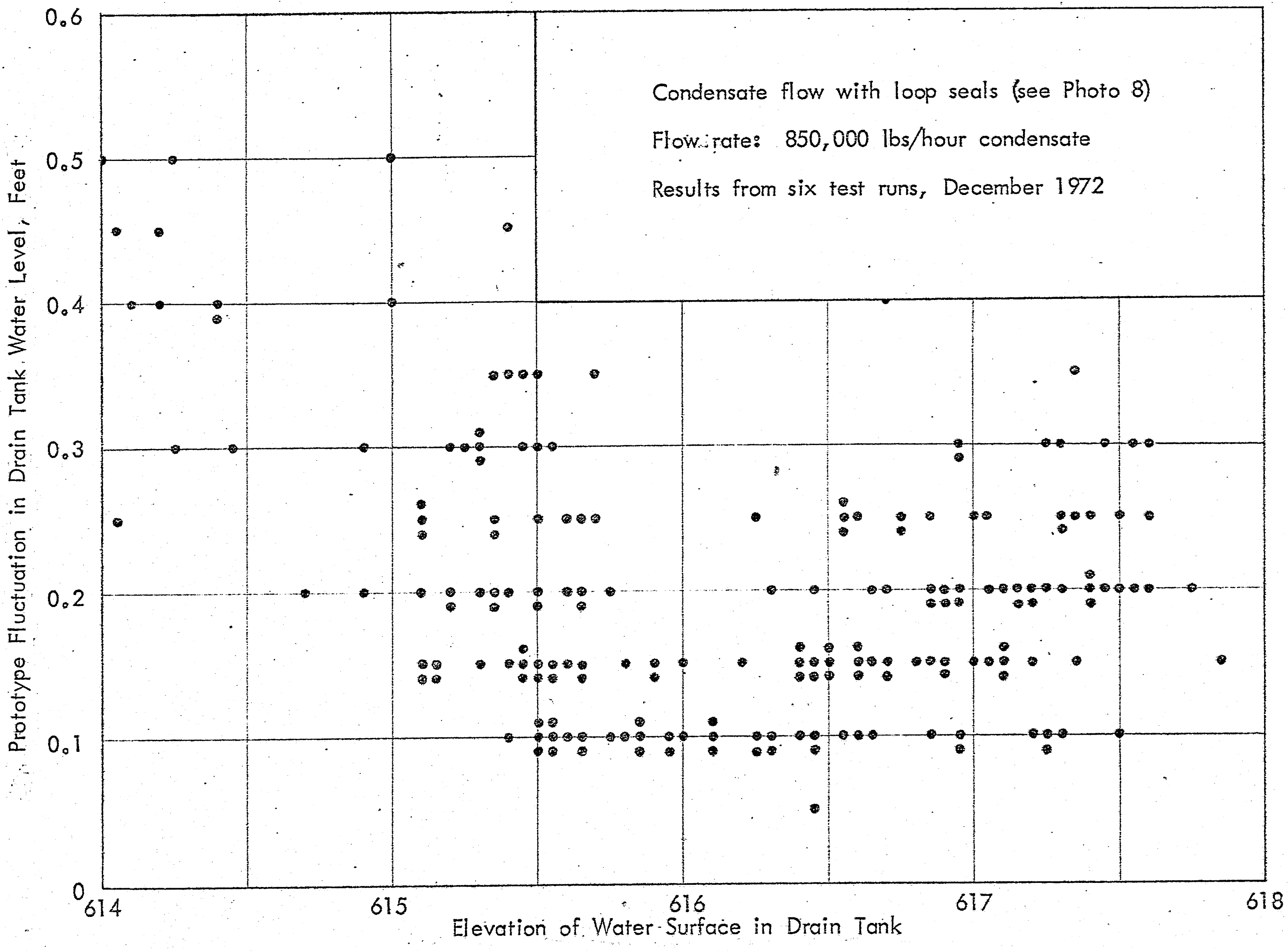
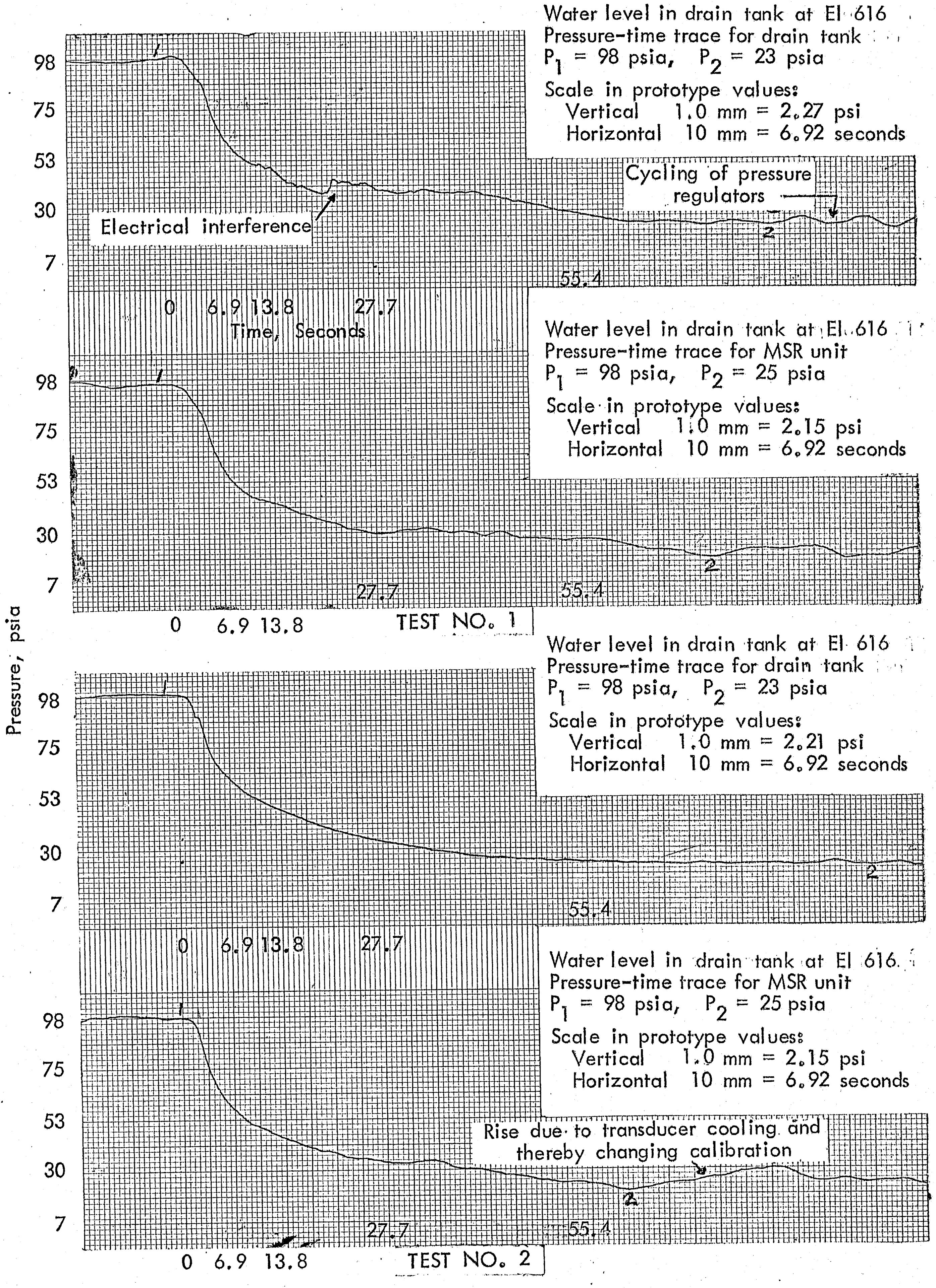


Fig. 5 - Drain Tank Level Fluctuations: 1.32 times Normal Flow Rate with Loop Seals



Water level in drain tank at El 616
Pressure-time trace for drain tank
P_1 = 98 psia, P_2 = 23 psia
Scale in prototype values:
Vertical 1.0 mm = 2.27 psi
Horizontal 10 mm = 6.92 seconds

Cycling of pressure regulators

Electrical interference

Water level in drain tank at El 616
Pressure-time trace for MSR unit
P_1 = 98 psia, P_2 = 25 psia
Scale in prototype values:
Vertical 1.0 mm = 2.15 psi
Horizontal 10 mm = 6.92 seconds

TEST NO. 1

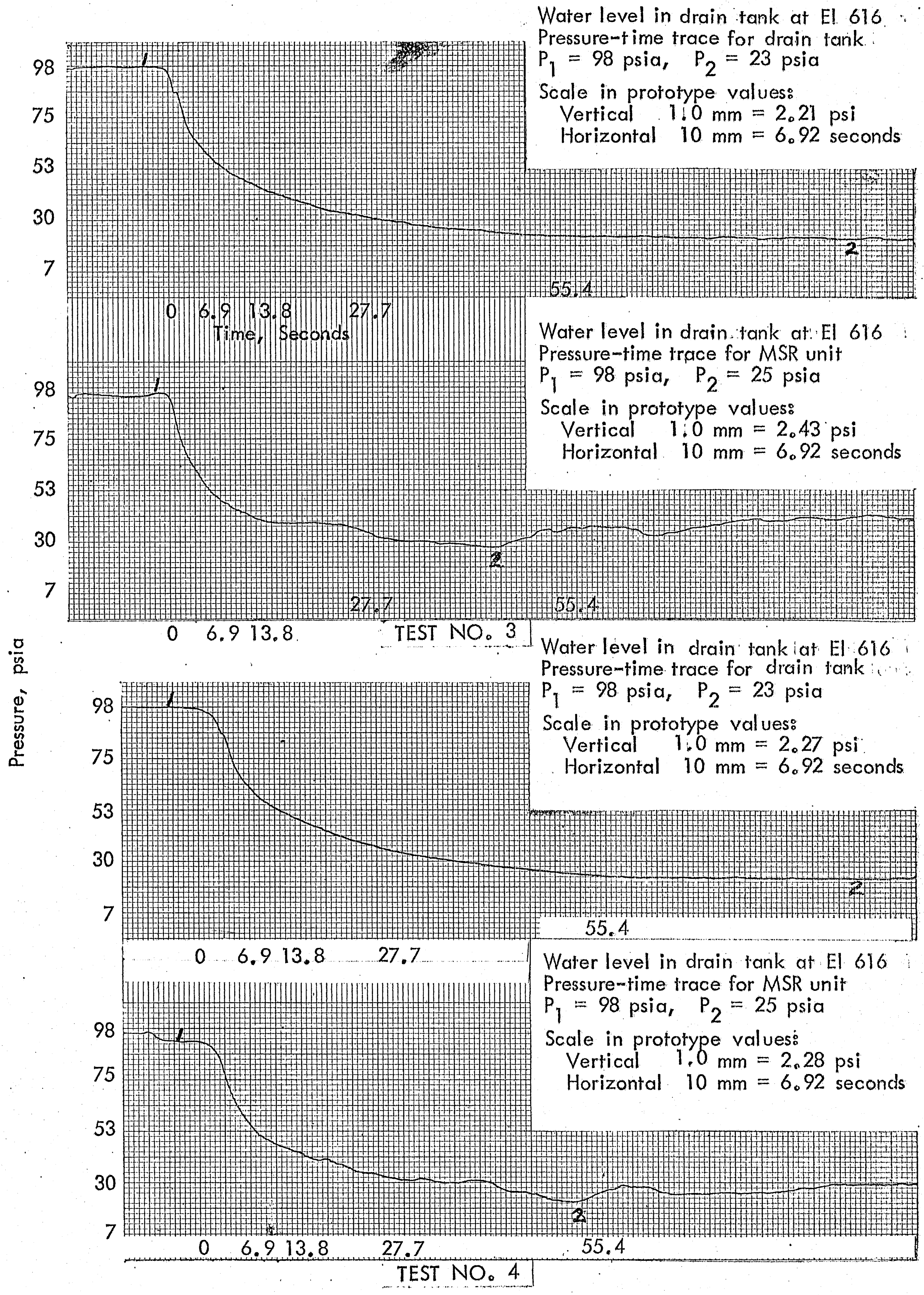
Water level in drain tank at El 616
Pressure-time trace for drain tank
P_1 = 98 psia, P_2 = 23 psia
Scale in prototype values:
Vertical 1.0 mm = 2.21 psi
Horizontal 10 mm = 6.92 seconds

Water level in drain tank at El 616
Pressure-time trace for MSR unit
P_1 = 98 psia, P_2 = 25 psia
Scale in prototype values:
Vertical 1.0 mm = 2.15 psi
Horizontal 10 mm = 6.92 seconds

Rise due to transducer cooling and thereby changing calibration

TEST NO. 2

Fig. 6a - Pressure-Time Curves during Rapid Pressure Drop in MSR Unit



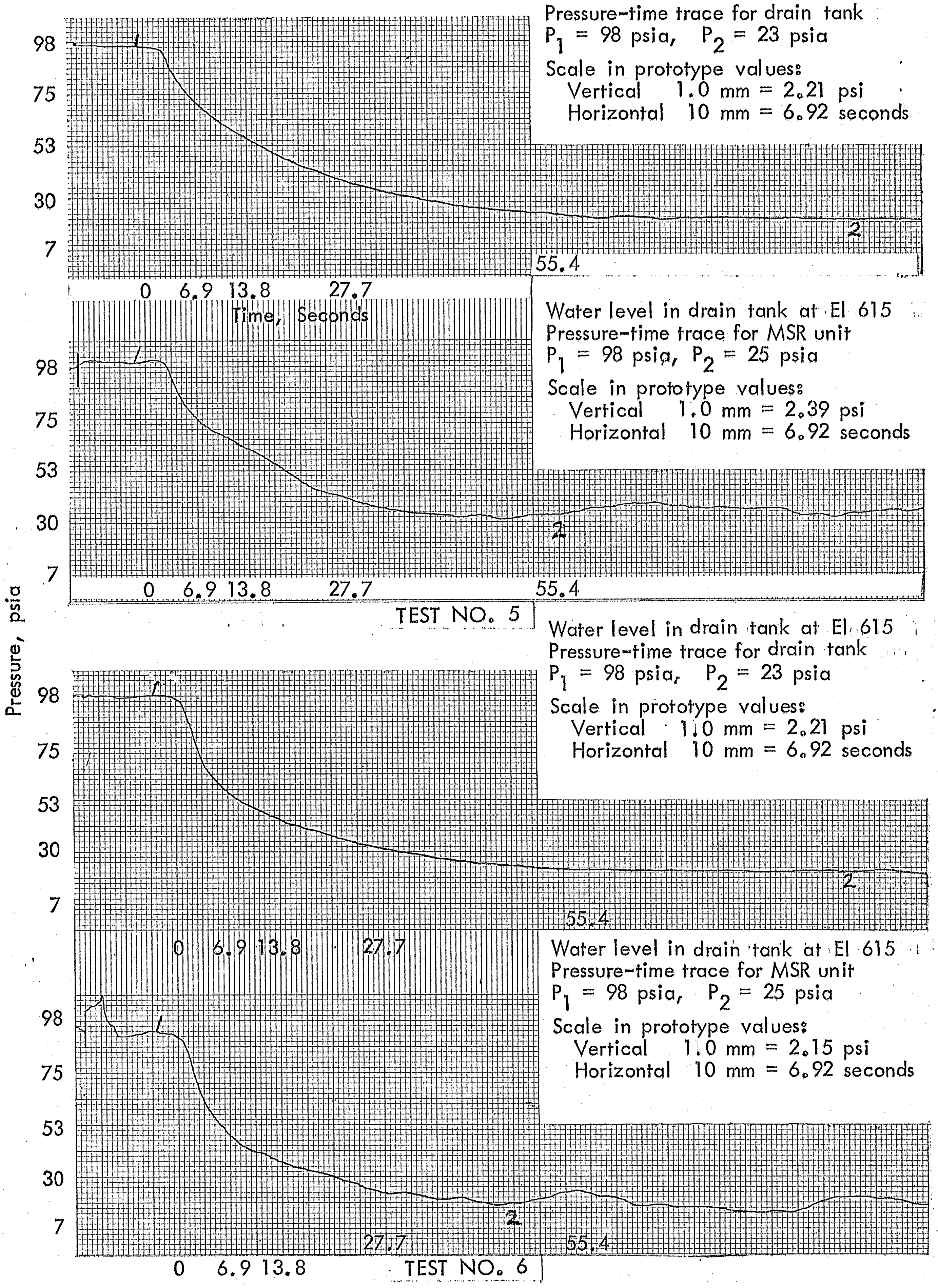
Water level in drain tank at El 616
Pressure-time trace for drain tank
P_1 = 98 psia, P_2 = 23 psia
Scale in prototype values:
Vertical 1.0 mm = 2.21 psi
Horizontal 10 mm = 6.92 seconds

Water level in drain tank at El 616
Pressure-time trace for MSR unit
P_1 = 98 psia, P_2 = 25 psia
Scale in prototype values:
Vertical 1.0 mm = 2.43 psi
Horizontal 10 mm = 6.92 seconds

Water level in drain tank at El 616
Pressure-time trace for drain tank
P_1 = 98 psia, P_2 = 23 psia
Scale in prototype values:
Vertical 1.0 mm = 2.27 psi
Horizontal 10 mm = 6.92 seconds

Water level in drain tank at El 616
Pressure-time trace for MSR unit
P_1 = 98 psia, P_2 = 25 psia
Scale in prototype values:
Vertical 1.0 mm = 2.28 psi
Horizontal 10 mm = 6.92 seconds

Fig. 6b - Pressure-Time Curves during Rapid Pressure Drop in MSR Unit



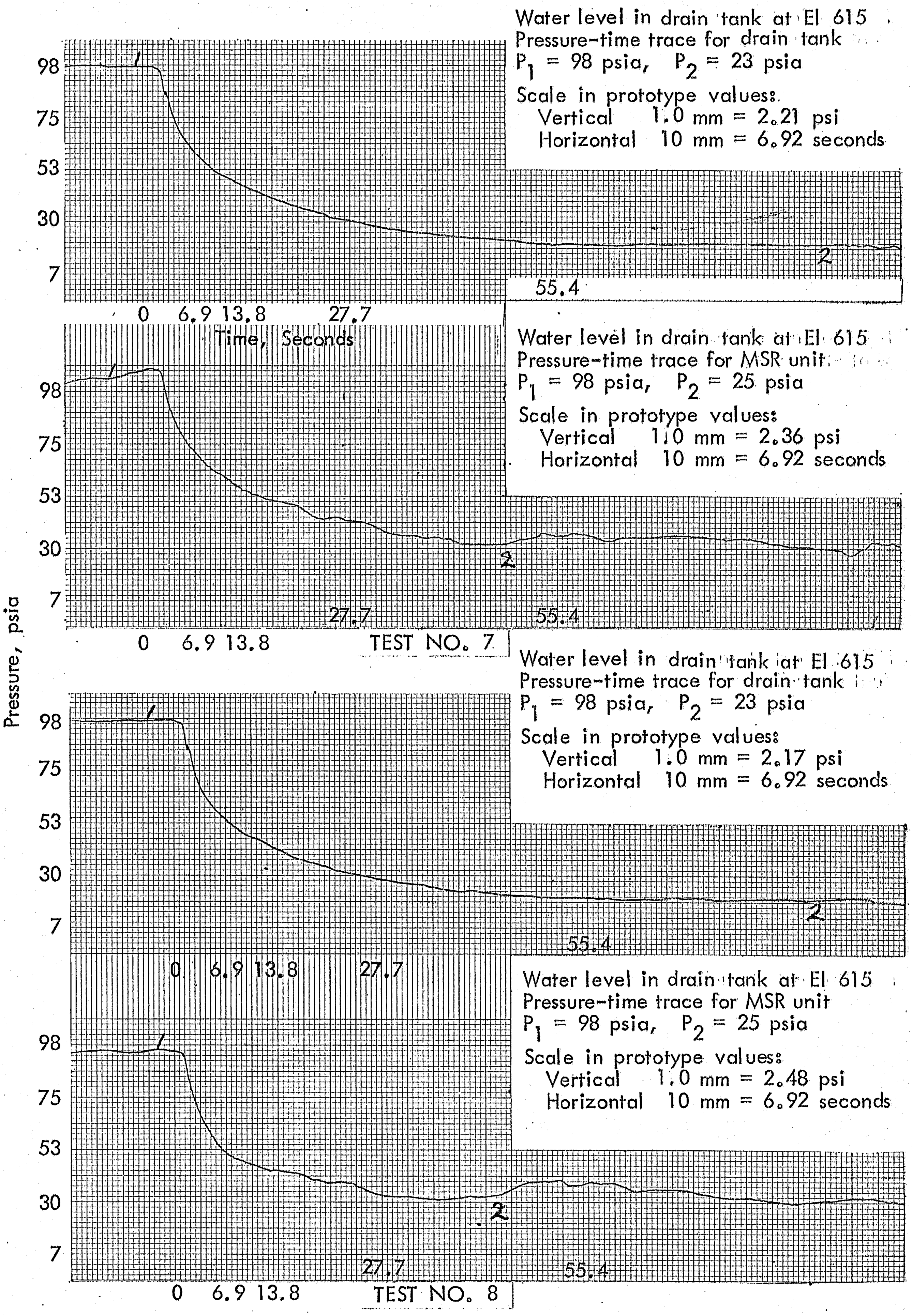
Water level in drain tank at El 615
Pressure-time trace for drain tank
P_1 = 98 psia, P_2 = 23 psia
Scale in prototype values:
Vertical 1.0 mm = 2.21 psi
Horizontal 10 mm = 6.92 seconds

Water level in drain tank at El 615
Pressure-time trace for MSR unit
P_1 = 98 psia, P_2 = 25 psia
Scale in prototype values:
Vertical 1.0 mm = 2.39 psi
Horizontal 10 mm = 6.92 seconds

Water level in drain tank at El 615
Pressure-time trace for drain tank
P_1 = 98 psia, P_2 = 23 psia
Scale in prototype values:
Vertical 1.0 mm = 2.21 psi
Horizontal 10 mm = 6.92 seconds

Water level in drain tank at El 615
Pressure-time trace for MSR unit
P_1 = 98 psia, P_2 = 25 psia
Scale in prototype values:
Vertical 1.0 mm = 2.15 psi
Horizontal 10 mm = 6.92 seconds

Fig. 6c - Pressure-Time Curves during Rapid Pressure Drop in MSR Unit



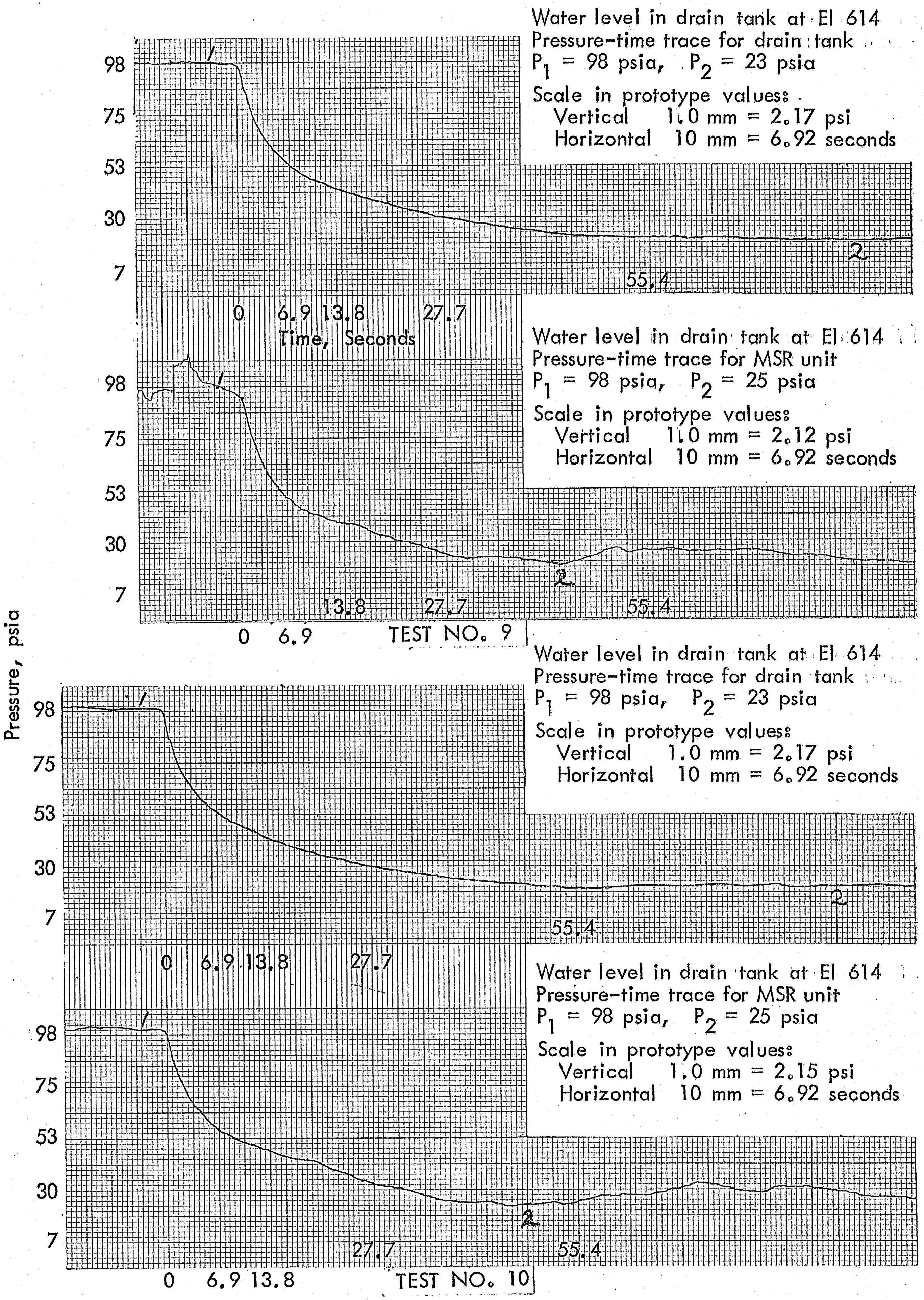
Water level in drain tank at El 615
Pressure-time trace for drain tank
P_1 = 98 psia, P_2 = 23 psia
Scale in prototype values:
Vertical 1.0 mm = 2.21 psi
Horizontal 10 mm = 6.92 seconds

Water level in drain tank at El 615
Pressure-time trace for MSR unit
P_1 = 98 psia, P_2 = 25 psia
Scale in prototype values:
Vertical 1.0 mm = 2.36 psi
Horizontal 10 mm = 6.92 seconds

Water level in drain tank at El 615
Pressure-time trace for drain tank
P_1 = 98 psia, P_2 = 23 psia
Scale in prototype values:
Vertical 1.0 mm = 2.17 psi
Horizontal 10 mm = 6.92 seconds

Water level in drain tank at El 615
Pressure-time trace for MSR unit
P_1 = 98 psia, P_2 = 25 psia
Scale in prototype values:
Vertical 1.0 mm = 2.48 psi
Horizontal 10 mm = 6.92 seconds

Fig. 6d - Pressure-Time Curves during Rapid Pressure Drop in MSR Unit



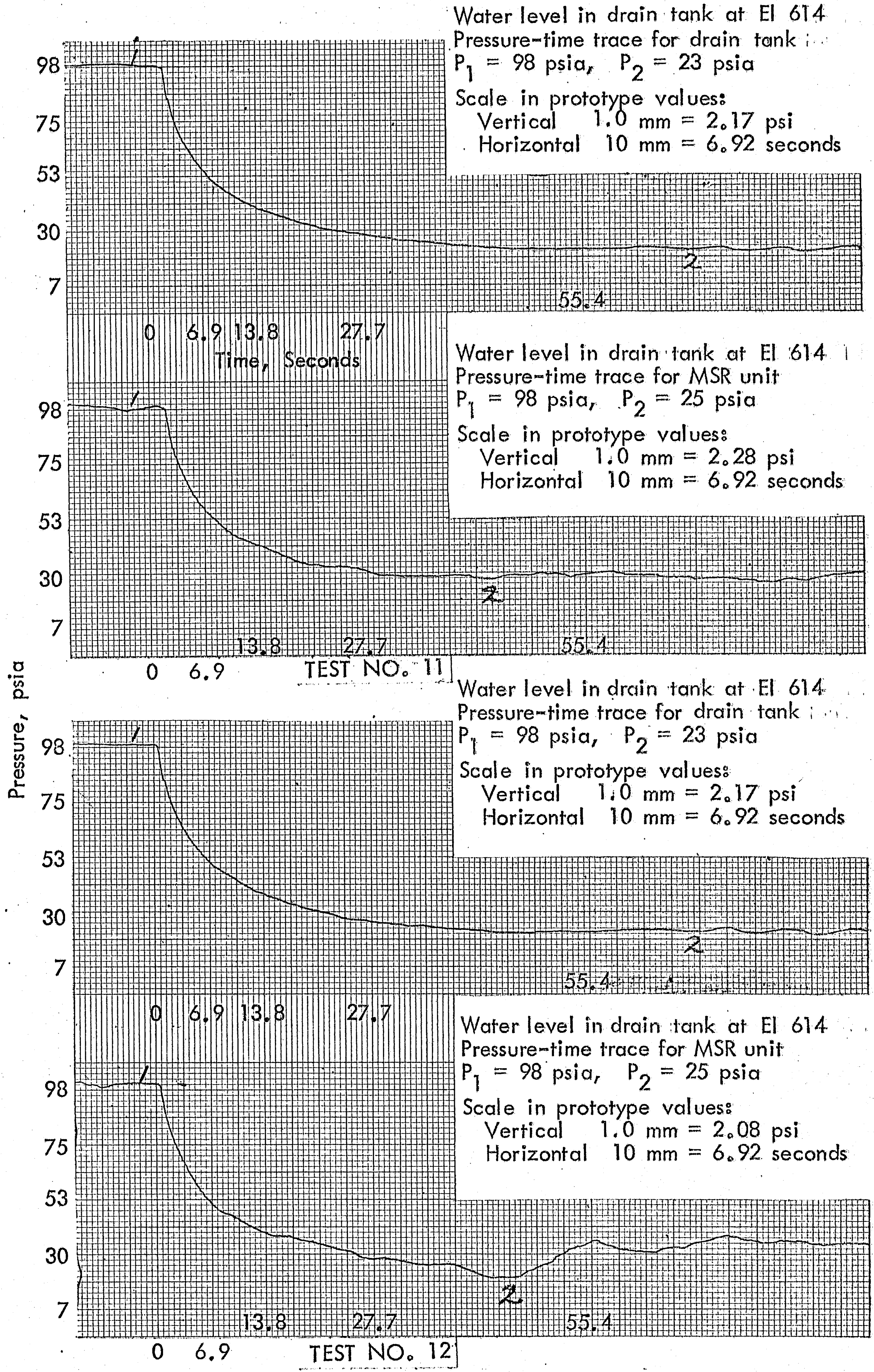
Water level in drain tank at El 614
Pressure-time trace for drain tank
P_1 = 98 psia, P_2 = 23 psia
Scale in prototype values:
Vertical 1.0 mm = 2.17 psi
Horizontal 10 mm = 6.92 seconds

Water level in drain tank at El 614
Pressure-time trace for MSR unit
P_1 = 98 psia, P_2 = 25 psia
Scale in prototype values:
Vertical 1.0 mm = 2.12 psi
Horizontal 10 mm = 6.92 seconds

Water level in drain tank at El 614
Pressure-time trace for drain tank
P_1 = 98 psia, P_2 = 23 psia
Scale in prototype values:
Vertical 1.0 mm = 2.17 psi
Horizontal 10 mm = 6.92 seconds

Water level in drain tank at El 614
Pressure-time trace for MSR unit
P_1 = 98 psia, P_2 = 25 psia
Scale in prototype values:
Vertical 1.0 mm = 2.15 psi
Horizontal 10 mm = 6.92 seconds

Fig. 6e - Pressure-Time Curves during Rapid Pressure Drop in MSR Unit



Water level in drain tank at El 614
Pressure-time trace for drain tank
P_1 = 98 psia, P_2 = 23 psia
Scale in prototype values:
Vertical 1.0 mm = 2.17 psi
Horizontal 10 mm = 6.92 seconds

Water level in drain tank at El 614
Pressure-time trace for MSR unit
P_1 = 98 psia, P_2 = 25 psia
Scale in prototype values:
Vertical 1.0 mm = 2.28 psi
Horizontal 10 mm = 6.92 seconds

TEST NO. 11

Water level in drain tank at El 614
Pressure-time trace for drain tank
P_1 = 98 psia, P_2 = 23 psia
Scale in prototype values:
Vertical 1.0 mm = 2.17 psi
Horizontal 10 mm = 6.92 seconds

Water level in drain tank at El 614
Pressure-time trace for MSR unit
P_1 = 98 psia, P_2 = 25 psia
Scale in prototype values:
Vertical 1.0 mm = 2.08 psi
Horizontal 10 mm = 6.92 seconds

TEST NO. 12

Fig. 6f - Pressure-Time Curves during Rapid Pressure Drop in MSR Unit

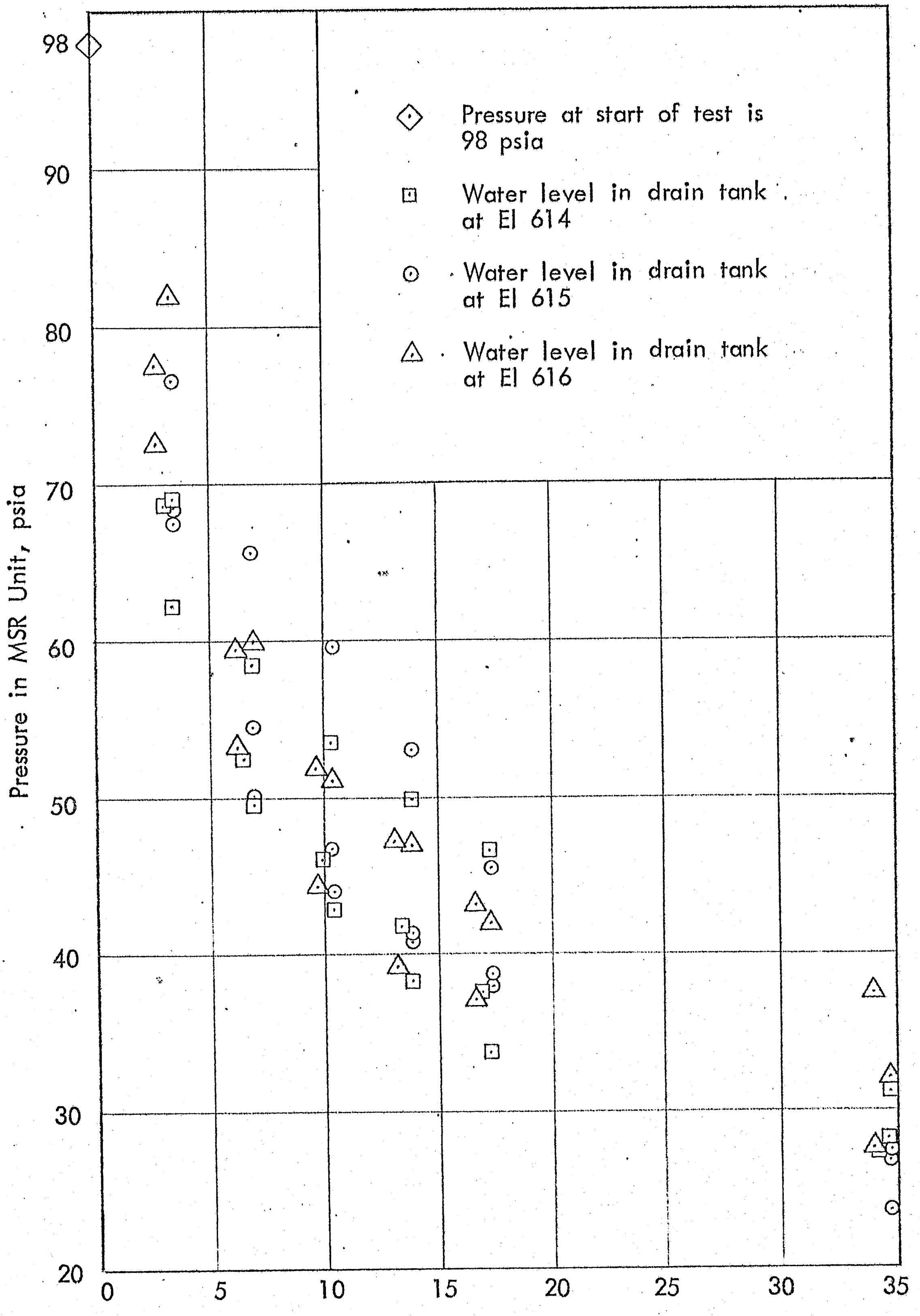


Fig. 7 – Pressure in MSR Unit as a function of Prototype Time during Sudden Pressure Drop

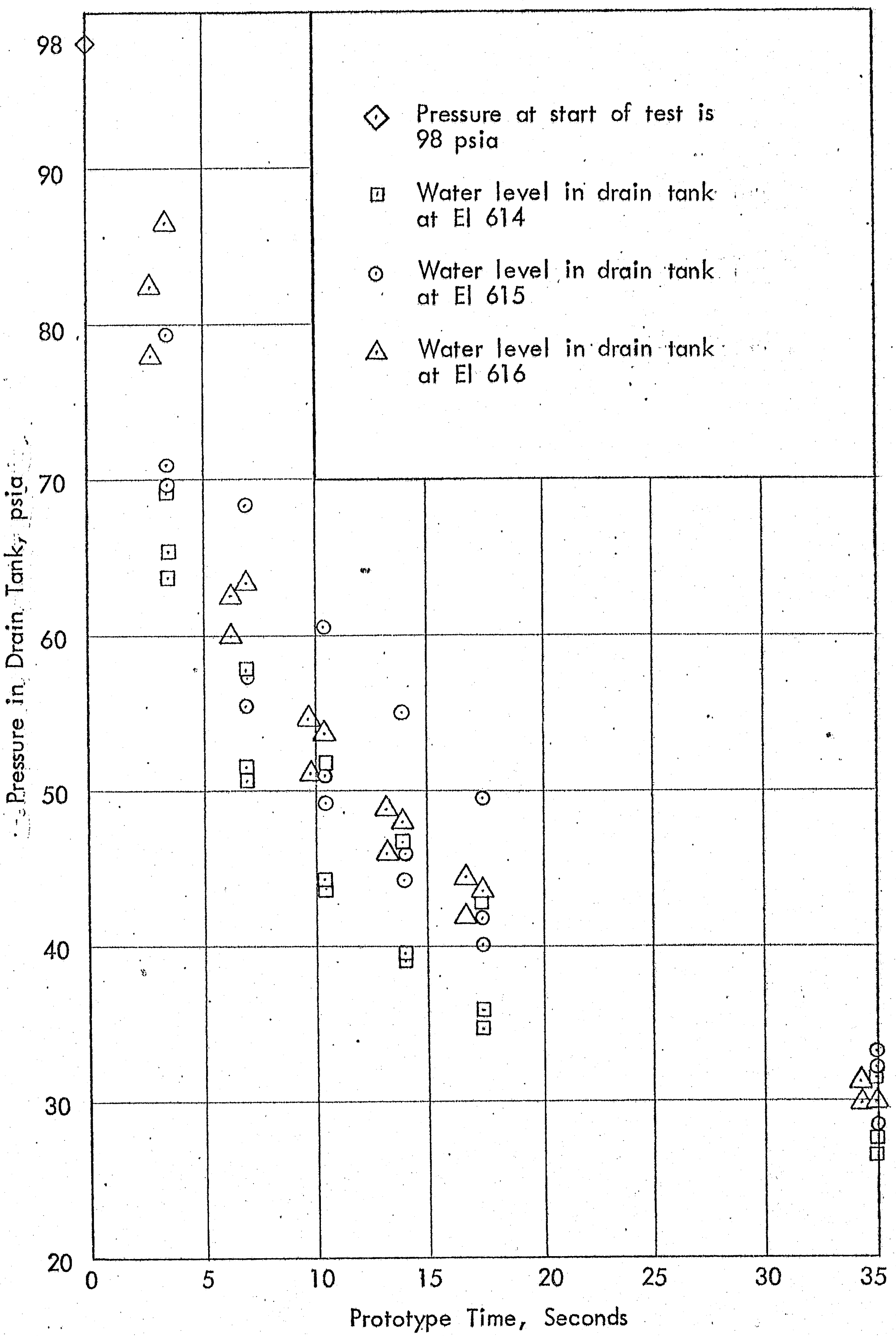


Fig. 8 - Pressure in Drain Tank as a function of Prototype Time during Sudden Pressure Drop in MSR Unit

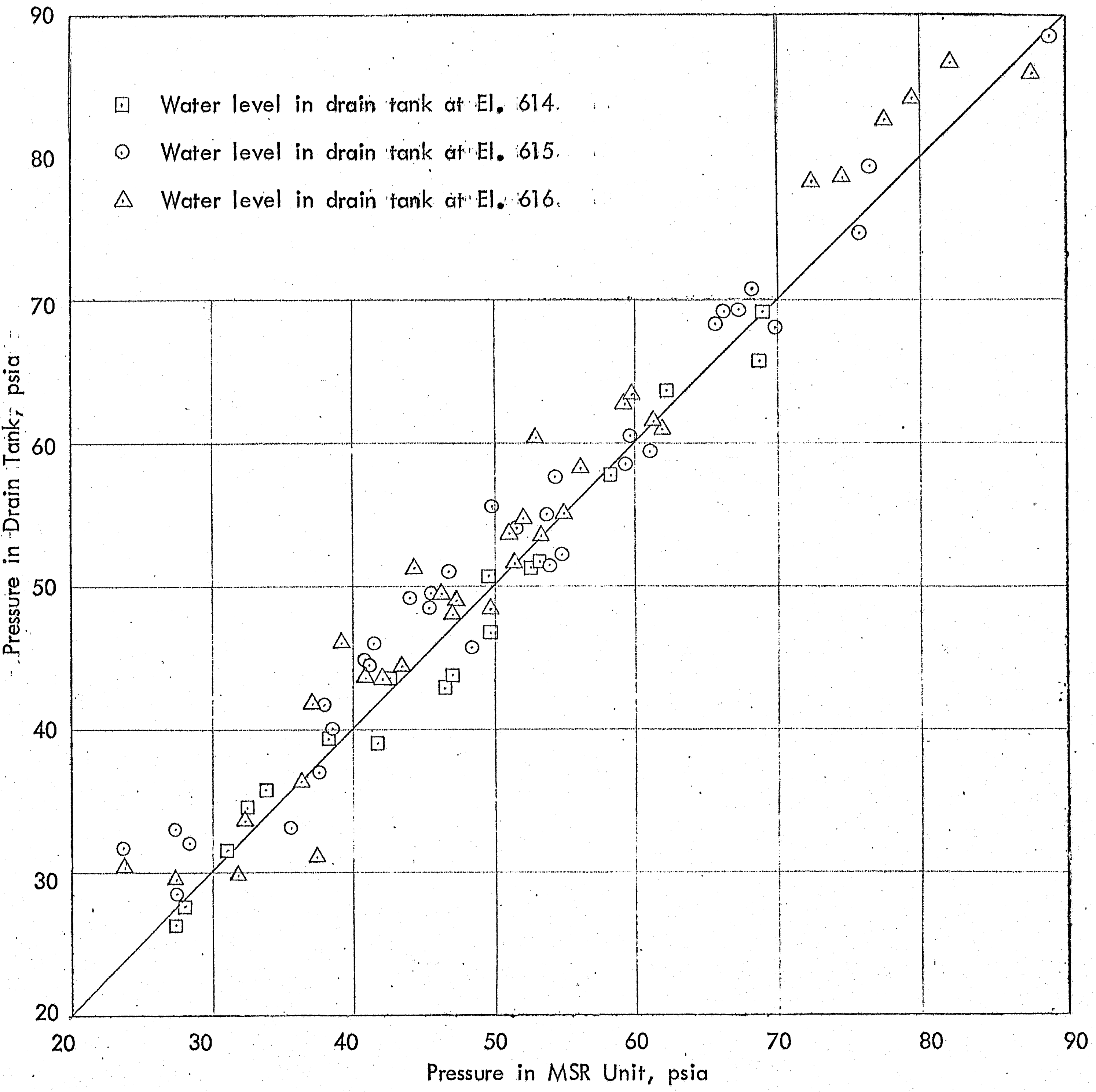


Fig. 9 - Pressure in Drain Tank as a function of Pressure in MSR Unit during a Sudden Pressure Drop

LIST OF PHOTOS

Photo No.	
1	Orifice Meters and Flow Control Valves (pressure regulators)
2	View of Supply System and Initial Portion of Cross-under Piping
3	Overall View of Entire Model, MSR and Cross-under Piping in foreground, Flow Control System in background. Note large discharge and pressure control valve and pressure transducer on top of MSR.
4	View of Drain Lines from MSR Unit and Cross-under Piping
5	Drain Lines and Drain Tank, Valves, and Rotometer used to control Discharge Flow of Condensed Steam
6	Small Drain Lines from Cross-under Piping, Ring to catch Condensate similar to that in Prototype installed where Drain Line is attached to Pipe (between weld and pig tail in photo)
7	Close-up of Drain Tank. Note pressure transducer and drain tank water level indicator.
8	Same as Photo 7, but shows location and shape of one of the loop seals tested.

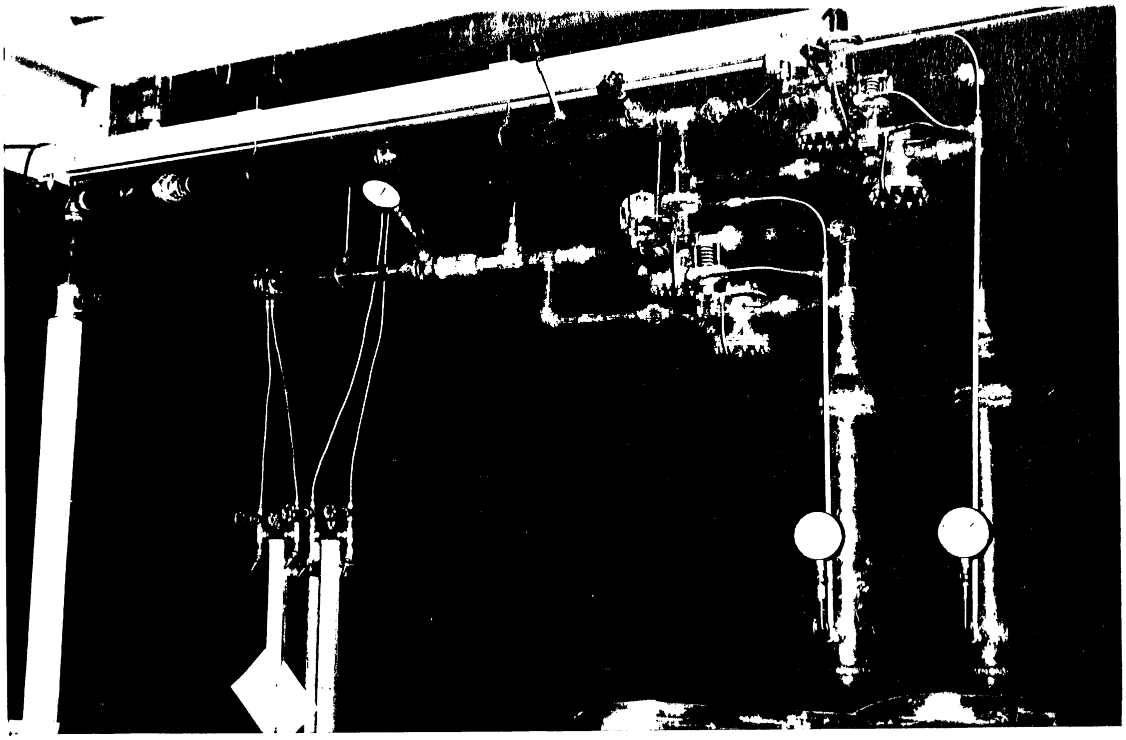


Photo 1 - Orifice Meters and Flow Control Valves (pressure regulators)

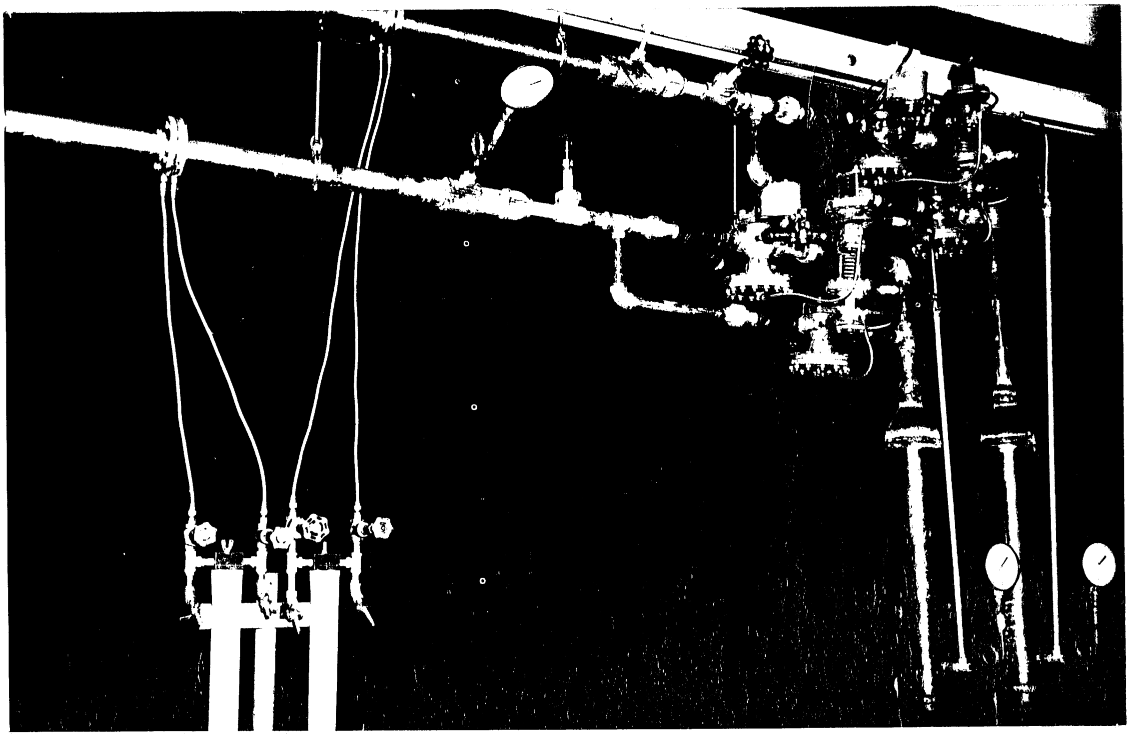


Photo 2 - View of Supply System and Initial Portion of Cross-under Piping

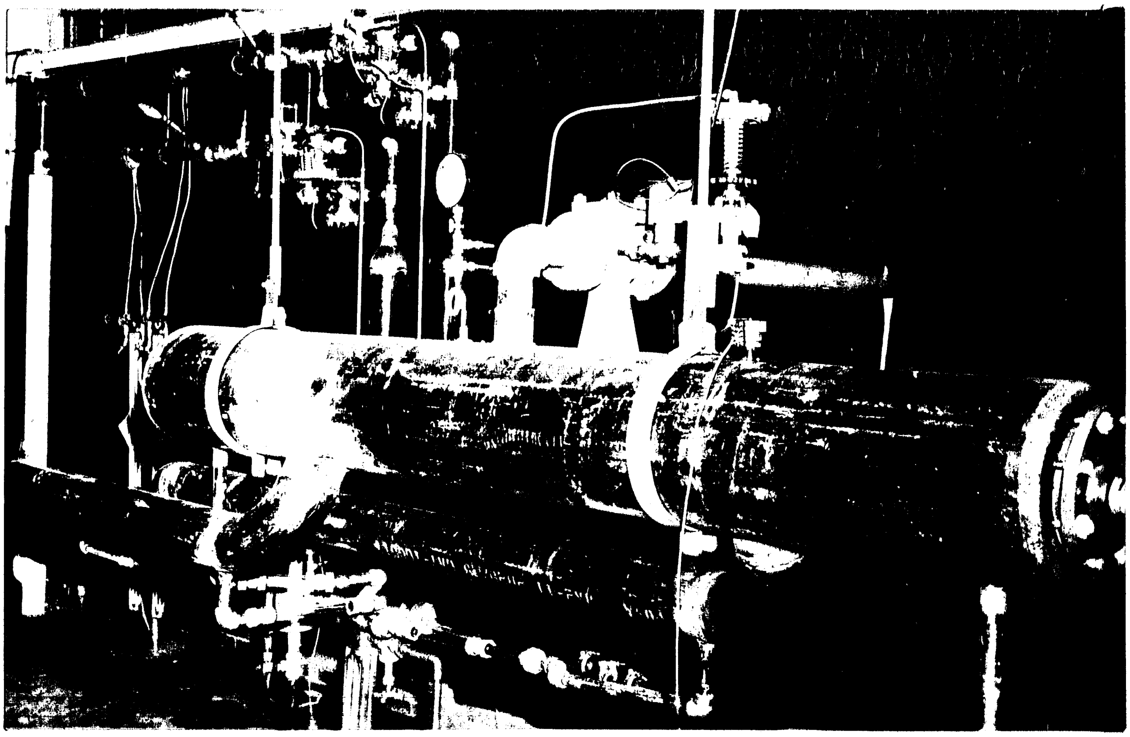


Photo 3 - Overall View of Entire Model, MSR and Cross-under Piping in foreground, Flow Control System in background. Note large discharge and pressure control valve and pressure transducer on top of MSR.

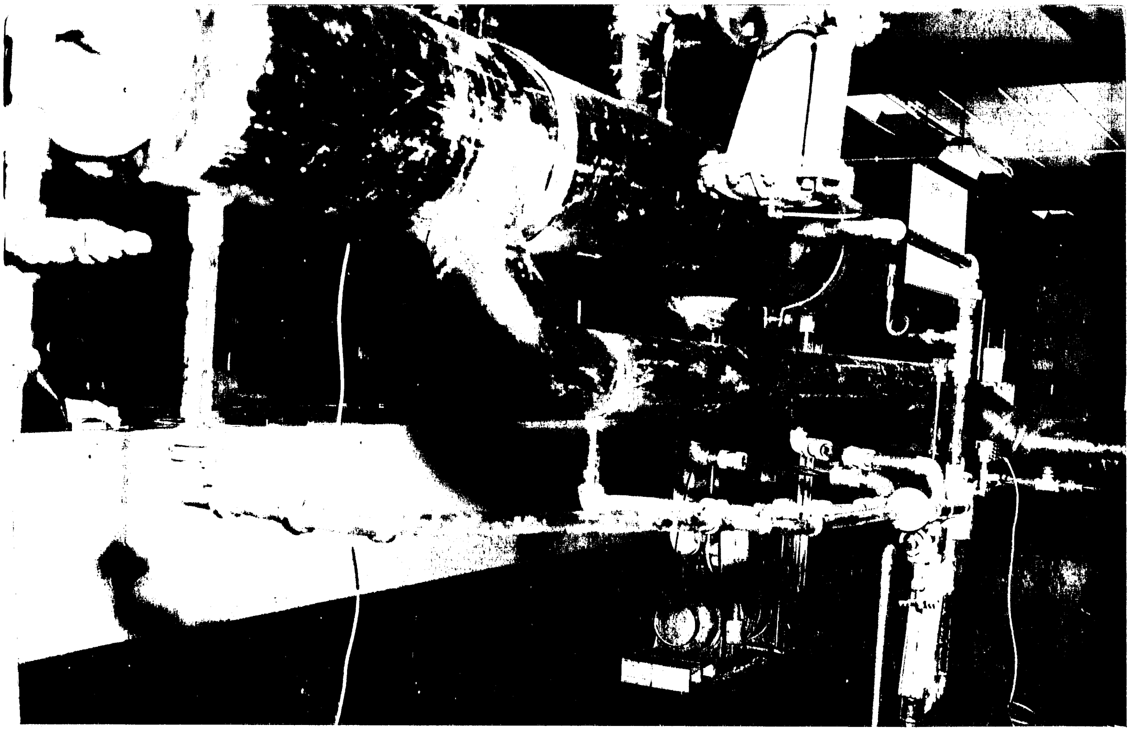


Photo 4 - View of Drain Lines from MSR Unit and Cross-under Piping

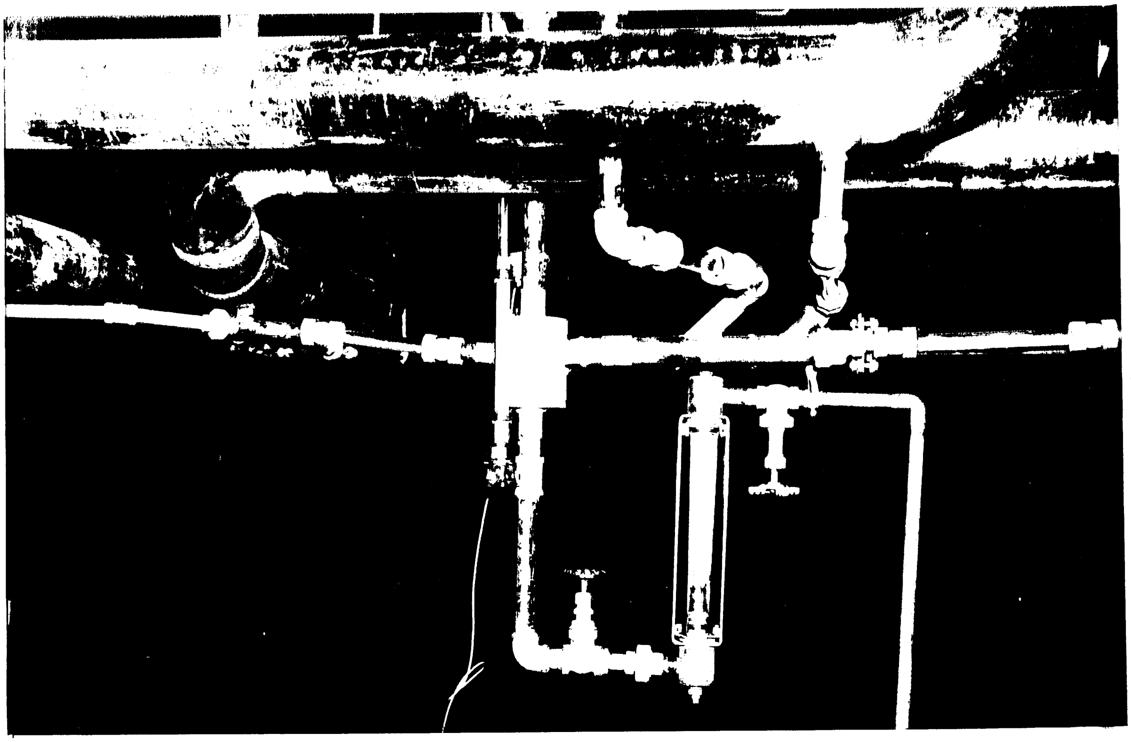


Photo 5 - Drain Lines and Drain Tank, Valves, and Rotometer used to control Discharge Flow of Condensed Steam

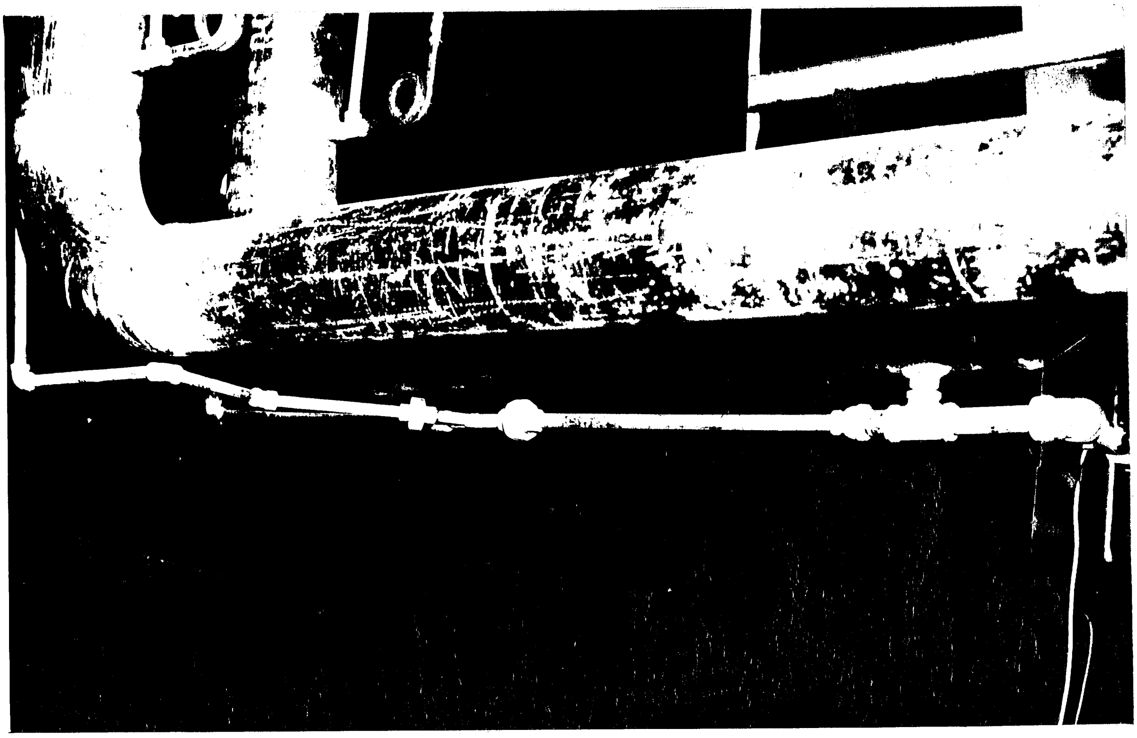


Photo 6 - Small Drain Lines from Cross-under Piping, Ring to catch Condensate similar to that in Prototype installed where Drain Line is attached to Pipe (between weld and pig tail in photo)

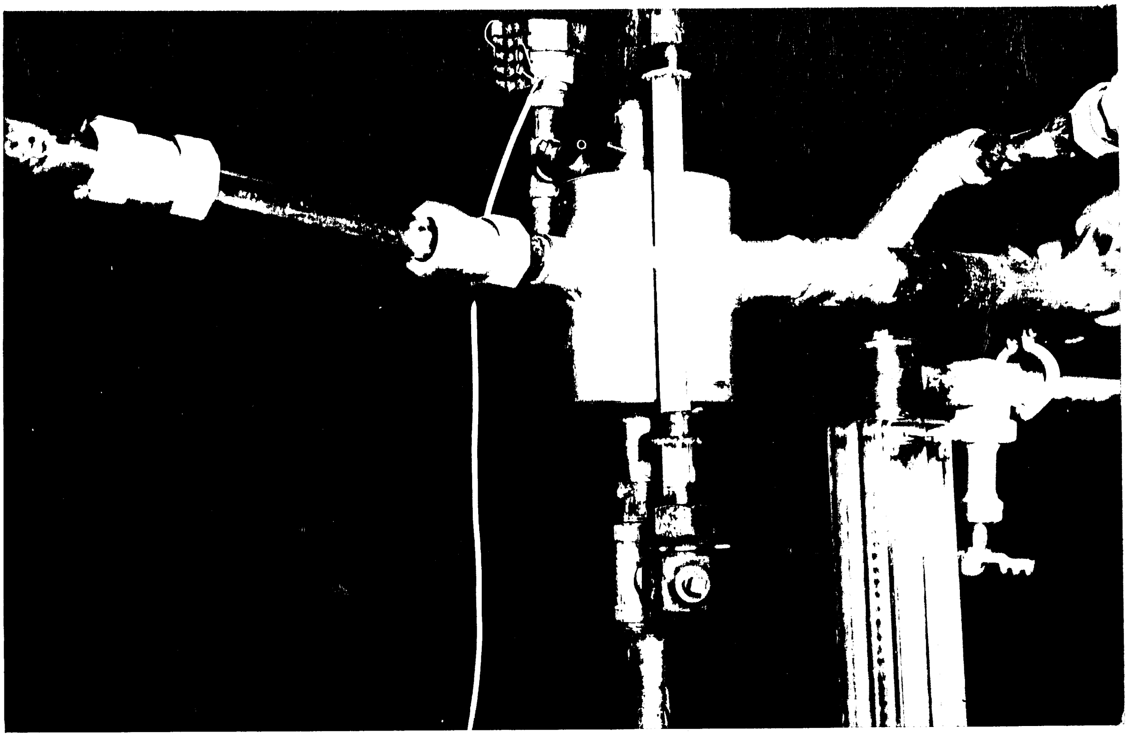


Photo 7 - Close-up of Drain Tank. Note pressure transducer and drain tank water level indicator.

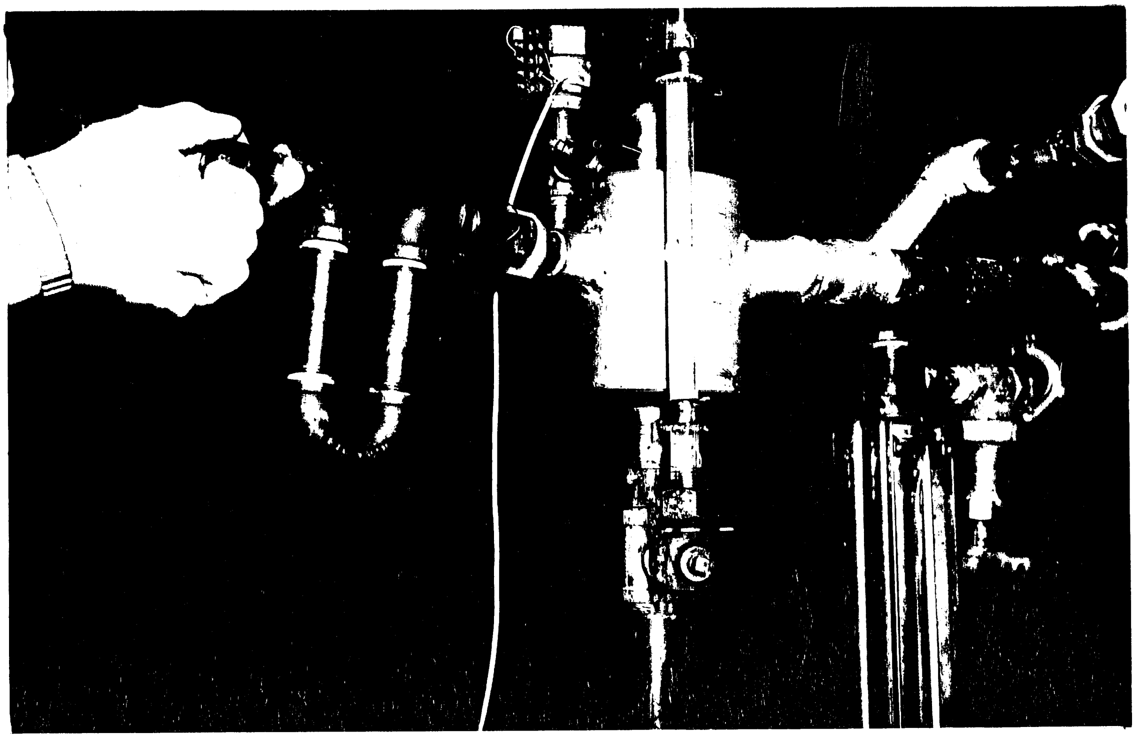


Photo 8 - Same as Photo 7, but shows location and shape of one of the loop seals tested.