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UNIT Engineering Measurements		
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OTHER		TWR 5008
	PROJECT Analysis of SRE Performance	DATE December 23, 1959
		PAGE 1 OF 12

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SUBJECT: Pressure Drop Measurements Across A Mockup of An SRE 7-Rod Fuel Element With An Orifice Plate at the Top

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I STATEMENT OF PROBLEM

Flow past a standard orifice plate on the bottom of an SRE fuel element can take two parallel paths: through the holes in the orifice plate, and through the annular clearance between the orifice plate and the process tube. Variations among the inside diameters of the process tubes in the SRE can result in a different proportion of bypass flow past the orifice plates, which in turn can contribute to unequal fuel-channel exit temperatures. It has been proposed[1] that the orifice plate be relocated to the top of the fuel element in the moderator spacer ring. The ID of the spacer ring is machined to a tolerance of $\pm$ 0.0005 in. and this variation would produce only slight changes in the proportion of bypass flow. Accordingly, a special assembly which could support a removable 6-hole orifice plate, and which would be located at the top of the fuel element, was designed and fabricated[2]. The purpose of this work was to determine experimentally the pressure drop-flow characteristics of a standard 7-rod SRE fuel element with this orifice assembly at the top.

II SUMMARY OF RESULTS AND RECOMMENDATIONS

Pressure-drop measurements were made across a simulated SRE process tube containing a mockup of a standard 7-rod fuel element with a 6-hole

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orifice assembly located at the top. Data were obtained using water as a test fluid and were converted to sodium at 750°F which is the arithmetical mean of the process tube entrance and exit temperatures.

Figure 1, page 6, is a plot of total core pressure drop versus flow rate for a fuel element using orifice plates with hole sizes from 1/4 to 3/4-inch diameter in 1/8-inch increments. Data are also included for a fuel element using: an orifice plate with no holes, the orifice assembly without an orifice plate, and no orifice assembly. The entire range of flow control possible with the upper orifice assembly is encompassed using these configurations.

Figure 2, page 7, is a cross plot of Figure 1 and shows orifice hole size versus flow rate for several constant core pressure drops.

Variations in the height of the moderator cans and changing temperatures in the core affect the elevation of the orifice plate in the moderator spacer ring. Hydraulic tests were performed on the fuel element with two orifice hole sizes at elevations ranging from 3/8-inch below the moderator spacer ring (3/8-inch into the process tube) to 1/2-inch above the moderator spacer (1/2-inch into the upper plenum). Flow rate past the orifice was constant with constant pressure drop for all elevations in which the orifice plate was positioned inside the spacer ring; however, changes in flow rate were observed when the orifice plate was positioned above or below the spacer ring. Therefore, it is recommended that the orifice plate be located at the vertical midpoint of the spacer ring, when the core is at operating temperature, to eliminate changes in flow rate due to variations in plate elevation.

III METHOD USED, DESCRIPTION OF EQUIPMENT, SAMPLE CALCULATIONS

The fuel element was supported by a 5/8-inch diameter hanger rod. A turnbuckle was included on the hanger rod to provide a means for testing the fuel element at different elevations in the process tube.

Figure 3A, page 8, shows the orifice assembly attached to the mock 7-rod fuel element used in this test. It also shows a detail of the turnbuckle used to adjust the elevation of the element in the fuel channel.

Figure 3B is a photograph of the orifice assembly with one half of the split orifice plate removed. The orifice assembly consists of four basic parts: orifice plate support, split orifice plate, upper guide and lock-nut. (See Figure 3A for nomenclature). Orifice plates are removed by loosening the lock-nut, raising the upper guide, lifting the halves of the orifice plate to clear the positioning pins, and removing.

A description of the water loop used for these tests is contained on page 2 of Reference 3. All pressure drops reported here are total core pressure drops. Pressure-differential measuring taps located in the simulated upper and lower plenums and attached to a differential manometer were used to determine the pressure drop.

DISCUSSION:

The test orifice plate was machined with appropriate dimensions to simulate the effect of thermal expansion upon the annular clearance around the orifice plate and also upon the holes in the orifice plate.

The test orifice plate was machined to 2.7575-inch O.D. instead of the standard 2.750-inch O.D. The former diameter provides an annular flow area in the hydraulic loop with water flowing at 170°F equal to the actual area in the SRE with sodium exiting from the fuel channel at 950°F.

The area of the orifice holes when tested in the hydraulic loop also differs from the area of the holes in the same plate when used in the SRE. This difference is due to the thermal expansion of the plate. An orifice plate with 0.250-inch holes (at room temperature) would have 0.2503-inch holes at 170°F and 0.2522-inch holes at 950°F, representing an increase of about 0.002-inches. Therefore, flow through a 0.250-inch 6-hole orifice plate in the hydraulic loop would be equivalent to flow through a 0.248-inch diameter hole size (at room temperature) when used in the SRE. By the same procedure it can be shown that water flow through a plate with 0.750-inch holes is equivalent to sodium flow through a plate with 0.744-inch holes. For ease of machining, the orifice holes were reamed to ± 0.001 in. from the even 1/8-inch increments Points on Figure 2 were then plotted using the equivalent orifice diameter in the SRE.

Elevation of the orifice plate with respect to the moderator spacer ring will vary from channel to channel in the SRE. This variation is due to differences in length of the moderator cans, differences in elevation of the hanger rod support steps in the top shield, and differences in length of the hanger rods. Elevation of the orifice plate will also vary with temperature. As the reactor temperature increases, the hanger rod will lengthen. This causes the orifice plate to move down with respect to the moderator cans. Increasing temperature also lengthens the moderator cans. The net effect of all thermal expansion is to move the orifice plate downward in the spacer ring by approximately 1-3/8 inches over a temperature range from 550°F to 950°F.

Hydraulic measurements were conducted for two hole sizes with the orifice plate located at the elevations noted in Figure 4, page 9. The orifice assembly is shown dotted in Figure 4 at elevation -2.5. Figure 5, page 10, is a plot of the raw data, obtained with water, for 3/8-inch orifice holes at the vertical locations noted in Figure 5. Figure 6, page 11, is a plot of the data in Figure 5 reduced to sodium at a temperature of 750°F. The data for elevations of -0.25, -0.50, -1.50, -2.50 and -3.50 all fall on the same straight line. Therefore, no variations in flow would result from changing the elevation as long as the orifice plate is completely inside the spacer ring. Figure 7, page 12, is a plot of the raw data obtained with water for 1/2-inch orifice holes at various vertical locations, all within the spacer ring. The 1/2-inch data verifies the fact that flow rate is independent of those elevations completely inside the spacer ring.

Overall pressure drop for the fuel element with no orifice plate is plotted in Figure 1. Flow rates obtained in this test are 7 to 19% higher, at the same pressure drop, than the flow rate determined in another test of the same fuel element (Reference 4).

The hydraulic measurements in Reference 4 were obtained using a different tube to simulate the coolant channel and it is likely that the interior of the Reference 4 tube may have offered a higher resistance to flow. The Reference 4 tube was made of mild steel and deposits of oxide (rust) quickly covered the interior; the tube used in the present experiments was made of type 304 stainless steel and was not subject to rusting.

Furthermore, the slope of the data in Reference 4 is 2.03, while the slope of the data in this experiment is 1.86. The pressure drop of a fuel element in a process tube is predominently frictional, and data should therefore yield a slope of approximately 1.84. The pressure drop measurements were repeated several weeks after the initial tests and produced identical data. Therefore, it is considered that the data reported in this work are more reliable.

IV REFERENCES

1. TDR 4112, "Hydraulic Tests of Methods of Decreasing Annular Flow Past an SRE Orifice", by R. J. Begley dated July 14, 1959.
2. IOL, "Proposed Orifice Plate Changes for the SRE", from E. R. Meise to W. S. DeBear, dated June 26, 1959.
3. TDR 4644, "Pressure-Drop Measurements Across a 4-Rod Fuel Element to be Tested in SRE", by R. J. Begley dated November 5, 1959.
4. TDR 3298, "Pressure Drop-Flow Tests of Two Types of SRE Fuel Elements", By J. A. Hagel, dated November 26, 1958.
5. Original data for this report are recorded on pages 34 to 42 in Laboratory Notebook A-082001.

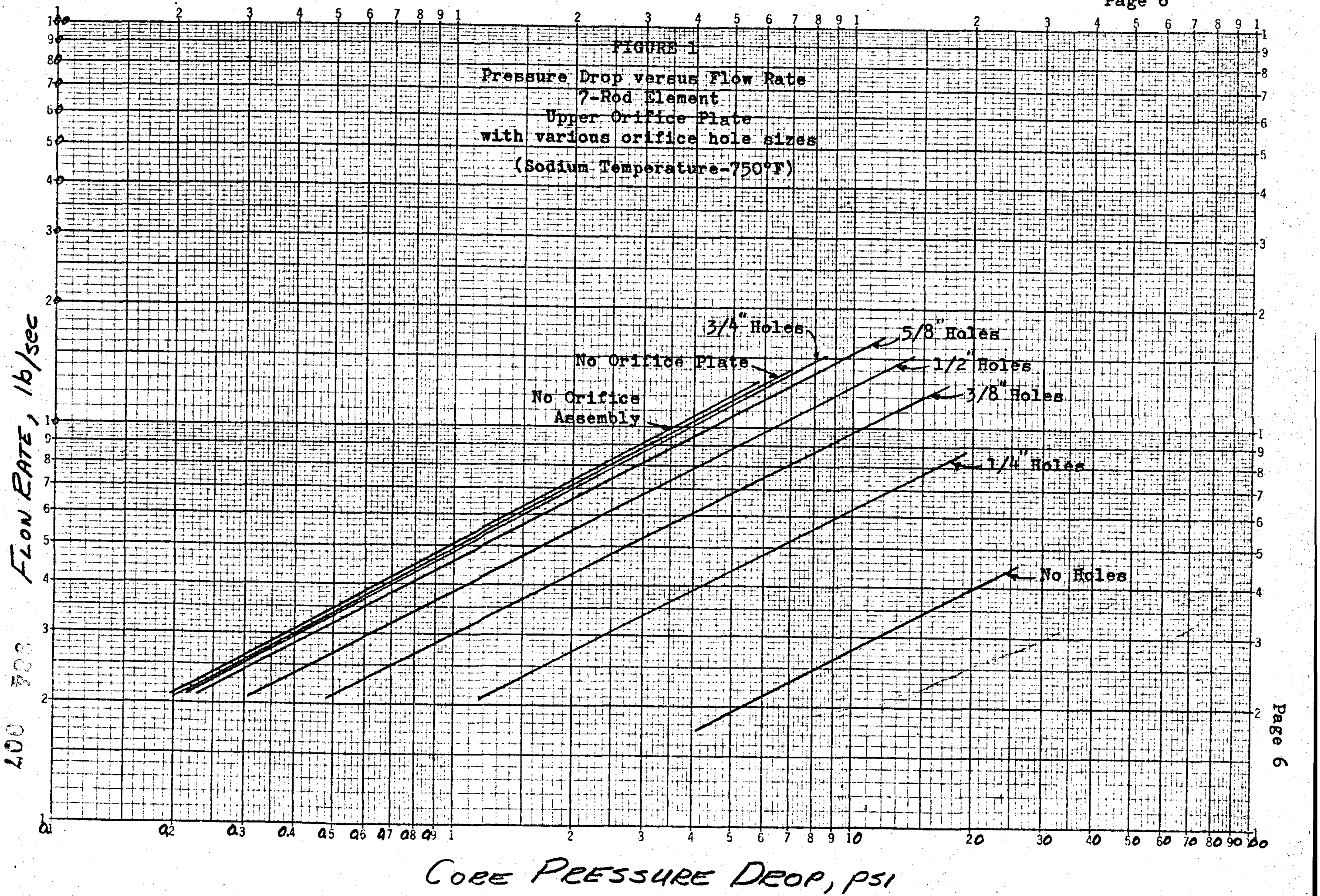


FIGURE 1
Pressure Drop versus Flow Rate
7-Rod Element
Upper Orifice Plate
with various orifice hole sizes
(Sodium Temperature-750°F)

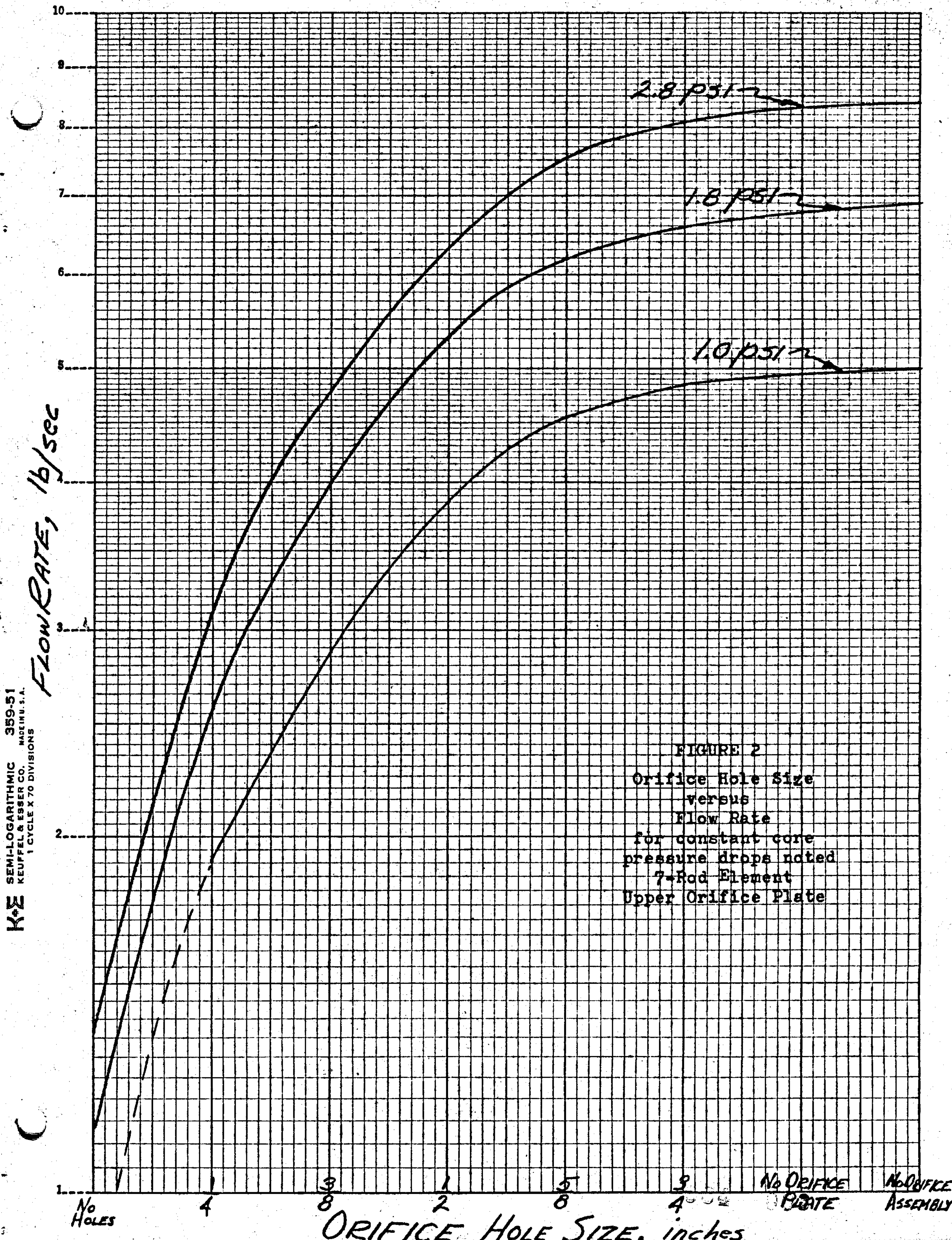
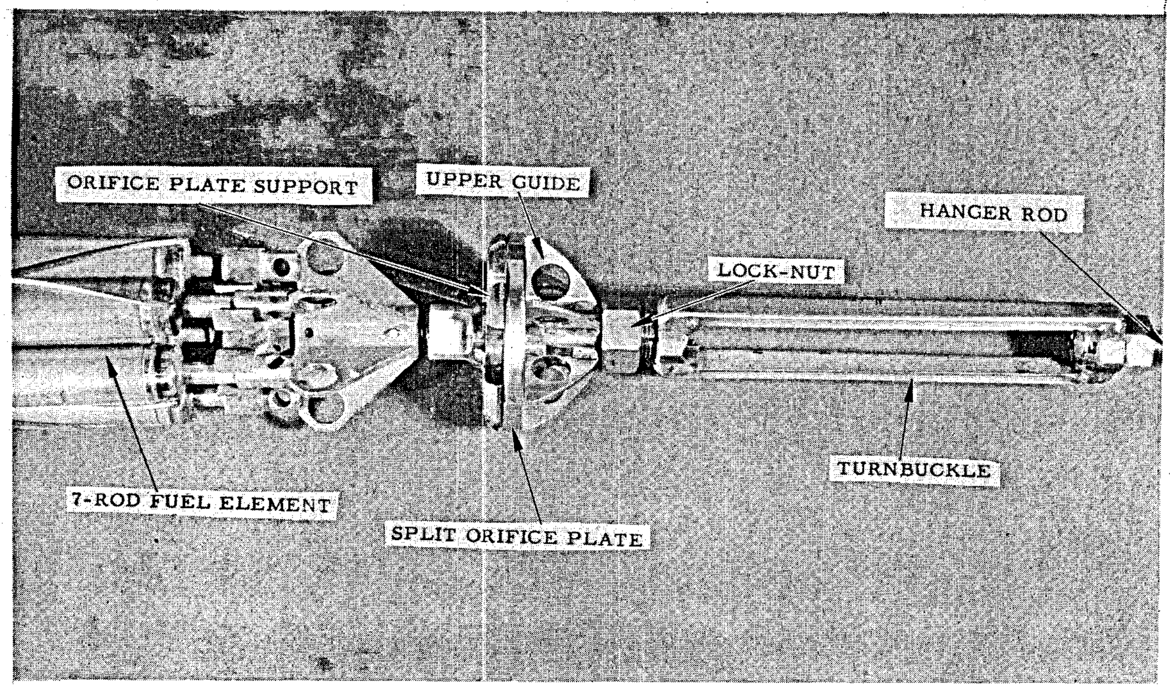
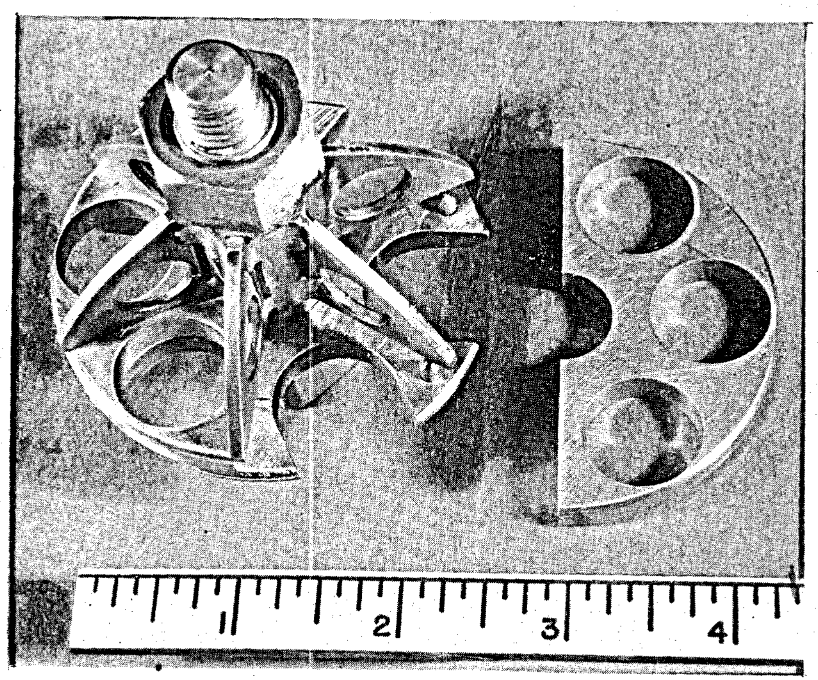


FIGURE 2
Orifice Hole Size
versus
Flow Rate
for constant core
pressure drops noted
7-Rod Element
Upper Orifice Plate
2.8 psi
1.8 psi
1.0 psi
FLOW RATE, lb/sec
ORIFICE HOLE SIZE, inches
No Holes
1/4
3/8
1/2
5/8
3/4
No Orifice Plate
No Orifice Assembly
10
9
8
7
6
5
3
2
1
K&E SEMI-LOGARITHMIC 359-51
KEUFFEL & ESSER CO. MADE IN U.S.A.
1 CYCLE X 70 DIVISIONS



3a



3b

Figure 3. Photographs of Orifice Assembly

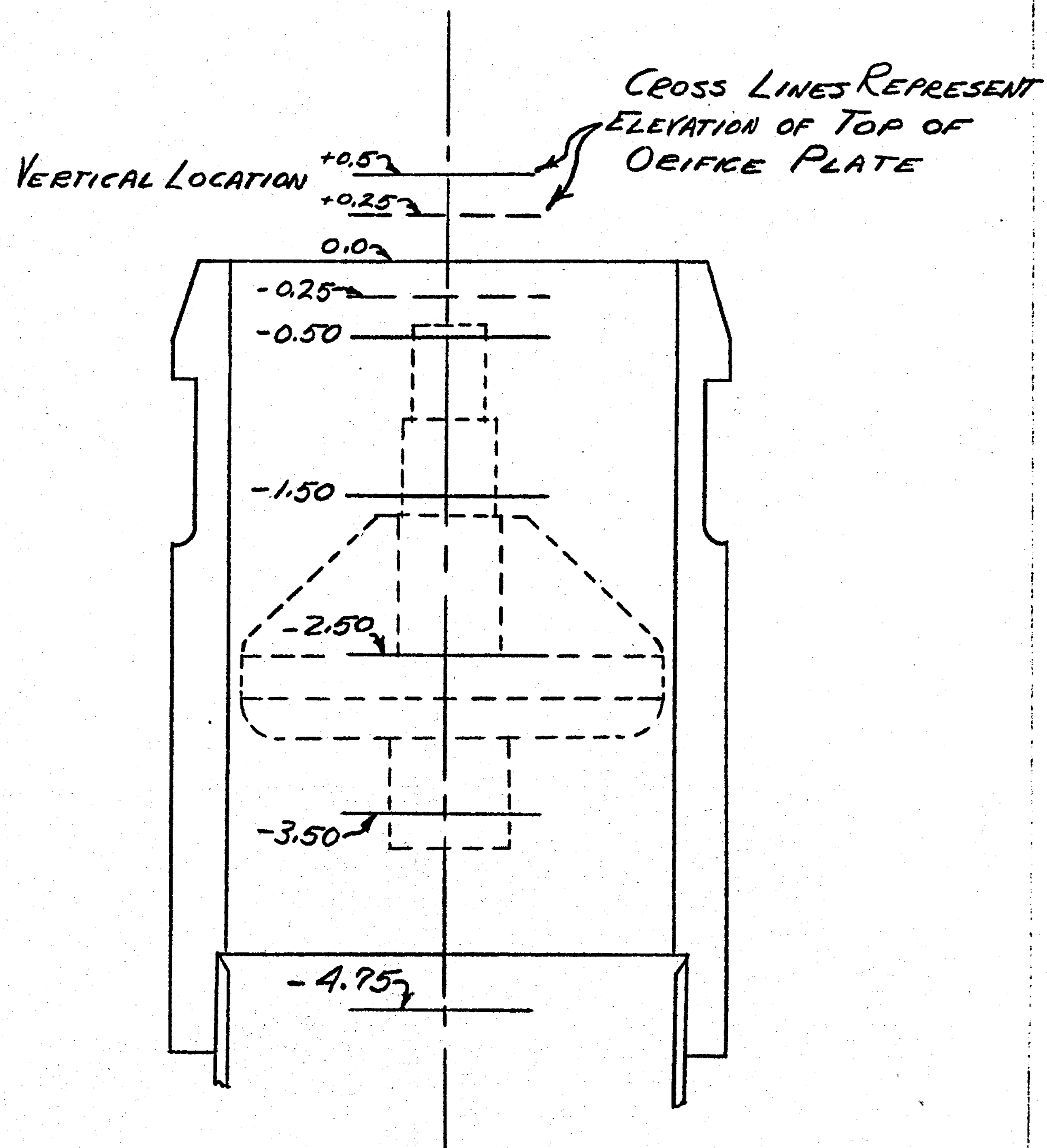


FIGURE 4 CROSS SECTION OF MODERATOR SPACER RING WITH ORIFICE ASSEMBLY LOCATED AT ELEVATION -2.5

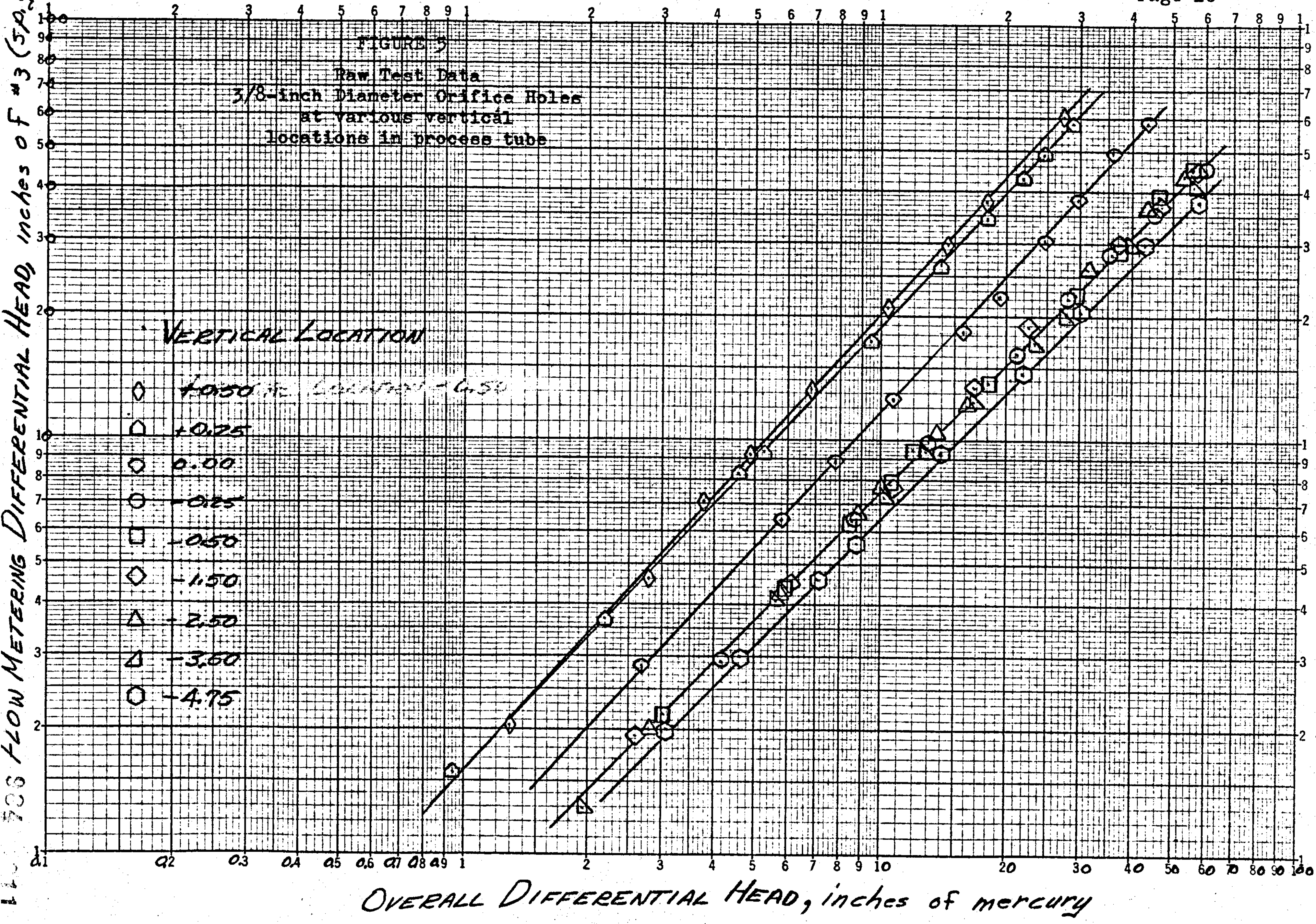


FIGURE 5
Raw Test Data
3/8-inch Diameter Orifice Holes
at various vertical
locations in process tube

Page 10

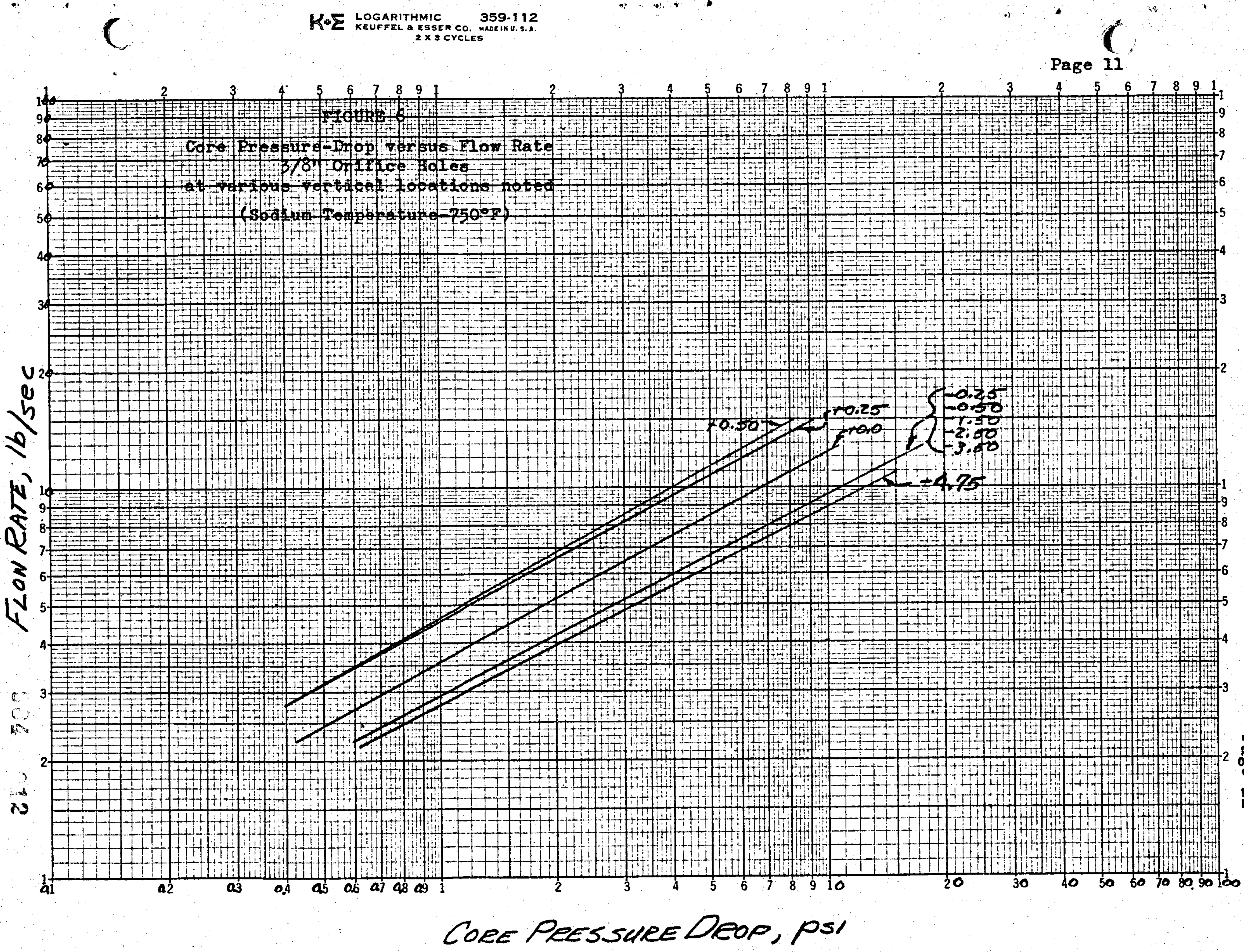
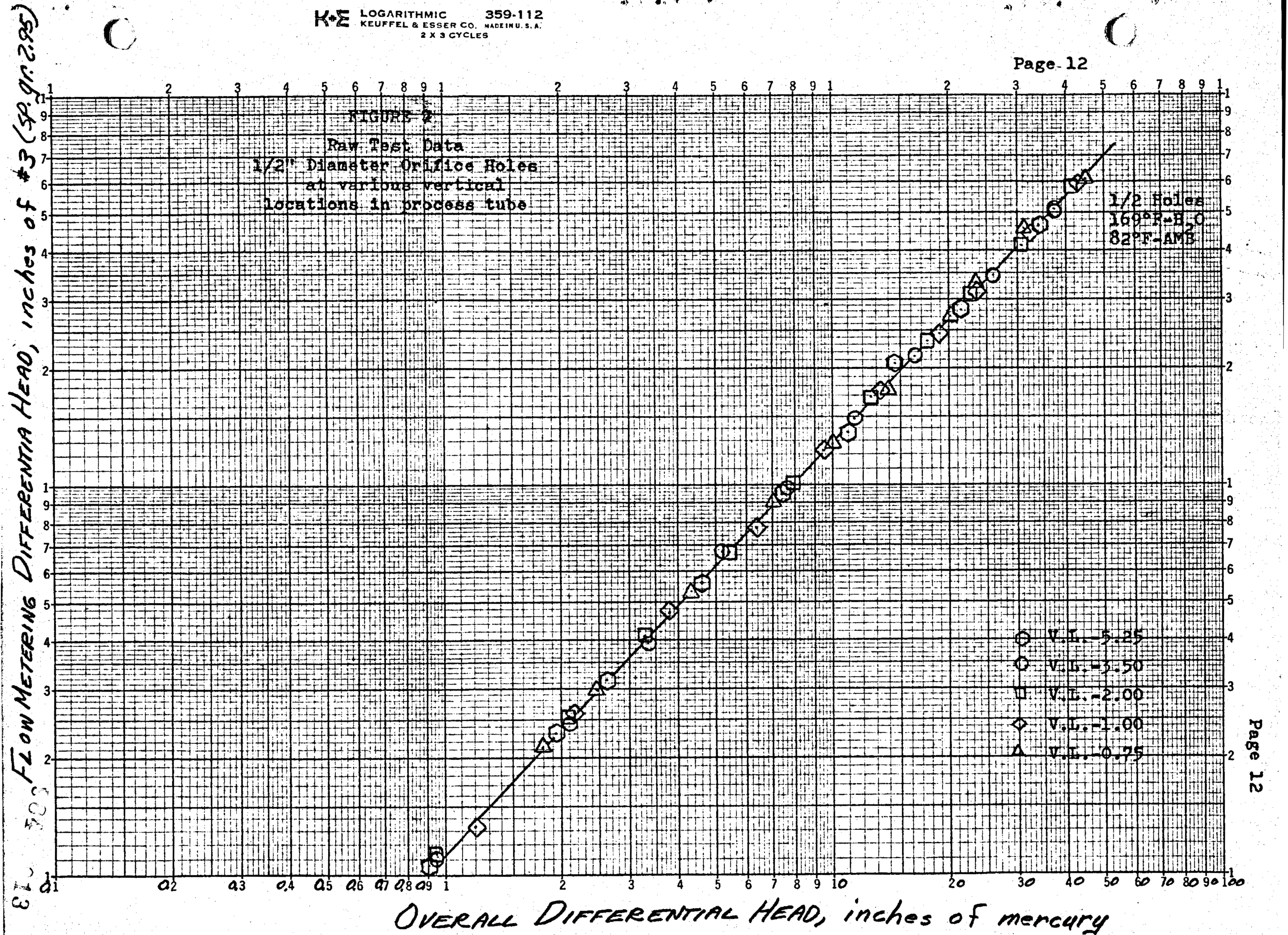


FIGURE 6
Core Pressure-Drop versus Flow Rate
3/8" Orifice Holes
at various vertical locations noted
(Sodium Temperature-750°F)


K+E LOGARITHMIC 359-112
KEUFFEL & ESSER CO. MADE IN U.S.A.
2 X 3 CYCLES
FIGURE 2
Raw Test Data
1/2" Diameter Orifice Holes
at various vertical
locations in process tube
1/2 Holes
169°F-H2O
82°F-AMB
V.L.-5.25
V.L.-3.50
V.L.-2.00
V.L.-1.00
V.L.-0.75
FLOW METERING DIFFERENTIA HEAD, inches of #3 (sp. gr. 2.95)
OVERALL DIFFERENTIAL HEAD, inches of mercury
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