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INTERIM REPORT

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LOFT TECHNICAL REPORT LTR-141-103

May 18, 1979

NRC P 394

RESULTS OF TESTS TO EVALUATE THE USE OF AN IN-CORE LIQUID LEVEL TRANSDUCER (LLT) TO MEASURE VOID FRACTION

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IDAHO OPERATIONS OFFICE UNDER CONTRACT DE-AC07-76ID01570

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LOFT TECHNICAL REPORT
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Results of Tests to Evaluate the Use of an In-core Liquid Level Transducer (LLT) to Measure Void Fraction	LTR-141-103

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Reed Hoskinson and Hugh Helbert	
PERFORMING ORGANIZATION	DATE
LOFT Test Support Branch	May 18, 1979
LOFT APPROVAL: Charles W. Solbrig / [signature]	

RSR ESB Mgr. LEPD Mgr.

This paper reports the results of tests conducted at the LOFT Test Support Facility (LTSF) using an in-core liquid level transducer (LLT) to measure void fraction. Results of the tests show that the LLT does respond to a change in void fraction. The output voltage increased about 0.1 volt when the void fraction increased from 5% to 25%. Variance of the voltage output from each sensor also increased with increasing void fraction.

DISPOSITION OF RECOMMENDATIONS

No disposition required.

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ABSTRACT

This paper reports the results of tests conducted at the LOFT Test Support Facility (LTSF) using a Liquid Level Transducer (LLT) to measure void fraction. The LLT used was an in-core transducer S/N 445.

The purpose of these tests was to evaluate the LLT as a void fraction measuring instrument.

Tests were conducted at atmospheric pressure and room temperature by partially filling a test column with demineralized water and bubbling oxygen from the bottom. The liquid level was measured with a metric rule on the side of the test column before any gas injection.

Results of the void fraction tests show that the LLT does respond to a change in void fraction. The output voltage increased about 0.1 volt when the void fraction increased from 5% to 25%. Variance of the voltage output from each sensor also increased with increasing void fraction.

Although these tests show that the LLT senses gas bubbles in a liquid, the void fraction levels at which the tests were conducted were not high enough to evaluate all void fraction levels encountered by an LLT in LOFT, and provided no data on water droplets in a gas mixture. Further tests are recommended at higher void fractions, which will require different equipment capable of producing a high void fraction environment.

CONTENTS

FIGURES

TABLES

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I. INTRODUCTION

This paper reports the results of tests conducted at the LOFT Test Support Facility (LTSF) using a Liquid Level Transducer (LLT) to measure void fraction. The LLT is presently used in nuclear reactors to measure the level of the liquid in the location in which the transducer is installed.

The purpose of these tests was to evaluate the LLT as a void fraction measuring instrument.

II. TEST PROCEDURE

The LLT used was an in-core transducer S/N 445. The in-core transducer has 19 electrodes spaced 9.78 cm apart, housed in a support column with slotted openings. Each sensor electrode measures the electrical conductance of the media between the electrode and the ground.

Input electrical signals to the electrodes were generated using the LLT system's scanner and signal conditioner (see Operation and Maintenance Manual for Liquid Level Transducer (LLT) System, OMM 141-2, May 1975). The output signals were displayed on an oscilloscope or its digital voltmeter.

All tests were done in a 122 cm plexiglass column of 10.16 cm ID. An additional column of 6.67 cm ID plexiglass was installed on top of the test column to support and protect the upper end of the LLT. Above this support was a flat plexiglass sheet used to support the electrode cables (Figure 1). Two removable plexiglass base plates were bolted to the bottom of the test column. The bottom plate allowed for filling and draining the liquid, and injection of the gas. The second plate was used to create bubbles. One of two different bubble plates with different sized holes were used to create "large" and "small" bubbles (Figure 2).

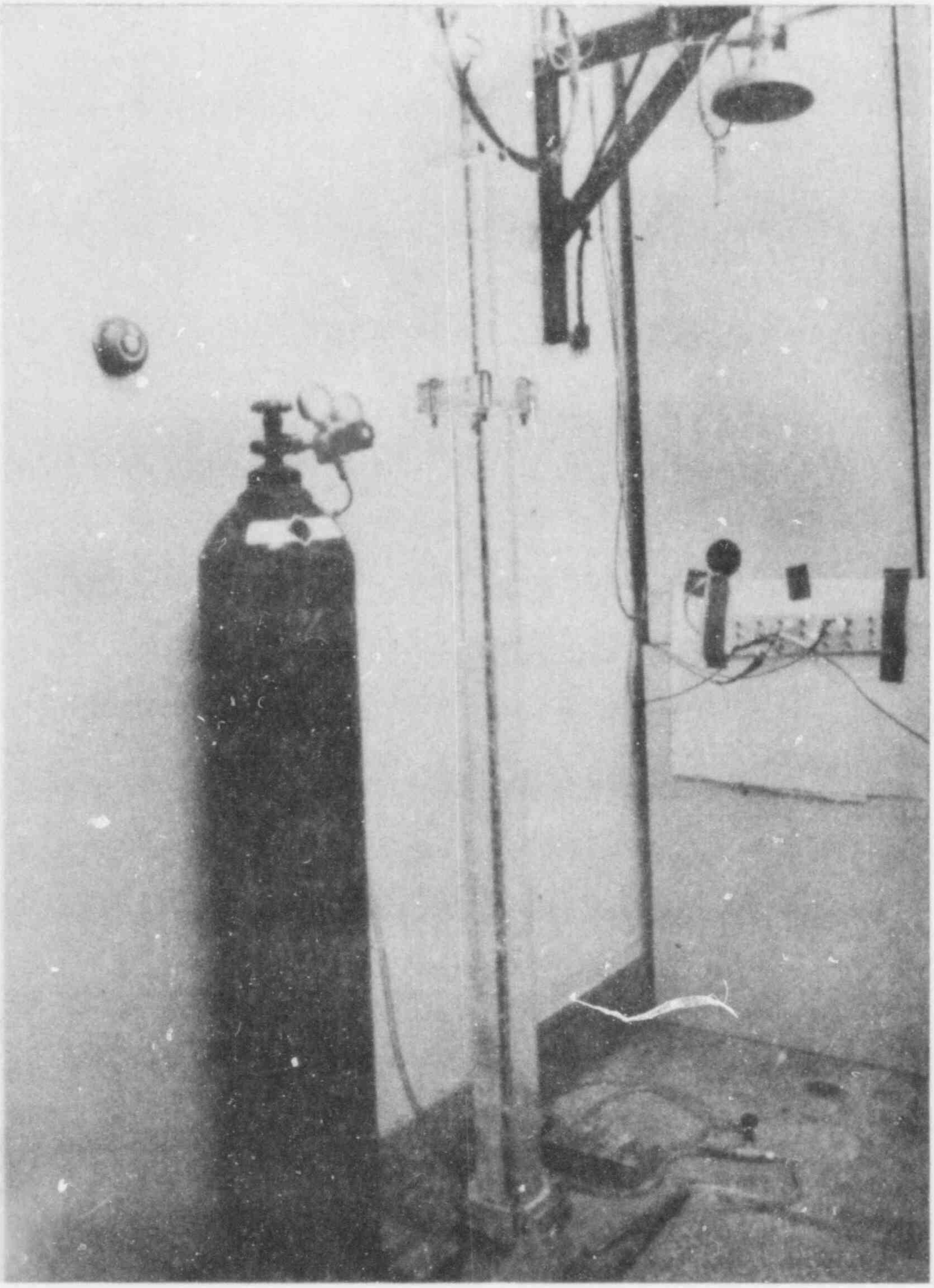

Figure 1. Void Fraction Test Equipment

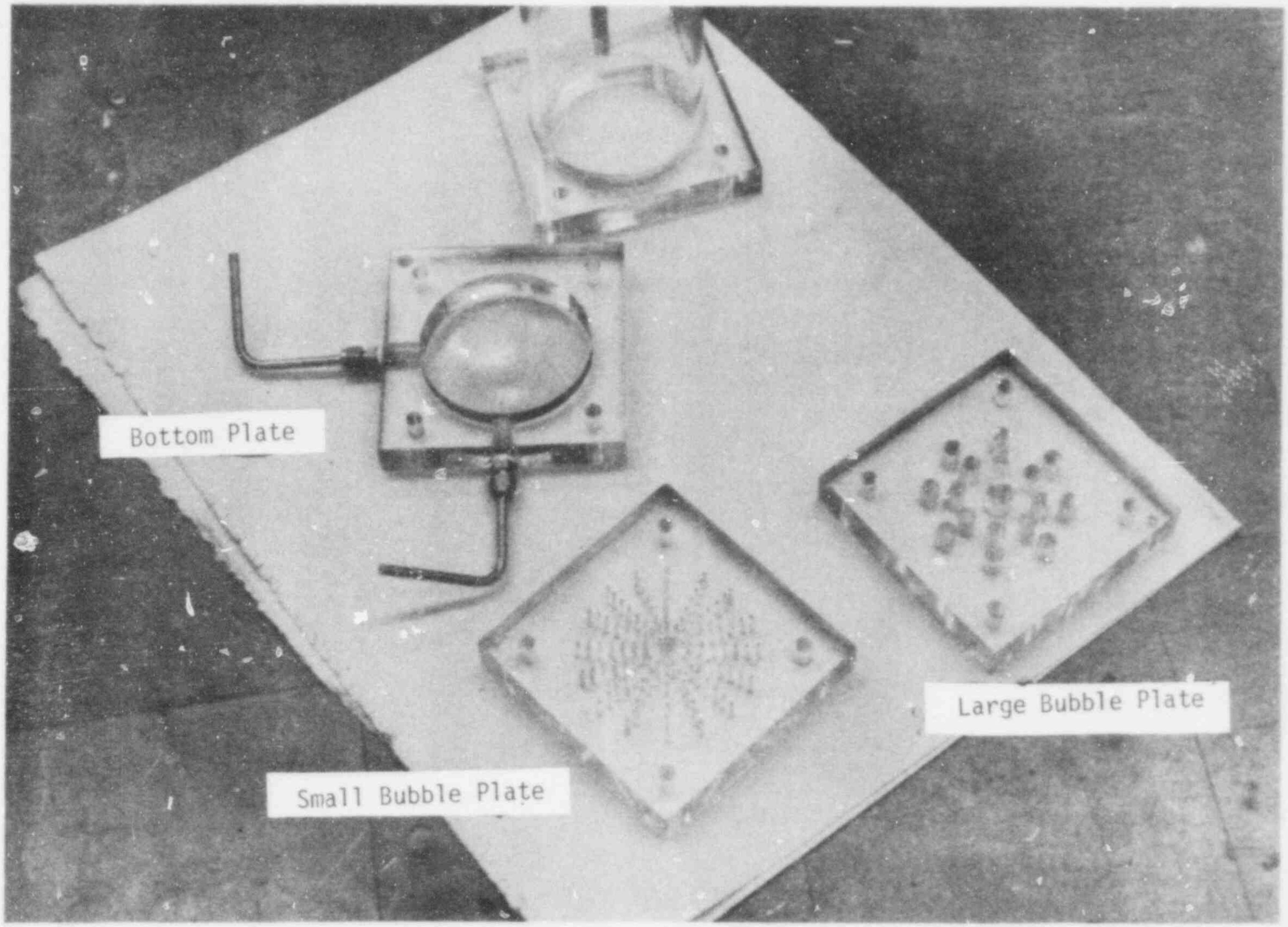

Figure 2. Bottom Plate and Bubble Plates for Void Fraction Tests.

Tests were conducted at atmospheric pressure and room temperature by partially filling the test column with demineralized water and bubbling oxygen from the bottom. The liquid level was measured with a metric rule on the side of the test column before any gas injection. For each test, the liquid level was also measured at each of five gas injection rates. Using the initial liquid level and the liquid level at each gas injection rate, the void fraction was then calculated for each rate by

$$\text{Void Fraction}_{\text{rate } i} = \frac{\text{liquid level}_{\text{rate } i} - \text{liquid level}_{\text{initial}}}{\text{liquid level}_{\text{rate } i}}$$

Because of the uncertainty of the measurement of liquid level, the best estimate of percent void fraction includes a systematic error estimated not to exceed ± 2% void fraction.

Output voltage data was collected from sensors 19, 18, 12 and 11. Sensors 19 and 18 were the bottom two electrodes on the LLT and sensors 12 and 11 were near the middle of that part of the LLT submerged.

An individual test consisted of 25 voltage measurements at each of five void fractions for a given sensor, using one bubble size. Each test was repeated. The following 16 void fraction tests were run:

1. sensor 19 - small bubble - series 1
2. sensor 19 - small bubble - series 2
3. sensor 18 - small bubble - series 1
4. sensor 18 - small bubble - series 2
5. sensor 12 - small bubble - series 1
6. sensor 12 - small bubble - series 2
7. sensor 11 - small bubble - series 1
8. sensor 11 - small bubble - series 2
9. sensor 19 - large bubble - series 1
10. sensor 19 - large bubble - series 2
11. sensor 18 - large bubble - series 1

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12. sensor 18 - large bubble - series 2
13. sensor 12 - large bubble - series 1
14. sensor 12 - large bubble - series 2
15. sensor 11 - large bubble - series 1
16. sensor 11 - large bubble - series 2

Two other tests were run. The first was a measurement of the change in output voltage of sensor 12 after the oxygen was turned off (Figure 3). Since the conductivity of the demineralized water increased with oxygen bubbled through it and decreased after the oxygen was turned off, void fraction measurements were taken only after the water had been bubbled for several minutes. Then all small bubble tests were run without turning the oxygen off. The same procedure was followed for the large bubble tests.

The second additional test measured the change in output voltage as the level of the liquid varied along the length of each sensor (Figure 4).

III. EXPERIMENTAL RESULTS

Plots of the 25 voltages collected at each of 5 void fractions for each test are given in Figures 5 through 20. Figures 21 through 36 are plots of the average voltage output at each void fraction for each test, and includes the first order regression line. Analysis suggests the physical relation may be more complex than represented by this line, but it is included as a comparable quantity between tests.

Table 1 lists the linear coefficients and R^2 values for each test, both for all data points and average values.

IV. DISCUSSION AND CONCLUSIONS

Results of the void fraction tests show that the LLT does respond to a change in void fraction. The output voltage increased about 0.1 volt when the void fraction increased from 5% to 25%. Variance of the voltage output from each sensor also increased with increasing void fraction.

Comparison of the series 1 and 2 tests for each sensor with the same bubble size showed good repeatability.

A trend noticed in almost every test was a slight decrease in voltage between 5% void fraction and 10% to 15% void fraction, then an increase in voltage with further increase in void fraction. Thus, the relation appears nonlinear.

Combination of these results suggests a generalized form for the voltage-void fraction relation, as denoted by the shaded area in Figure 37.

Linear regressions using the average output for each void fraction produced better fits than use of all data. This suggests that better void fraction determination might be possible using analog data. Analysis incorporating the phenomenon of increasing variation in output voltage with increasing void fraction would probably improve the measurement also.

Different bubble size did not affect the goodness of linear fit appreciably, but did seem to affect the coefficients of the relation. The poorest fit using average data was on sensor 19 using large bubbles. This was probably because sensor 19 was at the bottom of the test column. Observation of the gas-liquid mixture during that test suggested the sensor was not affected by all bubbles because the area of total mixing was located higher in the test column.

Effects of bubble size and sensor location might be better studies by improving the bubble generating system and by redesigning the LLT so that the sensors protrude outside the protective shroud into the gas-liquid mixture. This test suggests that a void fraction measuring instrument can be constructed, but much more detailed tests at higher void fractions and using LOFT chemistry water must be done. More

FIGURE 3. CHANGE IN OUTPUT AFTER OXYGEN TURNED OFF - SENSOR 12

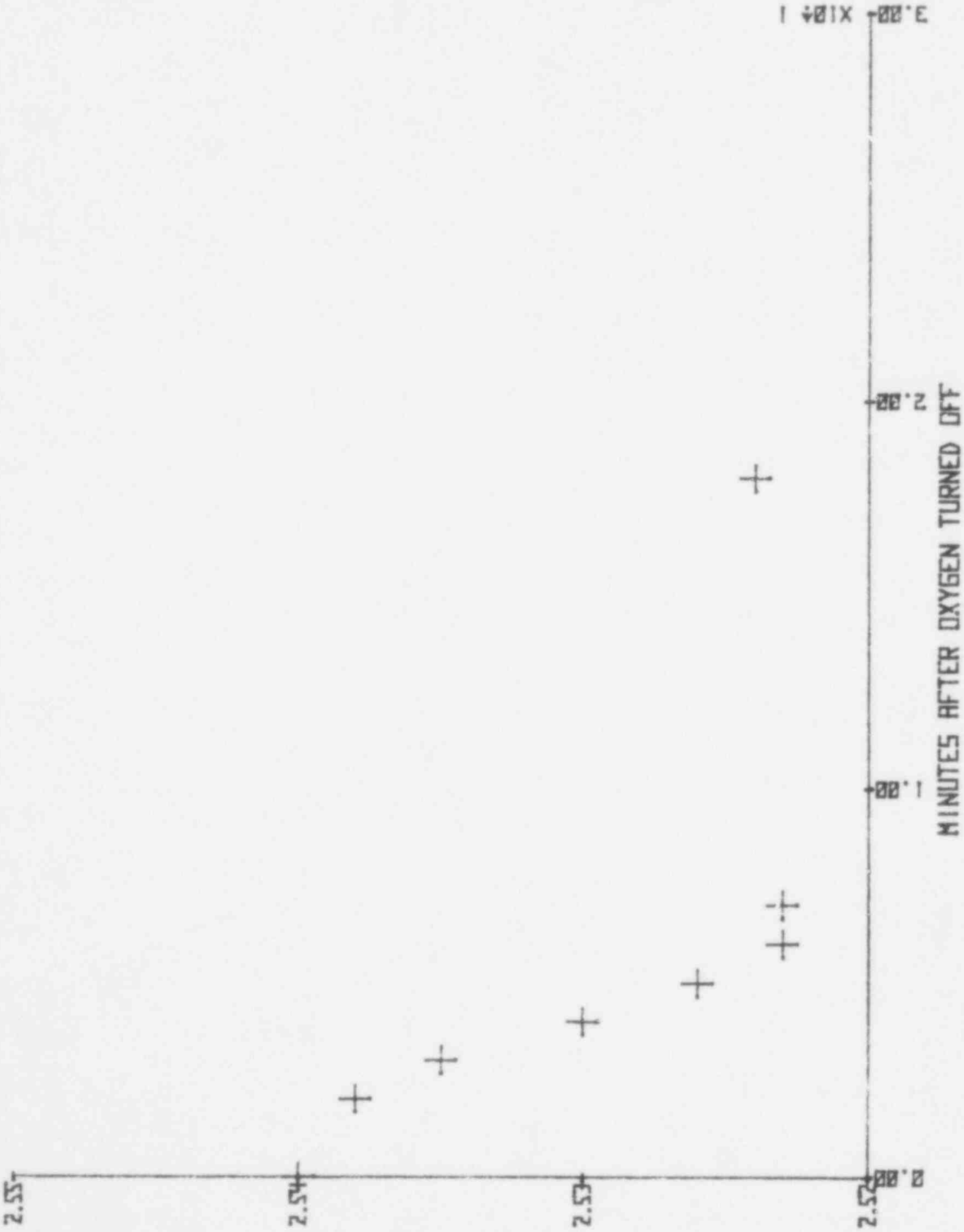

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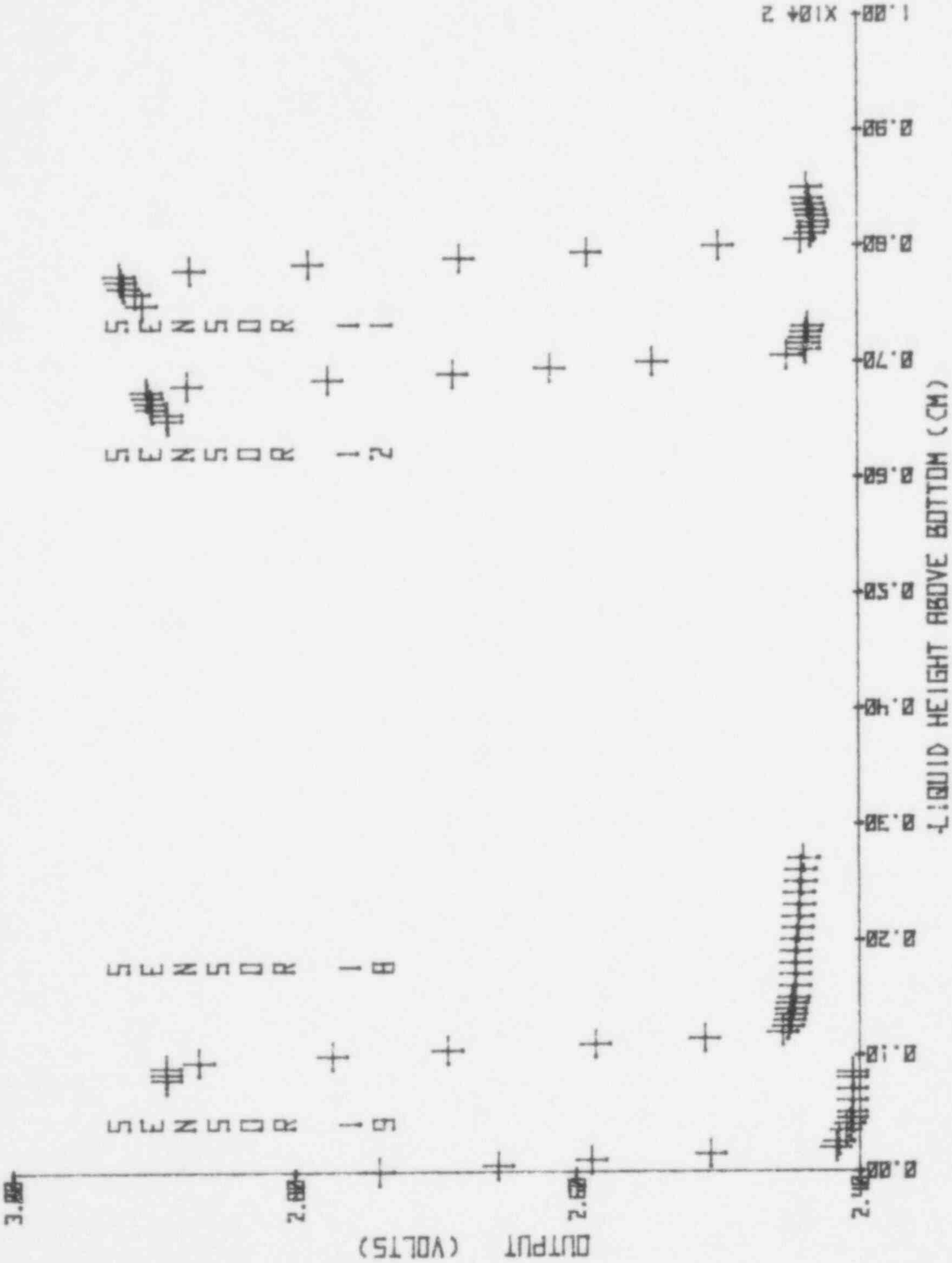
FIGURE 4. SENSOR OUTPUTS VERSUS LIQUID LEVEL - BOTTOM DRAINING



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sensitive electronics, new test equipment, and an LLT with sensors unprotected by a support column are suggested as the most important first changes.

FIGURE 5. SENSOR 19 - SMALL BUBBLE - SERIES 1

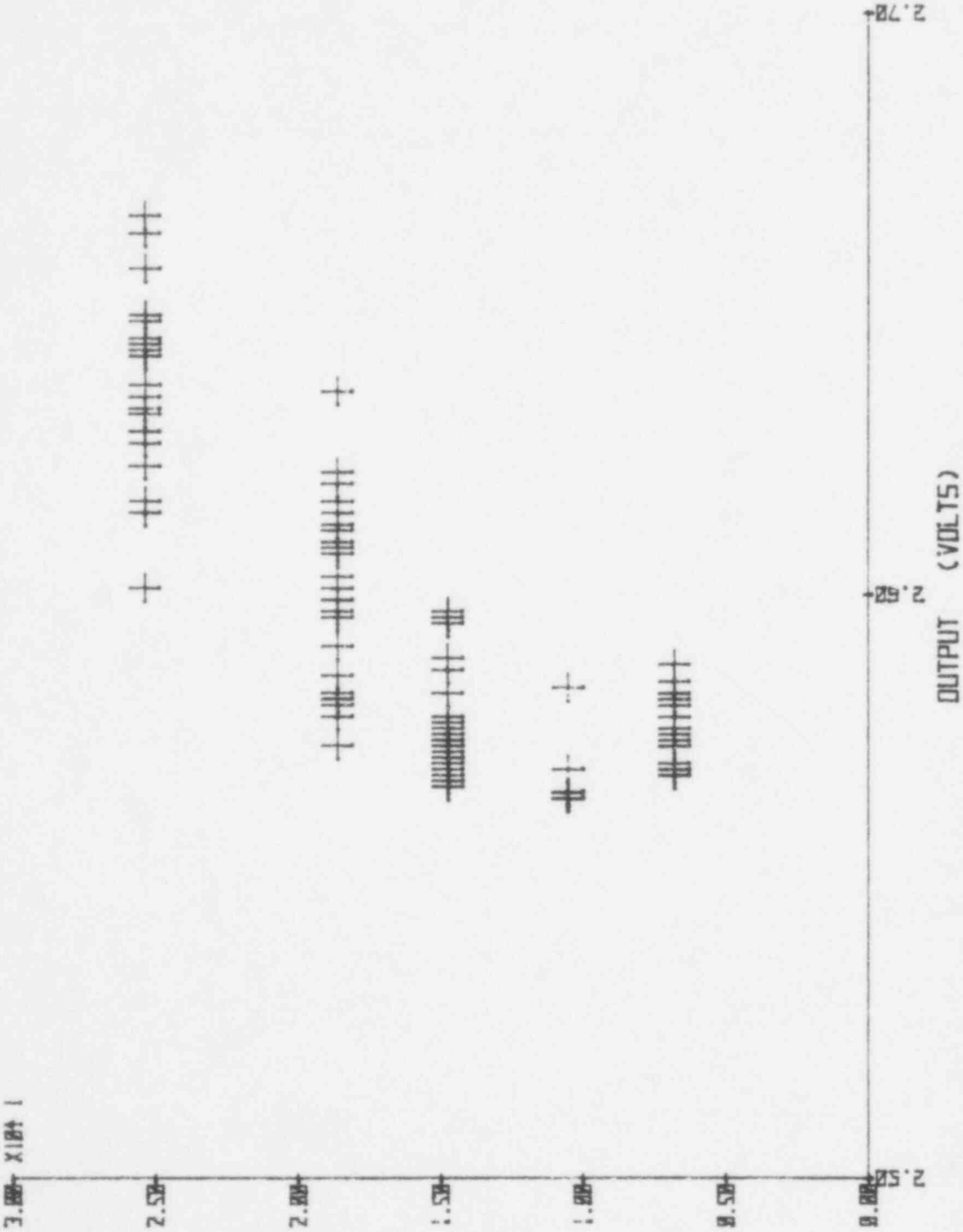
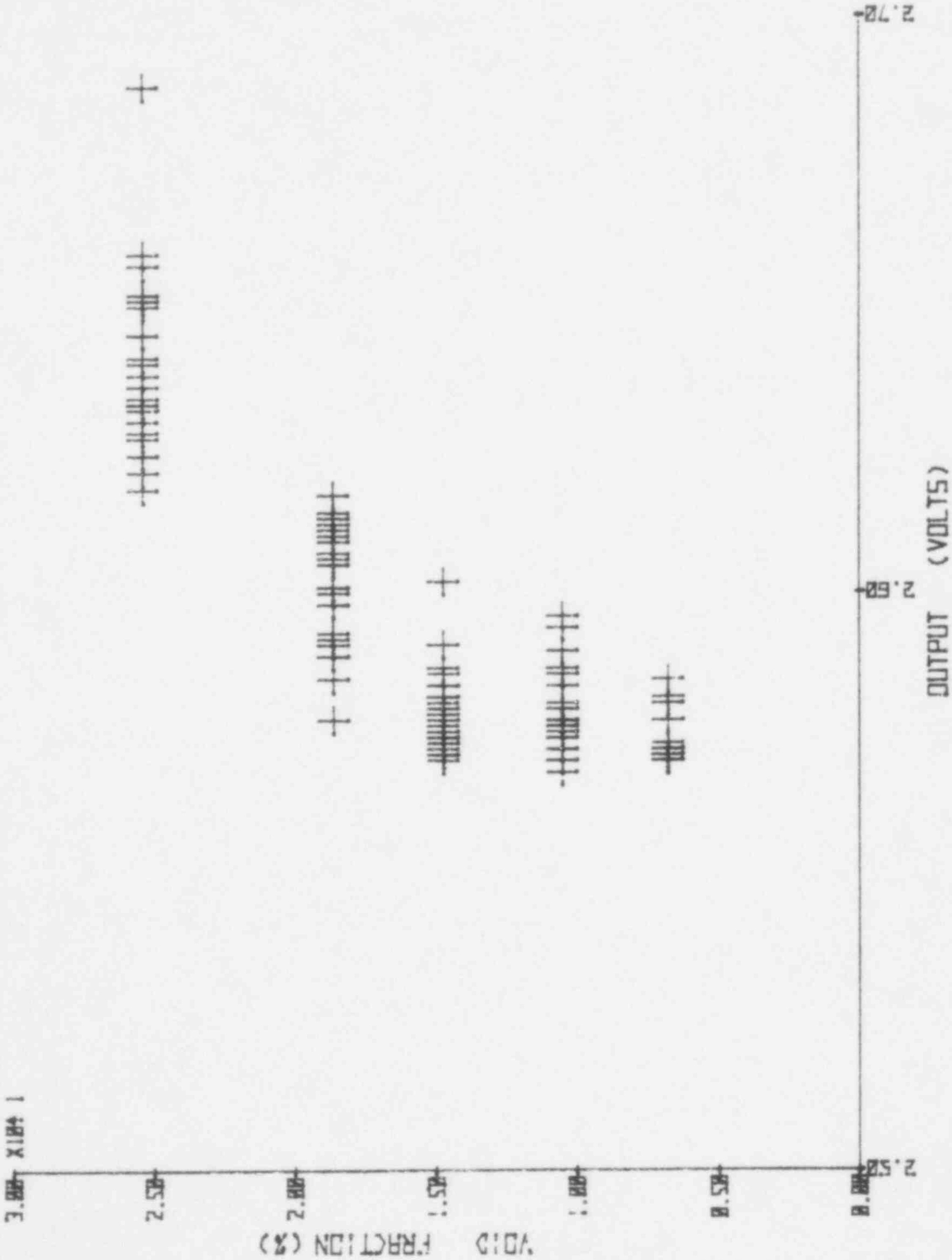


FIGURE 6. SENSOR 19 - SMALL BUBBLE - SERIES 2



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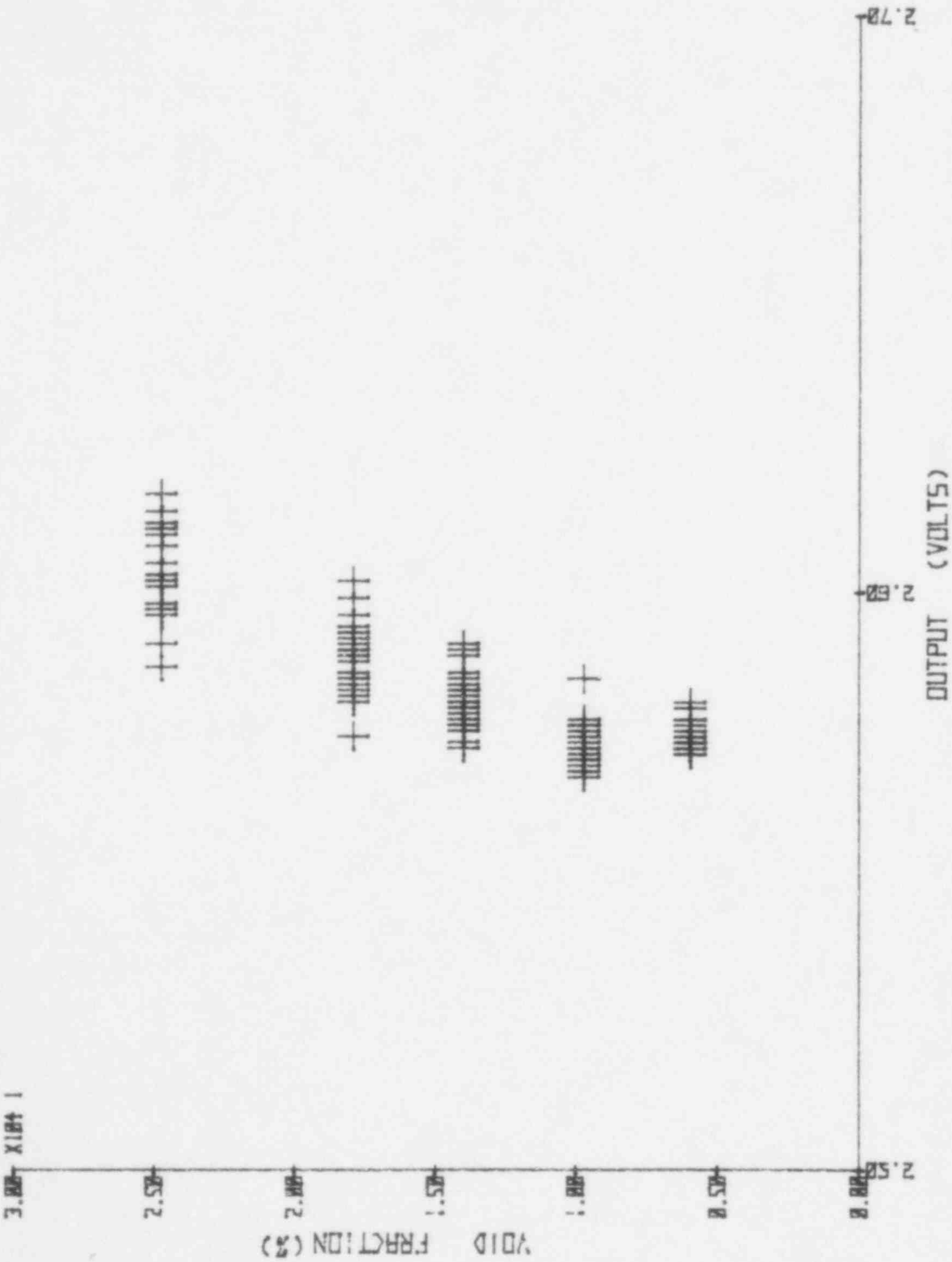

FIGURE 7. SENSOR 1B - SMALL BUBBLE - SERIES 1

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FIGURE 8. SENSOR 18 - SMALL BUBBLE - SERIES 2

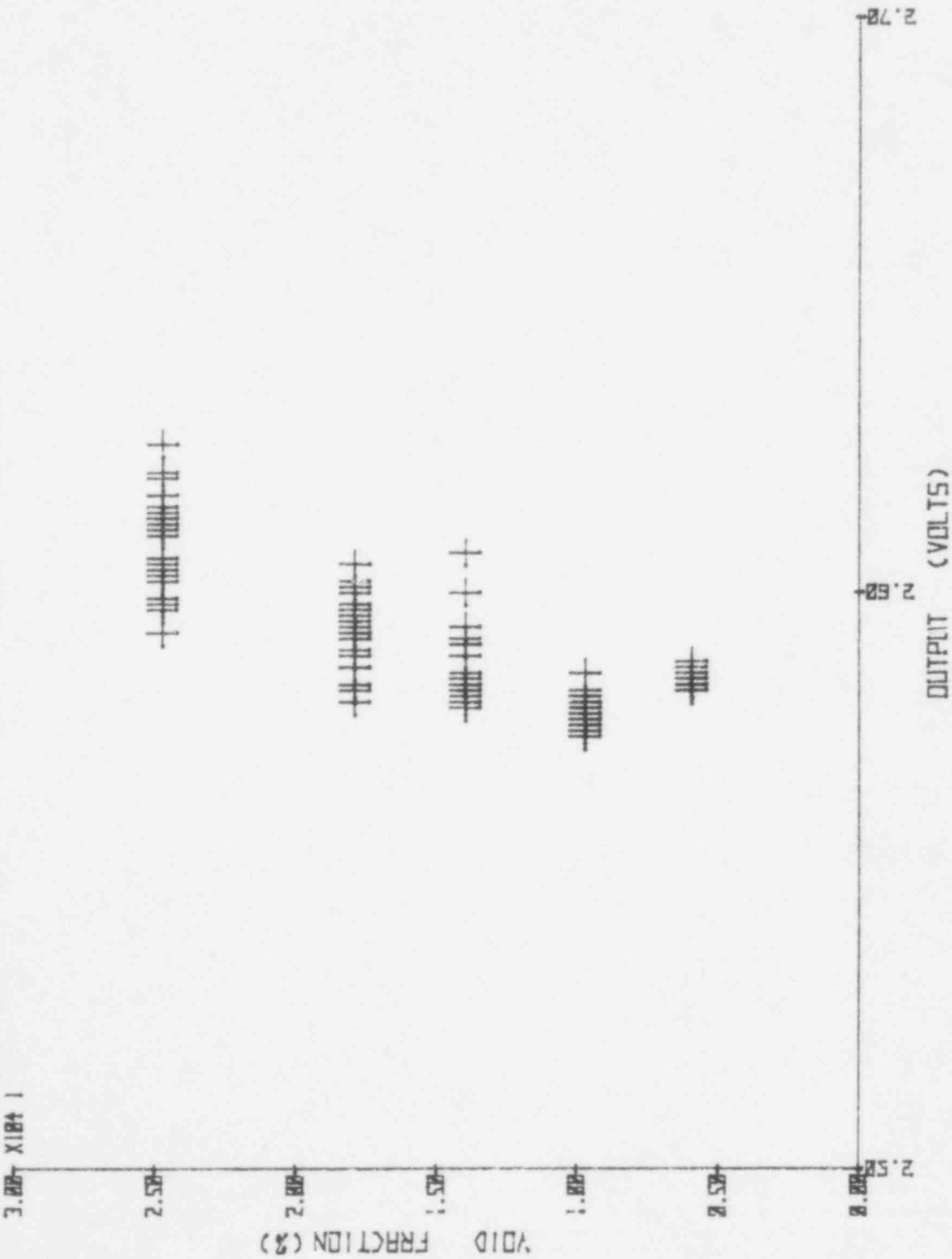

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FIGURE 9. SENSOR 12 - SMALL BUBBLE - SERIES 1

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FIGURE 10. SENSOR 12 - SMALL BUBBLE - SERIES 2

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FIGURE 11. SENSOR 11 - SMALL BUBBLE - SERIES 1

555268

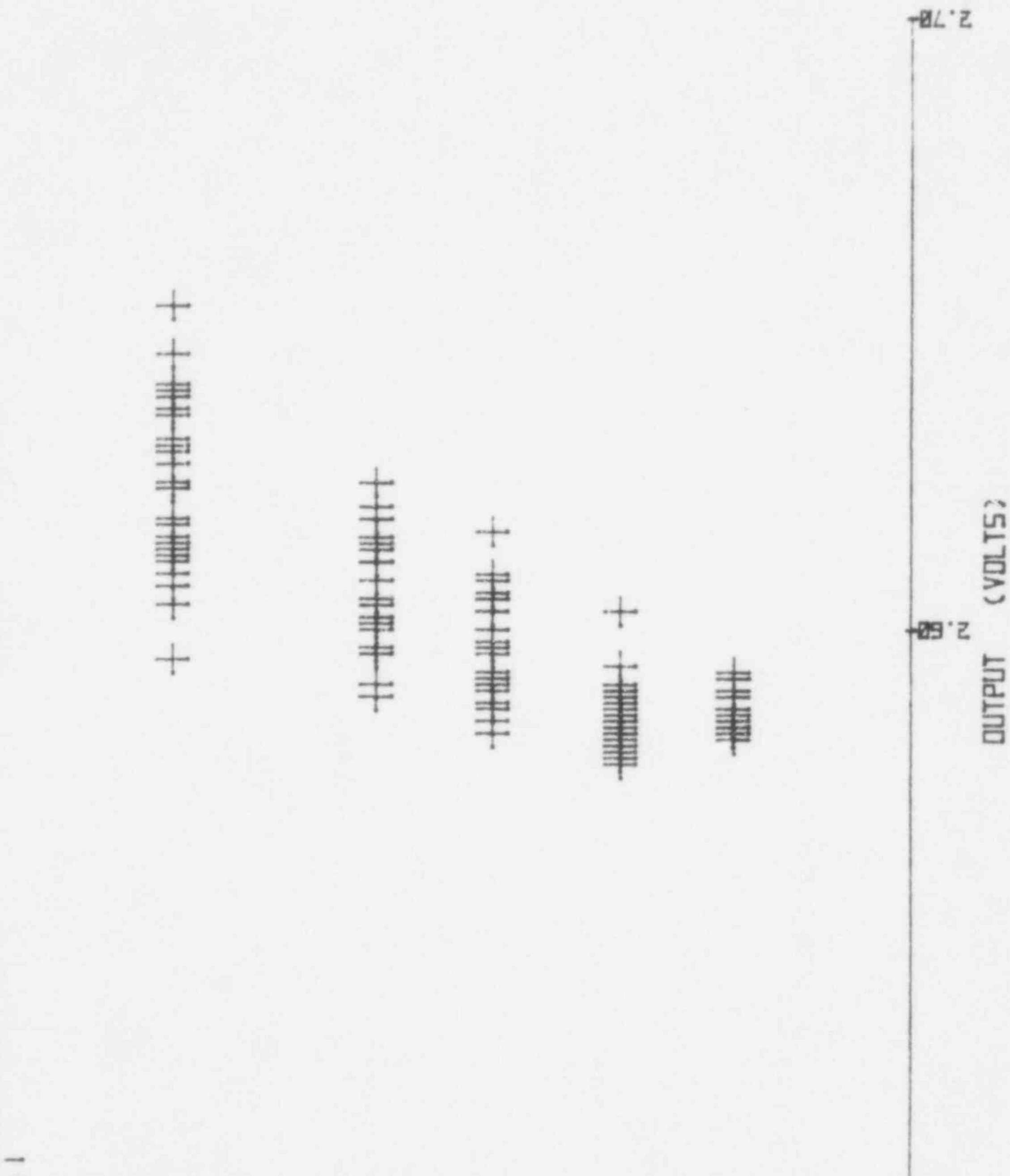

FIGURE 12. SENSOR 11 - SMALL BUBBLE - SERIES 2

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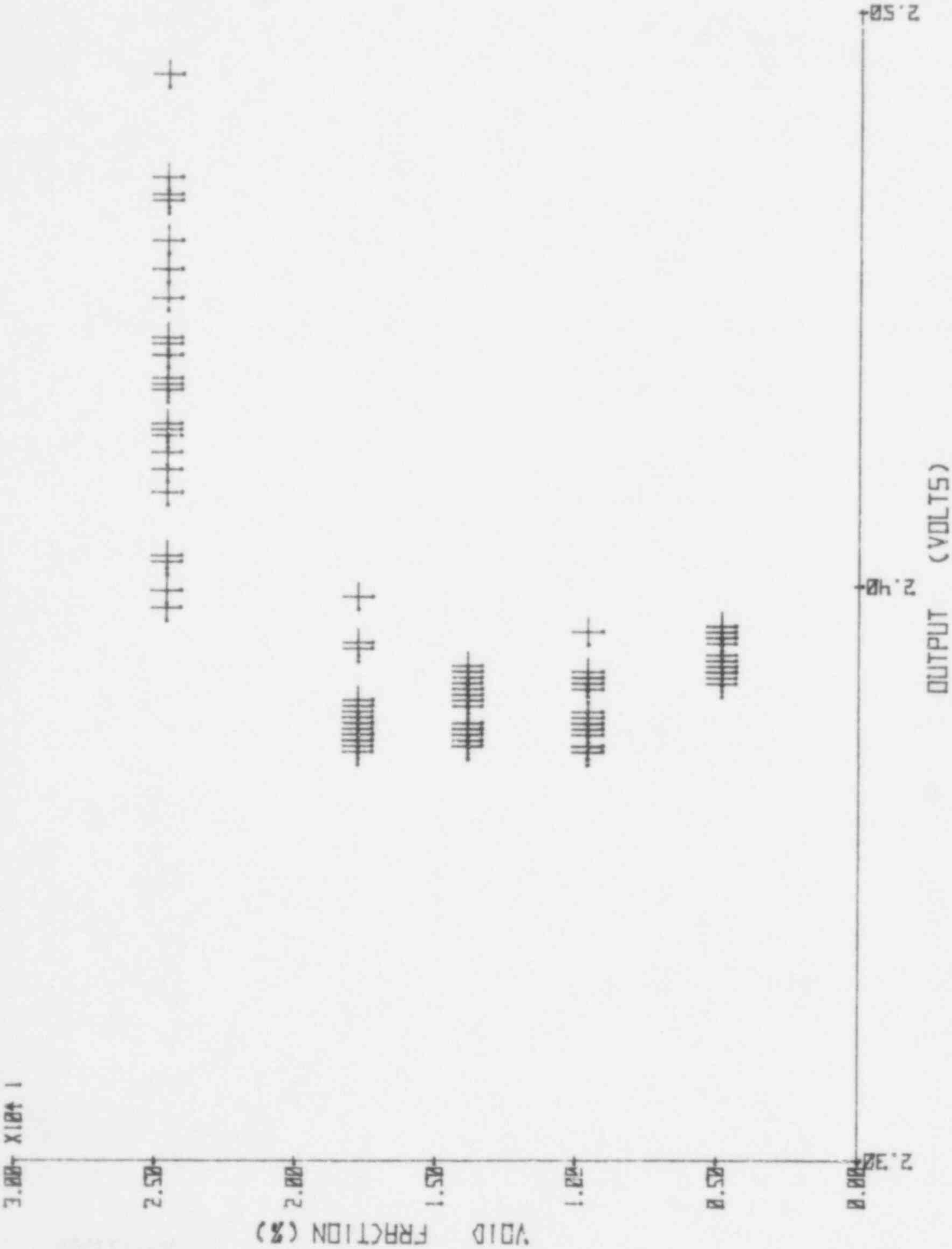

FIGURE 13. SENSOR 19 - LARGE BUBBLE - SERIES 1

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FIGURE 14. SENSOR 19 - LARGE BUBBLE - SERIES 2

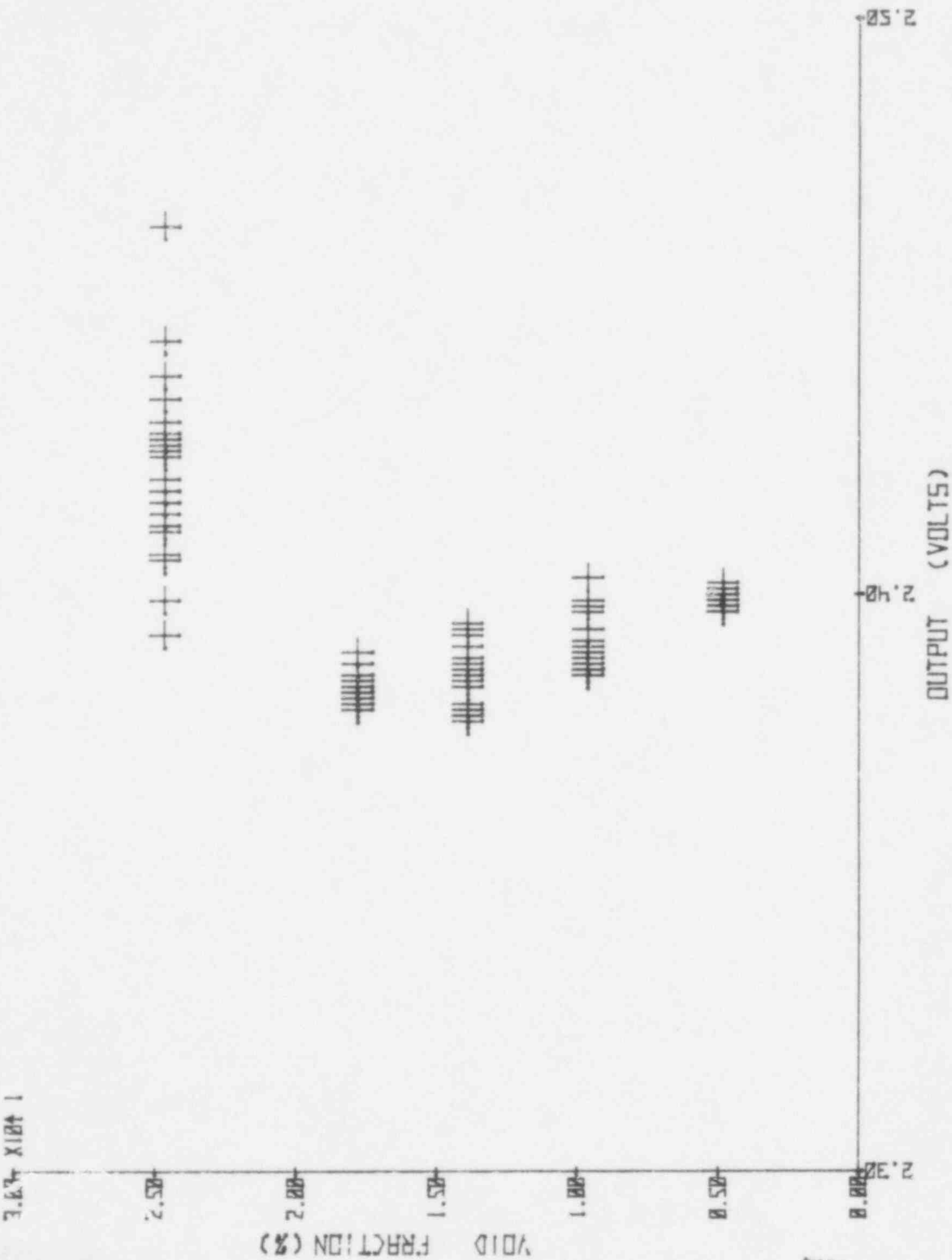

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FIGURE 15. SENSOR 1B - LARGE BUBBLE - SERIES 1

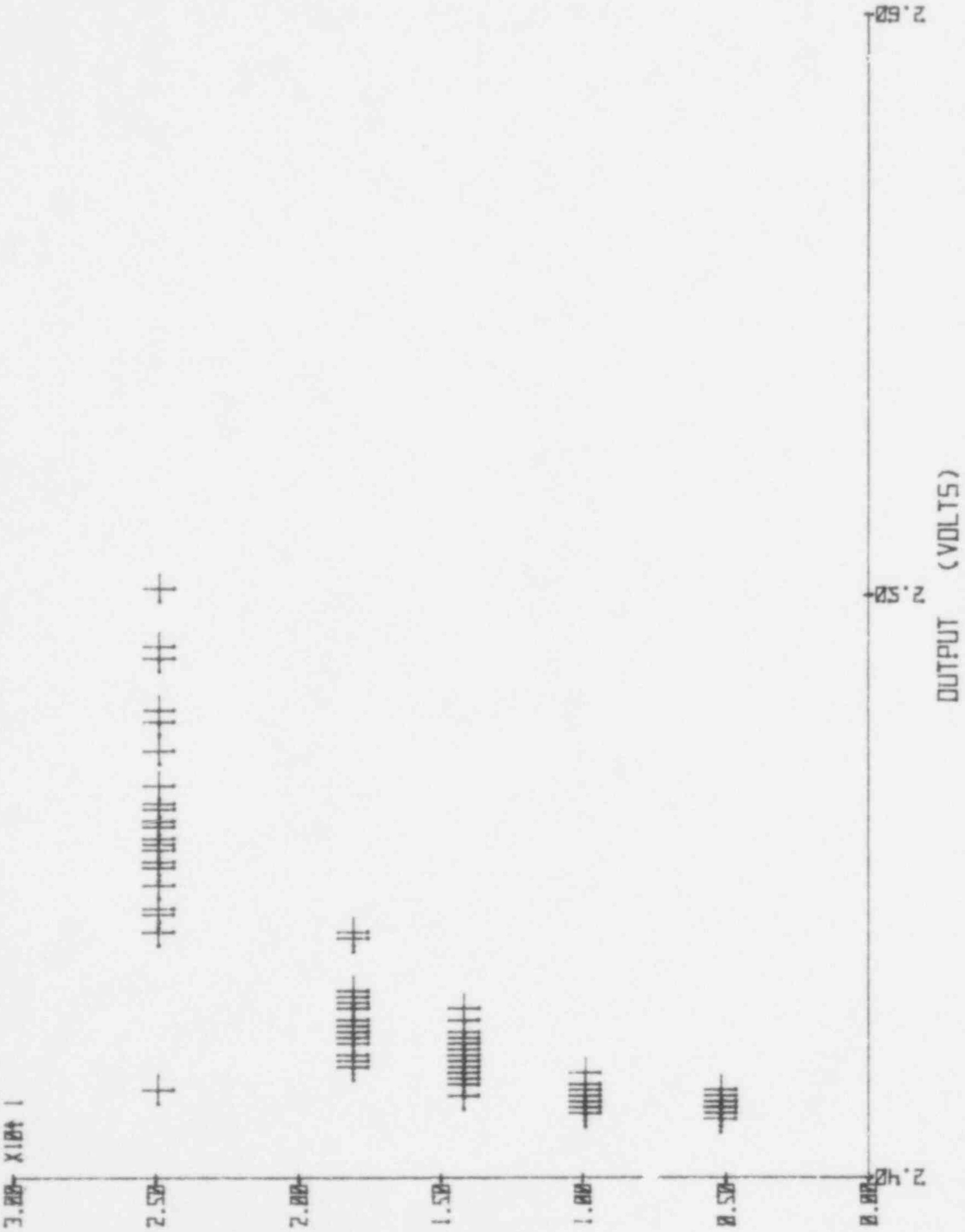

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FIGURE 16. SENSOR 18 - LARGE BUBBLE - SERIES 2

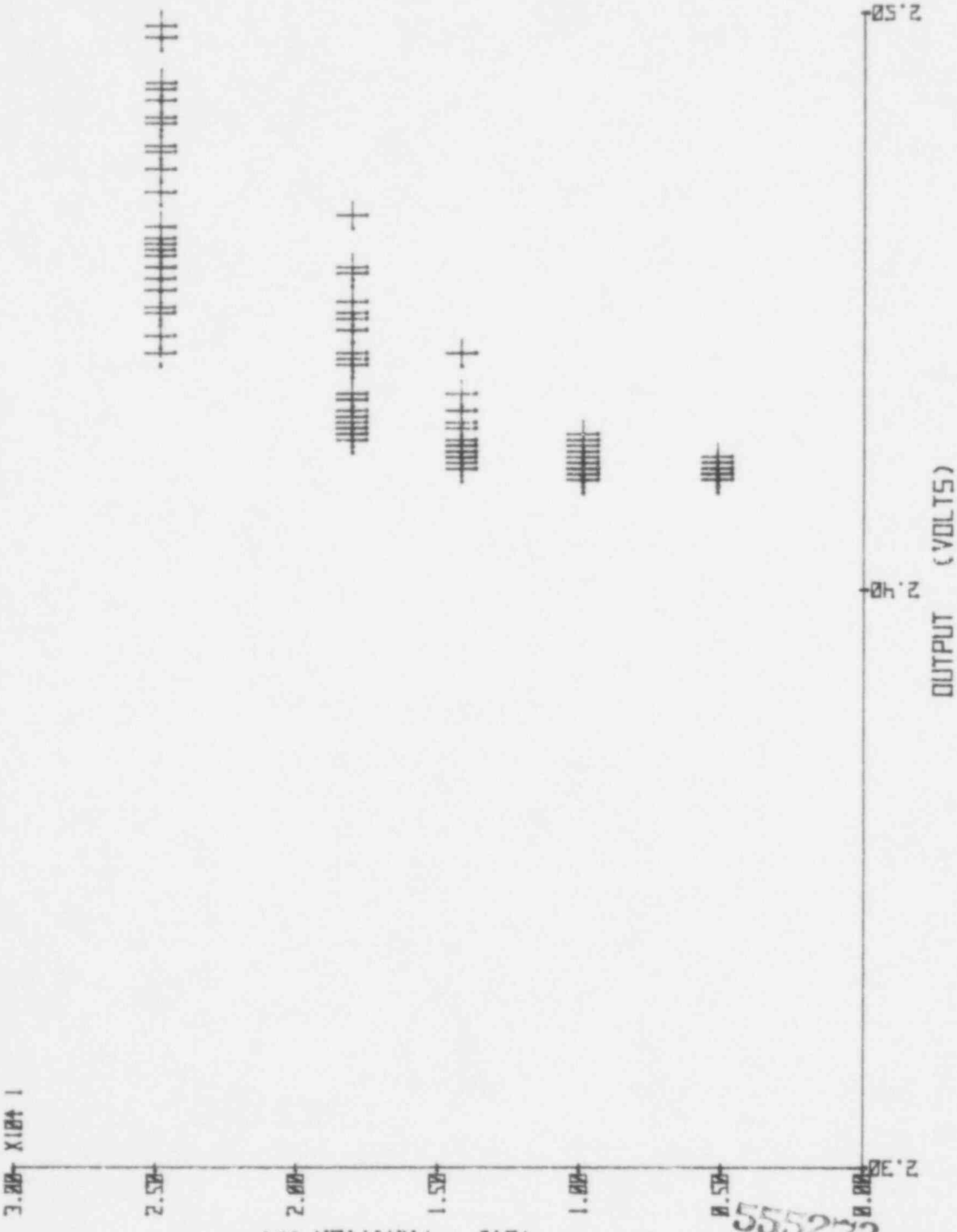

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FIGURE 17. SENSOR 12 - LARGE BUBBLE - SERIES 1

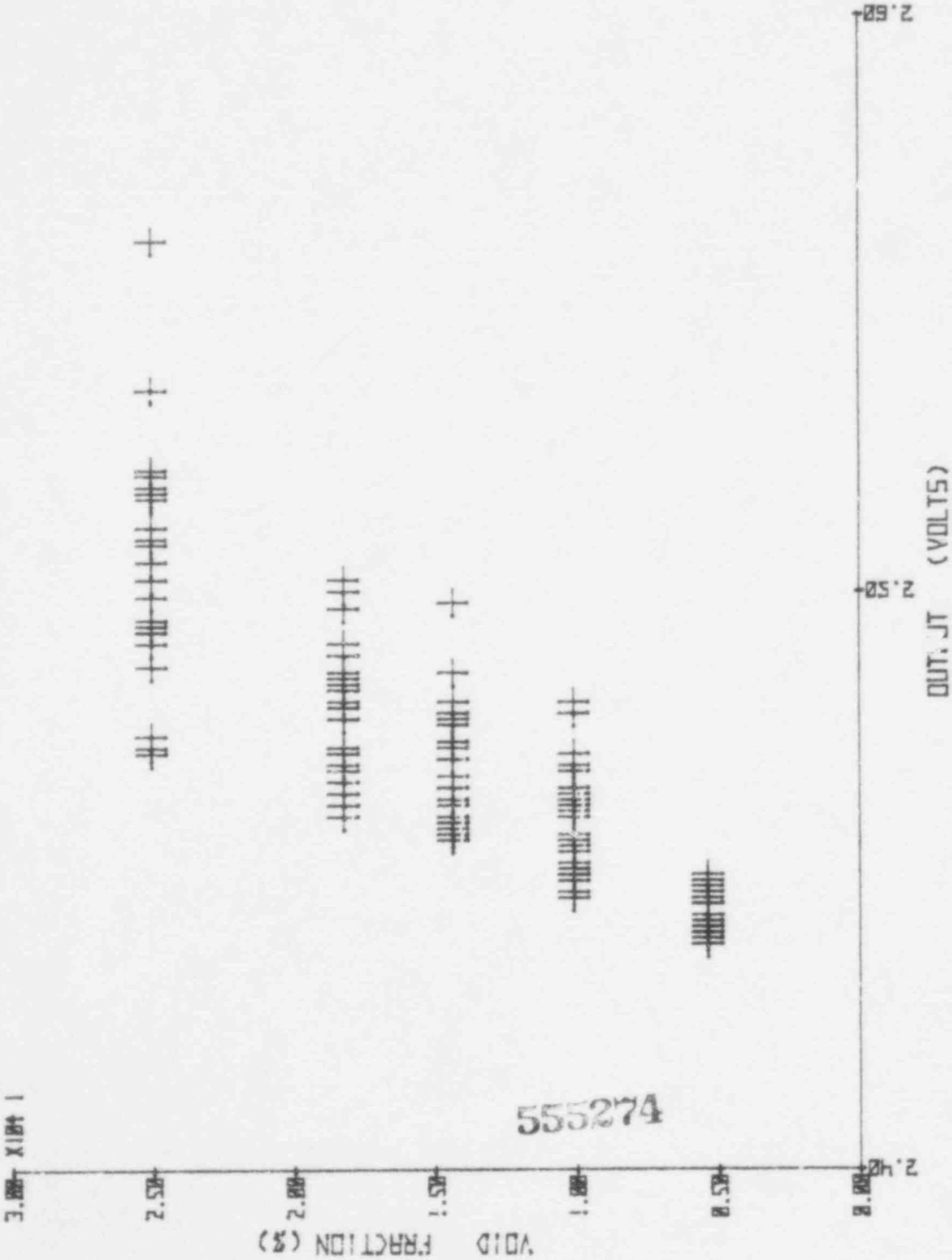
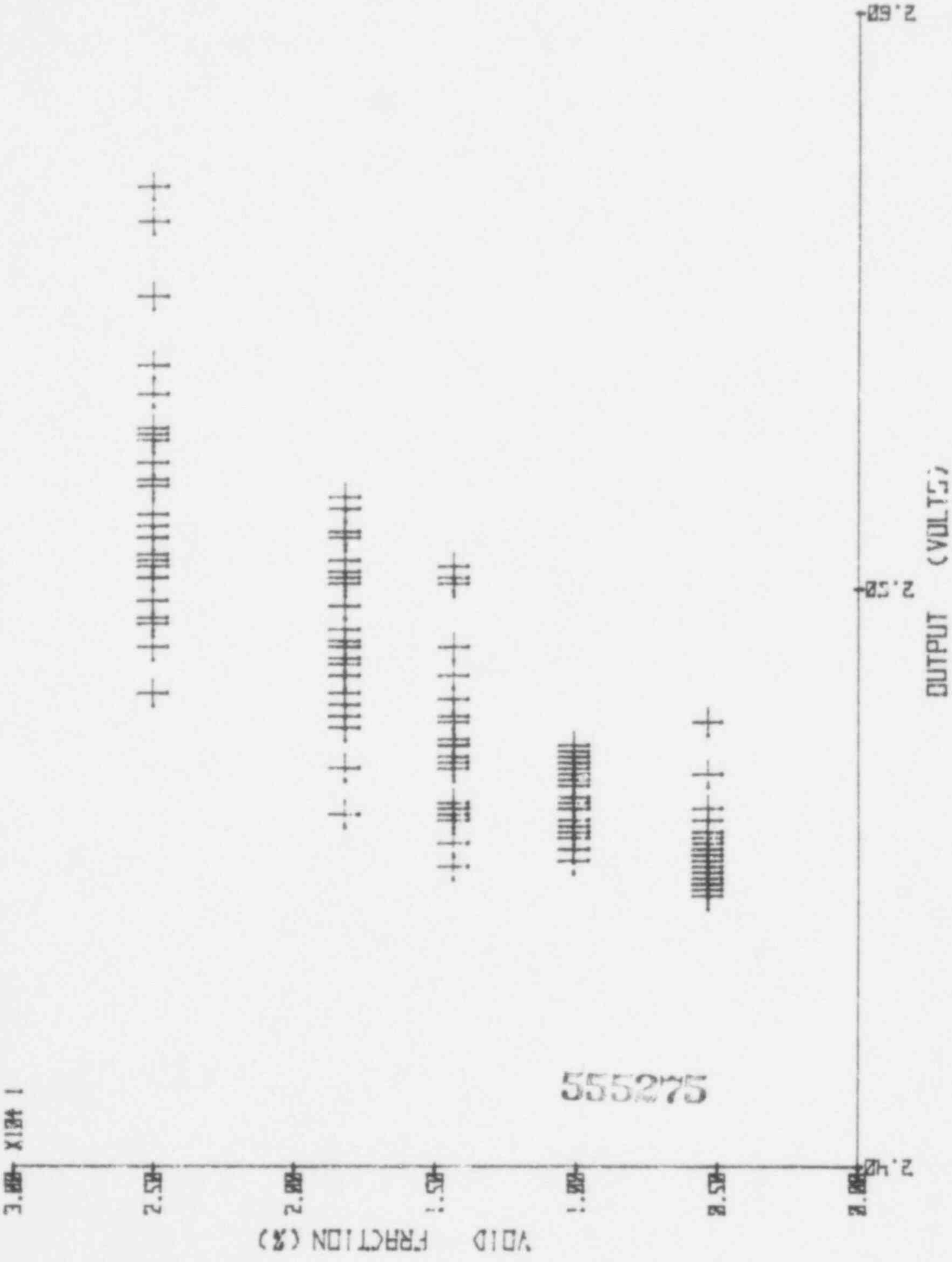


FIGURE 18. SENSOR 12 - LARGE BUBBLE - SERIES 2



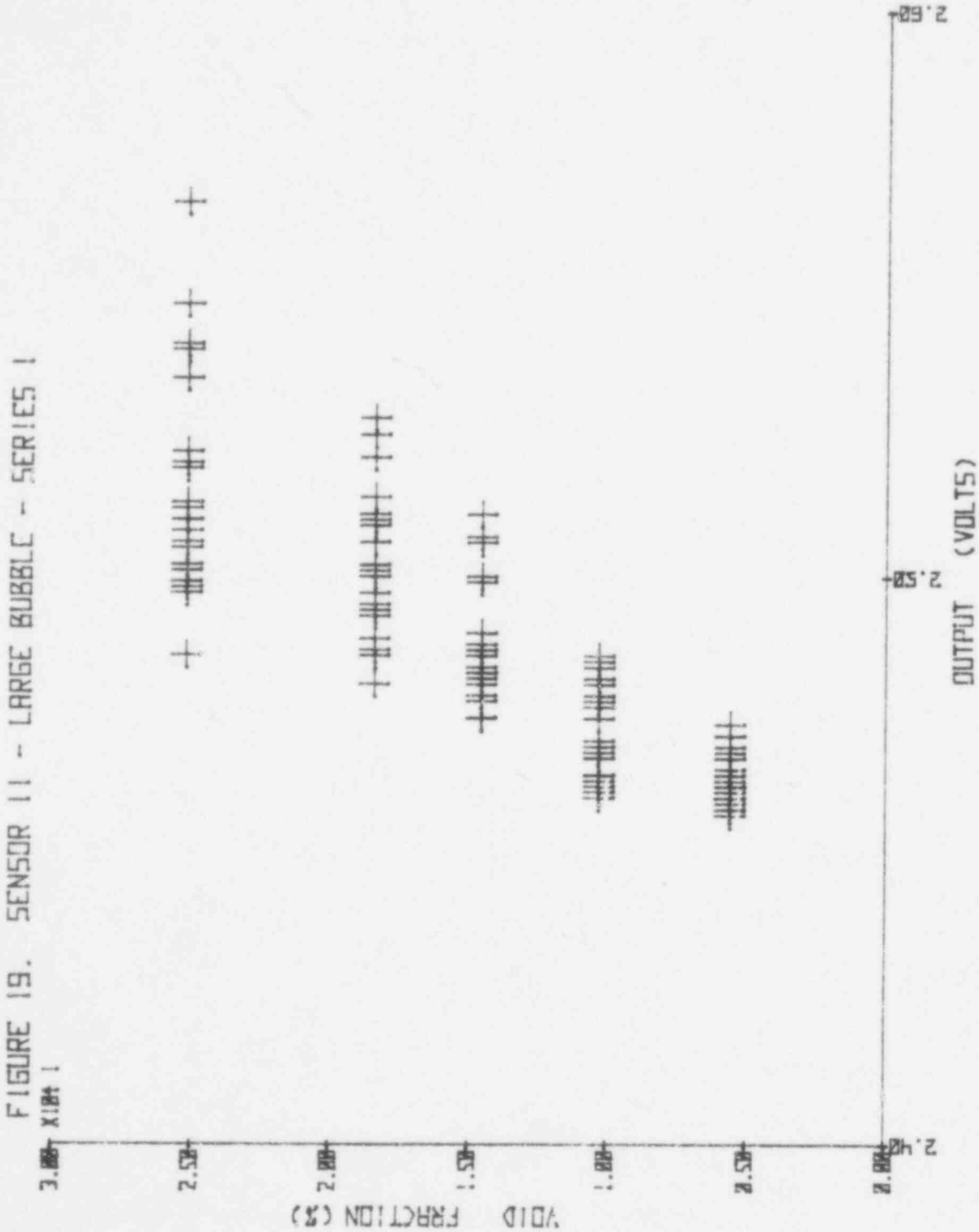


FIGURE 19. SENSOR 11 - LARGE BUBBLE - SERIES 1

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FIGURE 20. SENSOR 11 - LARGE BUBBLE - SERIES 2

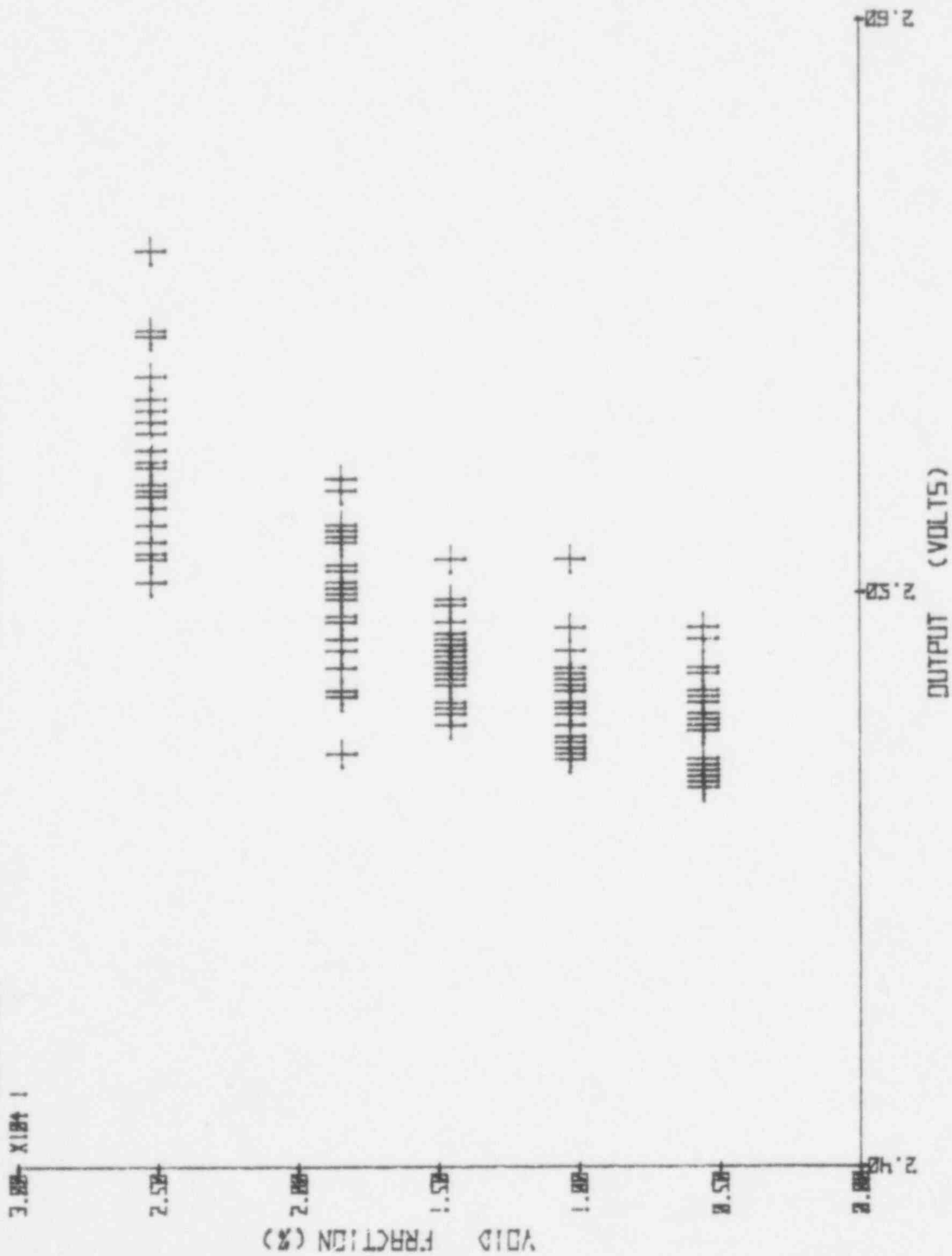

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FIGURE 21. SENSOR 19 - SMALL BUBBLE - SERIES 1 - AVERAGE OUTPUT

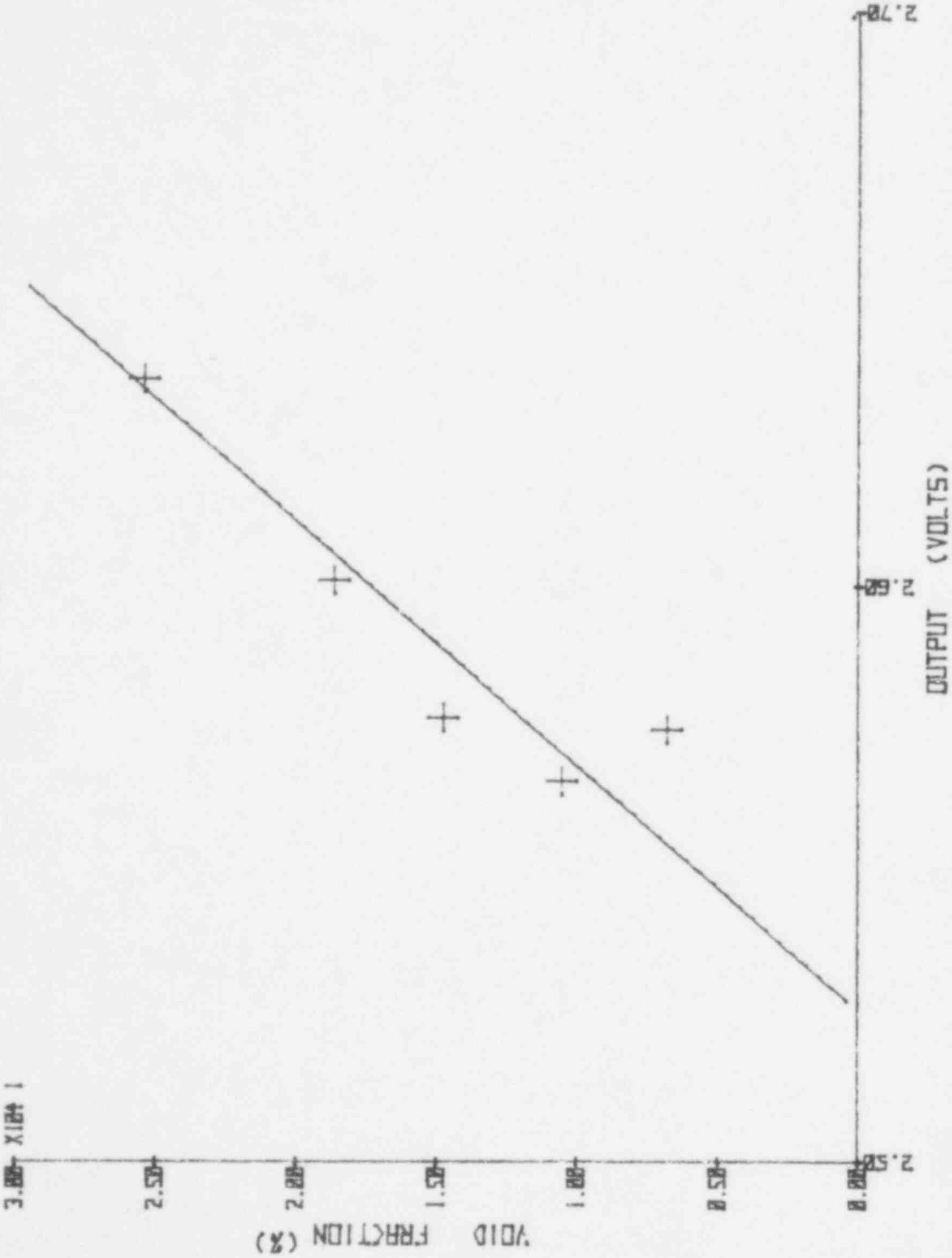

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FIGURE 22. SENSOR 19 - SMALL BUBBLE - SERIES 2 - AVERAGE OUTPUT

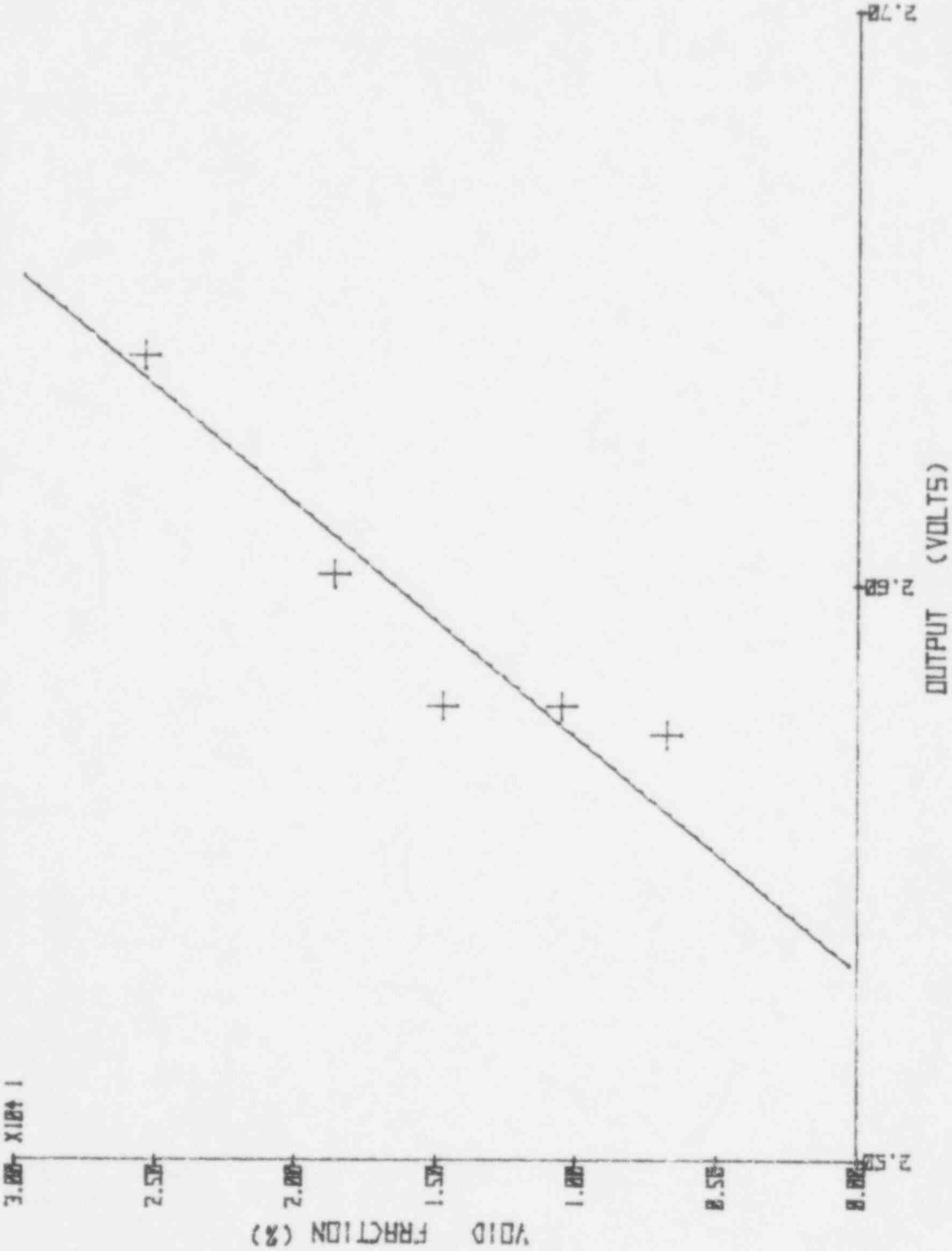

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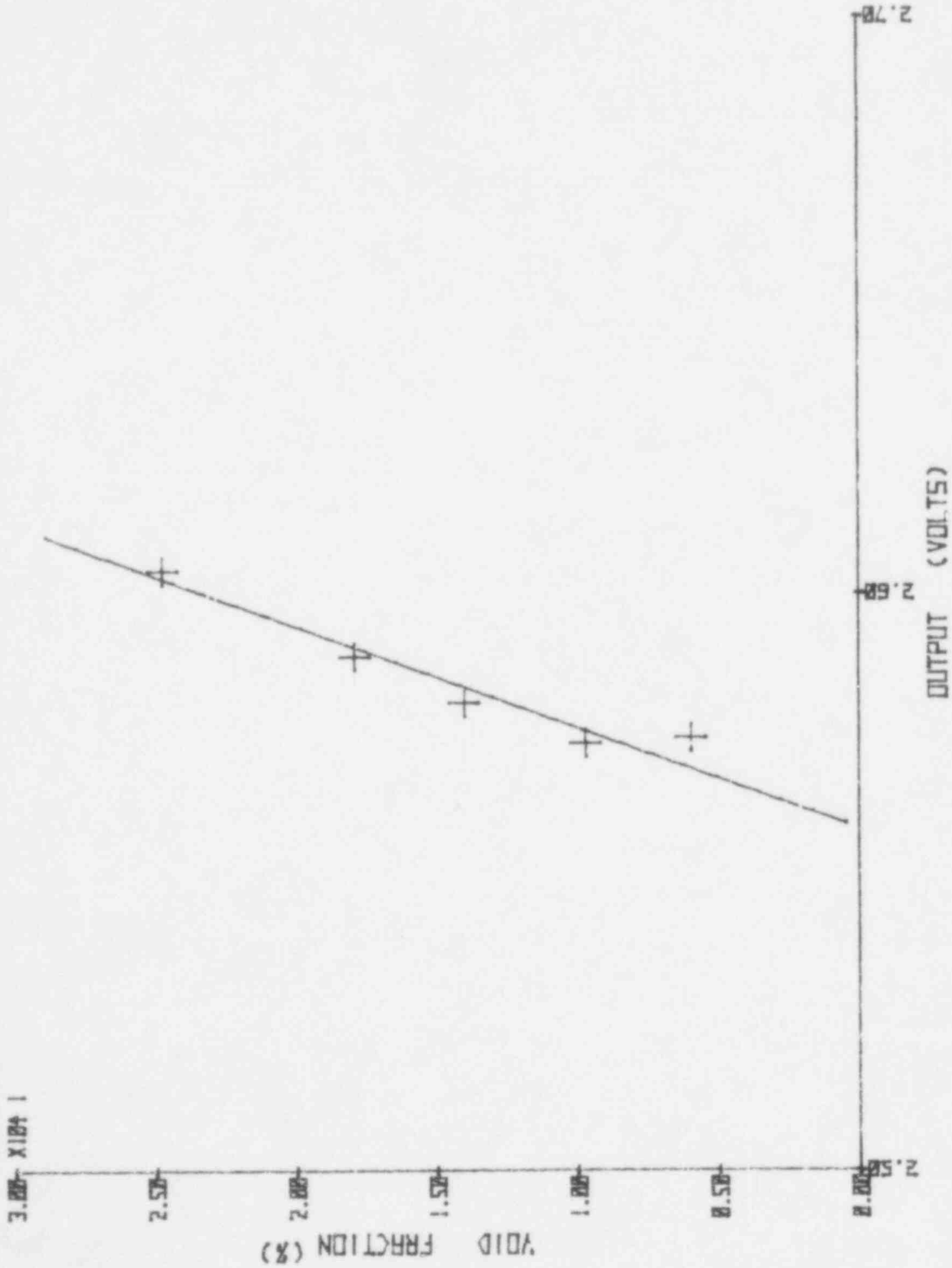
FIGURE 23. SENSOR 1B - SMALL BUBBLE - SERIES I - AVERAGE OUTPUT



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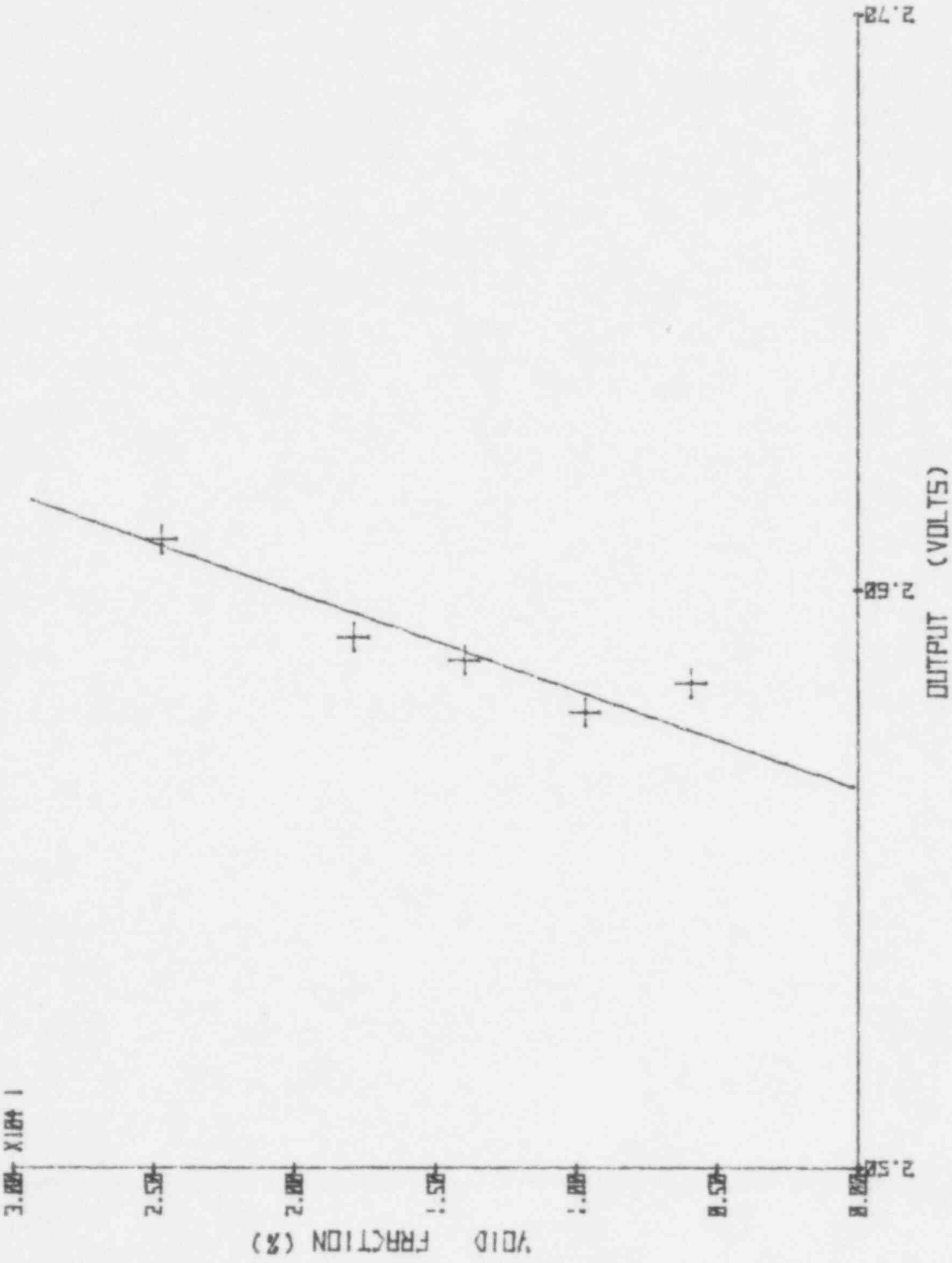

FIGURE 24. SENSOR 1B - SMALL BUBBLE - SERIES 2 - AVERAGE OUTPUT

FIGURE 25. SENSOR 12 - SMALL BUBBLE - SERIES 1 - AVERAGE OUTPUT

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FIGURE 26. SENSOR 12 - SMALL BUBBLE - SERIES 2 - AVERAGE OUTPUT

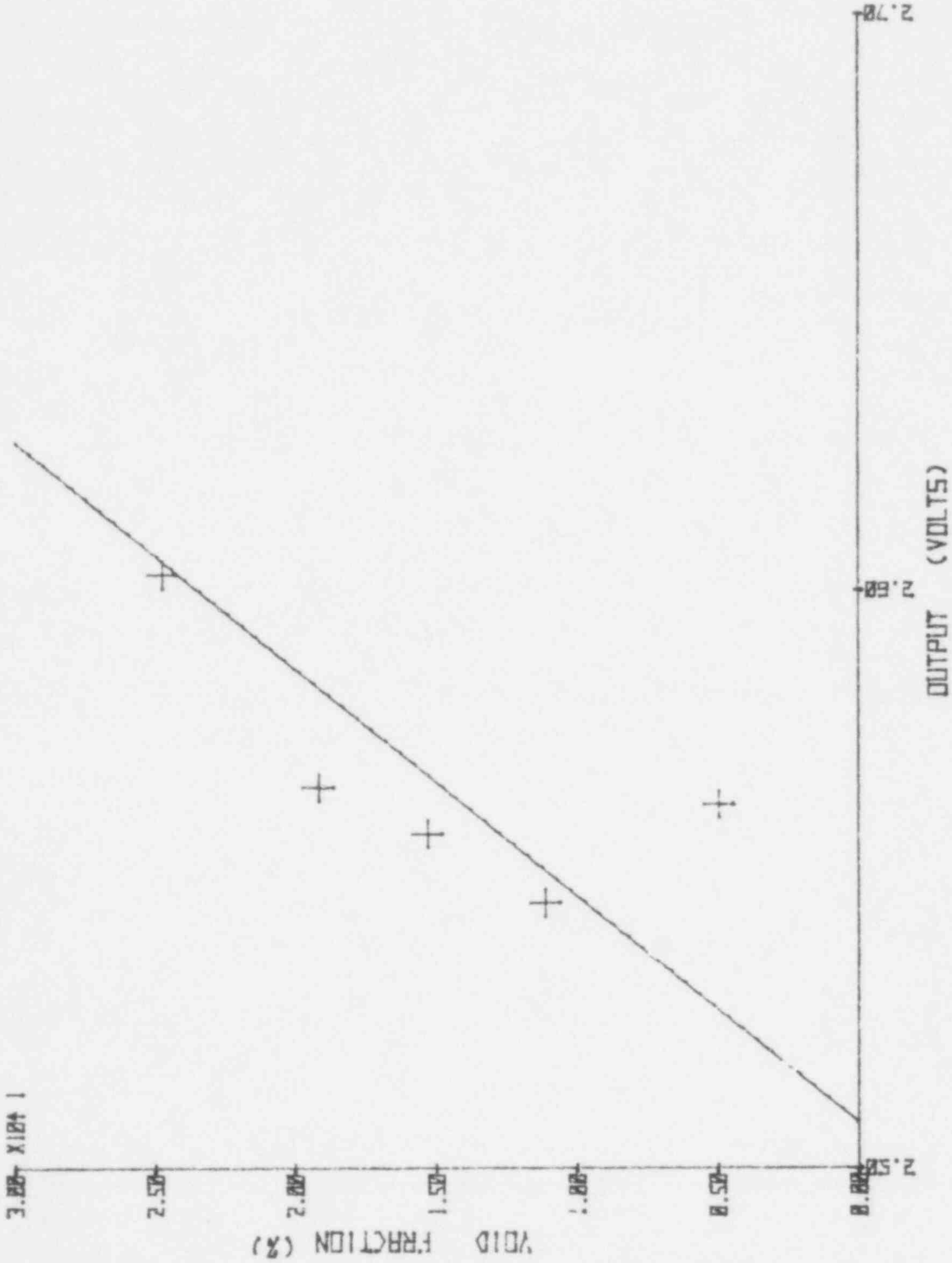

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FIGURE 27. SENSOR II - SMALL BUBBLE - SERIES I - AVERAGE OUTPUT

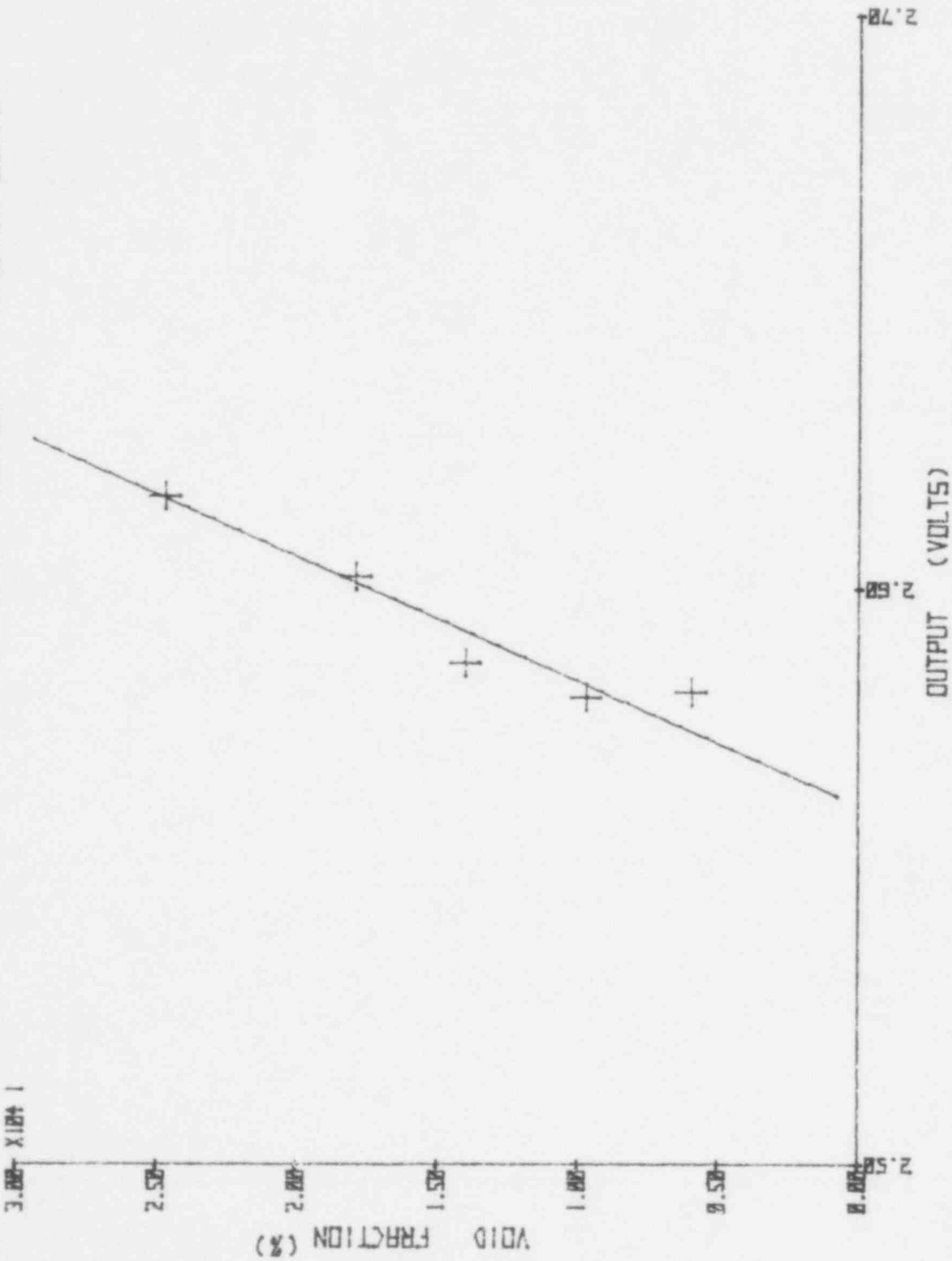

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FIGURE 28. SENSOR 11 - SMALL BUBBLE - SERIES 2 - AVERAGE OUTPUT

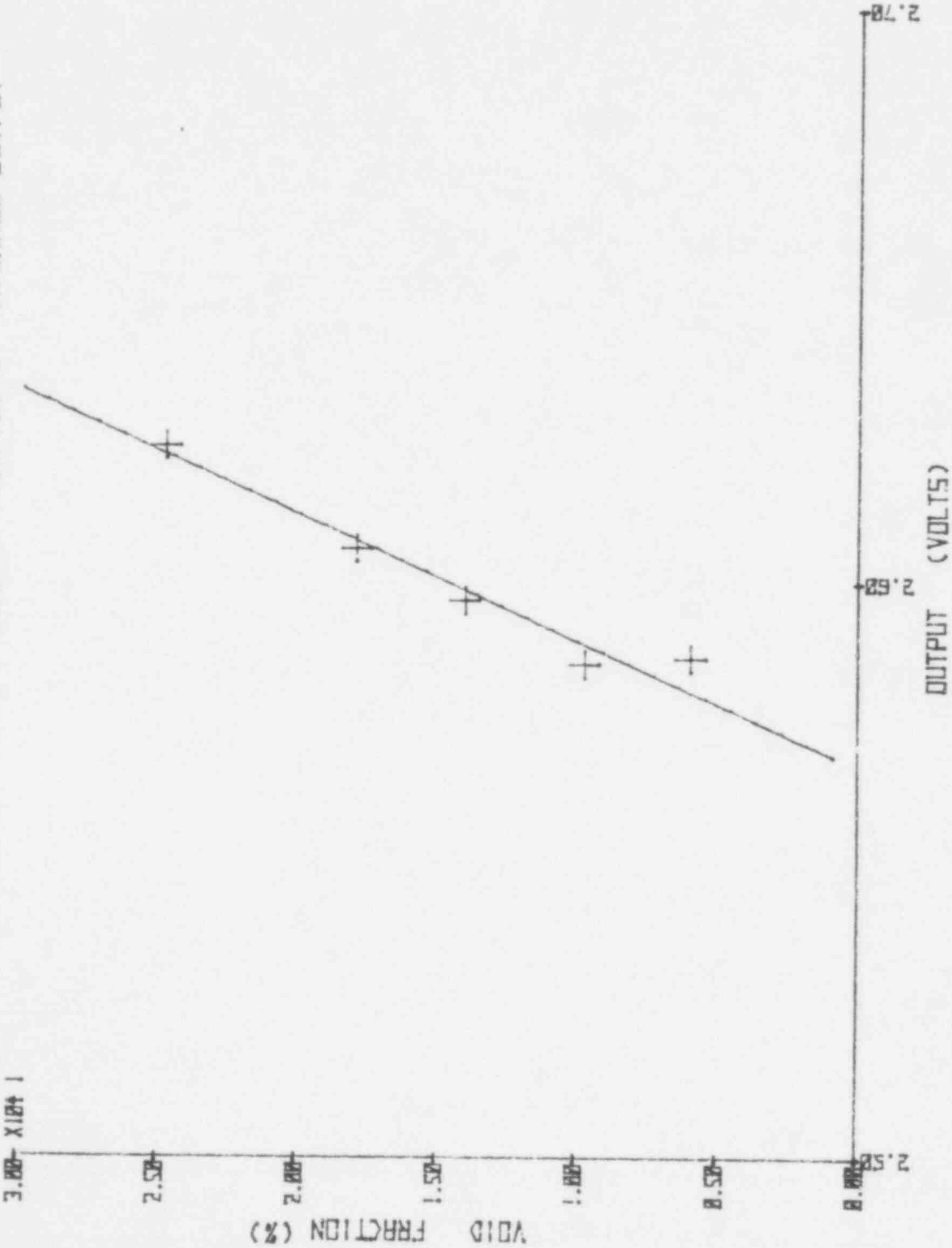

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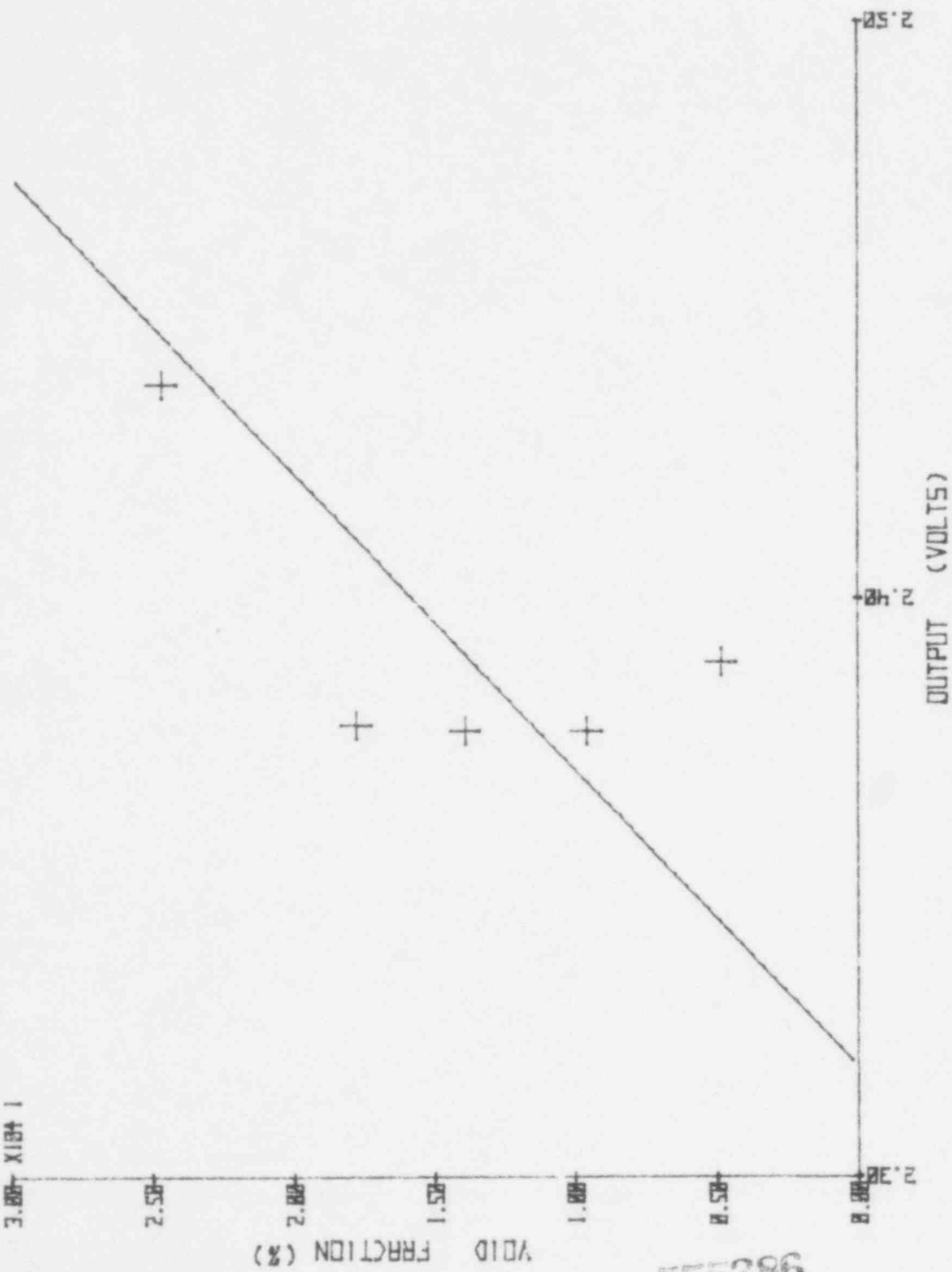
FIGURE 29. SENSOR 19 - LARGE BUBBLE - SERIES 1 - AVERAGE OUTPUT



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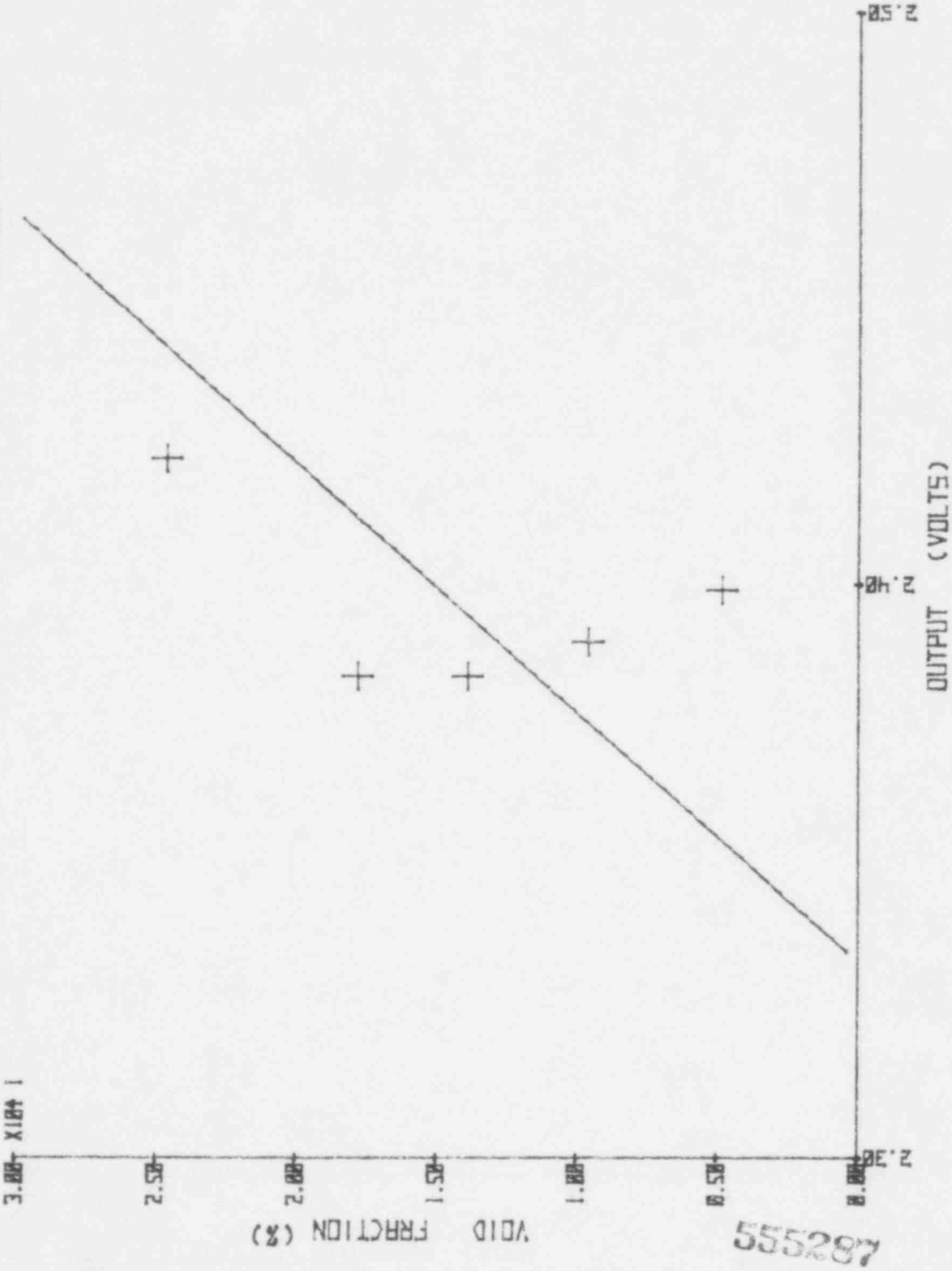

FIGURE 30. SENSOR 19 - LARGE BUBBLE - SERIES 2 - AVERAGE OUTPUT

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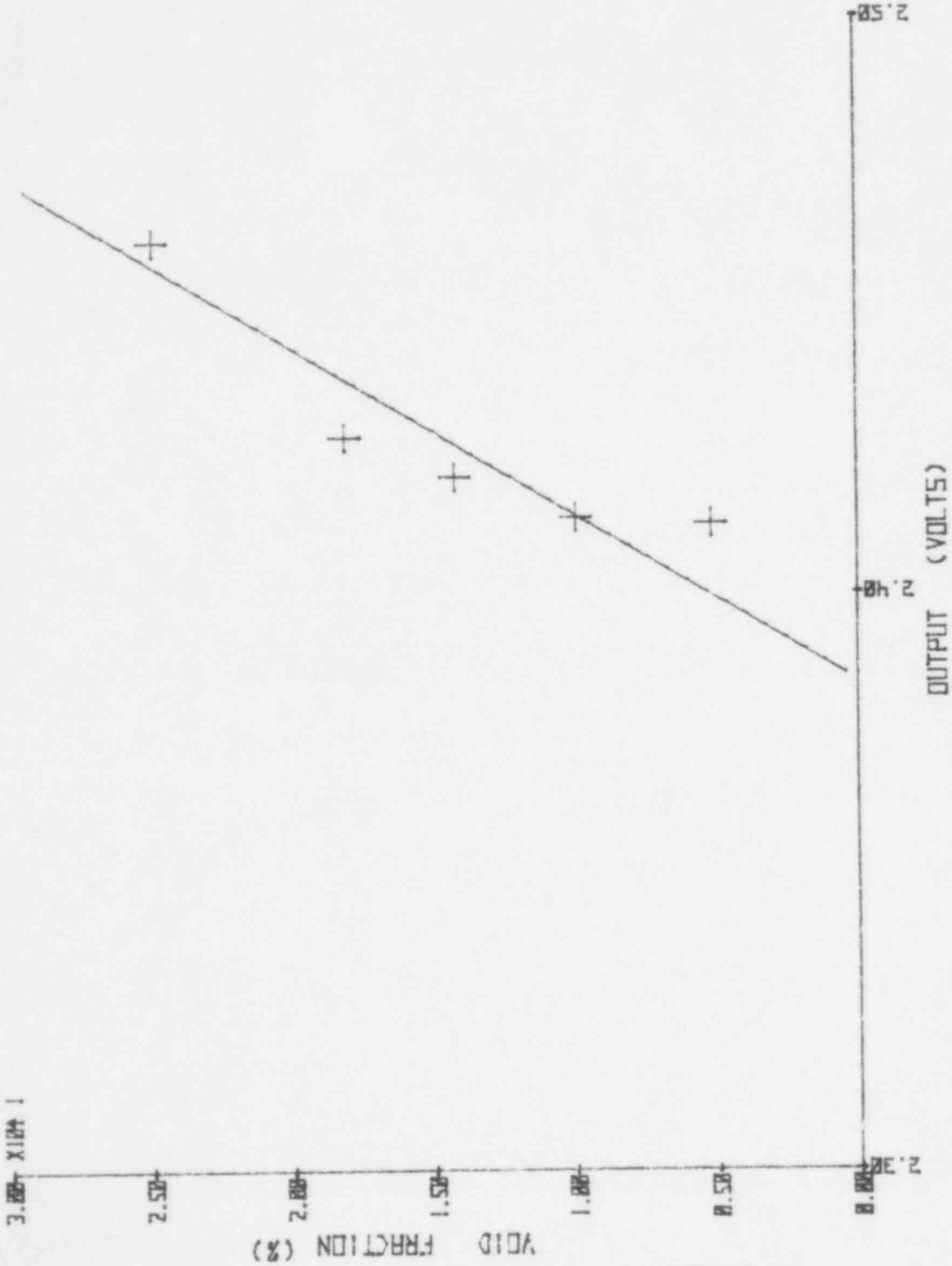
FIGURE 31. SENSOR 18 - LARGE BUBBLE - SERIES 1 - AVERAGE OUTPUT



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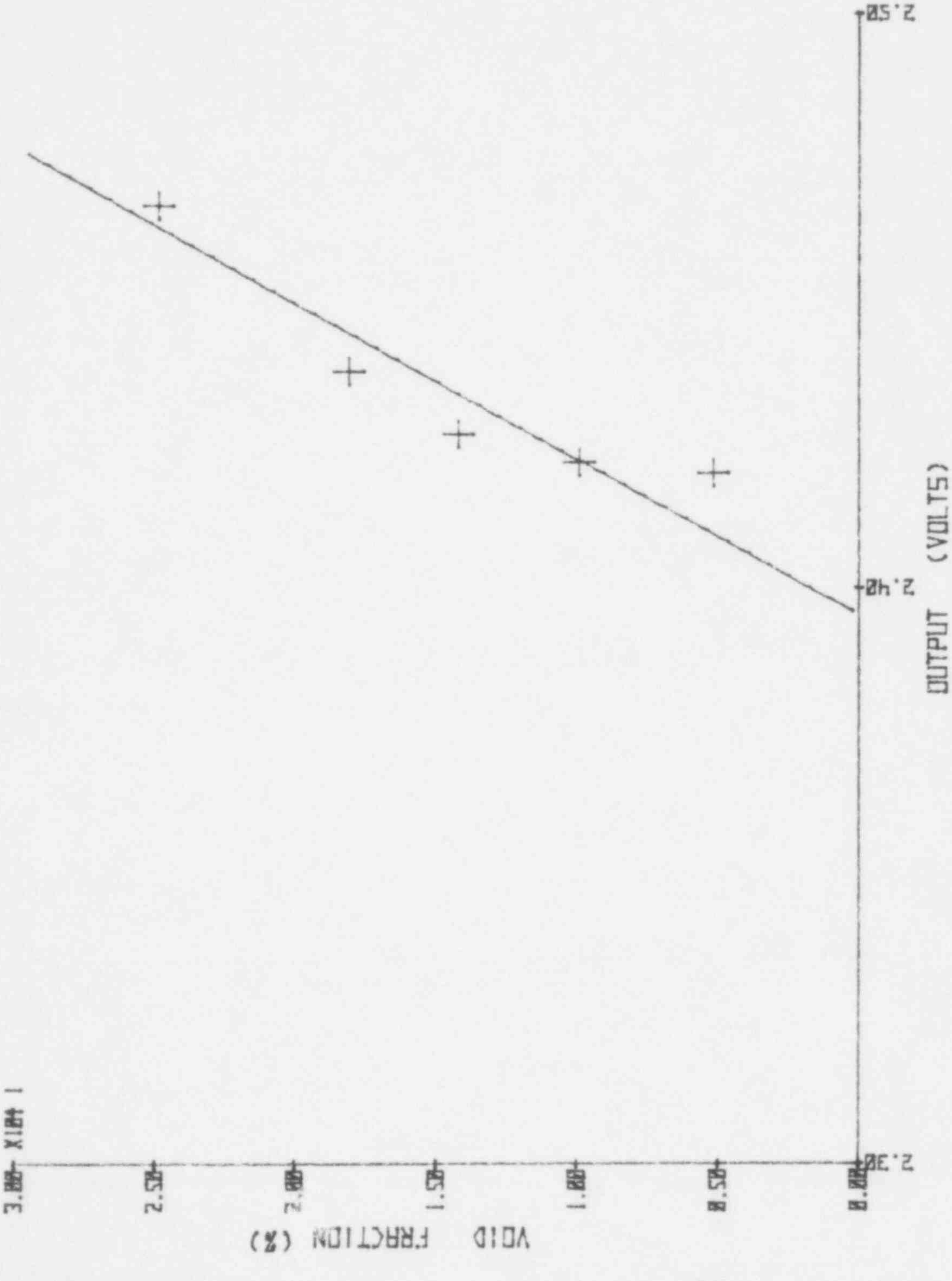

FIGURE 32. SENSOR 18 - LARGE BUBBLE - SERIES 2 - AVERAGE OUTPUT

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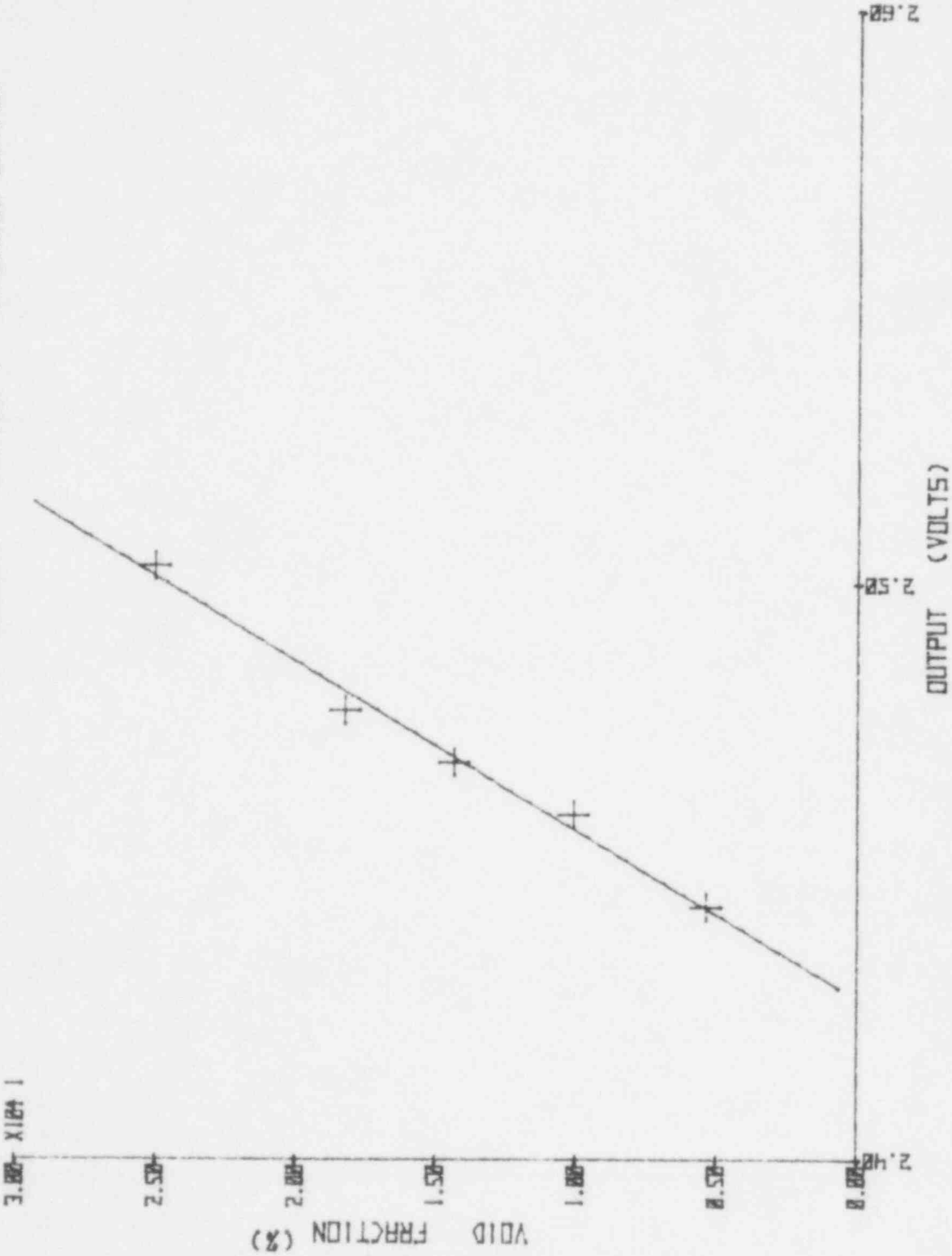

FIGURE 33. SENSOR 12 - LARGE BUBBLE - SERIES 1 -- AVERAGE OUTPUT

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FIGURE 34. SENSOR 12 - LARGE BUBBLE - SERIES 2 - AVERAGE OUTPUT

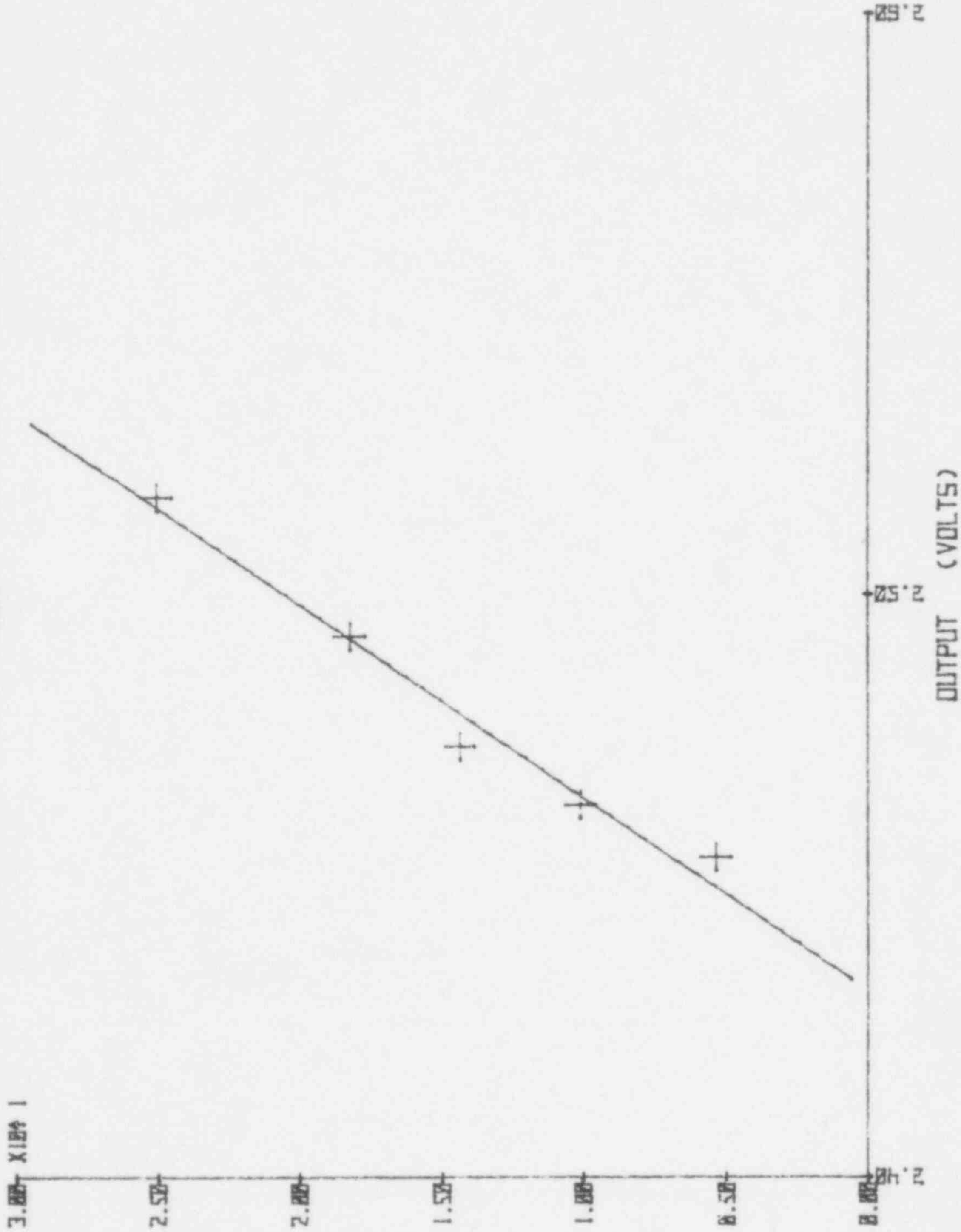

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FIGURE 35. SENSOR II - LARGE BUBBLE - SERIES I - AVERAGE OUTPUT

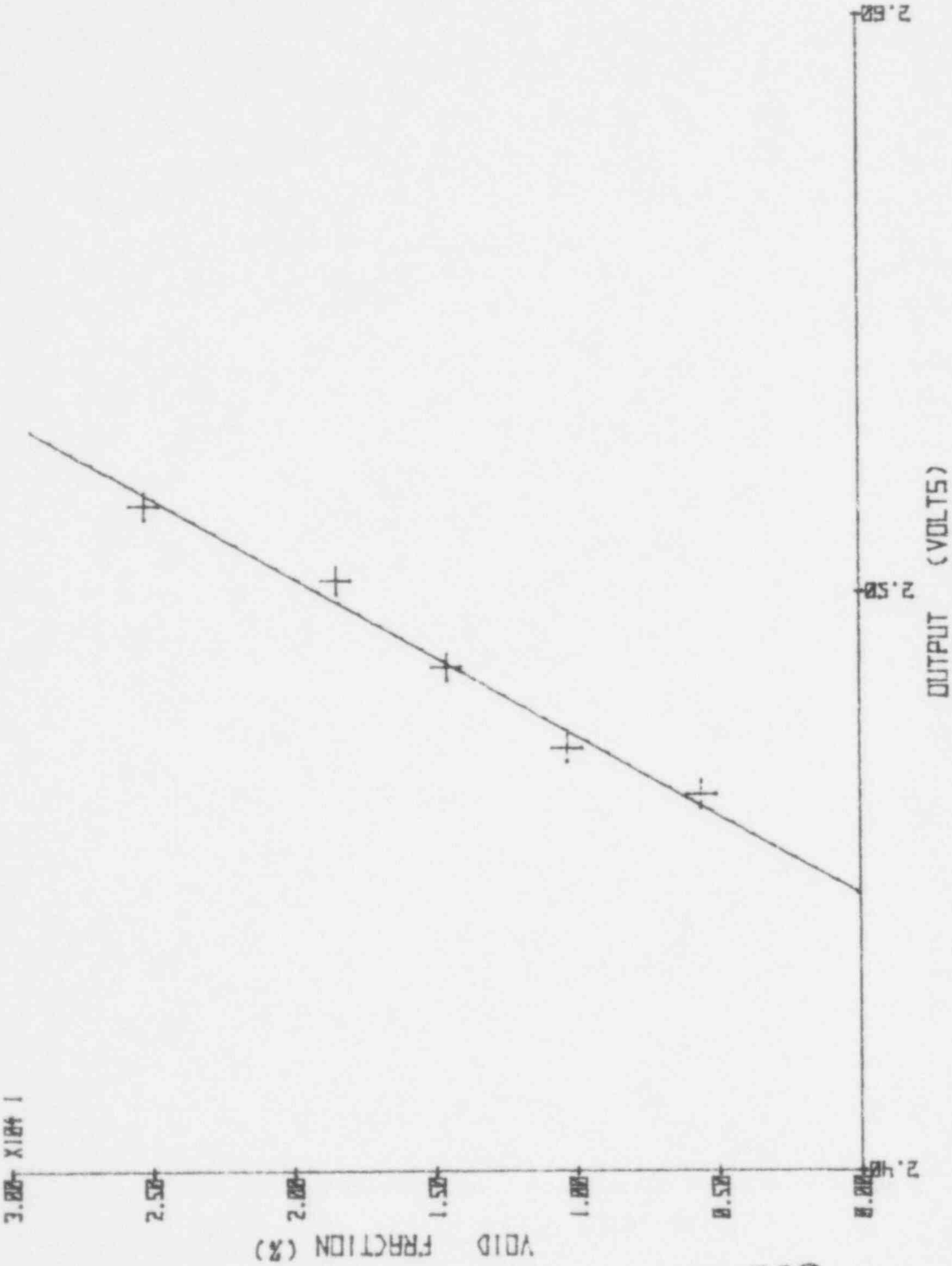

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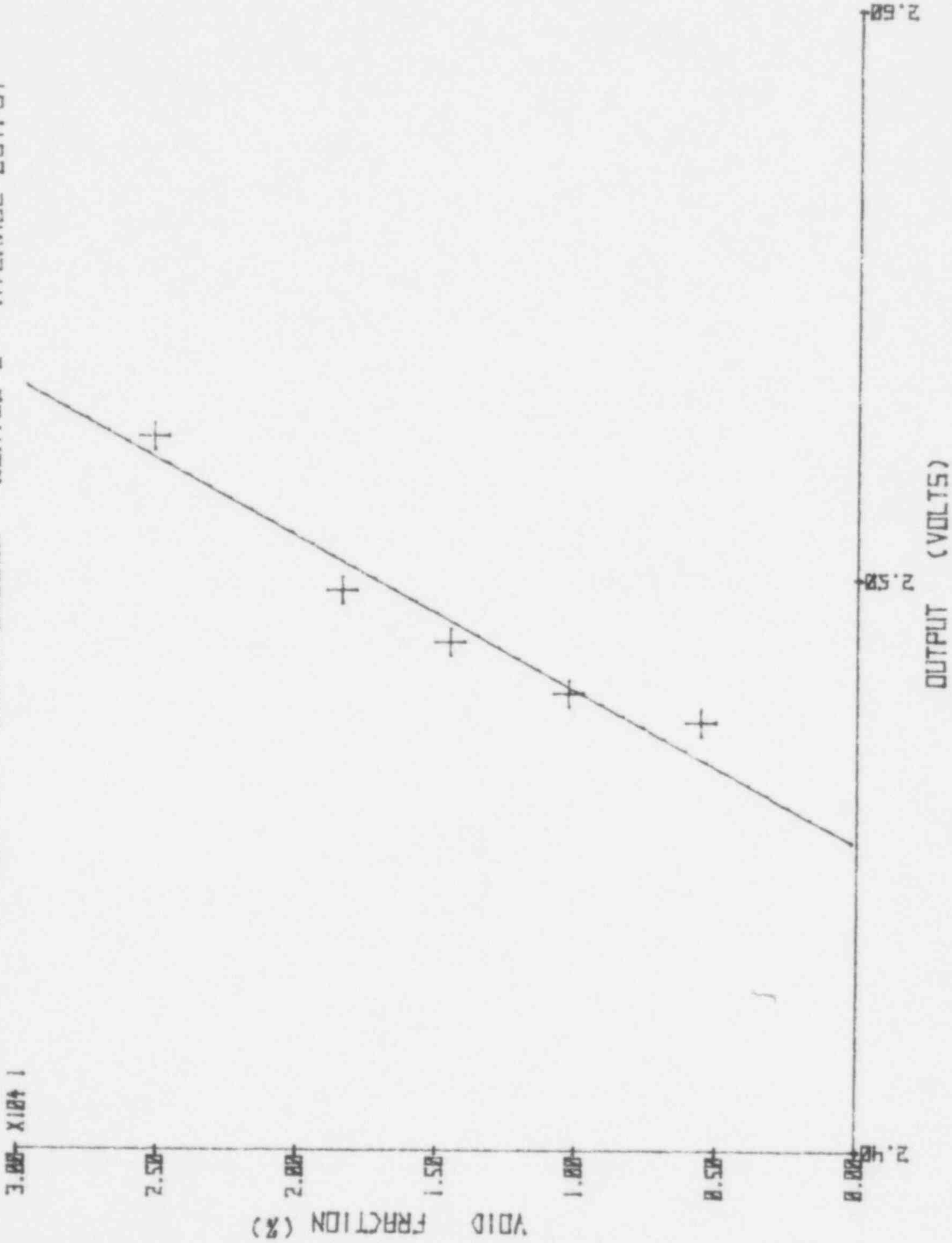
FIGURE 36. SENSOR 11 - LARGE BUBBLE - SERIES 2 - AVERAGE OUTPUT



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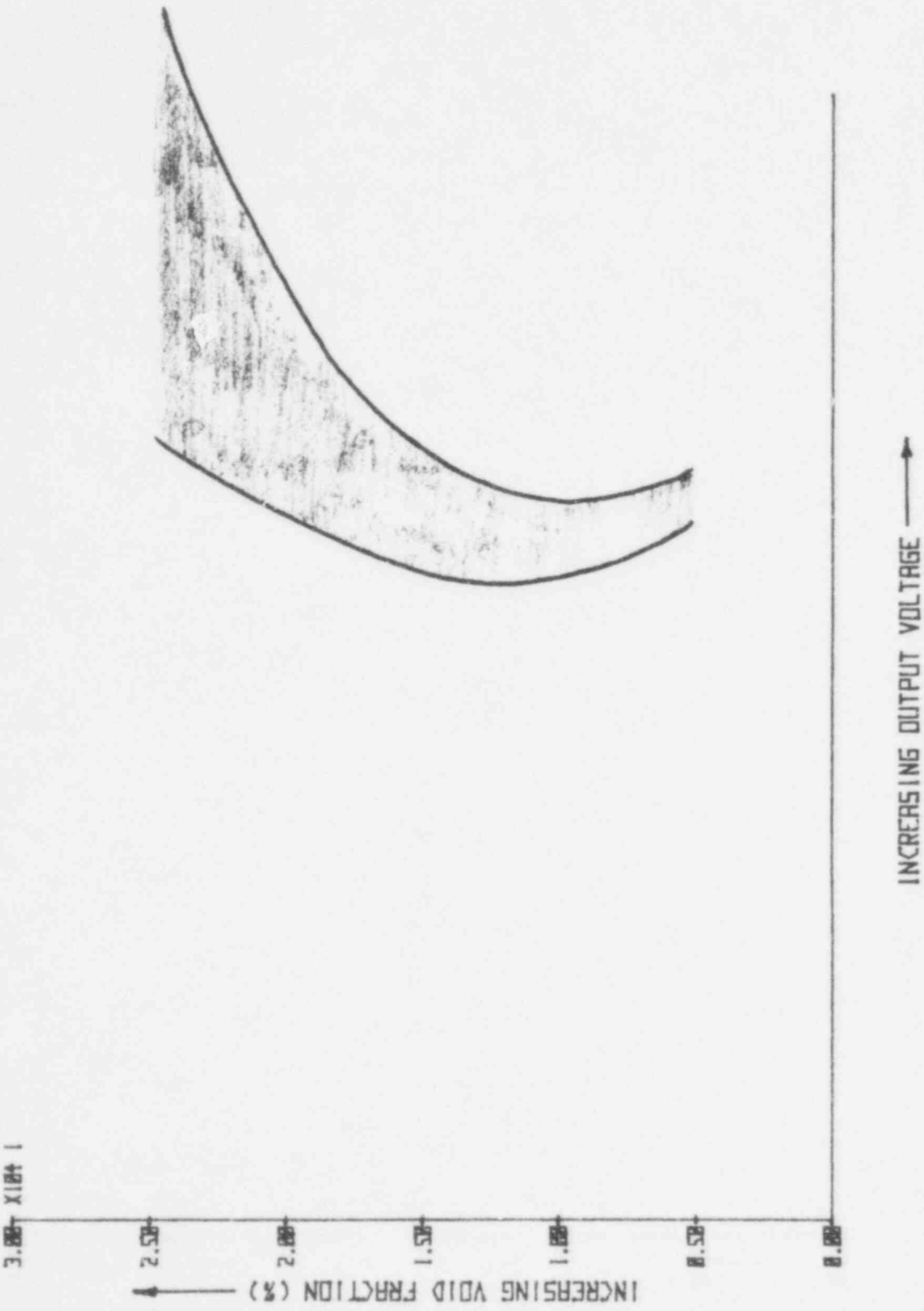

FIGURE 37. GENERALIZED FORM OF THE VOLTAGE - VOID FRACTION RELATION

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TABLE [illegible]

LINEAR REGRESSION COEFFICIENTS AND
R^2 VALUES USING ALL DATA AND AVERAGE VALUES

	Sensor	Series	Using All Data D_o	Using All Data D_1	Using All Data R^2	Using Average Values D_o	Using Average Values D_1	Using Average Values R^2
Small Bubble								
	19	1	- 504.7	200.7	0.713	- 594.0	235.1	0.844
	19	2	- 541.0	214.4	0.761	- 622.0	245.6	0.871
	18	1	-1176.7	460.8	0.766	-1455.3	568.7	0.930
	18	2	-1160.6	453.6	0.641	-1498.8	584.2	0.840
	12	1	- 695.7	278.1	0.578	- 918.1	365.0	0.757
	12	2	- 532.3	213.2	0.435	- 636.8	253.9	0.517
	11	1	- 850.0	333.3	0.659	-1187.4	463.4	0.916
	11	2	- 837.6	327.4	0.687	-1162.8	452.8	0.948
Large Bubble								
	19	1	- 362.3	157.4	0.357	- 451.8	194.8	0.439
	19	2	- 418.1	180.4	0.178	- 536.5	229.8	0.230
	18	1	- 672.8	283.2	0.682	- 823.0	345.1	0.842
	18	2	- 686.3	287.8	0.679	- 878.2	366.6	0.871
	12	1	- 600.8	249.1	0.728	- 832.0	342.7	0.989
	12	2	- 529.0	219.2	0.708	- 733.0	301.4	0.974
	11	1	- 631.2	259.6	0.698	- 893.5	365.0	0.982
	11	2	- 688.7	274.1	0.685	- 910.6	371.2	0.942