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FORM EG&G-398
(Rev. 12-78)

INTERIM REPORT

Accession No. ______

Report No. EGG-SEMI-5030

Contract Program or Project Title: Semiscale Program

Subject of this Document: Summary Data Report on Air-Water Calibration of Small Break (S-07-10) Spool Piece 41 (Air-Water Test Series SB1, SB2, and SB3)

Type of Document: Data Report

Author(s): J. L. Anderson

Date of Document: September 1979

Responsible NRC Individual and NRC Office or Division: W. D. Lanning, RSR

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Idaho Falls, Idaho 83401

for H. P. Pearson, Supervisor
Information Processing

Prepared for the
U.S. Nuclear Regulatory Commission
and the U.S. Department of Energy
Idaho Operations Office
Under contract No. EY-76-C-07-1570
NRC FIN No.
A6038

90010189

INTERIM REPORT

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EGG-SEMI-5030

September 1979

SUMMARY DATA REPORT ON AIR-WATER CALIBRATION OF SMALL BREAK (S-07-10) SPOOL PIECE 41 (AIR-WATER TEST SERIES SB-1, SB-2, AND SB-3)

James L. Anderson

U.S. Department of Energy
Idaho Operations Office • Idaho National Engineering Laboratory

This is an informal report intended for use as a preliminary or working document

NRC Research and Technical Assistance Report

U. S. Nuclear Regulatory Commission

EG&G Idaho

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Reactor Safety Research

> This document was prepared primarily for preliminary or internal use. It has not received full review and approval. Since there may be substantive changes, this document should not be considered final.

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Prepared for the
U.S. Nuclear Regulatory Commission
Washington, D.C.
Under DOE Contract No. DE-AC07-76ID01570
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SUMMARY DATA REPORT
ON
AIR-WATER CALIBRATION
OF
SMALL BREAK (S-07-10) SPOOL PIECE 41

(Air-Water Test Series SB1, SB2, and SB3)

by

James L. Anderson

September 1979

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Experimental Instrumentation Branch

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SUMMARY

Three sets of air-water tests were performed using the small break (S-07-10) spool piece 41 to investigate annular-mist two-phase flow effects upon the drag coefficient of a full-flow multihole drag plate. Spool piece 41 was used in Semiscale Test S-07-10 to measure the break mass flow rate, and detailed information about the two-phase drag coefficient is required to made an accurate mass flow rate measurement. This report summarizes the air-water data taken for the purposes of developing drag coefficient correlations. Data presented includes fluid properties, mass flow rates, drag force measurements, density distributions, and momentum flux distributions.

I. INTRODUCTION

During the Semiscale small break Test S-07-10 a spool piece, consisting of a hinged multihole drag plate and a low energy densitometer, was installed between the break orifice and the rupture disc assembly. This spool piece was installed to provide a mass flow rate measurement of the steam/water mixture exiting the system. During air/water check out tests (designated test series SB1) of the spool prior to its installation for the small break test, it was discovered that at the high momentum fluxes and low density flows, such as predicted at this measurement location for the S-07-10 test, the value of the drag coefficient for the hinged multihole hole drag plate was increasing from its single phase (water) value. This increase was found to be on the order of 4 times the single phase value. Calculation of the mass flow rate for the Semiscale small break test requires an accurate knowledge of the drag coefficient. Therefore, following S-07-10 two test series (designated SB2 and SB3) were performed in the air/water loop. The primary purpose of both of these test series was to investigate the effect of various annular-mist flows on the drag coefficient for the drag plate. The two test series were essentially identical (test point designations and flow rates were the same) with two major differences. During test series SB2 a Cd-109 source was used with the scanning densitometer, and the flow disperser (part number 411018-3) was installed (as it was for test series SB1). During test series SB3 an Am-241 source was used with the scanning densitometer (with single channel analyzer window set on the 17.8 keV x-ray peak), and the flow disperser was not installed. The Am-241 source was used to provide better low density resolution and the flow disperser was not installed to investigate its effect on the drag coefficient.

This report provides a summary of the experimental set-up used and the data which was taken. Some data reduction has been performed (i.e. calculation of individual phase densities and mass flow rates), however, analysis of particular aspects of the data will be summarized in later reports.

II. DESCRIPTION OF HARDWARE

Calibration of the small-break spool piece 41 was carried out in the Air-Water Loop Test facility using the horizontal 1-1/2 in. schedule 160 pipe line between the air-water mixer and the separater tank. Physical arrangement of the components and instrumentation utilized for this calibration is shown in Figure 1, and described in the following section. The small-break spool piece 41, and the low-energy scanning densitometer are described in detail in individual sections.

1. TEST SECTION CONFIGURATION

The test section configuration used for the small break spool piece calibration is shown in Figure 1. The plexiglass pipe section together with the low-energy scanning densitometer were mounted approximately 150 diameters from the air-water mixer. Spool piece 41 was mounted 10.3 diameters downstream of the plexiglass pipe section, and the instrument washer immediately after and against the spool piece.

A hinged multihole drag plate (shown in Figure 2) was mounted in the instrument washer and used to measure two-phase momentum flux. Mounting configuration was with the force transducer in the horizontal plane. The force transducer used was a variable reluctance transducer developed by EG&G as a force sensor for the measurement of the drag force on the body. The force exerted on the perforated drag plate compresses a spring, the displacement of which is proportional to the exerted force. The voltage output from the signal conditioning electronics is thus proportional to the spring displacement and the exerted force. This transducer was designed for a full scale displacement (at the spring) of 1.27 mm (0.05 in.) at which point the output voltage equals 10V.

A differential pressure cell (noted as ΔP_{DRAG} in tabulated data) was connected between the interconnecting flanges of the two spool pieces with the instrument washer sandwiched between, allowing

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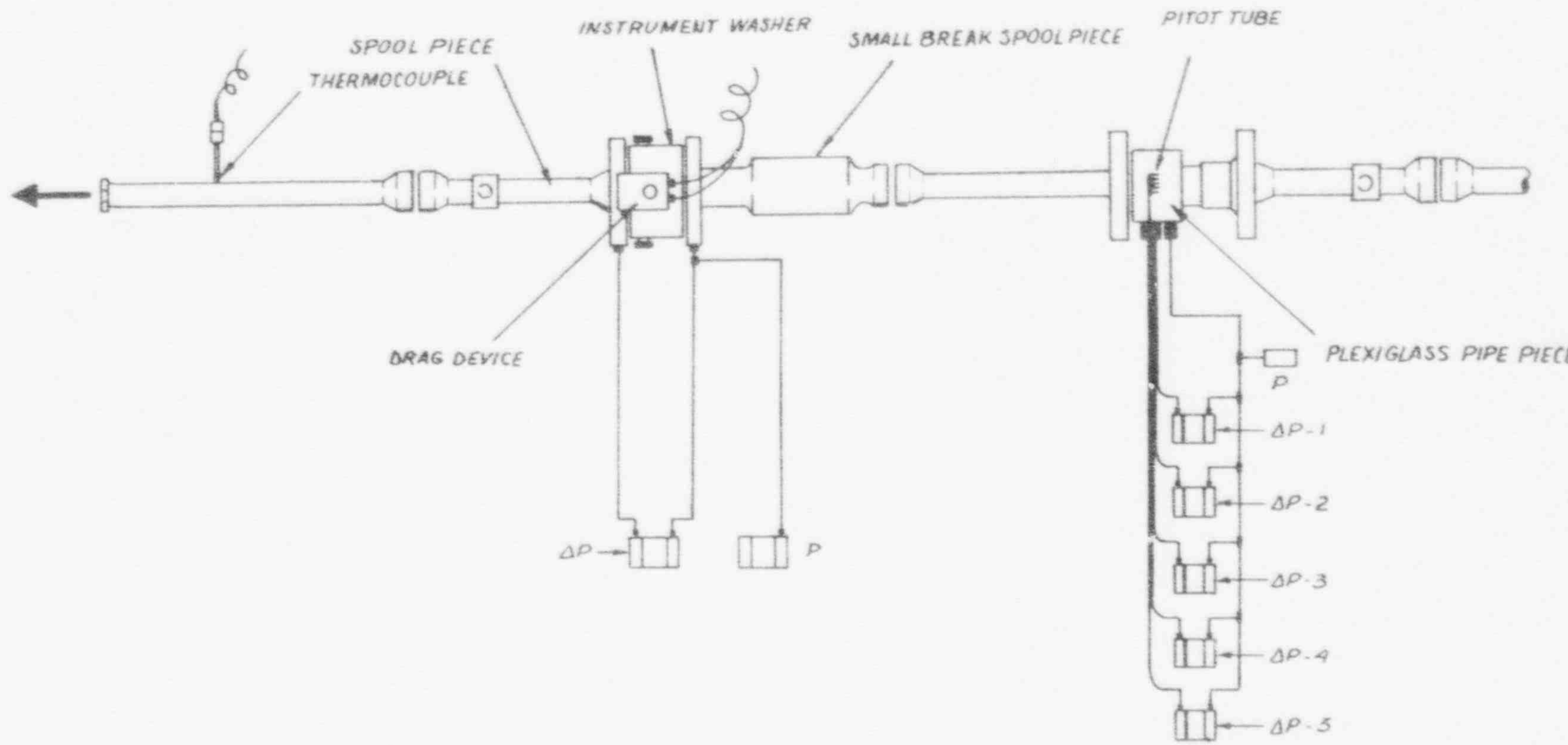

Fig. 1 Test Section Configuration for Air-Water Test Series SB1, SB2, and SB3.

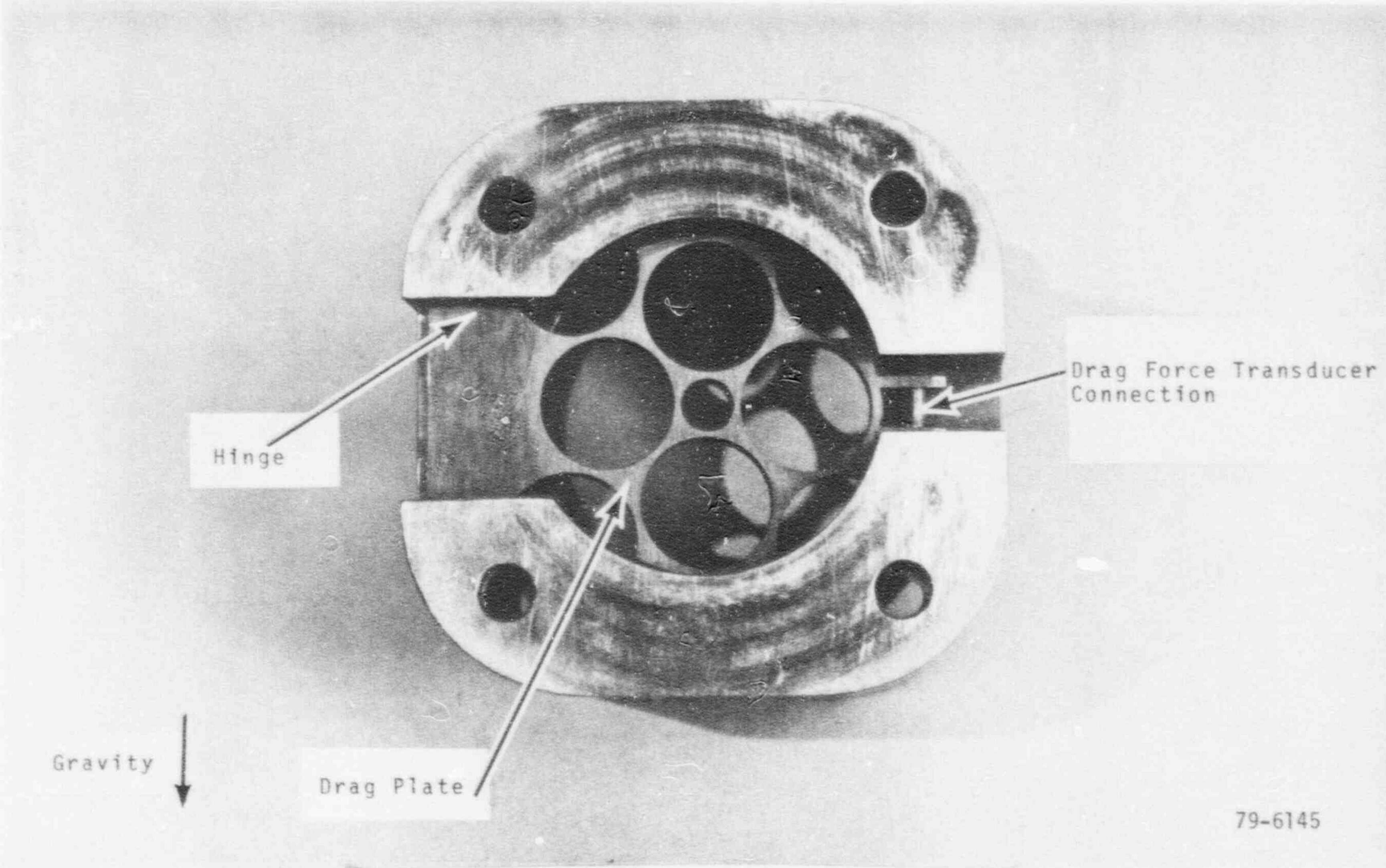

Fig. 2 Hinged multihole drag plate used in S-07-10 spool piece 41. Shown in mounting block.

measurement of the pressure drop across the drag device. A pressure cell was also connected on the high pressure leg of the differential pressure cell and was used for measurement of pressure at the drag device.

A five point pitot-tube rake (shown in Figure 3) was inserted in the plexiglass pipe section with the object of measuring the momentum flux profile along a vertical pipe diameter. This was accomplished by connecting the high pressure side of a differential pressure cell to each tube of the rake and connecting the low pressure side of the cell to a common header, which was connected to a static pressure wall tap in the plexiglass pipe section. Figure 4 shows the plexiglass pipe segment with the pitot tube rake installed. This arrangment allowed measurement of the dynamic pressure of the fluid at five locations along the vertical diameter. Since the dynamic pressure of the fluid is a direct function of the momtentum flux, this measurement is equivalent to a local momentum flux measurement.

The scanning densitometer was mounted at the plexiglass pipe section. Data obtained provided both density distribution information and accurate cross-sectional average densities.

Three reference turbine flowmeters of different ranges and a thermocouple were installed in the water supply line, upstream of the air-water mixer with the purpose of measuring the water mass flow rate. Also, two reference turbine flow meters, a pressure cell and a thermocouple provided measurement information of the flow, pressure, and temperature of the air in the air supply line for determination of the air mass flow rate prior to the air-water mixer.

A thermocouple downstream of the instrument washer measured the fluid temperature at the output of the spool piece.

A complete list of instrumentation from which data was taken is provided in Table I.

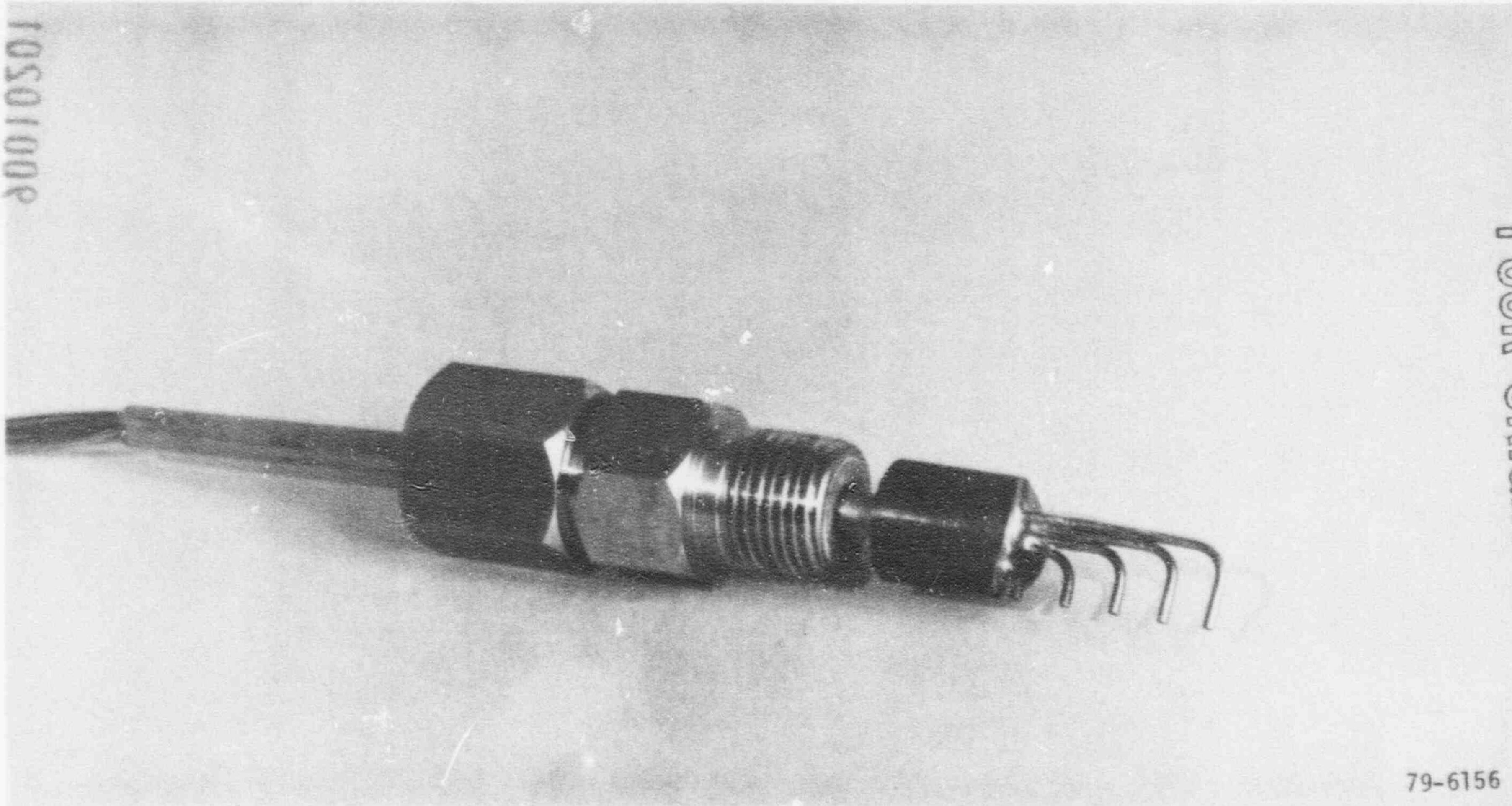

Fig. 3 Five-tube pitot tube rake for use in air-water testing involving 1-1/2-inch schedule 160 size piping.

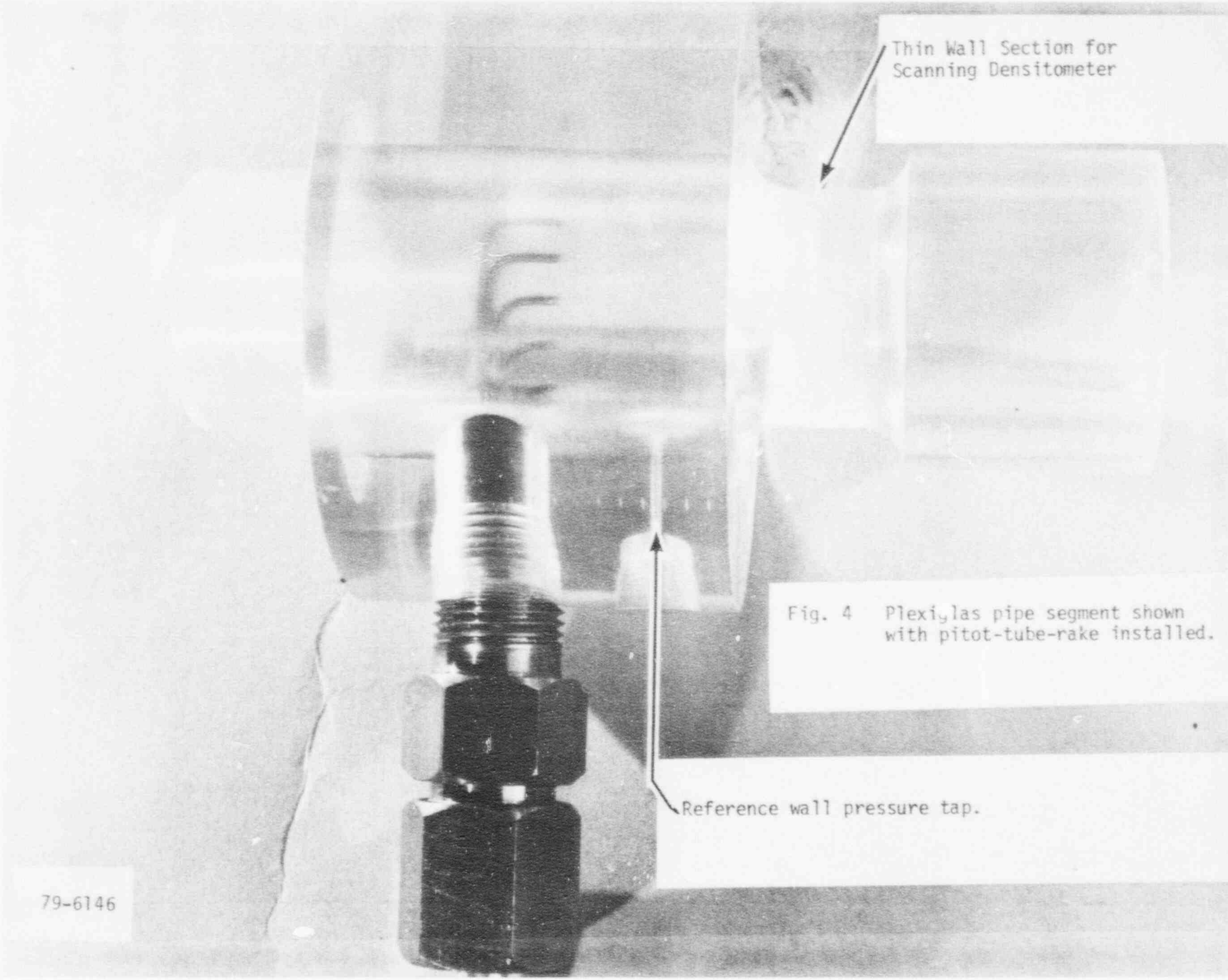

Fig. 4 Plexiglas pipe segment shown with pitot-tube-rake installed.

TABLE I

INSTRUMENTATION LIST AND RANGES

Transducer ID	Serial Number	Measurement Range	Measurement Uncertainty
Reference Water Turbines			
QW 3/4 (3/4 in., Flow Technology)	120747	0.060-1.577 L/s	±0.015 L/s
QW 1 (1 in. Flow Technology)	160521	0.32-3.155 L/s	±0.03 L/s
QW 3 (3 in. Flow Technology)	48127	2.5-18.93 L/s	±0.2 L/s
Reference Air Turbines			
QA 3/4 (3/4 in., Flow Technology)	120745	0.5-11.8 L/s	±0.25 L/s
QA 2 (2-1/2 in. Flow Technology)	7425-2012	14.0-118.0 L/s	±2.5 L/s
Test Section Temperature	N/A	273-584°K	±2 °K
Air Inlet Temperature	N/A	273-584°K	±2 °K
Water Inlet Temperature	N/A	273-584°K	±2 °K
Air Inlet Pressure	CEC-69874A	86.2-1471.0 kPa	±14.7 kPa
Test Section Pressure	BLH-77711	86.2-432.2 kPa	±4.3 kPa
Pressure at Scanning Densitometer	CEC-4667	186.2-509.0 kPa	±5.1 kPa
Differential Pressure Across Drag Plate	BLH-72385	0-169.4 kPa	±1.7 kPa
Drag Force[a]	SD004	0-18.57 N 0-46.0 N	±0.093 ±0.23
Pitot Tube Rake			
DP1 (Top)	BLH-53324	0-99.7 kPa	±0.5 kPa
DP2	BLH-77932	0-102.3 kPa	±0.5 kPa
DP3 (Center)	BLH-44296	0-102.9 kPa	±0.5 kPa
DP4	BLH-72384	0-167.7 kPa	±0.9 kPa
DP5 (Bottom)	BLH-73542	0-167.5 kPa	±0.9 kPa

a The force transducer has interchangeable springs to vary the range. Two different ranges were used in the testing.

2. SMALL BREAK SPOOL PIECE

The instrumented spool piece used in these air-water tests was comprised of an instrument washer (DN 410963)[a] containing a hinged multihole drag plate, sandwiched between two spool piece halves. The upstream spool piece half was the spool piece made for the small break tests (DN 411004-1) and contained the filler sleeve for mounting the flow disperser (DN 411018-1 and 3). The mounting configuration of the assembly used during the Semiscale small test is shown in drawing number 411021. The downstream spool piece half was a standard broken loop spool piece (1-1/2 ABL-3, DN407671) made for inserting a turbine housing. This spool was used during the air-water testing to provide a proper mating surface for sealing to the instrument washer. Standard Semiscale type pressure ports were provided in the flanges on each of the spool piece halves.

3. SCANNING DENSITOMETER

The primary purpose of these test series was to investigate the effects of annular-mist flow regimes on the two-phase drag coefficient of the multihole drag plate. However, to calculate the drag coefficient, one must first calculate the two-phase momentum flux. This calculation requires an accurate measurement of the void fraction (or cross-sectional average density) at the test section. To obtain the void fraction measurement a low energy scanning densitometer was used.

The scanning densitometer[b] consists of a fixed single x-ray source (Cd-109 or Am-241 were used) located on the horizontal centerline of the test section. A liquid-nitrogen-cooled Si(Li) detector moves in a circular arc about the source on the far side of the plexiglass pipe section.

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a. Applicable drawings are attached.

b. See Appendix A for a more complete description of the scanning densitometer.

This pulse-type system uses a single-channel analyzer set on an K_α x-ray peak, and a counter and timer. For these tests the detector was stopped for a set counting time at each of 25 positions over the flow cross section. The total number of counts at each position was output on a teletype while the detector was moving to the next position.

The successive detector positions essentially cover the entire flow area giving a sufficient number of data points to indicate steady state density distributions and to obtain cross sectional average densities very accurately. A detailed description of the scanning densitometer is provided in Appendix A. As a part of the data reduction for the scanning densitometer, background and scattering corrections were applied as required. These corrections were only required when the Am-241 was used and are detailed in Appendix B. Density distributions obtained from the scanning densitometer are presented in Figures 6 through 106. In these figures the chordal average density obtained for each beam is plotted versus the elevation of the beam center (nondimensionalized by the pipe radius).

III. TEST DESCRIPTION

The Air-Water Test Facility where the calibration of the small-break spool piece 41 was carried out consists of a centrifugal pump, air compressor, air-water mixer, separation tank, heat exchanger and associated control valves. Also provided are single phase turbine flow meters, and pressure and temperature measurement instruments necessary to calculate separate mass flow rates of the air and water flows before mixing. Data acquisition and engineering unit conversion was provided by a Hewlet-Packard 2100 computer. Calibration was conducted in horizontal 1-1/2 in. schedule 160 piping.

A pictorial view of the Semiscale Air-Water Test Facility showing the physical location of the test section is given in Figure 5.

1. TEST PROCEDURE

The general test procedure was to establish a desired flow condition and then to collect data during a 16 s sample period consisting of 4600 actual samples per measurement. During this time period, the scan of the scanning densitometer was initiated, and care was taken to maintain constant air and water flow rates until the scan was completed. All data (other than from the scanning densitometer) was recorded on digital magnetic tape and later processed by a computer program which (assuming steady-state conditions) reduced the 4600 actual samples to a single average value per measurement.

Prior to the start of two-phase testing a set of single phase flows (i.e. all water and all air) were run to obtain the single phase drag coefficient of the drag plate. During the two-phase testing, sets of test points were run with a constant air superficial velocity at the test section during the set, and with the water superficial velocity increasing between test points. The flow was returned to zero before and after each set of test points to check for mechanical sticking of the drag force transducer and drift in the differential pressure transducers.

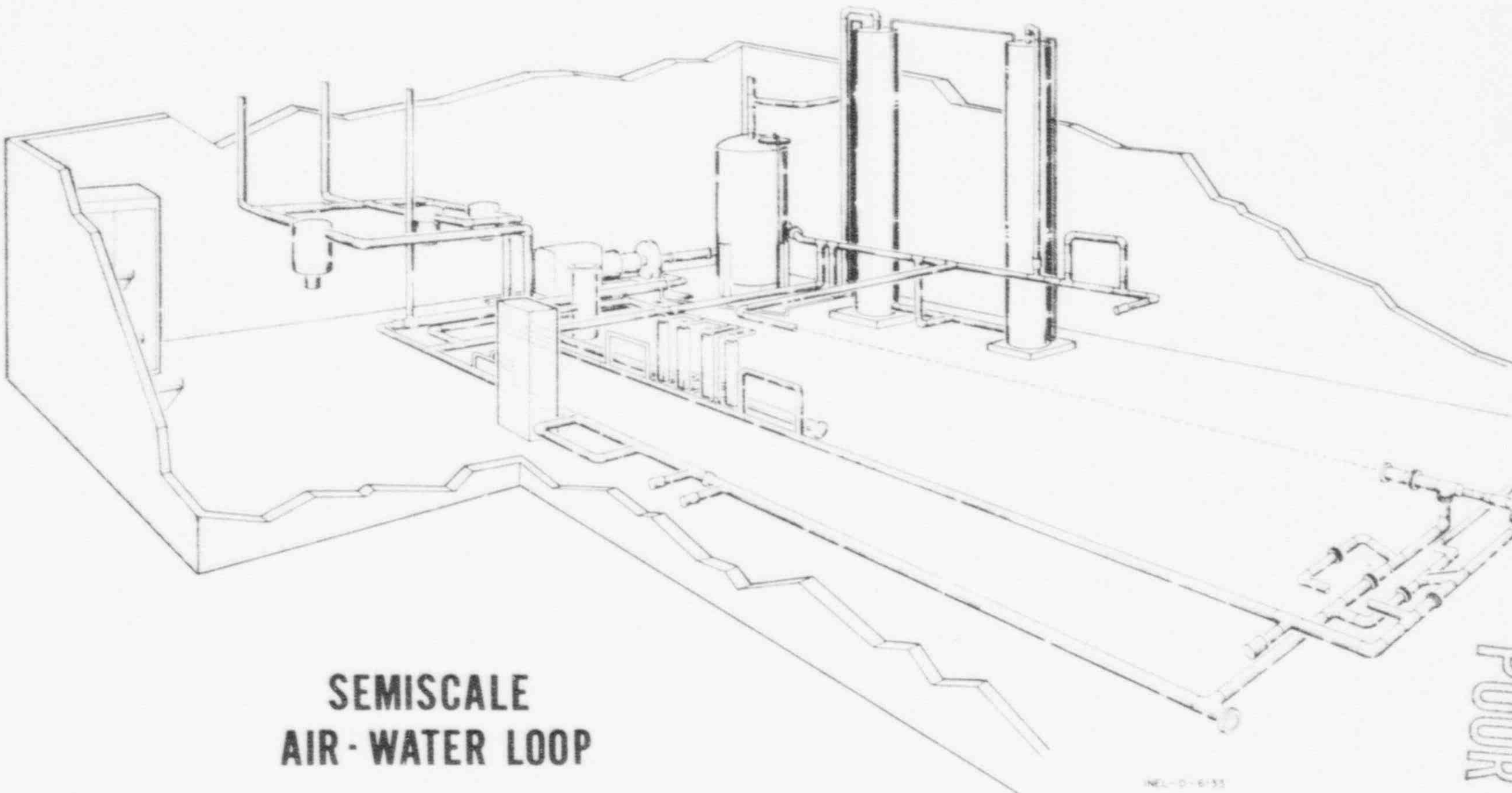

Figure 5. Semiscale Air-Water Test Facility

IV. CALCULATIONAL FORMULAS

The following formulas were used to obtain the thermodynamic properties of the individual phases at the reference turbines and test section, and the mass flow rates of the individual phases.

1. AIR DENSITY

The density of the air is obtained by assuming the ideal gas law, resulting in

$$\rho_A\ (\mathrm{kg/m^3}) = 3.49\ \frac{\mathrm{kg}\text{-}^{\circ}\mathrm{K}}{\mathrm{m^3}\text{-}\mathrm{kPa}}\ \frac{P\ (\mathrm{kPa})}{T\ (^{\circ}\mathrm{K})} \tag{1}$$

where P is the pressure at the measurement location

T is the temperature at the measurement location.

2. WATER DENSITY

The density of the water was obtained using a computerized set of steam tables which are based on the ASME steam tables.[2]

3. AIR VISCOSITY

The viscosity of the air is obtained from a linear fit to a table[1] of air viscosity versus temperature, over the temperature range of 285-430°K. The resulting linear fit is,

$$\mu_A\ (\mathrm{poise}) = \left[-0.846 + 0.1558\sqrt{T(^{\circ}\mathrm{K})}\right] \times 10^{-4} \tag{2}$$

4. WATER VISCOSITY

The formula for the viscosity of the water is given in the ASME Steam Tables[2]

$$\mu_w\ (\mathrm{poise}) = \left\{2.416 \times 10^{\left[\frac{247.8}{T(^{\circ}\mathrm{K})-140}\right]}\right\} \times 10^{-4} \tag{3}$$

5. SURFACE TENSION AT AIR-WATER INTERFACE

The surface tension at the air-water interface is obtained from a third order fit to data, over a temperature range of 290-320°K and is given by

$$\sigma(\text{dynes/cm}) = 4231.77 - 40.272\ T\ (^{\circ}K) + 0.130416\ T\ (^{\circ}K)^2 - 1.41328 \times 10^{-4}\ T\ (^{\circ}K)^3 \quad (4)$$

6. AIR MASS FLOW RATE

The mass flow rate of the air is obtained by multiplying the air density at the reference turbine (obtained from Equation 1 using the temperature and pressure at the turbine) by the volumeteric flow rate as measured by the reference turbine or,

$$\dot{m}_A\ (\text{kg/s}) = \rho_A\ (\text{kg/m}^3) \times \dot{Q}_A(\text{L/s}) \div 1000\ (\text{L/m}^3) \quad (5)$$

7. WATER MASS FLOW RATE

The mass flow rate of the inlet water is similarly obtained by multiplying the water density (obtained from the steam tables based on the fluid temperature) by the volumetric flow rate measured by the reference turbine, or

$$\dot{m}_W\ (\text{kg/s}) = \rho_W\ (\text{kg/m}^3) \times \dot{Q}_W(\text{L/s}) \div 1000\ (\text{L/m}^3) \quad (6)$$

8. FLOW QUALITY

The flow quality of the two-phase mixture is defined as the ratio of the gas mass flow rate to the total mass flow rate and is given by

$$x = \dot{m}_A/(\dot{m}_A + \dot{m}_W) \quad (7)$$

9. VOID FRACTION

The cross-sectional average void fraction of the flow is obtained using the cross-sectional average density, from the scanning densitometer, and the individual phase densities

$$\alpha = (\rho_w - \bar{\rho})/(\rho_w - \rho_a)$$

where $\bar{\rho}$ is the cross-sectional average density from the scanning densitometer.

V. DATA PRESENTATION

The following tables present the time averaged values for the data collected during the three air-water test series reported here. Tables 2, 3, and 4 present the raw data. Tables 5, 6, and 7 present the calculated quantities (i.e. mass flow rates, phase densities, flow qualities, etc.). These quantities are all calculated using the time averaged values from Tables 2-4. Tables 8, 9, and 10 list the thermodynamic fluid properties of the individual phases of the test section using the measured temperature and pressure. Tables 11, 12, and 13 list the data obtained from the pitot tube rakes, in terms of local momentum flux[a], and the pressure drop across the drag device. Density distributions obtained from the scanning densitometer are presented in Figures 6 through 106.

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a. The values listed are equal to twice the measured pressure drop in Pascals (i.e. 1 Pa = 1 kg/m-s^2).

TABLE 2

MEASURED QUANTITIES FOR TEST SERIES SB1

TEST	AIR FLOW (L/s)	AIR TEMP (K)	AIR PRES (kPa)	WATER FLOW (L/s)	WATER TEMP (K)	TEST TEMP (K)	SECTION PRES (kPa)	DRAG FORCE (N)	VOID FRACTION	ΔP_{DRAG} (kPa)
SB09A	0.0000	300.	86.0	1.5300	302.	302.	86.0	.350	0.0000	.5
SB09B	0.0000	300.	86.0	1.5400	309.	309.	86.0	.400	0.0000	.6
SB09C	0.0000	300.	86.0	1.5400	309.	309.	86.0	.380	0.0000	.6
SB10A	0.0000	300.	86.0	2.0300	303.	303.	86.0	.570	0.0000	.9
SB10B	0.0000	300.	86.0	2.0100	309.	309.	86.0	.560	0.0000	.9
SB10C	0.0000	300.	86.0	2.0300	309.	309.	86.0	.540	0.0000	.8
SB11A	0.0000	300.	86.0	2.3400	303.	303.	86.0	.750	0.0000	1.2
SB11B	0.0000	300.	86.0	2.3000	309.	309.	86.0	.740	0.0000	1.1
SB11C	0.0000	300.	86.0	2.3100	310.	309.	86.0	.710	0.0000	1.1
SB12A	0.0000	300.	86.0	2.5900	304.	304.	86.0	.920	0.0000	1.5
SB12B	0.0000	300.	86.0	2.5900	309.	309.	86.0	.930	0.0000	1.5
SB12C	0.0000	300.	86.0	2.5600	310.	310.	86.0	.870	0.0000	1.3
SB13A	0.0000	300.	86.0	3.1400	304.	304.	86.0	1.340	0.0000	2.2
SB13B	0.0000	300.	86.0	3.1100	308.	308.	86.0	1.320	0.0000	2.1
SB13C	0.0000	300.	86.0	3.1500	310.	310.	86.0	1.330	0.0000	2.0
SB14A	0.0000	300.	86.0	3.6200	305.	305.	86.0	1.760	0.0000	2.9
SB14B	0.0000	300.	86.0	3.6200	308.	308.	86.0	1.790	0.0000	2.8
SB14C	0.0000	300.	86.0	3.6200	310.	310.	86.0	1.750	0.0000	2.7
SB15A	0.0000	300.	86.0	4.3900	305.	305.	86.0	2.560	0.0000	4.1
SB15B	0.0000	300.	86.0	4.4200	308.	308.	86.0	2.640	0.0000	4.1
SB15C	0.0000	300.	86.0	4.4600	310.	310.	86.0	2.640	0.0000	4.1
SB16A	0.0000	300.	86.0	5.0600	306.	306.	86.0	3.390	0.0000	5.4
SB16B	0.0000	300.	86.0	5.0700	308.	308.	86.0	3.460	0.0000	5.4
SB16C	0.0000	300.	86.0	5.0600	310.	310.	86.0	3.400	0.0000	5.2
SB17A	0.0000	300.	86.0	5.6600	306.	306.	86.0	4.230	0.0000	6.7
SB17B	0.0000	300.	86.0	5.6500	308.	308.	86.0	4.290	0.0000	6.6
SB17C	0.0000	300.	86.0	5.6400	310.	310.	86.0	4.220	0.0000	6.5
SB18A	0.0000	300.	86.0	8.0100	307.	307.	86.0	8.420	0.0000	12.9
SB18B	0.0000	300.	86.0	7.9600	308.	308.	86.0	8.390	0.0000	12.8
SB18C	0.0000	300.	86.0	8.0000	311.	311.	86.0	8.430	0.0000	12.9
SB19A	0.0000	300.	86.0	8.3700	307.	307.	86.0	9.350	0.0000	14.2
SB19B	0.0000	300.	86.0	8.3600	307.	307.	86.0	9.330	0.0000	14.2
SB19C	0.0000	300.	86.0	8.3800	311.	311.	86.0	9.380	0.0000	14.2
SB27A	10.9800	294.	416.3	0.0000	300.	282.	90.7	.310	1.0000	.5
SB27B	10.0100	296.	414.8	0.0000	300.	293.	89.6	.330	1.0000	.6
SB27C	9.9380	296.	415.3	0.0000	300.	294.	89.2	.320	1.0000	.5
SB28A	15.2200	298.	416.6	0.0000	300.	280.	94.9	.640	1.0000	1.7
SB28B	14.2200	296.	415.3	0.0000	300.	292.	93.7	.640	1.0000	1.9
SB28C	14.1300	296.	415.8	0.0000	300.	294.	93.1	.640	1.0000	1.6
SB29A	21.6100	299.	415.1	0.0000	300.	288.	[illegible]	1.360	1.0000	1.7
SB29B	21.5500	296.	417.9	0.0000	300.	291.	104.0	1.450	1.0000	3.2
SB29C	21.7900	296.	415.5	0.0000	300.	293.	104.0	1.460	1.0000	2.9

TABLE 2 (contd)

TEST	AIR FLOW (L/s)	AIR TEMP (K)	AIR PRES (kPa)	WATER FLOW (L/s)	WATER TEMP (K)	TEST TEMP (K)	SECTION PRES (kPa)	DRAG FORCE (N)	VOID FRACTION	ΔP_{DRAG} (kPa)
SB30A	30.2400	299.	413.8	0.0000	300.	289.	113.9	2.490	1.0000	4.3
SB30B	29.6900	296.	416.5	0.0000	300.	290.	113.6	2.650	1.0000	5.3
SB30C	29.3200	297.	414.4	0.0000	300.	292.	114.7	2.460	1.0000	4.6
SB31A	37.6900	299.	412.1	0.0000	300.	288.	124.6	4.070	1.0000	7.6
SB31B	37.3600	295.	415.8	0.0000	300.	289.	125.3	4.280	1.0000	6.4
SB31C	37.5800	297.	413.2	0.0000	300.	292.	126.8	4.140	1.0000	8.0
SB32A	47.5200	299.	414.6	0.0000	300.	289.	142.9	6.260	1.0000	12.4
SB32B	48.5300	294.	415.6	0.0000	300.	289.	146.1	6.660	1.0000	13.2
SB32C	48.5400	296.	412.1	0.0000	300.	291.	146.5	6.490	1.0000	12.9
SB33A	84.0000	298.	477.6	0.0000	300.	288.	272.5	14.240	1.0000	28.7
SB33B	79.6200	289.	414.9	0.0000	300.	287.	233.7	12.110	1.0000	24.6
SB33C	82.2700	294.	415.5	0.0000	300.	290.	237.7	12.310	1.0000	25.0
SB34A	81.7300	290.	549.8	0.0000	300.	289.	314.1	16.150	1.0000	33.1
SB037	16.7100	299.	707.3	.1900	300.	299.	87.3	5.320	.9879	9.8
SB038	30.8700	303.	694.4	.2000	302.	295.	129.3	10.190	.9920	21.1
SB043	.3600	298.	699.2	4.2300	299.	299.	150.5	5.830	.3431	13.6
SB044	.6500	299.	697.0	4.2000	301.	301.	161.9	6.560	.4205	14.1
SB045	2.6500	301.	697.8	4.1500	303.	304.	222.4	10.530	.5927	19.6
SB046	5.8600	301.	700.6	4.1700	304.	304.	305.2	16.150	.7083	31.0
SB048	17.8700	296.	696.6	4.0600	302.	302.	461.1	27.530	.7965	55.2
SB049	15.8400	296.	696.7	4.0400	303.	303.	461.2	27.250	.7885	54.9
SB056	1.2000	292.	690.0	7.7000	296.	298.	286.2	20.620	.2602	49.7
SB057	2.7900	292.	684.9	7.2900	301.	303.	352.9	23.400	.4075	50.5
SB058	5.0600	293.	690.6	6.8700	304.	304.	418.2	27.200	.5264	56.8
SB059	7.0200	294.	692.7	6.6000	305.	305.	460.0	29.770	.5886	60.8

TABLE 3

MEASURED QUANTITIES FOR TEST SERIES SB2

TEST	AIR FLOW (L/s)	AIR TEMP (K)	AIR PRES (kPa)	WATER FLOW (L/s)	WATER TEMP (K)	TEST TEMP (K)	SECTION PRES (kPa)	DRAG FORCE (N)	VOID FRACTION	ΔP_{DRAG} (kPa)
SB009	0.0000	300.	100.0	1.3530	308.	308.	100.0	.400	0.0000	.7
SB010	0.0000	300.	100.0	1.8330	308.	308.	100.0	.630	0.0000	1.0
SB011	0.0000	300.	100.0	2.8650	309.	309.	100.0	1.480	0.0000	2.2
SB012	0.0000	300.	100.0	4.6890	308.	308.	100.0	3.940	0.0000	5.1
SB013	0.0000	300.	100.0	6.2480	308.	308.	100.0	7.000	0.0000	9.0
SB014	0.0000	300.	100.0	8.2300	308.	308.	100.0	12.390	0.0000	15.7
SB09B	0.0000	300.	100.0	1.3450	312.	312.	100.0	.310	0.0000	15.7
SB10B	0.0000	300.	100.0	1.8200	313.	313.	100.0	.570	0.0000	15.7
SB11B	0.0000	300.	100.0	2.8120	313.	313.	100.0	1.390	0.0000	15.7
SB12B	0.0000	300.	100.0	4.6700	313.	313.	100.0	3.760	0.0000	15.7
SB13B	0.0000	300.	100.0	6.2150	314.	314.	100.0	6.710	0.0000	15.7
SB14B	0.0000	300.	100.0	8.2600	314.	314.	100.0	12.250	0.0000	15.7
SB023	24.0700	306.	344.0	0.0000	300.	295.	141.8	1.050	1.0000	.1
SB024	28.4300	307.	344.6	0.0000	300.	295.	141.4	1.500	1.0000	.7
SB025	35.9900	312.	379.0	0.0000	300.	296.	172.4	2.380	1.0000	2.0
SB026	37.4300	314.	346.2	0.0000	300.	298.	139.6	2.800	1.0000	2.7
SB027	42.2000	313.	345.5	0.0000	300.	302.	142.0	3.640	1.0000	4.0
SB028	60.4100	313.	327.0	0.0000	300.	303.	189.8	10.810	1.0000	16.6
SB030	65.9600	315.	343.4	0.0000	299.	300.	203.7	12.430	1.0000	20.3
SB22B	18.7700	300.	[illegible]	0.0000	300.	299.	140.6	1.450	1.0000	20.3
SB23B	23.5700	301.	[illegible]	0.0000	300.	299.	141.0	1.670	1.0000	20.3
SB24B	28.2500	303.	349.6	0.0000	300.	298.	140.1	1.960	1.0000	20.3
SB25B	33.1200	304.	[illegible]	0.0000	300.	298.	140.4	2.610	1.0000	20.3
SB26B	37.4900	307.	349.5	0.0000	300.	298.	139.7	3.380	1.0000	20.3
SB27B	42.4300	310.	[illegible]	0.0000	300.	298.	139.9	4.420	1.0000	20.3
SB031	56.3000	318.	344.7	.0770	300.	304.	204.5	12.480	.9916	20.3
SB032	70.5500	311.	410.5	.0730	301.	296.	247.5	12.720	.9916	21.1
SB033	68.4600	322.	[illegible]	.1450	302.	297.	254.9	13.400	.9914	22.0
SB034	65.9700	323.	424.0	.2070	302.	299.	264.4	14.250	.9893	23.3
SB035	62.4100	322.	453.2	.2970	303.	301.	276.8	15.520	.9864	25.3
SB036	57.9000	324.	475.9	.4560	303.	301.	295.3	17.870	.9823	29.1
SB037	52.8700	323.	509.8	.6370	303.	301.	315.2	20.820	.9743	32.9
SB038	45.6900	318.	547.0	.9120	303.	302.	339.1	23.120	.9433	35.9
SB039	36.2000	317.	549.3	1.3460	303.	303.	335.0	23.640	.9071	37.5
SB040	[illegible]	312.	550.1	1.8200	303.	303.	318.5	20.220	.8792	33.5

TABLE 3 (contd)

TEST	AIR FLOW (L/s)	AIR TEMP (K)	AIR PRES (kPa)	WATER FLOW (L/s)	WATER TEMP (K)	TEST TEMP (K)	SECTION PRES (kPa)	DRAG FORCE (N)	VOID FRACTION	ΔP_{DRAG} (kPa)
SB042	56.5200	305.	346.7	.0830	303.	295.	208.6	7.040	.9981	10.5
SB043	56.5200	306.	347.0	.1320	304.	296.	208.5	8.600	.9966	12.9
SB044	56.7200	309.	347.0	.1930	305.	298.	208.2	10.370	.9939	15.9
SB045	56.5100	314.	421.6	.2950	305.	300.	252.6	14.050	.9929	22.1
SB046	57.6300	317.	541.3	.4600	305.	302.	334.8	20.780	.9917	33.1
SB048	25.2700	294.	345.2	.0690	298.	289.	138.6	2.630	.9944	3.8
SB049	25.5200	306.	345.3	.1450	301.	293.	137.6	3.710	.9926	5.3
SB050	25.4800	312.	345.4	.2070	302.	296.	141.2	4.350	.9895	6.3
SB051	38.2400	315.	345.9	.2970	306.	300.	208.2	6.900	.9911	10.1
SB052	37.8800	321.	346.2	.4570	309.	305.	208.3	9.560	.9857	14.2
SB053	42.3000	316.	416.5	.6260	309.	307.	277.3	14.280	.9838	21.1
SB054	39.2900	314.	474.2	.9100	309.	307.	295.9	19.270	.9736	30.7
SB058	18.6800	306.	346.2	.2010	310.	303.	124.6	3.170	.9852	5.3
SB059	28.0000	308.	345.8	.2990	311.	306.	194.3	4.600	.9850	7.1
SB060	26.0200	312.	345.8	.4520	311.	308.	196.1	6.170	.9730	9.7
SB061	28.0100	313.	345.3	.6350	311.	309.	197.1	8.250	.9611	13.3
SB062	29.6300	314.	382.9	.9060	311.	310.	237.7	11.070	.9445	18.2
SB063	26.6000	316.	462.5	1.3500	311.	310.	270.3	15.080	.9193	26.3
SB066	11.1600	296.	349.0	.0780	299.	293.	134.2	.400	.9459	1.0
SB067	11.1600	299.	349.3	.1430	302.	293.	133.4	.580	.9293	1.2
SB068	11.2000	302.	349.2	.1880	302.	295.	135.4	.670	.9114	1.3
SB069	11.1400	303.	349.4	.2970	304.	300.	133.3	1.000	.8976	1.8
SB070	11.1300	304.	349.5	.4430	306.	303.	136.0	1.430	.8817	2.6
SB071	11.1700	305.	349.5	.6350	307.	305.	135.9	2.100	.8677	3.6
SB073	7.4800	305.	349.3	.0720	307.	303.	136.0	.160	.9206	.2
SB074	7.5100	306.	349.8	.1390	309.	304.	135.0	.260	.8974	.4
SB075	7.5200	306.	349.8	.2130	310.	306.	135.6	.390	.8846	.6
SB076	7.5200	307.	349.9	.2960	311.	308.	134.2	.570	.8776	1.0
SB077	7.5100	307.	349.7	.4470	312.	309.	135.5	.880	.8636	1.6
SB079	4.6900	295.	418.5	.0810	302.	296.	134.4	.150	.9577	.3
SB080	4.7600	296.	418.9	.1390	307.	297.	133.4	.200	.9319	.4
SB081	4.7200	298.	418.8	.2090	309.	302.	133.6	.290	.9234	.5
SB082	4.7500	300.	418.9	.2990	310.	306.	132.5	.460	.9082	1.0

TABLE 4

MEASURED QUANTITIES FOR TEST SERIES SB3

TEST	AIR FLOW (L/s)	AIR TEMP (K)	AIR PRES (kPa)	WATER FLOW (L/s)	WATER TEMP (K)	TEST TEMP (K)	SECTION PRES (kPa)	DRAG FORCE (N)	VOID FRACTION	ΔP_{DRAG} (kPa)
SB007	0.0000	300.	300.0	.6382	306.	305.	100.0	.110	0.0000	-R [a]
SB008	0.0000	300.	300.0	.9132	305.	304.	100.0	.220	0.0000	-R
SB009	0.0000	300.	300.0	1.3441	304.	304.	100.0	.440	0.0000	-R
SB010	0.0000	300.	300.0	1.8400	303.	303.	100.0	.780	0.0000	-R
SB011	0.0000	300.	300.0	2.8330	302.	302.	100.0	1.820	0.0000	-R
SB012	0.0000	300.	300.0	4.7450	301.	301.	100.0	4.720	0.0000	-R
SB013	0.0000	300.	300.0	6.3220	300.	300.	100.0	8.230	0.0000	-R
SB014	0.0000	300.	300.0	8.2200	299.	299.	100.0	13.910	0.0000	-R
SB020	9.4400	299.	349.9	0.0000	300.	298.	144.6	.130	1.0000	-R
SB021	11.7300	299.	412.0	0.0000	300.	298.	145.8	.300	1.0000	-R
SB022	15.7800	299.	412.3	0.0000	300.	297.	146.2	.670	1.0000	-R
SB023	19.6900	300.	411.7	0.0000	300.	297.	140.5	1.050	1.0000	-R
SB024	23.6700	301.	411.0	0.0000	300.	296.	145.3	1.480	1.0000	-R
SB025	27.5600	303.	411.3	0.0000	300.	296.	146.7	1.890	1.0000	-R
SB026	31.4800	311.	412.1	0.0000	300.	299.	143.0	2.630	1.0000	-R
SB027	35.4500	314.	411.4	0.0000	300.	299.	143.5	3.360	1.0000	-R
SB028	62.5000	318.	665.8	0.0000	300.	300.	280.3	18.080	1.0000	-R
SB030	47.4400	285.	733.6	0.0000	300.	284.	259.7	15.280	1.0000	-R
SB30A	56.3500	299.	692.0	0.0000	300.	286.	280.9	16.690	1.0000	-R
SB031	46.6800	296.	742.1	.0797	303.	290.	294.6	14.050	.9991	-R
SB032	47.3400	307.	738.6	.1391	303.	296.	312.5	15.110	.9978	-R
SB033	47.3300	315.	726.9	.2020	304.	299.	319.2	15.640	.9964	-R
SB034	47.1600	319.	733.7	.2959	305.	302.	338.2	17.200	.9946	-R
SB035	47.5000	320.	734.0	.4496	304.	303.	368.5	18.420	.9922	-R
SB036	47.4300	299.	740.3	.6453	296.	294.	415.3	15.790	.9891	-R
SB037	46.5500	324.	723.7	.9086	300.	300.	415.3	25.120	.9830	-R
SB038	41.3600	326.	755.2	1.3434	302.	302.	432.0	27.340	.9571	-R
SB39B	36.1600	322.	786.9	1.8342	304.	304.	432.0	29.060	.9327	-R
SB40B	25.5700	322.	804.9	2.8579	305.	305.	429.4	28.640	.8978	-R
SB041	31.5700	295.	409.5	0.0000	300.	290.	144.8	2.890	1.0000	-R
SB042	47.4200	296.	411.1	.0799	297.	289.	207.0	6.980	.9958	-R
SB043	46.8700	309.	411.3	.1460	300.	293.	208.5	7.410	.9949	-R
SB044	47.0600	314.	411.5	.1986	301.	296.	209.6	9.150	.9939	-R
SB045	57.7100	314.	414.7	.2951	303.	300.	274.2	23.580	.9932	-R
SB046	47.6200	309.	736.1	.4495	302.	299.	372.5	22.460	.9922	-R
SB047	25.5500	302.	340.1	0.0000	300.	298.	139.1	1.220	1.0000	-R
SB048	25.6600	298.	342.1	.0819	302.	296.	137.2	2.860	.9923	-R
SB049	32.0700	297.	411.1	.1389	302.	296.	205.9	4.340	.9920	-R
SB050	31.8500	305.	411.2	.2030	303.	298.	208.4	4.920	.9908	-R
SB051	32.1000	312.	411.3	.2940	304.	301.	209.0	6.020	.9885	-R
SB052	31.6300	314.	411.3	.4506	305.	303.	209.4	8.060	.9839	-R
SB053	31.7800	315.	411.5	.6351	306.	304.	210.9	10.520	.9773	-R
SB054	36.1400	290.	478.6	.9109	299.	297.	281.0	18.820	.9735	-R
SB055	15.8300	305.	413.4	0.0000	300.	298.	139.5	.660	1.0000	-R

TABLE 4 (contd)

TEST	AIR FLOW (L/s)	AIR TEMP (K)	AIR PRES (kPa)	WATER FLOW (L/s)	WATER TEMP (K)	TEST TEMP (K)	SECTION PRES (kPa)	DRAG FORCE (N)	VOID FRACTION	ΔP_{DRAG} (kPa)
SB056	15.7200	301.	413.7	.0542	305.	297.	136.2	1.260	.9869	-R
SB057	15.7900	303.	414.6	.1465	307.	299.	137.2	2.010	.9832	-R
SB058	15.6000	306.	414.1	.2083	308.	302.	139.2	2.370	.9790	-R
SB059	15.5800	309.	414.2	.2920	308.	304.	140.1	2.930	.9736	-R
SB060	16.1900	310.	413.4	.4529	309.	306.	137.0	4.210	.9650	-R
SB061	23.6500	309.	413.0	.6419	309.	307.	208.5	6.190	.9622	-R
SB062	23.6500	311.	413.1	.9121	309.	308.	207.6	8.330	.9476	-R
SB063	27.0800	317.	481.6	1.3458	309.	308.	275.6	13.260	.9337	-R
SB064	27.5900	322.	479.3	1.5237	308.	308.	284.1	13.900	.9290	-R
SB065	11.3500	300.	355.6	0.0000	300.	300.	138.2	.240	1.0000	-R
SB066	11.2500	298.	352.6	.0665	305.	300.	137.2	.720	.9652	-R
SB067	11.2500	299.	352.4	.1465	307.	302.	138.9	.810	.9629	-R
SB068	11.2500	299.	352.4	.2081	308.	304.	137.9	.990	.9576	-R
SB069	11.2700	300.	351.4	.2933	309.	306.	139.0	1.240	.9496	-R
SB070	11.2600	301.	351.5	.4381	310.	308.	138.0	1.790	.9344	-R
SB071	11.2800	301.	351.3	.6376	311.	309.	138.3	2.530	.9169	-R
SB72B	7.5200	298.	350.7	0.0000	300.	302.	144.1	.110	1.0000	-R
SB073	7.5800	294.	349.6	.0894	308.	304.	138.1	.320	.9546	-R
SB074	7.5400	295.	349.7	.1470	309.	303.	137.7	.390	.9490	-R
SB075	7.5700	298.	349.8	.2081	310.	306.	137.4	.510	.9415	-R
SB076	7.5900	300.	346.5	.2949	311.	308.	137.3	.710	.9296	-R
SB077	7.5200	300.	346.7	.4530	312.	309.	138.5	1.080	.9134	-R

a. -R indicates no data

TABLE 5

MEASURED AND CALCULATED QUANTITIES FOR TEST SERIES SBI

TEST	MASS FLOW RATES (kg/s) AIR	WATER	TOTAL	PHASE DENSITIES (kg/cu-m) AIR	WATER	VOID FRACTION	FLOW QUALITY	DRAG FORCE (N)
SB09A	0.0000	1.5248	1.5248	.993	996.6	0.0000	0.00000	.350
	(0.0000)	(.0158)	(.0158)	(.050)	(.5)	(.0050)	(0.00000)	(.230)
SB09B	0.0000	1.5312	1.5312	.970	994.3	0.0000	0.00000	.400
	(0.0000)	(.0157)	(.0157)	(.049)	(.5)	(.0050)	(0.00000)	(.230)
SB09C	0.0000	1.5312	1.5312	.970	994.3	0.0000	0.00000	.360
	(0.0000)	(.0157)	(.0157)	(.049)	(.5)	(.0050)	(0.00000)	(.230)
SB10A	0.0000	2.0225	2.0225	.989	996.3	0.0000	0.00000	.570
	(0.0000)	(.0314)	(.0314)	(.050)	(.5)	(.0050)	(0.00000)	(.230)
SB10B	0.0000	1.9985	1.9985	.970	994.3	0.0000	0.00000	.560
	(0.0000)	(.0313)	(.0313)	(.049)	(.5)	(.0050)	(0.00000)	(.230)
SB10C	0.0000	2.0184	2.0184	.970	994.3	0.0000	0.00000	.540
	(0.0000)	(.0313)	(.0313)	(.049)	(.5)	(.0050)	(0.00000)	(.230)
SB11A	0.0000	2.3313	2.3313	.989	996.3	0.0000	0.00000	.750
	(0.0000)	(.0314)	(.0314)	(.050)	(.5)	(.0050)	(0.00000)	(.230)
SB11B	0.0000	2.2868	2.2868	.970	994.3	0.0000	0.00000	.740
	(0.0000)	(.0313)	(.0313)	(.049)	(.5)	(.0050)	(0.00000)	(.230)
SB11C	0.0000	2.2959	2.2959	.970	993.9	0.0000	0.00000	.710
	(0.0000)	(.0313)	(.0313)	(.049)	(.5)	(.0050)	(0.00000)	(.230)
SB12A	0.0000	2.5796	2.5796	.986	996.0	0.0000	0.00000	.920
	(0.0000)	(.0314)	(.0314)	(.050)	(.5)	(.0050)	(0.00000)	(.230)
SB12B	0.0000	2.5752	2.5752	.970	994.3	0.0000	0.00000	.930
	(0.0000)	(.0313)	(.0313)	(.049)	(.5)	(.0050)	(0.00000)	(.230)
SB12C	0.0000	2.5444	2.5444	.967	993.9	0.0000	0.00000	.870
	(0.0000)	(.0313)	(.0313)	(.049)	(.5)	(.0050)	(0.00000)	(.230)
SB13A	0.0000	3.1274	3.1274	.986	996.0	0.0000	0.00000	1.340
	(0.0000)	(.0314)	(.0314)	(.050)	(.5)	(.0050)	(0.00000)	(.230)
SB13B	0.0000	3.0933	3.0933	.973	994.6	0.0000	0.00000	1.320
	(0.0000)	(.0314)	(.0314)	(.049)	(.5)	(.0050)	(0.00000)	(.230)
SB13C	0.0000	3.1308	3.1308	.967	993.9	0.0000	0.00000	1.330
	(0.0000)	(.0313)	(.0313)	(.049)	(.5)	(.0050)	(0.00000)	(.230)
SB14A	0.0000	3.6043	3.6043	.983	995.7	0.0000	0.00000	1.760
	(0.0000)	(.1882)	(.1882)	(.050)	(.5)	(.0050)	(0.00000)	(.230)
SB14B	0.0000	3.6006	3.6006	.973	994.6	0.0000	0.00000	1.790
	(0.0000)	(.1880)	(.1880)	(.049)	(.5)	(.0050)	(0.00000)	(.230)
SB14C	0.0000	3.5979	3.5979	.967	993.9	0.0000	0.00000	1.750
	(0.0000)	(.1879)	(.1879)	(.049)	(.5)	(.0050)	(0.00000)	(.230)
SB15A	0.0000	4.3709	4.3709	.983	995.7	0.0000	0.00000	2.360
	(0.0000)	(.1882)	(.1882)	(.050)	(.5)	(.0050)	(0.00000)	(.230)
SB15B	0.0000	4.3963	4.3963	.973	994.6	0.0000	0.00000	2.640
	(0.0000)	(.1880)	(.1880)	(.049)	(.5)	(.0050)	(0.00000)	(.230)
SB15C	0.0000	4.4328	4.4328	.967	993.9	0.0000	0.00000	2.640
	(0.0000)	(.1879)	(.1879)	(.049)	(.5)	(.0050)	(0.00000)	(.230)
SB16A	0.0000	5.0363	5.0363	.980	995.3	0.0000	0.00000	3.390
	(0.0000)	(.1881)	(.1881)	(.049)	(.5)	(.0050)	(0.00000)	(.230)

TABLE 5 (contd)

POOR ORIGINAL

TEST	MASS FLOW RATES (kg/s) AIR	WATER	TOTAL	PHASE DENSITIES (kg/cu-m) AIR	WATER	VOID FRACTION	FLOW QUALITY	DRAG FORCE (N)
SB16B	0.0000 (0.0000)	5.0428 (.1880)	5.0428 (.1880)	.973 (.049)	994.6 (.5)	0.0000 (.0050)	0.00000 (0.00000)	3.460 (.230)
SB16C	0.0000 (0.0000)	5.0291 (.1879)	5.0291 (.1879)	.967 (.049)	993.9 (.5)	0.0000 (.0050)	0.00000 (0.00000)	3.400 (.230)
SB17A	0.0000 (0.0000)	5.6335 (.1881)	5.6335 (.1881)	.980 (.049)	995.3 (.5)	0.0000 (.0050)	0.00000 (0.00000)	4.230 (.230)
SB17B	0.0000 (0.0000)	5.6196 (.1880)	5.6196 (.1880)	.973 (.049)	994.6 (.5)	0.0000 (.0050)	0.00000 (0.00000)	4.290 (.230)
SB17C	0.0000 (0.0000)	5.6056 (.1879)	5.6056 (.1879)	.967 (.049)	993.9 (.5)	0.0000 (.0050)	0.00000 (0.00000)	4.220 (.230)
SB18A	0.0000 (0.0000)	7.9698 (.1881)	7.9698 (.1881)	.976 (.049)	995.0 (.5)	0.0000 (.0050)	0.00000 (0.00000)	8.420 (.230)
SB18B	0.0000 (0.0000)	7.9172 (.1880)	7.9172 (.1880)	.973 (.049)	994.6 (.5)	0.0000 (.0050)	0.00000 (0.00000)	8.390 (.230)
SB18C	0.0000 (0.0000)	7.9481 (.1878)	7.9481 (.1878)	.964 (.049)	993.5 (.5)	0.0000 (.0050)	0.00000 (0.00000)	8.430 (.230)
SB19A	0.0000 (0.0000)	8.3280 (.1881)	8.3280 (.1881)	.976 (.049)	995.0 (.5)	0.0000 (.0050)	0.00000 (0.00000)	9.350 (.230)
SB19B	0.0000 (0.0000)	8.3180 (.1881)	8.3180 (.1881)	.976 (.049)	995.0 (.5)	0.0000 (.0050)	0.00000 (0.00000)	9.330 (.230)
SB19C	0.0000 (0.0000)	8.3257 (.1878)	8.3257 (.1878)	.964 (.049)	993.5 (.5)	0.0000 (.0050)	0.00000 (0.00000)	9.380 (.230)
SB27A	.0542 (.0023)	0.0000 (0.0000)	.0542 (.0023)	1.121 (.054)	997.1 (.5)	1.0000 (.0050)	1.00000 (.05925)	.310 (.230)
SB27B	.0489 (.0021)	0.0000 (0.0000)	.0489 (.0021)	1.066 (.052)	997.1 (.5)	1.0000 (.0050)	1.00000 (.06095)	.330 (.230)
SB27C	.0486 (.0021)	0.0000 (0.0000)	.0486 (.0021)	1.058 (.051)	997.1 (.5)	1.0000 (.0050)	1.00000 (.06103)	.320 (.230)
SB28A	.0742 (.0118)	0.0000 (0.0000)	.0742 (.0118)	1.181 (.054)	997.1 (.5)	1.0000 (.0050)	1.00000 (.22509)	.640 (.230)
SB28B	.0695 (.0118)	0.0000 (0.0000)	.0695 (.0118)	1.118 (.052)	997.1 (.5)	1.0000 (.0050)	1.00000 (.24018)	.640 (.230)
SB28C	.0692 (.0118)	0.0000 (0.0000)	.0692 (.0118)	1.104 (.052)	997.1 (.5)	1.0000 (.0050)	1.00000 (.24163)	.640 (.230)
SB29A	.1046 (.0120)	0.0000 (0.0000)	.1046 (.0120)	1.233 (.053)	997.1 (.5)	1.0000 (.0050)	1.00000 (.16254)	1.360 (.230)
SB29B	.1060 (.0122)	0.0000 (0.0000)	.1060 (.0122)	1.246 (.052)	997.1 (.5)	1.0000 (.0050)	1.00000 (.16295)	1.450 (.230)
SB29C	.1066 (.0122)	0.0000 (0.0000)	.1066 (.0122)	1.237 (.052)	997.1 (.5)	1.0000 (.0050)	1.00000 (.16142)	1.460 (.230)
SB30A	.1459 (.0125)	0.0000 (0.0000)	.1459 (.0125)	1.374 (.053)	997.1 (.5)	1.0000 (.0050)	1.00000 (.12163)	2.490 (.230)
SB30B	.1456 (.0127)	0.0000 (0.0000)	.1456 (.0127)	1.368 (.053)	997.1 (.5)	1.0000 (.0050)	1.00000 (.12337)	2.650 (.230)
SB30C	.1426 (.0126)	0.0000 (0.0000)	.1426 (.0126)	1.369 (.052)	997.1 (.5)	1.0000 (.0050)	1.00000 (.12476)	2.460 (.230)
SB31A	.1811 (.0131)	0.0000 (0.0000)	.1811 (.0131)	1.506 (.053)	997.1 (.5)	1.0000 (.0050)	1.00000 (.10235)	4.070 (.230)

POOR ORIGINAL

TABLE 5 (contd)

TEST	MASS FLOW RATES (kg/s) AIR	WATER	TOTAL	PHASE DENSITIES (kg/cu-m) AIR	WATER	VOID FRACTION	FLOW QUALITY	DRAG FORCE (N)
SB31B	.1835	0.0000	.1835	1.511	997.1	1.0000	1.00000	4.280
	(.0133)	(0.0000)	(.0133)	(.053)	(.5)	(.0050)	(.10282)	(.230)
SB31C	.1822	0.0000	.1822	1.514	997.1	1.0000	1.00000	4.140
	(.0132)	(0.0000)	(.0132)	(.052)	(.5)	(.0050)	(.10252)	(.230)
SB32A	.2297	0.0000	.2297	1.723	997.1	1.0000	1.00000	6.260
	(.0141)	(0.0000)	(.0141)	(.053)	(.5)	(.0050)	(.08681)	(.230)
SB32B	.2391	0.0000	.2391	1.786	997.1	1.0000	1.00000	6.660
	(.0145)	(0.0000)	(.0145)	(.053)	(.5)	(.0050)	(.08556)	(.230)
SB32C	.2355	0.0000	.2355	1.755	997.1	1.0000	1.00000	6.490
	(.0143)	(0.0000)	(.0143)	(.053)	(.5)	(.0050)	(.08581)	(.230)
SB33A	.4692	0.0000	.4692	3.298	997.1	1.0000	1.00000	14.240
	(.0198)	(0.0000)	(.0198)	(.057)	(.5)	(.0050)	(.05969)	(.230)
SB33B	.3984	0.0000	.3984	2.838	997.1	1.0000	1.00000	12.110
	(.0186)	(0.0000)	(.0186)	(.056)	(.5)	(.0050)	(.06606)	(.230)
SB33C	.4053	0.0000	.4053	2.857	997.1	1.0000	1.00000	12.310
	(.0187)	(0.0000)	(.0187)	(.055)	(.5)	(.0050)	(.06513)	(.230)
SB34A	.5401	0.0000	.5401	3.788	997.1	1.0000	1.00000	16.150
	(.0216)	(0.0000)	(.0216)	(.058)	(.5)	(.0050)	(.05650)	(.230)
SB037	.1378	.1895	.3272	1.018	997.1	.9879	.42104	5.320
	(.0197)	(.0158)	(.0541)	(.051)	(.5)	(.0050)	(.09202)	(.230)
SB038	.2466	.1993	.4459	1.528	996.6	.9920	.55301	10.190
	(.0196)	(.0157)	(.0500)	(.052)	(.5)	(.0050)	(.07605)	(.230)
SB043	.0029	4.2190	4.2219	1.754	997.4	.3431	.00070	5.630
	(.0019)	(.1885)	(2.7757)	(.051)	(.5)	(.0050)	(.00065)	(.230)
SB044	.0053	4.1868	4.1921	1.875	996.9	.4205	.00126	6.560
	(.0019)	(.1884)	(1.5365)	(.051)	(.5)	(.0050)	(.00065)	(.230)
SB045	.0214	4.1346	4.1560	2.550	996.3	.5927	.00515	10.530
	(.0020)	(.1883)	(.4257)	(.052)	(.5)	(.0050)	(.00071)	(.230)
SB046	.0475	4.1532	4.2007	3.499	996.0	.7083	.01132	16.150
	(.0022)	(.1883)	(.2710)	(.054)	(.5)	(.0050)	(.00090)	(.230)
SB048	.1466	4.0461	4.1927	5.322	996.6	.7965	.03496	27.530
	(.0196)	(.1884)	(.5944)	(.061)	(.5)	(.0050)	(.00682)	(.230)
SB049	.1300	4.0250	4.1549	5.305	996.3	.7885	.03128	27.250
	(.0196)	(.1883)	(.6553)	(.061)	(.5)	(.0050)	(.00682)	(.230)
SB056	.0099	7.6854	7.6953	3.348	998.1	.2602	.00128	20.620
	(.0020)	(.1887)	(1.5348)	(.055)	(.5)	(.0050)	(.00036)	(.230)
SB057	.0228	7.2671	7.2900	4.060	996.9	.4075	.00313	23.400
	(.0020)	(.1884)	(.6655)	(.056)	(.5)	(.0050)	(.00040)	(.230)
SB058	.0416	6.8423	6.8839	4.795	996.0	.5264	.00604	27.200
	(.0022)	(.1883)	(.4083)	(.059)	(.5)	(.0050)	(.00047)	(.230)
SB059	.0577	6.5713	6.6290	5.257	995.7	.5886	.00870	29.770
	(.0023)	(.1882)	(.3279)	(.060)	(.5)	(.0050)	(.00056)	(.230)

a. Numbers in parentheses are the uncertainties in the quantities immediately above. The 95% confidence level was used.

TABLE 6

MEASURED AND CALCULATED QUANTITIES FOR TEST SERIES SB2

TEST	MASS FLOW RATES (kg/s) AIR	WATER	TOTAL	PHASE DENSITIES (kg/cu-m) AIR	WATER	VOID FRACTION	FLOW QUALITY	DRAG FORCE (N)
SB009	0.0000 (0.0000)[a]	1.3457 (.0157)	1.3457 (.0157)	1.132 (.049)	994.6 (.5)	0.0000 (.0050)	0.00000 (0.00000)	.400 (.230)
SB010	0.0000 (0.0000)	1.8232 (.0313)	1.8232 (.0313)	1.132 (.049)	994.6 (.5)	0.0000 (.0050)	0.00000 (0.00000)	.630 (.230)
SB011	0.0000 (0.0000)	2.6488 (.0314)	2.6488 (.0314)	1.128 (.049)	994.3 (.5)	0.0000 (.0050)	0.00000 (0.00000)	1.480 (.230)
SB012	0.0000 (0.0000)	4.6638 (.1880)	4.6638 (.1880)	1.132 (.049)	994.6 (.5)	0.0000 (.0050)	0.00000 (0.00000)	3.940 (.230)
SB013	0.0000 (0.0000)	6.2144 (.1950)	6.2144 (.1880)	1.132 (.049)	994.6 (.5)	0.0000 (.0050)	0.00000 (0.00000)	7.000 (.230)
SB014	0.0000 (0.0000)	8.1858 (.1880)	8.1858 (.1880)	1.132 (.049)	994.6 (.5)	0.0000 (.0050)	0.00000 (0.00000)	12.390 (.230)
SB09B	0.0000 (0.0000)	1.3358 (.0157)	1.3358 (.0157)	1.117 (.049)	993.1 (.5)	0.0000 (.0050)	0.00000 (0.00000)	.310 (.080)
SB10B	0.0000 (0.0000)	1.8068 (.0313)	1.8068 (.0313)	1.114 (.048)	992.7 (.5)	0.0000 (.0050)	0.00000 (0.00000)	.570 (.080)
SB11B	0.0000 (0.0000)	2.7915 (.0313)	2.7915 (.0313)	1.114 (.048)	992.7 (.5)	0.0000 (.0050)	0.00000 (0.00000)	1.390 (.080)
SB12B	0.0000 (0.0000)	4.6360 (.1876)	4.6360 (.1876)	1.114 (.048)	992.7 (.5)	0.0000 (.0050)	0.00000 (0.00000)	3.760 (.080)
SB13B	0.0000 (0.0000)	6.1673 (.1876)	6.1673 (.1876)	1.110 (.048)	992.3 (.5)	0.0000 (.0050)	0.00000 (0.00000)	6.710 (.080)
SB14B	0.0000 (0.0000)	8.1955 (.1876)	8.1955 (.1876)	1.110 (.048)	992.3 (.5)	0.0000 (.0050)	0.00000 (0.00000)	12.250 (.080)
SB023	.0943 (.0101)	0.0000 (0.0000)	.0943 (.0101)	1.675 (.052)	997.1 (.5)	1.0000 (.0050)	1.00000 (.15154)	1.050 (.230)
SB024	.1112 (.0104)	0.0000 (0.0000)	.1112 (.0104)	1.671 (.052)	997.1 (.5)	1.0000 (.0050)	1.00000 (.13231)	1.500 (.230)
SB025	.1524 (.0117)	0.0000 (0.0000)	.1524 (.0117)	[illegible] (.052)	997.1 (.5)	1.0000 (.0050)	1.00000 (.10812)	2.380 (.230)
SB026	.1438 (.0110)	0.0000 (0.0000)	.1438 (.0110)	1.533 (.051)	997.1 (.5)	1.0000 (.0050)	1.00000 (.10788)	2.600 (.230)
SB027	.1624 (.0115)	0.0000 (0.0000)	.1624 (.0115)	1.639 (.051)	997.1 (.5)	1.0000 (.0050)	1.00000 (.09979)	3.640 (.230)
SB028	.2928 (.0158)	0.0000 (0.0000)	.2928 (.0158)	2.183 (.052)	997.1 (.5)	1.0000 (.0050)	1.00000 (.07646)	10.610 (.230)
SB030	.3266 (.0167)	0.0000 (0.0000)	.3266 (.0167)	2.367 ([illegible])	997.4 (.5)	1.0000 (.0050)	1.00000 (.07248)	12.430 (.230)
SB22B	.0764 (.0101)	0.0000 ([illegible])	.0764 (.0101)	1.639 (.051)	997.1 (.5)	1.0000 (.0050)	1.00000 (.18768)	1.450 (.080)
SB23B	.0955 (.0104)	0.0000 (0.0000)	.0955 (.0104)	1.644 (.051)	997.1 (.5)	1.0000 (.0050)	1.00000 (.15384)	1.670 (.080)
SB24B	.1136 (.0107)	0.0000 (0.0000)	.1136 (.0107)	1.639 (.051)	997.1 (.5)	1.0000 (.0050)	1.00000 (.13259)	1.960 (.080)
SB25B	.1328 (.0110)	0.0000 (0.0000)	.1328 (.0110)	1.642 (.051)	997.1 (.5)	1.0000 (.0050)	1.00000 (.11736)	2.610 (.080)
SB26B	.1488 (.0113)	0.0000 (0.0000)	.1488 (.0113)	[illegible] (.051)	997.1 (.5)	1.0000 (.0050)	1.00000 (.10746)	3.380 (.080)
SB27B	.1667 (.0117)	0.0000 (0.0000)	.1667 (.0117)	1.636 ([illegible])	997.1 (.5)	1.0000 (.0050)	1.00000 (.09932)	4.420 (.080)

POOR ORIGINAL

TABLE 6 (contd)

TEST	MASS FLOW RATES (kg/s) AIR	WATER	TOTAL	PHASE DENSITIES (kg/cu-m) AIR	WATER	VOID FRACTION	FLOW QUALITY	DRAG FORCE (N)
SB031	.3261 (.0166)	.0768 (.0156)	.4028 (.0282)	2.345 (.052)	997.1 (.5)	.9916 (.0050)	.80940 (.17607)	12.480 (.230)
SB032	.3246 (.0160)	.0728 (.0156)	.3972 (.0282)	2.914 (.054)	996.9 (.5)	.9916 (.0050)	.81686 (.18579)	12.720 (.230)
SB033	.3115 (.0154)	.1445 (.0157)	.4560 (.0546)	2.991 (.054)	996.6 (.5)	.9914 (.0050)	.68314 (.08847)	13.400 (.230)
SB034	.3090 (.0153)	.2063 (.0157)	.5153 (.0469)	3.082 (.054)	996.6 (.5)	.9893 (.0050)	.59963 (.06219)	14.250 (.230)
SB035	.3052 (.0153)	.2959 (.0157)	.6011 (.0440)	3.205 (.054)	996.3 (.5)	.9864 (.0050)	.50775 (.04505)	15.520 (.230)
SB036	.2983 (.0153)	.4543 (.0157)	.7526 (.0467)	3.420 (.055)	996.3 (.5)	.9823 (.0050)	.39635 (.03192)	17.670 (.230)
SB037	.2909 (.0156)	.6346 (.0157)	.9255 (.0546)	3.650 (.055)	996.3 (.5)	.9743 (.0050)	.31431 (.02503)	20.820 (.230)
SB038	.2751 (.0161)	.9086 (.0157)	1.1837 (.0721)	3.914 (.056)	996.3 (.5)	.9433 (.0050)	.23243 (.01960)	23.120 (.230)
SB039	.2186 (.0155)	1.3410 (.0158)	1.5596 (.1119)	3.854 (.056)	996.3 (.5)	.9071 (.0050)	.14019 (.01412)	23.640 (.230)
SB040	.1734 (.0153)	1.8132 (.0314)	1.9867 (.1762)	3.664 (.055)	996.3 (.5)	.8792 (.0050)	.08730 (.01097)	20.220 (.230)
SB042	.2239 (.0134)	.0827 (.0157)	.3066 (.0612)	2.465 (.053)	996.3 (.5)	.9981 (.0050)	.73032 (.15216)	7.040 (.230)
SB043	.2219 (.0133)	.1315 (.0157)	.3534 (.0473)	2.455 (.053)	996.0 (.5)	.9966 (.0050)	.62801 (.09206)	8.600 (.230)
SB044	.2220 (.0135)	.1922 (.0157)	.4142 (.0420)	2.435 (.053)	995.7 (.5)	.9939 (.0050)	.53604 (.06306)	10.370 (.230)
SB045	.2645 (.0145)	.2937 (.0157)	.5582 (.0428)	2.935 (.054)	995.7 (.5)	.9929 (.0050)	.47380 (.04452)	14.050 (.230)
SB046	.3430 (.0170)	[illegible] (.0157)	[illegible] (.0483)	3.804 (.056)	995.7 (.5)	.9917 (.0050)	.42822 (.03341)	20.780 (.230)
SB048	.1034 (.0106)	.0688 (.0158)	.1722 (.0432)	1.672 (.052)	997.6 (.5)	.9944 (.0050)	.60038 (.16288)	2.630 (.230)
SB049	.1004 (.0102)	.1445 (.0156)	.2449 (.0360)	1.637 (.052)	996.9 (.5)	.9928 (.0050)	.40983 (.07410)	3.710 (.230)
SB050	.0983 (.0100)	.2063 (.0157)	.3046 ([illegible])	1.663 ([illegible])	996.6 (.5)	.9895 (.0050)	.32277 (.05273)	4.350 (.230)
SB051	.1464 (.0110)	.2986 (.0157)	.4450 (.0407)	2.41[illegible] ([illegible])	995.3 (.5)	.9911 (.0050)	.32116 (.03938)	6.900 (.230)
SB052	.1424 (.0108)	.4544 (.0157)	.5968 (.0496)	2.360 (.052)	994.3 (.5)	.9857 (.0050)	.23861 (.02683)	9.560 (.230)
SB053	.1943 (.0129)	.6234 (.0157)	.8167 (.0566)	3.143 (.053)	994.3 (.5)	.9838 (.0050)	.23793 (.02211)	14.280 (.230)
SB054	.2068 (.0140)	.9048 (.0157)	1.1116 (.0779)	3.360 (.054)	994.3 (.5)	.9736 (.0050)	.18605 (.01815)	19.270 (.230)
SB056	.0737 (.0098)	.1998 (.0157)	.2734 (.0423)	1.433 (.050)	993.9 (.5)	.9852 (.0050)	.26940 (.05507)	3.170 (.080)
SB059	.1096 (.0104)	.2971 (.0157)	.4066 (.0461)	2.213 (.051)	993.5 (.5)	.9850 (.0050)	.26946 (.03877)	4.600 (.080)

TABLE 6 (contd)

TEST	MASS FLOW RATES (kg/s) AIR	WATER	TOTAL	PHASE DENSITIES (kg/cu-m) AIR	WATER	VOID FRACTION	FLOW QUALITY	DRAG FORCE (N)
SB060	.1082	.4491	.5573	2.219	993.5	.9730	.19423	6.170
	(.0102)	(.0157)	(.0562)	(.051)	(.5)	(.0050)	(.02685)	(.080)
SB061	.1080	.6309	.7389	2.223	993.5	.9611	.14619	6.250
	(.0102)	(.0157)	(.0723)	(.051)	(.5)	(.0050)	(.01988)	(.080)
SB062	.1259	.9001	1.0261	2.673	993.5	.9445	.12274	11.070
	(.0112)	(.0157)	(.0927)	(.051)	(.5)	(.0050)	(.01554)	(.080)
SB063	.1416	1.3412	1.4826	3.039	993.5	.9193	.09547	15.080
	(.0133)	(.0157)	(.1405)	(.052)	(.5)	(.0050)	(.01274)	(.080)
SB066	.0459	.0778	.1237	1.596	997.4	.9459	.37088	.400
	(.0022)	(.0158)	(.0257)	(.052)	(.5)	(.0050)	(.07917)	(.080)
SB067	.0454	.1425	.1880	1.587	996.6	.9293	.24178	.580
	(.0022)	(.0157)	(.0226)	(.052)	(.5)	(.0050)	(.03128)	(.080)
SB068	.0451	.1874	.2325	1.576	996.6	.9114	.19415	.670
	(.0021)	(.0157)	(.0224)	(.051)	(.5)	(.0050)	(.02090)	(.080)
SB069	.0448	.2958	.3406	1.549	996.0	.8978	.13147	1.000
	(.0021)	(.0157)	(.0243)	(.051)	(.5)	(.0050)	(.01127)	(.080)
SB070	.0446	.4409	.4855	1.564	995.3	.8817	.09186	1.430
	(.0021)	(.0157)	(.0289)	(.051)	(.5)	(.0050)	(.00699)	(.080)
SB071	.0446	.6318	.6764	1.553	995.0	.8677	.06596	2.100
	(.0021)	(.0157)	(.0363)	(.050)	(.5)	(.0050)	(.00473)	(.080)
SB073	.0299	.0716	.1015	1.564	995.0	.9206	.29418	.160
	(.0016)	(.0157)	(.0229)	(.051)	(.5)	(.0050)	(.06822)	(.080)
SB074	.0299	.1382	.1681	1.548	994.3	.8974	.17798	.260
	(.0016)	(.0157)	(.0211)	(.050)	(.5)	(.0050)	(.02422)	(.080)
SB075	.0300	.2117	.2417	1.545	993.9	.8848	.12399	.390
	(.0016)	(.0157)	(.0220)	(.050)	(.5)	(.0050)	(.01306)	(.080)
SB076	.0299	.2941	.3240	1.519	993.5	.8778	.09222	.570
	(.0016)	(.0157)	(.0243)	(.050)	(.5)	(.0050)	(.00847)	(.080)
SB077	.0298	.4439	.4737	1.528	99[illegible].1	.8636	.06294	.880
	(.0016)	(.0157)	[illegible]	[illegible]	(.5)	(.0050)	(.00521)	(.080)
SB079	.0232	.0815	.1047	1.583	996.6	.9577	.22147	.150
	(.0014)	(.0157)	(.0212)	(.052)	(.5)	(.0050)	(.04695)	(.080)
SB080	.0235	.1383	.1618	1.566	995.0	.9319	.14513	.200
	(.0014)	(.0157)	(.0209)	(.052)	(.5)	(.0050)	(.02072)	(.080)
SB081	.0231	.2478	[illegible]	1.542	994.3	.9234	.10012	.290
	(.0014)	(.0157)	(.0221)	[illegible]	(.5)	(.0050)	(.01153)	(.080)
SB082	.0231	[illegible]	[illegible]	[illegible]	993.9	.9082	.07218	.460
	(.0014)	(.0157)	(.0259)	[illegible]	(.5)	(.0050)	(.00732)	(.080)

a. Numbers in the parentheses are the uncertainties in the quantities immediately above. The 95% confidence level was used.

TABLE 7

POOR ORIGINAL

MEASURED AND CALCULATED QUANTITIES FOR TEST SERIES SB3

TEST	MASS FLOW RATES (kg/s) AIR	WATER	TOTAL	PHASE DENSITIES (kg/cu-m) AIR	WATER	VOID FRACTION	FLOW QUALITY	DRAG FORCE (N)
SB007	0.0000 (0.0000)[a]	.6352 (.0157)	.6352 (.0157)	1.143 (.050)	995.3 (.5)	0.0000 (.0007)	0.00000 (0.00000)	.110 (.093)
SB008	0.0000 (0.0000)	.9092 (.0157)	.9092 (.0157)	1.147 (.050)	995.7 (.5)	0.0000 (.0007)	0.00000 (0.00000)	.220 (.093)
SB009	0.0000 (0.0000)	1.3387 (.0158)	1.3387 (.0158)	1.147 (.050)	996.0 (.5)	0.0000 (.0007)	0.00000 (0.00000)	.440 (.093)
SB010	0.0000 (0.0000)	1.8332 (.0314)	1.8332 (.0314)	1.150 (.050)	996.3 (.5)	0.0000 (.0007)	0.00000 (0.00000)	.780 (.093)
SB011	0.0000 (0.0000)	2.8233 (.0314)	2.8223 (.0314)	1.154 (.050)	996.6 (.5)	0.0000 (.0007)	0.00000 (0.00000)	1.820 (.093)
SB012	0.0000 (0.0000)	4.7301 (.1884)	4.7301 (.1884)	1.156 (.050)	996.9 (.5)	0.0000 (.0007)	0.00000 (0.00000)	4.720 (.093)
SB013	0.0000 (0.0000)	6.3039 (.1885)	6.3039 (.1885)	1.162 (.051)	997.1 (.5)	0.0000 (.0007)	0.00000 (0.00000)	6.220 (.093)
SB014	0.0000 (0.0000)	8.1986 (.1886)	8.1986 (.1886)	1.166 (.051)	997.4 (.5)	0.0000 (.0007)	0.00000 (0.00000)	13.910 (.093)
SB020	.0385 (.0019)	0.0000 (0.0000)	.0385 (.0019)	1.691 (.052)	997.1 (.5)	1.0000 (.0007)	1.00000 (.05978)	.130 (.093)
SB021	.0563 (.0023)	0.0000 (0.0000)	.0563 (.0023)	1.705 (.052)	997.1 (.5)	1.0000 (.0007)	1.00000 (.05870)	.300 (.093)
SB022	.0758 (.0117)	0.0000 (0.0000)	.0758 (.0117)	1.716 (.052)	997.1 (.5)	1.0000 (.0007)	1.00000 (.21764)	.670 (.093)
SB023	.0942 (.0118)	0.0000 (0.0000)	.0942 (.0118)	1.649 (.052)	997.1 (.5)	1.0000 (.0007)	1.00000 (.17712)	1.050 (.093)
SB024	.1127 (.0120)	0.0000 (0.0000)	.1127 (.0120)	1.711 (.052)	997.1 (.5)	1.0000 (.0007)	1.00000 (.15010)	1.480 (.093)
SB025	.1304 (.0121)	0.0000 (0.0000)	.1304 (.0121)	1.727 (.052)	997.1 (.5)	1.0000 (.0007)	1.00000 (.13156)	1.890 (.093)
SB026	.1454 (.0121)	0.0000 (0.0000)	.1454 (.0121)	1.667 (.051)	997.1 (.5)	1.0000 (.0007)	1.00000 (.11776)	2.630 (.093)
SB027	.1619 (.0123)	0.0000 (0.0000)	.1619 (.0123)	1.673 (.051)	997.1 (.5)	1.0000 (.0007)	1.00000 (.10723)	3.360 (.093)
SB028	.4561 (.0202)	0.0000 (0.0000)	.4561 (.0202)	3.257 (.054)	997.1 (.5)	1.0000 (.0007)	1.00000 (.06250)	16.080 (.093)
SB030	.4197 (.0227)	0.0000 (0.0000)	.4197 (.0227)	3.187 (.057)	997.1 (.5)	1.0000 (.0007)	1.00000 (.07647)	15.280 (.093)
SB30A	.4546 (.0216)	0.0000 (0.0000)	.4546 (.0216)	3.423 (.058)	997.1 (.5)	1.0000 (.0007)	1.00000 (.06708)	16.690 (.093)
SB031	.4079 (.0222)	.0794 (.0157)	.4873 (.1002)	3.541 (.057)	996.3 (.5)	.9991 (.0007)	.83706 (.17814)	14.050 (.093)
SB032	.3970 (.0215)	.1386 (.0157)	.5356 (.0674)	3.680 (.056)	996.3 (.5)	.9978 (.0007)	.74124 (.10150)	15.110 (.093)
SB033	.3607 (.0206)	.2012 (.0157)	.5619 (.0554)	3.721 (.056)	996.0 (.5)	.9964 (.0007)	.65424 (.07164)	15.640 (.093)
SB034	.3781 (.0205)	.2946 (.0157)	.6727 (.0512)	3.903 (.056)	995.7 (.5)	.9948 (.0007)	.56203 (.05255)	17.200 (.093)

TABLE 7 (contd)

TEST	MASS FLOW RATES (kg/s) AIR	WATER	TOTAL	PHASE DENSITIES (kg/cu-m) AIR	WATER	VOID FRACTION	FLOW QUALITY	DRAG FORCE (N)
SB035	.3798 (.0205)	.4478 (.0157)	.8275 (.0533)	4.239 (.057)	996.0 (.5)	.9922 (.0007)	.45890 (.03854)	18.420 (.093)
SB036	.4093 (.0221)	.6441 (.0158)	1.0534 (.0624)	4.924 (.061)	998.1 (.5)	.9891 (.0007)	.38857 (.03116)	15.790 (.093)
SB037	.3624 (.0199)	.9060 (.0158)	1.2684 (.0731)	4.825 (.059)	997.1 (.5)	.9830 (.0007)	.28572 (.02276)	25.120 (.140)
SB038	.3340 (.0202)	1.3388 (.0156)	1.6728 (.1033)	4.986 (.060)	996.6 (.5)	.9671 (.0007)	.19965 (.01727)	27.340 (.140)
SB39B	.3080 (.0210)	1.8268 (.0314)	2.1348 (.1501)	4.953 (.059)	996.0 (.5)	.9327 (.0007)	.14428 (.01413)	29.060 (.140)
SB40B	.2228 (.0210)	2.8455 (.0314)	3.0683 (.2913)	4.907 (.059)	995.7 (.5)	.8878 (.0007)	.07261 (.00972)	28.640 (.140)
SB041	.1527 (.0127)	0.0000 (0.0000)	.1527 (.0127)	1.740 (.053)	997.1 (.5)	1.0000 (.0007)	1.00000 (.11767)	2.890 (.093)
SB042	.2296 (.0142)	.0797 (.0158)	.3093 (.0641)	2.497 (.055)	997.9 (.5)	.9958 (.0007)	.74221 (.16040)	6.980 (.093)
SB043	.2175 (.0135)	.1456 (.0158)	.3630 (.0453)	2.480 (.054)	997.1 (.5)	.9949 (.0007)	.59899 (.08347)	7.410 (.093)
SB044	.2150 (.0133)	.1980 (.0158)	.4129 (.0416)	2.468 (.053)	996.9 (.5)	.9939 (.0007)	.52057 (.06158)	9.150 (.093)
SB045	.2657 (.0145)	.2940 (.0157)	.5597 (.0426)	3.186 (.054)	996.3 (.5)	.9932 (.0007)	.47468 (.04454)	23.680 (.140)
SB046	.3954 (.0213)	.4480 (.0157)	.8434 (.0542)	4.342 (.058)	996.6 (.5)	.9922 (.0007)	.46884 (.03931)	22.460 (.140)
SB047	.1003 (.0102)	0.0000 (0.0000)	.1003 (.0102)	1.627 (.051)	997.1 (.5)	1.0000 (.0007)	1.00000 (.14453)	1.220 (.093)
SB048	.1027 (.0104)	.0816 (.0157)	.1843 (.0402)	1.616 (.052)	996.6 (.5)	.9923 (.0007)	.55712 (.13408)	2.660 (.093)
SB049	.1547 (.0127)	.1384 (.0157)	.2931 (.0411)	2.425 (.053)	996.6 (.5)	.9920 (.0007)	.52780 (.08579)	4.340 (.093)
SB050	.1497 (.0124)	.2022 (.0157)	.3519 (.0399)	2.438 (.053)	996.3 (.5)	.9908 (.0007)	.42530 (.05966)	4.920 (.093)
SB051	.1475 (.0121)	.2928 (.0157)	.4403 (.0432)	2.420 (.052)	996.0 (.5)	.9885 (.0007)	.33498 (.04281)	6.020 (.093)
SB052	.1444 (.0120)	.4486 (.0157)	.5931 (.0534)	2.409 (.052)	995.7 (.5)	.9839 (.0007)	.24350 (.02982)	8.060 (.093)
SB053	.1447 (.0120)	.6321 (.0157)	.7768 (.0671)	2.418 (.052)	995.3 (.5)	.9773 (.0007)	.18628 (.02226)	10.520 (.093)
SB054	.2079 (.0151)	.9085 (.0158)	1.1164 (.0832)	3.298 (.055)	997.4 (.5)	.9735 (.0007)	.18621 (.01936)	18.820 (.140)
SB055	.0748 (.0115)	0.0000 (0.0000)	.0748 (.0115)	1.632 (.051)	997.1 (.5)	1.0000 (.0007)	1.00000 (.21695)	.660 (.093)
SB056	.0753 (.0116)	.0540 (.0157)	.1293 (.0426)	1.598 (.052)	995.7 (.5)	.9869 (.0007)	.58255 (.21219)	1.260 (.093)
SB057	.0753 (.0116)	.1458 (.0157)	.2211 (.0415)	1.599 (.051)	995.0 (.5)	.9832 (.0007)	.34065 (.08268)	2.010 (.093)

TABLE 7 (contd)

TEST	MASS FLOW RATES (kg/s) AIR	WATER	TOTAL	PHASE DENSITIES (kg/cu-m) AIR	WATER	VOID FRACTION	FLOW QUALITY	DRAG FORCE (N)
SB058	.0736	.2072	.2808	1.607	994.6	.9790	.26208	2.370
	(.0114)	(.0157)	(.0466)	(.051)	(.5)	(.0007)	(.06098)	(.093)
SB059	.0728	.2904	.3632	1.606	994.6	.9736	.20041	2.930
	(.0113)	(.0157)	(.0599)	(.050)	(.5)	(.0007)	(.04544)	(.093)
SB060	.0753	.4503	.5256	1.561	994.3	.9650	.14319	4.210
	(.0113)	(.0157)	(.0810)	(.050)	(.5)	(.0007)	(.03082)	(.093)
SB061	.1102	.6382	.7484	2.367	994.3	.9622	.14722	6.190
	(.0117)	(.0157)	(.0815)	(.051)	(.5)	(.0007)	(.02239)	(.093)
SB062	.1095	.9069	1.0164	2.349	994.3	.9476	.10773	8.330
	(.0116)	(.0157)	(.1093)	(.051)	(.5)	(.0007)	(.01628)	(.093)
SB063	.1434	1.3381	1.4815	3.119	994.3	.9337	.09679	13.260
	(.0133)	(.0157)	(.1382)	(.053)	(.5)	(.0007)	(.01272)	(.093)
SB064	.1431	1.5155	1.6587	3.215	994.6	.9290	.08630	13.900
	(.0130)	(.0157)	(.1521)	(.053)	(.5)	(.0007)	(.01115)	(.093)
SB065B	.0469	0.0000	.0469	1.606	997.1	1.0000	1.00000	.240
	(.0022)	(0.0000)	(.0022)	(.051)	(.5)	(.0007)	(.06612)	(.093)
SB066	.0464	.0662	.1126	1.594	995.7	.9652	.41202	.720
	(.0022)	(.0157)	(.0273)	(.051)	(.5)	(.0007)	(.10166)	(.093)
SB067	.0462	.1458	.1920	1.603	995.0	.9629	.24073	.610
	(.0022)	(.0157)	(.0226)	(.051)	(.5)	(.0007)	(.03053)	(.093)
SB068	.0462	.2070	.2532	1.581	994.6	.9576	.18253	.990
	(.0022)	(.0157)	(.0226)	(.050)	(.5)	(.0007)	(.01845)	(.093)
SB069	.0460	.2916	.3376	1.583	994.3	.9496	.13628	1.240
	(.0022)	(.0157)	(.0242)	(.050)	(.5)	(.0007)	(.01170)	(.093)
SB070	.0458	.4354	.4813	1.562	993.9	.9344	.09523	1.790
	(.0022)	(.0157)	(.0266)	(.050)	(.5)	(.0007)	(.00723)	(.093)
SB071	.0459	.6335	.6794	1.560	993.5	.9189	.06755	2.530
	(.0022)	(.0157)	(.0362)	(.050)	(.5)	(.0007)	(.00481)	(.093)
SB072B	.0308	0.0000	.0308	1.663	997.1	1.0000	1.00000	.110
	(.0016)	(0.0000)	(.0016)	(.051)	(.5)	(.0007)	(.07466)	(.093)
SB073	.0314	.0889	.1203	1.583	994.6	.9548	.26107	.320
	(.0017)	(.0157)	(.0222)	(.050)	(.5)	(.0007)	(.05008)	(.093)
SB074	.0312	.1462	.1773	1.584	994.3	.9490	.17570	.390
	(.0016)	(.0157)	(.0212)	(.051)	(.5)	(.0007)	(.02300)	(.093)
SB075	.0310	.2068	.2378	1.565	993.9	.9415	.13024	.510
	(.0016)	(.0157)	(.0220)	(.050)	(.5)	(.0007)	(.01396)	(.093)
SB076	.0306	.2930	.3235	1.554	993.5	.9296	.09444	.710
	(.0016)	(.0157)	(.0244)	(.050)	(.5)	(.0007)	(.00870)	(.093)
SB077	.0303	.4499	.4802	1.362	993.1	.9134	.06308	1.080
	(.0016)	(.0157)	(.0305)	(.050)	(.5)	(.0007)	(.00523)	(.093)

a. Numbers in parentheses are the uncertainties in the quantities immediately above. The 95% confidence level was used.

TABLE 8

TEST SECTION FLUID PROPERTIES FOR TEST SERIES SB1

TEST NO.	TEMP. (K)	PRES. (kPa)	DENSITITIES AIR (kg/cu-m)	DENSITITIES WATER (kg/cu-m)	VISCOSITIES AIR (kPa·s)	VISCOSITIES WATER (kPa·s)	SURFACE TENSION (dynes/cm)
SB09A	302.	86.0	.99	996.6	1.84	81.73	71.4
SB09B	309.	86.0	.97	994.3	1.88	70.63	70.3
SB09C	309.	86.0	.97	994.3	1.88	70.63	70.3
SB10A	303.	86.0	.99	996.3	1.85	79.98	71.2
SB10B	309.	86.0	.97	994.3	1.88	70.63	70.3
SB10C	309.	86.0	.97	994.3	1.88	70.63	70.3
SB11A	303.	86.0	.99	996.3	1.85	79.98	71.2
SB11B	309.	86.0	.97	994.3	1.88	70.63	70.3
SB11C	309.	86.0	.97	993.9	1.88	70.63	70.3
SB12A	304.	86.0	.99	996.0	1.85	78.29	71.1
SB12B	309.	86.0	.97	994.3	1.88	70.63	70.3
SB12C	310.	86.0	.97	993.9	1.89	69.24	70.1
SB13A	304.	86.0	.99	996.0	1.85	78.29	71.1
SB13B	308.	86.0	.97	994.6	1.88	72.07	70.4
SB13C	310.	86.0	.97	993.9	1.89	69.24	70.1
SB14A	305.	86.0	.98	995.7	1.86	76.66	70.9
SB14B	308.	86.0	.97	994.6	1.88	72.07	70.4
SB14C	310.	86.0	.97	993.9	1.89	69.24	70.1
SB15A	305.	86.0	.98	995.7	1.86	76.66	70.9
SB15B	308.	86.0	.97	994.6	1.88	72.07	70.4
SB15C	310.	86.0	.97	993.9	1.89	69.24	70.1
SB16A	306.	86.0	.98	995.3	1.86	75.08	70.8
SB16B	308.	86.0	.97	994.6	1.88	72.07	70.4
SB16C	310.	86.0	.97	993.9	1.89	69.24	70.1
SB17A	306.	86.0	.98	995.3	1.86	75.08	70.8
SB17B	308.	86.0	.97	994.6	1.88	72.07	70.4
SB17C	310.	86.0	.97	993.9	1.89	69.24	70.1
SB18A	307.	86.0	.98	995.0	1.87	73.55	70.6
SB18B	308.	86.0	.97	994.6	1.88	72.07	70.4
SB18C	311.	86.0	.96	993.5	1.89	67.90	70.0
SB19A	307.	86.0	.98	995.0	1.87	73.55	70.6
SB19B	307.	86.0	.98	995.0	1.87	73.55	70.6
SB19C	311.	86.0	.96	993.5	1.89	67.90	70.0
SB27A	282.	90.7	1.12	997.1	1.76	134.22	76.9
SB27B	293.	89.6	1.07	997.1	1.80	100.54	73.2
SB27C	294.	89.2	1.06	997.1	1.81	98.14	73.0
SB28A	280.	94.9	1.18	997.1	1.75	142.15	77.8
SB28B	292.	93.7	1.12	997.1	1.80	103.04	73.5
SB28C	294.	93.1	1.10	997.1	1.81	98.14	73.0
SB29A	286.	101.9	1.23	997.1	1.78	114.04	74.6
SB29B	291.	104.0	1.25	997.1	1.80	105.63	73.7
SB29C	293.	104.0	1.24	997.1	1.80	100.54	73.2

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TABLE 8 (contd)

TEST NO.	TEMP. (K)	PRES. (kPa)	DENSITITIES AIR (kg/cu-m)	DENSITITIES WATER (kg/cu-m)	VISCOSITIES AIR (kPa·s)	VISCOSITIES WATER (kPa·s)	SURFACE TENSION (dynes/cm)
SB30A	289.	113.9	1.37	997.1	1.79	111.13	74.3
SB30B	290.	113.8	1.37	997.1	1.79	108.33	74.0
SB30C	292.	114.7	1.37	997.1	1.80	103.04	73.5
SB31A	288.	124.6	1.51	997.1	1.78	114.04	74.6
SB31B	289.	125.3	1.51	997.1	1.79	111.13	74.3
SB31C	292.	126.8	1.51	997.1	1.80	103.04	73.5
SB32A	289.	142.9	1.72	997.1	1.79	111.13	74.3
SB32B	289.	148.1	1.79	997.1	1.79	111.13	74.3
SB32C	291.	146.5	1.75	997.1	1.80	105.63	73.7
SB33A	288.	272.5	3.30	997.1	1.78	114.04	74.6
SB33B	287.	[illegible]	2.84	997.1	1.78	117.07	75.0
SB33C	290.	237.7	2.86	997.1	1.79	108.33	74.0
SB34A	289.	314.1	3.79	997.1	1.79	111.13	74.3
SB037	299.	87.3	1.02	997.1	1.83	87.34	71.9
SB038	295.	129.3	1.53	996.6	1.81	95.82	72.8
SB043	299.	156.5	1.75	997.4	1.83	87.34	71.9
SB044	301.	161.9	1.87	996.9	1.84	83.53	71.6
SB045	304.	222.4	2.55	996.3	1.85	78.29	71.1
SB046	304.	305.2	3.50	996.0	1.85	78.29	71.1
SB048	302.	461.1	5.32	996.6	1.84	81.73	71.4
SB049	303.	461.2	5.31	996.3	1.85	79.98	71.2
SB056	298.	286.2	3.35	998.1	1.83	89.35	72.1
SB057	303.	352.9	4.06	996.9	1.85	79.58	71.2
SB058	304.	418.2	4.79	996.0	1.85	78.29	71.1
SB059	305.	460.0	5.26	995.7	1.86	76.66	71.9

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TABLE 9

TEST SECTION FLUID PROPERTIES FOR TEST SERIES SB2

TEST NO.	TEMP. (K)	PRES. (kPa)	DENSITITIES AIR (kg/cu-m)	DENSITITIES WATER (kg/cu-m)	VISCOSITIES AIR (kPa·s)	VISCOSITIES WATER (kPa·s)	SURFACE TENSION (dynes/cm)
SB009	308.	100.0	1.13	994.6	1.88	73.92	70.4
SB010	308.	100.0	1.13	994.6	1.88	73.92	70.4
SB011	309.	100.0	1.13	994.3	1.88	71.60	70.3
SB012	308.	100.0	1.13	994.6	1.88	73.92	70.4
SB013	308.	100.0	1.13	994.6	1.88	73.92	70.4
SB014	308.	100.0	1.13	994.6	1.88	73.92	70.4
SB09B	312.	100.0	1.12	993.1	1.90	66.92	69.8
SB10B	313.	100.0	1.11	992.7	1.91	66.00	69.6
SB11B	313.	100.0	1.11	992.7	1.91	66.00	69.6
SB12B	313.	100.0	1.11	992.7	1.91	66.00	69.6
SB13B	314.	100.0	1.11	992.3	1.91	65.09	69.5
SB14B	314.	100.0	1.11	992.3	1.91	65.09	69.5
SB022	295.	141.8	1.66	997.1	1.81	101.46	72.8
SB024	295.	141.4	1.67	997.1	1.81	101.46	72.8
SB025	296.	172.4	2.03	997.1	1.82	99.34	72.5
SB026	296.	139.6	1.63	997.1	1.83	95.10	72.1
SB027	302.	142.0	1.64	997.1	1.84	86.63	71.4
SB028	303.	189.8	2.18	997.1	1.85	84.51	71.2
SB030	300.	203.7	2.37	997.4	1.84	90.87	71.8
SB22B	299.	140.6	1.64	997.1	1.83	92.99	71.9
SB23B	299.	141.0	1.64	997.1	1.83	92.99	71.9
SB24B	298.	140.1	1.64	997.1	1.83	95.10	72.1
SB25B	298.	140.4	1.64	997.1	1.83	95.10	72.1
SB26B	298.	139.7	1.63	997.1	1.83	95.10	72.1
SB27B	298.	139.9	1.64	997.1	1.83	95.10	72.1
SB031	304.	204.5	2.34	997.1	1.85	82.39	71.1
SB032	296.	247.5	2.91	996.9	1.82	99.34	72.5
SB033	297.	254.9	2.99	996.6	1.82	97.22	72.3
SB034	299.	264.4	3.08	996.6	1.83	92.99	71.9
SB035	301.	276.8	3.21	996.3	1.84	88.75	71.6
SB036	301.	295.3	3.42	996.3	1.84	88.75	71.6
SB037	301.	315.2	3.65	996.3	1.84	88.75	71.6
SB038	302.	339.1	3.91	996.3	1.84	86.63	71.4
SB039	303.	335.0	3.85	996.3	1.85	84.51	71.2

TABLE 9 (contd)

TEST NO.	TEMP. (K)	PRES. (kPa)	DENSITITIES AIR (kg/cu-m)	DENSITITIES WATER (kg/cu-m)	VISCOSITIES AIR (kPa·s)	VISCOSITIES WATER (kPa·s)	SURFACE TENSION (dynes/cm)
SB040	303.	316.5	3.66	996.3	1.85	84.51	71.2
SB042	295.	206.5	2.46	996.3	1.81	101.46	72.8
SB043	296.	208.5	2.46	996.0	1.82	99.34	72.5
SB044	298.	208.2	2.44	995.7	1.83	95.10	72.1
SB045	300.	252.6	2.93	995.7	1.84	90.87	71.8
SB046	302.	324.[illegible]	3.66	995.7	1.84	86.63	71.4
SB048	289.	138.6	1.67	997.6	1.79	114.17	74.3
SB049	293.	137.6	1.64	996.9	1.80	105.70	73.2
SB050	296.	141.2	1.66	996.6	1.82	99.34	72.5
SB051	300.	206.2	2.42	995.3	1.84	90.87	71.8
SB052	305.	206.3	2.36	994.3	1.86	80.27	70.9
SB053	307.	277.3	3.15	994.3	1.87	76.04	70.5
SB054	307.	295.9	3.36	994.3	1.87	76.04	70.6
SB058	303.	124.6	1.43	993.9	1.85	84.51	71.2
SB059	306.	194.3	2.21	993.5	1.86	78.16	70.8
SB060	308.	196.1	2.22	993.5	1.88	73.92	70.4
SB061	309.	197.1	2.22	993.5	1.88	71.80	70.3
SB062	310.	237.7	2.67	993.5	1.89	69.68	70.1
SB063	310.	270.3	[illegible]	993.5	1.89	69.68	70.1
SB066	293.	134.2	[illegible]	997.4	1.80	105.70	73.2
SB067	293.	[illegible]	[illegible]	996.6	1.80	105.70	73.2
SB068	295.	135.4	[illegible]	996.6	1.83	92.99	71.9
SB069	300.	133.3	1.55	996.0	1.84	90.87	71.8
SB070	303.	136.3	1.56	995.3	1.85	84.51	71.2
SB072	305.	135.9	1.55	995.0	1.86	80.27	70.9
SB073	303.	136.3	1.56	995.0	1.85	84.51	71.2
SB074	304.	[illegible]	[illegible]	994.3	1.85	82.39	71.1
SB075	306.	135.6	1.54	993.9	1.86	78.16	70.8
SB076	308.	134.2	[illegible]	[illegible]	1.88	73.92	70.4
SB077	309.	[illegible]	[illegible]	993.1	1.88	71.80	70.3
SB079	296.	134.4	[illegible]	996.0	1.82	99.34	72.5
SB080	297.	133.4	[illegible]	[illegible]	1.82	97.22	72.3
SB081	302.	133.6	1.54	994.3	1.84	86.63	71.4
SB082	306.	132.5	1.51	993.0	1.86	78.16	70.8

POOR ORIGINAL

TABLE 10

TEST SECTION FLUID PROPERTIES FOR TEST SERIES SB3

TEST NO.	TEMP. (K)	PRES. (kPa)	DENSITITIES AIR (kg/cu-m)	DENSITITIES WATER (kg/cu-m)	VISCOSITIES AIR (kPa·s)	VISCOSITIES WATER (kPa·s)	SURFACE TENSION (dynes/cm)
SB007	305.	100.0	1.14	995.3	1.86	76.66	70.9
SB008	304.	100.0	1.15	995.7	1.85	78.29	71.1
SB009	304.	100.0	1.15	996.0	1.85	78.29	71.1
SB010	303.	100.0	1.15	996.3	1.85	79.98	71.2
SB011	302.	100.0	1.15	996.6	1.84	81.73	71.4
SB012	301.	100.0	1.16	996.9	1.84	83.53	71.6
SB013	300.	100.0	1.16	997.1	1.84	85.41	71.8
SB014	299.	100.0	1.17	997.4	1.83	87.34	71.9
SB020	298.	144.6	1.69	997.1	1.83	89.35	72.1
SB021	298.	145.8	1.71	997.1	1.83	89.35	72.1
SB022	297.	146.2	1.72	997.1	1.82	91.43	72.3
SB023	297.	140.5	1.65	997.1	1.82	91.43	72.3
SB024	296.	145.3	1.71	997.1	1.82	93.58	72.5
SB025	296.	146.7	1.73	997.1	1.82	93.58	72.5
SB026	299.	143.0	1.67	997.1	1.83	87.34	71.9
SB027	299.	143.5	1.67	997.1	1.83	87.34	71.9
SB028	300.	280.3	3.26	997.1	1.84	85.41	71.8
SB030	284.	259.7	3.19	997.1	1.76	126.93	76.1
SB30A	286.	280.9	3.42	997.1	1.77	120.23	75.3
SB031	290.	294.6	3.54	996.3	1.79	108.33	74.0
SB032	296.	312.5	3.68	996.3	1.82	93.58	72.5
SB033	299.	319.2	3.72	996.0	1.83	87.34	71.9
SB034	302.	338.2	3.90	995.7	1.84	81.73	71.4
SB035	303.	368.5	4.24	996.0	1.85	79.98	71.2
SB036	294.	415.3	4.92	998.1	1.81	98.14	73.0
SB037	300.	415.3	4.83	997.1	1.84	85.41	71.8
SB038	302.	432.0	4.99	996.6	1.84	81.73	71.4
SB39B	304.	432.0	4.95	996.0	1.85	78.29	71.1
SB40B	305.	429.4	4.91	995.7	1.86	76.66	70.9
SB041	290.	144.8	1.74	997.1	1.79	108.33	74.0
SB042	289.	207.0	2.50	997.9	1.79	111.13	74.3
SB043	293.	208.5	2.48	997.1	1.80	100.54	73.2
SB044	296.	209.6	2.47	996.9	1.82	93.58	72.5
SB045	300.	274.2	3.19	996.3	1.84	85.41	71.8
SB046	299.	372.5	4.34	996.0	1.83	87.34	71.9
SB047	298.	139.1	1.63	997.1	1.83	89.35	72.1
SB048	296.	137.2	1.62	996.6	1.82	93.58	72.5
SB049	296.	205.9	2.42	996.6	1.82	93.58	72.5
SB050	298.	208.4	2.44	996.3	1.83	89.35	72.1

TABLE 10 (contd)

TEST NO.	TEMP. (K)	PRES. (kPa)	DENSITITIES AIR (kg/cu-m)	WATER (kg/cu-m)	VISCOSITIES AIR (kPa·s)	WATER (kPa·s)	SURFACE TENSION (dynes/cm)
SB051	301.	209.0	2.42	996.0	1.84	83.53	71.6
SB052	303.	209.4	2.41	995.7	1.85	79.98	71.2
SB053	304.	210.9	2.42	995.3	1.85	78.29	71.1
SB054	297.	281.0	3.30	997.4	1.82	91.43	72.3
SB055	298.	139.5	1.63	997.1	1.83	89.35	72.1
SB056	297.	138.2	1.60	995.7	1.82	91.43	72.3
SB057	299.	137.2	1.60	995.0	1.83	87.34	71.9
SB058	302.	139.2	1.61	994.6	1.84	81.73	71.4
SB059	304.	140.1	1.61	994.6	1.85	78.29	71.1
SB060	306.	137.0	1.56	994.3	1.86	75.08	70.8
SB061	307.	208.5	2.37	994.3	1.87	73.55	70.6
SB062	308.	207.6	2.35	994.3	1.88	72.07	70.4
SB063	308.	275.6	3.12	994.3	1.88	72.07	70.4
SB064	308.	284.1	3.22	994.6	1.88	72.07	70.4
SB065B	300.	138.2	1.61	997.1	1.84	85.41	71.8
SB066	300.	137.2	1.59	995.7	1.84	85.41	71.8
SB067	302.	138.9	1.60	995.0	1.84	81.73	71.4
SB068	304.	137.9	1.58	994.6	1.85	78.29	71.1
SB069	306.	139.0	1.58	994.3	1.86	75.08	70.8
SB070	308.	138.0	1.56	993.9	1.88	72.07	70.4
SB071	309.	138.3	1.56	993.5	1.88	70.63	70.3
SB072B	302.	144.1	1.66	997.1	1.84	81.73	71.4
SB073	304.	138.1	1.58	994.6	1.85	78.29	71.1
SB074	303.	137.7	1.58	994.3	1.85	79.98	71.2
SB075	306.	137.4	1.57	993.9	1.86	75.08	70.8
SB076	308.	137.3	1.55	993.5	1.88	72.07	70.4
SB077	309.	138.5	1.56	993.1	1.88	70.63	70.3

TABLE 11

PITOT TUBE AND DIFFERENTIAL PRESSURE MEASUREMENTS FROM SB1

Test Number	DP1 (Top)	DP2	DP3	DP4	DP5 (Bottom)	ΔP_{DRAG}
	$kg/m \cdot s^2$	$kg/m \cdot s^2$	$kg/m \cdot s^2$	$kg/m \cdot s^2$	$kg/m \cdot s^2$	(kPa)
9A	2800	4000	4800	4000	3000	0.5
B	2800	4000	4800	4000	3000	0.6
C	3000	4000	4800	4000	3000	0.6
10A	4800	6600	7800	6600	5000	0.9
B	4600	6400	7600	6600	4800	0.9
C	4800	6800	7800	6000	5000	0.8
11A	6200	8600	10400	8800	6400	1.2
B	6000	8400	9800	8600	6400	1.1
C	6200	8400	10200	8600	6400	1.1
12A	7800	10800	12600	10800	7800	1.5
B	7600	10600	12400	10600	8000	1.5
C	7600	10200	12400	10600	7800	1.3
13A	11000	15600	18600	15800	11800	2.2
B	11000	15200	17800	15400	11500	2.1
C	11400	15400	18600	16000	11800	2.0
14A	14800	20600	24400	20800	15400	2.9
B	14800	20400	23800	20600	15600	2.8
C	15200	20400	24200	20800	15400	2.7
15A	17400	30000	35400	30600	22800	4.1
B	22200	30200	35400	30600	23200	4.1
C	23000	30800	36400	31400	23200	4.1
16A	29200	39600	46800	40400	30200	5.4
B	29200	39800	46200	40400	30400	5.4
C	29600	39600	46600	40600	30200	5.2
17A	36600	49600	58000	50400	37800	6.7
B	36600	49400	57400	49600	37400	6.6
C	36800	49000	57400	50000	37400	6.5
18A	73800	99000	114000	100000	75600	12.9
B	72400	97400	112000	101000	74800	12.8
C	74200	98400	114000	100000	75000	12.9
19A	80600	108000	123000	109000	82600	14.2
B	80400	108000	123000	109000	82600	14.2
C	81800	108000	124000	110000	82200	14.2
27A	1400	4600	3400	3200	4000	0.5
B	4800	4600	5200	3400	4200	0.8
C	4500	4400	5400	3400	4200	0.5
28A	600	4800	3800	3400	5200	1.7
B	4800	5800	7000	4800	4600	1.9
C	6800	7800	9200	6800	6600	1.0
29A	7400	13000	13200	11800	10800	1.7
B	11200	14000	16600	13200	11400	3.2
C	12000	15000	17800	14400	12400	2.9

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TABLE 11 (contd)

Test Number	DP1 (Top)	DP2	DP3	DP4	DP5 (Bottom)	ΔP_{DRAG}
	$kg/m \cdot s^2$	$kg/m \cdot s^2$	$kg/m \cdot s^2$	$kg/m \cdot s^2$	$kg/m \cdot s^2$	(kPa)
30A	15000	23000	25200	22200	18600	4.3
B	18800	24000	28000	23200	19800	5.3
C	18000	23000	27000	22000	19000	4.8
31A	22200	32800	36000	32600	28400	7.8
B	25400	33200	38800	32600	26800	8.4
C	25800	33400	39200	32800	27200	8.0
32A	31000	44400	49400	43400	35000	12.4
B	35600	46400	54200	46000	37200	13.2
C	35000	45800	53400	45200	36600	12.9
33A	66200	92000	104000	92000	70600	28.7
B	59600	78800	90800	79200	61800	24.6
C	60800	80400	92600	80600	62600	25.0
34A	79800	106000	120000	107000	81600	33.1
37	25400	49200	59600	52000	55000	9.8
38	56800	77800	91400	81400	82800	21.1
43	40400	58800	67200	57200	42400	13.8
44	47800	68000	74200	66000	52000	14.1
45	93000	109000	104000	109000	100000	19.6
46	156000	152000	139000	162000	166000	31.0
48	263000	184000	164000	213000	272000	55.2
49	258000	181000	164000	208000	274000	54.9
56	114000	157000	178000	162000	122000	49.7
57	144000	200000	224000	206000	156000	50.5
58	181000	251000	277000	257000	197000	56.8
59	207000	282000	298000	283000	226000	60.8

TABLE 12

PITOT TUBE AND DIFFERENTIAL PRESSURE MEASUREMENTS FROM SB2

Test Number	DP1 (Top)	DP2	DP3	DP4	DP5 (Bottom)	ΔP_{DRAG}
	$kg/m \cdot s^2$	$kg/m \cdot s^2$	$kg/m \cdot s^2$	$kg/m \cdot s^2$	$kg/m \cdot s^2$	(kPa)
10	3630	5560	6040	5690	4370	1.0
11	9290	13560	14820	14110	10970	2.2
12	23110	34020	36880	35310	27250	5.1
13	40690	60020	65140	62470	47990	9.0
14	70730	104280	112460	107070	82330	15.7
7B	450	680	850	730	650	0.17
8B	910	1360	1630	1470	1170	0.27
9B	1970	2920	3350	3110	2390	0.51
10B	3670	5320	5990	5630	4230	0.87
11B	8870	12700	14000	13400	10100	1.95
12B	22300	33200	36600	34900	26800	5.03
13B	39500	58700	64200	61100	46900	8.90
14B	69400	104000	113000	107000	81700	15.86
23	2120	5270	5850	8550	3350	0.1
24	4480	8610	9510	12010	6110	0.7
25	9880	16090	17690	20050	13830	2.0
26	10000	16890	18610	20350	12950	2.7
27	13480	21910	24090	25470	16990	4.0
28	36430	55950	60770	60450	43050	16.6
21B	3810	3680	3400	2190	1070	
22B	5350	6000	5980	4650	2690	0.12
23B	7530	8940	9240	7770	5130	0.65
24B	9950	12300	13000	11400	7310	0.96
25B	12600	16400	17500	15700	11000	1.65
26B	15000	20400	21900	20000	14500	2.62
27B	18300	25200	27200	25100	18500	3.88
28B	71800	105000	113000	117000	81300	34.57
30	42870	63980	70880	68970	50860	20.3
31	42990	64360	71160	69030	51260	20.3
32	47490	86520	97820	97810	62660	21.1
33	47450	92000	103320	104230	66400	22.0
34	47410	97880	108660	112670	71880	23.3
35	48810	106240	116340	124250	80580	25.3
36	50250	122080	129580	143050	102440	29.1
37	5[illegible]870	156100	150100	150130	143110	32.9
38	72410	190920	171420	182370	166100	35.6
39	84830	198100	161860	197950	125300	37.[illegible]
40	93070	134940	133020	156810	128040	33.5
41	136850	146620	146560	167250	145660	33.1
42	22420	44960	51860	47930	33460	10.5
43	29900	61580	69140	68830	43580	12.9
44	32560	72100	79680	80890	51740	15.9
45	40000	90940	100120	106470	70740	22.1
46	56620	140920	146520	155590	114020	33.1

TABLE 12 (contd)

Test Number	DP1 (Top)	DP2	DP3	DP4	DP5 (Bottom)	ΔP_{DRAG}
	$kg/m \cdot s^2$	$kg/m \cdot s^2$	$kg/m \cdot s^2$	$kg/m \cdot s^2$	$kg/m \cdot s^2$	(kPa)
48	5240	16120	24130	23620	12240	3.8
49	7740	30750	37830	33960	15780	5.3
50	8840	40300	45410	44520	18160	6.3
51	19360	60400	66330	71360	41940	10.1
52	22140	86660	88010	92780	58860	14.2
53	31860	125540	116970	127800	100300	21.2
54	57840	171740	142770	159120	132920	30.7
56	890	1190	14860	11820	5120	3.0
57	3350	24790	29840	27380	8160	3.7
58	4890	32870	38060	34820	8560	5.3
59	9390	42470	49420	57640	21180	7.1
60	13350	62910	65380	80740	23960	9.7
61	14310	78210	73480	97400	31620	13.3
62	25350	92890	87420	109280	54860	18.2
63	41250	119150	111960	135620	110460	26.3
66	2220	3470	4310	2810	2320	1.0
67	2560	4830	5570	3010	4200	1.2
68	620	3410	3190	1710	7260	1.3
69	2280	8190	6850	2530	9880	1.8
70	4080	13470	11010	5830	14500	2.6
71	5760	21510	19410	10410	18400	3.6

a. Test numbers 7-14 are single phase (water) flows and test numbers 21-28 are single phase (air) flows.

TABLE 13

PITOT TUBE AND DIFFERENTIAL PRESSURE MEASUREMENTS FROM SB3

Test Number	DP-1T	DP-2	DP-3	DP-4	DP-5B	ΔP_{DRAG}
	$kg/m \cdot s^2$	$kg/m \cdot s^2$	$kg/m \cdot s^2$	$kg/m \cdot s^2$	$kg/m \cdot s^2$	(kPa)
7	3220	3480	-	3100	1620	
8	3460	4160	-	3820	2100	
9	4960	5640	-	5340	3220	
10	6780	8140	-	7900	5160	
11	12000	15400	-	15500	11600	
12	27000	36000	41000	36500	27000	
13	46200	61700	61900	62600	46000	
14	75500	101000	113000	103000	75400	
6A	290	270	360	1490	270	0.00
7A	370	610	720	1650	530	0.09
8A	810	1270	1580	2690	1090	0.32
9A	1870	2750	3610	4490	2370	0.98
10A	3730	5250	5860	7410	4270	1.09
11A	9190	12600	13860	16100	10200	2.62
12A	23700	32800	35900	39400	26700	6.50
13A	42100	58700	56600	68600	47900	11.44
14A	70900	98600	97600	111000	80700	19.18
20	560	920	3540	1800	-[c]	-
21	1660	2320	5100	3260	-	-
22	3820	5220	8280	6260	2140	-
23	5520	7700	11000	8780	3960	0.04
24	8160	11100	-	12300	6560	0.71
25	10300	14000	17900	15300	8800	1.34
26	13600	18600	23000	20000	12400	2.52
27	16800	22900	27800	24600	15700	3.64
28	69800	93600	105000	96300	67300	29.19
20A	920	1140	1380	7620	1020	0.14
21A	1940	2520	2860	9340	2020	0.44
22A	3960	5340	5840	12300	4240	1.01
23A	6300	8420	9220	15400	6800	1.68
24A	8360	11200	12300	18600	9000	2.33
25A	11300	15300	16600	22600	12800	3.33
26A	14800	20000	21800	28100	16600	4.77
27A	18400	24700	27200	33200	20600	6.32
28A	59100	83100	90800	107000	69700	31.37
30A	60900	87700	94800	110000	71000	25.68
31A	52900	86400	95700	111000	63600	22.79
32A	57200	102000	118000	133000	72200	26.86
33A	60000	118000	133000	148000	74400	28.32
34A	71700	159000	167000	20900	103000	35.55
30	54800	79400	85900	100000	64400	32.29
36	98100	199000	193000	235000	131000	40.30
37	124000	[b]	206000	243000	174000	42.68
38	184000	[b]	241000	248000	199000	48.01

TABLE 13 (contd)

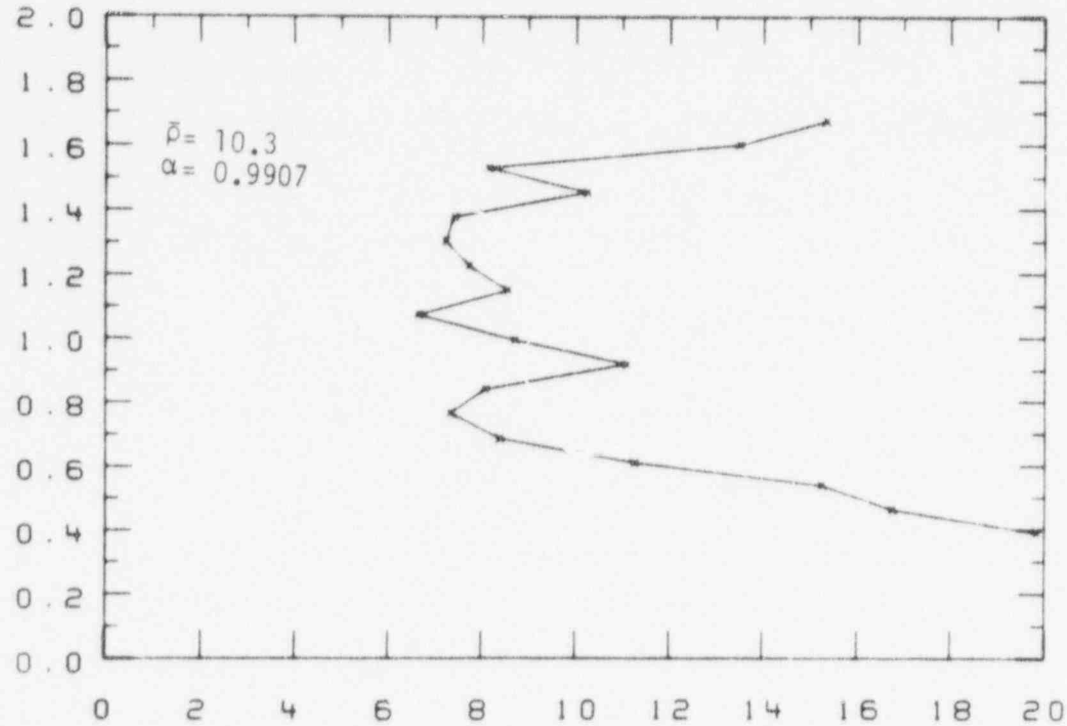
Test Number	DP-1T	DP-2	DP-3	DP-4	DP-5B	ΔP_{DRAG}
	$kg/m \cdot s^2$	$kg/m \cdot s^2$	$kg/m \cdot s^2$	$kg/m \cdot s^2$	$kg/m \cdot s^2$	(kPa)
38B	191000	b	257000	252000	215000	52.77
39B	195000	b	267000	250000	175000	53.83
40B	b	b	201000	229000	232000	53.52
41B	8580	16200	16300	22100	13500	2.7
42B	28300	54000	63300	72000	35200	11.31
43B	22600	49700	54900	74400	37600	11.93
44B	36300	78900	87300	102000	47800	15.74
45B	47300	103000	113000	140000	67500	20.32
46B	78100	162000	174000	212000	99800	36.40
47B	3060	280	2940	8680	2760	0.54
48B	4740	23000	27300	31300	11400	3.90
49B	17800	43300	49700	58800	21800	6.51
50B	20200	51600	51900	74100	25600	7.41
51B	29000	68400	72400	98900	34300	9.32
52B	36700	98000	91100	130000	55700	12.62
53B	52500	126000	105000	154000	82400	17.24
54B	92500	173000	144000	206000	128000	27.82
56B	6880	11400	11900	16400	4460	2.32
57B	10400	23700	26600	25700	5940	3.42
58B	12200	39400	35000	30800	6020	3.93
59B	14100	50700	46100	39500	7240	4.87
60B	17000	64300	65000	61200	11600	7.16
61B	31400	80400	79600	134000	29000	10.30
62B	41200	89100	91900	133000	74200	15.04
63B	75100	126000	11800	157000	132000	24.25
64B	91700	128000	125000	158000	133000	25.82
66	4330	9740	7290	8240	3560	1.26
67	4490	11400	7670	8540	5000	1.44
68	5450	14400	8110	8540	6960	1.75
69	6670	18400	9170	9180	10200	2.21
70	8590	31000	14500	12100	16000	3.08
71	12800	43900	26900	15900	23500	4.48
73	-	-	-	1860	160	0.59
74	-	-	-	2620	1820	0.86
75	-	-	-	2800	380	1.19
76	1880	1670	410	5300	6160	1.64
77	4600	6830	2510	8460	10400	2.38

a. Test numbers 6-14 are for single phase (water) flows and test numbers 20-28 are for single phase (air) flows.

b. Transducer was saturated.

c. Dashes in place of data represents bad data (too low of range, etc.).

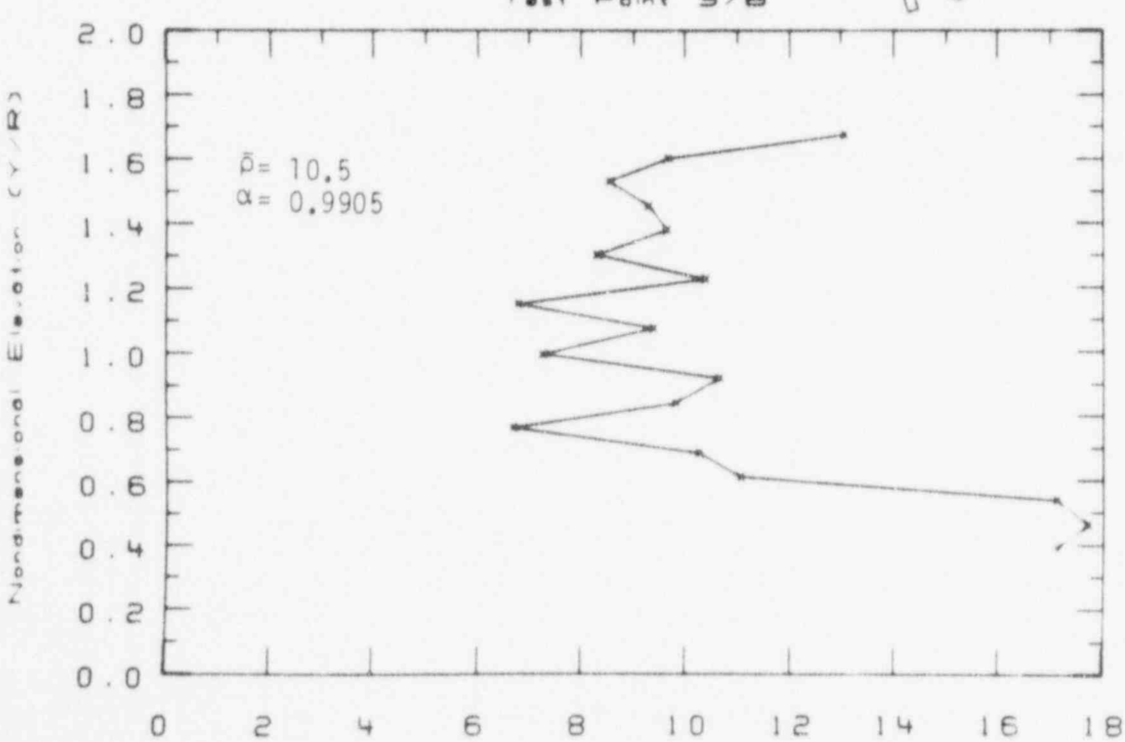
Test Point 37A



Local Density (kg/m³)

Fig. 6 Density distribution from scanning densitometer for test series * SB1 *

Test Point 37B



Local Density (kg/m³)

Fig. 7 Density distribution from scanning densitometer for test series * SB1 *

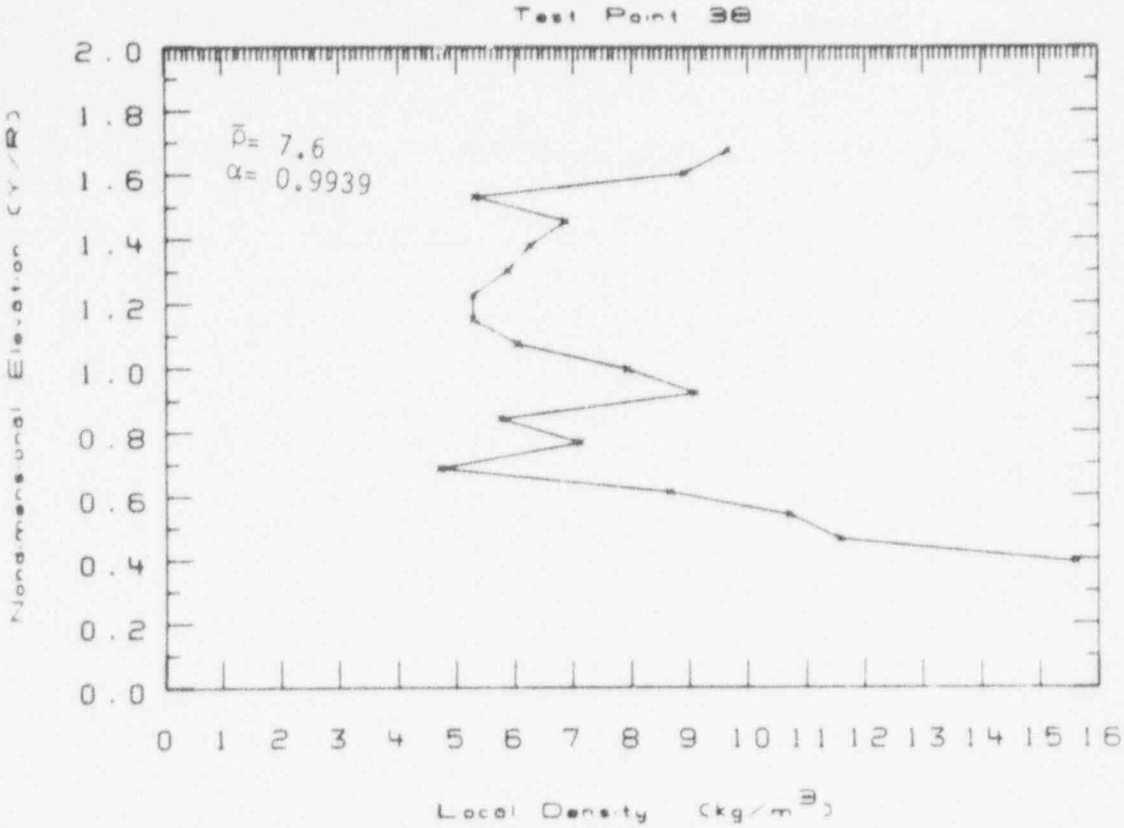


Fig. 8 Density distribution from scanning densitometer, for test series - SB1 -

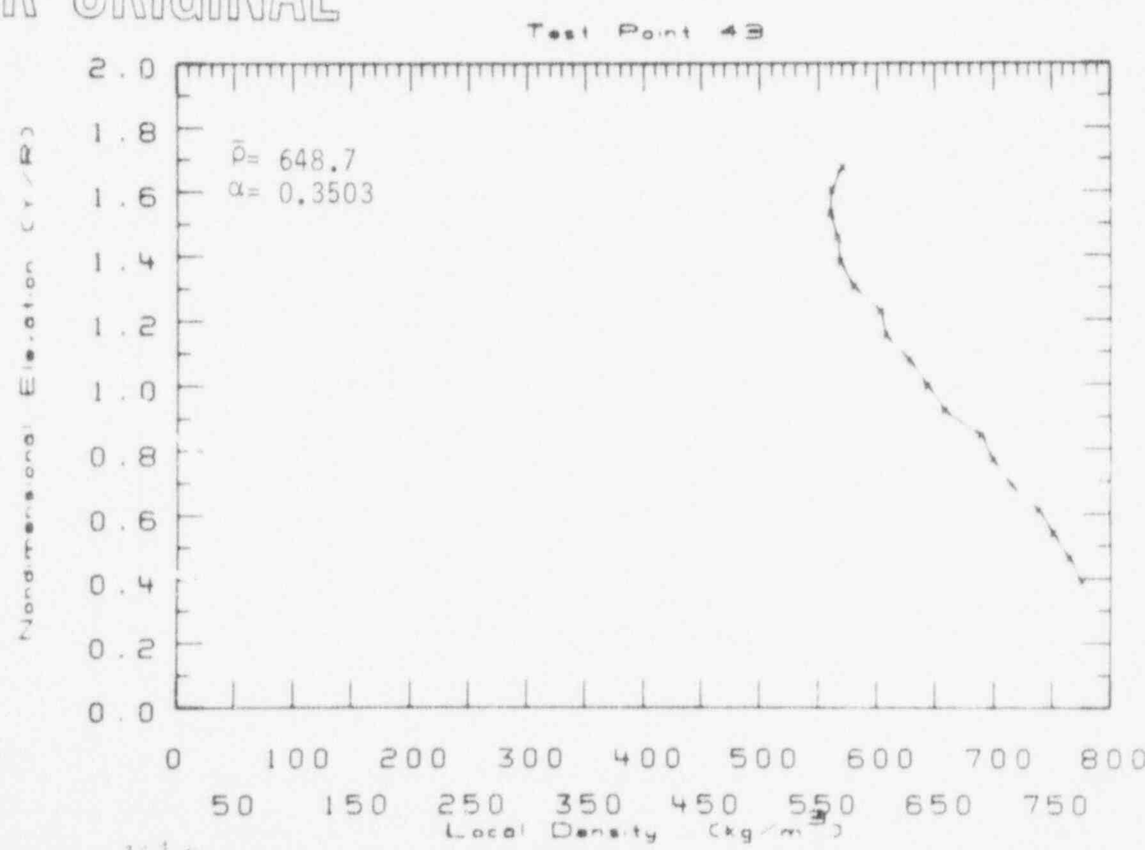


Fig. 9 Density distribution from scanning densitometer, for test series - SB1 -

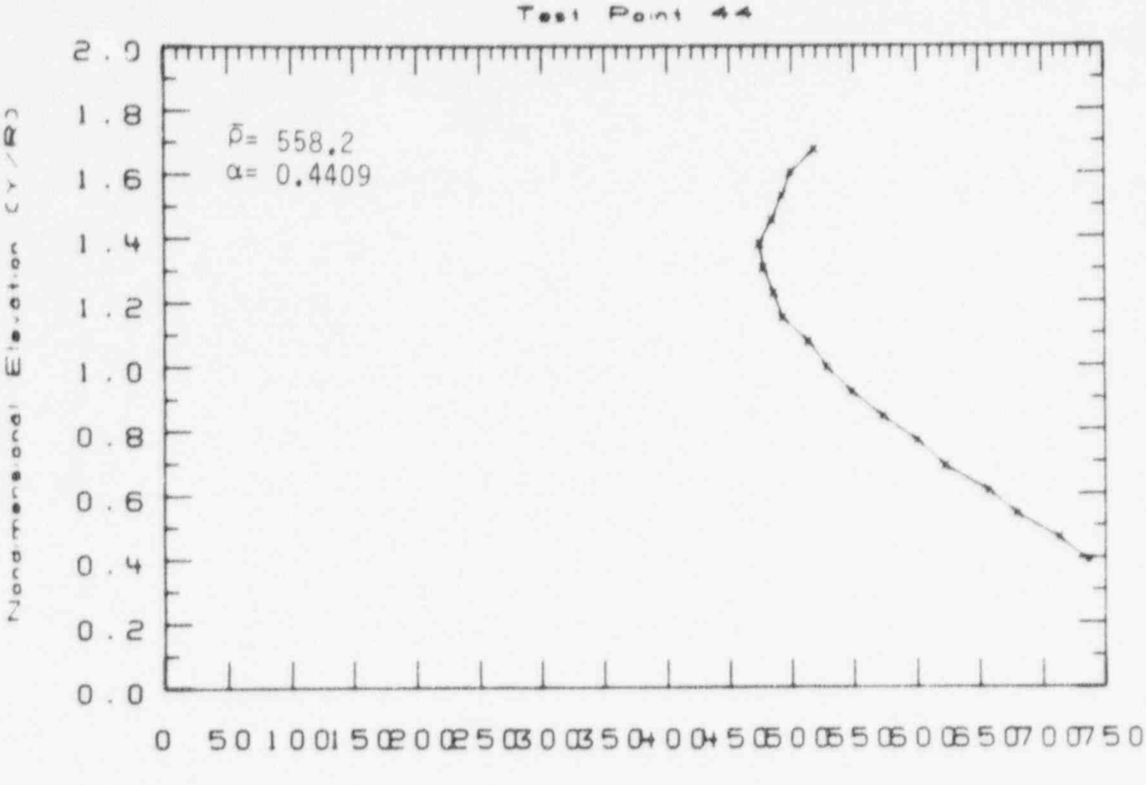


Fig. 10 Density distribution from scanning densitometer, for test series * SB1 *

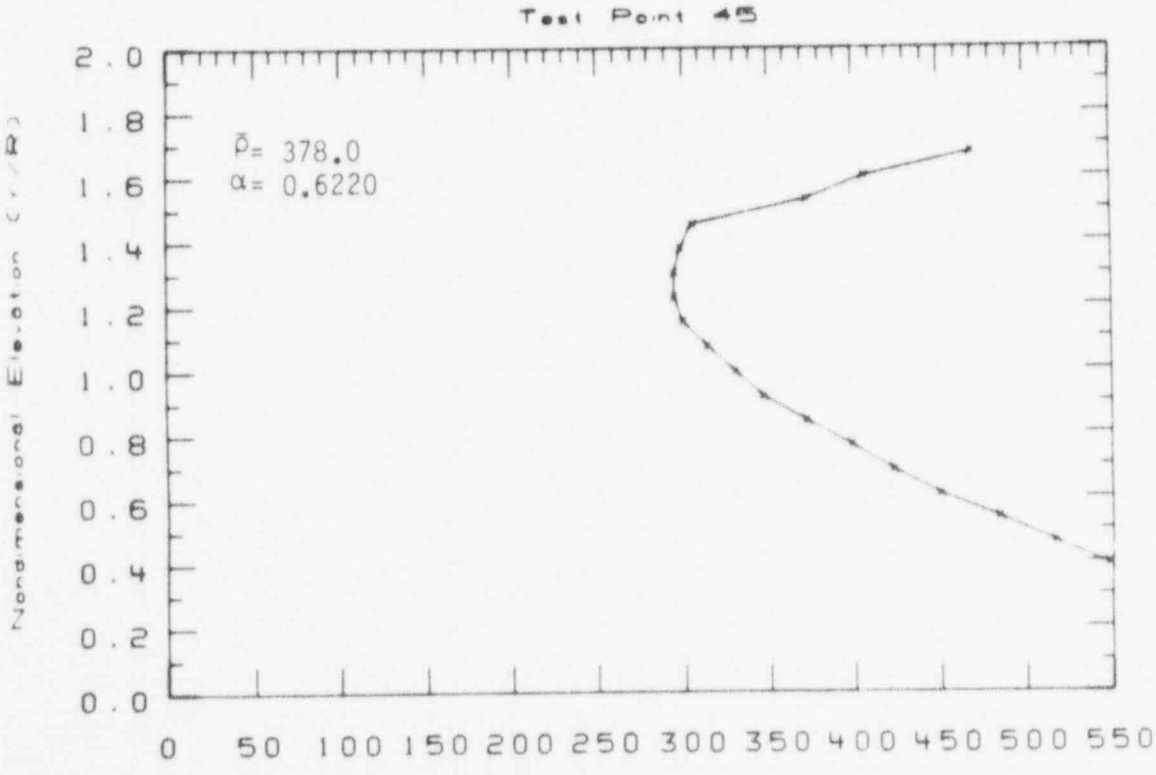


Fig. 11 Density distribution from scanning densitometer, for test series * SB1 *

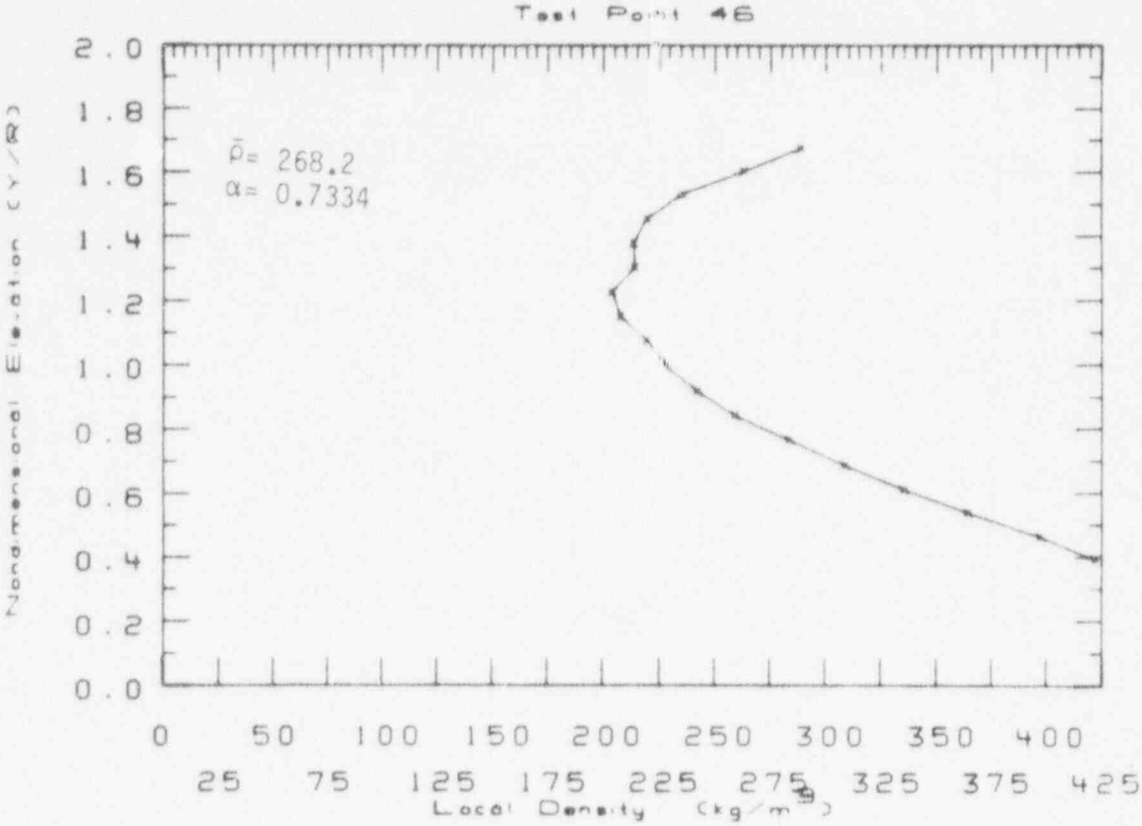


Fig. 12 Density distribution from scanning densitometer, for test series - SB1 -

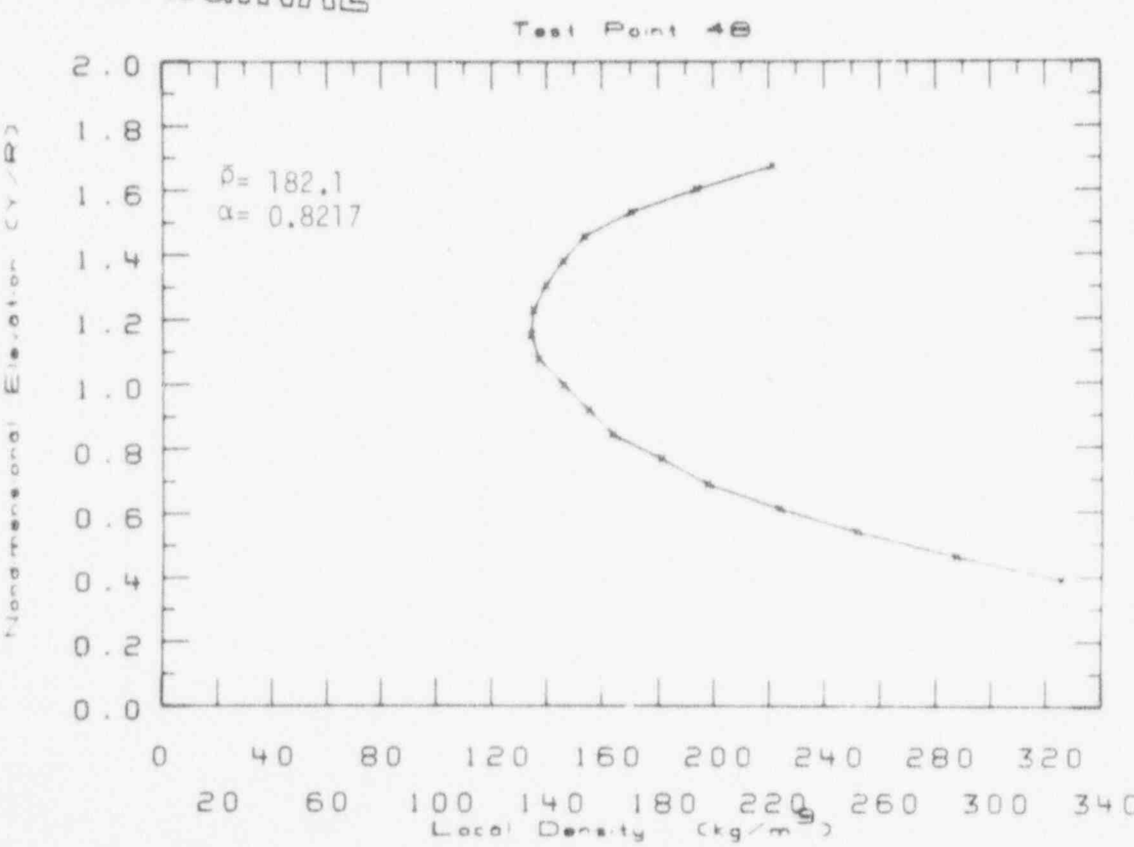


Fig. 13 Density distribution from scanning densitometer, for test series - SB1 -

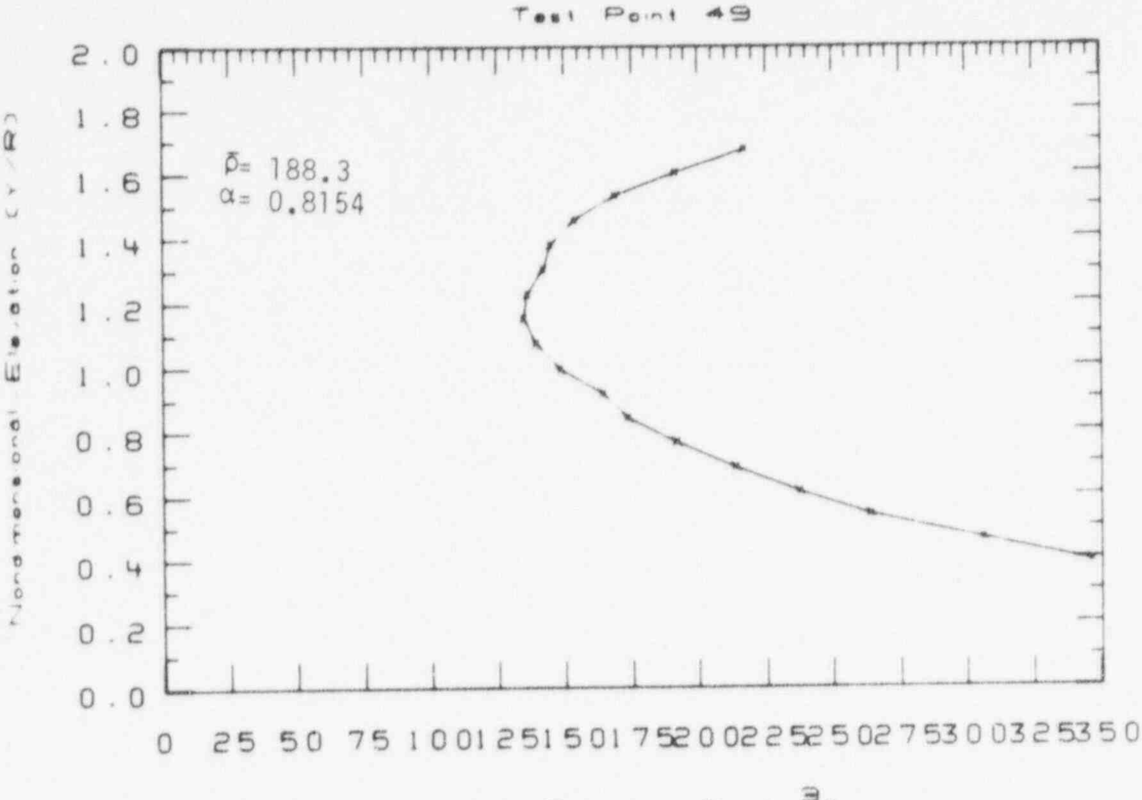


Fig. 14 Density distribution from scanning densitometer, for test series * SB1 *

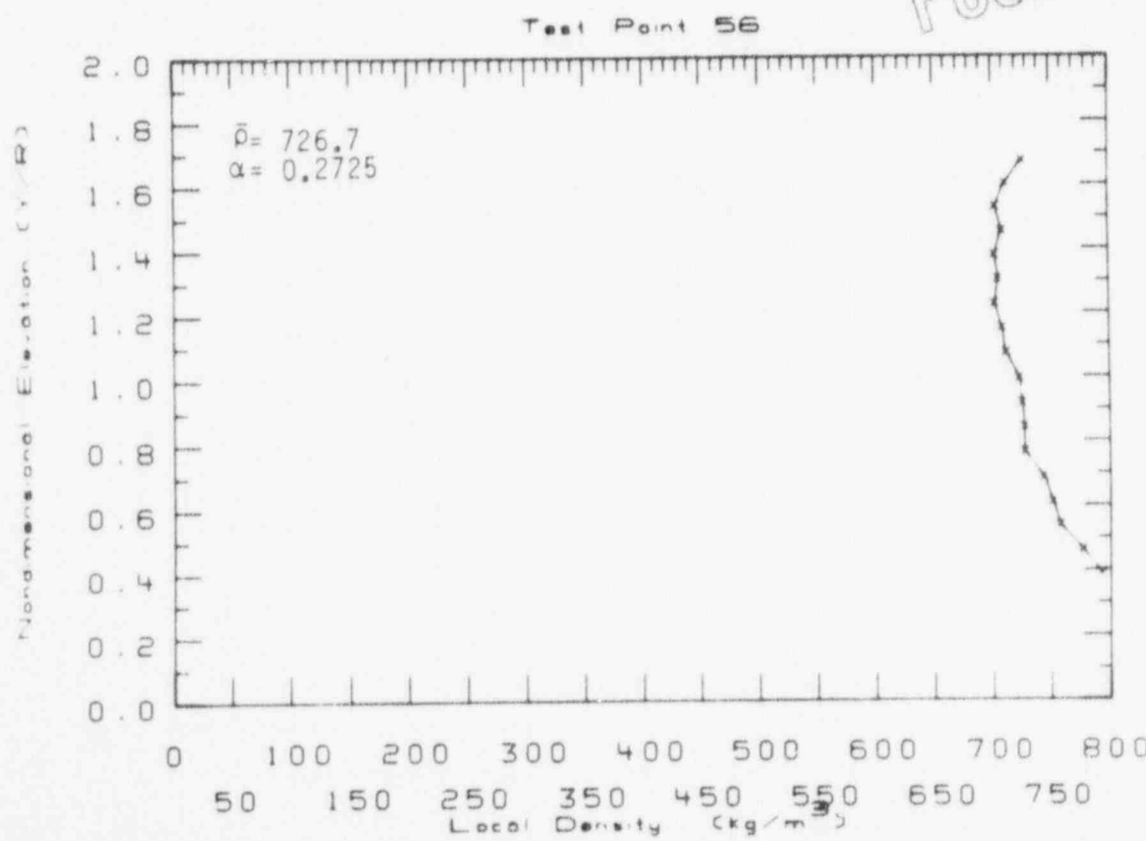


Fig. 15 Density distribution from scanning densitometer, for test series * SB1 *

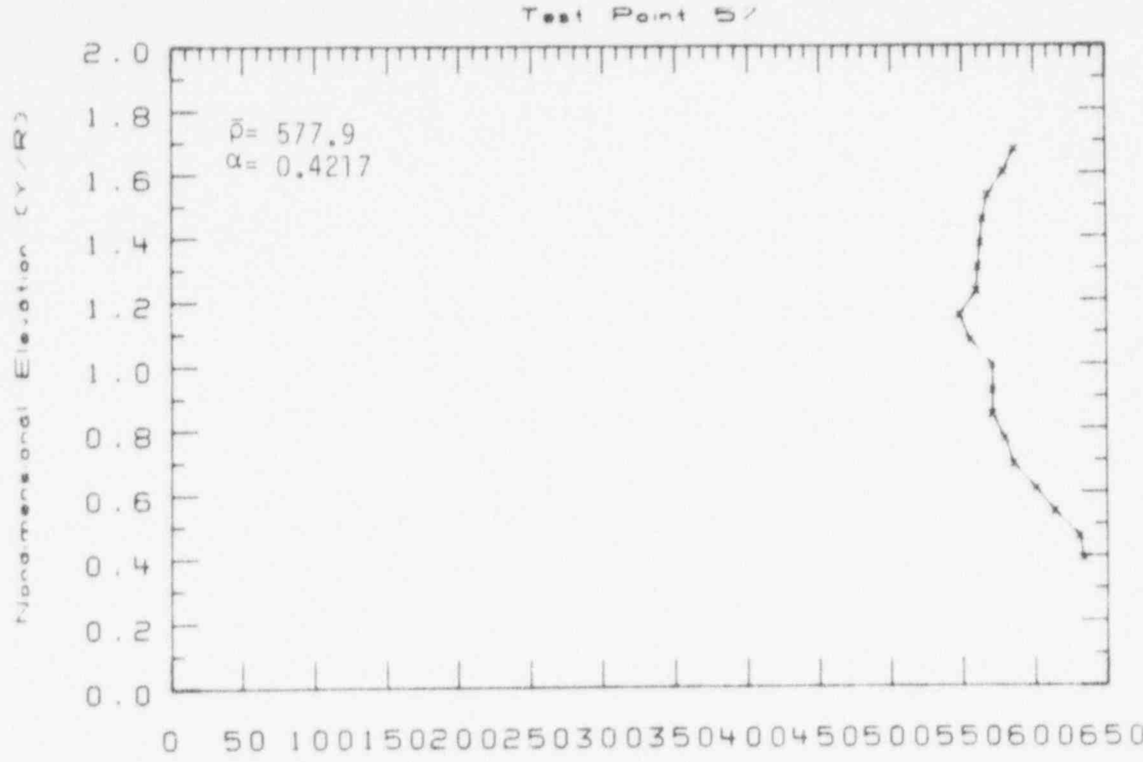


Fig. 16 Local Density (kg/m³)
Density distribution from scanning densitometer, for test series * SB1 *

POOR ORIGINAL

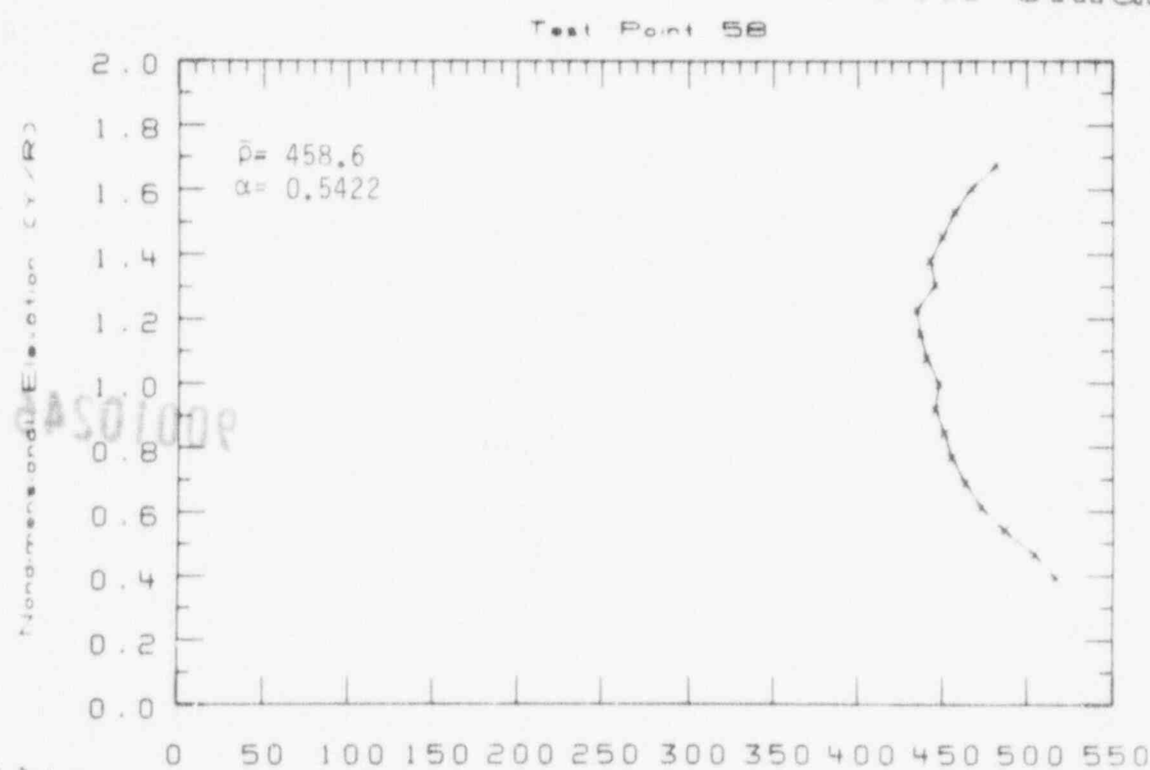


Fig. 17 Local Density (kg/m³)
Density distribution from scanning densitometer, for test series * SB1 *

90010245

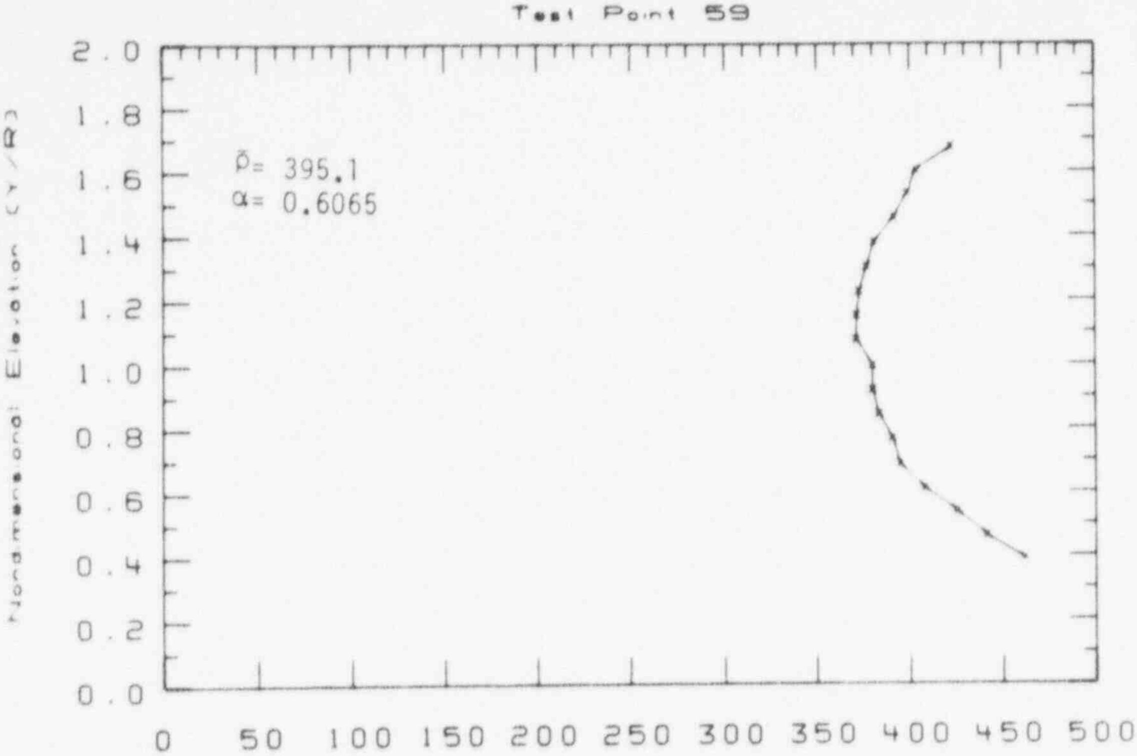


Fig. 18 Density distribution from scanning densitometer, for test series * SB1 *

POOR ORIGINAL

90010246

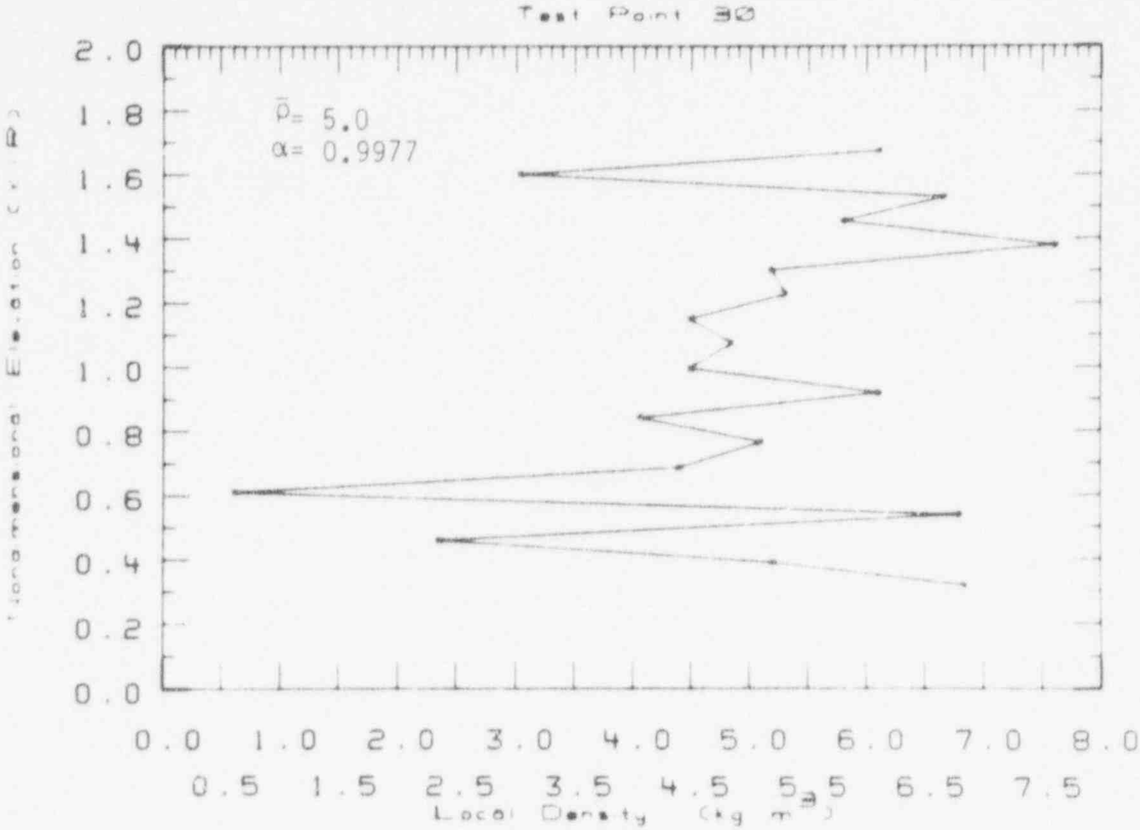


Fig. 19 Density distribution from scanning densitometer for test series - SB2 -

POOR ORIGINAL

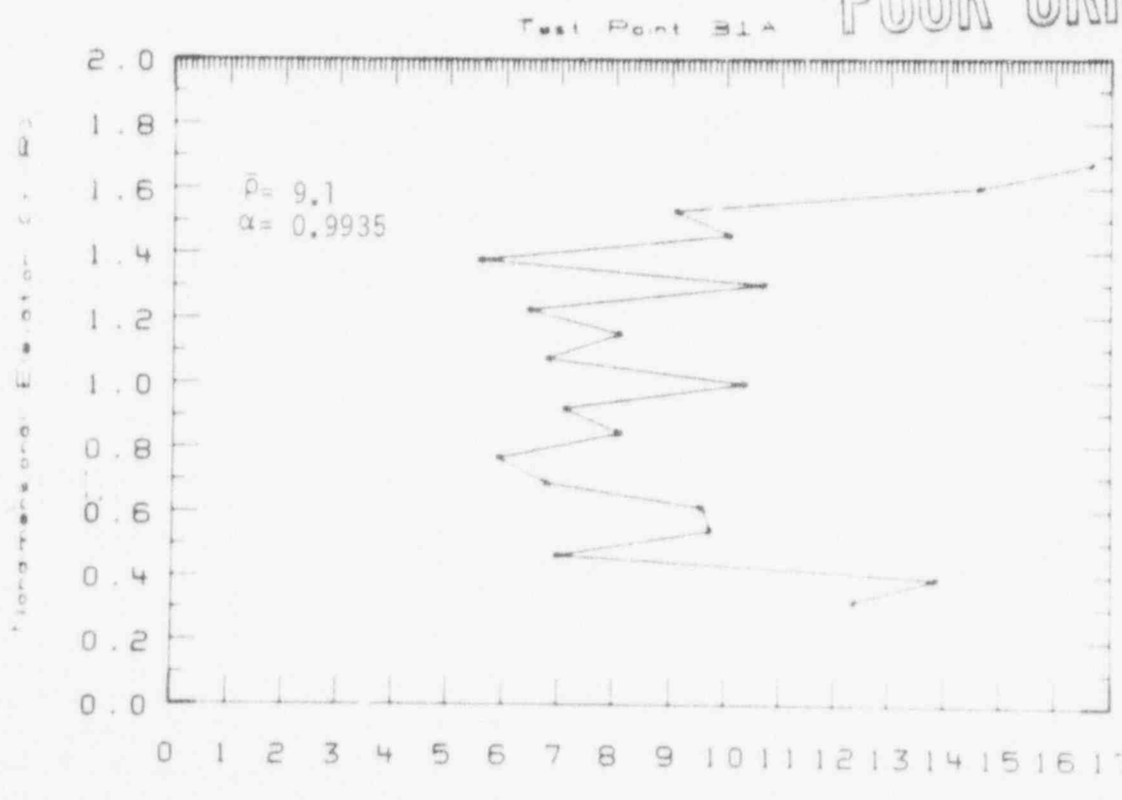


Fig. 20 Density distribution from scanning densitometer for test series - SB2 -

9001024B

90010247

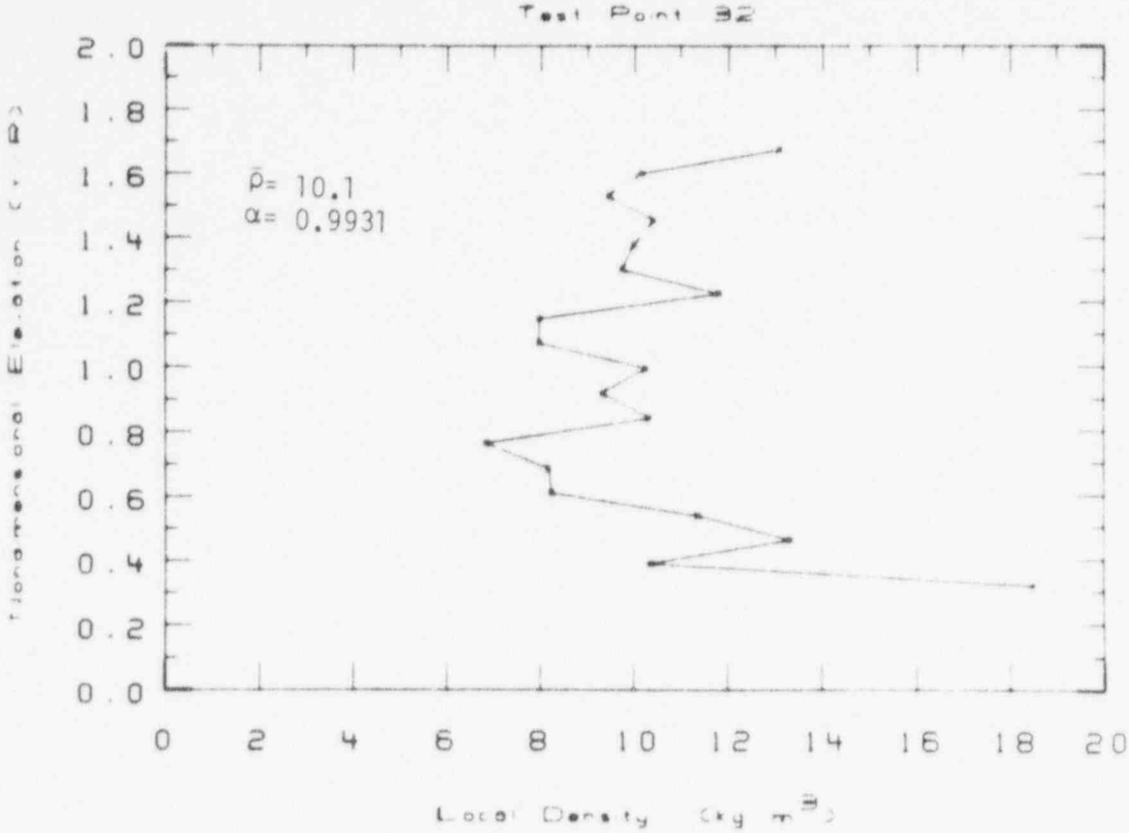


Fig. 21 Density distribution from scanning densitometer for test series - SB2 -

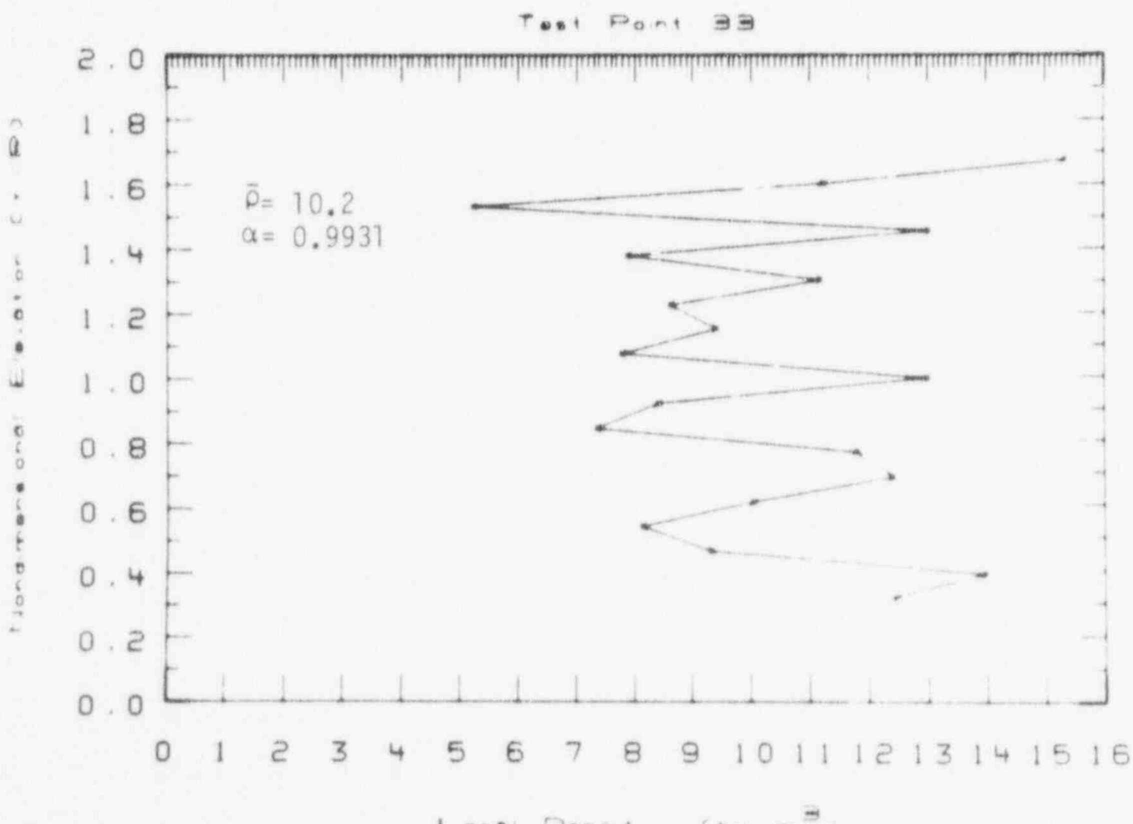


Fig. 22 Density distribution from scanning densitometer for test series - SB2 -

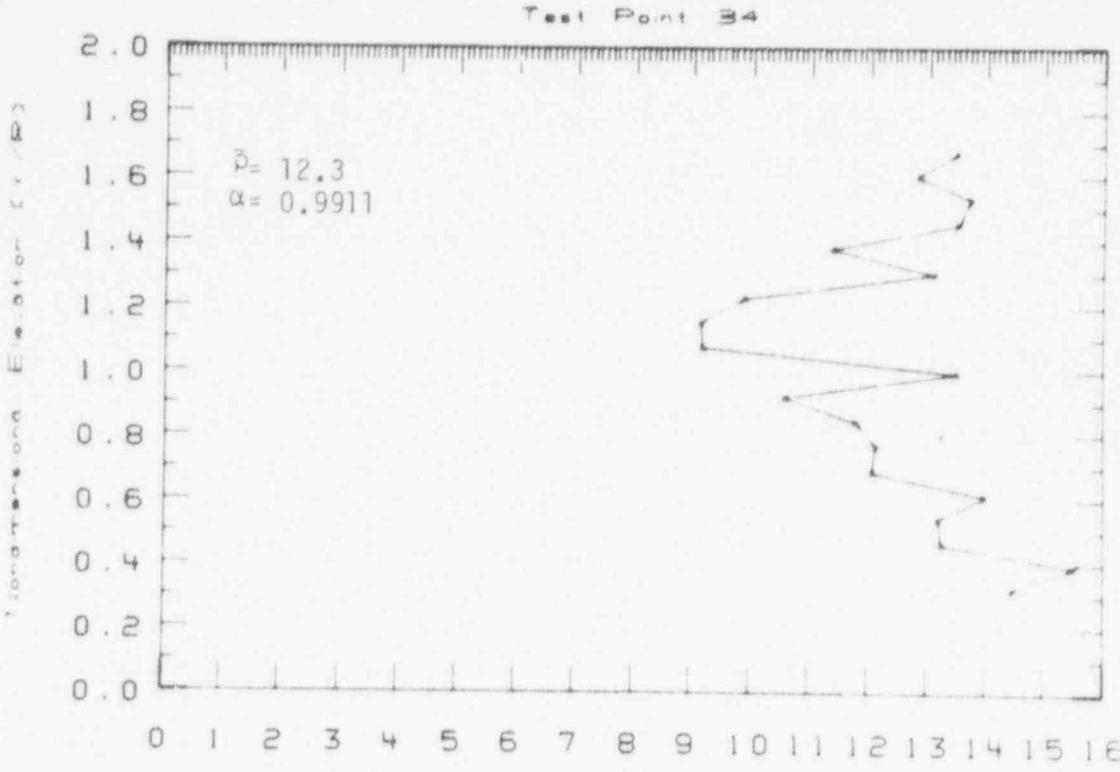


Fig. 23 Density distribution from scanning densitometer for test series - SB2 -

POOR ORIGINAL

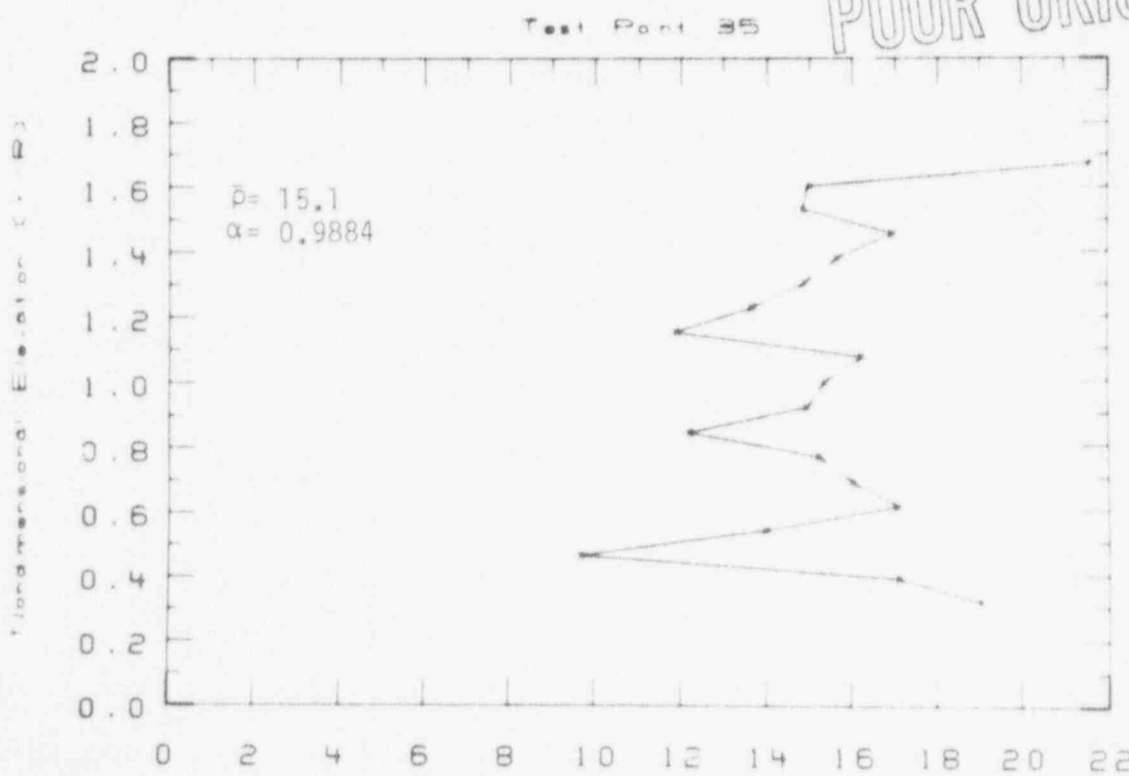


Fig. 24 Density distribution from scanning densitometer for test series - SB2 -

90010249

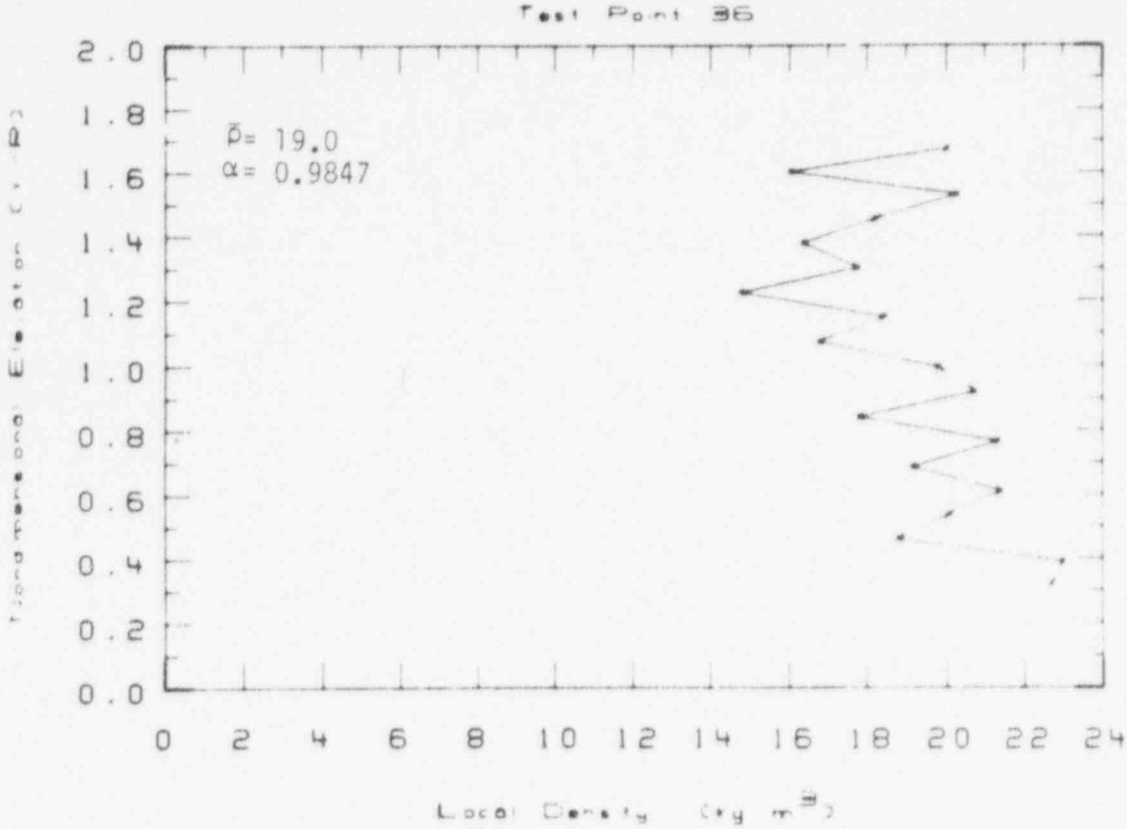


Fig. 25 Density distribution from scanning densitometer for test series * SB2 *

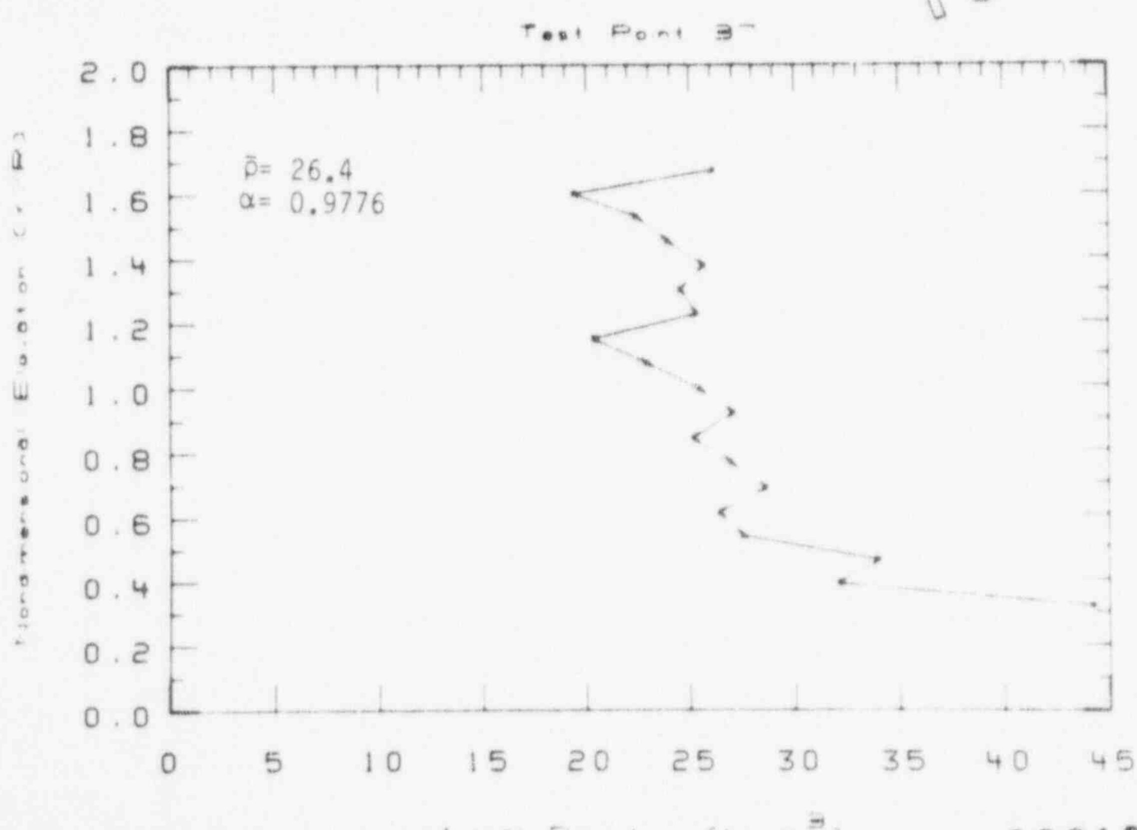


Fig. 26 Density distribution from scanning densitometer for test series * SB2 *

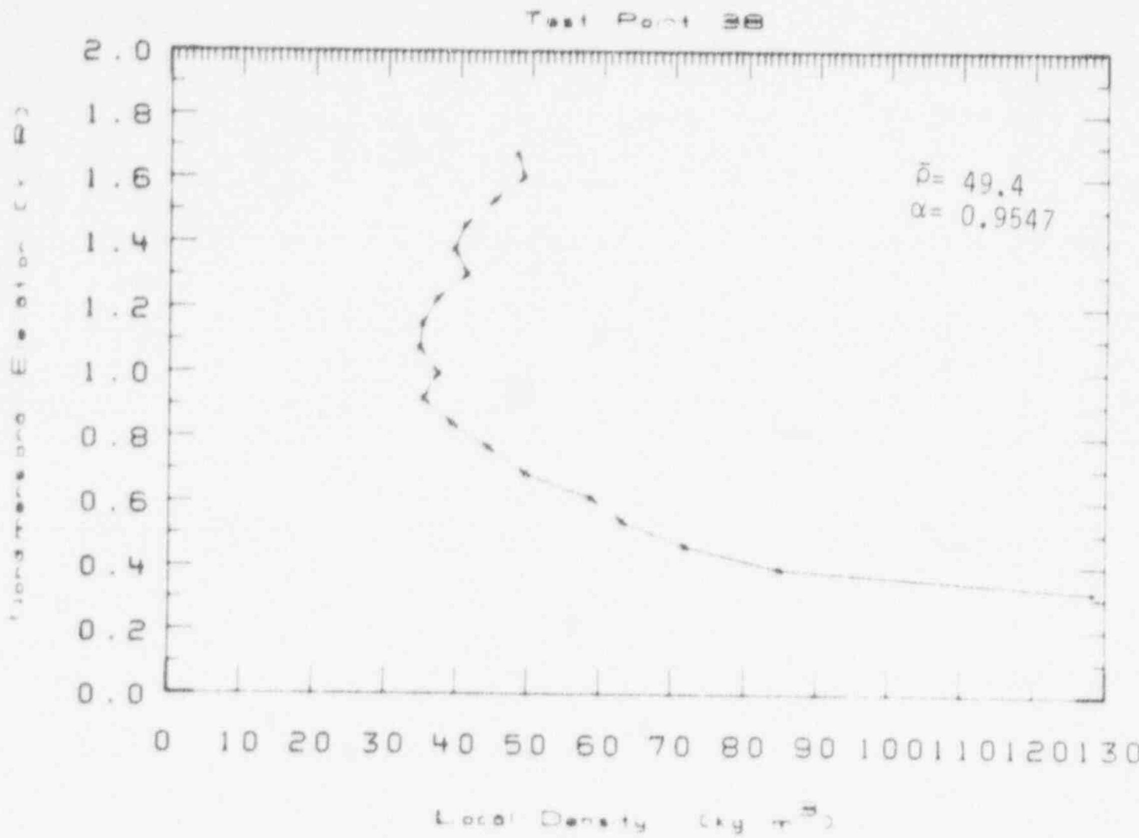


Fig. 27 Density distribution from scanning densitometer for test series - SB. -

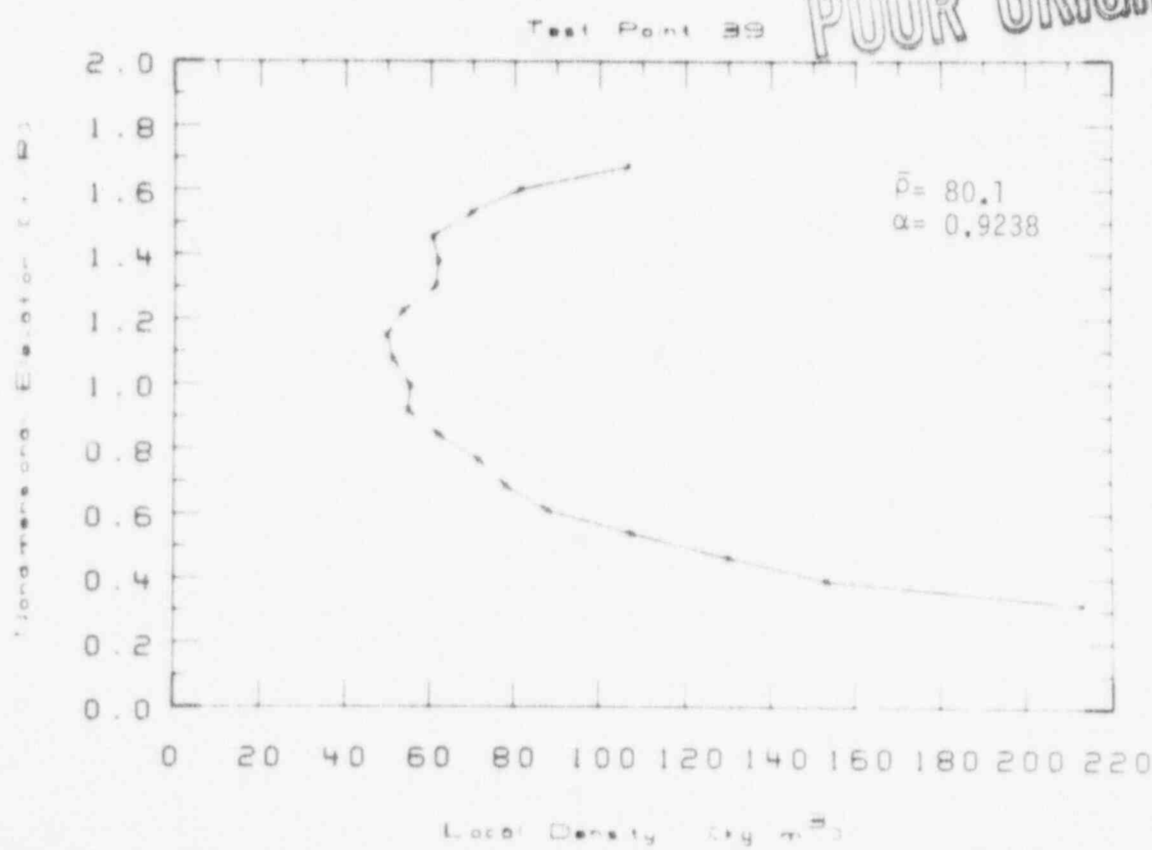


Fig. 28 Density distribution from scanning densitometer for test series - SB. -

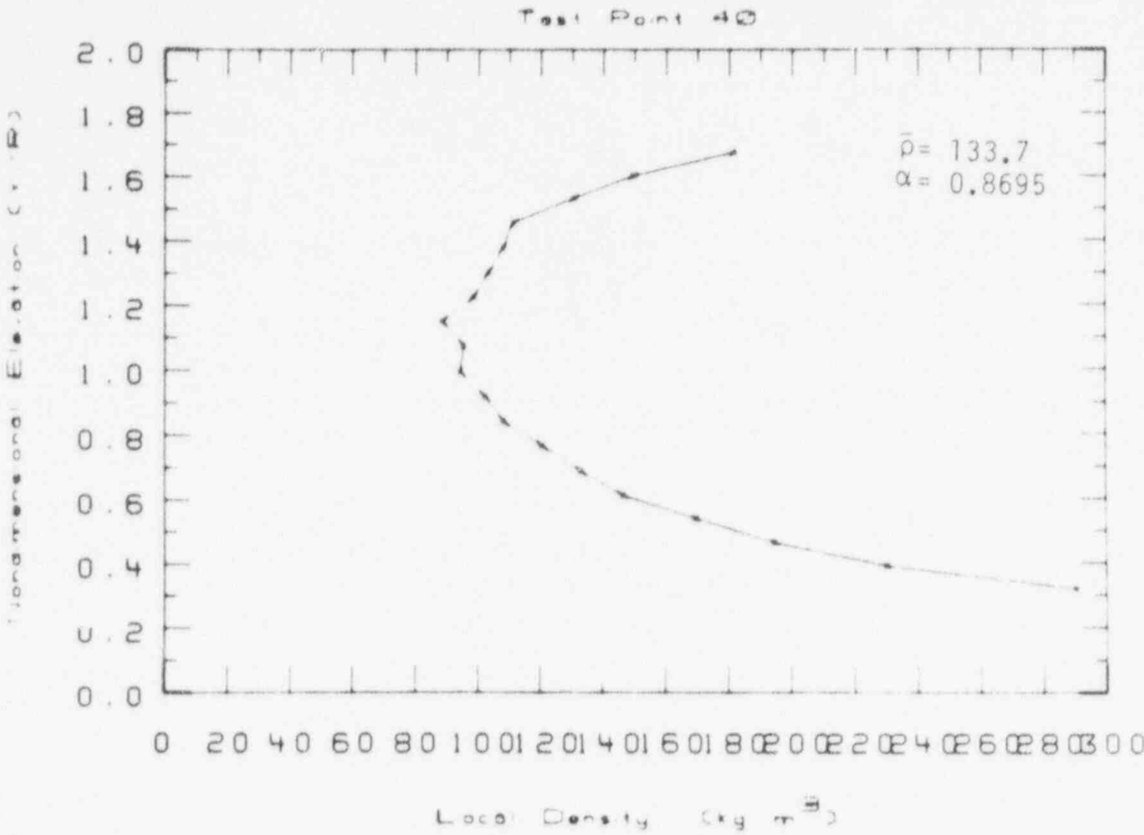


Fig. 29 Density distribution from scanning densitometer for test series * SB2 *

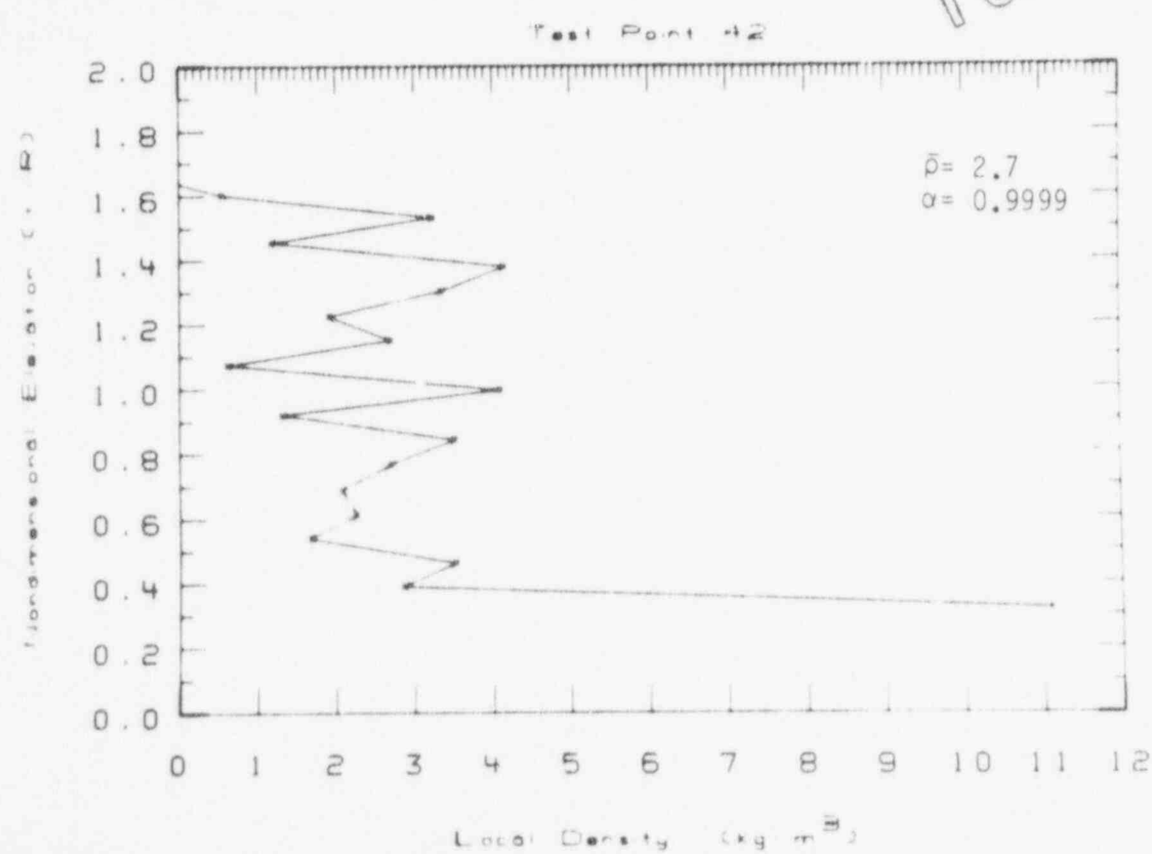


Fig. 30 Density distribution from scanning densitometer for test series * SB2 *

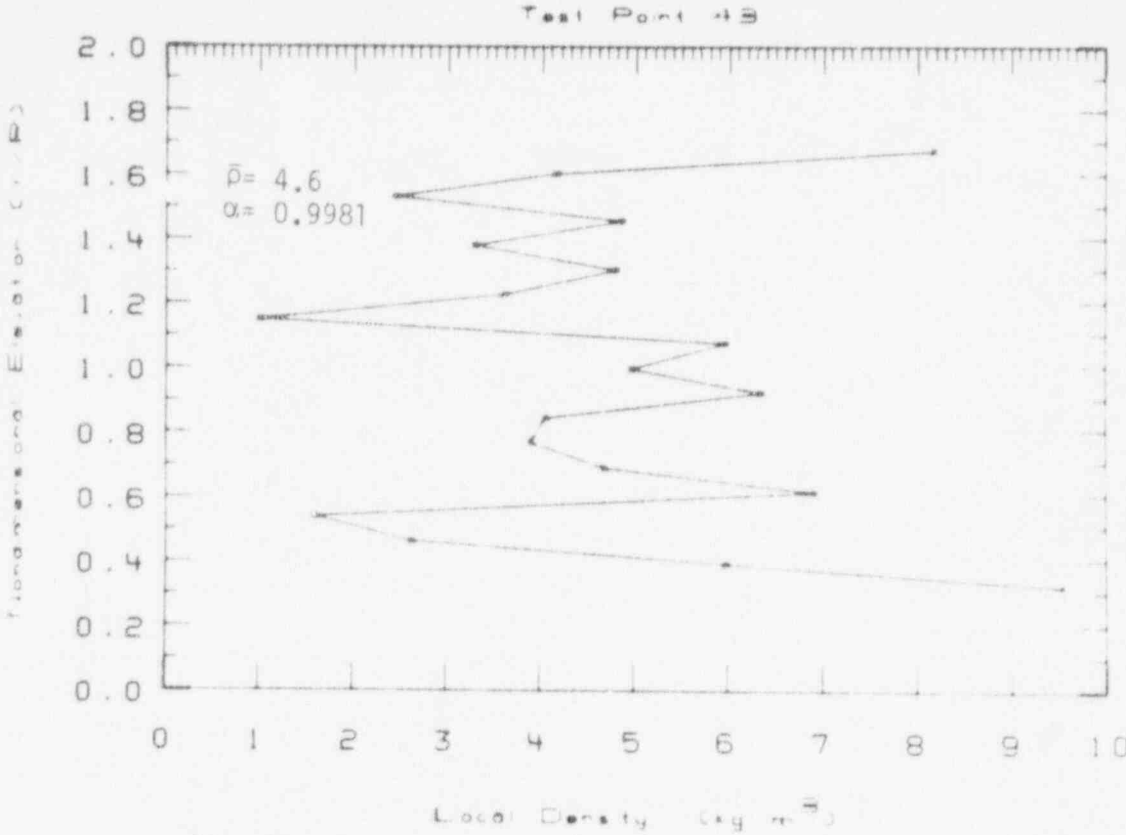


Fig. 31 Density distribution from scanning densitometer for test series - SB2 -

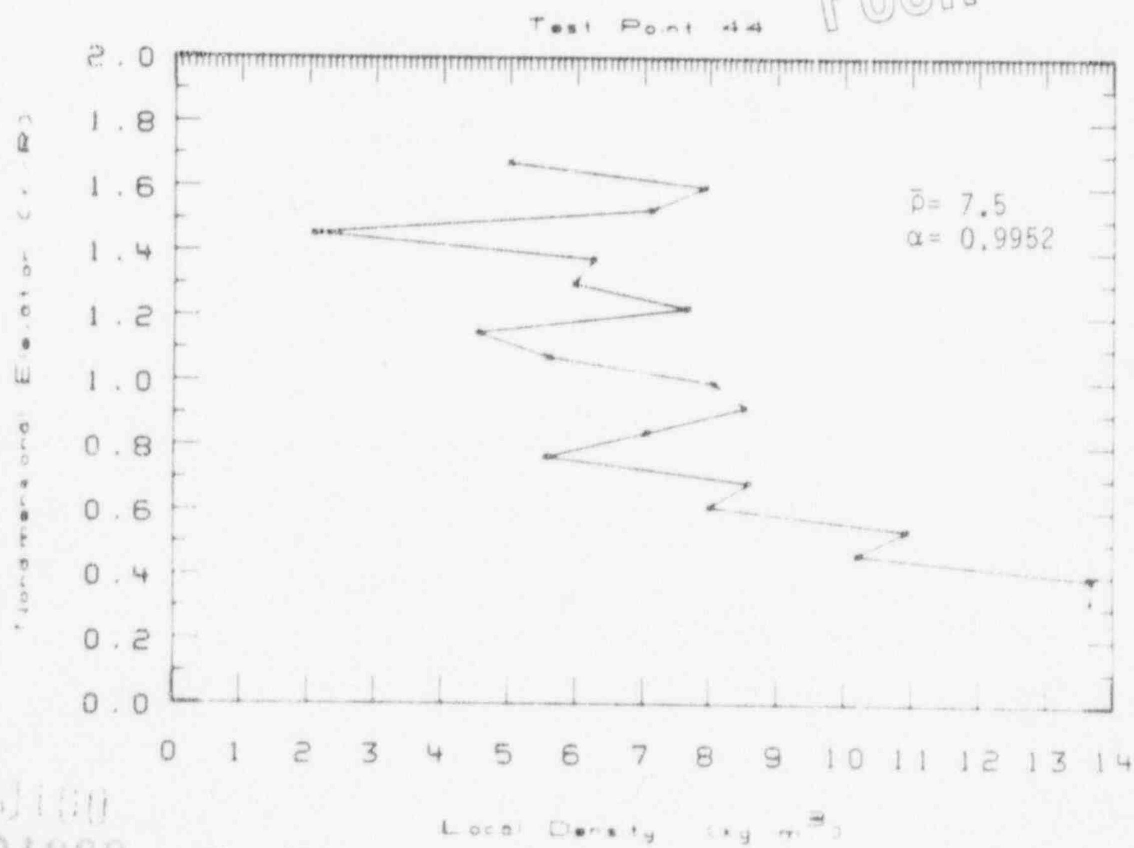


Fig. 32 Density distribution from scanning densitometer for test series - SB2 -

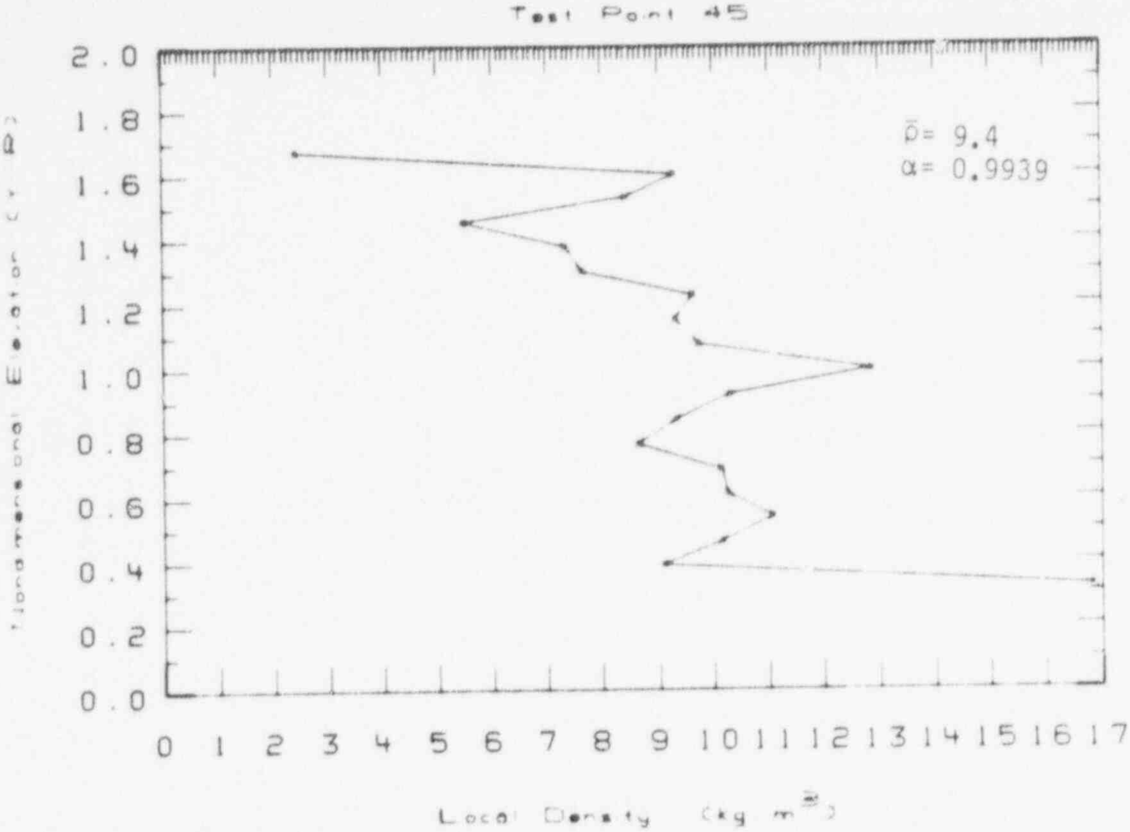


Fig. 33 Density distribution from scanning densitometer for test series - SB2 -

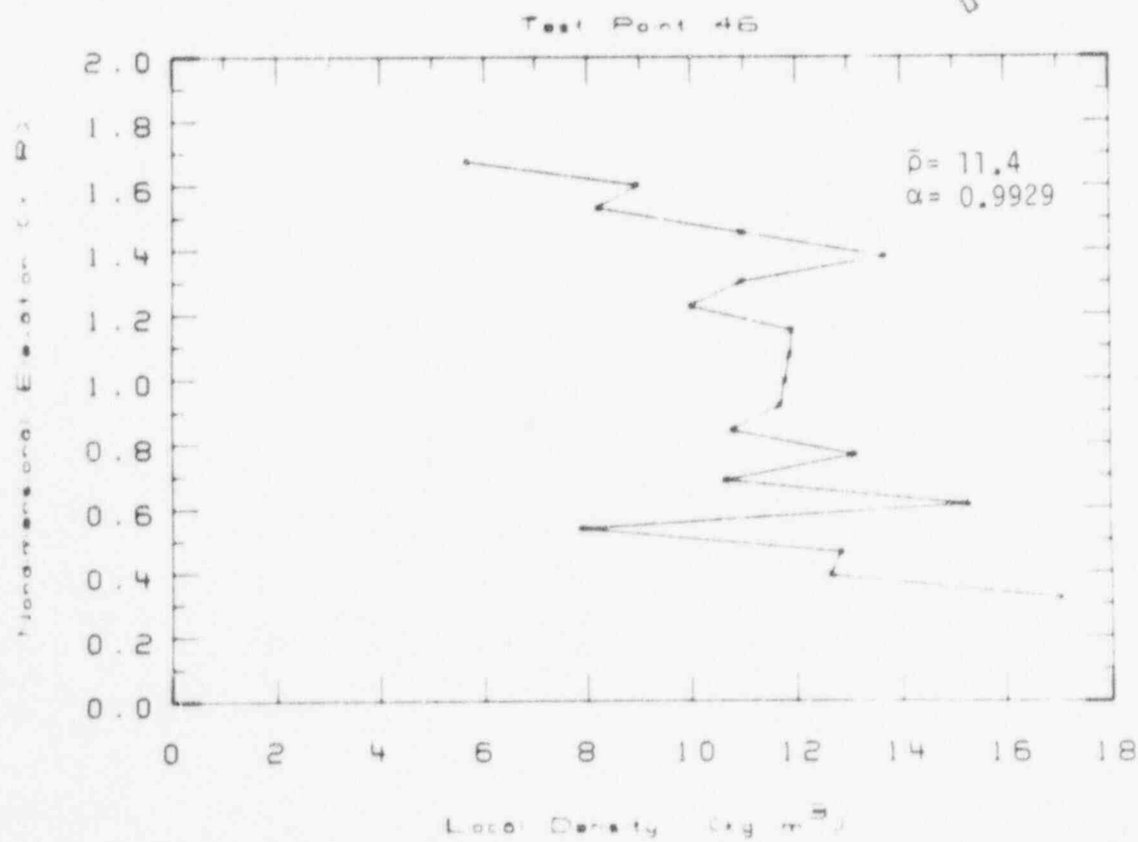


Fig. 34 Density distribution from scanning densitometer for test series - SB2 -

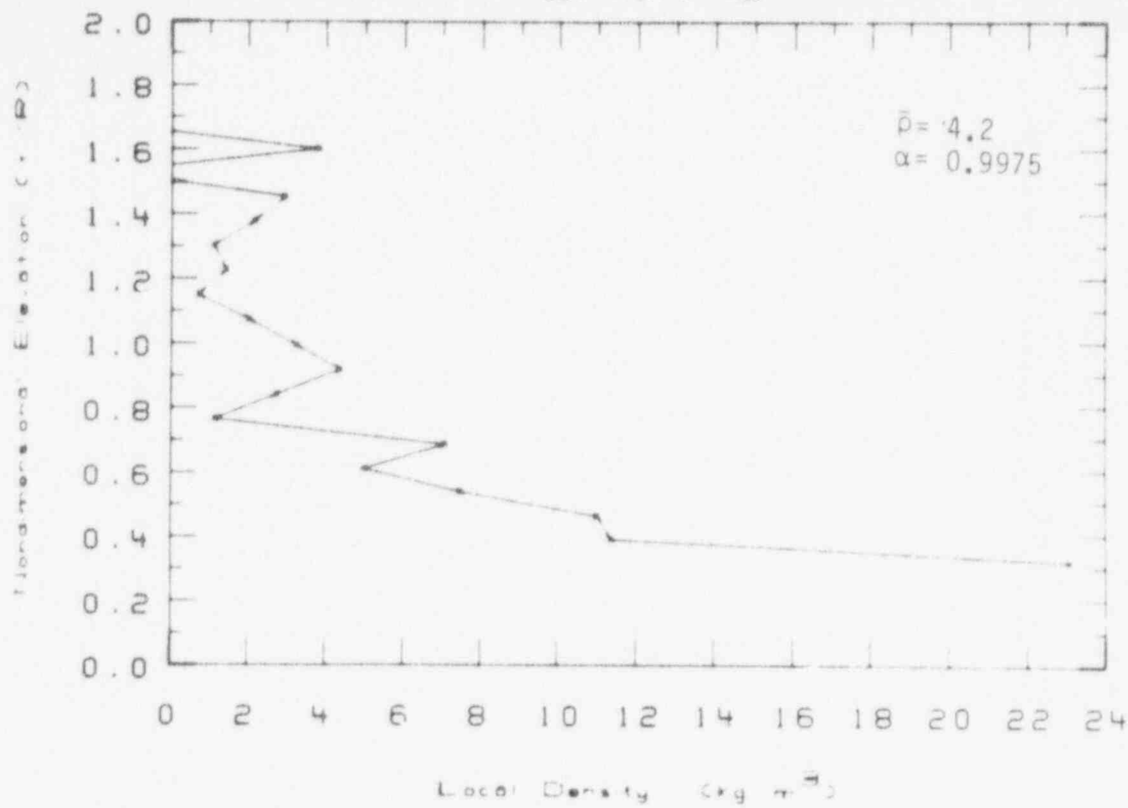


Fig. 35 Density distribution from scanning densitometer for test series * SB2 *

POOR ORIGINAL

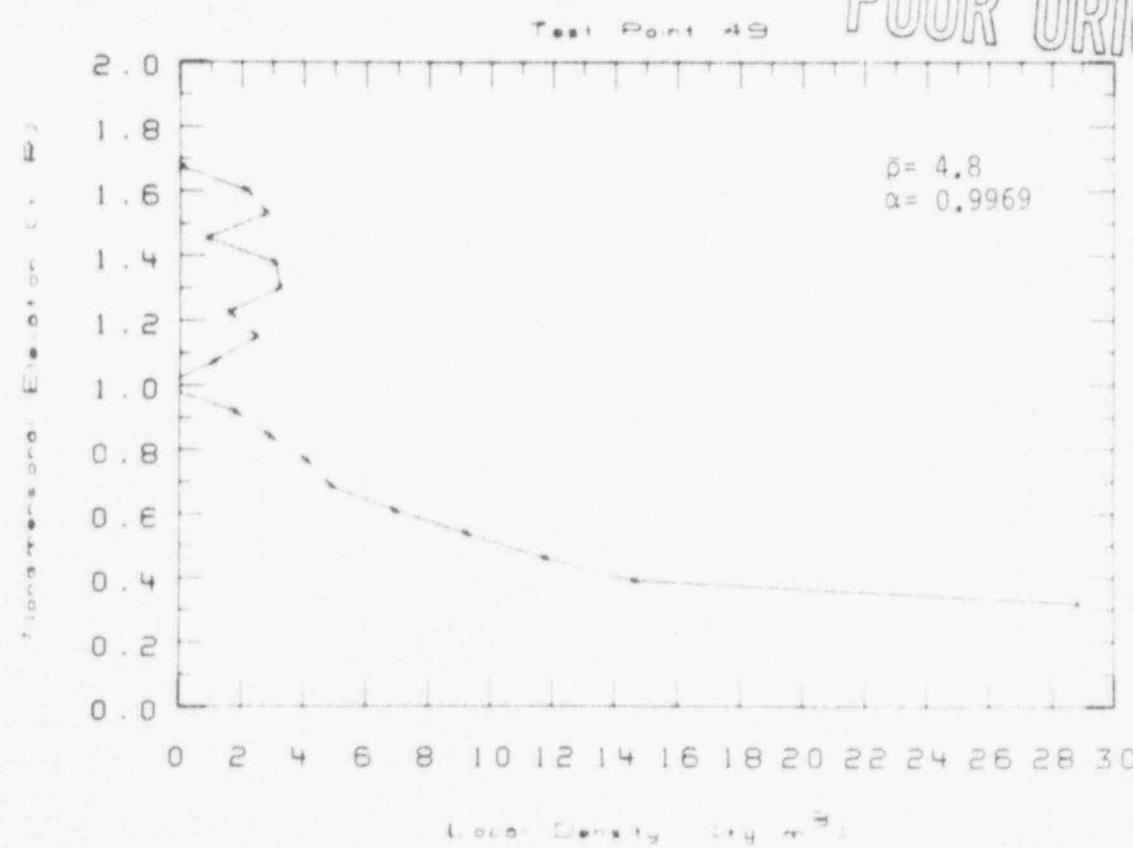


Fig. 36 Density distribution from scanning densitometer for test series * SB2 *

90010255

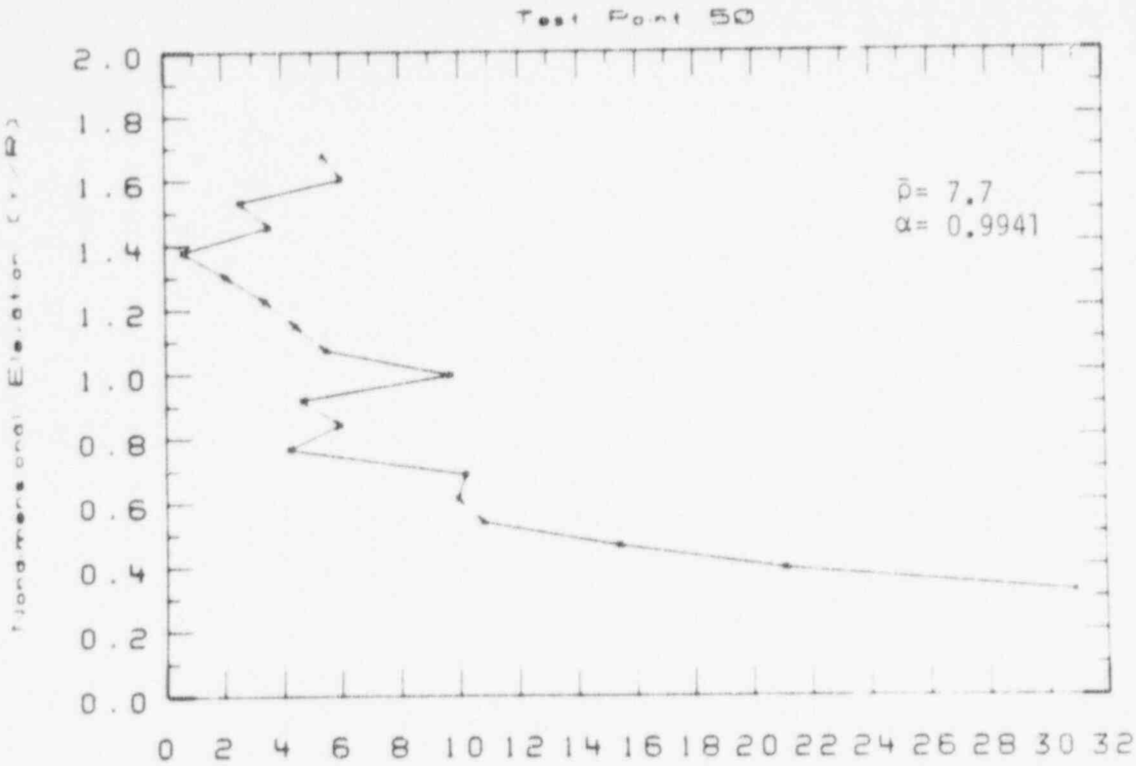
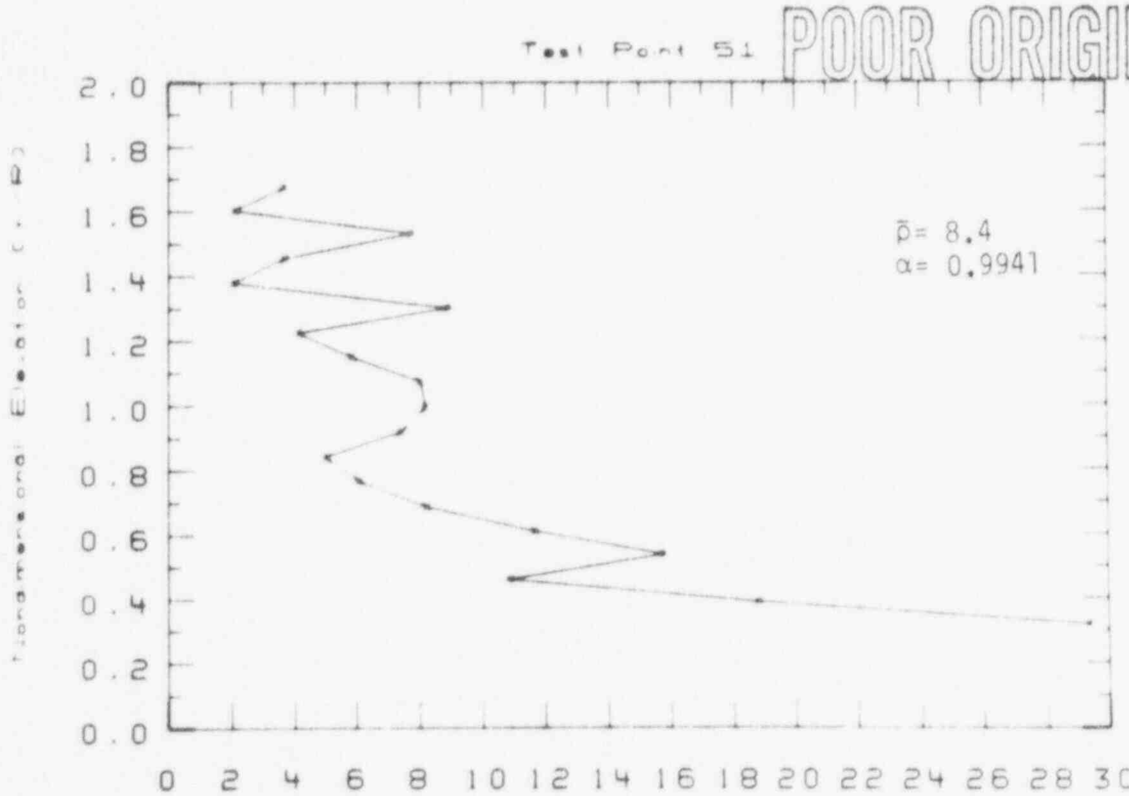


Fig. 37 Density distribution from scanning densitometer for test series - SB2 -



POOR ORIGINAL

Fig. 38 Density distribution from scanning densitometer for test series - SB2 -

90010256

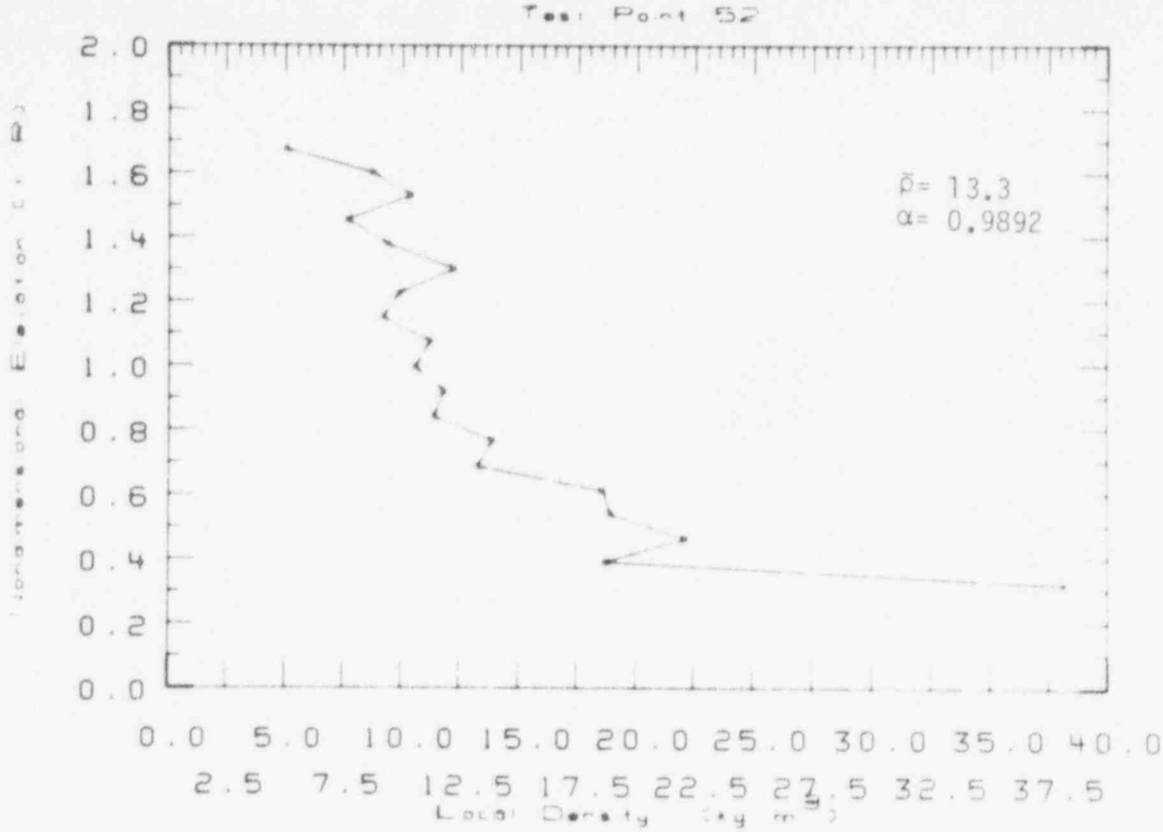


Fig. 39 Density distribution from scanning densitometer for test series - SB2 -

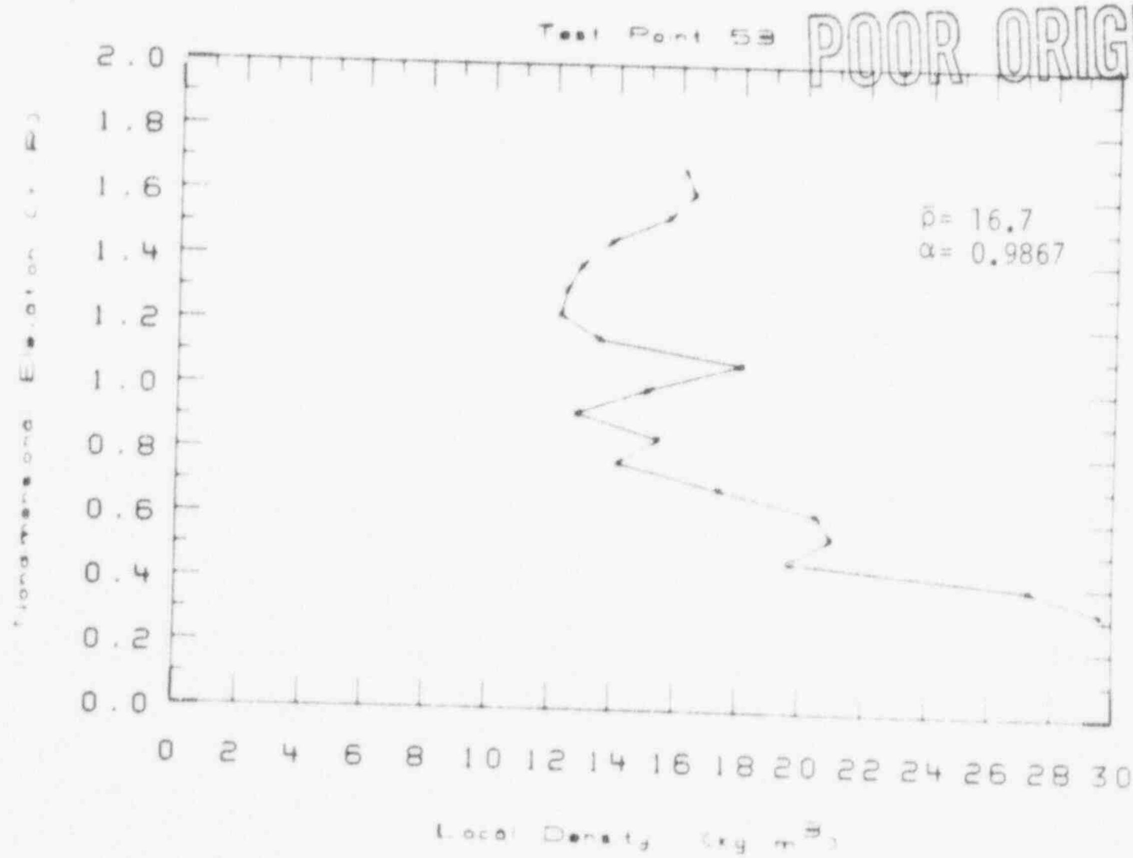


Fig. 40 Density distribution from scanning densitometer for test series - SB2 -

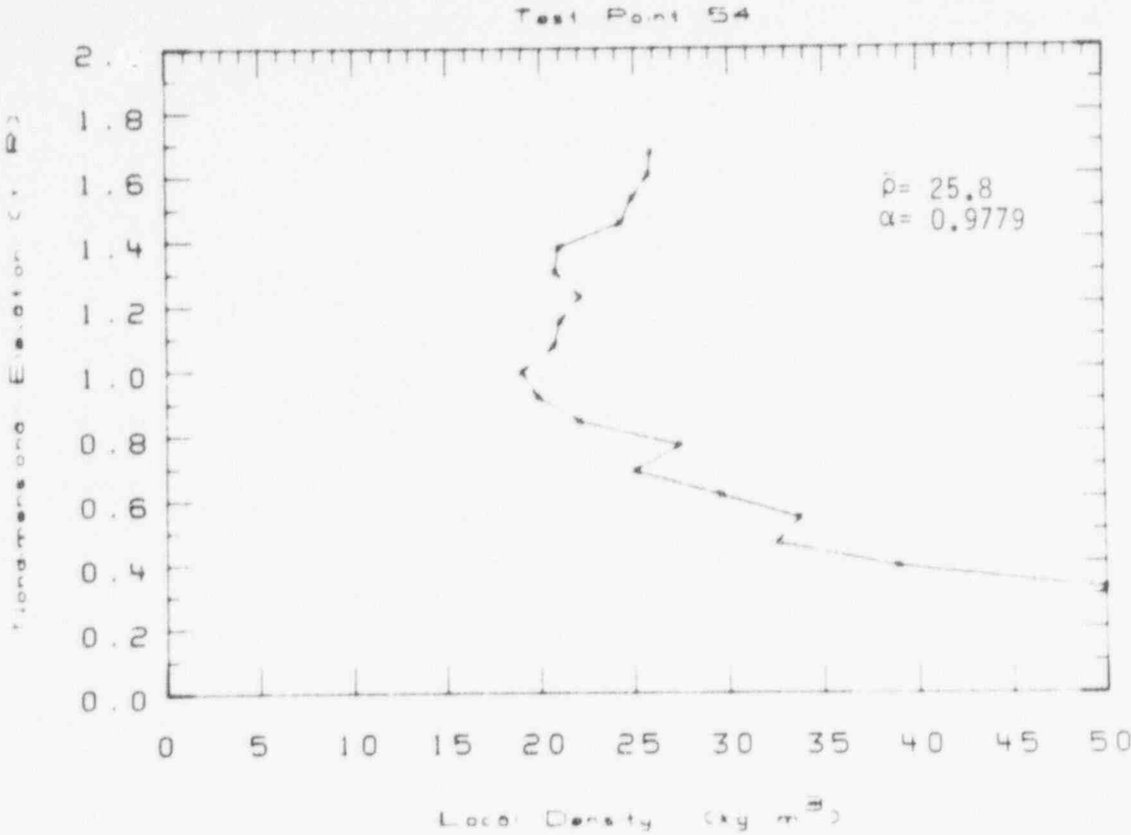


Fig. 41 Density distribution from scanning densitometer for test series * SB2 *

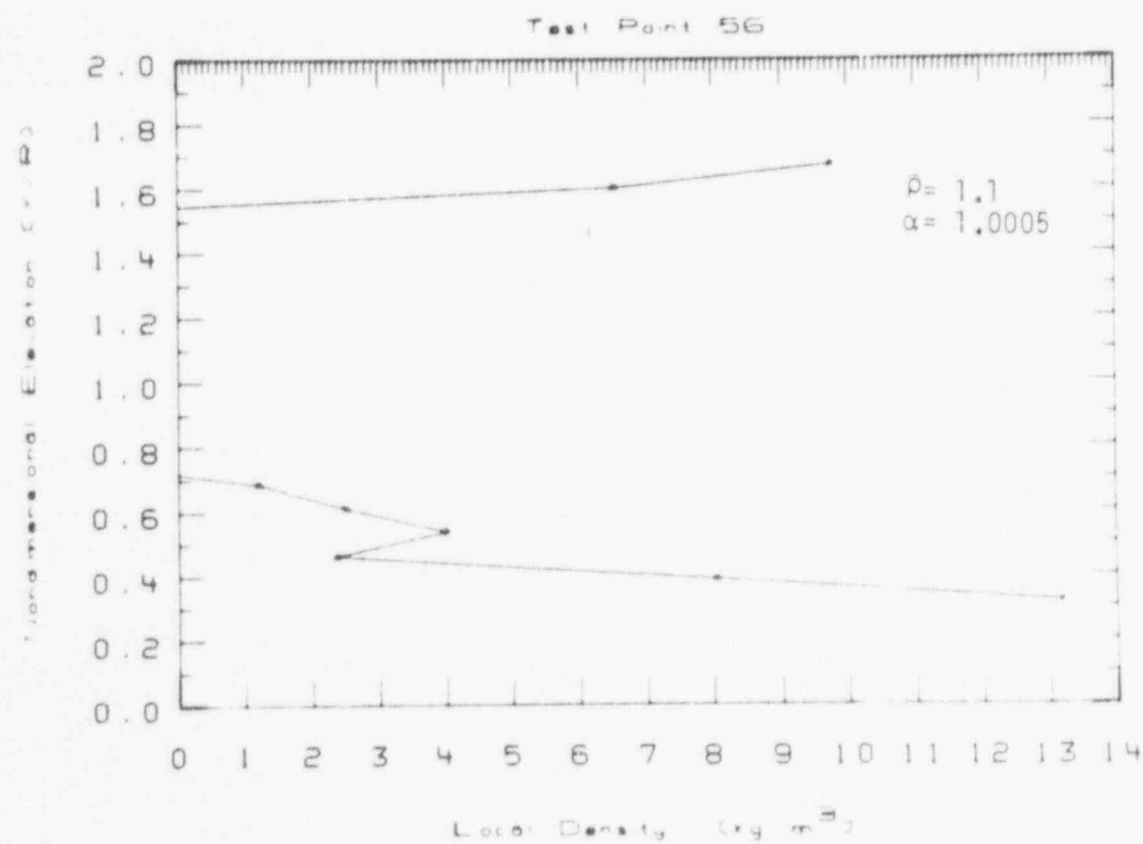


Fig. 42 Density distribution from scanning densitometer for test series * SB2 *

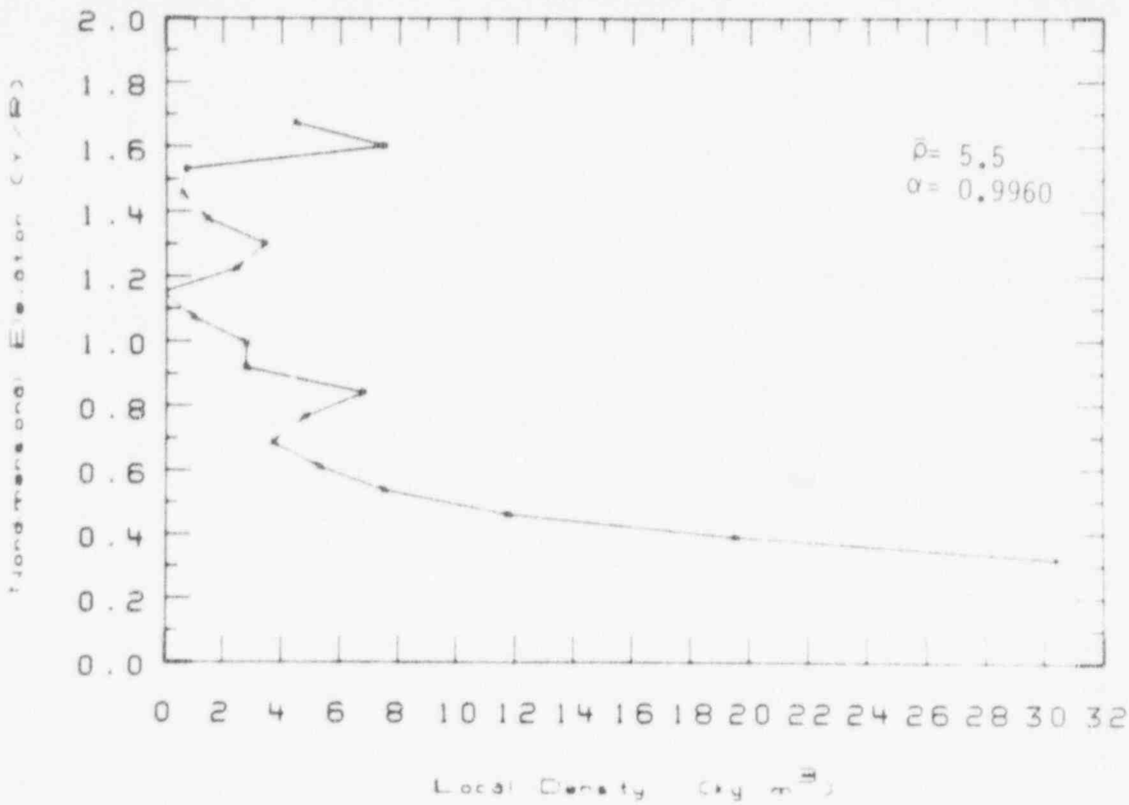


Fig. 43 Density distribution from scanning densitometer for test series - SB2 -

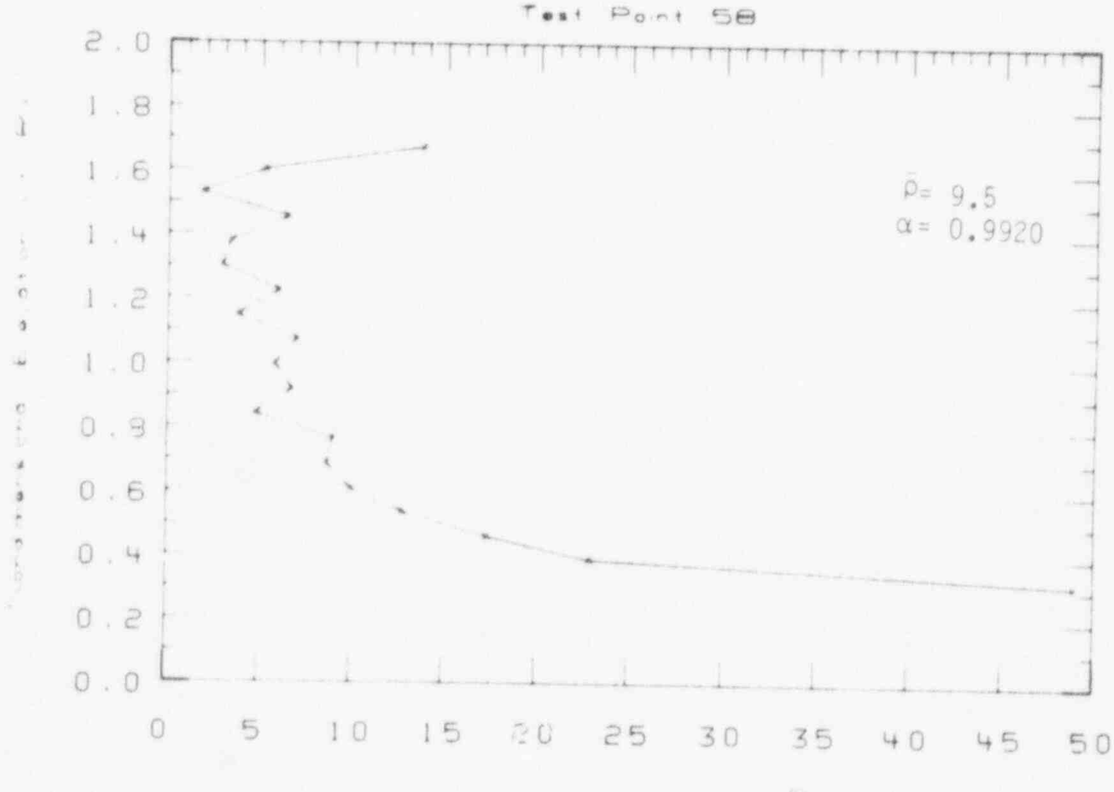


Fig. 44 Density distribution from scanning densitometer for test series - SB2 -

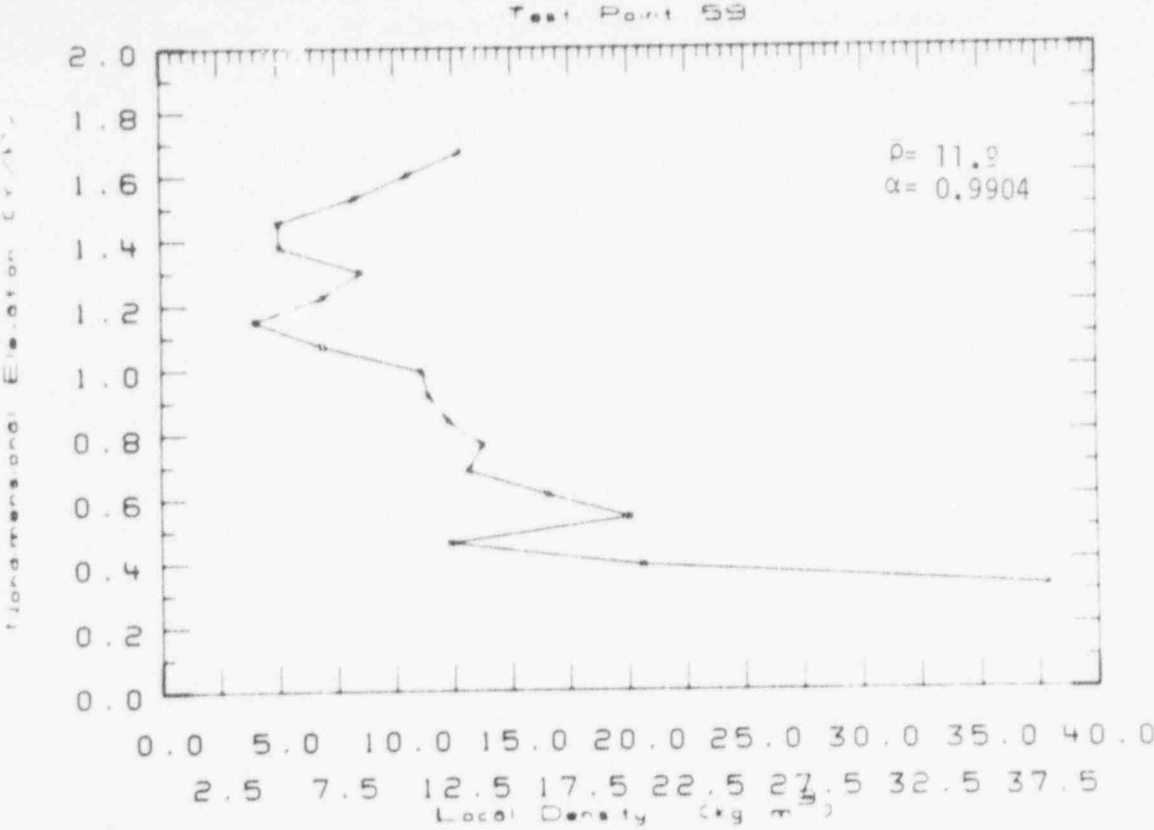


Fig. 45 Density distribution from scanning densitometer for test series * SB2 *

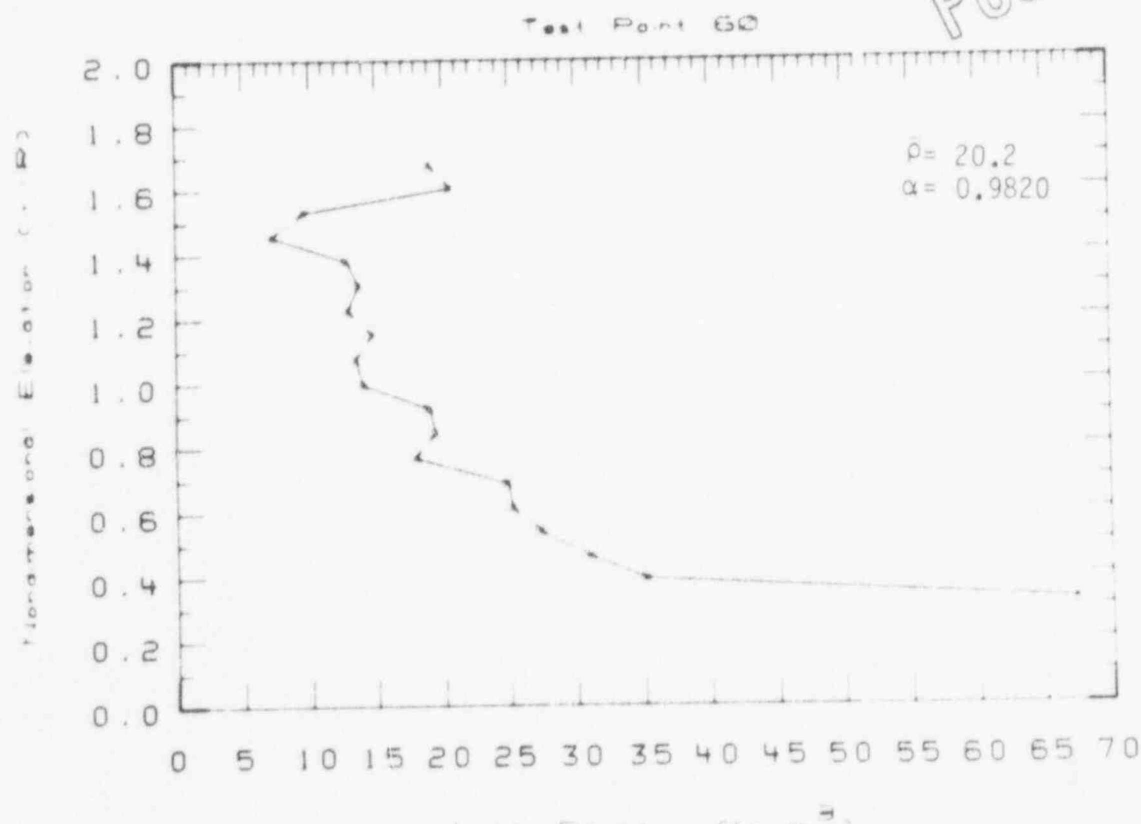


Fig. 46 Density distribution from scanning densitometer for test series * SB2 *

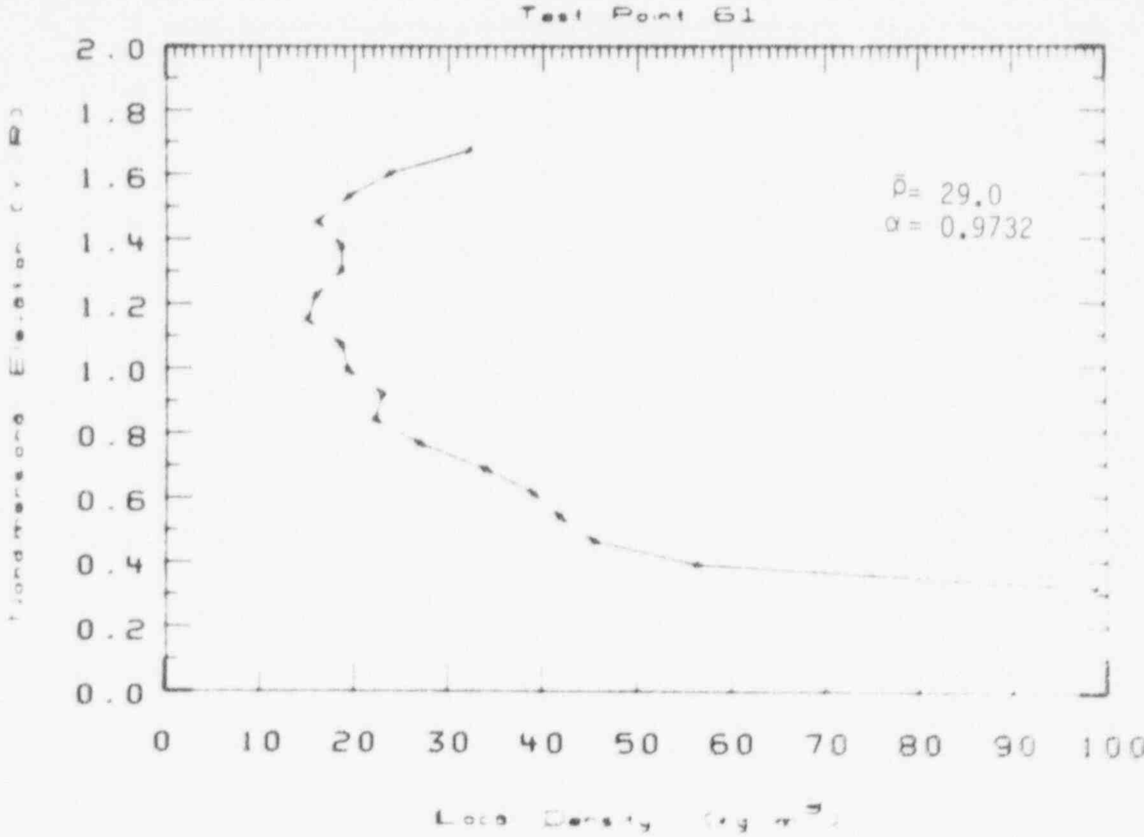


Fig. 47 Density distribution from scanning densitometer for test series - SB2 -

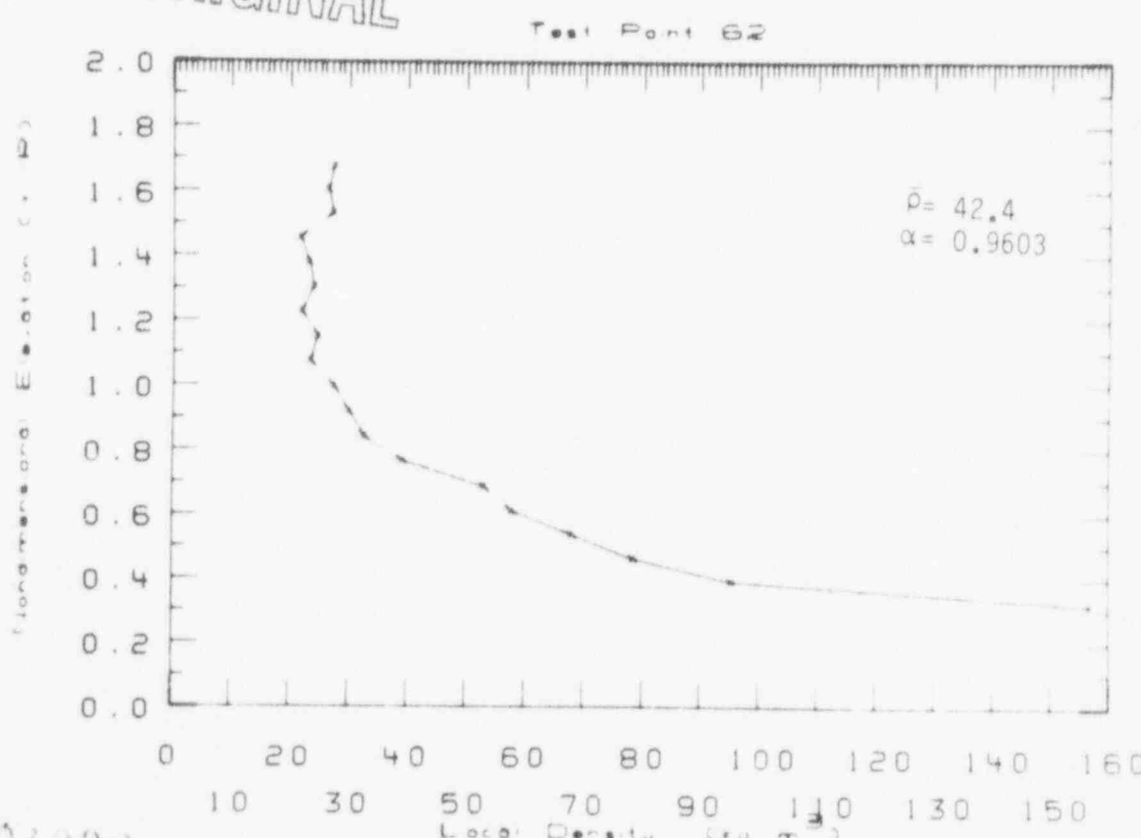


Fig. 48 Density distribution from scanning densitometer for test series - SB2 -

Test Point 63

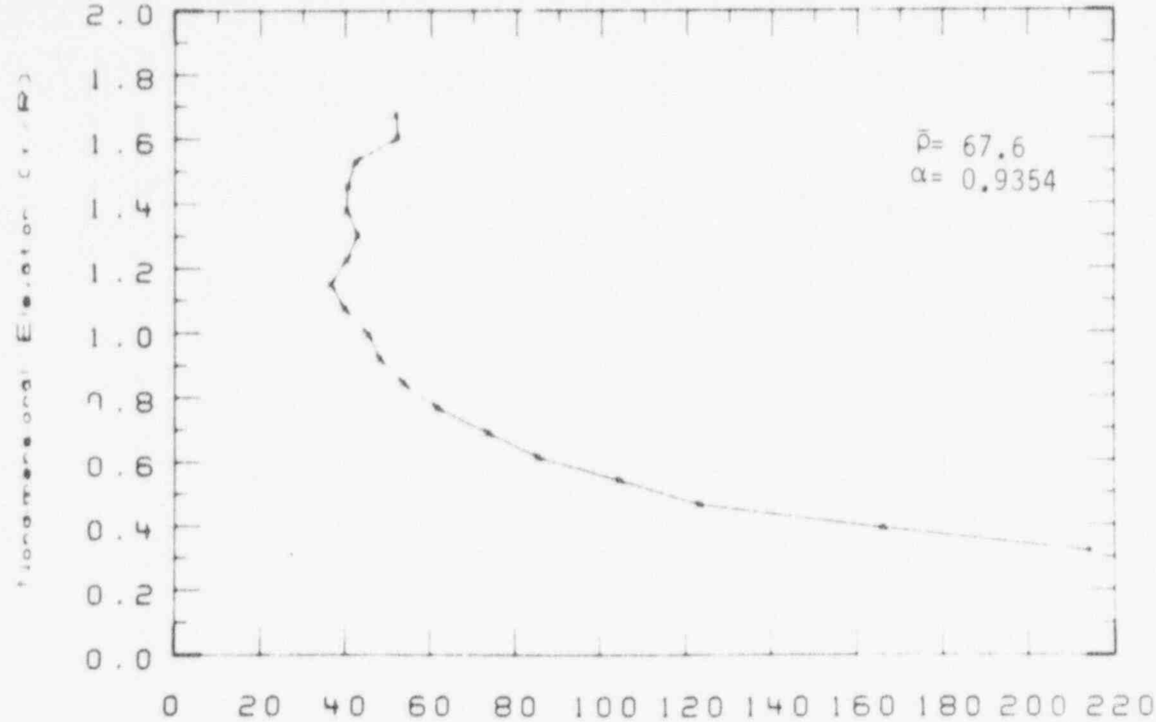


Fig. 49 Density distribution from scanning densitometer for test series - SB2 -

POOR ORIGINAL

Test Point 66

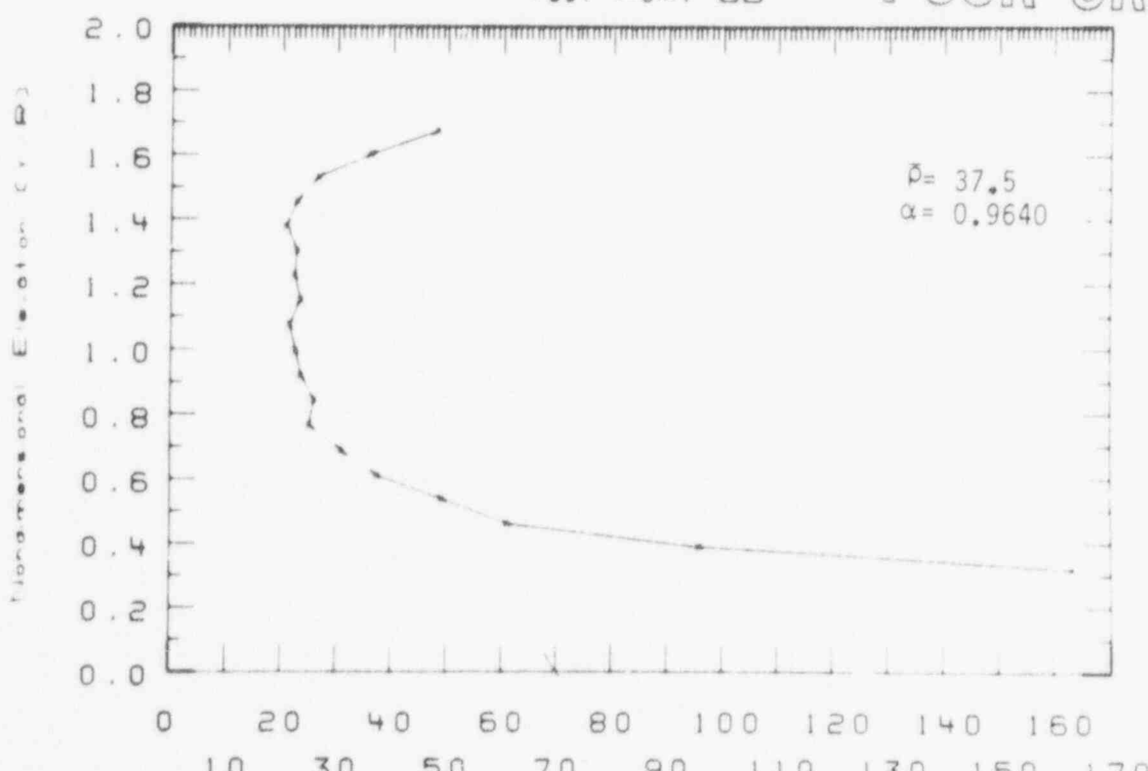


Fig. 50 Density distribution from scanning densitometer for test series - SB2 -

90010262

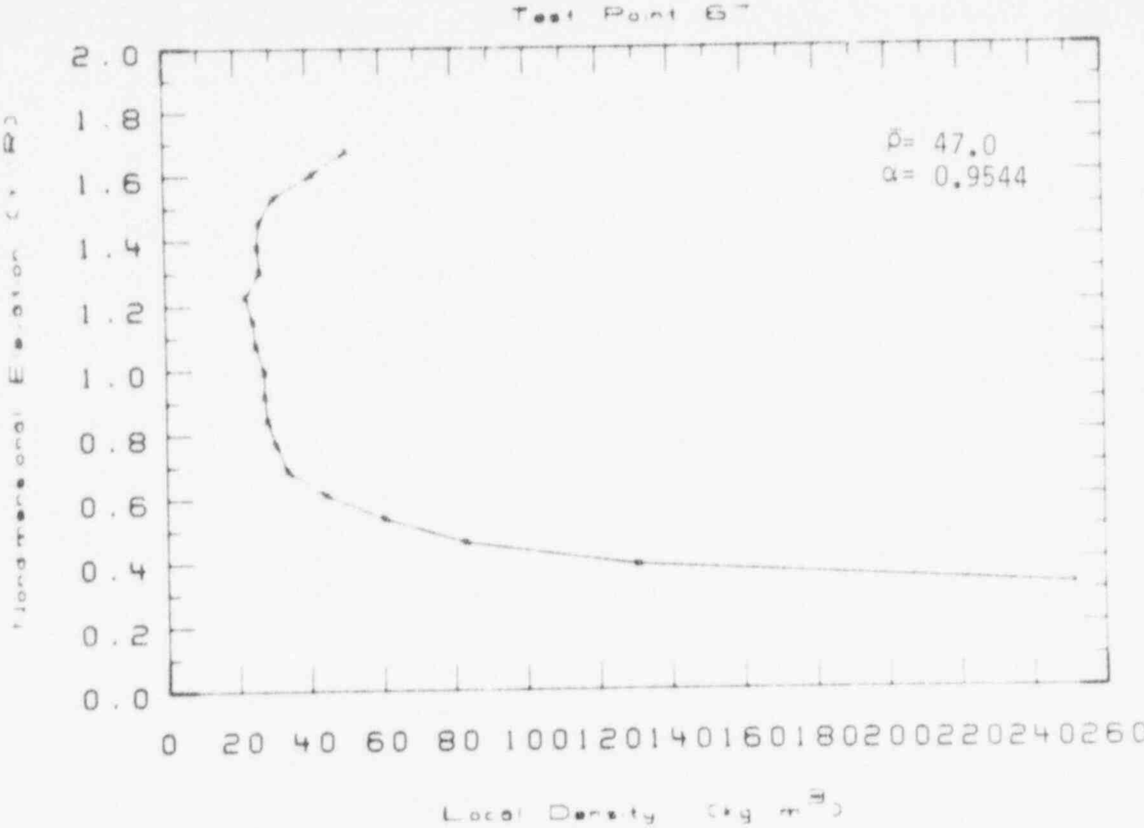


Fig. 51 Density distribution from scanning densitometer for test series * SB2 *

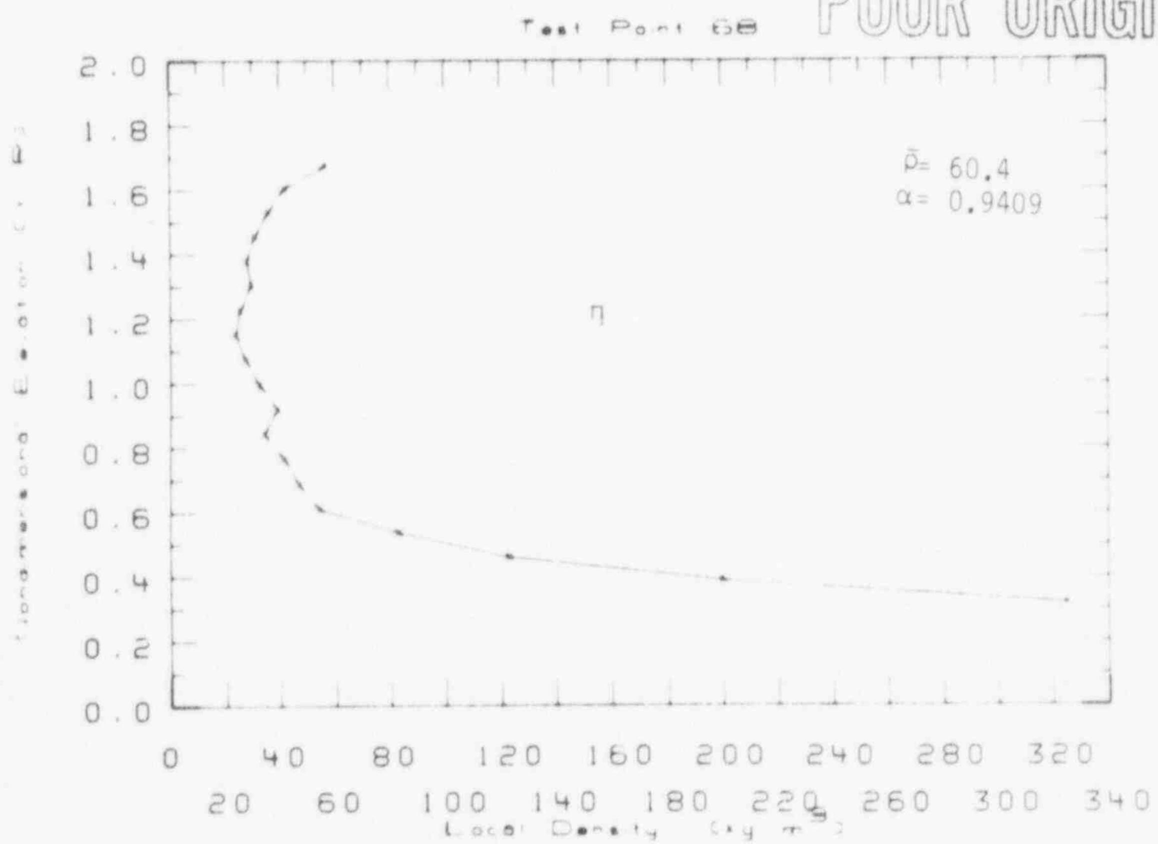
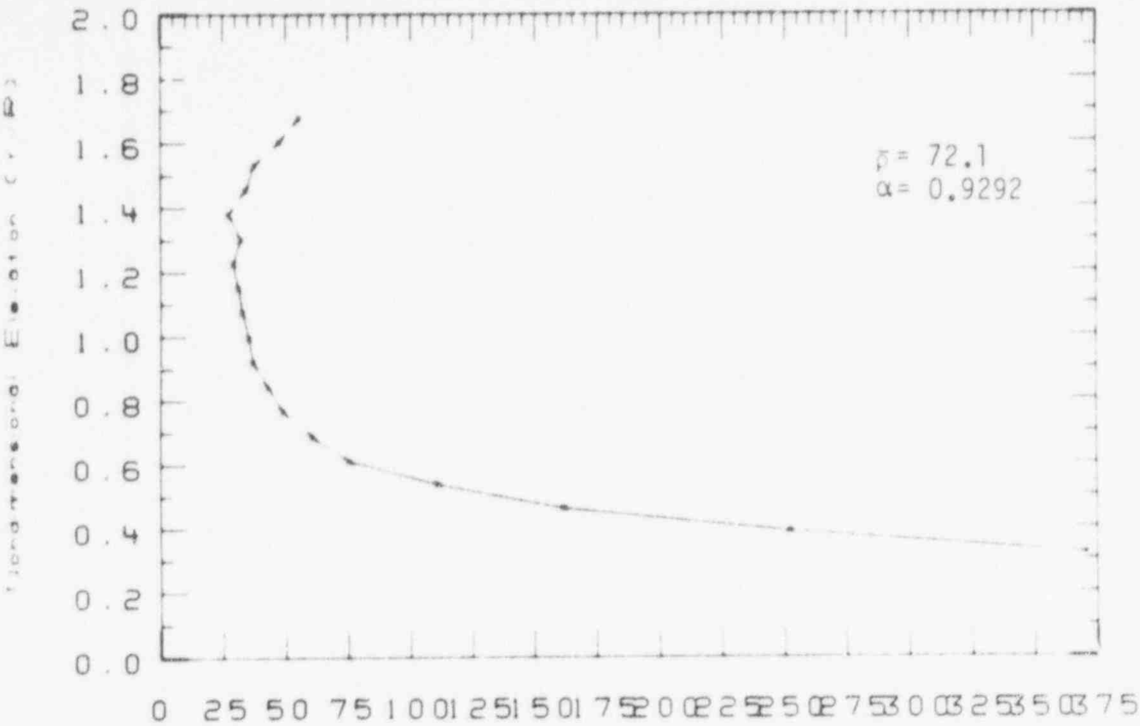


Fig. 52 Density distribution from scanning densitometer for test series * SB2 *

Test Point 69

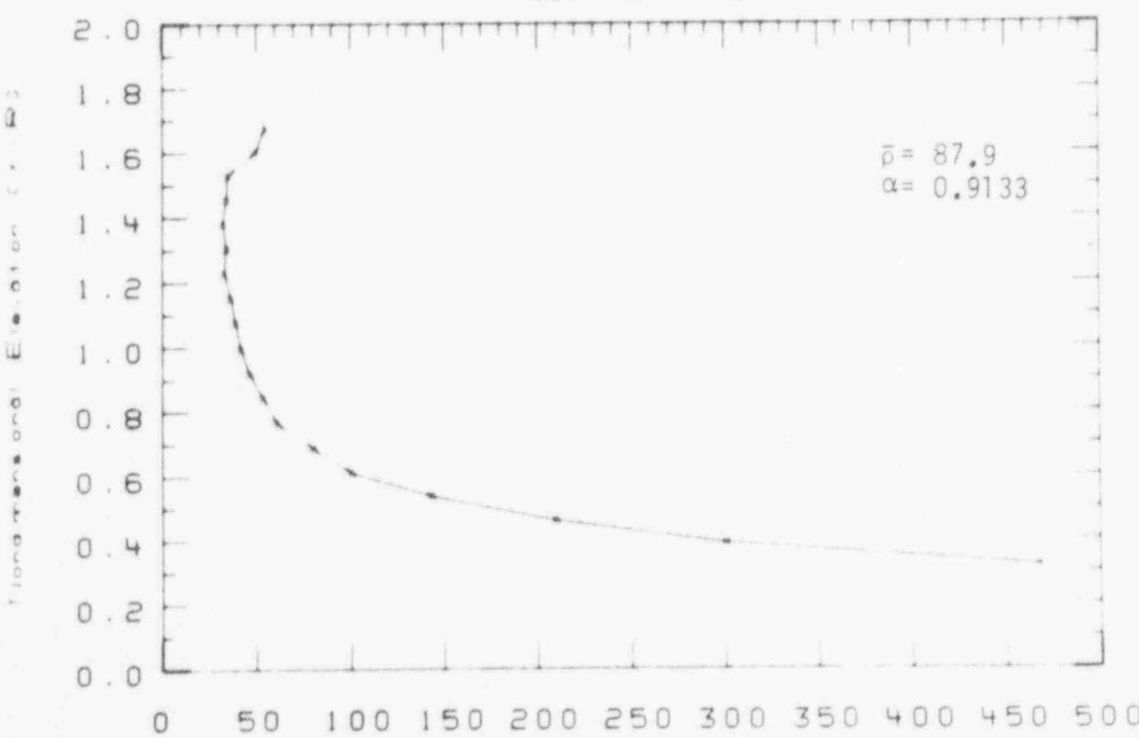


Local Density (kg m⁻³)

Fig. 53 Density distribution from scanning densitometer for test series SB2

POOR ORIGINAL

Test Point 70



Local Density (kg m⁻³)

Fig. 54 Density distribution from scanning densitometer for test series SB2

90010264

Test Point 71

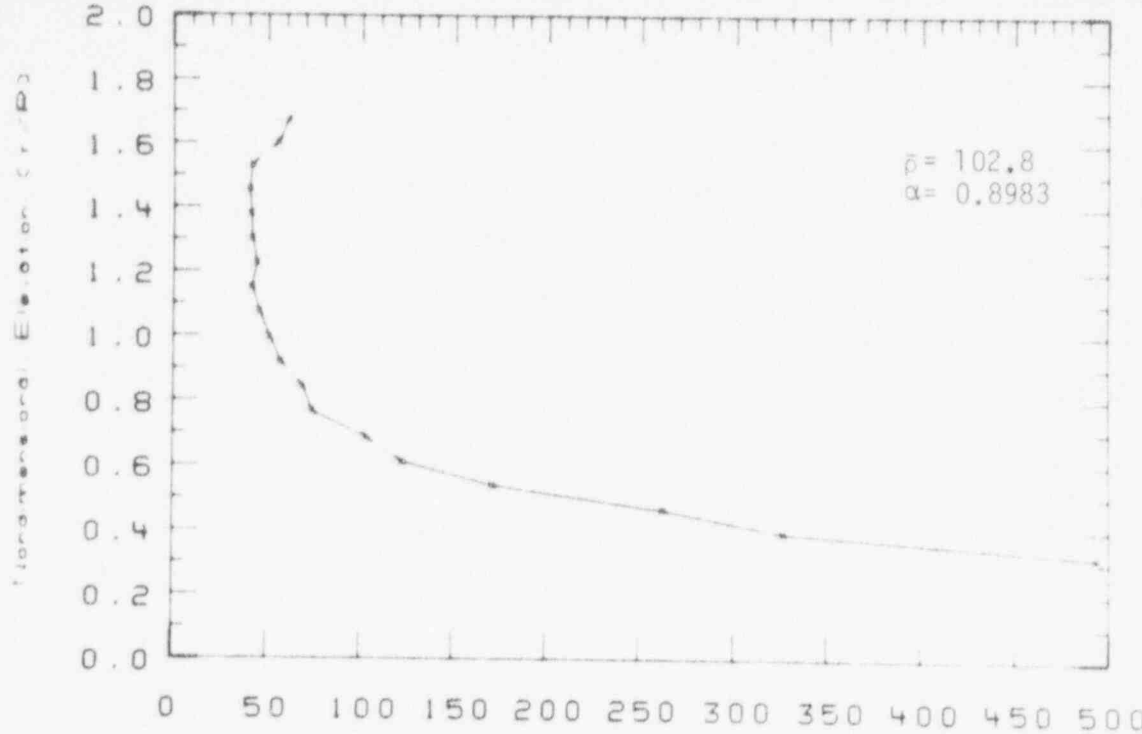


Fig. 55 Density distribution from scanning densitometer for test series - SB2 -

POOR ORIGINAL

Test Point 73

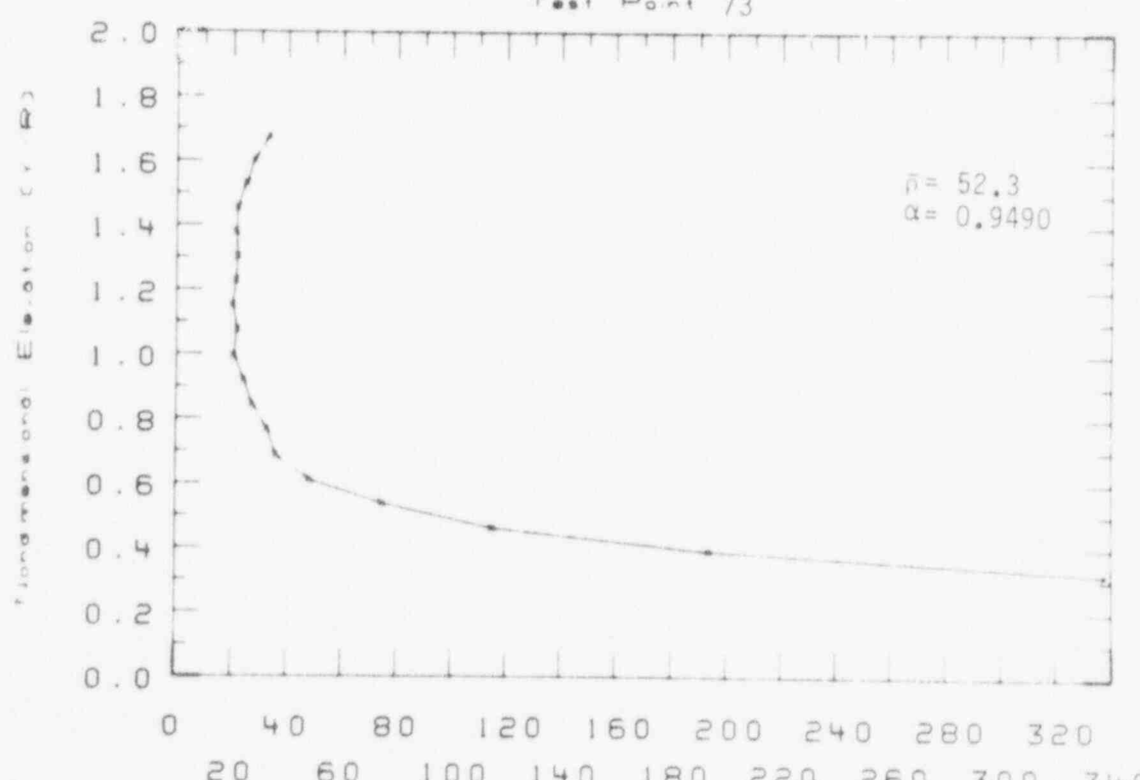


Fig. 56 Density distribution from scanning densitometer for test series - SB2 -

90010265

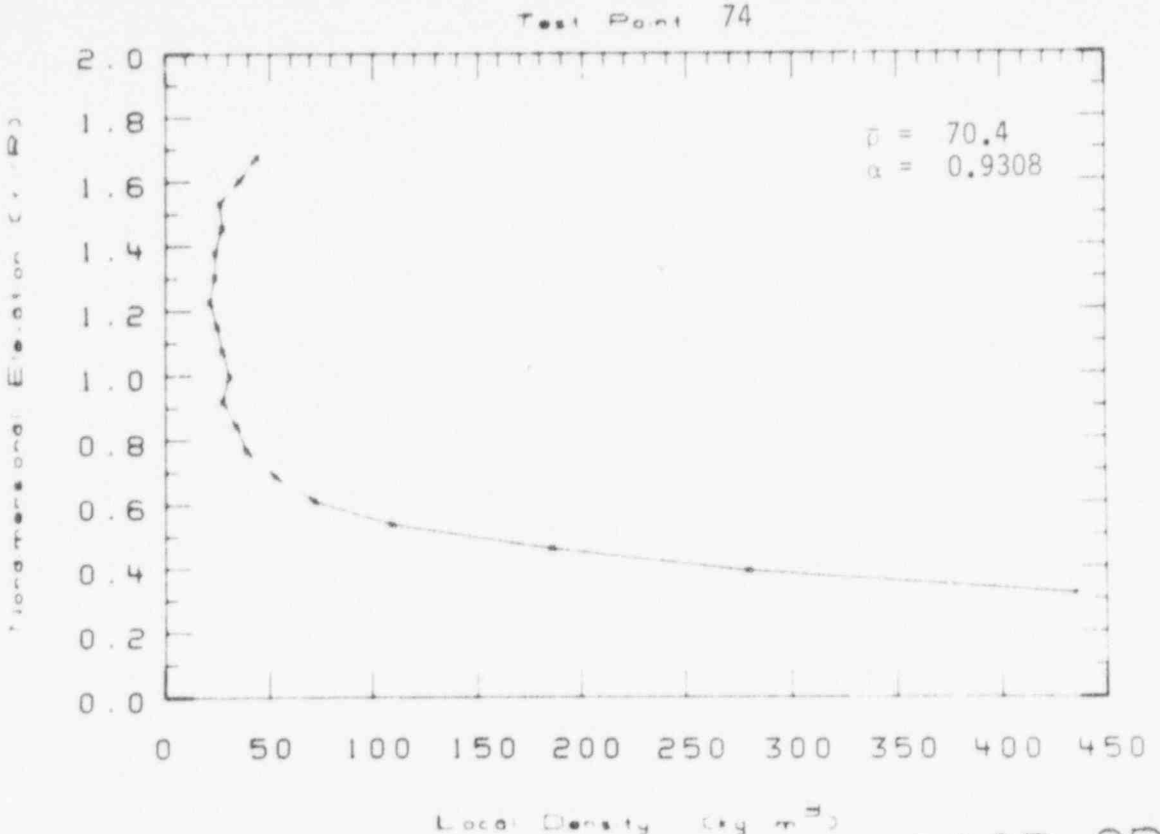


Fig. 57 Density distribution from scanning densitometer for test series - SB2 -

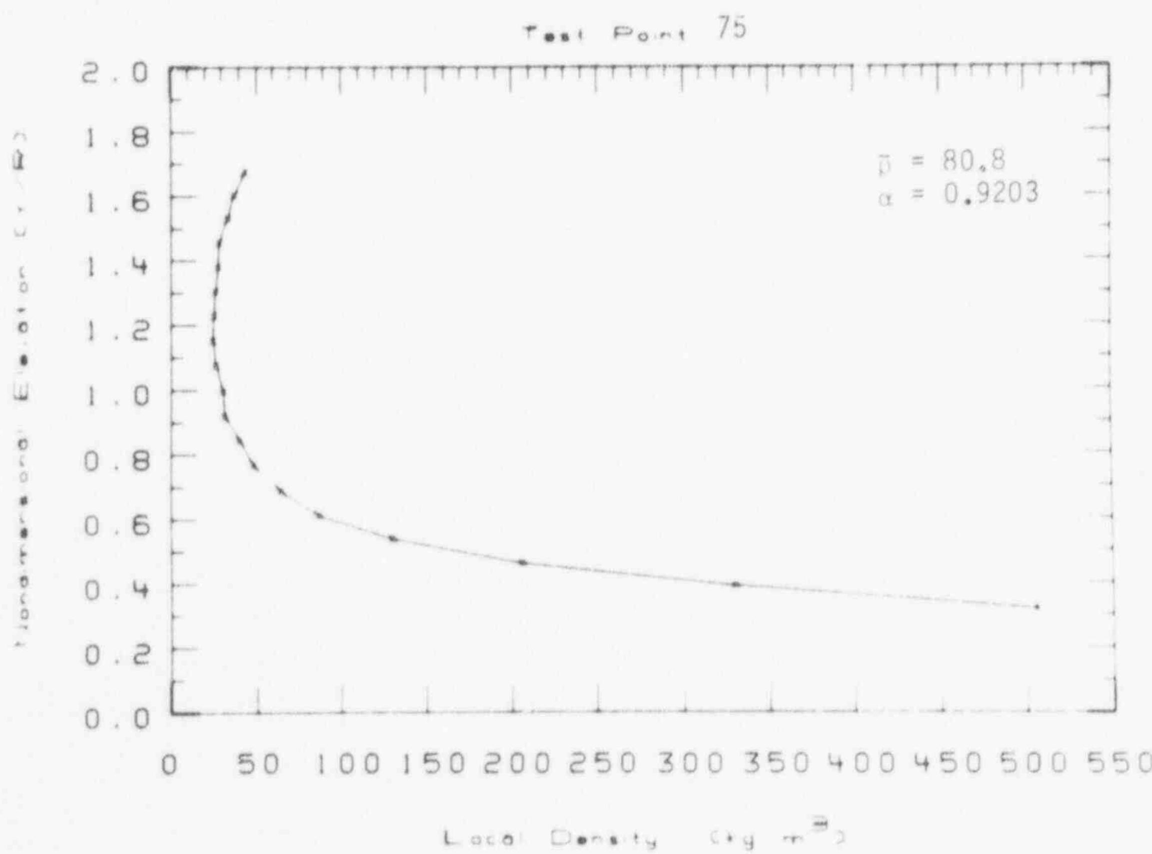


Fig. 58 Density distribution from scanning densitometer for test series - SB2 -

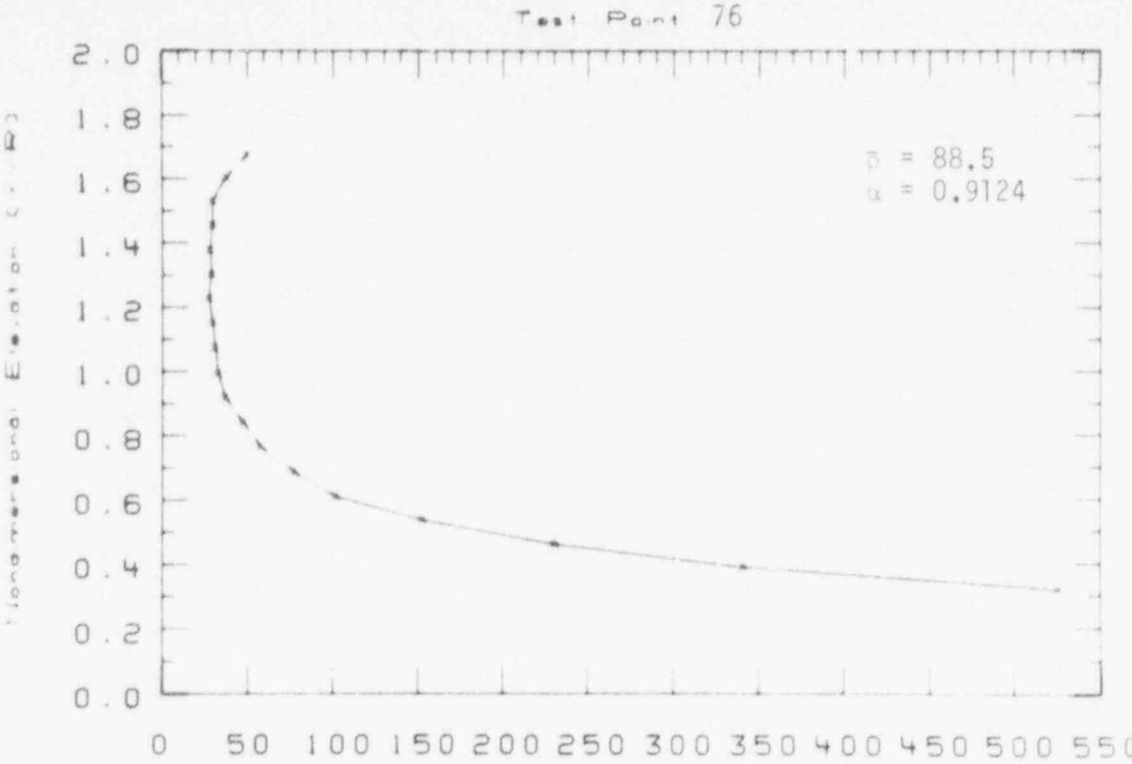


Fig. 59 Density distribution from scanning densitometer for test series * SB2 *

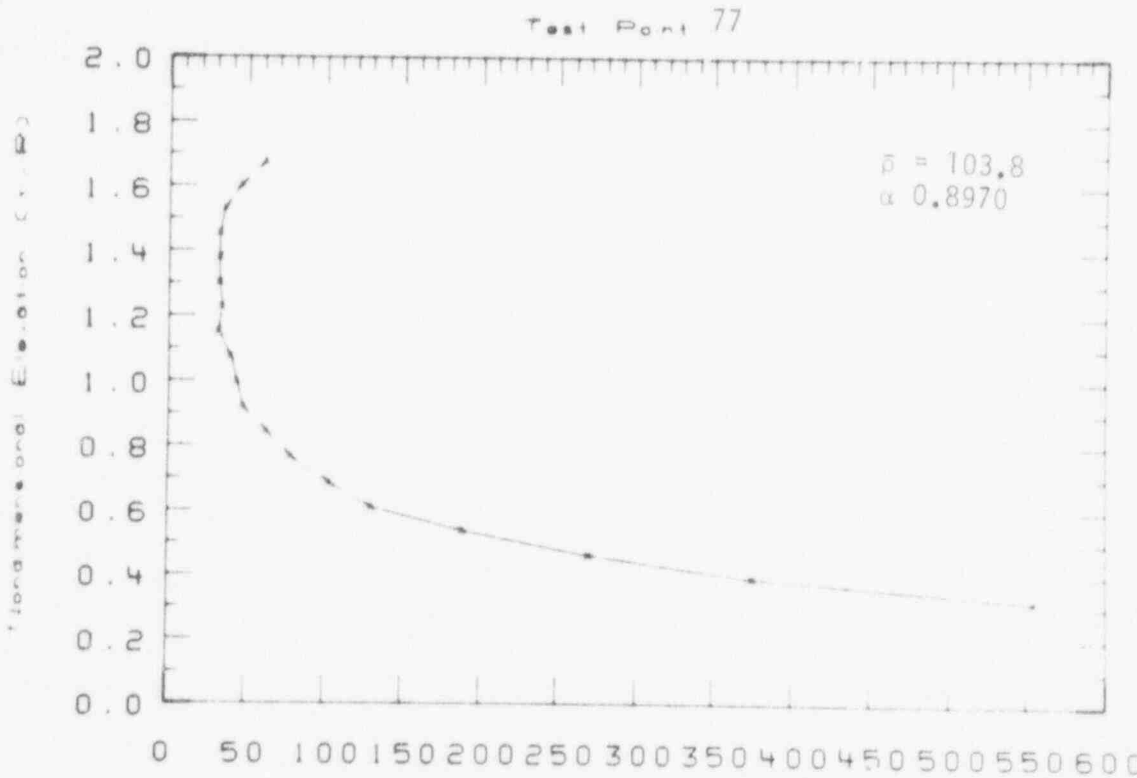


Fig. 60 Density distribution from scanning densitometer for test series * SB2 *

Test Point 79

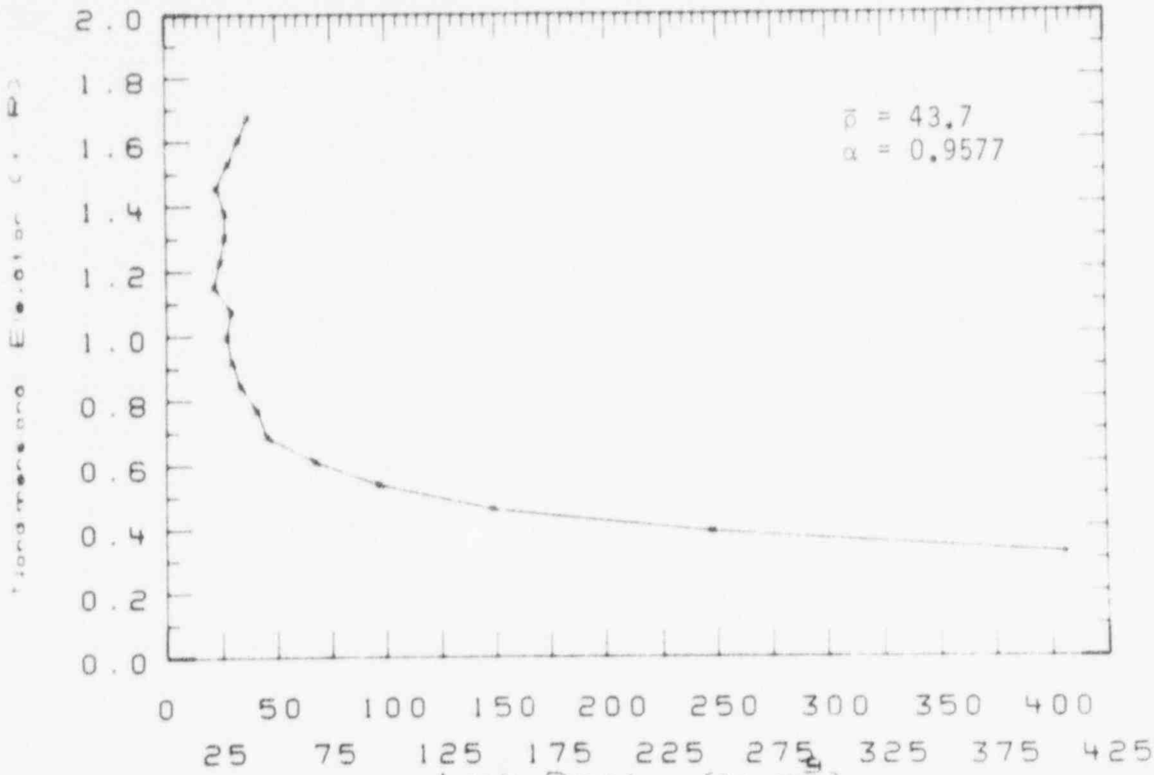


Fig. 61 Density distribution from scanning densitometer for test series * SB2 *

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Test Point 80

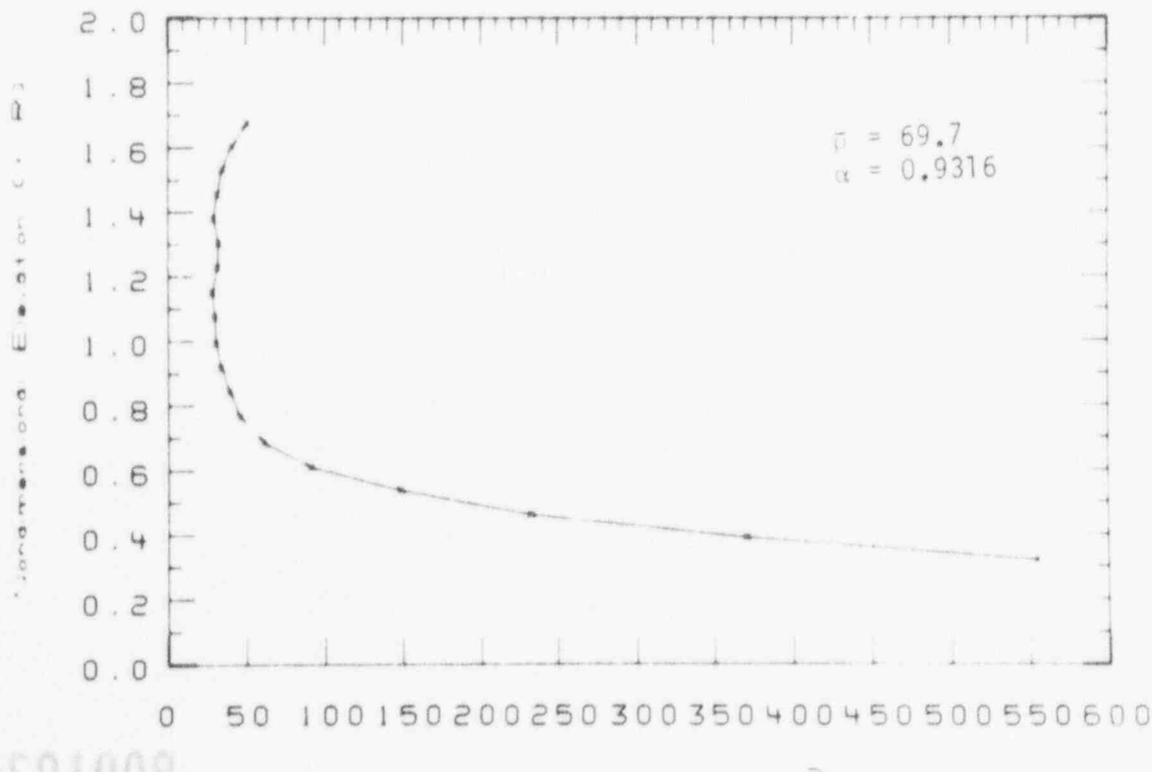

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Fig. 62 Density distribution from scanning densitometer for test series * SB2 *

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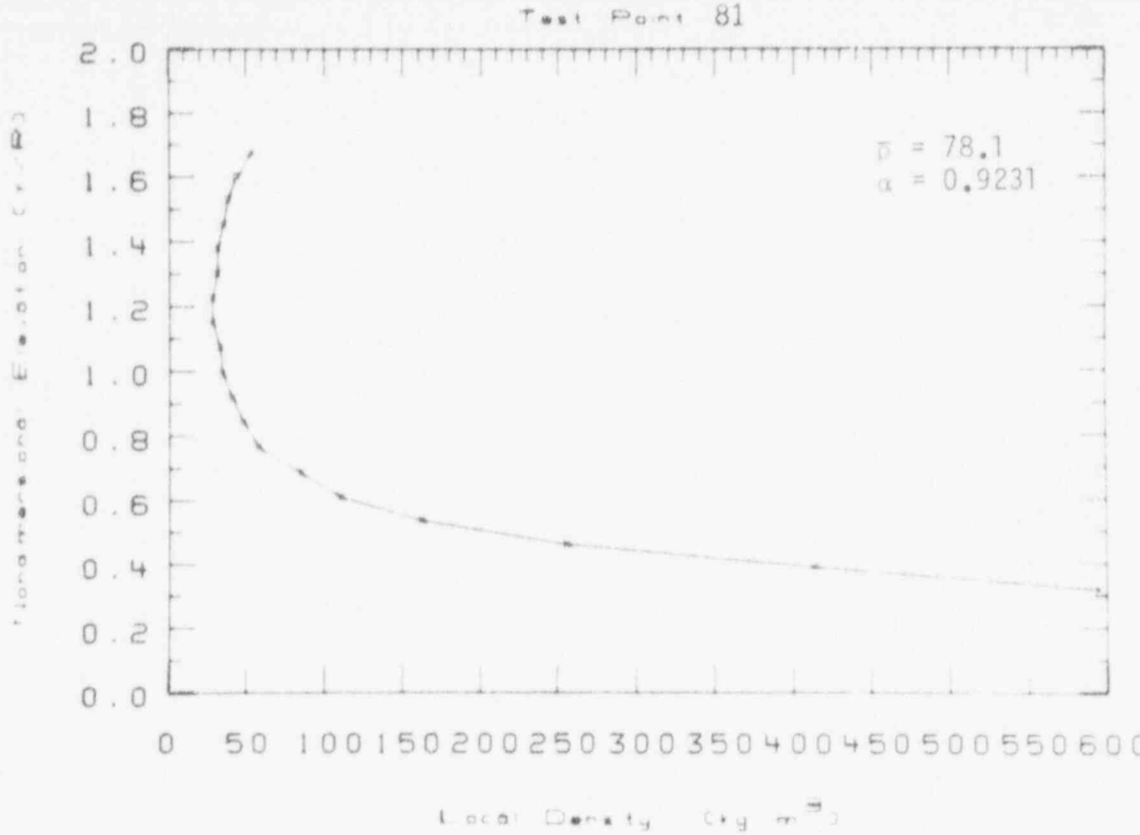

Fig. 63 Density distribution from scanning densitometer for test series - SB2 -

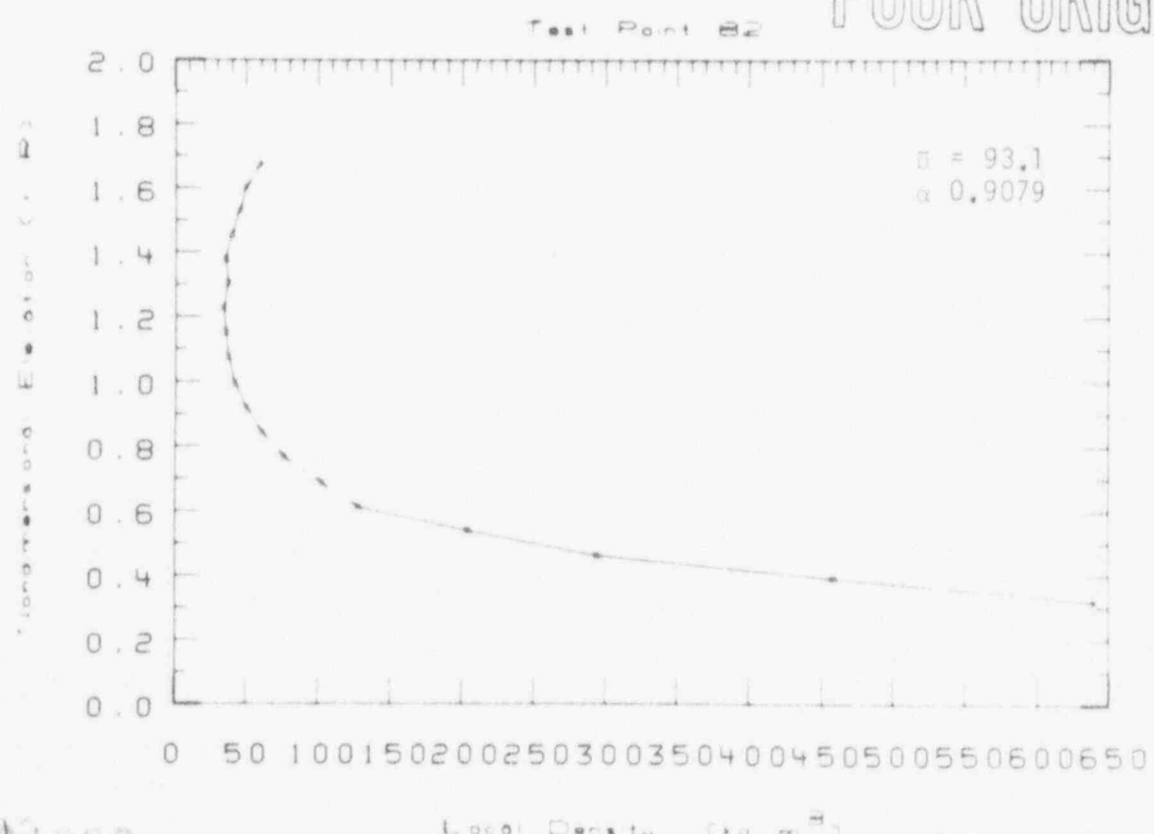

Fig. 64 Density distribution from scanning densitometer for test series - SB2 -

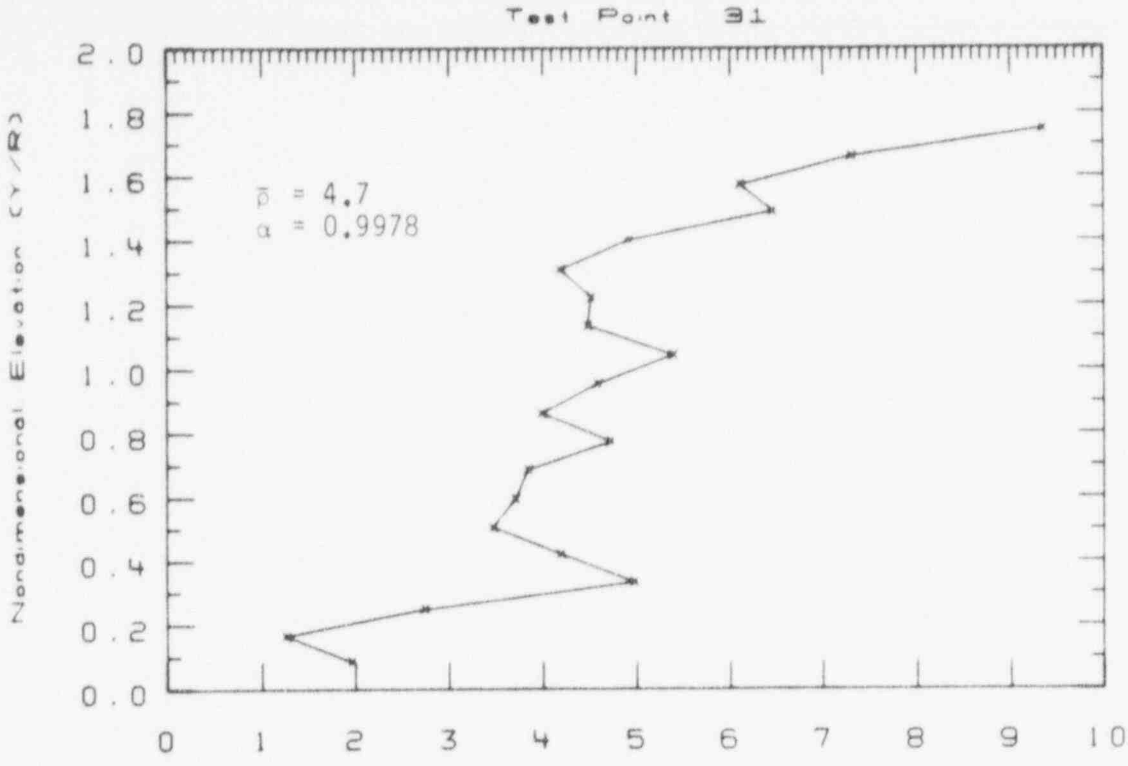

Fig. 65 Density distribution from scanning densitometer, for test series * SB3 *

POOR ORIGINAL

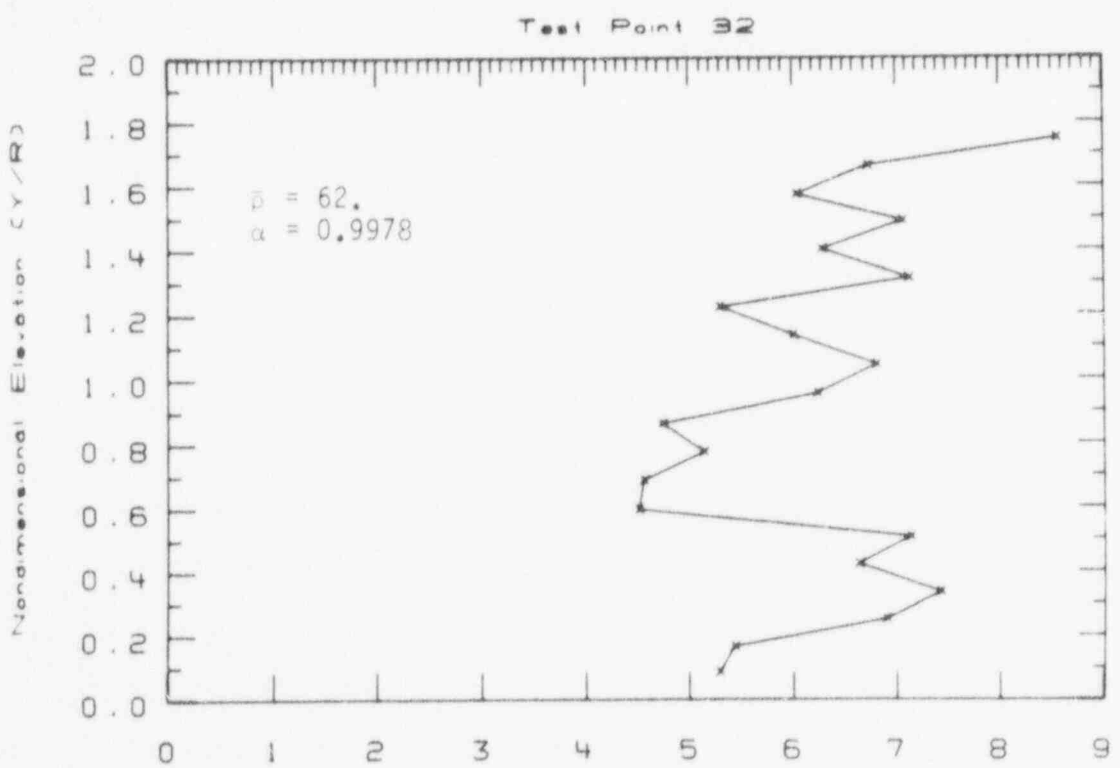

Fig. 66 Density distribution from scanning densitometer, for test series * SB3 *

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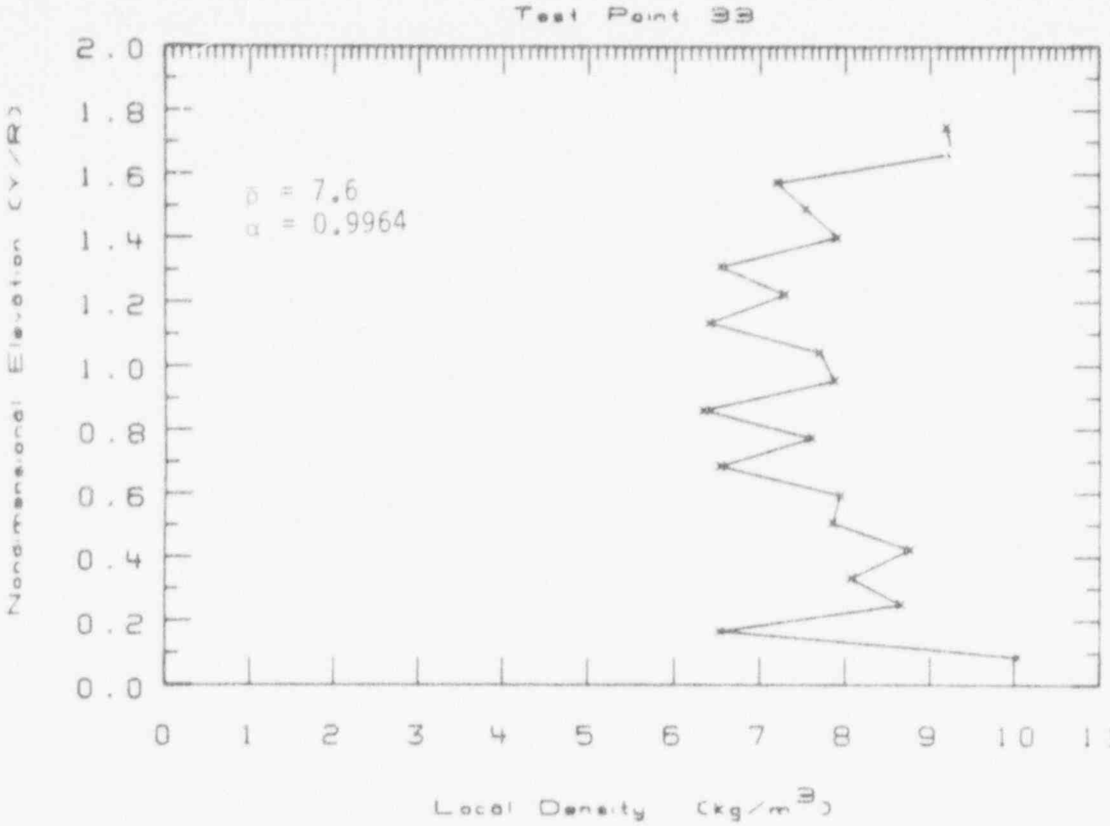


Fig. 67 Density distribution from scanning densitometer, for test series * SB3 *

POOR ORIGINAL

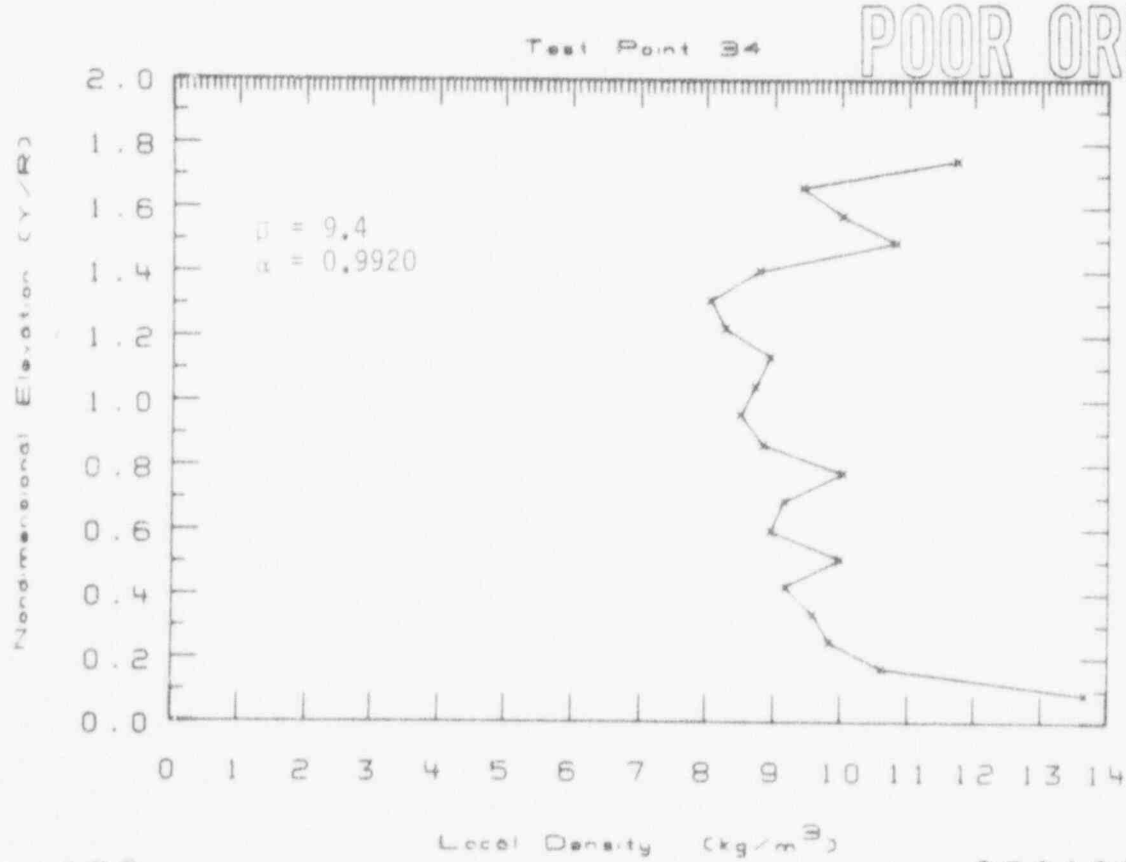


Fig. 68 Density distribution from scanning densitometer, for test series * SB3 *

90010271

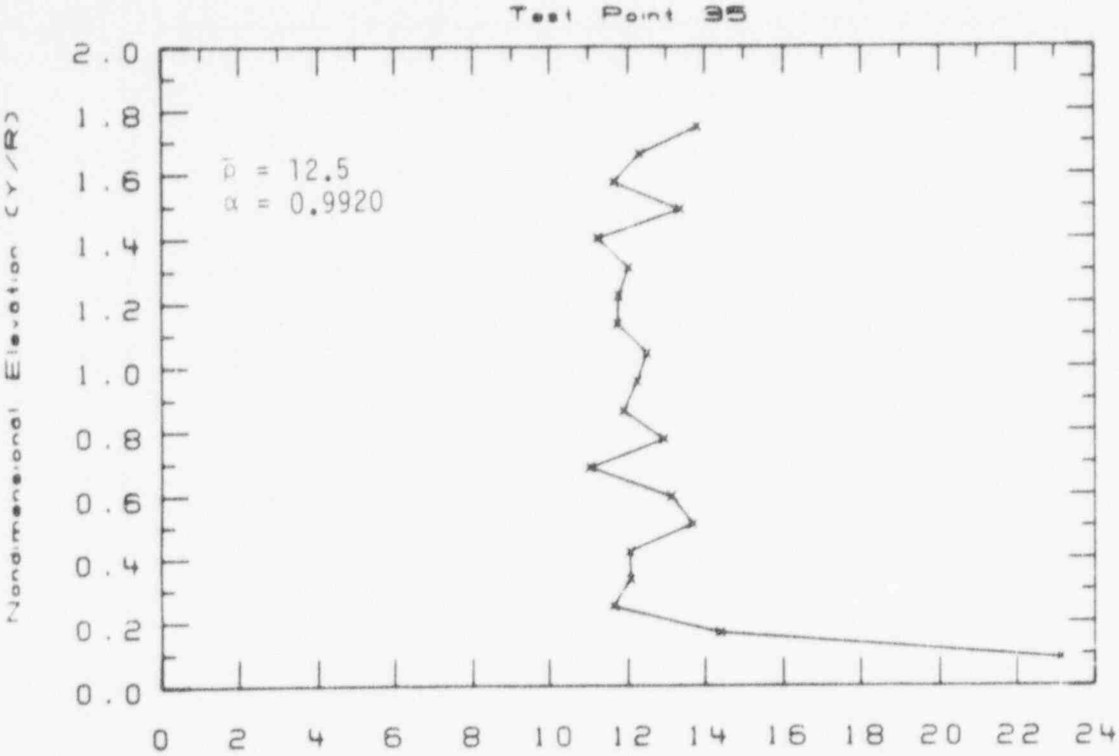


Fig. 69 Density distribution from scanning densitometer, for test series - SB3 -

POOR ORIGINAL

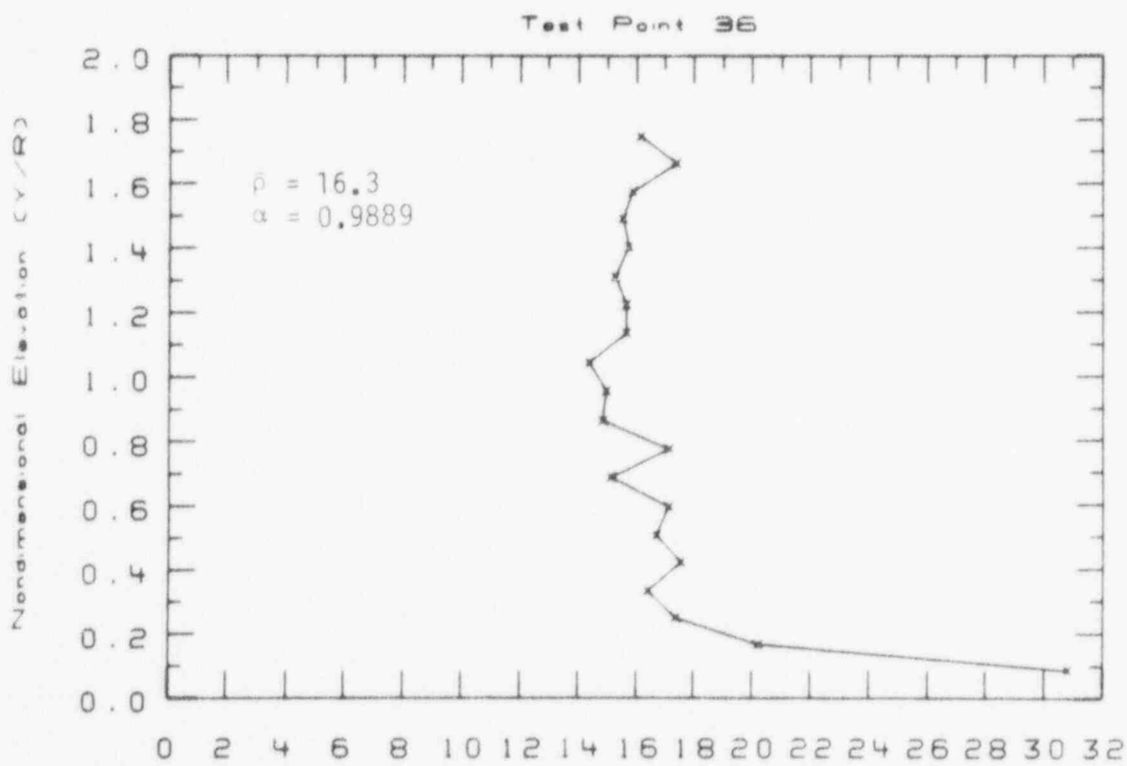
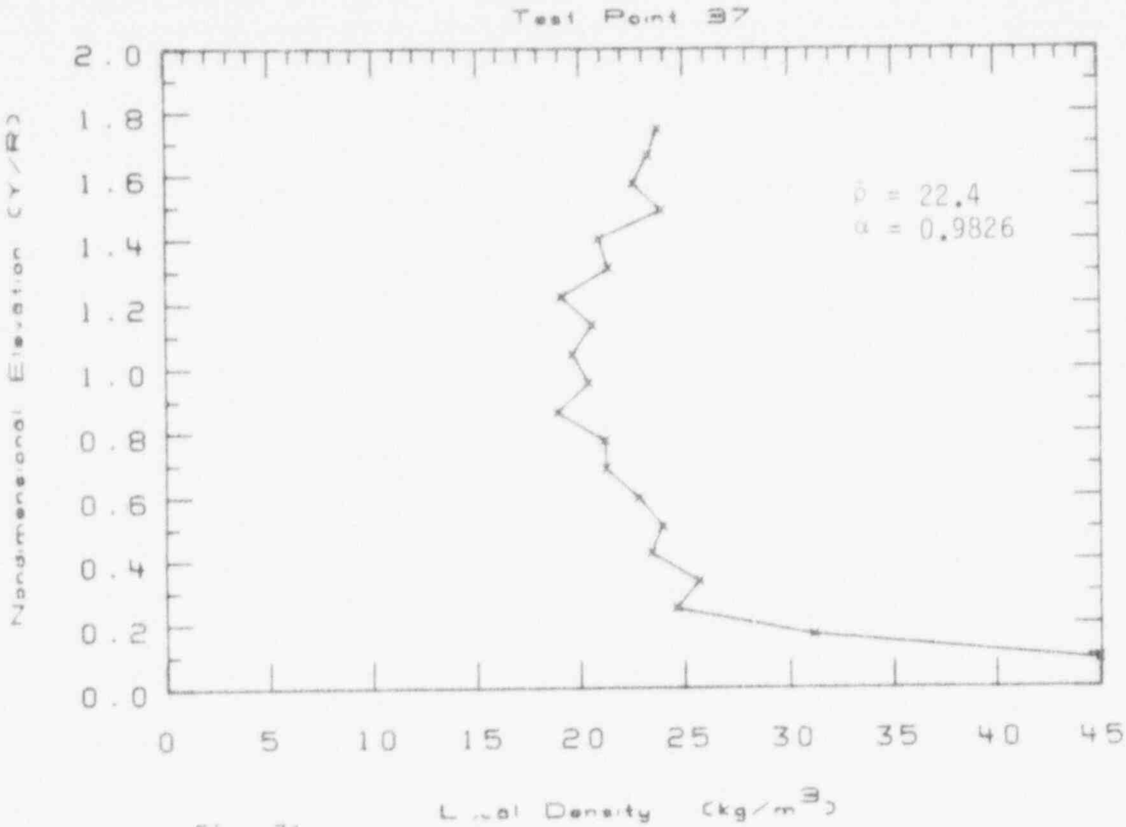


Fig. 70 Density distribution from scanning densitometer, for test series - SB3 -

90010272



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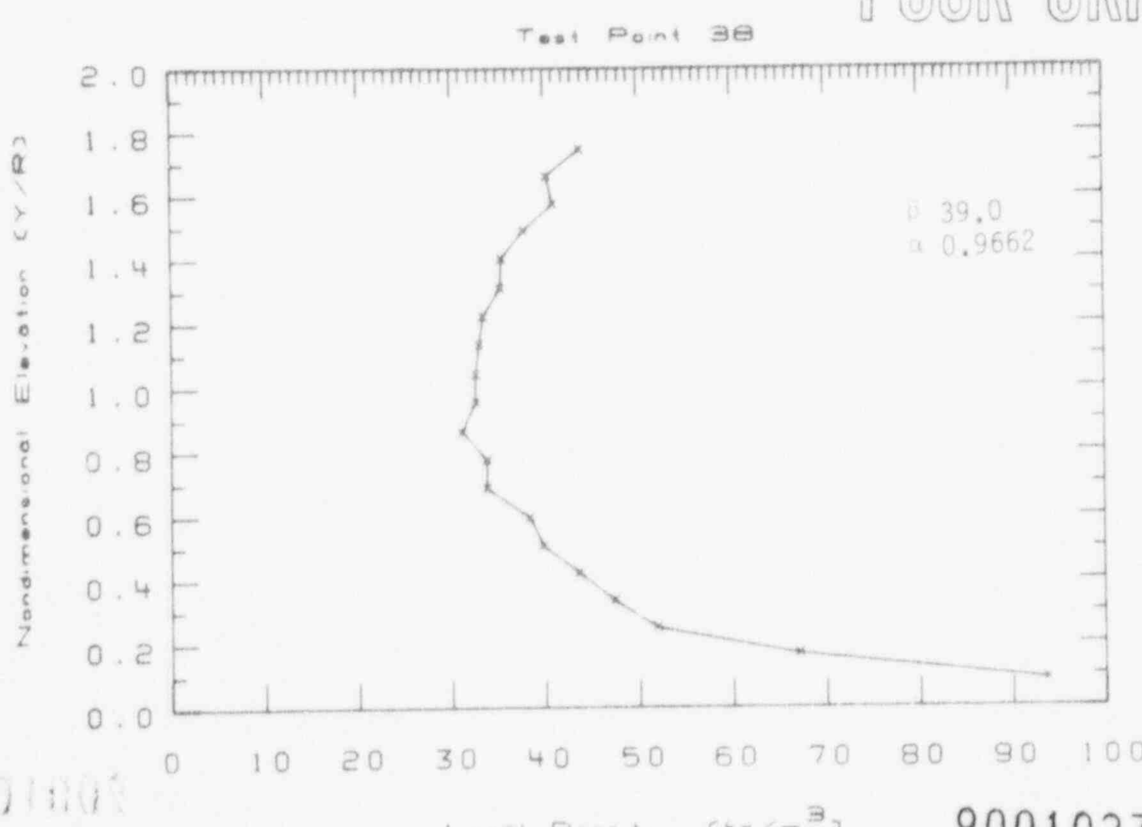

Fig. 72 Density distribution from scanning densitometer, for test series * SB3 *

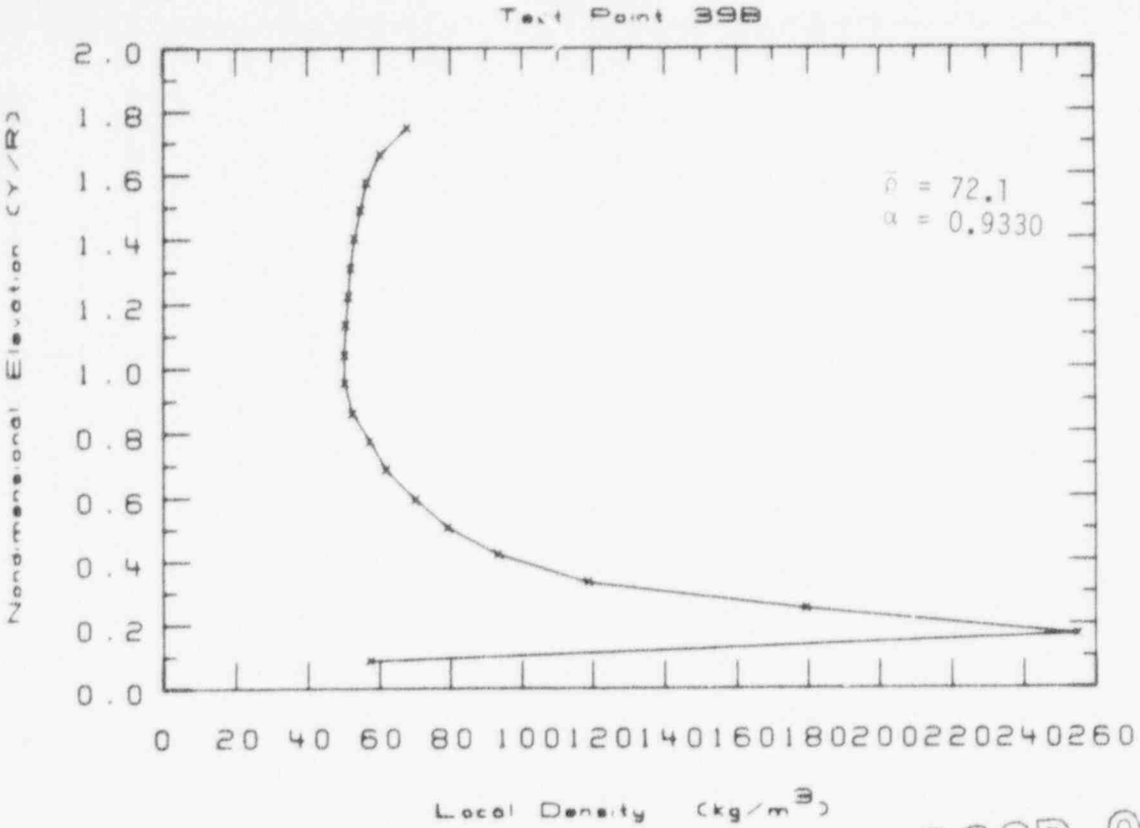

Fig. 73 Density distribution from scanning densitometer, for test series * SB3 *

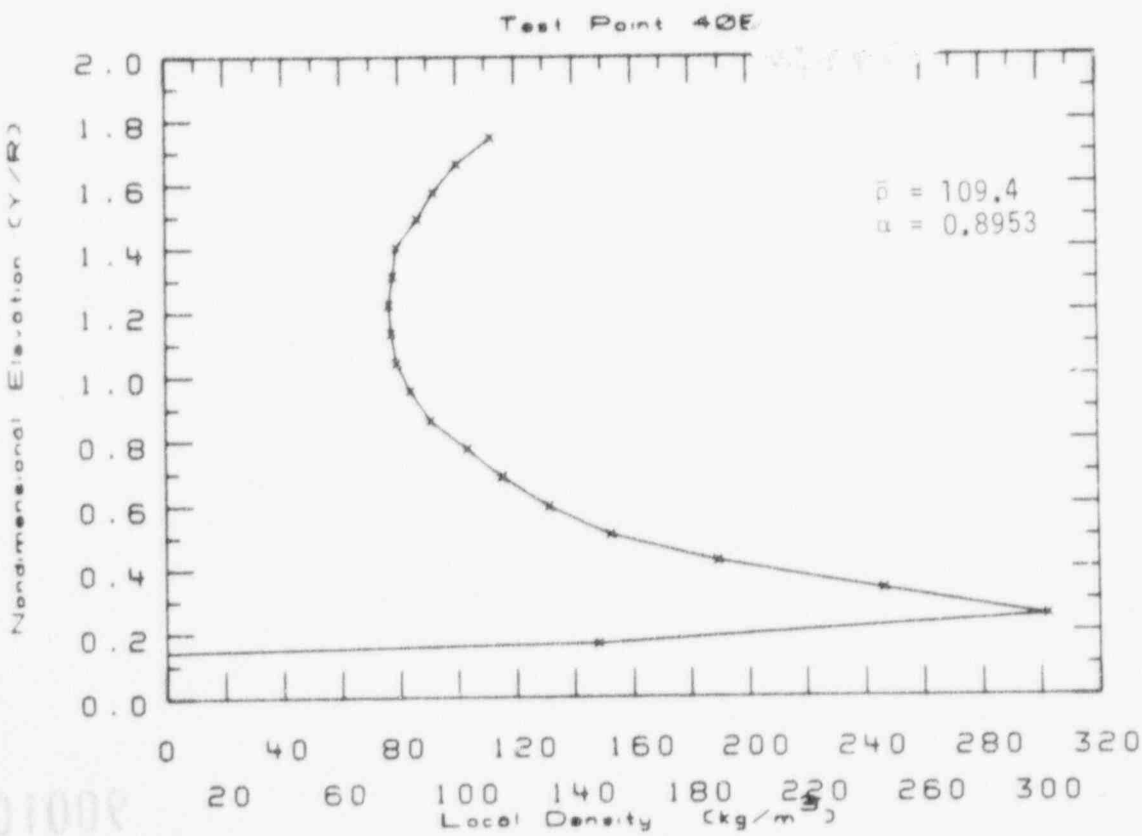

Fig. 74 Density distribution from scanning densitometer, for test series * SB3 *

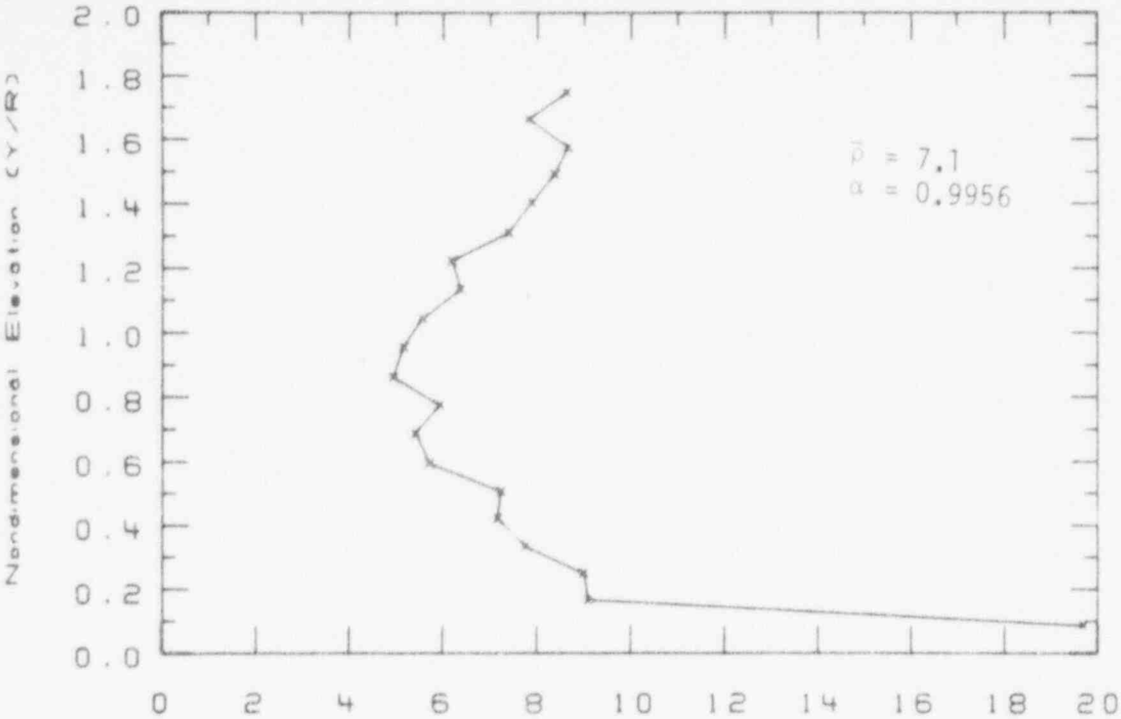

Fig. 75 Density distribution from scanning densitometer, for test series * SB3 *

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Test Point 43

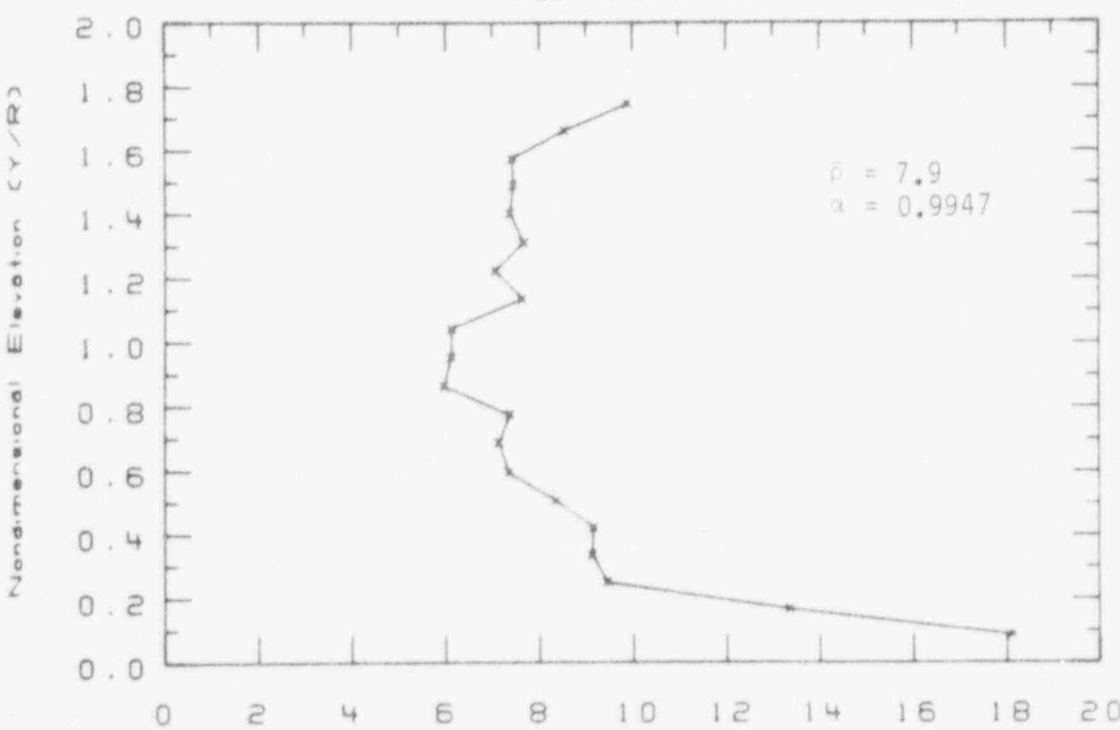


Fig. 76 Density distribution from scanning densitometer, for test series * SB3 *

90010275

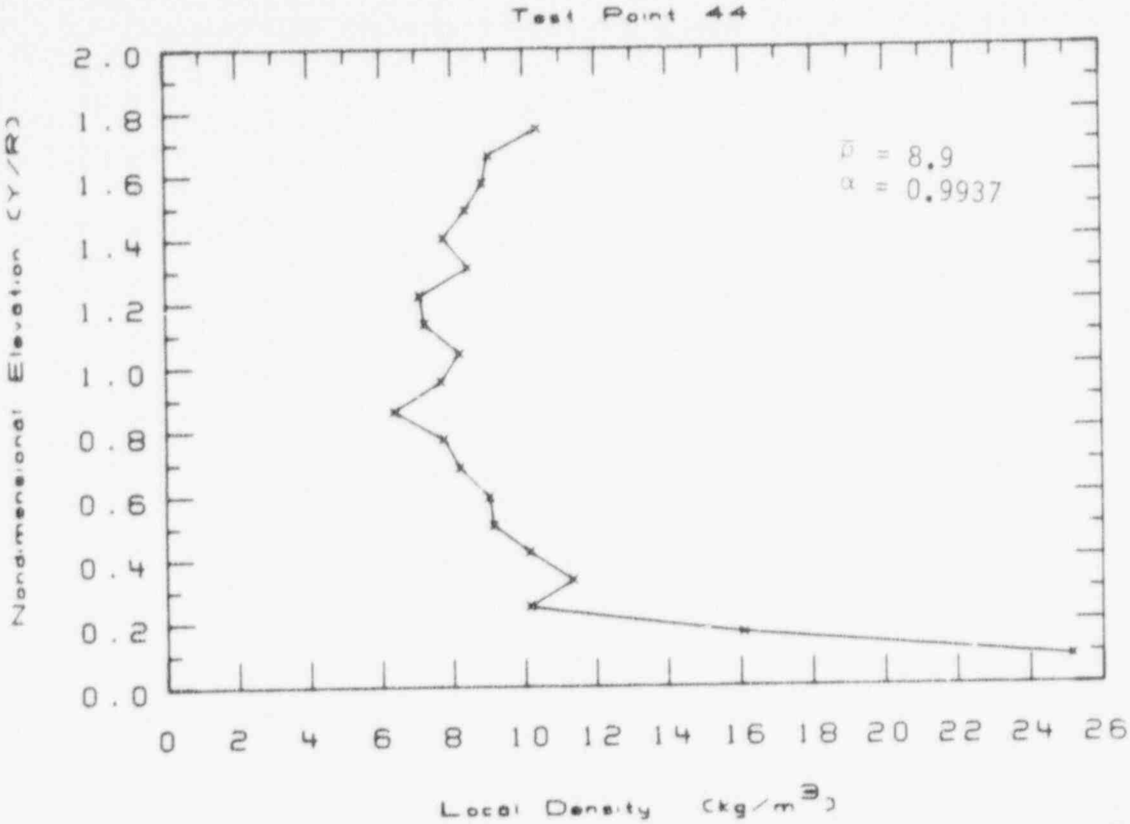


Fig. 77 Density distribution from scanning densitometer, for test series * SB3 *

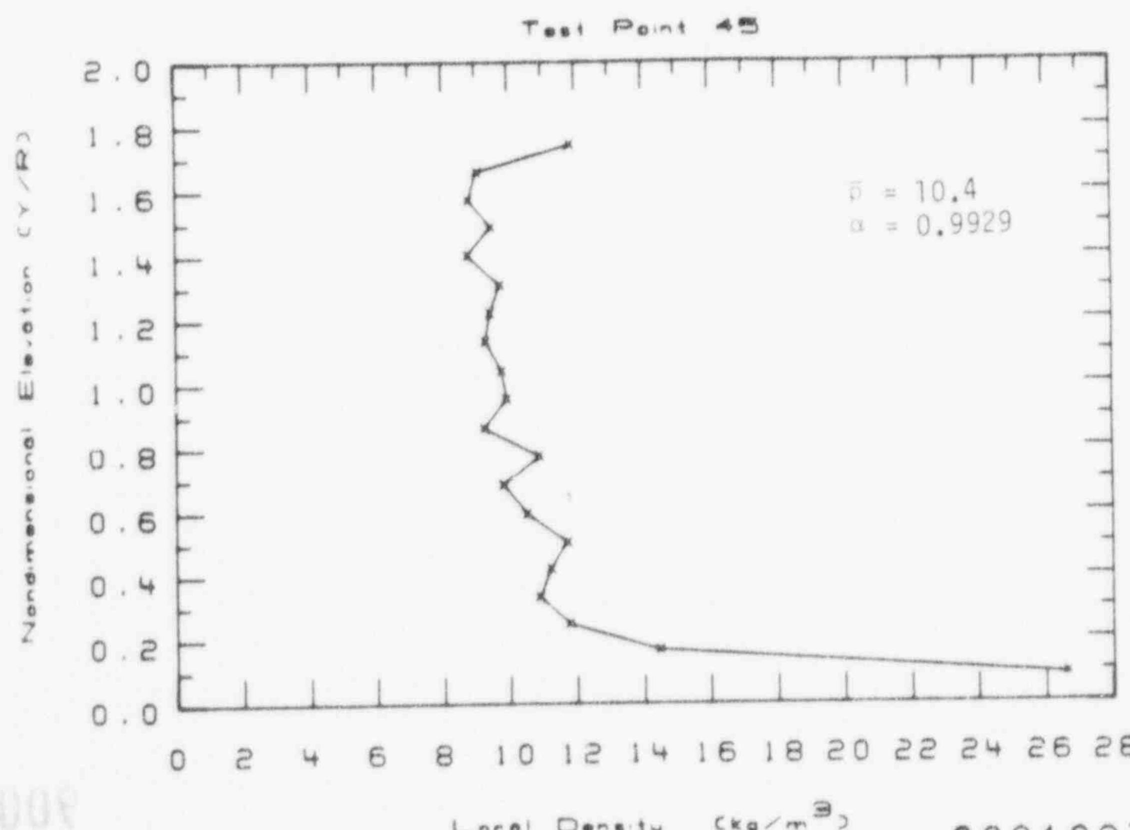


Fig. 78 Density distribution from scanning densitometer, for test series * SB3 *

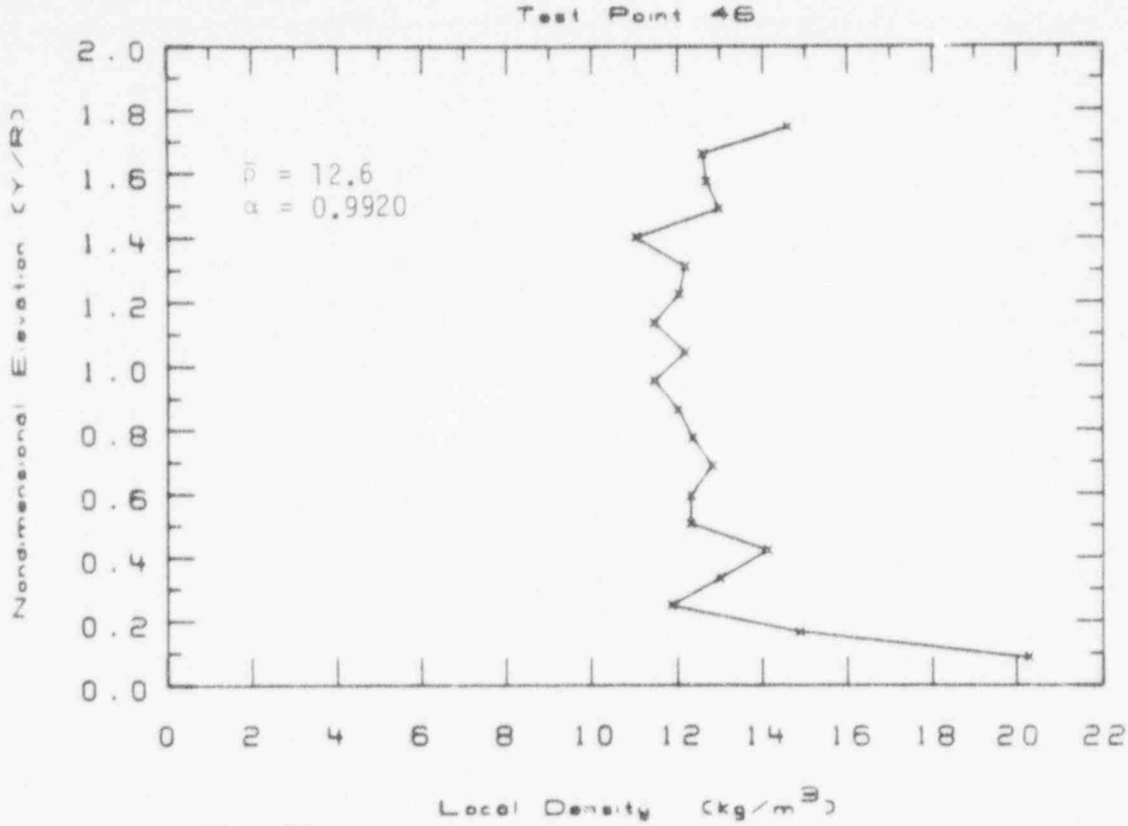


Fig. 79 Density distribution from scanning densitometer, for test series * SB3 *

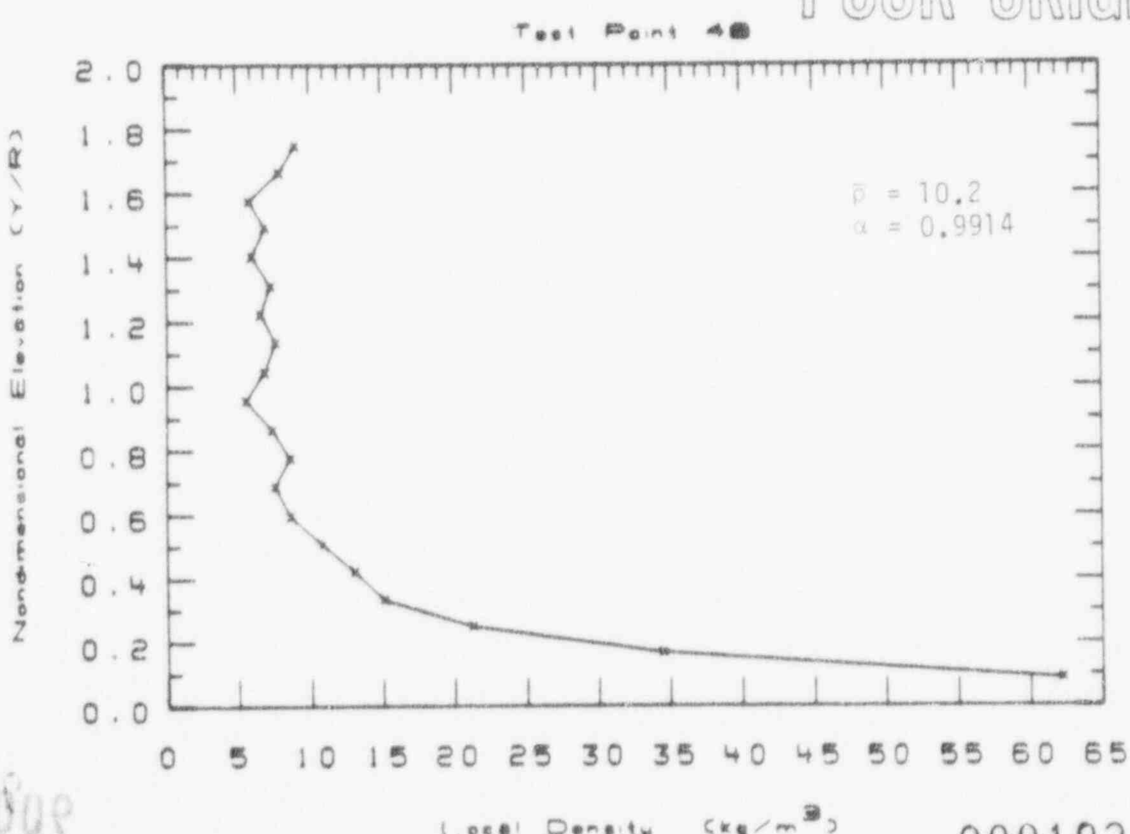


Fig. 80 Density distribution from scanning densitometer, for test series * SB9 *

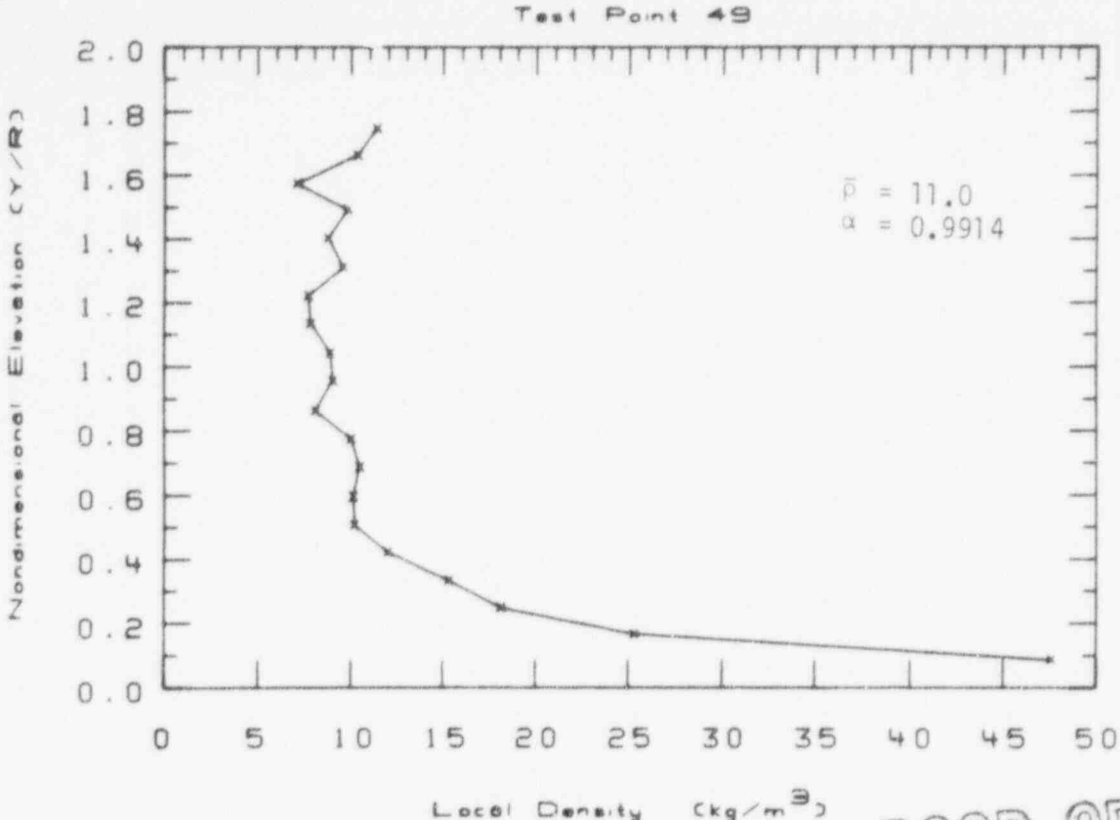
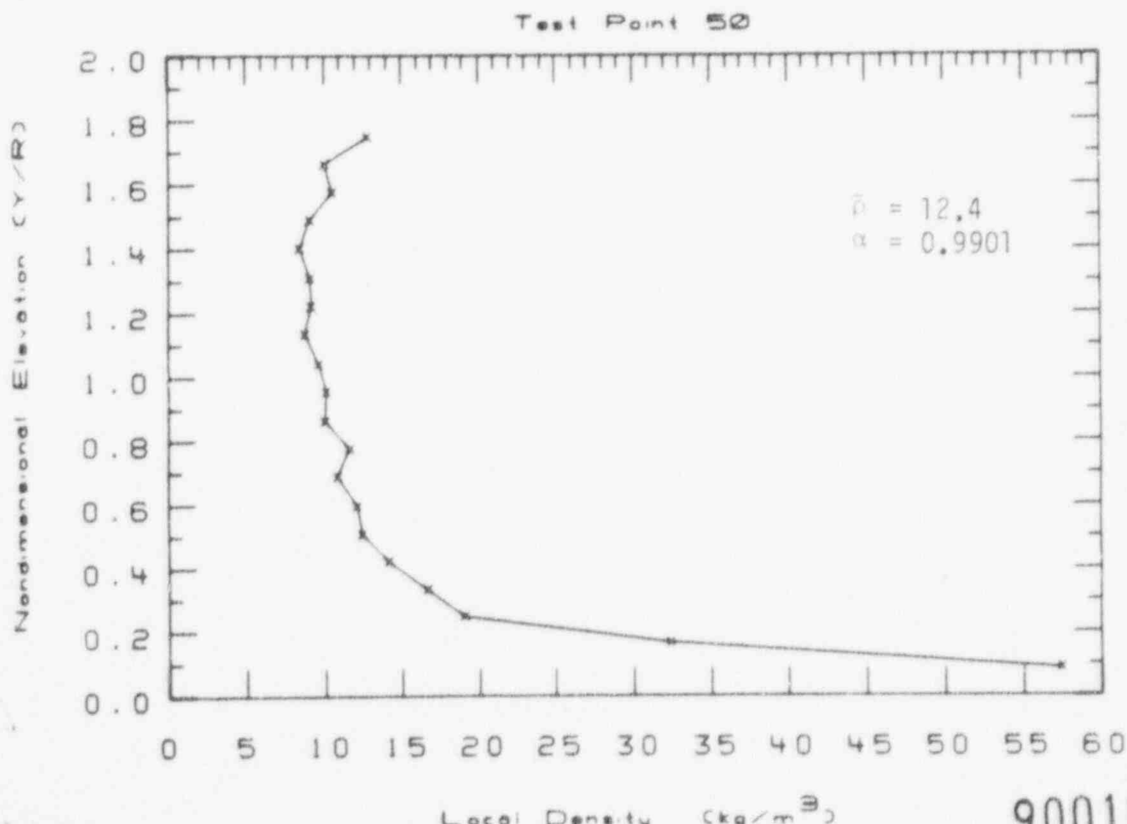


Fig. 81 Density distribution from scanning densitometer, for test series * SB3 *



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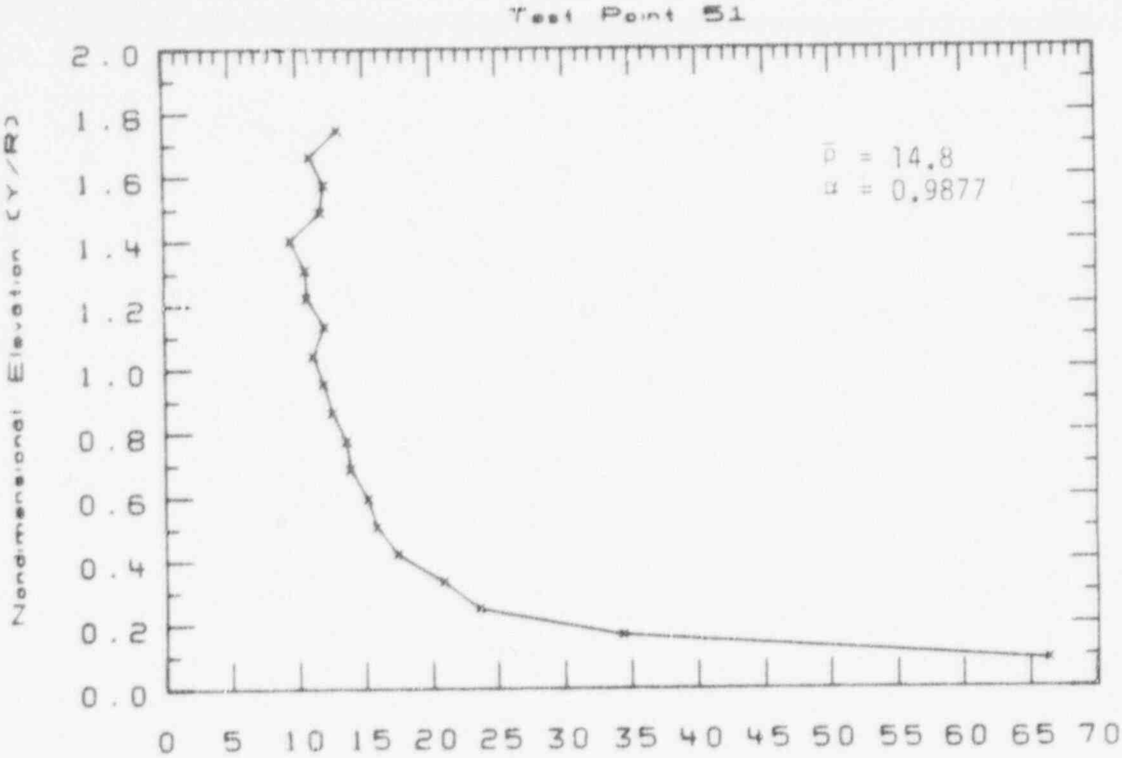

Fig. 83 Density distribution from scanning densitometer, for test series * SB3 *

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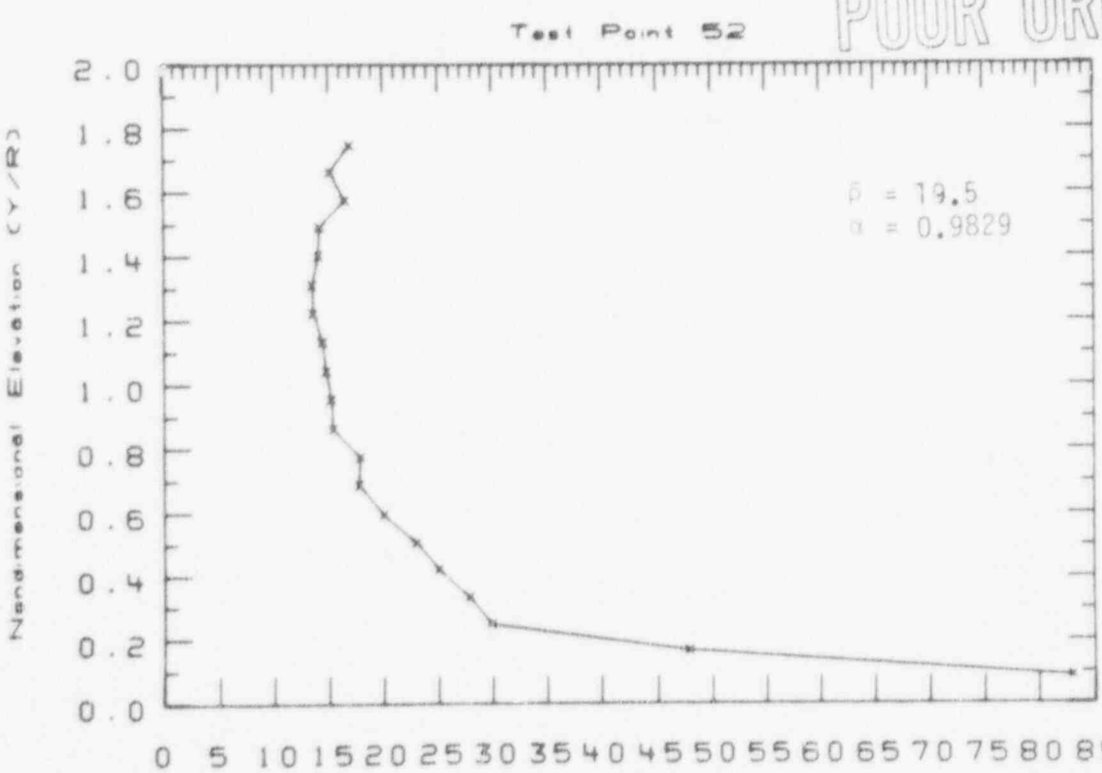

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Fig. 84 Density distribution from scanning densitometer, for test series * SB3 *

Test Point 53

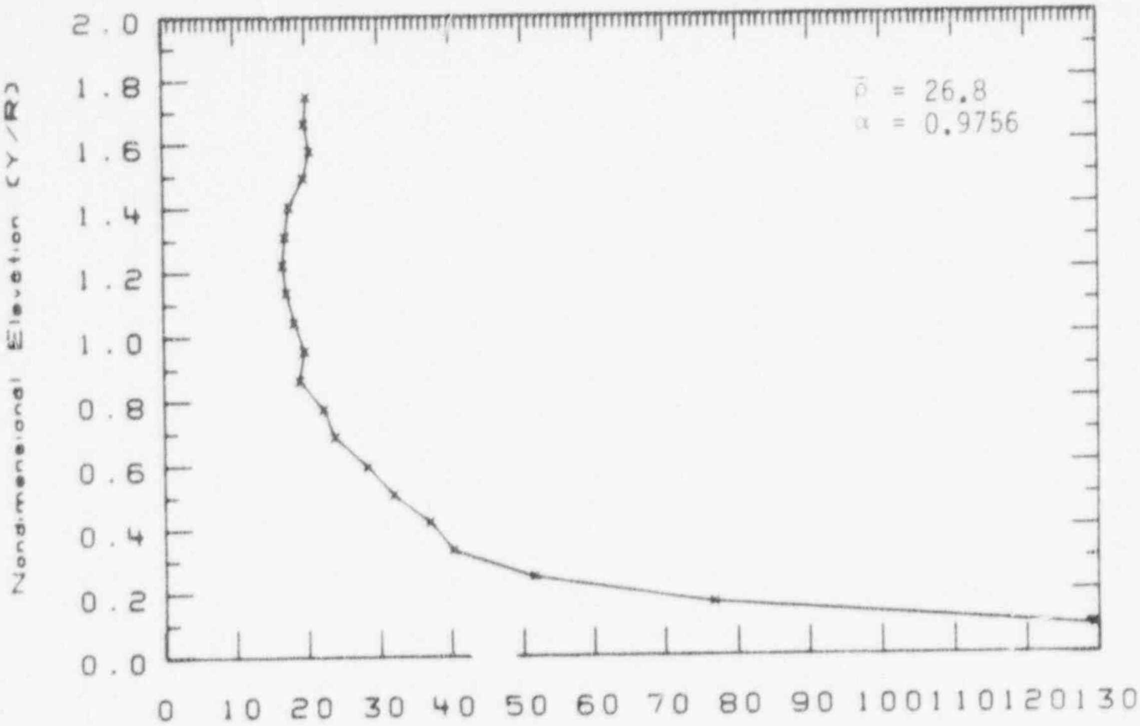

Fig. 85 Density distribution from scanning densitometer, for test series * SB3 *

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Test Point 54

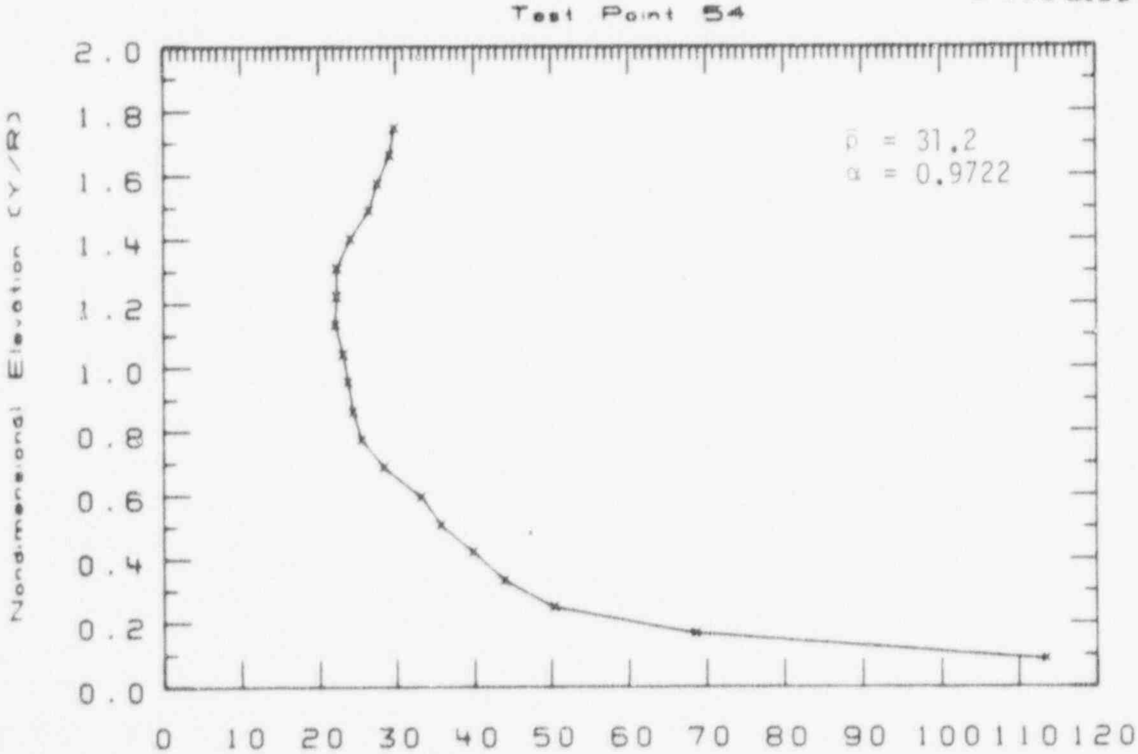

Fig. 86 Density distribution from scanning densitometer, for test series * SB3 *

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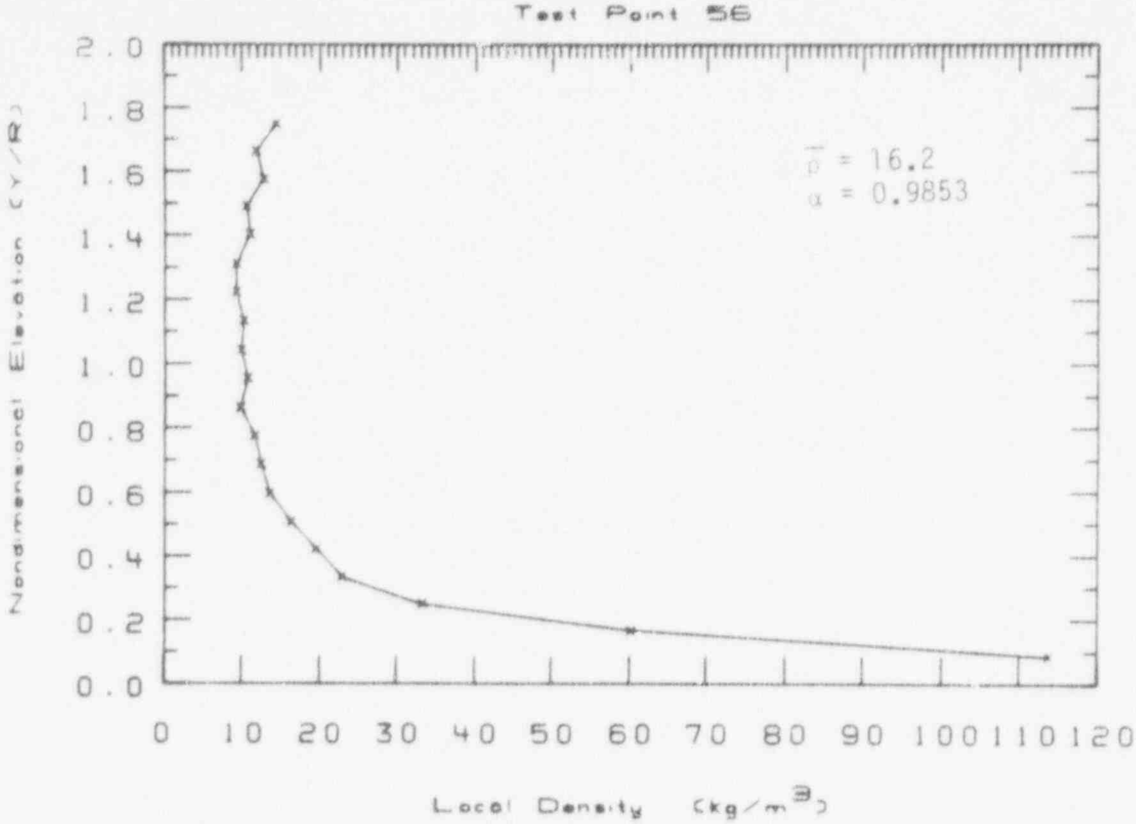

Fig. 87 Density distribution from scanning densitometer, for test series * SB3 *

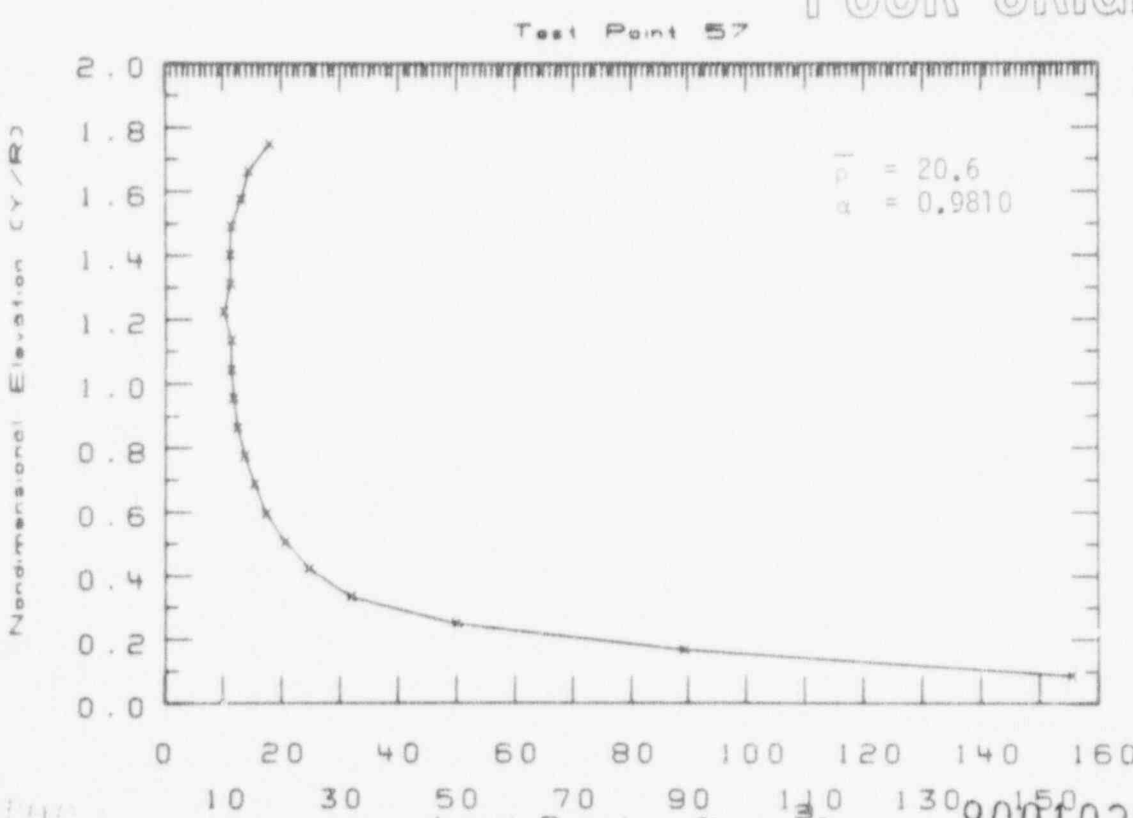

Fig. 88 Density distribution from scanning densitometer, for test series * SB3 *

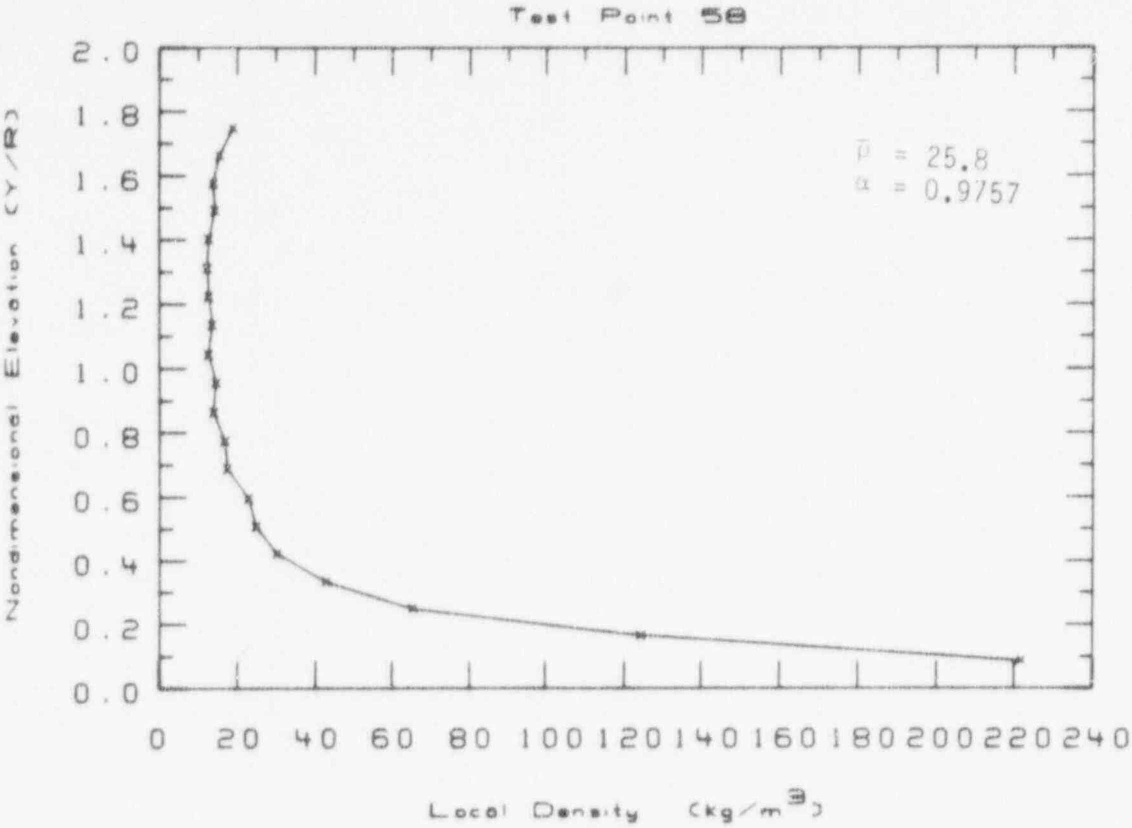

Fig. 89 Density distribution from scanning densitometer, for test series * SB3 *

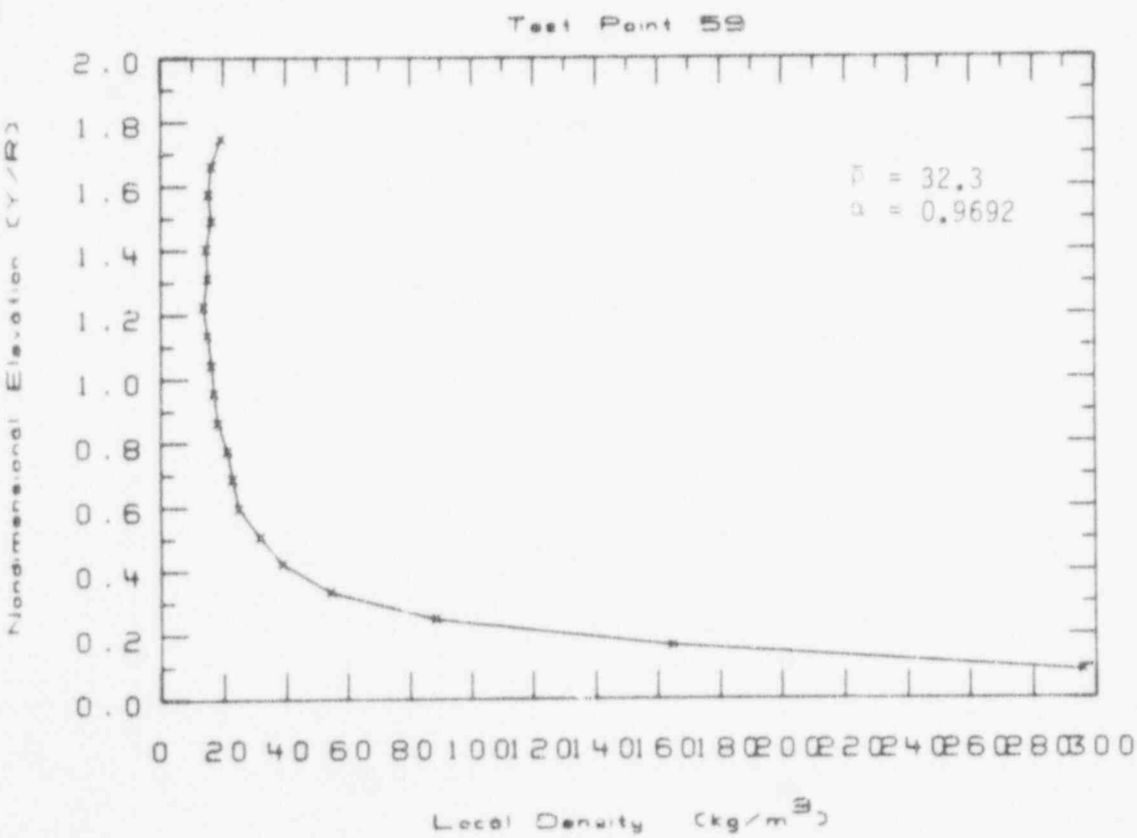

Fig. 90 Density distribution from scanning densitometer, for test series * SB3 *

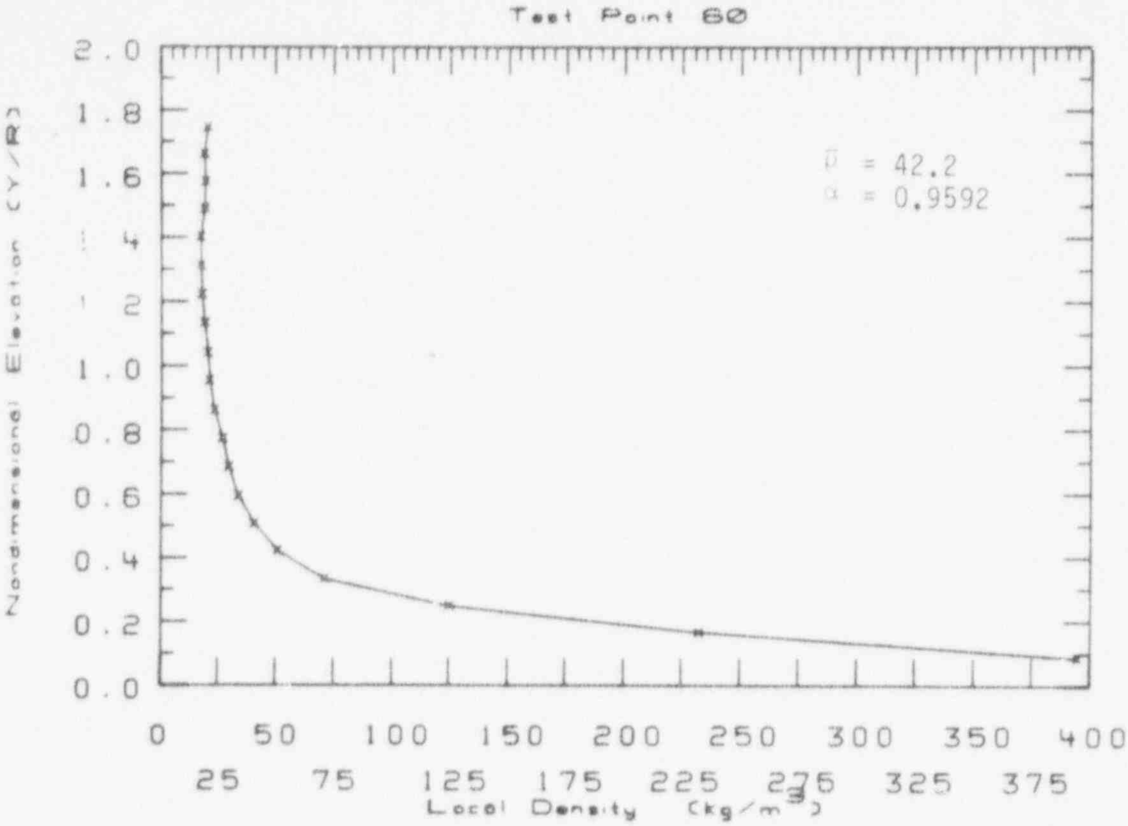

Fig. 91 Density distribution from scanning densitometer, for test series * SB3 *

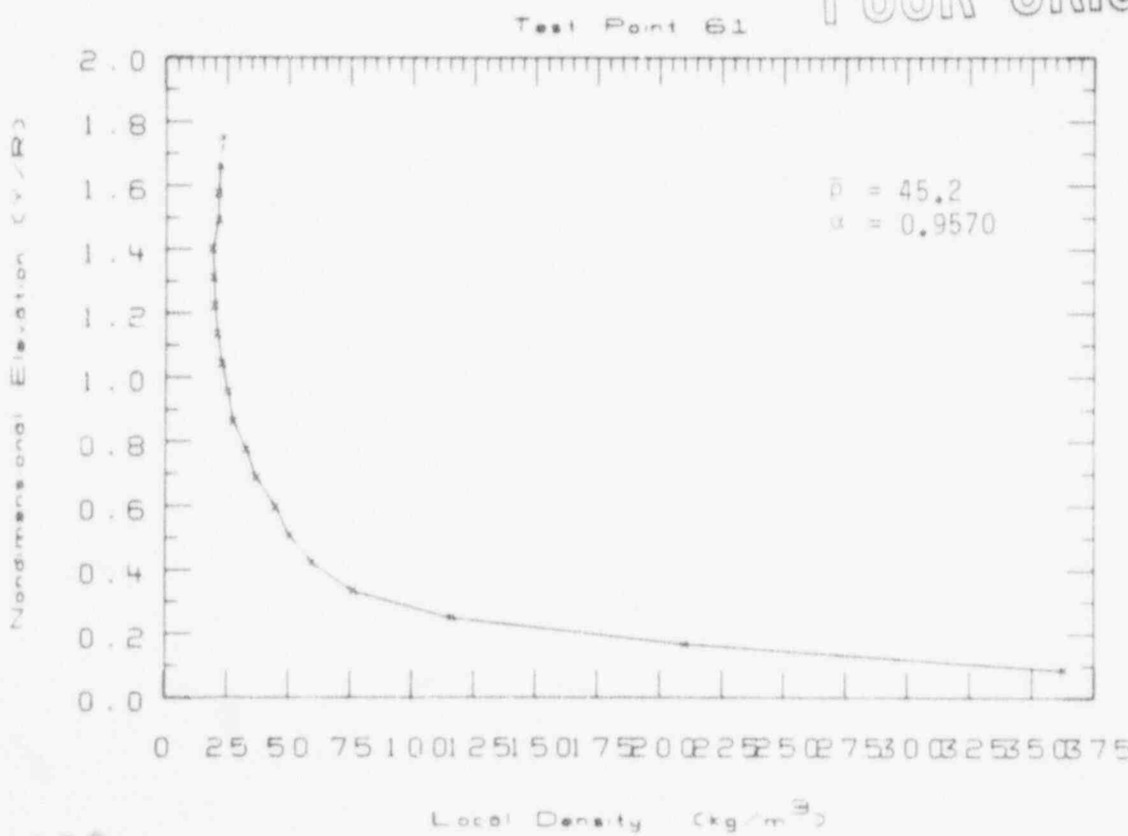

Fig. 92 Density distribution from scanning densitometer, for test series * SB3 *

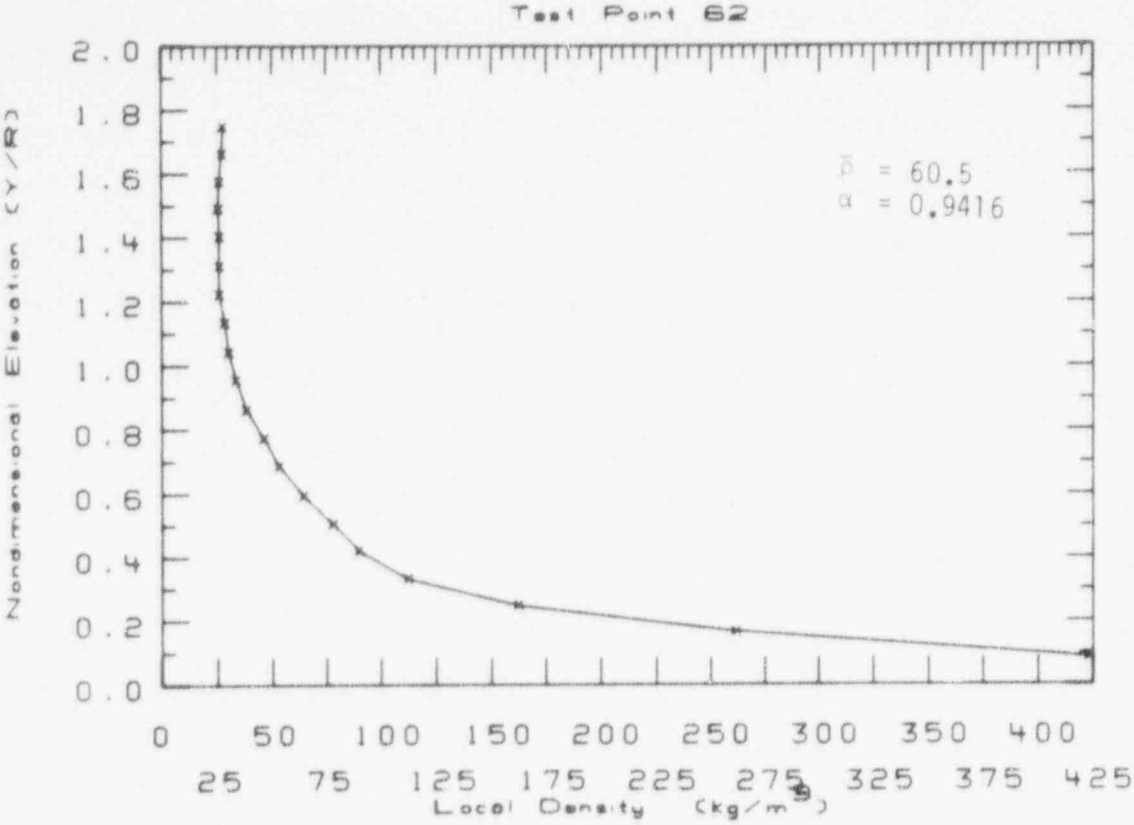

Fig. 93 Density distribution from scanning densitometer, for test series * SB3 *

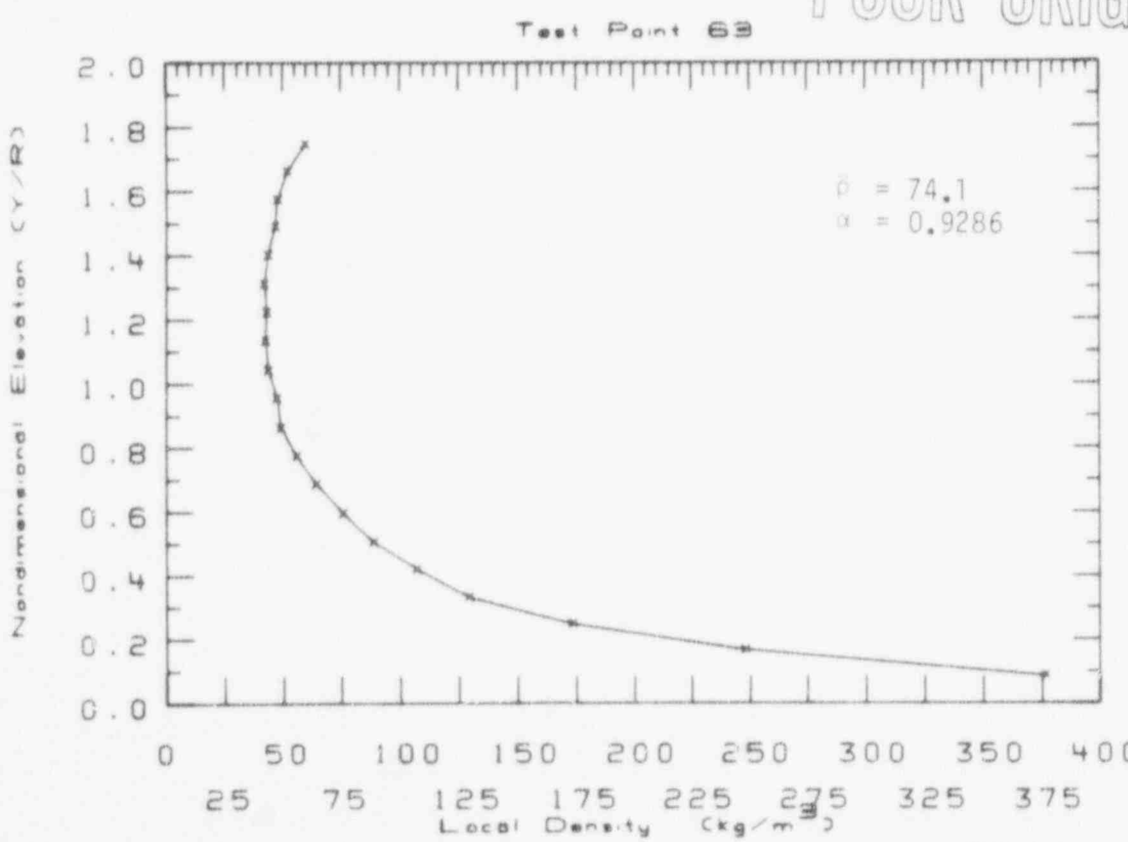

Fig. 94 Density distribution from scanning densitometer, for test series * SB3 *

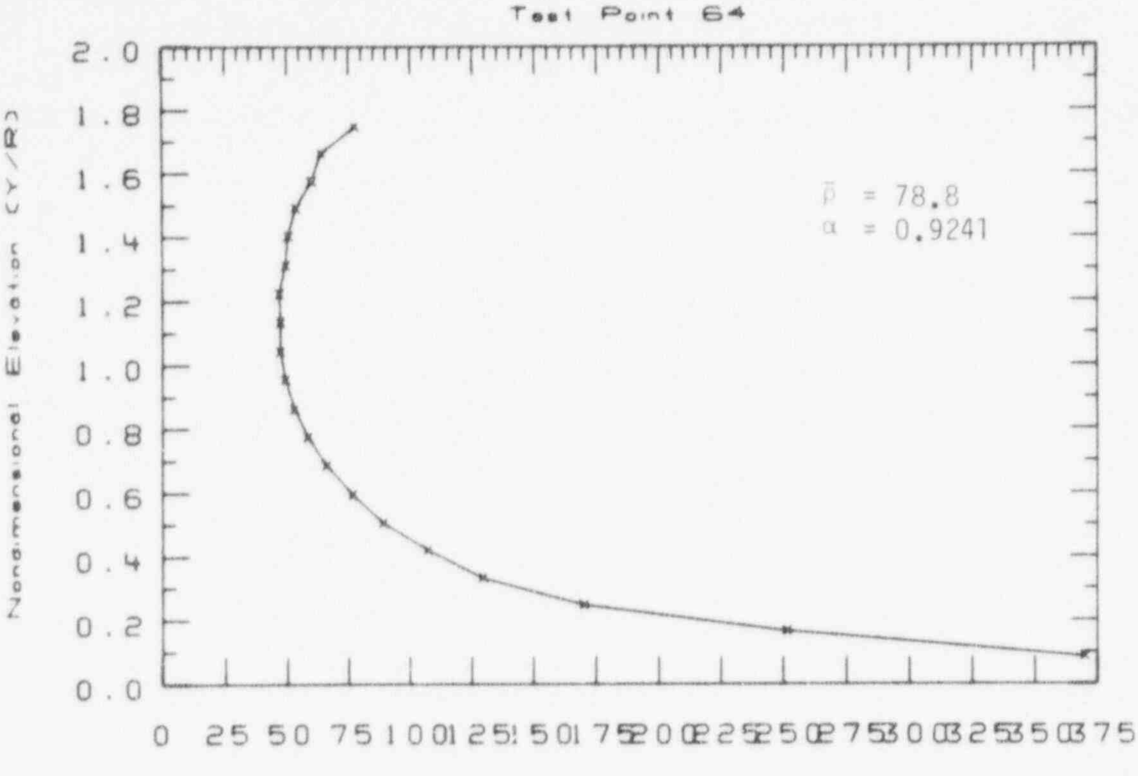

Fig. 95 Density distribution from scanning densitometer, for test series → SB3 ←

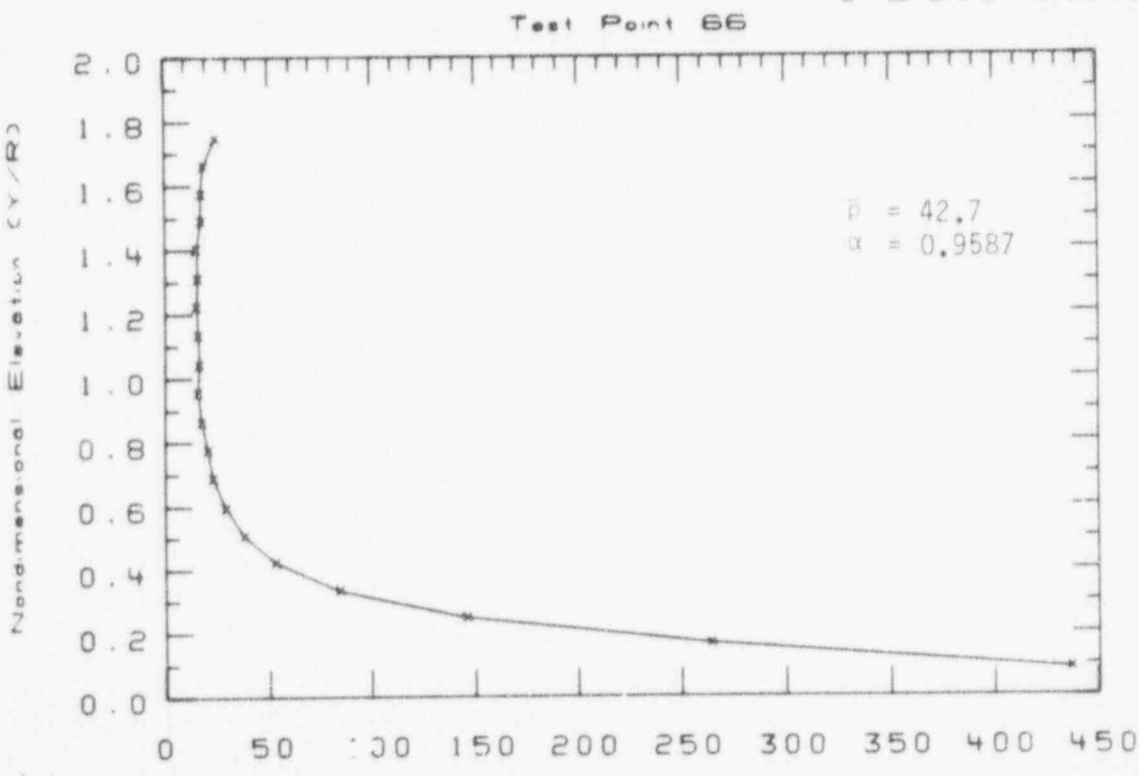

Fig. 96 Density distribution from scanning densitometer, for test series → SB3 ←

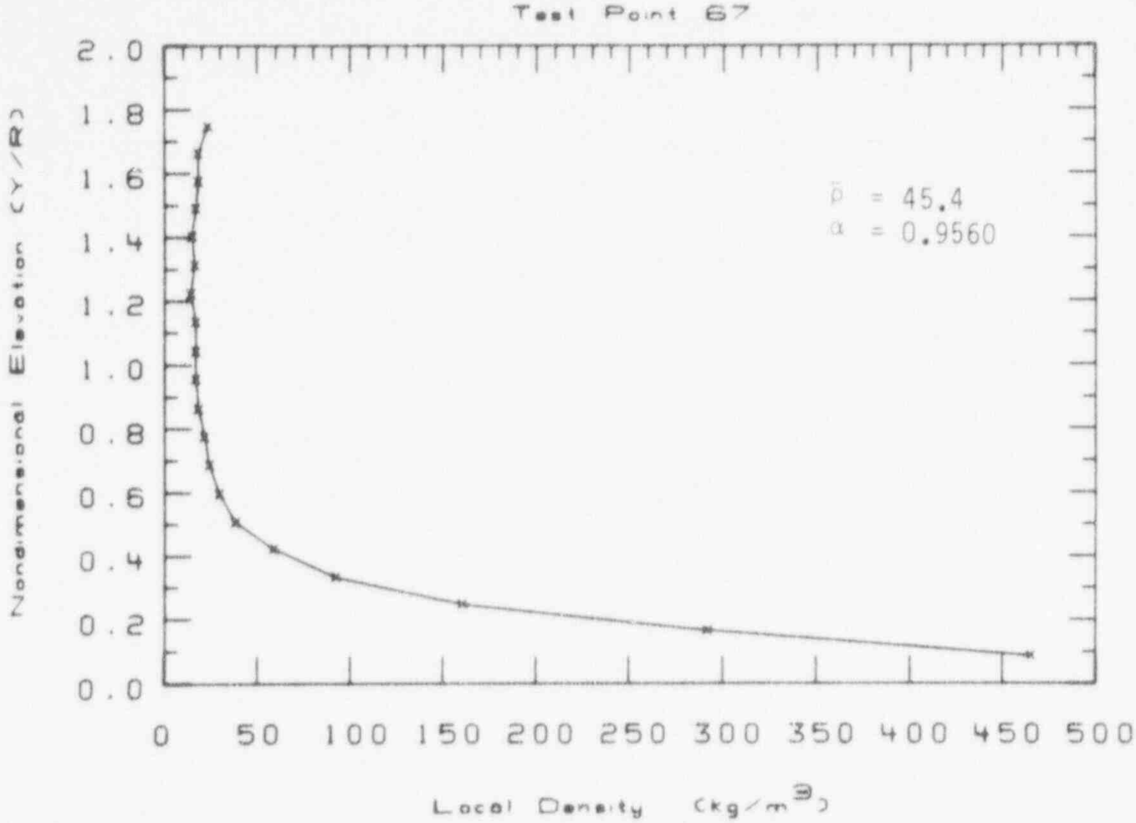

Fig. 97 Density distribution from scanning densitometer, for test series * SB3 *

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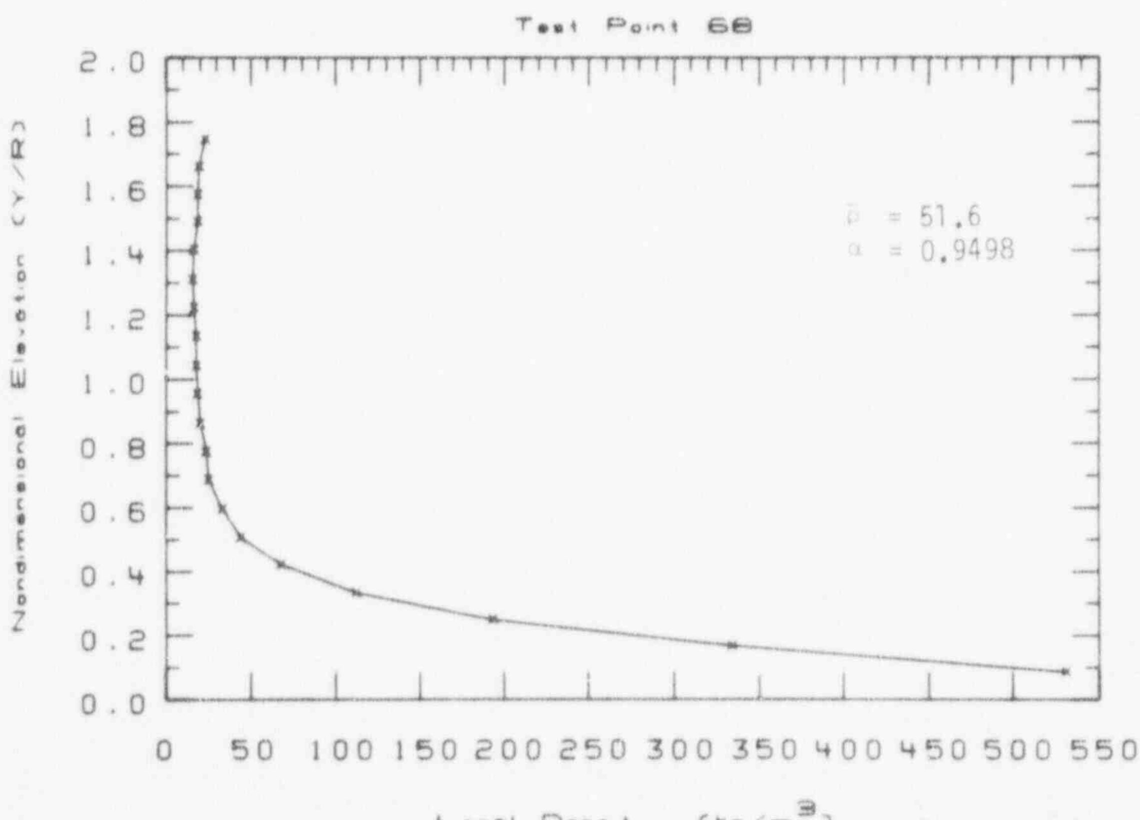

Fig. 98 Density distribution from scanning densitometer, for test series * SB3 *

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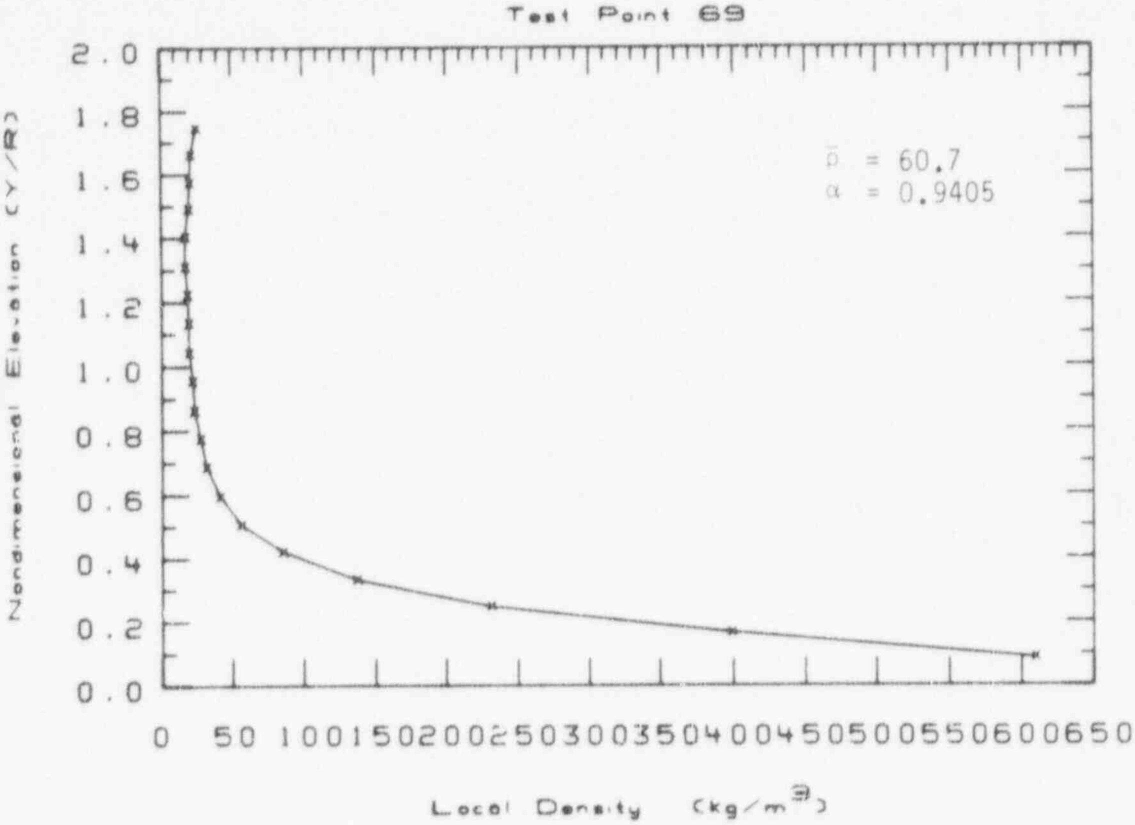

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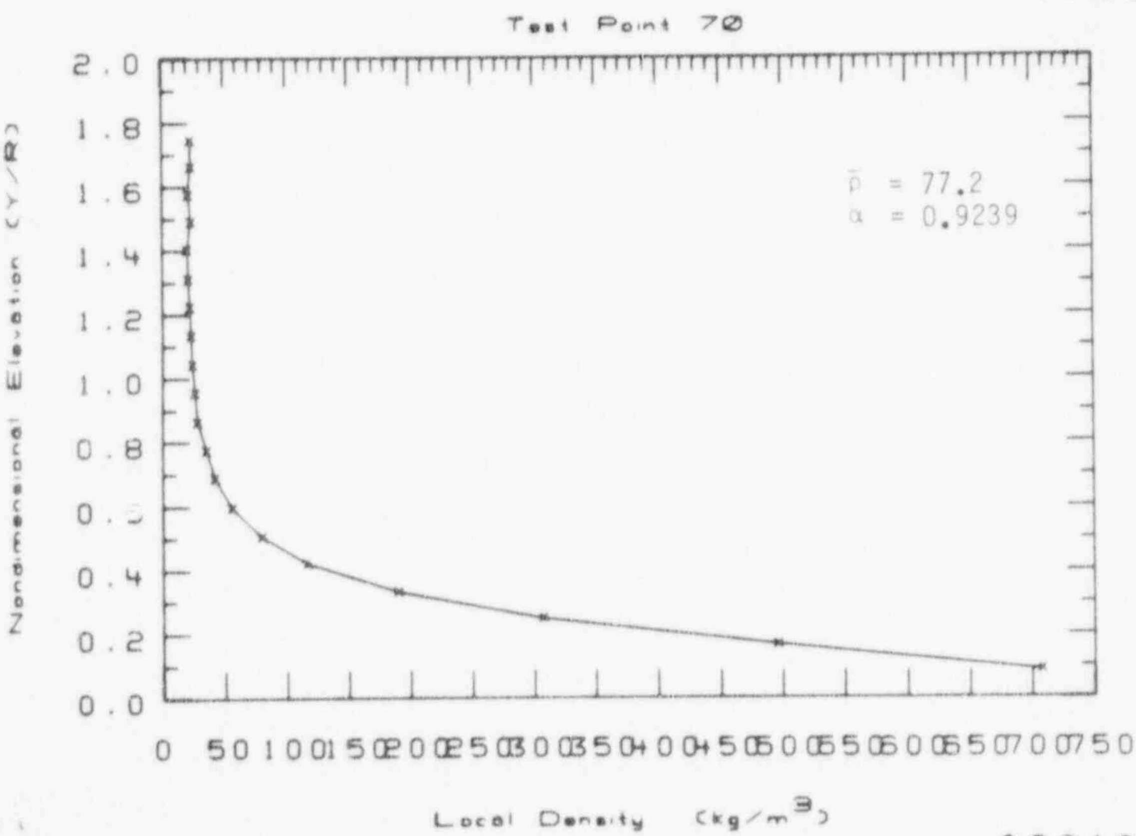

Fig. 100 Density distribution from scanning densitometer, for test series * SB3 *

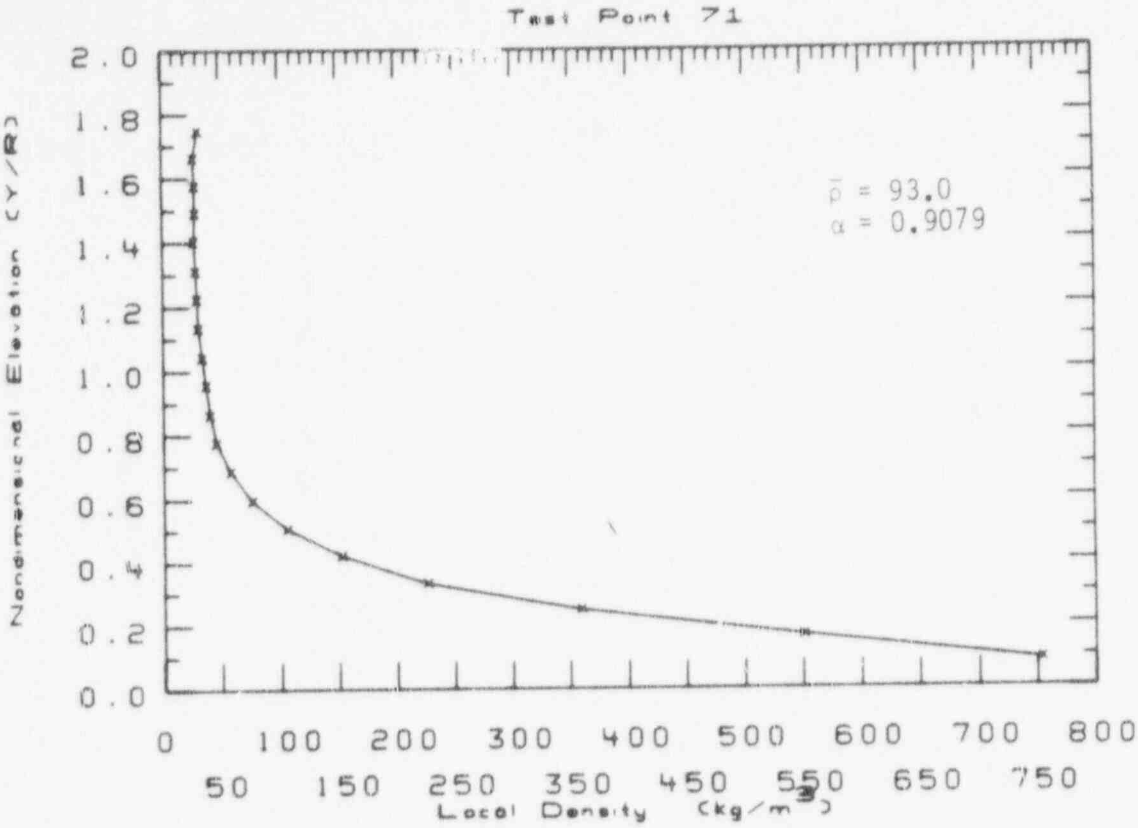

Fig. 101 Density distribution from scanning densitometer, for test series * SB3 *

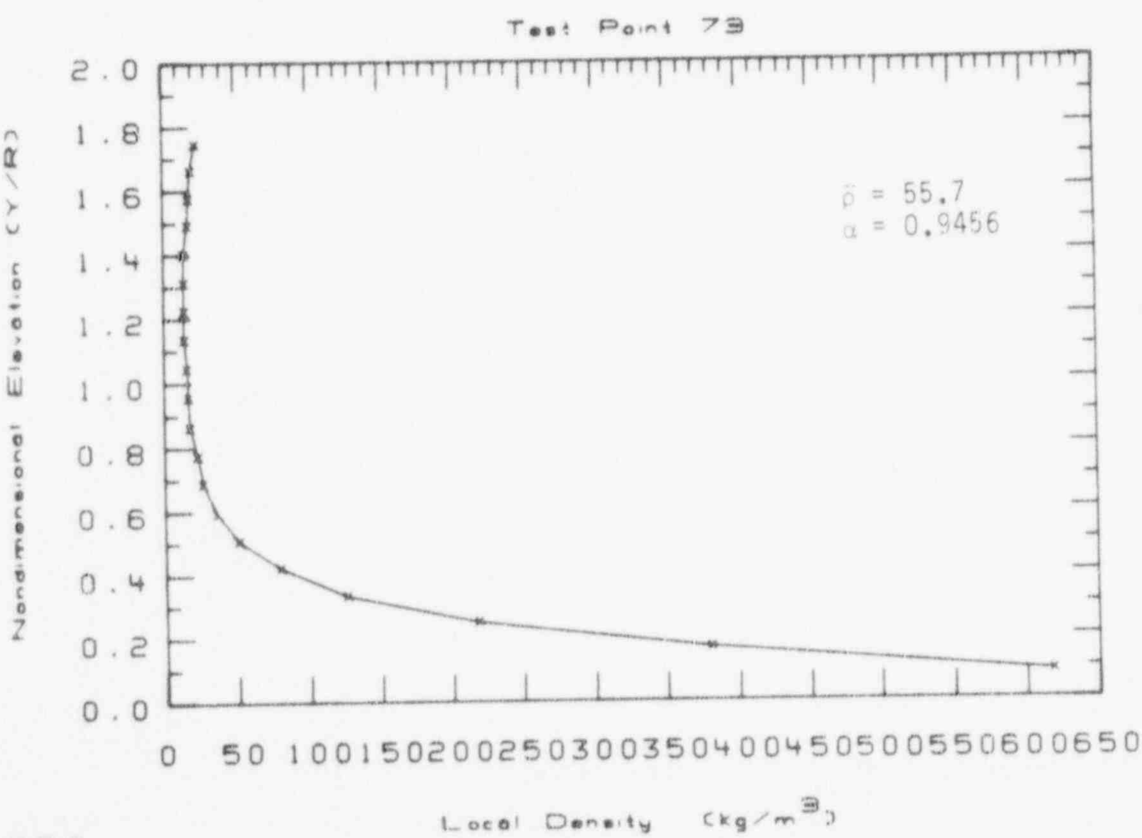

Fig. 102 Density distribution from scanning densitometer, for test series * SB3 *

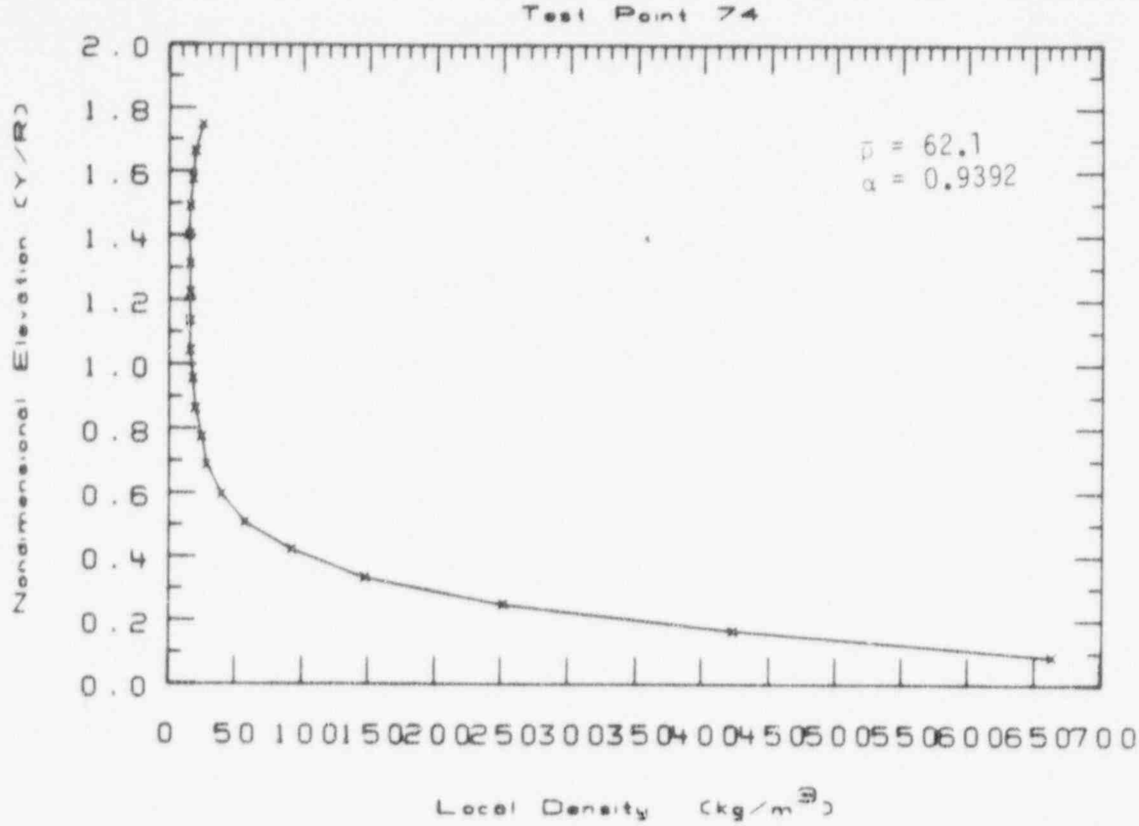

Fig. 103 Density distribution from scanning densitometer, for test series * SB3 *

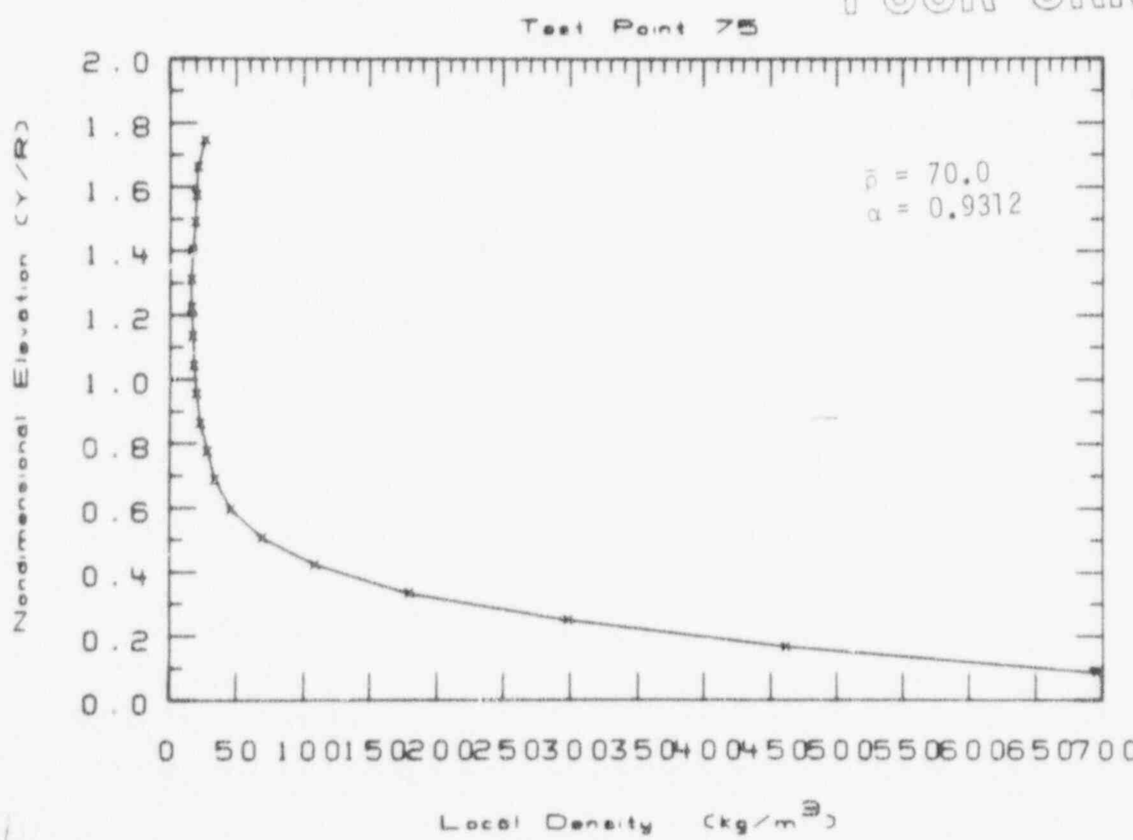

Fig. 104 Density distribution from scanning densitometer, for test series * SB3 *

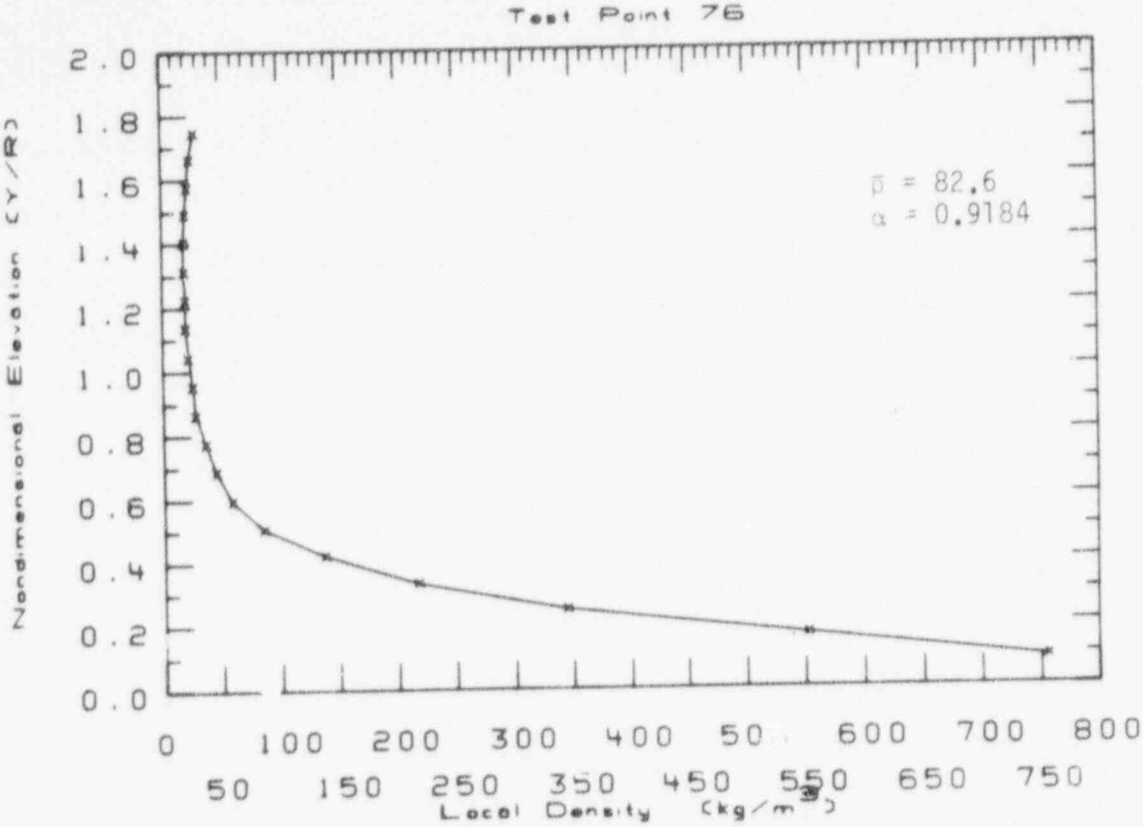

Fig. 105 Density distribution from scanning densitometer, for test series - SB3 -

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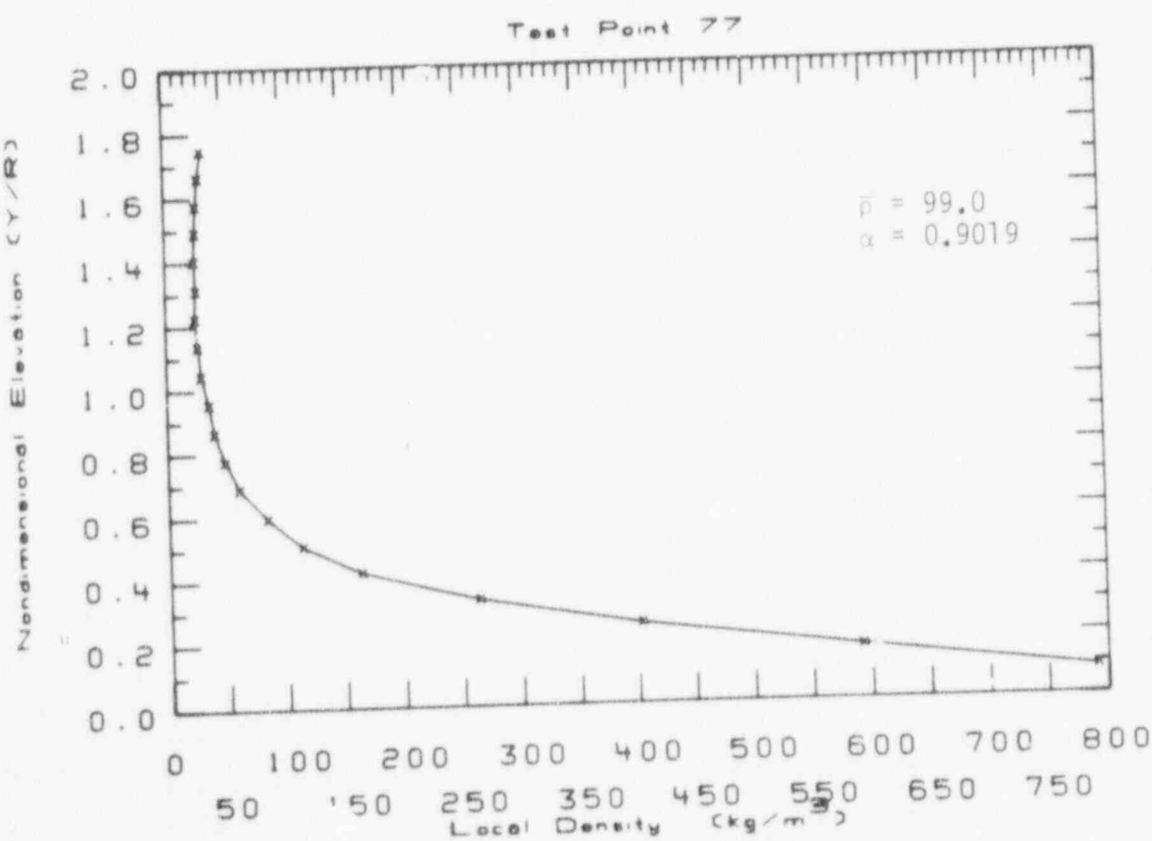

Fig. 106 Density distribution from scanning densitometer, for test series - SB3 -

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VI. REFERENCES

1. J. H. Keenan and J. Kaye, "Gas Tables", John Wiley and Sons, Inc., New York, 1948.

2. "ASME Steam Tables", Third Edition, The American Society of Mechanical Engineers, New York, 1977.

APPENDIX A

SCANNING DENSITOMETER-DETAILED DESCRIPTION

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APPENDIX A

SCANNING DENSITOMETER DETAILED DESCRIPTION[a]

The scanning densitometer is a low photon energy, moving - detector system (Figure A-1) assembled and checked out at EG&G Idaho, Inc. Significant portions of the system were purchased from Westinghouse Nuclear Energy Systems where it had been used previously[2]. For use at EG&G, Idaho, a new spool piece and traversing framework were built, a new source was supplied, and these were combined with the Westinghouse detector, electronics, and traversing motor and control to form the new system.

At the spool horizontal centerline, a 19.18 mm diameter hole was drilled in each flange at a distance of 7.19 cm from the center of the flange bore. A 19.05 mm diameter shaft, aligned like a flange bolt, was mounted through and between these holes, and served two functions: (1) it was the axle about which the detector rotated, and (2) it housed the radioactive source. An axial hole was drilled halfway down the shaft, and the source, mounted at the end of the source holder rod, was inserted in this hole. The wall of the tube, on the side nearest the plexiglass pipe segment, was cut away at the source location so that only air existed between the source and the plexiglass. Thus, the source was not collimated. A roll pin was used to lock the source holder rod, axle/source tube, and the upstream flange in relative position. This assured that the source was maintained in a known, fixed position, relative to the plexiglass, regardless of detector position.

For Test SB3 a new source holder was fabricated to be used with the standard Semiscale low energy source configuration. A photo of this source holder is shown in Figure A-2. Two separate axis (one

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a Significant portions of the follow description are from Reference 1 and used by permission of the author.

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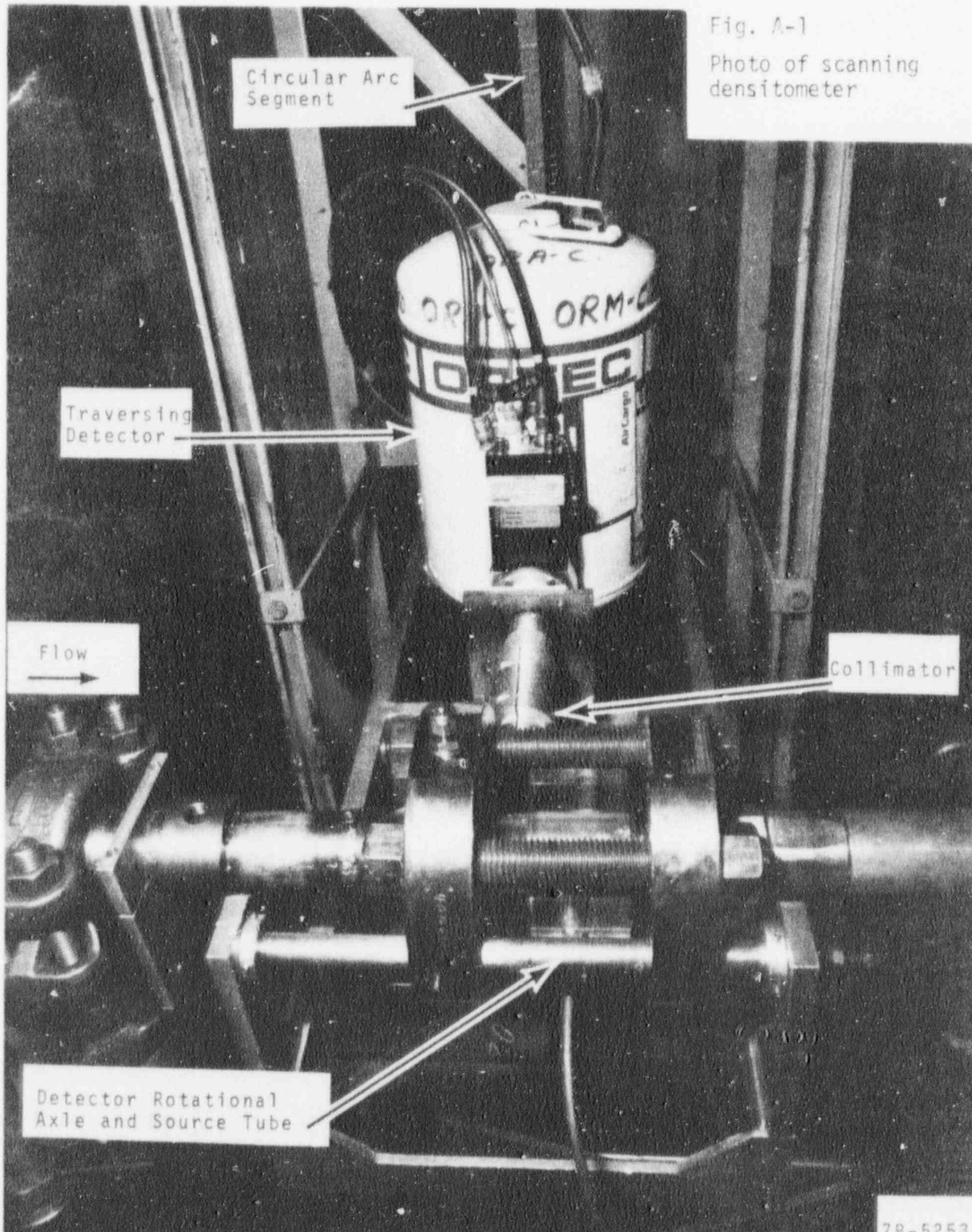
Fig. A-1

Photo of scanning densitometer



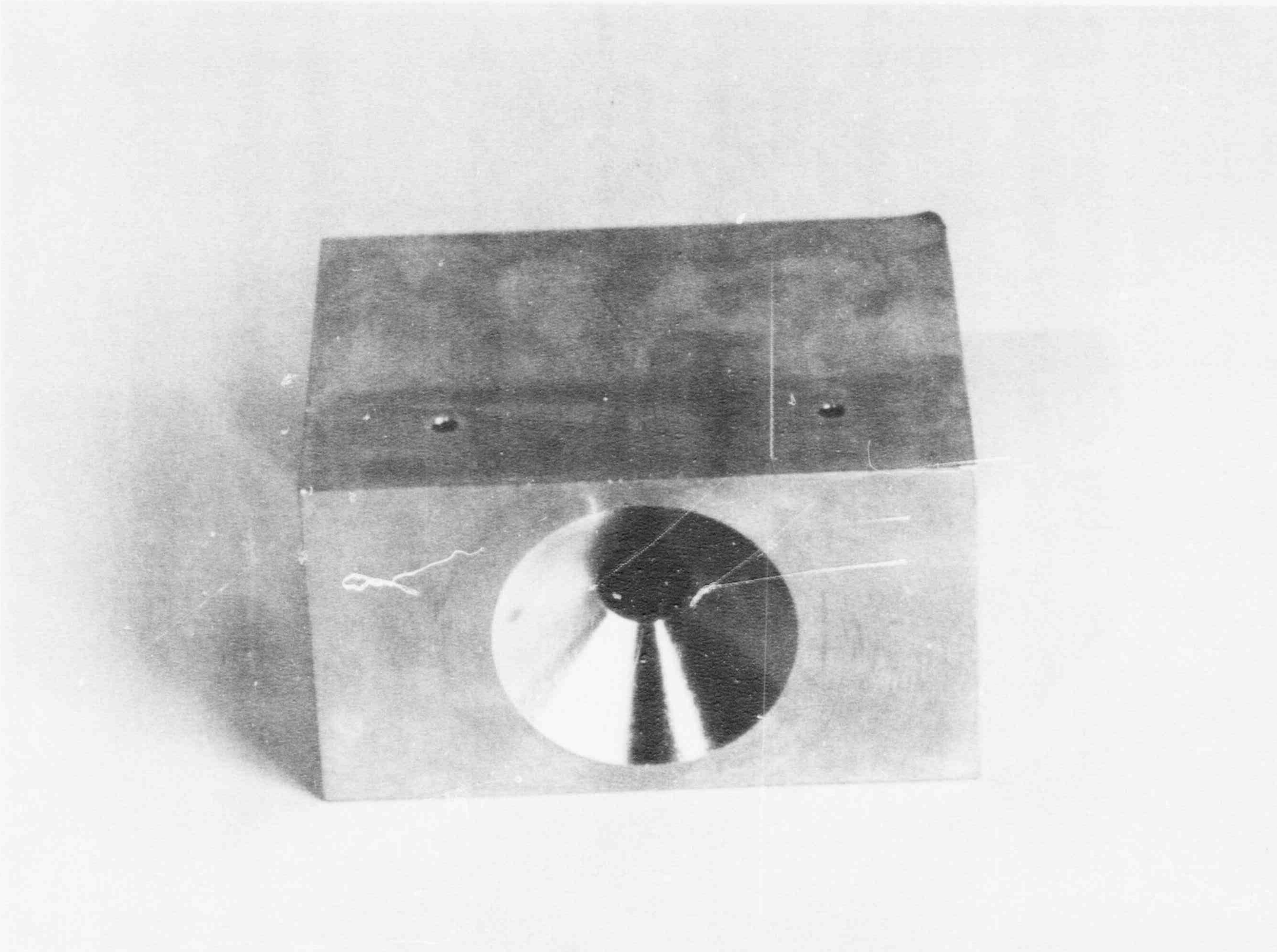


Fig. A-2 Source holder used in conjunction with Am-241 source for test series SB3

on each end of the source holder) passed from the holder through the holes drilled in the flanges and roll pins were used to lock the holder, axials, and flanges in relative position.

The liquid nitrogen dewar and x-ray detector were mounted on a traversing frame constructed of rectangular aluminum tubing. At one end of the frame, vertical arms connected it to the axle/source tube. Sealed ball bearings were pressed into the arms and provided low frictional resistance between the stationary axle and rotating arms and frame. At the frame's outer end, a vertical circular arc segment was attached to the frame. A chain from the drive motor sprocket was attached to the bottom of the arc, so that pulling upward on the chain raised the detector. The chain unwrapped from the circular segment causing a detector movement linearly related to the rotation of the drive motor.

The radioactive source used for test series SB1 and SB2 consisted of approximately 45 mCi of accelerator-grade Cd-109, prepared in May 1977 by New England Nuclear Company. The active material was electroplated on a silver disc which was housed in an hermetically sealed short cylinder, the ensemble noted as capsule Model LE-66A. The primary radiation is the 22.1 keV silver K_α x-ray with a yield of better than 95% per disintegration. K_β x-rays are also present at 24.9 and 25.4 keV, as is an 88 keV gamma. The electron capture decaying isotope has a half life of about 453 days.

The radioactive source used for test series SB3 consisted of approximately 350 mCi of Am-241 prepared in November 1978 by New England Nuclear Company. The active material was in the form of a ceramic cylinder housed in an 1100 series aluminum capsule, Model LE-66B. Photons of only two energies were used in the experiment: the 60 keV gamma ray with a yield of approximately 36% per disintegration and the 17.8 keV Np L x-ray with a yield of approximately 18%. The yield, self absorption and capsule transmission losses precluded effective use of the other Np x- and

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gamma-rays. None of the high energy alpha particles emitted in the decay of this 430 year half life isotope were detected exterior to the capsule. The 17.8 keV x-ray was used exclusively for the final data taking, because of its significantly greater sensitivity; the 60 keV gamma was used only for some initial setup work.

The detector was a 1.0-cm diameter by 5-mm active depth Si (Li) crystal, cooled to near liquid nitrogen temperature in a common vacuum 5 liter dewar, Ortec Model 78916-10300. The 3.81-cm diameter evaculated cryostat snout was sealed against the atmosphere with a 0.0254 mm thick beryllium window. A detector shield was mounted on the front of the cryostat. It consisted of a lead sleeve and 25.4 mm thick shield. A rectangular collimating hole was machined in the shield and had a cross section 10 mm wide by 3.17 mm high. Thus, the collimating hole length-to-height ratio was approximately 8 to 1.

With the source/detector distance of 17.79 cm, the 3.17 mm collimating slot height corresponded to an angular beam height of 1.02 degrees, and constituted 1/10 of the flow diameter. Photon energy resolution of the detector was 274 eV full width half maximum at 15,000 of the 22.1 keV x-rays per second with a main amplifier shaping time constant of 2 μs.

Figure A-3 is a block diagram of the pulse counting system and detector traversing control. Charge pulses generated in the detector by photoelectric absorption of incident x-rays are integrated and amplified in the preamplifier. The resulting voltage pulses are inverted, shaped, and further amplified in the main amplifier and presented to the input of the single channel analyzer (SCA) or dual discriminator. The pulse height is proportional to the absorbed x-ray energy, so a pulse height or x-ray energy window can be set by adjusting the upper and lower discriminators. If the pulses are of a height to fall in the window, a slow-logic pulse is sent by the SCA to the dual counter/timer where it is counted. Pulses are counted for

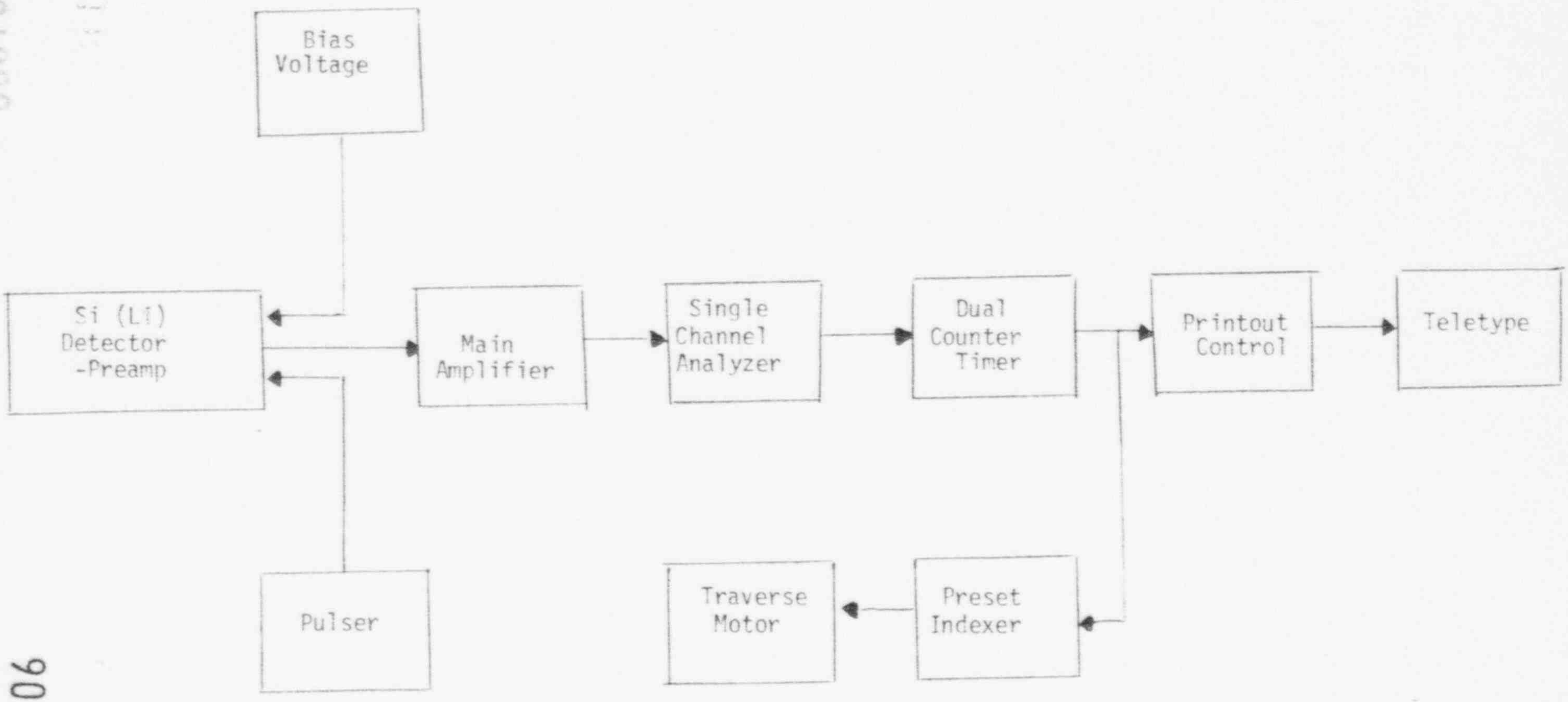

Figure A-3. Scanning Densitometer Block Diagram.

the selected preset time (that is, 10 s for tests SB1 and SB2, 20 s for test series SB3) set on the dual counter/timer. At the end of the preset time, the number of pulses counted is transferred by the printout control to the teletype. Upon completion of printout, the counter is reset to zero and counting automatically reinitiated. Also at the end of the preset time, a control signal is sent from the counter/timer to the preset indexer to start the detector traverse motor and move the detector to its next azimuthal position. The traverse motor is a precise, phase switched dc stepping motor whose output shaft turns 1.8 degrees per step (or preset indexer output pulse). When the preset number of steps (200) have been accomplished, power to the motor is turned off. The speed of the stepping motor is adjusted so that the detector is moved to its next position in slightly less time than is used by the teletype for data printout, that is, slightly less than 3 s.

Thus, a traverse is started by moving the detector to its initial position. The x-ray pulses are counted for 10 s (or 20 s), and the number counted is typed on the teletype. While the typing is proceeding, the detector is moved by the stepping motor to position 2. The counter is reset and counting reinitiated at the new position. This procedure is repeated automatically for the 25 azimuthal detector positions, at which time the operator stops the process and returns the detector to its initial position for the next data run.

Main amplifier gain was set at 45 so that the 22 keV photons from the Cd-109 produced pulses of about 2.4 volts; thus the accompanying 88 keV gamma rays did not saturate the amplifier. Bias voltage used was -1500 Vdc, and upper and lower discriminators were set at 2.50 and 2.10 volts, respectively for Tests SB1 and SB2. For Test SB3 the upper ahd lower discriminators were set at 1.69 volts and 1.25 volts, with a main amplifier gain setting of 35. A multichannel analyzer, Ortec Model 6240-04, was used in setup of the pulse height windows and to provide information for applying scattering and background

corrections. For the test series SB1 and SB2 in which the Cd-109 source was used, it was found that the scattering and background corrections were negligible. However, for test series SB3, in which the Am-241 source was used, the effects of scattering and background radiation were significant and considerable care was taken to account for these effects in the data reduction. Details of these corrections are provided in Appendix B. Dead time corrections were also found unnecessary at the count rates encountered in these tests.

As noted above, a total traverse consisted of obtaining data at 25 positions, each position separated by 200 preset indexer steps corresponding to an angular movement of 1.207 degrees. Thus, the 1.02 degree-wide interrogating window was moved the 1.207 degrees from position to position. Measurements of traverse angle were made for all 25 positions. The 1.207 degrees per 200 indexer steps represents the average angular displacement. Standard deviation of this measurement was 0.017 degrees. Data were obtained at several detector positions in the plexiglass wall, outside the flow area. This was done as a means of verifying repeatable positioning of the detector, regardless of flow condition. As the total angular range covering the flow area was 18.1 degrees, two phase data were obtained at 18 positions.

Densitometer calibration was accomplished by obtaining count rate traverse data for known density, all-liquid and all-dry air conditions. Data were reduced using the scanning densitometer data reduction computer program, PATDR. Chordal average densities are calculated using Equation (A-1) and cross sectional average fluid density is calculated using Equation (A-2). The weighting factor used in the latter equation accounts for the angular segment beam area associated with the polar coordinate setup of source and detector.

$$\rho_c(\theta) = \rho_f - (\rho_f - \rho_g) \frac{\ln \frac{I(\theta)}{I_f(\theta)}}{\ln \frac{I_g(\theta)}{I_f(\theta)}} \qquad \text{(A-1)}$$

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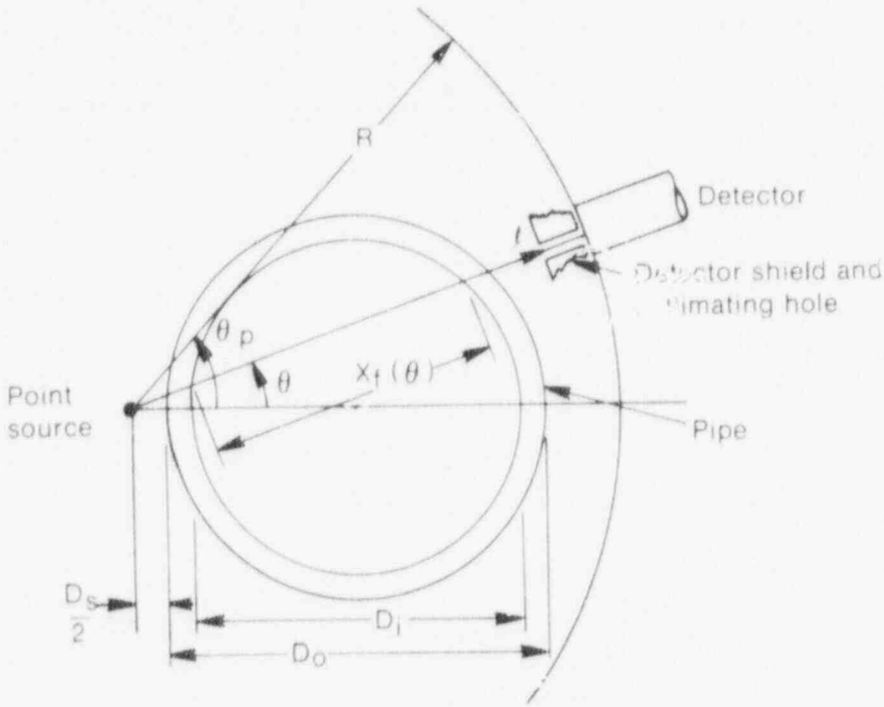

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Figure A-4. Scanning Densitometer Source, Pipe, Detector Geometry.

$$\bar{\rho} = \frac{\sum_{i=4}^{22} [\rho_c(\theta_i)\ 0.5\ (D_o+D_s)(\cos\theta_i)\ X_f(\theta_i)\Delta\theta]}{\sum_{i=4}^{22} 0.5(D_o+D_s)(\cos\theta_i)\ X_f\ (\theta_i)\Delta\theta} \quad \text{(A-2)}$$

where

ρ_f = the density of the subcooled water giving rise to traverse count rates $I_f(\theta)$

ρ_g = the air density yielding count rates $I_g(\theta)$

ρ_c = the chordal average density determined from the two phase fluid count rates $I(\theta)$

D_o = plexiglass pipe segment outer diameter

D_s = twice the distance from source center to nearest outer surface of the plexiglass pipe segment

θ = traverse angle (Figure A-4)

X_f = fluid chordal path length = $(D_i^2-(D_o+D_s)^2\sin^2\theta)^{1/2}$

D_i = plexiglass pipe segment inner diameter.

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REFERENCES

1. A. G. Stephens, "Experimental Data for Determination of Uncertainty of Two-Phase Mass Flow Rate in Semiscale Mod-3 System Spool Piece at Karlsruhe Kernforschungzentrum", SEMI-TR-006 (June 1979).

2. G. P. Lilly, A. G. Stephens, L. E. Hochreiter, "Mixing of Emergency Core Cooling Water with Steam: 1/14th Scale Testing Phase," Electric Power Research Institute (EPRI) Report 294-2 (January 1975).

APPENDIX B

SCATTERING CORRECTIONS APPLIED TO SB3 DENSITY DATA

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APPENDIX B

SCATTERING CORRECTIONS APPLIED TO SB3 DENSITY DATA

For test series SB3, Am-241 was used as the x-ray source for the scanning densitometer. The 17.8 keV x-ray was used to increase the sensitivity of low density measurements. At an x-ray energy of 17.8 keV the ratio of count rates[a] for all air to all water is 32.3, whereas for the 22 keV x-ray (the primary Cd-109 peak) this ratio is only 7.8. However, to use the 17.8 keV Am-241 x-ray extra data reduction was found necessary to correct the Single-Channel Analyser (SCA) data for scattering. The scattering correction decreases the SCA count rate to eliminate those x-rays counted, the energies of which had decreased since leaving the source (i.e., eliminate those x-rays counted which had had some interaction with test section or fluid atoms before being detected). The effect is described by equation (B-1):

$$I_{SCA} - I_{back} = BI_{uncoll} \qquad \text{(B-1)}$$

where

I_{SCA}	=	The SCA count rate
I_{back}	=	The background count rate (due to the 20.8, 26, and 60 keV x-rays)
I_{uncoll}	=	The uncollided 17.8 keV count rate
B	=	The buildup fact (due to scattered 17.8 keV x-rays detected within the SCA window).

Figures B-1 shows typical photon energy spectra obtained (with the multi-channel analyzer system) at the diameterical detector position for the given reference fluid condition, i.e., all air. In

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a This ratio is quoted for the detector position at the pipe diameter and is given by:

$$R = (I_g/I_f) = \text{Exp}\left|\left(\frac{\mu}{\rho}\right)_f (\rho_f - \rho_g)\ X_f\right|$$

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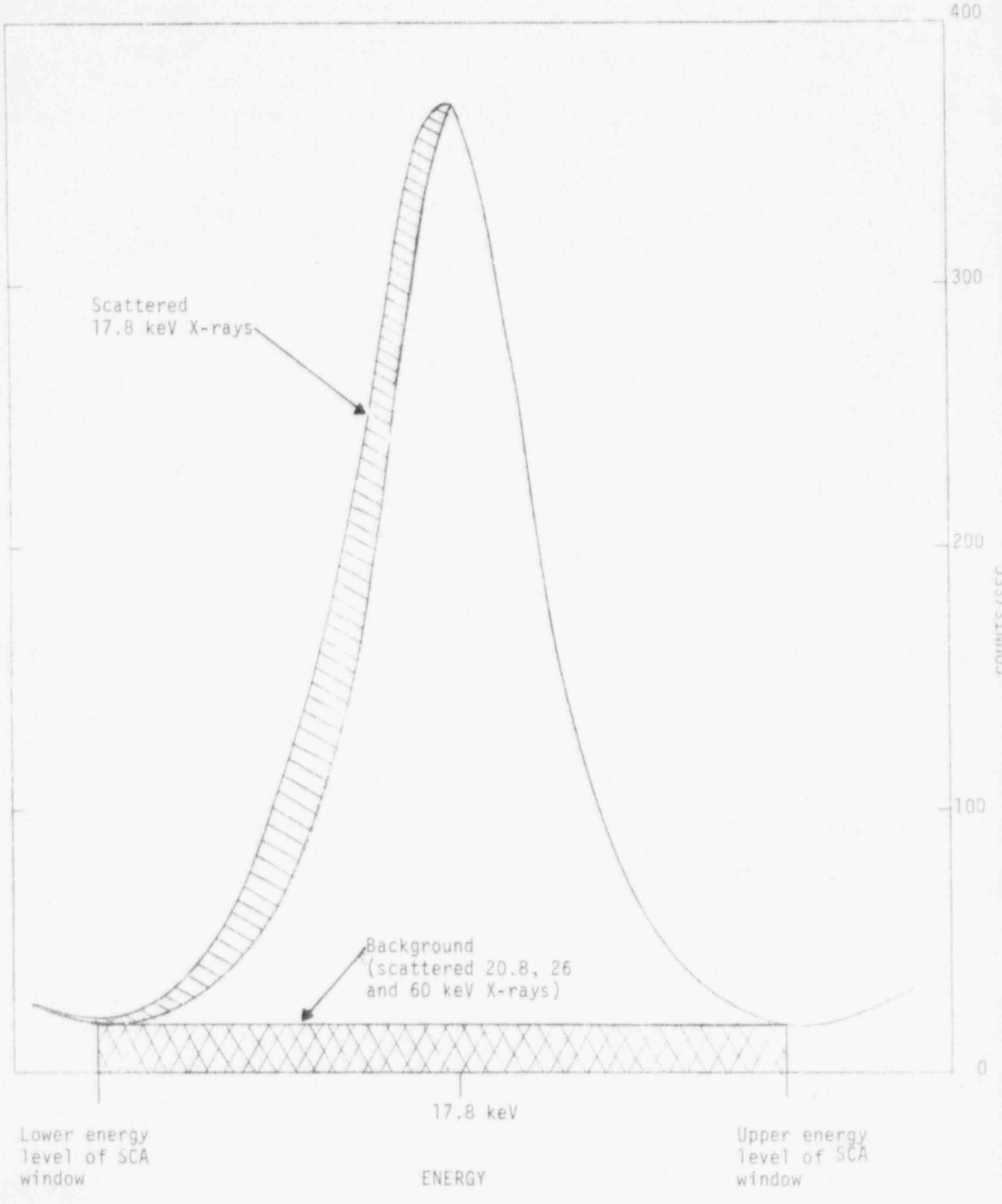

Figure B-1. MCA data for all air condition at horizontal pipe diameter. Scattering corrections are shown.

this figure, the symmetrical, unshaded area is associated with the uncollided flux of 17.8 keV x-rays. The cross-hatched area at the base of the figure is associated with non 17.8 keV x-ray photons (these are principally scattered 60 keV photons) designated as background. The shaded area, at the left of the figure, is the portion of the total signal due to scattered 17.8 keV photons. Then, B, the buildup factor, which is the ratio of scattered plus uncollided x-rays to uncollided, is given, in terms of the figure, by:

$$B = 1 + \frac{\text{SHADED AREA}}{\text{UNSHADED AREA}}$$

which is simply a restatement of equation (B-1). Values of B were determined from MCA data on all-air and all-water fluid conditions by using equation (B-1) and calculating values for I_{uncoll} (double the high energy side of the spectral peak), for I_{back} (average the high energy side background and multiply by the total number of MCA channels associated with the 17.8 keV peak), and I (sum the counts in the total number of 17.8 keV MCA channels). These B values were then plotted versus the corresponding n values, n being the total number of mean free path lengths as given by equation (B-7). (The n values could be calculated directly since the reference densities (ρ_f, ρ_g) were known.) This plot lead to the empirical relation:

$$B\ (n) = C_1 + C_2\ n \tag{B-2}$$

where the least-squares-fitted values of the coefficients were found to be:

COEFFICIENT	VALUE
C_1	1.048
C_2	0.015

With the relation for B and an additional fit for I_{back} (given next), equation B-1 was used to determined values of I_{uncoll} from SCA-system values of I_{SCA} for all-air and all-water fluid conditions, i.e.,

$$I_g(\theta) \equiv I_{uncoll}^{air} = \frac{I_{air} - I_{back}}{B} \qquad (B-3)$$

$$I_f(\theta) \equiv I_{uncoll}^{water} = \frac{I_{water} - I_{back}}{B} \qquad (B-4)$$

where I_{air}, I_{water} are SCA-system reference fluid condition count rates; B is given by Equation (B-2); I_g and I_f are the reference air and water count rates corrected for scattering; and I_{back} is given by Equation (B-5):

$$I_{back} = C_3 + C_4 I_{SCA} \qquad (B-5)$$

COEFFICIENT	VALUE
C_3	251.43 counts/sec
C_4	0.127

The above procedure, used to correct all-air and all-water condition reference rates for scattering, could not be used to correct tests run count rates because, with the fluid density unknown, n values (hence B values) could not be calculated. Thus to correct the run data for scattering, the following iterative solution was used: at a given value of θ, an initial value of I_{uncoll} was chosen (I_{SCA}) and a value of $\bar{\rho}_c$ calculated. This value of $\bar{\rho}_c$ was used to derive a value of n and subsequently B. The B value, along with I_{SCA} and I_{back} values, were then used to calculate a new value of I_{uncoll}. This sequence is shown in the list of equations below.

$$\bar{\rho}_c(\theta) = \rho_f - (\rho_f - \rho_g) \frac{\ln [I(\theta)/I_f(\theta)]}{\ln [I_g(\theta)/I_f(\theta)]} \qquad (B-6)$$

$$n(\theta, E) - \mu_p(E)X_p(\theta) + (\tfrac{\mu}{\rho})_f(E)\, \bar{\rho}_c(\theta)X_f(\theta) + \mu_a(E)X_a(\theta) \qquad (B-7)$$

$$B = C_1 + C_2\, n \qquad (B-8)$$

$$I_{back} = C_3 + C_4 I_{SCA} \qquad (B-9)$$

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$$I(\theta) \equiv I_{uncoll}^{mix} = \frac{I_{SCA} - I_{back}}{B} \quad \text{(B-10)}$$

where

$\mu_p(E)$, $\mu_a(E)$	=	are the linear attenuation coefficients for the pipe wall and air at an energy of 17.8 keV
$X_p(\theta)$, $X_f(\theta)$, $X_a(\theta)$	=	are the path lengths at the angle θ within the pipe, fluid, and air, respectively
$(\mu/\rho)_f(E)$	=	is the mass attenuation coefficient for the fluid at an energy of 17.8 keV.

This iterative procedure was considered complete when successive values of I_{uncoll} did not differ significantly i.e., when the relation $\left| I_{uncoll}^{old} - I_{uncoll}^{new} \right| < \left(\frac{I_{uncoll}^{old} + I_{uncoll}^{new}}{t_c} \right)^{1/2}$ was satisfied. In this relation t_c is the counting time at each position. A typical printout of data from the data reduction program is shown in Table B-1. Values of raw, and uncollided count rates, along with chordal-average density, are shown at each value of detector azimuthal position.

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TABLE B-1

TYPICAL PRINTOUT FROM DATA REDUCTION PROGRAM

Position Angle of Det. (degrees)	I_{SCA} Raw Data (c/s)[a]	% Loss	Data Converted to MCA Equivalent[b] (c/s)	I_{back} Back-Ground (c/s)	B Scattering Buildup Factor	Uncoll Data (c/s)	Average Chrodal Density (gm/cm^3)	Position No.
12.67	9968.5	0.00	9976.3	1518.4	0.0000	0.0[b]	0.0000	1
11.47	11260.4	0.00	11288.4	1685.1	0.0000	0.0	0.0000	2
10.26	12229.2	0.00	12272.4	1810.0	1.0583	9877.5	.1116	3
9.05	12855.9	0.00	12909.0	1890.9	1.0577	10408.9	.1000	4
7.85	13328.3	0.00	13388.8	1951.8	1.0572	10809.4	.0916	5
6.64	13668.2	0.00	13734.0	1995.7	1.0569	11097.7	.0860	6
5.43	14028.5	0.00	14099.9	2042.1	1.0565	11403.9	.0789	7
4.23	14151.9	0.00	14225.3	2058.0	1.0564	11508.5	.0775	8
3.02	14248.6	0.00	14323.5	2070.5	1.0563	11590.5	.0763	9
1.81	14248.8	0.00	14323.7	2070.5	1.0564	11590.2	.0773	10
.60	14185.3	0.00	14259.2	2062.3	1.0565	11536.0	.0790	11
-.60	13969.1	0.00	14039.7	2034.5	1.0567	11352.0	.0838	12
-1.81	13619.0	0.00	13684.0	1989.3	1.0571	11054.7	.0907	13
-3.02	13102.8	0.00	13159.8	1922.7	1.0577	10615.6	.1034	14
-4.22	12574.6	0.00	12623.3	1854.6	1.0583	10167.6	.1153	15
-5.43	12011.1	0.00	12050.9	1781.9	1.0590	9689.1	.1314	16
-6.64	11334.7	0.00	11363.9	1694.6	1.0598	9115.7	.1523	17
-7.85	10347.0	0.00	10360.7	1567.2	1.0612	8278.9	.1892	18
-9.05	9141.7	0.00	9136.5	1411.8	1.0631	7259.5	.2462	19
-10.26	8339.6	0.00	8321.7	1308.3	1.0645	6582.5	.3024	20
-11.47	10862.0	0.00	10883.7	1633.7	1.0599	8719.8	.3240	21
-12.67	15649.4	0.00	15746.3	2251.2	1.0549	12782.1	.3438	22
-13.88	6199.9	0.00	6148.4	1032.3	0.0000	0.0	0.0000	23
-15.09	52.0	0.00	-96.0	239.2	0.0000	0.0	0.0000	24
-16.29	46.2	0.00	-101.9	238.5	0.0000	0.0	0.0000	25

AVERAGE DENSITY (KG/CU-M)= 109.4 RHOG= 5.76
AVERAGE VOID FRACTION = .8953 RHOF= 995.7
AVERAGE HOMOGENEOUS QUALITY (%)= 4.71

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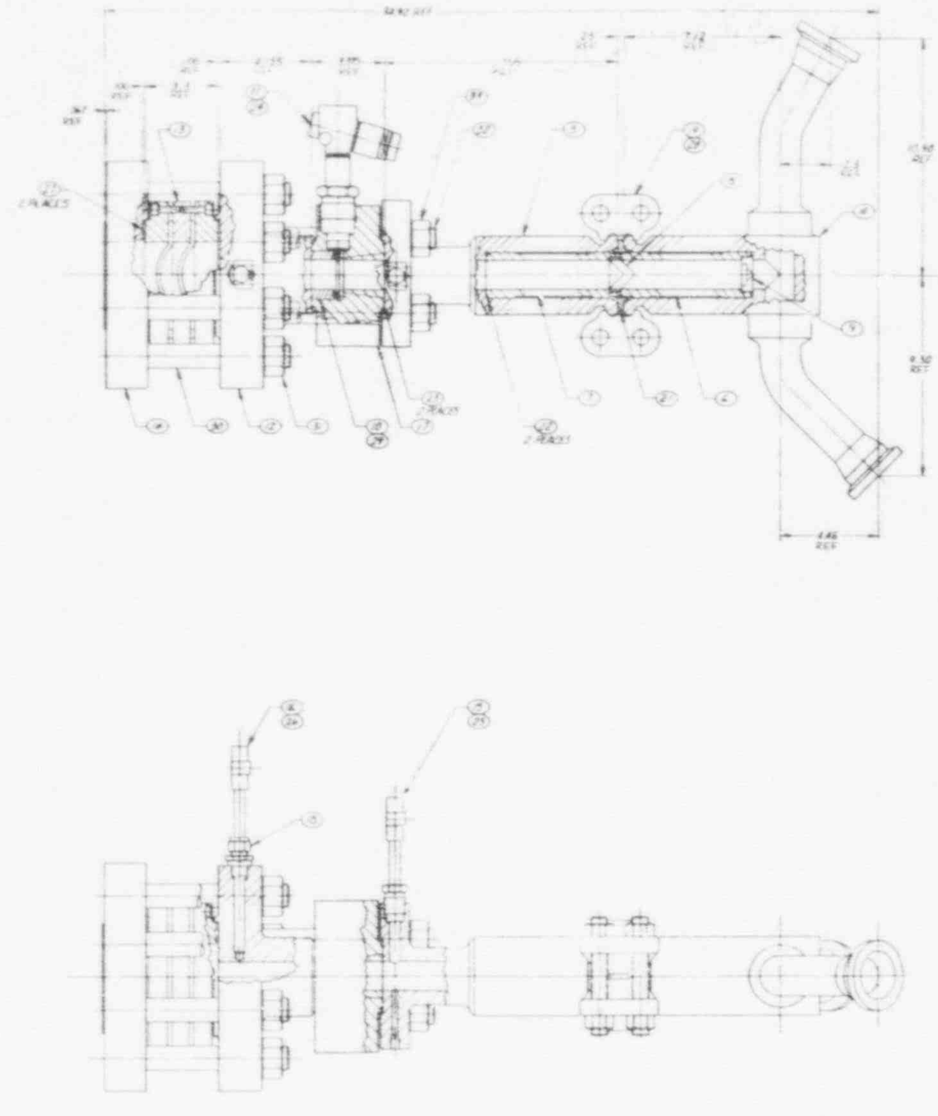
a. (Counts/sec).

b. To use the MCA derived scattering corrections, the SCA data must first be converted to an MCA equivalent. This is due to the slightly different energy window settings in the set up of the SCA and MCA.

c. For positions 1, 2, 23, 24, and 25 the x-ray beam was partially or completely within the pipe wall and therefore densities were not calculated.

NOTES:

1. REMOVE ALL BURRS AND SHARP EDGES
2. SURFACE ROUGHNESS [illegible] UNLESS OTHERWISE NOTED
3. CLEANLINESS PER ANC STD 7022, LEVEL C.
4. PRESERVE AND PROTECT PER ANC STD 7028 CLASS E
5. BOLT TORQUE REQUIREMENTS ARE AS FOLLOWS:
   A. 1 INCH 1500 LB FLANGE STUDS [illegible]
   B. 1/2 INCH 1500 LB FLANGE STUDS [illegible]
   C. SIZE 2 GRAYLOK CLAMP STUDS 50 TO 65 FT-LBS



ASSEMBLY

QTY	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL/SPECIFICATION		ITEM NO.
					34
4		HEX. NUT 1-8UNC-2B	C.S [illegible]	II	33
4		BOLT STUD 1-8UNC-2A x 7.25 LONG	ALLOY STEEL [illegible]	II	32
8		HEX. NUT 1/2-13UNC-2B	C.S [illegible]	II	31
8		STUD 1/2-13UNC x 2.25 LONG	ALLOY STEEL [illegible]	II	30
4		SCREW, SOCKET HEAD CAP [illegible] LONG	18-8 SST	II	29
					28
2	[illegible]	GASKET, SST WITH ASBESTOS STD FILLER	FLEXITALLIC GASKET CO. [illegible]	II	27
1	[illegible]	O-RING, METALLIC	UNITED AIRCRAFT PRODUCTS DAYTON, OHIO	II	26
1	[illegible]			II	25
1	[illegible]			II	24
2	[illegible]			II	23
2	[illegible]	O-RING, METALLIC		II	22
1	[illegible]	SEAL RING	GRAY TOOL COMPANY HOUSTON, TEXAS	II	21
1	[illegible]	[illegible]		II	20
1	[illegible]	CLAMP		II	19
1	401334-4	MODIFIED O-RING CONNECTOR			18
1	[illegible]	INSTRUMENT WASHER			17
1	[illegible]	1 INCH WATER COOLED PRESSURE PROBE			16
1	[illegible]	1 INCH WATER COOLED PRESSURE PROBE			15
1	[illegible]	TRANSITION FLANGE			14
1	[illegible]	RUPTURE ASSEMBLY			13
1	[illegible]	INTERCONNECTION FLANGE			12
1	[illegible]	WATER COOLED [illegible] TRANSDUCER ASSEMBLY			11
1	[illegible]	DRAG SCREEN ASSEMBLY			10
1	[illegible]	ORIFICE SLEEVE			9
1	[illegible]	FILTER RING			8
1	[illegible]	ORIFICE SLEEVE			7
1	[illegible]	ORIFICE SLEEVE			6
1	[illegible]	SPOOL, SMALL BREAK			5
1	[illegible]	SPOOL, [illegible]			4
					3
					2
		ASSEMBLY		II	1

PARTS LIST

SEMISCALE SYSTEM
SMALL BREAK SPOOL
[illegible]
SUB ASSEMBLY

SCALE: NONE

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POOR ORIGINAL


POOR ORIGINAL
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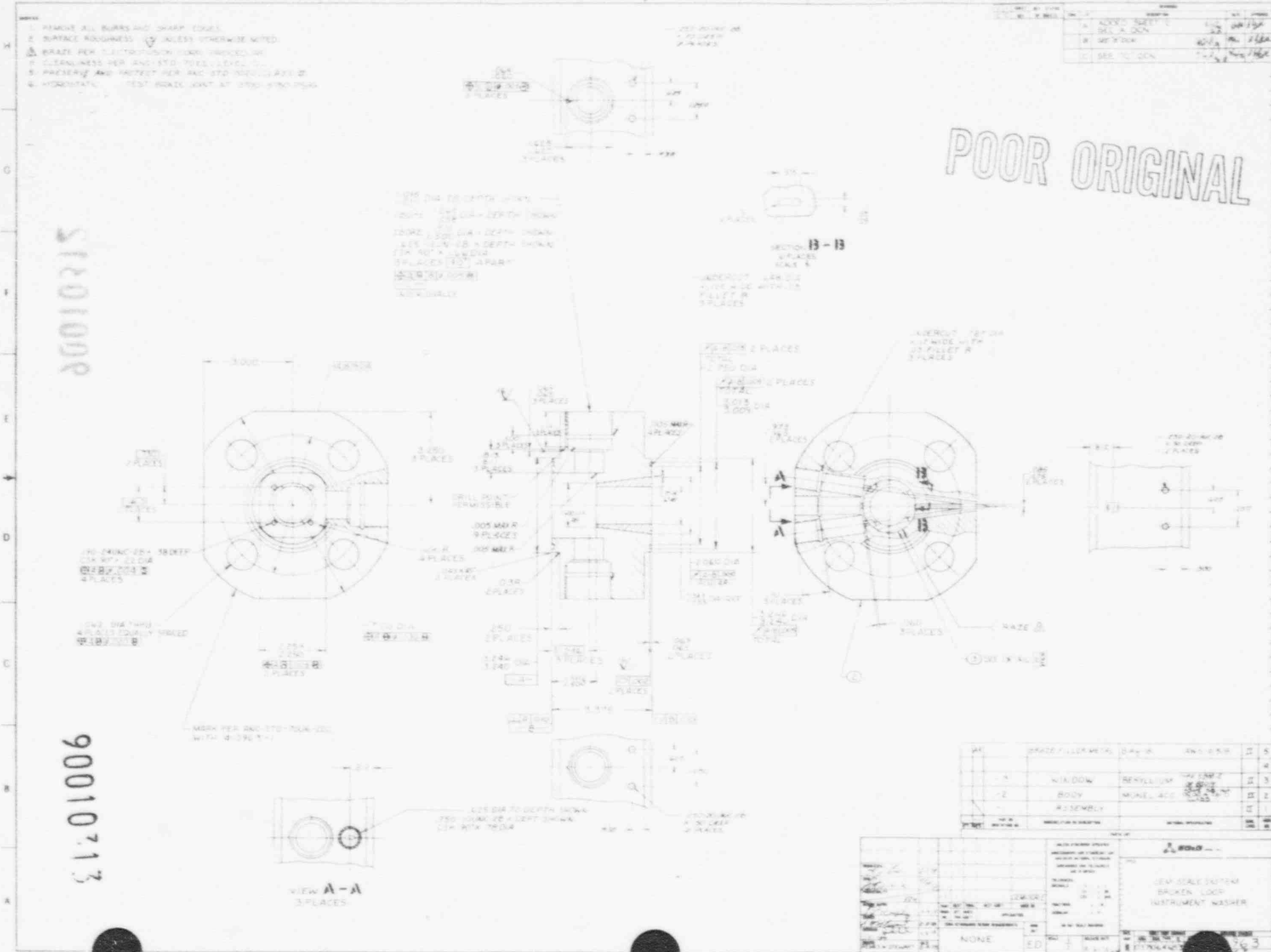
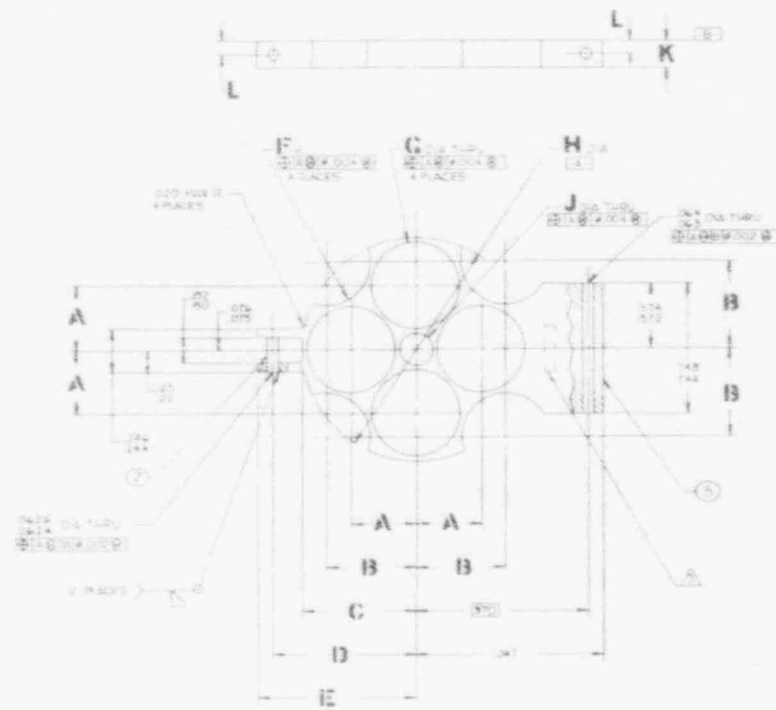

POOR ORIGINAL
NOTES:
1. REMOVE ALL BURRS AND SHARP EDGES.
2. SURFACE ROUGHNESS UNLESS OTHERWISE NOTED.
BRAZE PER
5. PRESERVE AND PROTECT PER
6. HYDROSTATIC TEST BRAZE JOINT AT
SECTION B-B
VIEW A-A
3 PLACES
BRAZE FILLER METAL
-1 WINDOW BERYLLIUM
-2 BODY MONEL
ASSEMBLY
NONE
SEMISCALE SYSTEM
BROKEN LOOP
INSTRUMENT WASHER

90010713



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POOR ORIGINAL