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Vitrinite reflectance data for the Paleocene Fort Union and Eocene Wind River Formations, and burial history of a drill hole located in central Wind River Basin, Wyoming

by

Vito F. Nuccio ¹

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¹ USGS, Denver, CO

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INTRODUCTION

Recent discoveries of oil in the Paleocene Fort Union Formation, and oil shows in the Eocene Wind River Formation, have sparked an interest in the burial and thermal history of these units in the Wind River Basin, Wyoming (fig. 1). The purpose of this report is to present new vitrinite reflectance data, and burial and thermal information for these and other units for a recently-drilled well in the central part of the Wind River Basin. By knowing the burial and thermal history of an area, one can characterize the petroleum potential of source rocks present, and develop an intelligent petroleum exploration strategy.

METHODS

Vitrinite, a maceral derived from woody plant material, is common in coal and carbonaceous shale. Vitrinite reflectance (R_O) is a measurement of the proportion of light reflected from a polished vitrinite grain. It is related to the degree of metamorphism of the vitrinite grain and can be directly converted to coal rank. R_O values have been correlated with oil and gas generation for potential source rocks (Dow, 1977; Waples, 1985). For example, Waples (1985) stated that oil generation begins over a range of R_O values depending on the type of kerogen; onset of oil generation ranges from about 0.45 percent R_O to 0.50 percent R_O for high-sulfur kerogen, to 0.60 percent R_O for type II kerogen, to 0.65 percent R_O for type III kerogen. The end of oil generation also occurs over a range of R_O values, but 1.35 percent R_O is commonly accepted as the value at which oil begins to break down into shorter chain hydrocarbons. Dow (1977) states that oil generation by liptinitic-rich (Type I) source rocks occurs between 0.50 and 1.35 percent R_O . Wet gas is generated from mixed (Types I, II, and III) organic matter and from the breakdown of oil between R_O values of 0.80 percent and 2.0 percent. Dry gas, or thermogenic methane, is generated from humic organic matter and from the breakdown of wet gas between R_O values of about 1.0 percent and 3.0 percent. Biogenic gas can be generated at levels of maturity as low as those for peat (0.20 percent R_O). For this study, "mature" for oil occurs at 0.60 percent R_O (see fig. 2).

Eighteen coal samples were collected from cleaned cuttings from the Paleocene Fort Union and Eocene Wind River Formations (fig. 3) from the Larry Barnes Petroleum, Inc., Carvner Fed. no. 22-15 well in sec. 15 - T. 37 N. - R. 94 W. (fig. 1). The samples were prepared for R_O analysis by crushing, mounting in epoxy on a microscope slide, planing off when hardened, and polishing. The mean random R_O (from randomly oriented indigenous vitrinite grains) was determined using plane-polarized incident white light and a 546 nm monochromatic filter, in immersion oil, on a reflected light microscope with a nonrotating stage (Bostick, 1979; Bustin, 1986). Thirty measurements were made for each sample, and a mean R_O value calculated (see Appendix 1 for individual data sheets).

A burial curve and thermal history model (fig. 4) were constructed for the well using information from several sources. The thickness of the Fort Union and Wind River Formations were measured directly from a geophysical log of the well (see fig. 3). Ages of the Fort Union Formation members were adapted from Nichols and Flores (1993). Thicknesses and ages of post lower Eocene, Oligocene and Miocene strata were estimated using data from Love (1988), Keefer (1970), and Van Houten (1964). The basin modeling computer program BasinMod (Platte River Associates) was used for construction of the burial history, and in modeling the vitrinite reflectance. For this well, a heat flow of 45 mWm^{-2} was used. This agrees with present-day heat flow values for the Wind River Basin (range from 36 to 48 mWm^{-2}) and also in the range of values that likely existed as far back as Late Cretaceous (Barker and Crysedale, 1993).

DISCUSSION

Mean R_O values for samples from the well studied range from 0.61 percent (uppermost sample collected, 3240-3300 ft) in the Eocene Wind River Formation to 0.90 percent (lowermost sample collected, 9050-9060 ft) in the Paleocene lower member of the Fort Union Formation (fig. 5, Appendix 1). Assuming that 0.60 percent R_O represents the beginning of oil generation, the lower part of the Wind River River Formation, and the entire Fort Union Formation are in the oil window. The major Tertiary oil source rock in the Wind River Basin is the Waltman Shale Member of the Fort Union Formation (Palacas and others, 1993). Katz and Liro (1993) characterized the Waltman Shale as containing types II and III kerogen, with total organic carbon content values as high as 7.0 percent. Based on these geochemical parameters, and the level of thermal maturity (0.75 to 0.80 for the Waltman zone; fig. 5) from this study, the Waltman would have to be considered an excellent source rock, and the likely source of the oil produced in this well. It is also probable that some of the coals, as well as carbonaceous shales that occur throughout the entire well, may have generated some gas.

Figure 4 illustrates the burial and temperature history of units in the well. Assuming that the burial reconstruction at the well site is accurate, a heat flow of 45 mWm^{-2} was required to match the modeled maturity with the measured R_O values (fig. 5). Using this heat flow, the base of the Fort Union (base of the Paleocene) was buried to around 12,300 ft, and reached temperatures exceeding 250°F at maximum burial 15 Ma. R_O values of 0.90 percent characterize this horizon. The top of the Waltman Shale Member was buried to 10,200 ft, and achieved a temperature of around 250°F at maximum burial 15 Ma. As mentioned above, R_O values are around 0.75 to 0.80 percent at the Waltman level. The Paleocene-Eocene boundary was buried to approximately 8,000 ft, and reached temperatures of nearly 200°F at maximum burial and temperature 15 Ma. R_O values cluster around 0.60 to 0.65 at this stratigraphic horizon.

Based on the information presented in this report, the Waltman Shale Member of the Fort Union Formation has reached the proper thermal maturity to be in the oil window. It is more than likely that the oil produced from the Fort Union reservoirs, as well as oil shows in the Wind River Formation were sourced from the Waltman.

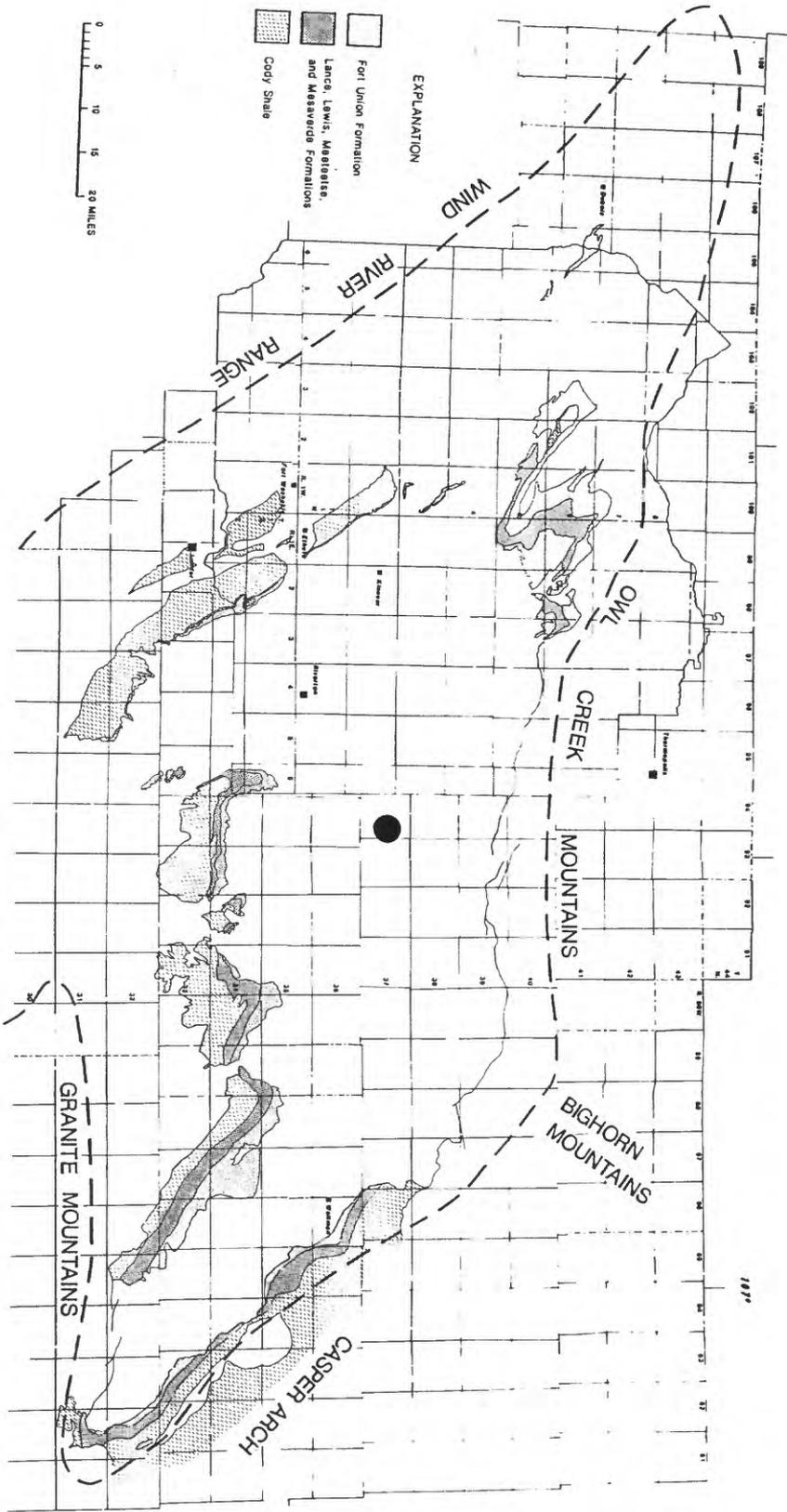


FIGURE 1--Index map of the Wind River Basin, Wyoming showing location (large dot) of the Larry Barnes Petroleum, Inc., Carver Fed. no. 22-15 well, located in sec. 15 - T. 37 N. - R. 94W.

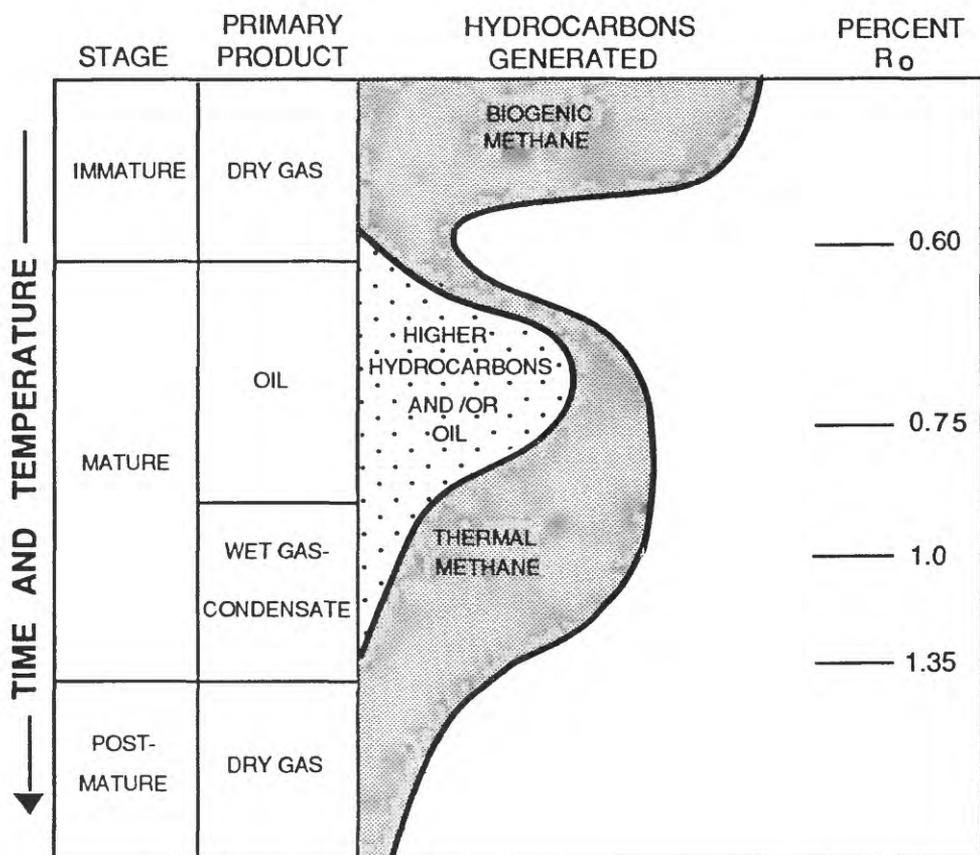


FIGURE 2--Generalized scheme for oil and gas generation as a function of thermal maturity (expressed as R_0) of source rocks.

System	Series	Stratigraphic Unit or event	Thickness (in feet)	Ages (Ma)	
Tertiary	mid. Mio.-present	uplift and erosion	-3,380	15 - 0	
	Miocene	Split Rock Formation	900	24 - 15	
	Oligocene	White River Formation	500	38 - 24	
	Eocene		Post lower Eocene rocks undivided	1,980	55 - 38
			Wind River and Indian Meadows Formations undifferentiated	4,625	
	Paleocene	Fort Union Formation	Shotgun Member	2,175	59 - 55
			Waltman Shale Member	840	60 - 59
			Lower member	1,350	66 - 60

FIGURE 3--Generalized stratigraphic column for Tertiary units of the Wind River Basin discussed in this report. Thicknesses and ages of units used to reconstruct the burial history of the well are also presented.

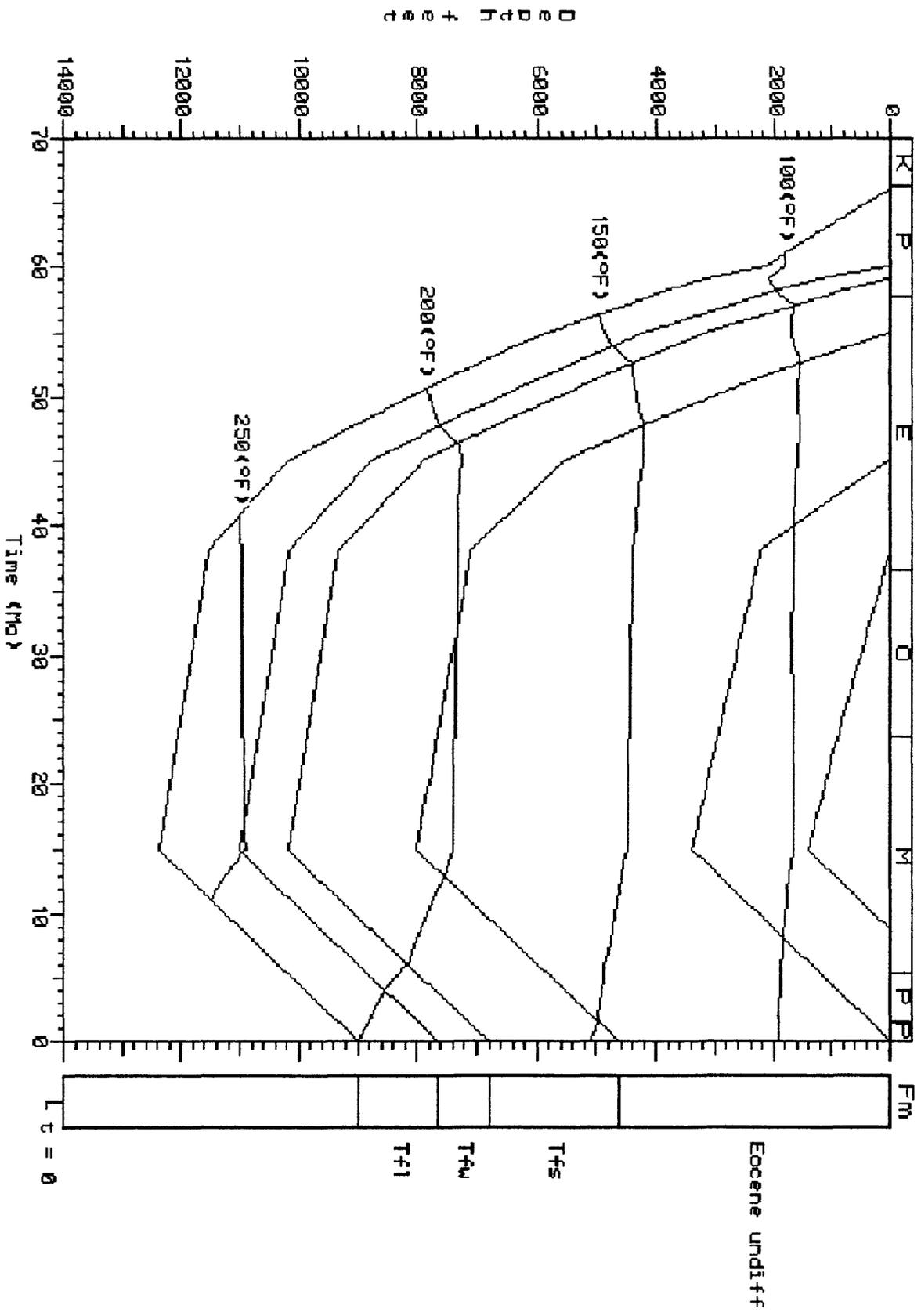


FIGURE 4--Burial and temperature history of Tertiary units discussed in this report.

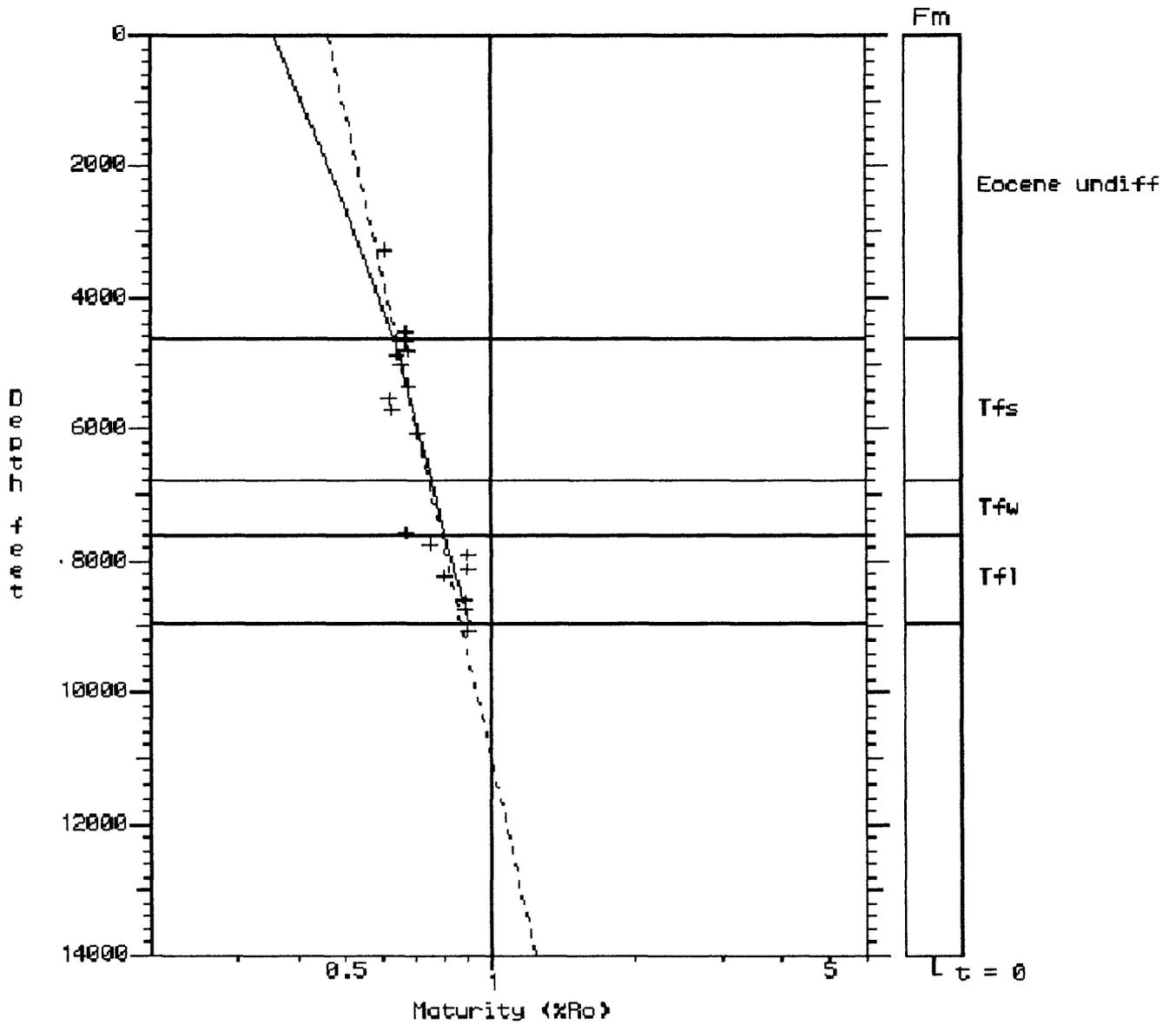


FIGURE 5--Graph showing measured vitrinite reflectance data [(+) and dashed line], and the modeled maturity line (solid line). A constant heat flow of 45 mWm^{-2} was used to match the measured and modeled lines.

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APPENDIX 1

Vitrinite reflectance data

Each data sheet represents the mean random vitrinite reflectance data for the individual coal samples. The File Name is the project name. The Channel Name is the name of the analyst, and Comment 1 is information regarding the quality of the sample. For each coal sample several vitrinite grains were measured. These are listed on the data sheet in the Pt. column, and correspond to the values in the Meas 1 column. The minimum reading (Min), maximum reading (Max), mean value of all readings (Mean), and standard deviation (StDev) are given. The Mean is the R_0 value for the sample, and is the value plotted in fig.5 and discussed in the text. The histogram for measurements of the sample are also given.

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 Comment 1: Good sample, Clean and consistent
 Comment 2:
 Comment 3:
 Comment 4:
 Comment 5:
 Comment 6:

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Min:	0.54			
Max:	0.68			
Mean:	0.61			
StDev:	0.04			

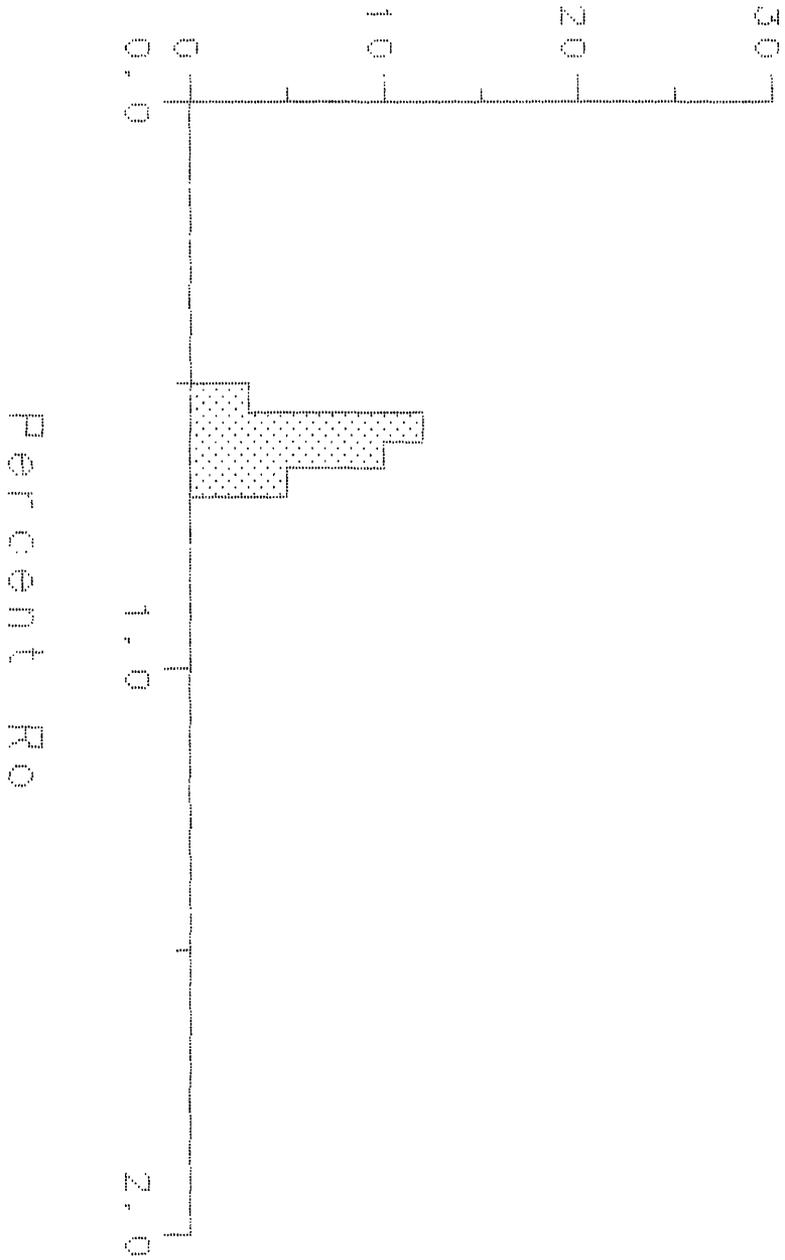
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7				0.66			
8				0.59			
9				0.64			
10				0.57			
11				0.58			
12				0.61			
13				0.60			
14				0.58			
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16				0.59			
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18				0.64			
19				0.60			
20				0.60			
21				0.59			
22				0.57			
23				0.55			
24				0.59			
25				0.54			
26				0.56			
27				0.68			
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Frequency

5240-5300
CH 2-2 MH

0.81 SD

0.04

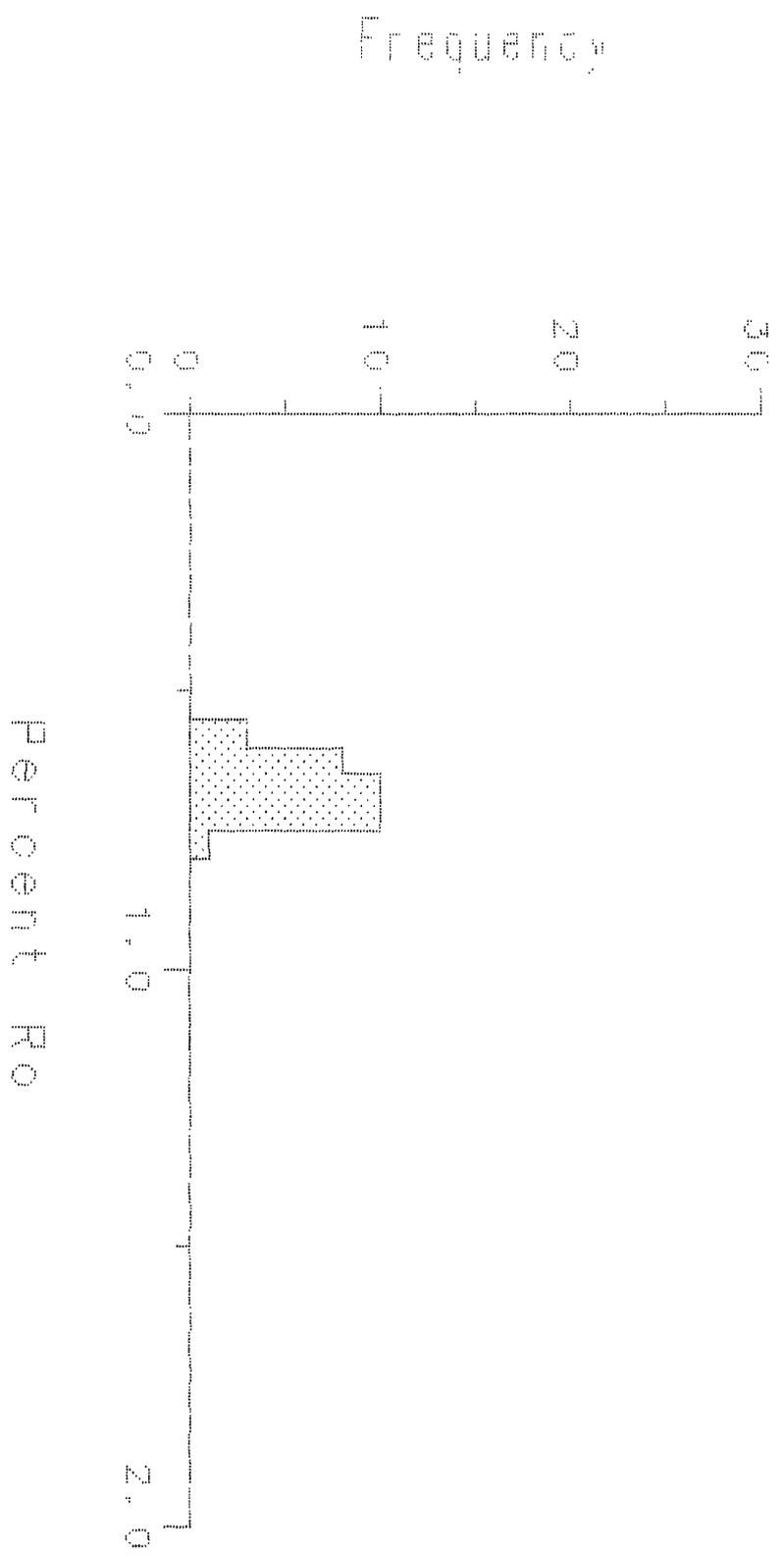


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 Comment 4:
 Comment 5:
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Max:	0.76			
Mean:	0.67			
StDev:	0.05			

Pt.	X-Pos	Y-Pos	Z-Pos	Meas1	Meas2	Ratio	Conc.
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2				0.64			
3				0.61			
4				0.64			
5				0.59			
6				0.58			
7				0.67			
8				0.68			
9				0.65			
10				0.62			
11				0.62			
12				0.67			
13				0.73			
14				0.59			
15				0.69			
16				0.68			
17				0.65			
18				0.69			
19				0.62			
20				0.69			
21				0.71			
22				0.76			
23				0.67			
24				0.71			
25				0.70			
26				0.71			
27				0.61			
28				0.75			
29				0.72			
30				0.74			
31				0.71			
32				0.73			

4500 - 4550
 CH 2 - 2 MH
 0.67 SD
 0.08



File Name: RFVN
 Channel Name: Nuccio
 Description: 4650-4680
 Comment 1: Good sample, Clean and consistent
 Comment 2:
 Comment 3:
 Comment 4:
 Comment 5:
 Comment 6:

	Meas1	Meas2	Ratio	Conc.
Min:	0.61			
Max:	0.76			
Mean:	0.67			
StDev:	0.04			

Pt.	X-Pos	Y-Pos	Z-Pos	Meas1	Meas2	Ratio	Conc.
1				0.64			
2				0.65			
3				0.64			
4				0.67			
5				0.63			
6				0.66			
7				0.64			
8				0.66			
9				0.68			
10				0.64			
11				0.63			
12				0.65			
13				0.65			
14				0.67			
15				0.76			
16				0.75			
17				0.70			
18				0.73			
19				0.69			
20				0.68			
21				0.67			
22				0.66			
23				0.61			
24				0.71			
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28				0.63			
29				0.67			
30				0.65			

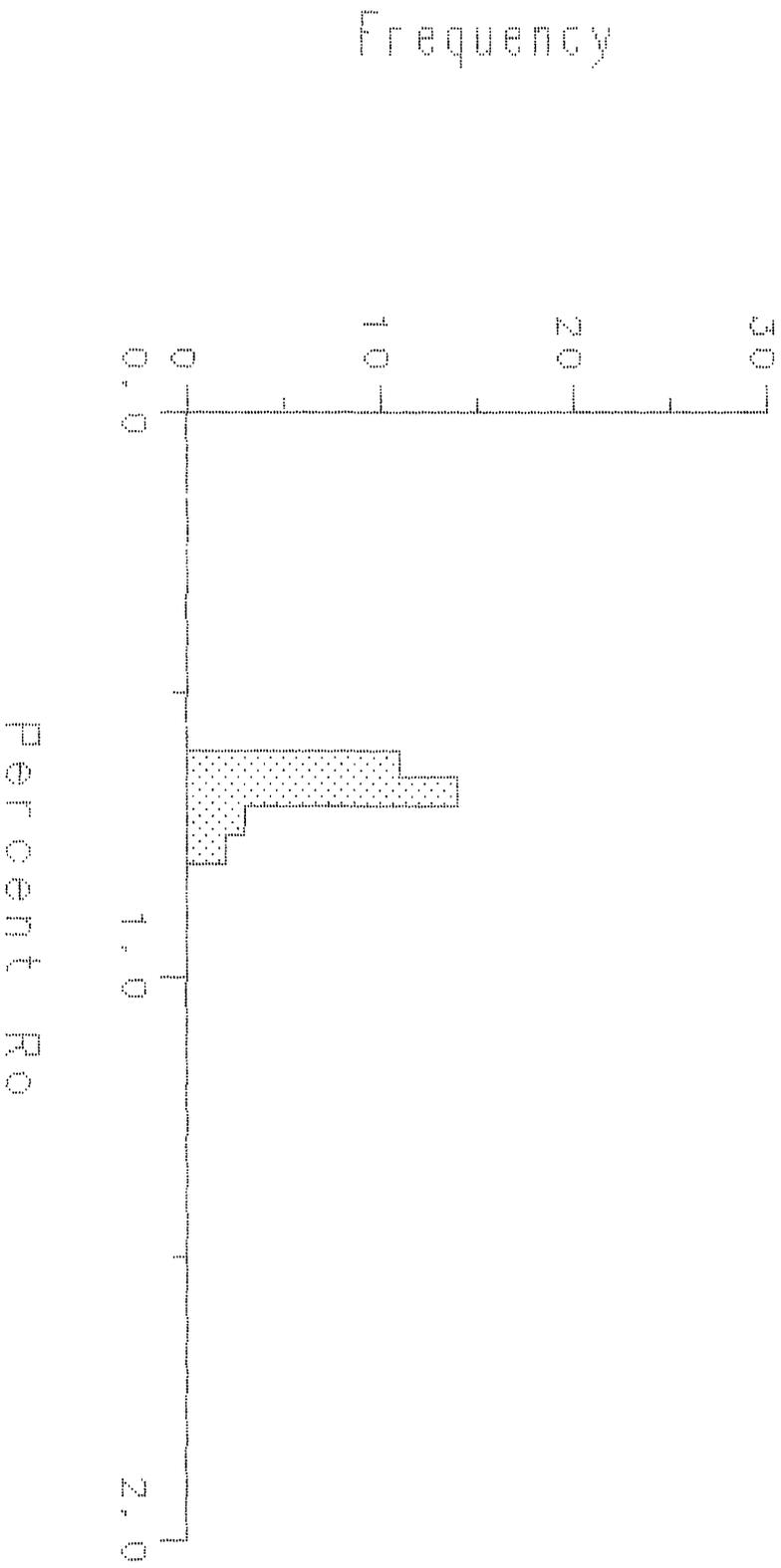


4650-4850

CH 2 - 2 Mn

0.67 SD

0.04



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 Comment 3:
 Comment 4:
 Comment 5:
 Comment 6:

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Max:	0.72			
Mean:	0.64			
StDev:	0.03			

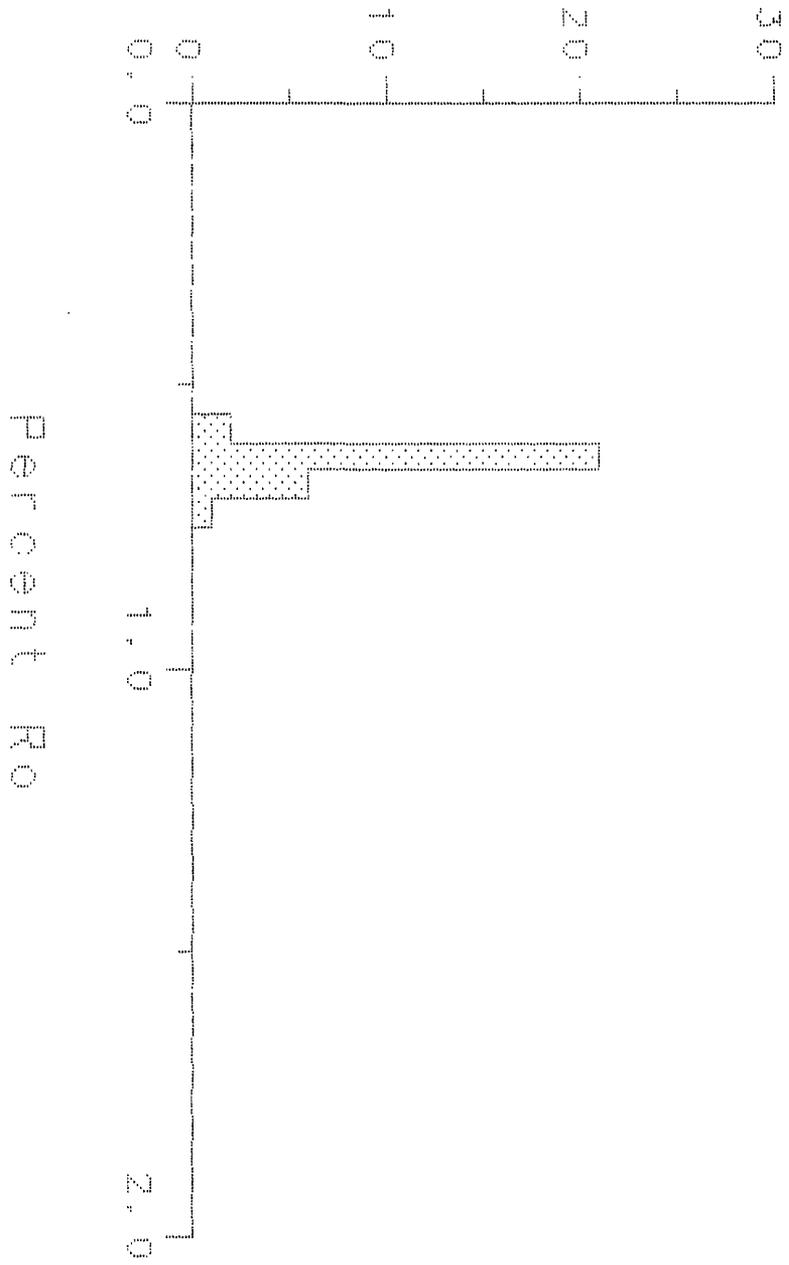
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7				0.64			
8				0.64			
9				0.63			
10				0.67			
11				0.63			
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14				0.63			
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16				0.60			
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23				0.60			
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25				0.63			
26				0.65			
27				0.64			
28				0.65			
29				0.64			
30				0.61			

Frequency

4860-4870
CH 2-2 Mn

0.64 SD

0.03



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 Comment 6:

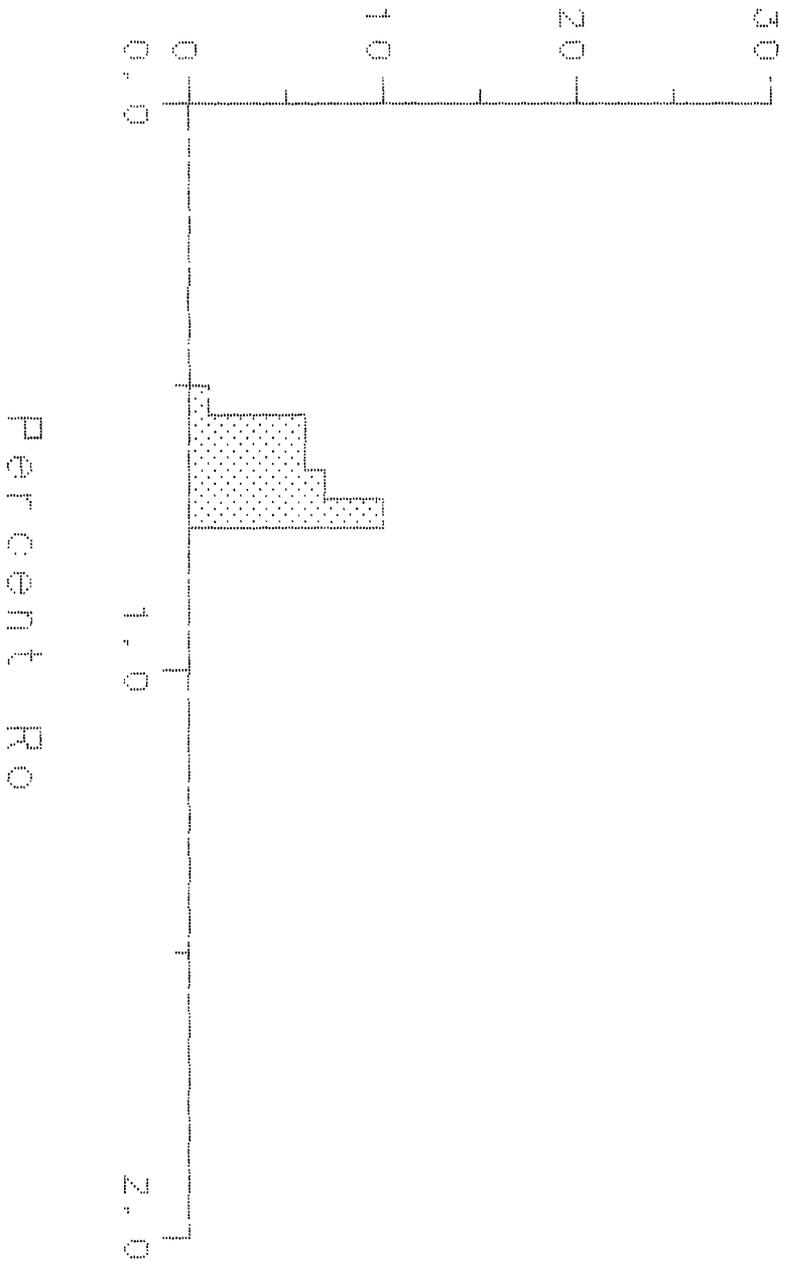
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Mean:				0.66			
StDev:				0.06			
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2				0.74			
3				0.70			
4				0.67			
5				0.65			
6				0.66			
7				0.67			
8				0.63			
9				0.63			
10				0.64			
11				0.59			
12				0.67			
13				0.60			
14				0.60			
15				0.59			
16				0.73			
17				0.74			
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25				0.53			
26				0.56			
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30				0.64			

Frequency

5020-5030
CH 2-2 MH

0.66 SD

0.08



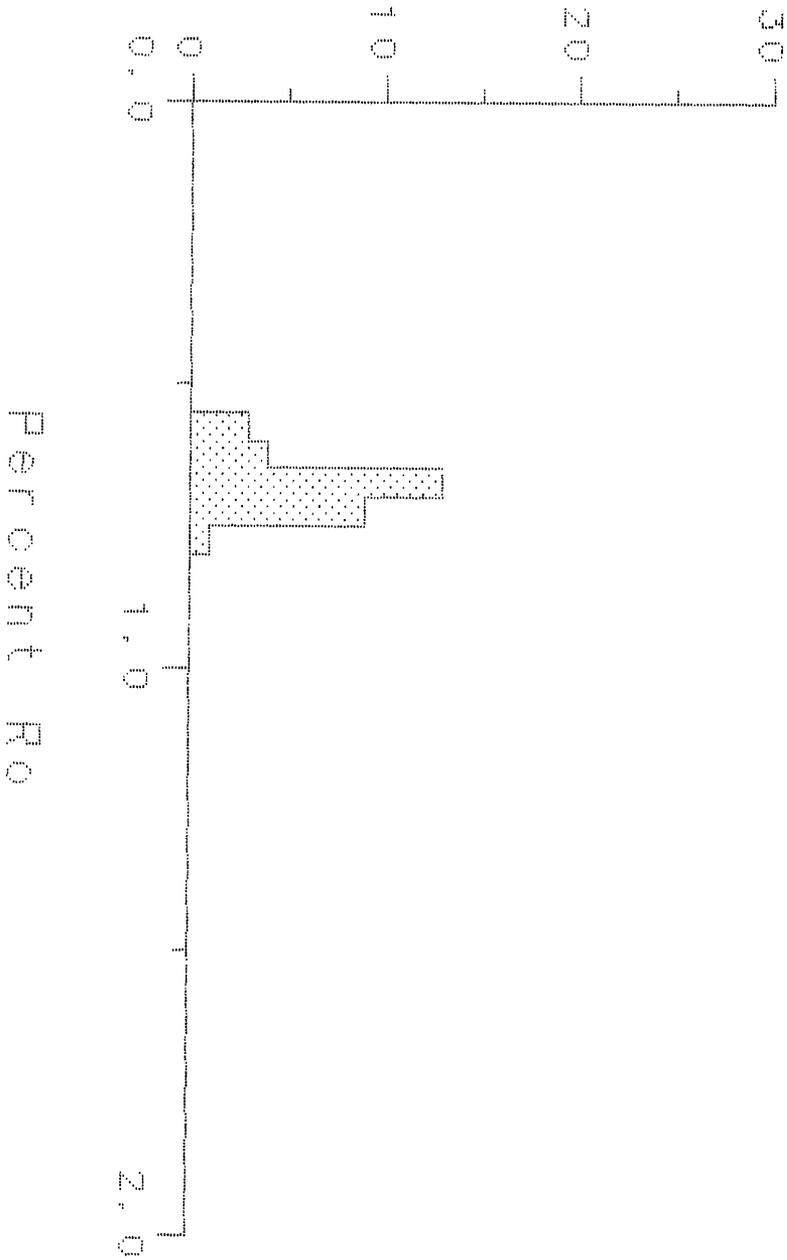
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Max:	0.76			
Mean:	0.68			
StDev:	0.05			

Pt.	X-Pos	Y-Pos	Z-Pos	Meas1	Meas2	Ratio	Conc.
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Frequency

5320-5340
CH2-Z MM 0.05 SD 0.05



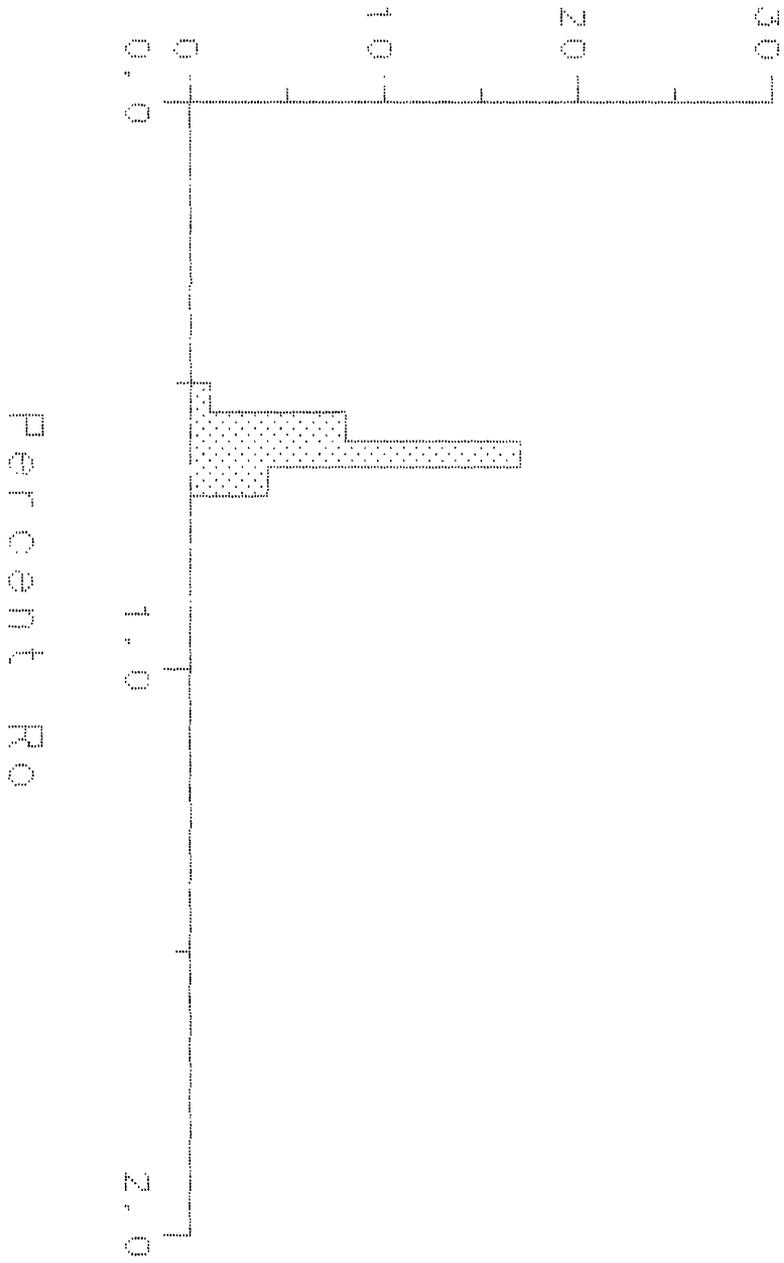
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 Comment 3:
 Comment 4:
 Comment 5:
 Comment 6:

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Max:	0.67			
Mean:	0.62			
StDev:	0.03			

Pt.	X-Pos	Y-Pos	Z-Pos	Meas1	Meas2	Ratio	Conc.
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24				0.60			
25				0.61			
26				0.61			
27				0.62			
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29				0.61			
30				0.60			

Frequency

5530-5540
CH 2 - 2 MH
0.62 SD
0.03



File Name: RFVN
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 Comment 3:
 Comment 4:
 Comment 5:
 Comment 6:

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Mean:	0.63			
StDev:	0.04			

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6				0.65			
7				0.71			
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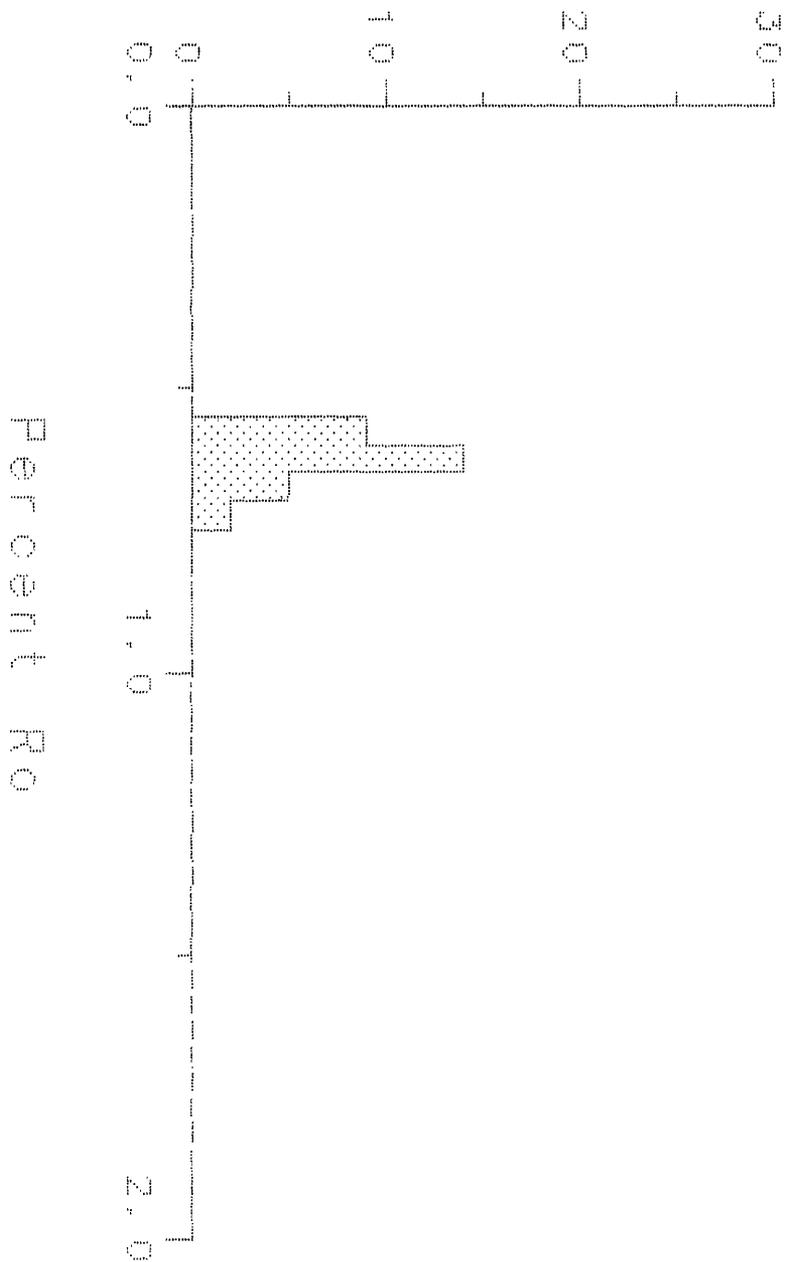
Frequency

5700-5710

CH 2 - 2 MHz

0.53 SD

0.04



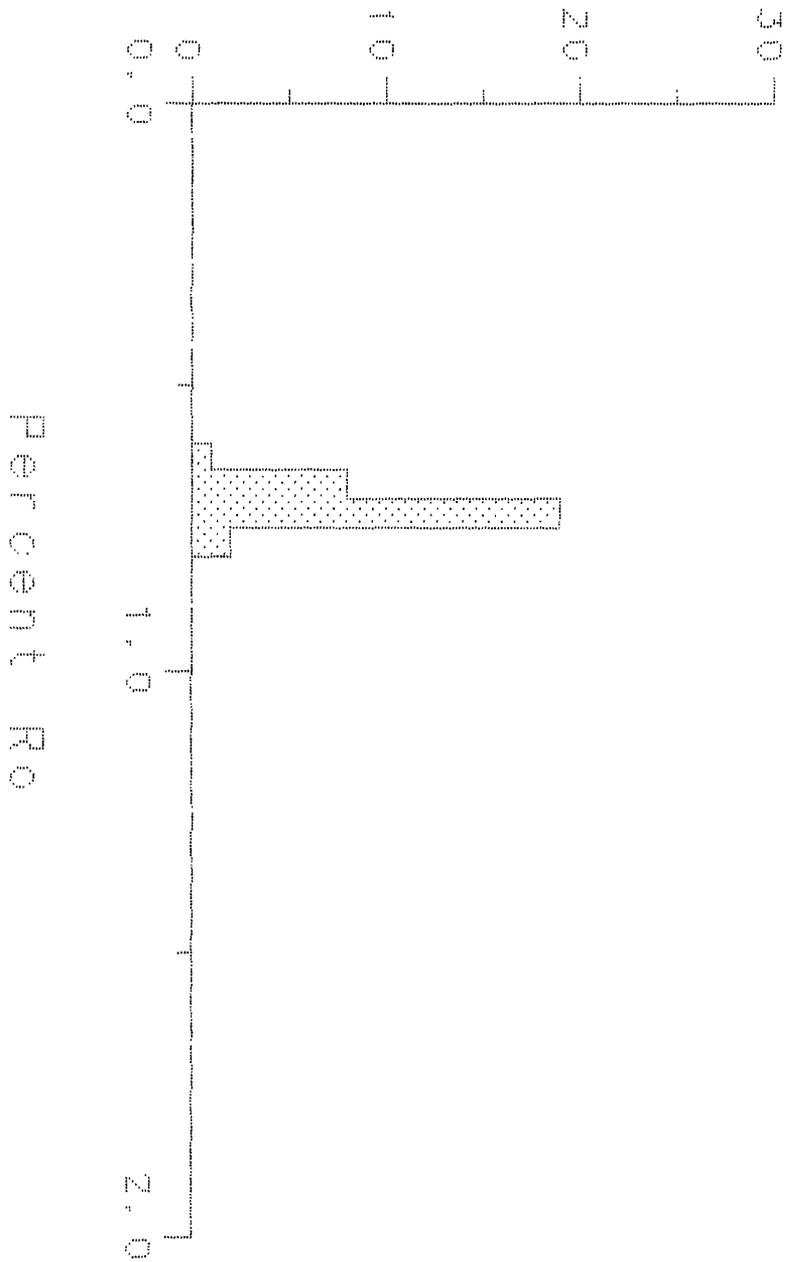
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 Comment 2:
 Comment 3:
 Comment 4:
 Comment 5:
 Comment 6:

	Meas1	Meas2	Ratio	Conc.
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Max:	0.75			
Mean:	0.71			
StDev:	0.02			

Pt.	X-Pos	Y-Pos	Z-Pos	Meas1	Meas2	Ratio	Conc.
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5				0.70			
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16				0.71			
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25				0.70			
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30				0.70			

Frequency

6060-6070
CH2-2 MHz 0.71 SD 0.02



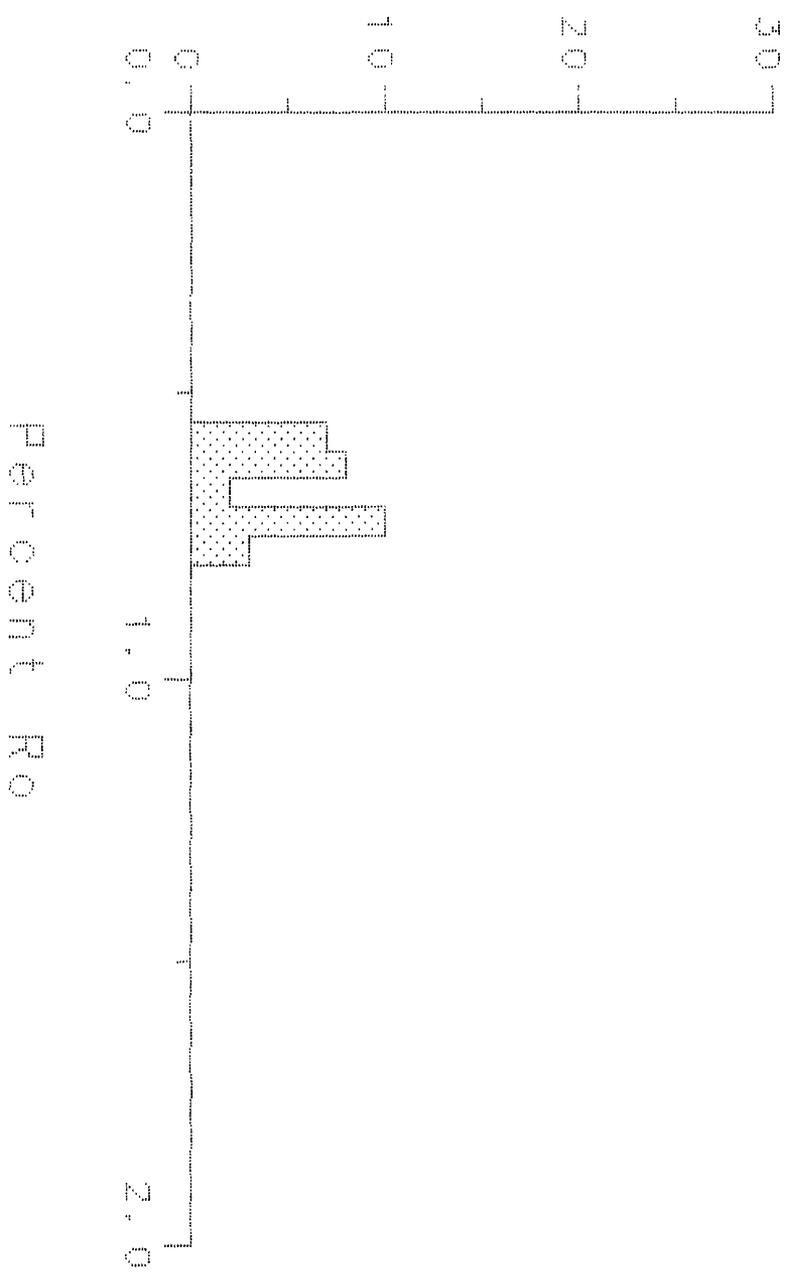
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 Comment 1: Good sample, Clean and consistent
 Comment 2:
 Comment 3:
 Comment 4:
 Comment 5:
 Comment 6:

	Meas1	Meas2	Ratio	Conc.
Min:	0.56			
Max:	0.78			
Mean:	0.67			
StDev:	0.07			

Pt.	X-Pos	Y-Pos	Z-Pos	Meas1	Meas2	Ratio	Conc.
1				0.74			
2				0.74			
3				0.70			
4				0.73			
5				0.72			
6				0.74			
7				0.73			
8				0.72			
9				0.69			
10				0.70			
11				0.58			
12				0.56			
13				0.60			
14				0.64			
15				0.65			
16				0.63			
17				0.65			
18				0.64			
19				0.65			
20				0.63			
21				0.57			
22				0.58			
23				0.57			
24				0.73			
25				0.77			
26				0.78			
27				0.76			
28				0.58			
29				0.61			
30				0.63			

Frequency

7540-7560
CH 2-2 Mm 0.07 SD 0.07



File Name: RFVN
 Channel Name: Nuccio
 Description: 7740-7750
 Comment 1: Good sample, Clean and consistent
 Comment 2:
 Comment 3:
 Comment 4:
 Comment 5:
 Comment 6:

	Meas1	Meas2	Ratio	Conc.
Min:	0.72			
Max:	0.77			
Mean:	0.75			
StDev:	0.01			

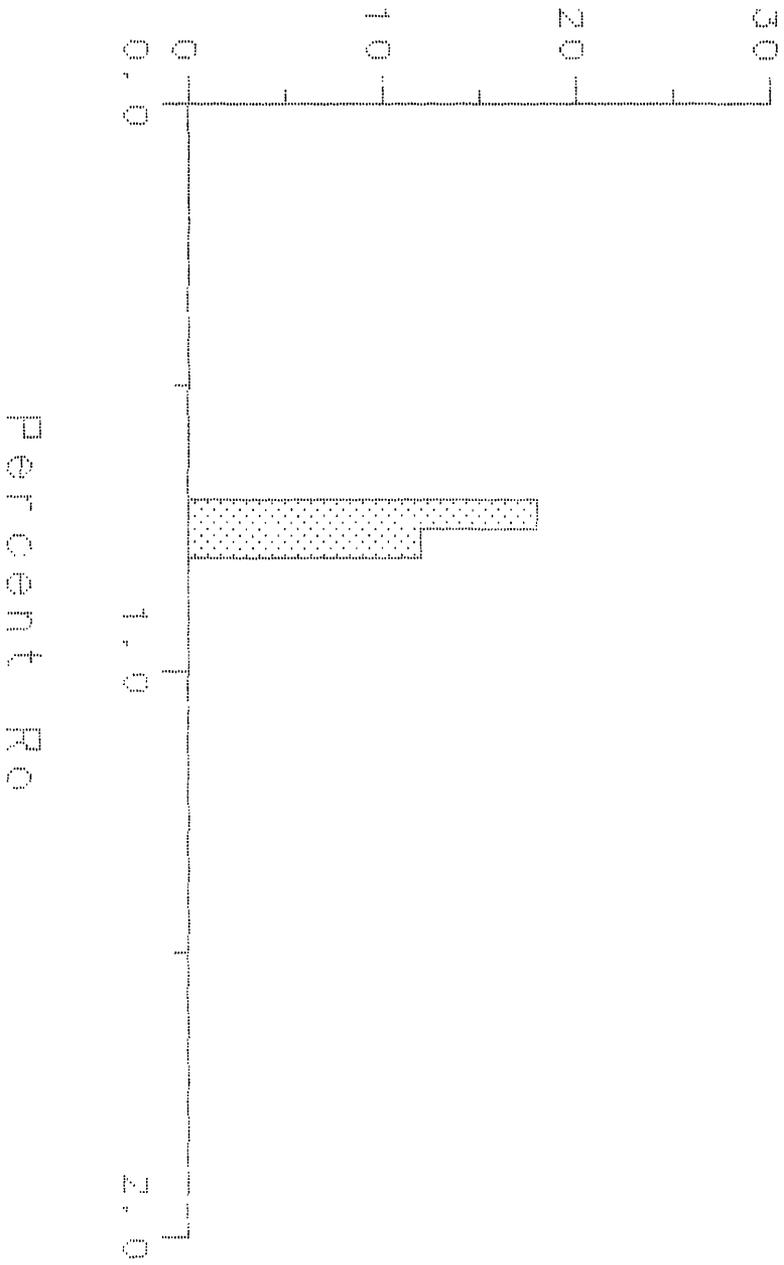
Pt.	X-Pos	Y-Pos	Z-Pos	Meas1	Meas2	Ratio	Conc.
1				0.76			
2				0.77			
3				0.75			
4				0.75			
5				0.74			
6				0.72			
7				0.76			
8				0.76			
9				0.77			
10				0.77			
11				0.77			
12				0.76			
13				0.74			
14				0.73			
15				0.75			
16				0.74			
17				0.72			
18				0.75			
19				0.75			
20				0.75			
21				0.74			
22				0.74			
23				0.76			
24				0.75			
25				0.75			
26				0.72			
27				0.75			
28				0.75			
29				0.75			
30				0.72			

Frequency

7740-7750
CH2-2 MH

0.75 SD

0.01



File Name: RFVN
 Channel Name: Nuccio
 Description: 7900-7910
 Comment 1: Good sample, Clean and consistent
 Comment 2:
 Comment 3:
 Comment 4:
 Comment 5:
 Comment 6:

	Meas1	Meas2	Ratio	Conc.
Min:	0.79			
Max:	0.97			
Mean:	0.90			
StDev:	0.05			

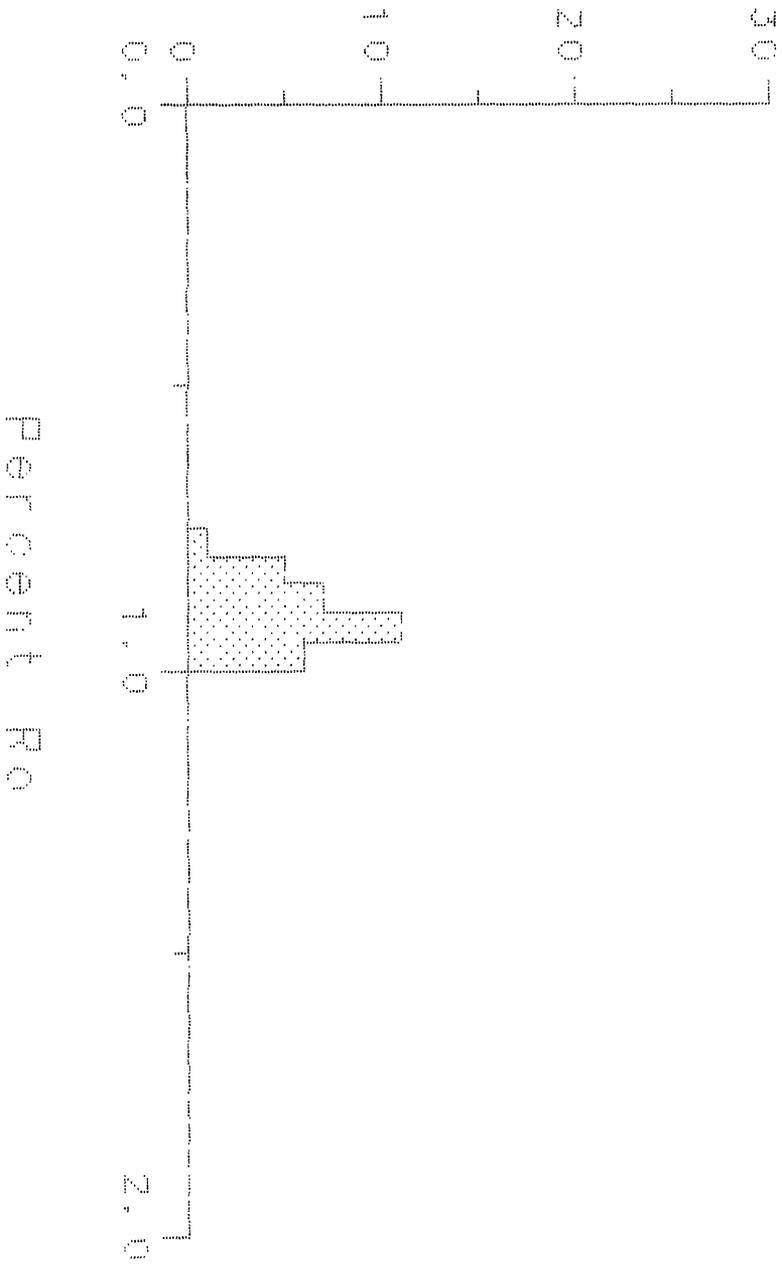
Pt.	X-Pos	Y-Pos	Z-Pos	Meas1	Meas2	Ratio	Conc.
1				0.93			
2				0.96			
3				0.96			
4				0.93			
5				0.82			
6				0.84			
7				0.82			
8				0.91			
9				0.91			
10				0.94			
11				0.79			
12				0.92			
13				0.95			
14				0.97			
15				0.95			
16				0.95			
17				0.95			
18				0.92			
19				0.96			
20				0.83			
21				0.87			
22				0.87			
23				0.88			
24				0.89			
25				0.85			
26				0.93			
27				0.93			
28				0.89			
29				0.86			
30				0.83			

Frequency

7900-7910
CH2-2.MH

0.40 SD

0.05



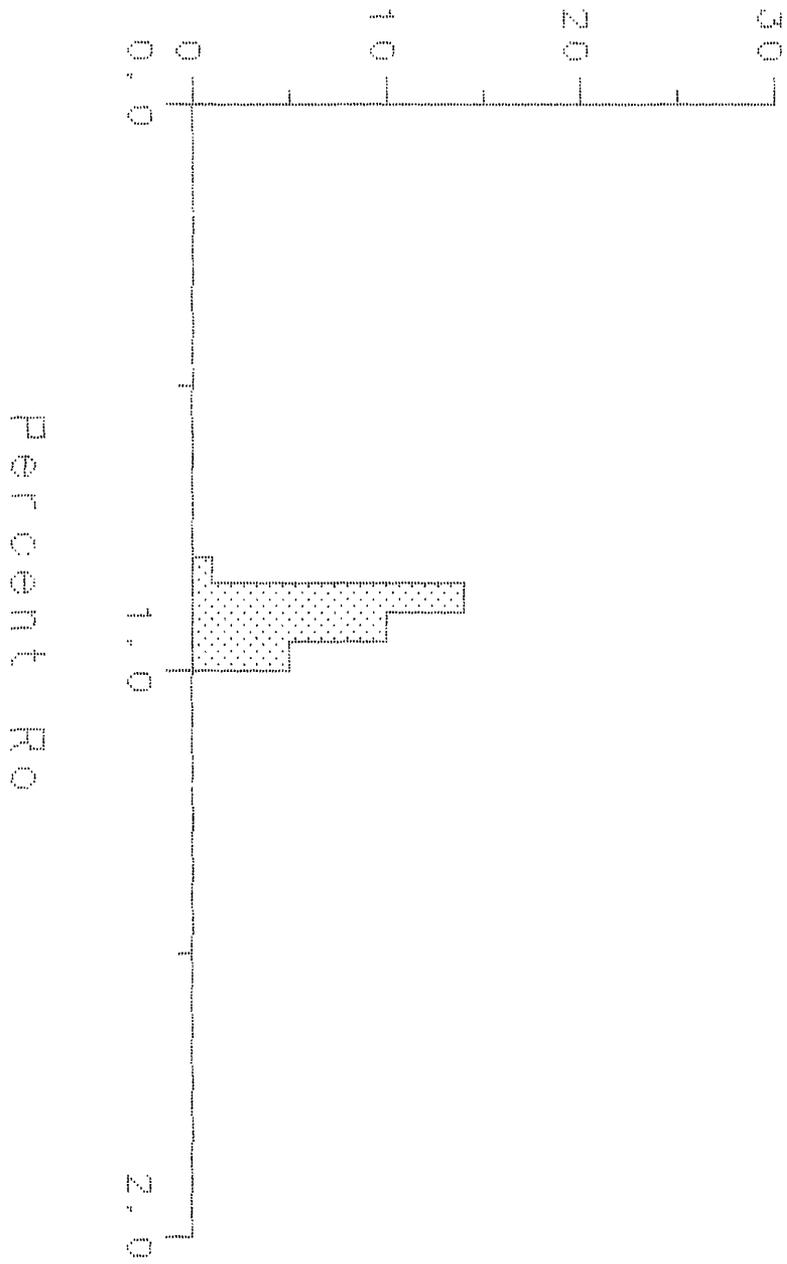
File Name: RFVN
 Channel Name: Nuccio
 Description: 8120-8130
 Comment 1: Good sample, Clean and consistent
 Comment 2:
 Comment 3:
 Comment 4:
 Comment 5:
 Comment 6:

	Meas1	Meas2	Ratio	Conc.
Min:	0.81			
Max:	0.97			
Mean:	0.90			
StDev:	0.04			

Pt.	X-Pos	Y-Pos	Z-Pos	Meas1	Meas2	Ratio	Conc.
1				0.89			
2				0.90			
3				0.96			
4				0.95			
5				0.86			
6				0.86			
7				0.87			
8				0.96			
9				0.89			
10				0.96			
11				0.88			
12				0.97			
13				0.91			
14				0.92			
15				0.89			
16				0.86			
17				0.93			
18				0.93			
19				0.92			
20				0.91			
21				0.94			
22				0.95			
23				0.88			
24				0.88			
25				0.81			
26				0.85			
27				0.87			
28				0.89			
29				0.85			
30				0.90			

Frequency

8120-8130
CH2-2 MH 0.90 SD 0.04



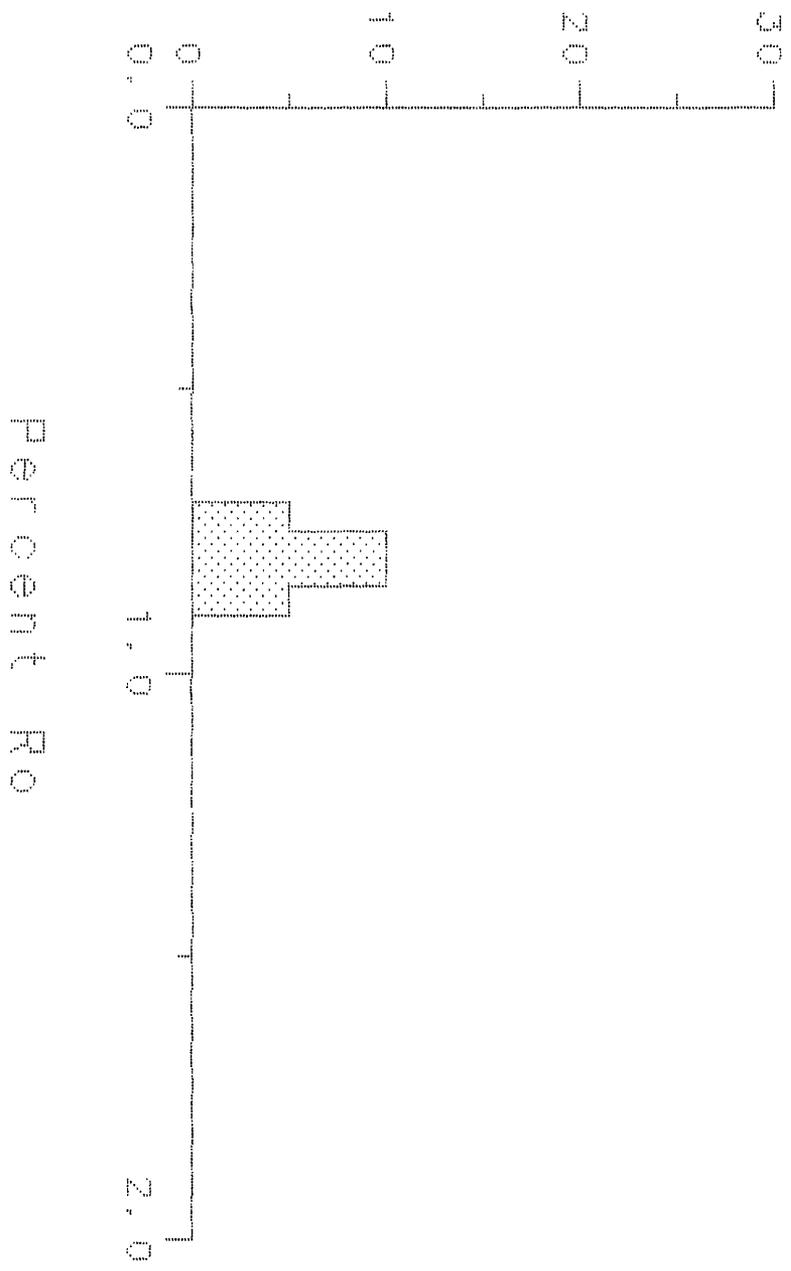
File Name: RFVN
 Channel Name: Nuccio
 Description: 8220-8230
 Comment 1: Good sample, Clean and consistent
 Comment 2:
 Comment 3:
 Comment 4:
 Comment 5:
 Comment 6:

	Meas1	Meas2	Ratio	Conc.
Min:	0.73			
Max:	0.87			
Mean:	0.80			
StDev:	0.04			

Pt.	X-Pos	Y-Pos	Z-Pos	Meas1	Meas2	Ratio	Conc.
1				0.76			
2				0.74			
3				0.80			
4				0.86			
5				0.87			
6				0.84			
7				0.75			
8				0.85			
9				0.78			
10				0.74			
11				0.77			
12				0.83			
13				0.81			
14				0.76			
15				0.73			
16				0.85			
17				0.84			
18				0.85			
19				0.74			
20				0.76			
21				0.77			
22				0.74			
23				0.85			
24				0.83			
25				0.75			
26				0.81			
27				0.78			
28				0.78			
29				0.81			
30				0.81			

Frequency

6220-6230
CH 2-2 Mn
0.80 SD
0.04



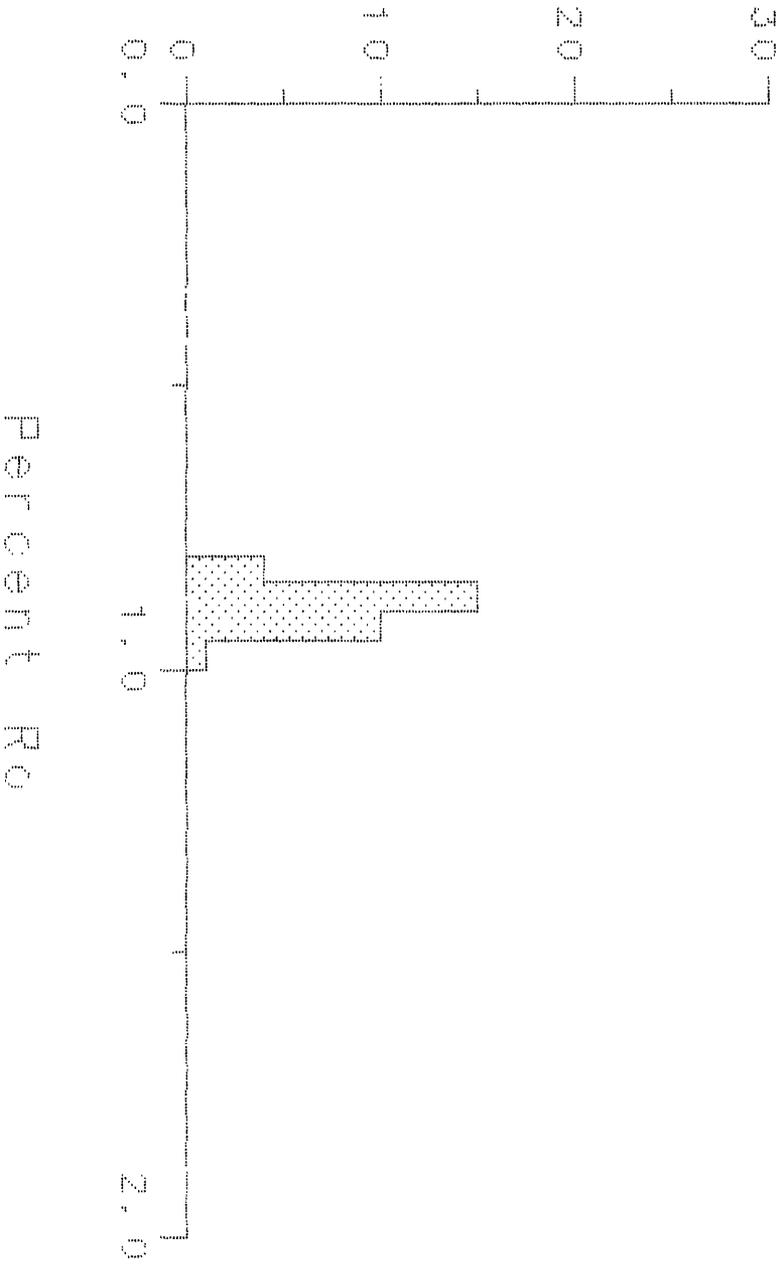
File Name: RFVN
 Channel Name: Nuccio
 Description: 8580-8590
 Comment 1: Good sample, Clean and consistent
 Comment 2:
 Comment 3:
 Comment 4:
 Comment 5:
 Comment 6:

	Meas1	Meas2	Ratio	Conc.
Min:	0.82			
Max:	1.00			
Mean:	0.89			
StDev:	0.04			

Pt.	X-Pos	Y-Pos	Z-Pos	Meas1	Meas2	Ratio	Conc.
1				0.88			
2				0.89			
3				0.92			
4				0.89			
5				0.90			
6				0.91			
7				0.91			
8				0.87			
9				0.85			
10				0.93			
11				0.89			
12				0.91			
13				0.87			
14				0.89			
15				0.89			
16				0.84			
17				0.86			
18				0.88			
19				0.83			
20				0.89			
21				1.00			
22				0.88			
23				0.94			
24				0.85			
25				0.87			
26				0.82			
27				0.86			
28				0.93			
29				0.94			
30				0.92			

Frequency

6560-8590
CH 2 - 2 MH
0.89 SD
0.04



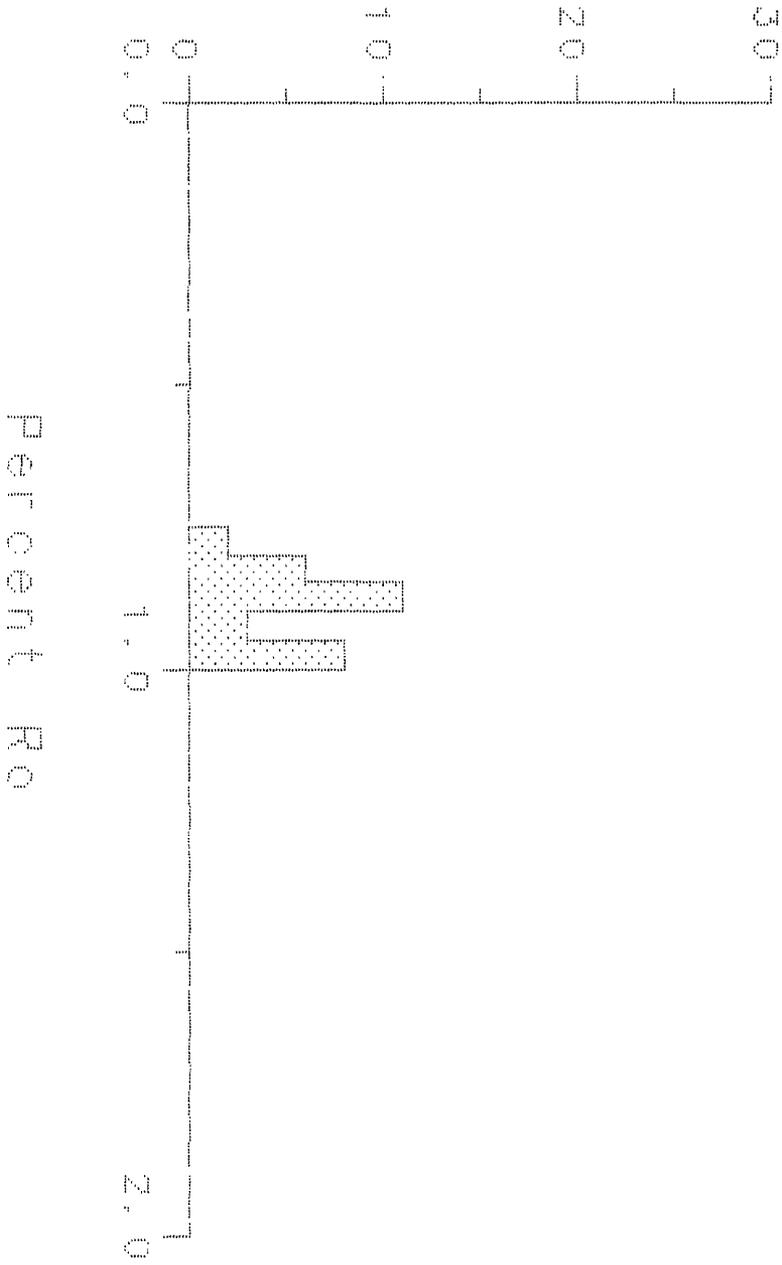
File Name: RFVN
 Channel Name: Nuccio
 Description: 8720-8730
 Comment 1: Good sample, Clean and consistent
 Comment 2:
 Comment 3:
 Comment 4:
 Comment 5:
 Comment 6:

	Meas1	Meas2	Ratio	Conc.
Min:	0.80			
Max:	0.99			
Mean:	0.89			
StDev:	0.06			

Pt.	X-Pos	Y-Pos	Z-Pos	Meas1	Meas2	Ratio	Conc.
1				0.80			
2				0.80			
3				0.95			
4				0.97			
5				0.97			
6				0.96			
7				0.97			
8				0.94			
9				0.99			
10				0.87			
11				0.96			
12				0.96			
13				0.83			
14				0.85			
15				0.85			
16				0.88			
17				0.89			
18				0.89			
19				0.87			
20				0.87			
21				0.90			
22				0.81			
23				0.86			
24				0.89			
25				0.92			
26				0.91			
27				0.89			
28				0.89			
29				0.84			
30				0.84			

Frequency

6720-6730
CH2-2.MN
0.89 SD
0.06



File Name: RFVN
 Channel Name: Nuccio
 Description: 9050-9060
 Comment 1: Good sample, Clean and consistent
 Comment 2:
 Comment 3:
 Comment 4:
 Comment 5:
 Comment 6:

	Meas1	Meas2	Ratio	Conc.
Min:	0.81			
Max:	0.94			
Mean:	0.90			
StDev:	0.03			

Pt.	X-Pos	Y-Pos	Z-Pos	Meas1	Meas2	Ratio	Conc.
1				0.88			
2				0.93			
3				0.90			
4				0.91			
5				0.88			
6				0.92			
7				0.89			
8				0.93			
9				0.91			
10				0.82			
11				0.92			
12				0.87			
13				0.82			
14				0.81			
15				0.92			
16				0.93			
17				0.92			
18				0.89			
19				0.87			
20				0.89			
21				0.89			
22				0.92			
23				0.92			
24				0.93			
25				0.94			
26				0.94			
27				0.93			
28				0.92			
29				0.91			
30				0.92			

Frequency

9050-9060
CH 2-2 MH
0.90 SD
0.03

