



Determination of mixedness characteristics in Kenics Corporations static mixer
by William Bennington Fyock

A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of
MASTER OF SCIENCE in Chemical Engineering
Montana State University
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Abstract:

The Static Mixer, as developed by Kenics Corporation, is a new type of mixing device that, with, no-moving parts, combines materials pumped' into it; the only power requirements are those involved in pumping the components to be mixed through, the device.

Previous work has indicated that the Static Mixer may be useful in combining fluids of highly different viscosities. It was the purpose of this research to quantitatively measure the mixing performance of the device when several sets of components of varying viscosity ratios were combined in the mixer, Various concentrations and flow rates of sodium carboxymethylcellulose (CMC), an ionic polymer, and water were the components combined; either CMC or water was used during the mixing runs as the main-stream component, with the remaining component injected into the main stream in the center of the inlet pipe to the mixer. Quantitative conductivity measurements were taken with a conductivity probe and wire mesh electrode. Well-mixed solutions of the same overall polymer concentrations found in the mixing runs were also analyzed, and the maximum concentration deviations observed were used in setting the boundary for the region of high mixedness in analyzing concentration deviations during mixing runs.

Based on measurements of mean, standard, and maximum deviation and on the percentage of run time that polymer concentrations fluctuated outside of the well-mixed region, it was concluded that 1%-by weight CMC solutions (viscosity ratio ~1500/1) are combined with a relatively high degree of mixedness, 2% solutions (viscosity ratio ~3,000/1) are combined with a high-degree of mixedness at low polymer flow rates, but with a much lower degree at high, polymer flow rates, and k% solutions . (viscosity ratio 30,000/1) are combined with a very low degree of mixedness. Also from measurements taken across the tube cross-section, it was concluded that polymer concentrations are higher at the tube walls than in the tube center during mixing runs.

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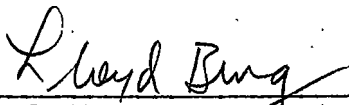
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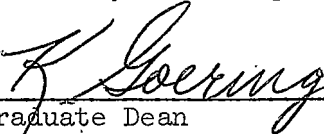
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ABSTRACT

The Static Mixer, as developed by Kenics Corporation, is a new type of mixing device that, with no moving parts, combines materials pumped into it; the only power requirements are those involved in pumping the components to be mixed through the device.

Previous work has indicated that the Static Mixer may be useful in combining fluids of highly different viscosities. It was the purpose of this research to quantitatively measure the mixing performance of the device when several sets of components of varying viscosity ratios were combined in the mixer. Various concentrations and flow rates of sodium carboxymethylcellulose (CMC), an ionic polymer, and water were the components combined; either CMC or water was used during the mixing runs as the main-stream component, with the remaining component injected into the main stream in the center of the inlet pipe to the mixer. Quantitative conductivity measurements were taken with a conductivity probe and wire mesh electrode. Well-mixed solutions of the same overall polymer concentrations found in the mixing runs were also analyzed, and the maximum concentration deviations observed were used in setting the boundary for the region of high mixedness in analyzing concentration deviations during mixing runs.

Based on measurements of mean, standard, and maximum deviation and on the percentage of run time that polymer concentrations fluctuated outside of the well-mixed region, it was concluded that 1%-by weight CMC solutions (viscosity ratio $\sim 1500/1$) are combined with a relatively high degree of mixedness, 2% solutions (viscosity ratio $\sim 13,000/1$) are combined with a high degree of mixedness at low polymer flow rates, but with a much lower degree at high polymer flow rates, and 4% solutions (viscosity ratio $30,000/1$) are combined with a very low degree of mixedness. Also from measurements taken across the tube cross-section, it was concluded that polymer concentrations are higher at the tube walls than in the tube center during mixing runs.

I. INTRODUCTION

A. Theory of Operation

The Static Mixer, as designed by the consulting firm of Arthur D. Little, Inc. and further refined and marketed by Kenics Corporation, is a continuous, in-line mixer that combines materials with no power requirements other than those necessary to pump the materials to be mixed through the unit. The mixer is constructed of a series of short right and left-hand helices welded together such that the trailing edge of one element is rotated 90 degrees in relation to the leading edge of the next element (10).

Materials are mixed in the Static Mixer as a result of four processes (3):

- (1) Flow Division: As the flowing material contacts the leading edge of each element, it is divided in two. Thus, the total number of divisions increase exponentially according to equation (1), where S is the number of divisions and n the number of elements.

$$S = 2^n \quad (1)$$

In this way, twenty helical elements produce over one million divisions, while thirty elements produce over 1,000 million.

- (2) Flow Reversal: Because the mixer elements are right and left-handed, circular material flow alternates to the right and to the left. This alternation of flow constantly changes the

orientation of material presented to each new element, resulting in cumulative rather than repetitive mixing action.

- (3) Flow Inversion: Within ten elements, a slug or particle of material travels from the center of the tube to the outer wall and back again. This has the effect of increasing the heat transfer efficiency of the mixer from 60 to 300 percent over straight tubing.
- (4) Back Mixing: As each new element is encountered, the profile of maximum flow velocity changes, with the result of thorough axial mixing.

B. Applications

As a mixing unit, the Static Mixer is applicable to processes involving conventional mixing operations, and in the production of dispersions, emulsions, and slurries. Due to the flow-inversion and flow-reversal mixing actions, the unit also finds application in the area of increasing heat transfer efficiencies. Grace (6) provides heat transfer correlations, experimental heat transfer coefficients, and pressure drop correlations for Static Mixer systems in laminar flow; he goes on to describe existing and possible uses of the Static Mixer when both mixing and heat-transfer processes are in operation. Examples include the application of the unit in catalytic reformers, polymerization processes, the heating and cooling of viscous liquids, and in laminar flow reactors. The usefulness of the Static Mixer in these processes is dependent upon

the ability of the unit's unique mixing actions to increase the internal heat transfer coefficient and eliminate channeling. This serves to (1) prevent hot spots and catalyst deterioration in catalytic reformers, thus allowing the process to be carried out at higher temperatures with improved yields, (2) provide better temperature control in polymerization processes, thus eliminating hot spots and overcoming the control problems caused by the high heats of polymerization and low thermal conductivities of monomer and polymer slurry, (3) decrease the energy consumption and lessen the danger of thermal damage in the heating and cooling of viscous liquids, especially those that are temperature-sensitive, and (4) improve the yields and decrease by-product losses in laminar flow reactors, since with the use of a Static Mixer a high proportion of the reaction mass is at reaction temperature for the optimum period.

Especially in the area of laminar flow reactors, Grace makes an important assumption, that being that the mixing performance of the Static Mixer is independent of velocity or viscosity.

Chen and Macdonald (4) further explore the possibilities of using the Static Mixer in polymer processing. Their work deals especially with the mixing of such materials as antioxidants, flame retardants, colorants, plasticizers, pigments, and light and heat stabilizers intimately into the polymer stream. As stated in their article, the mixing of such additives "often involves additive ratios of 1 to 2%, and viscosity ratios of several orders of magnitude between constituents. Achieving a terminal

blend under these adverse conditions poses a serious problem to the process engineer" (4). Here again, an understanding of the actual mixing characteristics of the Static Mixer, especially in the area of intimately combining fluids of highly different viscosities, is crucial if the unit is to find applications in the field of polymer processing.

Although Chen, Fan, and Watson (5) have studied the mixing mechanisms of solid particles in the Static Mixer, no quantitative studies have been done to determine the mixing characteristics and limitations of the unit in the area of combining fluids of highly different viscosities. It was for this reason that the present project was undertaken.

II. RESEARCH OBJECTIVE

The objective of this research was to determine quantitatively the mixing characteristics of Kenics Corporation's Static Mixer when fluids of varying viscosity ratios and flow rates were combined in the unit.

III. EXPERIMENTAL APPARATUS AND PROCEDURE

A. Method of Mixedness Analysis: Comparison of Indices of Refraction of Solution Samples

In the initial phase of mixedness testing, pure glycerin and distilled water were the components to be combined in the Static Mixer. After several trials, the flow system shown in Figure 1 was adopted; the mixer and entrance and exit tubing were assembled vertically to minimize flow complications caused by the density difference between glycerin and water. Distilled water, the main-stream component, was pumped by means of a Vibrostaltic pump from a large holding tank through Tygon tubing to a flowmeter; from the flowmeter the water was pumped through more Tygon tubing to the entrance section of plastic piping (inside diameter: 1/2"). Glycerin, the high-viscosity component in this case, was pumped by means of another Vibrostaltic pump through Tygon tubing to another flowmeter; from the flowmeter the glycerin proceeded through more Tygon tubing to an inlet nozzle positioned at the base of the entrance section of plastic piping at a point two inches above the fitting at the entrance to the Static Mixer. The inlet nozzle, as shown in Figure 2, was constructed of a Swagelok fitting into which a segment of rigid plastic tubing (inside diameter: 3/32 inch) was inserted. The end of the tubing positioned inside the entrance section of the flow system was filled with epoxy, and a downward-facing hole, 1/8 inch in diameter, was drilled in the plastic tubing to serve as the actual entrance port for the glycerin. During this and all other phases of the research, the entrance port of the inlet nozzle was positioned at the center of the entrance piping.

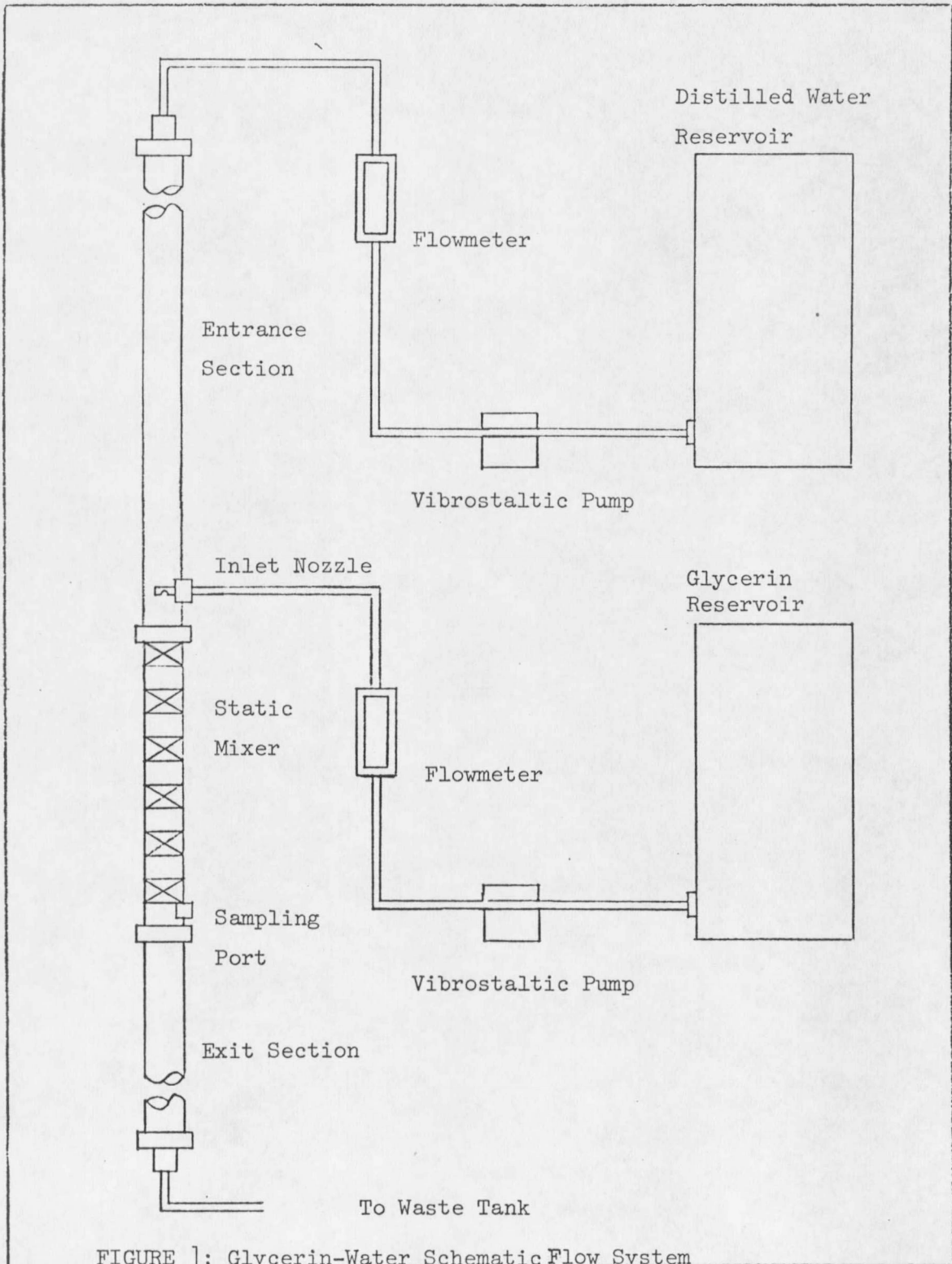
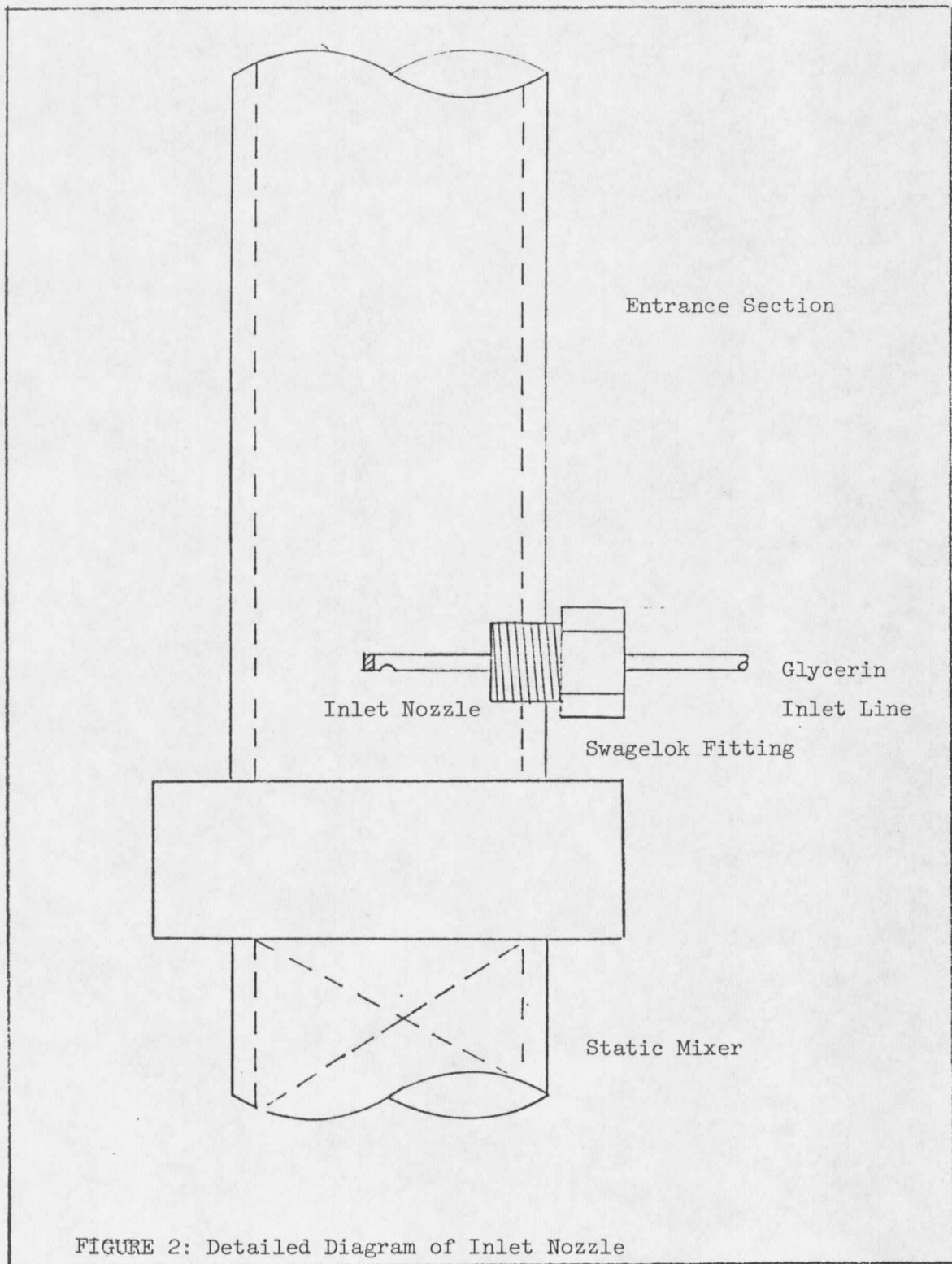


FIGURE 1: Glycerin-Water Schematic Flow System



As water flowed down through the entrance section, a stream of glycerin was pumped through the inlet nozzle, and both components entered the Static Mixer. Exiting from the mixer, the combined components flowed down through an exit section of plastic piping (inside diameter: 1/2 inch) and into a waste tank through a section of Tygon tubing. The Static Mixer used was 1/2-inch in inside diameter and contained 21 helical mixing elements; it was supplied by Kenics Corporation.

Samples of solution were extracted through a Swagelok sampling port positioned in the wall of the Static Mixer approximately 1/2-inch below the last mixer element; sampling was accomplished with the use of a hypodermic needle and syringe. After extraction, the sample was transferred to a refractometer in which the index of refraction of the sample was determined. The volume of each sample taken was approximately one milliliter; this was the smallest practical volume that could be accurately analyzed in the refractometer. The time involved in extracting and determining the index of refraction of one sample was approximately five to eight minutes.

After several mixing runs were made, the use of glycerin as the high-viscosity component was abandoned, due to the relatively low viscosity difference between glycerin and water. A polymer of a much higher viscosity range, sodium carboxymethylcellulose (CMC), was decided upon as a substitute.

Because of the relatively long time involved in extracting and analyzing one sample, and because of the relatively large volume of the sample analyzed, the method of determining solution composition at a point by means of refractometer measurements was abandoned. Instead, a method was adopted in which the composition of the solution at a point was measured by means of the electrical conductivity of the solution at the point of measurement.

B. Method of Analysis: Comparison of Mixed-Solution Point Conductivities

During the initial portion of this phase of experimentation, distilled water was again the main-stream component. In these, the "mixing" runs, distilled water was taken directly from the laboratory tap; it flowed through Tygon tubing to a flowmeter, and from the flowmeter through more Tygon tubing to the entrance section of the flow system, as shown in Figure 3.

Sodium carboxymethylcellulose, or CMC, was the high-viscosity component. Purchased in the form of a powder, the CMC was dissolved in distilled water to form the high-viscosity fluid; as the weight-percent of CMC in water increased, the viscosity of the solution increased.

The particular CMC solution to be mixed with the main stream of distilled water was placed in a high-pressure stainless-steel holding tank; the tank was pressurized with air. The CMC solution was pumped from the tank by means of a Zenith gear pump through rigid plastic tubing,

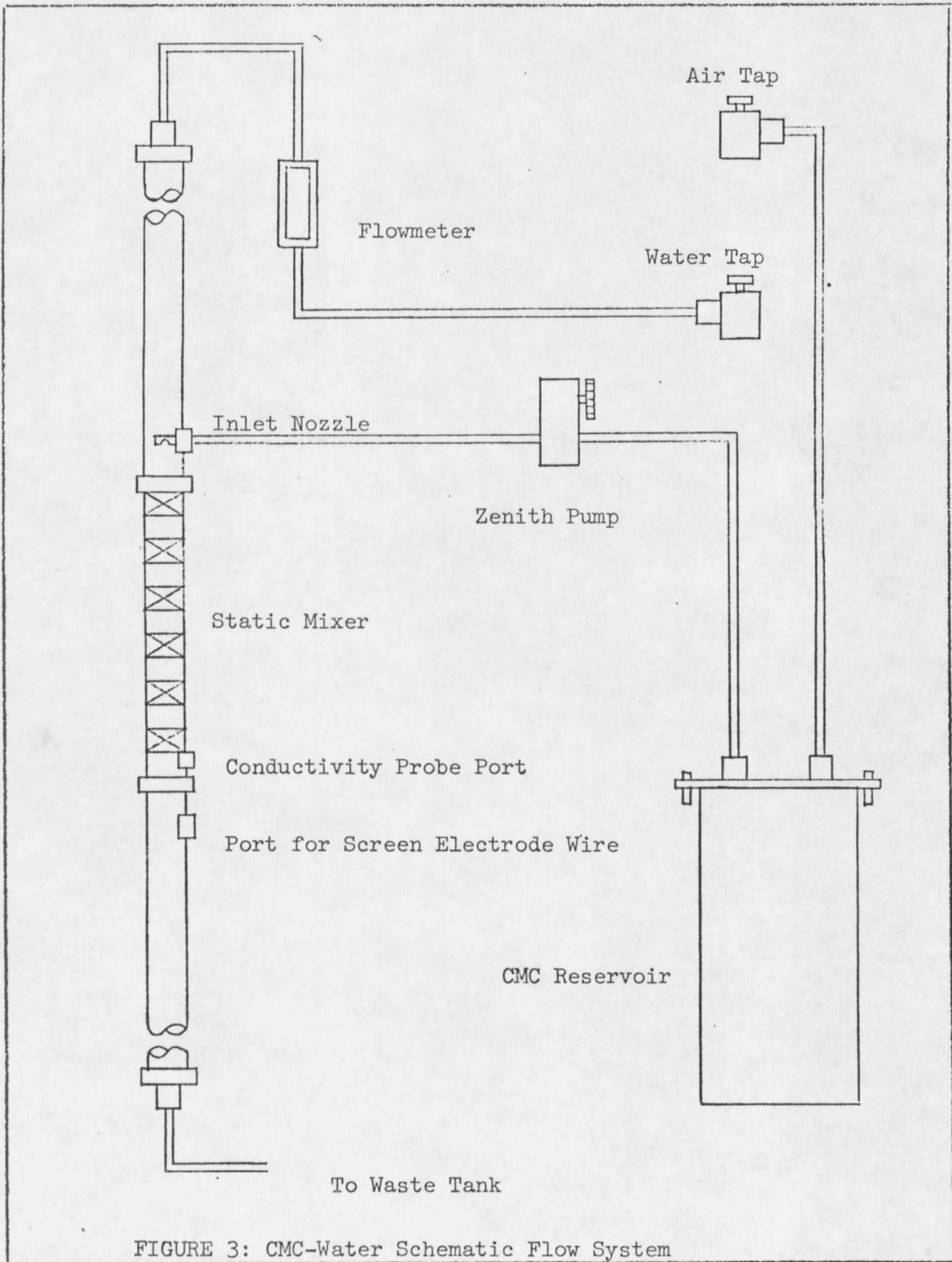


FIGURE 3: CMC-Water Schematic Flow System

metal pipe, and Tygon tubing to the inlet nozzle previously described in Figure 2. The steady stream of CMC solution flowed through the inlet nozzle into the main stream of distilled water; both components then flowed into the Static Mixer and out of the flow system through the exit section and Tygon tubing into a waste tank. Determination of water flow rate was accomplished by reading the flowmeter; determination of CMC solution flow rate was done by using a stopwatch and graduated cylinder at times before and after each mixing run.

In the latter portion of this phase of experimentation, CMC solution was the main-stream component. Here, CMC solution was pumped into the entrance section of the flow system; distilled water flowed from the tap through a flowmeter and into the inlet nozzle. Water flow rate was determined from the flowmeter; CMC solution flow rate was determined by subtracting the water flow rate from the total flow rate, which was measured several times during a mixing run with a stopwatch and graduated cylinder.

To determine the solution composition at a point, a conductivity probe, as shown in Figure 4, was employed. The probe was constructed of 22-gauge nichrome wire sheathed in a glass tube; the end of the tube was sealed with epoxy, so that only the lateral cross-section of the wire was exposed. The probe was inserted in the sampling port, 1/2-inch below the last mixer element in the wall of the Static Mixer. For accurate conductivity measurements at a point, another, much larger,

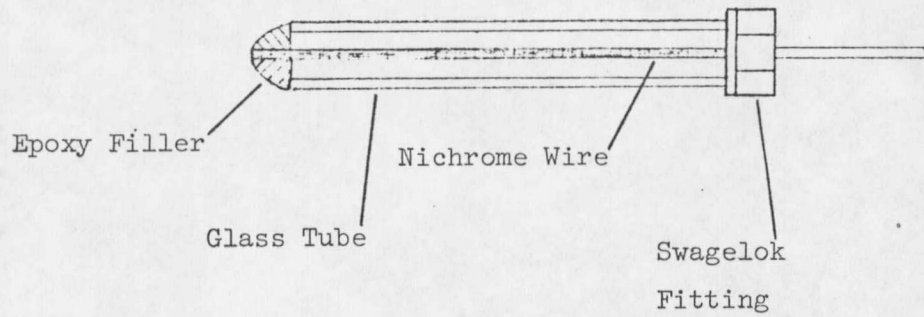


FIGURE 4: Detailed Drawing of Conductivity Probe

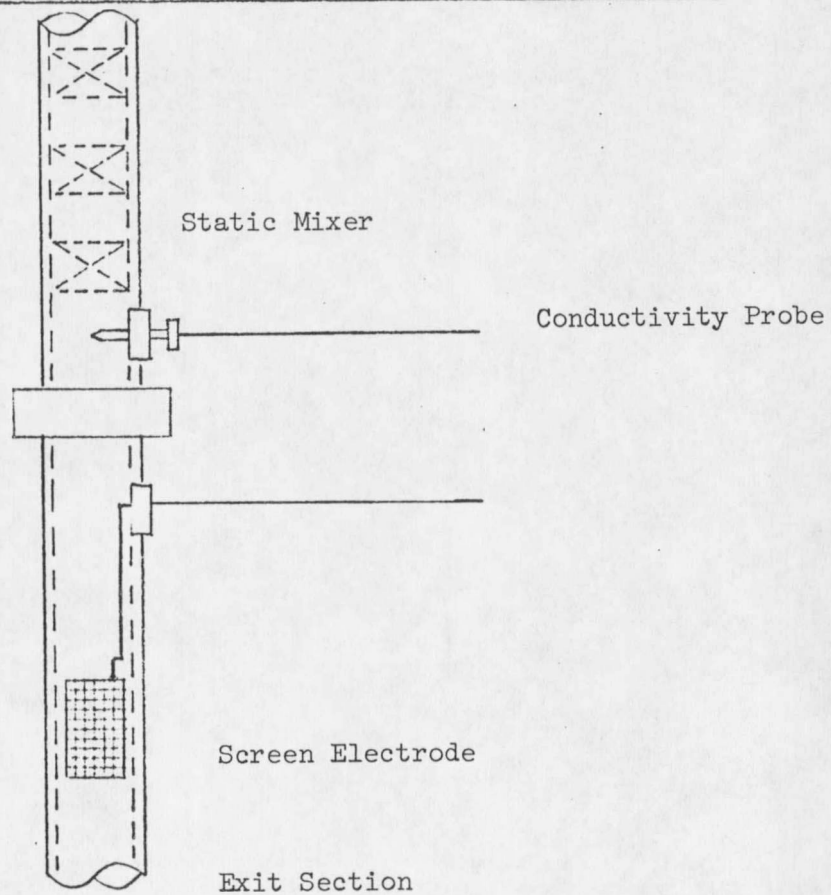


FIGURE 5: Conductivity Probe and Screen Electrode Schematic

electrode is necessary; for this purpose, a 10-square inch section of fine wire mesh was coiled and inserted into the exit section of piping at a point 5-1/2 inches below the conductivity probe, as shown in Figure 5. An insulated wire soldered to this screen was brought through a Swagelok fitting to the outside of the flow system.

The wires from the probe and screen electrodes were connected to an amplifier built for the project, as shown in Figure 6. The amplifier was powered by a 270-volt Heathkit power supply, and was connected to a 1500-kc Heathkit signal generator. Voltage output lines from the amplifier were connected to a Hewlett-Packard digital voltmeter; from the digital voltmeter, the voltage reading was further processed in a MSU Electronics Research Laboratory digital translator, and finally recorded on a teletype. The design for the conductivity probe and the electronic circuitry for the amplifier was adopted from Lamb, Manning, and Wilhelm (9).

As shown in Lamb, Manning, and Wilhelm (9), the conductivity probe measures the solution conductivity only in the small volume of solution immediately surrounding the exposed tip of the probe; this volume is in the range of 10^{-4} to 10^{-5} cc. The small area of the probe, as compared with the much larger area of the screen electrode, is responsible for the fact that only the conductivity of this small volume of solution is measured and recorded.

The voltages recorded on the teletype correspond directly to the

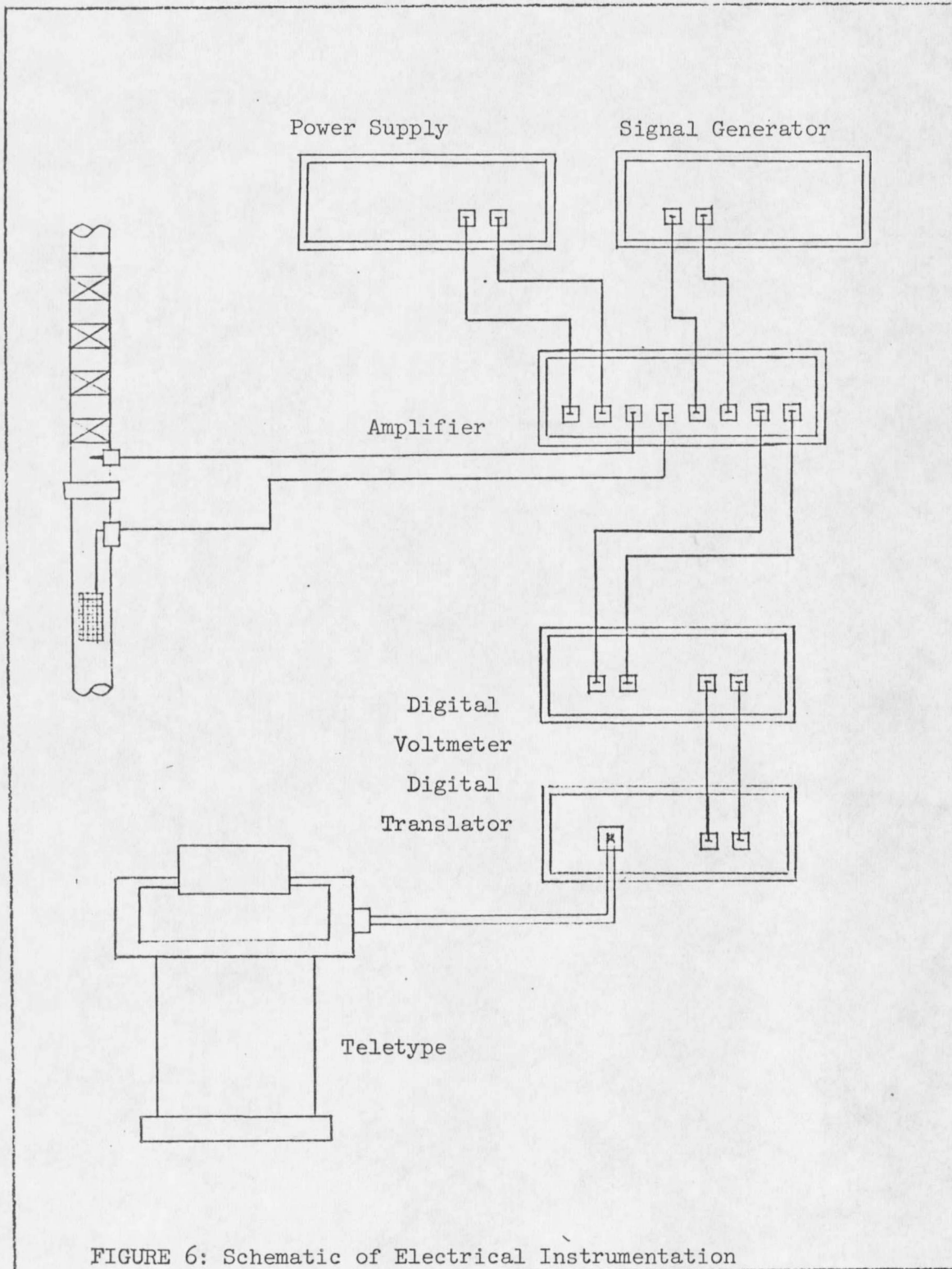


FIGURE 6: Schematic of Electrical Instrumentation

electrical conductivity of the solution at the point of measurement; thus, if the conductivity increases, due to a higher concentration of the ionic CMC polymer, the recorded voltage increases. A calibration curve was derived for the probe by placing a volume of solution in the mixer (at rest) and measuring the voltage (see appendix). This curve has a characteristic S-shape, and will be referred to later in this report.

For all but one of the mixing runs in this part of the project, the location of the probe was held constant: the tip of the probe was positioned in the center of the Static Mixer cross-section. Measurements of conductivity with respect to time at this position were extremely numerous in a single run; the rapidity of taking data was limited only by the mechanical limitations of the teletype. Thus, an average of one conductivity measurement per second was taken during the mixing runs; 300 consecutive conductivity measurements were used in analyzing one run.

Before and after each run, a measurement was taken of the instrumental or "background" voltage produced by the electronic equipment. As this voltage varied slightly with time, one set of 300 measurements of background voltage were taken for variations analysis.

From flow-rate measurements, the overall composition of the stream exiting from the mixer, in terms of weight-percent polymer and weight-percent water, was determined for each run. A large quantity of solution of this composition was made up for each run in a holding tank; this was

pumped into the entrance section and through the flow system with a Vibrostaltic pump. As the solution flowed through the Static Mixer, data were taken with the conductivity probe in the same manner as in the mixing runs. The results from these, the "Well-Mixed" runs, were used in the analysis of the mixing runs.

IV. RESULTS AND DISCUSSION

As stated in the Apparatus and Procedure section of this report, 300 consecutive conductivity-probe measurements were used in the analysis of each experimental run. In all but one of the runs, the probe position was constant; time was the only variable over which solution conductivities were measured. The basic analysis technique employed, then, was to compare solution conductivities (and, thus, compositions) at different times.

At the present time, the degree of mixedness of two combined fluids can only be described qualitatively. There are no specific quantitative criteria for "solutions" that are "well-mixed", "partially mixed", or "unmixed". Some idea can be gained about the degree of mixedness, however, by first calculating an average value for a set of data points, and then calculating the mean and standard deviations away from this average value for the set. When several sets of data are compared, then, the degree of mixedness decreases as the values of the mean and standard deviations increase.

In analyzing each set of conductivity measurements, an average value for the 300 data points was first calculated. The mean deviation was then calculated using equation (2).

$$\text{Mean Deviation} = \frac{\sum |X_i - \bar{X}|}{300} \quad (2)$$

where X_i represents the individual conductivity readings and $\bar{X}$ represents the average reading. The standard deviation was calculated using

equation (3):

$$\text{Standard Deviation} = \sqrt{\frac{\sum (X_i - \bar{X})^2}{300}} \quad (3)$$

To give a better idea of the degree of mixedness accomplished by the Static Mixer for each run, a technique using "criteria levels" was employed. Here, the concentration deviation for each data-point was first calculated using equation (4):

$$\text{Deviation} = |X_i - \bar{X}| \quad (4)$$

As stated above, as the deviation increases, the degree of mixedness decreases. In addition, the percentage of the deviations that are large is also significant. If, for instance, for one set of data, only five percent of the deviations calculated are large, the run analyzed in that set had a higher degree of mixedness than if twenty percent of the deviations were large.

As shown in Figure 7, criteria levels were established at several intervals away from the average value for each set of data. As each data point was encountered, its deviation was grouped according to size; at the end of the analysis, calculations were made to indicate the percentage of the time that the solution conductivity deviated from the average value by the amount assigned to each criteria level or deviation interval.

Criteria 10, in all cases, was set at zero. Thus, 100% of all deviations were greater than Criteria 10. This criteria level was used

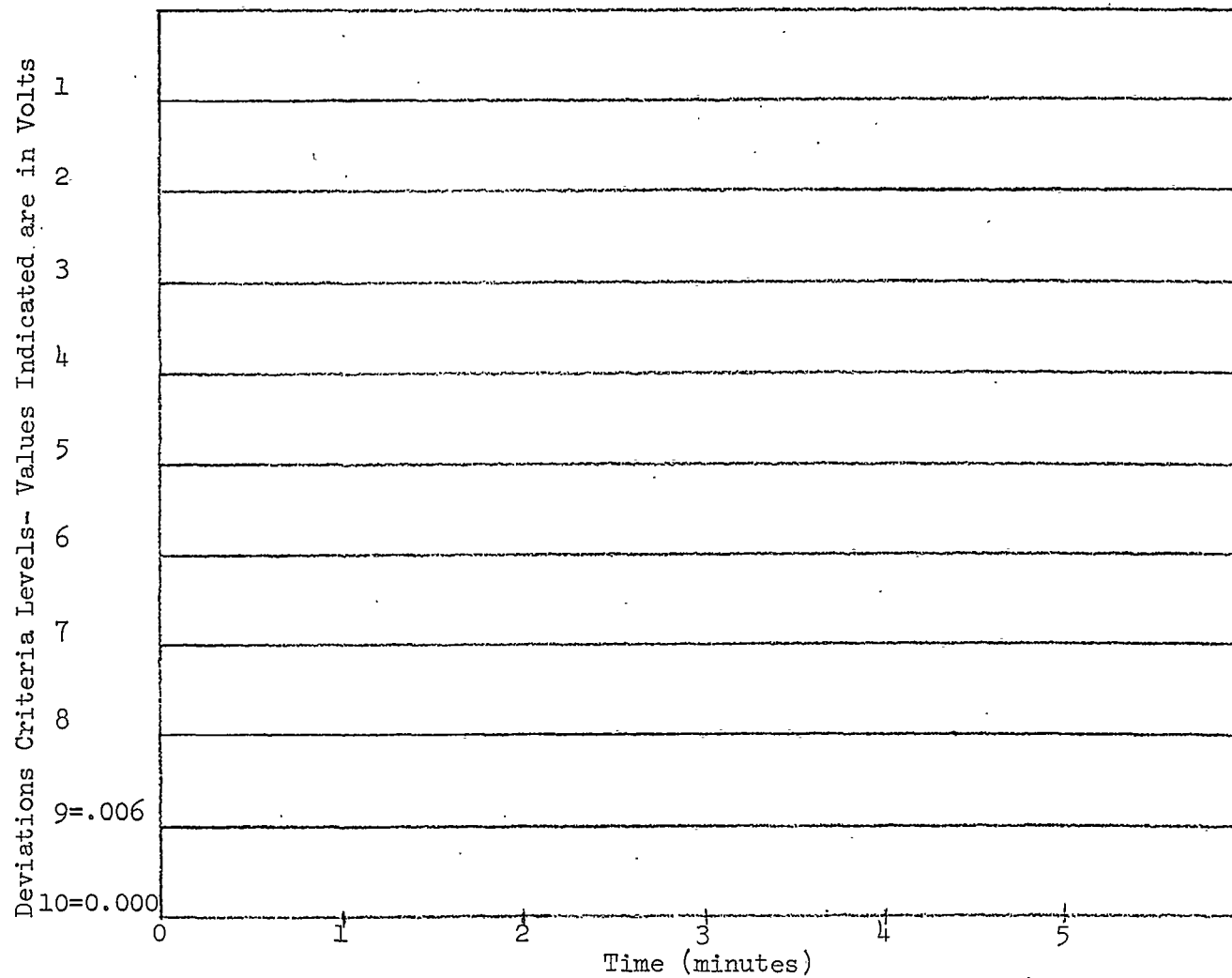


FIGURE 7: Criteria Levels Used in Deviations Analysis

only to facilitate data analysis by a computer.

Criteria 9, in all cases, was set at 0.006 volts. This was the maximum deviation encountered when 300 readings of instrumental variation or background noise were taken, and it is one measurement of experimental error or sensitivity. All deviations less than 0.006 volts are considered meaningless, since the deviations could have occurred as a result of voltage fluctuations within the instrumentation and not as a result of conductivity variations.

Criteria 8 was set at various values for the various runs analyzed. Before a particular mixing run was analyzed, the well-mixed run corresponding to it was analyzed to determine the maximum deviation present in 300 data points; this maximum deviation was used as Criteria 8 in the mixing run analysis. Criteria 8 is important in determining the degree of mixedness for a mixing run; the percentage of deviations greater than Criteria 8 as compared to the percentage less is a useful indicator. If the majority of deviations are less than Criteria 8, the degree of mixedness is higher than if the majority lie outside Criteria 8, since deviations less than Criteria 8 can be thought of as deviations inherent in the instrumental analysis of a well-mixed solution. Thus, Criteria 8 is another measurement of experimental error or instrument sensitivity.

Criteria 1 through 7 varied for each individual run. Criteria 1, which represented the largest interval away from the average value, was

set such that 90 to 100% of all deviations encountered would be less than it. Criterias 2 through 7 were distributed evenly between the values of Criterias 1 and 8.

Experimental results derived when well-mixed solutions were passed through the mixer are shown in Table 1. Run numbers listed in the table correspond to a mixing run; thus "Well-Mixed Run 1% #1" corresponds to Mixing Run 1% #1. The concentration of the well-mixed solution used in the well-mixed run is the overall concentration, by weight, of CMC in water at the outlet of the mixer in the corresponding mixing run. The Absolute Average Conductivity listed for each run is obtained by subtracting the Average Background Voltage from the Average Conductivity. This was done because the Average Background Voltage in the instrumentation varied slightly from day to day.

Also listed in Table 1 are the Mean Deviation, Standard Deviation, and Maximum Deviation in volts for each run. The Maximum Deviation, in volts, was used in analyzing the Mixing Run as Criteria 8, and was the borderline of the "Well-Mixed Region" in those analyses.

The Absolute CMC Concentration, in grams polymer per gram total solution, was used along with the Absolute Average Conductivity in deriving a calibration curve to convert conductivities and deviations from volts into concentration units. The Calibration Curve is shown in Figure 8; it too has the characteristic S-shape of the curve derived for the still-fluid case (see appendix). For all but one mixing run, the

TABLE 1

EXPERIMENTAL RESULTS OF WELL-MIXED RUNS

Run No.	1% #1	1% #2	2% #1	2% #2
Absolute CMC Conc. g CMC/g Total x 10^3	0.658	1.300	1.025	2.286
Average Conductivity- volts	1.1935	1.4239	1.2176	1.7939
Average Background- volts	0.974	0.950	0.949	0.955
Absolute Average Conductivity- volts	0.2195	0.4739	0.2686	0.8389
Maximum Deviation- volts	0.0065	0.0200	0.0255	0.0195
Mean Deviation- volts x 10^3	1.621	3.400	12.445	4.968
Standard Deviation- volts x 10^3	2.027	4.778	14.968	6.337
Maximum Concentration Variation- g CMC/g Total x 10^6	16.957	52.174	66.522	50.870
Maximum Concentration Variation- % Total CMC Conc.	2.577	4.013	6.490	2.225

TABLE 1 (CONTINUED)

EXPERIMENTAL RESULTS OF WELL-MIXED RUNS

Run No.	2% #3	4% #1	4% #2	1% MSP	2% MSP
Absolute CMC Conc.- g CMC/g Total x 10^3	2.430	2.053	4.425	3.775	11.111
Average Conductivity- Volts	1.8651	1.8427	2.7948	2.1172	3.8340
Average Background- volts	0.955	0.991	0.960	1.014	1.010
Absolute Average Conductivity- volts	0.9101	0.8517	1.8348	1.1032	2.8240
Maximum Deviation- volts	0.0125	0.0315	0.0325	0.0080	0.0240
Mean Deviation- volts x 10^3	3.530	12.242	2.935	3.087	7.077
Standard Deviation- volts x 10^3	4.567	15.202	5.275	3.665	8.722
Maximum Concentration Variation- g CMC/g Total x 10^6	32.609	35.218	84.783	20.870	62.609
Maximum Concentration Variation- % Total CMC Conc.	1.342	1.715	1.916	0.553	0.563

1
2
1

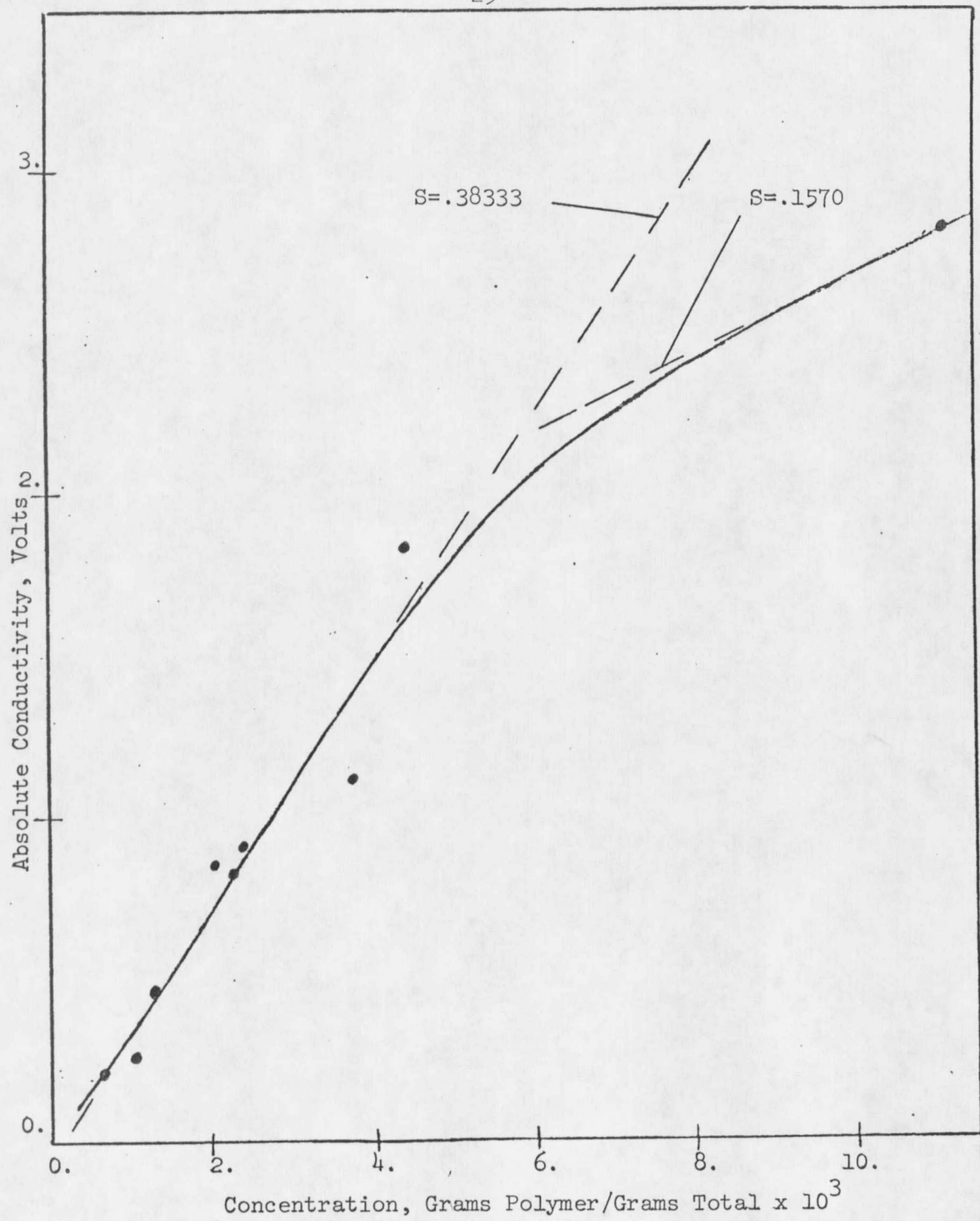


FIGURE 8: Conductivity Probe Calibration Curve

Calibration Curve can be approximated by a straight line of slope 0.38333×10^{-3} . For the mixing run distant from this line, a line of slope 0.1570×10^{-3} was used to roughly approximate the calibration curve in this region. From these two lines, which are shown as dashed lines in Figure 8, voltage differences were converted into concentration differences by using equation (5):

$$\Delta C = \frac{\Delta V}{S} \quad (5)$$

where $S = 0.38333 \times 10^{-3}$ or 0.1570×10^{-3} .

Using equation (5), the Maximum Voltage Deviations shown in Table 1 were converted into Maximum Concentration Variations, also shown in Table 1 in units of grams polymer per gram total solution and as a percentage of the total CMC concentration.

Experimental results derived from the Mixing Runs are shown in Table 2. Run numbers shown are indicative of the CMC concentration (in grams polymer per gram total solution) in the polymer stream to be mixed with water. Thus, "1% #1" indicates that a polymer solution, 1% by weight CMC, was mixed with water (water being the main-stream component) at the flow rates for water and polymer solution shown. The designation "1% MSP" indicates that a 1%-by weight polymer solution was mixed with water, with polymer solution as the main-stream component. Table 2 also contains the Average Conductivity, Average Background Voltage, and the Absolute Average Conductivity for each run. Mean deviation, standard deviation, and

TABLE 2
EXPERIMENTAL RESULTS OF MIXING RUNS

Run No.	1% #1	1% #2	2% #1	2% #2
Water Flow Rate- ml/sec	9.45	9.60	9.75	9.40
Polymer Flow Rate- ml/sec	0.622	1.250	0.50	1.113
Average Conductivity- volts	1.1135	1.2764	1.1671	1.3487
Average Background- volts	0.891	0.895	0.911	0.917
Absolute Average Conductivity- volts	0.2225	0.3814	0.2561	0.4317
Mean Deviation- volts x 10^3	4.042	11.948	12.023	40.438
Standard Deviation- volts x 10^3	5.177	15.506	16.675	50.798

TABLE 2 (CONTINUED)

EXPERIMENTAL RESULTS OF MIXING RUNS

Run No.	1% #1	1% #2	2% #1	2% #2
Maximum Deviation- volts $\times 10^3$	13.460	69.614	80.927	166.330
Mean Concentration Variation- g CMC/g Total $\times 10^6$	10.544	31.169	31.365	105.491
Mean Concentration Variation- % Total CMC Conc.	1.602	2.398	3.060	4.615
Standard Concentration Variation- g CMC/g Total $\times 10^6$	13.505	40.451	43.500	132.518
Standard Concentration Variation- % Total CMC Conc.	2.052	3.112	4.244	5.797
Maximum Concentration Variation- g CMC/g Total $\times 10^6$	35.113	181.603	211.116	433.908
Maximum Concentration Variation- % Total CMC Conc.	5.336	13.970	20.597	18.981

TABLE 2 (CONTINUED)

EXPERIMENTAL RESULTS OF MIXING RUNS

Run No.	4% #1	4% #2	1% MSP	2% MSP
Water Flow Rate- ml/sec	8.75	8.85	2.35	2.20
Polymer Flow Rate- ml/sec	0.450	0.983	1.425	2.750
Average Conductivity- volts	1.3260	1.7475	2.4402	3.7829
Average Background- volts	0.939	0.925	0.967	0.960
Absolute Average Conductivity- volts	0.3870	0.8225	1.4732	2.8229
Mean Deviation- Volts x 10^3	57.783	198.946	8.166	60.217
Standard Deviation- volts x 10^3	83.283	254.481	10.514	78.430

TABLE 2 (CONTINUED)

EXPERIMENTAL RESULTS OF MIXING RUNS

Run No.	4% #1	4% #2	1% MSP	2% MSP
Maximum Deviation- volts x 10 ³	403.023	929.480	58.223	276.920
Mean Concentration Variation- g CMC/g Total x 10 ⁶	150.740	518.994	21.303	383.548
Mean Concentration Variation- % Total CMC Conc.	7.342	11.729	0.564	3.452
Standard Concentration Variation- g CMC/g Total x 10 ⁶	217.262	663.869	27.428	499.554
Standard Concentration Variation- % Total CMC Conc.	10.583	15.003	0.727	4.496
Maximum Concentration Variation- g CMC/g Total x 10 ⁶	1051.373	2424.752	151.887	1763.822
Maximum Concentration Variation- % Total CMC Conc.	51.212	54.797	4.023	15.875

TABLE 2 (CONTINUED)

EXPERIMENTAL RESULTS OF MIXING RUNS

Run No.	2% #3A	2% #3B	2% #3C	2% #3D	2% #3E
Water Flow Rate- ml/sec	9.14	9.14	9.14	9.14	9.14
Polymer Flow Rate- ml/sec	1.133	1.133	1.133	1.133	1.133
Average Conductivity- volts	1.4103	1.5991	1.4016	1.6219	1.4363
Average Background- volts	0.956	0.956	0.956	0.956	0.956
Absolute Average Conductivity- volts	0.4543	0.6431	0.4456	0.6659	0.4803
Mean Deviation- volts x 10^3	56.222	31.246	46.124	45.247	57.364
Standard Deviation- volts x 10^3	74.247	39.192	57.963	53.893	73.094

TABLE 2 (CONTINUED)
EXPERIMENTAL RESULTS OF MIXING RUNS

Run No.	2% #3A	2% #3B	2% #3C	2% #3D	2% #3E
Maximum Deviation- volts x 10 ³	181.670	87.930	196.45	118.18	217.72
Mean Concentration Variation- g CMC/g Total x 10 ⁶	146.667	81.512	120.325	118.037	149.647
Mean Concentration Variation- % Total CMC Conc.	6.036	3.354	4.952	4.857	6.158
Standard Concentration Variation- g CMC/g Total x 10 ⁶	193.690	102.241	151.209	140.592	190.682
Standard Concentration Variation- % Total CMC Conc.	7.971	4.207	6.223	5.786	7.847
Maximum Concentration Variation- g CMC/g Total x 10 ⁶	473.926	229.385	512.483	308.298	567.970
Maximum Concentration Variation- % Total CMC Conc.	19.503	9.440	21.090	12.687	23.373

maximum deviation are shown in both voltage units and as converted to concentration units; these measurements comprise a portion of the quantitative mixing analysis.

The actual viscosities of polymer solutions used, as given by Hercules, Inc. (8), are not exact, since the viscosity at one concentration varies over a range of values. Approximate values for solution viscosities, derived from Hercules, Inc. (8) are shown in Table 3.

TABLE 3

SOLUTION VISCOSITIES OF VARIOUS CMC CONCENTRATIONS

Percent (by weight) CMC	Approximate Solution Viscosity (centipoises at 25 C)
1%	1500.
2%	13000.
4%	30000.

(Viscosity values listed are from Hercules, Inc. (8))

As can be seen from Table 2, both mean and standard deviations increase as the concentration of CMC in solution, and hence the viscosity, increase. Thus, the degree of mixedness accomplished by the Static Mixer decreased as polymer solution viscosity increased. For CMC concentrations of 1%, the degree of mixedness was relatively high, the maximum concentration variations for low and high flow rates being 5.3% and 14.0% of the total CMC concentration respectively. For CMC concentrations of 2%, the maximum concentration variations increased to 20.6% and 19.0% for the two flow rates; degree of mixedness declined here, especially in the case of 2% #2. For CMC concentrations of 4%, the maximum concentration variations increased markedly to 51.2% and 54.8% for the two flow rates; degree of mixedness here is extremely low.

Where polymer solution comprised the main-stream component, the degree of mixedness decreased in a fashion similar to the above with increasing viscosity of the polymer solution. For the 1% MSP run, the maximum concentration variation was 4.0%, showing a high degree of mixedness, but for the 2% MSP run, the maximum concentration variation was 15.9%, showing a decreased degree of mixedness.

To further compare the mixing runs, results of the criteria-levels analysis are shown in Table 4 and are plotted in Figure 9. Values in the body of Table 4 are percentages; each value indicates, for the criteria level and run number listed, the percentage of run time that concentration deviations were larger than the criteria level indicated. The actual

TABLE 4

RESULTS OF CRITERIA LEVELS ANALYSIS

Level	Run No.	1% #1	1% #2	2% #1	2% #2
1		1.667	0.000	0.667	0.000
2		4.000	0.333	1.334	5.667
3		4.333	0.666	1.334	5.667
4		6.666	0.999	2.667	22.000
5		7.666	2.666	3.000	30.333
6		11.666	6.333	4.333	50.000
7		18.666	10.000	4.666	64.000
8		20.999	17.667	6.999	73.000
9		23.999	66.667	70.999	91.000
10		99.999	100.000	99.999	100.000

(Values in body of table are percent deviations greater than criteria level indicated)

TABLE 4 (CONTINUED)

RESULTS OF CRITERIA LEVELS ANALYSIS

Level	Run No.	4% #1	4% #2	1% MSP	2% MSP
1		3.000	2.667	0.000	0.000
2		4.333	6.000	0.000	0.333
3		5.000	11.333	0.000	2.666
4		6.000	18.333	0.000	5.666
5		7.333	41.000	0.333	20.333
6		16.666	72.000	0.666	31.666
7		53.333	87.000	12.999	49.333
8		67.333	89.000	40.999	71.000
9		94.000	99.667	55.666	92.000
10		100.000	100.000	99.999	100.000

(Values in body of table are percent deviations greater than criteria level indicated)

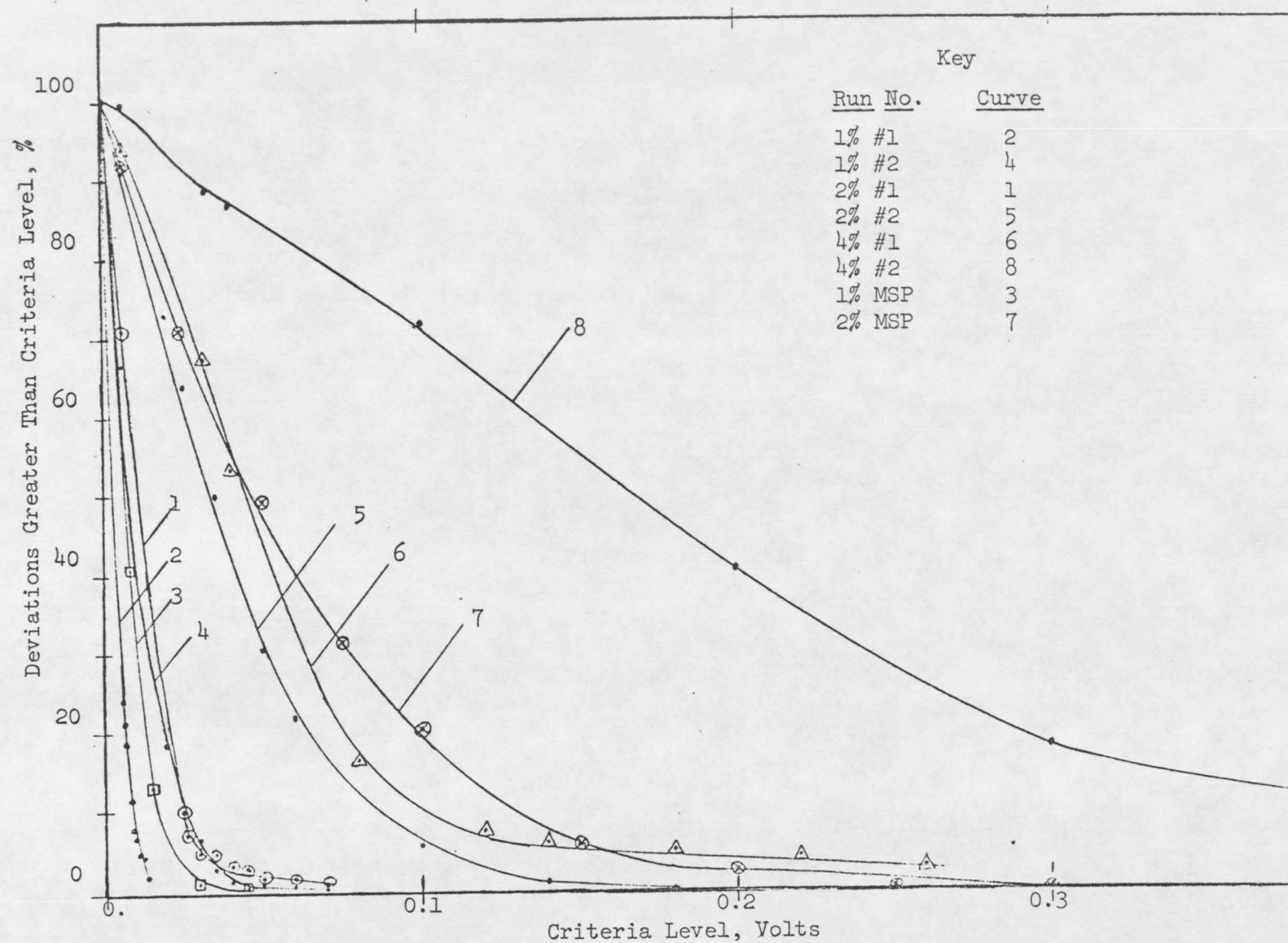


FIGURE 9: Criteria Level Analysis

TABLE 5

VOLTAGE VALUES OF CRITERIA LEVELS

Criteria Level Values - Volts x 10³

Run No.	1	2	3	4	5	6	7	8	9	10
1% #1	13.0	12.0	11.0	10.0	9.0	8.0	7.0	6.5	6.0	0.0
1% #2	70.0	60.0	50.0	40.0	35.0	30.0	25.0	20.0	6.0	0.0
2% #1	70.0	60.0	50.0	45.0	40.0	35.0	30.0	25.5	6.0	0.0
2% #2	180.0	140.0	100.0	60.0	50.0	35.0	25.0	19.5	6.0	0.0
4% #1	260.0	220.0	180.0	140.0	120.0	80.0	40.0	31.5	6.0	0.0
4% #2	600.0	500.0	400.0	300.0	200.0	100.0	40.0	32.5	6.0	0.0
1% MSP	120.0	100.0	75.0	60.0	45.0	30.0	15.0	8.0	6.0	0.0
2% MSP	300.0	250.0	200.0	150.0	100.0	75.0	50.0	24.0	6.0	0.0

values at which the criteria levels were set are shown in Table 5.

The most important set of values in Table 4 are those associated with level 8; these values indicate the percentage of run time that concentration deviations lay outside of the well-mixed region. For the 1% mixing runs, deviations lay outside of the well-mixed region 21.0% and 17.7% of the run times for the two flow rates; this indicates that approximately 80% of the time the concentration of the mixed solution fluctuated within the well-mixed region. For the 2% runs, deviations were outside the well-mixed region 7.0% and 73.0% of the run times; this indicates that at low flow rates of 2%-polymer solution the degree of mixedness is high, but at the higher flow rate, the degree of mixedness has declined sharply. For solutions of 4% CMC, deviations lay outside of the well-mixed region 67.3% and 89.0% of the time, indicating that the degree of mixedness for solutions of this viscosity range is relatively poor.

When polymer solution was used as the main-stream component, deviations outside of the well-mixed region again increase with the viscosity of the polymer solution. For the 1% MSP run, deviations were outside of the well-mixed region 41.0% of the time, while for the 2% MSP run, deviations were outside of the well-mixed region 71.0% of the run time.

As shown in Figure 9, the ability of the Static Mixer to supply a high degree of mixedness declines as the viscosity of one of the components

increases. Curves for the runs 1% #1, 1% #2, 2% #1, and 1% MSP lie very close to the boundary of the region of instrumental variation (.006 volts), and lie within the well-mixed region for each case a significant majority of the time. The performances of the mixer during these runs can, then, be described as supplying a relatively high degree of mixedness. Curves for the runs 2% #2, 4% #1, and 2% MSP lie at a moderate distance from the boundary of instrumental variation; the degree of mixedness supplied here is decreased. Finally, for the run 4% #2, the curve lies a great distance from the boundary, and a very large percentage of concentration deviations lie outside the well-mixed region, indicating that the degree of mixedness here is low.

Although both the mean, standard, and maximum deviations analysis and the criteria levels analysis reveal the same general trends, a comparison of results for individual runs is revealing; especially noteworthy is the run 2% #1. In terms of voltage units, the mean, standard, and maximum deviations for this run are close to the values obtained for the 1% #2 run. In terms of percent total CMC concentrations, the values are close to those obtained for the 2% #2 run. This can be resolved when it is noted that the actual overall concentration of CMC in water is smaller in 2% #1 than in 1% #2; thus, deviations of similar voltage magnitudes have higher values in 2% #1 in terms of percent total concentration than in 1% #2.

If, however, values for mean, standard, and maximum deviation in

terms of percent total CMC are taken as the basis for comparison, it nevertheless appears that the cases 1% #2, 2% #1, and 2% #2 are quite close, and a conclusion could be made on this basis that the degrees of mixedness for the three cases are quite similar. A comparison of results for the three runs from the criteria levels analysis, however, reveals that this is erroneous. Here we see that the percentage of deviations outside the well-mixed region is 17.7% for 1% #2, 6.7% for 2% #1, and 73.0% for 2% #2. In other words, the concentration of polymer in solution varies for 1% #2 and 2% #1 for the most part within the well-mixed region, while for 2% #2, the concentration varies a great percentage of the time outside of this region. From this, it is concluded that the degrees of mixedness for 1% #2 and 2% #1 are quite similar and are higher than the degree of mixedness for the 2% #2 case. The fact that all three cases have similar mean, standard, and maximum deviations in terms of percent total CMC can be explained by noting again that the overall concentration of CMC was much higher in the 2% #2 case; large voltage variations here appear to be much smaller when placed in percentage units.

From the above analysis, it is apparent that the Static Mixer combines 1%-CMC solutions with water (viscosity ratio $\sim 1,500/1$) with a relatively high degree of mixedness. When 2%-CMC solutions are combined with water (viscosity ratio $\sim 13,000/1$) the degree of mixedness is still high at low polymer-stream flow rates, but declines markedly at higher

polymer-stream flow rates. When 4%-CMC solutions are combined with water (viscosity ratio $\sim 30,000/1$) the degree of mixedness is low for both low and high polymer flow rates. Similar trends are observed for the case when polymer solution is the main-stream component; when the polymer solution is 1% CMC, values for mean, standard, and maximum deviations lie within the region of values obtained for the 1% solution when water was main-stream, while when the polymer solution is 2% CMC, the results are similar to those obtained when water was main stream, and the polymer solution was 2% CMC at high flow rate. A difference does exist in the criteria levels analysis, however, for the 1% cases. When water was the main stream component, concentration deviations lay outside the well-mixed region 21.0% and 17.7% of the time, but when polymer was main-stream, the deviations lay outside 41.0% of the time. Very little difference exists between the 2% MSP and 2% #2 cases, however; deviations outside the well-mixed region are 7.0% for 2% #1, and 73.0% for 2% #2, as compared to 71.0% for 2% MSP.

When Tables 1 and 2 were compared during the analysis, it was noted that the values for Absolute Average Conductivity for the well-mixed runs were higher in general than the values for the corresponding mixing runs. One possible explanation for this is that polymer concentration during the mixing runs varies with position across the tube cross-section; if the concentration was higher at the wall than in the tube center, the Average Conductivity Reading would be lower during mixing runs than

during well-mixed runs, since the probe was positioned in the tube center. To test this hypothesis, the run designated "2% #3" was made; during the run, the probe was positioned at three places across the tube cross-section. One hundred data-points were taken at each position, and data was taken at the two extreme positions twice. Sets designated 2% #3A and 2% #3C were taken at the tube center; sets designated 2% #3B and 2% #3D were taken very close to the tube wall, and the set designated 2% #3E was taken at a point halfway between the center of the tube and the tube wall. Results shown in Table 2 indicate that the Absolute Average Conductivity was indeed consistently higher at the wall than in the center, and, therefore, the polymer concentration at the wall was higher than in the tube center. However, the values at the tube wall for Absolute Average Conductivity are still below the value for the well-mixed run, indicating that yet another factor is involved. Part of this could be due to errors in flow rate measurements, or to angular concentration variations, but the exact nature of this phenomenon is unknown at this time.

V. CONCLUSIONS

A general conclusion that can be made on the basis of the results of this project is that the mixing performance of the Static Mixer is indeed affected by the viscosity ratio and flow velocities of the components to be mixed. When polymer solutions containing 1% CMC by weight were combined with water, the degree of mixedness was relatively high, as shown by the relatively low values obtained for mean, standard, and maximum deviation, and percentage of run time the deviations were outside the well-mixed region. At low polymer flow rate, CMC solution containing 2% CMC was also combined with water with a high degree of mixedness, but with the 2% solution at a higher flow rate, the degree of mixedness declined markedly, as shown by much higher values for mean, standard, and maximum deviations, and especially by the much higher percentage of run time that solution concentrations varied outside the well-mixed region. For solutions containing 4% CMC, the ability of the Static Mixer to combine the polymer solution with water is quite limited, as shown by a very low degree of mixedness for both flow rates as determined by the above criteria.

Similar trends were evident during runs in which polymer solution comprised the main-stream component; degree of mixedness was high for the 1% CMC solution, and declined with the 2% CMC solution. The degree of mixedness obtained did not depend to any great degree upon which fluid comprised the main-stream component.

In general, the solutions of various viscosities that were mixed

could be combined into three general groups. One-percent solutions at both low and high flow rates (viscosity ratio $\sim 1,500/1$), 2% solution at low flow rate (viscosity ratio $\sim 3,000/1$) and 1% solution as main-stream component were combined with water with a high degree of mixedness; 2% solution, water being main stream, at high flow rate, 2% solution as main stream component, and 4% solution at low flow rate (viscosity ratio $\sim 30,000/1$) were combined with water with a much lower degree of mixedness; and 4% solution at high flow rate was combined with water with a very low degree of mixedness.

From data taken across the tube cross-section, it was found that polymer concentration was higher at the tube wall than in the tube center during mixing runs.

VI. RECOMMENDATIONS FOR FUTURE WORK

Future investigations indicated by this research would most probably be in the area of improving the mixer performance when the viscosity ratio of the components to be combined is in the order of 30,000/1. Possible methods for increasing performance would include varying the position of the inlet nozzle across the cross-section of the entrance tube, increasing the number of mixer elements, or modifying the design of the individual mixer element.

Another area of investigation would be a more comprehensive study of concentration variations across the tube cross-section than was carried out during this project. Results of such an investigation could be useful in redesigning mixer elements to improve the mixer performance.

VII. APPENDIX

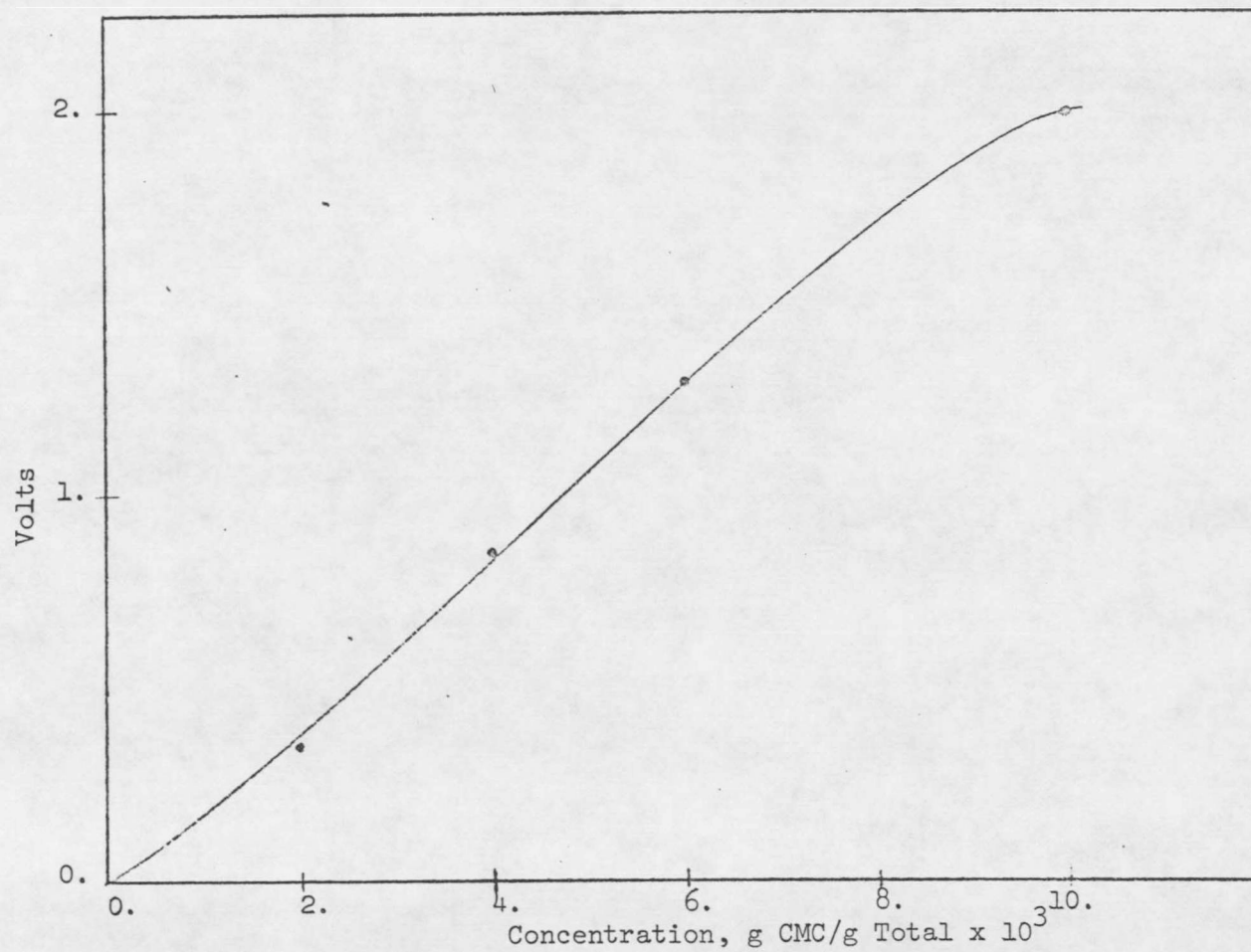


FIGURE 10: Still-Fluid Calibration Curve

1013., 1013., 1013., 1013., 1020., 1018., 1920\ \ 1020., 1021., 1019., 1021.
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 1014., 1016., 1013., 1017., 1016., 1015., 1015., 1014., 1015., 1014.

Table 6: Background Variation Data (volts $\times 10^3$)

1193., 1194., 1197., 1197., 1190., 1193., 1194., 1193., 1195., 1195.
 1193., 1193., 1193., 1195., 1195., 1192., 1192., 1194., 1193., 1194.
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Table 7: Data for Well-Mixed Run 1% #1 (volts x 10^3)

1423., 1421., 1419., 1420., 1425., 1426., 1420., 1424., 1428., 1451.
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 1413., 1423., 1422., 1423., 1428., 1421., 1424., 1423., 1422., 1420.
 1424., 1422., 1422., 1427., 1430., 1422., 1433\ 23., 1424., 1424., 1420.
 1425., 1423., 1423., 1424., 1423., 1421., 1426., 1421., 1425., 1413.
 1431., 1420., 1421., 1423., 1427., 1420., 1426., 1420., 1420., 1419.
 1421., 1430., 1425., 1426., 1419., 1423., 1421., 1423., 1421., 1423.
 1422., 1427., 1424., 1422., 1424., 1427., 1423., 1426., 1423., 1431.
 1433., 1426., 1422., 1429., 1427., 1421., 1420., 1421., 1423., 1428.
 1427., 1425., 1430., 1429., 1418., 1418., \., 1421., 1451., 1417., 1422.
 1426., 1426., 1431., 1423., 1420., 1424., 1421., 1415., 1426., 1422.
 1426., 1425., 1421., 1420., 1421., 1426., 1420., 1425., 1421., \., 1436.
 1422., 1424., 1426., 1426., 1423., 1419., 1421., 1416., 1422., 1422.
 1442., 1426., 1427., 1426., 1422., 1427., 1424., 1426., 1424., 1427.
 1432., 1420., 1430., 1419., 1420., 1424., 1425., 1426., 1427., 1429.
 1425., 1413., 1430., 1420., 1421., 1429., 1413., 1423., 1429., 1423.

Table 8: Data for Well-Mixed Run 1% #2 (volts x 10^3)

1242., 1243., 1247., 1242., 1240., 1243., 1236., 1209., 1205., 1210.
 1207., 1210., 1214., 1206., 1213., 1206., 1206., 1208., 1205., 1205.
 1206., 1203., 1203., 1214., 1211., 1210., 1210., 1209., 1210., 1230.
 1243., 1246., 1243., 1247., 1236., 1239., 1236., 1207., 1210., 1206.
 1208., 1207., 1212., 1207., 1211., 1204., 1203., 1204., 1209., 1206.
 1206., 1212., 1211., 11\210., 1211., 121:\0., 1211., 1209., 1208., 1232.
 1243., 1242., 13\251., 1243., 1243., 1242., 1236., 1208., 1213., 1214.
 1209., 1211., 1212., 1214., 1204., 1208., 1203., 1211., 1204., 1207.
 1212., 1211., 1211., 1213., 1210., 1212., 1214., 1212., 1210., 1217.
 1242., 1252., 1249., 1247., 1245., 1246., 1238., 1212., 1211., 1206.
 1203., 1211., 1216., 1213., 1212., 1205., 1207., 1208., 1211., 1211.
 1210., 1210., 1212., 1212., 1215., 1212., 1212., 1211., 1212., 1214.
 1244., 1250., 1250., 1244., 1244., 1243., 1240., 1206., 1213., 1207.
 1206., 1208., 1215., 1214., 1223., 1204., 1206., 1205., 1209., 1212., \
 1206., 1214., 1211., 1213., 1220., 1211., 1211., 1212., 1213., 1210., \
 1241., 1250., 1244., 1241., 1230., 1241., 125\41., 1200., 1210., 1214., \
 1201., 1205., 1210., 1201., 1221., 1206., 1200., 1205., 1211., 1206.
 1206., 1220., 1214., 1210., 1214., 1200., 1210., 1214., 1200., 1216.
 1242., 1245., 1244., 1246., 1240., 1240., 1242., 1204., 1208., 1206.
 1203., 1206., 1203., 1212., 1223., 1201., 1207., 1205., 1206., 1209., \
 1207., 1207., 1210., 1213., 1204\14., 1210., 1209., 1211., 1211., 1207.
 1245., 1243., 1249., 1245., 1242., 1236., 1243., 1210., 1211., 1206.
 1208., 1207., 1210., 1211., 1213., 1206., 1207., 1203., 1209., 1208., \
 1210., 1211., 1212., 1215., 1212., 1211., 1210., 1209., 1209., 1210.
 1242., 1243., 1244., 1245., 1241., 1245., 1245., 1210., 1210., 1206.
 1207., 1206., 1204., 1210., 1212., 1205., 1206., 1210., 1209., 1204.
 1210., 1214., 1210., 1212., 1212., 1214., 1215., 1214., 1209., 1213.
 1244., 1247., 1246., 1241., 1244., 1243., 1246., 1209., 1209., 1212., \
 1203., 1205., 1209/\., 1204., 1213., 1206., 1206., 1208., 1204., 1209.
 1203., 1215., 1209., 1212., 1214., 1213., 1214., 1213., 1208., 1212.

Table 9: Data for Well-Mixed Run 2% #1 (volts x 10^3)

1758., 1734., 1732., 1802., 1790., 1782., 1782., 1786., 1793., 1737.
 1801., 1794., 1736., 1793., 1795., 1801., 1790., 1805., 1733., 1796.
 1794., 1796., 1799., 1793., 1802., 1792., 1793., 1799., 1796., 1800.
 1787., 1782., 1789., 1797., 1792., 1792., 1791., 1791., 1789., 1791.
 1804., 1795., 1788., 1792., 1792., 1796., 1732., 1798., 1791., 1790.
 1792., 1790., 1802., 1793., 1803., 1792., 1802., 1791., 1794., 1807.
 1773., 1788., 1790., 1802., 1789., 1791., 1789., 1792., 1788., 1792.
 1792., 1795., 1789., 1790., 1794., 1790., 1789., 1804., 1737., 1792.
 1799., 1800., 1789., 1804., 1803., 1796., 1807., 1803., 1803., 1807.
 1777., 1737., 1737., 1798., 1798., 1739., 1790., 1792., 1790., 1796.
 1793., 1796., 1783., 1737., 1788., 1791., 18\788., 1804., 1785., 1796.
 1800., 1801., 1786., 1799., 1802., 1735., 1808., 1804., 1794., 1802.
 1791., 1790., 1787., 1803., 1794., 1792., 1795., 1793., 1794., 1794.
 1800., 1799., 1791., 1793., 1794., 1791., 1798., 1805., 1794., 1791.
 1795., 1792., 1795., 1803., 1805., 1788., 1801., 1805., 1802., 1805.
 1782., 1791., 1794., 1804., 1790., 1794., 1790., 1791., 1781., 1791.
 1800., 1800., 1731., 1731., 1794., 1804., 1790., 1796., 1791., 1795\4.
 1790., 1794., 1800., 1795., 1791., 1791., 1800., 1806., 1791., 1815.
 1784., 1792., 1791., 1793., 178\96., 1737., 1798., 1791., 1800., 1795.
 1793., 1801., 1794., 1736., 1794., 1788., 1794., 1794., 1792., 1791.
 1790., 1792., 1800., 1804., 1803., 1793., 1800., 1806., 1796., 1803.
 1796., 1790., 1784., 1794., 1793., 1787., 1792., 1784., 1792., 1792.
 1793., 1783., 1786., 1791., 1796., 1788., 1795., 1790., 1792., 1796.
 1794., 1793., 1790., 1793., 1792., 1802., 1794., 1793., 1804., 1810.
 1781., 1791., 1786., 1790., 1798., 1787., 1786., 1788., 1790., 1795.
 1796., 1787., 1787., 1794., 1783., 1786., 1798\89., 1793., 1796., 1796.
 1791., 1794., 1796., 1800., 1802., 1795., 1800., 1794., 1799., 1806.
 1785., 1789., 1796., 1794., 1794., 1786., 1793., 1785., 1796., 1795.
 1787., 1799., 1791., 1793., 1793., 1794., 1791., 1790., 1796., 1788.
 1804., 1797., 1792., 1796., 1788., 1799., 1800., 1794., 1794., 1816.

Table 10: Data for Well-Mixed Run 2% #2 (volts x 10^3)

13 63., 13 67., 13 71., 13 74., 13 73., 13 69., 13 72., 13 66., 13 73., 13 68.
 13 76., 13 63., 13 64., 13 67., 13 71., 13 74\3., 13 69., 13 62., 13 62., 13 64.
 13 62., 13 62., 13 60., 13 65., 13 63., 13 64., 13 66., 13 67., 13 65., 13 66.
 13 71., 13 66., 13 67., 13 70., 13 73., 13 73., 13 71., 13 73., 13 65., 13 59.
 13 63., 13 66., 13 68., 13 71., 13 70., 13 53., 13 53., 13 63., 13 64., 13 62.
 13 66., 13 66., 13 64., 13 65., 13 64., 13 64., 13 62., 13 66., 13 66., 13 66.
 13 66., 13 64., 13 65., 13 69., 13 75., 13 67., 13 70., 13 72., 13 74., 13 64.
 13 72., 13 71., 13 70., 13 70., 13 61., 13 6\54., 13 70., 13 62., 13 59., 13 65.
 13 62., 13 66., 13 60., 13 66., 13 62., 13 64., 13 63., 13 63., 13 65., 13 67.
 13 61., 13 62., 13 63., 13 63., 13 73., 13 76., 13 64., 13 66., 13 74., 13 66.
 13 66., 13 63., 13 70., 13 65., 13 61., 13 54., 13 67., 13 64., 13 59., 13 64.
 13 60., 13 66., 13 64., 13 67., 13 65., 13 65., 13 65., 13 63., 13 65\4., 13 63.
 13 67., 13 61., 13 69., 13 74., 13 63., 13 68., 13 70., 13 69., 13 63., 13 63.
 13 64., 13 63., 13 66., 13 62., 13 73., 13 52., 13 59., 13 52., 13 59., 13 61.
 13 60., 13 64., 13 59., 13 62., 13 62., 13 65., 13 66., 13 62., 13 60., 13 66.
 13 61., 13 61., 13 65., 13 60., 13 70., 13 71., 13 71., 13 77., 13 76., 13 60.
 13 60., 13 63., 13 61., 13 61., 13 71., 13 57., 13 66., 13 51., 13 60., 13 61.
 13 60., 13 60., 13 60., 13 65., 13 60., 13 60., 13 60., 13 60., 13 61., 13 61.
 13 64., 13 62., 13 67., 13 64., 13 72., 13 64., 13 63., 13 70., 13 72., 13 64.
 13 72., 13 64., 13 66., 13 70., 13 65., 13 62., 13 63., 13 67., 13 63., 13 63.
 13 62., 13 62., 13 61., 13 61., 13 61., 13 63., 13 60., 13 62., 13 60., 13 65.
 13 61., 13 67., 13 60., 13 62., 13 70., 13 70., 13 65., 13 65., 13 65., 13 64., \
 13 72., 13 64., 13 66., 13 62., 13 61., 13 64., 13 68., 13 64., 13 61., 13 63.
 13 63., 13 60., 13 63., 13 61., 13 67., 13 64., 13 59., 13 66., 13 62., 13 62.
 13 63., 13 65., 13 60., 13 66., 13 66., 13 76., 13 72., 13 66., 13 61., 13 69.
 13 74., 13 65., 13 64., 13 71., 13 54., 13 66., 13 57., 13 67., 13 65., 13 64.
 13 61., 13 64., 13 65., 13 64., 13 64., 13 66., 13 63., 13 62., 13 66., 13 67.
 13 69., 13 74., 13 74., 13 67., 13 67., 13 71., 13 72., 13 67., 13 67., 13 73.
 13 71., 13 69., 13 64., 13 67., 13 64., 13 59., 13 56., 13 65., 13 61., 13 65.
 13 65., 13 60., 13 64., 13 64., 13 63., 13 64., 13 63., 13 65., 13 66., 13 71.

Table 11: Data for Well-Mixed Run 2% #3 (volts x 10^3)

1310., 1351., 1334., 1352., 1324., 1341., 1334., 1345., 1322., 1350.
 1332., 1352., 1331., 1356., 1335., 1342., 1334., 1354., 1354., 1352.
 1318., 1355., 1353., 1343., 1353., 1337., 1359., 1334., 1361., 1322.
 1312., 1350., 1337., 1354., 1343., 1347., 1341., 1343., 1323., 1351., \
 1334., 1354., 1335., 1355., 1340., 1342., 1335., 1351., 1356., 1352.
 1315., 1355., 1346., 1353., 1361., 1345., 1360., 1339., 1360., 1325.
 1313., 1349., 1337., 1353., 1339., 1350., 1339., 1345., 1326., 1350.
 1334., 1354., 1337., 1355., 1342., 1343., 1342., 1304., 1323., 1354., \
 1325., 1357., 1320., 1355., 1356., 1343., 1364., 1343., 1362., 1333.
 1322., 1343., 1336., 1350., 1342., 1351., 1345., 1343., 1332., 1353.
 1339., 1355., 1345., 1308., 1345., 1344., 1342., 1308., 1343., 1359.
 1333., 1362., 1337., 1360., 1321., 1352., 1347., 1354., 1369., 1347.
 1324., 1350., 1341., 1353., 1338., 1354., 135\41., 1346., 1334., 1355.
 1339., 1354., 1346., 1309., 1346., 1346., 1344., 1308., 1343., 1356.
 1345., 1361., 1346., 1360., 1330., 1355., 1323., 1356., 1342., 1351.
 1323., 1352., 1343., 1353., 1337., 1352., 1343., 1343., 1336., 1352.
 1345., 1354., 1345., 13\311., 1343., 1347., 1343., 1309., 1353., 1311.
 1352., 1361., 1351., 1357., 1343., 1361., 1335., 1360., 133\21., 1354.
 1330., 1353., 1345., 1357., 1339., 1306., 1346., 1349., 1339., 1352.
 1351., 1356., 1343., 1316., 1351., 1343., 1346., 1313., 1356., 1322.
 1356., 1317., 1356., 1362., 1343., 1362., 1344., 1365., 1333., 1361.
 1332., 1304., 1347., 1357., 1343., 1309., 1321., 1350., 1346., 1355.
 1350., 1353., 1350., 1322., 1353., 1352., 1346., 1313., 1357., 1337.
 1360., 1332., 1360., 1315., 1352., 1366., 1353., 1367., 1344., 1365.
 1336., 1310., 1346., 1354., 1333., 1314., 1311., 1350., 1350., 1307.
 1351., 1308., 1350., 1322., 1353., 1351., 1347., 1319., 1314., 1344.
 1361., 1341., 1359., 1327., 1356., 1316., 1359., 1370., 1346., 1369.
 1340., 1319., 1343., 1357., 1333., 1315., 1323., 1349., 1343., 1306.
 1354., 1313., 1351., 1324., 1353., 1349., 1347., 1323., 1322., 1350.
 1363., 1349., 1362., 1339., 1360., 1329., 1356., 1322., 1356\1356., 1366.

Table 12: Data for Well-Mixed Run 4% #1 (volts x 10^{-3})

2799., 2794., 2796., 2793., 2794., 2791., 2792., 2794., 2789., 2790.
 2794., 2792., 2793., 2793., 2796., 2794., 2739., 2796., 2792., 2793.
 2793., 2796., 2799., 2794., 2802., 2794., 2790., 2793., 2797., 2795.
 2799., 2792., 2792., 2794., 2794., 2798., 2792., 2793., 2792., 2795.
 2790., 2790., 2796., 2793., 2794., 2794., 2797., 2795., 2788., 2792.
 2791., 2796., 3\ 2795., 2795., 2799., 2792., 2790., 2796., 2795., 2787.
 2793., 2794., 2739., 2794., 2798., 2794., 2794., 2798., 2796., 2792.
 2794., 2794., 2797., 2796., 2793., 2795., 2794., 2788., 2797., 2790.
 2739., 2795., 2795., 2796., 2803., 2797., 2798., 2795., 2792., 2794.
 2802., 2792., 2792., 2794., 2800., 2794., 2797., 2791., 2794., 2795.
 2798., 2797., 2797., 2796., 2798., 2794., 2799., 2793., 2793\ 2., 2796.
 2795., 2800., 2793., 2797., 2800., 2792., 2792., 2791., 2794., 2793.
 2802., 2790., 2791., 2787., 2794., 2795., 2794., 2795\ 4., 2733., 2789.
 2794., 2793., 2791., 2795., 2794., 2792., 2794., 2733., 2794., 2795.
 2794., 2794., 2793., 2794\ 5., 2803., 2790., 2790., 2793., 2788., 2795.
 2797., 2794., 2795., 2793., 2791., 2790., 2787., 2790., 2793., 2794.
 2790., 2790., 2799., 2790., 2790., 2790., 2794., 2794., 2794., 2730.
 2794., 2794., 2792., 2794., 2802., 2794., 2792., 2790., 2792., 2792.
 2801., 2793., 2790., 2793., 2797., 2796., 2789., 2794., 2795., 2790.
 2794., 2797., 2797.\., 2796., 2788., 2798\ 7., 2795., 2787., 2797., 2796.
 2796., 2795., 2797., 2797., 2799., 2790., 2798., 2793., 2793., 2794.
 2796., 2794., 2794., 2792., 2796., 2795., 2812., 2790., 2793., 2797.
 3\ 2796., 2795., 2793., 2794., 2798., 2797., 2793., 2792., 2800., 2797.
 2797., 2795., 2800., 2794., 2800., 2792., 2796., 2798., 2799., 2793.
 2793., 2792., 2795., 2797., 2798., 2796., 2834., 2793., 2790., 2794.
 2796., 2793., 2794., 2796., 2794., 2793., 2797., 2792., 2796., 2798.
 2795., 2800., 2794., 2794., 2800., 2800., 2797., 2798., 2800., 2795.
 2793., 2793., 2796., 2793., 2795., 2795., 2852., 2791., 2793., 2792.
 2794., 2793., 2797., 2799., 2797.\., 2792., 2791., 2796., 2793., 2792.
 2797., 2800., 2794., 2793., 2801., 2791., 2794., 2800., 2796., 2794.

Table 13: Data for Well-Mixed Run 4% #2 (volts x 10^3)

2113., 2120., 2120., 2112., 2113., 2117., 2113., 2123., 2113., 2120.
 2119., 2115., 2117., 2120., 2115., 2122., 2117., 2120., 2121., 2122.
 2119., 2113., 2123., 2117., 2113., 2125., 2119., 2120., 2125., 2124.
 2114., 2114., 2115., 2109., 2111., 2115., 2113., 2116., 2115., 2120.
 2116., 2114., 2122., 2112., 2117., 2113., 2121., 2113., 2117., 2116.
 2116., 2115., 2116., 2120., 2116., 2116., 2119., 2121., 2120., 2121.
 2122., 2114., 2117., 2110., 2116., 2116., 2113., 2123., 2124., 2121.
 2120., 2114., 2113., 2114., 2114., 2119., 2121., 2121., 2122., 2120.
 2113., 2120., 2122., 2118., 2119., 2122., 2113., 2121., 2125., 2119.
 2110., 2119., 2115., 2110., 2116., 2119., 2114., 2119., 2113., 2117.
 2115., 2116., 2113., 2113., 2119., 2119., 2112., 2114., 2116., 2116.
 2115., 2113., 2115., 2117., 3\2117., 2120., 2115., 2119., 2122., 2117.
 2119., 2110., 2112., 2109., 2113., 2116., 2116., 2116., 2121., 2114.
 2114., 2114., 2113., 2117., 2115., 2119., 2112., 2114., 2114., 2122.
 2119., 2120., 2121., 2120., 2119., 2123., 2114., 2120., 2113., 2121.
 2117., 2124., 2110., 2116., 2110., 2111., 2111., 2124., 2111., 2110.
 2114., 2116., 2120., 2116., 2110., 2110., 2110., 2110., 2120., 2120.
 2110., 2110., 2110., 2124., 2110., 2120., 2110., 2120., 2120., 2124.
 2109., 2114., 2112., 2112., 2113., 2120., 2116., 2119., 2113., 2113.
 2113., 2117., 2117., 2116., 2117., 2117., 2112., 2115., 2120., 2114.
 2116., 2115., 2117., 2115., 2121., 2122., 2122., 2116., 2122., 2123.
 2119., 2121., 2113., 2112., 2114., 2122., 2117., 2122., 2123., 2113., \
 2114., 2114., 2120., 2114., 2115., 2113., 2119., 2120., 2117., 2120.
 2119., 2116., 2121., 2119., \., 2120., 2113., 2119., 2119., 2113., 2123.
 2116., 2116., 2113., 2111., 2110., 2117., 2115., 2116., 2120., 2113.
 2112., 2110., 2120., 2114., 2114., 2117., 2116., 2119., \., 2115., 2115.
 2113., 2121., 2122., 2117., 2120., 2120., 2114., 2120., 2121., 3\2121.
 2113., 2121., 2117., 2116., 2112., 2120., 2113., 2121., 2119., 2114.
 2113., 2112., 2119., 2113., 2114., 2120., 2120., 2116., 2117., 2114.
 2120., 2121., 2117., 2113., 2120., 2117., 2121., 2117., 2123., 2121.

Table 14: Data for Well-Mixed Run 1% MSP (volts x 10^3)

33 26., 33 24., 33 24., 33 27., 33 27., 33 34., 33 23., 33 26., 33 23., 33 36.
 33 34., 33 19., 33 31., 33 30., 33 30., 33 31., 33 33., 33 29., 33 41., 33 37.
 33 33., 33 49., 33 42., 33 46., 33 44., 33 48., 33 36., 33 40., 33 35., 33 53.
 33 15., 33 13., 33 23., 33 24., 33 23., 33 24., 33 35., 33 32., 33 32., 33 34.
 33 33., 33 32., 33 24., 33 29., 33 37., 33 36., 33 33., 33 34., 33 30., 33 45.
 33 45., 33 39., 33 43., 33 39., 33 42., 33 48., 33 42., 33 46., 33 47., 33 57.
 33 27., 33 15., 33 24., 33 32., 33 35., 33 28., 33 19., 33 21., 33 31., 33 24.
 33 30., 33 33., 33 31., 33 35., 33 30., 33 30., 33 31., 33 41., 33 33., 33 46.
 33 35., 33 40., 33 37., 33 41., 33 37., 33 41., 33 42., 33 38., 33 43., 33 52.
 33 27., 33 29., 33 32., 33 22., 33 29., 33 20., 33 31., 33 30., 33 24., 33 35.
 33 42., 33 35., 33 35., 33 32., 33 31., 33 33., 33 35., 33 40., 33 37., 33 24.
 33 41., 33 42., 33 35., 33 37., 33 46., 4\ 33 40., 33 51., 33 46., 33 43., 33 47.
 33 24., 33 29., 33 13., 33 30., 33 22., 33 26., 33 30., 33 34., 33 26., 33 26.
 33 37., 33 27., 33 28., 33 30., 33 37., 33 41., 33 34., 33 45., 33 41., 33 36.
 33 37., 33 39., 33 44., 33 39., 33 43., 33 34., 33 54., 33 35., 33 46., 33 52.
 33 20., 33 10., 33 11., 33 20., 33 34., 33 20., 33 10., 33 20., 33 20., 33 20.
 33 30., 33 30., 33\ 33 30., 33 20., 33 30., 33 40., 33 30., 33 30., 33 30., 33 30.
 33 40., 33 40., 33 40., 33 30., 33 40., 33 30., 33 40., 33 40., 33 40., 33 46.
 33 23., 33 13., 33 30., 33 24., 33 25., 33 30., 33 31., 33 30., 33 4\ 31., 33 34.
 33 41., 33 31., 33 30., 33 34., 33 36., 33 37., 33 43., 33 44., 33 37., 33 33.
 33 43., 43 4\ \ 33 36., 33 41., 33 40., 33 40., 33 52., 33 36., 33 49., 33 34., 33 51.
 33 22., 33 19., 33 26., 33 27., 33 21., 33 21., 33 30., 33 28., 33 36., 33 24.
 33 31., 33 32., 33 35., 33 28., 33 27., 33 34., 33 34., 33 41., 33 32., 33 32.
 33 37., 33 39., 33 45., 33 35., 33 43., 33 46., 33 37., 33 48., 33 36., 33 46.
 33 22., 2\ 33 23., 33 29., 33 24., 33 31., 33 26., 33 29., 33 32., 33 25., 33 31.
 33 33., 33 32., 33 37., 33 23., 33 36., 33 39., 33 33., 33 5\ 41., 33 40., 33 36.
 33 43., 33 42., 33 34., 33 43., 33 45., 33 42., 33 50., 33 44., 33 44., 33 46.
 33 17., 33 27., 33 27., 33 23., 33 22., 33 26., 33 19., 33 23., 33 34., 33 21.
 33 21., 33 32., 33 25., 33 35., 33 32., 33 43., 33 29., 33 39., 33 43., 33 42.
 33 29., 33 41., 33 46., 33 48., 33 41., 33 42., 33 40., 33 38., 33 33., 33 44.

Table 15: Data for Well-Mixed Run 2% MSP (volts x 10^3)

1103., 1117., 1111., 1113., 1115., 1115., 1112., 1112., 1117., 1113.
 1117., 1110., 1114., 1114., 1112., 1120., 1120., 1117., 1124., 1113.
 1114., 1113., 1116., 1110., 1115., 1115., 1113., 1117., 1120., 1112.
 1099., 1110., 1110., 1117., 1115., 1116., 1116., 1116., 1114., 1116.
 1107., 1109., 1109., 1107., 1106., 1106., 1111., 1116., 1116., 1116.
 1113., 1113., 1114., 1113., 1106., 1122., 1114., 1112., 1116., 1116.
 1100., 1105., 1105., 1116., 1106., 1121., 1105., 1111., 1111., 1114.
 1105., 1116., 1108., 1115., 1114., 1112., 1118., 1122., 1117., 1121.
 1110., 1121., 1109., 1113., 1109., 1115., 1112., 1114., 1114., 1120.
 1111., 1107., 1111., 1116., 1114., 1121., 1103., 1117., 1109., 1113.
 1104., 1113., 1107., 1117., 1112., 1124., 1114., 1121., 1112., 1121.
 1116., 1132., 1110., 1122., 1117., 1118., 1113., 1112., 1113., 1121.
 1117., 1106., 1119., 1109., 1117., 1119., 1114., 1118., 1106., 1114.
 1113., 1114., 1113., 1125., 1114., 1117., 1116., 1113., 1110., 1114.
 1111., 1114., 1109., 1111., 1116., 1111., 1120., 1111., 1112., 1120.
 1124., 1101., 1110., 1116., 1121., 1111., 1124., 1101., 1106., 1110.
 1111., 1100., 1110., 1116., 1115., 1101., 1121., 1100., 1124., 1101.
 1116., 1116., 1116., 1110., 1111., 1101., 1121., 1115., 1116., 1111.
 1113., 1111., 1110., 1105., 1110., 1107., 1112., 1106., 1112., 1106.
 1116., 1108., 1121., 1115., 1117., 1112., 1122., 1110., 1116., 1104.
 1114., 1109., 1113., 1116., 1122., 1110., 1116., 1112., 1119., 1112.
 1111., 1124., 1114., 1116., 1113., 1110., 1112., 1104., 1117., 1109.
 1117., 1107., 1116., 1110., 1120., 1112., 1118., 1115., 1119., 1116.
 1124., 1114., 1112., 1111., 1114., 1110., 1107., 1114., 1109., 1111.
 1103., 1116., 1110., 1117., 1111., 1117., 1112., 1112., 1116., 1114.
 1114., 1109., 1103., 1114., 1111., 1115., 1113., 1112., 1112., 1115.
 1113., 1111., 1109., 1114., 1116., 1119., 1112., 1126., 1114., 1113.
 1115., 1122., 1103., 1113., 1111., 1109., 1109., 1111., 1109., 1107.
 1107., 1103., 1106., 1117., 1110., 1114., 1114., 1116., 1114., 1115.
 1117., 1114., 1109., 1122., 1117., 1126., 1112., 1113., 1112., 1117.

Table 16: Data for Mixing Run 1% #1 (volts x 10³)

1297., 1230., 1233., 1234., 1233., 1273., 1271., 1267., 1236., 1261.
 1234., 1273., 1255., 1292., 1271., 1266., 1272., 1236., 1230., 1274.
 1269., 1273., 1274., 1256., 1272., 1270., 1293., 1290., 1268., 1272.
 1300., 1238., 1307., 1276., 1264., 1271., 1260., 1296., 1237., 1255.
 1243., 1296., 1277., 1275., 1285., 1259., 1295., 1267., 1279., 1269.
 1291., 1262., 1249., 1264., 1248., 1266., 1231., 1271., 1234., 1235.
 1276., 1299., 1286., 1242., 1231., 1261., 1272., 1253., 1268., 1253.
 1266., 1314., 1277., 1254., 1303., 1234., 1234., 1296., 1232., 1273.
 1293., 1260., 1268., 1233., 1254., 1236., 1230., 1311., 1273., 1261.
 1234., 1270., 1270., 1268., 1291., 1250., 1268., 1241., 1310., 1236.
 1231., 1277., 1262., 1272., 1268., 1295., 1275., 1255., 1264., 1257.
 1275., 1230., 1273., 1231., 1256., 1236., 1235., 1274., 1256., 1268.
 1277., 1244., 1303., 1346., 1232., 1268., 1279., 1299., 1294., 1234.
 1236., 1267., 1268., 1276., 1261., 1231., 1276., 1309., 1268., 1260.
 1290., 1233., 1272., 1294., 1259., 1230., 1271., 1273., 1238., 1270.
 1250., 1261., 1291., 1277., 1230., 1260., 1231., 1274., 1260., 1261.
 1231., 1231., 1261., 1276., 1290., 1294., 1277., 1276., 1230., 1230.
 1251., 1260., 1297., 1276., 1254., 1310., 1259., 1260., 1261., 1276.
 1314., 1273., 1261., 1299., 1233., 1230., 1304., 1274., 1230., 1235.
 1232., 1276., 1261., 1239., 1291., 1265., 1269., 1271., 1303., 1259.
 1271., 1236., 1273., 1269., 1258., 1273., 1306., 1263., 1277., 1233.
 1294., 1274., 1230., 1233., 1293., 1271., 1233., 1273., 1230., 1234.
 1230., 1275., 1291., 1293., 1262., 1257., 1239., 1275., 1233., 1259.
 1296., 1277., 1259., 1263., 1273., 1279., 1279., 1267., 1235., 1296.
 1235., 1291., 1234., 1235., 1233., 1277., 1310., 1269., 1277., 1279.
 1275., 1290., 1236., 1250., 1279., 1254., 1279., 1252., 1253., 1230.
 1293., 1257., 1230., 1263., 1233., 1241., 1263., 1273., 1235., 1264.
 1303., 1230., 1271., 1294., 1292., 1290., 1275., 1260., 1272., 1271.
 1231., 1267., 1269., 1232., 1296., 1255., 1327., 1240., 1237., 1236.
 1231., 1258., 1260., 1230., 1264., 1267., 1270., 1238., 1270., 1270.

Table 17: Data for Mixing Run 1% #2 (volts x 10^3)

1167., 1164., 1139., 1154., 1164., 1176., 1162., 1156., 1165., 1207.
 1173., 1150., 1162., 1152., 1173., 1164., 1167., 1177., 1176., 1153.
 1152., 1164., 1173., 1170., 1172., 1176., 1181., 1153., 1157., 1159.
 1177., 1159., 1165., 1164., 1130., 1161., 1157., 1171., 1155., 1173.
 1155., 1160., 1173., 1159., 1162., 1177., 1156., 1154., 1153., 1161.
 1163., 1157., 1175., 1137., 1173., 1151., 1163., 1169., 1130., 1160.
 1149., 1176., 1184\3., 1161., 1166., 1176., 1142., 1139., 1151., 1175.
 1166., 1149., 1162., 1192., 1144., 1150., 1156., 1169., 1162., 1152.
 1165., 1175., 1170., 1152., 1162., 1166., 1177., 1164., 1165., 1135.
 1160., 1235., 1193., 1184., 1215., 1156., 1149., 1217., 1153., 1160.
 1216., 1172., 1147., 1194., 1153., 1184., 1188., 1163., 1167., 1253.
 1147., 1143., 1234., 1170., 1167., 1243., 1176., 1185., 1217., 1155.
 1166., 1203., 1160., 1153., 1163., 1170., 1155., 1155., 1181., 1177.
 1153., 1151., 1163., 1174., 1152., 1174., 1203., 1130., 1142., 1159.
 1153., 1173., 1170., 1160., 1176., 1179., 1150., 1149., 1162., 1177.
 1154., 1174., 1171., 1170., 1164., 1160., 1160., 1161., 1154., 1160.
 1164., 1171., 1160., 1166., 1175., 1160., 1150., 1165., 1150., 1176.
 1160., 1160., 1180., 1171., 1150., 1151., 1150., 1170., 1160., 1160.
 1177., 1131., 1161., 1161., 1192., 1160., 1133., 1150., 1174., 1176.
 1152\3., 1169., 1193., 1148., 1149., 1165., 1164., 1179., 1163., 1173.
 1207., 1145., 1159\0., 1153., 1172., 1176., 1166., 1177., 1139., 1163.
 1159., 1172., 1130., 1143., 1164., 1159., 1157., 1153., 1166., 1172.
 1134., 1146., 1154., 1154., 1170., 1176., 1156., 1136., 1138., 1159.
 1160., 1154., 1163., 1163., 1156., 1179., 1188., 1155., 1155., 1153.
 1134., 1154., 1147., 1157., 1131., 1164., 1151., 1163., 1174., 1150.
 1151., 1163., 1171., 1159., 1160., 1134., 1163., 1151., 1163., 1161.
 1179., 1165., 1154., 1174., 1131., 1141., 1151., 1159., 1166., 1164.
 1156., 1167., 1164., 1196., 1162., 1202., 1161., 1154., 1153., 1165.
 1163., 1164., 1160., 1173., 1206., 1148., 1161., 1165., 1174., 1155.
 1169., 1133., 1164., 1153., 1162., 1150., 1169., 1155., 1153., 1132.

Table 18: Data for Mixing Run 2% #1 (volts x 10^3)

1301., 1316., 1313., 1450., 1308., 1312., 1457., 1314., 1359., 1359.
 1354., 1470., 1324., 1283., 1365., 1391., 1393., 1321., 1315., 1421.
 1271., 1364., 1327., 1470., 1452., 1352., 1362., 1299., 1321., 1431.
 1293., 1335., 1294., 1420., 1291., 1328., 1398., 1304., 1305., 1361.
 1349., 1373., 1328., 1338., 1356., 1347., 1358., 1313., 1280., 1292.
 1339., 1372., 1286., 1334., 1434., 1326., 1325., 1287., 1347., 1300.
 1293., 1361., 1336., 1350., 1329., 1364., 1393., 1362., 1366., 1337., \
 1326., 1358., 1319., 1382., 1479., 1316., 1438., 1329., 1297., 1285.
 1300., 1381., 1317., 1365., 1386., 1374., 1316., 1410., 1371., 1325.
 1271., 1356., 1301., 1318., 1379., 1323., 1449., 1352., 1283., 1359.
 1294., 1397., 1354., 1386., 1420., 1373., 1466., 1342., 1342., 1430.
 1310., 1326., 1322., 1323., 1339., 1388., 1273., 1374., 1355., 1341.
 1305., 1301., 1273., 1351., 1360., 1306., 1338., 1362., 1357., 1350.
 1299., 1403., 1416., 1352., 1398., 1336., 1353., 1416., 1323., 1515.
 1296., 1314., 1332., 1348., 1319., 1266., 1277., 1334., 1419., 1383.
 1301., 1331., 1290., 1350., 1351., 1291., 1361., 1380., 1291., 1380.
 1341., 1410., 1391., 1280., 1350., 1350., 1300., 1401., 1281., 1400.
 1301., 1310., 1310., 1305., 1291., 1330., 1271., 1301., 1370., 1335.
 1410., 1341., 1320., 1344., 1377., 1321., 1312., 1368., 1308., 1310.
 1276., 1437., 1329., 1291., 1324., 1453., 1288., 1337., 1428., 1350.
 1306., 1344., 1304., 1307., 1389., 1321., 1300., 1332., 1335., 1374.
 1506., 1334., 1316., 1320., 1370., 1435., 1337., 1362., 1310., 1273.
 1346., 1435\6., 1358., 1283., 1323., 1478., 1376., 1289., 1427., 1296.
 1348., 1307., 1298., 1290., 1438., 1335., 1450., 1495., 1350., 1393.
 1359., 1285., 1390., 1291., 1338., 1405., 1392., 1356., 1375., 125\65.
 1346., 1399., 1327., 1269., 1336., 1483., 1335., 1330., 1444., 1297.
 1309., 1295\4., 1312., 1334., 1419., 1316., 1472., 1394., 1312., 1342.
 1314., 1351., 1304., 1299., 1280., 1346., 1352., 1379., 1324., 1308.
 1376., 1386., 1287., 1315., 1372., 1431., 1324., 1373., 1415., 1284.
 1288., 1324., 1321., 1370., 1346., 1326., 1390., 1429., 1319., 1334.

Table 19: Data for Mixing Run 2% #2 (volts x 10^3)

1274.,1251.,1263.,1280.,1247.,1269.,1286.,1264.,1330.,1265.
 1286.,1272.,1288.,1262.,1354.,1322.,1359.,1317.,1357.,1348.
 1266.,1263.,1261.,1539.,1460.,1396.,1344.,1305.,1259.,1317.
 1277.,1250.,1359.,1317.,1260.,1259.,1294.,1285.,1304.,1404.
 1265.,1262.,1268.,1260.,1348.,1272.,1337.,1336.,1386.,1402.
 1259.,1241.,1298.,1314.,1262.,1289.,1422.,1319.,1306.,1421.
 1274.,1289.,1300.,1299.,1292.,1284.,1351.,1313.,1367.,1372.
 1227.,1286.,1298.,1595.,1448.,1476.,1396.,1342.,1247.,1367.
 1270.,1243.,1290.,1292.,1236.,1252.,1283.,1257.,1292.,1446.
 1230.,1256.,1374.,1280.,1287.,1256.,1333.,1330.,1368.,1332.
 1267.,1297.,1307.,1729.,1430.,1550.,1355.,1358.,1267.,1293.
 1296.,1243.,1298.,1334.,1254.,1306.,1290.,1266.,1322.,1358.
 1270.,1267.,1312.,1270.,1294.,1275.,1337.,1323.,1336.,1324.
 1260.,1306.,1267.,1657.,1415.,1551.,1324.,1334.,1249.,1309.
 1391.,1271.,1331.,1420.,1240.,1340.,1260.,1240.,1271.,1340.
 1251.,1271.,1310.,1281.,1330.,1310.,1330.,1341.,1371.,1301.
 1281.,1250.,1281.,1601.,1440.,1450.,1340.,1430.,1230.,1290.
 1304.,1342.,1360.,1309.,1287.,1334.,1293.,1256.,1268.,1276.
 1270.,1318.,1291.,1254.,1288.,1324.,1290.,1274.,1399.,1288.
 1245.,1266.,1272.,1698.,1556.,1392.,1326.,1330.,1239.,1358.
 1252.,1294.,1313.,1337.,1298.,1245.,1253.,1264.,1270.,1289.
 1355.,1295.,1402.,1287.,1295.,1369.,1316.,1294.,1331.,1325.
 1299.,1276.,1372.,1668.,1570.,1366.,1313.,1313.,1233.,1332.
 1289.,1308.,1358.,1366.,1344.,1268.,1274.,1295.,1291.,1283.
 1419.,1289.,1302.,1299.,1609.,1426.,1421.,1301.,1271.,1350.
 1268.,1302.,1395.,1385.,1297.,1262.,1256.,1375.,1290.,1286.
 1388.,1334.,1323.,1288.,1284.,1314.,1295.,1283.,1444.,1306.
 1334.,1260.,1235.,1468.,1603.,1396.,1430.,1252.,1230.,1315.

Table 20: Data for Mixing Run 4% #1 (volts x 10³)

1726.,1577.,1522.,2496.,1770.,1552.,1581.,1537.,1446.,1517.
 1531.,1829.,1580.,1816.,2204.,1736.,1933.,1728.,1676.,2403.
 1977.,1646.,1971.,1593.,1736.,1554.,1727.,1646.,1780.,1522.
 2034.,1615.,1641.,2256.,1769.,1593.,1502.,1513.,1483.,1438.
 1502.,1684.,1512.,1969.,2390.,1670.,1981.,1570.,1563.,2392.
 1900.,1602.,1686.,1517.,1910.,2082.,1809.,1436.,2117.,1492.
 1684.,1658.,1590.,2287.,1548.,2024.,1470.,1534.,1431.,1486.
 1611.,1563.,1488.,2098.,2068.,1639.,1712.,1757.,1725.,2373.
 1804.,1624.,1637.,1531.,1586.,1869.,1526.,1459.,1849.,1940.
 1625.,1633.,1542.,2317.,1485.,1804.,1704.,1715.,1386.,1474.
 1537.,2074.,1726.,2168.,1954.,1626.,1823.,2211.,1608.,2254.
 1901.,1634.,1569.,1724.,1530.,1712.,1498.,1515.,1660.,1604.
 1687.,1676.,1515.,2246.,1467.,1529.,1919.,1484.,1622.,1549.
 1412.,1767.,1764.,2346.,2107.,2183.,1804.,1755.,1523.,2222.
 1612.,1629.,1515.,1823.,1623.,1755.,1807.,1601.,1638.,1691.
 1664.,1760.,1830.,2221.,1621.,1611.,2051.,1830.,1531.,1507.
 1504.,1564.,2111.,2296.,2121.,1876.,1850.,1740.,1521.,2191.
 1470.,1556.,1520.,1701.,1760.,1676.,1686.,1825.,1550.,1980.
 1922.,1544.,1874.,1895.,1663.,1724.,1576.,1805.,1879.,1520.
 1522.,1523.,1767.,2273.,2194.,1672.,1757.,1607.,1502.,2215.
 1594.,1537.,1738.,1842.,1585.,1678.,1733.,1640.,1583.,1877.
 1820.,1706.,1482.,2153.,1816.,1808.,1508.,1534.,1616.,1604.
 1506.,1438.,1810.,2186.,1941.,1520.,1757.,1686.,1473.,2466.
 1590.,1596.,1947.,1658.,1502.,1760.,1541.,1927.,2005.,2242.
 1590.,1560.,1430.,1886.,1782.,1712.,1507.,1583.,1670.,1623.
 1572.,1452.,1683.,2234.,1862.,1594.,1655.,1728.,1740.,2275.
 1625.,1529.,1753.,1642.,1476.,2234.,1529.,1550.,2331.,2605.
 1421.,1578.,1394.,1800.,1631.,1764.,1959.,1929.,1703.,1778.
 1634.,1554.,1718.,2230.,1807.,1708.,1594.,1877.,1610.,2106.
 1593.,2316.,1769.,1940.,1517.,1640.,1484.,1414.,1869.,2677.

Table 21: Data for Mixing Run 4% #2 (volts x 10³)

1315.,1389.,1516.,1335.,1651.,1359.,1352.,1427.,1395.,1385.
 1449.,1381.,1409.,1304.,1599.,1348.,1349.,1414.,1346.,1343.
 1427.,1384.,1346.,1345.,1576.,1400.,1380.,1379.,1322.,1418.
 1435.,1382.,1364.,1332.,1556.,1403.,1418.,1322.,1328.,1360.
 1372.,1444.,1323.,1355.,1470.,1428.,1516.,1323.,1331.,1359.
 1365.,1446.,1383.,1364.,1393.,1441.,1431.,1394.,1350.,1450.
 1396.,1364.,1468.,1474.,1400.,1402.,1370.,1421.,1330.,1405.
 1457.,1577.,1494.,1433.,1515.,1376.,1367.,1685.,1432.,1433.
 1398.,1540.,1354.,1369.,1433.,1328.,1370.,1592.,1408.,1357.
 1365.,1506.,1389.,1356.,1434.,1376.,1467.,1470.,1471.,1370.

Table 22: Data for Mixing Run 2% #3A (volts x 10^3)

1663.,1585.,1560.,1592.,1584.,1587.,1584.,1654.,1557.,1662.
 1589.,1518.,1505.,1592.,1559.,1610.,1617.,1616.,1555.,1687.
 1570.,1553.,1538.,1601.,1608.,1608.,1661.,1621.,1564.,1603.
 1548.,1505.,1554.,1615.,1611.,1586.,1638.,1654.,1571.,1595.
 1601.,1522.,1557.,1639.,1641.,1573.,1619.,1642.,1633.,1567.
 1583.,1591.,1610.,1604.,1582.,1615.,1616.,1549.,1671.,1543.
 1574.,1592.,1608.,1578.,1529.,1614.,1613.,1571.,1659.,1555.
 1612.,1642.,1599.,1587.,1512.,1585.,1588.,1682.,1621.,1639.
 1605.,1652.,1595.,1616.,1553.,1619.,1614.,1616.,1600.,1620.
 1626.,1627.,1580.,1653.,1578.,1651.,1617.,1614.,1626.,1657.

Table 23: Data for Mixing Run 2% #3B (volts x 10^3)

1408.,1408.,1456.,1422.,1338.,1454.,1387.,1491.,1321.,1466.
 1313.,1440.,1409.,1426.,1414.,1484.,1598.,1378.,1327.,1360.
 1455.,1511.,1416.,1448.,1338.,1372.,1482.,1366.,1437.,1364.
 1435.,1392.,1408.,1386.,1332.,1330.,1430.,1544.,1388.,1372.
 1388.,1372.,1365.,1334.,1314.,1339.,1452.,1483.,1384.,1458.
 1360.,1485.,1333.,1320.,1395.,1526.,1394.,1474.,1345.,1441.
 1366.,1404.,1359.,1336.,1383.,1370.,1423.,1418.,1454.,1433.
 1400.,1406.,1342.,1330.,1400.,1366.,1382.,1400.,1479.,1415.
 1349.,1434.,1431.,1398.,1381.,1378.,1404.,1369.,1554.,1383.
 1352.,1414.,1385.,1330.,1350.,1475.,1313.,1319.,1471.,1331.

Table 24: Data for Mixing Run 2% #3C (volts x 10^3)

1593.,1563.,1625.,1592.,1692.,1706.,1641.,1659.,1674.,1622.
 1557.,1581.,1570.,1592.,1639.,1702.,1694.,1642.,1659.,1640.
 1502.,1597.,1536.,1640.,1602.,1673.,1715.,1641.,1624.,1675.
 1530.,1619.,1585.,1600.,1638.,1625.,1694.,1591.,1630.,1734.
 1562.,1689.,1672.,1583.,1660.,1618.,1697.,1607.,1636.,1710.
 1581.,1624.,1653.,1550.,1594.,1656.,1590.,1690.,1590.,1671.
 1592.,1523.,1540.,1561.,1594.,1668.,1594.,1740.,1552.,1682.
 1595.,1493.,1495.,1583.,1600.,1656.,1639.,1656.,1579.,1688.
 1577.,1568.,1591.,1576.,1608.,1652.,1640.,1580.,1666.,1676.
 1586.,1583.,1702.,1636.,1591.,1656.,1660.,1539.,1682.,1656.

Table 25: Data for Mixing Run 2% #3D (volts x 10^3)

1626.,1375.,1366.,1428.,1465.,1432.,1357.,1499.,1491.,1353.
1540.,1349.,1527.,1381.,1447.,1441.,1442.,1424.,1402.,1530.
1654.,1441.,1450.,1438.,1440.,1453.,1371.,1379.,1445.,1382.
1479.,1405.,1385.,1494.,1338.,1511.,1380.,1377.,1387.,1415.
1386.,1534.,1401.,1428.,1395.,1467.,1328.,1417.,1359.,1494.
1384.,1466.,1570.,1380.,1334.,1340.,1360.,1461.,1384.,1355.
1396.,1480.,1593.,1436.,1410.,1389.,1426.,1495.,1407.,1401.
1361.,1449.,1518.,1391.,1436.,1451.,1425.,1574.,1584.,1447.
1445.,1366.,1426.,1476.,1639.,1406.,1384.,1422.,1466.,1389.
1548.,1371.,1388.,1550.,1367.,1412.,1338.,1396.,1627.,1381.

Table 26: Data for Mixing Run 2% #3E (volts x 10^3)

2462., 2443., 2436., 2446., 2436., 2453., 2450., 2445., 2442., 2448.
 2435., 2445., 2425., 2460., 2423., 2425., 2420., 2382., 2438., 2449.
 2446., 2428., 2433., 2450., 2432., 2458., 2447., 2432., 2440., 2408.
 2469., 2434., 2438., 2437., 2443., 2444., 2435., 2463., 2448., 2438.
 2433., 2445., 2436., 2443., 2433., 2414., 2429., 2445., 2447., 2447.
 2440., 2432., 2445., 2445., 2444., 2436., 2426., 2433., 2454., 2418.
 2448., 2446., 2447., 2441., 2451., 2454., 2415., 2466., 2447., 2443.
 2437., 2442., 2441., 2436., 2433., 2429., 2430., 2450., 2447., 2444.
 2448., 2439., 2434., 2437., 2438., 2440., 2442., 2437., 2435., 2431.
 2453., 2444., 2437., 2449., 2450., 2457., 2427., 2453., 2437., 2433.
 2439., 2454., 2423., 2453., 2450., 2442., 2426., 2451., 2445., 2437.
 2451., 2431., 2436., 2445., 2436., 2430., 2434., 2441., 2442., 2432.
 2466., 2449., 2428., 2448., 2458., 2456., 2422., 2425., 2448., 2444.
 2428., 2442., 2443., 2429., 2433., 2436., 2443., 2453., 2450., 2440.
 2422., 2438., 2432., 2439., 2431., 2446., 2450., 2445., 2447., 2434.
 2451., 2441., 2440., 2421., 2440., 2446., 2446., 2441., 2450., 2441.
 2420., 2431., 2444., 2436., 2446., 2431., 2444., 2455., 2421., 2441.
 2420., 2430., 2430., 2456., 2434., 2436., 2445., 2445., 2431., 2430.
 2457., 2447., 2428., 2434., 2438., 2428., 2433., 2453., 2436., 2442.
 2442., 2438., 2437., 2432., 2448., 2447., 2420., 2448., 2442., 2440.
 2436., 2438., 2434., 2445., 2430., 2424., 2442., 2438., 2436., 2442.
 2453., 2452., 2436., 2438., 2440., 2446., 2429., 2436., 2452., 2435.
 2437., 2444., 2433., 2428., 2447., 2454., 2423., 2450., 2435., 2447.
 2436., 2436., 2439., 2451., 2451., 2441., 2444., 2441., 2439., 2448.
 2454., 2454., 2434., 2427., 2442., 2444., 2436., 2430., 2448., 2432.
 2445., 2453., 2443., 2437., 2447., 2450., 2427., 2454., 2445., 2460.
 2424., 2434., 2428., 2450., 2451., 2424., 2436., 2441., 2438., 2452.
 2450., 2439., 2434., 2448., 2445., 2440., 2454., 2457., 2464., 2436.
 2453., 2441., 2439., 2432., 2456., 2438., 2434., 2440., 2441., 2447.
 2421., 2446., 2436., 2450., 2446., 2427., 2426., 2442., 2443., 2441.

Table 27: Data for Mixing Run 1% MSP (volts x 10^3)

3860., 3864., 3714., 3764., 3789., 3902., 3828., 3788., 4004., 3828.
 3789., 3854., 3645., 3670., 3826., 3760., 3813., 3786., 3755., 3787.
 3782., 3718., 3859., 3657., 3730., 3771., 3751., 3591., 3842., 3722.
 3852., 3818., 3710., 3650., 3711., 3850., 3843., 3806., 3995., 3767.
 3858., 3839., 3702., 3810., 3704., 3580., 3856., 3721., 3726., 3743.
 3792., 3778., 3805., 3667., 3816., 3861., 3642., 3677., 3816., 3794.
 3855., 3886., 3698., 3772., 3792., 3838., 3761., 3786., 3991., 3859.
 3853., 3898., 3802., 3763., 3644., 3733., 3844., 3722., 3768., 3850.
 3780., 3742., 3712., 3682., 3791., 3804., 3648., 3741., 3844., 3796.
 3784., 3905., 3743., 3750., 3831., 3774., 3750., 3846., 3896., 3905.
 3816., 3888., 3782., 3863., 3723., 3744., 3793., 3716., 3763., 3845.
 3728., 3740., 3672., 3671., 3768., 3703., 3557., 3826., 3798., 3739.
 3761., 3933., 3816., 3713., 3908., 3816., 3776., 3766., 3774., 3818.
 3832., 3865., 3826., 3864., 3574., 3802., 3786., 3723., 3785., 3836.
 3776., 3765., 3624., 3706., 3687., 3667., 3697., 3901., 3762., 3782.
 3794., 3950., 3870., 3746., 3890., 3810., 3760., 3890., 3770., 3760.
 3832., 3790., 3834., 3870., 3763., 3774., 3760., 3760., 3784., 3700.
 3780., 3782., 3582., 3714., 3736., 3610., 3764., 3912., 3680., 3784.
 3798., 3892., 3885., 3797., 3888., 3780., 3780., 3893., 3794., 3805.
 3842., 3862., 3787., 3700., 3769., 3842., 3750., 3752., 3743., 3826.
 3812., 3828., 3647., 3752., 3750., 3623., 3748., 3927., 3801., 3639.
 3801., 3838., 3864., 3789., 3914., 3857., 3818., 3859., 3816., 3796.
 3783., 3886., 3798., 3711., 3810., 3811., 3822., 3829., 3776., 3795.
 3720., 3879., 3657., 3808., 3776., 3662., 3738., 3834., 3777., 3590.
 3832., 3859., 3782., 3861., 3835., 3859., 3852., 3815., 3776., 3800.
 3796., 3898., 3768., 3638., 3800., 3809., 3754., 3792., 3812., 3752.
 3710., 3914., 3726., 3819., 3824., 3719., 3630., 3702., 3792., 3596.
 3874., 3897., 3718., 3914., 3881., 3748., 3823., 3824., 3721., 3838.
 3673., 3845., 3791., 3742., 3833., 3741., 3727., 3752., 3845., 3757.
 3781., 3878., 3747., 3867., 3858., 3784., 3705., 3506., 3790., 3648.

Table 28: Data for Mixing Run 2% MSP (volts x 10^3)

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