LEVEL II

Materials Research Report 3-78

29 AUGUST 1978

REVIEW OF DATA GENERATED WITH INSTRUMENTS USED TO DETECT AND MEASURE IONIC CONTAMINANTS ON PRINTED-WIRING ASSEMBLIES

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MATERIALS RESEARCH REPORT NO. 3-78

SUBJECT: Review of Data Generated with Instruments Used to Detect and Measure Ionic Contaminants on Printed-Wiring Assemblies

ABSTRACT:

The comparison of test methods; the manufacture, cleaning, and controlled ionic contamination of the printed wiring assemblies; the calibration of each test instrument; and the test data are presented. The steps of each method are detailed. Interim instrument factors are elucidated as well as the rationale for their development.

INTRODUCTION:

An investigation was undertaken to measure various contaminant levels on equivalent printed wiring assemblies. The results obtained utilizing the procedure in a Naval Avionics Center (NAC) Modified MIL-P-28809 test were compared with those obtained using commercially available test instruments. Measurements in the NAC-Modified MIL-P-28809 test were made with a Beckman Conductivity Bridge (Model RC-16C) and a digital read-out Markson ElectroMark Conductivity Analyzer (Model J-4405). Comparison measurements were made with a NAC-Modified Alpha Ionograph ®, a Kenco Omega Meter ® (Model 200), and a NAC-Modified DuPont Ion Chaser ®. Uncomplicated printed wiring assemblies were used in studies documented in Materials Research Report 3-72. However, printed wiring assemblies with quite different assembly components were designed for this study. These varied assemblies were designed to detect any difference in response of the various test procedures.

For constant levels of contamination, the amount of contamination indicated by each instrument invariably fell in the same order. The highest to the lowest indications of ionic contaminants always fell in this order:

Highest - NAC-Modified DuPont Ion Chaser®
NAC-Modified Alpha Ionograph®
Kenco Omega Meter®

Lowest - NAC-Modified MIL-P-28809

Inspection of the data indicated that each test instrument had good

precision. The proposed interim instrument factors are the consensus judgment of representatives from industry and NAC present at a review meeting* held at NAC on 9-10 February 1978.

PROCEDURE:

In order to determine the effect of the printed wiring assemblies configuration on the response of the various test instruments, nine different printed wiring assemblies were designed and eighteen of each kind were fabricated (Appendix A-2 - A-10). The configurations of these assemblies show the probability of a wide range of possible entrapment of ionic contaminants.

Verification of the cleaning procedure was accomplished in the following manner. Eighteen AV21921 jumper-wire-assembly boards (Appendix A-10) were first cleaned in the vapor area of a degreaser using inhibited 1-1-1 trichloroethane. Next, all eighteen printed wiring assemblies were transferred to a cleaning system containing a wash solution composed of 75 volume-% isopropyl alcohol and 25 volume-% deionized water (Appendix A-11). The resistivity of this wash solution was originally greater than 25×10^6 ohm-cm. After introduction of the assemblies, the resistivity of the wash solution fell to 13.8×10^6 ohm-cm. The wash solution was circulated through the cleaning system until its resistivity reached 20×10^6 ohm-cm. At that time, the assemblies were removed from the cleaning system and spray rinsed using a plastic squeeze wash bottle containing wash solution with a resistivity greater than 25×10^6 ohm-cm. Handled with clean forceps, the printed wiring assemblies were blown dry with water pumped nitrogen and placed in individual known-clean plastic bags. The bags were closed and sealed with plastic tape.

Proof of cleaning was established by testing all of the above printed wiring assemblies by the NAC-Modified MIL-P-28809 Method using a Beckman Conductivity Bridge. The volume of test solution collected was equal to 10-ml per square inch of board plus component area. Statistical analysis of the resistivity of the collected test solution of each individual printed wiring assembly gave the following results:

$$\bar{X} = 11.468 \times 10^6 \text{ ohm-cm}; \quad \sigma = 3.59 \times 10^6 \text{ ohm-cm}$$

$$\bar{X} + 3\sigma = 22.22 \times 10^6 \text{ ohm-cm}$$

$$\bar{X} - 3\sigma = 5.92 \times 10^6 \text{ ohm-cm}$$

Since the lowest resistivity of washings measured was 9.0×10^6 ohm-cm, it is evident that the printed wiring assemblies were adequately cleaned.

* *See list of attendees, PWB Ionic Contaminants Meeting, Naval Avionics Center, 9-10 Feb 1978 (Appendix A-1).*

Each unique group of 18 printed wiring assemblies was cleaned in this manner. The lot cleaning was deemed to be adequate when the measured resistivity of test solution from any specimen in the sample of three printed wiring assemblies was not lower than 9×10^6 ohm-cm when tested by the NAC-Modified MIL-P-28809 method. These three proof-of-cleaning printed wiring assemblies were not used subsequently. The remaining fifteen printed wiring assemblies were then contaminated with MIL-F-14256D, Type RA Flux.

Contamination of the printed wiring assemblies was accomplished by dipping the assemblies into the flux and withdrawing them at the rate of eight inches per minute by a synchronous motor. The flux-coated assemblies were hung vertically and allowed to drain for five minutes; hung in an air circulating oven for thirty minutes at 107°C (225°F); removed, allowed to cool; and placed in individual known-clean plastic bags. The top of each bag was folded over to form a flap which was secured with plastic tape.

The above flux was composed of 50 g/l WW gum rosin, purchased to meet requirements of LL-R-626; 1 g/l hexadecyltrimethyl ammonium chloride (Eastman Chemical Co., Catalog #9536); and the remainder ACS Reagent Grade Isopropyl Alcohol. The flux had a specific gravity of 0.807 at 23°C (73°F). The resistivity of water extract, determined in accordance with MIL-F-14256D, was 5.8×10^4 ohm-cm. This value meets the water extract resistivity requirements for MIL-F-14256D, type RA Flux.

NAC TEST APPARATUS:

It became evident that the procedure in para 4.8.3 of MIL-P-28809 is most satisfactory for small test assemblies. Since larger assemblies required more test solution[1] than was convenient to deliver from a plastic squeeze wash-bottle, MIL-P-28809 was modified. A five-gallon plastic rectangular carboy containing the test solution was elevated so that the distance from the top of the contained solution to the top of the work bench was 4 feet 8 inches. The test solution passed through Tygon® tubing to a mixed-bed deionizer column, through an in-line conductivity cell, thence to a stainless steel needle valve, and through additional Tygon® tubing terminating in a stainless steel nozzle 2.75 inches (70 mm) long with a nominal inside diameter of 0.0625 inches (1.59 mm). The test solution was sprayed over both sides of the specimens which were suspended over an 8" polyethylene funnel. The test solution was collected in a TPX-polymethyl pentene beaker which was premarked to a computed volume (10 ml/sq.in.-area computed from both board and component dimensions). Resistivity and conductivity

[1] *Throughout this report, "test solution" denotes a solution composed of 75 volume-percent ACS Reagent Grade 2-Propanol (Isopropyl Alcohol) and 25 volume-% deionized water.*

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readings were made with a CEL-A001 dip cell (K-0.0100/cm) attached to a Beckman Model RC-16C Conductivity Bridge. Conductivity measurements were made subsequently on the same solution with a Model J-4405 Markson ElectroMark Conductivity Analyzer. The test solution reservoir level was maintained to standardize head pressure and consequently the velocity of the test solution at the delivery tip. The Conductivity Bridge was connected to a double-pole double-throw switch. Thus, resistivity measurements of the test solution were made before delivery and after spraying the test specimens.

New plastic ware was cleaned and reserved exclusively for this test. It is imperative that this laboratory ware be used for this test only. Experimentation proved that rinsing the dip probe, funnel and beaker with fresh solution provided sufficient cleaning between test runs on the same day.

This modified apparatus improved the precision of measurements because the solution was fresh from the ion-exchange column and had no opportunity to absorb carbon dioxide from the air before being ejected at the delivery tip. Typical resistivity of the test solution before use is 25 x 10^6 ohm-cm. Also, for continuous operation, elimination of the squeeze bottle significantly reduced operator fatique.

> ADEQUATE VENTILATION SHOULD BE PROVIDED WHEN PERFORMING IONIC CONTAMINANT TESTING IN ACCORDANCE WITH MIL-P-28809. PREFERABLY, TESTING WITH PORTABLE INSTRUMENTATION SHOULD BE PERFORMED IN A FUME HOOD!

BECKMAN CONTINUITY BRIDGE:

The Beckman, Model RC-16C, Conductivity Bridge (Beckman Instruments, Cedar Grove, NJ 07009) is a compact, portable, completely solid state, manually balanced general purpose conductivity bridge. It is a wide-range instrument of high sensitivity and accuracy operating on self-contained batteries or direct from an AC Line. It may be used for measurements in grounded or isolated containers. It is provided with a dual color-coded scale for simultaneous resistance and conductance measurements over the ranges of 0.2 to 2,500,000 ohms-cm and 0.4 to 5,000,000 micromhos/cm. This range is modified with the cell constant of the conductivity cell. The test solution in this study is poorly conductive. The use of a conductivity dip cell with a low constant (CEL-AC[illegible]; K=0.0100/CM) is required. Measurements are made utilizing the null indicating meter which also functions as a battery condition indicator.

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MARKSON CONDUCTIVITY ANALYZER:

The Markson®, Model J-4405, ElectroMark Conductivity Analyzer (Markson Science, Inc., Del Mar, CA 92014) is a digital display conductivity meter with an operating range of 0 - 199,900 micromhos/cm. The sensing probe is a cylindrical tube with gold-plated electrodes inside. A thermistor inside the tube provides automatic temperature compensation from 0 - 100°C.

KENCO OMEGA METER

The Kenco, Model 200, Omega Meter®, (Kenco Alloy and Chemical Co., Inc., Addison, IL 60101) is an instrument specifically designed for measuring ionic contaminants on printed wiring assemblies. It consists of a reservoir of test solution, mixed-bed deionizer columns in parallel, a pump, a test chamber with conductivity cell, a timer, a plotter and a control console. It has a programmable electronic interlock system. In use, the pump forces the test solution out of the reservoir, through the deionizer columns into the test chamber and back into the reservoir. When the resistivity of the test solution in the test chamber has reached a preselected value, the test chamber is isolated from the loop. The volume of test solution in the test chamber is adjusted for the surface area of the specimens being examined. The printed wiring assemblies are immersed in the chamber and a magnetic stirrer agitates the test solution. A timer is set and, as the test proceeds, the resistivity is continously measured and recorded on chart paper.

ALPHA IONOGRAPH®, NAC-MODIFIED:

The Ionograph® (Alpha Metals, Jersey City, NJ 07304) is an instrument designed for measuring ionic contaminants on printed wiring assemblies. It consists of a metering pump, a mixed-bed deionizer column, a test chamber, an in-line conductivity cell, a meter, an integrator, a plotter and a control console. It is a closed loop system in which the test solution continuously circulates throughout the test. When a test is underway, the metering pump forces the test solution through the deionizer column, through the test chamber in which the specimen is suspended, through the in-line conductivity cell and back to the pump. The sodium chloride equivalent of the ionic contaminants is continuously measured, integrated, and plotted on chart paper. NAC modified the instrument by installing a larger mixed-bed deionizer (Barnstead Hose Nipple cartridge, D8902HN, Ultra-pure), a relay to stop the pump when a pre-selected conductivity base-line is reached, and a test chamber with a capacity of four liters. A magnetic stirrer agitates this large volume of test solution.

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DUPONT ION CHASER®, NAC-MODIFIED:

The Ion Chaser ("Freon" Products Laboratory, E. I. du Pont de Nemours & Co., Wilmington, DE 19898) is an instrument used for measuring the ionic contaminants level on printed wiring assemblies. It consists of a metering pump, a mixed-bed deionizer column, six test chambers connected with Tygon® tubing and twelve 3-way valves (two per test chamber), an in-line conductivity cell, a multiple magnetic stirrer, a meter, an integrator, a plotter, and suitable consoles. Prior to a test, the solution in all six chambers is circulated sequentially until a preselected conductivity base line is obtained. The test chambers are isolated from the loop. A specimen is placed in each chamber and allowed to extract for one hour. The specimens are removed from the chambers. Test solution from each chamber is then consecutively pumped through the measuring section until the preselected conductivity base line is reached. The integrator then displays the sodium chloride equivalent of the ionic contaminants. The instrument was modified by installing a larger mixed bed deionizer column (Barnstead Hose-Nipple Cartridge, D8902HN Ultra-pure).

NAC-MODIFIED MIL-P-28809 METHOD, CALIBRATION CURVE FOR:

STANDARD SODIUM CHLORIDE SOLUTIONS:

SOLUTION TO BE ADDED FROM A MICROLITER SYRINGE:

1. Dry reagent grade sodium chloride at 105°C for 4 hours minimum or overnight. Cool in a dessicator.
2. Weigh 10.0000± 0.0002 g of the dried salt and carefully transfer to a clean 1-liter volumetric flask.
3. Dissolve with high quality distilled or deionized water and dilute to 1-liter. Stopper tightly.
4. Label: NaCl-S; 10 g/l NaCl (30 µl = 300 µg NaCl).

SOLUTION TO BE ADDED FROM A 50-ml BURET:

1. Dry reagent grade soldium chloride at 105°C for 4 hours minimum or overnight. Cool in a desiccator.
2. Weigh 6.0000 ± 0.0002 g of the dried salt and carefully transfer to a clean 1-liter volumetric flask.

3. Dissolve with high quality distilled or deionized water and dilute to 1-liter. Label NaCl-A; 6 g/l NaCl.
4. Pipet 10 ml of the NaCl-A solution to a clean 1-liter volumetric flask. Dilute to 1-liter with test solution[a]. Stopper and mix well.
5. Label: NaCl-B; 0.06 g/l NaCl (5-ml = 300μ NaCl).

ACQUISITION OF CALIBRATION DATA:

Operate the conductivity and/or resistivity bridge, with appropriate conductivity cell, according to the manufacturer's instructions. It should measure accurately resistivity in the range between 1×10^6 ohm-cm and 25×10^6 ohm-cm (conductivity in the range between 0.04×10^{-6} mho/cm and 1×10^{-6} mho/cm).

Add 2-liters of test solution to a clean TPC-Polymethyl pentene beaker. Stir magnetically for two minutes. Measure the resistivity/conductivity of the solution with the bridge that is to be calibrated. If resistivity measures less than 6×10^6 ohm-cm (conductivity measures more than 0.167×10^{-6} mho/cm), reclean the apparatus and repeat procedure. A valid calibration cannot be made unless the virgin test solution has a resistivity of at least 6×10^6 ohm-cm (conductivity = 0.167×10^{-6} mho/cm).

ADDITION OF STANDARD SODIUM CHLORIDE SOLUTION WITH A MICROLITER SYRINGE:

1. Measure and record the temperature of the test solution above.
2. Add 30μl of NaCl-S (30μl = 300μg NaCl) with a microliter syringe.
3. Mix test solution for 2 minutes. Measure and record the resistivity/conductivity.
4. Repeat steps 2 and 3 until a total of ten 30μl additions of NaCl-S (3000μg NaCl) has been made.

ADDITION OF STANDARD SODIUM CHLORIDE SOLUTION WITH A 50-ml BURET:

Proceed as above, adding 5-ml portions of NaCl-B, until a total of ten 5-ml additions of NaCl-B (3000μg NaCl) has been made.

[a] *75-volume-percent 2-propanol solution (minimum resistivity - 25×10^6 ohm-cm) was used to dilute this standard. If water was used for this dilution, error would be introduced because the final alcohol-water ratio of the test solution would not be 75% 2-propanol, 25% water.*

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PLOTTING CALIBRATION CURVE:

This method is valid for additions made with either NaCl-S or NaCl-B solutions.

Study the Calibration Curve for MIL-P-28809 Method using Beckman Bridge (Appendix A-12) and the Calibration Curve for MIL-P-28809 using Markson Meter (Appendix A-13).

Plot the calibration curve on 2-cycle log-log graph paper. Plot this carefully because it will be used to calculate the amount of ionic contaminants.

IONOGRAPH®, CALIBRATION CURVE FOR:

NaCl Standard Solutions: Prepare appropriate NaCl Standard Solutions as described on pages 6 and 7.

PREPARATION OF TEST INSTRUMENT:

1. Fill the Ionograph® with test solution according to the manufacturer's instructions. NAC's test chamber for this study had a volume of four liters.
2. Turn on the electrical power switch.
3. Set the pump rate adjustment to 9.
4. Set the integrator count rate at 40 counts/sec.
5. Set the meter range to X1.
6. Turn on the pump.
7. Turn on the recorder.
8. Run the pump until the conductivity meter reads 0.025 μ mho/cm.
9. Adjust the integrator to turn off the counter and stop the pump. (On unmodified Ionographs, the pump may be stopped manually when the meter falls to 0.025 μ mho/cm. Null and balance the integrator against this level as a base line.)

ADDITION OF STANDARD SODIUM CHLORIDE SOLUTION WITH A MICROLITER SYRINGE:

1. Measure and record the temperature of the test solution.
2. Add 30μ l of NaCl-S (30μ l = 300μ g NaCl).
3. Turn on the electrical power switch.
4. Turn on the pump.

5. Turn on the integrator counter.
6. Turn on the recorder.
7. Allow the pump to run until the conductivity meter reads 0.025 μ mho/cm.
8. Turn off the pump. (The NAC-Modified Ionograph automatically turns off the pump upon reaching the set base line.)
9. Record the integrator count on the strip chart.
10. Repeat steps 2-9 increasing the amount of NaCl-S by 30μl each time until the final addition is 300μl (3000μg NaCl).

ADDITION OF STANDARD SODIUM CHLORIDE SOLUTION WITH A 50-ml BURET:

Proceed as above. Add NaCl-B in 5 ml increments until the final addition is 50 ml (3000 μg NaCl).

PLOTTING CALIBRATION CURVE:

This method is valid for additions made with either NaCl-S or NaCl-B Standard Solutions.

Study the Calibration Curve for the Ionograph® (Appendix A-14).

Plot the calibration curve on 2-cycle log-log paper. Plot this carefully because it will be used to calculate the amount of ionic contaminants.

ION CHASER®, CALIBRATION CURVE FOR:

NaCl Standard Solutions: Prepare appropriate NaCl Standard Solutions as described on pages 6 and 7.

PREPARATION OF TEST INSTRUMENT:

1. Fill the Ion Chaser® with test solution according to manufacturer's instructions.
2. Turn on the electrical power.
3. Set pump rate setting on 9.
4. Check valving to make sure solution is being pumped to and from cell number 1.
5. Make sure that conductivity meter is operating on the green scale.
6. Turn on the integrator power.
7. Adjust integrator counter to zero.

8. Allow the pump to run until the conductivity meter reads 0.025 μ mho/cm.
9. Adjust the integrator to turn off the counter.

ADDITION OF STANDARD SODIUM CHLORIDE SOLUTION WITH A MICROLITER SYRINGE:

1. Measure and record the temperature of the solution.
2. Add 30 μ l of NaCl-S solution (30 μ l = 300 μ g NaCl) to cell number 1.
3. Turn on the electrical power.
4. Turn on the pump.
5. Turn on integrator counter.
6. Turn on recorder.
7. Run the pump until the conductivity meter reads 0.025 μ mho/cm. (The indicator light should go out at this reading.)
8. Turn off the pump.
9. Record the integrator count.
10. Repeat steps 2-9 increasing the amount of NaCl-S by 30 μ l each time until the final addition is 300 μ l (3000 μ g NaCl).

ADDITION OF STANDARD SODIUM CHLORIDE SOLUTION WITH A 50 ml-BURET:

Proceed as above. Add NaCl-B in 5 ml increments until the final addition is 50 ml (3000 μ g NaCl).

PLOTTING CALIBRATION CURVE:

This method is valid for either NaCl-S or NaCl-B Standard Solutions.

Study the Calibration Curve for the Ion Chaser (Appendix A-15).

Plot the calibration curve on 2 cycle log-log paper. Plot this carefully because it will be used to calculate the amount of ionic contaminants.

OMEGA METER®, CALIBRATION CURVE FOR:

NaCl Standard Solutions: Prepare appropriate NaCl Standard Solutions as described on pages 6 and 7.

PREPARATION OF TEST INSTRUMENT:

1. Fill the Omega Meter® with test solution.

2. Turn on the electrical power.
3. Adjust the high limit set point past 20.
4. Turn on the Clean Cycle.
5. Fill and empty the test chamber until the meter needle reaches the maximum resistivity setting.
6. Adjust the resistivity high limit set point to 20. This illuminates the Clean Cycle COMPLETE button and activates an audible alarm.
7. Manipulate drain and fill push-switches until the test chamber contains exactly 2 liters of test solution (50 sq.in. line on test chamber). The instrument is now ready for calibration.

ADDITION OF STANDARD SODIUM CHLORIDE SOLUTION WITH MICROLITER SYRINGE:

1. Measure and record the temperature of the test solution in the test chamber.
2. Set the timer for 3 minutes.
3. Add 30μl of NaCl-S solution (30μl = 300μg NaCl).
4. Push on the Recorder ON switch.
5. Push on the Test Cycle ON switch. (Unless Clean Cycle COMPLETE switch is illuminated, no calibration or test can be performed.)
6. At the end of three minutes, an alarm will sound, the ACCEPT indicator will be illuminated, and the timer will reset automatically. Read and record the resistivity of the solution.
7. Adjust the high limit set point on the meter to a value somewhat less than the reading in Step 6.
8. Push Clean Cycle ON button. Clean Cycle COMPLETE button should illuminate immediately. An alarm will sound. Instrument is now ready for further calibration.
9. Repeat steps 3-8 until a total of ten 30μl additions of NaCl-S solution has been made. (300μl = 3000μg NaCl).

ADDITION OF STANDARD SODIUM CHLORIDE SOLUTION WITH A 50-ml BURET:

Proceed as above, adding 5-ml portions of NaCl-B, until a total of ten 5-ml additions of NaCl-B (3000μg NaCl) has been made.

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PLOTTING CALIBRATION CURVE:

This method is valid for additions made with either NaCl-S or NaCl-B Standard Solution.

Study the Calibration Curve for the Omega Meter (Appendix A-16).

Plot the calibration curve on 2 cycle log-log paper. Plot this carefully because it will be used to calculate the amount of ionic contaminants.

IONIC CONTAMINANT TESTING:

GENERAL:

The results of all assemblies tested with each method were entered as raw data in a log book. To maintain as much objectivity as possible, the raw data was not converted until the entire series of comparison tests was completed.

The assemblies were always handled with clean forceps or clean hemostats. These assemblies were always stored individually in known-clean plastic bags during any in-process delay. The continued accuracy of the test instruments was assured by periodic standardization with standard salt solutions. Three printed wiring assemblies of each drawing number of MIL-F-14256 Type RA flux contaminated assemblies were tested by each test method.

NAC-MODIFIED MIL-P-28809 TEST METHOD (See pages 3 and 4):

A scrupulously clean TPX-Polymethyl pentene beaker was premarked to the computed volume (10 ml/sq.in. - area computed from the board and attached component dimensions). A scrupulously clean polyethylene funnel was used to direct the 25 x 10^6 ohm-cm test solution into the beaker. This test solution was directed from a nozzle at a constant head in such a manner as to uniformly wash all surfaces of the printed wiring assembly. Washing was stopped when the premarked volume was reached.

BECKMAN CONDUCTIVITY BRIDGE, Model RC-16C, Serial No. 5503;
CEL-A001 DIP Cell (K - 0.0100/cm):

Essentially, the Beckman Instrument was used in accordance with the manufacturer's instructions to measure the resistivity of the test solution collected by the NAC-Modified MIL-P-28809 Test Method.

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MARKSON ELECTROMARK® CONDUCTIVITY ANALYZER, Model J4005, Serial No. 7211:

Essentially, the Markson ElectroMark® Conductivity Analyzer was used in accordance with the manufacturer's instructions to measure the conductivity of the wash solution that was first measured with the Beckman Conductivity Bridge. This measurement was made immediately following the Beckman Conductivity Bridge measurement.

KENCO OMEGA® METER, Model 200, Serial No. 1008:

All printed wiring assemblies were tested according to the manufacturer's operating instructions except for assemblies with so much surface area that 40 ml/in^2 of surface would exceed the test chamber's capacity. A 15 minute extraction time was used for each printed wiring assembly. Those printed wiring assemblies with so much surface area that they could not be tested with 40 ml/in^2 without overflowing the test chamber were tested with 20 ml/in^2 of test solution. It should be noted that the calibration curve generated for the Kenco Omega® Meter was used to convert the measured resistivities to μg NaCl equivalent/in^2.

ALPHA IONOGRAPH®, NAC-MODIFIED, Serial No. 207-WI:

The NAC-Modified Alpha Ionograph® was filled with test solution. It was operated per the manufacturer's instructions except 0.050μ mho/cm was used as the conductivity baseline or cutoff, rather than the so-called natural conductivity base line (the lowest conductivity that the system could attain). Generally, a system factor, μg of NaCl added divided by the number of integrator counts accumulated in returning to the baseline, was determined before each set of three printed wiring assemblies of a given drawing number were tested. This system factor multiplied by the integrator count determined the μg of NaCl equivalents on the printed wiring assembly tested.

DUPONT ION CHASER®, NAC-MODIFIED:

The NAC-Modified DuPont Ion Chaser® was filled with test solution. It was used according to DuPont's Instructions except 0.050μ mho/cm was used as the conductivity baseline or cutoff rather than the so-called natural conductivity (the lowest conductivity that the system could attain). Generally, a system factor, μg of NaCl added divided by the number of integrator counts accumulated in returning to the baseline, was determined for each of three test chambers before each set of three printed wiring assemblies of a given drawing number were

tested. In the testing mode, each printed wiring assembly was allowed to extract for one hour; then the assembly was removed. The contents of each individual tank were circulated through the system until the system reached the set base line (0.050μ mho/cm). The integrator count multiplied by the system factor for the tank used gave theμ g of NaCl equivalents on the printed wiring assembly tested.

DISCUSSION:

The NAC test values found by each method are tabulated in Table I (Appendix A-17). The calibration curves (Appendix A-12 through A-16) were used to convert the raw test data to μ g of NaCl equivalents per square inch of the total board and component area for each printed wiring assembly tested by the NAC-Modified MIL-P-28809 Test Method and the Kenco Omega® Meter. As a systems factor was found for both the NAC-Modified Alpha Ionograph® and the NAC-modified DuPont Ion Chaser®, it was deemed superfluous to use calibration curves. However, where the printed wiring assembly being tested has less than 400μ g salt equivalents of soil, it would be well to determine the system factor with an amount of NaCl which approximates the expected amount of ionic contaminants to be found on the printed wiring assembly.

The calibration curves for the NAC-Modified MIL-P-28809 Method (Beckman Bridge and Markson Meter) and the Omega Meter® were used as follows to calculate the μ g of NaCl equivalents per square inch of printed wiring assembly.

1. Extend the resistivity or conductivity, as appropriate, horizontally from its value on the y-axis until it intersects the calibration curve.
2. Extend a vertical from the point of intersection to the x-axis. Read μ g/l NaCl.
3. Multiply the concentration in μ g NaCl/l by the total liters of test solution used. This result indicates the total μ g of NaCl equivalents removed from the printed wiring board.
4. Divide the μ g of NaCl equivalents determined in Step 3 by the area (board plus components) of the printed wiring assembly expressed as square inches or square centimeters. This yields the micrograms of NaCl equivalents per square inch or square centimeter.

The data generated is in Table I (Appendix A-17). The average amount of ionic contaminants expressed a μ g NaCl equivalents per

square inch found for each group of three printed-wiring assemblies of the same drawing number tested by each method was plotted (Appendix A-18). It is evident that each test method has reasonable precision. For a given level of ionic contamination, it is apparent the NAC-Modified MIL-P-28809 Method gave the lowest indication of ionic contaminants. In ascending order, the NAC-Modified MIL-P-28809 Method, the Kenco Omega Meter®, the NAC-Modified Alpha Ionograph®, and the NAC-Modified DuPont Ion Chaser®, gave higher indications of that level of ionic residue.

MANUFACTURERS - MILITARY

The test instrument manufacturers and the involved military personnel met at Naval Avionics Center in Indianapolis on 9-10 February 1978. A representative of one of these test instrument manufacturers commented that the NAC-developed-and-modified Ionic Contaminant Test using 2×10^6 ohm-cm resistivity ($10.06\,\mu g/in^2$ or $1.56\,\mu g/cm^2$ sodium chloride equivalents) as the limit of ionic contaminants for a printed wiring assembly has been used successfully for over 5 years in producing high reliability electronic gear. Therefore, it was proposed that the grand average ($\bar{\bar{X}}$) be computed for the ionic contaminants found by each test method. An interim "equivalence factor" for each test would be calculated by dividing its grand average ($\bar{\bar{X}}$) by the grand average of the NAC-Modified MIL-P-28809 Method. This met the approval of the attendees.

The following were computed and will be acceptable as interim "equivalence factors".

	$\bar{\bar{X}}$		INSTRUMENT "ACCEPTANCE LIMIT"	
METHOD	$\mu g\ NaCl/in^2$	Equivalence Factor	$\mu gNaCl/Cm^2$	$\mu gNaCl/in^2$
MIL-P-28809-Beckman	7.47	$\frac{7.545}{7.545} = 1$	1.56	10.06
MIL-P-28809-Markson	7.62 (7.545)	$\frac{7.545}{7.545} = 1$	1.56	10.06
Omega Meter	10.51	$\frac{10.51}{7.545} = 1.39$	2.2	14
Ionograph	15.20	$\frac{15.20}{7.545} = 2.01$	3.1	20
Ion Chaser	24.50	$\frac{24.50}{7.545} = 3.25$	5.1	32

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It is hoped that the IPC Round Robin of Ionic Contaminant Testing will elucidate our findings and make plain a reasonable and lasting solution.

CONCLUSION:

All of the instruments tested are suitable for determining ionic contaminants remaining after solvent cleaning of post-soldering rosin-flux residues as described in MIL-P-28809 providing the interim equivalence factors are employed. THIS CENTER IN NO WAY ENDORSES OR RECOMMENDS A PREFERRED INSTRUMENT. Each prospective buyer must evaluate and purchase what he feels to be most acceptable to him.

REPORT PREPARED BY:

W. T. HOBSON, Materials Engineer

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R. J. DENOON, Chemist

APPROVED BY:

R. D. Hott

R. D. HOTT, Head, Metallurgical Materials Branch

B. C. Vaughn

B. C. VAUGHN, Director, Materials Laboratory and Consultants Division

APPENDIX

MRR No. 3-78
712:WTH:RJD:mjr
29 August 1978

APPENDIX

Attendees at the PWB Ionic Contaminants Meeting, Naval Avionics Center, 9-10 February 1978:*

NAME	AFFILIATION	TELEPHONE
John W. McCormick	RADC	315-330-4029
Jack Brous	Alpha Metals 57 Freeman Street Newark, NJ 07105	201-589-2007
William G. Kenyon	E. I. DuPont Freon® Products Lab Wilmington, DE 19898	302-999-4167
Ed Wolfgram	Kenco 418 W. Belden Ave. Addison, IL 60101	312-543-2510
Richard E. Martz	NAC, D/714	317-353-3274
David O. Pond	NAC, D/714	317-353-3274
Michael Cowart	NAC, D/714	317-353-3274
William T. Hobson	NAC, D/712	317-353-3266
R. J. DeNoon	NAC, D/712	317-353-3266

ADDITIONAL DISTRIBUTION:

Jerry Inman, Code 5541
Naval Weapons Center
China Lake, CA 93555

John Kerr, Code 50452
NESC

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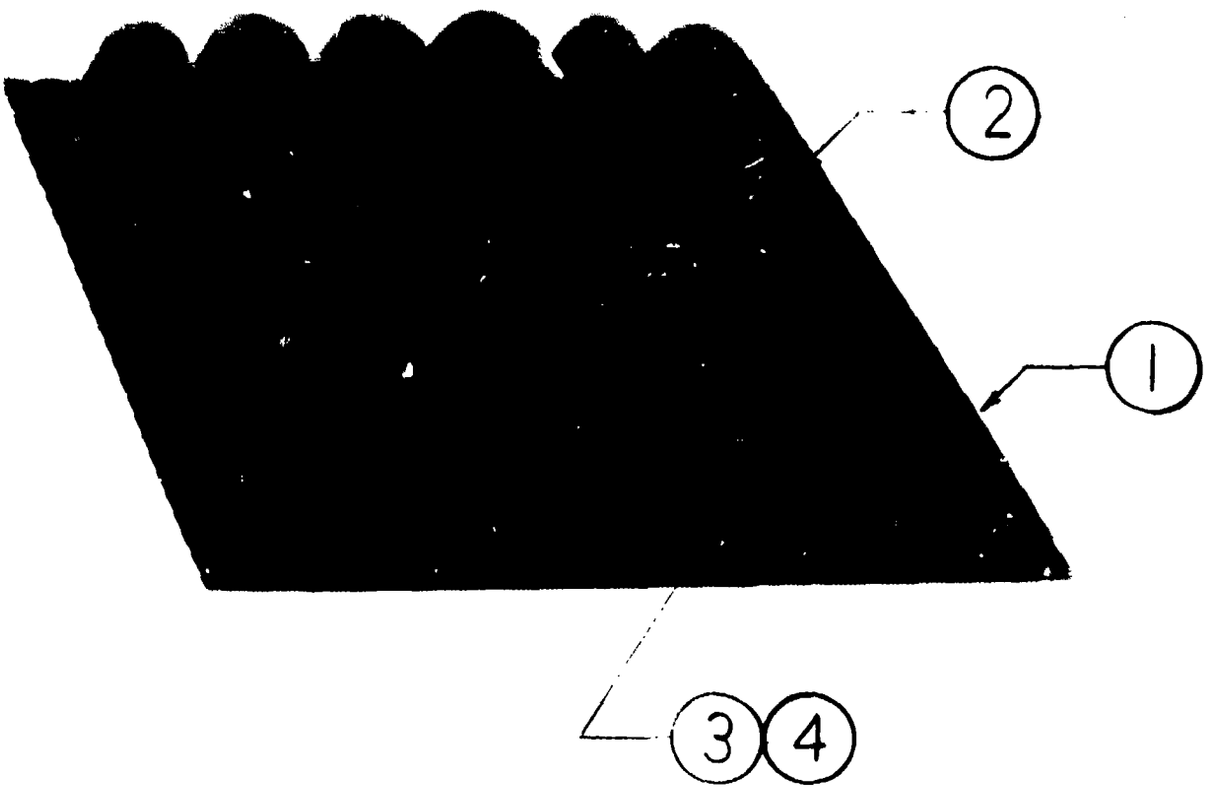
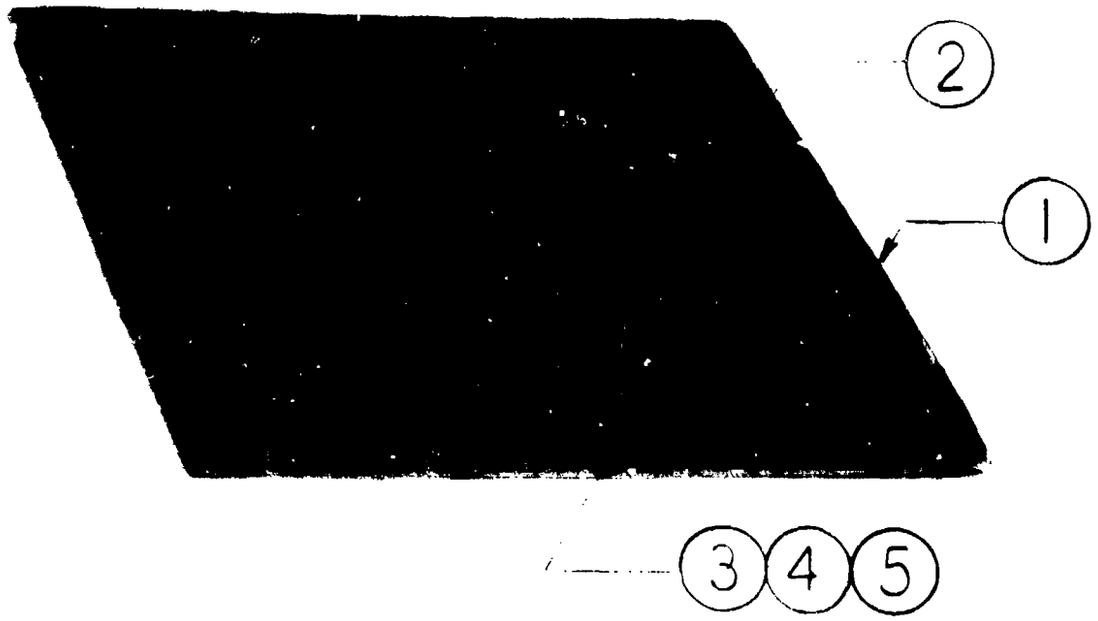
NOTE: All attendees listed are to receive one copy each.

MRR 3-78



ITEM	QTY.	PART No.	DESCRIPTION	REF.
4	AS REQD	MIL-F-14256	FLUX	
3	AS REQD	QQ-S-571	SOLDER	
2	108	40 C 501	CAPACITOR, SPRAGUE ELECTRIC CO.	
1	1	AV 21902	RESISTOR, CAPACITOR BD	

	DRAWN BY J. Washow	CAPACITOR ASSY. BOARD		
	PROJ. ENGR. R.E. Marty	SIZE A	CODE IDENT NO. 02387	DRAWING NO. AV 21923
A-2	DATE 8-3-77	SCALE ~	REV	SHEET 1 of 1

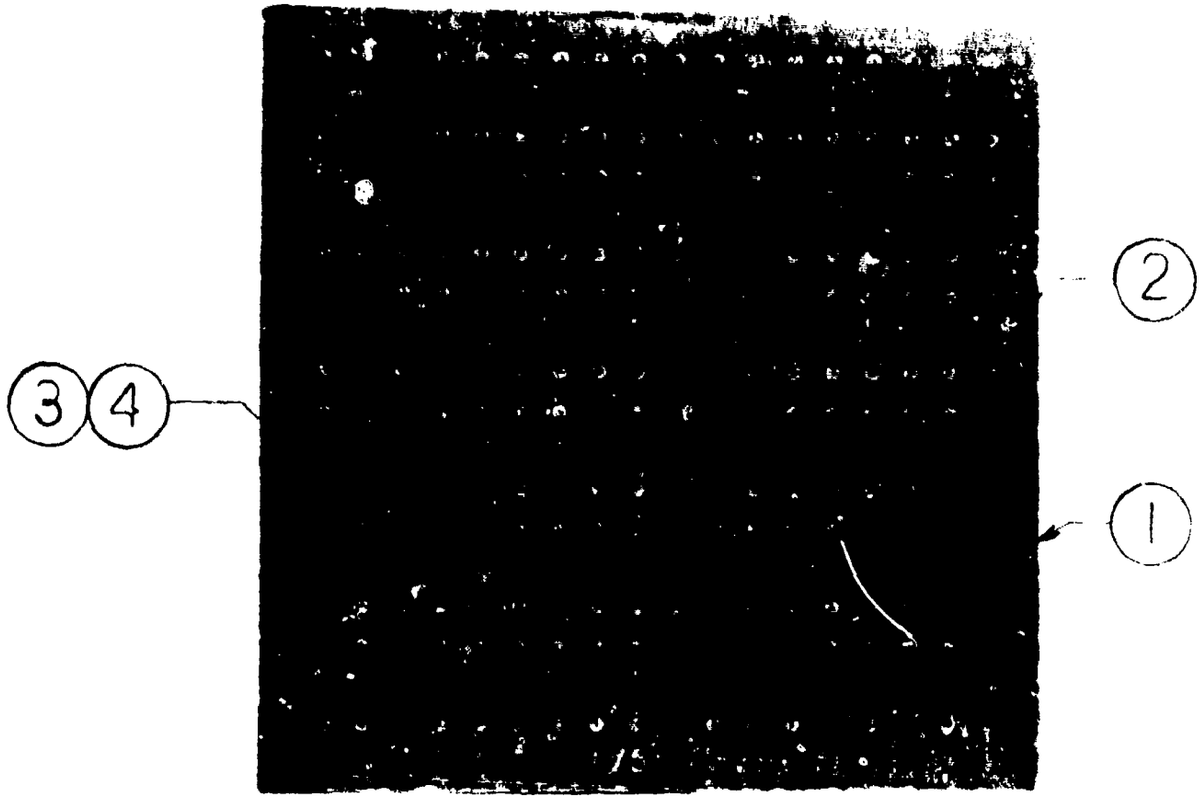


ITEM	QTY.	PART No,	DESCRIPTION	REF.
5	96	~	SOLUBLE MOUNTING PADS	
4	AS RQD	MIL-F-14256	FLUX	
3	AS RQD	QQ-S-571	SOLDER	
2	32	TO-5 CASE	TRANSISTOR	
1	1	AV 21906	TRANSISTOR BOARD	

DRAWN BY J. Wishon — TRANSISTOR ASSY. BOARD

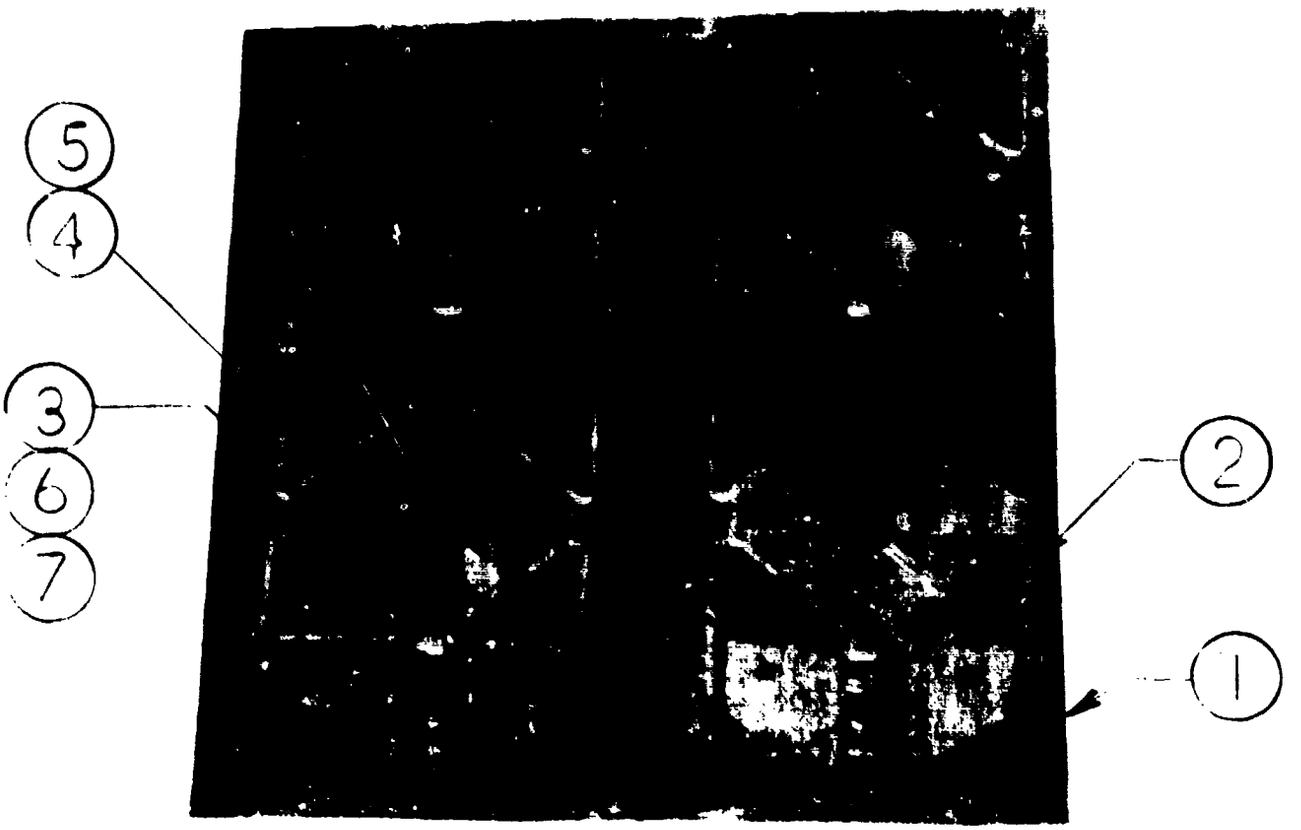
PROJ. ENGR. Richard Mast — SIZE A — CODE IDENT NO. 02387 — DRAWING NO. AV 21924

DATE 8-4-77 — SCALE ~ — REV — SHEET 1 of 1



ITEM	QTY.	PART No.	DESCRIPTION	REF.
4	AS RQD	MIL-F-14256	FLUX	
3	AS RQD	QQ-S-571	SOLDER	
2	108	RCR05G	RESISTOR, 1/8 WATT	
1	1	AV 21902	RESISTOR, CAPACITOR BOARD	

DRAWN BY J. Washow	RESISTOR ASSEMBLY BOARD		
PROJ. ENGR. R. E. Mart	SIZE A	CODE IDENT NO. 02387	DRAWING NO. AV 22100
DATE 8-8-77	SCALE ~	REV	SHEET 1 of 1



ITEM	QTY.	PART No.	DESCRIPTION	REF.
7	AS RQD	MIL-F-14256	FLUX	
6	AS RQD	QQ-S-571	SOLDER	
5	8	6-32 FIL HD. SCREW, CRES 3/8 LONG		
4	8	6-32 HX. HD NUT, CRES		
3	4	TO-66 CASE	TRANSISTOR	
2	4	690-66-P	HEAT SINK, WAKEFIELD ENGINEERING INC	
1	1	AV 21903	POWER TRANSISTOR WITH HEAT SINK BOARD	

DRAWN BY J. Washow	POWER TRANSISTOR W/HT SK ASY BD		
PROJ. ENGR. R E Marty	SIZE A	CODE IDENT NO. 02387	DRAWING NO. AV 21926
DATE 8-5-77	SCALE ~	REV	SHEET 1 of 1

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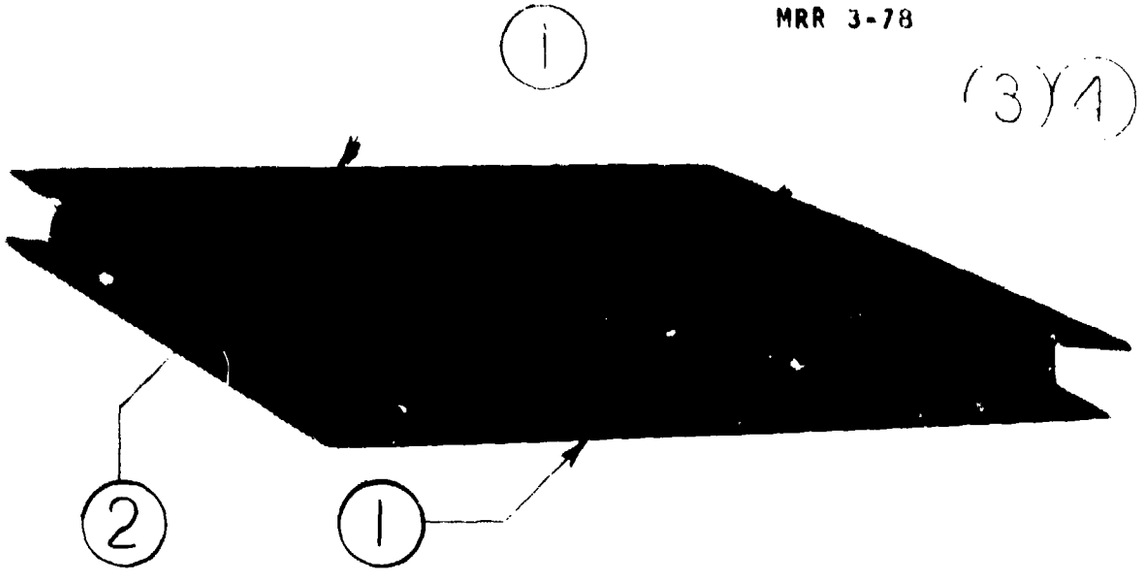
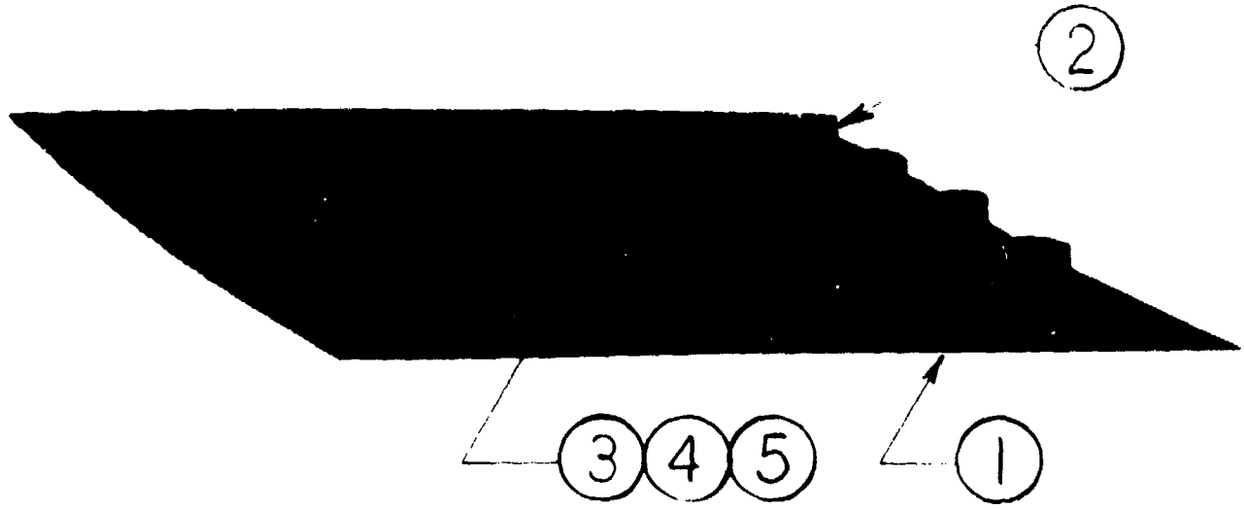


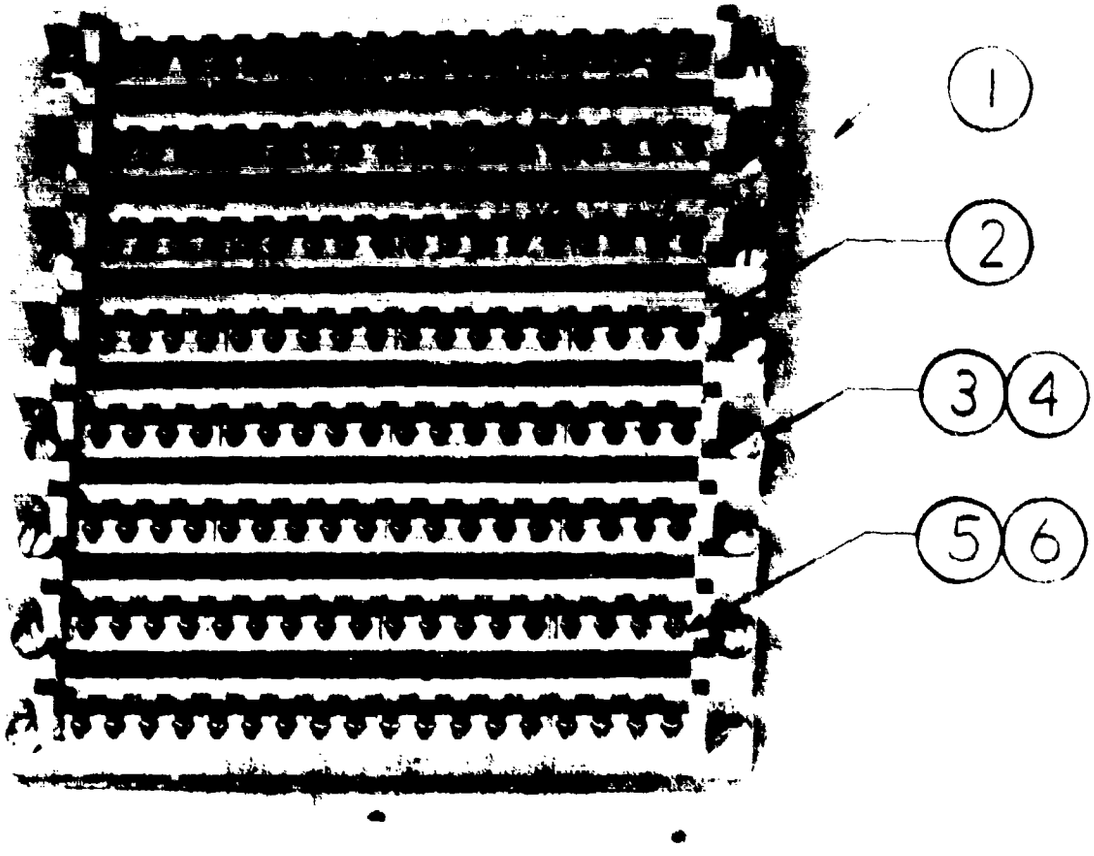
ITEM	QTY.	PART No.	DESCRIPTION	REF.
4	AS RQD	MIL-F-14256	FLUX	
3	AS RQD	QQ-S-571	SOLDER	
2	361	RCR20G	RESISTOR, ½ WATT	
1	2	AV21904	CORDWOOD PACK BD.	

DRAWN bY J. Washon	CORDWOOD PACK ASSEMBLY BD.		
PROJ. ENGR. RE Marty	SIZE A	CODE IDENT NO. 02387	DRAWING NO. AV 22102
DATE 8-9-77	SCALE —	REV	SHEET 1 of 1



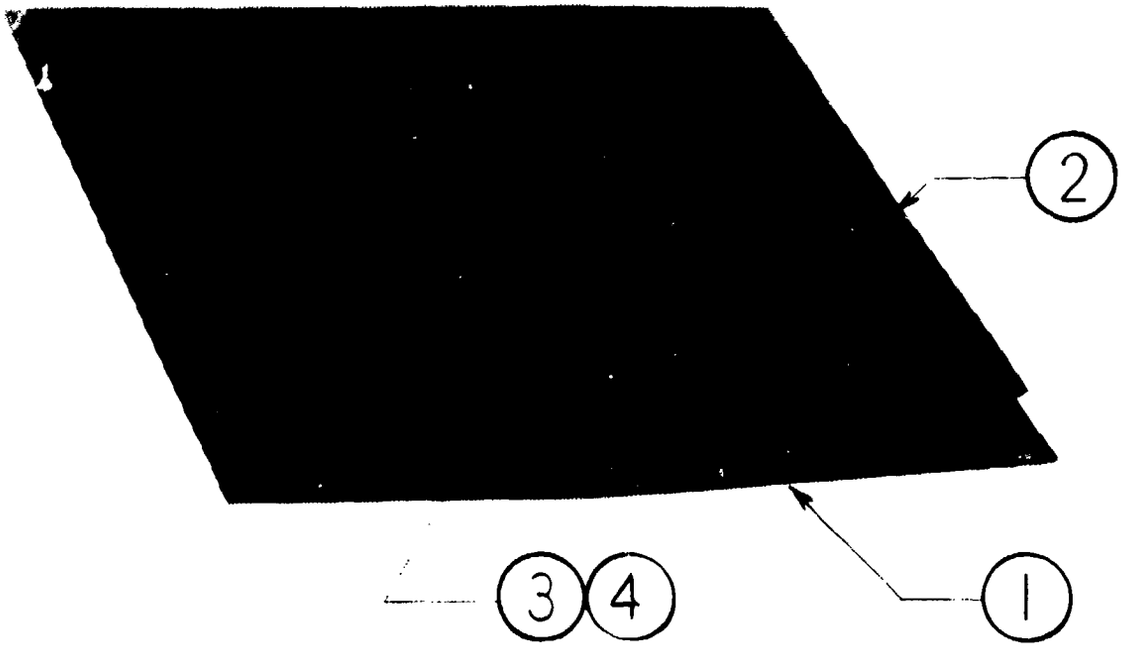
ITEM	QTY.	PART No.	DESCRIPTION	REF.
5	AS RQD	MIL-F-14256	FLUX	
4	AS RQD	QQ-S-571	SOLDER	
3	32	7717-86N	TRANSISTOR PADS, THERMALLOY COMPANY	
2	32	TO-5 CASE	TRANSISTOR	
1	1	AV 21906	TRANSISTOR BOARD	

DRAWN BY J. Washon	TRANSISTOR W/PADS ASSY. BD.		
PROJ. ENGR. R.E. Martz	SIZE A	CODE IDENT NO. 02387	DRAWING NO. AV 22103
DATE 8-9-77	SCALE ~	REV	SHEET 1 of 1



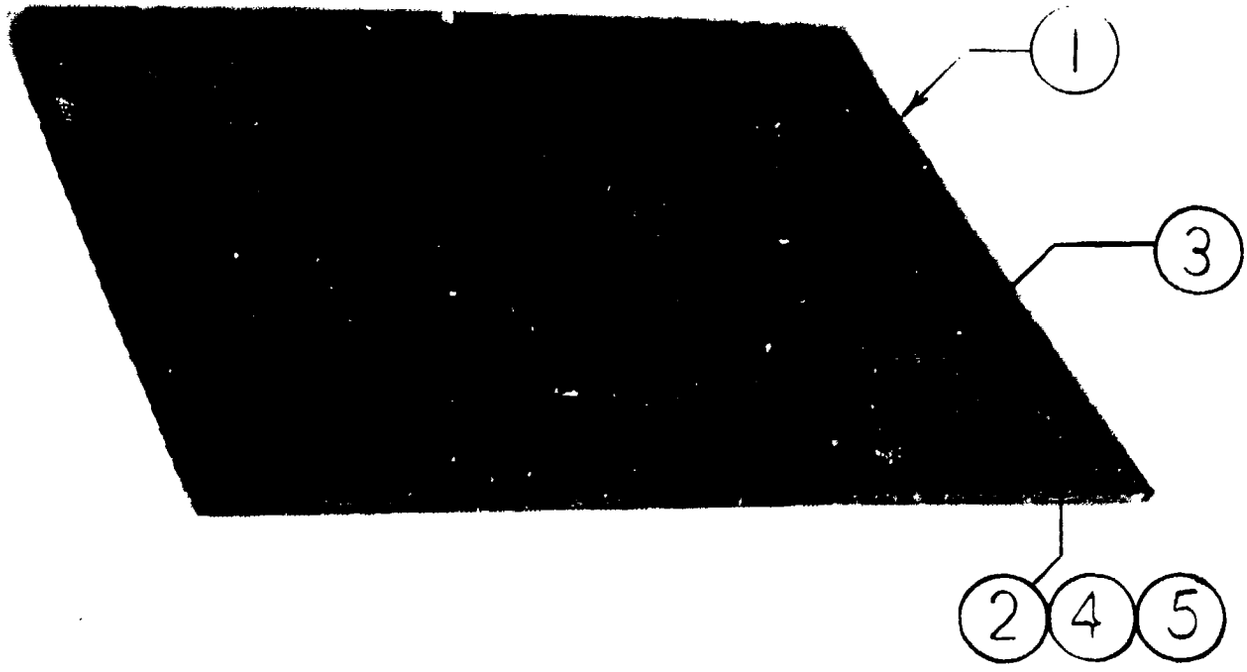
ITEM	QTY.	PART No.	DESCRIPTION	REF.
6	AS RQD	MIL-F-14256	FLUX	
5	AS RQD	QQ-S-571	SOLDER	
4	16	6-32 HEX HEAD NUT, CRES		
3	16	6-32 FIL HD. SCR., CRES 5/8 LONG		
2	8	00-5007-018-163-001	18 PIN EDGE CARD CONN.	ELCO CORP.
1	1	AV 21907	EDGE CARD CONNECTOR BOARD	

DRAWN BY J. Washom	EDGE CARD CONNECTOR ASSY. BD.		
PROJ. ENGR. RE Martz	SIZE A	CODE IDENT NO. 02387	DRAWING NO. AV 22101
DATE 8-9-77	SCALE ~	REV	SHEET 1 of 1



ITEM	QTY.	PART No.	DESCRIPTION	REF.
4	AS RQD	MIL-F-14256	FLUX	
3	AS RQD	QQ-S-571	SOLDER	
2	50	MIL-M-38510C D-1 CASE	DIP, 14 LEAD, 1/4" X 3/4" CASE	
1	1	AV 21909	DIP BOARD	

DRAWN BY J. Washom	DIP ASSEMBLY BOARD		
PROJ. ENGR. R.E. Marty	SIZE A	CODE IDENT NO. 02387	DRAWING NO. AV 21925
DATE 8-3-77	SCALE ~	REV	SHEET 1 of 1



ITEM	QTY.	PART No.	DESCRIPTION
1	1	AV 21910	JUMPER WIRE BOARD
2	96	57A5A52-1	TERMINAL, STUD
3	48	200AS108-9	WIRE, 3 1/8" LONG, STRIPPED 3/8" BOTH ENDS
4	AS REQD	QQ-S-571	SOLDER
5	AS REQD	MIL-F-14256	FLUX

DRAWN by J. Washon	JUMPER WIRE ASSY. BOARD		
PROJ. ENGR R.E. Marty	SIZE A	CODE IDENT NO. 02387	DRAWING NO. AV 21921
DATE 8-2-77	SCALE ~	REV	SHEET 1 of 1

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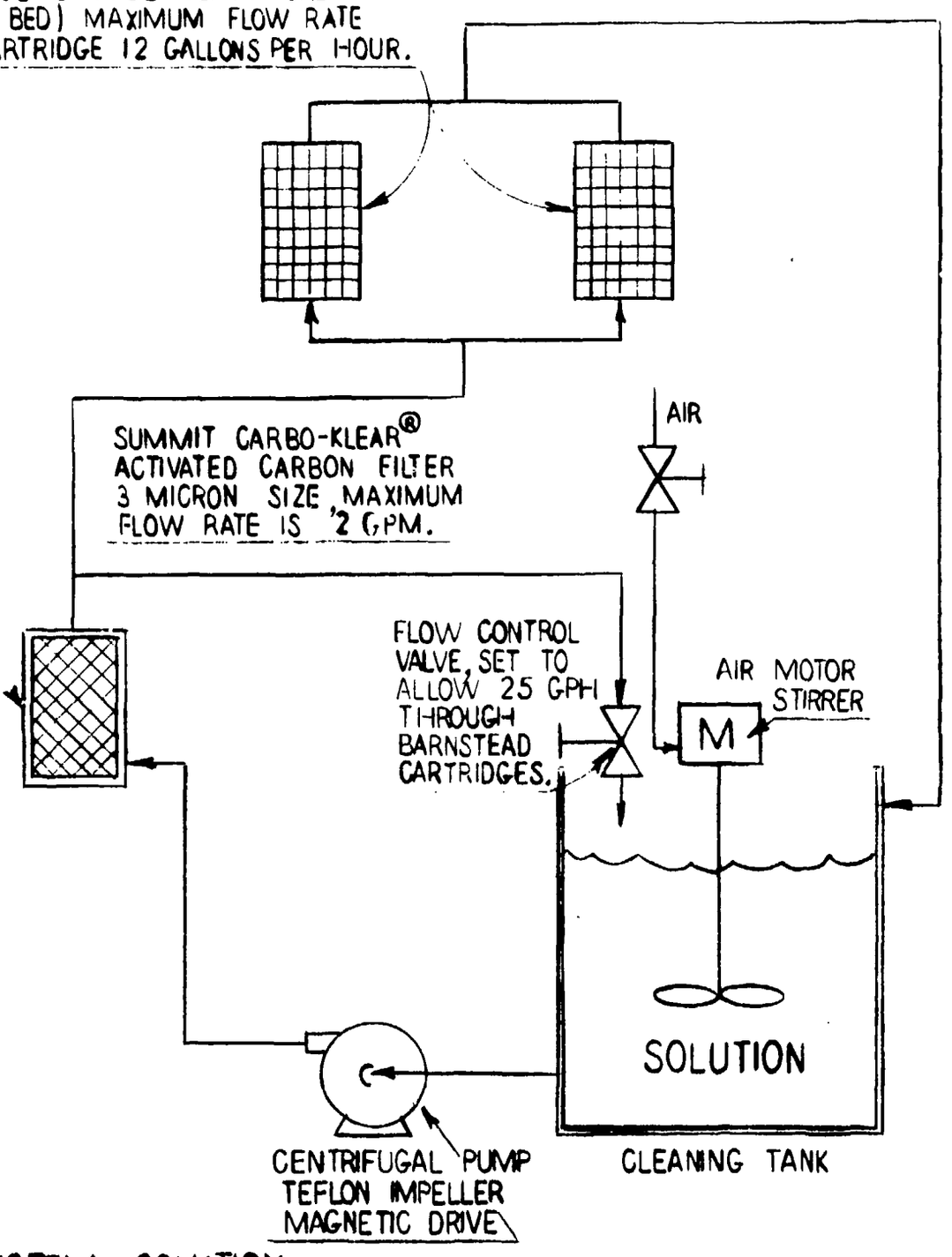
BARNSTEAD HOSE NIPPLE
CARTRIDGE D 8902 ULTRA-PURE
(MIXED BED) MAXIMUM FLOW RATE
PER CARTRIDGE 12 GALLONS PER HOUR.

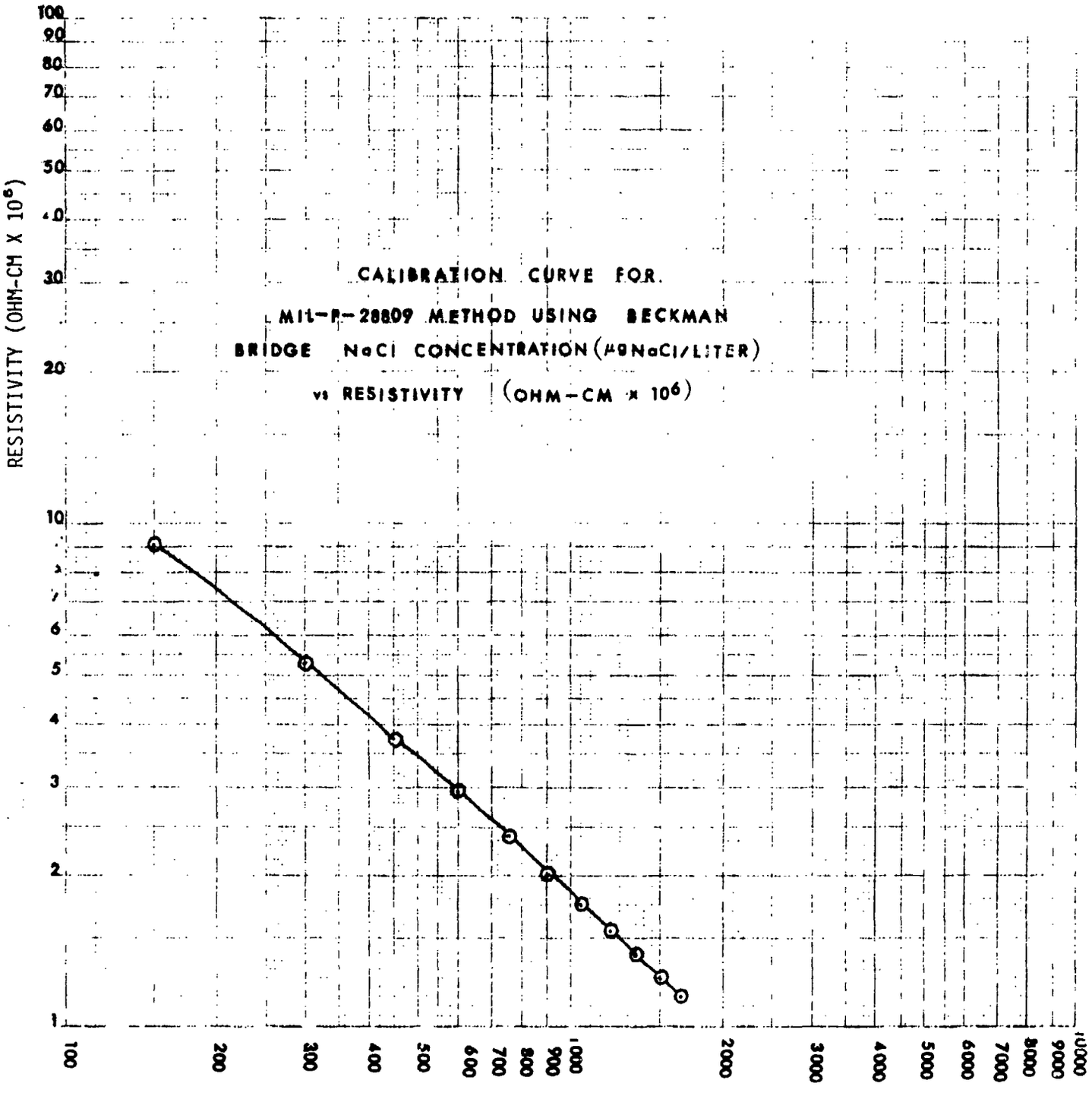


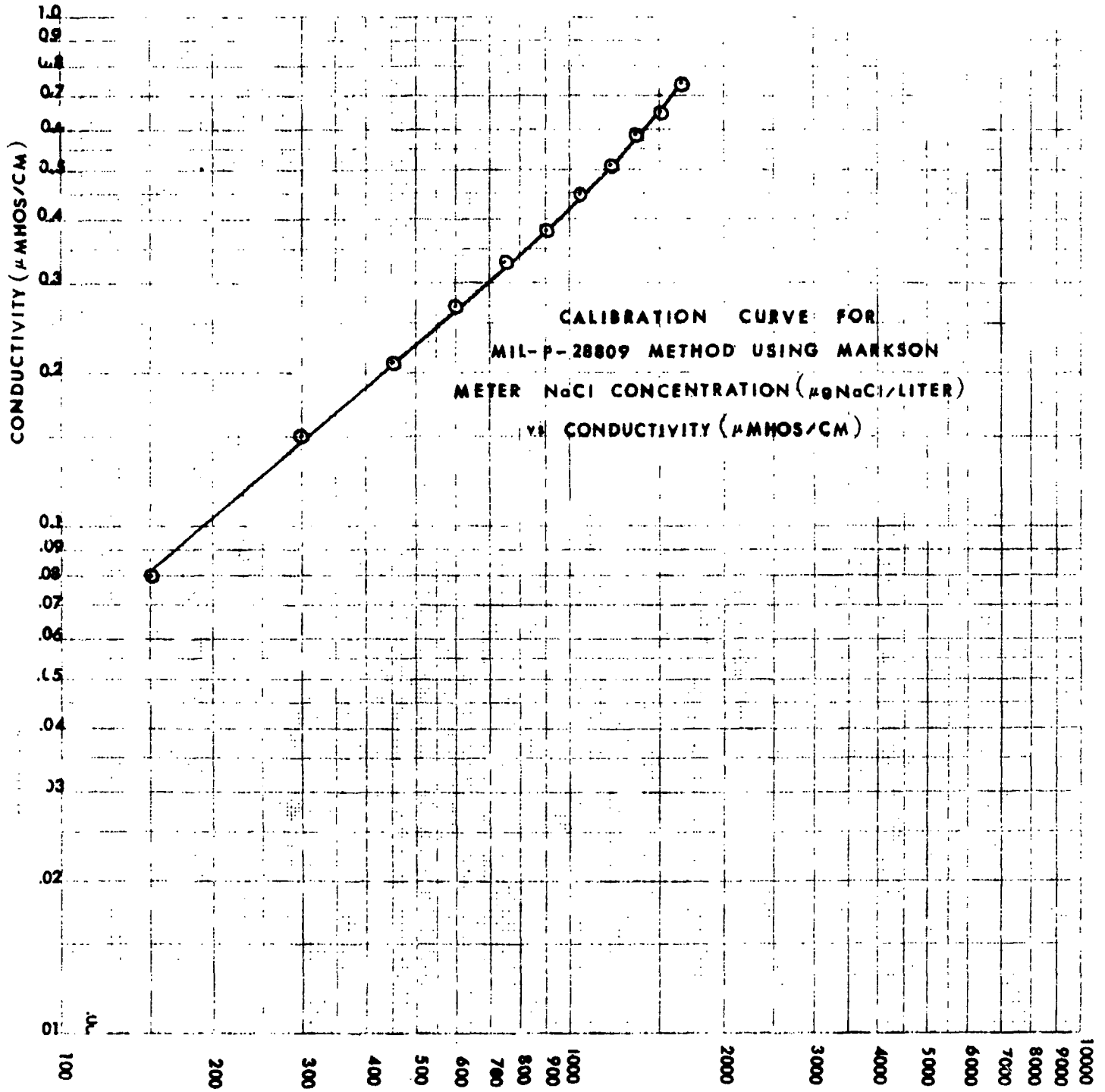
SYSTEM SOLUTION

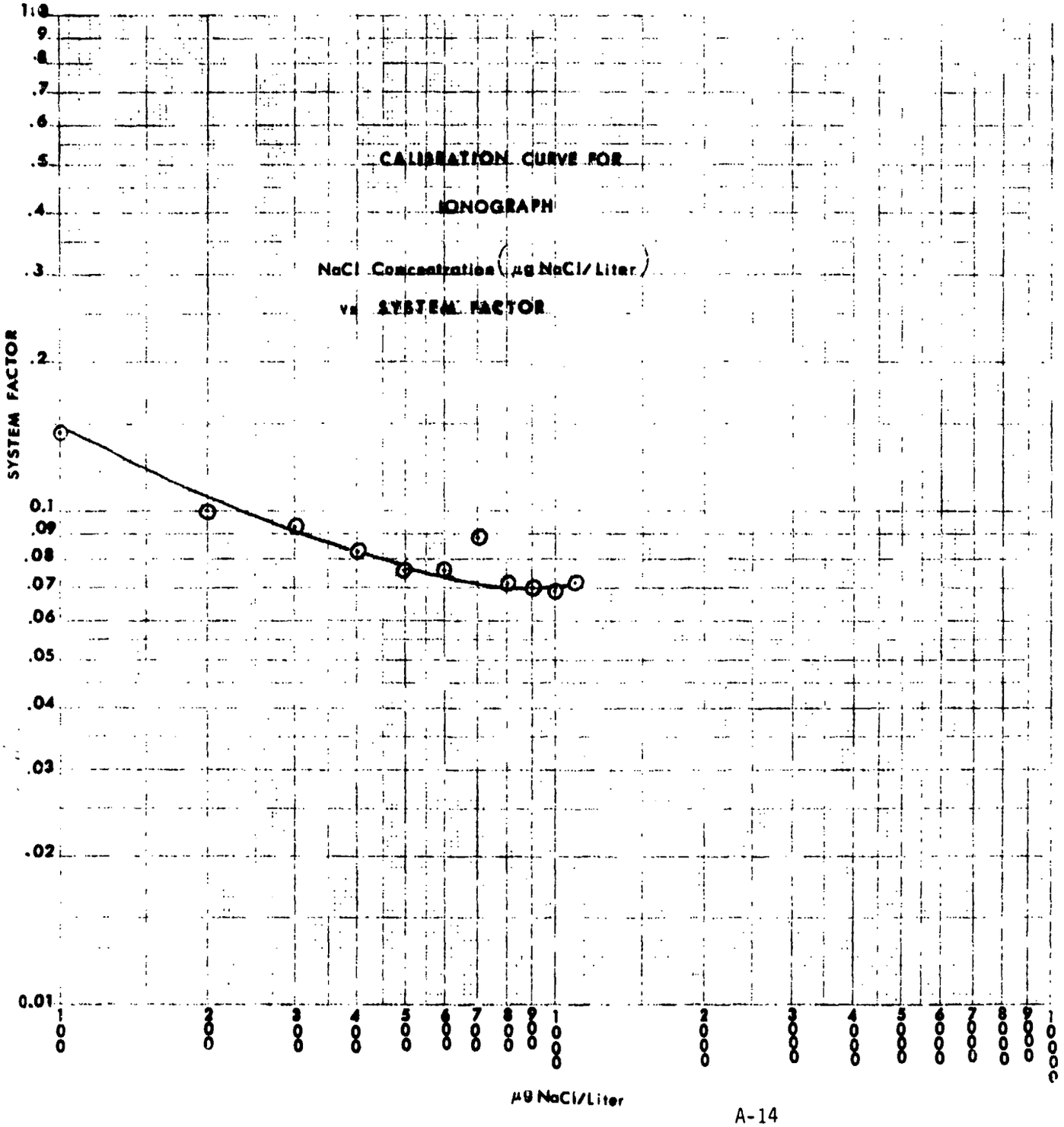
75% 2-PROPANOL
25% DEIONIZED WATER
APPROXIMATELY 12 GALLONS

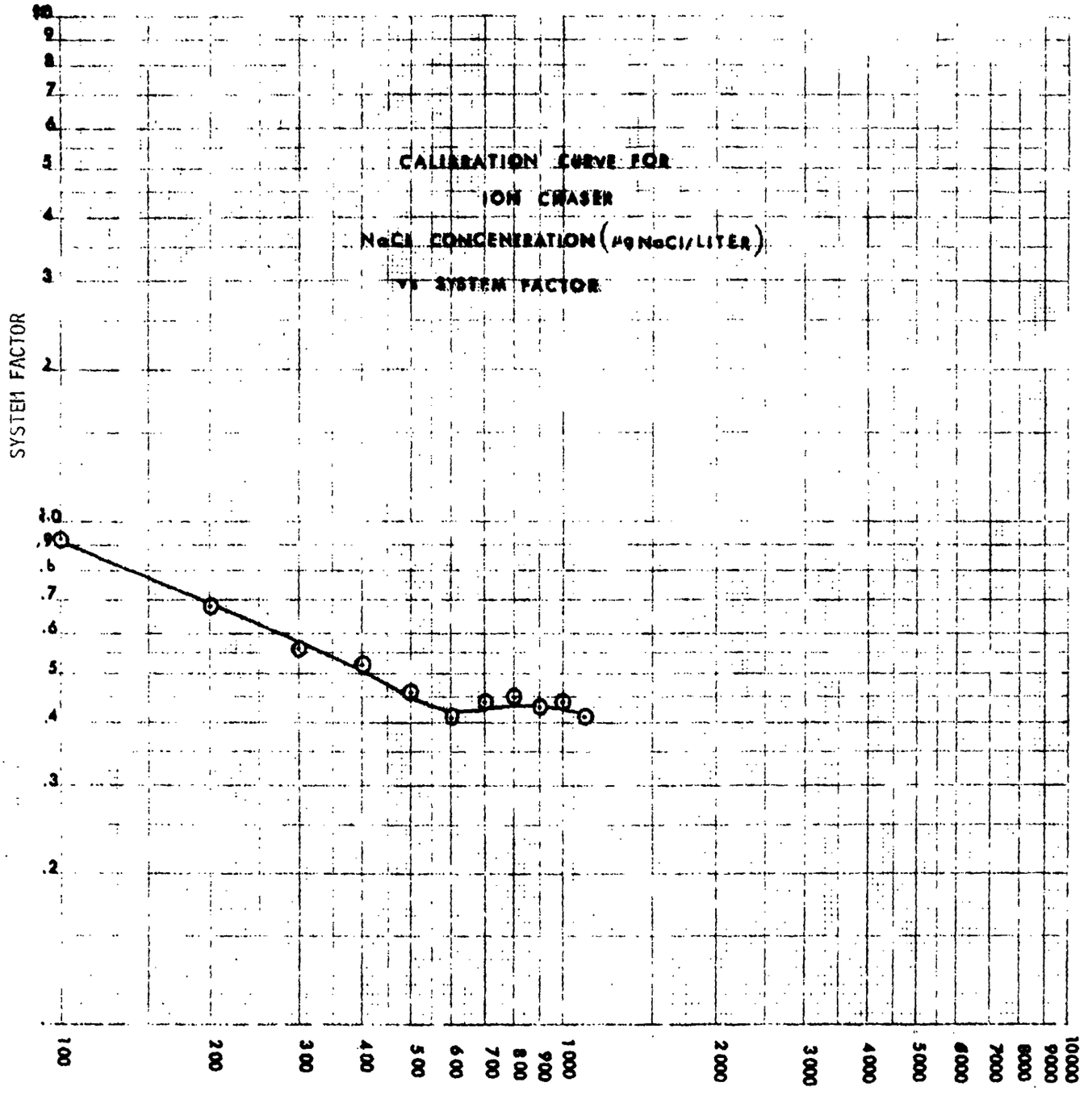
A-11

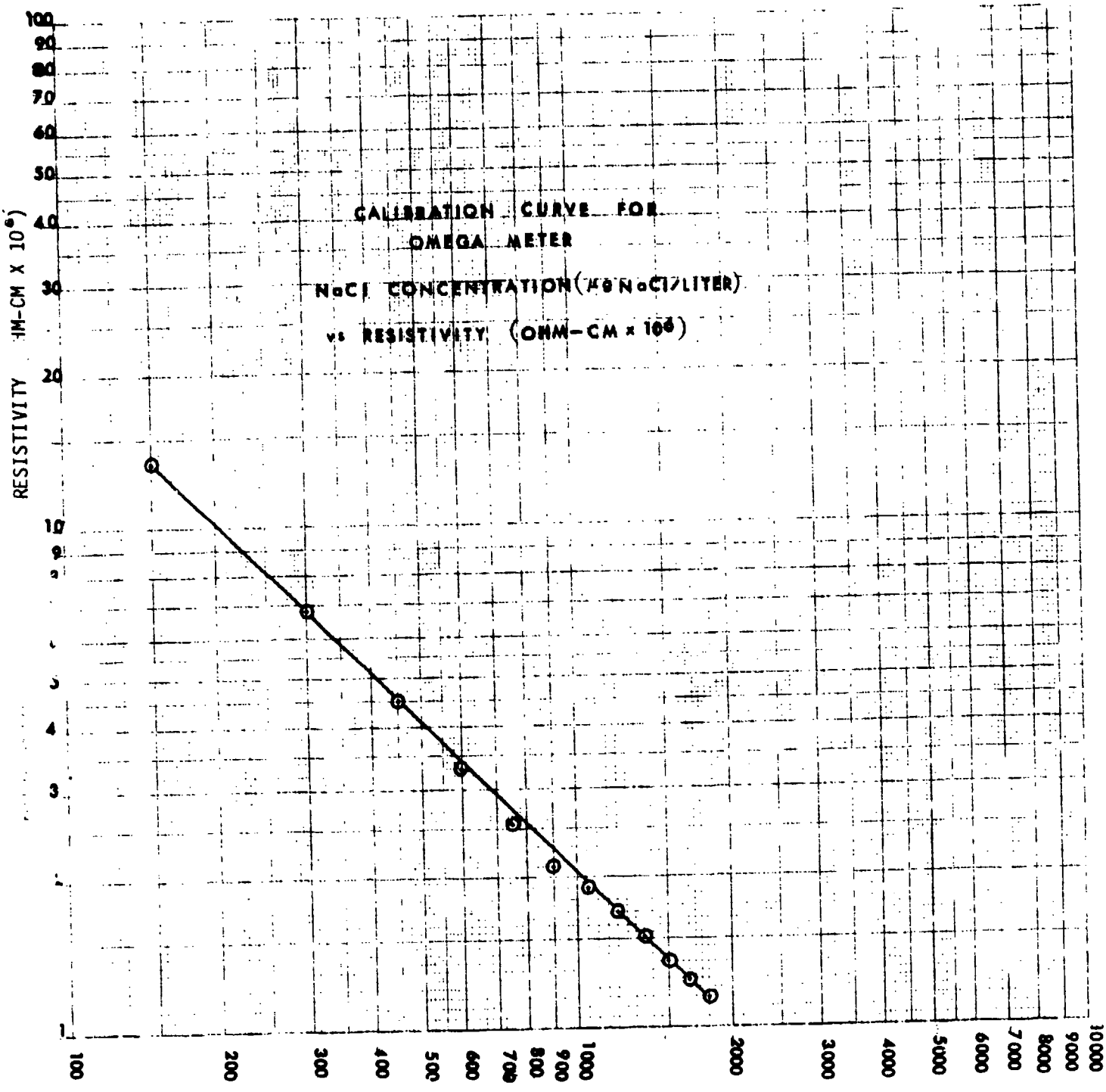
DRAWN BY J. Washow	CLEANING SYSTEM SCHEMATIC		
PROJ. ENGR. R.E. Martz	SIZE A	CODE IDENT NO. 02387	DRAWING NO. AV 21922
DATE 8-2-77	SCALE ~	REV	SHEET 1 of 1


CALIBRATION CURVE FOR
MIL-P-28809 METHOD USING BECKMAN
BRIDGE NaCl CONCENTRATION (µg NaCl/LITER)
vs RESISTIVITY (OHM-CM x 10⁶)
RESISTIVITY (OHM-CM X 10⁶)
100
90
80
70
60
50
40
30
20
10
7
6
5
4
3
2
1
100
200
300
400
500
600
700
800
900
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
µg NaCl/LITER


CALIBRATION CURVE FOR
MIL-P-28809 METHOD USING MARKSON
METER NaCl CONCENTRATION (μg NaCl/LITER)
vs CONDUCTIVITY (μMHOS/CM)
CONDUCTIVITY (μMHOS/CM)
μg NaCl / LITER


CALIBRATION CURVE FOR
IONOGRAPH
NaCl Concentration (µg NaCl/ Liter)
vs SYSTEM FACTOR
SYSTEM FACTOR
1.0
.9
.8
.7
.6
.5
.4
.3
.2
0.1
.09
.08
.07
.06
.05
.04
.03
.02
0.01
100
200
300
400
500
600
700
800
900
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
µg NaCl/Liter


CALIBRATION CURVE FOR
ION CHASER
NaCl CONCENTRATION (µg NaCl/LITER)
VS SYSTEM FACTOR
SYSTEM FACTOR
µg NaCl/LITER
10
9
8
7
6
5
4
3
2
1.0
.9
.8
.7
.6
.5
.4
.3
.2
100
200
300
400
500
600
700
800
900
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000


CALIBRATION CURVE FOR
OMEGA METER
NaCl CONCENTRATION (μg NaCl/LITER)
vs RESISTIVITY (OHM-CM x 10⁶)
RESISTIVITY (M-CM X 10⁶)
μg NaCl/LITER

	AV 21923 Capacitor 56.2 in.² (363 cm²)	AV 21924 Transistor 65 in.² (419 cm²)	AV 22100 Resistor 55 in.² (355 cm²)	AV 21926 Power Transistor w/heat sink 157 in.²(1010 cm²)	AV 22102 Cordwood Pack 162 in² (1050 cm²)	AV 22103 Transistor w/pad 72 in²(465 cm²)	AV 22101 Edge Card Connector 139 in²(897 cm²)	AV 21925 Dip 103 in² (665 cm²)	AV 21921 Jumper Wire 66 in²(426 cm²)	Contaminants Expressed as Micrograms NaCl Equivalents per in² as Found by Noted Test Procedures
MIL-P-28809 Beckman Conductivity Bridge	6.74	6.75	5.55	7.07	7.65	6.75	10.8	13.1	5.92	
RA Flux (2)	6.30	5.40	6.07	5.61	6.15	6.07	12.1	12.8	5.92	(2) Instrument Factor
	7.25	6.37	5.85	6.08	6.07	6.56	12.5	8.55	5.70	
$\bar{X}$	6.76	6.17	5.82	6.25	6.63	6.46	11.8	11.5	5.85	7.47
MIL-P-28809 Markson Meter Bridge	6.44	6.22	4.65	6.30	8.35	6.44	12.3	13.8	6.21	
RA Flux (4)	5.70	5.69	5.18	5.47	6.75	6.00	13.1	13.8	6.00	(4) $\bar{X} = 7.55$ $\frac{7.55}{7.55} = 1$
	7.26	6.49	5.18	5.77	6.75	8.10	13.5	8.85	5.70	
$\bar{X}$	6.47	6.14	5.00	5.84	7.45	6.85	13.0	11.9	5.97	7.62
Kenco Omega Meter	10.9	10.2	10.5	7.76	8.40	10.2	11.6	14.5	10.2	
RA Flux (6)	10.8	9.72	10.5	6.22	7.80	11.4	10.4	17.1	9.61	(6) $\bar{X} = 10.5$ $\frac{10.5}{7.55} = 1.39$
	11.5	9.95	9.87	8.21	8.56	10.7	11.6	16.5	9.00	
$\bar{X}$	11.1	9.96	10.29	7.40	8.25	10.8	11.2	16.0	9.60	
Alpha Iono-graph	13.8	11.6	12.6	7.89	--	14.8	18.5	26.1	16.1	
RA Flux (8)	13.7	11.8	11.6	8.18	--	13.4	20.7	25.0	12.8	(8) $\bar{X} = 15.20$ $\frac{15.20}{7.55} = 2.01$
	15.4	13.4	12.9	6.91	--	15.2	24.1	23.1	15.9	
$\bar{X}$	14.3	12.3	12.3	7.49	--	14.5	21.1	24.7	14.9	
DuPont Ion Chaser	24.1	22.7	22.7	11.1	18.5	20.8	36.5	40.9	--	
RA Flux (10)	25.2	22.2	20.3	14.1	16.0	22.1	35.8	50.0	22.3	(10) $\bar{X} = 24.5$ $\frac{24.5}{7.55} = 3.25$
	28.5	16.5	16.9	11.5	17.9	23.8	40.0	36.3	24.4	
$\bar{X}$	25.9	20.5	20.0	12.2	17.5	22.2	37.4	42.4	22.35	

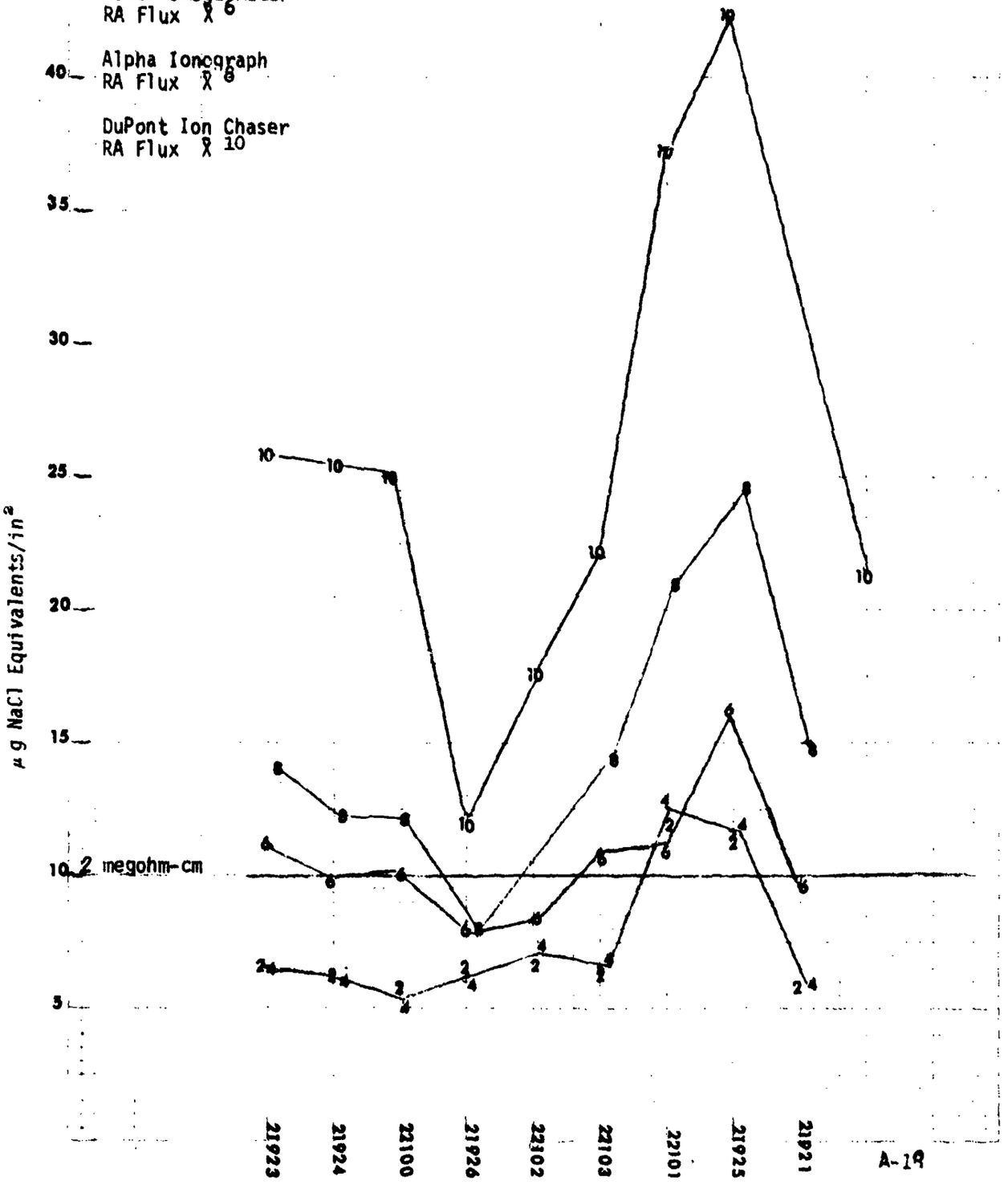
TABLE I.

DATA POINTS

MIL-P-28809 Beckman Conductivity Bridge
RA Flux X 2

MIL-P-28809 Markson Meter Bridge
RA Flux X 4

Kenco Omega Meter
RA Flux X 6

Alpha Ionograph
RA Flux X 8

DuPont Ion Chaser
RA Flux X 10