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HIGHWAY RESEARCH REPORT

AN ELECTRICAL METHOD FOR EVALUATING BRIDGE DECK COATINGS

71-15

BUSINESS AND TRANSPORTATION AGENCY

DEPARTMENT OF PUBLIC WORKS

DIVISION OF HIGHWAYS

MATERIALS AND RESEARCH DEPARTMENT

RESEARCH REPORT

NO. M & R 635116-5

Prepared in Cooperation with the U.S. Department of Transportation, Federal Highway Administration June , 1971

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STATE OF CALIFORNIA—TRANSPORTATION AGENCY

RONALD REAGAN, Governor

DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS
MATERIALS AND RESEARCH DEPARTMENT
5900 FOLSOM BLVD., SACRAMENTO 95819

June 1971

Research Report
M&R No. 635116-5
FHP D-3-11

Mr. J. A. Legarra
State Highway Engineer

Dear Sir:

Submitted herewith is a research report titled:

An Electrical Method for Evaluating
Bridge Deck Coatings

Donald L. Spellman
Principal Investigator

Richard F. Stratfull
Co-Investigator

Richard R. Trimble
Stephen Dukelow
Joseph Halterman
Assistants

Very truly yours,

JOHN L. BEATON
Materials and Research Engineer

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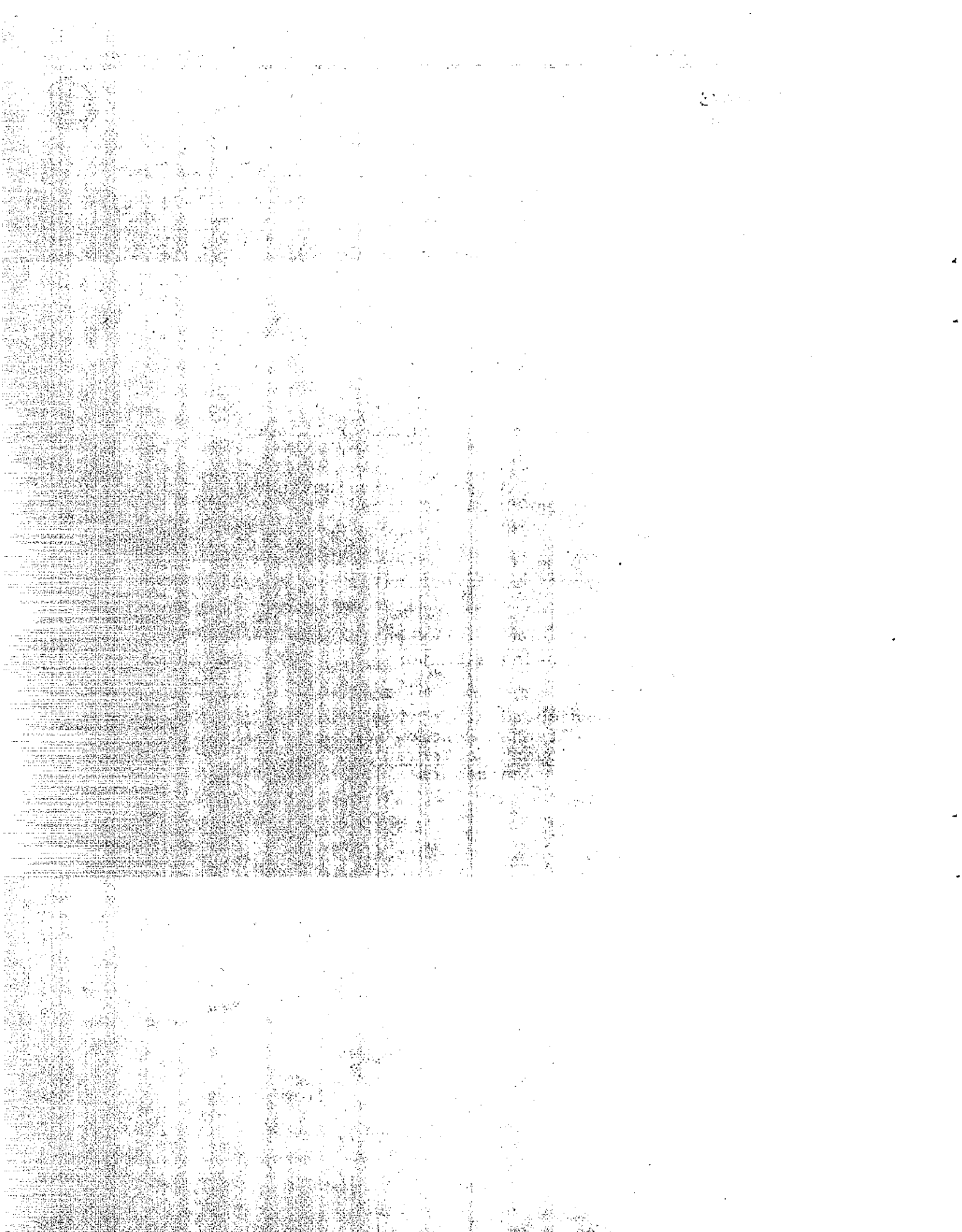

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Reference: Spellman, Donald L.; Stratfull, Richard F. "An Electrical Method for Evaluating Bridge Deck Coatings", State of California, Department of Public Works, Division of Highways, Materials and Research Department, Research Report M&R 635116-5, August, 1970

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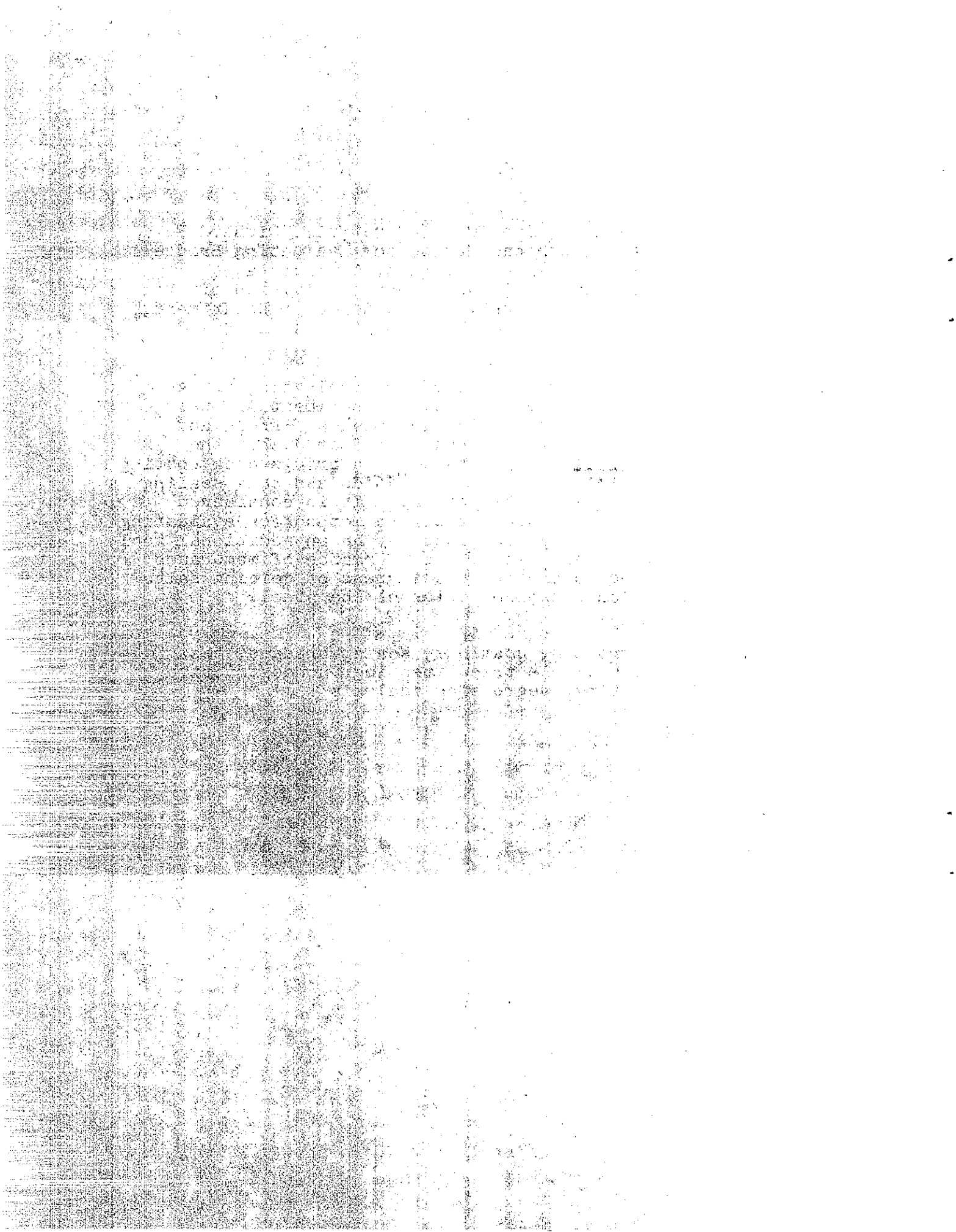

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ACKNOWLEDGMENT

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The opinions, findings, and conclusions expressed in this report are those of the authors and not necessarily those of the Federal Highway Administration.

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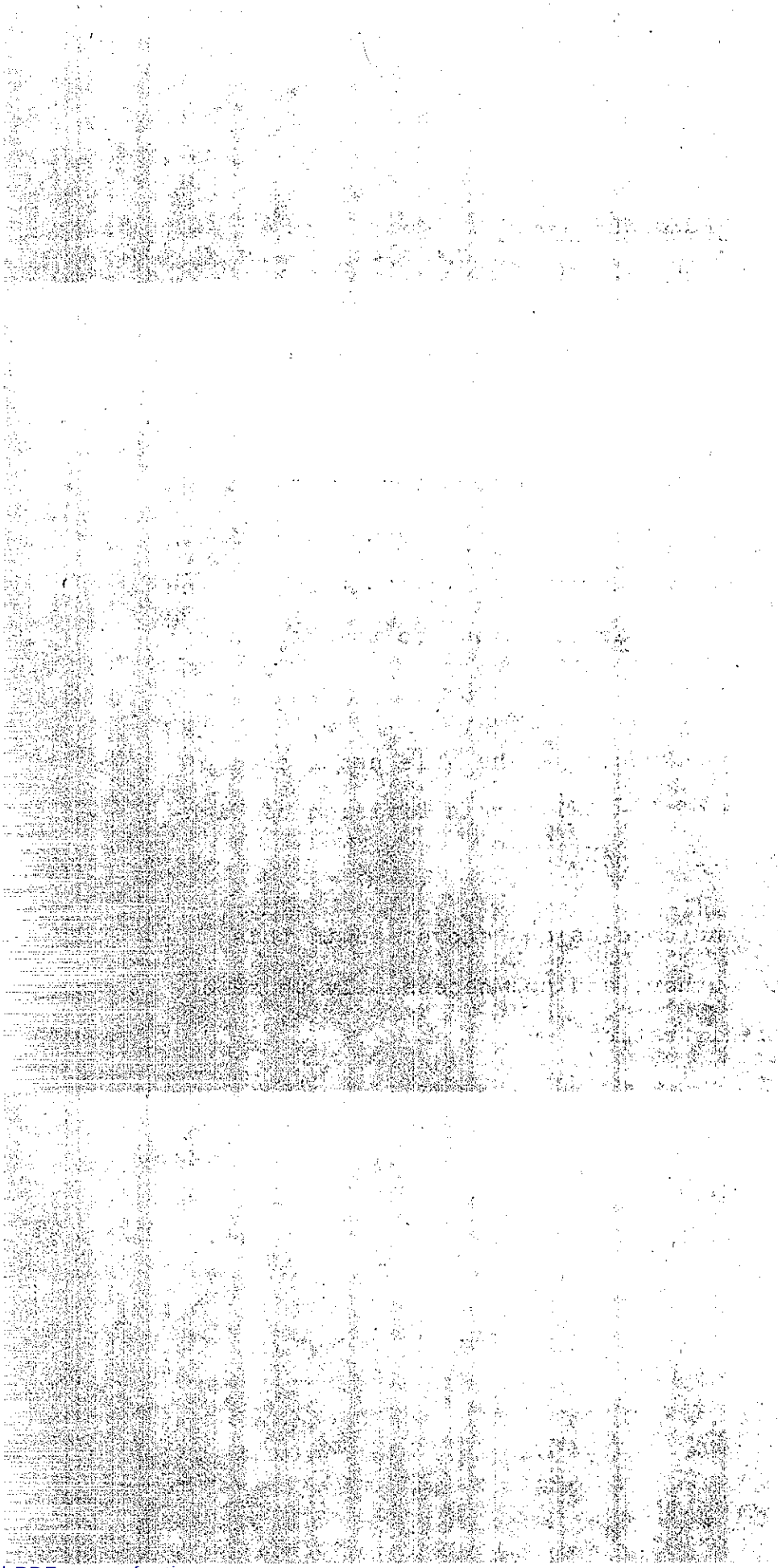

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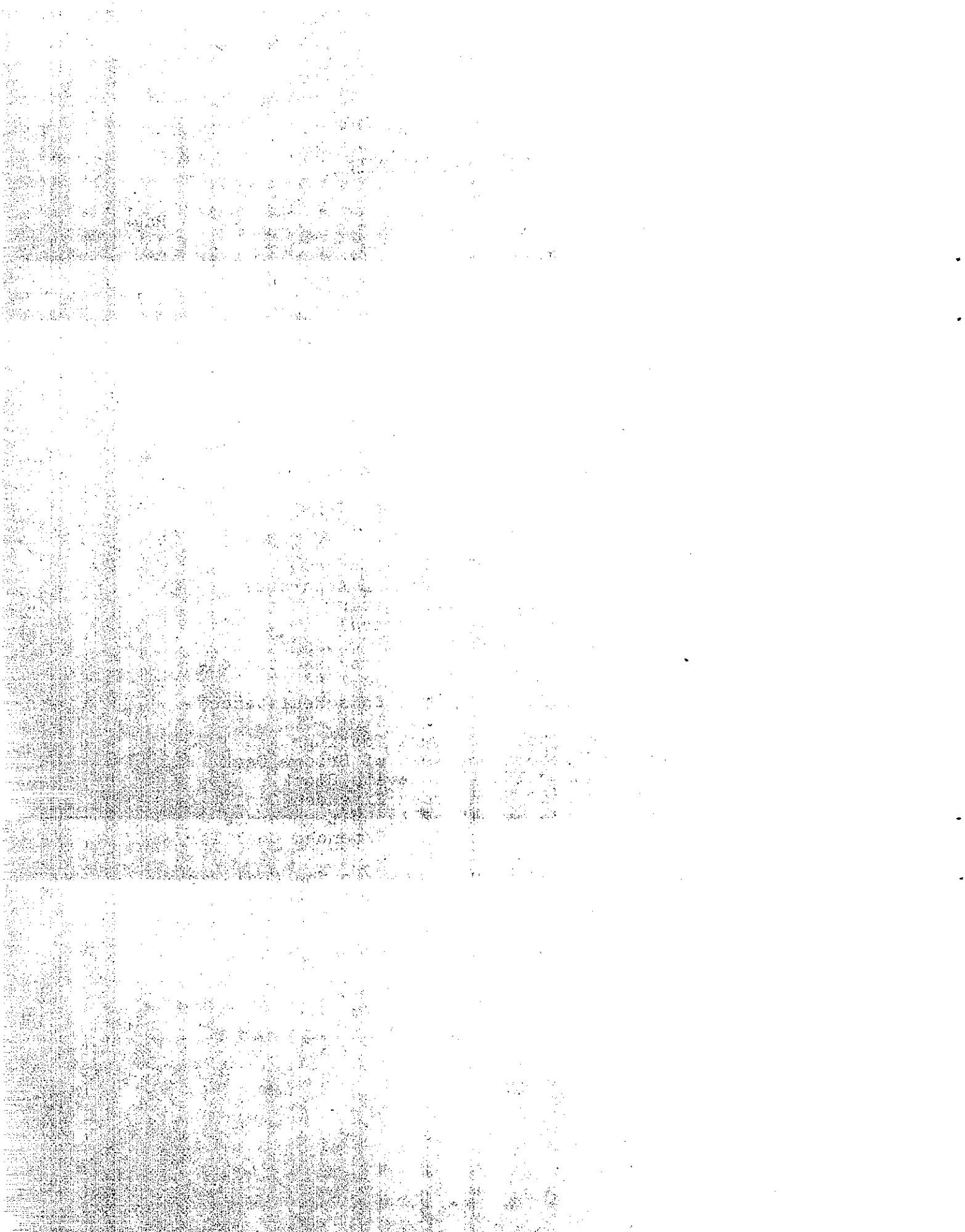

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AN ELECTRICAL METHOD FOR EVALUATING BRIDGE DECK COATINGS

By
Donald L. Spellman and Richard F. Stratfull*

INTRODUCTION

In recent years, an increasing amount of attention is being devoted to the problem of bridge deck deterioration[1-11]. Most recently, the Highway Research Board has published a finding that indicates that one of the most significant causes of bridge deck deterioration is spalling of the concrete resulting from the use of deicing chemicals[12]. In general, the spalling of the concrete has been found to be the result of corrosion of the reinforcing steel[10,12]. One method to prevent the corrosion of the steel caused by deicing salt is to apply a waterproof membrane to the bridge deck[12] before any salt is used. However, literature has not been found by the authors which describe a technique for the field evaluation of the waterproofing ability of bridge deck seals. It has been reported that a measure of the performance of a membrane is its ability to remain in place on the deck surface[3,12,13]. In this study, one additional criteria for performance of a bridge deck coating is that it be a waterproof membrane. In the case of a di-electric type material being used in the seal, it is assumed that the electrical resistance of the coating should be a measure of the waterproofing ability of the coating. For example, it is assumed that if a coating is porous and water can pass through these pores, then the coating should have a low electrical resistance because of the multiple paths that are available for current flow. Conversely, if the coating is not porous and is of a di-electric nature, then the electrical resistance of the coating should be high. Although the authors are not aware of any specific reports concerning measuring of the electrical resistance of bridge deck coatings, they are aware that such techniques have been previously utilized on buried pipelines[14]. Therefore the concept of the measurement of electrical resistance of a coating is not considered to be new - but the use of this technique as applied to the measurement of the electrical resistance of bridge deck coatings may be unique.

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INSTRUMENTATION

The basic concept for the instrumentation is to connect one lead of the ohmmeter to a plate or contact which could be placed on the surface of the bridge deck and thus measure gross electrical resistance. This arrangement would permit the measurement of the electrical resistance from the reinforcing steel through the concrete, through the membrane and/or surface coatings, and then to the contact placed on top of the deck surface. In order to facilitate the measurement of the electrical resistance on the surface of the bridge, a moist sponge is used as a conducting medium that will electrically complete the current. See Figure 1. In constructing the contact, a piece of copper plate 7"x9"x1/8" thick was used and an electrical connection was made to the plate. A nonmetallic handle was attached to the plate for convenience in moving and placing the plate at various points on the bridge surface. Two sponges totaling about 63 square inches of area on the bottom of the plate facilitate contact with the surface. These sponges are attached by means of wooden dowels that are inserted into the sponges and secured to the plate. Because many bridge deck surfaces contain an asphaltic concrete wearing surface, water containing a wetting agent was utilized to increase the rapidity of the penetration through the asphaltic concrete. The wetting agent used is a nontoxic, nonvolatile, practically odorless ester of a sulphonated dicarboxylic acid. The wetting agent is mixed with water at the ratio of about 95 mls of wetting agent to 5 gallons of water and has a specific resistance of 2350 ohm cm.

The ohmmeter used was an ordinary general purpose voltmeter having an input impedance of 100,000 ohms per volt in the DC voltage ranges, and had a maximum readable resistance value of 200 million ohms. Figure 2 is a photo of the metal plate contact assembly which is touched to the surface of the concrete to measure the gross electrical resistance. Figure 3 shows the general setup and operations for measuring the electrical resistance of the coating.

In using direct current type ohmmeters, a problem of nonreproducible values has developed when measuring low electrical resistance values. The cause of this problem is the generation of an external voltage that results from the galvanic coupling of the copper plate to the reinforcing steel. Normally, when external galvanic voltages are present, they cannot be balanced out by shorting of the instrument leads as is normally done. Therefore, depending on the magnitude of the external galvanic voltages that exist, gross errors can occur in the low resistance

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ranges. For example, with the leads connected with one polarity, the apparently measured values can be in the order of 1000 ohms. By reversing the leads or polarity, the resistance values can be in the order of 3000 or 4000 ohms.

Two techniques for measuring coating resistance have been utilized. One is by obtaining at least twenty resistance measurements at random across the deck. The values are then plotted on probability paper as shown on Figure 6. The other method is to systematically measure the resistance values on approximately 5-foot interval grid across the bridge deck. Then by making a contour map of equal resistance values, areas of low resistance contours could indicate the location of significant larger perforations of the coating.

Greater precision can be obtained by reversing polarity and averaging the resistance values. Using impressed voltages[15] could result in even more accurate measurements. However, at this time, it is not considered necessary to go to more sophisticated instrumentation since these errors are significant only in the low resistance range where readings would indicate a conducting or highly permeable membrane. In the areas of high dielectric strength of say greater than 1,000,000 ohms, an error of 2000 or 3000 ohms in most cases is not significant or even readable on the instrument scale.

Sealant Voids and Electrical Resistance

In order to determine what effect perforations in a coating would have on the electrical resistance, studies were made on two bridge decks that were coated with California State Specification 35 epoxy. Initially, locations on the sealant were selected where the gross electrical resistance was in excess of 8,000,000 ohms. Then, by means of various sized drill bits, holes were drilled into the coating and the electrical resistance was remeasured by repeatedly placing the copper over the hole. By the method of least squares, an equation was derived which related the area of the drilled holes to the measured resistance. In one case, the resulting equation was:

$$A = 79.6R^{-0.76}$$

Wherein: A = area of the holes in coating in square inches
R = ohms resistance

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The coefficient of correlation for this equation was -0.989, the number of observations were 31, and the standard error of estimate was $0.091 \log_{10}$.

For the second bridge, the same procedure of drilling holes and measuring resistance of the coating was repeated. The resulting equation and correlation is shown on Figure 4. As indicated by Figure 4, when the area of the hole is reduced by about one-half, the electrical resistance approximately triples. A further graphic representation of the influence of the perforations made in the coating to the gross electrical resistance is shown on Figure 5. In this figure, it will be noted that what might be considered a large area of holes or openings in the coating (approximately one-tenth square inch), the measured electrical resistance would be about 30,000 ohms. What might be considered as a small area of perforation (0.02 square inch), the measured resistance would be approximately 250,000 ohms. Fortunately, in the area of holes we are interested in, the sensitivity to electrical resistance is greatest.

From the preceding relationships, it is apparent that there is a significant value to measuring the electrical resistance of bridge deck sealants and this gross figure, although not precise, can be an indicator of the porosity of the coating to deicing salts. To further demonstrate the influence of the gross electrical influence on bridge deck coatings, Figure 6 shows some of the values that were measured on various types of bridge deck sealants. As will be noted, the average gross resistance of a 2-inch asphalt concrete overlay was in the order of 3500 ohms per square foot.

In one case the average electrical resistance of a reinforced coal tar emulsion coating having an asphalt concrete overlay was about 22,000 ohms/sq.ft. A single layer of epoxy was approximately 110,000 ohms/sq.ft., while a double layer of epoxy was in excess of 2,500,000 ohms/sq.ft. In calculating the resistance on a square foot basis, it was assumed that the holes in the membranes that were tested were randomly and normally distributed. Therefore, since our apparatus had approximately 63 square inches of contact surface, the reported gross ohms/sq.ft. was directly calculated as an inverse proportion of a square foot to the 63 square inches of contacting electrode. Table 1 shows the results of a number of tests on bridges on which electrical resistance measurements were made. To further check these gross resistance values insofar as a tool which may be applicable to laboratory work, coatings were constructed on 3"x18"x24" concrete blocks. In order to

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measure the electrical resistance of the coating, a metal plate was first placed on the bench, on top of that a sponge wetted with water containing a wetting agent, then the block was placed above but in contact with the sponge. The metal plate/sponge assembly as shown on Figure 2 was placed on the sealed concrete block surface. In constructing these membranes in the laboratory, we attempted to create conditions similar to those which would be encountered in the field, as far as possible. The sealants were placed on the concrete and if required, hot asphalt concrete was compacted in the laboratory by means of a roller. In general, in the laboratory, the asphalt concrete was compacted to a density of approximately 90% or better.

Table 2 shows the gross resistance tests of laboratory specimens and also some field test results. As will be noted, the values are not exactly the same; however, if one refers to Figure 5, and the magnitude of the resistance values, then we would consider that there is a close approximation between the laboratory and the field tests of the gross electrical resistance of the coatings.

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DISCUSSION

A technique for comparing the electrical resistance of bridge deck sealing coatings has been presented. Although no correlation between measured resistance and sealant performance in the field has been possible due to the short time these sealants have been in place, it is hoped that with time, such data may become availalbe. However, if these measurements are made on new sealants and on a periodic basis, it is considered that this technique may enable researchers to have a common tool whereby they can report on the apparent porosity of bridge deck coatings as related to the penetration of deicing chemicals.

Because of seasonal and climatic variations, it is obvious that there may be variable moisture conditions on the surface of a coating and within the matrix of an asphaltic mix overlay that can affect electrical measurements. For this reason, the specific values for gross resistance will not be closely reproducible except in broad terms. For example, it is speculated that an excellent waterproof coating for bridges would always have an electrical resistance greater than 500,000 ohms/sq.ft., while a poor or perforated coating would never have a resistance greater than about 100,000 ohms/sq.ft. Uniformity of measurements can be improved in some cases by thoroughly and repeatedly wetting the overlay (asphaltic concrete) at the locations to be measured and allowing time for the water to permeate the layer before making measurements. This may require different waiting periods depending upon the permeability of the asphaltic concrete layer. For example, on dry asphaltic concrete overlays of about 4" thick, it has taken as long as 1-1/2 hours for the applied water to penetrate the asphalt to the concrete deck surface. As a result, the electrical measurements could be misleading in that high values on a dry asphalt concrete overlay would be recorded which would imply the presence of a "waterproof" membrane seal.

Because of the observed and measurable time element for water to penetrate a "dry" asphalt concrete, further work is being considered in evaluating the applicability of resistance measurements as an empirical permeability type of test for asphalt concrete and soils.

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Table 1

Gross Resistance of Bridge Decks

Bridge	Coating	Average Resistance Ohms/Sq.Ft.	Standard Deviation Factor ÷ or X	Number of Observations "n"
Grizzly Cr.	None	300	2.251	24
	Coal Tar Emulsion + 2" Asph. Conc.	22,000	7.799	31
Sacramento Riv. #2-02	None	2,600	1.174	42
	Epoxy 35	21,000	2.458	42
Sims Road #6-111	None	1,700	1.689	19
	Coal Tar Emulsion	2,638,000	7.722	19
	Coal Tar Emulsion +1" Asph. Conc.	18,000	2.020	14
Yuba Pass #17-23-R	None	1,300	2.963	23
	Epoxy 35	114,000	3.141	20
Yolo Bypass #22-124R	None	2,000	1.304	22
	Epoxy - 91 (8x16)	73,000	1.660	14
	Epoxy - 91 (4x8)	82,000	1.776	18
	*Epoxy - 45 (4x8)	178,000	2.138	35
	Epoxy - 45 (8x16)	679,000	3.933	42
	Epoxy 2-layer 35 (4x8) under 45, (8x16)	2,505,000	5.097	29
	Epoxy 35, (4x8)	195,000	2.990	47
	Epoxy 35, (8x16)	541,000	5.881	61
	Asph. Emuls. shoulder	12,000	1.677	25
Yolo Causeway	None	1,700	1.463	43
	2" Asph.Conc. overlay	3,500	2.512	38
Towle OH #19-40	None	1,000	1.380	33
	Thermoplastic	97,180	2.485	22

Table 2

Gross Resistance Tests of Coatings
Ohms/Sq.Ft.

Type	Laboratory Tests	Field Tests
Bare concrete	1,100	1,300
Reinforced Coal Tar Emulsion - No Asphalt Concrete	43,800,000	2,600,000
Reinforced Coal Tar Emulsion + 1-1/2 In. asphalt concrete	15,000	18,000-43,800
Thermoplastic + 1-1/2"	660,000	350,000

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METHOD FOR MEASURING RESISTANCE

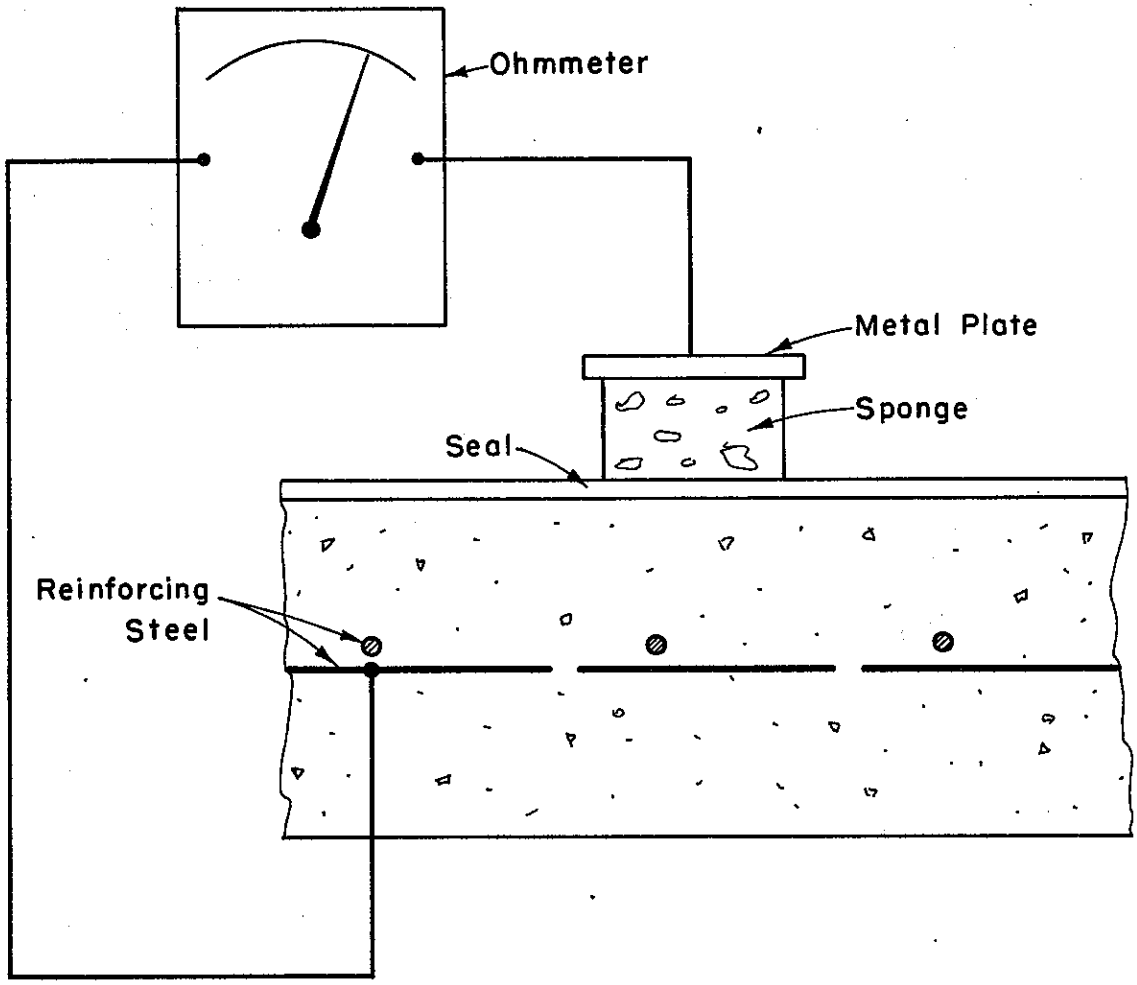

Figure 1

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Volt-ohm-meter and apparatus to measure bridge deck coating.

Figure 2

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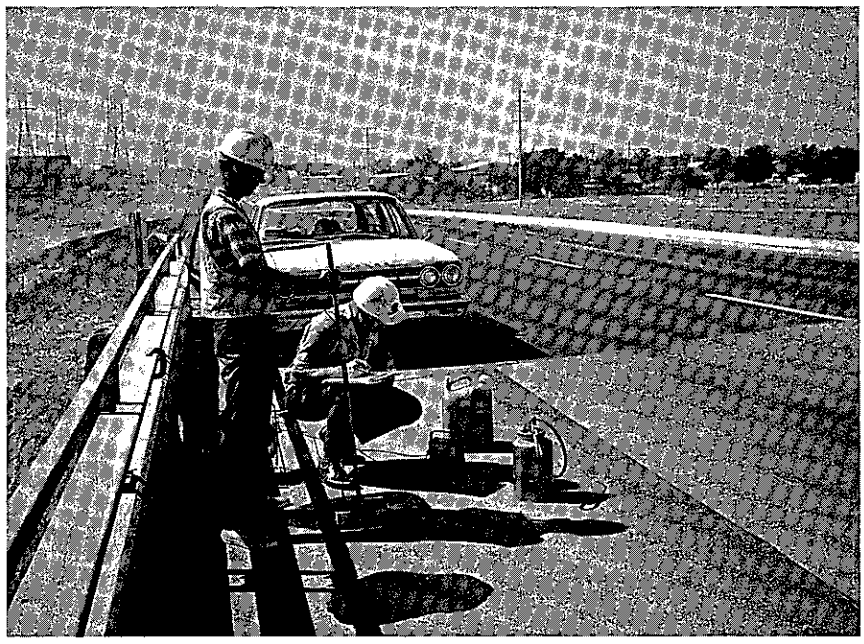

Measuring electrical resistance of Bridge Deck Coating.

Figure 3

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AREA OF PERFORATIONS VERSUS OHMS RESISTANCE - EPOXY

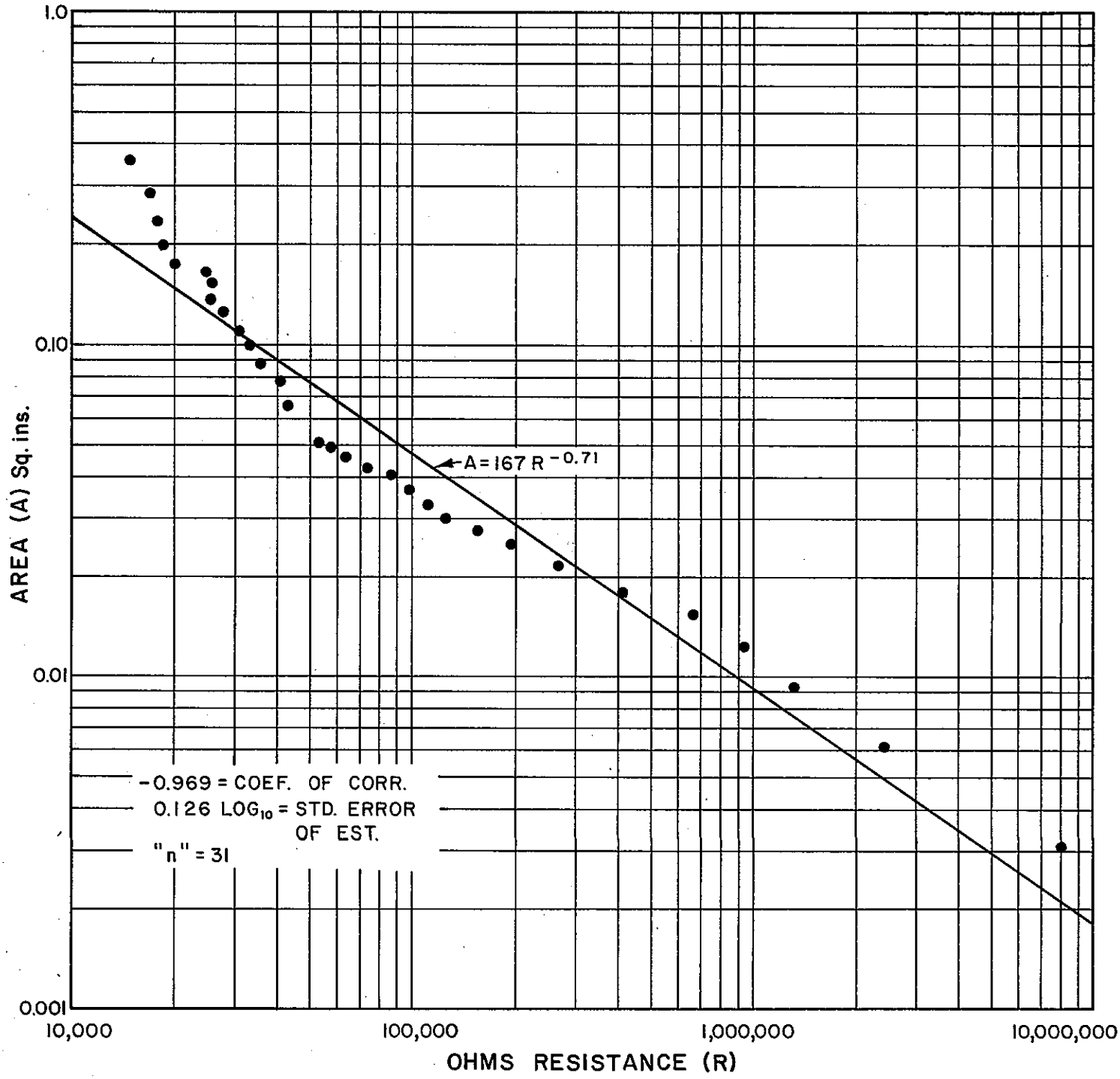

Figure 4

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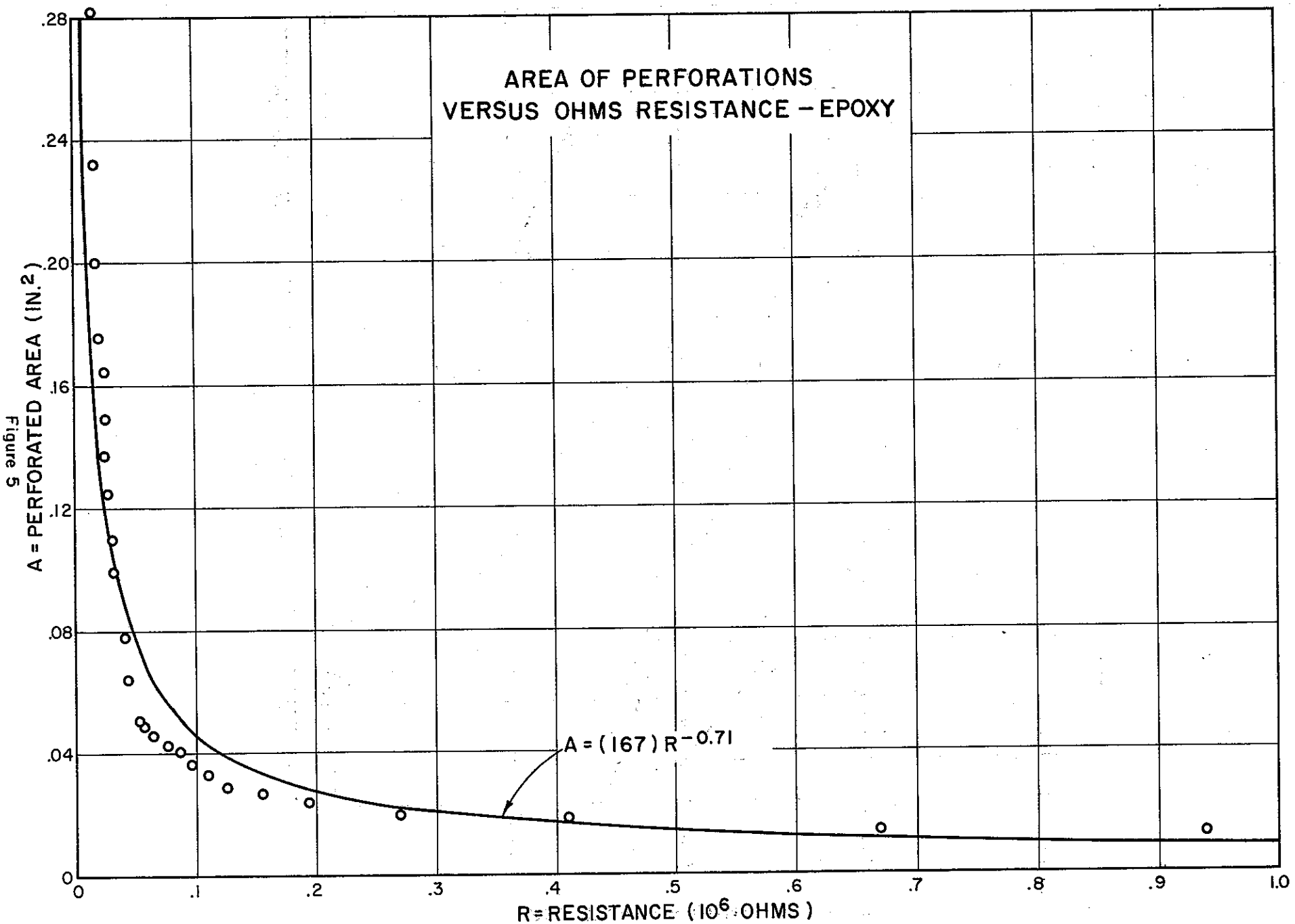

Figure 5

GROSS RESISTANCE OF DECK COATINGS

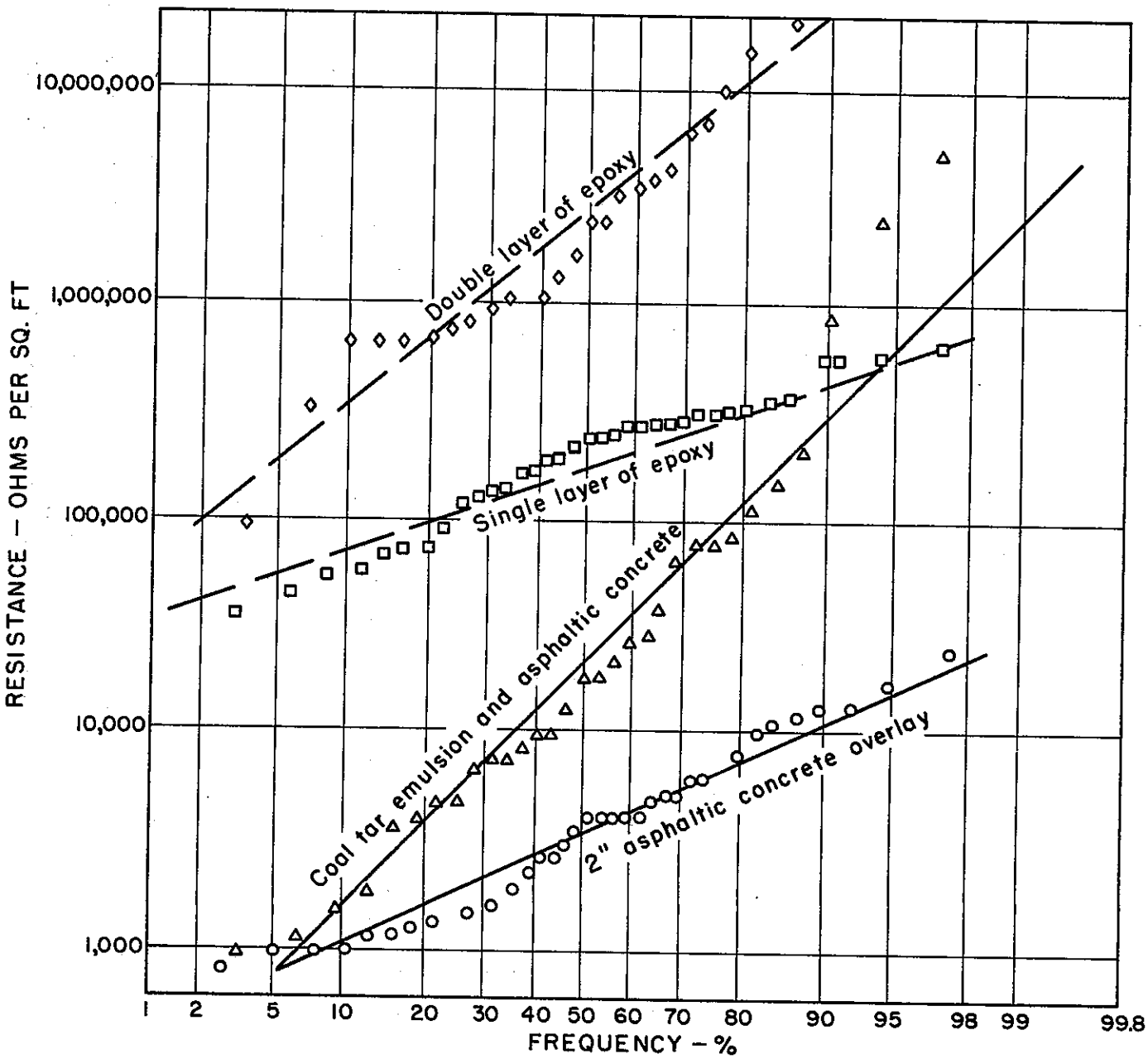

Figure 6

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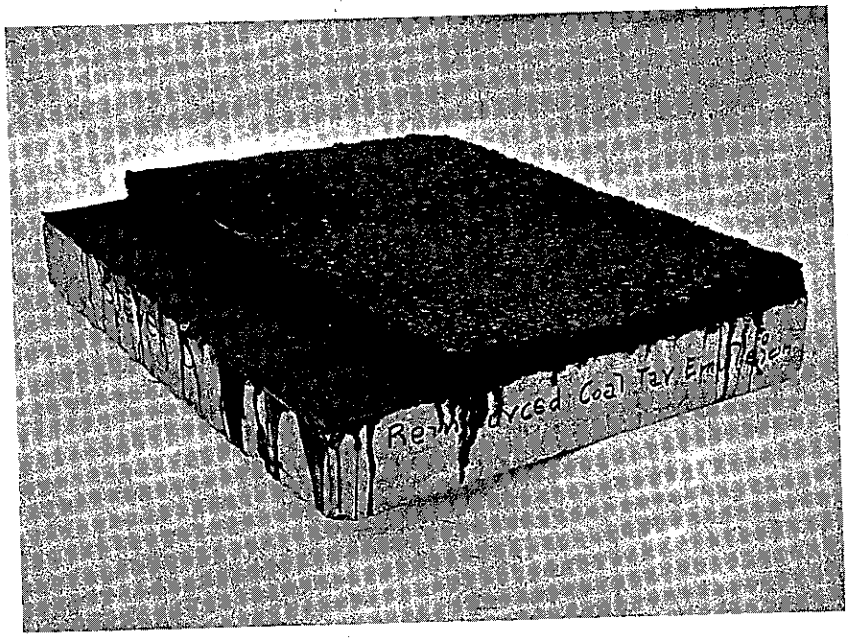

Laboratory test of bridge deck coating on 3" x 18" x 24" concrete block.

Figure 7

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RESISTANCE OF REINFORCED EXTENDED COAL TAR MEMBRANE AND 1" OF ASPHALT CONCRETE

SUSAN RIVER BRIDGE 02-LAS-395

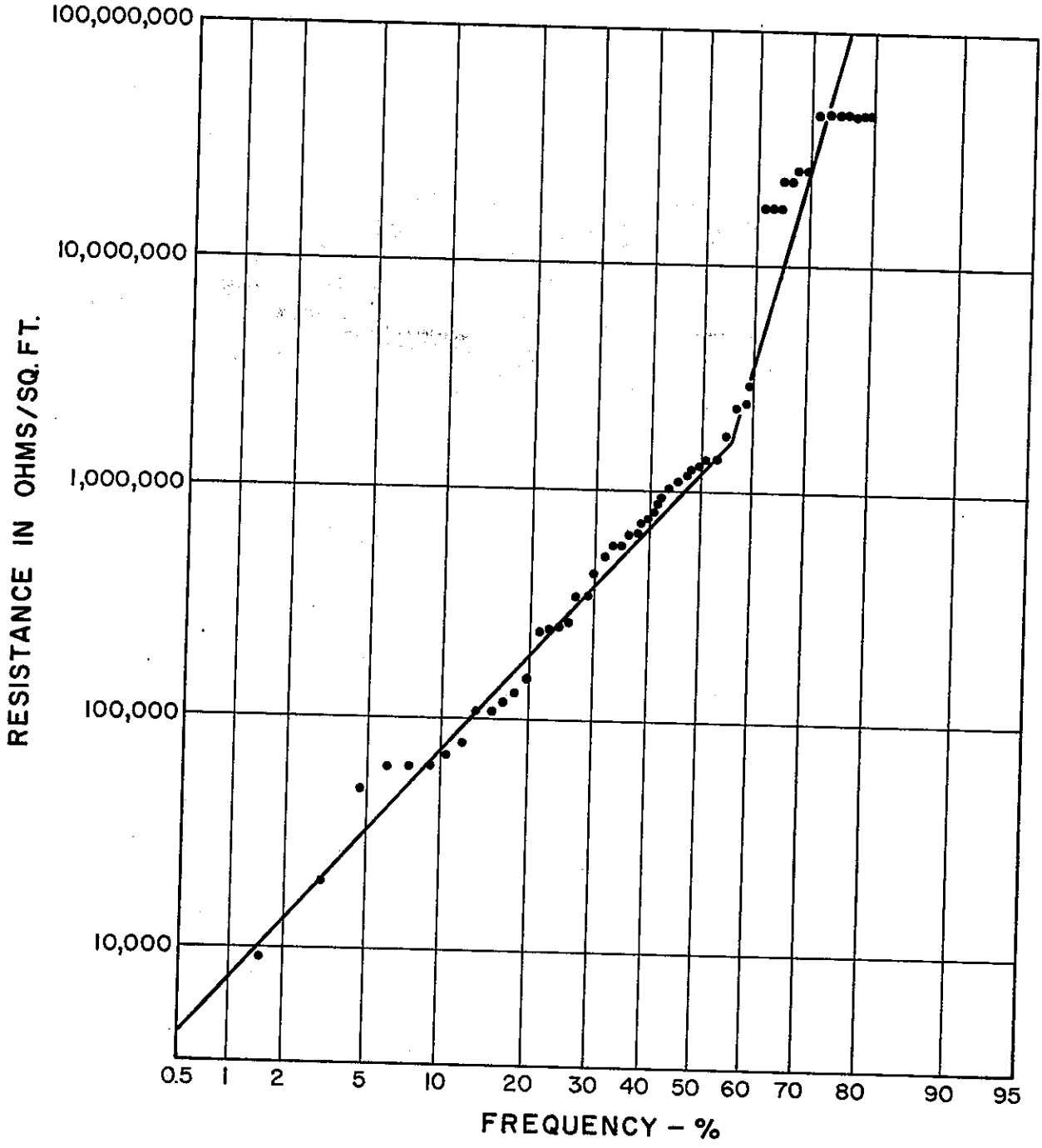

Figure 8

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RESISTANCE OF REINFORCED EXTENDED COAL TAR AND 3 INCHES OF ASPHALT CONCRETE

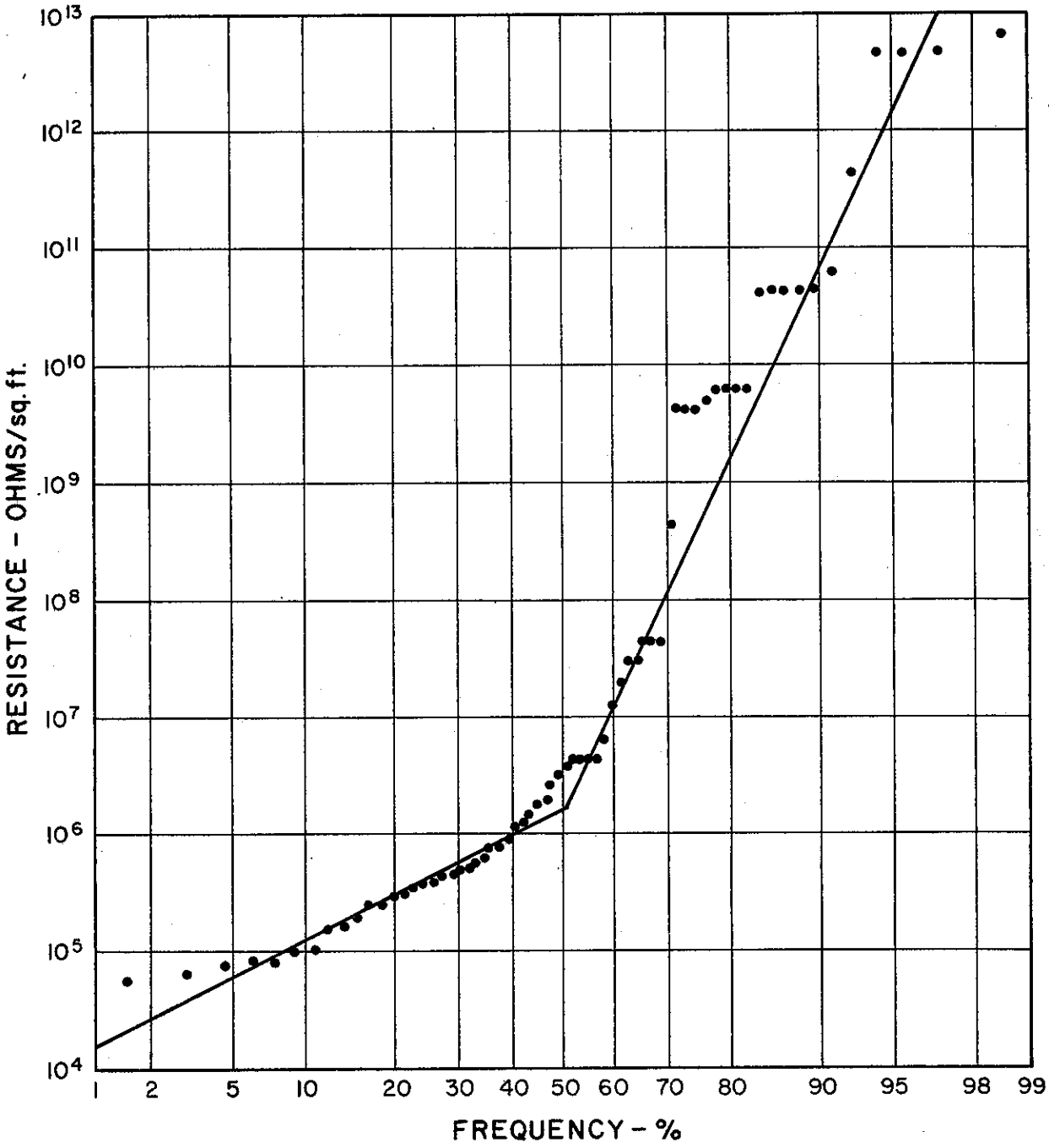

Figure 9

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RESISTANCE OF REINFORCED EXTENDED COAL TAR WITH 1 AND 3 INCHES OF ASPHALT CONCRETE

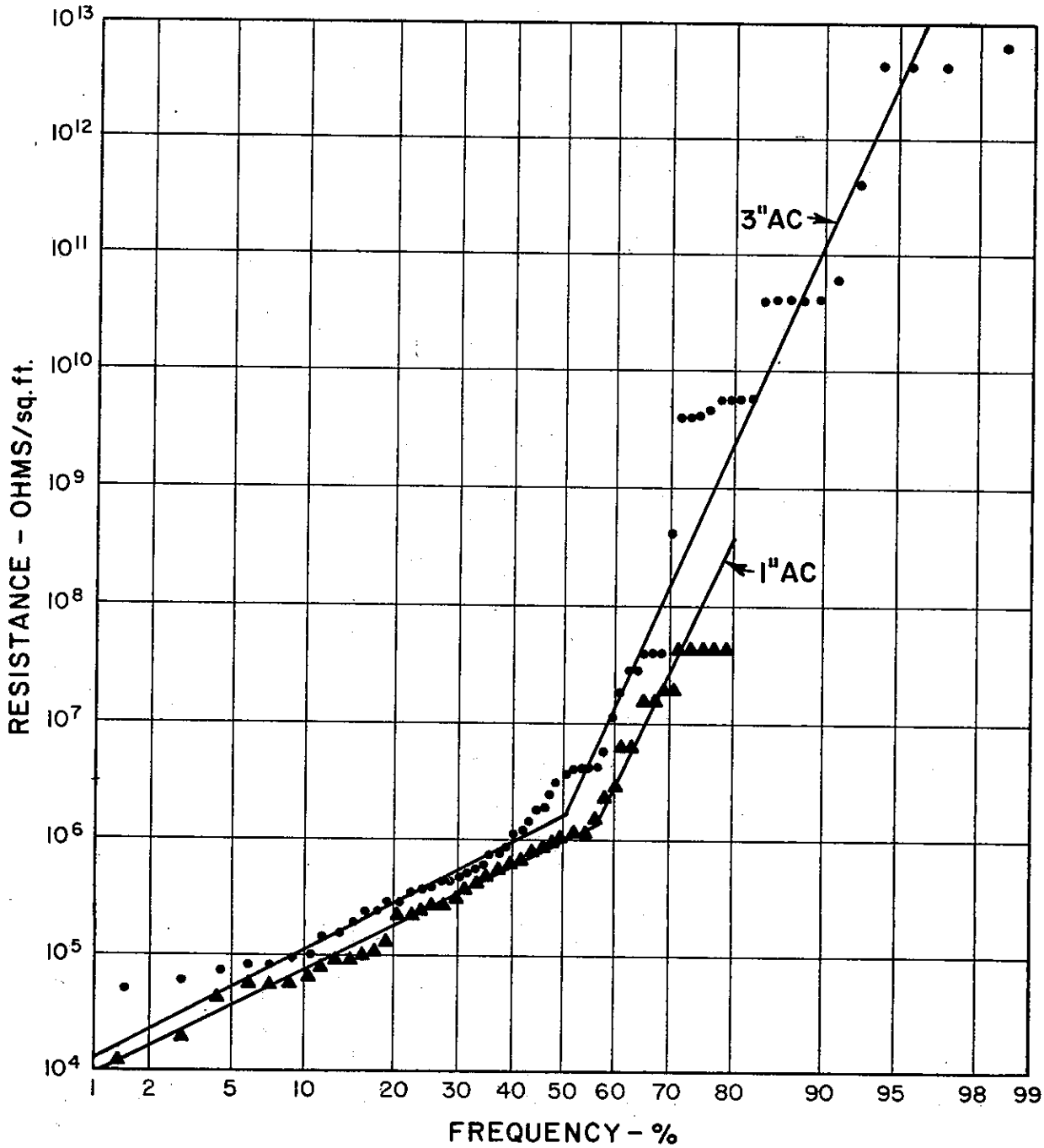

Figure 10

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EQUI-RESISTANCE CONTOURS
OF BRIDGE DECK MEMBRANE-OHMS/SQ. FT.

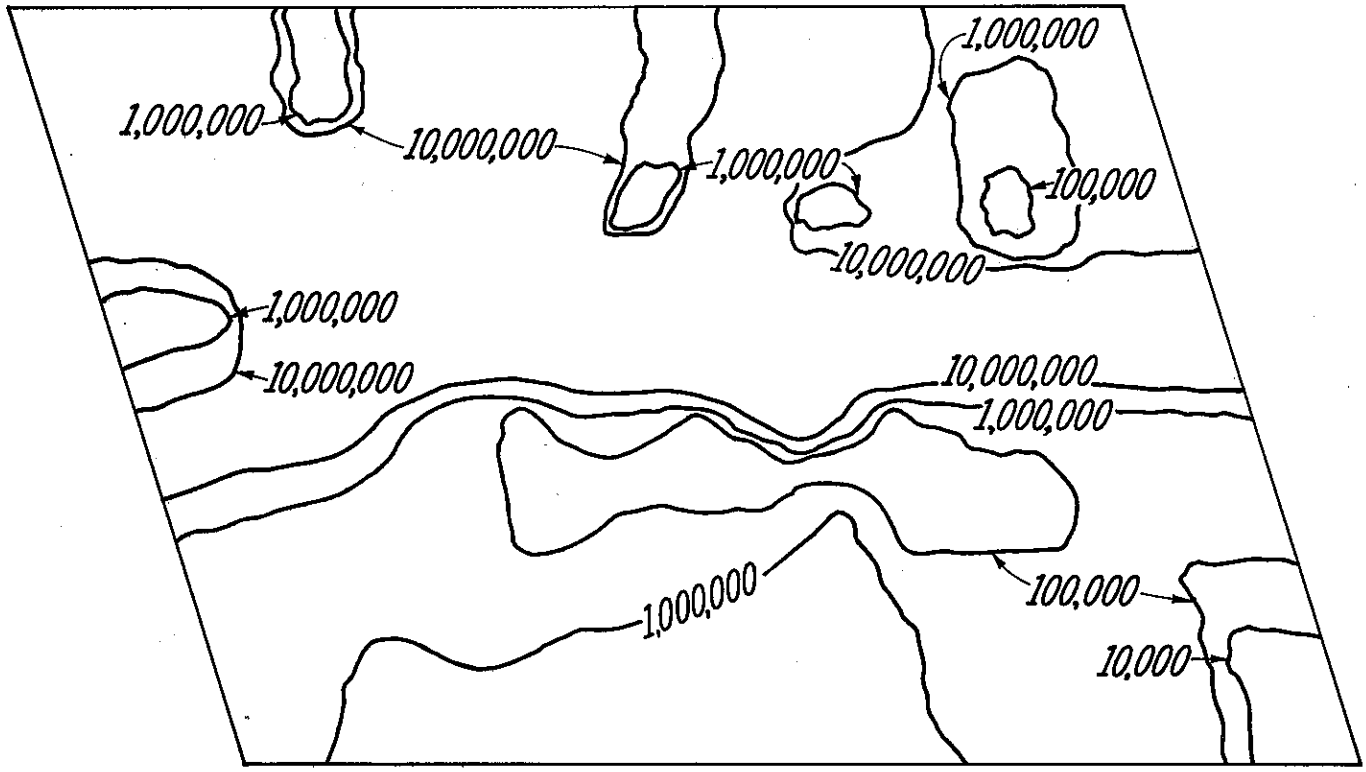

Figure 11

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EQUI-RESISTANCE CONTOURS
OF BRIDGE DECK MEMBRANE MEG-OHMS/SQ. FT.

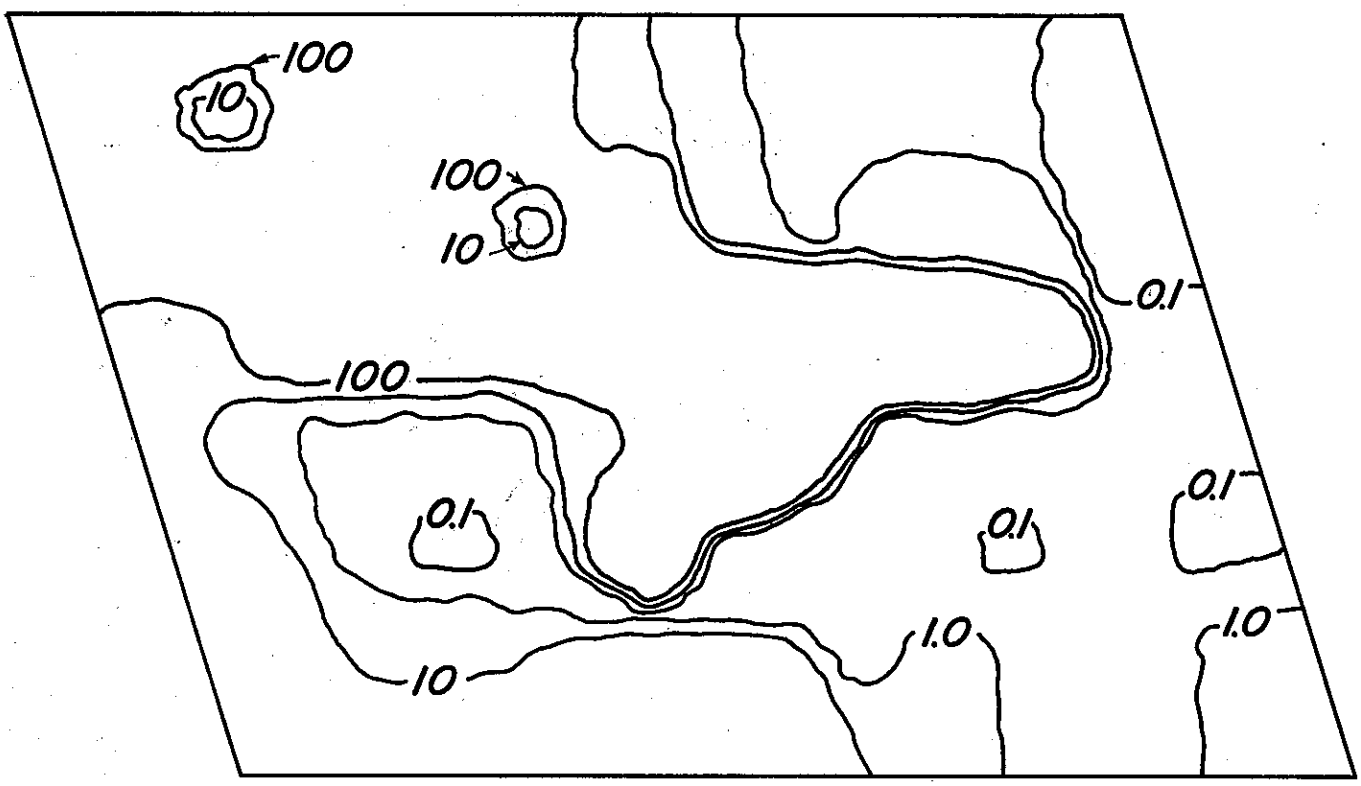

Figure 12

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