BRIDGE DECK DETERIORATION STUDY

FINAL REPORT

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INTRODUCTION

The cause and extent of bridge deck deterioration have been the concern of all highway agencies in recent years. Extensive investigations have been made in states where extreme icing occurs during the winter months. Reinforcing steel corrosion and its associated problems have long been recognized in these states. However, it has been only recently that symptoms of reinforcing steel corrosion have begun to occur with any regularity in Louisiana; and this is more or less confined to the northern section of the state where icing of bridges occurs only a few times a year. This state, like most others, endeavors to keep open to traffic all major traffic routes during these brief icing periods for emergency vehicles and necessary transportation. Since our icing periods are brief, this is probably the reason that the corrosion related problems are only now showing up. We are therefore indebted to those who pioneered the means of detecting corrosion problem areas.

PURPOSE

The basic purpose of this study was to investigate three bridges in the northern section of Louisiana in an attempt to determine if there is sufficient deterioration and corrosion of the reinforcing steel to warrant a comprehensive study of bridge decks in this area of the state which is exposed to icing conditions during the winter months.

SCOPE

The bridges selected for investigation represent three decades of construction: one bridge selected was constructed during the 1930's, one during the 1940's, and one during the 1950's. Upon examination of the bridges the physical appearance (scaling, spalling and cracking) was documented in addition to the corrosion potential and the chloride ion concentration present in the decks.

METHOD OF PROCEDURE

The conditions of the decks investigated were determined using the following procedures:

1. Active Corrosion. A Cu-$CuSO_4$ half-cell was used in conjunction with a DC-Null Voltmeter to determine the electrical potentials of the decks. (See Figure No. 1 for a schematic of the arrangement.) The decks were divided into four-or five-foot grids and isopleths of the electrical potentials were plotted.

2. Depth of Reinforcing Steel. A James Electronics Company Pacometer, Model No. C-4946, was used to check the cover of the reinforcing steel of each corner of the grids previously marked.

3. Scaling. Visual observations were made and photodocumented.

4. Spalling. Visual observations were made and photodocumented.

5. Cracking. Visual observations were made and photodocumented.

6. Delamination of the decks. A simple six-foot long chain was dragged over the surface of the decks. Delaminated areas were indicated by a dull sound produced by the chain. These areas were outlined with chalk and plotted on a chart.

7. Chloride Ion Content. Cores of the concrete deck were taken. These cores were sliced into one-half inch increments, and each increment was tested for chloride ion content by the chemical testing laboratory using the recommended procedures published by the Federal Highway Administration.

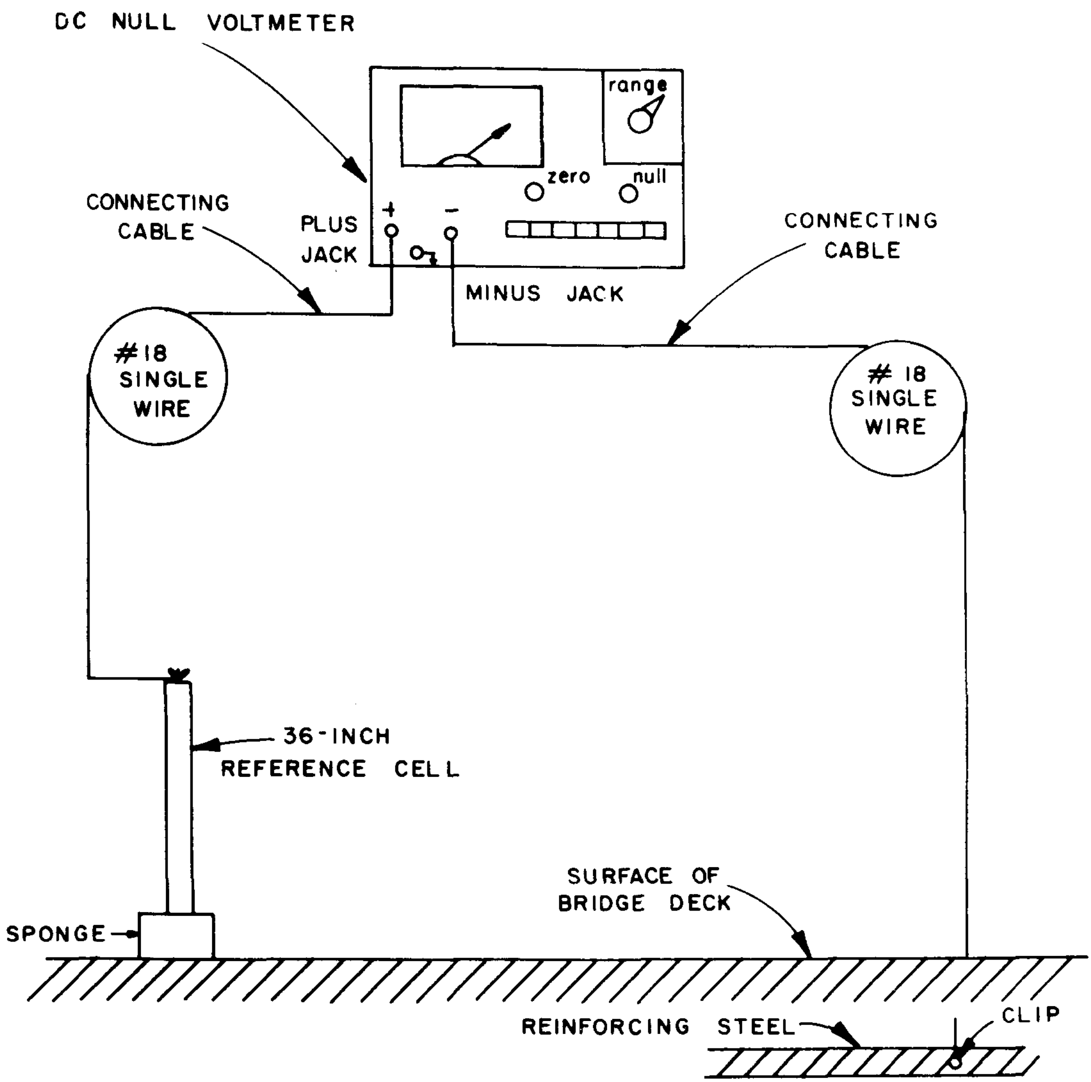

FIGURE 1
Schematic Diagram Cu-$CuSO_4$ Device

DISCUSSION OF RESULTS

Prior to the discussion of results, it must be pointed out that these bridges do not necessarily represent a typical bridge that was constructed during the time periods. They were not selected by any means of randomization, but were selected primarily for ease of traffic control and close proximity to each other in order to minimize travel requirements. However, since this was a survey study to determine if there is any corrosion or potential corrosion of the reinforcing steel in bridge decks in Louisiana, it was felt that the manner in which the bridges were selected was irrelevant.

Depth of Top Reinforcing Steel: In all cases the depth of reinforcing steel met or exceeded the design depth for each bridge investigated. Therefore, no further mention is made to concrete cover in this report.

Active Corrosion: It has been determined by previous research that if potential readings are more negative than 0.35 volts, there is a 95 percent chance that active corrosion is occurring to the top reinforcing steel. Voltage readings lower than 0.30 volts indicate that active corrosion generally is not present in the deck. Voltage readings between 0.30 and 0.35 are an indication that the concrete surrounding the reinforcing steel is in a stage of changing from a passive to an active medium, and corrosion to the reinforcing steel may or may not be present. Very active corrosion is occurring when readings are above 0.45 volts. The half-cell corrosion detection charts have been isoplethed from the potential readings obtained from the decks studied to reflect the aforementioned values.

Chloride Ion Content: The intrusion of deicing salts in the form of chloride ions into concrete has been shown to provide the electrolyte for ionic flow to occur. When the chloride ion content reaches approximately one pound per cubic yard of concrete, ionic flow may begin to occur. Ionic flow, and thus active corrosion, is said to be defintely occurring where contents are above 1.5 or 2.0 pounds of chloride ion per cubic yard of concrete. The chloride ion content between 1.0 and 2.0 pounds per cubic yard of concrete is the transition phase where the concrete is changing from a passive to an active situation. The exact point of transition would depend upon may unavailables, and the exact threshold limit is very hard to determine. However, in order to determine the condition of a given bridge deck, the chloride ion analysis is an important tool when used in conjunction with the half-cell device.

Bridge No. 1: U.S. 171 Texas and Pacific Railroad Overpass (1937)

This is a 22-span overpass. Span numbers 2, 13, 14 and 21 were selected for investigation, with spans 13 and 14 being the top two spans on the bridge.

The following observations were made from the visual observations, the Half-Cell Corrosion charts and the Chloride Ion table. (See figures 1 through 11 and Table 1.)

1. There is active corrosion occurring adjacent to the gutter lines in all spans investigated.

2. Spans 13 and 14 have more corrosion than spans 2 and 21. This could be due to the fact that the drainage characteristics are different. Spans 13 and 14 are relatively flat and could allow the applied deicing salts to penetrate, while the grades on spans 2 and 21 are much greater and would allow the salts to run off at a much higher rate and thus not have time to penetrate the concrete.

3. There is ample choride ion content in the bridge deck for corrosion and its effect to continue.

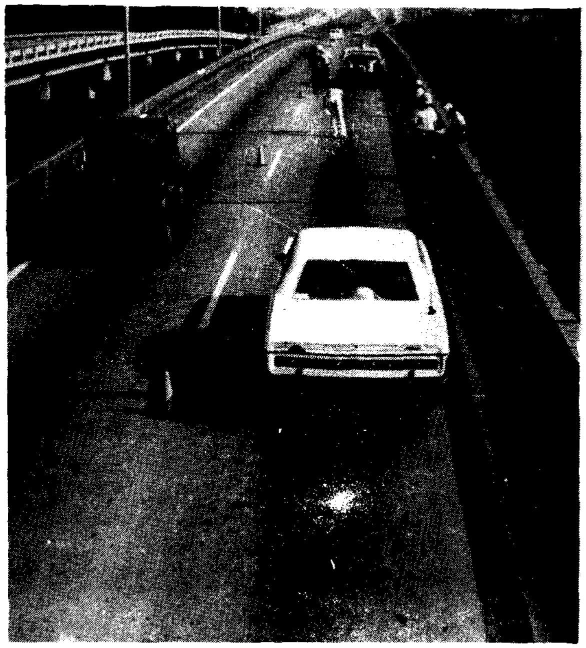

FIGURE 2
Bridge No. 1: Northbound Lane

FIGURE 3
Bridge No. 1: Cracking and spalling is evident over the reinforcing steel in which corrosion is occurring.

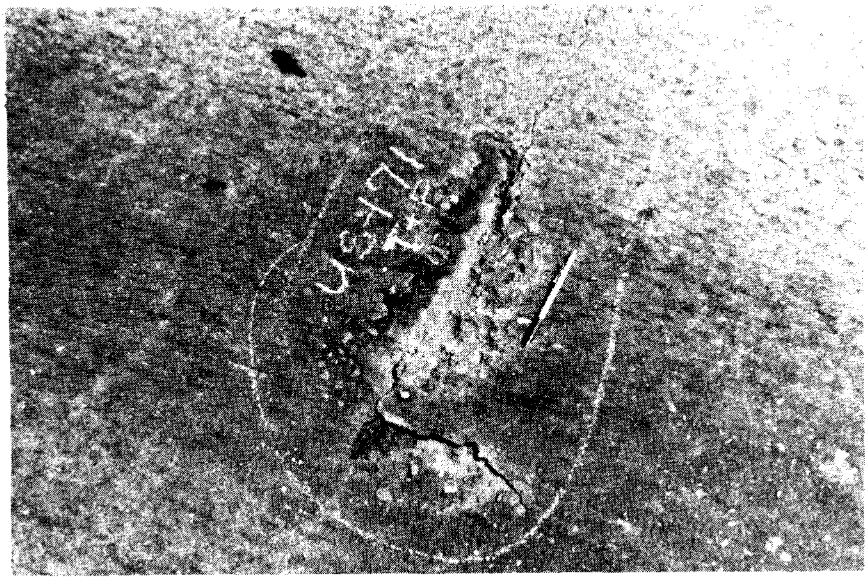

FIGURE 4
Bridge No. 1: A close-up of the lower right corner of Figure No. 2.

FIGURE 5
Bridge No. 1: Surface scaling is occurring at this section.

FIGURE 6
Bridge No. 1: Delamination has occurred to this area.

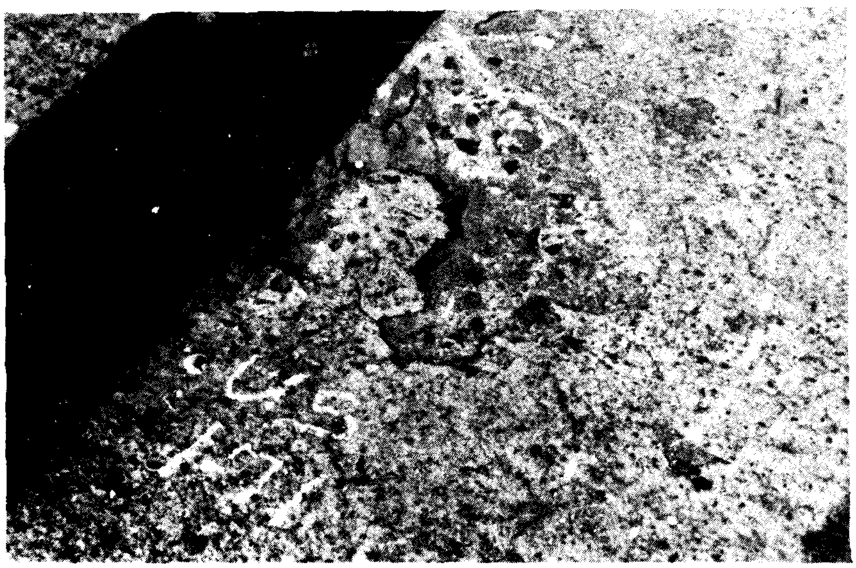

FIGURE 7
Bridge No. 1: Spalling at the armor joint is a troublesome maintenance problem.

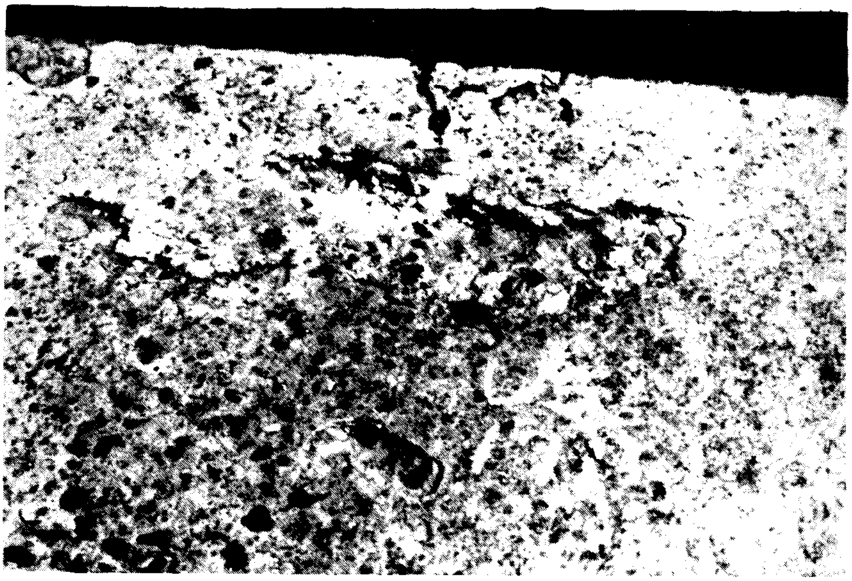

FIGURE 8
Bridge No. 1: This area will spall out in time.

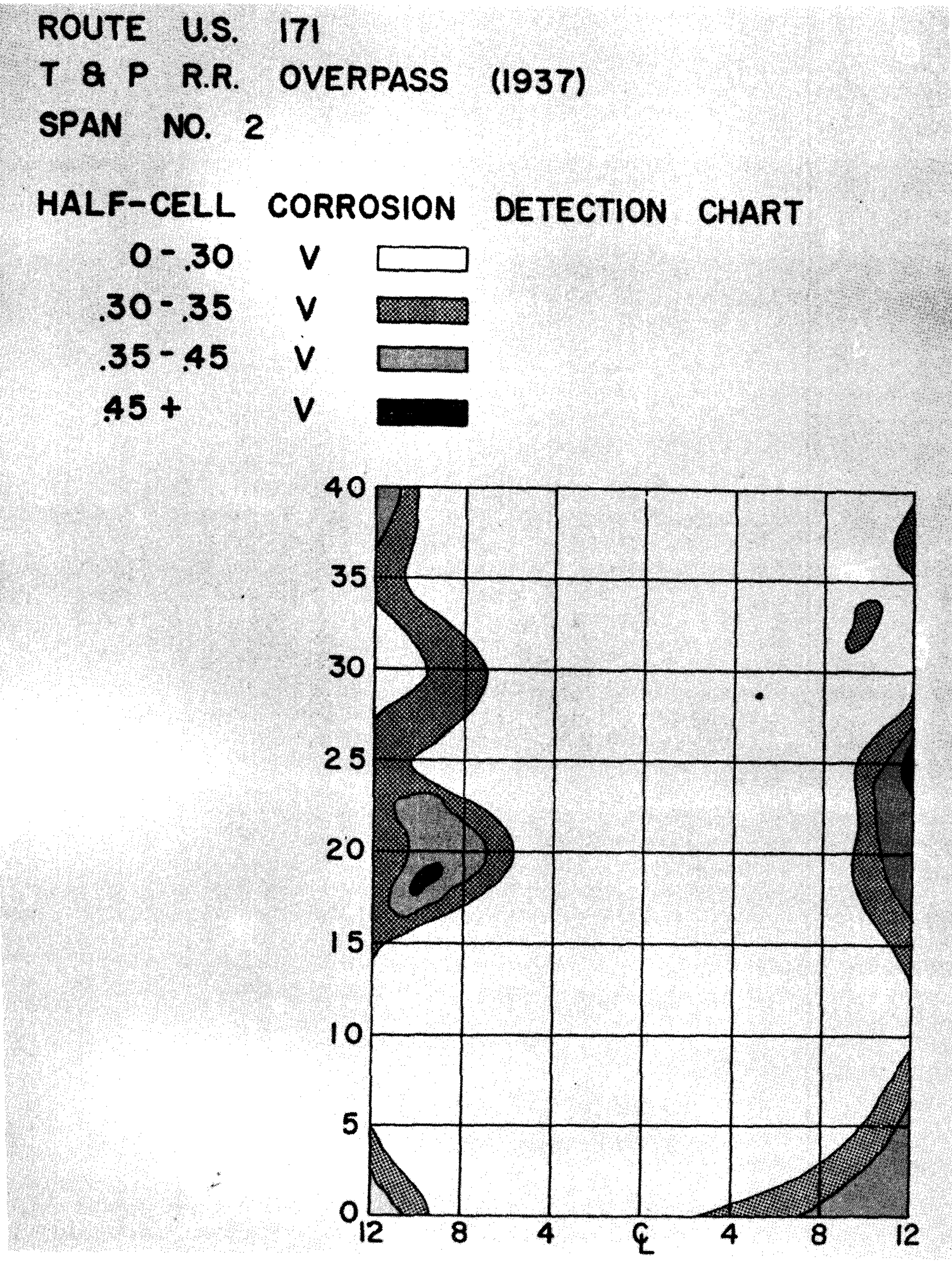

FIGURE 9
Bridge No. 1: Half-Cell Corrosion Chart

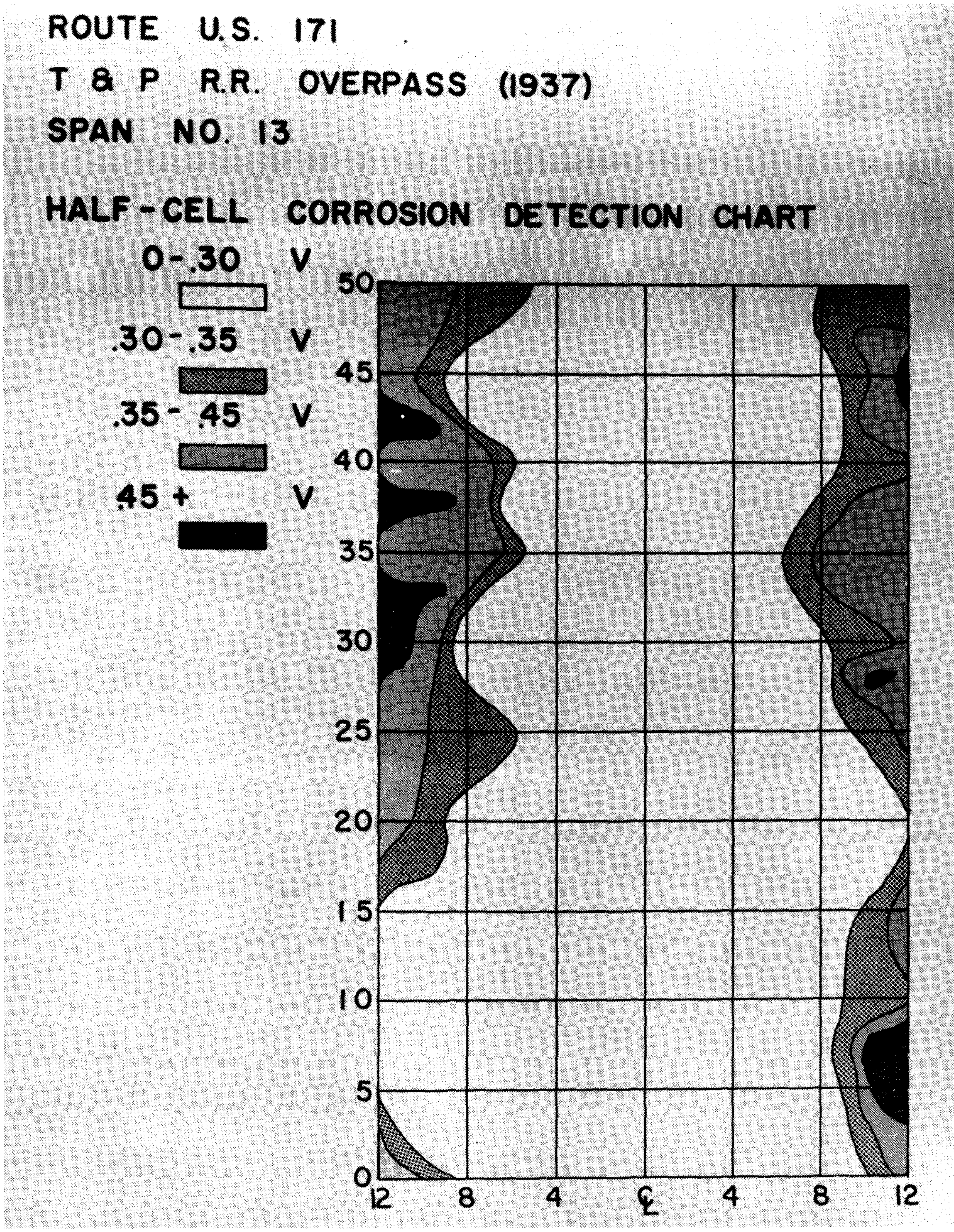

FIGURE 10
Bridge No. 1: Half-Cell Corrosion Chart

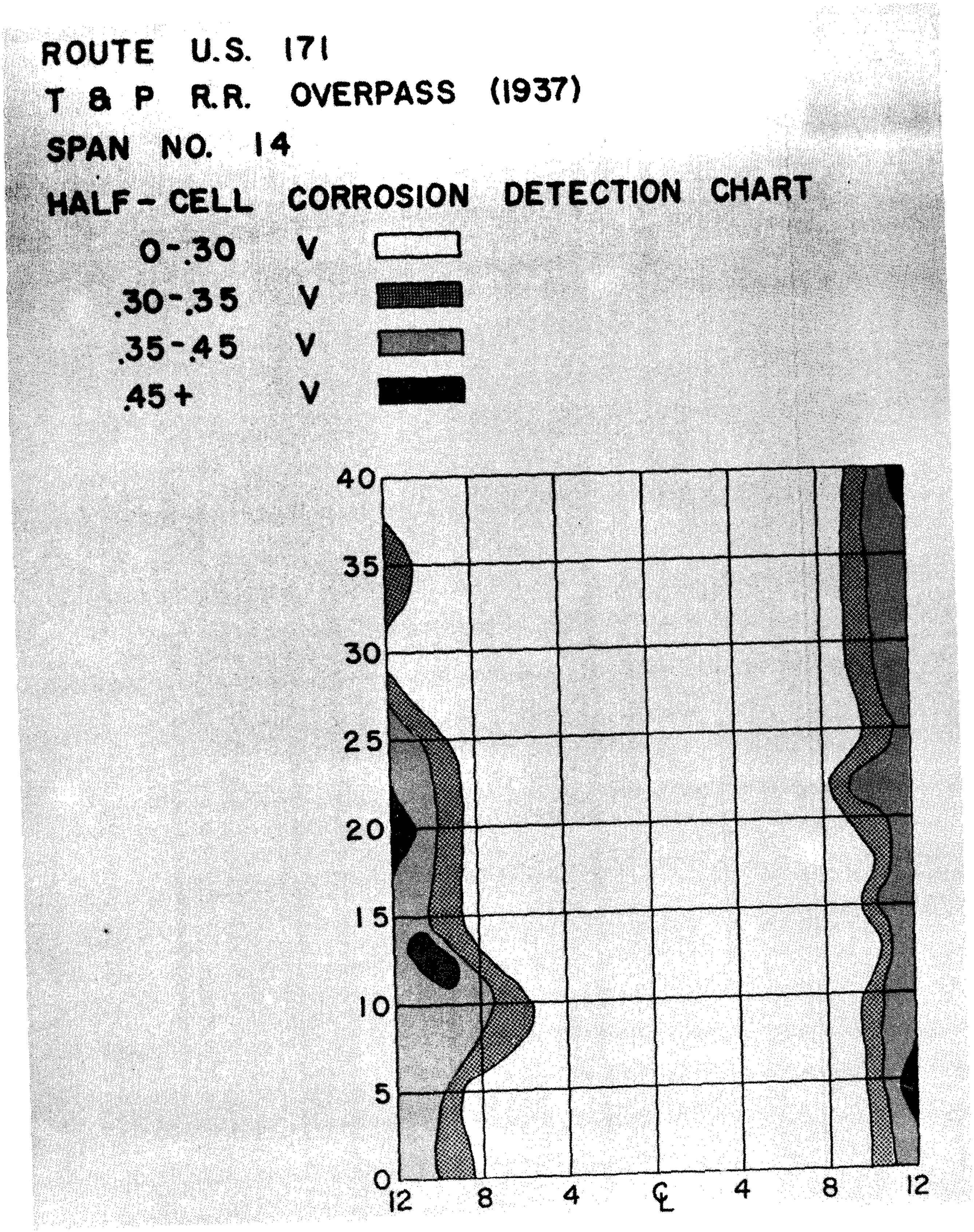

FIGURE 11
Bridge No. 1: Half-Cell Corrosion Chart

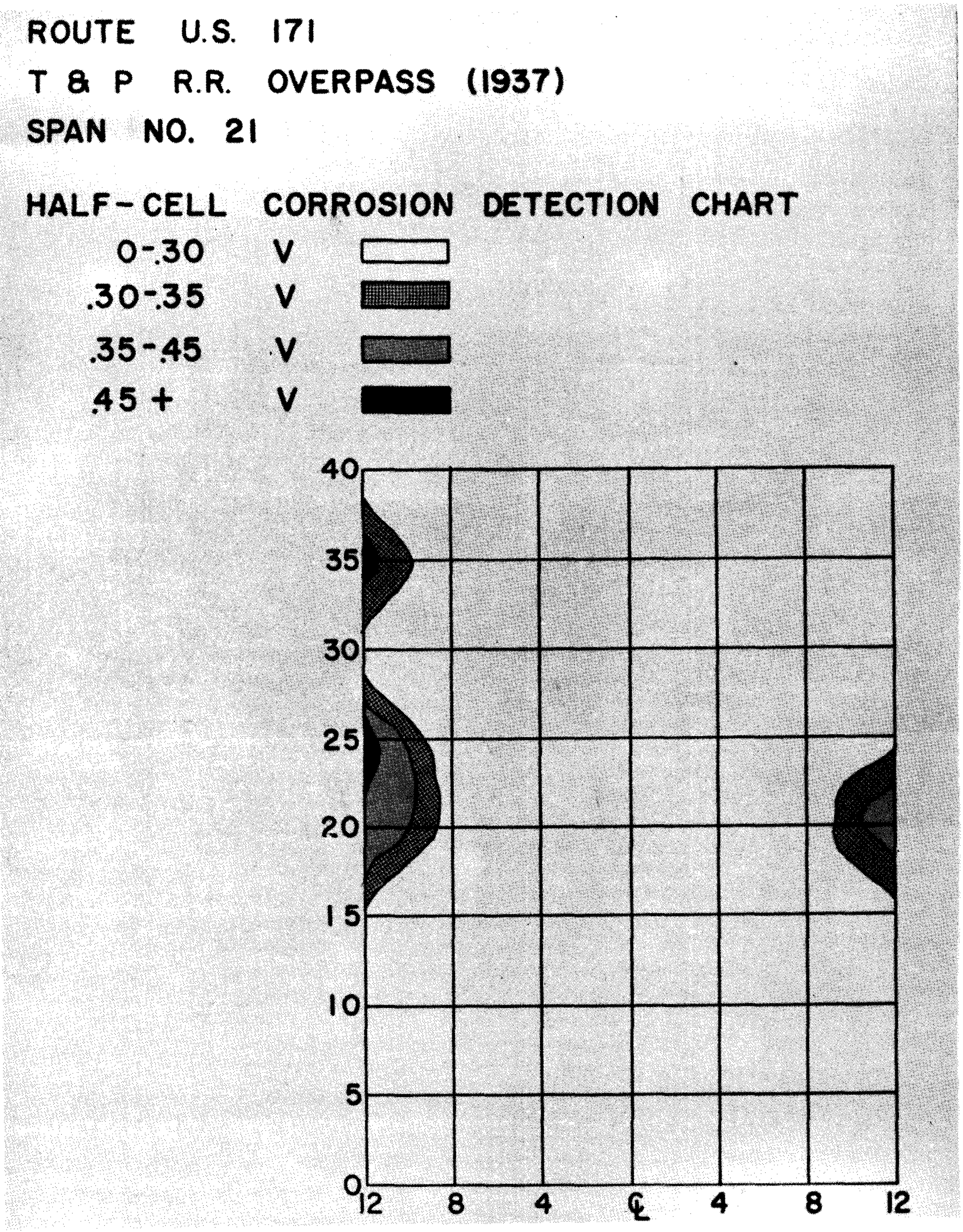

FIGURE 12
Bridge No. 1: Half-Cell Corrosion Chart

TABLE 1
BRIDGE NO. 1
CHLORIDE ION ANALYSIS OF CORES

Span	Core No.	Lane	Potential Voltage	Cl^- above rebar #/cy. (0-1 1/2")	Cl^- at rebar #/cy. (1 1/2-2")	Cl^- below rebar #/cy. (2"plus)
2	14	Left	.38	5.54	1.58	0.0
2	7	Right	.02	1.84	0.70	*
13	12	Left	.19	1.60	1.60	1.20
13	13	Left	.39	0.00	0.00	0.00
13	5	Right	.04	1.80	0.24	0.20
13	6	Right	.34	0.79	0.40	0.00
14	10	Left	.02	2.84	0.92	0.28
14	11	Left	.15	4.04	2.20	0.92
14	3	Right	.20	1.20	0.80	0.00
14	4	Right	.28	0.80	1.60	1.00
21	8	Left	.08	1.36	0.78	*
21	9	Left	.12	3.56	0.80	0.28
21	1	Right	.17	1.16	0.00	0.00
21	2	Right	.14	1.48	0.24	0.00

* Core fractured and further depth not available.

Bridge No. 2: 12-Mile Bayou Bridge U.S. 71 (1936-48-56)

This is a flat crossing which was lengthened twice after the original structure was completed in 1936. This bridge offered the unique possibility to investigate the chloride ion retention, or build-up over a 20-year period in a structure with an identical condition. The following observations may be made from visual observation, the Half-Cell Corrosion chart and the Chloride Ion table. (See figures 1 through 21 and Table 2.)

1. There is active corrosion in all spans investigated.

2. Most of the corrosion activity protrudes from the gutter line; however, islands of corrosion do occur in each span.

3. There is sufficient chloride ion content in each span for corrosion to continue.

4. The chloride ion content in Span 5L (1936) is, on the average, less than that in those constructed in 1948 and 1956. This could be due to the fact that deicing salts were not applied with any degree of regularity until the late 1940's or early 1950's and that portion had 15 years for a natural road film to develop and form somewhat of a barrier to the intrusion of the deicing salts. The newer spans had deicing salts applied to them at an earlier age; and, therefore, absorbed more of the chloride.

FIGURE 13
Bridge No. 2: The 12-Mile Bayou Bridge

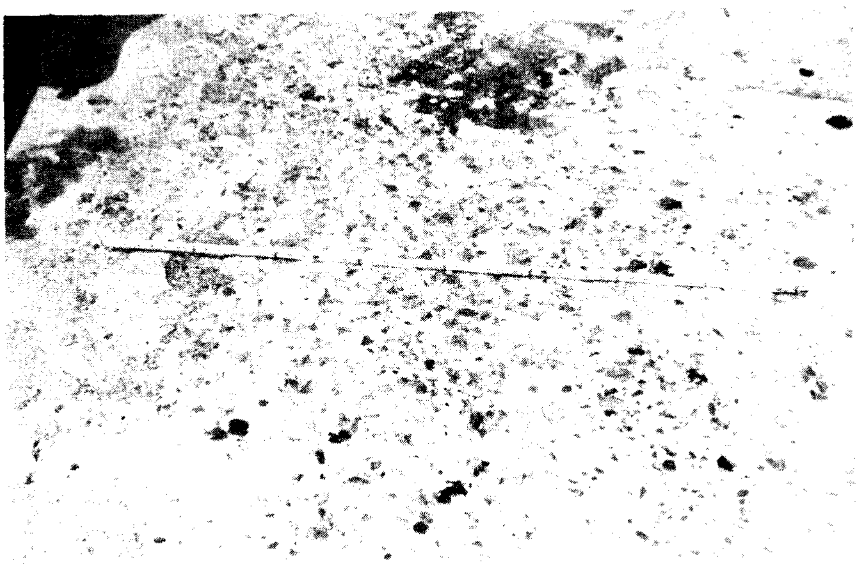

FIGURE 14
Bridge No. 2: This area is heavily scaled

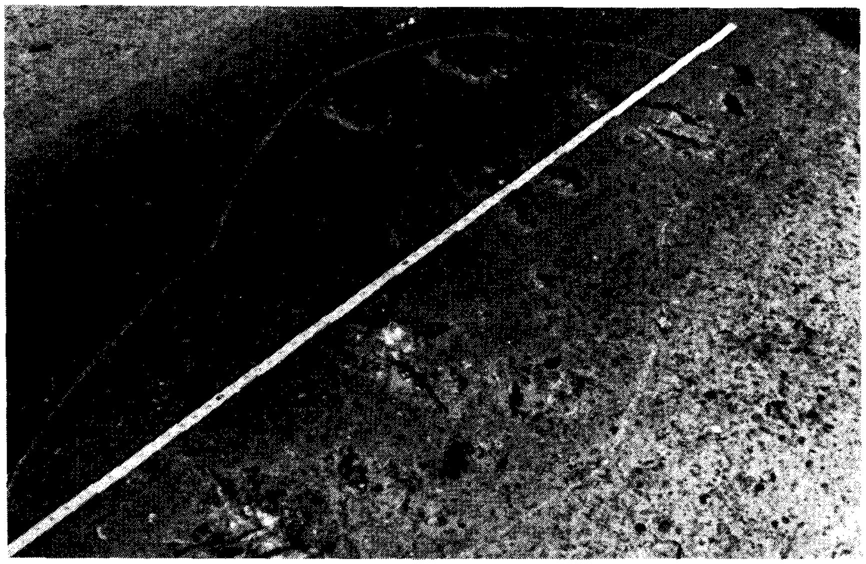

FIGURE 15
Bridge No. 2: Delamination is outlined in chalk. Spalling occurs within the delaminated area.

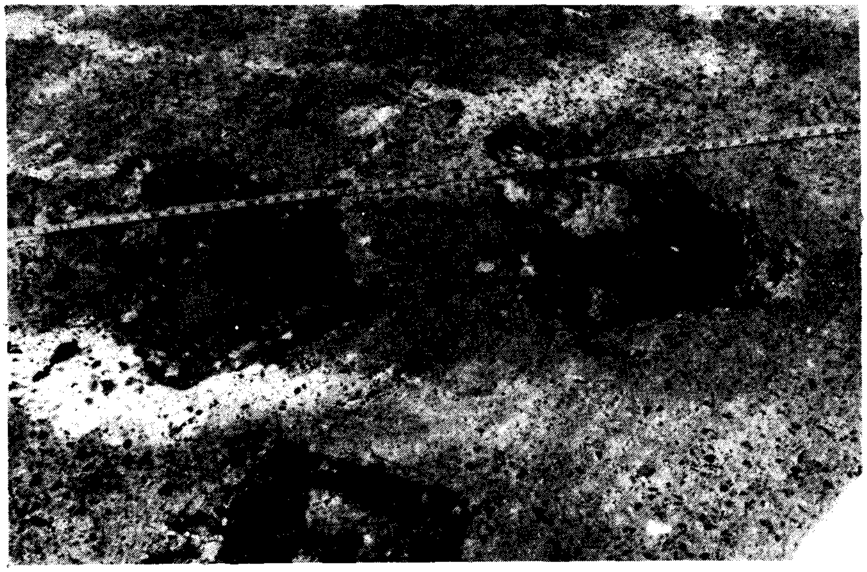

FIGURE 16
Bridge No. 2: Spalled areas

FIGURE 17
Bridge No. 2: Looking south

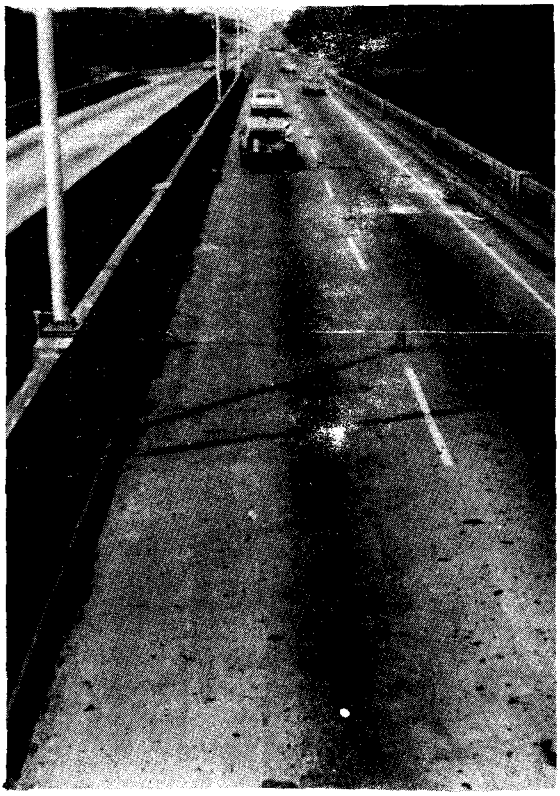

FIGURE 18
Bridge No. 2: Looking north

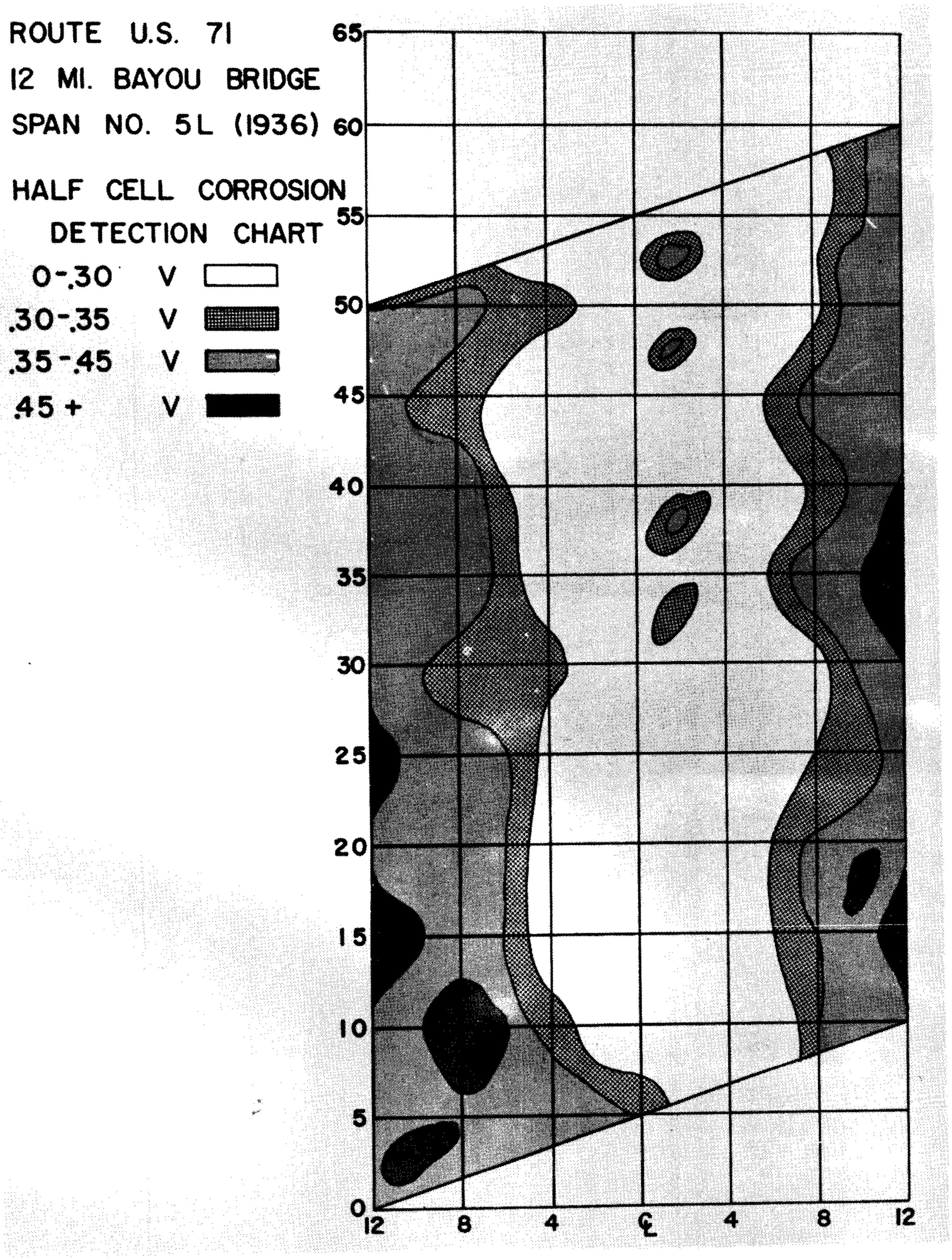

FIGURE 19
Bridge No. 2: Half-Cell Corrosion Chart

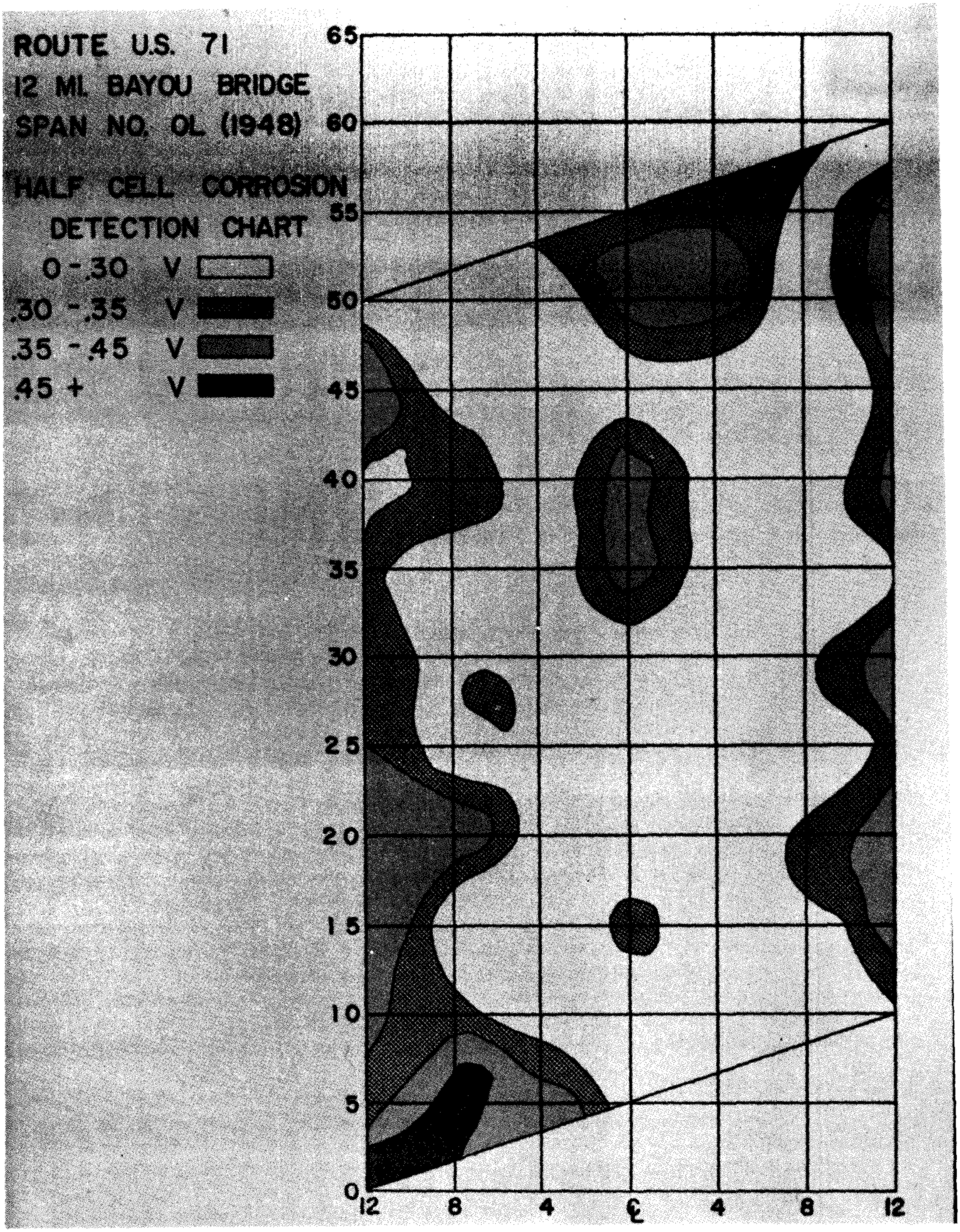

FIGURE 20
Bridge No. 2: Half-Cell Corrosion Chart

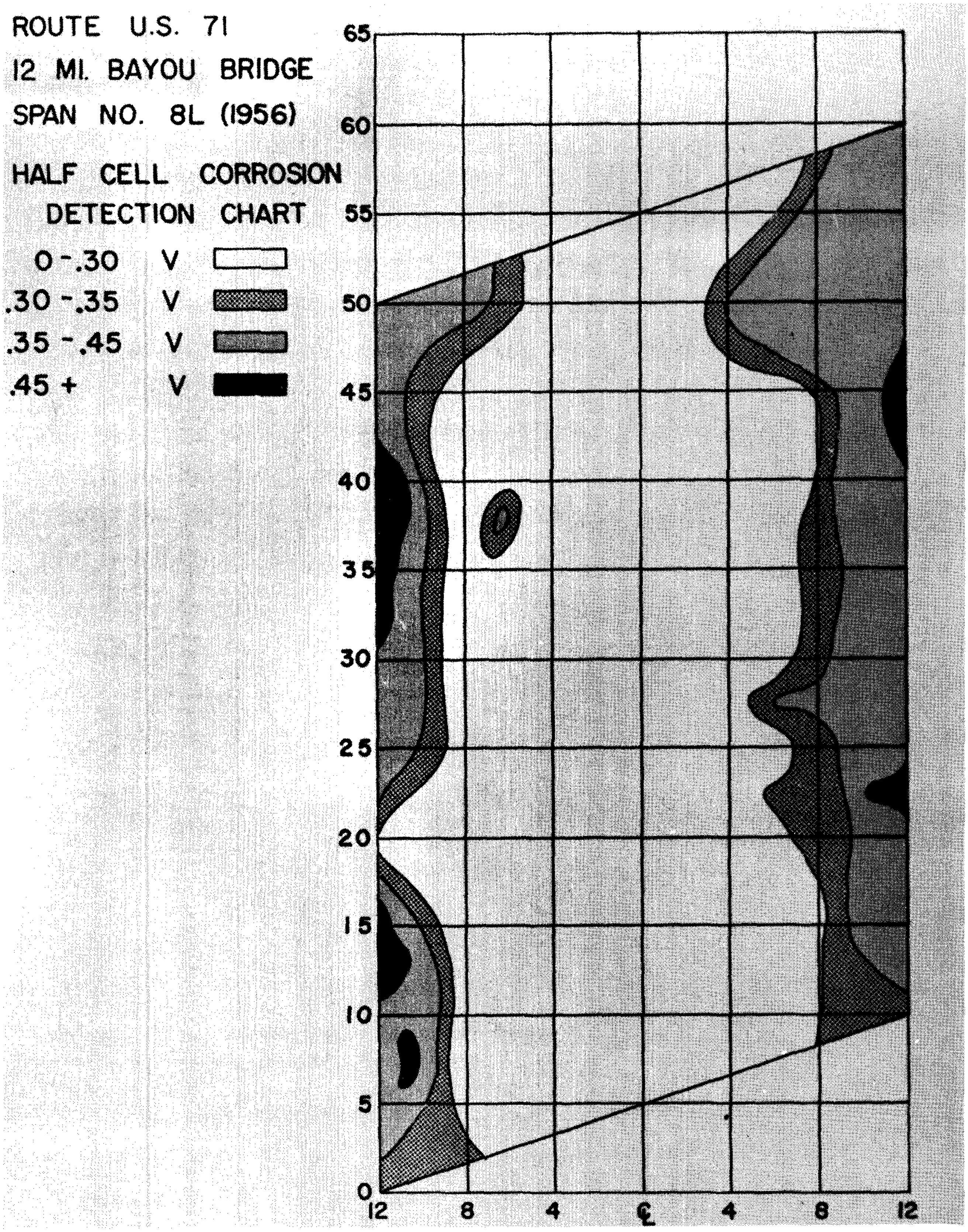

FIGURE 21
Bridge No. 2: Half-Cell Corrosion Chart

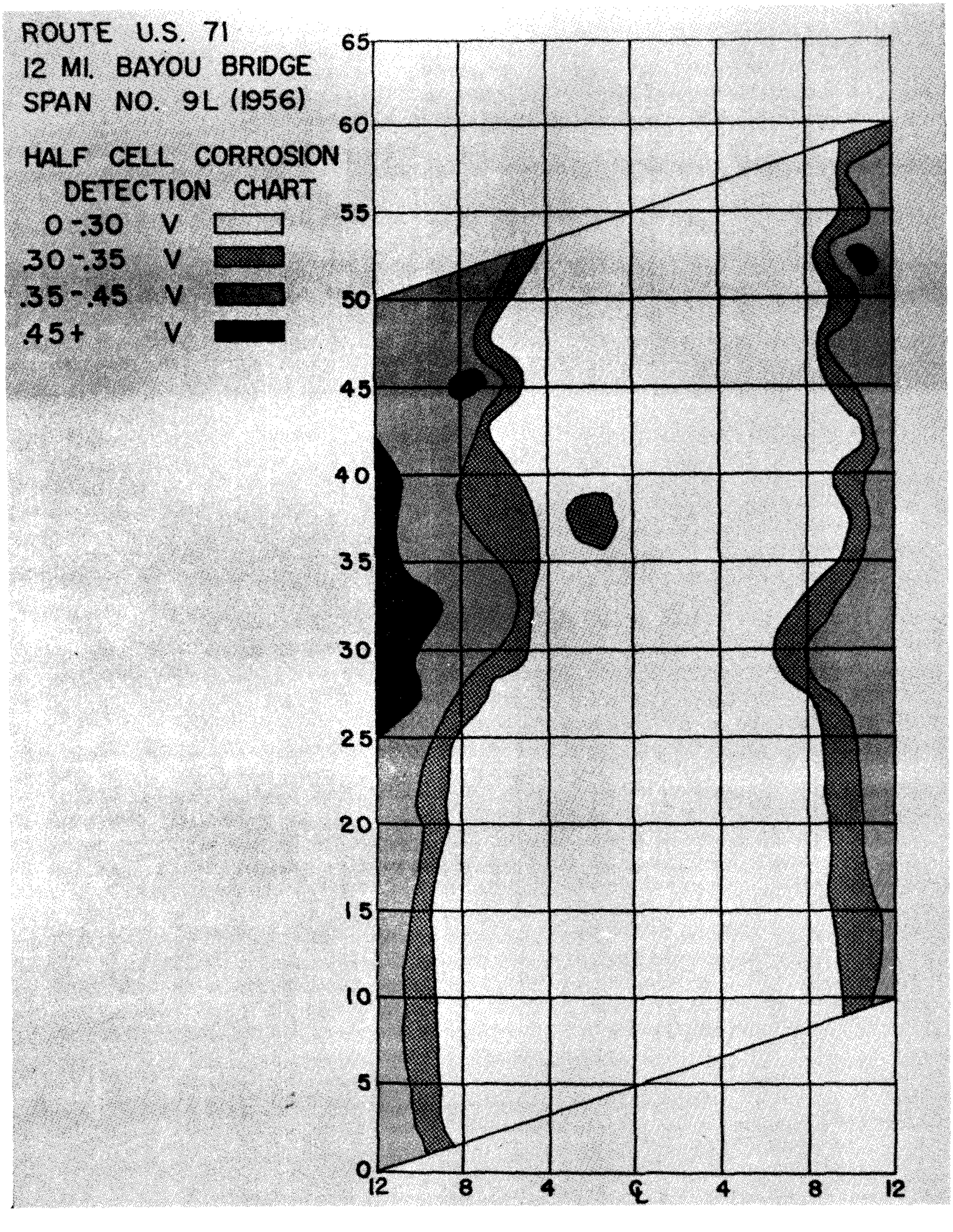

FIGURE 22
Bridge No. 2: Half-Cell Corrosion Chart

TABLE 2
BRIDGE 2
CHLORIDE ION ANALYSIS OF CORES

Date Span	Core No.	Lane	Potential Voltage	Cl^- above rebar #/cy. (0-1 1/2")	Cl^- at rebar #/cy. (1 1/2-2")	Cl^- below rebar #/cy. (2"plus)
0L (1948)	15	Left	0.32	*	*	*
0L (1948)	16	Left	0.09	*	*	*
0L (1948)	7	Right	0.34	2.80	0.40	0.52
0L (1948)	8	Right	0.33	4.00	2.12	1.68
5L (1936)	13	Left	0.12	2.60	2.60	1.96
5L (1936)	14	Left	0.40	1.98	0.00	0.00
5L (1936)	5	Right	0.31	1.24	1.76	1.92
5L (1936)	6	Right	0.43	1.20	1.20	0.80
8L (1954)	11	Left	0.00	2.76	0.88	0.24
8L (1956)	12	Left	0.14	3.04	3.04	1.28
8L (1956)	3	Right	0.19	4.36	1.88	1.04
8L (1956)	4	Right	0.43	7.52	6.33	2.37
9L (1956)	9	Left	0.34	1.19	0.00	0.00
9L (1956)	10	Left	0.43	1.60	2.80	2.80
9L (1956)	1	Right	0.16	*	*	*
9L (1956)	2	Right	0.12	0.96	0.80	0.44

* Core not available for analysis.

Bridge No. 3: U.S. 71 Over La. 1 (1948)

This is a flat overcrossing that has five spans with the main span constructed segmentally, and the bridge is 80-feet long. The following observations may be made from visual observation, the Half-Cell Corrosion chart and the Chloride Ion Content table. (See figures 23 through 27 and Table 3.)

1. There is active corrosion occurring over approximately 95 percent of the deck.

2. There is ample chloride ion content for corrosion to continue.

3. The corrosion is not confined to an area near the gutter line.

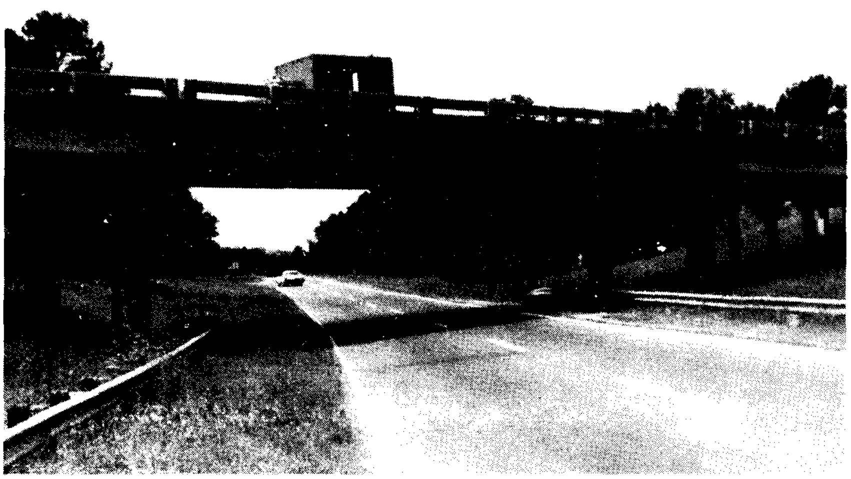

FIGURE 23
Bridge No. 3: Main Span

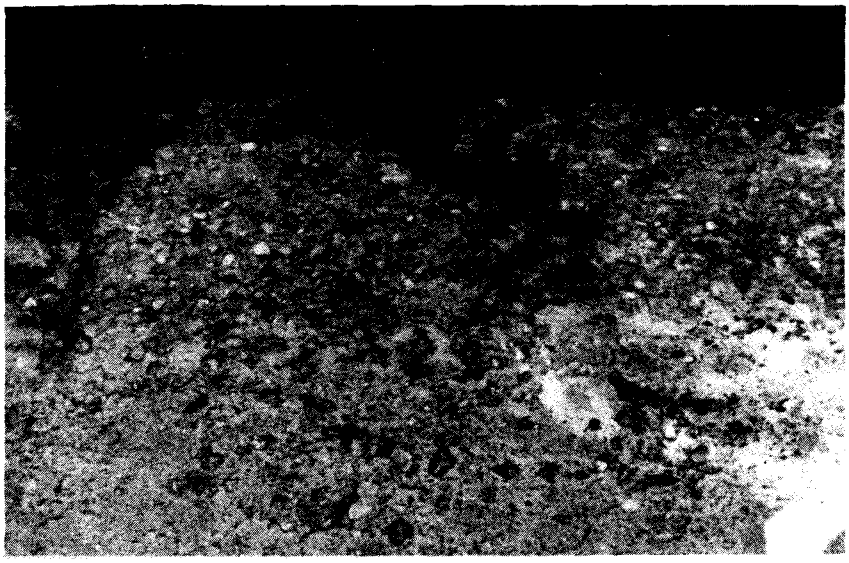

FIGURE 24
Bridge No. 3: Heavily scaled area

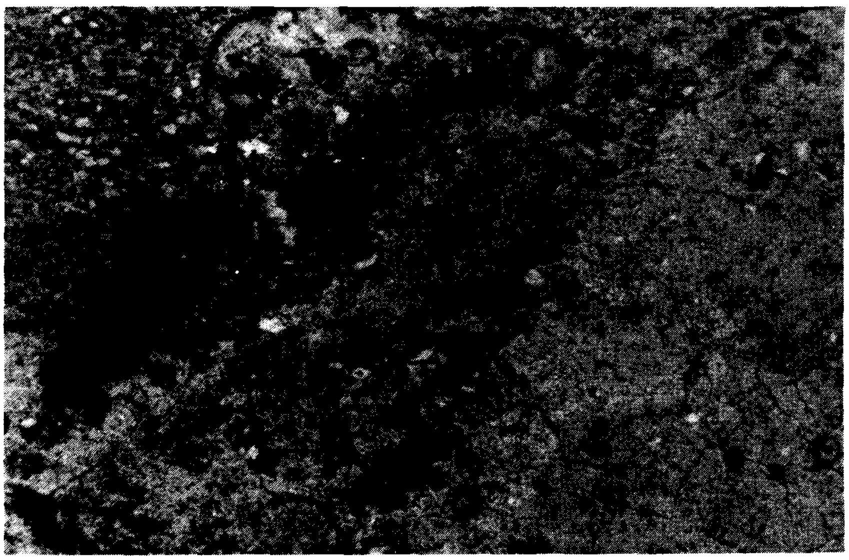

FIGURE 25
Bridge No. 3: Heavily scaled area with delamination and spalling beginning to occur

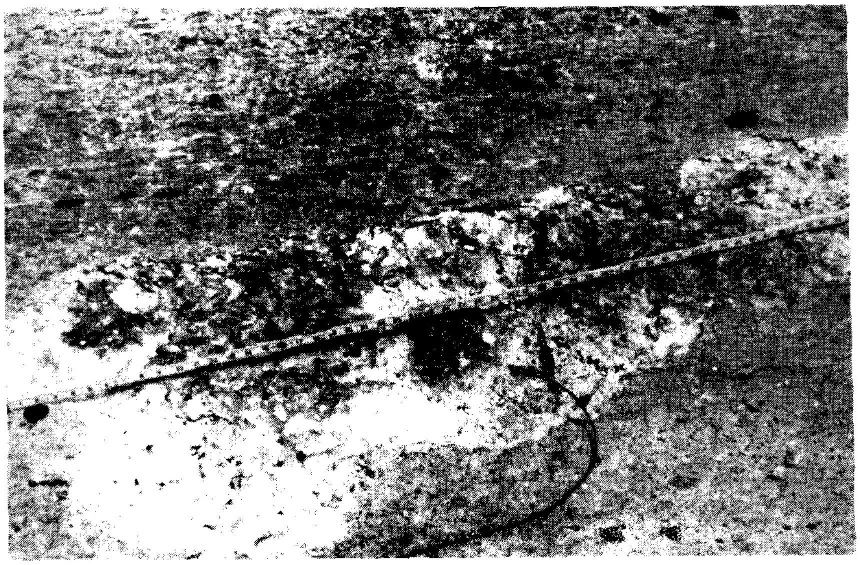

FIGURE 26
Bridge No. 3: Spalled area. Note exposed reinforcing steel with active corrosion.

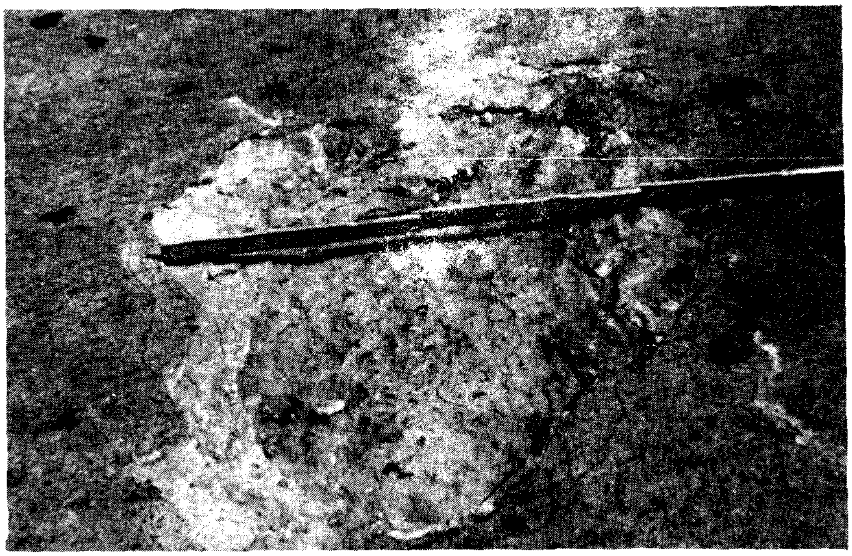

FIGURE 27
Bridge No. 3: Spalled area

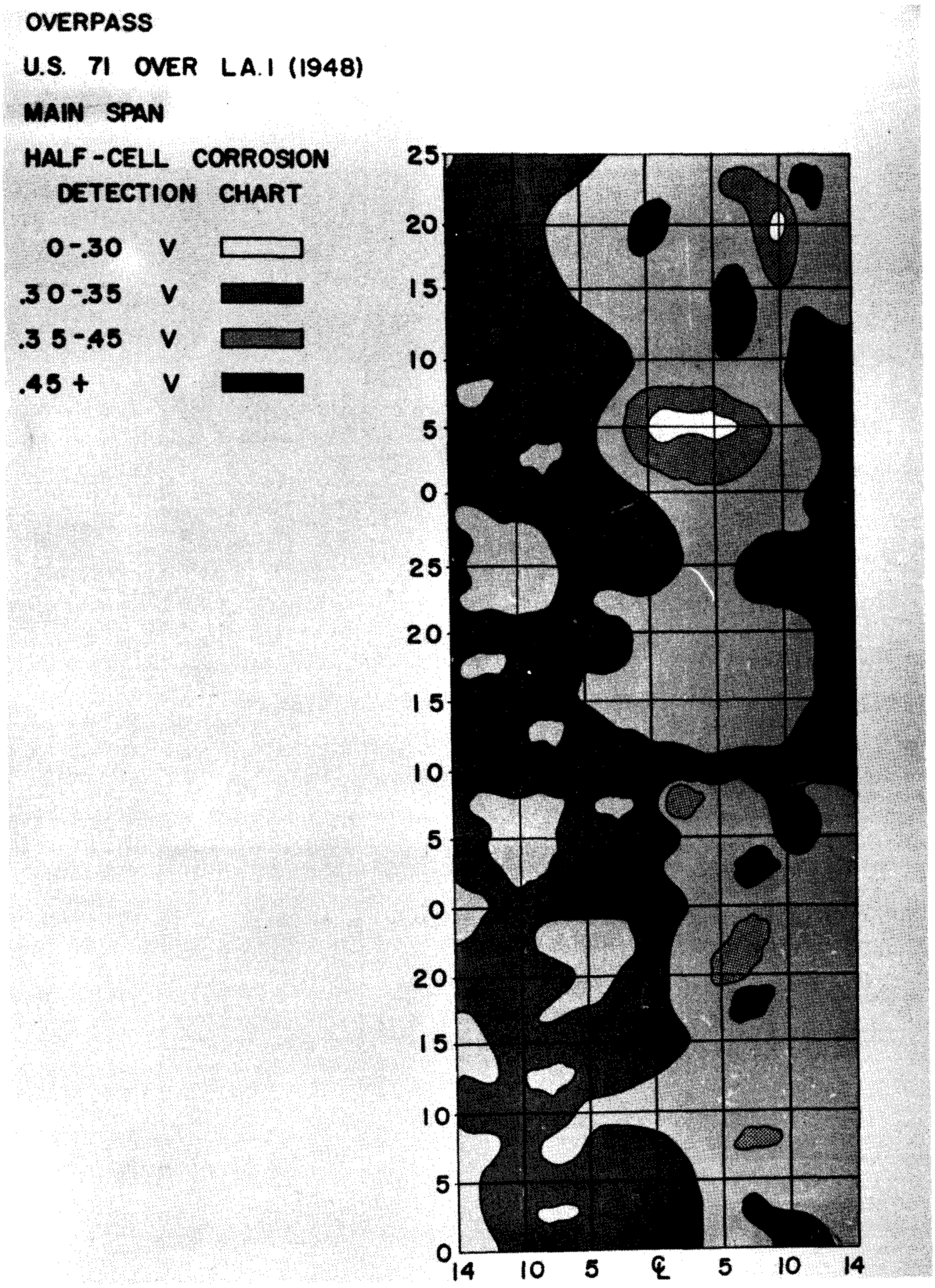

FIGURE 28
Bridge No. 3: Half-Cell Corrosion Chart

TABLE 3
BRIDGE 3
CHLORIDE ION ANALYSIS OF CORES

Span	Core No.	Lane	Potential Voltage	Cl^- above rebar #/cy. (0-1 1/2")	Cl^- at rebar #/cy. (1 1/2-2")	Cl^- below rebar #/cy. (2"plus)
Center	1	Right	.45	9.10	7.91	5.14
Center	2	Right	.42	5.54	3.56	*
Center	3	Right	.40	4.75	3.69	*
Center	4	Right	.44	5.20	3.76	*
Center	5	Right	.29	5.00	1.60	0.28
Center	6	Right	.41	7.20	3.24	2.84
Center	7	Right	.38	2.56	3.64	*
Center	8	Right	.48	4.00	4.00	4.00
Center	**9	Left	.46	**	**	**
Center	10	Left	.43	8.48	4.84	*
Center	**11	Left	.47	**	**	**
Center	12	Left	.49	7.60	1.60	1.60
Center	**13	Left	.49	**	**	**
Center	14	Left	.53	6.40	1.60	**

* Core fractured and further depth not available.

** Core not available for analysis.

CONCLUSIONS

The basic premise of the study has been answered. There are bridges in Louisiana that are infected with reinforcing steel corrosion, and this is primarily due to the intrusion of deicing salts over a period of time. Some of the spans have begun to exhibit the symptoms of corrosion: spalling over the reinforcing steel, delamination of the deck and scaling of the surface. Data from cores and spot checks with the half-cell detection device taken from other locales indicate that corrosion is primarily limited to the northern section of the state where icing conditions occur and deicing salts are applied most frequently.

RECOMMENDATIONS

As has been pointed out, this survey is by no means all-inclusive and does not pretend to indicate that all bridges in the northern area of the state have active corrosion occurring in the decks. But it does point out the possibility that this may be occurring to more decks than originally was thought. It is therefore important that a more comprehensive study be performed to determine the extent of corrosion and bridge deck chloride ion content.

The scope of an expanded study should include the areas covered by Districts 04, 05, 58, 07 and 08. The parameters of a study of that magnitude are greater than the manpower available from the Concrete Research Unit, and it would be requested that district maintenance personnel assist in gathering the half-cell data. The selection of the bridges for analysis should be made on the basis of randomization in order to make a systematized logistical projection. Selected personnel in each district would be equipped with the Half-Cell Corrosion Detector. Upon completion of the study, the detector should remain in each district for future detection of areas that need repair.

In addition, it is recommended that a laboratory and field study be initiated to test the effectiveness of bridge deck waterproofing membranes for Louisiana. That study should determine the parameters of acceptance for conditions that are prevalent in this state. The field application for the membranes should be limited to one bridge until the results of the more comprehensive study determine the need and economical limits of protection.

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