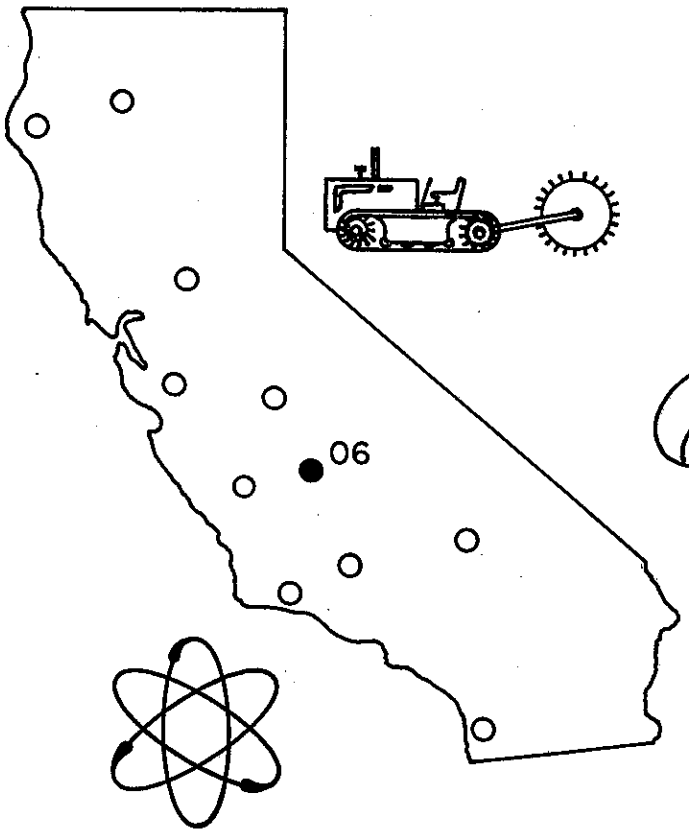
EVALUATION OF THE NUCLEAR COMPACTION TEST METHOD

DISTRICT 06



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STATE OF CALIFORNIA

TRANSPORTATION AGENCY

DEPARTMENT OF PUBLIC WORKS

DIVISION OF HIGHWAYS

MATERIALS AND RESEARCH DEPARTMENT

RESEARCH REPORT

NO. M & R 632697-4

Prepared in Cooperation with the U.S. Department of Commerce, Bureau of Public Roads May 1967

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State of California
Department of Public Works
Division of Highways
Materials and Research Department

May 1, 1967

Lab. Auth. 632697-4
HPR-1(2), F-04-03

Mr. J. C. Womack
State Highway Engineer
Division of Highways
Sacramento, California

Dear Sir:

Submitted for your consideration is:

INTERIM REPORT #4

on

EVALUATION OF THE

NUCLEAR COMPACTION TEST METHOD

DISTRICT 06

Study made by ..... Foundation Section
Under general direction of ..... Travis Smith
Work supervised by ..... W. G. Weber, Jr.
Report prepared by ..... Bobby Lister

Very truly yours,

JOHN L. BEATON
Materials and Research Engineer

Attach.
cc: LR Gillis
AC Estep
JF Jorgensen
WL Welch
CG Beer
N Humiston
Research Files

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Discussion of Project

This Materials and Research Department research study was financed with the Bureau of Public Roads 1-1/2 percent research funds under authorization HPR 1(2) F-04-03.

This is an abbreviated interim data report on a project in District 06 and is in compliance of Mr. D. J. Steele's letter stating "it would not be necessary to present formal interim reports" on each project. This report is patterned after the previous interim reports #1 in District 03, #2 in District 05 and #3 in District 02. A detailed explanation of the figures and tables of this report can be found in the first three interim reports.

The project is located on Route 5 in Fresno County between 0.3 mile south of Manning Avenue and Merced County line, west of Mendota, approximately 20.7 miles in length. The location map, shown in Figure 1, illustrates the general layout of the project. The road work consisted of grading a 4-lane divided freeway and grading and paving cross roads on aggregate base.

A backscatter type nuclear moisture and density gage, manufactured by Numec, was used throughout most of the project, however a malfunction near the end of construction necessitated the use of another backscatter gage manufactured by the Nuclear Chicago Company. The Nuclear Chicago gage had been correlated to the Numec gage for in-place density on each type of material prior to the breakdown, as a precaution for such an emergency. Sand volume densities were used to check the validity of this curve periodically.

The dry weight method of obtaining percent relative compaction was used during the first four months of the project. The wet weight method was adopted after a resident engineer's critique, on January, 1966, at the Materials and Research Laboratory; and used until the termination of construction.

The problems encountered here were very similar to the ones noted in the first three interim reports, such as, site preparation, nuclear gage malfunctions and erratic counts near culverts.

The opinions, findings, and conclusions expressed in this publication are those of the authors and not necessarily those of the Bureau of Public Roads.

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TABLE I

Impact Compaction Maximum Densities

Wet Density lbs/ft^3	Dry Density lbs/ft^3	% Moist.	Type of Material
132.4	114.2	18.2	Clayey Sand Emb.
128.7	110.5	18.2	" " "
126.5	108.3	18.2	" " "
134.7	117.0	17.7	" " "
129.0	113.5	15.5	" " "
130.1	112.6	17.5	" " "
130.1	116.4	13.7	" " "
134.0	115.0	19.0	" " "
131.2	114.2	17.0	" " "
128.5	107.3	21.2	" " "
128.5	109.6	18.9	" " "
135.9	117.8	18.1	" " "
137.0	119.5	17.5	" " "
132.1	113.9	18.2	" " "
129.4	110.5	18.9	" " "
131.2	114.2	17.0	" " "
138.1	120.6	17.5	" " "
131.5	113.2	18.3	" " "
130.1	111.7	18.4	" " "
137.0	121.1	15.9	" " "
131.5	112.9	18.6	" " "
120.0	---	---	Sand & Gvl. Str. Bkf.
126.5	---	---	" " "
128.2	---	---	" " "
137.6	---	---	" " "
133.8	117.5	13.9	" " "
142.0	---	---	" " "
141.0	---	---	" " "
146.0	---	---	" " "
146.9	---	---	" " "
----	117.0	---	"P" Gravel"

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TABLE II

District 06
Calibration Data
Numec SN 108

Wet Density lbs/ft^3	Nuclear Density Count Ratio	Moisture lbs/ft^3	Nuclear Moisture Count Ratio	Type of Material
94.4	1.67	2.9	.288	Silty Sand (OG)
92.4	1.75	2.8	.319	" " "
127.2	1.61	-	-	" " "
96.0	1.56	-	-	" " "
107.3	1.62	-	-	" "w/rock (OG)
121.2	1.38	18.1	1.21	" "
90.8	1.73	3.2	.74	" " (OG)
104.4	1.57	3.5	.82	" " "
96.4	1.50	-	-	Clayey Sand (OG)
93.8	1.58	-	-	" " "
94.4	1.64	-	-	Silty Sand (OG)
108.9	1.56	12.9	.89	" " "
117.0	1.50	13.0	.98	" " "
106.3	1.56	11.0	.79	" " "
109.6	1.51	9.6	.71	" " "
122.3	1.35	9.4	.90	" " "
127.9	1.28	5.8	.54	Sand
135.0	1.24	3.0	.31	"
136.0	1.33	2.8	.22	Sand & Gravel
125.3	1.39	5.3	.37	" "
123.8	1.37	5.3	.33	" "
123.7	1.41	3.7	.26	Sand (finished grade)
119.2	1.39	3.7	.31	" "
121.6	1.37	-	-	Silt & Sand
121.6	1.38	-	-	" "
121.6	1.36	-	-	" "
123.0	1.41	-	-	" "
115.8	1.41	12.8	.96	" "
122.0	1.36	11.8	.93	" "
120.6	1.44	-	-	Clayey Sand
103.3	1.63	14.5	1.24	" "
103.3	1.64	10.7	1.14	" "
125.8	1.28	18.9	1.23	" "
123.2	1.36	18.5	1.26	" "
111.0	1.41	-	-	" "
121.7	1.34	-	-	" "
125.8	1.34	-	-	" "
121.5	1.36	-	-	" "
127.0	1.40	-	-	" "
114.9	1.43	-	-	" "
120.6	1.38	-	-	" "
129.2	1.29	-	-	" "
128.5	1.27	-	-	Clayey Sand
125.0	1.34	-	-	" "

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TABLE II (contd)

Wet Density lbs/ft^3	Nuclear Density Count Ratio	Moisture lbs/ft^3	Nuclear Moisture Count Ratio	Type of Material
125.8	1.30	-	-	Clayey Sand
125.4	1.36	16.1	1.10	" "
116.6	1.36	-	-	" "
121.6	1.35	-	-	" "
133.5	1.25	-	-	" "
126.1	1.29	-	-	" "
137.4	1.27	-	-	" "
134.4	1.39	12.8	.99	Sand & gvl(Str. Bkf.)
128.2	1.40	11.8	.84	" " "
123.2	1.34	-	-	" " "
120.5	1.49	9.2	.64	" " "
125.5	1.43	12.4	.93	" " "
124.2	1.45	9.2	.65	" " "
132.0	1.37	-	-	Clay-rock
		11.9	.75	Clayey Sand Emb.
		12.7	.77	" " "
		10.8	.83	" " "
		12.9	.86	" " "
		11.9	.92	" " "
		13.8	.92	" " "
		12.6	1.0	" " "
		14.4	1.1	" " "
		14.0	1.0	" " "
		16.7	1.0	" " "
		16.2	1.1	" " "
		16.1	1.1	" " "
		17.4	1.1	" " "
		17.8	1.1	" " "
		17.3	1.1	" " "
		17.6	1.2	" " "
		17.9	1.2	" " "
		19.6	1.2	" " "
		20.3	1.2	" " "
		11.5	.68	Sand & Gvl(Str. Bkf)
		11.7	.88	" " "
		10.2	.89	" " "
		11.9	.97	" " "
		14.9	1.1	" " "

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TABLE III

Calibration Data
Nuclear Chicago P-22

Count Ratio versus Sand Volume in Pounds per cubic foot

Count Ratio	Wet Density lbs/ft^3	Type of Material
.55	113.5	Clayey Sand Embankment
.59	116.1	" " "
.74	110.0	" " "
.70	124.0	" " "
.62	120.2	" " "
.66	120.2	" " "
.76	113.0	" " "
.49	146.5	Sand & Gravel (Str. Bkf)
.53	147.3	" " "
.62	138.0	Clayey rock

Nuclear Chicago Count Ratio versus Numec 108

In-place Wet Density

Nuclear Chicago Count Ratio	Numec 108 Density lbs/ft^3	Type of Material
.85	92.5	Clayey Sand Embankment
.82	97.5	" " "
.70	111.0	" " "
.70	114.0	" " "
.68	112.0	" " "
.65	113.0	" " "
.64	121.5	" " "
.64	121.5	" " "
.63	122.0	" " "
.63	121.7	" " "
.63	122.5	" " "
.62	119.9	" " "
.62	123.5	" " "
.62	125.5	" " "
.61	119.0	" " "
.60	125.5	" " "
.59	127.5	" " "
.58	126.5	" " "
.57	128.5	" " "
.57	131.5	" " "

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TABLE IV

Standard Deviation of Density Calibration Tests

Soil Type	Numec 108 No. of Tests	Standard Deviation (pcf) Calculated Regression Line
Embankment	50	6.7
Structure Backfill	9	5.6

Soil Type	Nuclear Chicago P-22 No. of Tests	Standard Deviation (pcf) Calculated Regression
Embankment	30	7.1

Standard Deviation of Moisture Calibration Tests

Soil Type	Numec 108 No. of Tests	Standard Deviation (pcf) Calculated Regression
Embankment	43	2.4
Structure Backfill	10	1.6

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Rte. 05-Fre

SUMMARY OF RELATIVE COMPACTION DATA

90% R.C. Required

TABLE V

Cont. 06-032814

Date	Test No.	Relative Compaction, % #1	#2	#3	#4	#5	#6	Avg.	Accept	Reject	Remarks
7-12-65	37.17.1-0020	90	100	94	92	86	92	92	X		Clayey Sand
7-14-65	-0021	97	98	93	99	96	91	96	X		" "
7-15-65	-0022	96	98	97	95	86	93	94	X		" "
7-16-65	-0024	95	85	91	81	73		85		X	" "
7-19-65	-0025	89	89	87	89			89		X	" "
7-20-65	37.18.1-0026	94	100	96	97	82	86	92	X		" "
7-21-65	-0027	97	91	93	88	93	97	94	X		" "
7-23-65	-0029	97	97	93	91			95	X		" "
7-26-65	-0030	92	91	97	85	92	91	91	X		" "
7-27-65	-0032	89	90	95	94	83	84	89		X	" "
7-28-65	-0008	85	97	93	93	97	99	94	X		" "
7-29-65	-0009	97	93	90	91	92	95	93	X		" "
"	-0010	95	86	93	96	99	99	95	X		" "
8-2-65	-0012	88	88	91	99	94	100	93	X		" "
"	-0013	90	85	95	86	94	96	91	X		" "
8-3-65	37.17.1-0012	98	92	100	91	93	92	94	X		" "
"	37.18.1-0014	96	91	99	86	100	98	95	X		" "
8-4-65	-0015	92	82	90	93	92	93	90	X		" "
8-5-65	-0016	100	93	96	97	95	88	95	X		" "
8-6-65	-0017	94	94	98	96	91	86	93	X		" "
8-9-65	-0018	86	91	93	100	93	93	93	X		" "
"	-0019	88	95	98	93	91	94	93	X		" "
8-10-65	-0000	82	87	92	91	89	90	89		X	" "
"	-00	93	96	96	98	97	84	94	X		" "
"	37.17.1-00	80	69					75		X	" "
8-11-65	37.18.1-00	90	101	92	101	104	91	97	X		" "
8-12-65	"	93	93	97	96	91	101	95	X		" "
8-13-65		86	91	95	87	94	83/94	90		X	" "
8-16-65	37.18.1-00	85	91	93	92	87	85	89		X	" "
"	"	89	97	92	99			93	X		" "
"	"	81	90	95	86	83	87	89		X	" "
8-17-65	"	97	97	99	102	98	100	99	X		" "
"	"	93	95	99	97	95	97	96	X		" "
8-18-65	"	95	93	95	90	93	93	93	X		" "
8-18-65	"	90	90	96	95	99	93	94	X		" "

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SUMMARY OF RELATIVE COMPACTION DATA

90% R.C. Required

TABLE V (contd)

Rte. 05-Fre

Cont. 06-032814

Date	Test No.	Relative Compaction, % #1	#2	#3	#4	#5	#6	Avg.	Accept	Reject	Remarks
9-20-65	-0074	92	94	90	94			93	X		Clayey Sand
"	-0075	94	97	87	98	97	87	93	X		" "
9-21-65	-0076	92	94	94	89	92	83	91	X		" "
9-22-65	-0080	99	91	94	88	93	96	93	X		" "
"	-0077	92	96	96	95	93	90	93	X		" "
"	-0078	89	87	101	102	94	93	94	X		" "
9-23-65	-0079	90	96	92	97	92	88	93	X		" "
"	-0081	91	91	94	93	92	97	93	X		" "
9-24-65	-0082	88	97	91	93	90	93	92	X		" "
9-27-65	-0083	98	97	85	99			95	X		" "
9-28-65	37.17.1-0017	84	79	95	98	91	88	91		X	" "
"	37.18.1-0084	95	98	95	99	93	91	95	X		" "
9-29-65	" -0085	99	91	94	92	89	96	94	X		" "
9-30-65	-0086	90	94	100	94	97	93	96	X		" "
"	-0087	99	93	95	96	90	100	96	X		" "
10-1-65	-0088	85	92	89	96	89		90	X		" "
10-4-65	-0089	96	101	92	92	100	87	95	X		" "
"	-0090	101	103	93				100	X		" "
"	-0091	96	94	89	92	89	96	93	X		" "
10-7-65	-0094	96	89	87	92	89	90	91		X	" "
"	-0095	92	88	91	90	89	94	91	X		" "
10-8-65	-0096	95	96	94	92	98	94	95	X		" "
"	-0097	94	93	92	93	95	92	93	X		" "
10-11-65	-0100	94	89	87	89	81		90		X	" "
"	-0101	96	82	92	87	92	100	92	X		" "
10-13-65	-0102	95	94	91	94	90	89	92	X		" "
"	-0103	92	91	90	89	88	89	90		X	" "
10-14-65	-0108	85	83	89				86		X	" "
10-15-65	-0105	90	81	82	85	77		83		X	" "
"	-0105	90	89	87	86	78		86		X	" "
10-18-65	-0109	91	95	90	92	92	95	93	X		" "
"	-0110	90	86	91				89		X	" "
10-19-65	-0111	94	95	95	95	91	98	95	X		" "
10-20-65	-0114	92	86	96	88	85	92	90		X	" "
"	-0115	90	86	85	95			89		X	" "

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SUMMARY OF RELATIVE COMPACTION DATA

90% R.C. Required

TABLE V (contd)

Rte. 05-Fre

Cont. 06-032814

Date	Test No.	Relative Compaction, % #1	#2	#3	#4	#5	#6	Avg.	Accept	Reject	Remarks
12-13-65	-0161	70						70		X	Clayey Sand
12-16-65	-0162	100	99	95	94	93	84	94	X		" "
12-17-65	-0163	98	95	94				96	X		" "
"	-0164	91	91	97	92	92	94	93	X		" "
"	-0165	93	96	91	99	92	94	94	X		" "
12-20-65	-0166	90	91	86	91	88	95	90	X		" "
"	-0167	97	99	97	101	82	98	96	X		" "
12-21-65	-0168	103	97	98	86	101	98	97	X		" "
"	37.17.1-0018	98	99	87	92			94	X		" "
12-22-65	37.18.1-0169	98	97	93	92	94	92	94	X		" "
"	-0170	92	95	93				93	X		" "
12-23-65	-0171	93	89	92	90	89	93	91	X		" "
1-5-66	-0173	93	100	93	92	90	89	93	X		" "
1-6-66	37.13.1-0029	100	102	103	100	99		101	X		" "
1-10-66	37.18.1-0174	98	100	100	96			99	X		" "
"	-0175	95	95	105	105	102	103	101	X		" "
"	-0176	102	96	105				101	X		" "
1-11-66	-0177	102	99	102	99			100	X		" "
1-12-66	-0178	98	97	96	94			97	X		" "
"	-0179	104	103	100	96	93	101	99	X		" "
"	-0180	98	97	96	96	100	98	97	X		" "
1-19-66	37.18.1-0	91	94	93				93	X		" "
"	"	95	96	101	100	99	88	96	X		" "
"	"	100	95	100	99	98	95	98	X		" "
"	"	94	97	99	91	97	98	96	X		" "
1-20-66	"	91	94	92	90	91	90/91	91	X		" "
1-21-66	-0172	91	89	91	92	86	94	90	X		" "
1-24-66	37.18.1-0	92	90	93	90	91		91	X		" "
1-27-66	"	94	94	94	95	97/99	95/100	96	X		" "
1-28-66	-0192	97	100	97	96	93	90	96	X		" "
2-14-66	37.18.1-0	97	100	96	95	95/97	100/95	97	X		" "
"	"	92	92	92	95	97/95	83/95	93	X		" "
"	"	97	94	97	91	91	92	94	X		" "
2-15-66	"	98	100	102	101	95/99	99/99	99	X		" "
2-16-66	"	98	93	96	98	94	97	96	X		" "

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SUMMARY OF RELATIVE COMPACTION DATA

90% R.C. Required

TABLE V (contd)

Rte. 05-Fre

Cont. 06-032814

Date	Test No.	Relative Compaction, % #1	#2	#3	#4	#5	#6	Avg.	Accept	Reject	Remarks
2-16-66	37.17.1-0	102	96	98	97			98	X		Clayey Sand
2-17-66	37.18.1-0	101	96	95	95	94	93	96	X		" "
2-21-66	"	95	95	99	97	96	90	95	X		" "
"	"	99	99	98	98	97	98	98	X		" "
2-23-66	"	90	95	98	86	94	90	92	X		" "
2-24-66	"	94	94	88	94	100	96	94	X		" "
"	37.18.1-02	94	98	96	97			96	X		" "
3-1-66	"	94	99	101				98	X		" "
"	"	96	92	95	95	88	92	93	X		" "
"	"	96	88	85	86	89	95	90		X	" "
3-2-66	"	98	96	99	97	96		97	X		" "
3-5-66	"	102	95	97	100	90	91	96	X		" "
3-9-66	"	100	98	99	88			96	X		" "
3-11-66	"	86	91	96	89			90.5	X		" "
3-12-66	"	91	93	91	93	95	86	92	X		" "
"	"	98	94	94	95	95	98	96	X		" "
"	"	94	97	92	92			94	X		" "
3-17-66	"	94	94	89	88			91	X		" "
3-23-66	"	93	93	92	77	95	97	91	X		" "
3-24-66	"	88	103	100	96	98	95/103	96	X		" "
"	37.18.1	85	88	91	93	97	95	92	X		" "
3-25-66		93	93	97	79	100	90/88	91	X		" "
"		85	94	85	88			88		X	" "
3-28-66	37.18.1-02	94	78	89	91	90	81	91	X		" "
3-31-66	"	89	95	93	91	97	94	94	X		" "
"	"	89	95	93	91	97	94	94	X		" "
"	"	86	98	95	94	100/107	82/94	94	X		" "
"	"	93	89	100	94	103	99/98	97	X		" "
"	"									X	" "
4-1-66	"	91	96	97				95	X		" "
"	"	96	97	97	100	97/100	95/100	98	X		" "
4-5-66	" -0	95	80	92	97	99		93	X		" "
"	"	93	86	95	88	94	77	89		X	" "
4-12-66	"	94	89	96	95			94	X		" "
4-13-66	"	98	93	97	95	96	93	95	X		" "

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SUMMARY OF RELATIVE COMPACTION DATA

90% R.C. Required

TABLE V (contd)

Rte. 05-Fre

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Date	Test No.	Relative Compaction, % #1	#2	#3	#4	#5	#6	Avg.	Accept	Reject	Remarks
5-23-66	37.18.1-0	77	95	81	91	86	81	86		X	Clayey Sand
"	"	96	86	95	89	96	94	93	X		" "
5-25-66	"	82	96	93	98	96	95	93	X		" "
"	"	99	94	71	85	93	93	91	X		" "
5-26-66	"	93	91	94	79	91	96	92	X		" "
6-1-66	"	91	96	95	97	94/94	89/94	94	X		" "
"	"	90	97	94	94	94/96	92/96	94	X		" "
"	"	75	80	97	96			87		X	" "
6-2-66	37.18.1-03	100	100	99	98	97	97	99	X		" "
6-9-66		95	99	86	97	89	97/92	93	X		" "
"	37.18.1-0	95	96	95	97			96	X		" "
7-25-66	"	90	86	90	94			90	X		" "
"	"	102	103	101	102	97/100	93/101	100	X		" "
7-29-66	"	89	94	95	94	95		93	X		" "
8-4-66	"	100	99	98	90	100	94	97	X		" "
8-5-66	"	95	88	88	95	98/97	96/97	94	X		" "
8-15-66	"	96	95	94				95	X		" "
"	"	96	95	95	97	92/93	91/95	94	X		" "

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SUMMARY OF RELATIVE COMPACTION DATA

90% R.C. Required
TABLE V (contd)

Rte. 05-Fre

Cont. 06-032814

Date	Test No.	Relative Compaction, % #1	#2	#3	#4	#5	#6	Avg.	Accept	Reject	Remarks
8-19-65	37.18.1-00	93	95	87	97	99	98	95	X		Clayey-Sand
"	"	91	96	85	92	100	92	92	X		" "
8-20-65	37.17.1-0	90	88	91	84	88	85	88		X	" "
"	37.18.1-00	95	89	98				94	X		" "
"	"	91	91	97	91	91	85	91	X		" "
"	"	90	90	90	89	93	94	91			
"	"	92	86	103	94			94	X		" "
8-24-65	"	89	91	86	86	94	94	90		X	" "
"	"	97	87	87				90		X	" "
"	"	96	82	91	94	90	91	91	X		" "
8-26-65	"	94	102	96	93	94	96	96	X		" "
8-27-65	"	82	86	91				86		X	" "
"	"	84	98	95	84	93	93	91	X		" "
"	"	94	90	86	83	91	91	89		X	" "
8-30-65	"	91	95	95				94	X		" "
8-31-65		89	86	85				87		X	" "
"	37.18.1-0	92	79	90	88	94	94	89		X	" "
9-1-65		97	85	90	101	93	97	96	X		" "
"		87	85	94	88			88		X	" "
9-2-65		94	97	95	91	90	96	94	X		" "
"		93	93	96	94	100	94	95	X		" "
9-7-65	37.18.1-0	89	92	85	79	80		85		X	" "
"	"	93	88	87	98			89		X	" "
9-13-65	"	86	92	94	92	96	97	93	X		" "
"	"	96	94	94	92	85	87	91	X		" "
9-14-65	"	89	75	77	84			81		X	" "
"	"	85	88	96	88	90	90	89		X	" "
"	"	82	87					85		X	" "
9-15-65	"	95	92	89	96	86	87	91		X	" "
"	"	86	84	91	87	88	89	88		X	" "
9-16-65	37.18.1-0072	88	88	85				87		X	" "
"	-0071	88	90	89				89		X	" "
"	-0070	85	85	88				86		X	" "
9-17-65	-0069	92	93	89	98	96	98	95	X		" "
9-20-65	-0073	86	95	89	93	99	88	91	X		" "

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SUMMARY OF RELATIVE COMPACTION DATA

90% R.C. Required

TABLE V (contd)

Cont. 06-032814

Date	Test No.	Relative Compaction, % #1	#2	#3	#4	#5	#6	Avg.	Accept	Reject	Remarks
10-21-65	-0112	98	94	97	95	100	94	96	X		Clayey Sand
"	-0113	93	90	99	93			94	X		" "
10-22-65	-0116	90	93	99	98	89	91	93	X		" "
"	-0117	96	89	91	91			92	X		" "
"	-0118	93	84	76	84	90	87	86		X	Sand &Gravel
10-23-65	-0119	95	87	93	92	103	95	94	X		Clayey Sand
10-25-65	-0120	102	94	98	97			98	X		" "
"	-0121	95	98	100	92	93	90	95	X		" "
10-26-65	-0122	91	84	77	90			86		X	" "
"	-0123	90	94	98	86	90	96	92	X		" "
10-27-65	-0124	91	93	85	87	92	100	91	X		" "
"	-0125	92	91	99	88	95	92	93	X		" "
"	-0126	96	94	97	99	94	96	96	X		" "
10-28-65	-0127	92	92	93	96	95	93	94	X		" "
"	-0128	81	93	87	93	91	86	90		X	" "
10-29-65	-0129	94	93	94	94	93	93	94	X		" "
"	-0130	94	82	91	90	87	89	90		X	" "
"	-0131	92	90	92	92	94	94	93	X		" "
11-1-65	-0133	96	102	98	96	92	99	97	X		" "
"	37.18.1-0	97	93	101	103	102		100	X		" "
11-2-65	" =0135	80	79	83				81	X		" "
"	" -	100	102	94				97	X		" "
11-3-65	"	93	100	96				97	X		" "
"	-0138	100	88	94	91	97	95	94	X		" "
"	-0139	94	98	90	100	97	99	96	X		" "
"	-0140	89	90	93	89			90	X		" "
11-4-65	-0141	94	100	99	97			98	X		" "
11-5-65	-0143	87	91	92	84	95	88	90		X	" "
11-8-65	-0144	90	93	96	94			93		X	" "
11-8-65	-0146	97	93	84	94	91	93	92	X		" "
11-9-65	-0147	98	95	92	97			97	X		" "
"	-0148	91	94	89	96			93	X		" "
12-6-65	-0156	90	90	94	94	92	95	93	X		" "
12-9-65	-0158	76						76		X	" "
12-10-65	-0160	84	86		93	95	93	91	X		" "

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SUMMARY OF RELATIVE COMPACTION DATA

90% R.C. Required

TABLE V (contd)

Rte. 05-Fre

Cont. 06-032814

Date	Test No.	Relative Compaction, % #1	#2	#3	#4	#5	#6	Avg.	Accept	Reject	Remarks
4-13-66	37.18.1-0026	96	93	97	93	93	93	94	X		Clayey Sand
4-18-66	" -0	95	86	97	73	72	93	86		X	" "
4-19-66	"	81	89	94	95	93	87	90	X		" "
"	" -02	95	85	91	88	95		91	X		" "
4-20-66	"	78	81	99	95	95	87	89		X	" "
4-21-66	" -0	94	85	91	88	98	75/97	89		X	" "
4-22-66	"	91						91		X	" "
"	37.13.1-00	78	84	80				81		X	" "
"	37.18.1-02	95	92	95	92	92	90/92	93	X		" "
"	"	97	69	70	90	95	94/86	86		X	" "
"	"	90	89	92	99	95	75	90	X		" "
4-25-66		92	91	94	94	92/87	85/93	91	X		" "
4-27-66		98	94	94	94	97/99	94/97	96	X		" "
"		94	83	97	85	85	87	89		X	" "
"	"	98	94	94	96	98	96	96	X		" "
"	37.13.1-0	90	90	91	92	89	91	91	X		Clayey Sand
5-3-66	"	98	92	91	98			95	X		" "
5-5-66	37.18.1-0	91	89	95	93	96	97	94	X		" "
5-9-66	"	95	89	91	93	90	86	91	X		" "
"	"	95	97	95	84	87	85	89		X	
"	"	92	88	90	92			91	X		" "
5-10-66	"	90	93	93	92	94	91	92	X		" "
"	"	89	96	93	87	85	94	94	X		" "
5-11-66	"	90	95	97	97			95	X		" "
"	"	93	84	92	95			91	X		" "
"	"	81	87	79	84	85	85/86	84		X	" "
5-12-66	"	91	95	87	82	89	95	88		X	" "
"	"	93	93	91	92	91	92/92	92	X		" "
5-16-66	"	90	93	88	93	95	93	92	X		" "
"	"	87	93	89	92			90	X		" "
5-18-66	"	91	91	91	88			90	X		" "
"	"	94	93	94	93	93	94	94	X		" "
5-19-66	"	94	90	92	92	91/91	91/91	91	X		" "
5-20-66	"	92	85	90	81			87		X	" "
5-21-66	"	96	91	95	91	88/95	97/88	93	X		" "
"	"	95	92	84	81	89/89	92/89	89		X	" "

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TABLE
SUMMARY OF RELATIVE COMPACTION DATA
95% R. C. Required
TABLE VI

Rte. 05-Fre

Cont. 06-032814

Date	Test No.	Relative Compaction, % #1	#2	#3	#4	#5	#6	Avg.	Accept	Reject	Remarks
7-22-65	37.18.1-0028	95	98	98	97	95	98	97	X		Clayey Sand
7-27-65	" 0031	94	89	89	90			91		X	" "
8-9-65		94	93	96	97			95		X	" "
10-5-65	" 0092	94	97	102	106	104	107	102	X		" "
10-6-65	" 0093	105	101	105	99	102	103	103	X		" "
10-11-65	" 0099	97	100	96	96	98	100	98	X		" "
10-14-65	" 0106	103	94	95	104/95	94/84	94/87	89		X	" "
11-1-65	" 0132	95	94	94	95	95	94	95		X	" "
11-2-65	" 0145	96	92	92	92			93		X	" "
11-5-65	" 0142	95	94	100	92			95		X	" "
11-10-65	" 0149	102	96	97	101	100	101	99	X		" "
11-10-65	" 0150	90	93	94				92		X	" "
11-10-65	" 0151	101	101	100	104	93	102	100	X		" "
11-11-65	" 0152	88	98	98	98	97	92	95	X		" "
11-12-65	" 0153	100	101	97	98	95	88	98	X		" "
11-12-65	" 0154	99	99	96	98	97	90	97	X		" "
12- 6-65	" 0155	97	96	92	93	97	104	97	X		" "
12- 8-65	" 0157	98	98	99	100	95	97	98	X		" "
1-4-66	" 0172	96	98	96	103	99		97	X		" "
1-27-66		97	93	95	98	93	93	95		X	" "
3-3-66		98	97	98	94	94	98	97	X		" "
3-4-66		93	96					94		X	Clayey rock
3-5-66		97	92					95		X	" "
3-8-66		97	97					97	X		Clayey sand
3-12-66		95	76	91	92			89		X	" "
3-14-66		99	99	97	95	96	98	98	X		Clayey rock
3-14-66		103	94	103	109	106	95				
"		100	98					101	X		Sand
3-15-66		97	98	97				97		X	Clay (Remaining grade loose)
3-15-66		99	96	94	89	97	96	95	X		"
3-16-66		95	98	95	95	98	98	97	X		Clayey sand
3-18-66		104	98	98	100	97	96	99	X		Clayey rock
3-18-66		97	94	97	97	104	98	98	X		" "
3-18-66		88	87	92	94	97	92	92		X	" "
3-21-66		98	95	100	95	95	103	98	X		" "

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TABLE (contd)
SUMMARY OF RELATIVE COMPACTION DATA
95% R. C. Required
TABLE VI (contd)

Rte. 05-Fre

Cont. 06-032814

Date	Test No.	Relative Compaction, % #1	#2	#3	#4	#5	#6	Avg.	Accept	Reject	Remarks
3-22-66		99	93	96	101	100		98	X		Clay
3-23-66		99	98	105	98	99	92	99	X		Clayey Sand
4-4-66		99	100	98	100	98	100	99	X		Clayey rock
4-5-66		97	102	101	102	102	98				
"		98	98					100	X		" "
"		99	95	99	101	88	95	98	X		" "
"		103	98	103	101	104	98				
		105						102	X		" "
"		97	94	99	103	100	101	99	X		Sand
4-8-66		109	100	109	97	102	103				
		104	109					104	X		Clayey rock
4-8-66		105	100	106	102	105	105	105	X		" "
4-9-66		103	100	103	103	102	101	102	X		" "
4-11-66		98	100	98	99	92	101				
		100	98					98	X		" "
4-25-66		98	95	87	76	95	92			X	Clayey Sand
		82	92					90			
6-7-66		95	94	96	97			96	X		" "
9-6-66		90	91	87	91	94	94				
		88						90		X	" "
9-7-66		100	100	100	99	99	101	100	X		Aggregate Base
9-7-66		95	99	100	100	97	96	98	X		" "
9-8-66		97	97	98	99	97	99	98	X		Clayey Sand
9-29-66		90	100	99	98	97	96				
		98						97	X		Aggregate Base
7-19-65	37.13.1-0001	86	92	100				93		X	Sand & gravel (structure bkfl.)
7-20-65	" 0002	91	84	84	83	89	91	87		X	" " "
8-4-65	0004	100	96					98	X		" " "
8-10-65		103	105	97	97			101	X		" " "
8-12-65		91	100	96				99	X		" " "
8-12-65		107	102					105	X		" " "
8-13-65		97	101					99	X		" " "
8-17-65		101	111					106	X		" " "
8-18-65		96	113					105	X		" " "
10-14-65		100	101	102				101	X		" " "
10-14-65		93	109	98				100	X		" " "

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SUMMARY OF RELATIVE COMPACTION DATA

95% R. C. Required

TABLE VI (contd)

Rte. 05-Fre

Cont. 06-032814

Date	Test No.	Relative Compaction, % #1	#2	#3	#4	#5	#6	Avg.	Accept	Reject	Remarks
10-15-65		98	103	100	101			100	X		Sand & gravel (Structure bkfl.)
10-18-65		99	96	96	104	105	98	100	X		" " " "
10-20-65		107	102	94	101	103	96	100	X		" " " "
10-21-65		100	102	100	95			99	X		" " " "
10-21-65	37.13.1-0019	102	97	98	98			99	X		" " " "
10-22-65	" 0021	87	98	99	97	94		95	X		" " " "
10-25-65	" 0022	106	97	104	105	102	102	103	X		" " " "
10-26-65	" 0023	94	97	98	101			98	X		" " " "
10-26-65	" 0024	96	94	95	96	96	98	96	X		" " " "
12-9-65	" 0025	102	103	110	103	111	106	105	X		" " " "
		110	98	102	102						
12-16-65	" 0026	99	101	94	96	97	103	98	X		" " " "
12-17-65	" 0027	99	99					99	X		" " " "
12-20-65	" 0028	102	88					95		X	" " " "
12-28-65		101	102	102	102	101	101	101	X		" " " "
		101	100								
1-21-66		102	100	98	97	96	103	99	X		" " " "
1-24-66		100	100	100	100	100	100	100	X		" " " "
1-28-66		105	105	105				105	X		" " " "
2-3-66		87	93	93	96	88	83	90		X	" " " "
2-3-66		91	93	86	91			90		X	" " " "
2-8-66		85	92	97				91		X	" " " "
2-15-66		96	99	96	97	96		97	X		" " " "
2-15-66		98	99	101	99			99	X		" " " "
2-25-66		90	88	82	84			86		X	" " " "
2-25-66		96	97					96	X		" " " "
3-14-66		103	104	106	106			105	X		" " " "
3-22-66		100	98	101				100	X		" " " "
3-24-66		110	106	100	100			104	X		" " " "
3-25-66		98	89	86	87	100		92		X	" " " "
3-25-66		92	96	98				95	X		" " " "
3-29-66		97	96					96	X		" " " "
3-31-66		98	95	93	99			96	X		" " " "
4-7-66		99	97	99	101	99	92	98	X		" " " "
4-7-66		101	102					101	X		" " " "
4-15-66		100	99	101	104			101	X		" " " "

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95% R. C. Required

TABLE VI (contd)

Rte. 05-Fre

Cont. 06-032814

Date	Test No.	Relative Compaction, % #1	#2	#3	#4	#5	#6	Avg.	Accept	Reject	Remarks
4-18-66		104	100	99	100	99		100	X		Sand & gravel (structure bkfl.)
4-20-66		94	90	98	96			94		X	" " " "
4-26-66		102	102	98	102	102		101	X		" " " "
4-28-66		95	97	95	95	95	98				
		98	100					97	X		" " " "
4-29-66		104	107	104	94			102	X		" " " "
5-2-66		103	101	99	101	05	101				
		96	99					99	X		" " " "
5-2-66		100	99	96	100			99	X		" " " "
5-3-66		101	101	100	101	101	103				
		101	104					101	X		" " " "
5-4-66		102	101	103	101			102	X		" " " "
5-4-66		101	89	94	94	95		94		X	" " " "
5-5-66		102	100	103	102	100	98				" " " "
		101						101	X		" " " "
5-5-66		105	100	100	100			101	X		" " " "
5-5-66		97	101	102	103			101	X		" " " "
5-6-66		99	98	104	104			102	X		" " " "
5-10-66		105	102	102	104			103	X		" " " "
5-13-66		98	94	100	96	103	106				
		100						99	X		" " " "
5-13-66		99	100	102				100	X		" " " "
5-14-66		101	99	100	97	100	100				
		100						100	X		" " " "
5-17-66		99	101	103	102			101	X		" " " "
5-17-66		98	99	91	94	96	101				
		101	97					97	X		" " " "
5-18-66		98	95					97	X		" " " "
5-19-66		97	103	98	98	103		100	X		" " " "
5-20-66		102	94	96				97	X		" " " "
5-24-66		111	110	107				109	X		" " " "
5-26-66		107	111	107				108	X		" " " "
6-13-66		94	95	94				94		X	" " " "
6-15-66		95	99	97	102	100		99	X		" " " "
6-17-66		96	97	101	99	96	105	99	X		" " " "

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95% R.C. Required

TABLE VI (contd)

Rte. 05-Fre

Cont. 06-032814

Date	Test No.	Relative Compaction, % #1	#2	#3	#4	#5	#6	Avg.	Accept	Reject	Remarks
6-20-66		99	99	94	95	101	100				
		96	97					98	X		Sand & gravel (structure bkfl.)
6-20-66		101	96	96	99			98	X		" " " "
6-21-66		106	98	100	96	109	107	103	X		" " " "
6-22-66		109	106	100	103			105	X		" " " "
6-28-66		103	103	100	98	103	96/103	101	X		" " " "
6-29-66		101	102	102	102	95/97	97/91	98	X		" " " "
"		99	105	97	98	104/100	97/97	100	X		" " " "
7-1-66		100	99	96	97	99/100	99/97	98	X		Sand Rock
"		98	98	99	98	101/98	98/97	98	X		" "
7-6-66		98	96	98	103	99	97	99	X		" "
7-8-66		106	103	100	96	97/99	102/101	100	X		" "
"		97	97	99	99	96/95	97/99	97	X		" "
"		99	96	100	97			99	X		" "
7-18-66		94	94	105	98	79	88/80	91		X	" "
7-22-66		95	98	98	98	96/97	107/109	100	X		" "
8-8-66		99	99	102	106	99	99	101	X		" "
8-12-66		102	100	89	100	98	102	99	X		" "
8-22-66		120	105	99	99	99	100	104	X		" "
8-24-66		95	102	101	104	104	100	101	X		" "
2-28-66		95	101	91				96	X		Pea gravel
3-4-66		83	82	97	99	86	84	89		X	" "
3-7-66		95	86	101				94		X	" "
3-8-66		93	92	89				91		X	" "
3-9-66		87	86	88	82			86		X	" "
3-14-66			100		98			99	X		" "
5-24-66		100	100	103	96	101		100	X		" "
5-27-66		101	96	96	96	95/98	96/98	97	X		" "
"		100	101					101	X		" "
"		98	95	95	96	100/103	99/96	98	X		" "
5-31-66		103	96	97	100/93	95/96	97/104	98	X		" "
6-1-66		100	98	100	101	101/101	105/98	100	X		" "
6-3-66	37.13.1-0016	98	100	100	100			100	X		" "
6-6-66		108	94/97	101	95	102/100	96/101	99	X		" "
"		97	100	97	108	95/97	99/108	100	X		" "
"		99	96	96	101			98	X		" "

HMR T-2135(Orig. 12/66)

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SUMMARY OF RELATIVE COMPACTION DATA

95% R. C. Required

TABLE VI (contd)

Rte. 05-Fre

Cont. 06-032814

Date	Test No.	Relative Compaction, % #1	#2	#3	#4	#5	#6	Avg.	Accept	Reject	Remarks
6-6-66		98	98	101	97			98	X		Pea Gravel
6-8-66		103	99	99	100	100/104	103/101	101	X		" "
"		96	104	98	104	101/99	100/101	100	X		" "
"		101	105	98	102	100/100	105/105	102	X		" "
6-10-66		98	96	105	104	100/102	103/100	101	X		" "
"		98	98	98	102	104/103	103/104	101	X		" "
6-15-66		108	99	100	100	102/100	104/106	102	X		" "
6-17-66		99	103	101	98			100	X		" "
8-23-66		95	95	98	98			97	X		" "
8-24-66		100	107	100	90			99	X		" "

HMR T-2135(Orig. 12/66)

TABLE VII

Percentage of Total Tests that Failed to Meet the Minimum Requirements by the 2/3 Areas Passing, Average Passing, and Both

	No. of Tests	Percentage of Total Tests
Number of test areas which failed due to the 2/3 requirement and the average was at or above the minimum specification	23	5
Number of test areas which failed due to minimum average RC requirement and less than 1/3 failed	3	1
Number of failing test areas which do not satisfy both the 2/3 and minimum average RC requirements	67	16

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TABLE VIII

Record of Nuclear Gage Malfunctions - Numec 108

Description of Malfunction	Date Gage Out	Date Back on Job	Downtime, Working Days
Moisture count erratic. Broken high voltage connection.	4-28-65	4-30-65	3
Loose connections in cable. Also modified probe by replacing 5 resistors with one.	7-22-65	7-22-65	1/2
Battery charger not functioning.	7-28-65	7-28-65	1/2
Scaler would not count. Voltage reference batteries on circuit cards defective.	9-10-65	9-13-65	1
Moisture counts erratic. Replaced mercury battery on circuit card.	9-27-65	9-27-65	1/2
The scaler would not stop counting after the 90 second count. A half hour warm-up eliminated this.	12-23-65	12-23-65	0
Density portion will not count and the moisture standard counts are 33,000 which are normally 7,200. Found cracked ground connection and replaced mercury batteries on circuit card.	1-14-66	1-25-66	8

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Record of Nuclear Gage Malfunctions
Numec 108
(contd)

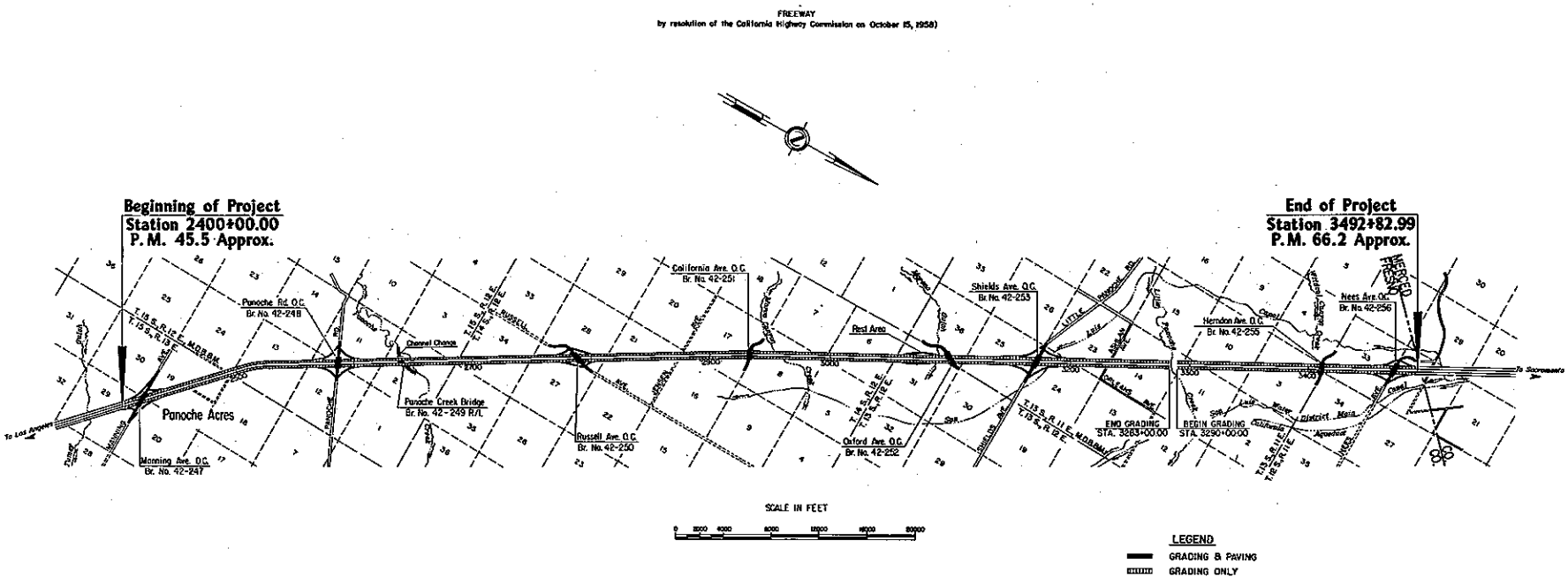
Description of Malfunction	Date Gage Out	Date Back on Job	Downtime Working Days
Interconnecting cable broken at one of the connectors .	2-8-66	2-10-66	2
Scaler will not count on moisture or density. Bad connection between cable and probe.	3-10-66	3-14-66	3
Interconnecting cable broken at one of the connectors.	3-29-66	3-30-66	1
Density counts erratic. Had a leaky capacitor.	4-1-66	4-11-66	7

Record of Nuclear Gage Malfunctions
Nuclear Chicago

Description of Malfunction	Date Gage Out	Date Back on Job	Downtime Working Days
Scaler will not count on moisture. Trigger tube replaced and bad solder joint.	8-1-66	8-3-66	2

$$\frac{\text{Downtime}}{\text{Working Days}} \quad \frac{28\ 1/2}{330} = 9\% \text{ downtime}$$

In Fresno County between 0.3 mile south of Manning Avenue and Merced County Line



Length of Project: 109,283 Feet=20.7 Miles

Figure 1

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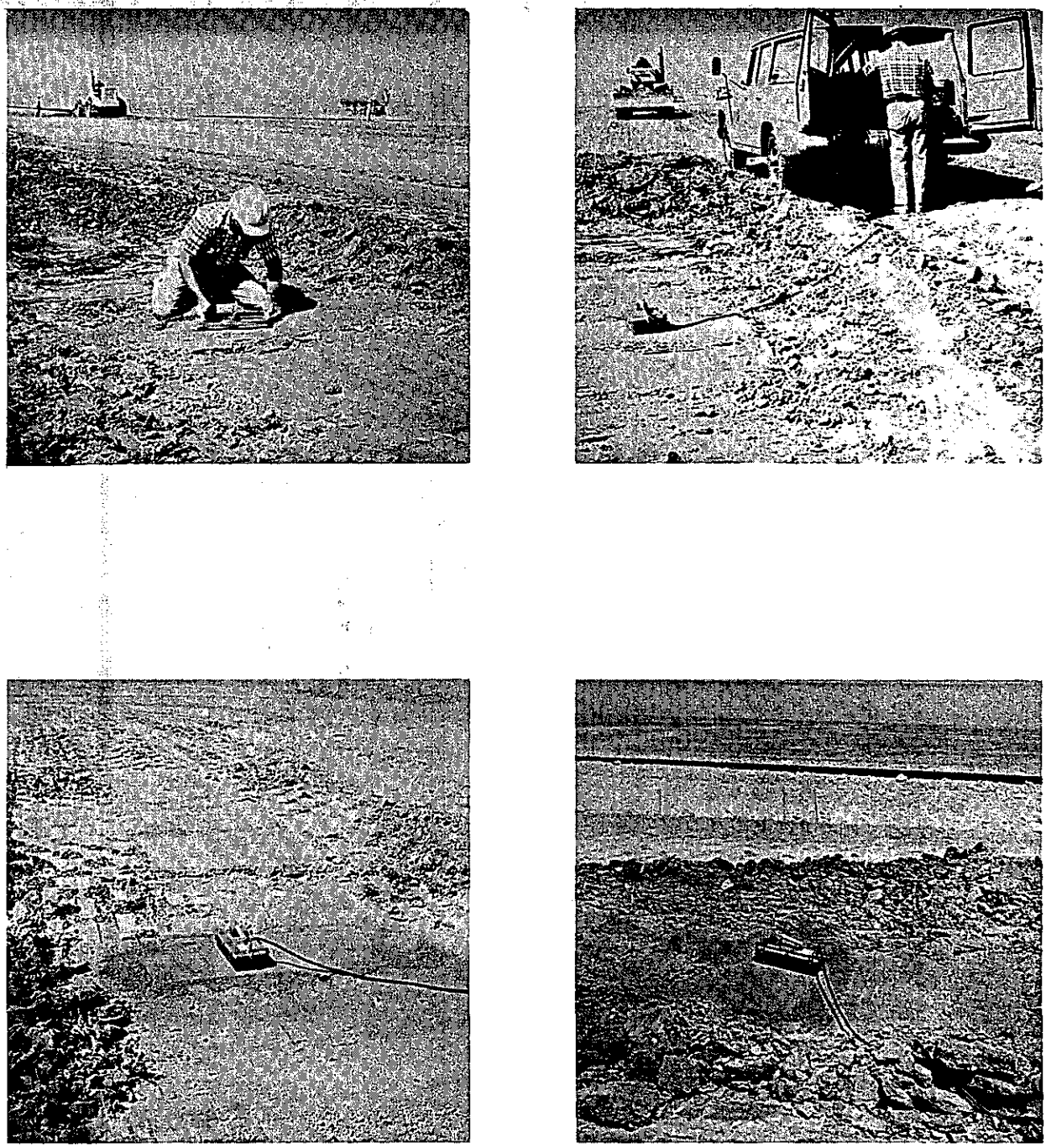

Figure 2. Illustration of Nuclear Test Equipment

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Figure 3

DENSITY CALIBRATION CURVES FOR NUMEC 108

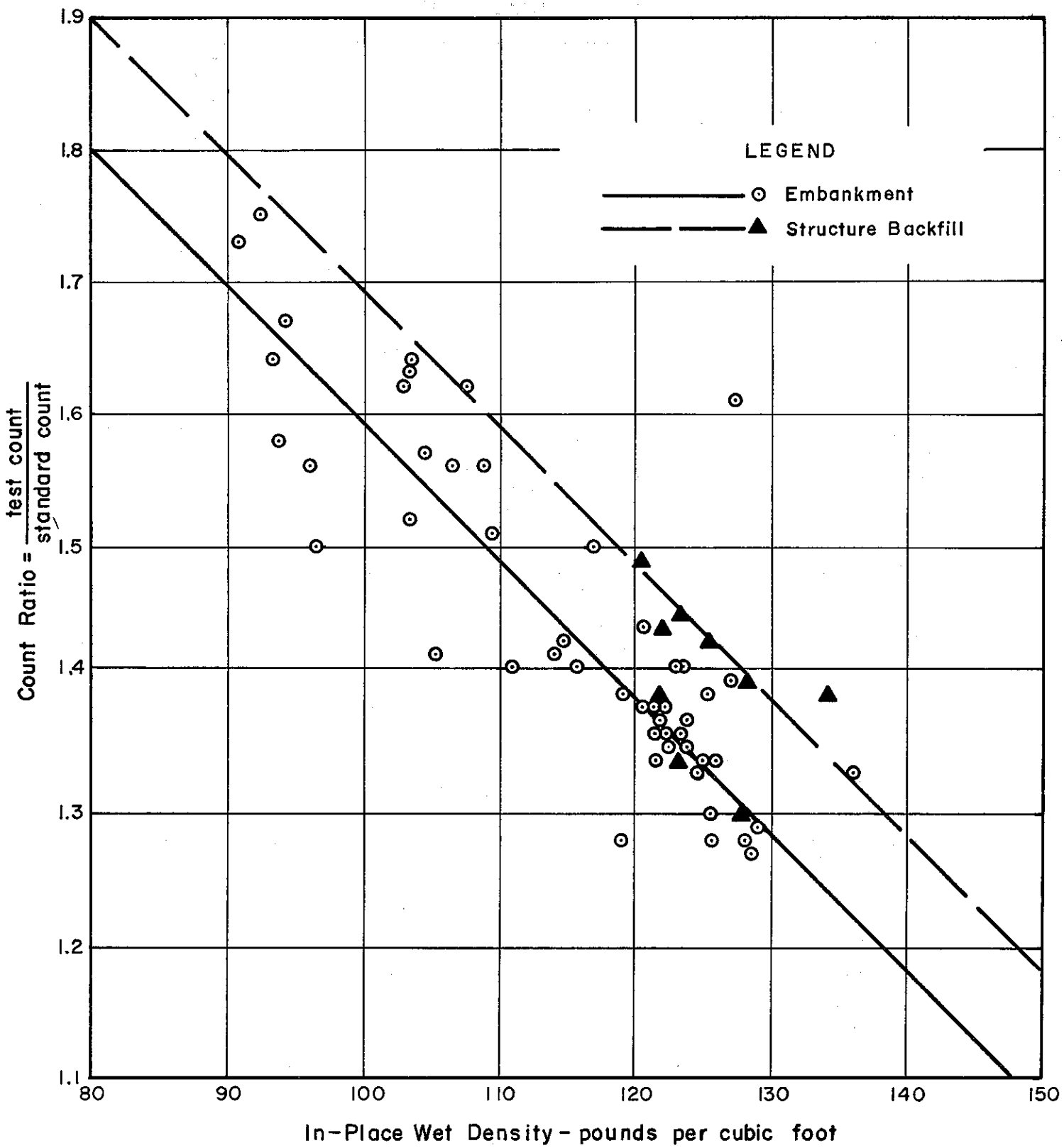

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Figure 4

MOISTURE CALIBRATION CURVE FOR NUMEC 108

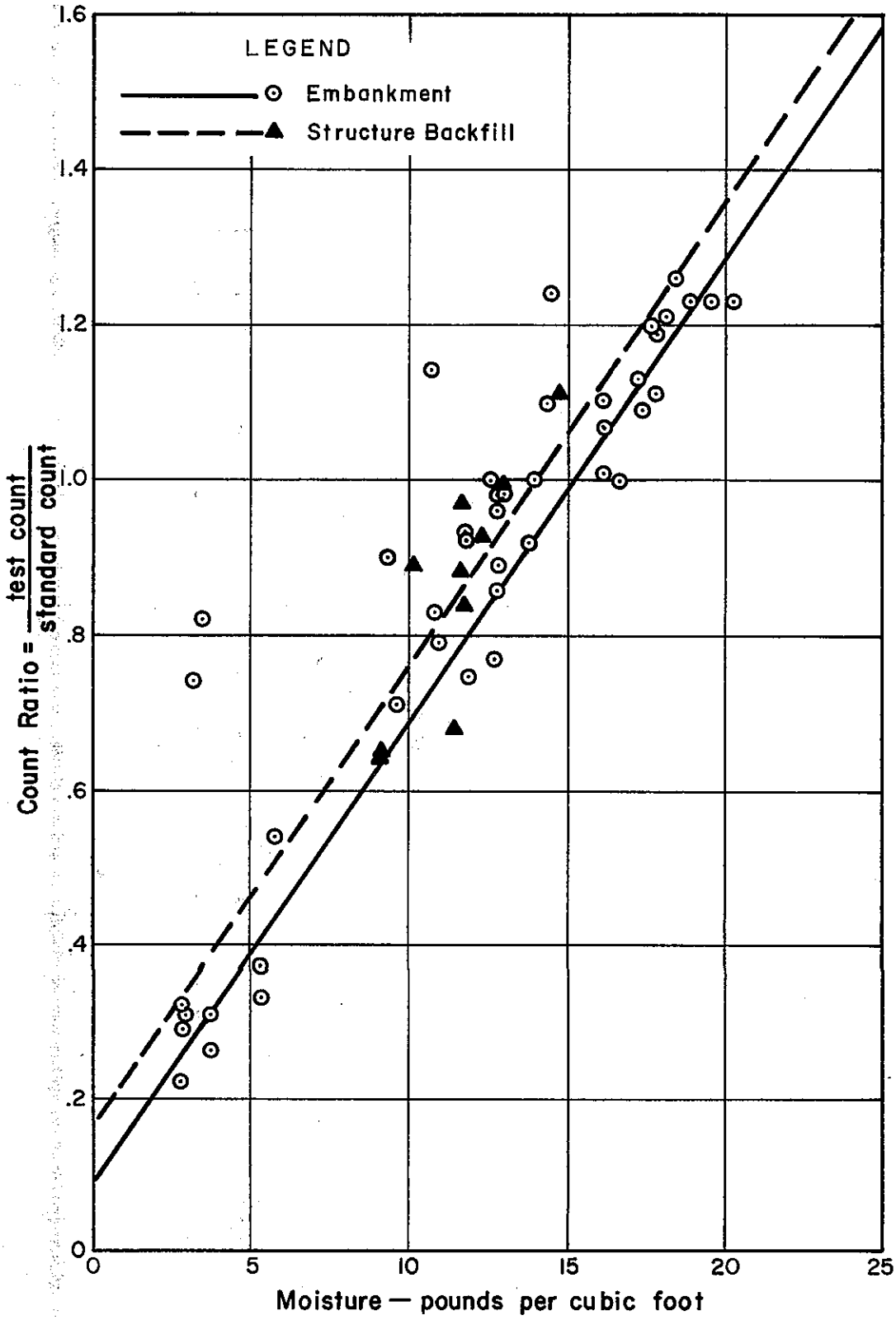

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Figure 5

DENSITY CALIBRATION CURVE FOR NUCLEAR CHICAGO P22

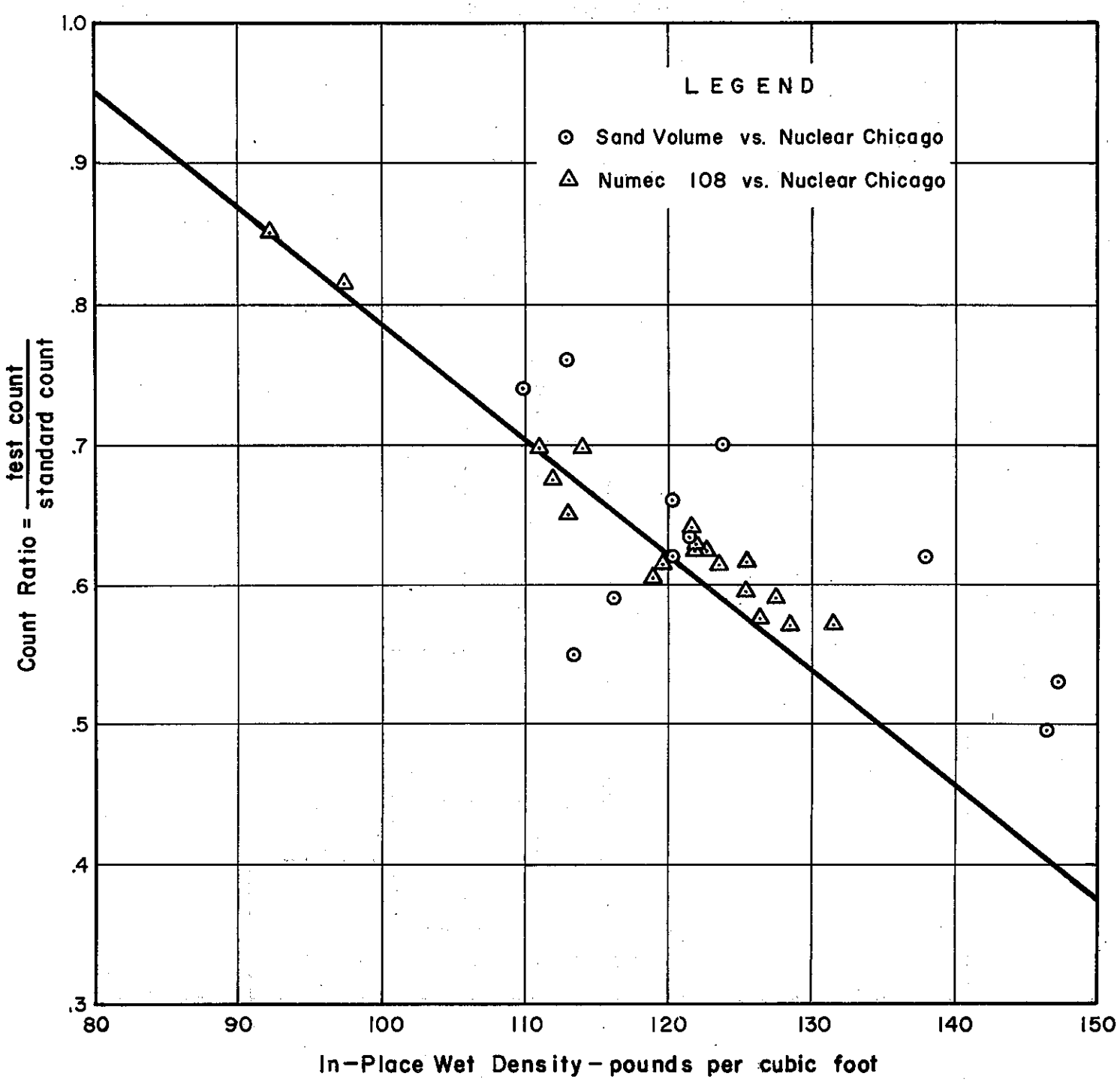

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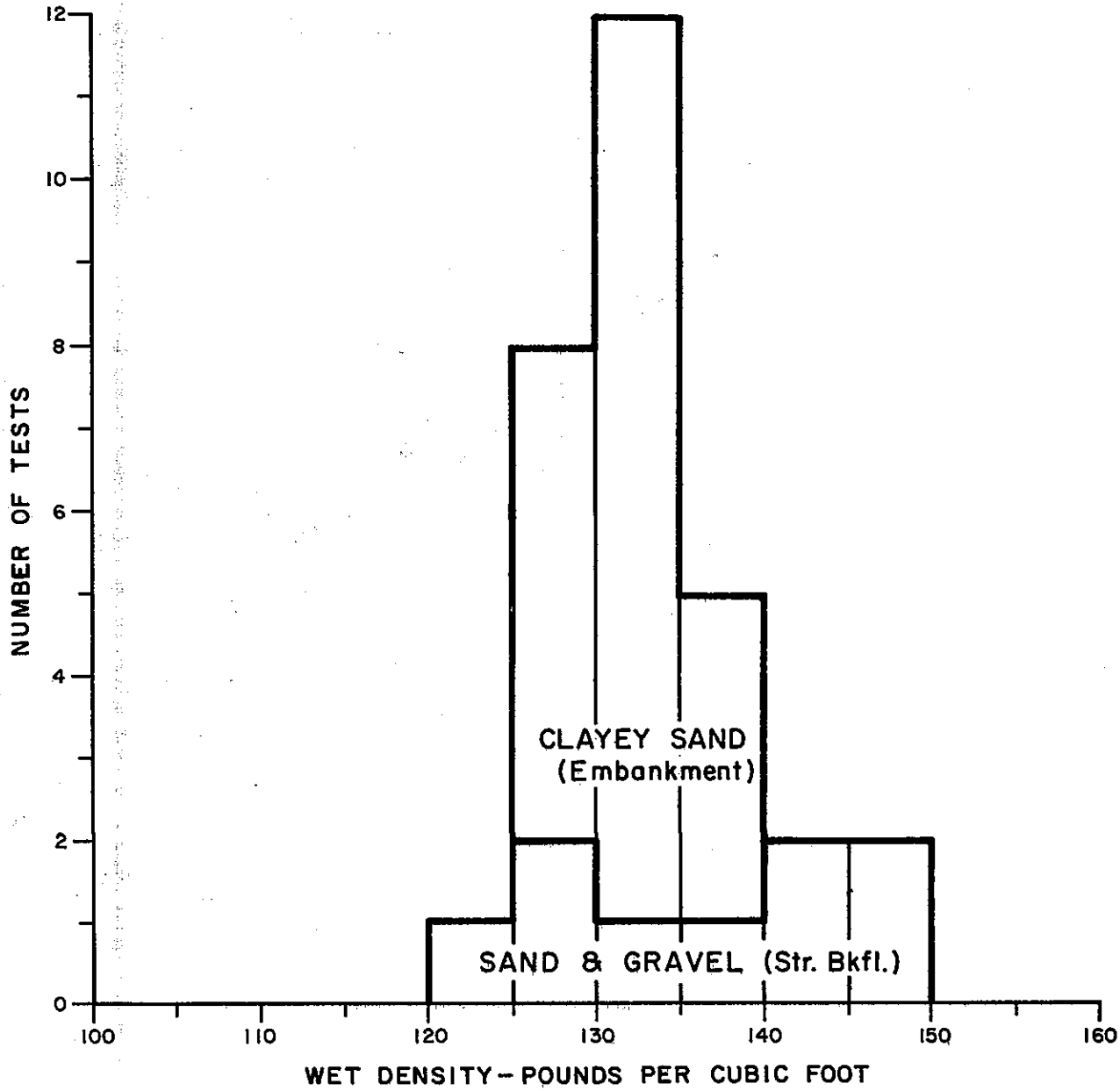
Figure 6

FREQUENCY DISTRIBUTION OF IMPACT COMPACTION MAXIMUM WET DENSITIES



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FREQUENCY DISTRIBUTION OF IMPACT COMPACTION MAXIMUM DRY DENSITIES

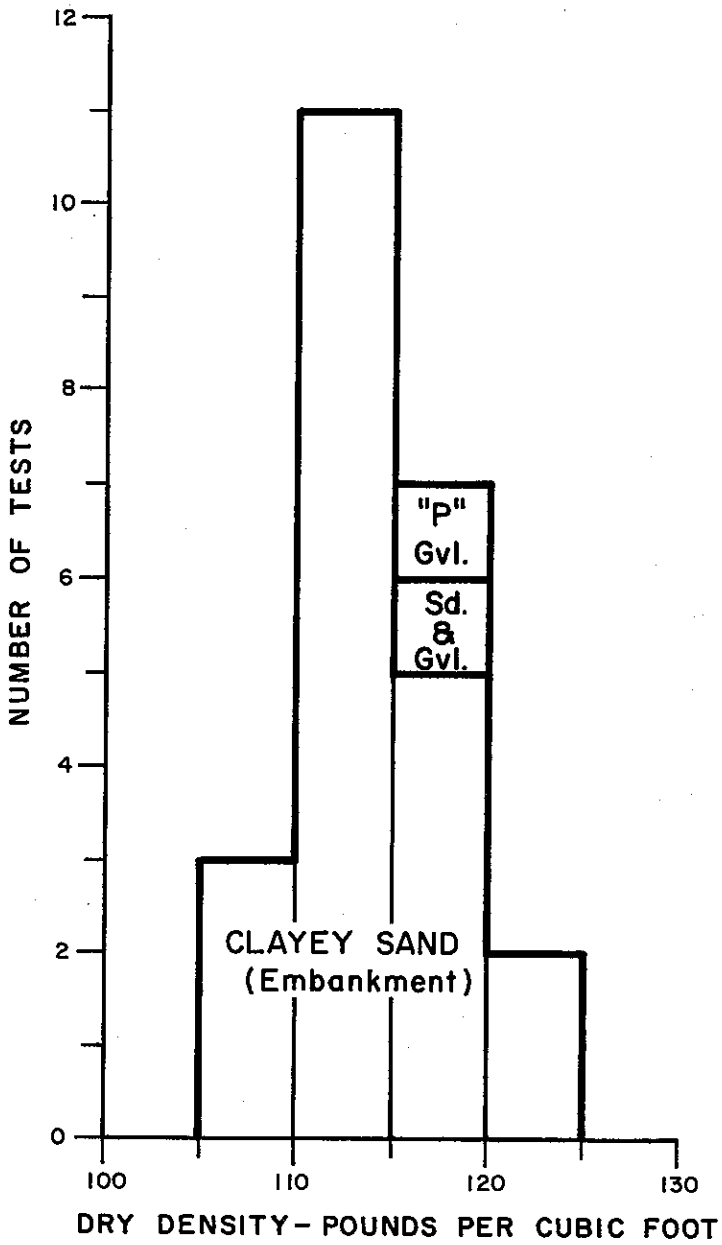

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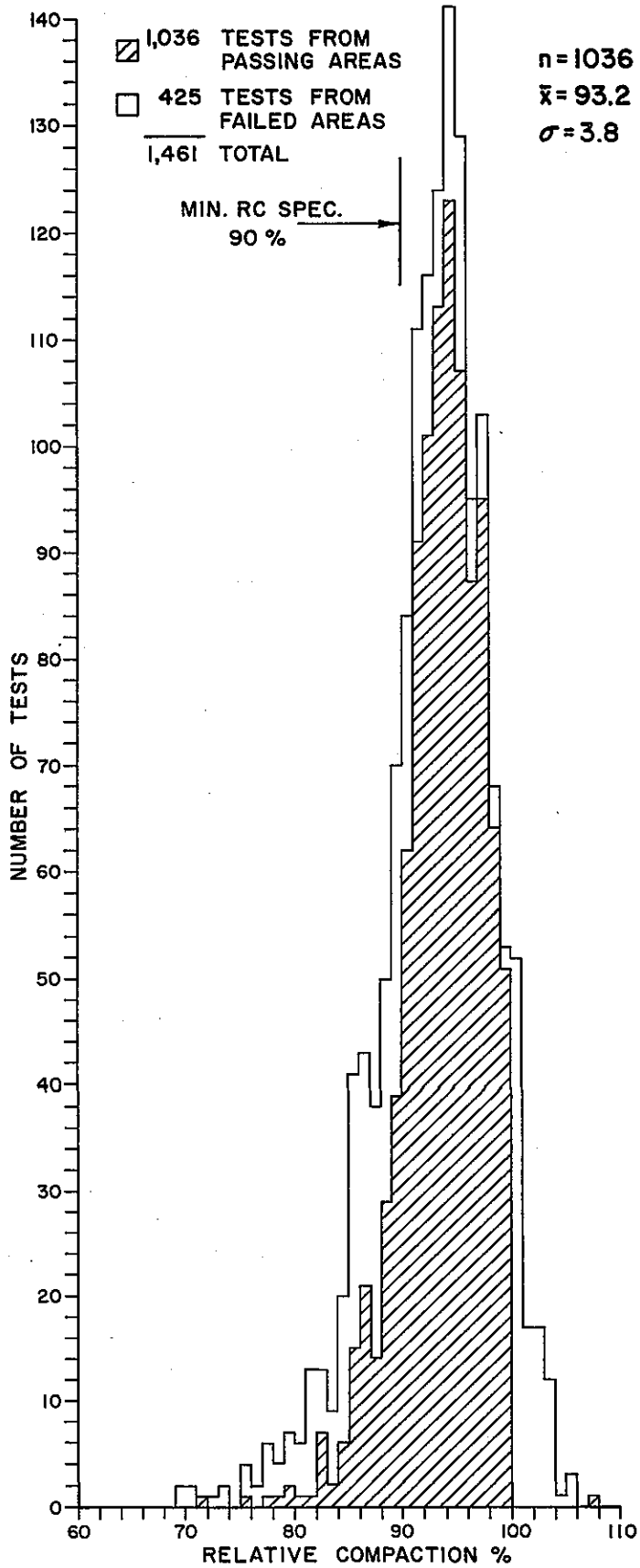
Figure 8

FREQUENCY DISTRIBUTION OF RELATIVE COMPACTIONS AT INDIVIDUAL TEST SITES EMBANKMENT



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FREQUENCY DISTRIBUTION OF RELATIVE COMPACTIONS AT INDIVIDUAL TEST SITES STRUCTURE BACKFILL, AS & AB

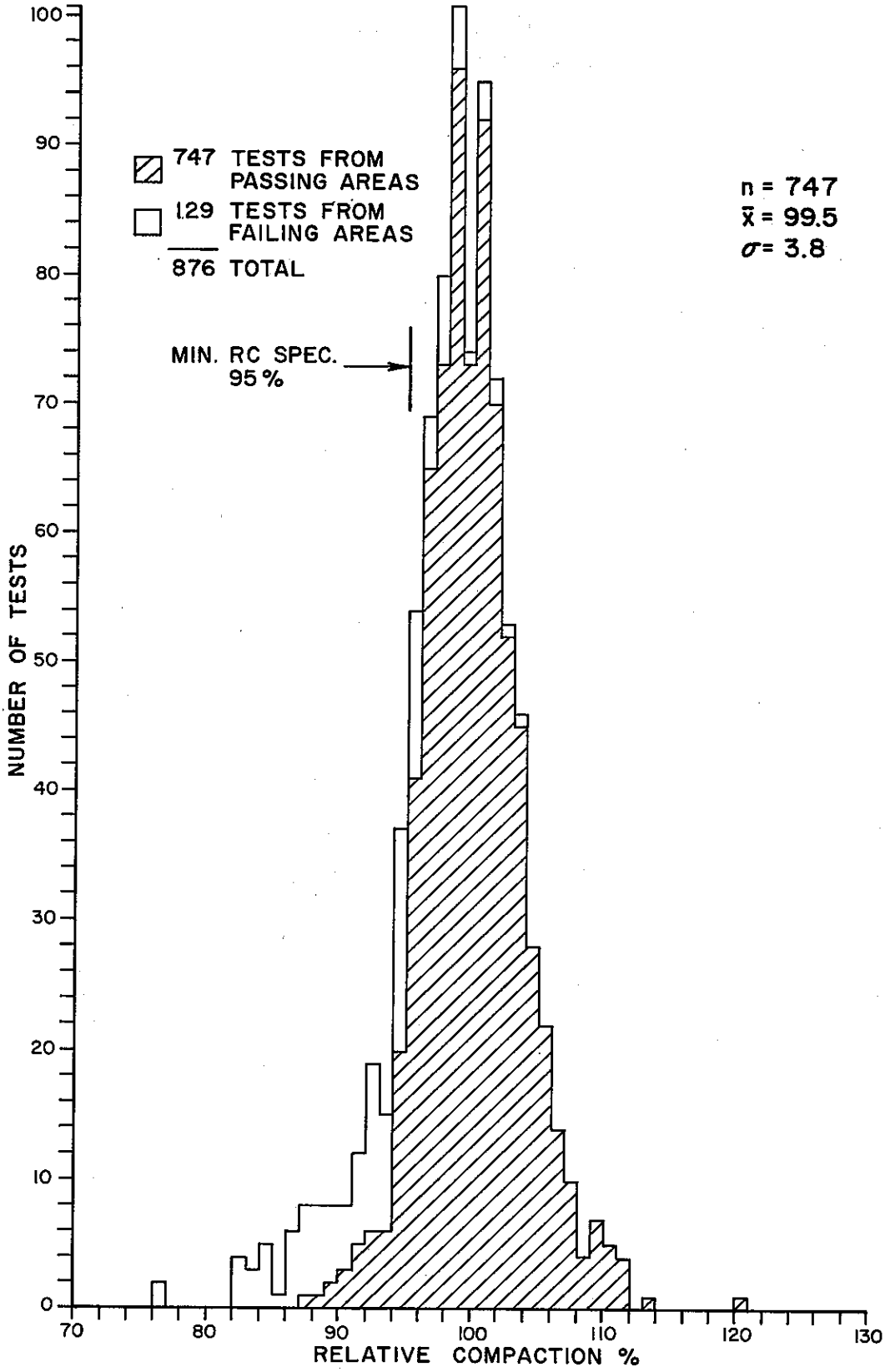

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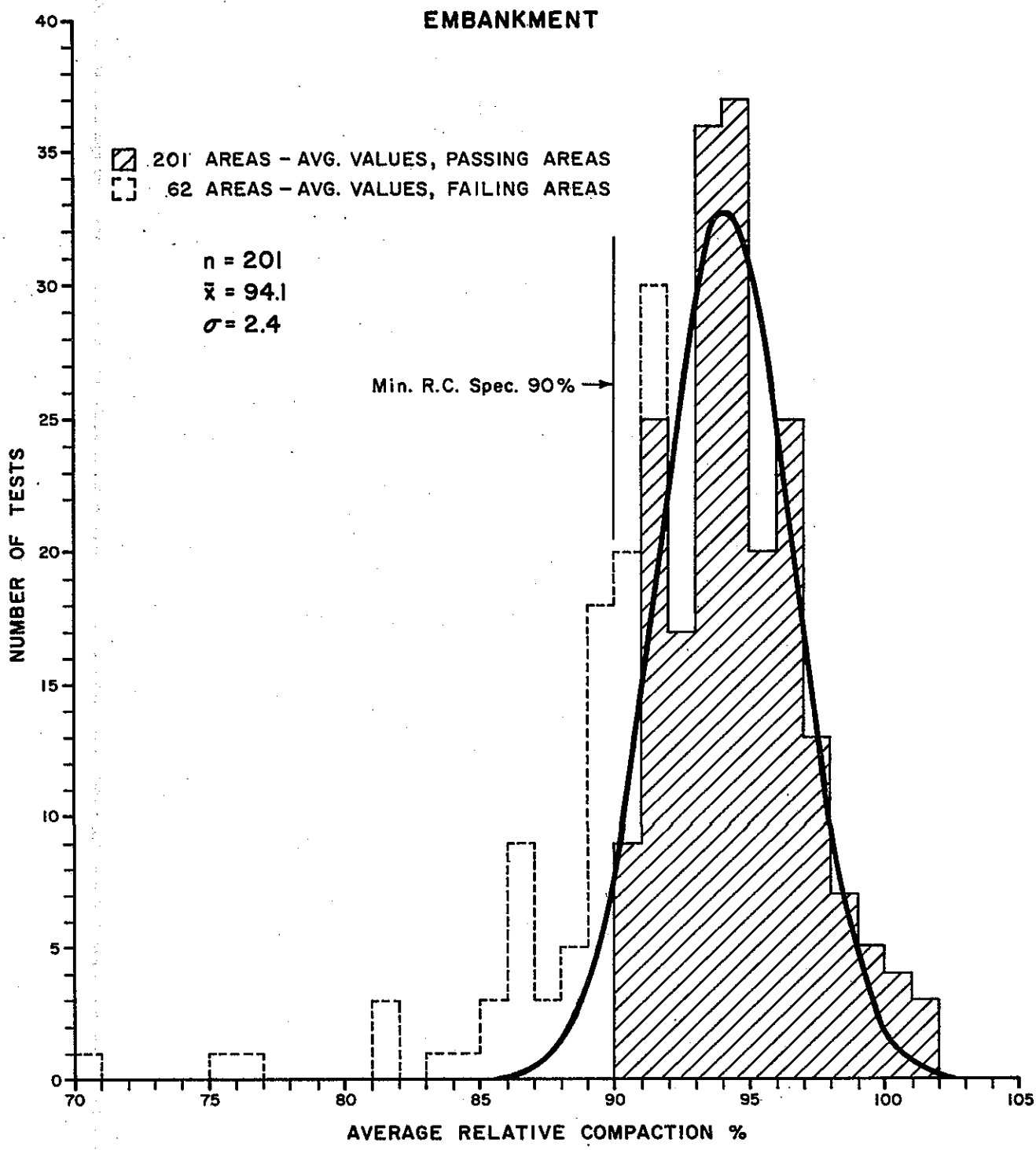
FIGURE 10

FREQUENCY DISTRIBUTION OF AVERAGE RELATIVE COMPACTIONS FOR AREAS



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FREQUENCY DISTRIBUTION OF AVERAGE RELATIVE COMPACTIONS FOR AREAS

STRUCTURE BACKFILL
SUBGRADE, AB

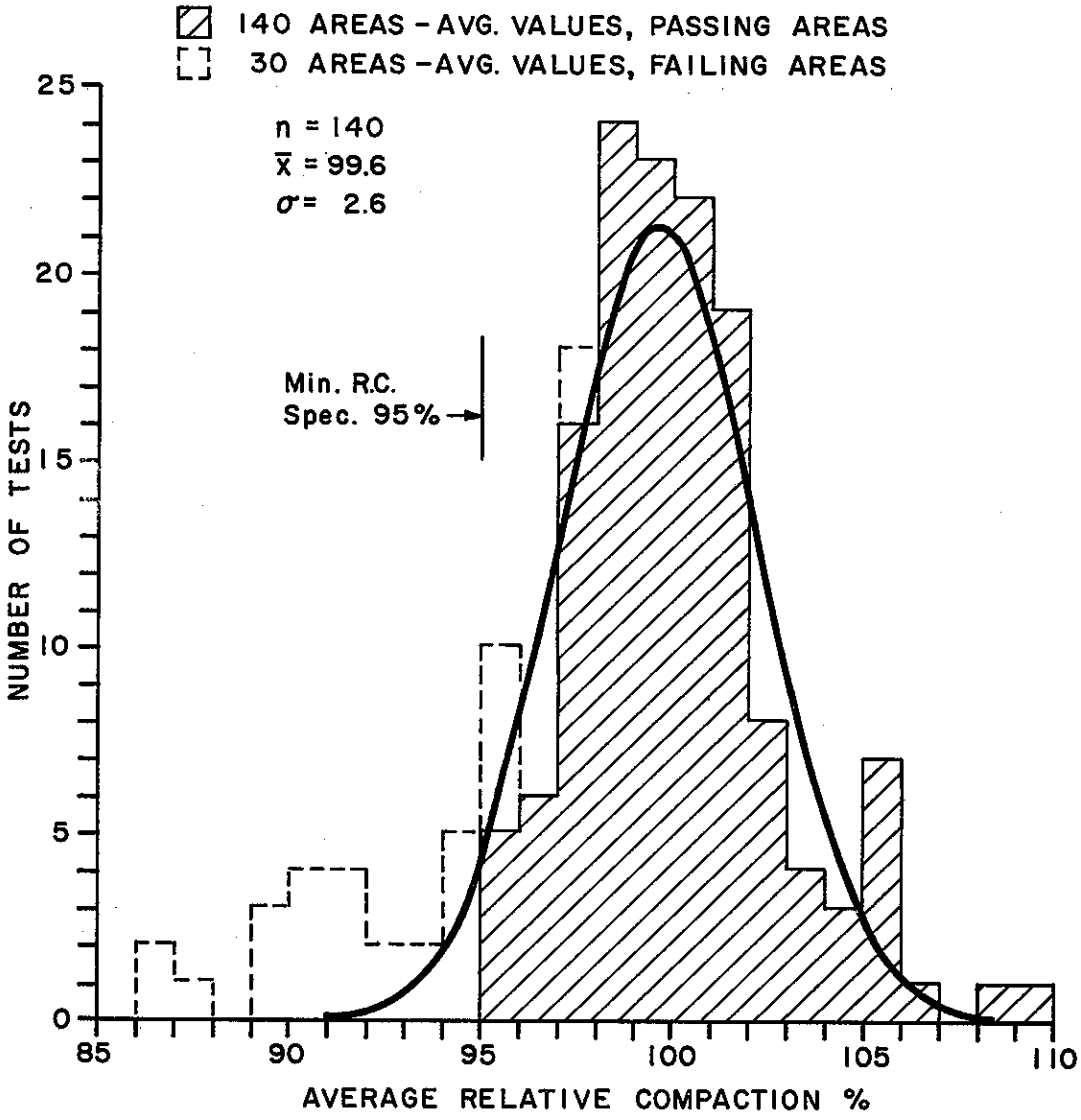

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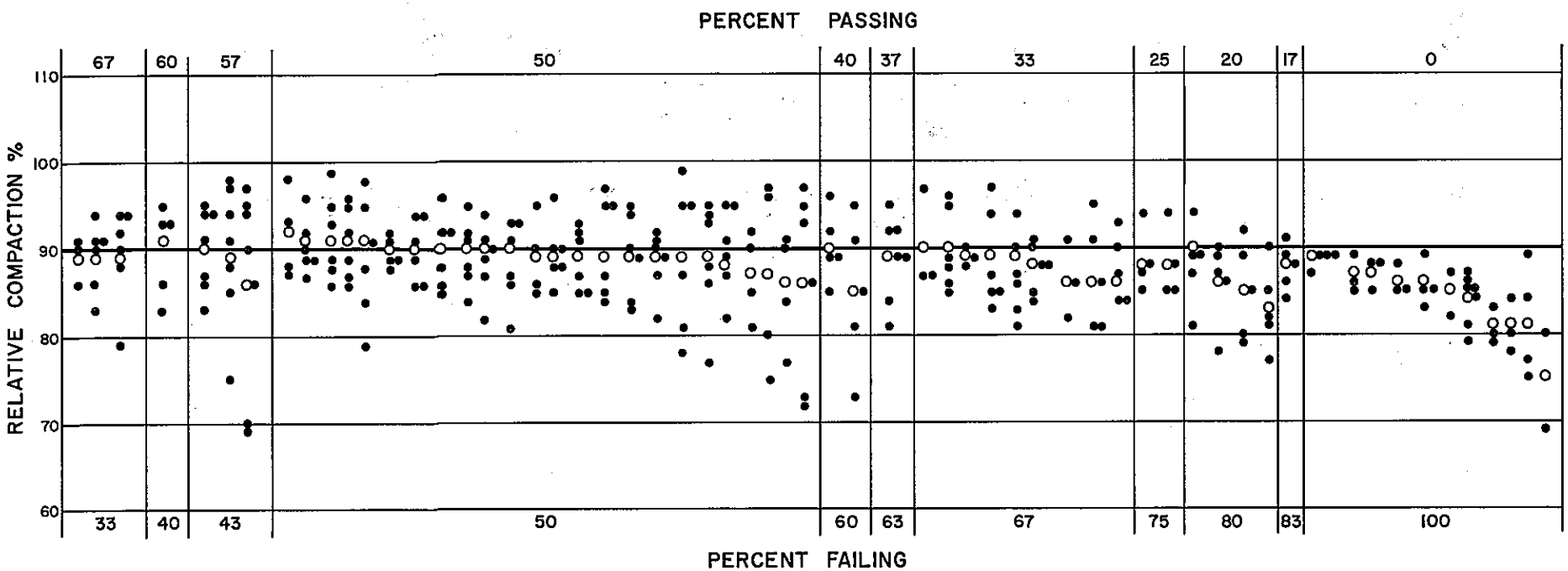
Figure 12

EMBANKMENT

AREAS WHICH FAILED TO MEET 90% MINIMUM REQUIREMENTS

○ Area Averages ● Individual Tests



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STRUCTURE BACKFILL AB, AS

AREAS WHICH FAILED TO MEET 95% MINIMUM REQUIREMENT

o Area Averages • Individual Tests

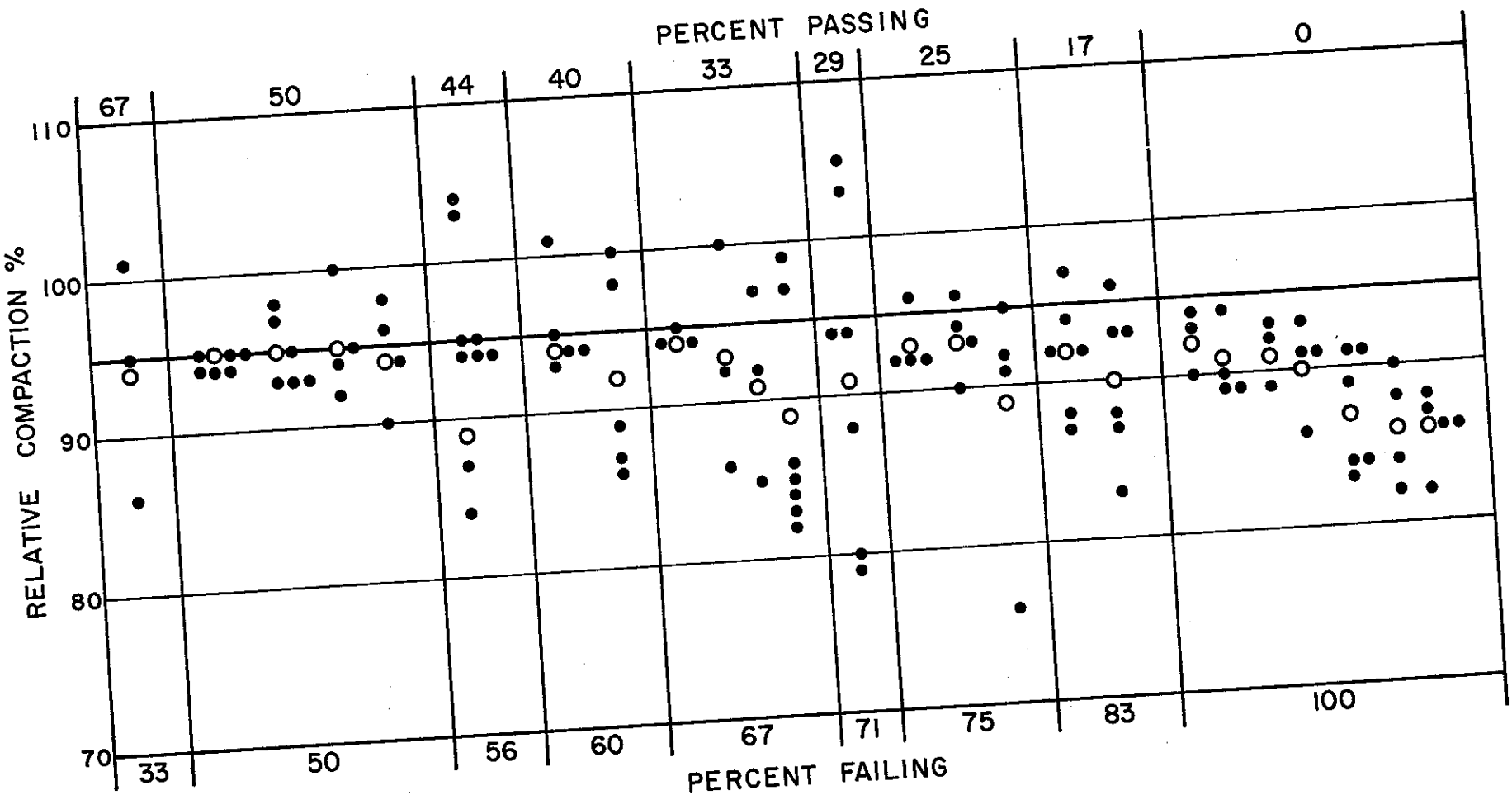

FIGURE 13

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APPENDIX A

Resident Engineer's Final Report
Nuclear Compaction Testing

06-Fre-5 45.5/62.2
06-032814

Following is a report on Nuclear Test Method No. Calif. T-231 as used to determine relative compaction on this project.

Experience with this method was generally satisfactory and enabled the project personnel to maintain sufficient control of the construction of embankments, backfill, subbases and bases. The end result of the test could be obtained more quickly than with conventional sand volume tests. The average results were probably equal in accuracy. We believe that each individual test varied more from an absolute answer than does the sand volume but this discrepancy was more than counteracted by a greater number of tests.

Equipment Used:

The major portion of the project was tested with a "back-scatter" type instrument manufactured by Nuclear Materials and Equipment Corp., commonly called Numec. Near the end of the project the Nuclear-Chicago instrument was substituted. Project personnel were much more satisfield with this latter instrument.

A number of breakdowns of the Numec occurred. While the service company came directly to the job and were usually able to make the necessary repairs there were two breakdowns that left the project without a means of legally testing the compaction. Substitute gages were shipped or brought to the project but nevertheless some delays did occur.

A carryall vehicle was used to carry the gage. A metal box was mounted in the rear and both the gage and scaler were placed therein. The box was capable of being locked. A reel was fitted to contain the cord while being transported. No provision was made to operate the gage off the vehicle battery but this should be incorporated in future installations.

A lockable storage box was provided in an isolated corner of the field office. No particular problems with storage or transportation of the equipment was encountered.

Personnel:

Two operators were trained at Sacramento for operation of the gage. One of these people did most of the testing on the project with the other primarily for "back-up". The Resident Engineer was also fully qualified as an operator. As a result no personnel lack was encountered. At least one trained

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operator was always available.

It is recommended that on future projects two fully trained operators would not be needed for each project, but a "back-up" operator should be available on immediate notice.

Testing:

The majority of the excavation and imported borrow on the project was a silty clay and rock mixture. The structure backfill consisted of a gravel reject from a nearby rock plant. Eventually two density curves were developed for the project: Embankment (both excavation and imported borrow) and structure backfill.

Approximately two days were needed to develop a density curve for each instrument in each material. It is suggested that whenever possible these curves be developed prior to start of embankment construction. It might be possible to perform some preliminary compaction for test purposes by change order.

Usually the nuclear instrument operator is pretty fully occupied with the taking of tests, checking, record keeping and other work involving the machine. An assistant will be needed on most larger jobs to take care of other testing, helping with preparation of tests sites, etc.

The "Numec" device required very careful site preparation. The "personal opinion" factor as to the suitability of test site preparation left the possibility of erratic results. In our opinion this device would achieve satisfactory control only if one operator did all the testing. His results could not be directly checked by another person. If this device is used we believe that a more definite gage of site preparation quality will have to be developed. The Nuclear-Chicago device used for some time is not as susceptible to this "opinion" factor.

The nuclear gage was affected by the presence of an adjacent pipe or concrete or side of the trench. A satisfactory test in such case could only be taken by developing a density curve under the same conditions. We finally concluded that the "Numec" was virtually incapable of taking a valid test of confined backfill material. We resolved this situation by taking one accompanying sand volume test and correlating the nuclear readings to a typical density curve using the reading at the site of the sand volume test as a "take-off" point. Whether this method was valid or not we believe good control of backfill was obtained.

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Embankment material with a high percentage of rock on the north end of the project resulted in great difficulty in preparing test sites. However, test results appeared to be as valid as sand volume testing of the same type of material.

The test method outline presented some problems. The standard deviation of 250 counts could not be obtained from the "Numec". A realistic standard deviation of 1000 counts was covered by change order.

Conclusions:

The compaction control on this project was adequate in our opinion. A considerable savings in time was generally achieved. The "Numec" device is not as satisfactory a type as is the Nuclear-Chicago or as would be a "probe" type. The ability to give the contractor immediate results on the grade once density curves had been determined is a major step forward.

A contract change order was written permitting the State to use the nuclear method on a nearby project. This project consisted of widening and raising the existing embankment with river run sand and then placing aggregate base topped with asphalt concrete. On these uniform materials very good control and immediate results were possible. The contractor was extremely satisfied with the method. On the major project the contractor appeared generally indifferent. He accepted the results readily and expressed no satisfaction or dissatisfaction with the times involved.

The contractor on neither project made any effort to use the test method to modify his embankment construction scheduling or methods.

In general, we believe the nuclear test method will tighten our control procedures and is a satisfactory improvement.

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