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STATE OF CALIFORNIA
TRANSPORTATION AGENCY
DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS

# THE NUCLEAR AGE AND COMPACTED EMBANKMENT CONTROL

By

Travis Smith

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# THE NUCLEAR AGE AND COMPACTED EMBANKMENT CONTROL

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## SUMMARY

California's experience with a new test procedure for earth compaction control is described. Important aspects of the new procedure are (1) use of nuclear gages and (2) the "area concept" procedure which is a statistical approach. Use of the test method as the specified means of measuring compaction on a contract is presented. Advantages of this new testing procedure are a savings in time resulting in lower bid prices and better control of projects.

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KEY WORDS: construction control, compaction control, rapid compaction control, compaction tests, embankments, highway embankments, nuclear methods, nuclear equipment, quality control, statistical quality control.

ABSTRACT: In 1966 the California Division of Highways implemented a change in testing procedure for earth compaction control. The new test procedure consists of two parts (1) the use of the nuclear gage and (2) the "area concept" procedure which is a statistical approach. Moisture and density measurements by nuclear devices began in the mid 1950's. After experimental work, both laboratory and field, it was believed the technical considerations involved could be managed. In 1964 a project was constructed in northern California using nuclear gages and the area concept as the specified means of measuring compaction of approximately one million cubic yards of embankment material. No particular difficulty was encountered in compacting the material and the test method proved quite satisfactory. The test procedure consists of randomly selecting six or more locations in an area ready for compaction and making moisture and density determinations at these points. A maximum compaction test is made on representative material from the area. If the average of the six locations exceeds the minimum compaction requirement and not more than two individual locations fail to pass, the compaction is considered acceptable. The Resident Engineers have indicated they were better satisfied with quality. The contractors have indicated it resulted in less delay and more efficient operation of equipment. The savings in time should result in lower bid prices thus saving money for the California Highway Program. Some problems have evolved such as maintenance of the gages and new specifications have been prepared for purchasing nuclear gages.

REFERENCE: Smith, Travis, "The Nuclear Age and Compacted Embankment Control."

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# THE NUCLEAR AGE AND COMPACTED EMBANKMENT CONTROL

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In October of 1966 a decision was made by the California Division of Highways to implement a change in testing procedure for earth compaction control that would permit the use of nuclear gages and an "area concept." This change potentially may save as much as one million dollars annually for the California highway program. This saving can be brought about by a saving in time and a smoother operation for contractors. Indications from the contractors have been that this new test procedure may permit a saving in the order of one-half cent per cubic yard for handling roadway excavation and even higher savings in structural section material. If a one-half cent per cubic yard saving is applied to the approximately 200,000,000 cubic yards of material placed annually on State projects a saving of $1,000,000 would result. In addition to possible savings this test method has other advantages.

There are two important aspects to this new test procedure. They are: (1) the use of the nuclear gage and (2) the area concept procedure which is a statistical approach. Both of these parts are necessary to the effective operation of the new test procedure.

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The California Division of Highways first became involved in measurement of moisture and density by nuclear devices in the mid 1950's. Most of this earlier work consisted of measuring change in moisture and density in boreholes in soft foundations underlying embankments.

One of the first available commercial devices for surface measurement of moisture and density was purchased in 1958. Considerable experimental work was done between 1958 and 1964 with this gage and other commercial gages that were purchased or used. Most of this work dealt with the technical problems involved in measuring moisture and density with nuclear gages. Some of these problems resulted from evaluation of types of gages, surface conditions, chemical composition of soils, types of materials, depth of measurement, and backscatter versus transmission methods. Consideration was also given to such items as air gap, collimation, standardization and other processes. Data from these studies are available in various technical publications, primarily, through the HRB, and the California Division of Highways. By early 1964 it was believed the technical considerations involved in nuclear testing could be managed. The next phase in the work consisted of an evaluation of the testing procedure under actual field conditions, that is, actual use of the test method as the specified means of measuring compaction on a contract.

In 1964 a project was constructed in northern California using nuclear gages and the area concept as the specified means of measuring compaction of embankment material. A backscatter gage was used. The job included approximately one

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million cubic yards of embankment material. No particular difficulty was encountered in compacting the material and the test method proved quite satisfactory. Figure 1 shows distribution curves for test results on this project. Both the Resident Engineer for the State and Project Manager for the contractor were well satisfied with this means of compaction control. Some of the success of this experimental project might be attributed to lack of compaction difficulties on the material encountered, a desire on the part of the Resident Engineer to make the test method work and a receptive attitude on the part of the Project Manager.

The test method consists of randomly selecting six or more locations in an area of homogeneous material that is ready for testing. Moisture and density determinations are made with a nuclear gage at these locations. A maximum compaction test is made on representative material from the area. If the average of the six locations exceeds the minimum compaction requirement and not more than two individual locations fail to pass, the compaction is considered acceptable. Figure 2 illustrates typical data using this test procedure.

Based on the results of the above study it was decided to construct eleven additional projects during 1965 and 1966 using this test method. These projects were selected throughout the State in order to give representative coverage of such variables as geography, geology, types of soil, size of projects, construction personnel and manufacturers of nuclear gages. Ten new gages were purchased for this study at approximately $4500 each. Both transmission and backscatter gages were used.

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Figure 3 illustrates the principals of the backscatter and transmission type gages. Both embankment material and processed material such as structure backfill, subbase, base and cement treated base were tested by this process. These represent a total of approximately 45 million cubic yards of material. The operation of the gages and control of the projects were the responsibility of district construction personnel. The correlation and research in connection with the project was handled by personnel of the Materials and Research Department. Six of the projects are finished and four are nearing completion. One project will not be complete until late 1968.

Some problems have evolved in the prosecution of this research project. These should be considered in evaluating the possibilities of the use of nuclear gages. Maintenance of the gages has been a more serious problem than might be anticipated. Causes of the breakdowns in gages have been varied. These have involved broken cords, burned out tubes, minor electrical failures, poor workmanship and other items. Major malfunction of the gages has been fairly infrequent, but has occurred in some cases. Lack of adequate repair facilities on the part of the gage manufacturer or on the part of the State has contributed to this problem. Variations in soil characteristics has necessitated recalibration of the gages in some instances. This recalibration has been particularly true of the backscatter gages. This process is frequently very time consuming. Figure 4 shows a gage in use

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on rocky embankment material. Training of gage operators has been a major item. In order to comply with health and safety regulations a week's training has been provided for each operator. Standby operators have also been trained.

Considerably more tests as well as better coverage were available on which to evaluate compaction control. Figure 5 shows the distribution of test results on embankment and processed material for one of these projects. The Resident Engineers have unanimously indicated they were better satisfied with quality and their knowledge of the compaction. The test works particularly well on processed material such as base. Figure 6 shows a transmission gage in use on structure backfill. Testing by this process costs approximately the same as by the former method used in California (sand volume for in-place density). The contractors have generally indicated that they were satisfied with this new testing procedure. They have indicated that it resulted in less delay on the part of construction equipment and more efficient operation of their spreading and compacting equipment. Figure 7 shows a test being made with heavy equipment operating nearby. Thus, a saving in time and a saving in bid prices should result. Although the backscatter gage gives satisfactory results, the transmission gage is believed to be superior for most work.

As a result of the research work in California new specifications have been prepared for purchasing nuclear gages. Figure 8 shows a gage manufactured to these specifications. These specifications require that the gage be capable of both backscatter and transmission type measurement. In the trans-

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mission part of the gage the detector is housed in the rod that extends into the soil and the source is housed in the main part of the gage. The use of these specifications, competitive bidding by the manufacturers, and purchases in quantity have resulted in appreciable savings in the purchase of gages. These gages are being purchased for approximately $2000 each as compared with $4500 at an earlier date. These gages have been purchased from three manufacturers. Several other manufacturers have submitted bids. Figure 9 shows a gage built to the California specifications with both the scaler and the probe in a single unit.

Based on the favorable results of this study the decision was made in October 1966 to use the nuclear gages and the area concept as a method for control of compacted material on state highway projects.

At the present time 31 contracts representing approximately 100 million cubic yards of embankment and nine million tons of processed material are covered by this specified procedure. Between 35 and 40 nuclear gages are presently in use. By the end of 1967 approximately 50 projects will be controlled by this method. These projects represent the larger earthwork jobs in progress at the present time. Personnel of the Materials and Research Department have trained the necessary district personnel for administration of this program. District personnel will train the actual gage operators and control the future work. Each of the eleven districts has been licensed by the California Department of Public Health to administer this program.

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In most states licensing would be the responsibility of the Atomic Energy Commission.

The future of nuclear testing in the California highway system will largely be dependent upon experience as more projects are built using this method of control. It is possible that at some foreseeable date as many as 200 contracts might be handled by this test method. While it is anticipated that this method is most applicable on the large earthwork jobs it probably has some application on very small jobs where one test operator will control several small projects. It is anticipated that contractors may make effective use of their own nuclear gages as a means of determining or improving the effectiveness of various construction procedures.

In summary, the California Division of Highways has launched a program of control of compacted materials using nuclear gages and the area concept procedure. This decision is based on extensive experimental data, both in the laboratory and under actual field conditions. Little or no saving is anticipated in the cost of testing. Better control of projects will be possible. Possibly as much as a million dollars per year in savings may be realized as a result of more favorable bid prices. The gages are primarily being used on large projects at the present time. The future of this process is largely dependent upon the experience that will be gained as more use is made of the gages.

Although the views expressed are not necessarily those of the U. S. Department of Transportation, Federal Highway Administration, Bureau of Public Roads, much of the research leading to the decision to use the nuclear gage was made in cooperation with the BPR.

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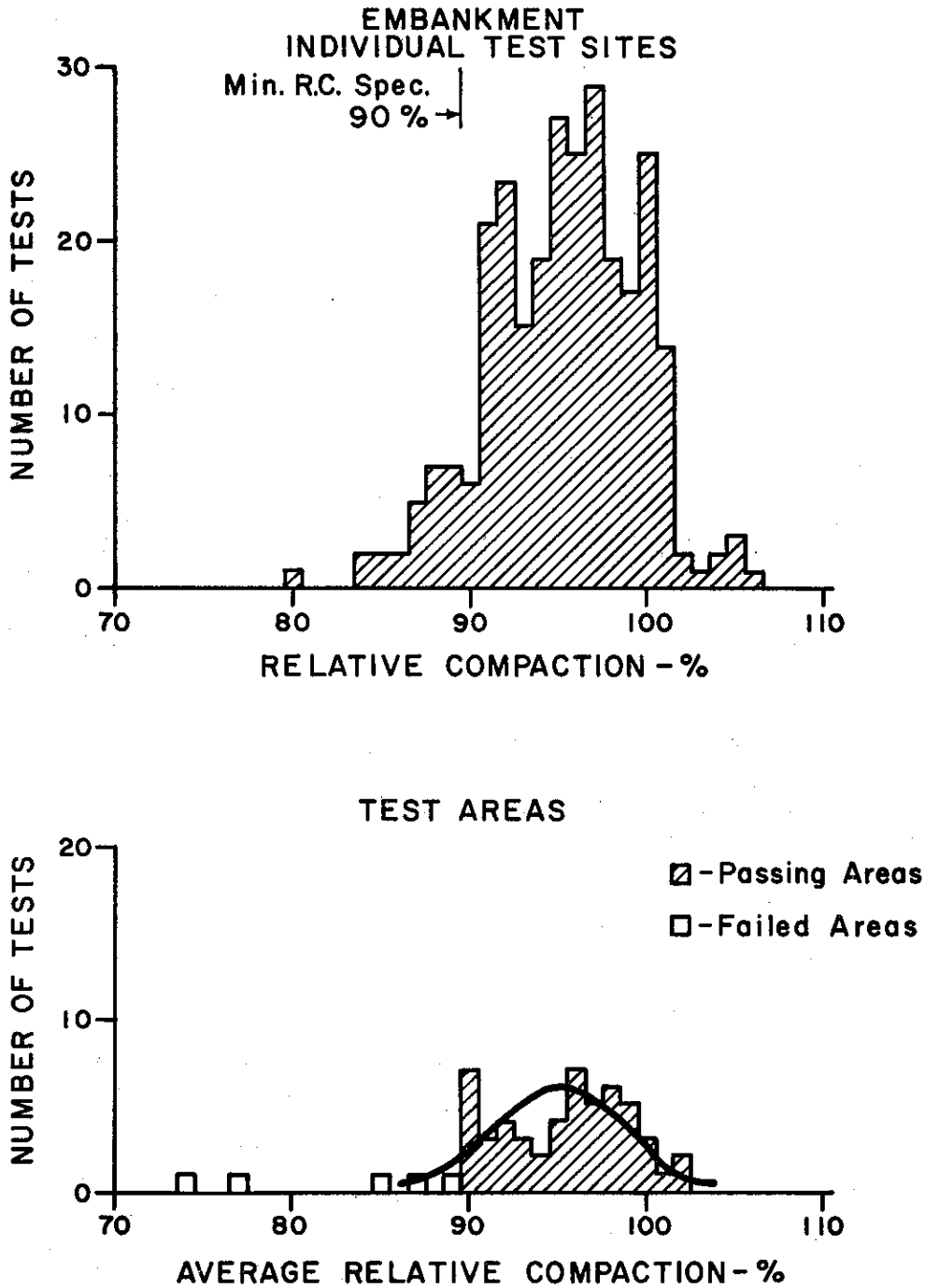


FIG. 1 FREQUENCY DISTRIBUTION PILOT PROJECT

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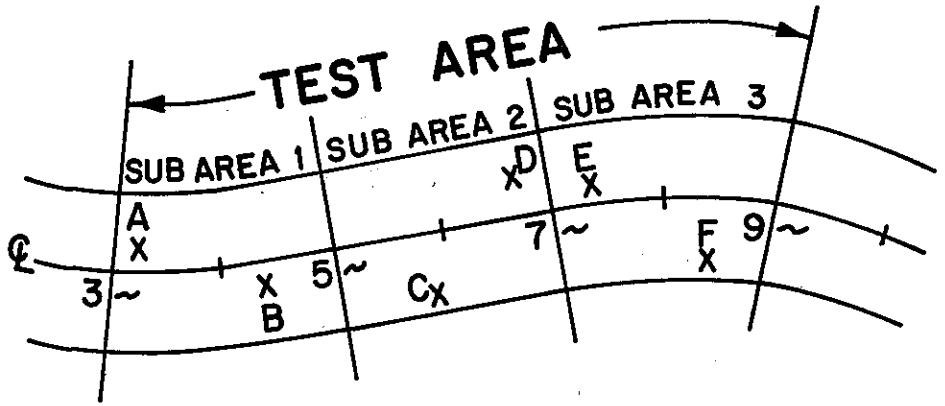


SPECS:
MIN R.C. 90%

FIELD DATA

LAB TEST:
MAX WET DEN. 139 pcf

| SUB AREA | SITE | SITE WET DENSITY | RELATIVE COMPACTION |
|---|---|---|---|
| 1 | A<br>B | 119 pcf<br>128 | 86%<br>92 |
| 2 | C<br>D | 131<br>125 | 94<br>90 |
| 3 | E<br>F | 124<br>129 | 89<br>93 |
| AVERAGES | | 126 | 91 |

ANALYSIS: SINCE SITE AVG. = 91 > 90 SPEC. AND NOT MORE THAN 1/3 OF THE SITES HAVE RC VALUES < 90 SPEC. THE AREA PASSES.

FIG. 2 EXAMPLE OF FIELD DENSITY CONTROL

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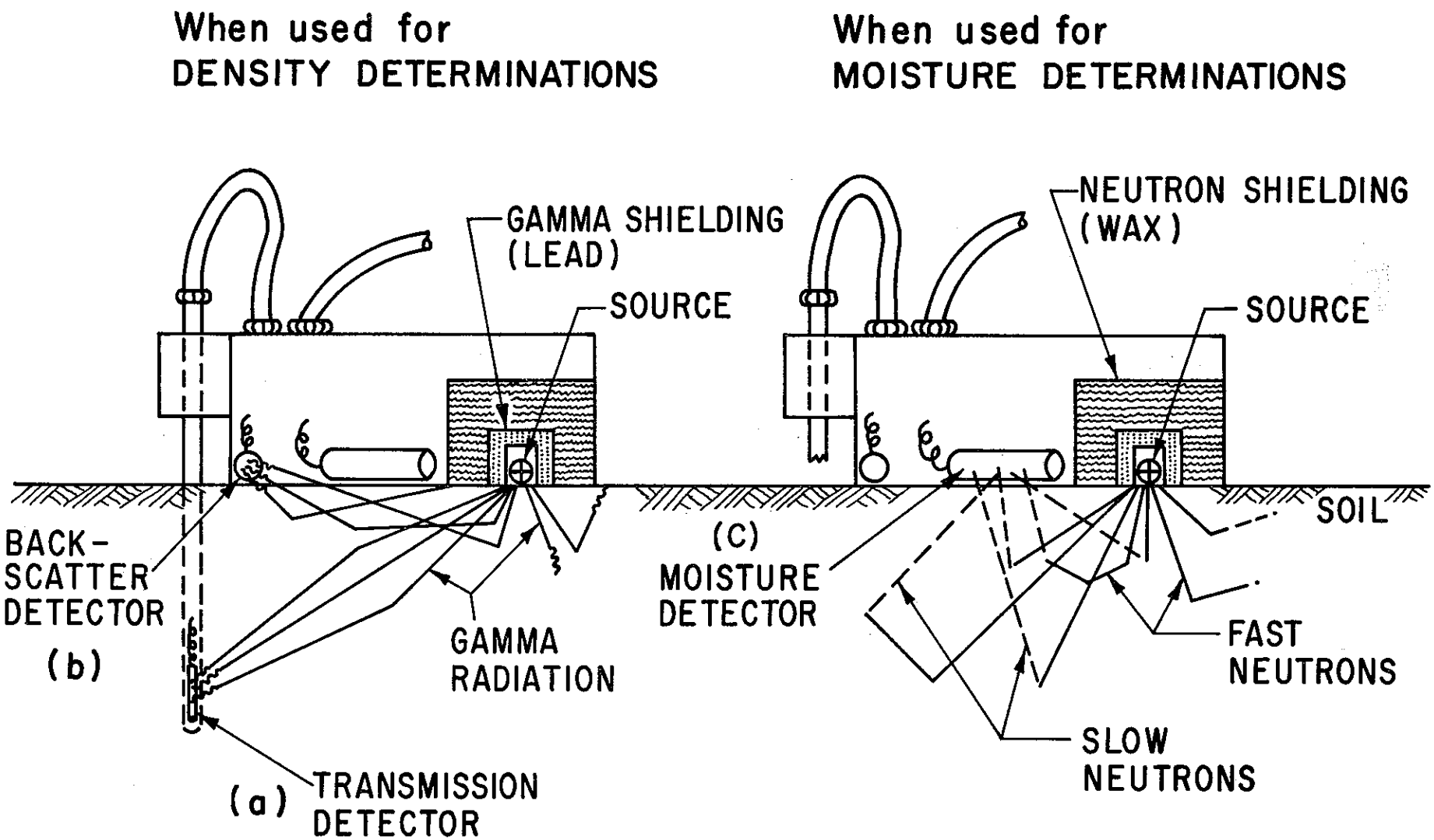


FIG. 3 TRANSMISSION TYPE NUCLEAR DENSITY-MOISTURE PROBE

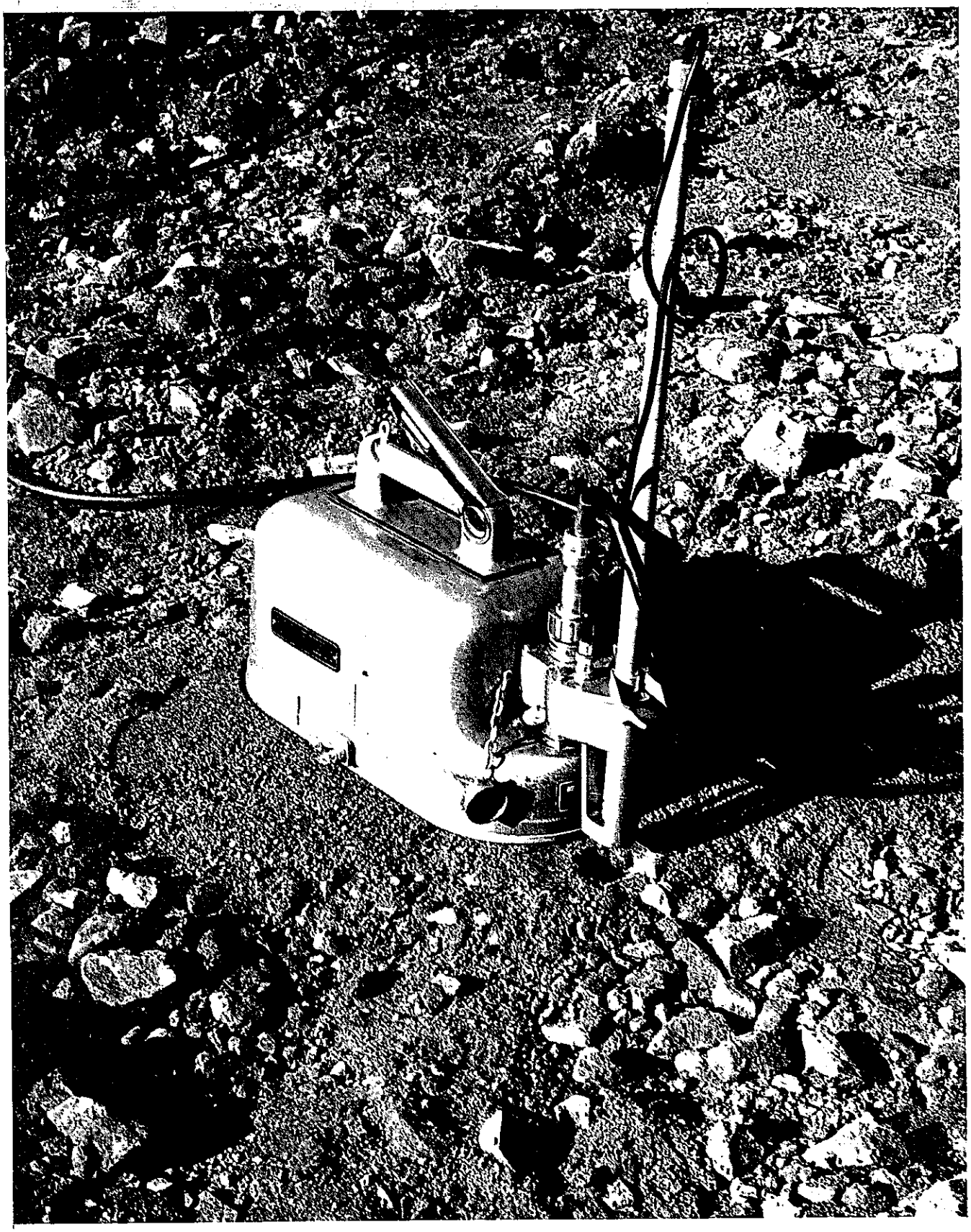

FIG. 4 ROCKY EMBANKMENT MATERIAL-TRANSMISSION GAGE

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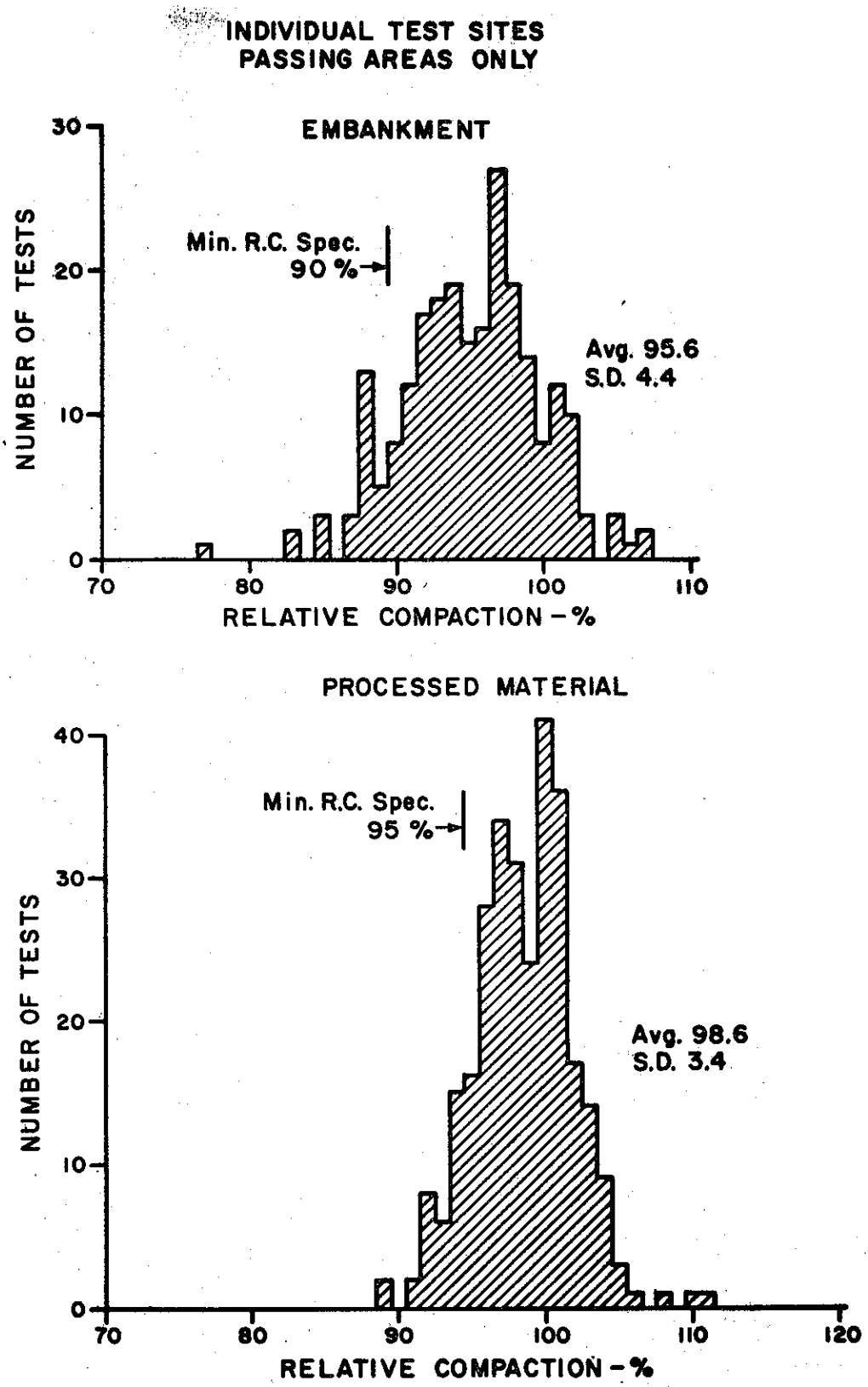


FIG. 5 FREQUENCY DISTRIBUTION - PROJECT NO. 2

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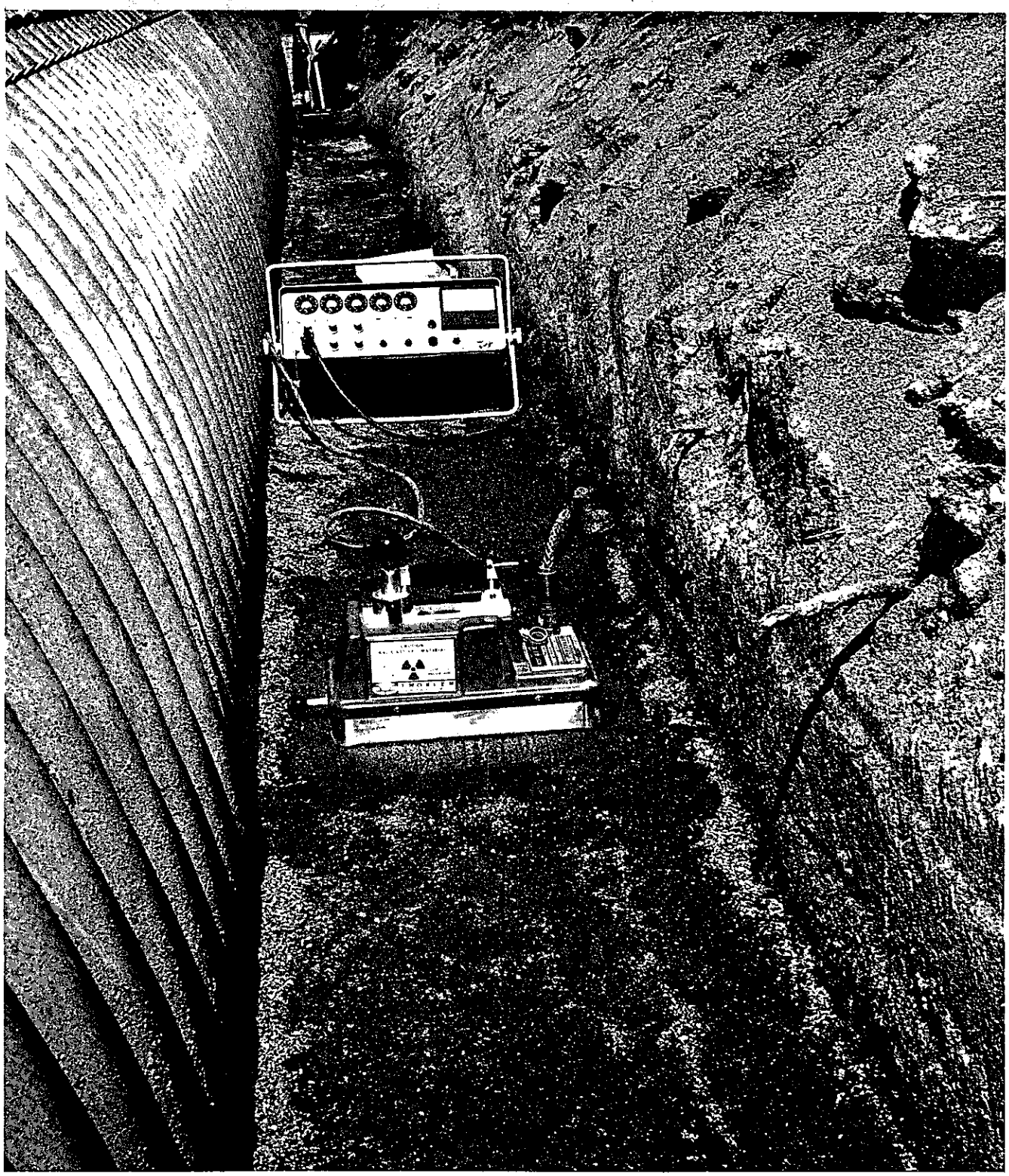

FIG. 6 TESTING STRUCTURE BACKFILL - TRANSMISSION GAGE

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FIG. 7 HEAVY EQUIPMENT OPERATING NEARBY AS TEST IS MADE

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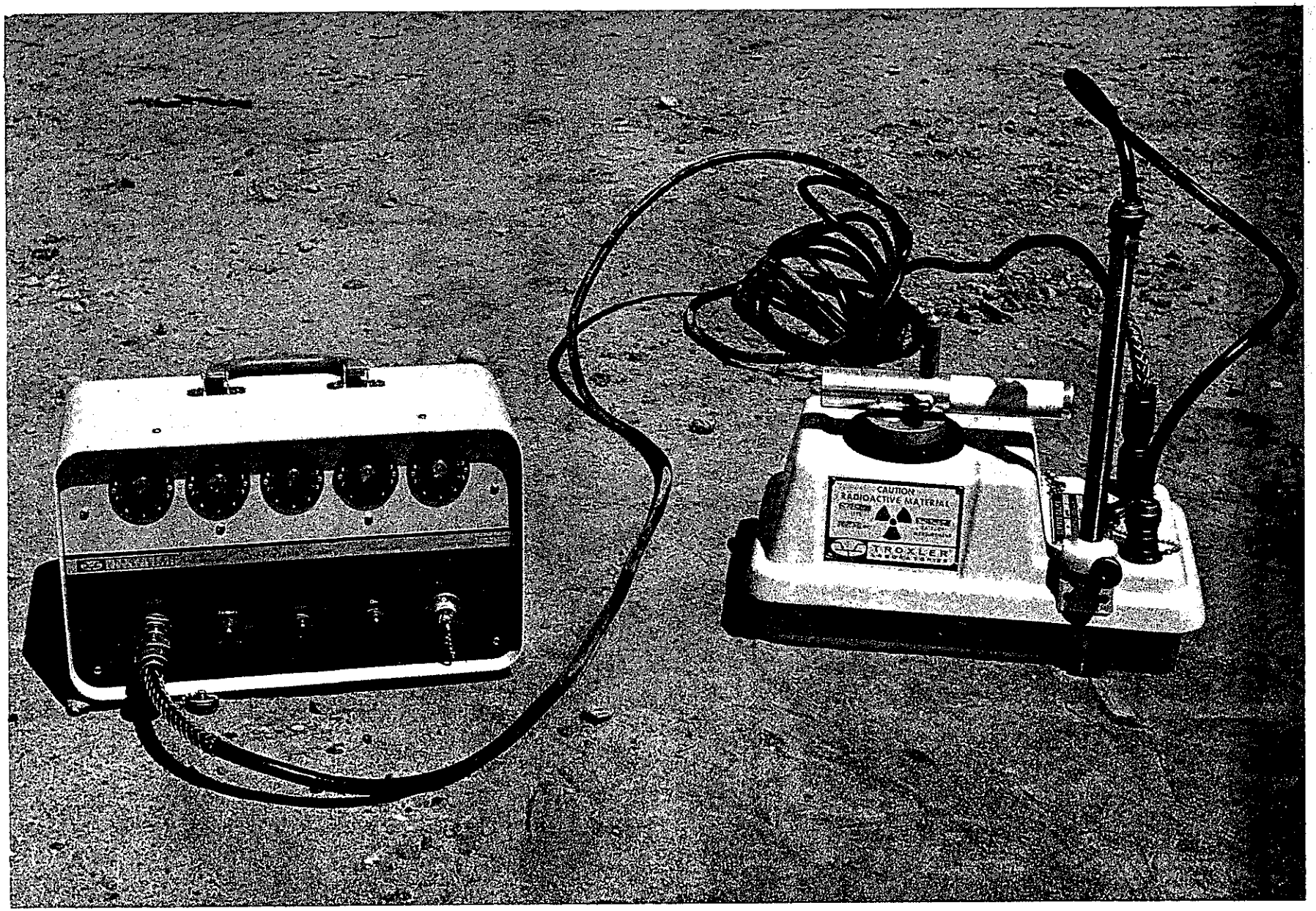


FIG. 8 TRANSMISSION AND BACKSCATTER GAGE - NEW SPECIFICATIONS

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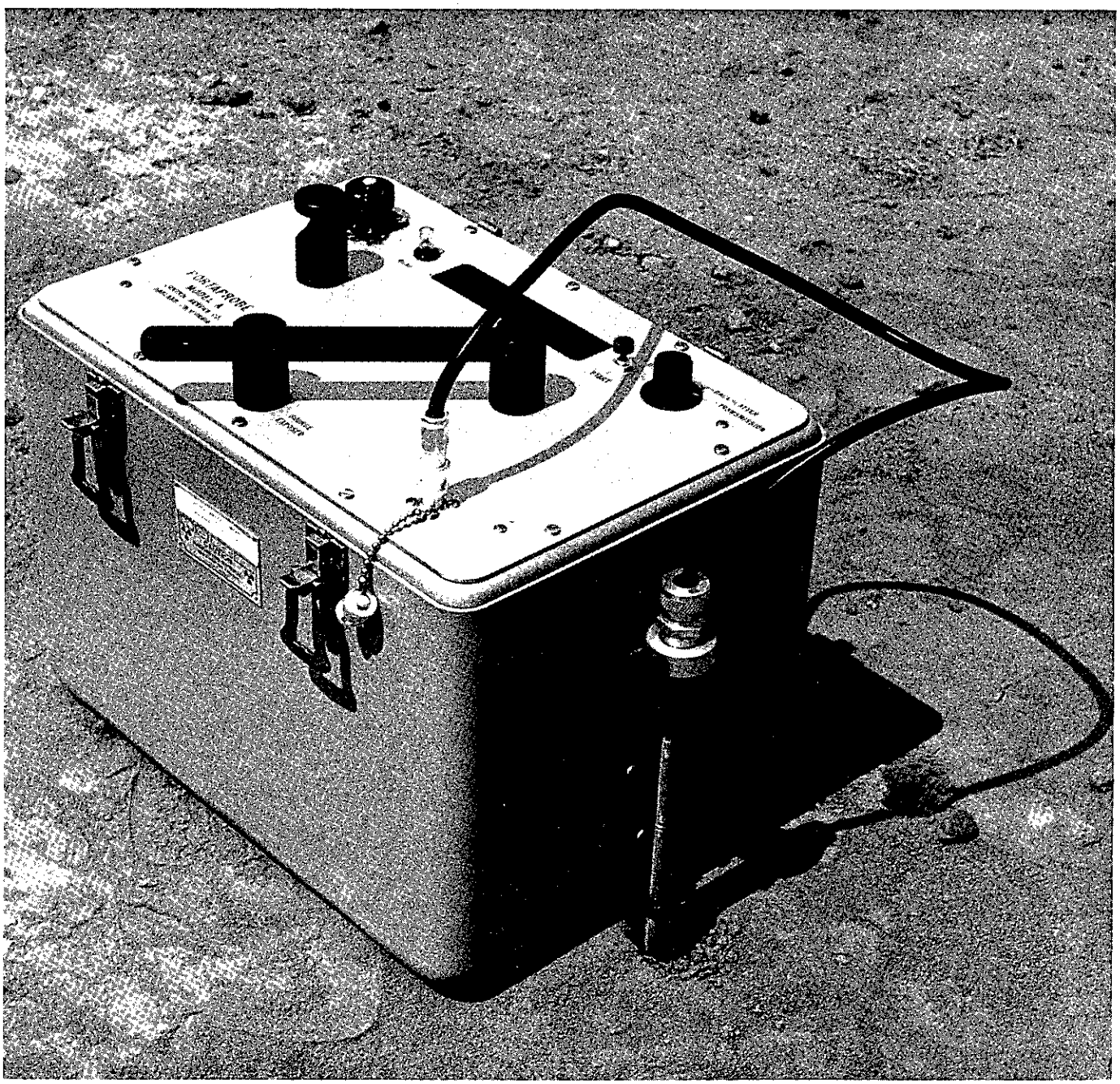

FIG. 9 SCALER AND PROBE IN A SINGLE UNIT

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