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STATE SURVEY OF PROCEDURES AND SPECIFICATIONS FOR THE USE OF NUCLEAR GAUGES

Acknowledgment

The analysis of the questionnaire was done by a subcommittee consisting of the following persons: Donald W. Anderson, Chairman; John C. Cook, Wilbur J. Dunphy, Jr., and C. H. Shepard.

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INSTRUMENTATION PRINCIPLES AND APPLICATIONS

RESULTS OF THE 1973 QUESTIONNAIRE ON PROCEDURES AND SPECIFICATIONS FOR THE USE OF NUCLEAR GAUGES

In October 1973, the Transportation Research Board contacted the 50 state highway agencies, the Canadian provinces, and numerous counties, cities and other nuclear moisture-density gauge users to request information on current procedures and specifications concerning their use of this equipment. The results of a similar survey conducted in 1969 were published in Highway Research Circular No. 125, April 1971.

Because of increasing utilization of nuclear testing (1), it is important that agencies using or contemplating the use of nuclear gauges be aware of new or developing trends or applications which may be of value to them. This report provides such information and indicates through relative popularity the more successful procedures in use.

Analysis of the questionnaire data does not reveal any large differences among the replies from states, provinces, or city-county groupings. For this reason and for brevity, only the replies from state highway agencies are reported here.

PROCEDURES

Items included in this report are those concerned with the following technical aspects of conducting a nuclear density and moisture testing program and the application of nuclear tests to construction control.

(1) "Results of the 1973 Questionnaire on Highway Applications of Nuclear Techniques" Highway Research Circular No. 159, July 1974.

I. Basic Gauge Calibration

A. Density
B. Moisture

II. Operational Checks

III. Safety

IV. Training

V. Repair Facilities

VI. Gauge Seating

VII. Test Count

VIII. Density Test Configuration and Materials Tested

Because answers were not always given to all questions and some states reported multiple answers to some questions, totals will not always be 100% of the number of respondents.

I. Basic Gauge Calibration	Percentage of Respondents
A. Density Calibration	
1. Used manufacturer's calibration	58
2. Established calibration with local material compacted into molds	12
3. Established calibration from permanent stone, concrete, metal or similar standards	56
4. Calibrated with conventional field tests	36
5. Other	2

Many states reported the use of more than one calibration method. For instance, the use of field comparisons or permanent laboratory standards to verify the manufacturer's calibration was indicated by some states.

B. Moisture Calibration	Percentage of Respondents
1. Used manufacturer's calibration	70
2. Established calibration with permanent or semipermanent laboratory standards	22
3. Calibrated by comparison with conventional tests (oven-dried, speedy, etc.)	46
4. Other	0

As with density calibration, a combination of procedures was used in some instances.

II. Operational Checks. Gauge manufacturers specify that certain checks be made, usually upon portable standards, to detect gauge malfunction or drift and, in some instances, to permit minor adjustments. The 50 state highway agencies reported their frequency of operational checks as follows:

	Number of Respondents
A. Two or more times daily	18
B. Daily	29
C. Less than daily	3
D. Other	0

III. Safety. Monitoring of radiation exposure to the gauge operator by use of a film badge has become a routine procedure for most state highway agencies. The use of radiation monitoring devices was indicated as follows:

	Number of Respondents
Film badges	40
Survey meters	8
Dosimeters	6
(Three states used all of the above)	
Neutron survey meter	1
Unspecified	1

Radiation leak tests were reportedly conducted in accordance with the time intervals listed below. Twenty-six states described a wipe test; and one, a wet-dry disc method. The other state replies did not contain this information. Additionally, one state agency requires a survey meter leak test "before, during and after each nuclear test," as well as a six-month wipe test.

Leak Test Intervals	Percentage of Respondents
5 months	2
6 months	68
Annually	24
Not indicated	6
	100

IV. Training. The establishment of formal training programs for persons utilizing nuclear gauges has increased greatly, with 40 state highway agencies now following this practice. Duration of classroom training varied from 0 to 3 days with an average of 1.2 days, and field training was reported to have a duration of from 0 to 10 days with an average of 2.1 days.

V. Repair Facilities. The number of states performing all or part of gauge repairs has risen to 21, while 29 states utilize only the manufacturer's repair facilities.

VI. Gauge Seating. All manufacturers emphasize the importance of proper seating of nuclear gauges upon the tested material in order to obtain maximum precision. Fourteen states include a specified maximum allowable deviation from a plane surface in their test procedures. Of these, 13 limit this deviation to 1/8 inch maximum while the other one limits it to 1/32 inch. Only two states actually measure this deviation; the other 12 rely upon visual estimation.

Thirty-eight states specify the type of material to be used to fill small depressions in the test surface. Because some states permit the use of more than one type of fines, the total exceeds this number.

Type of Material	Number of Respondents
Sand	13
Native fines	37
Cement	1
Not Specified	12

VII. Test Count. Simpler procedures are being accepted as adequate for accurate nuclear testing of moisture and density. This fact is revealed in the number and duration of test counts required for a single determination where one one-minute count has become the most widely used test count. These counts and their durations are listed below for both density and moisture testing. This survey did not determine whether any rotation or other movement of the gauge is made between counts.

A. Density Test Counts	Number of Respondents
1 count(s) of 1/2 minute(s)	1
1 " 1 "	22
2 " 1 "	13
3 " 1 "	8
4 " 1 "	6
2 " 2 "	1
1 " 4 "	1
Total*	52

*Two states reported using a different number of counts for different materials.

B. Moisture Test Counts				Number of Respondents
1 count(s)	of	1 minute(s)		22
2	"	1	"	12
3	"	1	"	7
4	"	1	"	5
2	"	2	"	1
1	"	4	"	1
			Total	48

VIII. Density Test Configuration and Materials Tested. Three basic and different density test configurations are considered here. They are direct transmission, backscatter and dual-gauge. For the purpose of this survey the only dual-gauge method considered was the air-gap method, because it is by far the most widely used dual-gauge test procedure. Each questionnaire recipient was asked about his use of each test mode and the type of materials tested with the various gauge configurations.

1. Direct Transmission

Forty-three of the 50 states reported using this test method which measures density by determining radiation attenuation through the tested material and is especially suitable where precise control of depth is desirable or where minor disturbance of the material is not detrimental.

Material	Percentage of Respondents
Bituminous Mixes	26
Granular Materials	60
Soil or Subgrade	76
Other	6

The use of direct transmission density testing of fresh concrete on an experimental basis was reported by one state.

2. Backscatter

Thirty-seven states indicated use of this test method. This procedure requires only that the gauge be placed directly upon the leveled surface of the material tested. Most frequently the ratio between the count thus obtained and a count upon an unchanging standard is then used to determine density from a prepared curve or tables. Utilization of this test method was strongly biased in favor of bituminous materials, probably because of the ease and rapidity of testing without disturbance of the test surface.

Material	Percentage of Respondents
Bituminous Mixes	92
Granular Materials	35
Soil and Subgrade	24
Other	0

3. Backscatter with Air Gap

This dual-gauge procedure is intended to partially compensate for the effect of variations in the composition of the tested material and consists of determining the ratio between a normal backscatter count and a count upon the same location with the gauge in an elevated position. This ratio is then used, as in other configurations, to determine the density from a curve or table. Twenty-one states report the use of this nuclear test procedure on the following materials.

Material	Percentage of Users
Bituminous Mixes	81
Granular Materials	52
Soil and Subgrade	52
Concrete	10
Other	0

4. Other Modes

In addition to the three listed test procedures, one state reported the use of an air-gap direct transmission test and another indicated the use of depth probes.

SPECIFICATIONS

Utilization of density test results to determine compliance with specifications is done in a variety of ways ranging from reliance upon the results of a single test to a semi-statistical utilization of moving averages or control test strips. It has been necessary in this report to group some procedures which, in fact, may have slight differences.

Materials Tested

A. Bituminous Surfacing

Acceptance or rejection for density of a specified quantity or lot based upon the results of:

	Number of Respondents
Single test	9
More than one test, no average*	8
Average of 2 tests	2
Average of 3 tests	1
Average of 5 tests	10

Eighteen of the above states reported the use of a control strip method.

*Maximum reported: 10 tests

B. Granular Base -- treated or untreated

	Number of Respondents
Single test	18
More than one test, no average*	8
Average of 2 tests	1
Average of 3 tests	3
Average of 5 tests	5
Average of more than 5 tests	3

Maximum reported: 5 tests

C. Subgrade

	Number of Respondents
Single test	21
More than one test, no average*	5
Average of 2 tests	1
Average of 3 tests	3
Average of 5 or more tests	4

Three of the states reported the use of a control strip method.

Maximum reported: 5 tests

Conformance with A.S.T.M.

A.S.T.M. has established procedures for the calibration of and testing with nuclear gauges. Forty-seven of the states indicated that they are in basic agreement with A.S.T.M. procedures.

DISCUSSION OF THE 1973 QUESTIONNAIRE

The report of the 1969 questionnaire on procedures and specifications concluded with a discussion of the results, including the recommendations of those procedures appearing to offer the greatest potential for maximum gauge utilization as well as those receiving widest acceptance. It is obvious that the numerous procedural options available make it possible to tailor the use of nuclear gauges to a wide range of applications. For this reason an attempt will be made to discuss again some of these options and suggest those which presently appear to offer the greatest potential as indicated by the 1973 questionnaire and a comparison with the previous questionnaire.

Procedures

I. Calibration

A. Previously, the most widely used method of density calibration was through the utilization of local materials compacted into molds. As predicted, this cumbersome procedure has lost favor and in its place users are placing greater reliance upon the manufacturer's calibration and the establishment of permanent standards constructed of a stable material. Calibration by comparison with conventional field tests has also increased but it is likely that this procedure is used principally to check or adjust an existing calibration rather than as a basic means of constructing a calibration curve or table. The use of permanent standards is recommended with some reservations concerning the use of concrete blocks, principally because of problems with uniformity and stability. Calibration schools conducted by institutions or manufacturers remain an excellent opportunity to gain proficiency and expertise in the use and calibration of nuclear gauges.

B. The manufacturer's moisture calibration is relied upon by most gauge users. However, the extensive use of other methods as well indicates that the calibration is frequently field checked. Because stable and reasonably economical permanent moisture standards are now commercially available or simple to construct, it is probable that they will gain in popularity for moisture calibration in a similar manner to the increase in use of permanent density standards.

II. Operational Checks

The manufacturer's recommendation will normally be adequate.

III. Safety

Film badges remain the preferred and recommended method of monitoring operator exposure to both gamma and neutron radiation. A single badge for the operator should be sufficient. State or federal regulations will generally govern the frequency of leak tests and are adequate unless the gauge exhibits physical damage. Survey meters are extremely useful for monitoring storage areas or for the unlikely possibility of an accident involving source leakage.

It is strongly urged that any user of nuclear moisture-density gauges establish a safety program to insure that state, federal, or other legal requirements are met, monitor leak tests and radiation exposures, develop accident procedures, and perform any other similar duties which might otherwise be too easily overlooked.

IV. Training

The widespread establishment of formal training programs for nuclear gauge operators indicates their usefulness. This practice should be continued.

V. Repair Facilities

The trend in modern gauge design continues toward ease of repair and has encouraged owner servicing. Also aiding in this direction has been an increase in the numbers of gauges owned by individual agencies or users, increased familiarity and expertise of owners, and greater availability of recalibration facilities.

VI. Gauge Seating

Deviations no greater than 1/8 inch from a plane surface and the use of native fines for seating continue to be recommended.

VII. Test Count

With modern gauge design there is little to be gained by long or complex test counts. An increase in the number of density or moisture determinations utilizing simple count procedures is normally preferable. Most gauge manufacturers have accumulated considerable experience which may be utilized in establishing an optimum test count.

VIII. Density Test Configuration and Materials

The material to be tested will frequently govern the type of gauge configuration to be preferred. Where it is reasonably simple to drive or drill the required hole without significant disturbance of the material around the hole, the direct transmission test offers greatest accuracy and control of depth of test. When density measurements are less than about three inches in depth or when it is not practicable or desirable to disturb the test material, the air gap and backscatter methods are used with the air gap showing a slight superiority in accuracy.

Virtually all types of construction material requiring density control are now being tested by nuclear gauges. The greatest increase since the last questionnaire has been with bituminous materials, where the nuclear test probably offers its greatest advantage over previously used conventional test methods. The possibility of improved control of portland cement concrete through density testing while in the plastic state is under study and may provide yet another material for testing.

Specifications

Establishment of a satisfactory density test program to determine specification compliance remains one of the most difficult construction control problems. Variability in density, especially with soils, makes reliance upon a single density determination for acceptance or rejection unsatisfactory if accuracy is a goal. Recognition of this is revealed by the large number of state highway agencies now using control strips, random multiple determinations, averages and moving averages, or any other semi-statistical concept in density testing and control. Local conditions will frequently indicate a preferred testing program and it is suggested that a review of literature or contact with other states or gauge users would be of benefit to those contemplating an upgrading of their program.

CONCLUSIONS

The nuclear method of testing for density and moisture presents a flexible approach to construction control which should satisfy almost any requirement. The rapidly increasing numbers of users is the best evidence of satisfaction with this test method and its equipment.

The nuclear gauges presently commercially available exhibit some differences in basic design which may have considerably greater importance than would be apparent. In order to select the type of gauge best suited to the purpose and program of the user who has not yet acquired familiarity with all types, it is suggested that other users be contacted for the benefit of their experience.

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