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16. Abstract

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PREFACE

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ABSTRACT

This report presents the results of an evaluation of the Troxler 3241-B Asphalt Content Gauge. Based on these findings, the asphalt content gauge is an accurate and reliable piece of equipment that can be readily used in the field environment. The importance of specific procedures and their influence on measurements obtained are discussed in detail.

KEY WORDS: nuclear asphalt content gauge, asphalt content, asphalt concrete quality control, asphalt

SUMMARY

The nuclear asphalt content gauge was evaluated to determine whether accurate and reliable measurements could be expected. The initial evaluation was performed in the laboratory under well-controlled conditions. The effects of materials, temperature, and environment were carefully explored. Under these conditions, the device performed well within the acceptable criteria for determining asphalt content. The device was then evaluated in the field environment. With the experience from the laboratory evaluation and using the recommended procedures, the nuclear asphalt content gauge was used on four field projects. Each project used a different aggregate and gradation and, in some cases, a different asphalt.

IMPLEMENTATION STATEMENT

Based on the results of this study, the nuclear asphalt content gauge will produce accurate and reliable measurements for asphalt content in an asphalt mixture. Therefore, the device can be used as a rapid means for determining asphalt content in the field. It is recommended that the device be used by the Districts of the Texas State Department of Highways and Public Transportation to enhance their quality control of asphalt mixtures.

CHAPTER 2. RESEARCH APPROACH

In order to adequately evaluate the nuclear asphalt content gauge, the gauge results were compared to results obtained by extraction. Two extraction procedures were used as set forth by the Texas Test Method Tex-210-F (*1*). The research approach included both a laboratory and field evaluation as discussed below. In addition, the gauge used in this project is also described.

NUCLEAR ASPHALT CONTENT GAUGE

The nuclear gauge used in this evaluation was the Troxler 3241B Asphalt Content Gauge (Fig 1). The Model 3241B satisfies all requirements of ASTM Method D-4125-83, Standard Method of Test for Asphalt Content of Bituminous Mixtures by the Nuclear Method (*3*).

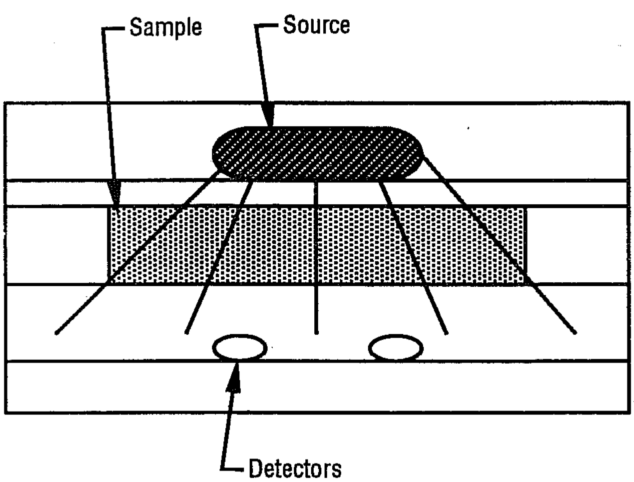

Fig 1. Diagram of nuclear asphalt content gauge.

Model 3241B operates on the principal of neutron moderation. Neutrons emitted from a source are slowed by the hydrogen in the mixture and are then detected and counted. This count could include moisture in the mixture as well as asphalt. However, experience in this study confirmed the findings of previous studies that the moisture in hot mixed asphalt concrete is negligible or nonexistent and, therefore, has not proved to be a problem in determining the asphalt content of the mixture. Thus the counts displayed are directly proportional to the amount of asphalt in the sample (*2*).

The model 3241B gauge contains a microprocessor which computes the asphalt content from these neutron counts and compares it to the calibration mixture contents. In order for the gauge to be applicable to the mixture being produced and tested, it is necessary to properly calibrate the gauge using the same materials. The neutron counts for calibration are determined by taking counts from mixtures of known asphalt contents and developing an asphalt content calibration curve. The calibration process is described later in this chapter.

LABORATORY EVALUATION

The initial effort in evaluating the nuclear gauge was to become familiar with its operation. The operating procedures were followed as outlined in the instruction manual. In some instances, other procedures were explored to determine if significant time could be saved without loss of accuracy.

BACKGROUND COUNT

Efforts have been made by Troxler to reduce the effect of neutrons from outside sources. It was determined, however, that this effect cannot be totally eliminated and can produce significant effects on the readings. Thus a background count must be performed. Once the background count has been determined, the gauge should remain in the same position during calibration. The Model 3241-B gauge is equipped with a firmware program that will compensate for minor changes in background counts occurring between the calibration and subsequent measurements.

While the laboratory environment is generally constant with time, background counts were performed on several occasions during the study. The changes in background count, as expected, were not large and would not have caused errors. This may not be true in other laboratories (see Field Evaluations section of this report), especially field laboratories.

CALIBRATION

The calibration of the nuclear asphalt content gauge is very important to the accuracy and reliability of the results. The sensitivity of the gauge is such that asphalt which may not be extractable will be detected by the gauge. Therefore, an accurate calibration must be performed, preferably at the location where it will be used, before the gauge is used. The calibration procedure described in the accompanying manual was evaluated initially. Variations of the procedure were used to evaluate the effect of different variables such as temperature, aggregate and asphalt.

The calibration procedure required that a minimum of two mixtures with different asphalt contents be used. In this study, extreme care was taken and a minimum of four mixtures with four different asphalt contents were used during calibration.

An important factor in the calibration and sample preparation is the packing of the material to be measured. The nuclear device performs calculations based on volume rather than weight. Therefore, the material should be uniformly packed in the sample pan in order to maintain a uniform density. As a result of this study, it is recommended that in addition to the manufacturer's instructions, the sample weights be as close to the same as possible. This will aid in maintaining a constant density in the sample pan. The edges and center of the pan should also be "squared off" as shown in Fig 2. In addition, the gauge requires that the asphalt be dispersed throughout the mixture and that the aggregate be coated, rather than simply adding a known quantity of asphalt to the aggregate and not mixing it. The effect of these two procedures is discussed later.

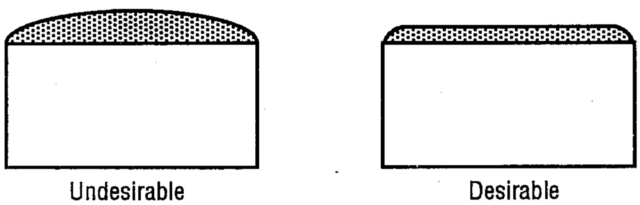

Fig 2. Configuration of sample in pan before packing.

TEMPERATURE EFFECT

In addition to compensating for the background count, the Model 3241-B also compensates for the effect of mixture temperature. This compensation for temperature is provided by firmware in the microprocessor which uses the formula (2):

$$\%AC\ Change = ((\%AC)^2 A + (\%AC) B + C)\ (CALT - CURT)$$

where:

$\%AC\ Change$ = change in percent asphalt cement
$CALT$ = calibration temperature, °F
$CURT$ = current (sample) temperature, °F
A = -1.92×10^{-5}
B = 4.65×10^{-5}
C = -5.70×10^{-5}

As part of this study, typical sample temperatures were used to evaluate the temperature effects. Statewide, mixing temperatures for hot mix asphalt concrete range from about 275°F to 325°F. However, generally within a given district the temperature range would probably be less.

AGGREGATE EFFECT

The effect of aggregate on the nuclear gauge is compensated for during the calibration process. For the most part, the aggregate itself will not cause a change in the asphalt content readings. However, the absorption factor of an aggregate can affect the readings if moisture is present. While water tends to be the primary source of hydrogen that will tend to produce a change in readings, it should also be noted that anything with a hydrogen component, such as solvents, could affect the readings.

ASPHALT EFFECT

As with the aggregate, the asphalt effects are provided for in the calibration procedure. In previous discussions, it was noted that the nuclear device operates on the principle of neutron moderation. Since the asphalt cement is the source of the hydrogen which causes the neutrons to be slowed, a change in asphalt source, and hence a change in hydrogen content, can change the asphalt content readings. In order to understand the degree of this change, three asphalts commonly used in Texas that have very different physical properties were used in the evaluation process.

FIELD EVALUATION

Once the laboratory evaluation was completed, the device was taken into the field. Four projects in three districts were evaluated. The nuclear asphalt content gauge was field tested on type D and type B mixtures. The results were compared to both the centrifuge and vacuum extraction methods (*1*). Sampling was performed in a random manner, with each sample being split, one for solvent extraction and one for nuclear determination. A sample was also taken at the same time that the state inspector sampled for the project in order to compare results. All tests with the nuclear asphalt content device reported in this study were performed by Center for Transportation Research personnel. The manufacturer's publication on procedures was sufficient to operate the equipment safely and efficiently.

CHAPTER 3. DISCUSSION OF RESULTS

The results of the laboratory and field evaluations are presented in this chapter. In addition, problems encountered and their solutions are also discussed. By understanding the principles used by the nuclear gauge to arrive at an asphalt content, erroneous readings can be recognized and resolved the majority of the time.

LABORATORY EVALUATION RESULTS

As previously discussed, several operational characteristics and sample variables were investigated. The calibration procedure and temperature effects were evaluated as operational characteristics. The effects of aggregates and asphalts were considered sample variables.

EVALUATION OF CALIBRATION PROCEDURE

The calibration procedure described in the operations manual was strictly followed in the evaluation process. The calibration was established using the four asphalt contents of 4.5, 5.0, 5.4, and 6.0 percent, which represent the range of asphalt contents typically used in Texas. The results of this calibration procedure are shown in Table 1.

TABLE 1. NUCLEAR ASPHALT CONTENT GAUGE CALIBRATION FOR AC-10 WITH ONE MINUTE COUNT

Asphalt Content	Nuclear Asphalt Content				
	1	2	3	4	Average
4.50	4.49	4.49	4.51	4.53	4.51
5.00	5.02	4.88	4.89	4.89	4.92
5.40	5.37	5.39	5.45	5.40	5.40
6.00	5.97	6.03	5.99	5.97	5.99

Correlation Coefficient = 0.998

In order to evaluate the effect of the "time of count" during calibration, the asphalt contents of four mixtures with known asphalt contents were measured using the nuclear gauge. The asphalt contents were chosen to coincide with the calibration points. Readings were taken for 1, 4, 8, and 16 minute counts, as shown in Table 2. The maximum difference between the actual asphalt content and the measured content for the one minute count was 0.12 for the mixture with 5 percent asphalt. The difference between the actual asphalt content and the average of four readings on the 5 percent mixture was only 0.08 percentage points. All other readings produced a smaller difference. The maximum differences observed in asphalt content for the 4, 8, and 16 minute counts were 0.11, 0.05, and 0.07, respectively. The actual neutron counts for the values summarized in Table 1 are recorded in the appendix.

TABLE 2. CORRELATION COEFFICIENTS FOR EACH COUNT TIME

Count Time, minutes	Correlation Coefficient
1	0.998
4	0.997
8	0.999
16	0.998

The correlation coefficients for the relationships between the actual asphalt content and the measured asphalt content were calculated for each of the four different time counts (Table 2). A perfect correlation would be represented by a correlation coefficient of 1.

After performing the calibration procedure, efforts were made to develop a more abbreviated and rapid method of calibration. The most time-consuming effort is in the preparation of the calibration mixtures. To reduce the sample preparation time, the asphalt was simply poured over the aggregate without mixing and then measured by the nuclear device. When 5 percent asphalt was poured on the aggregate, the nuclear asphalt content gauge read an asphalt content of 3.94 percent. Therefore, the asphalt must be well dispersed throughout the mixture in order to obtain an accurate estimate of the asphalt content.

EVALUATION OF TEMPERATURE EFFECTS

As discussed in Chapter 2, the Model 3241-B gauge provides a means for compensating for the effect of the sample temperature. The calculation used by the microprocessor compensates for the difference between the calibration temperature and the sample temperature. To evaluate the effect of the temperature compensation firmware, temperatures were input into the device that were different from the actual mixture temperature. The asphalt contents were determined from a calibration at 275°F for the asphalt used. As shown in Table 3, the difference between the mixture temperature and the input

TABLE 3. EFFECT OF GAUGE TEMPERATURE SELECTION ON ASPHALT CONTENT OF 5.3%

Actual Mixture Temperature	Input Temperature		
	275 °F	300 °F	325 °F
275 °F	5.35%	5.40%	5.42%
300 °F	5.31%	5.29%	5.37%
325 °F	5.35%	5.37%	5.31%

temperature is not significant for a 5.3 percent asphalt content. However, at higher asphalt contents a change of 50°F can produce a difference. This should not pose a problem, since a quick measurement of the sample should produce a temperature reasonably close to actual mixture temperature and therefore not significantly affecting the nuclear gauge reading.

EVALUATION OF AGGREGATE EFFECTS

The aggregates and asphalts used to calibrate the gauge must be the same as the materials being tested to obtain asphalt content estimates. If the aggregates are changed, then a new calibration must be established, since aggregates can be either highly absorptive or virtually non-absorptive. To determine if this change will affect the accuracy of the nuclear gauge, mixtures were produced that used the same asphalt source and grade but contained different aggregate types. Before the evaluation, a calibration was performed for each aggregate type. In order to produce realistic mixtures, the asphalt contents for the different aggregates were significantly different. However, the nuclear device accurately measured the asphalt content for each of the different aggregates, as shown in Table 4.

Another variation associated with aggregates is gradation. Since the gauge calculates asphalt content on a volume basis, it was felt that minor changes in gradation might effect the asphalt content being measured. Table 5 shows the effect of gradation variations on the Number 10 sieve. The Number 10 sieve was used because it is a major control sieve for hot mix asphalt concrete by the Texas State Department of Highways and Public Transportation (SDHPT). In the column "Change on No. 10 Sieve," the zero represents the amount retained on the Number 10 sieve for the gradation used for calibration. The percent retained on the Number 10 was then changed to retain more (5%, 10%) and less (–5%, –10%, –15%) than the calibration gradation. Therefore, the first mixture retained 10 percent more aggregate on the Number 10 than the calibration gradation, and the last mixture retained 15 percent less. Thus, the mixtures became finer toward the bottom of the table. As expected, changing the amount of material on the Number 10 sieve changed the asphalt content reading. In this particular example, the maximum change was a 0.17 percent difference in asphalt content. While the difference was not considered to be very large, the need for proper samples is illustrated.

TABLE 4. EFFECT OF AGGREGATE TYPE ON NUCLEAR ASPHALT CONTENT GAUGE READINGS

Aggregate Type	Asphalt Source	Actual Asphalt Content, %	Nuclear Asphalt Content, %
Limestone	Exxon	5.30	5.27
Rhyolite	Exxon	6.20	6.24
River Gravel	Exxon	4.80	4.81
Sandstone	Exxon	5.50	5.44

TABLE 5. EFFECT OF CHANGE OF GRADATION ON NUCLEAR ASPHALT CONTENT GAUGE USING A TYPICAL TYPE D MIXTURE (AC CONTENT = 5.3%)

Change on No. 10 Sieve, %	Limestone		River Gravel		Sandstone	
	Actual Asphalt Content	Nuclear Gauge Reading	Actual Asphalt Content	Nuclear Gauge Reading	Actual Asphalt Content	Nuclear Gauge Reading
10	5.3	5.12	4.8	4.94	5.5	5.48
5	5.3	5.13	—	—	—	—
0	5.3	5.29	4.8	4.88	5.5	5.45
–5	5.3	5.21	—	—	—	—
–10	5.3	5.19	4.8	4.98	5.5	5.56
–15	5.3	5.18	—	—	—	—

EVALUATION OF ASPHALT EFFECTS

A change in asphalt source can potentially affect the nuclear gauge reading, presumably because the hydrogen content of asphalts can vary significantly between sources. To evaluate this effect, three asphalts from different sources were mixed with a limestone and the asphalt contents determined using the nuclear gauge. In Table 6, the calibration established for the Exxon asphalt was used to determine the content for all three mixtures. The nuclear measurements on the Exxon and Fina asphalts were accurate, but the measurements on the Diamond Shamrock asphalt were unacceptable. In Table 7, the asphalt content was measured using the appropriate calibration and produced excellent results.

In addition to evaluating the effect of asphalt source change, a change in grade was also investigated. As shown in Table 8, an AC-5 from each of two different sources was used to evaluate the effect of grade on the nuclear gauge results. Calibration curves for both Fina and Diamond Shamrock for an AC-5 and AC-20 were used to determine the asphalt content of a mixture with an AC-5. In both cases where the AC-5 mixtures were tested and the appropriate calibrations were used, the results were very good (see underlined values). However, in every case where the incorrect calibration was used, the resulting asphalt contents determined by the gauge were unacceptable.

TABLE 6. COMPARISON OF THREE ASPHALTS USING EXXON CALIBRATION AND A LIMESTONE AGGREGATE

Asphalt Content	Actual Asphalt Content	Nuclear Asphalt Content	Difference
Exxon	4.50	4.51	0.01
	5.50	5.44	–0.06
	6.50	6.46	–0.04
Diamond Shamrock	4.50	4.89	0.39
	5.50	5.99	0.49
	6.50	7.11	0.61
Fina	4.50	4.53	0.03
	5.50	5.42	–0.08
	6.50	6.54	0.04

TABLE 7. EFFECT OF ASPHALT SOURCE ON NUCLEAR ASPHALT CONTENT GAUGE ESTIMATES

Asphalt Source	Actual Asphalt Content, %	Nuclear Asphalt Content, %	Difference
Fina	5.30	5.35	0.05
Exxon	5.30	5.27	–0.03
Diamond Shamrock	5.30	5.30	0

EVALUATION OF MOISTURE EFFECTS

In an attempt to evaluate effect of moisture on asphalt content, water was added to the aggregate prior to mixing. Unfortunately, in every case the moisture was driven off during mixing and was not detected by the gauge. It was apparent that even with the more absorptive aggregates, the moisture was driven off during mixing and had no effect on the gauge reading.

Based on the efforts in this study, the only effect of moisture that appeared significant was associated with positioning the gauge next to a large external water source such as a drinking water container. This arrangement greatly affected the background count taken for calibration purposes. The problem arises from a change in background count. If the water container was not disturbed, the gauge could correct for its presence. However, if the volume of the water changed throughout the day, the background count would change and therefore the gauge results would be incorrect. Therefore, the nuclear asphalt content gauge should not be positioned near such items. It is recommended that the test procedure adopted for the use of this gauge contain a caution statement to this effect.

FIELD EVALUATION RESULTS

Four field projects in three districts were sampled for the field evaluation. Three projects involved type D mixtures and one involved type B. All nuclear gauge measurements were made in the field. In all cases, the gauge was located in a field laboratory with a generally constant environment. The field sections were under construction during the summer with temperatures generally in the 90°F range. Humidity varied between projects but, because of the air conditioned laboratory, there was no detectable effect on the gauge. This was of some concern originally. After the measurements were made, the sample was returned to the laboratory to be extracted. The results of the field investigation are discussed below.

BACKGROUND COUNT

As previously discussed, the background count was found to be extremely important in the field. The location and placement of the nuclear device should be considered carefully. It should not be close to a large volume of water such as a water cooler or distilled water source. Either of these are sources of hydrogen which can significantly affect the gauge readings. In addition, the gauge should not be placed near other potential sources of hydrogen such as solvents. Once the background count has been established, the gauge should not be moved nor should sources of hydrogen be placed in close proximity.

CALIBRATION

The laboratory results have shown that it is imperative that the field calibration be performed using the field materials. Once the calibration has been performed, it should remain effective until the materials change. It would, however, be advisable to perform calibration checks by preparing a sample of known asphalt content periodically when a particular calibration is used over an extended period.

NUCLEAR GAUGE MEASUREMENT RESULTS

For each project, a nuclear measurement and an extraction were used to determine the asphalt content of the mixture. In reporting the extraction test results, Test Method Tex-210-F states that a 0.2 percent or less

TABLE 8. EFFECT OF ASPHALT GRADE AND SOURCE ON NUCLEAR ASPHALT CONTENT GAUGE RESULTS (LIMESTONE AGGREGATE MIXTURE WITH ASPHALT CONTENT = 5.3%)

	Fina		Shamrock	
Material Measured	AC-5	AC-20	AC-5	AC-20
Fina AC-5	5.42	5.51	5.8	5.91
Diamond Shamrock AC-5	5.04	5.03	5.36	6.32

retention factor should be disregarded. Since the nuclear asphalt content gauge will measure all asphalt present, the retention factor was determined and used in order to compare the extractions with the nuclear measurements. Each sample was taken from a different truck and standard sampling techniques were used.

The first project was a Type D mixture with a 5.8 percent design asphalt content and was located in the Paris District. The mixture design consisted of 50 percent Boorhem Fields sandstone (0.375-inch), 30 percent Boorhem Fields washed screenings, and 20 percent Tyne Pit field sand. The asphalt was Texaco AC-20. The extraction procedure used on this material was the centrifuge method. Over the course of two days the nuclear gauge generally estimated higher asphalt contents than measured by the extraction (Table 9). However, since the retention factor used in the table was not measured, it is quite possible that the actual retention factor could be higher.

The second project was located in the Bryan District. A Type B limestone mixture using 42.4 percent 1-inch and 25.7 percent 0.375-inch Texas Crushed Stone limestone, 10.6 percent Gifford-Hill washed sand, 11.0 percent Texas Crushed Stone screenings, and 8.5 percent Kmiec field sand using Exxon AC-20 as the design asphalt at a 5.8 percent content. A retention factor of 0.51 percent was also determined for the mixture. The centrifuge method of extraction was used for this material. The results of the asphalt content measurements for this project are shown in Table 10. It should be noted that the difference in measured asphalt content was much smaller than for the first project, where the retention factor was not determined. Only one measurement out of twelve had an asphalt difference greater than 0.2 percentage points. The average value for both extraction plus retention factor and the nuclear gauge was 5.7 percent asphalt content.

A Type D limestone mixture with a 5.8 percent design asphalt content was used in the third project, also located in the Bryan District. The design for this project included 62.4 percent D-F Blend from Texas Crushed Stone, 17.1 percent Gifford-Hill concrete sand, 7.7 percent Texas Crushed Stone screenings, and 12.8 percent Kmiec field sand. The asphalt was an Exxon AC-20. As with the second project, a retention factor of 0.28 percent was determined for the mixture. In this project, the vacuum extraction method was used instead of the centrifuge method used in the first two projects. A summary of the measured asphalt contents is shown in Table 11. By using the calculated retention factor, there were no differences in excess of 0.2 percentage points between the extracted and the nuclear gauge asphalt contents. The average asphalt content measured was 5.6 percent for both methods.

The fourth field project evaluated was located in the Beaumont District. The mixture used was a Type D limestone mixture consisting of 45 percent coarse Tower limestone, 18 percent intermediate grade Tower limestone, 11 percent Tower limestone screenings, and 26 percent Silsbee field sand. A Texaco AC-20 asphalt was used at 4.7 percent. A retention factor of 0.14 percent was determined for the material and the vacuum extraction method was used. Table 12 shows the asphalt content estimates using the extraction and nuclear gauge. The difference between the extracted values and the nuclear gauge readings did not exceed 0.2 percent. The average value for measurements made by both methods was 4.8 percent asphalt content.

TABLE 9. COMPARISON OF CENTRIFUGE EXTRACTION VERSUS NUCLEAR METHOD FOR DETERMINING ASPHALT CONTENT OF A FIELD PROJECT (DISTRICT 1, TYPE D MIXTURE, 5.8% ASPHALT CONTENT)

Sample	Extraction Content, %	Extraction Plus Retention Factor, %	Nuclear Gauge Content, %
1	5.73	5.93	6.00
2	5.28	5.48	5.82
3	6.00	6.20	6.40
4	6.06	6.26	5.80
5	5.04	5.24	5.63
6	5.08	5.28	5.54
7	5.94	6.14	5.92
8	5.24	5.44	5.60
9	5.34	5.54	5.64

SUMMARY OF RESULTS

In summary, the Model 3241-B gauge performed satisfactorily in the field. Due to the accuracy of the nuclear gauge in reading total asphalt content, the retention should be calculated and used when comparing an extraction with a nuclear gauge measurement. At one field project the nuclear device was giving readings inconsistent with the field extractions. Samples were taken at this location and returned to the laboratory for extraction. The extractions performed in the main laboratory supported the nuclear gauge results. Errors were corrected in the field laboratory and the gauge and extractions were in agreement. This is a strong indication that the nuclear gauge will produce reliable results if the correct procedures are followed.

TABLE 10. COMPARISON OF CENTRIFUGE EXTRACTION VERSUS NUCLEAR METHOD FOR DETERMINING ASPHALT CONTENT OF A FIELD PROJECT (DISTRICT 17, TYPE B MIXTURE, 5.6% ASPHALT CONTENT)

Sample	Extraction Content, %	Extraction Plus Retention Factor, %	Nuclear Gauge Content, %
1	5.04	5.55	5.70
1A	5.14	5.65	5.53
2	5.41	5.92	5.81
3	5.02	5.53	5.51
4	5.54	6.04	6.03
5	5.45	5.96	5.78
6	5.63	6.14	6.15
7	5.11	5.62	5.52
20	5.22	5.73	5.78
28	4.33	5.54	4.94
30	5.69	6.20	6.23
31	5.44	5.95	5.82

TABLE 11. COMPARISON OF VACUUM EXTRACTION VERSUS NUCLEAR METHOD FOR DETERMINING ASPHALT CONTENT OF A FIELD PROJECT (DISTRICT 17, TYPE D MIXTURE, 5.8% DESIGN ASPHALT CONTENT)

Sample	Extraction Content, %	Extraction Plus Retention Factor, %	Nuclear Gauge Content, %
21	5.33	5.61	5.53
22	5.36	5.64	5.60
23	5.27	5.55	5.60
24	5.17	5.45	5.62
25	5.21	5.49	5.68
26	5.39	5.67	5.78
27	5.28	5.56	5.65
29	5.28	5.56	5.63

TABLE 12. COMPARISON OF VACUUM EXTRACTION VERSUS NUCLEAR METHOD FOR DETERMINING ASPHALT CONTENT OF A FIELD PROJECT (DISTRICT 20, TYPE D MIXTURE, 4.7% DESIGN ASPHALT CONTENT)

Sample	Extraction Content, %	Extraction Plus Retention Factor, %	Nuclear Gauge Content, %
1	4.82	4.96	4.91
2	4.65	4.79	4.76
3	4.70	4.84	4.81
4	4.49	4.63	4.57
5	4.47	4.61	4.77
7	4.87	5.01	4.89
9	4.88	5.02	5.00
10	4.72	4.86	4.83
11	4.52	4.66	4.80

CHAPTER 4. CONCLUSIONS AND RECOMMENDATIONS

Based on the results of this study, certain conclusions can be drawn and recommendations made.

GENERAL CONCLUSIONS

The instruction manual provided by the manufacturer is well written and informative. It should be read and studied prior to using the equipment to better understand its operation, as well as acquaint the operator with good safety practices. While there is no radiation hazard to the operator when proper handling procedures are followed, a potential hazard does exist if the gauge is not properly used.

The following conclusions are made based on the results presented in this report:

1) The calibration procedure must be followed carefully with special attention paid to the measurement of the asphalt in the calibration sample. Unless the asphalt is properly mixed with the aggregate, erroneous results will be obtained.
2) The background count is extremely important for the nuclear device to measure asphalt contents accurately. This is particularly important when the device is being used in the field.
3) A calibration is good only for the exact materials used in the calibration sample. If any of the materials, material quantities, or gradation are changed, a new calibration should be performed.
4) Since hydrogen is the element measured by the nuclear gauge, different asphalt sources or grades can produce difference counts and different estimated asphalt contents.
5) Care must be exercised in locating the gauge. Proximity to water or solvent sources can yield erroneous values.
6) The effect of moisture content was found to be insignificant due to the high temperatures at which hot mix asphalt concrete is produced. Hot mixed-cold laid asphalt concrete was not evaluated. Therefore the effect on the device of moisture or volatiles associated with this mix is uncertain.
7) The retention factor must be calculated in order to compare a nuclear gauge measurement with the extraction results from a mixture.
8) When the proper calibration and test procedures are followed, the gauge will give satisfactory results for the four major aggregate types, varying gradations, and the varying asphalt types and grades investigated in this study.
9) The nuclear gauge will give satisfactory results in the field when the proper procedure is used for hot mixed-hot laid asphalt concrete.

RECOMMENDATIONS

The results of this evaluation study indicate that the nuclear asphalt content gauge will produce satisfactory results. It will measure the asphalt content without need for solvents and will produce results at a much faster rate. This would provide for better and more frequent quality control testing. Based on the findings of this study, it would appear that the nuclear asphalt content gauge would be an excellent addition to field laboratories and, when operated according to the appropriate procedures, will produce acceptable and reliable results.

It is recommended that:

1) A test method be adopted by the Texas SDHPT that closely follows the method in the 1988 Annual Book of ASTM Standards, ASTM D-4125-87. The method should contain the procedure for properly placing the material in the pan (Fig 2) and should contain a cautionary statement about locating the gauge near water and solvent supplies.
2) The Texas SDHPT standard specifications be revised to permit the use of the nuclear asphalt content gauge.

REFERENCES

1. Test Method Tex-210-F, Manual of Test Procedures, "Determination of Asphalt Content of Bituminous Mixtures," Texas State Department of Highways and Public Transportation, November 1987.
2. 3241B Asphalt Content Gauge Manual, Troxler Electronic Laboratories, Inc., March 1986.
3. ASTM D-4125-87, Annual Book of ASTM Standards, "Standard Method of Test for Asphalt Content of Bituminous Mixtures by the Nuclear Method," American Society for Testing and Materials, 1987.