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DEPARTMENT of TRANSPORTATION

Field Evaluation of a Non-nuclear Density Pavement Quality Indicator

Final Report

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16. Abstract

The field performance of a non-nuclear density gauge was evaluated for measuring hot mix asphalt (HMA) pavement density. The gauge used is called the Pavement Quality Indicator (PQI) Model 300, invented and manufactured by TransTech Systems, Incorporated. The PQI's operation is based upon the density of asphalt being directly proportional to the measured dielectric constant of the material, i.e. the material's ability to store electrostatic energy per unit volume.

Ten (10) sites were selected from ongoing paving projects in Connecticut for use in the evaluation of the PQI Model 300 in the field. For comparison, nuclear density tests were performed at the same locations where PQI readings were taken. Finally, cores were drilled and tested according AASHTO T 166.

Based upon the results of the research study, it was concluded that poor correlation exists between PQI Model 300 instrument density and core density obtained in the field, as indicated by an average R-squared value of 0.28 for the ten (10) sites evaluated. This poor correlation may be due to the presence of moisture introduced into the HMA during rolling operations. Quality Assurance testing with the PQI Model 300 was not recommended.

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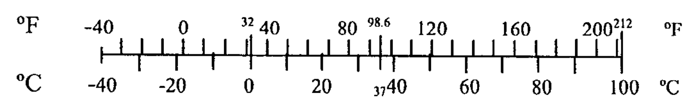
METRIC CONVERSION FACTORS

APPROXIMATE CONVERSIONS FROM METRIC MEASURES

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
		LENGTH		
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square centimeters	cm^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	Acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	2.5	grams	g
lb	pounds	30	kilograms	kg
	short tons (2000 lb.)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	centimeters	cm
tbsp	tablespoons	15	centimeters	cm
fl oz	fluid ounces	30	meters	m
c	cups	0.24	kilometers	km
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

APPROXIMATE CONVERSIONS FROM METRIC MEASURES

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	centimeters	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tones (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	36	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Farenheit temperature	°F



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Field Evaluation of a Non-Nuclear Density
Pavement Quality Indicator

Background

In December 1999, this study was initiated in order to evaluate the field performance of a non-nuclear density gauge for measuring hot mix asphalt (HMA) pavement density. The gauge used is called the Pavement Quality Indicator (PQI), invented and manufactured by TransTech Systems, Inc (see Figure 1). The PQI's operation is based upon the density of asphalt pavement being directly proportional to the measured dielectric constant of the material [10], i.e. the material's ability to store electrostatic energy per unit volume.

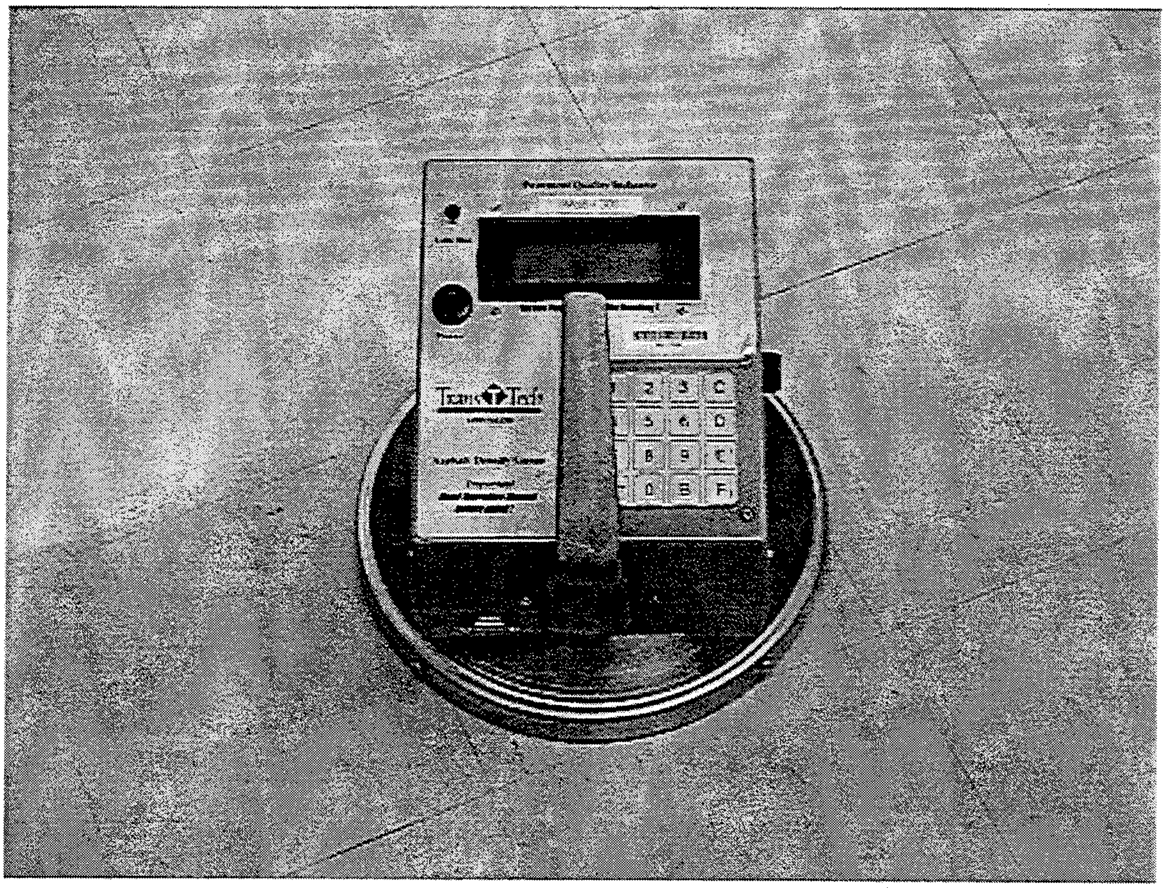

Figure 1 - Model 300 Pavement Quality Indicator (PQI).

The PQI consists of a transmitter, isolation ring, and receiver. A toroidal shaped electrical field is transmitted through the pavement and is detected by the receiver (see Figure 2). Next, the amperage is measured and the impedance (resistance to AC electricity flow) of the material is determined by using the formula V=IZ, where V=voltage, I=amperage and Z=impedance. Once the electrical impedance of the material is known, the overall dielectric constant of the material can be determined.

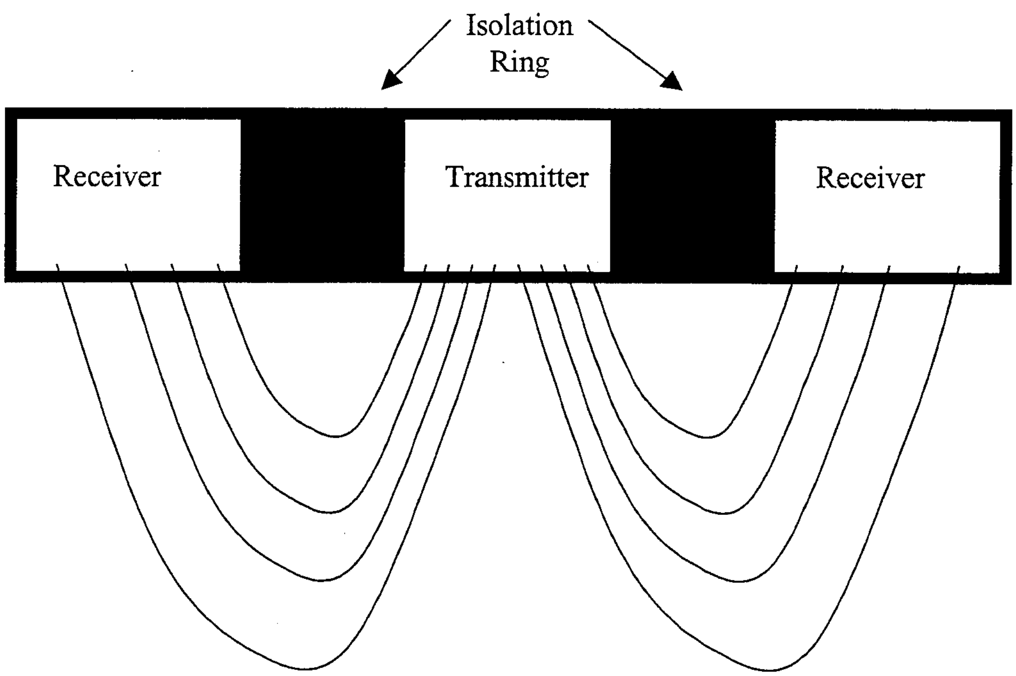

Figure 2 - Profile of toroidal electrical sensing field.

The overall dielectric constant of a material is a function of the volume of each component times its individual dielectric constant. HMA consists of aggregate, asphalt binder and air. The dielectric constant of air is approximately 1.0 and the dielectric constant of aggregate and asphalt binder is between 5-6. HMA compaction yields less percentage air, and consequently a higher overall dielectric constant.

Moisture is introduced into a HMA pavement during construction, especially during rolling operations. The dielectric constant of water is approximately equal to 80. This is problematic because even trace amounts of moisture in the pavement can have a profound effect on the measured dielectric constant. Therefore, it is necessary to determine the HMA pavement moisture content in order to correct for its relatively high dielectric constant.

TransTech's first non-nuclear asphalt density gauge, the PQI Model 100, did not have a moisture indicator. As a result, when moisture levels increased, density readings also tended to increase [7]. This, obviously, was unacceptable. Next, TransTech developed a Next Generation Model 200 unit, which included a larger measuring area, moisture indicator, and an on-board temperature sensor. Finally, TransTech made further improvements to the Model 200 unit and subsequently named it the Model 300 PQI. Note: the moisture indicator provides a correction factor, which is obtained from a phase angle[1] reading (named the H20 number by TransTech). The gauge does not provide the pavement's actual moisture content. Instead, the moisture indicator provides a relative moisture number (H20 number).

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[1] Phase angle reading is obtained by measuring the lag in the electrical signal [8].

TransTech did not provide data to indicate how strongly the H20 number relates to moisture content.

Personnel at Federal Highway Administration's (FHWA) Turner-Fairbank Highway Research Center Bituminous Mixtures Laboratory (BML) evaluated a prototype Next Generation PQI device and indicated that it showed potential in determining the density of laboratory prepared slabs [7]. Encouraged by BML results, Maryland State Highway Administration (MDSHA) personnel initiated a multi-state pooled fund study (SPR (3)(82)) entitled "Evaluation of the Next Generation PQI Device" and solicited Connecticut Department of Transportation (ConnDOT) participation.

The pooled fund study experimental plan consists of three stages [8]. The first stage is designed to determine the ability of the PQI to relate to density of asphalt concrete. The second stage is designed to determine the applicability of the results obtained. Finally, the third stage is designed to identify the limitations under which the PQI can be operated and provide possible sources of error. BML personnel are responsible for laboratory testing, while each participating state is responsible for performing field tests and forwarding data obtained to the BML.

The pooled fund project was approved for ConnDOT participation, with an obligation of $5,000 in FY 1999 and $5,000 in FY 2000, bringing the total amount pledged and obligated to $10,000. In addition to Connecticut and Maryland, other participant states include Minnesota, New York, Oregon and Pennsylvania. On April 19-20, 2000, FHWA sponsored a meeting with representatives from TransTech and each participant state to collaborate on a study work plan. Representatives from TransTech provided background and training for PQI operation. BML personnel presented preliminary results, based upon laboratory data collected to date. A general work plan was agreed upon, but individual augmentations were encouraged.

As of January 1, 2001, each participant state had completed field-testing operations and had forwarded their data to the BML. BML personnel will prepare a final report, which will include results from each participant state for the pooled fund study.

Study Objectives

The objective as stated in the study proposal was to introduce and evaluate the non-nuclear PQI unit as a safer and more reliable alternative to the nuclear gauge for measuring HMA pavement density [6]. To accomplish this goal, the following specific objectives were:

1. To determine whether correlation exists between the results of PQI density gauges and the core densities obtained in the field;

2. To compare the above correlation (if any) with correlation between the results of nuclear density gauges and the core densities obtained in the field;

3. To determine whether to use PQI density gauges in Quality Assurance (QA) for ConnDOT projects; and,

4. Should the PQI prove effective for use in QA, develop an implementation procedure that identifies and addresses all QA concerns.

Problem Statement

A need exists for the Department to introduce and evaluate the PQI unit as a possible alternative to nuclear devices currently used in testing HMA pavement density. The non-nuclear PQI unit appears to be a promising technology. It has safety and cost-saving potential. However, the Department cannot substitute the PQI for its nuclear gauge without a sound engineering study that addresses QA concerns.

Literature Review

Currently, ConnDOT personnel use nuclear density gauges for determining HMA density for pavement acceptance testing. QA specifications that include incentive/disincentive payments are being developed and have been used on a limited number of projects. One of the central issues has been whether to use nuclear density gauges, core densities, or both for determining HMA pavement density. Accordingly, the following literature review includes comparisons between nuclear density readings and core densities.

Burati and Elzoghbi [4] compared readings from three different nuclear gauges on two construction projects. They used a Troxler 3411-B, Seaman C-75BP, and a CPN M-2. The Troxler 3411-B included a $Cesium^{137}$ source and operated in the backscatter mode. The Seaman C-75BP included a $Radium^{226}$ source and operated in the air-gap ratio mode. Similar to the Troxler 3411-B, the CPN M-2 included a $Cesium^{137}$ source; however, the CPN M-2 is capable of operating in two backscatter modes, BS or AC. The AC mode is generally used for pavements between 1-1/2 and 2-1/2 inches thick, while the BS mode is generally used for pavements greater than 2-1/2 inches thick. They decided to use the BS mode in the research because they believed "...it provided density values closer to the core results."

They indicated that the means and variances differed significantly among the gauges. The occurrence of these statistical differences would be problematic during ConnDOT projects using QA procedures, since the contractor (or their representative) would be using one gauge for Quality Control (QC) and the Department (or representative) another for Acceptance. A potential scenario: QC testing results indicate an incentive payment, while Acceptance testing indicates a disincentive payment.

Barati and Elzoghbi [4] also indicated that from project to project the nuclear gauges did not consistently correlate with the core results, and they recommended that test strips be employed when nuclear gauges are used for acceptance. Of course, the test strip should be constructed with the same mix and materials that will be used on the project. They also recommended that the same gauge that is used on the test strip be used on the project.

A similar investigation to identify possible correlations between nuclear gauge readings and core density results was conducted by Choubane et al [5]. They employed five Troxler nuclear gauge units (Models 3401, 3440 (2), 3450, and 4640) and operated them in the back-scatter mode. Their findings support those of Barati and Elzoghbi, as the five nuclear gauge density units did not consistently correlate with the core densities. They also indicated that the nuclear density testing variability differed from location to location within each gauge.

Brown [3] compared existing methods of specifying density of asphalt mixtures and reviewed the two primary methods of density measurement: bulk density of cores taken from the in-place pavement and use of a nuclear gauge. He concluded that the use of a nuclear gauge is not as accurate as measuring the bulk density of cores and recommended that nuclear gauges not be used alone for acceptance testing. If a nuclear gauge is used for acceptance testing, he recommended, "Some cores should be taken routinely to verify the accuracy of the gauge and to ensure that an acceptable density is obtained."

State of Maine Department of Transportation (MDOT) Research personnel recently conducted a study to compare density test methods [2]. These methods included the use of three nuclear thin lift gauges, a non-nuclear PQI and core samples. They indicated that results from the three nuclear gauges were not comparable to each other or to core density values. For that reason, they concluded that MDOT should continue to use core results for QA purposes and indicated "nuclear testing does not appear to be providing a true measure of the actual density of the pavement." Their report did not discuss how well the PQI performed in comparison to the nuclear gauges or to core density values.

At this time, the only available literature regarding the evaluation of the PQI's performance is based on laboratory data collected at FHWA's Turner-Fairbank Highway Research Center [9]. Romero indicated that the PQI device is capable of determining relative changes in asphalt concrete density under constant temperature and humidity. Romero's assessment was based on high R-squared values when comparing PQI densities to slab densities. Romero also indicated that changes in moisture could be monitored with the PQI's H20 values. Of particular interest, Romero concluded "small amounts of surface moisture in the asphalt concrete do not affect the ability of the PQI-300 device to provide a relative measure of density as long as the moisture remains constant." Conversely, he concluded, "High contents of internal moisture continue to provide problems with the density determined using the PQI-300 device." What constitutes a high H20 number? Romero indicated that TransTech did not provide specific guidelines, but he suggested that H20 numbers greater than 5 can lead to less accurate density readings.

Data Collection

Ten (10) sites were selected from ongoing paving projects in Connecticut for use in the evaluation of the PQI in the field. Paving projects were selected based upon availability, safety issues, and suitability for the study. Safety issues were paramount and eliminated many projects that may have otherwise been highly desirable. Coring for density measurement is not typically performed on ConnDOT contracts and special arrangements had to be made in order to obtain those cores required for this study. All data were collected between May and September 2000, and HMA produced at several different plants throughout Connecticut was used.

The ten (10) projects selected are listed in Table 1. Nine (9) projects used a ConnDOT 12.5-mm Class 1 mix and one (1) project used a 37.5-mm Superpave mix. Weather data were collected for each day tests were performed and are provided in Table 2.

Table 1 - ConnDOT projects and dates where data were collected.

Site	**Project**	**Date**	**Route**	**Town**	**Mix Design**	**Lift Thickness**
1	137-137	5/16/00	2	Stonington	37.5-mm Superpave	75-mm
2	174-290H	5/31/00	55	Sherman	Class 1	50-mm
3	174-289	6/1/00	20	Barkhamsted	Class 1	50-mm
4	174-290K	6/8/00	73	Waterbury	Class 1	50-mm
5	172-320I	6/19/00	154	Old Saybrook	Class 1	50-mm
6	172-320	6/23/00	117	Groton	Class 2	37.5-mm
7	174-290D	7/12/00	172	Southbury	Class 1	50-mm
8	171-290I	7/18/00	72	Bristol	Class 1	50-mm
9	109-150	9/13/00	84	Plainville	Class 1	50-mm
10	171-290J	9/29/00	99	Rocky Hill	Class 1	50-mm

Table 2 - Weather conditions during testing operations.

Site	Date	Sky Cover	Ambient Temperature	Relative Humidity	Wind
			(°F)	(%)	
1	5/16/00	Clear	65	30	Light
2	5/31/00	Partly Cloudy	68	63	Light
3	6/1/00	Partly Cloudy	84	60	Light
4	6/8/00	Overcast	73	50	Light
5	6/19/00	Overcast	70	68	Calm
6	6/23/00	Overcast	77	50	Light
7	7/12/00	Partly Cloudy	80	63	Calm
8	7/18/00	Partly Cloudy	87	58	Breezy
9	9/13/00	Partly Cloudy	71	73	Light
10	9/29/00	Clear	48	42	Light

PQI Density Measurements

PQI density measurements were performed as recommended during an April 19, 2000 one-day PQI training program provided by TransTech Systems. PQI density measurements were accomplished by first placing the instrument on the asphalt mat within a drawn footprint of either the PQI or CPN Model MC-3 Portaprobe nuclear density gauge. Next, using a clockwise rotation a minimum of five (5) readings were recorded, one at the center of the drawn footprint, and the other four (4) around the center, moving the instrument at least 2-inches between readings. Care was taken to ensure that there was total contact between the bottom surface of the PQI and the surface being tested, and no hands or other objects were in contact with the PQI during operation (see Figure 3). The five (5) readings were recorded and then averaged to determine the pavement density.

Figure 3 - PQI density measurements in progress.

The PQI Model 300 has two operational modes: shallow and deep penetration. The PQI Model 300 Operator's Handbook [10] indicates that the deep penetration mode of operation is preferred because it minimizes the effects of surface irregularities, provides more depth and better volume averaging. Accordingly, the deep mode of operation was used for all tests performed for this study. Note: during the one-day training program, TransTech personnel specifically recommended that the deep penetration mode be used for this study.

The PQI Model 300 includes two calibration parameters: offset and slope. These parameters are best described by the equation of a straight line, $y = mx + b$, where m is the slope and b the offset (y-intercept). TransTech recommended that the slope be kept constant at the manufacturer's set value of 4.93. TransTech provided instructions for adjusting the PQI's offset, but since core density results were not immediately available in the field, a standard offset of 133.0 lb/ft^3 was generally used. The offset value of 133.0 lb/ft^3 was selected because it appeared to provide reasonable density readings in comparison to nuclear density and core density values.

Three reading modes are available on the PQI Model 300, including single reading mode, continuous reading mode, and average reading mode. The first of five (5) readings taken at each location was measured in the continuous mode in order that a voltage reading could be recorded. Note: the continuous mode is the only mode that provides a voltage reading. The remaining four (4) readings were measured in the single reading mode for a 5-second count.

Recorded data included five (5) density readings (which were subsequently averaged), an H20 number, pavement temperature and voltage (see Appendix A). The H20 number, pavement temperature and voltage were taken from the first of five (5) readings. An effort was made to perform tests at locations where H20 numbers were low (<5) and relatively the same, but these ideal conditions were generally not obtainable.

Pavement temperature was monitored with an infrared temperature probe attached to a connector at the front of the PQI. As much as was practical, measurements were taken on pavement of the same temperature, but there were time constraints. Gauge measurements had to be taken and cores had to be cut before the paving train and traffic patterns were moved. Therefore, when the pavement temperature was too hot, there was not enough time to wait for the pavement to cool. When the pavement was too cool, it was not practical to locate a new test area in order to obtain higher temperatures.

PQI Calibration

For each site, ConnDOT personnel calibrated the PQI gauge as described below. The calibration was performed for the benefit of the pooled fund study and does not affect correlation values (R-squared). Note: this procedure closely follows that described in PA Test Method No. 403, Section 5.4.

1. A minimum of five (5) test locations within a 10-foot length (in the direction of traffic) on the asphalt mat were identified and marked (see Figure 4).
2. The instrument was placed on the asphalt mat at one of the test locations within the drawn footprint of either the PQI or CPN nuclear gauge.
3. Using a clockwise rotation a minimum of five (5) single shot readings were recorded, one (1) within the drawn footprint, and the other four (4) around the center, moving the instrument at least 2-inches between readings.
4. Readings were recorded.
5. Cores were drilled from the center of the marked footprint.
6. This procedure was repeated for the other four (4) additional test locations identified in Step 1.
7. Core densities were determined by measuring the bulk specific gravity according to AASHTO T 166, Bulk Specific Gravity of Compacted Bituminous Mixtures Using Saturated Surface-Dry Specimens.
8. Readings measured with the PQI were compared to core densities.
9. The numeric difference between the average density values of the PQI and the core densities were calculated.
10. The numeric difference from Step 9 was added or subtracted to/from the offset number found in the PQI instrument.

It should be noted that since core densities were not immediately available, Step 10 was modified as follows: readings were recorded at an arbitrary offset value (usually 133.0), and density readings were adjusted in the office by adding or subtracting the numeric difference calculated in Step 9 (see Appendix A).

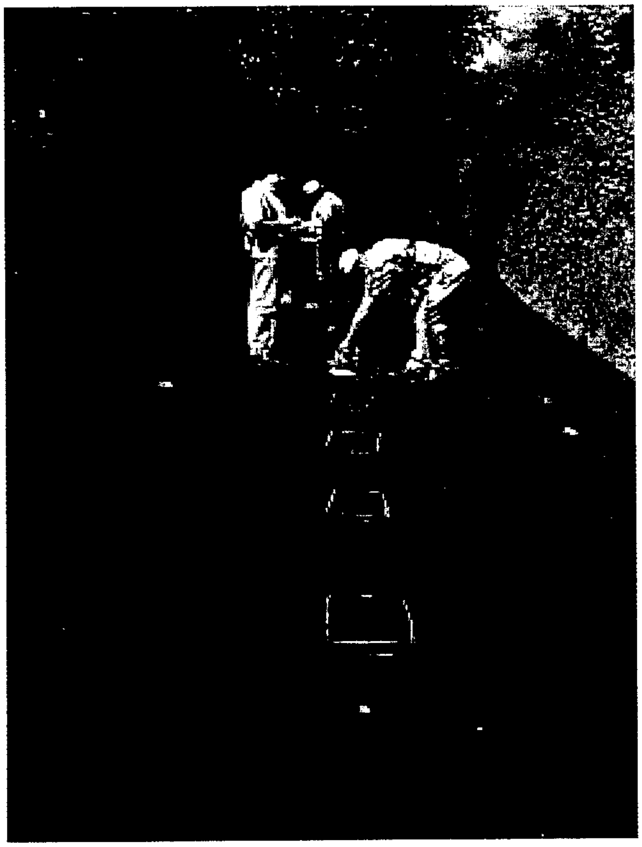

Figure 4 - Five test locations within a 10-foot length identified and marked for calibration purposes.

Nuclear Density Gauge Tests

For comparison, nuclear density tests were performed at the same locations as those identified in Step 1. The tests were performed in accordance with ASTM D 2950, amended as noted in Section 6.29 of the ConnDOT Lab Manual (see Appendix B). The instrument used was a CPN Model MC-3 Portaprobe (see Figure 5). All measurements were performed in the thin-lift mode of operation by setting the instrument handle to the AC (asphaltic concrete) position. For each location, a density test consisted of the calculated average of two readings taken at 180-degree angles to each other (handle parallel to paving train), rotated about the center point of the gauge. Each reading was measured in a 30-second count.

Figure 5 - CPN MC-3 Portaprobe Nuclear Density Gauge. Note gauge orientation, parallel to paving train.

Core Densities

Once the calibration tests were performed, ten (10) additional side-by-side density measurements were recorded with the PQI and nuclear gauge. Five (5) of these ten (10) locations were cored and tested at the ConnDOT Central Laboratory according to AASHTO T 166. Care was taken to ensure that cores were drilled at the exact location where nuclear and PQI gauge readings were measured.

Data Analysis

Once all the data were collected, they were entered into Microsoft Excel® for processing (see Appendix A). Scatter plots (Figures 6-35) of PQI density versus core density, nuclear gauge density versus core density, and PQI density versus nuclear gauge density were developed for each individual test site. Linear regression trendlines were added, including coefficient of simple determination (R-squared) values and estimated regression functions. Determination of whether correlation exists between the results of PQI density and core density, and between nuclear gauge density and core density, was based on these regression analyses.

PQI Density vs. Core Density Comparisons

Scatter plots of PQI density versus core density are presented for each test site in Figures 6-15. PQI data were synchronized to a standard offset of 133.0 lb/ft^3 in order that data from one project could be compared to those from another project. The offset value of 133.0 lb/ft^3 is arbitrary and does not influence the correlation results (R-squared values).

Table 3 presents the following data: Site, Average PQI H2O Number (phase angle), Coefficient of Simple Determination (R-squared), Estimated Regression Function, and Slope. PQI H2O numbers are provided because Romero [8] recommended that they be monitored, and he had indicated that high H2O numbers (>5) were problematic during the PQI laboratory evaluation. The estimated regression function is of the form y = mx + b, where m is the slope and b is the y-intercept. For the ideal regression function, m would equal 1 and b would equal 0. R-squared values provide an indication of how well PQI density correlated to core density. The limiting values of R-squared are 0 and 1. If the statistical relation between PQI gauge density and core density is perfect, R-squared = 1 (ideal). If there is no linear statistical relationship between the PQI density and core density, R-squared = 0.

Table 3 - Regression analysis data for PQI density vs. core density.

Site	**Average PQI H2O No. (Phase Angle)**	**Coef. of Simple Determination (R-squared)**	**Estimated Regression Function**	**Slope**
1	6.2	0.15	0.22x + 108.33	0.22
2	6.3	0.02	0.08x + 139.33	0.08
3	8.8	0.33	0.50x + 75.07	0.50
4	8.5	0.06	-0.12x + 172.38	-0.12
5	7.8	0.29	-0.29x + 191.78	-0.29
6	5.4	0.79	0.22x + 112.06	0.22
7	9.4	0.01	0.03x + 147.14	0.03
8	6.7	0.42	0.31x + 102.60	0.31
9	12.1	0.15	-0.21x+ 187.50	-0.21
10	11.0	0.58	0.30x + 109.88	0.30
Average	**8.2**	**0.28**	**NA**	**0.10**
Standard Deviation	2.2	0.26	NA	0.26

In general, the linear statistical relationship between PQI density and core density was poor. At nine out of ten sites, there was no or poor correlation between PQI and core density, as evidenced by a range of R-squared values between 0.01 and 0.58. The variability of R-squared values was high, as indicated by a standard deviation of 0.26. The slope of the regression equation relating PQI data to core data was flat, as indicated by an average slope of 0.10. Three (3) of the ten (10) sites evaluated had a reverse trend, as evidenced by their negative regression equation slopes (-0.12, -0.29, -0.21).

Average H20 numbers were high (>5) and may explain the poor correlations (low R-squared values). Table 7 provides H2O numbers for each individual test performed. Only eight (8) tests performed had H2O numbers less than 5.0. Note that five (5) of the eight (8) occurred at Site 1, where a 37.5-mm Superpave mix was used instead of the 12.5-mm Class 1 mix used at all other sites. At Site 6 the correlation was fair (R-squared = 0.79) and the average H2O number was lower (5.4) than at any other site, but this trend did not continue for the other tests with lower H20 numbers (6.2, 6.3, and 6.7), as indicated by their respective R-squared values (0.15, 0.02 and 0.42). This may be explained by Romero's [8] statement that accuracy decreased dramatically once H2O numbers were greater than 5.0. It should be noted that measurements where H2O numbers in the PQI display were less than 5.0 were virtually unobtainable at the ten sites used for this study.

Nuclear Gauge Density vs. Core Density Comparisons

Scatter plots of nuclear gauge density and core density are presented for each site in Figures 16-25. Table 4 provides a summary of R-squared values, estimated regression functions and slopes for their respective site locations. In general, the linear statistical relationship between nuclear gauge density and core density was not well defined. Poor correlation was exhibited at five (5) out of ten (10) sites (R-squared = 0.05, 0.09, 0.14, 0.34, 0.61), while fair to good correlation was exhibited at the other five (5) sites (R-squared = 0.79, 0.81, 0.85, 0.86, 0.97). The average R-squared value for the ten (10) sites evaluated was 0.55. The variability of R-squared values was high as indicated by the standard deviation of 0.36.

Table 4 - Regression analysis data for nuclear gauge density vs. core density.

Site	**Coef. of Simple Determination (R-squared)**	**Estimated Regression Function**	**Slope**
1	0.61	1.84x- 134.59	1.84
2	0.85	1.16x - 25.34	1.16
3	0.81	1.00x - 1.81	1.00
4	0.34	0.48x + 79.80	0.48
5	0.05	0.42x + 85.58	0.42
6	0.86	0.83x + 21.86	0.83
7	0.09	-0.35x + 200.28	-0.35
8	0.14	0.41x + 91.55	0.41
9	0.97	1.10x - 15.62	1.10
10	0.79	1.33x - 46.53	1.33
Average	**0.55**	**NA**	**0.82**
Standard Deviation	0.36	NA	0.61

The data for each Class 1 site were combined and plotted on one scatter plot (see Figure 36). The R-squared value for the combined data was 0.79, which indicates a fair relationship. In addition, the slope of the combined data was 0.97, which is very close to the ideal slope of 1.00. These data may indicate that when more data with a wider range of densities are obtained, the relationship between nuclear gauge density and core density becomes better defined. Note: data for each Class 1 site were not combined in a PQI density versus core density plot because TransTech recommended that the PQI be calibrated for each individual site evaluated; therefore, combined data may lead to misleading results.

PQI Density vs. Nuclear Gauge Density Comparisons

Scatter plots of PQI density versus nuclear gauge density are presented for each site in Figures 26-35. Table 5 presents a summary of average PQI H2O numbers, R-squared values, estimated regression functions, and estimated regression function slopes.

PQI density did not correlate well to nuclear gauge density, as indicated by the R-squared values. The average R-squared value for the ten (10) sites was 0.24 and only one (1) site (Site 10) showed good correlation (R-squared = 0.89). The predictive ability of the PQI with respect to the nuclear gauge varied from project to project, as indicated by the standard deviation of 0.29 and range of R-squared values between 0.05 and 0.89. The slope of the PQI density data was flat in comparison to nuclear gauge density data. The average slope of the ten (10) sites evaluated was 0.11.

Table 5 - Regression analysis data for PQI density versus nuclear gauge density.

Site	**Average PQI H2O No. (Phase Angle)**	**Coefficient of Simple Determination (R-squared)**	**Estimated Regression Function**	**Slope**
1	6.2	0.06	0.06x + 132.59	0.06
2	6.3	0.05	0.10x + 135.02	0.10
3	8.8	0.35	0.46x + 81.77	0.46
4	8.5	0.03	0.11x + 136.50	0.11
5	7.8	0.06	0.11x+ 133.50	0.11
6	5.4	0.61	0.22x + 113.21	0.22
7	9.4	0.15	-0.12x + 170.72	-0.12
8	6.7	0.06	0.11x + 133.50	0.11
9	12.1	0.16	-0.19x + 184.29	-0.19
10	11.0	0.89	0.25x + 116.97	0.25
Average	**8.2**	**0.24**	**NA**	**0.11**
Standard Deviation	2.2	0.29	NA	0.18

Discussion of Results

Table 6 presents a summary of R-squared values for the three (3) linear regression comparisons that were performed: PQI versus core density, nuclear gauge versus core density, and PQI versus nuclear gauge. The PQI did not correlate well to either core densities (average R-squared = 0.28) or nuclear gauge densities (average R-squared = 0.24). The relationship between the nuclear gauge and core densities (average R-squared = 0.55) was the strongest of the three (3) comparisons but was not well defined. Poor PQI Model 300 performance was likely the result of the presence of moisture in the hot pavement mat.

Table 6 - R-squared value comparison.

Site	PQI vs. Core Density R-squared	Nuclear Gauge vs. Core Density R-squared	PQI vs. Nuclear Gauge R-squared
1	0.15	0.61	0.06
2	0.02	0.85	0.05
3	0.33	0.81	0.35
4	0.06	0.34	0.03
5	0.29	0.05	0.06
6	0.79	0.86	0.61
7	0.01	0.09	0.15
8	0.42	0.14	0.06
9	0.15	0.97	0.16
10	0.58	0.79	0.89
Average	**0.28**	**0.55**	**0.24**
Standard Dev.	0.26	0.36	0.29

Although ConnDOT personnel were careful to keep track of the H2O number on the PQI display (Table 7 presents H2O numbers), it is likely that the moisture present in the pavement was too high for the PQI to operate effectively. Relatively low (<5) and consistent H2O numbers were desired; however, this was a field evaluation of the instrument to see how it performs in conditions similar to those for which it will be used if implemented into QA procedures. H2O numbers less than 5 were generally unobtainable, even after wiping the pavement and PQI sensor disk with a clean dry cloth. Note: measurements were not taken where signs of excessive surface moisture were present.

Romero [8] suggested that H2O numbers greater than 5 constitute high readings, and he indicated that once readings exceeded 5, the accuracy decreased dramatically. Therefore, it appears that the internal algorithms inside the PQI do not account for the effect of moisture once this threshold H2O number (H2O number = 5) is exceeded. The poor PQI versus core density relationship in this study is in keeping with this statement because H2O numbers were generally greater than this threshold value.

How much moisture is contained in the pavement mat following rolling operations? It has been reported that ConnDOT personnel have placed an inverted aluminum pan on top of an apparently dry hot pavement mat. They indicated that after turning the pan over they observed water in the bottom of the pan. Much of the surface moisture evaporates, but moisture in the form of vapor is still present in the hot mat. This vapor creates pressure inside the mat and has been reported to be a likely mechanism that can lead to blistering of asphalt pavement [1]. Over time, much of this vapor escapes from the pavement mat, suggestive of the existence of moisture content versus time curve. This curve will likely vary from project-to-project and from mix-to-mix.

Conclusions

Based upon the results of this research study, the following were concluded:

1. Sufficiently low moisture levels (H2O number < 5 in instrument display) for appropriate PQI Model 300 operation were generally unobtainable on ConnDOT paving projects.

2. Poor correlation exists between PQI gauge density and core density obtained in the field, as indicated by an average R-squared value of 0.28 (see Table 3). This poor correlation may be due to the presence of moisture introduced into the HMA mat during rolling operations.

3. The predictive ability of the PQI varied from project to project, as indicated by a standard deviation of R-squared values of 0.26 (see Table 3). This may also be due to the presence of moisture in the hot pavement mat.

4. The slope of the regression equation relating PQI data to core data was flat, as indicated by an average slope of 0.10 (see Table 3).

5. The correlation between nuclear density gauge results and core densities was stronger than that between PQI gauge results and core densities; however, the correlation was less than desirable and not well defined. For the ten (10) sites evaluated, the average R-squared value relating nuclear density gauge results to core densities was 0.55 (see Table 4), and the combined Class 1 R-squared value was 0.79 (see Figure 36).

6. The predictive ability of the nuclear gauge varied from project to project, as indicated by a standard deviation of R-squared values of 0.36 (see Table 4).

7. Poor correlation exists between PQI gauge density and nuclear gauge density in the field, as indicated by an average R-squared value of 0.24 (see Table 5). This poor correlation may be due to the presence of moisture introduced into the HMA during rolling operations.

8. The slope of the regression equation relating PQI data to nuclear gauge data was flat, as indicated by an average slope of 0.11 (see Table 5).

Recommendations

Based upon the conclusions of this research study, the following are recommended:

1. Agency Acceptance testing with the PQI Model 300 is absolutely not recommended.

2. Agency Independent Assurance (IA) testing with the PQI Model 300 is strongly not recommended.

3. Contractor Quality Control (QC) testing with the PQI Model 300 is not recommended.

4. The internal algorithms inside the PQI Model 300 must account for higher moisture levels (H2O numbers > 5). If TransTech can account for higher moisture levels, further research to evaluate its use within rolling patterns and other process control procedures should be considered, including establishing the following operational parameters:

   a. Offset and Slope calibration.

   b. H20 number operating range.

   c. Pavement temperature operating range.

   d. Acceptable environmental (ambient temperature, relative humidity, etc.) operating conditions.

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10. TransTech Systems Inc., "Pavement Quality Indicator Operating Instruction Handbook," by TB Bailey Consulting, 2000.

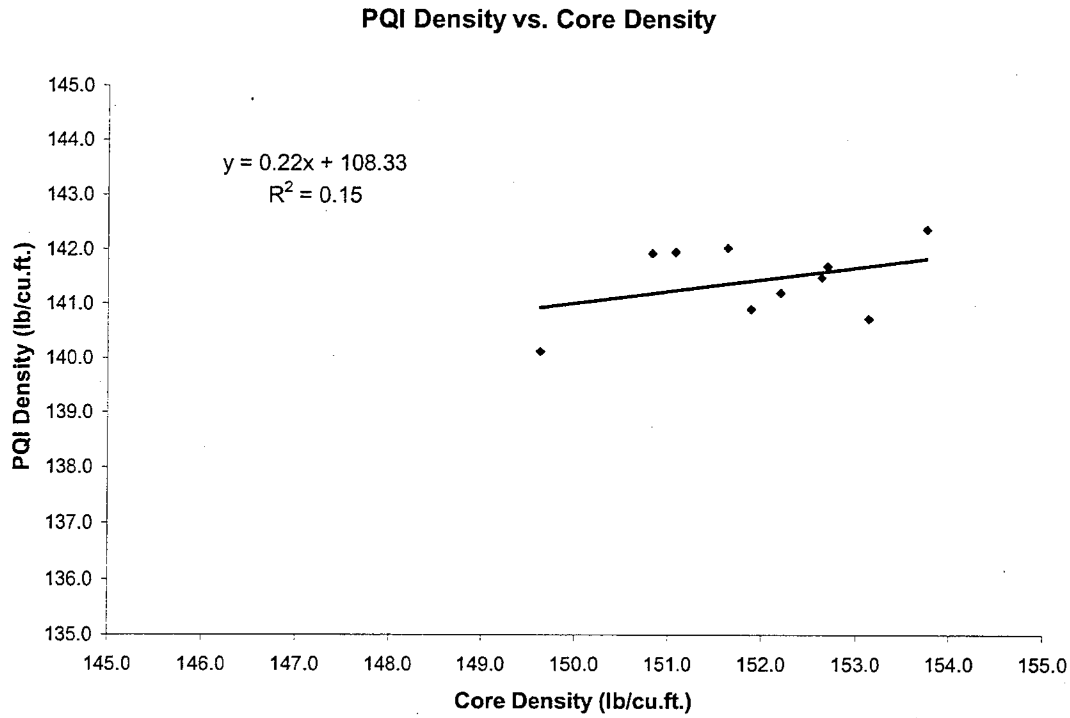

FIGURE 6 – PQI density versus core density scatter plot for Site 1.

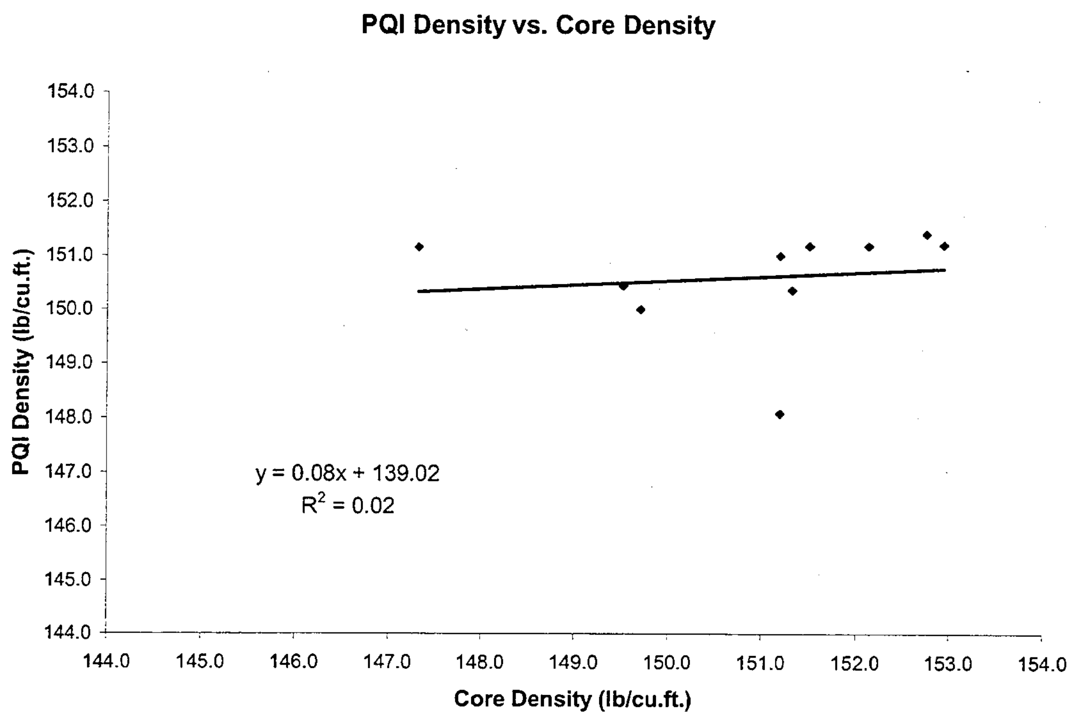

FIGURE 7 – PQI density versus core density scatter plot for Site 2.

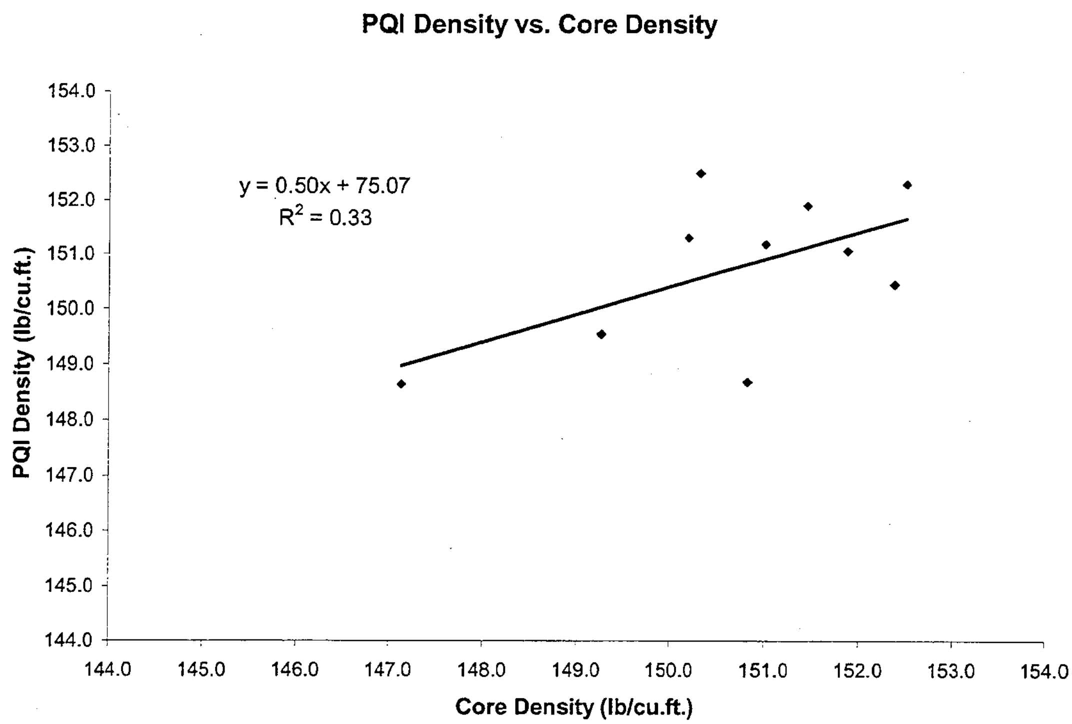

FIGURE 8 – PQI density versus core density scatter plot for Site 3.

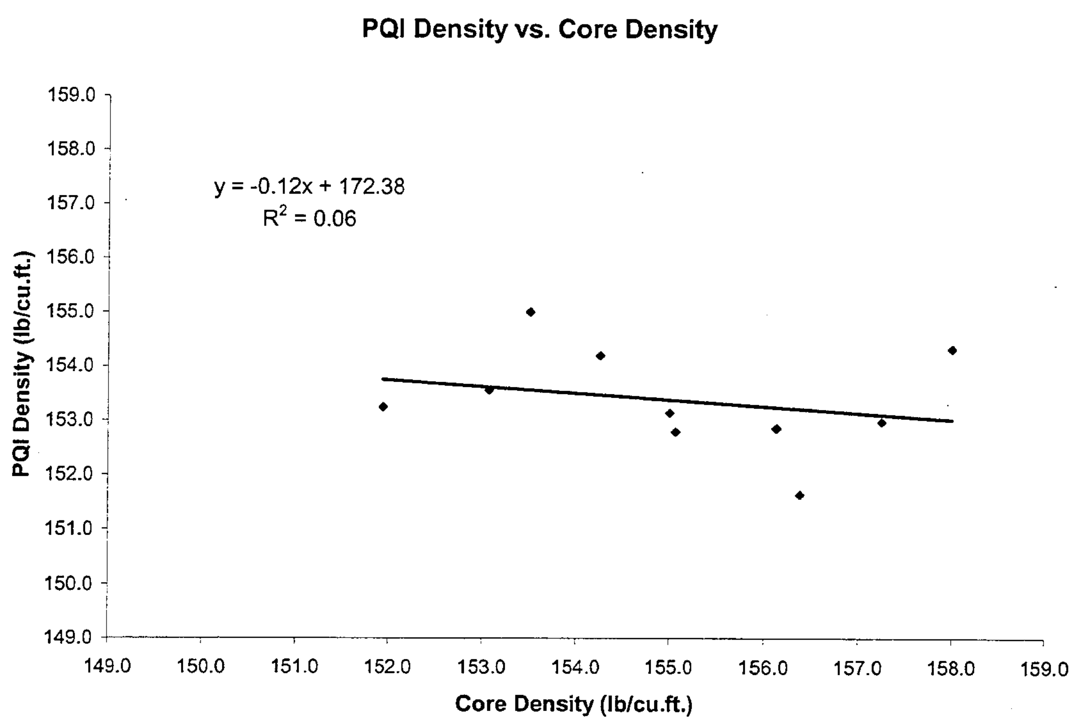

FIGURE 9 – PQI density versus core density scatter plot for Site 4.

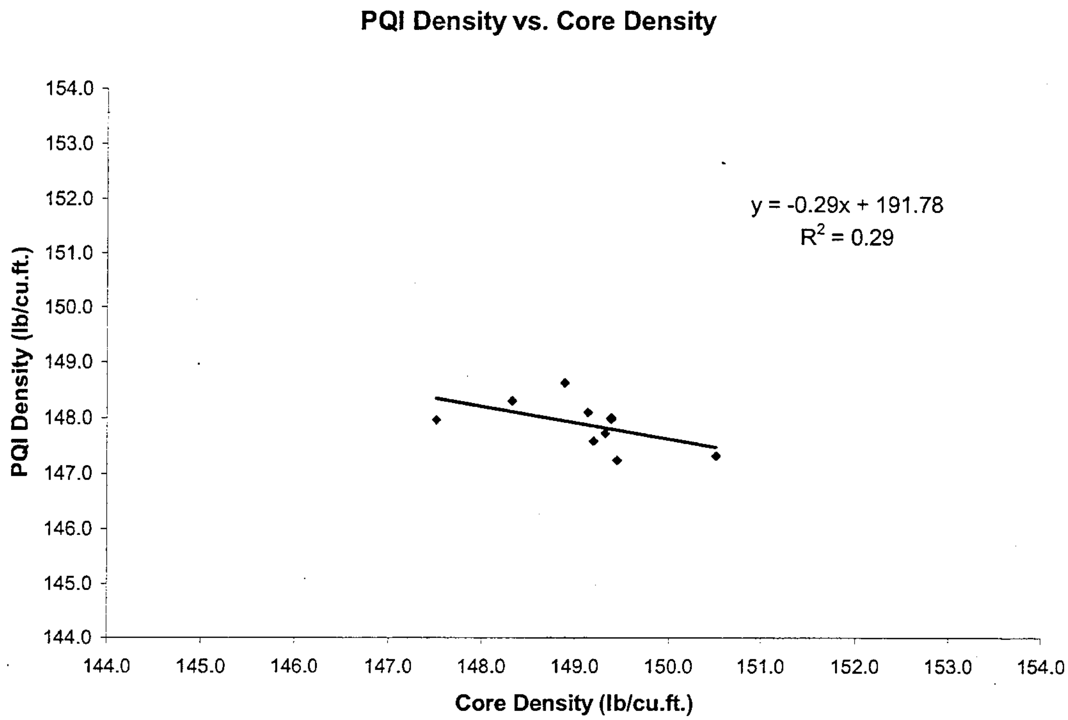

FIGURE 10 – PQI density versus core density scatter plot for Site 5.

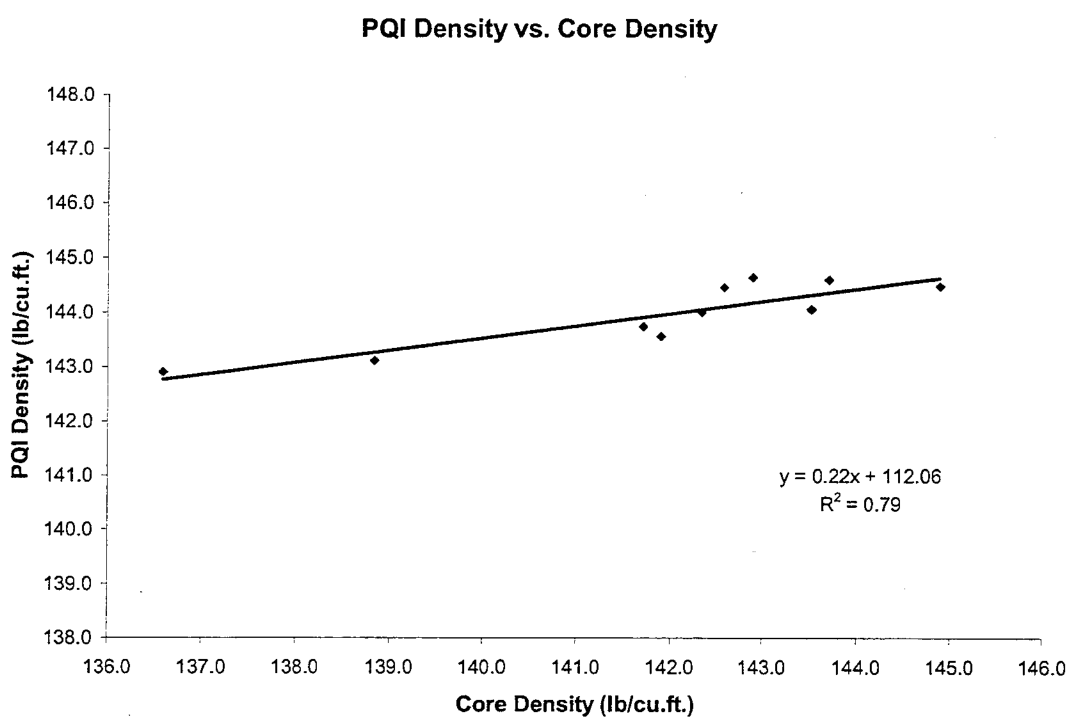

FIGURE 11 – PQI density versus core density scatter plot for Site 6.

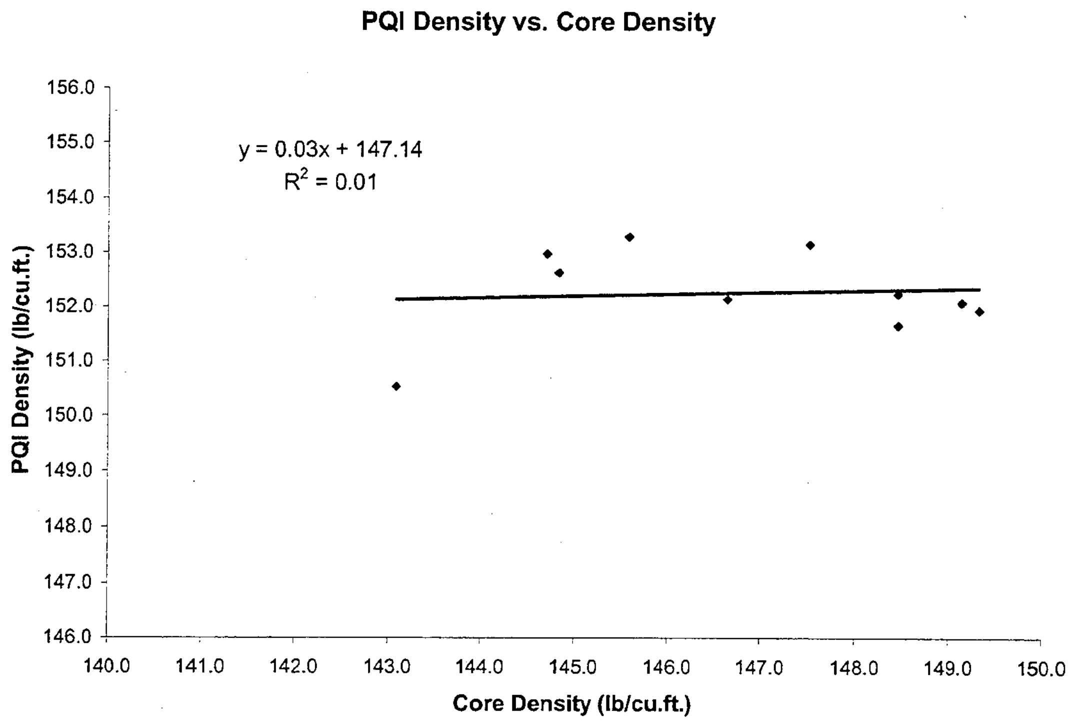

FIGURE 12 – PQI density versus core density scatter plot for Site 7.

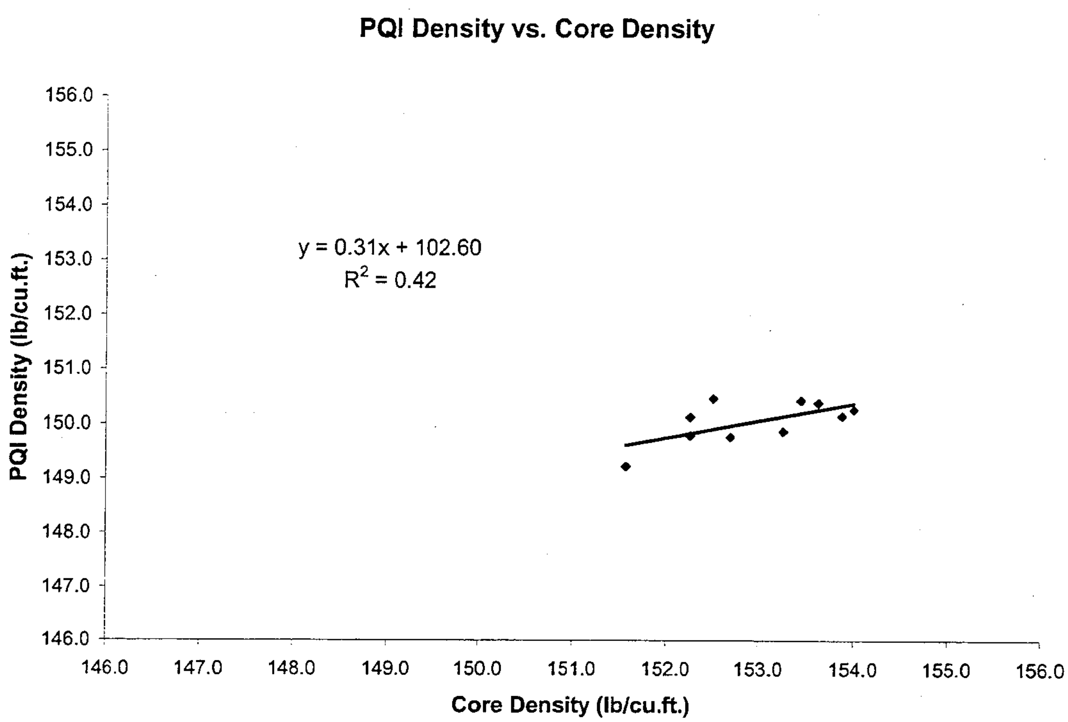

FIGURE 13 – PQI density versus core density scatter plot for Site 8.

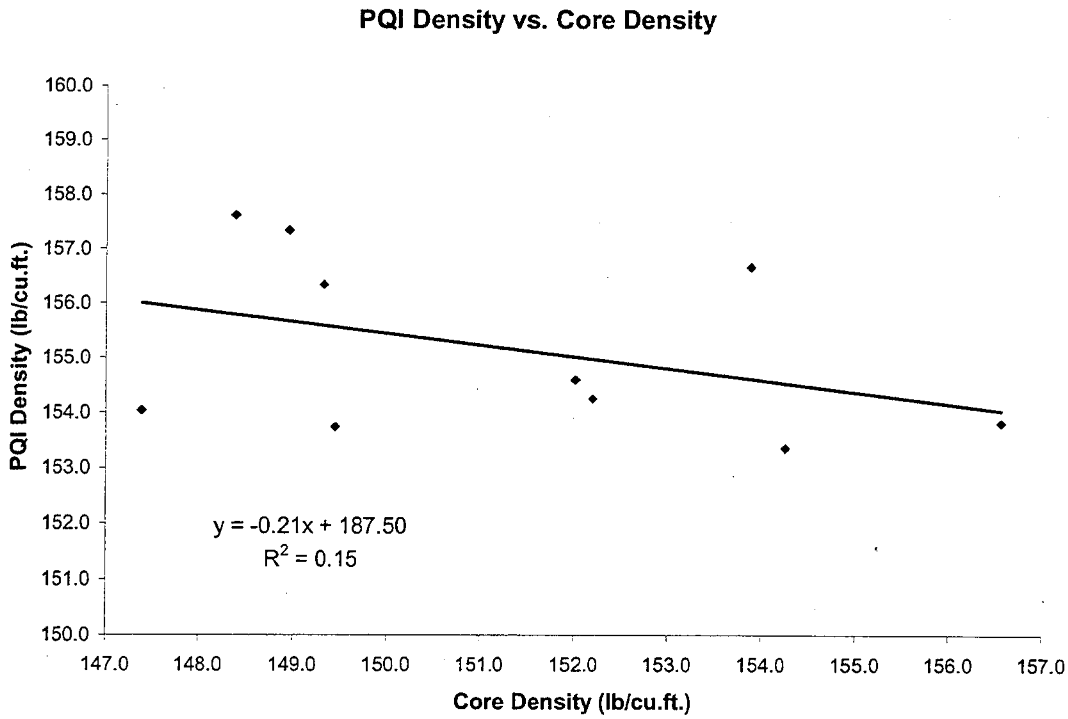

FIGURE 14 – PQI density versus core density scatter plot for Site 9.

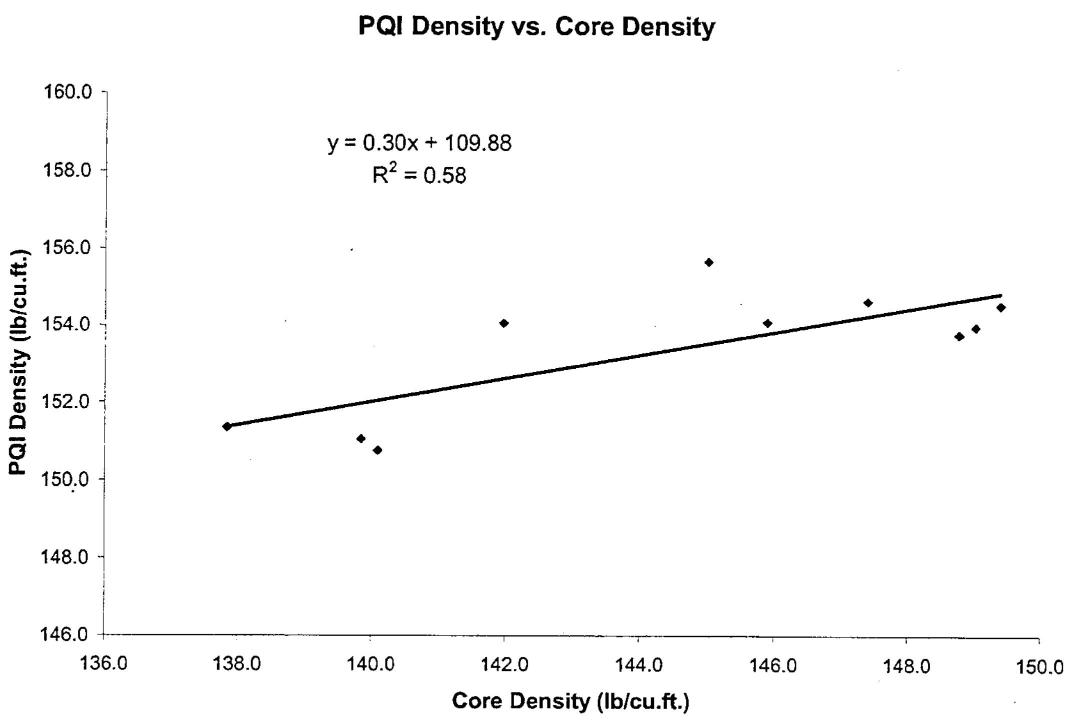

FIGURE 15 – PQI density versus core density scatter plot for Site 10.

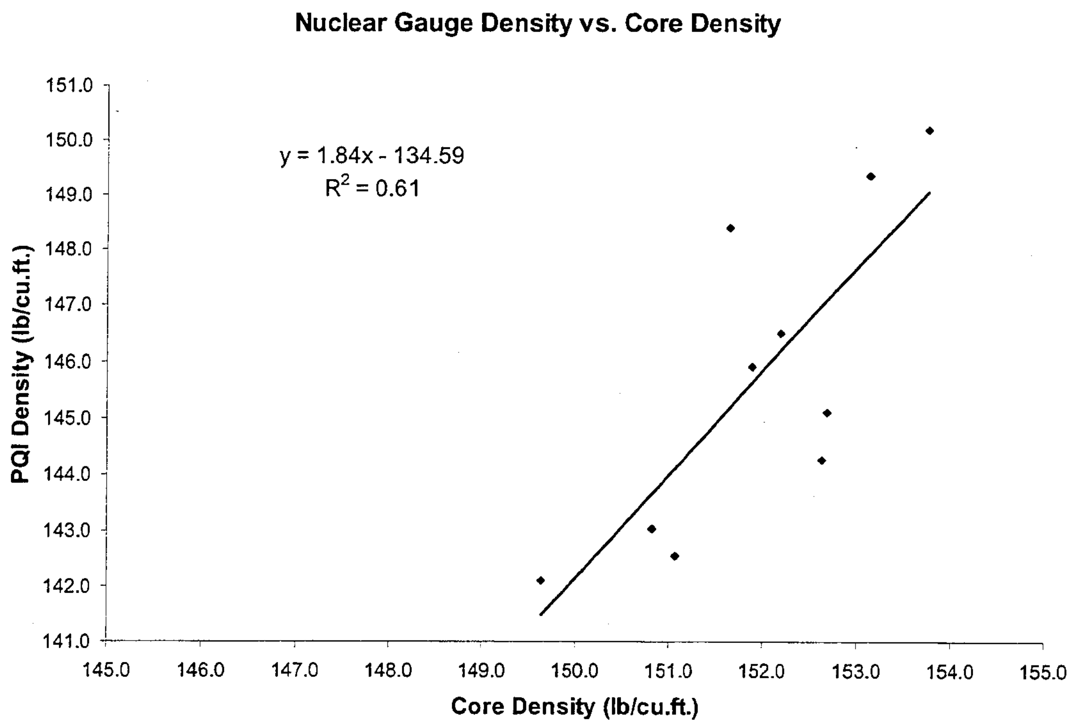

FIGURE 16 – Nuclear gauge density versus core density for Site 1.

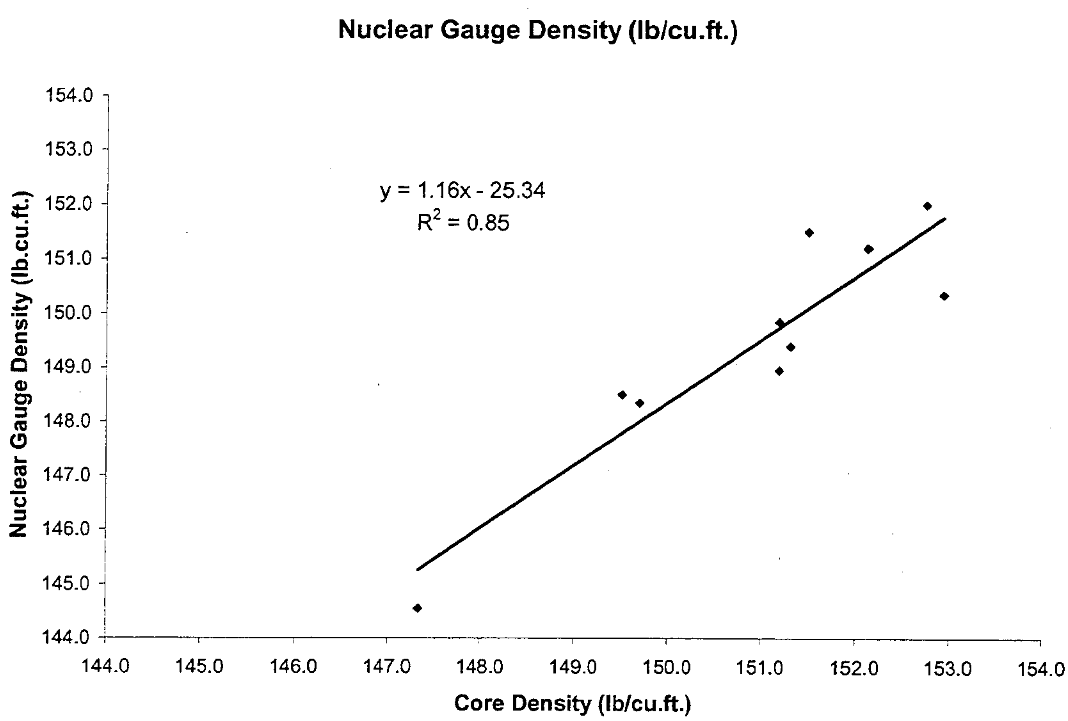

FIGURE 17 – Nuclear gauge density versus core density for Site 2.

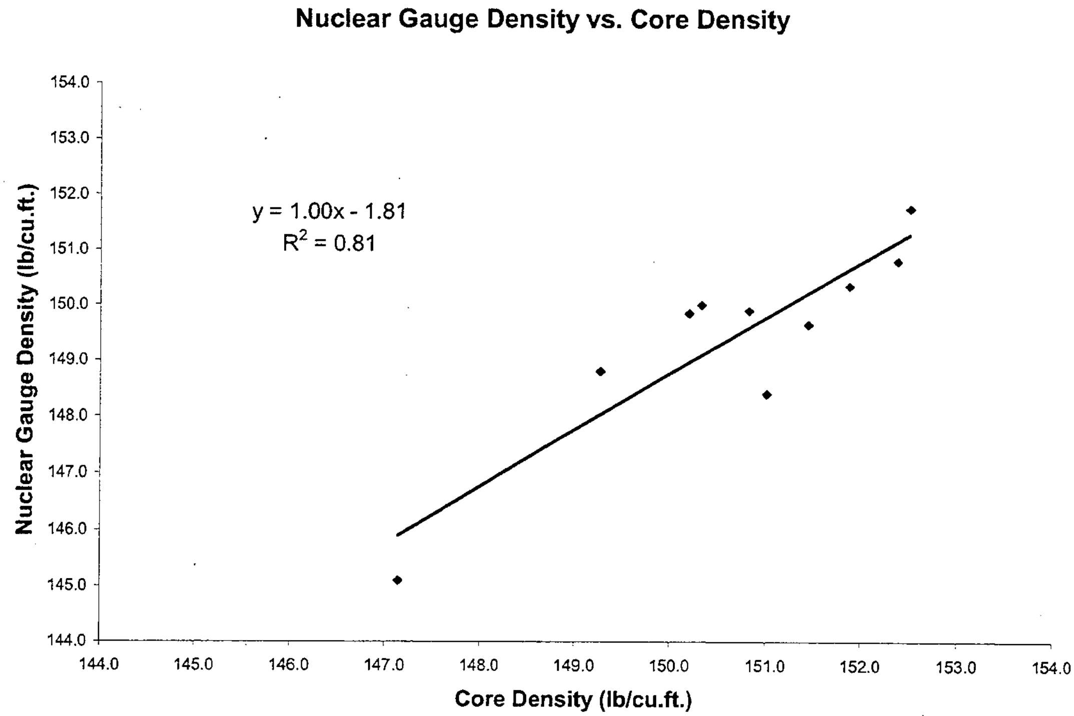

FIGURE 18 – Nuclear gauge density versus core density for Site 3.

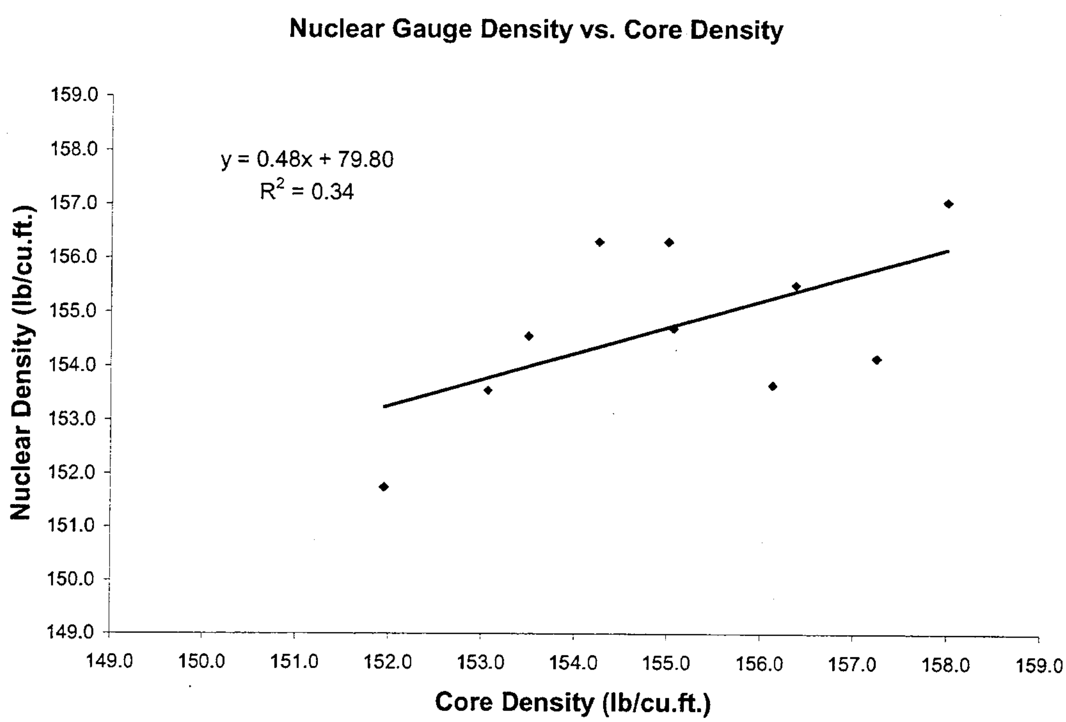

FIGURE 19 – Nuclear gauge density versus core density for Site 4.

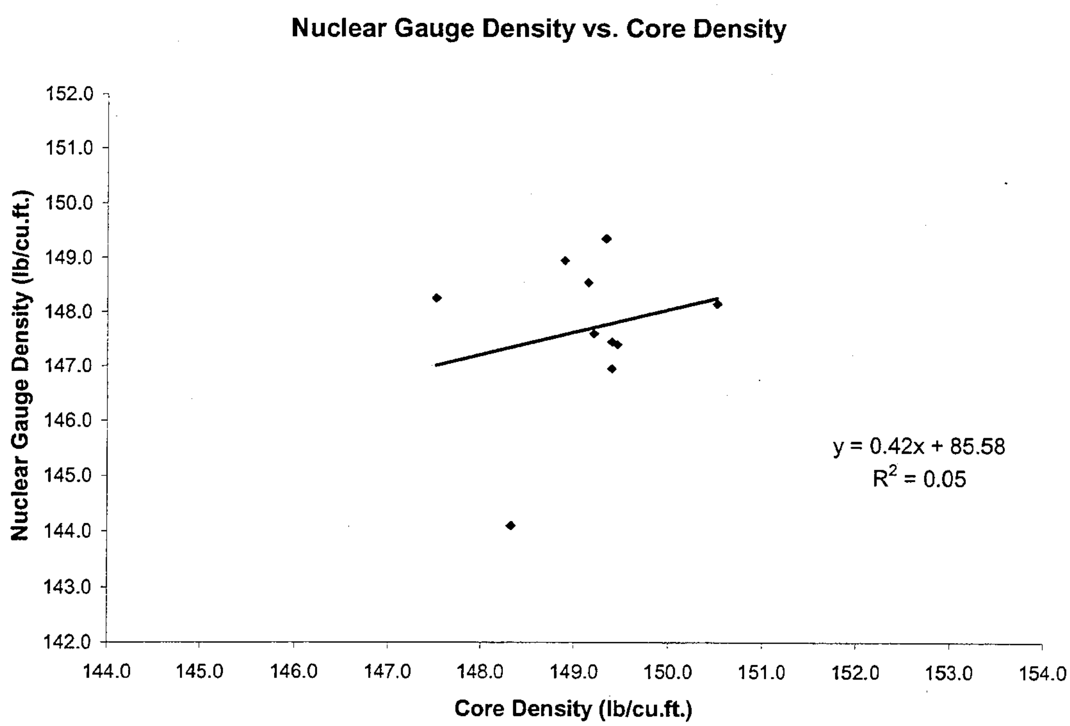

FIGURE 20 – Nuclear gauge density versus core density for Site 5.

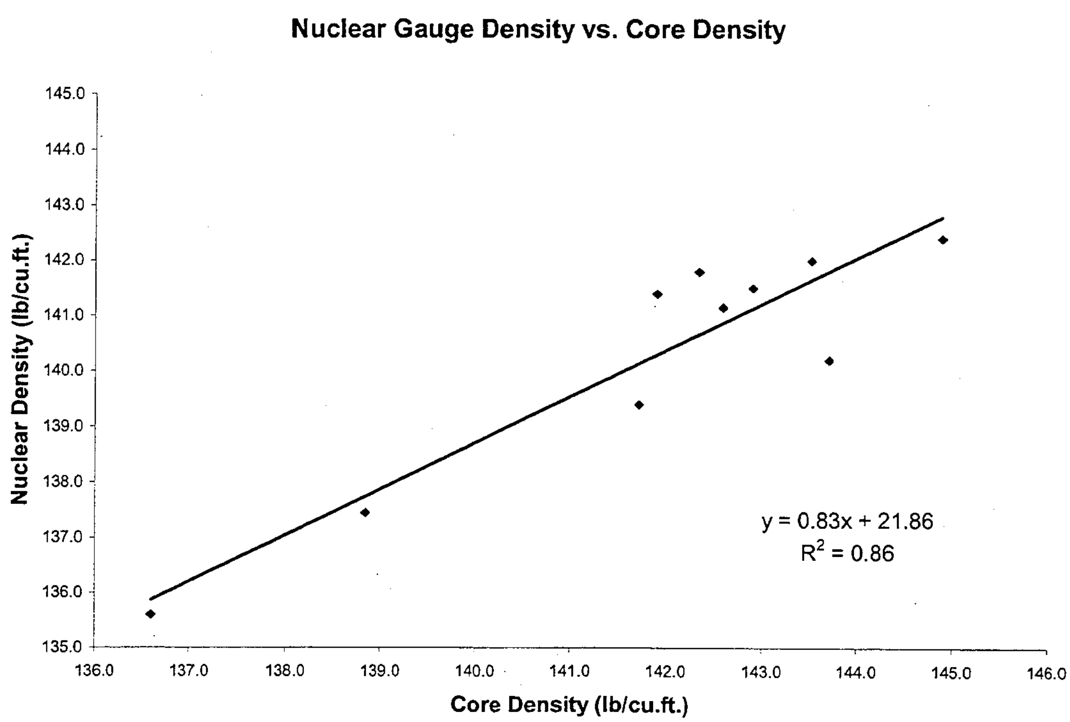

FIGURE 21 – Nuclear gauge density versus core density for Site 6.

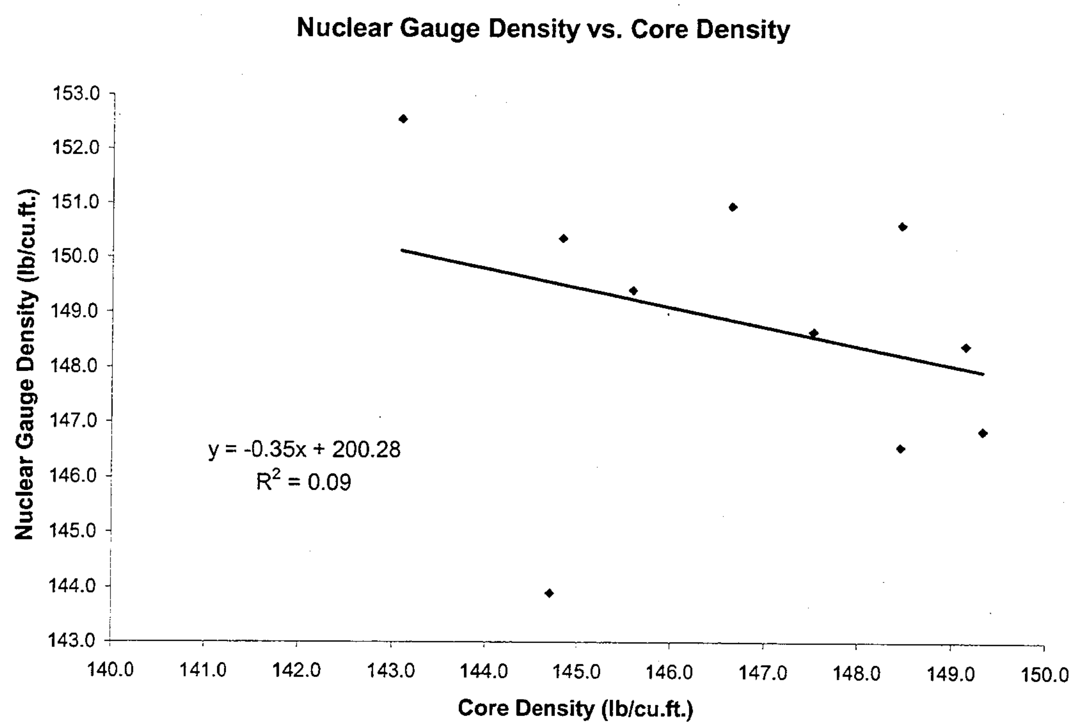

FIGURE 22 – Nuclear gauge density versus core density for Site 7.

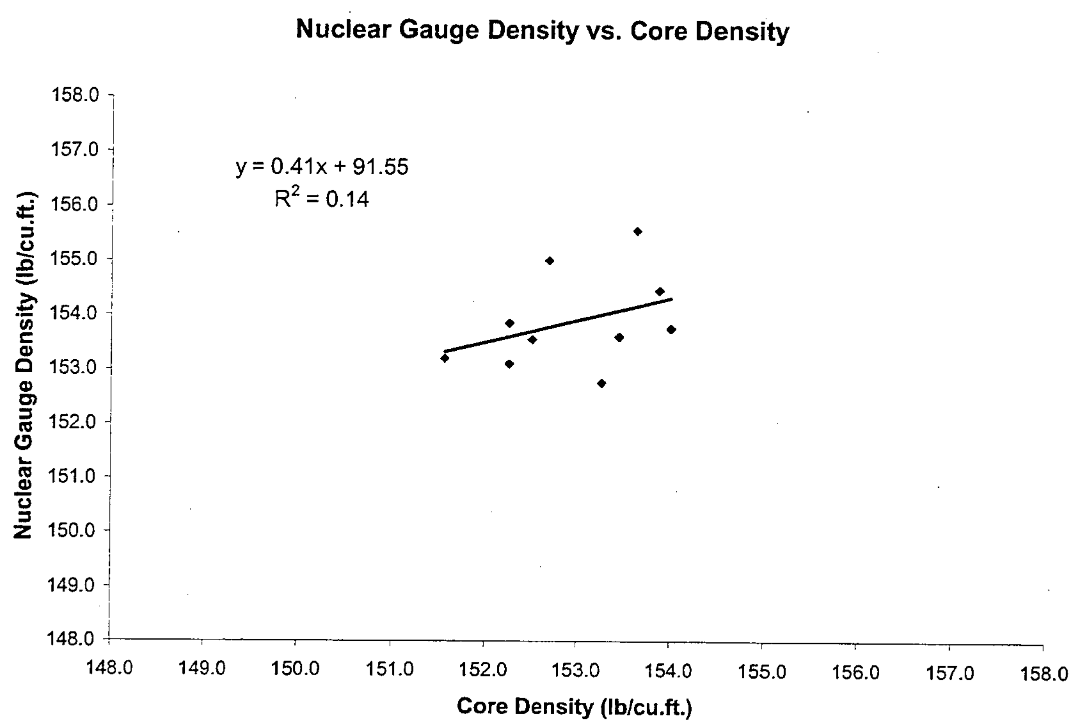

FIGURE 23 – Nuclear gauge density versus core density for Site 8.

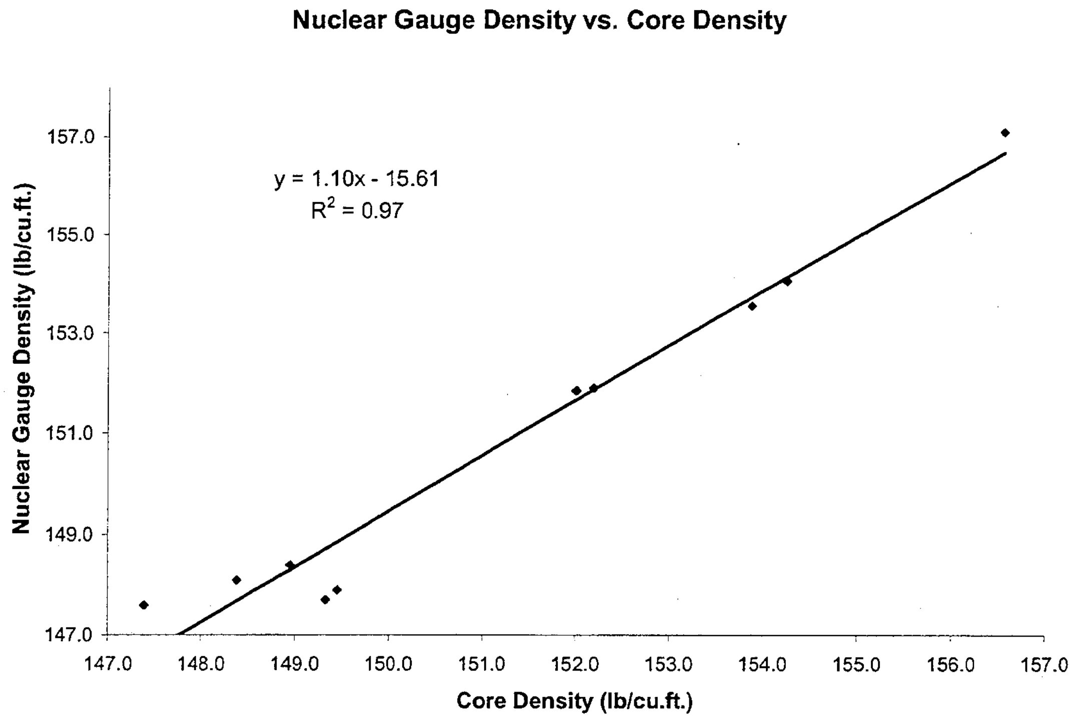

FIGURE 24 – Nuclear gauge density versus core density for Site 9.

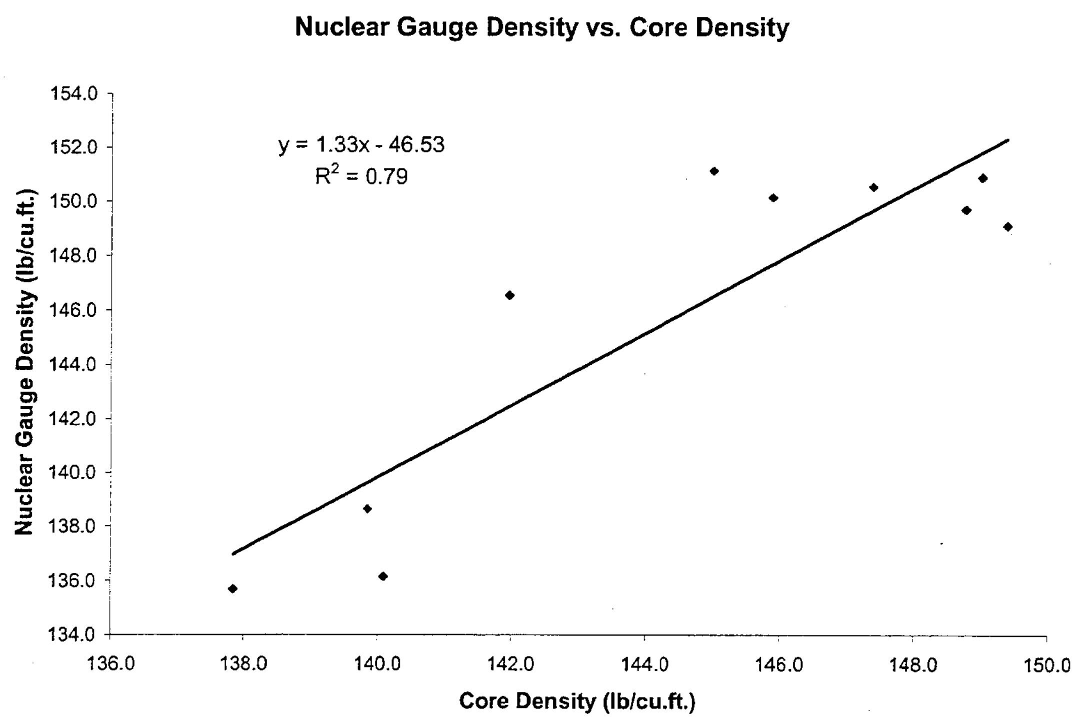

FIGURE 25 – Nuclear gauge density versus core density for Site 10

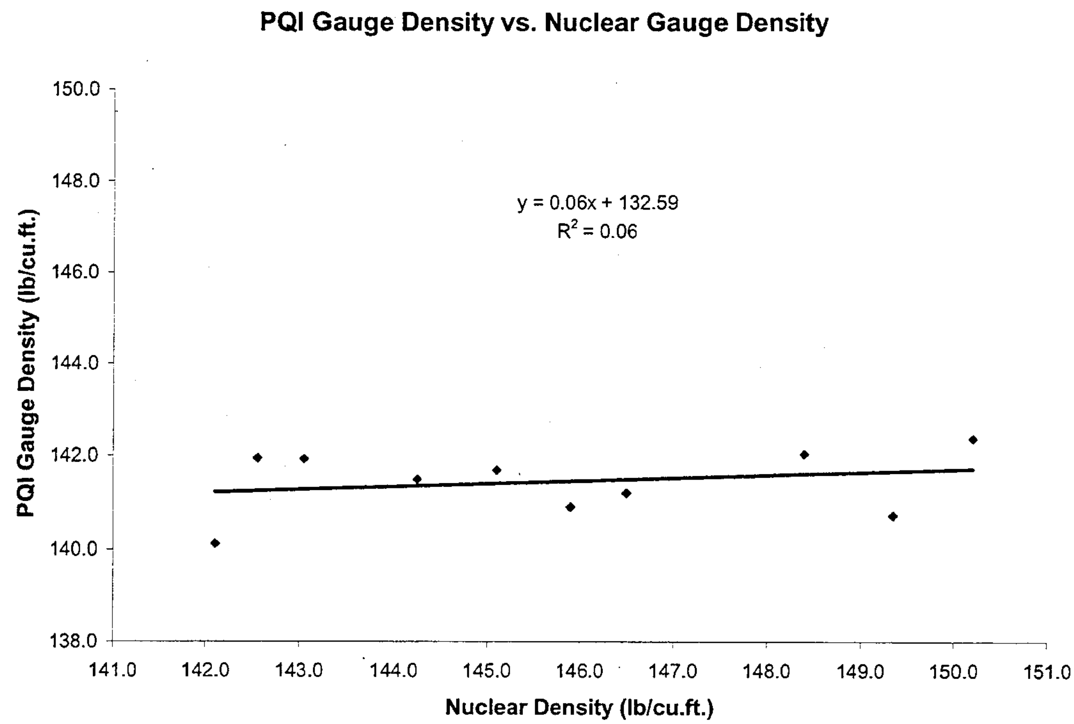

FIGURE 26 – PQI density versus nuclear gauge density for Site 1.

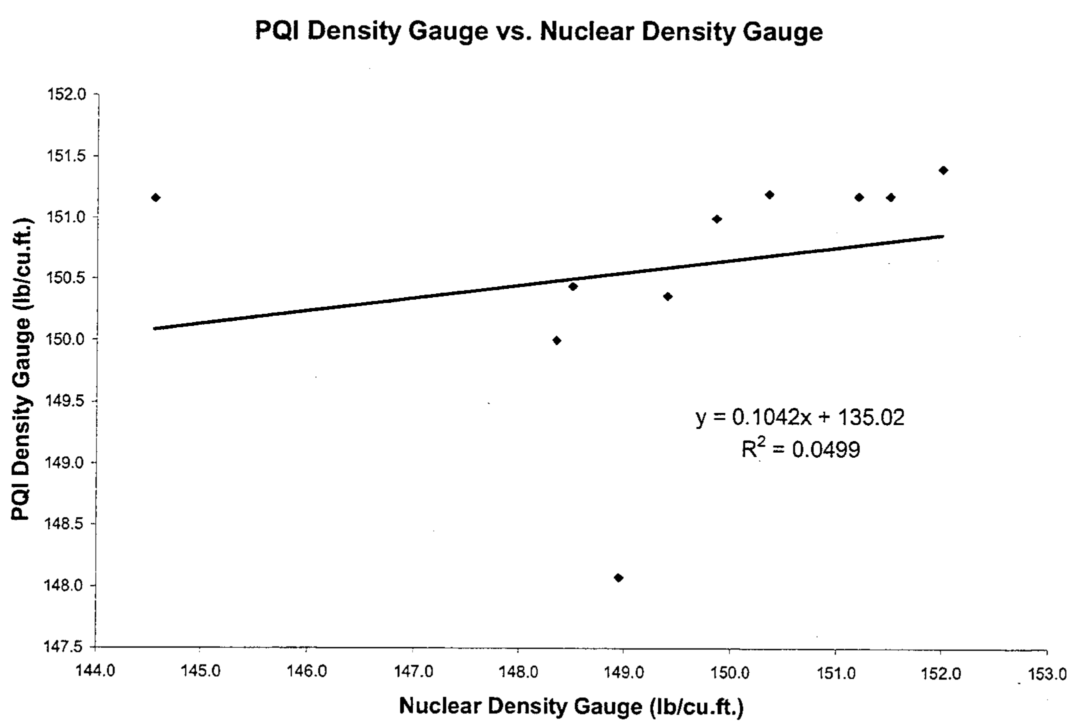

FIGURE 27 – PQI density versus nuclear gauge density for Site 2.

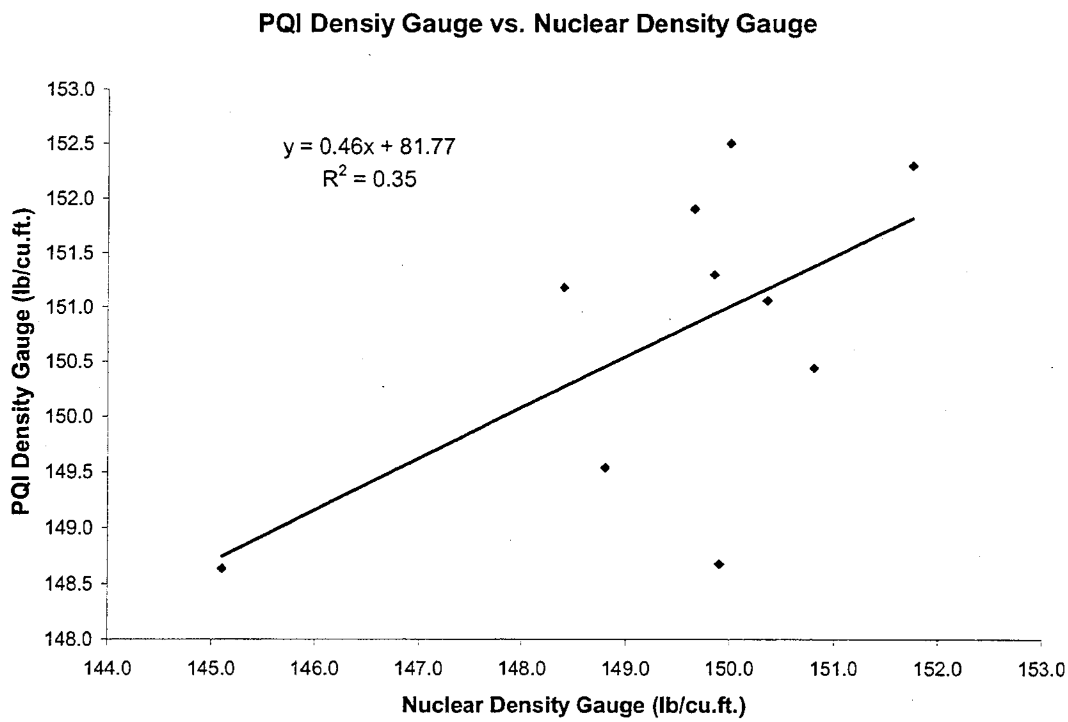

FIGURE 28 – PQI density versus nuclear gauge density for Site 3.

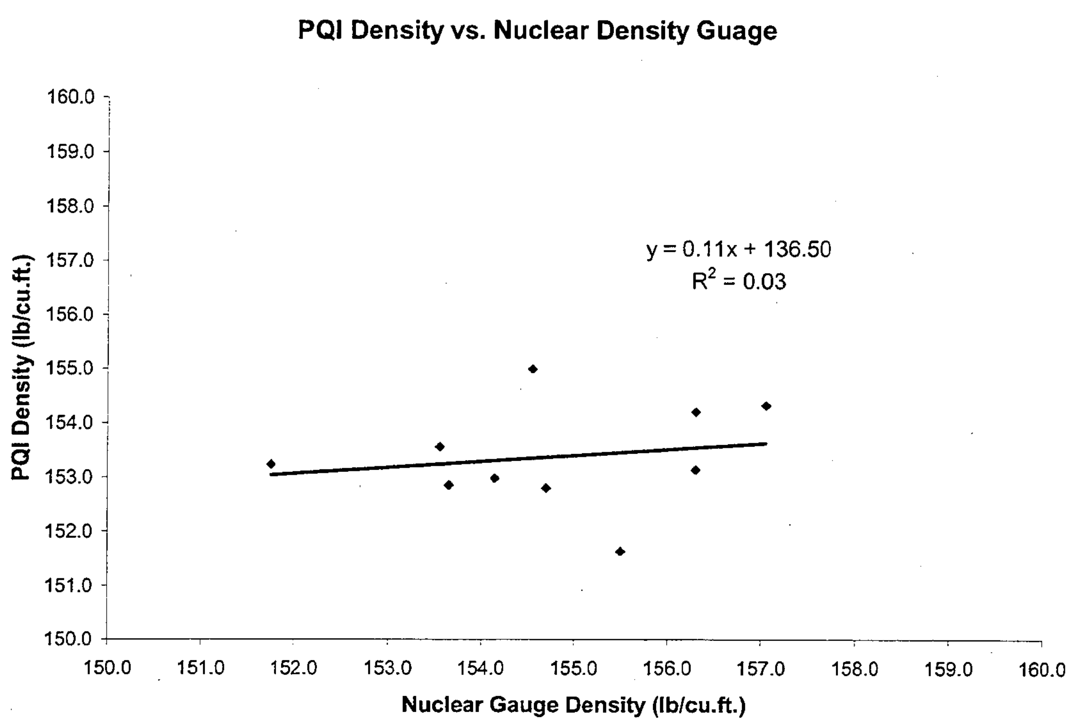

FIGURE 29 – PQI density versus nuclear gauge density for Site 4.

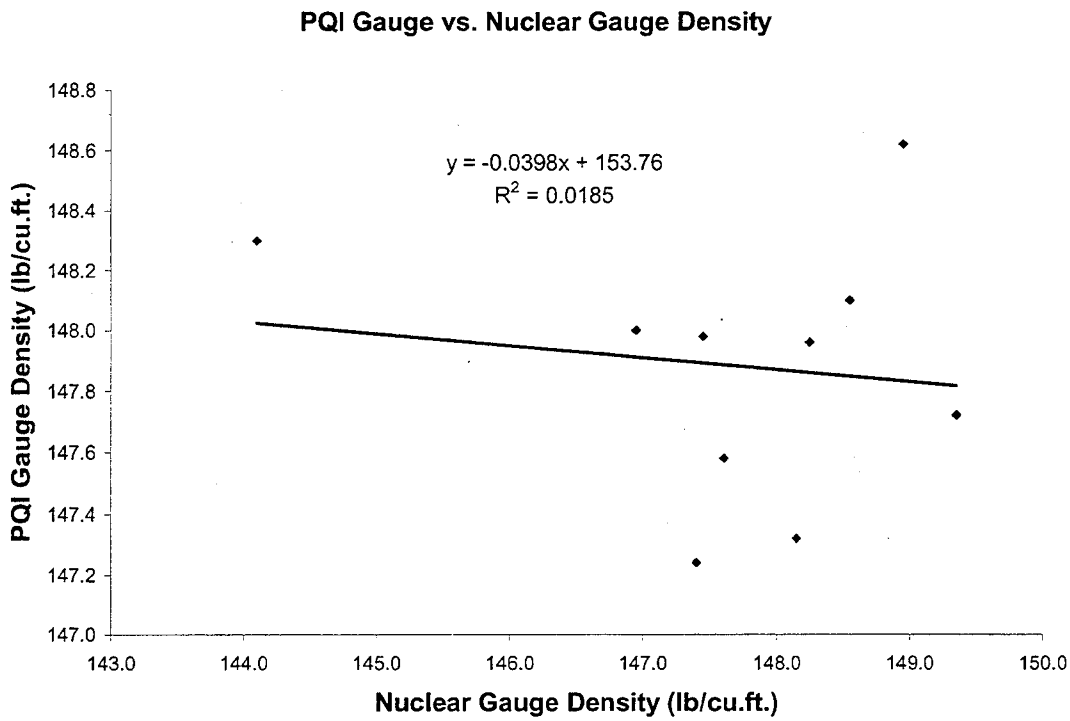

FIGURE 30 – PQI density versus nuclear gauge density for Site 5.

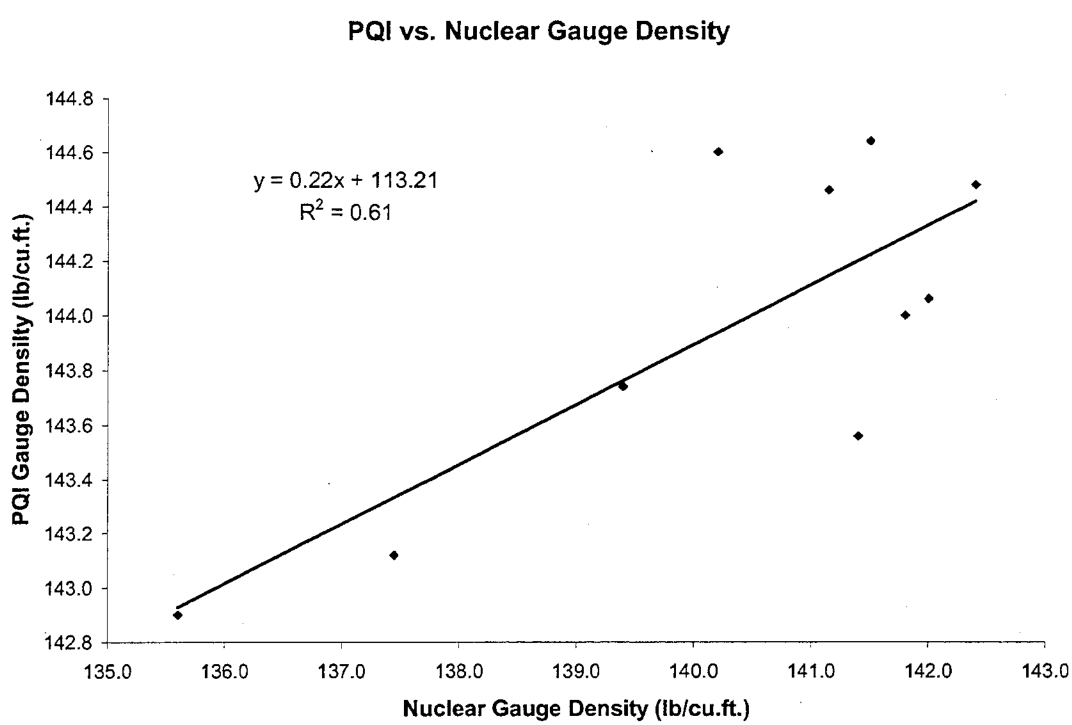

FIGURE 31 – PQI density versus nuclear gauge density for Site 6.

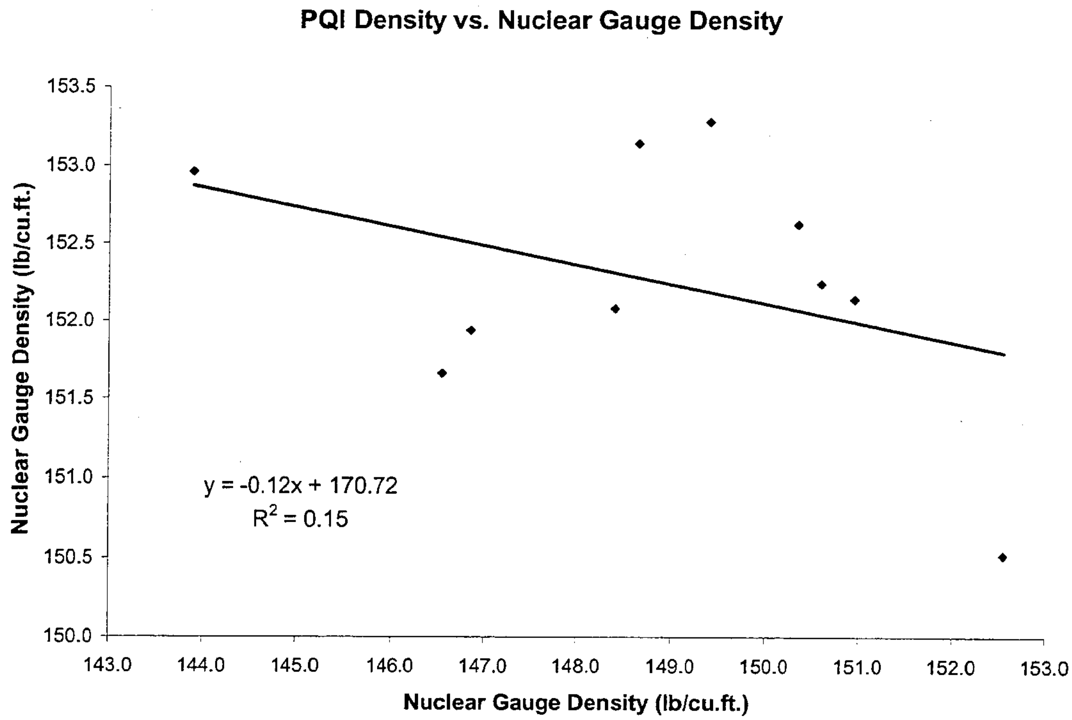

FIGURE 32 – PQI density versus nuclear gauge density for Site 7.

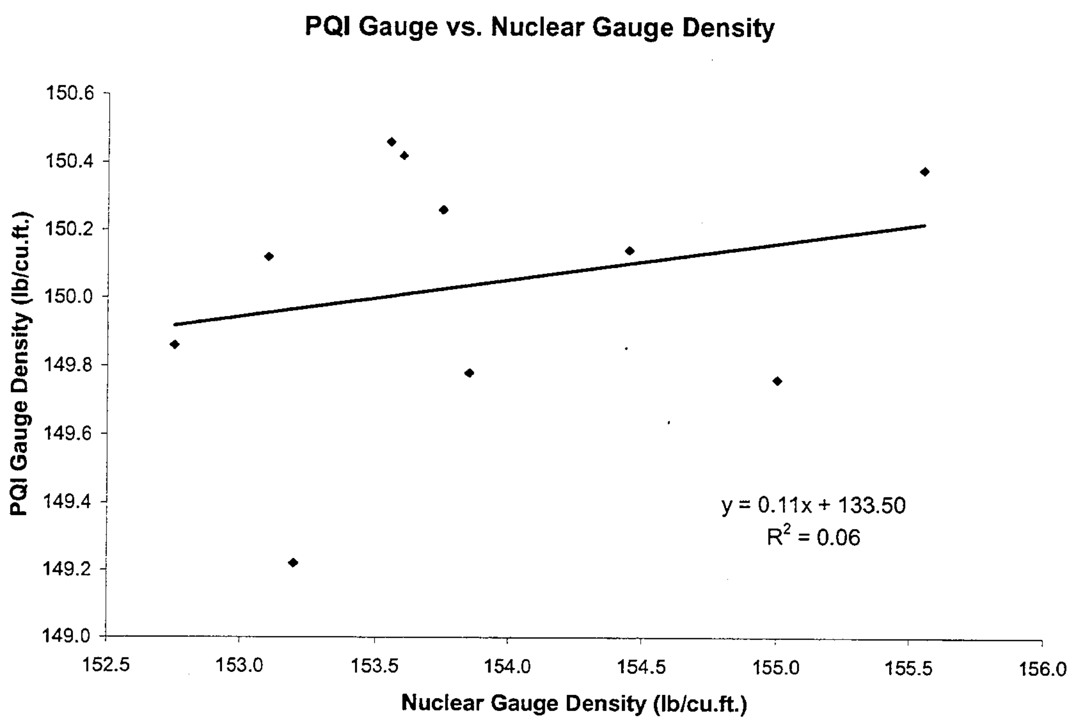

FIGURE 33 – PQI density versus nuclear gauge density for Site 8.

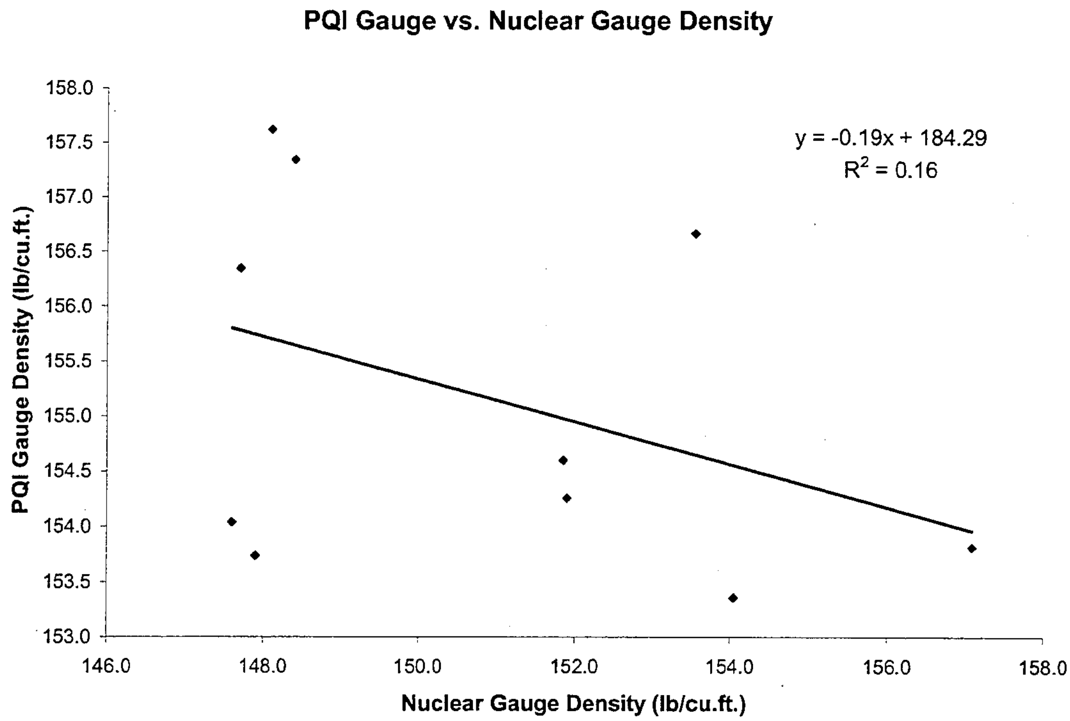

FIGURE 34 – PQI density versus nuclear gauge density for Site 9.

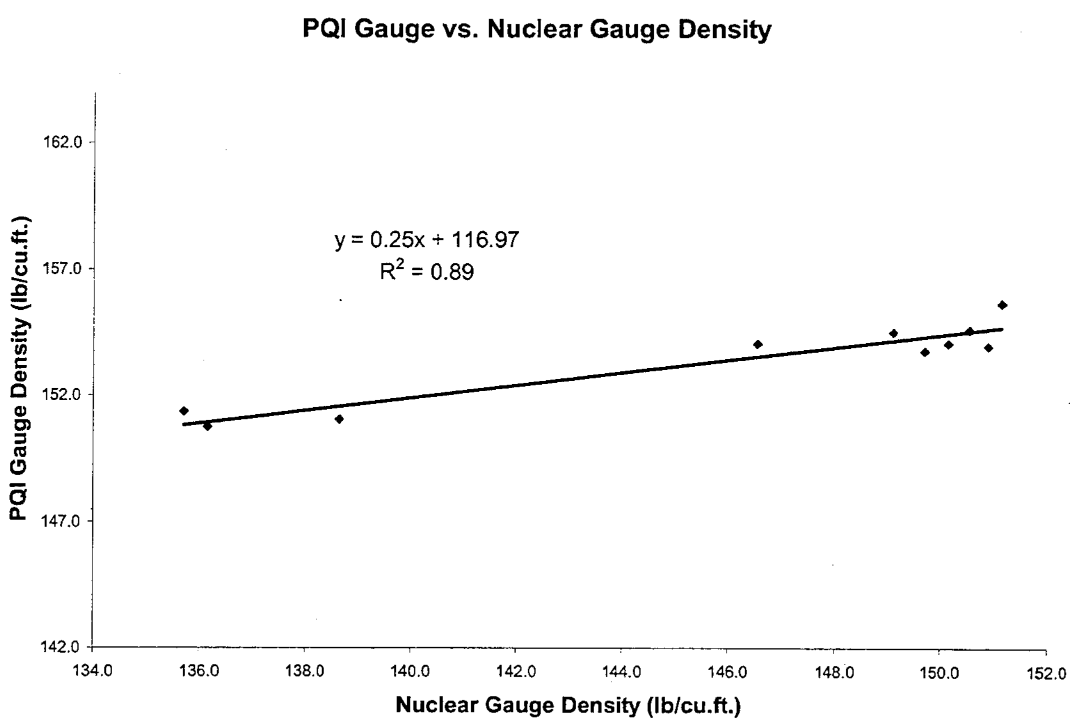

FIGURE 35 – PQI density versus nuclear gauge density for Site 10.

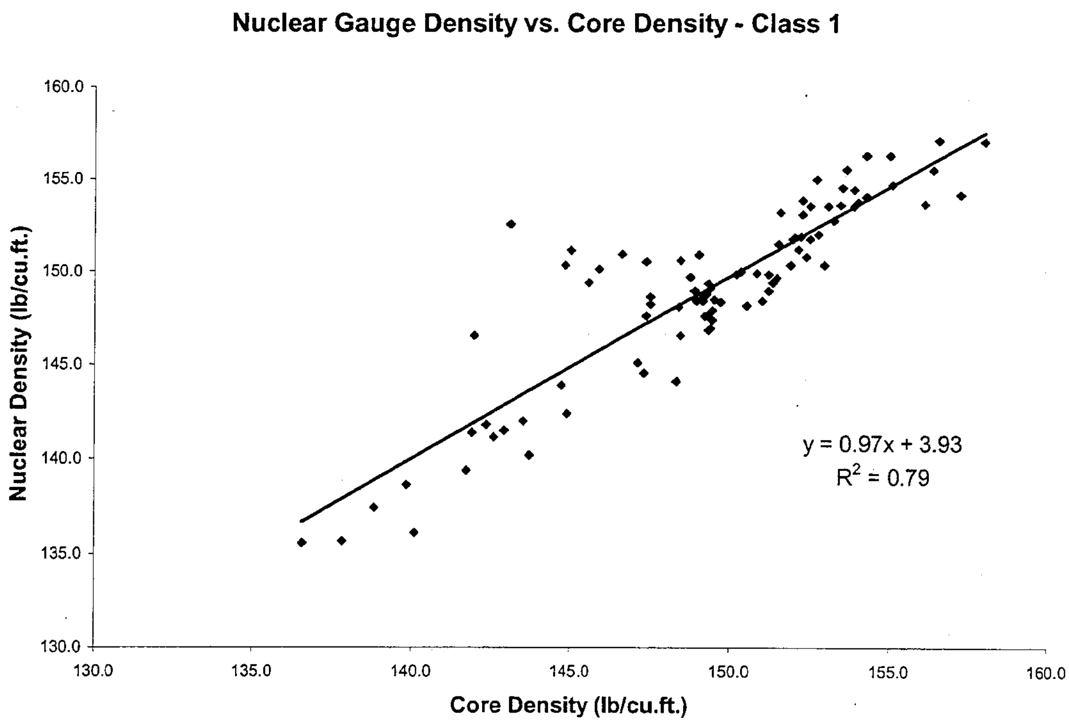

FIGURE 36 – Nuclear gauge density versus core density for combined Class 1 sites.

TABLE 7

PAVEMENT DENSITY DATA

Site #	Sample #	H2O No.	Pavement Temp.	PQI Test 1 (lb/cu ft)	PQI Test 2 (lb/cu ft)	PQI Test 3 (lb/cu ft)	PQI Test 4 (lb/cu ft)	PQI Test 5 (lb/cu ft)	PQI Average (lb/cu ft)	PQI Offset (lb/cu ft)	PQI Average w/ Standardardized 0ffset of 133.0 (lb/cu ft)	Nuc. Read 1 (lb/cu ft)	Nuc. Read 2 (lb/cu ft)	Nuc. Ave. (lb/cu ft)	Actual Gravity	Core Density (lb/cu ft)
1	2	11.0	153.1	152.7	149.5	150.8	150.9	152.9	151.4	142.0	142.4	150.3	150.1	150.2	2.464	153.8
1	3	8.4	149.0	149.5	148.5	149.1	148.6	149.9	149.1	142.0	140.1	140.4	143.8	142.1	2.398	149.6
1	4	8.9	147.1	150.6	150.3	148.8	150.3	148.6	149.7	142.0	140.7	151.2	147.5	149.4	2.454	153.1
1	6	9.5	147.5	149.9	149.8	149.8	150.9	150.6	150.2	142.0	141.2	148.2	144.8	146.5	2.439	152.2
1	9	4.6	150.4	151.6	149.5	149.3	149.5	149.6	149.9	142.0	140.9	145.1	146.7	145.9	2.434	151.9
1	11	3.6	141.5	151.2	151.7	150.9	150.9	150.4	151.0	142.0	142.0	147.5	149.3	148.4	2.43	151.6
1	12	3.8	135.5	150.9	150.3	150.6	152.4	150.4	150.9	142.0	141.9	143.8	142.3	143.1	2.417	150.8
1	13	4.1	131.8	151.4	150.6	150.9	150.6	151.2	150.9	142.0	141.9	140.5	144.6	142.6	2.421	151.1
1	14	4.1	136.1	151.2	150.4	150.6	150.6	150.6	150.7	142.0	141.7	142.5	147.7	145.1	2.447	152.7
1	15	4.2	133.3	151.2	151.1	149.8	150.4	149.9	150.5	142.0	141.5	145.7	142.8	144.3	2.446	152.6
2	1	6.2	100.3	160.3	159.5	158.2	159.6	159.2	159.4	142.0	150.4	148.7	150.1	149.4	2.425	151.3
2	2	6.1	101.2	160.5	159.5	160.2	160.1	160.6	160.2	142.0	151.2	151.3	151.7	151.5	2.428	151.5
2	3	6.2	104.3	160.3	160.0	159.9	160.1	159.7	160.0	142.0	151.0	149.9	149.8	149.9	2.423	151.2
2	4	6.0	97.1	160.6	159.8	160.5	160.4	160.7	160.4	142.0	151.4	151.1	152.9	152.0	2.448	152.8
2	5	6.3	98.9	160.6	160.0	159.5	159.7	161.1	160.2	142.0	151.2	151.1	151.3	151.2	2.438	152.1
2	7	6.9	100.8	160.5	159.6	158.8	158.1	160.2	159.4	142.0	150.4	149.4	147.6	148.5	2.396	149.5
2	9	6.7	96.7	160.4	159.9	160.2	160.1	160.4	160.2	142.0	151.2	150.0	150.7	150.4	2.451	152.9
2	11	5.5	97.3	159.0	159.7	158.9	158.9	158.5	159.0	142.0	150.0	147.5	149.2	148.4	2.399	149.7
2	13	6.6	78.9	160.5	160.0	159.8	160.3	160.2	160.2	142.0	151.2	144.2	144.9	144.6	2.361	147.3
2	15	6.6	99.9	160.5	154.0	156.2	157.0	157.7	157.1	142.0	148.1	148.6	149.3	149.0	2.423	151.2
3	1	10.3	129.3	162.0	161.8	160.3	162.6	160.8	161.5	142.0	152.5	151.0	149.0	150.0	2.409	150.3
3	2	10.1	129.8	161.9	160.8	160.2	161.6	160.0	160.9	142.0	151.9	148.8	150.5	149.7	2.427	151.4
3	3	9.3	140.2	160.0	160.7	159.3	159.6	160.7	160.1	142.0	151.1	150.4	150.3	150.4	2.434	151.9
3	4	9.3	140.1	160.3	159.8	160.3	160.7	160.4	160.3	142.0	151.3	150.1	149.6	149.9	2.407	150.2
3	5	9.4	139.6	160.6	160.3	160.3	159.6	160.1	160.2	142.0	151.2	148.7	148.1	148.4	2.42	151.0
3	6	9.0	153.2	159.6	159.1	159.6	158.9	160.0	159.4	142.0	150.4	150.1	151.5	150.8	2.442	152.4
3	7	9.1	120.1	161.3	160.2	161.3	160.7	163.0	161.3	142.0	152.3	152.6	150.9	151.8	2.444	152.5
3	8	7.5	143.4	158.4	157.9	156.9	158.2	157.0	157.7	142.0	148.7	149.3	150.5	149.9	2.417	150.8
3	9	7.9	124.3	158.9	157.8	158.4	158.6	159.0	158.5	142.0	149.5	148.6	149.0	148.8	2.392	149.3
3	10	6.5	126.3	158.0	157.6	157.3	157.6	157.7	157.6	142.0	148.6	146.0	144.2	145.1	2.358	147.1
4	1	9.0	88.7	154.9	154.6	153.5	154.4	154.2	154.3	133.0	154.3	156.9	157.2	157.1	2.532	158.0
4	2	8.9	79.1	154.4	153.9	154.1	154.7	153.9	154.2	133.0	154.2	156.3	156.3	156.3	2.472	154.3
4	3	10.7	80.2	155.3	155.5	154.4	154.4	155.4	155.0	133.0	155.0	155.1	154.0	154.6	2.460	153.5
4	4	8.9	78.7	153.6	153.9	153.7	153.5	153.1	153.6	133.0	153.6	153.3	153.8	153.6	2.453	153.1
4	5	8.8	82.3	153.1	153.5	153.1	152.9	153.6	153.2	133.0	153.2	151.7	151.8	151.8	2.435	151.9
4	11	7.6	81.6	153.6	152.0	151.8	150.3	150.5	151.6	133.0	151.6	155.8	155.2	155.5	2.506	156.4
4	12	7.4	82	153.1	152.6	153.8	152.6	152.8	153.0	133.0	153.0	153.7	154.6	154.2	2.520	157.2
4	13	7.6	82	153.0	153.3	152.4	153.0	152.6	152.9	133.0	152.9	152.4	154.9	153.7	2.502	156.1
4	14	7.7	81.5	153.6	153.5	152.1	154.0	152.5	153.1	133.0	153.1	156.5	156.1	156.3	2.484	155.0
4	15	8.1	82.1	153.5	153.3	152.6	152.1	152.5	152.8	133.0	152.8	155.7	153.7	154.7	2.485	155.1
5	6	6.6	75.1	147.7	146.9	146.9	147.5	147.6	147.3	133.0	147.3	149.3	147.0	148.2	2.412	150.5

TABLE 7

PAVEMENT DENSITY DATA

Site #	Sample #	H2O No.	Pavement Temp.	PQI Test 1 (lb/cu ft)	PQI Test 2 (lb/cu ft)	PQI Test 3 (lb/cu ft)	PQI Test 4 (lb/cu ft)	PQI Test 5 (lb/cu ft)	PQI Average (lb/cu ft)	PQI Offset (lb/cu ft)	PQI Average w/ Standardardized 0ffset of 133.0 (lb/cu ft)	Nuc. Read 1 (lb/cu ft)	Nuc. Read 2 (lb/cu ft)	Nuc. Ave. (lb/cu ft)	Actual Gravity	Core Density (lb/cu ft)
5	7	8.1	75.7	147.6	148.5	147.7	148.2	147.9	148.0	133.0	148.0	147.6	147.3	147.5	2.394	149.4
5	8	8.6	73.0	148.0	148.2	148.0	147.9	148.4	148.1	133.0	148.1	149.1	148.0	148.6	2.39	149.1
5	9	9.2	72.1	147.8	147.8	148.4	147.9	147.9	148.0	133.0	148.0	148.2	148.3	148.3	2.364	147.5
5	10	8.6	73.7	147.8	148.4	148.8	148.4	148.1	148.3	133.0	148.3	144.4	143.8	144.1	2.377	148.3
5	11	8.5	76.9	148.7	148.5	148.4	148.3	149.2	148.6	133.0	148.6	148.8	149.1	149.0	2.386	148.9
5	12	7.7	77.0	147.6	147.7	148.4	148.4	147.9	148.0	133.0	148.0	147.1	146.8	147.0	2.394	149.4
5	13	7.5	77.2	148.5	146.9	147.2	148.4	147.6	147.7	133.0	147.7	149.6	149.1	149.4	2.393	149.3
5	14	6.9	77.1	148.0	147.6	147.4	147.7	147.2	147.6	133.0	147.6	147.7	147.5	147.6	2.391	149.2
5	15	6.6	76.4	147.1	147.1	147.6	146.9	147.5	147.2	133.0	147.2	147.5	147.3	147.4	2.395	149.4
6	6	5.6	101.9	144.5	144.8	144.5	144.7	144.7	144.6	133.0	144.6	140.6	142.4	141.5	2.29	142.9
6	8	5.3	103.7	144.2	144.3	144.6	144.7	144.6	144.5	133.0	144.5	142.5	142.3	142.4	2.322	144.9
6	9	5.8	104.6	144.1	144.9	144.5	144.4	144.4	144.5	133.0	144.5	140.7	141.6	141.2	2.285	142.6
6	11	6.0	104.0	144.0	144.0	143.8	144.1	144.4	144.1	133.0	144.1	140.7	143.3	142.0	2.3	143.5
6	12	6.8	106.5	144.5	144.7	144.5	144.9	144.4	144.6	133.0	144.6	141.2	139.2	140.2	2.303	143.7
6	20	5	108.1	143.6	144.3	143.9	143.4	143.5	143.7	133.0	143.7	139.9	138.9	139.4	2.271	141.7
6	21	5	114.1	143.5	143.7	143.7	143.3	143.6	143.6	133.0	143.6	140.7	142.1	141.4	2.274	141.9
6	18	5.1	121.6	144.2	143.6	144.0	144.1	144.1	144.0	133.0	144.0	143.0	140.6	141.8	2.281	142.3
6	23	4.8	117.4	143.2	143.2	143.1	143.1	143.0	143.1	133.0	143.1	137.1	137.8	137.5	2.225	138.8
6	24	4.7	117.3	142.5	142.7	143.2	142.7	143.4	142.9	133.0	142.9	135.3	135.9	135.6	2.189	136.6
7	1	9.4	133.1	152.1	151.6	151.8	152.3	152.9	152.1	133.0	152.1	150.7	151.2	151.0	2.35	146.6
7	2	10	133.7	152.9	153.4	152.8	153.4	152.3	153.0	133.0	153.0	143.7	144.1	143.9	2.319	144.7
7	3	9.7	150.5	152.8	152.1	149.3	150.4	148.0	150.5	133.0	150.5	152.1	153.0	152.6	2.293	143.1
7	4	9.9	145.3	152.7	154.3	150.3	154.6	151.2	152.6	133.0	152.6	150.4	150.3	150.4	2.321	144.8
7	5	9.6	138.6	153.2	153.1	154.2	153.1	152.8	153.3	133.0	153.3	148.3	150.5	149.4	2.333	145.6
7	6	8.2	111.5	152.4	151.9	152.2	152.1	152.6	152.2	133.0	152.2	150.7	150.5	150.6	2.379	148.4
7	7	9.6	113.7	153.5	153.1	152.9	153.0	153.2	153.1	133.0	153.1	149.0	148.3	148.7	2.364	147.5
7	8	9.0	120.7	151.5	152.3	150.7	152.2	151.6	151.7	133.0	151.7	146.2	146.9	146.6	2.379	148.4
7	9	9.2	122.4	152.6	151.7	151.4	151.8	152.2	151.9	133.0	151.9	147.4	146.3	146.9	2.393	149.3
7	10	9.6	121.7	152.5	151.1	152.0	152.4	152.4	152.1	133.0	152.1	148.3	148.5	148.4	2.39	149.1
8	1	6.6	111.7	150.5	150.4	149.6	149.6	149.2	149.9	133.0	149.9	151.8	153.7	152.8	2.456	153.3
8	2	6.8	111	150.8	150.6	150.2	150.7	149.8	150.4	133.0	150.4	153.1	154.1	153.6	2.459	153.4
8	3	6.8	119.4	150.6	149.9	150.5	150.4	150.9	150.5	133.0	150.5	154.4	152.7	153.6	2.444	152.5
8	4	6.8	111.8	150.7	149.9	149.6	149.8	150.6	150.1	133.0	150.1	153.3	152.9	153.1	2.44	152.3
8	5	6.3	113.5	149.2	149.6	150.3	150.9	150.7	150.1	133.0	150.1	154.1	154.8	154.5	2.466	153.9
8	6	6.6	117.1	150.3	150.4	150.1	148.3	149.7	149.8	133.0	149.8	154.6	155.4	155.0	2.447	152.7
8	7	6.6	118.8	150.0	150.7	150.0	150.4	150.2	150.3	133.0	150.3	153.5	154.0	153.8	2.468	154.0
8	8	6.9	126.8	149.8	150.3	149.1	149.9	149.8	149.8	133.0	149.8	153.4	154.3	153.9	2.44	152.3
8	9	7.0	133.6	149.9	149.4	149.7	147.5	149.6	149.2	133.0	149.2	154.0	152.4	153.2	2.429	151.6
8	10	6.8	120.9	150.7	150.3	149.8	150.5	150.6	150.4	133.0	150.4	156.5	154.6	155.6	2.462	153.6
9	1	13.1	79.3	154.6	154.6	153.0	153.1	154.9	154.0	133.0	154.0	146.9	148.3	147.6	2.362	147.4
9	2	16.2	78.9	157.8	157.2	157.4	157.1	157.2	157.3	133.0	157.3	148.6	148.2	148.4	2.387	148.9

TABLE 7

PAVEMENT DENSITY DATA

Site #	Sample #	H2O No.	Pavement Temp.	PQI Test 1 (lb/cu ft)	PQI Test 2 (lb/cu ft)	PQI Test 3 (lb/cu ft)	PQI Test 4 (lb/cu ft)	PQI Test 5 (lb/cu ft)	PQI Average (lb/cu ft)	PQI Offset (lb/cu ft)	PQI Average w/ Standardardized Offset of 133.0 (lb/cu ft)	Nuc. Read 1 (lb/cu ft)	Nuc. Read 2 (lb/cu ft)	Nuc. Ave. (lb/cu ft)	Actual Gravity	Core Density (lb/cu ft)
9	3	11.7	80.4	154.8	153.4	153.6	153.9	153.0	153.7	133.0	153.7	147.4	148.4	147.9	2.395	149.4
9	4	12.7	78.4	155.5	157.1	156.9	155.9	156.3	156.3	133.0	156.3	148.1	147.3	147.7	2.393	149.3
9	5	13.1	78.8	156.4	156.4	156.7	156.9	156.9	156.7	133.0	156.7	154.4	152.7	153.6	2.466	153.9
9	6	13.5	80.3	155.6	156.4	158.7	158.1	159.3	157.6	133.0	157.6	148.4	147.8	148.1	2.378	148.4
9	7	10.6	85.9	154.7	154.2	154.0	153.7	154.7	154.3	133.0	154.3	151.4	152.4	151.9	2.439	152.2
9	8	10.2	84.6	154.7	154.7	154.1	154.8	154.7	154.6	133.0	154.6	152.3	151.4	151.9	2.436	152.0
9	9	9.4	87.9	153.5	154.2	153.6	153.9	153.9	153.8	133.0	153.8	156.5	157.7	157.1	2.509	156.6
9	10	10.1	87.7	154.0	153.1	153.1	154.3	152.3	153.4	133.0	153.4	154.4	153.7	154.1	2.472	154.3
10	1	11.3	106.1	154.1	153.0	154.1	154.2	154.4	154.0	133.0	154.0	150.9	150.9	150.9	2.388	149.0
10	2	12.2	108.2	154.3	153.9	154.9	154.2	155.3	154.5	133.0	154.5	149.9	148.3	149.1	2.394	149.4
10	3	12	90.1	155.6	156.2	155.2	155.8	155.5	155.7	133.0	155.7	151.4	150.9	151.2	2.324	145.0
10	4	10.7	82.9	153.9	155.2	154.9	155.0	154.1	154.6	133.0	154.6	151.4	149.7	150.6	2.362	147.4
10	5	10.9	79.1	154.3	154.6	152.8	154.7	153.9	154.1	133.0	154.1	146.8	146.3	146.6	2.275	142.0
10	6	9.5	76.1	149.8	151.8	150.6	151.7	149.9	150.8	133.0	150.8	136.1	136.2	136.2	2.245	140.1
10	7	10.9	106.5	153.7	154.6	153.7	154.9	153.5	154.1	133.0	154.1	150.1	150.2	150.2	2.338	145.9
10	8	10.7	99.6	150.7	151.3	151.8	151.9	151.1	151.4	133.0	151.4	135.4	136.0	135.7	2.209	137.8
10	9	10.7	100.8	150.7	150.9	152.6	150.1	151.0	151.1	133.0	151.1	138.8	138.5	138.7	2.241	139.8
10	10	10.8	90.6	154.8	153.6	153.1	153.2	154.1	153.8	133.0	153.8	149.3	150.1	149.7	2.384	148.8

Site: 1
State: CT
Route: 2
Town: Stoningtion
District: 2
Date: 5/16/00
Project No.: 137-137
Contractor: Tilcon
Mix Description: 37.5-mm Superpave
Mat Thickness: 3 inches
Compaction Targets: 90% min to 98% max
Technician Name: J. Henault
Testing Company: ConnDOT
Maximum Theoretical Density = 162.1 lb/cu.ft.
Offset = 142 lb/cu ft.
Slope = 4.93
Mode: Deep
Core Size: 6 inch

Testing:

	PQI Data										Nucl. Gauge Data			Core Data	
Test No.	mV	H20 No.	Temp (F)	PQI Read 1 (lb/cu ft)	PQI Read 2 (lb/cu ft)	PQI Read 3 (lb/cu ft)	PQI Read 4 (lb/cu ft)	PQI Read 5 (lb/cu ft)	PQI Ave. (lb/cu ft)	Corrected PQI Ave. (lb/cu ft)	Nucl. #1 (lb/cu ft)	Nucl. #2 (lb/cu ft)	Nucl. Ave. (lb/cu ft)	Actual Gravity	Actual Density (lb/cu ft)
1	1081	4.0	154.1	150.6	150.3	150.4	151.2	151.2	150.7	151.7	142.8	146.1	144.5		
2	1333	11.0	153.1	152.7	149.5	150.8	150.9	152.9	151.4	152.4	150.3	150.1	150.2	2.464	153.8
3	1066	8.4	149.0	149.5	148.5	149.1	148.6	149.9	149.1	150.1	140.4	143.8	142.1	2.398	149.6
4	1153	8.9	147.1	150.6	150.3	148.8	150.3	148.6	149.7	150.7	151.2	147.5	149.4	2.454	153.1
5	1242	5.1	128.3	153.8	151.6	151.2	152.5	151.4	152.1	153.1	149.9	152.0	151.0		
6	1110	9.5	147.5	149.9	149.8	149.8	150.9	150.6	150.2	151.2	148.2	144.8	146.5	2.439	152.2
7	1144	4.5	139.0	152.0	149.8	150.3	149.6	150.9	150.5	151.5	147.0	151.6	149.3		
8	1197	4.5	149.8	152.4	150.1	150.1	150.4	150.4	150.7	151.7	151.1	150.3	150.7		
9	1152	4.6	150.4	151.6	149.5	149.3	149.5	149.6	149.9	150.9	145.1	146.7	145.9	2.434	151.9
10	1203	9.8	144.0	151.2	149.9	150.4	150.1	150.6	150.4	151.4	149.3	147.7	148.5		
Average									150.5	151.5			147.8		152.1

Calibration Based on Cores:

	PQI Gauge										Nucl. Gauge Data			Core Density	
Test No.	mV	H20 No.	Temp (F)	PQI Read 1 (lb/cu ft)	PQI Read 2 (lb/cu ft)	PQI Read 3 (lb/cu ft)	PQI Read 4 (lb/cu ft)	PQI Read 5 (lb/cu ft)	PQI Ave. (lb/cu ft)	Corrected PQI Ave. (lb/cu ft)	Nucl. #1 (lb/cu ft)	Nucl. #2 (lb/cu ft)	Nucl. Ave. (lb/cu ft)	Actual Gravity	Actual Density (lb/cu ft)
11	1070	3.6	141.5	151.2	151.7	150.9	150.9	150.4	151.0	152.0	147.5	149.3	148.4	2.430	151.6
12	1042	3.8	135.5	150.9	150.3	150.6	152.4	150.4	150.9	151.9	143.8	142.3	143.1	2.417	150.8
13	1067	4.1	131.8	151.4	150.6	150.9	150.6	151.2	150.9	151.9	140.5	144.6	142.6	2.421	151.1
14	1069	4.1	136.1	151.2	150.4	150.6	150.6	150.6	150.7	151.7	142.5	147.7	145.1	2.447	152.7
15	1050	4.2	133.3	151.2	151.1	149.8	150.4	149.9	150.5	151.5	145.7	142.8	144.3	2.446	152.6
Average									150.8	151.8			144.7		151.8

PQI Calibration Correction = 151.8 - 150.8 = 1.0 lb/cu.ft.

Site: 2
State: CT
Route: 55
Town: Sherman
District: 4
Date: 5/31/2000
Project No.: 174-290H
Contractor: Waters
Mix Description: Class 1
Mat Thickness: 2.25-inches
Compaction Targets: 92-97%
Technician Name: J. Henault
Testing Company: ConnDOT
Maximum Theoretical Density: 159.6 lb/cu.ft.
Offset: 142 lb/cu.ft.
Slope: 4.93
Mode: Deep
Core Size: 6-inch

Testing:

	PQI Data										Nucl. Gauge Data			Core Data	
Test No.	mV	H20 No.	Temp (F)	PQI Read 1 (lb/cu ft)	PQI Read 2 (lb/cu ft)	PQI Read 3 (lb/cu ft)	PQI Read 4 (lb/cu ft)	PQI Read 5 (lb/cu ft)	PQI Ave. (lb/cu ft)	Corrected PQI Ave. (lb/cu ft)	Nucl. #1 (lb/cu ft)	Nucl. #2 (lb/cu ft)	Nucl. Ave. (lb/cu ft)	Actual Gravity	Actual Density (lb/cu ft)
6	1511	6.2	102.7	159.8	159.6	161.0	160.1	160.9	160.3	152.1	151.3	150.9	151.1		
7	1589	6.9	100.8	160.5	159.6	158.8	158.1	160.2	159.4	151.2	149.4	147.6	148.5	2.396	149.5
8	1502	7.2	100.7	158.9	158.6	157.5	158.6	157.8	158.3	150.1	145.0	142.9	144.0		
9	1554	6.7	96.7	160.4	159.9	160.2	160.1	160.4	160.2	152.0	150.0	150.7	150.4	2.451	152.9
10	1463	6.1	102.1	159.2	159.3	159.4	159.6	159.4	159.4	151.2	148.7	149.7	149.2		
11	1412	5.5	97.3	159.0	159.7	158.9	158.9	158.5	159.0	150.8	147.5	149.2	148.4	2.399	149.7
12	1550	6.6	97.3	160.4	160.2	159.5	160.9	160.5	160.3	152.1	148.6	148.4	148.5		
13	1501	6.6	78.9	160.5	160.0	159.8	160.3	160.2	160.2	152.0	144.2	144.9	144.6	2.361	147.3
14	1489	6.5	96.2	159.5	160.1	160.3	159.5	159.4	159.8	151.6	147.5	147.1	147.3		
15	1569	6.6	99.9	160.5	154.0	156.2	157.0	157.7	157.1	148.9	148.6	149.3	149.0	2.423	151.2
Average									159.4	151.2			148.1		150.1

Calibration Based on Cores:

	PQI Gauge										Nucl. Gauge Data			Core Density	
Test No.	mV	H20 No.	Temp (F)	PQI Read 1 (lb/cu ft)	PQI Read 2 (lb/cu ft)	PQI Read 3 (lb/cu ft)	PQI Read 4 (lb/cu ft)	PQI Read 5 (lb/cu ft)	PQI Ave. (lb/cu ft)	Corrected Average (lb/cu ft)	Nucl. #1 (lb/cu ft)	Nucl. #2 (lb/cu ft)	Nucl. Ave. (lb/cu ft)	Actual Gravity	Actual Density (lb/cu ft)
1	1532	6.2	100.3	160.3	159.5	158.2	159.6	159.2	159.4	151.2	148.7	150.1	149.4	2.425	151.3
2	1538	6.1	101.2	160.5	159.5	160.2	160.1	160.6	160.2	152.0	151.3	151.7	151.5	2.428	151.5
3	1549	6.2	104.3	160.3	160.0	159.9	160.1	159.7	160.0	151.8	149.9	149.8	149.9	2.423	151.2
4	1530	6.0	97.1	160.6	159.8	160.5	160.4	160.7	160.4	152.2	151.1	152.9	152.0	2.448	152.8
5	1550	6.3	98.9	160.6	160.0	159.5	159.7	161.1	160.2	152.0	151.1	151.3	151.2	2.438	152.1
Average									160.0	151.8			150.8		151.8

PQI Calibration Correction = 151.8 - 160.0 = -8.2

Site: 3
State: CT
Route: 20
Town: Barkhamsted
District: 4
Date: 6/1/2000
Project No.: 174-289
Contractor: Galasso
Mix Description: Class 1
Mat Thickness: 3-inch
Compaction Targets: 92-97%
Technician Name: J.Henault
Testing Company: ConnDOT
Maximum Theoretical Density: 163.1 lb/cu.ft.
Offset: 142 lb/cu.ft.
Slope: 4.93
Mode: Deep
Core Size: 6-inch

Testing:

	PQI Data										Nucl. Gauge Data			Core Data	
Test No.	mV	H20 No.	Temp (F)	PQI Read 1 (lb/cu ft)	PQI Read 2 (lb/cu ft)	PQI Read 3 (lb/cu ft)	PQI Read 4 (lb/cu ft)	PQI Read 5 (lb/cu ft)	PQI Ave. (lb/cu ft)	Corrected PQI Ave. (lb/cu ft)	Nucl. #1 (lb/cu ft)	Nucl. #2 (lb/cu ft)	Nucl. Ave. (lb/cu ft)	Actual Gravity	Actual Density (lb/cu ft)
6	1790	9.0	153.2	159.6	159.1	159.6	158.9	160.0	159.4	149.8	150.1	151.5	150.8	2.442	152.4
7	1796	9.1	120.1	161.3	160.2	161.3	160.7	163.0	161.3	151.7	152.6	150.9	151.8	2.444	152.5
8	1621	7.5	143.4	158.4	157.9	156.9	158.2	157.0	157.7	148.1	149.3	150.5	149.9	2.417	150.8
9	1605	7.9	124.3	158.9	157.8	158.4	158.6	159.0	158.5	148.9	148.6	149.0	148.8	2.392	149.3
10	1483	6.5	126.3	158.0	157.6	157.3	157.6	157.7	157.6	148.0	146.0	144.2	145.1	2.358	147.1
11	1420	6.2	136.2	156.7	156.7	156.8	157.2	156.7	156.8	147.2	143.8	146.2	145.0		
12	1541	6.7	146.7	157.7	158.2	157.9	158.5	158.4	158.1	148.5	150.5	151.2	150.9		
13	1586	7.2	151.4	157.7	157.5	157.8	158.2	158.0	157.8	148.2	148.3	149.7	149.0		
14	1659	7.4	146.0	159.1	157.5	158.1	157.6	158.7	158.2	148.6	151.2	152.5	151.9		
15	1616	7.0	147.6	158.6	157.9	158.1	157.8	159.0	158.3	148.7	152.6	154.8	153.7		
Average									158.4	148.8			149.7		150.4

Calibration Based on Cores:

	PQI Gauge										Nucl. Gauge Data			Core Density	
Test No.	mV	H20 No.	Temp (F)	PQI Read 1 (lb/cu ft)	PQI Read 2 (lb/cu ft)	PQI Read 3 (lb/cu ft)	PQI Read 4 (lb/cu ft)	PQI Read 5 (lb/cu ft)	PQI Ave. (lb/cu ft)	Corrected Average (lb/cu ft)	Nucl. #1 (lb/cu ft)	Nucl. #2 (lb/cu ft)	Nucl. Ave. (lb/cu ft)	Actual Gravity	Actual Density (lb/cu ft)
1	1926	10.3	129.3	162.0	161.8	160.3	162.6	160.8	161.5	151.9	151.0	149.0	150.0	2.409	150.3
2	1914	10.1	129.8	161.9	160.8	160.2	161.6	160.0	160.9	151.3	148.8	150.5	149.7	2.427	151.4
3	1791	9.3	140.2	160.0	160.7	159.3	159.6	160.7	160.1	150.5	150.4	150.3	150.4	2.434	151.9
4	1820	9.3	140.1	160.3	159.8	160.3	160.7	160.4	160.3	150.7	150.1	149.6	149.9	2.407	150.2
5	1831	9.4	139.6	160.6	160.3	160.3	159.6	160.1	160.2	150.6	148.7	148.1	148.4	2.42	151.0
Average									160.6	151.0			149.7		151.0

PQI Calibration Correction = 151.0 - 160.6 = -9.6 lb/cu.ft.

Site: 4
State: CT
Route: 73
Town: Waterbury
District: 4
Date: 6/8/2000
Project No.: 174-290K
Contractor: Tilcon
Mix Description: Class 1
Mat Thickness: 2"
Compaction Targets: 92-97%
Technician Name: J.Henault
Testing Company: ConnDOT
Maximum Theoretical Density: 163.7
Offset: 133
Slope: 4.93
Mode: Deep
Core Size: 4"

Testing:

	PQI Data										Nucl. Gauge Data				Core Data	
Test No.	mV	H20 No.	Temp (F)	Cont. Read 1 (lb/cu ft)	Cont. Read 2 (lb/cu ft)	Cont. Read 3 (lb/cu ft)	Cont. Read 4 (lb/cu ft)	Cont. Read 5 (lb/cu ft)	Cont. Ave. (lb/cu ft)	Corrected PQI Ave. (lb/cu ft)	Nucl. #1 (lb/cu ft)	Nucl. #2 (lb/cu ft)	Nucl. Ave. (lb/cu ft)	Corrected Nuc. Ave (lb/cu ft)	Actual Gravity	Actual Density (lb/cu ft)
1	1858	9.0	88.7	154.9	154.6	153.5	154.4	154.2	154.3	157.6	156.9	157.2	157.1	158.2	2.532	158.0
2	1788	8.9	79.1	154.4	153.9	154.1	154.7	153.9	154.2	157.5	156.3	156.3	156.3	157.4	2.472	154.3
3	1930	10.7	80.2	155.3	155.5	154.4	154.4	155.4	155.0	158.3	155.1	154.0	154.6	155.7	2.460	153.5
4	1739	8.9	78.7	153.6	153.9	153.7	153.5	153.1	153.6	156.9	153.3	153.8	153.6	154.7	2.453	153.1
5	1711	8.8	82.3	153.1	153.5	153.1	152.9	153.6	153.2	156.5	151.7	151.8	151.8	152.9	2.435	151.9
6	1829	8.8	123.9	152.6	151.5	152.7	150.9	152.2	152.0	155.3	154.9	154.6	154.8	155.9		
7	1808	8.8	135.2	152.0	151.4	151.7	153.0	152.3	152.1	155.4	157.1	154.3	155.7	156.8		
8	1535	6.9	141.6	148.7	148.5	148.9	149.2	148.7	148.8	152.1	153.1	151.5	152.3	153.4		
9	1725	7.3	139.6	151.5	151.4	151.5	151.2	151.4	151.4	154.7	153.7	155.4	154.6	155.7		
10	1912	10.0	138.7	152.5	152.7	154.2	152.0	153.5	153.0	156.3	153.9	156.9	155.4	156.5		
Average										156.1			154.6	155.7		154.2

Calibration Based on Cores:

	PQI Gauge										Nucl. Gauge Data				Core Density	
Test No.	mV	H20 No.	Temp (F)	Cont. Read 1 (lb/cu ft)	Cont. Read 2 (lb/cu ft)	Cont. Read 3 (lb/cu ft)	Cont. Read 4 (lb/cu ft)	Cont. Read 5 (lb/cu ft)	Cont. Ave. (lb/cu ft)	Corrected Average (lb/cu ft)	Nucl. #1 (lb/cu ft)	Nucl. #2 (lb/cu ft)	Nucl. Ave. (lb/cu ft)	Corrected Nuc. Ave (lb/cu ft)	Actual Gravity	Actual Density (lb/cu ft)
11	1683	7.6	81.6	153.6	152.0	151.8	150.3	150.5	151.6	154.9	155.8	155.2	155.5	156.6	2.506	156.4
12	1648	7.4	82	153.1	152.6	153.8	152.6	152.8	153.0	156.3	153.7	154.6	154.2	155.3	2.520	157.2
13	1653	7.6	82	153.0	153.3	152.4	153.0	152.6	152.9	156.2	152.4	154.9	153.7	154.8	2.502	156.1
14	1690	7.7	81.5	153.6	153.5	152.1	154.0	152.5	153.1	156.4	156.5	156.1	156.3	157.4	2.484	155.0
15	1707	8.1	82.1	153.5	153.3	152.6	152.1	152.5	152.8	156.1	155.7	153.7	154.7	155.8	2.485	155.1
Average									152.7	156.0			154.9	156.0		156.0

PQI Calibration Correction = 156.0 - 152.7 = 3.3 lb/cu.ft.

Site: 5
State: CT
Route: 154
Town: Old Saybrook
District: 2
Date: 6/19/2000
Project No.: 172-320 I
Contractor: Tilcon
Mix Description: Class 1
Mat Thickness: 1.75"
Compaction Targets: 92-97%
Technician Name: J.Henault
Testing Company: ConnDOT
Maximum Theoretical Density: 157.4 lb/cu.ft.
Offset: 133
Slope: 4.93
Mode: Deep
Core Size: 4"

Testing:

	PQI Data										Nucl. Gauge Data				Core Data	
Test No.	mV	H20 No.	Temp (F)	Cont. Read 1 (lb/cu ft)	Cont. Read 2 (lb/cu ft)	Cont. Read 3 (lb/cu ft)	Cont. Read 4 (lb/cu ft)	Cont. Read 5 (lb/cu ft)	Cont. Ave. (lb/cu ft)	Corrected PQI Ave. (lb/cu ft)	Nucl. #1 (lb/cu ft)	Nucl. #2 (lb/cu ft)	Nucl. Ave. (lb/cu ft)	Corrected Nuc. Ave (lb/cu ft)	Actual Gravity	Actual Density (lb/cu ft)
1	1413	7.7	112.6	147.8	147.1	147.7	148.2	148.1	147.8	149.2	154.2	152.7	153.5	154.6		
2	1306	6.5	117.3	146.5	146.3	146.4	146.8	147.2	146.6	148.0	149.3	149.4	149.4	150.5		
3	1222	5.5	122.6	145.6	145.3	145.3	145.7	145.9	145.6	147.0	145.7	148.4	147.1	148.2		
4	1341	7.3	120.5	146.5	145.8	146.4	146.5	146.8	146.4	147.8	151	149.2	150.1	151.2		
5	1255	6.8	122.4	145.4	144.8	144.6	145.2	145.2	145.0	146.4	144.1	145.5	144.8	145.9		
6	1246	6.6	75.1	147.7	146.9	146.9	147.5	147.6	147.3	148.7	149.3	147.0	148.2	149.3	2.412	150.5
7	1307	8.1	75.7	147.6	148.5	147.7	148.2	147.9	148.0	149.4	147.6	147.3	147.5	148.6	2.394	149.4
8	1320	8.6	73.0	148.0	148.2	148.0	147.9	148.4	148.1	149.5	149.1	148.0	148.6	149.7	2.390	149.1
9	1321	9.2	72.1	147.8	147.8	148.4	147.9	147.9	148.0	149.4	148.2	148.3	148.3	149.4	2.364	147.5
10	1335	8.6	73.7	147.8	148.4	148.8	148.4	148.1	148.3	149.7	144.4	143.8	144.1	145.2	2.377	148.3
Average									147.1	148.5			148.1	149.2		149.0

Calibration Based on Cores:

	PQI Gauge										Nucl. Gauge Data				Core Density	
Test No.	mV	H20 No.	Temp (F)	Cont. Read 1 (lb/cu ft)	Cont. Read 2 (lb/cu ft)	Cont. Read 3 (lb/cu ft)	Cont. Read 4 (lb/cu ft)	Cont. Read 5 (lb/cu ft)	Cont. Ave. (lb/cu ft)	Corrected Average (lb/cu ft)	Nucl. #1 (lb/cu ft)	Nucl. #2 (lb/cu ft)	Nucl. Ave. (lb/cu ft)	Corrected Nuc. Ave (lb/cu ft)	Actual Gravity	Actual Density (lb/cu ft)
11	1379	8.5	76.9	148.7	148.5	148.4	148.3	149.2	148.6	150.0	148.8	149.1	149.0	150.1	2.386	148.9
12	1262	7.7	77.0	147.6	147.7	148.4	148.4	147.9	148.0	149.4	147.1	146.8	147.0	148.1	2.394	149.4
13	1331	7.5	77.2	148.5	146.9	147.2	148.4	147.6	147.7	149.1	149.6	149.1	149.4	150.5	2.393	149.3
14	1284	6.9	77.1	148.0	147.6	147.4	147.7	147.2	147.6	149.0	147.7	147.5	147.6	148.7	2.391	149.2
15	1210	6.6	76.4	147.1	147.1	147.6	146.9	147.5	147.2	148.6	147.5	147.3	147.4	148.5	2.395	149.4
Average									147.8	149.2			148.1	149.2		149.2

PQI Calibration Correction = 149.2 - 147.8 = 1.4 lb/cu.ft.

Site 6
State: CT
Route: 117
Town: Groton
District: 2
Date: 6/23/2000
Project No.: 172-230
Contractor: Tilcon
Mix Description: Class 1
Mat Thickness: 1.75"
Compaction Targets: 92-97%
Technician Name: J.Henault
Testing Company: ConnDOT
Maximum Theoretical Density: 158.0 lb/cu.ft.
Offset: 133 lb/cu.ft.
Slope: 4.93
Mode: Deep
Core Size: 4-inch

Testing:

	PQI Data										Nucl. Gauge Data			Core Data	
Test No.	mV	H20 No.	Temp (F)	PQI Read 1 (lb/cu ft)	PQI Read 2 (lb/cu ft)	PQI Read 3 (lb/cu ft)	PQI Read 4 (lb/cu ft)	PQI Read 5 (lb/cu ft)	PQI Ave. (lb/cu ft)	Corrected PQI Ave. (lb/cu ft)	Nucl. #1 (lb/cu ft)	Nucl. #2 (lb/cu ft)	Nucl. Ave. (lb/cu ft)	Actual Gravity	Actual Density (lb/cu ft)
6	1090	5.6	101.9	144.5	144.8	144.5	144.7	144.7	144.6	141.4	140.6	142.4	141.5	2.290	142.9
7	1090	5.2	102.2	144.4	144.5	144.6	144.1	144.6	144.4	141.2	141.1	143.4	142.3		
8	1100	5.3	103.7	144.2	144.3	144.6	144.7	144.6	144.5	141.3	142.5	142.3	142.4	2.322	144.9
9	1083	5.8	104.6	144.1	144.9	144.5	144.4	144.4	144.5	141.3	140.7	141.6	141.2	2.285	142.6
10	1071	5.6	105.2	144.7	144.9	144.8	144.9	144.2	144.7	141.5	142.2	141.9	142.1		
11	1073	6.0	104.0	144.0	144.0	143.8	144.1	144.4	144.1	140.9	140.7	143.3	142.0	2.300	143.5
12	1125	6.8	106.5	144.5	144.7	144.5	144.9	144.4	144.6	141.4	141.2	139.2	140.2	2.303	143.7
22	1003	4.8	119.0	142.7	142.9	143.0	142.7	142.5	142.8	139.6	135.3	136.2	135.8		
19	1063	5.3	112.0	143.7	143.8	144.0	143.9	144.3	143.9	140.7	140.0	138.6	139.3		
Average									144.2	141.0			140.7		143.5

Calibration Based on Cores:

	PQI Gauge										Nucl. Gauge Data			Core Density	
Test No.	mV	H20 No.	Temp (F)	PQI Read 1 (lb/cu ft)	PQI Read 2 (lb/cu ft)	PQI Read 3 (lb/cu ft)	PQI Read 4 (lb/cu ft)	PQI Read 5 (lb/cu ft)	PQI Ave. (lb/cu ft)	Corrected Average (lb/cu ft)	Nucl. #1 (lb/cu ft)	Nucl. #2 (lb/cu ft)	Nucl. Ave. (lb/cu ft)	Actual Gravity	Actual Density (lb/cu ft)
20	1038	5.0	108.1	143.6	144.3	143.9	143.4	143.5	143.7	140.5	139.9	138.9	139.4	2.271	141.7
21	1049	5.0	114.1	143.5	143.7	143.7	143.3	143.6	143.6	140.4	140.7	142.1	141.4	2.274	141.9
18	1088	5.1	121.6	144.2	143.6	144.0	144.1	144.1	144.0	140.8	143.0	140.6	141.8	2.281	142.3
23	1038	4.8	117.4	143.2	143.2	143.1	143.1	143.0	143.1	139.9	137.1	137.8	137.5	2.225	138.8
24	985	4.7	117.3	142.5	142.7	143.2	142.7	143.4	142.9	139.7	135.3	135.9	135.6	2.189	136.6
Average									143.5	140.3			139.1		140.3

PQI Calibration Correction: 140.3 - 143.5 = -3.2 lb/cu.ft.

Site: 7
State: CT
Route: 172
Town: Southbury
District: 4
Date: 7/12/2000
Project No.: 174-290D
Contractor: O & G
Mix Description: Class 1
Mat Thickness: 2"
Compaction Targets: 92-97%
Technician Name: J.Henault
Testing Company: ConnDOT
Maximum Theoretical Density: 160.8 lb/cu.ft.
Offset: 133 lb/cu.ft.
Slope: 4.93
Mode: Deep
Core Size: 6-inches

Testing:

	PQI Data										Nucl. Gauge Data				Core Data	
Test No.	mV	H20 No.	Temp (F)	PQI Read 1 (lb/cu ft)	PQI Read 2 (lb/cu ft)	PQI Read 3 (lb/cu ft)	PQI Read 4 (lb/cu ft)	PQI Read 5 (lb/cu ft)	PQI Ave. (lb/cu ft)	Corrected PQI Ave. (lb/cu ft)	Nucl. #1 (lb/cu ft)	Nucl. #2 (lb/cu ft)	Nucl. Ave. (lb/cu ft)	Corrected Nuc. Ave (lb/cu ft)	Actual Gravity	Actual Density (lb/cu ft)
6	1806	8.2	111.5	152.4	151.9	152.2	152.1	152.6	152.2	144.9	150.7	150.5	150.6	146.2	2.379	148.4
7	1934	9.6	113.7	153.5	153.1	152.9	153.0	153.2	153.1	145.8	149.0	148.3	148.7	144.3	2.364	147.5
8	1789	9.0	120.7	151.5	152.3	150.7	152.2	151.6	151.7	144.4	146.2	146.9	146.6	142.2	2.379	148.4
9	1878	9.2	122.4	152.6	151.7	151.4	151.8	152.2	151.9	144.6	147.4	146.3	146.9	142.5	2.393	149.3
10	1900	9.6	121.7	152.5	151.1	152.0	152.4	152.4	152.1	144.8	148.3	148.5	148.4	144.0	2.390	149.1
11	1904	9.5	122.8	152.7	152.1	151.9	153.2	151.7	152.3	145.0	150.9	151.4	151.2	146.8		
12	1872	9.2	130.2	151.9	151.3	152.0	151.9	152.4	151.9	144.6	148.6	150.0	149.3	144.9		
13	1904	9.4	119.4	152.9	151.9	152.5	151.9	153.1	152.5	145.2	152.3	152.0	152.2	147.8		
14	1892	9.0	131.0	152.3	152.1	151.6	151.5	152.6	152.0	144.7	150.8	149.6	150.2	145.8		
15	1940	9.6	128.4	152.8	152.6	152.6	152.9	152.8	152.7	145.4	152.4	152.1	152.3	147.9		
Average									152.3	145.0			149.6	145.2		148.6

Calibration Based on Cores:

	PQI Gauge										Nucl. Gauge Data				Core Density	
Test No.	mV	H20 No.	Temp (F)	PQI Read 1 (lb/cu ft)	PQI Read 2 (lb/cu ft)	PQI Read 3 (lb/cu ft)	PQI Read 4 (lb/cu ft)	PQI Read 5 (lb/cu ft)	PQI Ave. (lb/cu ft)	Corrected Average (lb/cu ft)	Nucl. #1 (lb/cu ft)	Nucl. #2 (lb/cu ft)	Nucl. Ave. (lb/cu ft)	Corrected Nuc. Ave (lb/cu ft)	Actual Gravity	Actual Density (lb/cu ft)
1	1897	9.4	133.1	152.1	151.6	151.8	152.3	152.9	152.1	144.8	150.7	151.2	151.0	146.6	2.350	146.6
2	1977	10.0	133.7	152.9	153.4	152.8	153.4	152.3	153.0	145.7	143.7	144.1	143.9	139.5	2.319	144.7
3	2028	9.7	150.5	152.8	152.1	149.3	150.4	148.0	150.5	143.2	152.1	153.0	152.6	148.2	2.293	143.1
4	1996	9.9	145.3	152.7	154.3	150.3	154.6	151.2	152.6	145.3	150.4	150.3	150.4	146.0	2.321	144.8
5	1933	9.6	138.6	153.2	153.1	154.2	153.1	152.8	153.3	146.0	148.3	150.5	149.4	145.0	2.333	145.6
Average									152.3	145.0			149.4	145.0		145.0

PQI Calibration Correction = 145.0 - 152.3 = -7.3

Site: 8
State: CT
Route: 72
Town: Bristol
District: 1
Date: 7/18/2000
Project No.: 171-290I
Contractor: Tilcon
Mix Description: Class 1
Mat Thickness: 2.5"
Compaction Targets: 92-97%
Technician Name: J.Henault
Testing Company: ConnDOT
Maximum Theoretical Density = 163.4 lb/cu.ft.
Offset = 133 lb/cu.ft.
Slope = 4.93
Mode = Deep
Core Size: 6-inches

Testing:

	PQI Data										Nucl. Gauge Data			Core Data	
Test No.	mV	H20 No.	Temp (F)	PQI Read 1 (lb/cu ft)	PQI Read 2 (lb/cu ft)	PQI Read 3 (lb/cu ft)	PQI Read 4 (lb/cu ft)	PQI Read 5 (lb/cu ft)	PQI Ave. (lb/cu ft)	Corrected PQI Ave. (lb/cu ft)	Nucl. #1 (lb/cu ft)	Nucl. #2 (lb/cu ft)	Nucl. Ave. (lb/cu ft)	Actual Gravity	Actual Density (lb/cu ft)
6	1542	6.6	117.1	150.3	150.4	150.1	148.3	149.7	149.8	152.7	154.6	155.4	155.0	2.447	152.7
7	1533	6.6	118.8	150.0	150.7	150.0	150.4	150.2	150.3	153.2	153.5	154.0	153.8	2.468	154.0
8	1557	6.9	126.8	149.8	150.3	149.1	149.9	149.8	149.8	152.7	153.4	154.3	153.9	2.440	152.3
9	1593	7.0	133.6	149.9	149.4	149.7	147.5	149.6	149.2	152.1	154.0	152.4	153.2	2.429	151.6
10	1594	6.8	120.9	150.7	150.3	149.8	150.5	150.6	150.4	153.3	156.5	154.6	155.6	2.462	153.6
11	1679	7.3	129.8	151.1	150.3	150.4	150.5	151.1	150.7	153.6	158.1	158.3	158.2		
12	1604	7.1	140.0	149.6	149.2	148.9	149.4	149.3	149.3	152.2	154.8	153.2	154.0		
13	1612	7.4	137.0	149.7	149.7	149.7	149.7	149.6	149.7	152.6	153.3	151.6	152.5		
14	1565	7.1	141.8	149.0	149.2	148.5	149.4	149.2	149.1	152.0	151.7	151.7	151.7		
15	1577	7.4	142.6	148.9	149.0	148.3	149.4	149.3	149.0	151.9	152.1	152.1	152.1		
Average									149.7	152.6			154.0		152.8

Calibration Based on Cores:

	PQI Gauge										Nucl. Gauge Data			Core Density	
Test No.	mV	H20 No.	Temp (F)	PQI Read 1 (lb/cu ft)	PQI Read 2 (lb/cu ft)	PQI Read 3 (lb/cu ft)	PQI Read 4 (lb/cu ft)	PQI Read 5 (lb/cu ft)	PQI Ave. (lb/cu ft)	Corrected Average (lb/cu ft)	Nucl. #1 (lb/cu ft)	Nucl. #2 (lb/cu ft)	Nucl. Ave. (lb/cu ft)	Actual Gravity	Actual Density (lb/cu ft)
1	1538	6.6	111.7	150.5	150.4	149.6	149.6	149.2	149.9	152.8	151.8	153.7	152.8	2.456	153.3
2	1563	6.8	111.0	150.8	150.6	150.2	150.7	149.8	150.4	153.3	153.1	154.1	153.6	2.459	153.4
3	1591	6.8	119.4	150.6	149.9	150.5	150.4	150.9	150.5	153.4	154.4	152.7	153.6	2.444	152.5
4	1561	6.8	111.8	150.7	149.9	149.6	149.8	150.6	150.1	153.0	153.3	152.9	153.1	2.440	152.3
5	1426	6.3	113.5	149.2	149.6	150.3	150.9	150.7	150.1	153.0	154.1	154.8	154.5	2.466	153.9
Average									150.2	153.1			153.5		153.1

PQI Calibration Correction = 153.1 -150.2 = 2.9 lb/cu.ft.

Site: 9
State: CT
Route: 84
Town: Plainville
District: 1
Date: 9/13/2000
Project No.: 109-150
Contractor: Tilcon
Mix Description: Superpave
Mat Thickness: 2"
Compaction Targets: 92-97%
Technician Name: J.Henault
Testing Company: ConnDOT
Maximum Theoretical Density:
Offset: 133 lb/cu.ft.
Slope = 4.93
Mode: Deep
Core Size: 4-inches

Testing:

	PQI Data										Nucl. Gauge Data				Core Data	
Test No.	mV	H20 No.	Temp (F)	PQI Read 1 (lb/cu ft)	PQI Read 2 (lb/cu ft)	PQI Read 3 (lb/cu ft)	PQI Read 4 (lb/cu ft)	PQI Read 5 (lb/cu ft)	PQI Ave. (lb/cu ft)	Corrected PQI Ave. (lb/cu ft)	Nucl. #1 (lb/cu ft)	Nucl. #2 (lb/cu ft)	Nucl. Ave. (lb/cu ft)	Corrected Nuc. Ave (lb/cu ft)	Actual Gravity	Actual Density (lb/cu ft)
6	2072	13.5	80.3	155.6	156.4	158.7	158.1	159.3	157.6	151.8	148.4	147.8	148.1	148.9	2.378	148.4
7	1963	10.6	85.9	154.7	154.2	154.0	153.7	154.7	154.3	148.5	151.4	152.4	151.9	152.7	2.439	152.2
8	1849	10.2	84.6	154.7	154.7	154.1	154.8	154.7	154.6	148.8	152.3	151.4	151.9	152.7	2.436	152.0
9	1871	9.4	87.9	153.5	154.2	153.6	153.9	153.9	153.8	148.0	156.5	157.7	157.1	157.9	2.509	156.6
10	1899	10.1	87.7	154.0	153.1	153.1	154.3	152.3	153.4	147.6	154.4	153.7	154.1	154.9	2.472	154.3
11	1927	9.9	84.4	154.7	155.1	154.6	154.7	155.5	154.9	149.1	156.3	155.1	155.7	156.5		
12	1813	10.1	88.6	153.0	152.9	152.4	153.4	152.9	152.9	147.1	150.4	149.3	149.9	150.7		
13	2054	11.6	90.1	155.4	154.7	154.9	155.7	154.7	155.1	149.3	154.3	154.6	154.5	155.3		
14	1889	9.8	90.9	153.9	154.2	152.7	154.2	153.4	153.7	147.9	155.9	152.3	154.1	154.9		
15	1895	9.2	91.9	154.2	154.0	153.9	154.0	154.2	154.1	148.3	156.3	158.0	157.2	158.0		
Average									154.4	148.6			153.4	154.2		152.7

Calibration Based on Cores:

	PQI Gauge										Nucl. Gauge Data				Core Density	
Test No.	mV	H20 No.	Temp (F)	PQI Read 1 (lb/cu ft)	PQI Read 2 (lb/cu ft)	PQI Read 3 (lb/cu ft)	PQI Read 4 (lb/cu ft)	PQI Read 5 (lb/cu ft)	PQI Ave. (lb/cu ft)	Corrected Average (lb/cu ft)	Nucl. #1 (lb/cu ft)	Nucl. #2 (lb/cu ft)	Nucl. Ave. (lb/cu ft)	Corrected Nuc. Ave (lb/cu ft)	Actual Gravity	Actual Density (lb/cu ft)
1	1983	13.1	79.3	154.6	154.6	153.0	153.1	154.9	154.0	148.2	146.9	148.3	147.6	148.4	2.362	147.4
2	2314	16.2	78.9	157.8	157.2	157.4	157.1	157.2	157.3	151.5	148.6	148.2	148.4	149.2	2.387	148.9
3	1974	11.7	80.4	154.8	153.4	153.6	153.9	153.0	153.7	147.9	147.4	148.4	147.9	148.7	2.395	149.4
4	2043	12.7	78.4	155.5	157.1	156.9	155.9	156.3	156.3	150.5	148.1	147.3	147.7	148.5	2.393	149.3
5	2128	13.1	78.8	156.4	156.4	156.7	156.9	156.9	156.7	150.9	154.4	152.7	153.6	154.4	2.466	153.9
Average									155.6	149.8			149.0	149.8		149.8

PQI Calibration Correction = 149.8 - 155.6 = 5.8 lb/cu.ft.

Site: 10
State: CT
Route: 99
Town: Rocky Hill
District: 1
Date: 9/29/2000
Project No.: 171-289
Contractor: Tilcon
Mix Description: Class 1
Mat Thickness: 2"
Compaction Targets: 92-97%
Technician Name: J.Henault
Testing Company: ConnDOT
Maximum Theoretical Density: 153.9 lb/cu.ft.
Offset = 133 lb/cu.ft.
Slope = 4.93
Mode: Deep
Core Size: 4-inches

Testing:

	PQI Data										Nucl. Gauge Data			Core Data	
Test No.	mV	H20 No.	Temp (F)	PQI Read 1 (lb/cu ft)	PQI Read 2 (lb/cu ft)	PQI Read 3 (lb/cu ft)	PQI Read 4 (lb/cu ft)	PQI Read 5 (lb/cu ft)	PQI Ave. (lb/cu ft)	Corrected PQI Ave. (lb/cu ft)	Nucl. #1 (lb/cu ft)	Nucl. #2 (lb/cu ft)	Nucl. Ave. (lb/cu ft)	Actual Gravity	Actual Density (lb/cu ft)
6	1489	9.5	76.1	149.8	151.8	150.6	151.7	149.9	150.8	142.8	136.1	136.2	136.2	2.245	140.1
7	1907	10.9	106.5	153.7	154.6	153.7	154.9	153.5	154.1	146.1	150.1	150.2	150.2	2.338	145.9
8	1667	10.7	99.6	150.7	151.3	151.8	151.9	151.1	151.4	143.4	135.4	136.0	135.7	2.209	137.8
9	1668	10.7	100.8	150.7	150.9	152.6	150.1	151.0	151.1	143.1	138.8	138.5	138.7	2.241	139.8
10	1931	10.8	90.6	154.8	153.6	153.1	153.2	154.1	153.8	145.8	149.3	150.1	149.7	2.384	148.8
11	2052	12.6	159.1	154.9	154.7	153.8	156.3	156.2	155.2	147.2	147.7	146.7	147.2		
12	1941	10.6	179.6	150.5	152.8	152.1	153.9	151.6	152.2	144.2	152.4	152.8	152.6		
13	1583	10.4	162.9	151.4	152.7	154.4	152.5	151.7	152.5	144.5	146.9	145.5	146.2		
14	1529	9.8	167.9	150.3	151.8	155.4	153.1	151.9	152.5	144.5	147.8	148.5	148.2		
15	1890	12.1	185.4	155.4	156.0	156.3	154.8	156.3	155.8	147.8	149.1	150.3	149.7		
Average									152.9	144.9			145.4		142.5

Calibration Based on Cores:

	PQI Gauge										Nucl. Gauge Data			Core Density	
Test No.	mV	H20 No.	Temp (F)	PQI Read 1 (lb/cu ft)	PQI Read 2 (lb/cu ft)	PQI Read 3 (lb/cu ft)	PQI Read 4 (lb/cu ft)	PQI Read 5 (lb/cu ft)	PQI Ave. (lb/cu ft)	Corrected Average (lb/cu ft)	Nucl. #1 (lb/cu ft)	Nucl. #2 (lb/cu ft)	Nucl. Ave. (lb/cu ft)	Actual Gravity	Actual Density (lb/cu ft)
1	1956	11.3	106.1	154.1	153.0	154.1	154.2	154.4	154.0	146.0	150.9	150.9	150.9	2.388	149.0
2	2003	12.2	108.2	154.3	153.9	154.9	154.2	155.3	154.5	146.5	149.9	148.3	149.1	2.394	149.4
3	2035	12.0	90.1	155.6	156.2	155.2	155.8	155.5	155.7	147.7	151.4	150.9	151.2	2.324	145.0
4	1837	10.7	82.9	153.9	155.2	154.9	155.0	154.1	154.6	146.6	151.4	149.7	150.6	2.362	147.4
5	1860	10.9	79.1	154.3	154.6	152.8	154.7	153.9	154.1	146.1	146.8	146.3	146.6	2.275	142.0
Average									154.6	146.6			149.7		146.6

PQI Calibration Correction = 146.6 - 154.6 = -8.0

Appendix B

6.29 METHOD OF FIELD TESTING THE IN-PLACE DENSITY OF BITUNINOUS CONCRETE

Scope

This method covers the determination of the in-place density of bituminous concrete by gamma radiation using backscatter methods. The nuclear density is used to ensure that Bituminous Concrete density requirements for acceptance and payment purposes are met.

Sampling

Field Test Site Selection:

1. Select a repetitive feature located in the day's testing area, such as utility poles, to use as a suitable marker. Determine the number of markers present and divide it by the number of tests to be performed. For example, if there are 30 utility poles in the test area and 10 tests are to be taken, then the longitudinal test site location will be 30 divided by 10 resulting in one test at every third pole. All offsets of transverse measurements will be measured from the left edge of the pavement in the direction of paving. Using a random number chart, select any column of numbers. The first two digits of a random number will be used to determine the offset. Select the first random number in which the first two digits are less than the width of the pavement but greater than 0 (e.g., if pavement width is 4.3 m, first random number is .013, then the offset will be 0.1 m) . If the first two digits in the random number chosen are greater than the width of the pavement, disregard that number and move to the next one (e.g., if pavement width is 4.3 m and first random number is .930, then you disregard the .930 and move to the next number).

2. On-site selection for longitudinal joint offset calculations are not needed.

3. Distances to test sites may be approximated by pacing.

4. Optional method for selection of test sites may be in accordance with ASTM D 3665, Section 4.3 and 5.82.

Procedure

1. Field Testing:

   Field testing shall be in accordance with ASTM D 2950, amended as follows:

   1.1 For thick-lift bituminous concrete overlays of 63 mm or greater in depth, testing shall be performed using the testing position recommended by the manufacturer such that 90 percent of a single reading will be affected by the top 80 mm to 100 mm of material.

   1.2 For thin-lift bituminous concrete overlays 40 mm to 63 mm, the testing shall be performed using the testing position recommended by the manufacturer such that 90 percent of a single reading will be affected by the top 50 mm of material.

1.3 For all tests, each test location will have two readings taken at 90-degree angles to each other (rotated around the center of the gauge). The density value reported will be the average of the two readings.

2. Longitudinal Joint:

The test shall consist of two readings. The edge of the gauge shall be placed parallel along the longitudinal joint, which puts the gauge source rod approximately 150 mm from the joint. From this position, the first reading shall be taken. The second reading shall be taken after rotating the gauge 180 degrees.

The density results obtained by these methods shall be based on the average of the last ten tests from the source of supply (performed in accordance with AASHTO T 209). When the average value of the day's testing results approaches the specification limits, the average theoretical gravity from the same day's production shall be used in the computations.

3. The procedure for accuracy determination shall be as follows:

3.1 For gauges designed for taking a 4-minute count: two 4-minute counts (at 90-degree angles to each other, rotated about the center point of the gauge) shall be performed on a 2635 kg/cu.m pcf standard block.

3.2 For gauges having a maximum 1-minute test count: ten 1-minute counts will be obtained (five to be at a 90-degree angle to the first five 1-minute counts, rotated around the center of the gauge) on the 2635 kg/cu.m standard block.

3.3 The accuracy of the nuclear gauges shall be determined each year before the paving season. Determinations shall be made using a 2635 kg/cu.m standard: The State reserves the right to require accuracy measurements when there is evidence to suggest the source or the device is inaccurate.

3.3.1 When the source is located in the thick-lift position, test on the standard shall be ± 16 kg/cu.m of the standard 2635 kg/cu.m.

3.3.2 When the source is located in the thin-lift position, test on the standard shall be ± 24 kg/cu.m of the standard 2635 kg/cu.m.

3.3.3 If a gauge does not meet the accuracy requirements of Section 9.1.1 and 9.1.2, its chart of its bias shall be adjusted.

Specification

1. For field test density: See Standard Specifications Article M.06.04.

2. The longitudinal joint density requirement shall be applied to all construction and resurfacing projects where the compacted depth is a minimum of 40 mm and the total tonnage for the day is a minimum of 275 metric tons. The density for the longitudinal joint shall be compacted

to a minimum of 90 percent and a maximum of 97 percent of the theoretical density.

Report

Testing data shall be reported on Connecticut Department of Transportation Form CON-133, or on a form approved by the Director of Research and Materials, Division of Materials Testing.