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IDEA

Innovations Deserving Exploratory Analysis Project

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Report of Investigation

IDEA PROJECT FINAL REPORT
Contract NCHRP-47

IDEA Program
Transportation Research Board
National Research Council

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Pavement Quality Indicator
Field Operational Testing
and Product Transfer

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INNOVATIONS DESERVING EXPLORATORY ANALYSIS (IDEA) PROGRAMS
MANAGED BY THE TRANSPORTATION RESEARCH BOARD (TRB)

This NCHRP-IDEA investigation was completed as part of the National Cooperative Highway Research Program (NCHRP). The NCHRP-IDEA program is one of the four IDEA programs managed by the Transportation Research Board (TRB) to foster innovations in highway and intermodal surface transportation systems. The other three IDEA program areas are Transit-IDEA, which focuses on products and results for transit practice, in support of the Transit Cooperative Research Program (TCRP), Safety-IDEA, which focuses on motor carrier safety practice, in support of the Federal Motor Carrier Safety Administration and Federal Railroad Administration, and High Speed Rail-IDEA (HSR), which focuses on products and results for high speed rail practice, in support of the Federal Railroad Administration. The four IDEA program areas are integrated to promote the development and testing of nontraditional and innovative concepts, methods, and technologies for surface transportation systems.

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CONTENTS

SUMMARY 1

IDEA PROJECT 3

RESULTS 4

- Stage 1 Results 4
- Stage 2 Results 6
- Stage 3 Results 7
- Post Project Accomplishmlents 8

CHALLENGES 9

CONCLUSIONS 10

APPENDICES 13

- Appendix 1: Sample Test Procedure 14
- Appendix 2: Test Results 15
- Appendix 3: Test Strip Specifications 24
- Appendix 4: TransTech Systems's Pavement Quality Indicator Specs 26
- Appendix 5: Post-Project Test Results and Publicity 27

SUMMARY

Density of the hot mix asphalt is the most important construction variable in the durability of asphalt pavement surfaces. The current methods of measuring asphalt pavement density today have their limitations. Destructive core samples and laboratory measurement are time consuming and costly. Useful information does not reach the paving crew in time to make any corrections to the paving process. The alternative, nuclear instruments require strict licensing and usage procedures, take several minutes to get data, and have limitations in their accuracy, particularly for thin layers.

The Pavement Quality Indicator (PQI) developed in this IDEA project, NCHRP-47 and its predecessor project NCHRP-32, has been demonstrated to be a viable product for making real time measurements of asphalt pavement density in a non-destructive, non-nuclear format. The resulting product has several significant advantages over nuclear measurement instruments currently used for non-destructive asphalt density measurements. The electrically-based PQI is light weight and very easy to use. No licensing processes are required. Virtually any member of the paving crew or department of transportation can easily operate the Pavement Quality Indicator with little training. Pavement readings are instantaneous and data can be electronically transferred to a computer for processing. Field tests have demonstrated that the accuracy and repeatability of the PQI's density measurements meet or exceeds those of nuclear instruments.

The project has verified and debugged the prototype design through an intense "beta" type field test by selected high profile users in actual field usage. This process will help assure that the product that is initially introduced into the market place is of proven quality and performance. The use of this type of product verification process allows for the introduction of larger numbers of product at the initial launch due to reduced concerns of recalls or reworks that are often seen in newly released products. The results have demonstrated that the current prototype design is capable of making the critical density measurements required in the road construction industry with special features unavailable in competitive products.

TransTech's pavement quality indicator for measurement of asphalt density and compaction levels is based on a unique measurement technique for which TransTech has a pending patent. TransTech's technique is based on a constant current, low frequency, electrical impedance sensing approach. The approach is based on an innovative, toroidal electrical sensing field, which is established in the measured material by a flat sensing plate, which is placed on the surface of the measured material. Figure 1 shows a cross section of the sensing plate and sensing field.

Bulk density, or compaction level, is measured by the response of the TransTech electrical sensing field to changes in electrical impedance of the material matrix, which in turn is a function of the composite resistivity and dielectric constant of the material. Since varying matrix elements have different resistivities and dielectric properties, the unit is first calibrated to the material being measured. Once calibrated, direct measurement of density or compaction level variances may be made.

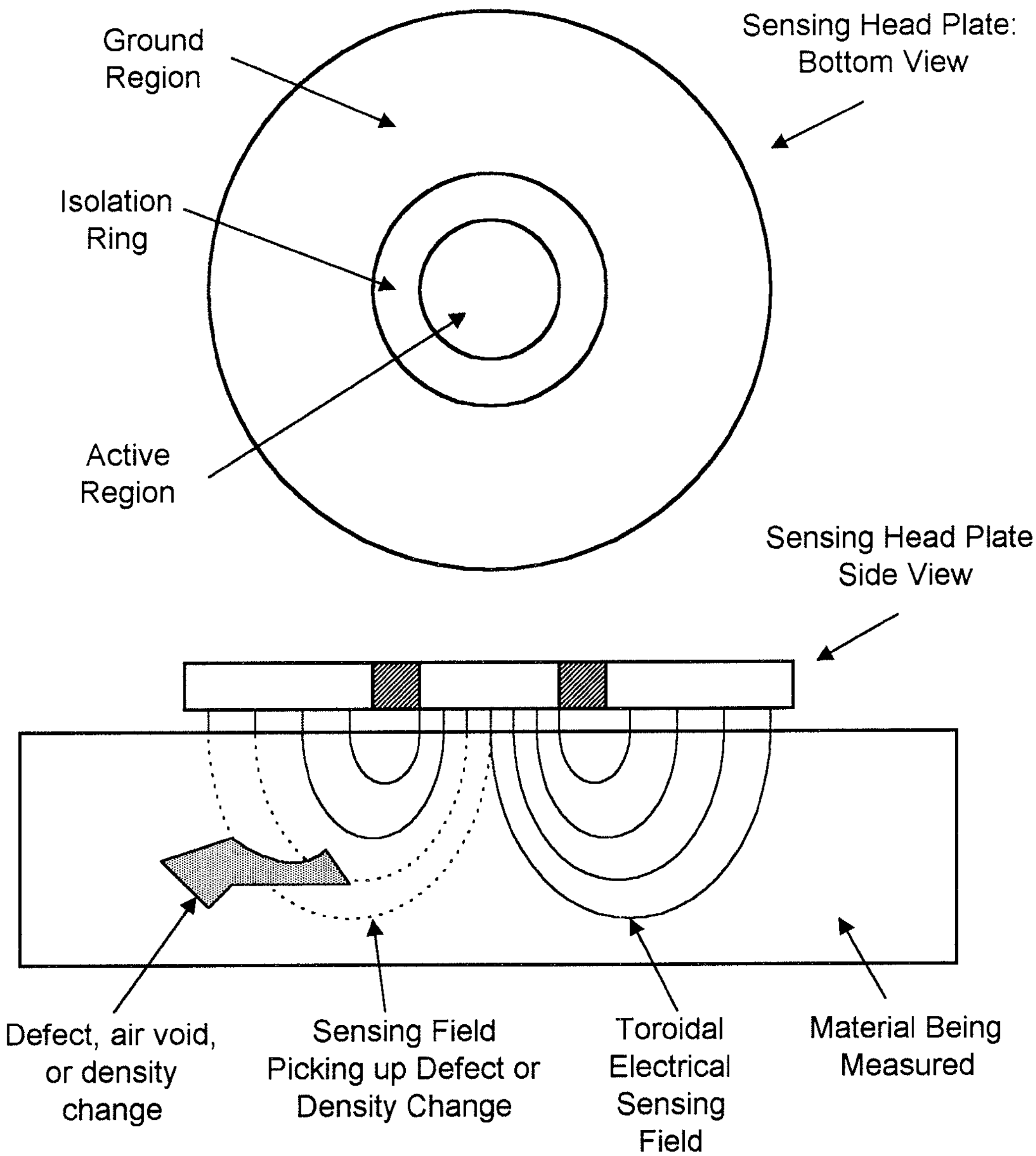


Figure 1. Simplified Concept Schematic of TransTech's PQI

The market potential for this product as a portable asphalt density measurement instrument is estimated to be over $100 million. Survey work indicates that the demand for this type of product is very high. Virtually all participants interviewed in the survey including contractors, state department of transportation officials, Federal Highway Administration officials, and testing services expressed high interest levels in the product and in obtaining one for use. The ability of the Pavement Quality Indicator to instantaneously read asphalt pavement density creates a cost effective opportunity to dramatically increase the number of density readings taken on the highway and provide real time feedback to the paving crew for timely corrective action.

THE PROJECT

IDEA Project NCHRP-47 represents the final phase of development and testing of TransTech's Pavement Quality Indicator. The project builds upon the successful accomplishments of a prior IDEA Project, NCHRP-32. The overall development and test effort, in addition to IDEA program sponsorship, has been co-funded by TransTech Systems, Inc., the New York State Energy Research and Development Authority (NYSERDA), and the U.S. Army Corps of Engineers Waterways Experiment Station (WES).

The recently completed phase of work under NCHRP-47 was divided into three distinct stages. The objectives of each of the three stages is described below.

Stage 1: Based on field data collected from trial tests, design upgrades to the system for pre-production operations testing. Establish the technical validity of the system in terms of electrical parameters measured and indicator levels derived for pavement quality. Develop information to optimize design configuration and corrections, if any, taking into consideration site and local variations in mix designs during paving operations. Construct at least 10 pre-production units ready for field trials. Convene the regional panel of experts to discuss issues on technical validity and reliability and evaluate project plans for field operational tests.

Stage 2: Perform field operational tests in at least 6 job sites. Analyze data and review results Revise product design and specifications to meet commercial standards. Convene a regional panel of experts to discuss findings and strategies for marketing.

Stage 3: Develop and implement strategies for transfer of the pavement quality indicator system to pavement practice. Develop and implement plans for establishing manufacturing sources.

Key results of this phase of the project, challenges which were encountered and met, and final conclusions are each detailed in the remainder of this report

RESULTS

Stage 1 Project Results

The following is a summary of the main accomplishments achieved in the first stage of the project:

- Measurement and indicator information was established.
- Numerous design changes were made to improve performance.
- Ten pre-production units were built.
- The regional panel of experts reviewed the design concepts and the test plan.
- Five controlled test asphalt mats with varying density sections were constructed and verification testing conducted.

During this project stage, it was determined that measurements must be made in density as pounds per cubic foot and in percent of compaction compared with the maximum theoretical density (determined during formulation). The range of reading requirements was established and the electrical to density relationships established based upon the data developed from previous testing. A calibration procedure was developed for initial start up on asphalt.

Design changes included the addition of a micro processor to perform the necessary mathematical calculations and to store data collected for future analysis. A key pad was added for input requirements. The sensing probe was redesigned for increased accuracy and a seven point averaging procedure was established which also increased accuracy. A battery power selection was made that exceeded daily operational time requirements. Several styling alternatives were reviewed that emphasized ease of use and field durability. A mobile, wheel-mounted unit was designed and considered for production, but later dropped based on user input.

A total of 10 pre-production units were produced. Figure 2 is a photograph of one of the prototype units.

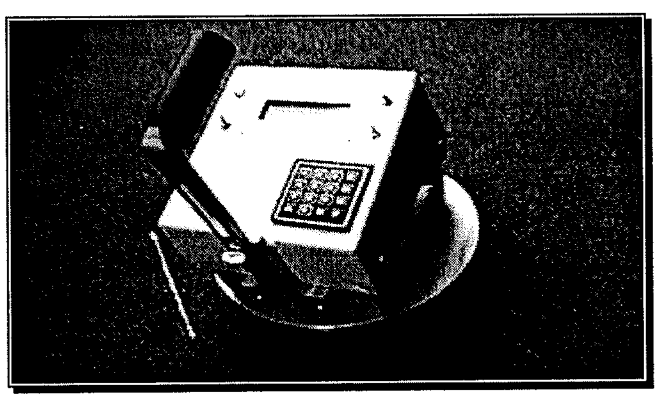


Figure 2 Prototype Pavement Quality Indicator Unit

A series of five 100 foot test strips were placed with a commercial paver and roller in an adjacent parking lot, as shown in Figures 3 through 5. The asphalt mixes consisted of type 6F, type 7F, P401 (airport mix), type 6FR, type 3RA (binder). The rolling pattern was established to provide strips of varying density not available on highway jobs. The strips were then measured with the nuclear gauge, then the PQI and a core sample taken at the measured location. Data was analyzed and used to establish the calibration procedure. Further measurements were taken to refine the calibration procedure as well as verify changes in the probe and circuit design.

A presentation of the unit and the data results was made to New York State Department of Transportation which included members of a panel of experts. NYDOT personal visited the asphalt test mat site and reviewed the data taken. The test procedure for the first field testing to be done in New York was reviewed by NYDOT members and approved.

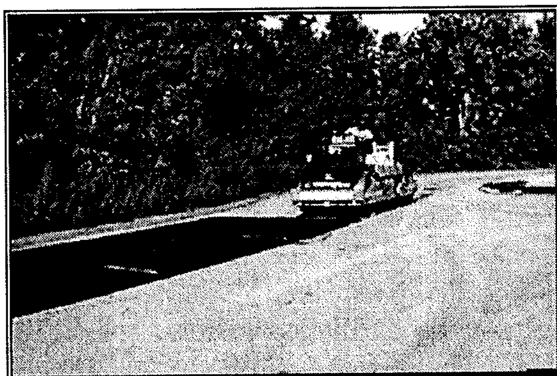


Figure 3. PQI Test Strip Under Construction

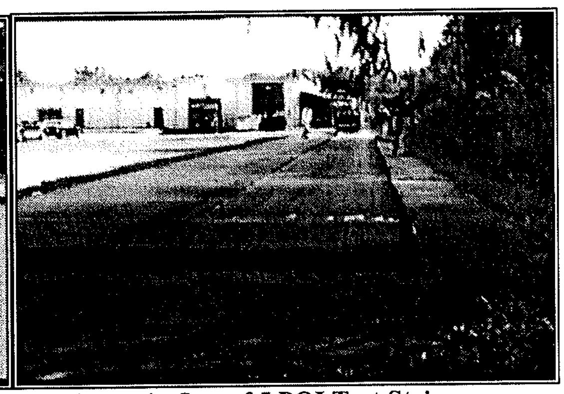


Figure 4. One of 5 PQI Test Strips

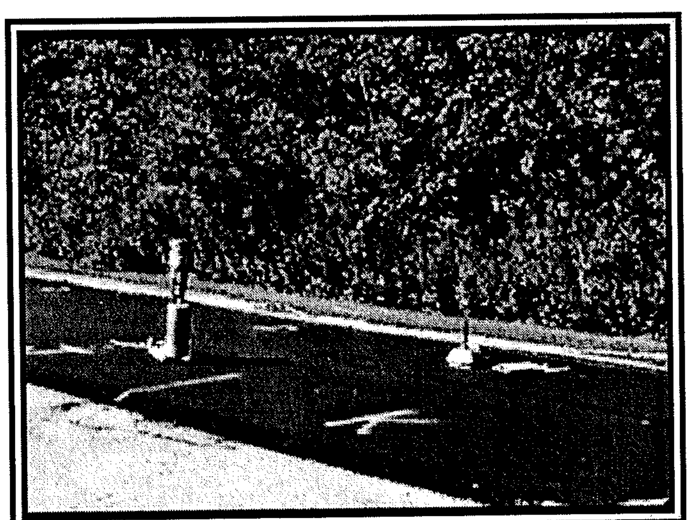


Figure 5. Testing Activity at Test Strip

Stage 2 Project Results

The following is a summary of the main accomplishments in the second stage of the project:

- Field operational testing was performed at 8 different sites.
- Data from each test was analyzed .
- Revisions were made to the product design.
- the regional panel of experts reviewed the test data and proposed design changes.

Eight field tests were conducted on varying types of asphalt pavement and aggregate including Superpave asphalt.

1. RT # 44 - Poughkeepsie, NY
2. Schenectady County Airport
3. RT#9W - Storm King Mountain, NY
4. Bangor Airport - Maine
5. RT#3 - Bar Harbor, Maine
6. Palisades Parkway - NJ
7. I-287- NJ
8. I-95 North - Melborne, Florida

More than 103 combined data points were taken at these locations. Valuable information was obtained from the users at each site that was used to improve the design or the features of the commercial product. The addition of a lighted display for night operation is one example.

As a representative example, the test procedure for the first test on RT#44 in Poughkeepsie, NY is contained in Appendix 1. Data taken at each site consisted of 4 or more nuclear gauge readings at the same pavement location averaged (this followed standard state DOT procedures), a series of PQI readings at the same location, followed by a core sample of the pavement measured. At certain locations, additional nuclear and PQI readings were taken without core samples. This was due to the time and logistical limitations of the coring process. Tabular results for each of the test sites are included in Appendix 2.

Revisions were made to the design including the addition of optional metric readings, a night lighted display, and a redesigned sensor probe to increase the area being measured.
Two different handle designs were tried during the test and a selection made based upon the field testing and user input. Each design change has been prototyped and tested.

The data analysis and summary were reviewed by the regional panel of asphalt experts. Some of them visited the site during testing .

Stage 3 Project Results

Summary accomplishments of the third phase of the project included:

- Preproduction Design Optimization and Debugging
- Manufacturing Design
- Field Verification/Additional Manufacturing Run

Each is described in more detail below.

Preproduction Design Optimization and Debugging

The pre-production design of the Pavement Quality Indicator was subjected to 3 separate field tests to debug unit operation and investigate the following operational parameters in greater detail under field conditions:

1. Temperature sensitivity of unit
2. Impact of moisture on measurements
3. Depth range of measurements
4. General operational feedback from a wide range of field conditions

As a result of these tests, the PQI design was improved through the following modifications:

- Modified the physical design of the sensing probe
- Added averaging capability to the unit's microprocessor logic
- Added a backlit readout screen for operation in conditions of darkness/dim lighting
- Added further calibration capabilities to the unit's microprocessor controls

Manufacturing Design

Specific manufacturing design issues were also addressed in this time period in anticipation of near-term volume production requirements. These included:

- Sensing probe manufacturing and assembly design and manufacturing procedures
- Unit paint and finish design and processing
- User operation and instruction manuals
- Manufacturing quality acceptance standards
- Battery selection for internal power supply optimization
- Read-out and display selection
- Calibration and burn-in of unit

Field Verification/Additional Manufacturing Run

Following the debugging process and design/manufacturing improvements detailed above, a pre-production run of 15 improved-design units was made and sent to the field for additional test and verification. Subsequently, and additional manufacturing run of 10 units was also made. Overall, responses have been very favorable.

Post Project Accomplishments

Following the formal conclusion of the project, a number of significant accomplishments were achieved which furthered the successful transition of the IDEA-sponsored PQI technology to widespread commercial implementation. These are listed below.

- Additional field test results were obtained from PQI testing at paving sites in Saginaw, Michigan and Chicago, Illinois. Appendix 5 contains a summary of the data, illustrating the continuing successful correlation of the instrument's measurements with current alternative and less attractive methods.

- Exposure of the technology and product offering received a significant early boost with the publication of full-page articles in "Asphalt Contractor" magazine, dealing with the operational features and advantages of the PQI (see Appendix 5).

- Numerous orders have been received domestically, based primarily on "word-of-mouth" advertising from one state official or contractor to another.

- Even though early in the product introduction cycle, there is now already serious consideration by two states using the PQI to implement changes to their specifications, wherein the TransTech PQI would be the preferred standard method of measuring compaction.

- Again, prior to any concerted, widespread advertising campaign for this product, international orders are beginning to be received, including a recent overseas order for multiple units.

CHALLENGES

Throughout the product development, testing, and improvement cycle, various technical challenges have arisen and have been addressed, either through unit design modifications or procedural developments. The following summary defines the major challenges and the corresponding resolutions.

Challenge: The sensor probe measures a fixed depth, while a variable depth feature would be desirable in some applications. ***Resolution:*** The probe is currently designed to be easily interchangeable with probes that will measure various depths, and a variable depth probe is in the design stages.

Challenge: An uneven surface will reduce the accuracy of the reading in the same way that it does with a nuclear gauge. ***Resolution:*** The immediate solution is to ensure that the surface where the measurement is being taken is even and free of small stones. This is the identical procedure successfully used with nuclear devices at this time.

Challenge: The probe measures a small area and can give misleading density readings where unusually large aggregate is in the measurement area or a large air void. ***Resolution:*** An averaging technique and microprocessor algorithm was developed and incorporated into the unit, which eliminates this concern, by allowing rapid measurement and averaging of multiple points, to minimize the effects of any small-scale analomies. An inherently larger area probe is also under design to further minimize any concerns.

Challenge: Large temperature changes and surface moisture will affect the PQI readings. ***Resolution:*** Analysis and design work for temperature and moisture compensation was initiated, in order to widen the application range and lessen application restraints. Operational procedures to prevent misapplication of the unit under extremes of moisture and temperature gradients have also been developed.

CONCLUSIONS

Summary Conclusions

TransTech Systems, Inc. has demonstrated a viable product that can make real time, in-situ measurements of asphalt pavement density in a non-destructive, non radioactive format. This product in its current form is a viable, advantageous alternative to nuclear measurement instruments currently used for non-destructive asphalt density measurements today. The current product is very easy to use. It weighs less than 20 pounds compared to 29 pounds for a nuclear instrument and is smaller in size. No licensing processes are required. Virtually any member of the paving crew or department of transportation can easily operate the Pavement Quality Indicator with little training. Pavement density readings take less than 5 seconds to obtain compared to 1 - 2 minutes per reading for nuclear instruments. Data can be electronically collected and transferred for analysis at chosen intervals by computer. The depth of measurement taken by the Pavement Quality Indicator is precise and can be varied to match the depth of the asphalt being placed on the highway. This capability includes precise measurement of thin asphalt layers. Nuclear instruments are not precise in their depth measurement. Demonstrated accuracy of the Pavement Quality Indicator is equal or better than current nuclear instruments and repeatability is excellent in all directions. The current design of this product is cost competitive with the nuclear instruments and as with many electrical designs, has the potential of being lower in cost with future designs. **The Pavement Quality Indicator is now a commercially viable product and provides an attractive alternative to existing nuclear density measurement instruments in use today.**

Product Payoff

Initial market research data indicates a substantial potential market for this product, on the order of a $100 million market. If this product can eventually replace the costly and time consuming core sample process of measurement used today, the market potential will be at least two to three times what has been estimated plus make a very significant contribution to improving the quality of our roadways while reducing costs. This improved product will be cost competitive with current products, and has the potential to be lower in cost.

The ability of the Pavement Quality Indicator to instantaneously read asphalt pavement density creates a cost effective opportunity to dramatically increase the number of density readings taken on the highway and provide real time feedback to the paving crew for instantaneous corrective action. It appears that this measurement technique could replace the current core sample and laboratory analysis used to determine asphalt densities today. Development and deployment of the Pavement Quality Indicator in the asphalt paving industry will yield more efficient paving operations, higher productivity and better quality control, and thus result in longer life pavements with lower overall life cycle costs.

In addition to the quality and productivity impacts of the PQI technology in the paving industry, the potential energy and environmental impacts are also substantial. Conservative estimates by TransTech of just the energy and environmental impacts associated with the paving process show the potential of saving $2.35\ (10)^{13}$ BTU per year and 90 tons per year of air emissions. These estimates are based on reasonable penetration rates for the technology, and do not include the added positive energy and environmental impacts from reduced traffic congestion due to less frequent road repair requirements.

A summary of the benefits which accrue from the TransTechs Pavement Quality Indicator include the following:

- Extend pavement life by enabling higher quality construction
- Greatly reduce response time for density readings
- Significantly reduce the cost per measurement of density measurements
- Improve the productivity of paving operations
- Reduce safety hazards, including nuclear material on job sites
- Reduces energy consumption and environmental emissions through improved paving productivity

Additional applications for the technology also exist in the area of soil density measurement, for subgrade quality control in pavement construction, as well as compaction measurements in a wide variety of civil construction applications.

Status of Product Transfer

Transfer of the product technology to the commercialization stage is proceeding on a rapid track. In addition to IDEA funding, substantial funding support for the project has been received from the New York State Energy Research and Development Authority. The U.S. Army Corps of Engineers, through the Waterways Experimental Station (WES) has also been a key supporter of the technology and has provided additional funding support as well as critical technical guidance. Figure 6 shows the development progression of the product hardware from laboratory concept to preproduction prototype design. Figure 7 shows the current, initial production version which is now commercially available.

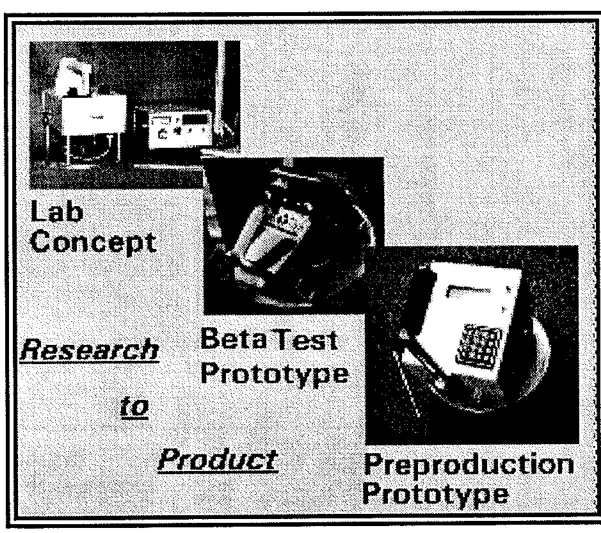


Figure 6. Progression of PQI from Concept to Prooduct

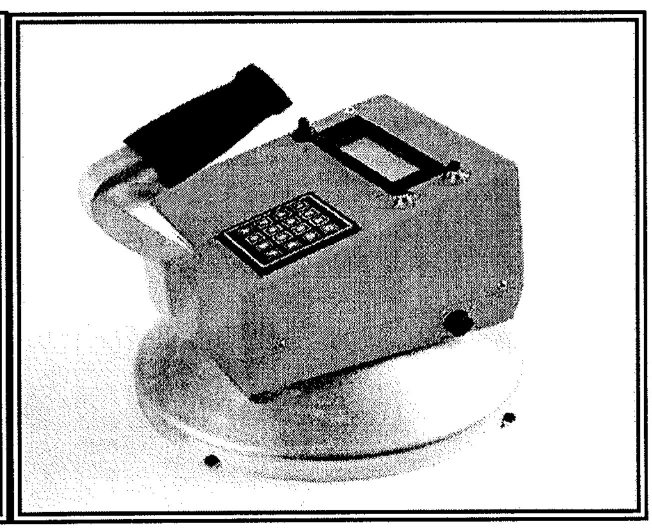


Figure 7. Current PQI Production Unit Design

Prospects for acceptance of the PQI technology in the marketplace are very strong. Initial market survey work, as well as feedback from test site participants indicated that the demand for this type of product, with the features we have demonstrated, is very high.

The strategy for introduction of this product to the market will focus on the Pavement Quality Indicator as a process tool for the contractor to provide real time feedback for improved asphalt lay down. All indications are that the demand for this type of product is very high. This approach will have an immediate impact on the quality of asphalt highways while accumulating an extensive history of performance that can be used to enter other market segments. A secondary strategy will focus on thin layer measurement of asphalt density. Evidence indicates that the nuclear instruments have significant shortcomings in measuring thin layers. The ability of the Pavement Quality Indicator to measure a precise depth will give a higher level of accuracy for thinner depths.

Based on successful completion of this project, full commercialization and market penetration has been initiated, and will be accelerated through the use of TransTech's existing transportation product marketing and sales network

APPENDICES

Appendix 1
Sample PQI Field Test Plan

Test Site:

PQI Test #3; NYDOT Rt. 44 Poughkeepsie; 1 ½" overlay type 6FRA

Test Procedure:

- The PQI instrument will work side by side with the nuclear instrument and any core samples taken.
- Initial operation will be by TransTech personnel. As familiarity is established, NYDOT and site contractor personnel will be encouraged to operate the instrument.
- For each nuclear instrument reading taken, a chalk outline will be made around the perimeter of the unit to identify the location of the reading.
- All data will be recorded on the data sheets.
- A total of 7 PQI readings will be randomly taken within the outline. Each reading will be recorded.
- The high and the low readings will be eliminated. The remaining 5 readings will be averaged. The average will be recorded.
- The average reading will then be located on the look-up chart to determine the pounds/ cubic foot . This number will be recorded.
- The nuclear instrument reading will be recorded.

Appendix 2

PQI Field Test Results

The tables contained in this appendix summarize the test results on the TransTech Pavement Quality Indicator performed at the following eight sites:

1. RT # 44 - Poughkeepsie, NY
2. Schenectady County Airport
3. RT#9W - Storm King Mountain, NY
4. Bangor Airport - Maine
5. RT#3 - Bar Harbor, Maine
6. Palisades Parkway - NJ
7. I-287- NJ
8. I-95 North - Melborne, Florida

NYSDOT - Rt #44
Poughkeepsie, NY
Mix= 6F-RA
MTD = 157.4

core#	PQI	NY NUCL	AT NUCL	CORE	PQI/Core	NY/Core	AT/Core
October 16,1997							
1	142.0	139.9	147.8	141.4	0.6	-1.5	6.4
2	138.6	134.3	148.0	137.7	0.9	-3.4	10.3
3	138.2	138.2	146.2	143.4	-5.2	-5.2	2.8
4	138.5	142.4	149.6	144.0	-5.5	-1.6	5.6
5	138.6	140.5	147.7	142.1	-3.5	-1.6	5.6
6	137.3	137.4	145.4	140.0	-2.7	-2.6	5.4
7	135.5	134.3	144.7	136.9	-1.4	-2.6	7.8
8	143.4	138.9	148.3	142.9	0.5	-4	5.4
			Average Variance		2.54	2.81	6.16
October 17,1997							
1	138.5	142.6	147.8	143.0	-4.5	-0.4	4.8
2	138.2	142.5	147.8	142.9	-4.7	-0.4	4.9
3	139.6	138.7	147.2	140.3	-0.7	-1.6	6.9
4	136.5	133.1	144.4	136.5	0	-3.4	7.9
5	137.0	135.7	145.7	138.4	-1.4	-2.7	7.3
6	137.6	136.6	146.0	138.6	-1.0	-2.0	7.4
7	137.0	137.0	146.4	138.7	-1.7	-1.7	7.7
			Average Variance		1.75	1.53	5.86
October 20,1997							
1	140.3	143	149.6	143.6	-3.3	-0.6	6
2	140.2	144.9	150.8	144.9	-4.7	0	5.9
			Average Variance		4.00	0.30	5.95
PQI = Initial TransTech density instrument readings							
NY NUCL = NYDOT nuclear instrument readings							
AT NUCL = Contractor's Testing service readings							

Schenectady County Airport
Oct. 24, Oct. 30, 1997
Mix = P-401

	PQI	Nuclear	Core	PQI/Core	Nuc/Core
24-Oct-97					
m-1	144.4	158.2	151.1	-6.7	7.1
m-2	145.0	156.4	149.6	-4.6	6.8
m-3	142.0	152.7	148.3	-6.3	4.3
30-Oct-97					
m-4	149.6	152.3	151.3	-1.7	1.0
m-5	148.8	151.0	149.8	-1.0	1.2
m-6	148.5	152.3	150.4	-1.9	1.9
m-7	149.4	153.2	151.2	-1.8	2.0
		Average Variance		3.43	3.48
24-Oct-97					
j-1	147.9	152.6	146.2	1.7	6.4
j-2	142	158.1	148.5	-6.5	9.6
j-3	148.1	153.6	148.5	-0.4	5.1
30-Oct-97					
j-4	151.4	150.3	148.8	2.6	1.5
j-5	151.1	153.1	149.9	1.2	3.2
j-6	150.5	147.7	147.5	3	0.2
j-7	149.4	153.6	148.7	0.7	4.9
		Average Variance		2.30	4.41
PQI = Initial TransTech density instrument readings					
Nuclear = Contractor's nuclear instrument readings					

NYDOT - 9W
Storm King Mountain, NY
Mix = Superpave
MTD = 158

November 6,1997								
PQI	**PQI-2**	**NY NUCL**	**AT NUCL**	**CORE**	**PQI/Core**	**PQI-2/Core**	**NY/Core**	**AT/Core**
139.3	147.3	144.5	144.2	146.5	-7.2	0.8	-2	-2.3
140.5	148.5	144.2	142.6	145.9	-5.4	2.6	-1.7	-3.3
141.1	149.1	147.9	145.5	148.8	-7.7	0.3	-0.9	-3.3
140.5	148.5	147	145.7	148.6	-8.1	-0.1	-1.6	-2.9
140.5	148.5	149.6	148.1	149.8	-9.3	-1.3	-0.2	-1.7
139.9	147.9	144.7	146.1	148.7	-8.8	-0.8	-4	-2.6
139.9	147.9	148.3	147	149.6	-9.7	-1.7	-1.3	-2.6
140.5	148.5	148.1	146.8	150.3	-9.8	-1.8	-2.2	-3.5
139.9	147.9	147	146.7	149.1	-9.2	-1.2	-2.1	-2.4
139.3	147.3	148.8	145.5	148.2	-8.9	-0.9	0.6	-2.7
				Ave. Var.	8.41	1.15	1.66	2.73

PQI = Initial TransTech density instrument readings
PQI-2 = Calibrated TransTech density instrument readings
NY NUCL = NYDOT nuclear instrument readings
AT NUCL = Contractor's Testing service nuclear instrument readings

Airport Ramp, Bangor, Maine
Mix = Superpave, 19mm binder, 10% RAP
MTD = 156

November 20,1997							
core#	**PQI**	**PQI-2**	**LN NUCL**	**CORE**	**PQI/Core**	**PQI-2/Core**	**LN/Core**
1	130.0	136.0	137.5	138.6	-8.6	-2.6	-1.1
2	130.0	136	138.0	139.0	-9	-3	-1
3	133.4	139.4	138.8	137.8	-4.4	1.6	1
4	134.4	140.4	139.9	139.8	-5.4	0.6	0.1
5	133.9	139.9	139.9	138.2	-4.3	1.7	1.7
6	134.9	140.9	141.0	138.7	-3.8	2.2	2.3
7	133.9	139.9	138.9	138.5	-4.6	1.4	0.4
8	132.4	138.4	137.3	138.0	-5.6	0.4	-0.7
9	130.5	136.5	138.4	137.6	-7.1	-1.1	0.8
10	134.9	140.9	140.3	138.4	-3.5	2.5	1.9
				Ave. Var.	5.63	1.71	1.1
PQI = Initial TransTech density instrument readings							
PQI-2 = Calibrated TransTech density instrument readings							
LN NUCL = Lane Construction nuclear instrument readings							

Rt #3 Bar Harbor, Maine
Mix = Superpave 19mm
MTD = 162

November 19,1997					
core#	**PQI-2**	**LN NUCL**	**CORE**	**LN/Core**	**PQI-2/Core**
1	152.6	149.5	146.8	2.7	5.8
2	144.2	143.5	144.3	-0.8	-0.1
3	140.3	141	141.3	-0.3	-1
4	141.3	137.9	139.0	-1.1	2.3
5	139.3	130.1	138.2	-8.1	1.1
6	139.3	136.5	140.6	-4.1	-1.3
7	137.9	137.2	140.5	-3.3	-2.6
8	140.8	139.7	143.2	-3.5	-2.4
				2.99	2.08
November 20,1997					
10	146.4	143.8	142.7	1.1	3.7
11	139	138.9	139.8	-0.9	-0.8
12	142	138.8	140.9	-2.1	1.1
13	142	139.7	142.2	-2.5	-0.2
14	146.4	146.7	144.9	1.8	1.5
15	145.6	136.6	143.3	-6.7	2.3
16	142.0	141.9	143.8	-1.9	-1.8
17	135.6	136.8	142.9	-6.1	-7.3
18	143.0	142.2	140.7	1.5	2.3
19	137.1	136.5	142.0	-5.5	-4.9
20	145.4	144.2	143.9	0.3	1.5
				2.76	2.49
PQI = Initial TransTech density instrument readings					
LN NUCL = Contractor nuclear instrument readings					
PQI-2 = Calibrated TransTech density instrument readings					

Palisades Parkway - NJ

December 1,1997				
core#	**PQI**	**CoreAirVo**	**CORE**	**PQI/Core**
1	167.2	0.030	151.6	15.6
2	163.4	0.020	153.2	10.2
3	166.5	0.029	151.8	14.7
4	161.5	0.023	152.7	8.8
5	163.4	0.031	151.5	11.9
6	169.7	0.047	149.0	20.7
7	168.1	0.054	147.9	20.2
8	168.5	0.041	149.9	18.6
9	160.2	0.047	149.0	11.2
10	169.9	0.054	147.9	22.0
Note: 1)PQI was not calibrated to the mat				
2) The asphalt mat was placed in July of 1997				
The mat contained noticeable maisture				

CONTI
I-287, New Jersey

Nov. 24,1997				
Location#	**PQI**	**NUCL**	**PQI/Nucl**	**PQI/Nucl**
1	147.0	147.0	0.0	
2	145.9	147.5	-1.6	*
3	145.7	148.0	-2.3	*
4	136.7	144.7	-8	*
5	139.4	148.6	-9.2	*
6	150.5	150.5	0	0
7	149.3	149.2	0.1	0.1
8	150.2	150.8	-0.6	-0.6
9	148.1	149.8	-1.7	-1.7
10	148.3	148.7	-0.4	-0.4
		Ave. Var.	2.39	0.56
PQI = Orange Unit w/7point average				
NUCL = CONTI nuclear instrument readings				
* wet pavement conditions				

APAC Mac Asphalt
I-95 North
Melborne, Florida
Mix = Superpave
MTD = 144

Location	PQI 2	Nuclear	Core	PQI/Core	Nuclear/Core
1	136.9	138.3			
2	135.5	138.0			
3	133.6	134.5			
4	137.4	138.3			
5	140.8	137.8			
6	136.4	137.0	136.7	-0.3	0.3
7	137.6	138.5			
8	137.7	137.5			
9	132.8	134.8			
10	138.6	138.0	137.7	0.9	0.3
		Avg Variance		0.6	0.3

Appendix 3

Test Strip Specifications

PQI TEST STRIPS

September 2, 1997

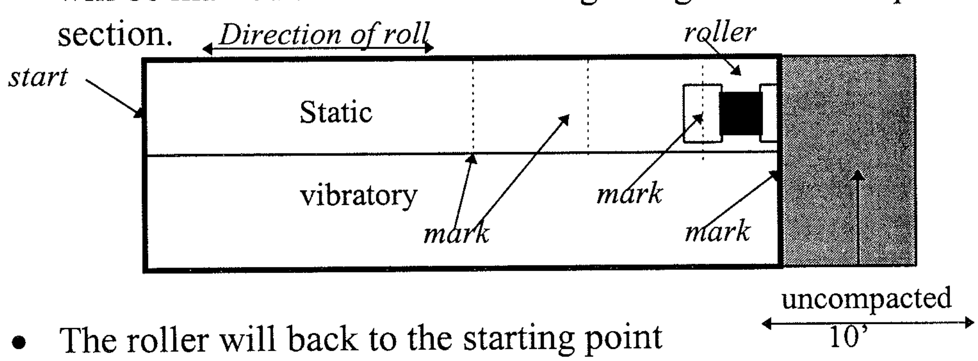
Location Northwest corner of the MTI North parking lot- 968 Albany Shaker Rd.

Material two (2) approimately 10'x 100' - 2 ½" mats **compacted to varying densities**

one (1) - type 6F top
one (1) - type 7F top

Compaction

- each mat will be divided into 2 longitudinal sections
  one section will be rolled with a static roller
  the other section will be rolled with a vibratory roller
- a 10' section at the end of the mat will be left unrolled and marked across the mat.
- the roller will begin at the other end of the mat and roll up to the mark at the unrolled section and stop. Behind the back of the roller will be marked across the mat designating the first compacted section.



- The roller will back to the starting point
- The roller will proceed forward to the last mark across the mat and stop. Behind the back of the roller will be marked across the mat designating the second compacted section.
- The procedure will be repeated until the remaining mat is completely divided into sections.
- The same procedure will be repeated for the vibratory roller.

PQI TEST STRIPS

October 13, 1997

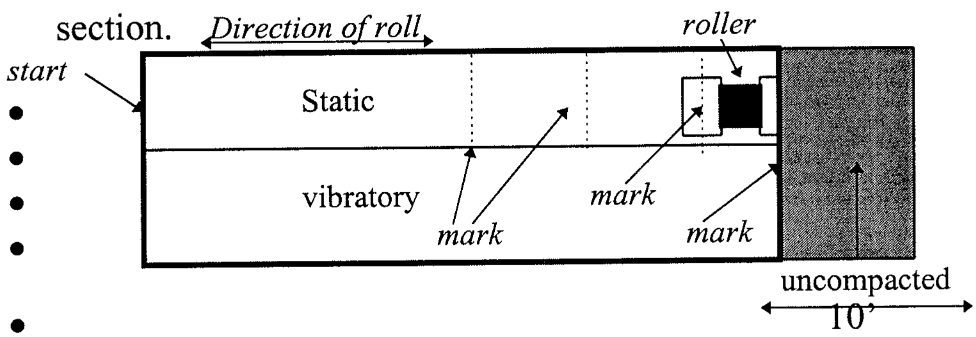
Location Northwest corner of the MTI North parking lot- 968 Albany Shaker Rd.

Material three (3) approimately 10'x 100' - 2 ½" mats **compacted to varying densities**

one (1) - type P401
one (1) - type 6FRA
one (1) - type 3RA binder

Compaction

- each mat will be divided into 2 longitudinal sections
  one section will be rolled with a static roller
  the other section will be rolled with a vibratory roller
- a 10' section at the end of the mat will be left unrolled and marked across the mat.
- the roller will begin at the other end of the mat and roll up to the mark at the unrolled section and stop. Behind the back of the roller will be marked across the mat designating the first compacted section.



- The roller will back to the starting point
- The roller will proceed forward to the last mark across the mat and stop. Behind the back of the roller will be marked across the mat designating the second compacted section.
- The procedure will be repeated until the remaining mat is completely divided into sections.
- The same procedure will be repeated for the vibratory roller.

Appendix 4

TransTech Systems's Pavement Quality Indicator Specifications

Unit Weight (with battery): 15 lb., 8 oz.
Unit Dimensions (with handle): 10 3/4 in. x 10 3/4 in. x 11 in. (L x W x H)
Shipping Case Dimensions: 27 3/4 in. x 17 3/4 in. x 13 in. (L x W x H)
Operating Temperature and Humidity: Ambient 20°F(-7°C) to 110°F(43°C) RH 95%
Storage Temperature & Humidity: 0°F(-18°C) to 150°F(66°C) RH 95% non-condensing
Maximum Surface Temperature: 350°F (177°C)
Power Supply: 12 volt DC 3.0 Amp Hr. Gel Cell
Current Drain: 215 ma
Battery Charger: Fast Charge 120Vac 60 Hz 0.2A 12V dc 300ma
Re-Charge Time: 4 hours
Output: 0-10 VDC (+/- 10VDC optional); proportional to sensing gap. Includes a +/-
10VDC Offset Control
Linearity: Typically +/- 2% of full scale or better. +/-.5% with limited range calibration.
(+/-.2% optional)
Range: Typically 100% of probe's sensor diameter or diametrical area equivalent.
Frequency Response: 232Hz standard; 3.5 KHz or 5 KHz or better optional (-3dB point)
Resolution: 1 mVdc
Display: 4 line alphanumeric, backlit
Scale Readings: in English Lb/CuFt or Metric Kg/CuM; user selectable by keypad
Sampling time: 5 seconds minimum
Measuring Depth: 1-1/2 in. nominal
Continuous Operational Time (fully charged battery): Typically greater than 13 hours
Accessories included with unit: Battery Charger: 120V AC to 12VDC Fast Charge; 12VDC Auto Adapter; Shipping Case; Operating Instructions Manual

Appendix 5

Post-Project Test Results and Publicity

Terry Burger-Saginaw Asphalt
June, 1998
Type 13A Mix - 2" Lift
517-752-8594

										Absolute Variance		
	PQI 5 Avg.	% Comp.	PQI 1 Shot	% Comp.	Nuclear	% Comp.	MTD	SSD Density	Dry Comp.	PQI 5 Avg.	PQI 1 Shot	Nuclear
14B	145.9	95.7%			146.7		152.5	144.9	94.6%	1.07		
14C	143.7	94.2%			147.5		152.5	146.5	95.9%	1.87		
15A	148.8	97.6%	149.5	98.0%	148.0	97.0%	152.5	145.3	94.4%	3.17	3.63	2.65
15B	145.4	95.3%	144.6	94.8%	146.8	96.3%	152.5	146.6	95.8%	0.46	0.98	0.46
15C	143.3	94.0%	145.3	95.3%	147.1	96.5%	152.5	146.1	95.5%	1.53	0.22	0.96
16A	144.4	94.7%	143.3	94.0%	146.0	95.7%	152.5	145.4	95.1%	0.41	1.13	0.64
16B	144.9	95.0%	145.7	95.5%	146.8	96.3%	152.5	146.5	95.5%	0.48	0.04	0.76
16C	143.0	93.8%	142.4	93.4%	146.8	96.3%	152.5	143.9	93.5%	0.27	0.12	2.76
17A	143.0	93.8%	141.5	92.8%	147.6	96.8%	152.5		94.5%	0.73	1.71	2.29
17B	143.3	94.0%	142.2	93.2%	147.0	96.4%	152.5		94.8%	0.63	1.35	1.79
17C	142.8	93.6%	142.7	93.6%	146.3	95.9%	152.5		95.7%	2.06	2.13	0.23
18A	142.6	93.5%	142.1	93.2%	146.7	96.2%	152.5		95.7%	2.19	2.52	0.50
18B	142.0	93.1%	143.5	94.1%	146.5	96.1%	152.5		94.4%	1.29	0.30	1.67
18C	146.3	95.9%	146.4	96.0%	147.2	96.5%	152.5		93.9%	2.03	2.10	2.62
19A	142.3	93.4%	143.1	93.9%	148.9	97.7%	152.4		95.1%	1.73	1.20	2.60
19B	146.2	95.9%	149.0	97.8%	149.4	98.0%	152.4		96.4%	0.47	1.37	1.63
19C	147.9	97.0%	145.6	95.5%	149.3	98.0%	152.4		96.2%	0.85	0.66	1.77
Average	144.5	94.7%	144.5	94.7%	147.3	96.6%		145.7	95.1%	1.25	1.30	1.56
									Std. Dev.	0.82	1.00	0.90

Location O'Hare Airport
Hold Pad 4 Right PaPa

Date/Time 6/4/98
12:38am thru
05:30am

Trans Tech

TRANS TECH SYSTEMS, INC.

Trans Tech Representative : David Apkarian - (616) 241-9369
Midwest Sales Manager 3501 Chamberlain Ave SE
Grand Rapids, MI 49508

Data Loging Sheet
Trans Tech Systems Inc.
2469 Albany Street
Schenectady, NY 12304
518-370-5558 - Phone
518-370-5538 - Fax

Reading Number	PQI Ave Mode Ave	PQI Single One Read	Nuclear #1 One Min	Core Data	Core ID	Dif Single from Nuc	Dif Ave from Nuc	Dif Sing Core	Dif Ave Core
1	145.1	144.3	146.3	XXX	XXX	-2.0	-1.2	XXX	XXX
2	148.5	146.9	146.7	XXX	XXX	0.2	1.8	XXX	XXX
3	142.9	142.7	146.2	XXX	XXX	-3.5	-3.3	XXX	XXX
4	150.2	150.8	149.5	XXX	XXX	1.3	0.7	XXX	XXX
5	152.0	151.1	150.7	XXX	XXX	0.4	1.3	XXX	XXX
6	146.1	146.0	149.4	XXX	XXX	-3.4	-3.3	XXX	XXX
7	145.4	145.1	145.5	XXX	XXX	-0.4	-0.1	XXX	XXX
8	147.3	146.7	146.6	XXX	XXX	0.1	0.7	XXX	XXX
9	147.1	146.1	146.2	XXX	XXX	-0.1	0.9	XXX	XXX
10	XXXX	149.5	149.5	149.0	J2-3	0.0	XXX	0.5	XXX
11	XXXX	148.9	145.9	149.5	M2-3	3.0	XXX	-0.6	XXX
12	XXXX	149.5	150.9	152.7	M2-1	-1.4	XXX	-3.2	XXX
13	XXXX	150.5	149.8	150.7	J2-1	0.7	XXX	-0.2	XXX
14	XXXX	145.8	145.6	146.3	J2-4	0.2	XXX	-0.5	XXX
15	XXXX	150.8	146.1	150.0	M2-4	4.7	XXX	0.8	XXX
16	149.9	150.6	XXX	150.6	M2-2	XXX	XXX	0.0	-0.7
17	149.6	150.1	XXX	149.7	J2-2	XXX	XXX	0.4	-0.1

	PQI Single	Nuclear #1		
PQI Single Read to Nuc	147.6	147.7	-0.1	Based on readings 1 - 15

	PQI Ave	Nuclear #1		
PQI Ave Read to Nuclear	147.2	147.5	-0.3	Based on readings 1- 9

	PQI Single	Core		
PQI Single Read to Core	179.0	179.6	-0.6	Based on readings 10 - 15

	Nuclear #1	Core		
Nuclear to Core	177.6	179.6	-2.1	Based on readings 10 - 15

Pavement quality indicator is an instant success

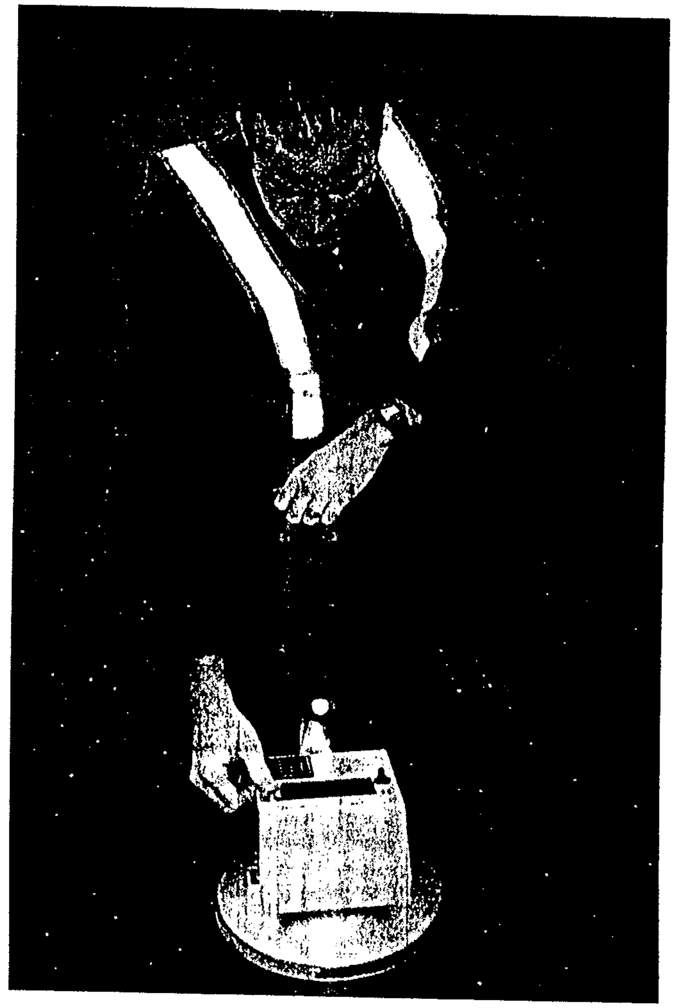
Contractors put non-nuclear gauge to work on quality acceptance jobs

Achieving strict contractor quality assurance numbers in Indiana is a little less of a challenge now for Milestone Contractors L.P., Indianapolis, since the company gave the pavement quality indicator (PQI) a non-nuclear density gauge from TransTech Systems, Latham, N.Y., a try. Because the tool has become an instant successs with the contractor, it is used in conjunction with the state specified nuclear density gauge to measure density on quality acceptance (QA) jobs, says Brad Cruea, Milestone's senior QA manager in Indianapolis. Cruea likes the PQI because at 10 pounds (4.5 kilograms) it is lightweight and easy to handle. His crew has had it for a few months, and has been using it chiefly on highway jobs where QA numbers factor into the pay. "The state of Indiana only recognizes the nuclear density gauge right now for quality acceptance," says Cruea. "We can control our mixes with any (tool), but as far as being paid (is concerned), we're paid by nuclear gauge (readings) or core (results), depending on the job location, traffic counts and ESALs."

On contractor acceptance jobs, the Indiana department of transportation (DOT) has asked contractors to use the PQI with nuclear testing to develop background data to support preliminary information they've gained from tests in New York, he says. "The Indiana DOT bought one to use and they're pretty good about asking the contractor for input too. We're trying to help get it accepted in Indiana also."

Right now the PQI has to be calibrated to a known density, and that's going to have to come from a core or a nuclear gauge reading, Cruea explains. Most companies doing hot mix asphalt construction have nuclear gauges anyway, so to get the PQI calibrated will require the use of the nuclear gauge the first day or first half day, he says. "The PQI is not adapted to be a standalone (tool), but it could be, maybe by the end of the year," he adds.

Using the PQI, says Cruea, requires minimal instruction. Milestone was introduced to the non-nuclear density gauge in a short demonstration at a recent state asphalt paving association meeting. "When they sent it to us three months later it took about 45 minutes going through the manual and we were able to turn it on and run it. It involves a very simple setup," he adds.



TransTech Systems' pavement quality indicator

To run the unit, the operator places it on the newly finished mat and takes a density reading. The PQI has several settings, and takes only 5 seconds for each reading, says Cruea. In the continuous mode the operator puts it down for a constant reading. "You can scoot it around the mat. It saves a lot of time, and where I find that advantageous is during test strips when we need to get the mix compacted before it cools down too quickly. You can set the PQI down and get instantaneous readings."

Cruea says this season Milestone is targeting the density gauge for use in high-production interstate work. They'll have the nuclear gauge on the site, take side-by-side sampling with the PQI gauge and compare the numbers for both to core results. ■

Write In 925

Here's How It Works

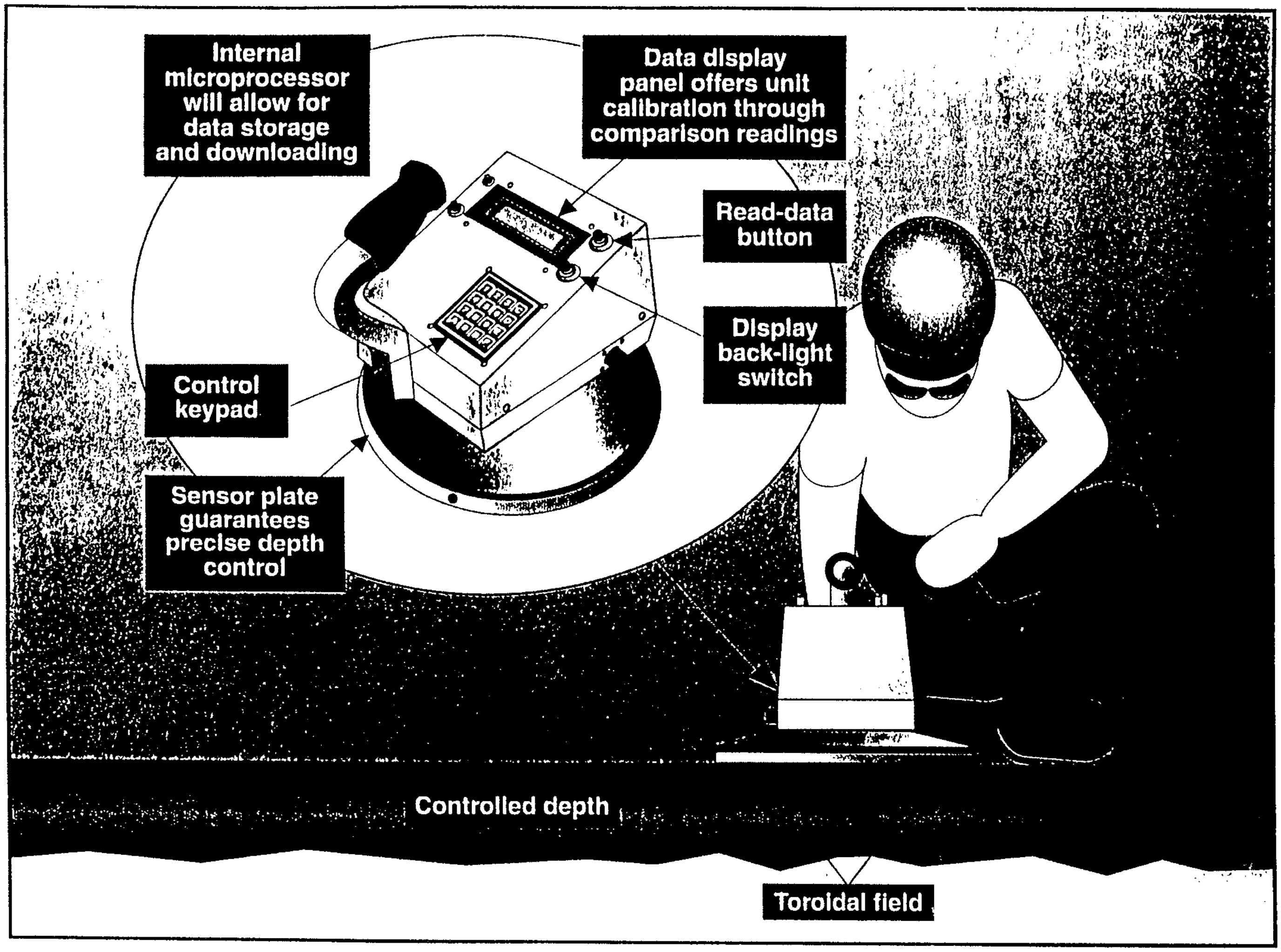


Illustration by David Hay

TransTech's Pavement Quality Indicator

• The Pavement Quality Indicator (PQI), from TransTech Systems Inc., Latham, N.Y., is first of its kind technology designed to quickly offer accurate, repeatable asphalt pavement density data. Lightweight at 15.5 lbs. (7 kilograms), it provides a constant current, low-frequency, complex impedence sensing approach for an accurate and instantaneous density measurement, says the manufacturer.

The density data is acquired via a non-nuclear toroidal electrical sensing field established in the measured material by a flat sensing plate. No license is required to operate the unit, so any member of the paving or quality control/quality assurance crew can generate a reading by placing it in contact with the surface of the pavement. Bulk density or compaction level is measured by the response of the electrical sensing field to changes in complex impedance of the material. This electrical sensing field response is a function of the composite resistivity and dielectric constant of the material.

Pavement readings are instantaneous and the unit may be programmed for single shot, multi-shot, or continuous reading modes. Unit calibration is easily achieved through comparison of readings taken against a known density reference usually derived from an existing core sample or from a rolling pattern test strip section. The PQI unit is 10.75 inches (270 mm) long by 10.75 inches (270 mm) wide by 11 inches (275 mm) high. It is powered by a 12 volt DC 3.0 Amp Hr. gel cell, with a 215 ma current drain and fast charge 120 Vac 60 Hz 0.2A 12V dc 300ma battery charger, and also features microprocessor technology that will allow data storage and downloading of data readings to a computer via an RS-232 port in future models for more detailed analysis.

Recharge time is 4 hours, and continuous operational time with a fully charged battery is 13 hours. Accessories include a battery charger, a 12VDC adapter, and shipping case.∎

Write In 852