J.K. Cable, L. McDaniel, R. Steffes

Evaluation of Paver Vibrator Frequency Monitoring and Concrete Consolidation

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Final

REPORT

IOWA STATE UNIVERSITY
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DISCLAIMER

"The opinions, findings, and conclusions expressed in this publication are those of the author and not necessarily those of the Iowa Department of Transportation or the U.S. Department of Transportation."

ACKNOWLEDGEMENTS

This project was the result of a combined effort of members of the Iowa DOT Office of Materials research staff, Iowa State University, and the Iowa Concrete Paving Association (ICPA). The efforts of Bob Steffes and Mohammad Mujeeb from the Office of Materials in data collection and review of the report were invaluable to the project. Through the work of Lisa McDaniel, Dan Redmond, Kari Rabe, and Su Hong the research analysis was completed and made available for this report.

This type of work is made possible in Iowa by the great cooperation shown by the members of the Iowa Concrete Paving Association and the Iowa DOT Construction Offices. The work would not have begun if it had not been for the concerns of the ICPA and the Iowa DOT research staff about adequate and proper consolidation and quality control of concrete paving. In this case the cooperative effort included representatives of the Fred Carlson Co. and Manatts Inc. for their patience and assistance in making the data collection possible and spending the time to install the test equipment. The Iowa DOT Cedar Rapids and Mount Pleasant construction inspection staff members were very supportive of the data collection activities.

This is the type of activity that moves Iowa forward in the continuous quality improvement of concrete paving.

ABSTRACT

Identification of ways to enhance consistency and proper entrained air content in hardened concrete pavement has long been a goal of state highway agencies and the Federal Highway Administration. The work performed in this study was done under FHWA Work Order No: DTFH71-97-PTP-IA-47 and referred to as Project HR-1068 by the Iowa DOT. The results of this study indicate that the monitoring devices do provide both the contractor and contracting authority a good way of controlling the consistent rate of vibration to achieve a quality concrete pavement product. The devices allow the contractor to monitor vibrator operation effectively and consistently. The equipment proved to be reliable under all weather and paver operating conditions. This type of equipment adds one more way of improving the consistency and quality of the concrete pavement.

TABLE OF CONTENTS

LIST OF FIGURES

Page

structure are being covered under a separate, but companion contract between Iowa State University, Civil and Construction Engineering (ISU/CCE) and the Portland Cement Association (PCA).

The work done under the FHWA / Iowa DOT funded study (HR-1068) and the ISU/CCE/ PCA project was directed at two goals. The first being an evaluation of the performance of two frequency monitoring devices and various vibrator models during actual paving operations. The second study addressed the vibrator monitoring process and its effect on the air matrix and uniformity of the hardened concrete.

RESEARCH OBJECTIVES

The FHWA/Iowa DOT project HR-1068 was designed to investigate, observe, and evaluate the overall vibrator monitoring system which includes the control box, connecting cables, junction boxes and the frequency pick up systems. It also considered user friendly aspects for the paver operator and equipment maintenance personnel and for highway agency inspectors.

The goals for the Vibrator Monitoring Project HR-1068 were as follows:

1. Evaluation of the accuracy, reliability and field worthiness of the vibrator frequency monitors.
2. Evaluation of each vibrator's performance.
3. Development of performance standards for monitoring devices and vibrators based on Iowa DOT experience.

4. Calculation of benefits based on the number of times the vibrators are out of specifications using the monitors compared to the likelihood of missing vibrators out of specifications under usual inspection procedures.

The goals for the PCA / ISU/CCE study were as follows:

1. Evaluation of the entrained air matrix produced by the various vibrator models in combination with of track speed and vibrator frequency
2. Compare the results of the Scanning Electron Microscope (SEM) method of analysis to those of the traditional Linear Traverse method of entrained air analysis. This objective was directed at advancing the speed and reducing the cost of analysis of entrained air content in hardened concrete while trying to reduce costs.
3. Identify the desirable vibrator size and type, spacing, angle, frequency, and paving machine track speed to produce an optimum product for the mixes and pavement designs evaluated.

TEST SITE CHARACTERISTICS

Test Site Description

The test sites for this project involved two locations and two separate contractors in Iowa. Both projects are rural in nature and involve the construction or reconstruction of four lane divided highways.

The first project is identified as IM-80-6(175)220- -13-48 on Interstate 80 in Iowa County. The location of the project is illustrated in Figure 1. It was located between

Iowa County Road F-35 (Station 626+50) and Iowa Highway 149 (Station 1074+00) near Williamsburg. The test sites were located in two areas of the eastbound lanes in this pavement reconstruction area. A portion of the testing was done in the area between Station 634+00 and Station 663+00, near the west end of the project, and a second site near the east end of the project between Station 1040+50 and Station 1053+75. The reconstructed pavement is 12 inches in thickness and was placed with a GOMACO Model GP-3000 slipform paver by Manatt's Inc. of Brooklyn, Iowa, on a recycled portland cement concrete base.

The second project was located in Washington County on US-218 near Crawfordsville, Iowa. The project is identified as NHS-218-3(49)- -19-32 and consists of paving for a four lane divided roadway on a newly constructed grade between Stations 536+00 and Station 1053+50. The location of this project is shown on the map in Figure 2. Test sites are located in the southbound lane between Station 606+75 and Station 746+50 and in the northbound lane between Station 618+75 and Station 636+00. Paving was constructed at a thickness of 10 inches with a CMI Model 450 slipform paver by the Fred Carlson Co. of Decorah, Iowa on a compacted subgrade.

Test Site Variables

In the case of the I-80 site, Manatt's Inc., the following variables were introduced:

Paving machine type and model: Gomaco, Model GP-3000

Vibrator monitor brand: Wyco Tool Co.

Vibrator models (two of each of three different models were installed on the paver for testing): W949760 (standard), W949760 (high energy), Super Spud 3000

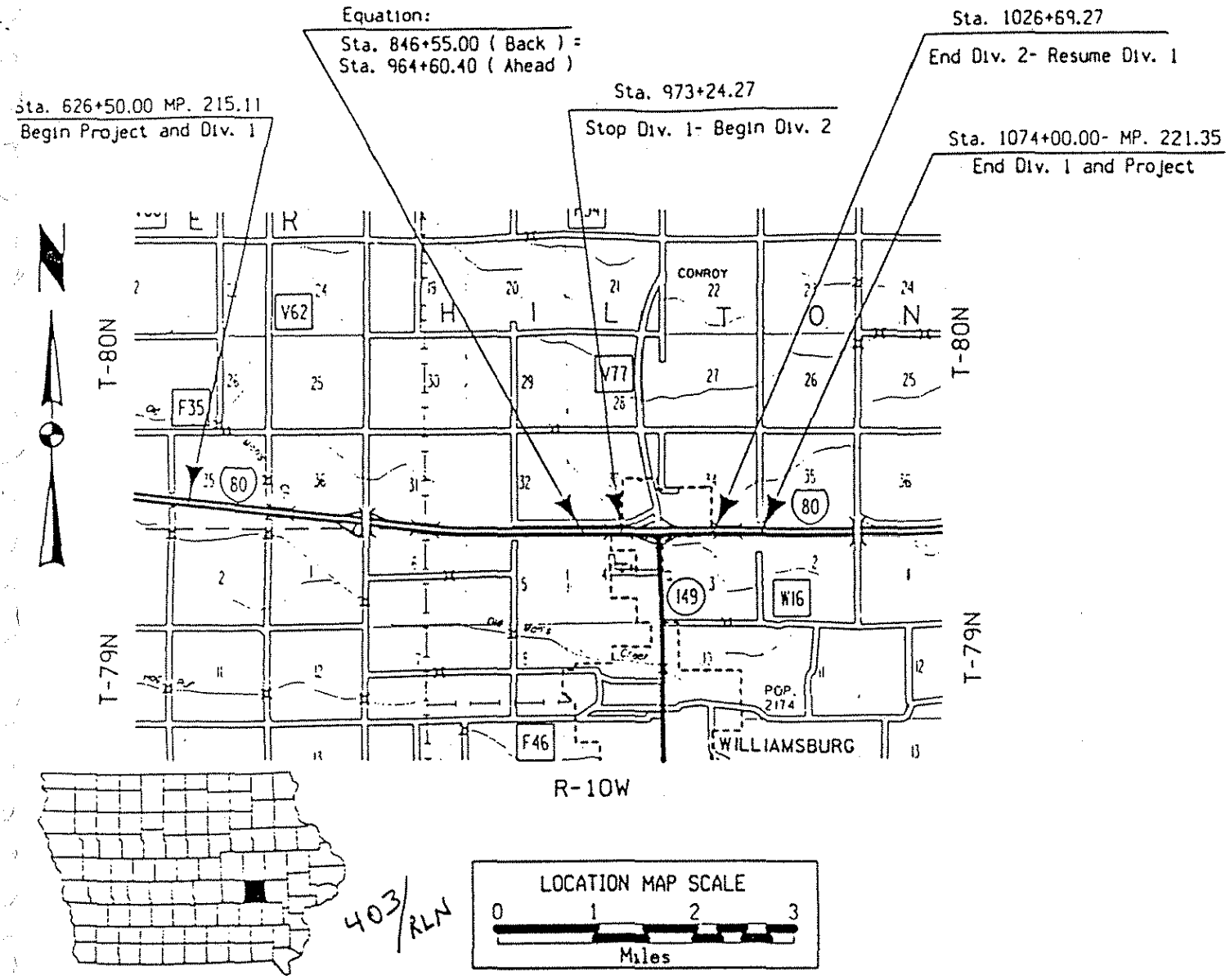


Figure 1 – Interstate 80, Iowa County Test Site

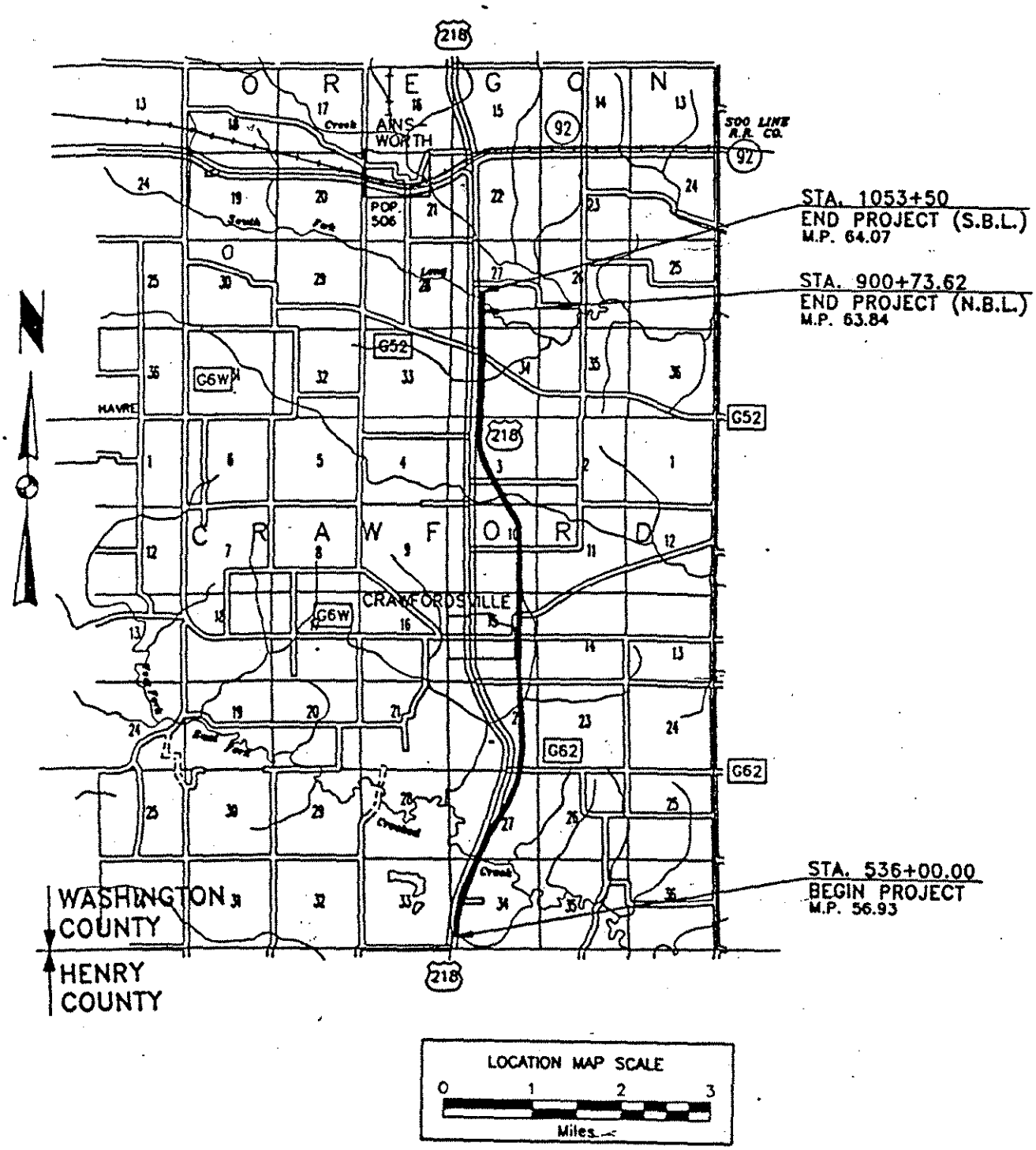


Figure 2 – U.S. 218, Washington County Test Site

Number of vibrators mounted on the paving machine: 20

Average vibrator spacing:15 1/2 inches c-c

Length of project: 6.24 miles

Width of pavement placed during testing: 26 feet

Thickness of pavement: 12 inches

Data collection dates: June 23, 26, and July 8, 1998

Location of data collection: Station 634+00 to Station 1053+75 eastbound lanes only

This project was built on the site of existing I-80. The existing pavement was crushed and placed as a drainable base for the new pavement as part of this project. The base was placed, compacted and trimmed to grade prior to paving and traffic was prohibited from traveling over the base prior to paving. Concrete was mixed in a central mix plant near the east end of the project and transported to the site in dump and agitor trucks. Concrete was placed with a belt placer, consolidated by the paving machine actions and finished with a "V" shaped bull float and manual finishing. The project included the installation of longitudinal subdrains along the outside edge only of the pavement for positive drainage. Some of the drains were in place from the prior paving and other sections were added as part of this project after paving.

In the case of the U.S.-218 project, Fred Carlson Co. Inc., the following variables were introduced:

Paving machine type and model: CMI, Model 450

Vibrator monitor brand: Minnich Manufacturing Co.

Vibrator models (two of each of three different models were installed on the paver for testing): HV-2PE, HV-2PEH, HV-4P

Number of vibrators mounted on paver: 17

Average spacing of vibrators:18 1/4 inches c-c

Length of project: 6.90 miles

Width of pavement placed during testing: 26 feet

Thickness of pavement: 10 inches

Data collection dates: July 17, 24 and 29, 1998

Location of data collection: Station 606+75 to 746+50 in the southbound lane and Station 618+75 to 636+00 in the northbound lane

This project was built as a relocation of U.S.-218. The pavement was placed on compacted soils for this project. Construction traffic was prohibited from traveling over the compacted base prior to paving. Concrete was mixed in a central mix plant near the north end of the project and transported to the site in dump and agitor trucks. Concrete was placed with a belt placer, consolidated by the paving machine actions and finished with an oscillating screed and manual finishing. The project included the installation of longitudinal sub-drains along the outside edge only of the pavement for positive drainage. These were added as part of this project, after paving.

Vibrator Monitoring System Description and Installation

The vibrators and monitoring device manufacturers were selected by the contractors on each project in conjunction with the equipment manufacturers and the Iowa Concrete Paving Association representatives. On the U.S. 218 project, the monitors

and vibrators were provided by the Minnich Manufacturing Co. of Mansfield, Ohio, and the Wyco Tool Co. of Racine, Wisconsin. Each manufacturer provided skilled technicians to assist the contractor in the installation and operation of both the vibrators and the monitoring devices. Only one combination of paving machine and vibrator monitor/vibrator manufacturer was employed in this experiment for each of the paving projects. The vibrators were standard, available models, but with the addition of an internal frequency sensor and connecting cables. It should also be noted that the concrete materials used in each project met the same mix design criteria but came from different sources.

In the case of the I-80, Manatts Co. project, the Wyco Tool Co. vibrators and monitors were utilized. Six vibrators and one monitor were installed on the paving machine prior to beginning the paving project in the eastbound lanes. The change in vibrators and the addition of the monitor was made on a Sunday afternoon, June 22, 1998, prior to the beginning of paving operations. A decision was made by the research team and the contractor to place all the test vibrators in the driving lane right portion of the pavement. The existing vibrator nearest the outside edge of the pavement was left in place to guard against problems with edge slump during the tests. The six existing vibrators adjacent to and left of this vibrator were removed and replaced with the new Wyco Tool Co. vibrators with frequency sensors. The new vibrators were installed in pairs from right to left (looking forward from the paver). The first two test vibrators were of the standard 2 1/4 inch diameter size (Model W949760, 2000 lb.). The second pair were of the same diameter, but equipped with a high energy capability (Model W949760, 2500 lb.). The last pair were 3 inches in diameter and equipped to provide a larger

amount of energy (Super Spud, 3000 lb.). All vibrators were placed at the same relative depth (near the level of the strike off plate) and angle as the existing vibrators. The average spacing of 15 1/2 inches c-c was also retained. A schematic of the vibrators and the measured spacing can be seen in Figure 3.

The installation utilized the services of two Wyco representatives and four of Manatts' paving staff and was completed in one hour. No particular problems were encountered in the installation over those associated with removal of concrete buildup on the attachment bolts.

The monitor was installed on the top of the paving machine near the operator in position for ease of viewing. It can be seen in Figure 4. The mounting did require some degree of electrical knowledge to properly ground the box to the machine to allow data to be seen on the monitor. Changes in the number of vibrators being monitored could be accomplished quickly assuming each vibrator had the sensor and additional wire for connection to the monitor. No other special tools or knowledge were required to complete the installation. Addition of the monitor and vibrator connections can easily be made during maintenance periods between two days of concrete placement or prior to beginning a paving operation.

The monitoring device required no special maintenance or training to operate. It consisted of a digital readout screen and a vibrator selection dial. The dial could be manually turned to monitor each of the vibrators in the test. A special face cover was included to protect the screen from vandalism and weather. The screen contained a minor amount of condensation on the inside of the mechanism after a heavy rain, but

I – 80
Iowa Co.
Manatts Inc.

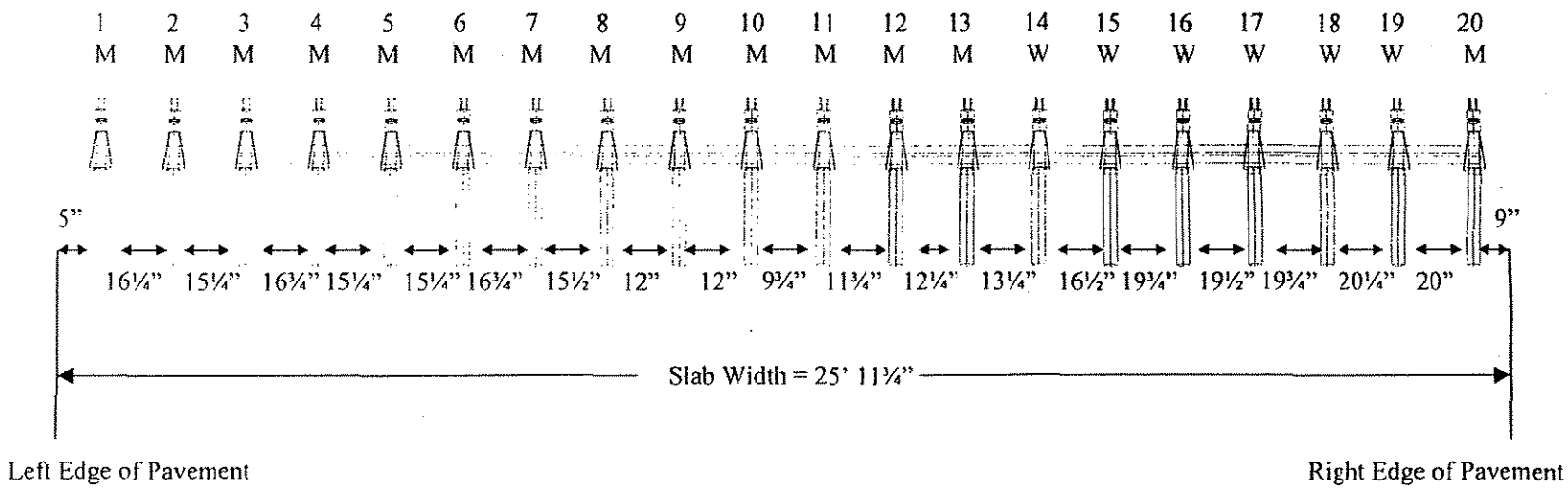


Figure 3 – Schmatic Diagram of I-80 Paver Vibrator Arrangement

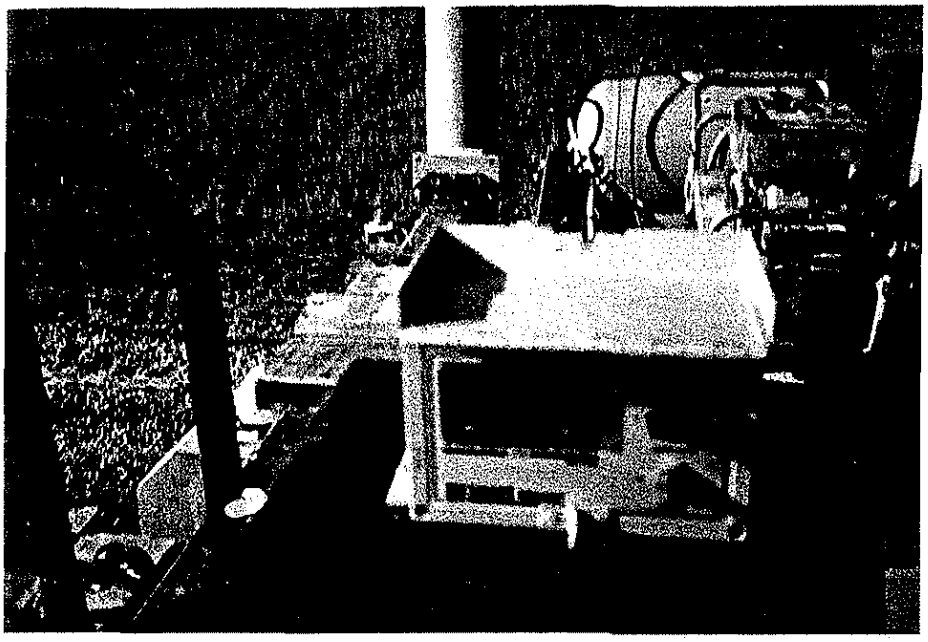


Figure 4 – WYCO Monitoring Device Mounted

showed no signs of that effecting the data collected. This device required the paver operator to physically turn the dial to select a vibrator and read the screen to check the individual operating frequency. A warning device for frequency limitations was not included in this prototype model.

The Fred Carlson Co. elected to replace the existing Minnich Manufacturing Co.vibrators with six Minnich Manufacturing Co. frequency equipped vibrators and a vibrator monitoring device on their CMI paver. The work was accomplished on the evening of July 16, 1997, after paving was completed for the day. Six existing vibrators were removed from the same portion of the pavement (driving lane) as in the I-80 test. The removal of the existing six vibrators went smoothly with only one requiring special

attention to remove the mounting bolts. The work was accomplished by two Minnich representatives and three Carlson employees.

The new vibrators were mounted in pairs. As at the other test site, the outside existing vibrator was left in place to control edge slump. Vibrators 2-7 numbered from the outer edge of the pavement were replaced. The first pair left of the existing vibrator were 2 3/8 inches in diameter (model HV-2PE) or normal energy vibrators. The second pair (model HV-2PEH) were of the same diameter, but with a higher centrifical force capability. The last pair (model HV-4P) measured 3 inches in diameter and had the highest centrifical force capability. A schematic of the vibrator locations and designations are shown in Figure 5.

The monitoring device for this project consisted of two boxes, as shown in Figure 6, mounted on the hand rail of the paving machine near the operator. Box number one acts as a junction box to receive the signal wiring from each vibrator that was included in the test. Mounted above this box is the control panel box with a digital screen and microchips for use in programming the monitoring effort. In this case, the monitor can be programmed to scan the bank of vibrators at a predetermined rate and provide the operator with the frequency of each on a revolving basis. It can also be used to compare the actual frequency of each vibrator to a designated range of values (e.g. upper and lower limits). In this mode the monitor can sound an audible alarm when the vibrator frequency is greater or less than, the established limits, or fails to operate.

On this project, the vibrators and monitor were installed and tested in approximately 2 1/2 hours. Some of this time was spent working out problems with the

US 218
Washington Co.
Fred Carlson Co. Inc.

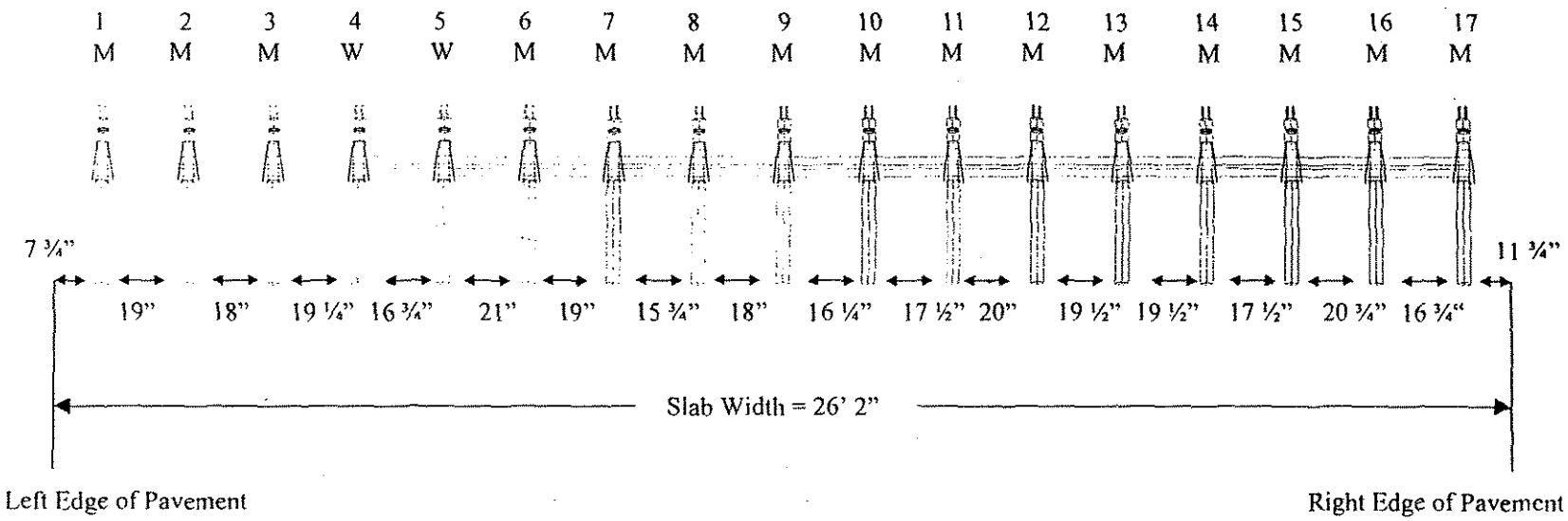


Figure 5 – Schematic Diagram of U.S. 218 Paver Vibrator Arrangement

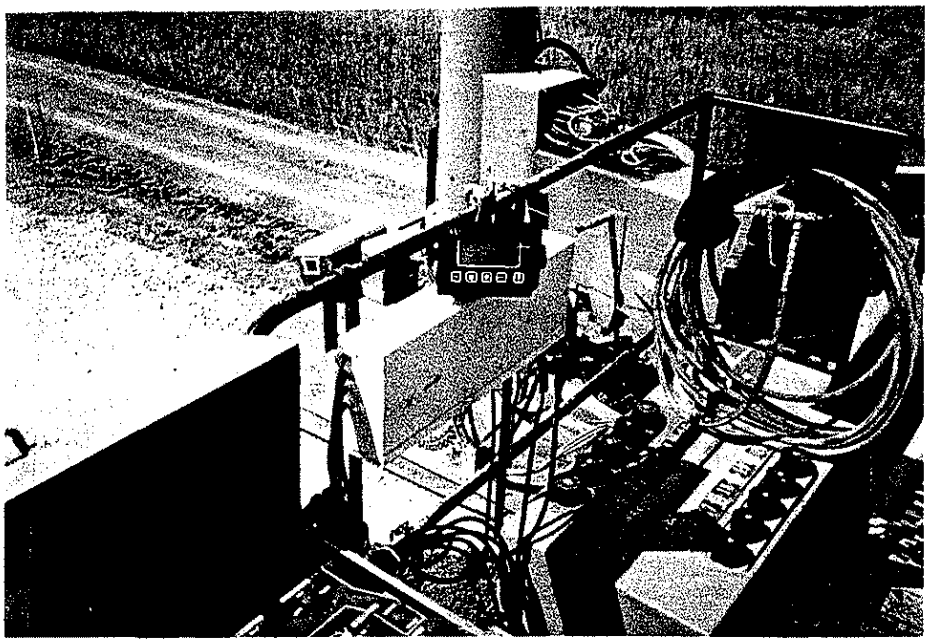


Figure 6 – Minnich Monitoring Device Mounted

sending cable on one of the vibrators. Training required for the operation and programming of the monitor was minimal and required no prior special knowledge.

There were no problems noted in the operation of the monitor during the testing period and no maintenance was required on the monitor. The sensing cables for one of the vibrators did provide concern and the vibrator was replaced. The warning sound was effective, but also annoying for the operator. This can be changed by turning it off or by changing the range of values to be accepted in terms of frequencies from each vibrator.

EXPERIMENTAL DESIGN

Data Collection

Data for this evaluation were collected through the efforts of a three person crew working in conjunction with the paving machine operator. Testing was conducted on

three separate days on the I-80 project and two separate days on the U.S. 218 project. The paving machine operator was instructed by the research staff representative, in each test, to set the forward speed of the machine at approximately 4 feet per minute to represent a slow forward speed or at approximately 6 to 6 1/4 feet per minute to represent a fast forward speed. The frequency variable was set at either 5000 or 8000 vibrations per minute based on results of previous Iowa DOT vibrator research results. Three separate testing periods for combination of the track speed and vibrator frequency were proposed from each day of testing.

Data collection consisted of measuring the actual frequency of each of the six test vibrators on the test paving machine with three separate monitoring devices. The first of these devices was the manufactured monitor. The second and third were nationally recognized devices that the Iowa DOT has used to check vibrators while paving is in progress.

One of those devices is the Standco tachometer shown in Figure 7. This device is mounted on the top of a 6-8 foot length of steel rod with a forked end at the bottom to allow the operator to keep the rod in contact with the vibrator during testing and to be an adequate distance from the vibrator for safety. The device contains a series of oscillating reeds that identify the frequency of the vibrator.

The third frequency measuring device used was the VIBRA-TAK. This tachometer, shown in Figure 8, consists of pencil sized and shaped device that extends a metal wand from its barrel. The rounded end of the barrel is placed against and perpendicular to the vibrator or the 6-8 foot steel rod contacting the vibrator. The wand

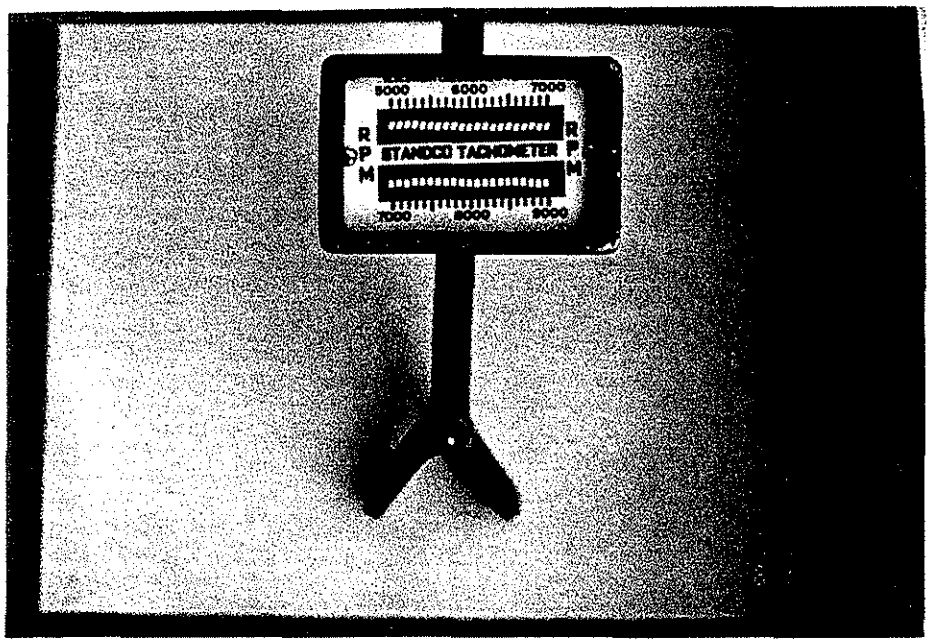


Figure 7 – Standco Tachometer

Figure 8 – VIBRA-TAK Tachometer Device

is extended or withdrawn until it reaches maximum oscillation. The scale on the barrel is graduated to indicate frequency values at maximum oscillation.

The test target frequency was set using the manufacturer's monitor and the paving machine's manual guidelines for setting of the hydraulic oil control valves to the individual vibrators. Track speeds were set by measuring the forward movement of the paving machine and adjusting the speed with the machine throttle.

The actual test values were obtained by reading the manufactured monitor at the same time the Standco tachometer (with rod) was touching the vibrator and VIBRA-TAK device was touching the same rod near the top end. Actual values obtained from each of the three devices were recorded and the team moved to the next vibrator. After readings were obtained from each of the test vibrators, the researcher and paving machine operator were free to return to a operator selected track speed and vibrator frequency or conduct another set of tests with the same or different set of the variables.

Observation of the montoring devices during testing revealed there is drift in the frequency values set on the device as the paving machine moves forward during concrete placement. The drift from the established frequency was found to be in the range of 200 cycles per minute, plus or minus, during operations. This occurs as a result of load shifts and other power demands on the hydraulic system of the paving machine. With this ongoing condition, there can be a significant difference in frequency readings even if taken only seconds apart by different frequency measuring devices. Therefore close uniformity results should not be expected in the Analysis of Variance (ANOVA).

The concrete finishers were not informed of the various combinations of track speed and frequency variables prior to the settings. After the frequency data were

collected for a given combination of the variables and prior to starting a new set, the finishers were observed by the research team. The amount of work required to complete the finishing of the concrete was subjectively recorded, along with a subjective assessment of the openness of the plastic concrete surface immediately behind the paving machine. This was done to document the problems that might be associated with the workability of the extruded concrete slab and the potential for additional or objectionable voids in the concrete pavement below the surface for concrete placed with a specific level of vibrating consolidation effort.

The cooperation between the paving company personnel and the research team on both projects was excellent. All participating parties were interested in finding the best possible combination of variables to produce a high quality product.

Data for the Portland Cement Association companion study were collected in the form of concrete cores from the finished pavements prior to their opening to traffic. Three separate cores were obtained from the path of each vibrator model, and between each model pair for each of the combinations of track speed and vibrator target frequency on each construction project. These cores were analyzed for relative hardened air content from the top to the bottom of the core in each location. In addition at one location on each project, three additional cores were taken to provide a total of six additional cores. These were used for a side by side test analysis by SEM and Linear Traverse determination of hardened air content.

DATA ANALYSIS

The results of the field measurements of frequency vs track speed were analyzed by ANOVA methods. This allowed the researchers to compare the results between the

combinations of track speed and frequency, and various monitoring devices ability to monitor accurately. Testing was done to determine:

1. The optimum track speed.
2. The optimum target vibrator frequency.
3. Differences in the monitoring devices.
4. Optimum combination of track speed and vibrator frequency.
5. The interaction between monitoring device and vibrator frequency.

The concrete cores were sent to the ISU/CCE Materials Analysis and Research Laboratory MARL for testing. The analysis was done using SEM technology on concrete core samples taken from the two paving sites of the Vibrator Monitoring Project HR-1068. At the laboratory, the cores were sliced vertically and polished to provide a clean, uniform surface for scanning. The top nine inch portion of each core was used for this test. Each core was then scanned by an electron microscope (SEM) in one inch vertical increments to determine the total air and hardened air content. The results were summarized into information for the top, middle and bottom one third of the core. It was then further summarized according to the vibrator type, frequency and track speed and is shown in the companion study report.

RESEARCH RESULTS

Statistical ANOVA testing was carried out on the field observations using the mean values from the series of tests completed at each site from three separate data collection periods. The data for each of the construction projects were arranged independently due to the differences in pavement thickness, materials and equipment being used. The

purpose of this testing was the evaluation of each type of manufactured monitoring equipment to accurately measure vibrator frequency and not the direct comparison of the two types of monitors.

The data were arranged in groups to determine the mean values and variances between means. Results of the analysis were then summarized in terms of the following parameters:

1. Vibrator Monitor Type:

   M = Manufactured monitor

   S = Standco Tachometer

   V = VIBRA-TAC

2. Paving Machine Target Track Speed

   TS(1) = Track Speed of 4 feet/minute

   TS(2) = Track Speed of 6 1/4 feet/minute

3. Vibrator Target Frequency

   F(5) = Frequency (5000 cycles /minute)

   F(8) = Frequency (8000 cycles/ minute)

The data sets were arranged as follows for the statistical analysis:

Set	Device	Track Speed	Frequency
1	M	TS(1)	F(5)
2	S	TS(1)	F(5)
3	V	TS(1)	F(5)
4	M	TS(2)	F(5)
5	S	TS(2)	F(5)
6	V	TS(2)	F(5)
7	M	TS(1)	F(8)
8	S	TS(1)	F(8)
9	V	TS(1)	F(8)
10	M	TS(2)	F(8)
11	S	TS(2)	F(8)
12	V	TS(2)	F(8)

ANOVA Test Results

1. $\mu = \mu_o$

- A t-test was conducted to determine if the average measured frequency of each monitoring device differed from the target frequency of 5000 at a track speed of 4 feet/minute. Results indicated equality between the average measured frequency of the monitor and the target frequency of 5000 and the VIBRA-TAC and the target frequency of 5000. However, the average

measured frequency of the Standco Tachometer is not equal to the target frequency of 5000 at a track speed of 4 feet/minute.

2. $\mu = \mu_o$

- A t-test was conducted to determine if the average measured frequency of each monitoring device differed from the target frequency of 8000 at a track speed of 4 feet/minute. Results indicated equality between the average measured frequency of all three monitoring devices and the target speed of 8000 at a track speed of 4 feet/minute.

3. $\mu = \mu_o$

- A t-test was conducted to determine if the average measured frequency of each monitoring device differed from the target frequency of 5000 at a track speed of 6 1/4 feet/minute. Results indicated no equality between the average measured frequency of each monitoring device and the target speed of 5000 at a track speed of 6 1/4 feet/minute.

4. $\mu = \mu_o$

- A t-test was conducted to determine if the average measured frequency of each monitoring device differed from the target frequency of 8000 at a track speed of 6 1/4 feet/minute. Results indicated no equality between the average measured frequency of each monitoring device and the target speed of 8000 at a track speed of 6 1/4 feet/minute.

5. $\mu_1 = \mu_4$

- An ANOVA was conducted to determine if the average measured frequency of the monitor at a track speed of 4 feet/minute and a target frequency of

5000 differed from the average measured frequency of the monitor at a track speed 6 ¼ feet/minute and a target frequency of 5000. Results indicated equality between the average measured frequency of the monitor at a target frequency of 5000 at a track speed of 4 feet/minute and the average measured frequency of the monitor at a target frequency of 5000 at a track speed of 6 1/4 feet/minute.

6. $\mu_2 = \mu_5$

- An ANOVA was conducted to determine if the average measured frequency of the Standco Tachometer at a track speed of 4 feet/minute and a target frequency of 5000 differed from the average measured frequency of the Standco Tachometer at a track speed 6 1/4 feet/minute and a target frequency of 5000. Results indicated equality between the average measured frequency of the Standco Tachometer at a target frequency of 5000 at a track speed of 4 feet/minute and the average measured frequency of the Standco rod at a target frequency of 5000 at a track speed of 6 1/4 feet/minute.

7. $\mu_3 = \mu_6$

- An ANOVA was conducted to determine if the average measured frequency of the VIBRA-TAC at a track speed of 4 feet/minute and a target frequency of 5000 differed from the average measured frequency of the VIBRA-TAC at a track speed 6 1/4 feet/minute and a target frequency of 5000. Results indicated equality between the average measured frequency of the VIBRA-TAC at a target frequency of 5000 at a track speed of 4 feet/minute and the

average measured frequency of the VIBRA-TAC at a target frequency of 5000 at a track speed of 6 1/4 feet/minute.

8. $\mu_1 = \mu_2 = \mu_3$

- An ANOVA was conducted to determine if the average measured frequency of each monitoring device at a track speed of 4 feet/minute and a target frequency of 5000 was different from each other. Results indicated <u>no equality</u> between the average measured frequency of each monitoring device at a track speed of 4 feet/minute and a target frequency of 5000 when compared with each other.

9. $\mu_4 = \mu_5 = \mu_6$

- An ANOVA was conducted to determine if the average measured frequency of each monitoring device at a track speed of 6 1/4 feet/minute and a target frequency of 5000 was different from each other. Results indicated <u>no equality</u> between the average measured frequency of each monitoring device at a track speed of 6 1/4 feet/minute and a target frequency of 5000 when compared with each other.

10. $\mu_7 = \mu_{10}$

- An ANOVA was conducted to determine if the average measured frequency of the monitor at a track speed of 4 feet/minute and a target frequency of 8000 differed from the average measured frequency of the monitor at a track speed 6 1/4 feet/minute and a target frequency of 8000. Results indicated <u>equality</u> between the average measured frequency of the monitor at a target frequency of 8000 at a track speed of 4 feet/minute and the average measured frequency

of the monitor at a target frequency of 8000 at a track speed of 6 1/4 feet/minute.

11. $\mu_8 = \mu_{11}$

- An ANOVA was conducted to determine if the average measured frequency of the Standco Tachometer at a track speed of 4 feet/minute and a target frequency of 8000 differed from the average measured frequency of the Standco Tachomter at a track speed 6 1/4 feet/minute and a target frequency of 8000. Results indicated equality between the average measured frequency of the Standco Tachometer at a target frequency of 8000 at a track speed of 4 feet/minute and the average measured frequency of the Standco Tachometer at a target frequency of 8000 at a track speed of 6 1/4 feet/minute.

12. $\mu_9 = \mu_{12}$

- An ANOVA was conducted to determine if the average measured frequency of the VIBRA-TAC at a track speed of 4 feet/minute and a target frequency of 8000 differed from the average measured frequency of the VIBRA-TAC at a track speed 6 1/4 feet/minute and a target frequency of 8000. Results indicated equality between the average measured frequency of the VIBRA-TAC at a target frequency of 8000 at a track speed of 4 feet/minute and the average measured frequency of the VIBRA-TAC at a target frequency of 8000 at a track speed of 6 1/4 feet/minute.

13. $\mu_7 = \mu_8 = \mu_9$

- An ANOVA was conducted to determine if the average measured frequency of each monitoring device at a track speed of 4 feet/minute and a target

frequency of 8000 was different from each other. Results indicated equality between the average measured frequency of each monitoring device at a track speed of 4 feet/minute and a target frequency of 8000 when compared with each other.

14. $\mu_{10} = \mu_{11} = \mu_{12}$

- An ANOVA was conducted to determine if the average measured frequency of each monitoring device at a track speed of 6 1/4 feet/minute and a target frequency of 8000 was different from each other. Results indicated equality between the average measured frequency of each monitoring device at a track speed of 6 1/4 feet/minute and a target frequency of 8000 when compared with each other.

15. $\mu_1 = \mu_7$

- An ANOVA was conducted to determine if the average measured frequency of the monitor at a track speed of 4 feet/minute and a target frequency of 5000 differed from the average measured frequency of the monitor at a track speed 4 feet/minute and a target frequency of 8000. Results indicated no equality between the average measured frequency of the monitor at a target frequency of 5000 at a track speed of 4 feet/minute and the average measured frequency of the monitor at a target frequency of 8000 at a track speed of 4 feet/minute.

16. $\mu_2 = \mu_8$

- An ANOVA was conducted to determine if the average measured frequency of the Standco Tachometer at a track speed of 4 feet/minute and a target frequency of 5000 differed from the average measured frequency of the

Standco Tachometer at a track speed 4 feet/minute and a target frequency of 8000. Results indicated no equality between the average measured frequency of the Standco Tachometer at a target frequency of 5000 at a track speed of 4 feet/minute and the average measured frequency of the Standco Tachometer at a target frequency of 8000 at a track speed of 4 feet/minute.

17. $\mu_3 = \mu_9$

- An ANOVA was conducted to determine if the average measured frequency of the VIBRA-TAC at a track speed of 4 feet/minute and a target frequency of 5000 differed from the average measured frequency of the VIBRA-TAC at a track speed 4 feet/minute and a target frequency of 8000. Results indicated no equality between the average measured frequency of the VIBRA-TAC at a target frequency of 5000 at a track speed of 4 feet/minute and the average measured frequency of the VIBRA-TAC at a target frequency of 8000 at a track speed of 4 feet/minute.

18. $\mu_4 = \mu_{10}$

- An ANOVA was conducted to determine if the average measured frequency of the monitor at a track speed of 6 1/4 feet/minute and a target frequency of 5000 differed from the average measured frequency of the monitor at a track speed 6 1/4 feet/minute and a target frequency of 8000. Results indicated no equality between the average measured frequency of the monitor at a target frequency of 5000 at a track speed of 6 1/4 feet/minute and the average measured frequency of the monitor at a target frequency of 8000 at a track speed of 6 1/4 feet/minute.

19. $\mu_5 = \mu_{11}$

- An ANOVA was conducted to determine if the average measured frequency of the Standco Tachometer at a track speed of 6 1/4 feet/minute and a target frequency of 5000 differed from the average measured frequency of the Standco Tachometer at a track speed 6 ¼ feet/minute and a target frequency of 8000. Results indicated <u>no equality</u> between the average measured frequency of the Standco Tachometer at a target frequency of 5000 at a track speed of 6 1/4 feet/minute and the average measured frequency of the Standco Tachometer at a target frequency of 8000 at a track speed of 6 1/4 feet/minute.

20. $\mu_6 = \mu_{12}$

- An ANOVA was conducted to determine if the average measured frequency of the VIBRA-TAC at a track speed of 6 1/4 feet/minute and a target frequency of 5000 differed from the average measured frequency of the VIBRA-TAC at a track speed 6 1/4 feet/minute and a target frequency of 8000. Results indicated <u>no equality</u> between the average measured frequency of the VIBRA-TAC at a target frequency of 5000 at a track speed of 6 1/4 feet/minute and the average measured frequency of the VIBRA-TAC at a target frequency of 8000 at a track speed of 6 1/4 feet/minute.

FIELD OBSERVATIONS:

The research staff noted the following observations from the time spent in evaluating each of the monitoring devices under installation and operation:

1. Each of the devices was easy to mount and required less than 3 hours to mount the device and replace six vibrators.
2. Each of the devices was operator friendly and required little (less than 30 minutes) instruction to train the paving machine operator or research staff in their operation.
3. Both devices proved durable in operation. Each of the monitoring devices required no maintenance over the testing period and there were no visible signs of malfunctions in either device. Maintenance centered on the electrical sending cable between the vibrator and monitor. This was usually associated with a malfunctioning vibrator and would be considered a normal problem on this type equipment.
4. The WYCO monitor did require special grounding to the paver frame and does exhibit some minor problems with condensation inside the monitor. The manufacturer is working to solve this problem. The Minnich device did not exhibit either of these problems, however, initially it did experience some difficulty transmitting a signal at low vibrator frequency.
5. Both devices proved their accuracy and reliability when compared to the other manual monitoring devices as shown in the statistical analysis. By testing at different times, locations, and with the changes in frequency and forward paver machine speeds, the devices proved their reliability in the field.
6. Paving machine operators and highway agency inspectors like both monitors in that they are easy to read and readily accessible for observation and adjustment in the event of changes in the vibrators or mix over the course of

the day. Spot checks of vibrator operation can be made by either with the monitors.

7. The Minnich warning device (audible) can be annoying, but does let the operator know when a vibrator goes out of established ranges of frequency. Proper setting of the range or specification limits being scanned can reduce the annoyance factor. The research team does recommend that the alarm not be equipped to allow avoidance by the operator.
8. The combination of low frequency (5000) and low forward speed (4 feet/minute) created the potential for open surfaces behind the paving machine if the consistency of the material being delivered varied in any way.
9. The higher frequency (8000) and consistency in concrete delivery to maintain the 6 1/4 feet/minute speed resulted in a surface free of voids and reduced any finishing requirements behind the paving machine by providing a uniform product and surface across the slab.

CONCLUSIONS

It is the conclusion of the research team that:

1. Both brands of monitoring systems tested are easily adapted to two brands of paving machines.
2. Operational durability and reliability of the equipment were shown to be good as each brand experienced only one easily correctable defect or malfunction during the testing period.

3. Paving machine vibrator frequency consistently fluctuates several hundred cycles per minute above and below the set target frequency.
4. Variations in frequency values between the three measuring methods, for one set of test readings, are due to the actual constant fluctuations in frequency of several hundred cycles per minute from the target setting. With readings taken only seconds apart, the result can be one of "no equality" statistically.
5. Frequency readings taken from the electronic monitor are in digital form and can be read much more accurately than a hand held mechanical tachometer scale.
6. The monitoring devices evaluated do provide the following benefits to the contractor:
   a. A method to ensure consistent vibration over the course of the day.
   b. A method to identify vibrator wear and other maintenance problems in advance.
   c. Provides a real time feedback to the contractor.
   d. Provides a way of extending vibrator life.
   e. Provides documentation to verify vibration in the event of hardened concrete problems.
7. The monitoring devices evaluated provide the following benefits to the highway agency:
   a. Allows for verification of consistent vibrator operation through continuous, real time measurements.
   b. Allows for verification of vibrator frequencies from a place of safety and reduces verification time.

8. Having the continuous readout vibrator monitoring system on a paving machine is a definite step in a positive direction toward improvements in quality control in concrete consolidation.

As a result of this research, the Iowa DOT has instituted a monitoring specification SP-97201. A copy is included in the appendix. It requires the use of the vibrator monitoring device on the paving machines being used for mainline paving on three different projects let in 1999.

The construction industry has seen the need for such devices and, in conjunction with the manufacturers, are working on advances in the monitoring and vibrator areas. Monitors are being equipped to both scan the vibrators and record data from those scans. The use of microchips may allow the operator to preprogram vibrator frequencies to meet changes in the mix or environmental conditions.

FUTURE RESEARCH NEEDS

Due to the funding and time constraints, only a selected number of variables could be evaluated in this study. The research team suggests that the relationship between the following variables and the air matrix in the hardened concrete need to be studied:

1. Vibrator variables
    a. Spacing
    b. Depth of vibrator tip
    c. Angle of vibrator from the horizontal
    d. Area of influence of a vibrator
2. Paving machine variables

a. Tamper bar operations

   1. Width of tamper bar

   2. Depth of movement relative to strikeoff bar

   3. Rate of tamping

b. Grout box operations

   1. Depth of grout in box

   2. Depth of vibrator vs depth of grout

   3. Disposition of materials from various levels in grout box to the slab

   4. Density of the materials at various levels in the box

REFERENCES

1. **Vibration Study for Consolidation of Portland Cement Concrete**, Project MLR-95-4, Iowa Department of Transportation, Shane Tymkowicz, Bob Steffes, January 1997, Transportation Research Board.
2. **Evaluation for Vibrator Consolidation of Portland Cement Concrete Paving**, Shane Tymkowicz, 1998.
3. **Image Analysis for Evaluating Air Void Parameters of Concrete**, HR-398 Iowa DOT and ISU-ERI-Ames Number 98403, Scott Schlorholtz, 1998.
4. **Efficient Consolidation of Concrete Using the Resonance Phenomenon**, Innotech International, Inc., 1996.
5. **Void Parameters of Concrete Cores from a Section of I-64**, Virginia Highway Research Council, Hollis N. Walker, Transportation Research Board, 1974.

APPENDIX

At the time of the research effort, both manufacturers were conducting their own research into the development of vibrator monitoring devices. The units used in the Iowa research represent prototypes of the "state of the art" in equipment at that time. Since the initial field testing was completed, both companies have continued to develop units that anticipate the needs of the highway industry. Included in this appendix are examples first of the equipment (monitors and vibrators) that were employed in the research and examples of the monitors that are now available. Unit costs for the equipment are also shown to provide the reader with an estimate of the cost associated with implementation of this type of equipment on any size paving machine.

A copy of the manufacturer's literature describing the VIBRA-TAC and Standco Tachometer is included.

Special Provision SP-97201, dated January 12, 1999 regarding Portland Cement Concrete Paver Vibrator Monitoring has been included to illustrate the advances that the Iowa DOT is making in this area as a result of this research.

INTRODUCING THE *Smart* HYDRAULIC PAVING VIBRATOR

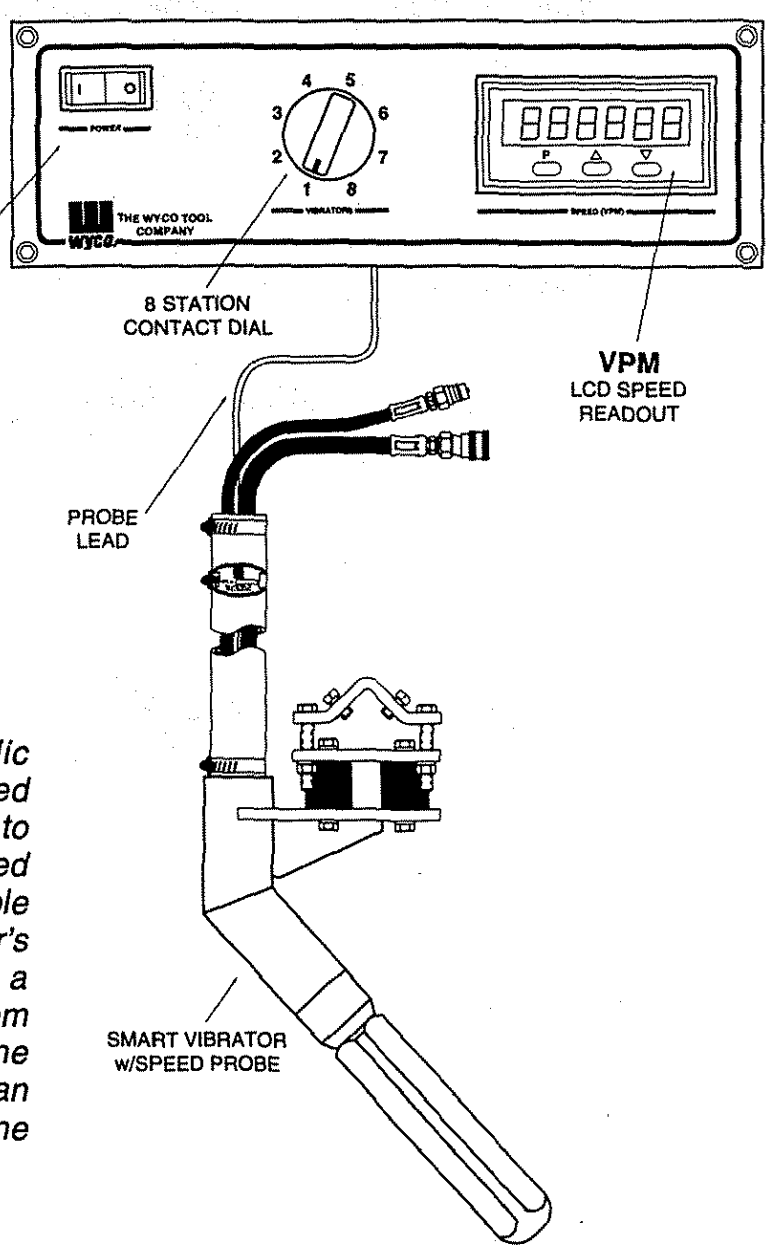
FEATURES:

Accurately monitors vibrator speed (vpm's)

Fits on any new or existing system

Allows individual vibrator control

Compatible with data acquisition or logging systems



o introduces a new generation of Hydraulic crete Paving Vibrators with heavy duty speed nsors embedded in the vibrator head assembly to rately monitor each vibrator's operating speed m's). These "Smart" Hydraulic Vibrators enable operator to adjust and control each vibrator's d independently during paving. This assures a re uniform output and end product. This system ws a continuous mechanical evaluation of the tor, eliminating unscheduled down time. It can o provide a more complete data history of the ment.

For more information, contact:

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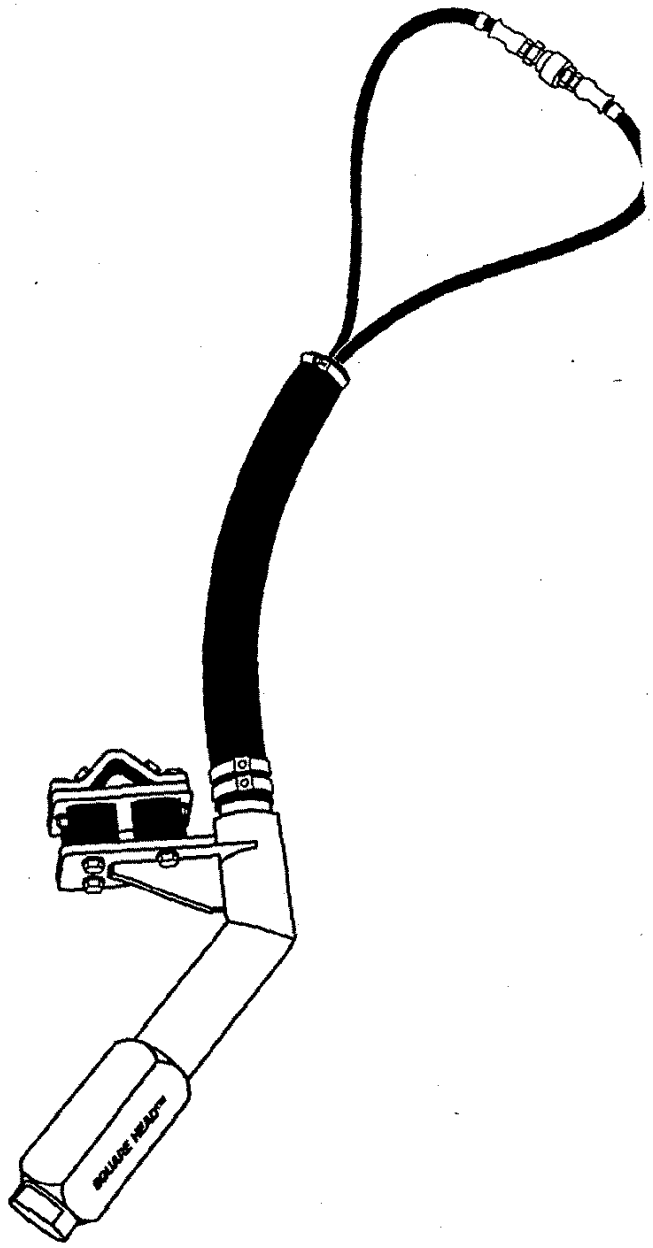
2200 South Street • Racine, Wisconsin 53404-1526
Telephone: (414) 639-6770 or 1-800-233-9926

W125 9/96 Printed in U.S.A.

INTRODUCING SUPER SPUD 3000 HYDRAULIC PAVING VIBRATOR

FEATURES:

- ***3000 lbs. force at 10,500 VPMs***
  This model can also be used to input a higher force than standard vibrators when lower speeds are specified.
- ***High strength, precision interlocking tool steel bearing cups***
- ***High load-carrying capacity cylindrical roller bearings***
- ***Oil Lubrication***
- ***Thru hardened alloy steel tip***
- ***Speed Sensing Available***



PRELIMINARY SPECIFICATIONS:

Head Size: 3 inch square
Eccentric Moment: .95 inch-lbs.
Amplitude: .110 inch

Flow Rate (GPM)	3	4	4.6
Pressure (PSI)	1,103	1,536	1,800
Speed (VPM)	7,100	9,200	10,500
Force (Lbs)	1,375	2,300	3,000

Hydraulic Hose: Inlet 1/4", Outlet 3/8"
Length – 8' Hyd Hose, 4' Protective Hose
Filtration: 10 Micron Absolute (ISO) 17/13 Fluid Cleanliness Required
Operating Temperature: 140°F, Optimum (165°F Max.)

For more information, contact:

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ENGINEERING BULLETIN

Smart Vibrators *Patent Pending*

Speed Sensing Vibrators

When Wyco Tool supplied vibrators have the speed sensing option, a cable exits the back of the hydraulic motor next to the hydraulic hoses. This armored and shielded sensor cable (Wyco # 420003) extends 9 feet away from the hydraulic motor. It runs parallel to the hydraulic hose and inside the protective hose. When protective hose is greater than 8 feet, extension cable will be needed to exit the last rubber plug. The shielded sensor cable can plug directly into the speed monitoring equipment. Extension cable is required when the 9 feet of shielded sensor cable is not long enough to reach the speed monitoring equipment. Extension cables are available in 10 foot (Wyco # 420010), 15 foot (Wyco # 420015) and 20 foot (Wyco # 420020) lengths. Lengths should be kept as short as possible to avoid interference. Avoid other electrical components when routing cable to avoid signal noise. The military quality connectors used are shielded, sealed and have a quick connecting and disconnecting feature.

Speed monitors should be bolted on a flat surface, where the display can be easily seen while adjusting the vibrator speed controls. Four mounting holes suitable for 1/4 inch bolts are available. Each unit can display speeds for up to 8 vibrators. A rotary switch is used for vibrator selection. Currently, three different configurations of speed monitors are available:

Wyco #	Description
420003	Horizontal; mounts on a horizontal surface
420044	Vertical Right Hand; mounts on a vertical surface on the right hand side of a cabinet or counsel
420046	Vertical Left Hand; mounts on a vertical surface on the left hand side of a cabinet or counsel

A 20 foot power cable is required with the above boxes (Wyco # 420006). Alternately, a power cable can be made up using Cannon connector #MS3106F16S-8S. The black wire (pin A) should be wired to ground and the white wire (pin D) should be wired to 12 volt DC. If the display does not turn on, try switching the wires.

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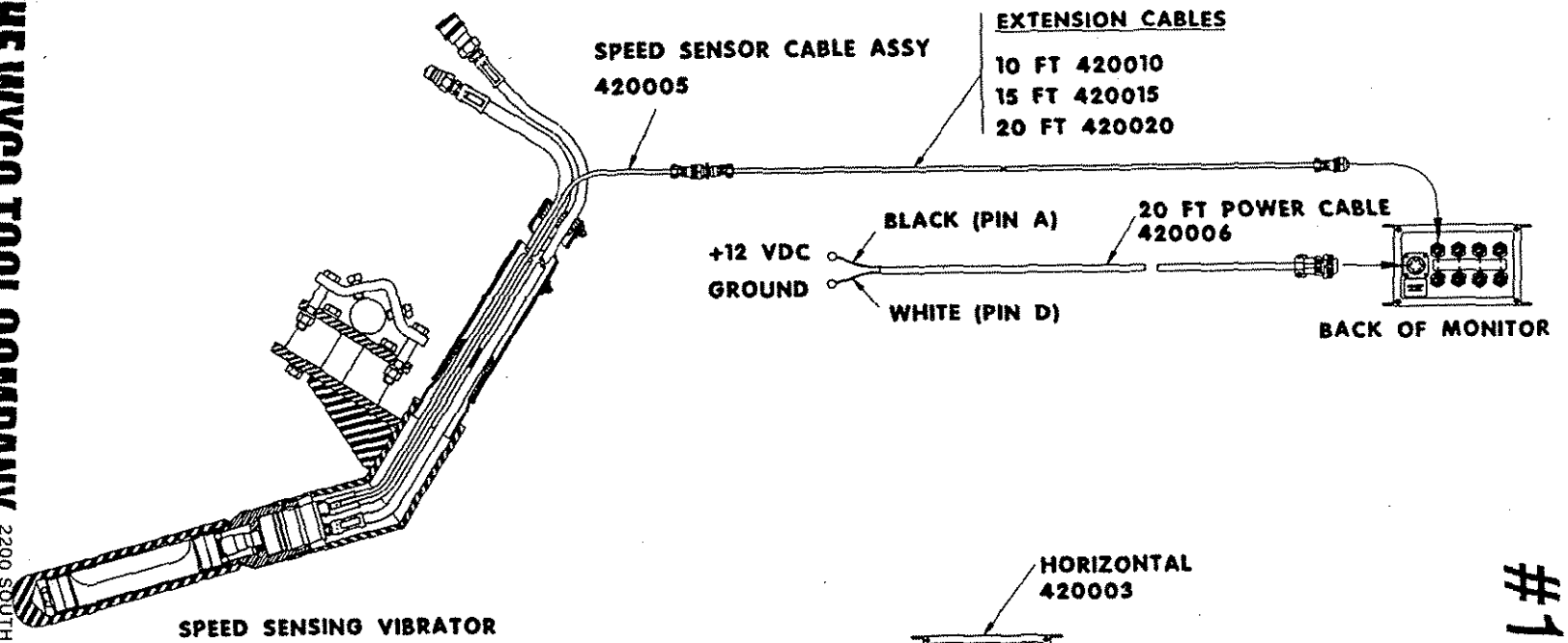
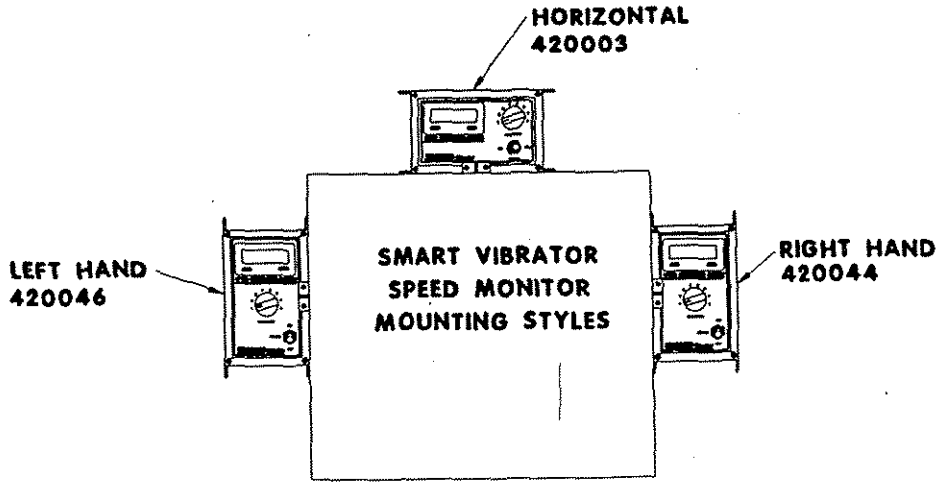
ENGINEERING BULLETIN

#19 PAGE 2





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"SMART"

STANDARD HYDRAULIC ANGLE

PART NUMBER	DESCRIPTION	LIST PRICE
949760	Standard Angle M-8	$1244.00
949960	SMART Vibrator	$1510.00

SPEED MONITORS

420003	Horizontal mount	$1370.00
420044	Vertical mount, right side	$1370.00
420046	Vertical mount, left side	$1370.00

CABLE ASSEMBLY

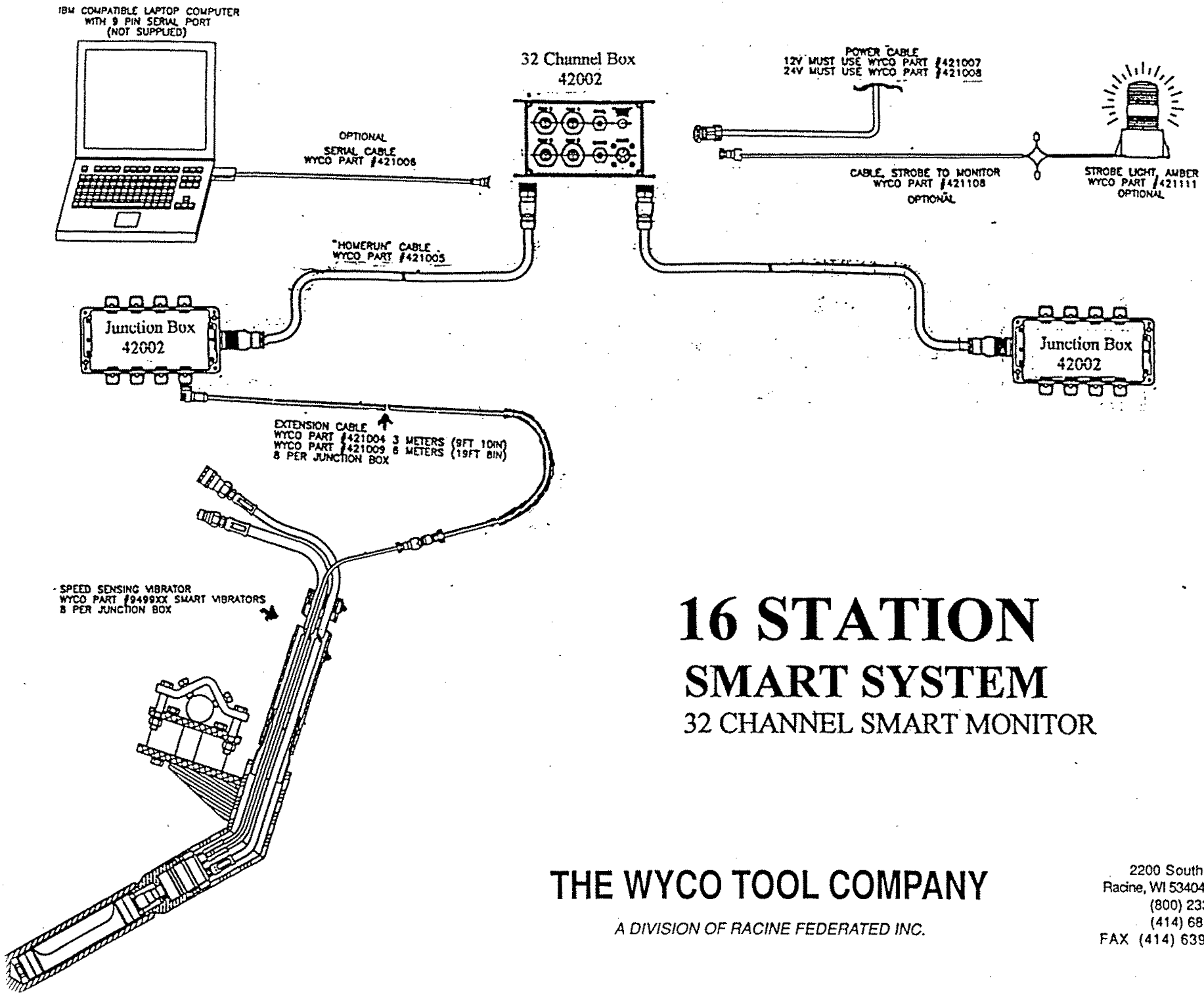
(INCLUDES SPEED SENSOR CONNECTOR, CONDUIT ASSEMBLY AND SPEED SENSOR VR.)

420005	Cable Assembly, Speed Sensor	$208.00
420006	20 Ft Power Cable	$90.00

CABLE EXTENSIONS

420010	10 Ft Cable Extension	$119.00
420015	15 Ft Cable Extension	$137.00
420020	20 Ft Cable Extension	$155.00

APRIL 1998



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32 CHANNEL SMART MONITOR

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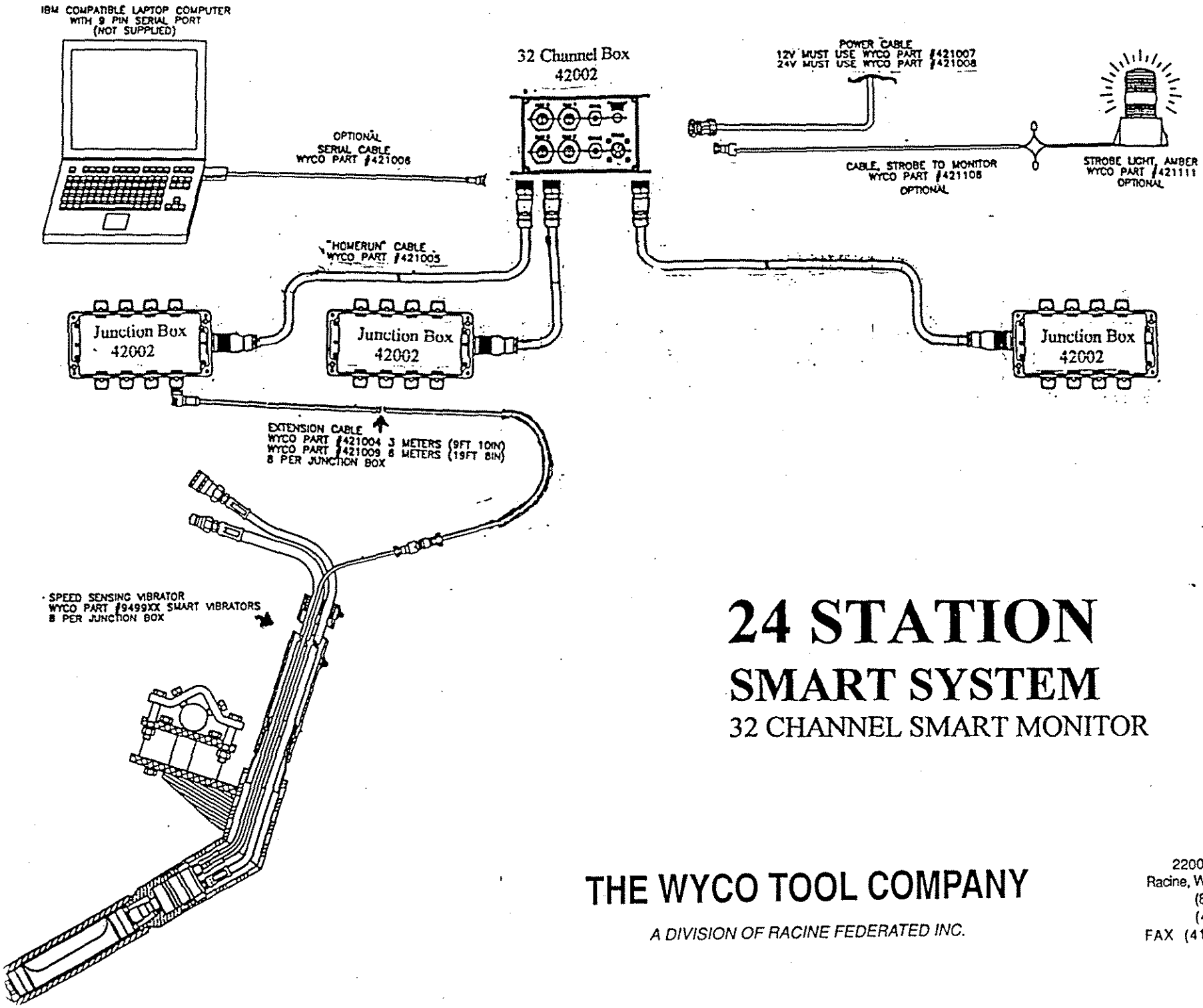

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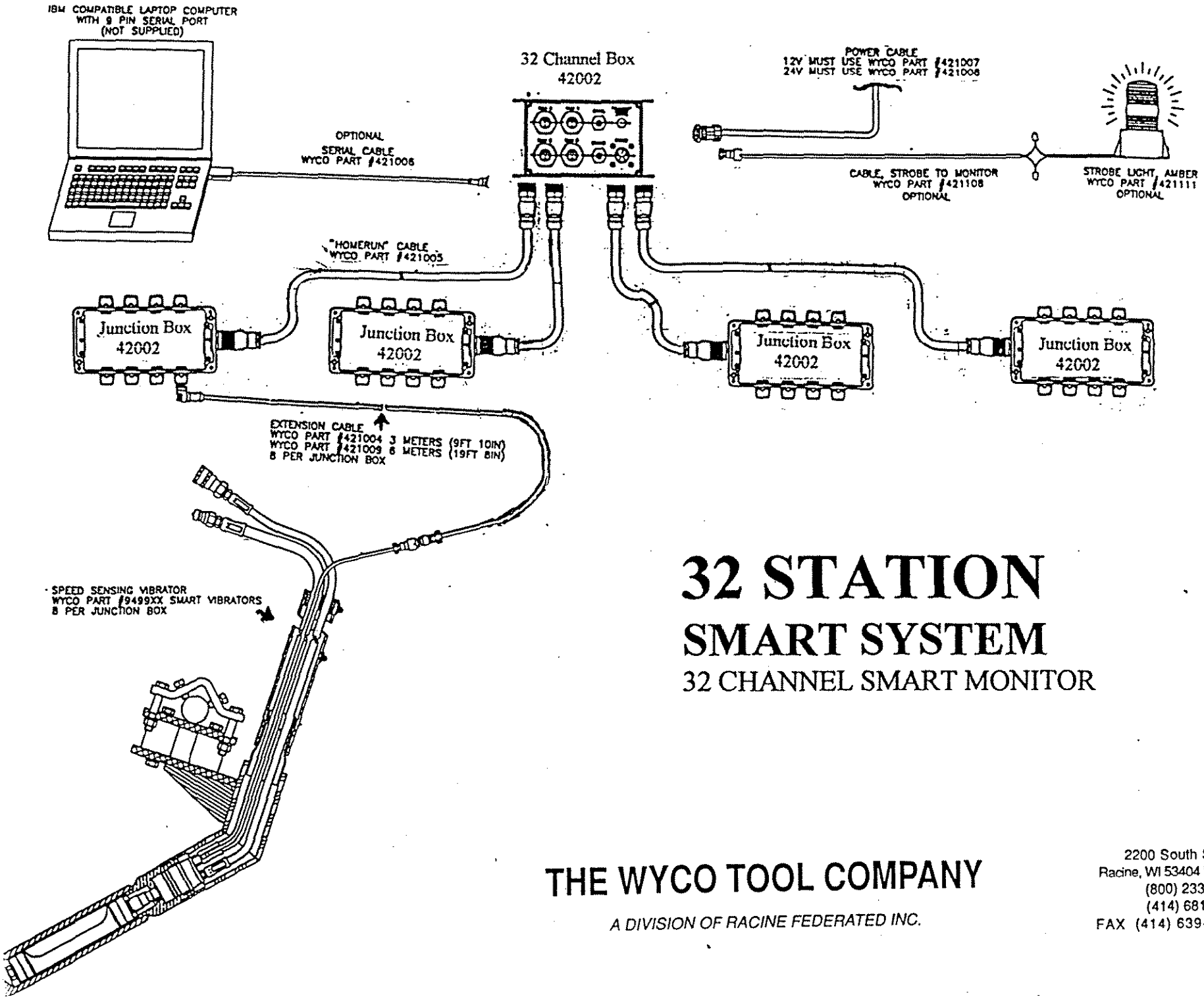

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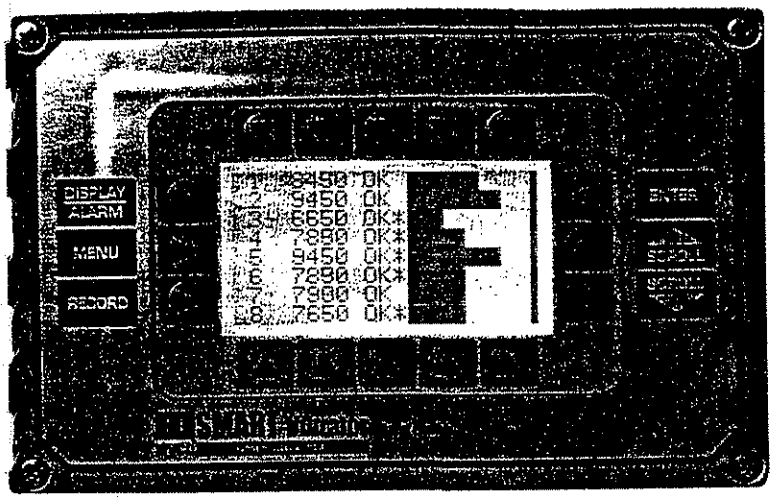
The *Smart* Hydraulic Paving Vibrator

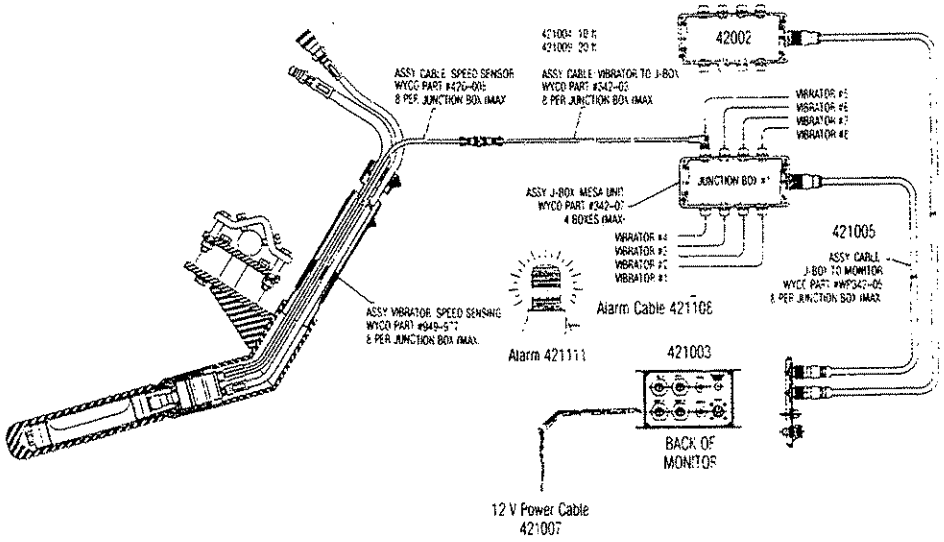
WYCO®

Provides Consistent Quality Concrete Consolidation



- Accurately monitors up to 32 vibrators
- Displays up to 8 visual readouts at a time
- Available in both analog and digital format
- Records service hours and prompts when maintenance is required
- Allows individual (high/low) vibrator alarms
- Vibrator alarms can be adjusted globally or individually
- Uses rugged, time-tested magnetic pick up technology
- Downloads data, such as time and individual vibrator speed, via any IBM-compatible computer serial port
- Equipped with (optional) high visibility strobe light

WYCO 32-Channel Smart System



WYCO offers a new generation of Hydraulic Concrete Paving Vibrators with heavy duty speed sensors embedded in the vibrator head assembly to accurately monitor each vibrator's operating speed (vpm's). These "Smart" Hydraulic Vibrators enable the operator to adjust and control each vibrator's speed independently during paving. This assures a more uniform output and end product. This system allows a continuous mechanical evaluation of the vibrator, eliminating unscheduled downtime. It can also provide a more complete data history of the pavement.

Fits on any new or existing system

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1-Jan-99

16 STATION SMART SYSTEM

Qty	Part #	Description	List	Ext. list
8-	W421-004	10 foot Extension	$ 120	$ 960
8-	W421-009	20 foot Extention	$ 133	$ 1,064
2-	W421-005	Homerun Cable	$ 477	$ 954
1-*	W421-007	12v Power Cable	$ 89	$ 89
2-	W421-002	Junction Box	$ 895	$ 1,790
1-	W421-003	32 Channel Smrt Box	$ 4,250	$ 4,250
			Total	$ 9,107

24 STATION SMART SYSTEM

Qty	Part #	Description	List	Ext. List
12-	W421-004	10 foot Extension	$ 120	$ 1,440
12-	W421-009	20 foot Extension	$ 133	$ 1,596
3-	W421-005	Homerun Cable	$ 477	$ 1,341
1-*	W421-007	12v Power Cable	$ 89	$ 89
3-	W421-002	Juntion Box	$ 895	$ 2,685
1-	W421-003	32 Channel Smrt Box	$ 4,250	$ 4,250
			Total	$ 11,401

32 STATION SMART SYSTEM

Qty	Part #	Description	List	Ext List
16-	W421-004	10 foot Extension	$ 120	$ 1,920
16-	W421-009	20 foot Extension	$ 133	$ 2,128
4-	W421-005	Homerun Cable	$ 447	$ 1,788
1-*	W421-007	12v Power Cable	$ 89	$ 89
4-	W421-002	Junction Box	$ 895	$ 3,580
1-	W421-003	32 Channel Smrt Box	$ 4,250	$ 4,250
			Total	$ 13,755

OPTIONAL SMART SYSTEM FEATURES

	Part #	Description	List
	W421-006	Serial Cable	$ 106
	W421-111	Strobe Light	$ 230
	W421-108	Strobe Cable	$ 67
*	W421-007	24v Power Cable	$ 89

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A SENSORING KIT THAT GIVES YOU:

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- **ALARM SETTINGS - HIGH AND LOW VPM**
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Minnich Manufacturing is proud to introduce the "Auto VIB" System that automatically scans your vibrators in sequence to give you an individual VPM readout. You may also select the Manual Mode which allows the operator to select any Vibrator for VPM setting or continuous monitoring.

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This Sensoring System may be purchased on new vibrators or may be retrofitted on your existing vibrators in stock.

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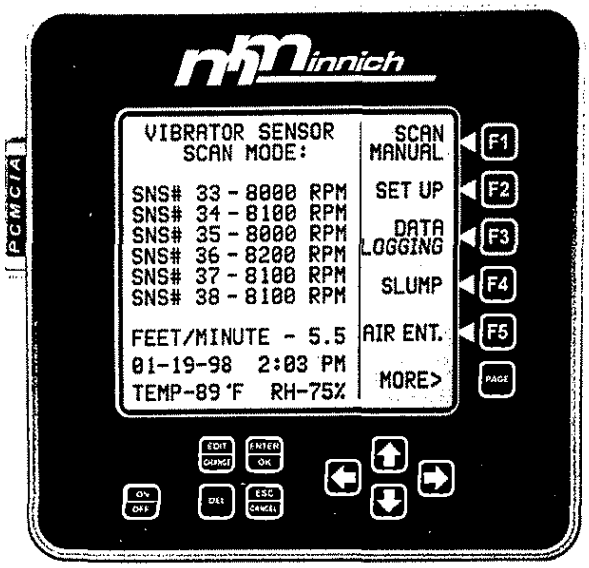

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- Individual Alarm Settings
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Get The BEST In
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Hydraulic Vibrator Specifications

Models: HV-2 HV-2B HV-2P

Head Diameter	2 3/8 in. (59mm)
Head Length	18 1/4 in. (464mm)
Eccentric Diameter	1 3/4 in. (45mm)
Eccentric Length	6 7/8 in. (175mm)
Centrifugal Force	1025 lbs. (4559n)
Amplitude	.038 in. (.965mm)
V.P.M.	10,000
Hydraulic Fluid Required	4 G.P.M.

Models: HV-2E HV-2BE HV-2PE

Head Diameter	2 3/8 in. (59mm)
Head Length	20 1/4 in. (514mm)
Eccentric Diameter	1 3/4 in. (45mm)
Eccentric Length	8 7/8 in. (225mm)
Centrifugal Force	1730 lbs. (7695n)
Amplitude	.059 in. (1.499mm)
V.P.M.	10,000
Hydraulic Fluid Required	4 G.P.M.

Models: HV-2EH HV-2BEH HV-2PEH

Head Diameter	2 3/8 in. (59mm)
Head Length	20 1/4 in. (514mm)
Eccentric Diameter	1 7/8 in. (48mm)
Eccentric Length	8 7/8 in. (225mm)
Centrifugal Force	2150 lbs. (9,565n)
Amplitude	.085 in. (2.159mm)
V.P.M.	10,000
Hydraulic Fluid Required	4 G.P.M.

Models: HV-4 HV-4B HV-4P

Head Diameter	3 in. (75mm)
Head Length	17 3/4 in. (451mm)
Eccentric Diameter	2 in. (50.8mm)
Eccentric Length	8 3/4 in. (222mm)
Centrifugal Force	2340 lbs. (10,408n)
Amplitude	.061 in. (1.549mm)
V.P.M.	10,000
Hydraulic Fluid Required	4 G.P.M.

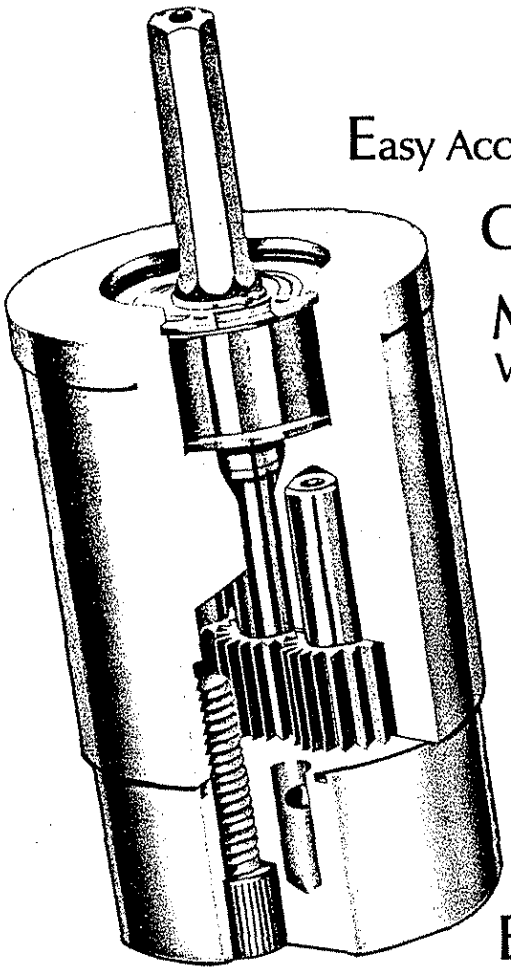
Model Code Definitions

HV=Hydraulic Vibrator **L**=Long **S,R & C**=Models Only **H**=Heavy Eccentric **2**=2 3/8 in. Head
B=Straight with Bracket **P**=Paving **E**=Long Eccentric **1**=1 3/4 in. Head **4**=3 in. Head

Vibrator Features & Benefits

- **Precision Heavy Duty High Speed Gear Motor**
- **Lightweight Allows Better Performance**
- **Proven Mounting Bracket And Isolators**
- **Matched-Universal Ground Bearings**
- **Direct Drive Allows Positive Couple Between Motor & Eccentric Weight**
- **Rigorous In House Testing On Each Unit Insures Top Performance**
- **Easy Access To Hydraulic Motor Seal Allows For Field Replacement With Only Partial Disassembly**

3–Gear Hydraulic Motor



Easy Access to Seal Without Complete Teardown

Case Hardened Steel Hex Drive Shaft

Motor Seal & Assembly Designed To Withstand High Back Pressures

Precision Machined Aluminum Body

3 Gears Allow Hydrostatic Balance For Extended Life

Designed to Provide Greater Starting Torque

Individual Components Inspected For Accuracy

Each Motor Tested Under Adverse Conditions To Assure Maximum Performance

Electric To Hydraulic Conversion Systems Available

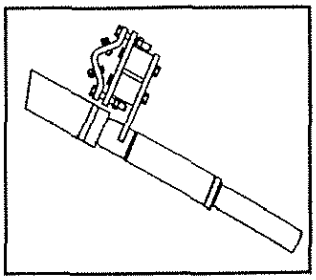
Includes:

- **Pressure Compensated Variable Flow, Piston Pump**
- **Pressure Compensated Flow Controls With Overspeed Protection (Manifold)**
- **Reservoir & Filter Assembly**
- **High Pressure Filter & Relief**
- **Heat Exchanger**
- **All Necessary Hose & Fitting Assemblies**

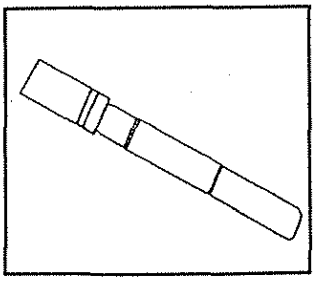
Offered In Separate Components Or As Complete Packages
Factory Assisted Installation Available Upon Request!

Paving Vibrator And Mounting Bracket Configurations

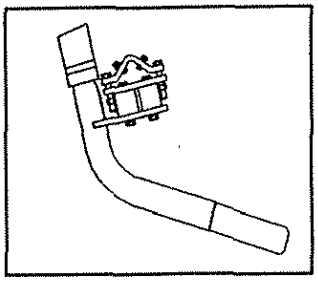
HV-3B



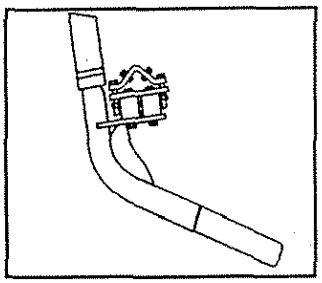
HV-2



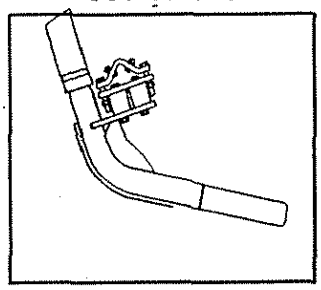
HV-2P



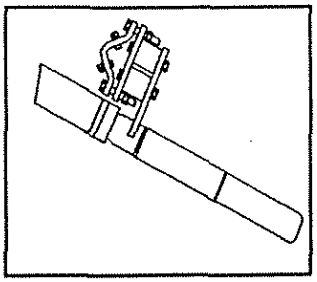
HV-2PE



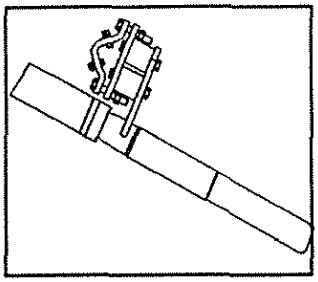
HV-2PBE



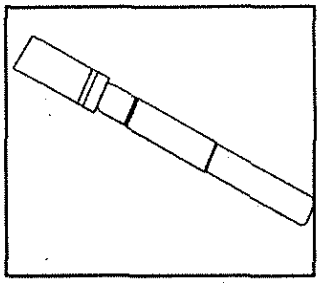
HV-2B



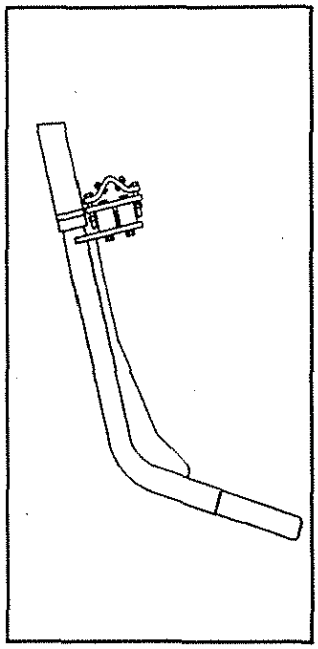
HV-2BE



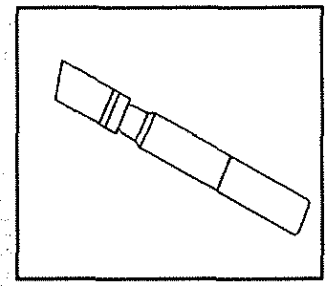
HV-2E



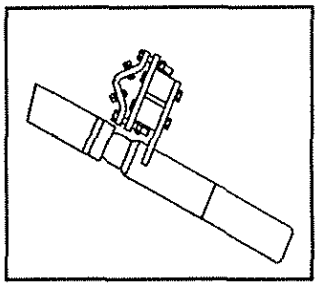
HV-2PL



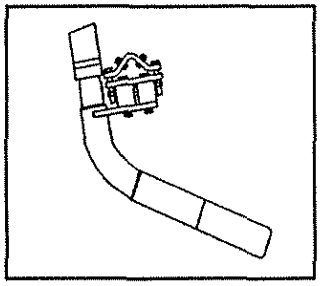
HV-4



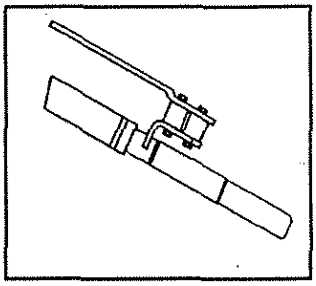
HV-4B



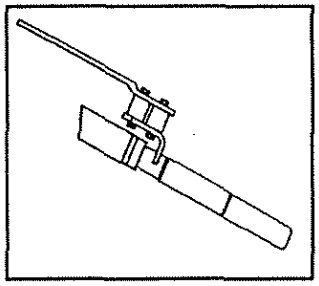
HV-4P



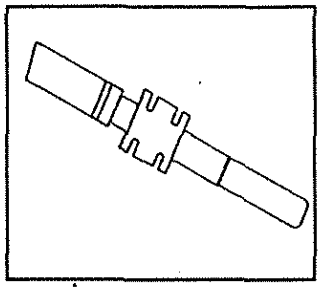
HV-2SR



HV-2S



HV-2CS



Minnich Manufacturing Co. Inc. ▪ P.O. Box 367 ▪ Mansfield, Ohio 44901
Tel. 419-524-1000 ▪ Fax. 419-524-4000

Minnich

Manufacturing Quality Products Since 1968

January 20, 1999

(Revised 4/15/99)

List prices for complete "AUTO VIBE" systems

No. Vibe's	AUTO VIBE I W/Internal Vibrator	AUTO VIBE II W/Internal Vibrator
1	$1,746.00	$11,668.00
2	$2,135.00	$12,102.00
3	$2,569.00	$12,536.00
4	$2,951.00	$12,970.00
5	$3,418.00	$13,404.00
6	$3,799.00	$13,838.00
7	$4,182.00	$14,272.00
8	$4,563.00	$14,702.00
9	$5,385.00	$15,632.00
10	$5,775.00	$16,073.00
11	$6,164.00	$16,514.00
12	$6,554.00	$16,955.00
13	$6,943.00	$17,395.00
14	$7,333.00	$17,837.00
15	$7,722.00	$18,277.00
16	$8,163.00	$18,777.00
17	$8,986.00	$19,708.00
18	$9,375.00	$20,149.00
19	$9,765.00	$20,590.00
20	$10,154.00	$21,031.00
21	$10,544.00	$21,472.00
22	$10,933.00	$21,913.00
23	$11,323.00	$22,354.00
24	$11,752.00	$22,841.00
25	$12,575.00	$23,772.00
26	$12,964.00	$24,212.00
27	$13,354.00	$24,653.00
28	$13,743.00	$25,094.00
29	$14,133.00	$25,535.00
30	$14,522.00	$25,976.00
31	$14,912.00	$26,417.00
32	$15,342.00	$26,904.00
33	$16,122.00	$27,787.00
34	$16,516.00	$28,233.00
35	$16,906.00	$28,674.00
36	$17,295.00	$29,115.00
40		$30,968.00
48		$35,031.00
56		$39,094.00
64		$43,157.00
72		$47,221.00

THE ABOVE FIGURES DO NOT INCLUDE THE PRICE OF THE VIBRATORS

Minnich

Manufacturing Quality Products Since 1968

January 20, 1999

(Revised 4/15/99)

Options

AUTO VIBE I or II

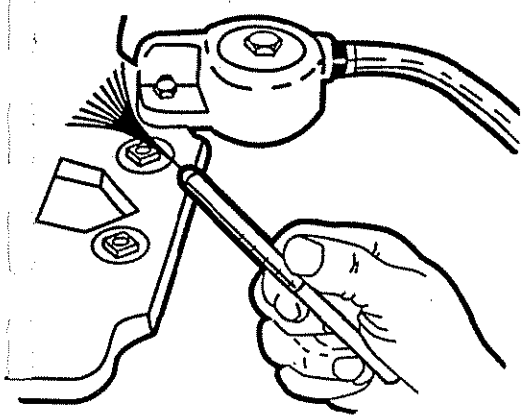
1. Using customer's rebuilt internal or external vibrators:	**Add $46.00** (for each vibrator)
2. For each spare/replacement internal vibrator installation:	**Add $295.83**
3. For each spare external vibrator installation:	**Add $438.00**
4. For each replacement of an internal vibrator with an external vibrator installation:	**Add $142.00**

AUTO VIBE II

Relative humidity and ambient temperature:	**Add $998.00**

THE ABOVE FIGURES DO NOT INCLUDE THE PRICE OF THE VIBRATORS

Check speed of vibration quickly, easily, and accurately



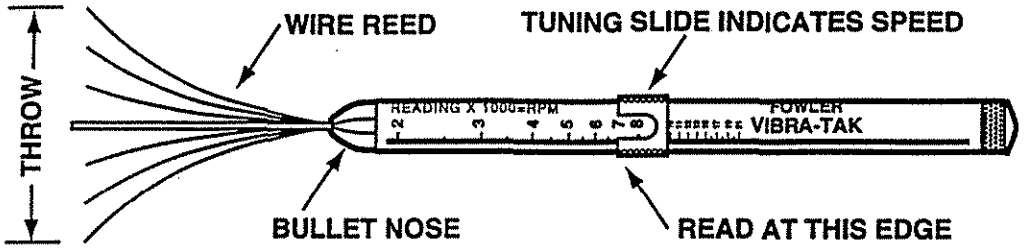
dicates speed of vibration on match plate

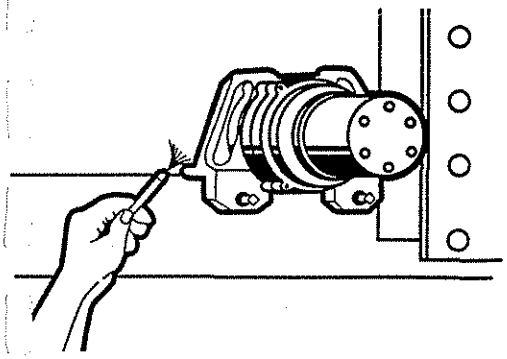
MARTIN®
VIBRA-TAK™
Vibration Indicator

The "Slide Rule" that:

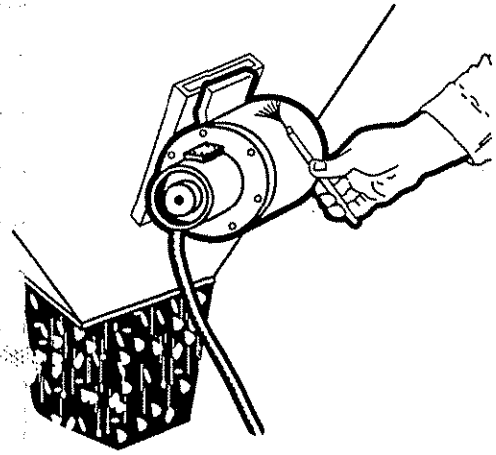
- Finds vibrations per minute
- Helps locate the source of unwanted vibration
- Finds "dead spots" on vibration equipment

This MARTIN® VIBRA-TAK™ vibration indicator is a simple, easy to use tool for accurately measuring the speed of a vibrating object.





Locate hopper car vibration rpm to help correct dangerous overspeed and inefficient underspeed.



Proper speed indicates good vibrator mounting.

How To Use:

1. Move tuning slide down scale until wire reed is fully extended outside of housing.
2. Press the bullet nose against the vibrating object.
3. Move tuning slide up scale until the wire reed reaches its maximum throw.
4. Multiply scale reading by 1,000 to find vibration cycles per minute, or shaft speed rpm.
5. The arc through which reed "throws" is in direct proportion to speed and stroke. Each 1/2" of "throw" equals .001" stroke.

Two Models Available

Low Speed - 200 to 2,000 rpm P/N 14831

High Speed - 2,000 to 21,000 rpm P/N 14830.

(Higher speeds do register and can be closely estimated.)

MARTIN ENGINEERING

One Martin Place
Neponset, Illinois 61345-9766 USA
1-800-544-2947 or 309-594-2384
FAX: 309-594-2432

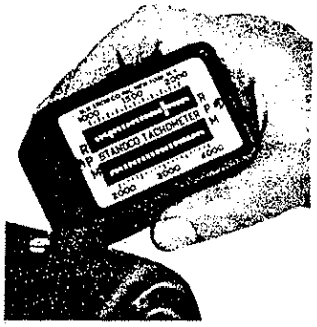
ABSOLUTELY, POSITIVELY, NO EXCUSES GUARANTEE

 Form No. 1191-12/94CP

INSTRUCTIONS

"STANDCO" Vibrating Reed Tachometers

. . . . . Hand Type, for portable use



"Standco" Vibrating Reed Tachometers operate on the well-known and time-tested principle of resonance. They measure speed of rotating machinery by picking up the rate of vibration on accurately calibrated reeds. These reeds are set in motion by the slight vibration of the rotating element. The RPM or vibrations per minute are indicated on the scale of these instruments by the visual pattern formed by one or more reeds while vibrating. See attached Bulletin No. 770C.

REVOLUTIONS PER MINUTE . . . .

"Standco" Vibrating Reed Hand Tachometers do not require brackets or any other accessories. These instruments are ideal for checking speeds of totally enclosed electrical equipment. Just hold the tachometer against the motor, turbine, pump, vacuum cleaner, compressor, outboard motor, sewing machine, or other similar equipment *anywhere* and read the speed. Speeds can be measured from 600 RPM to 100,000 RPM (in different models).

If vibration is excessive, cushion the Tachometer by a pad of rubber or cotton or with the hand. If vibration is insufficient, try different parts of the machine until a perfect pickup is made. Usually pickup is best if the row of reeds is parallel to the axis of the machine.

VIBRATIONS PER MINUTE . . . .

Since the reeds reflect vibrations as well as RPM, the instruments can be used as vibration indicators.

EXCESSIVE VIBRATION . . . .

With pneumatic equipment or other equipment where vibrations are severe, it is not recommended to hold the instrument directly against vibrating metal parts but to apply it to air hoses or other parts of the equipment. If this vibration is still too severe place hand on machine or hose and hold instrument against forearm and the vibration will be transmitted to the instrument reeds.

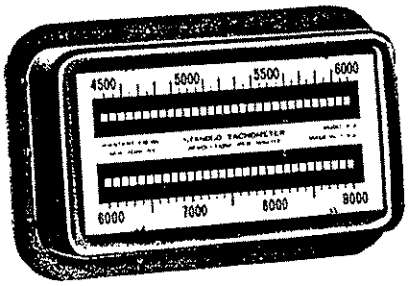
HARMONICS . . . .

Since all Vibrating Reed Tachometers operate on the principle of resonance, it is frequently the case that if a machine is running at let us say 1800 RPM another reed tuned at 3600 RPM may also respond, but at less amplitude. When a machine is running at 3600 RPM, however, a reed tuned at 1800 is not likely to respond.

INSTRUCTIONS

"STANDCO" Vibrating Reed Tachometers

. . . . . For Stationary Mounting



"Standco" Vibrating Reed Tachometers operate on the well-known and time-tested principle of resonance. They measure speed of rotating machinery by picking up the rate of vibration on accurately calibrated reeds. These reeds are set in motion by the slight vibration of the rotating element. The RPM or vibrations per minute are indicated on the scale of these instruments by the visual pattern formed by one or more reeds while vibrating. See attached Bulletin No. 770C.

HOW TO INSTALL STATIONARY TACHOMETERS . . . . . .

1. **Mount the Tachometer on its bracket.** Various types of brackets are available and should be carefully selected from our literature. If the Tachometer has been received without brackets, we recommend that brackets best suitable be ordered (at extra cost).

2. **After the Tachometer has been secured to the bracket,** hold it at or near the desired permanent location for a rough check of reed indication and the amplitude of the swing of the reeds. It is best to select a spot where the reeds which are in motion will show maximum vibration.

3. **When a location has been found** on the machine where the reeds vibrate at normal amplitude, fasten the bracket securely in that spot. It is recommended that the machine speed be then varied over the full range of the Tachometer to see that the reeds vibrate at the proper amplitude over the entire range.

4. **It is recommended** that the reeds are not allowed to vibrate continuously at an excessive amplitude. Usually the amplitude should not be greater than the scale opening which is usually 5/8" to 3/4". For high speeds, that is over 5000 or 6000 RPM, it is recommended that the amplitude should be less, or about 1/2" to 3/8", and still less for still higher speeds. Do not exceed these amplitudes under ordinary conditions.

5. **If the vibration amplitude of the reeds is excessive,** it is recommended that the instrument be cushioned by a suitable material, either between the instrument and bracket or between bracket and machine.

6. **If the machine for which the Tachometer is intended has very little vibration,** it is recommended that the Tachometer be tried at various locations as it is usually possible to find a point on the machine where the vibration is more pronounced than at other points.

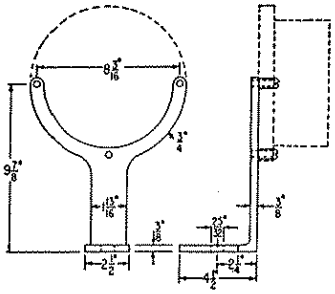
7. In such cases where this should not be possible, **vibration of the reeds can be increased** by using a Type T Mounting Bracket and attaching the Tachometer to a 3/4" steel rod 1-2 feet long, which in turn is secured to the machine. By lowering or raising the Tachometer, the best spot on the rod for maximum reed vibration is easily determined.

8. **As a general rule,** vibration of the reeds in any Tachometer is usually best if the reed row is parallel to the axis of the machine. Internal amplitude stimulators can be supplied if any of the other methods do not give satisfactory results.

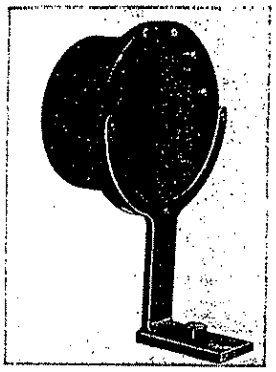
HARMONICS—*see reverse page . . . .*

VARIOUS STYLES OF MOUNTING BRACKETS

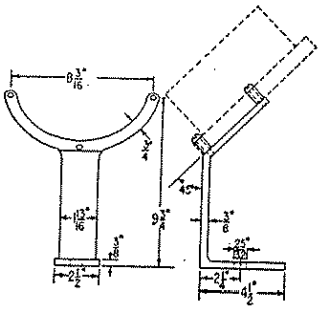
For Round Type Cases M-1 and M-2



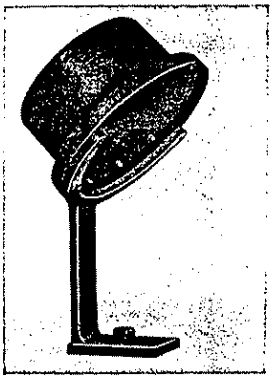
Type V Cat. No. 5400



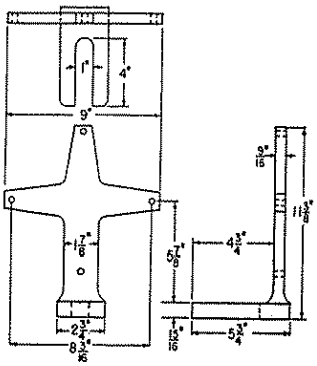
Vertical Mounting



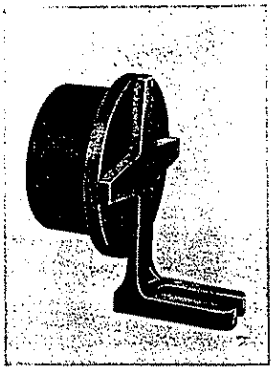
Type W Cat. No. 5401



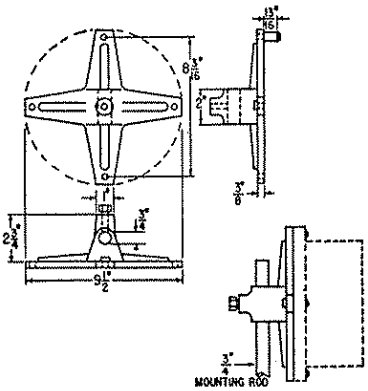
45° Mounting



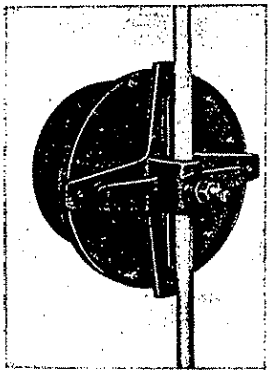
Type Z Cat. No. 5402



Vertical, heavy duty

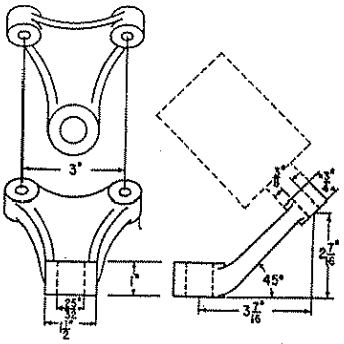


Type T Cat. No. 5403

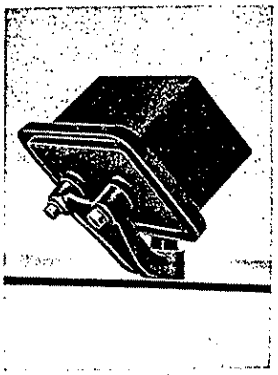


For mounting on 3/4" round rod (adjustable)

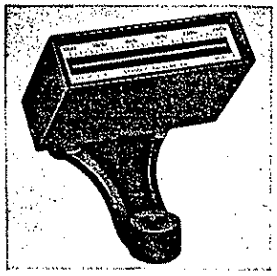
For Rectangular Cases



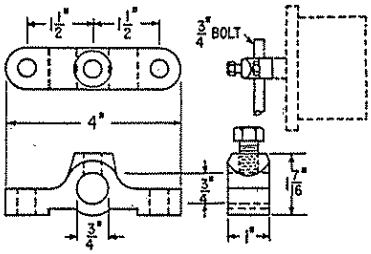
Type R Cat. No. 8400
45° Mounting



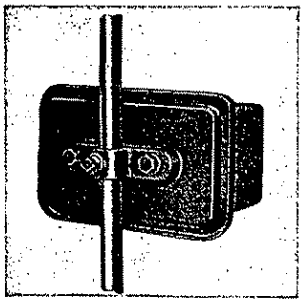
With Splashproof case instrument Types R-1 and R-2



With Rectangular Hand Type case with lugs Types H1-B and H2-B

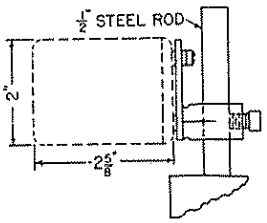


Type S Cat. No. 8401

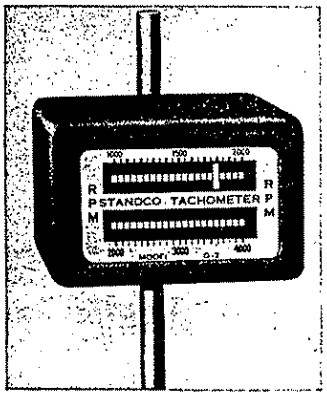


Adjustable Mounting on steel rod

For "DWARF" Type Instruments



Cat. No. 9401 90° Bracket



Adjustable Mounting on steel rod

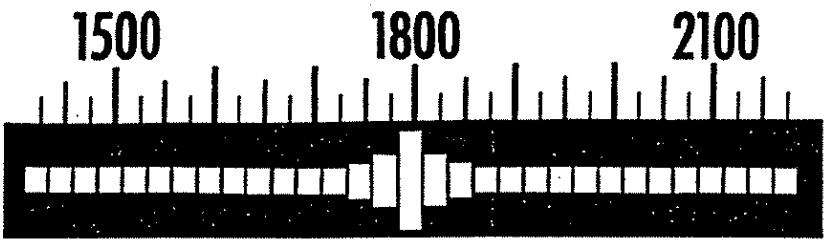
HOW TO READ VIBRATING REED TACHOMETERS

RPM or Vibrations per Minute are indicated on the scale of these instruments by the visual pattern formed by one or more reeds while vibrating. The following illustrations show how simple it is:

This is a typical scale of a "STANDCO" Vibrating Reed Tachometer (slightly reduced size) with a range from 1425-2175 RPM, designed for equipment with a normal speed of 1800 RPM. Interval between reeds is 25 RPM.

EVEN PATTERN:

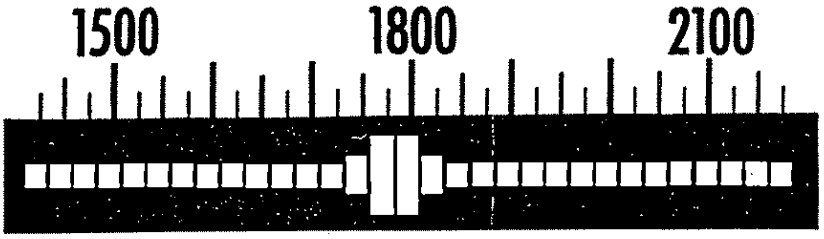
1800 RPM



One Reed has maximum amplitude, adjoining reeds on both sides have less but equal amplitude and form a similar pattern on both sides.
Speed is 1800 RPM.

TWO REEDS WITH SAME AMPLITUDE

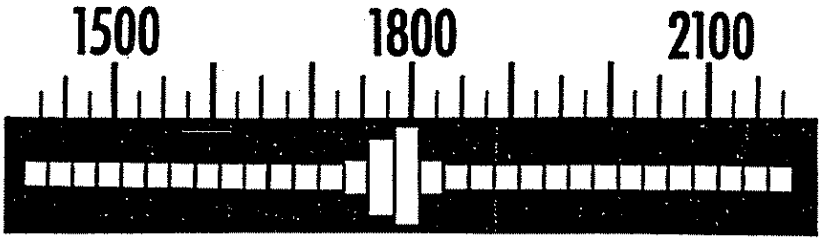
1788 RPM



Two adjoining reeds at 1800 RPM and 1775 RPM have same amplitude.
Speed is halfway between the two reeds=1788 RPM.

UNEVEN PATTERN BELOW 1800

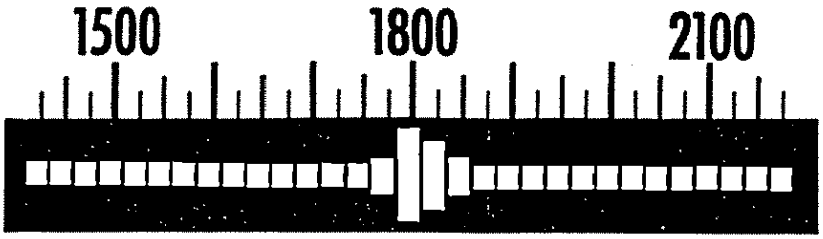
1794 RPM



One reed has maximum amplitude at 1800 RPM. Adjoining reed 1775 RPM vibrates almost as much. Other adjoining reeds below 1800 taper off proportionately.
Speed is one-quarter between 1800 and 1775=1794 RPM.

UNEVEN PATTERN ABOVE 1800

1806 RPM



This is the same pattern as above but on the high side of 1800 RPM.
Indicated speed is one-quarter between 1800 and 1825=1806 RPM.

Iowa Department of Transportation

SPECIAL PROVISIONS FOR PORTLAND CEMENT CONCRETE PAVER VIBRATOR MONITORING

Benton County, NHS-30-6(63)--19-06
Lee County, NHS-61-1(77)--19-56
Muscatine County, NHS-61-4(59)--19-70

January 12, 1999

THE STANDARD SPECIFICATIONS, SERIES 1997, ARTICLE 2301.07 AND ARTICLE 2301.35, ARE AMENDED BY THE FOLLOWING MODIFICATIONS. THESE ARE SPECIAL PROVISIONS AND SHALL PREVAIL OVER THOSE PUBLISHED IN THE STANDARD SPECIFICATIONS.

REPLACE Article 2301.07, Paragraph A(6)(a) with the following:

a. Vibrators

(1) The full width and depth of concrete requiring a finishing machine shall be consolidated by a single pass of an approved surface or internal vibrator. Surface vibrators shall be operated within a frequency range of 3500 to 6000 vibrations per minute. Internal vibrators shall be operated within a frequency range of 5000 to 8000 vibrations per minute. Vibrators shall not be operated in a manner to cause a separation of the mix ingredients; either a downward displacement of large aggregate particles or an accumulation of laitance on the surface of the concrete. Avoidance of separation of the mix may require a reduction in vibrator frequency when forward motion of the paver is reduced.

Paving machine operation shall stop if any vibrator fails to operate within specifications. Vibration shall be stopped whenever forward motion of the paver is stopped.

(2) An electronic monitoring device displaying the operating frequency of each individual internal vibrator shall be required for mainline pavement exceeding 600 ft. in length. The monitoring device shall have a readout display near the operator's controls visible to the paver operator and to the Contracting Authority. It shall operate continuously while paving, and shall display all vibrator frequencies with manual or automatic sequencing among all individual vibrators. For paving projects let after October 1, 1999 and thereafter, the monitoring system shall also record, at minimum, the following: clock time, station location, paver track speed and operating frequency of individual vibrators. Recordings shall be made after each 25 ft. of paving or after each five minutes of time. A record of the data shall be provided daily to the Contracting Authority.

(3) The depth of penetration into the concrete pavement slab of internal vibrators shall be set to mid slab or as deep as possible while passing above any reinforcing steel. An operating position locking device shall be provided so that no part of the vibrating unit can be lowered to the extent that it will come in contract with reinforcing steel or tie bars while paving.

(4) Horizontal spacing of vibrators shall not exceed the manufacturers recommendations, but in no case exceed 16 inches from center to center.

(5) The longitudinal axis of the vibrator body shall be mounted approximately parallel to the direction of paving with the exception that the trailing end of each vibrator shall be tilted downward to an approximate slope of 15 degrees below horizontal.

(6) Vibrators shall meet or exceed the following specifications at manufacturers design frequency of 10,000 vpm:

a) amplitude (peak to peak) 0.070 in.

b) centrifugal force 1200 lbs.

ADD the following to the last paragraph of **Article 2301.35**:

The cost of furnishing, installing, and monitoring vibrators and vibrator monitoring device shall be considered incidental to the contract unit price for PCC pavement.

NOTE: It is the intent that vibrator monitoring, as described herein, will be required on mainline paving projects on the Interstate and Primary highway systems for projects let after October 1, 1999.