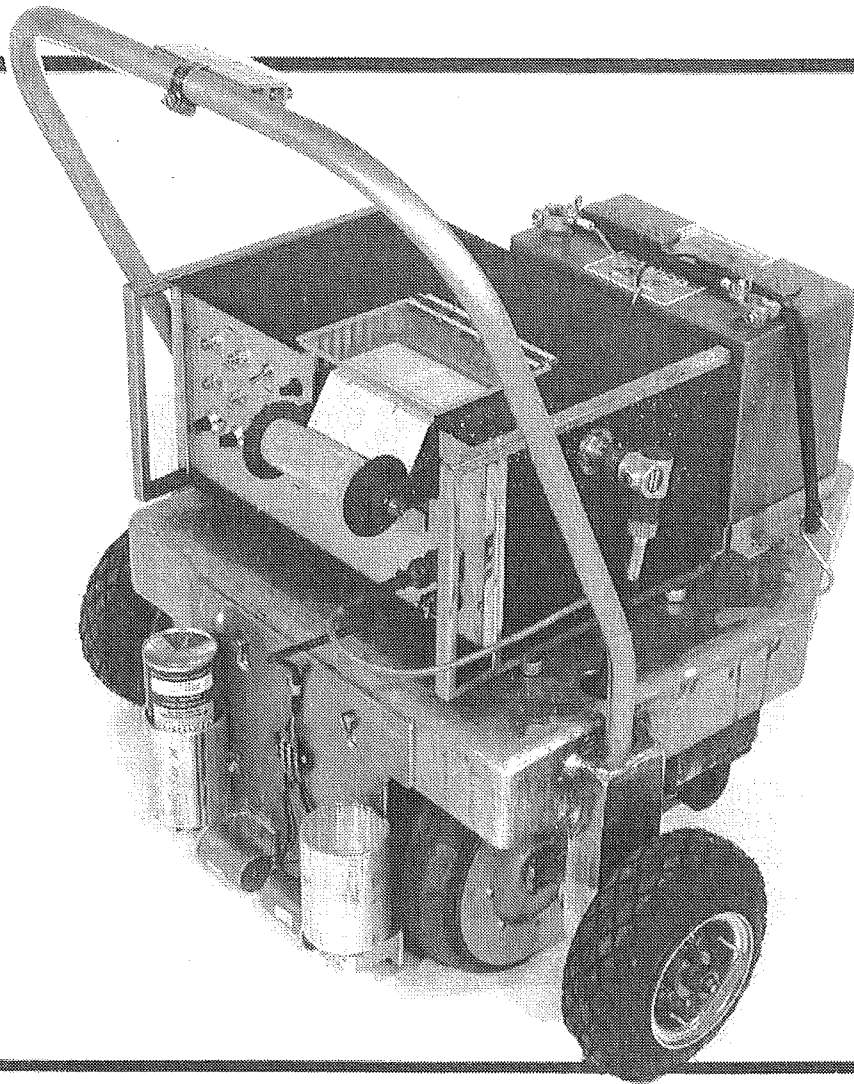


R-1058

INSTRUCTION MANUAL FOR BRIDGE DECK DELAMINATION DETECTOR



LAST COPY
DO NOT REMOVE FROM LIBRARY

MICHIGAN DEPARTMENT OF STATE HIGHWAYS AND TRANSPORTATION

**INSTRUCTION MANUAL FOR BRIDGE
DECK DELAMINATION DETECTOR**

**Research Laboratory Section
Testing and Research Division
Research Project 68 F-106
Research Report No. R-1058**

**Michigan State Highway Commission
Peter B. Fletcher, Chairman; Carl V. Pellonpaa,
Vice-Chairman, Hannes Meyers, Jr., Weston E. Vivian
John P. Woodford, Director
Lansing, April 1977**

SECTION 1
GENERAL INFORMATION

- 1.1 The MDSHT Delamination Detector is a small hand-propelled mobile cart equipped with a tapping system, acoustic sensors, and a recorder. It detects and indicates the location and extent of delaminated areas within a concrete bridge deck as it traverses the surface.

The apparatus is readily disassembled for storage in the trunk compartment of a conventional motor vehicle.

- 1.2 The complete equipment complement consists of the following items:

a) Delaminator Assembly, comprising:

- 1 Base Assembly with Removable Handle
- 1 Power Supply (Battery)
- 1 Electronics Unit (including Strip Chart Recorders)
- 2 Input Cables (Base Deck to Electronics Unit)
- 1 Flexible Chart Drive Cable

b) Calibration Standards

c) Accessories Kit containing:

- 1 Battery Charger
- 12 Rolls of Recorder Chart Paper

d) Optional Equipment:

- 1 Paint Spray Attachment

- 1.3 Care must be exercised in handling the base to avoid pinching or puncturing the thin-walled tires (inner tubes) on the acoustic wheels. The recorder pens also must be protected against bending.

- 1.4 Cables attached to the Electronics Unit are all equipped with plugs which can fit only into the proper receptacles of the base. Care must be taken, however, to connect each of the two signal cables properly. These cables connect the two BNC connectors on the Electronics Unit. Proper connection assures that the left tapper-acoustic receiver system is sending its signals to the left channel on the recorder and that the right channel is receiving signals from the right tapper receiver system.

- 1.5 A service and construction manual is available upon request.

SECTION 2 PRINCIPLES OF OPERATION

- 2.1 The Delamination Detector operates by applying to the surface of the concrete repetitive short-duration force impulses having sufficient energy to excite vibrations, within the concrete, which are characteristic of the separation of the material into two or more unbonded layers. This is accomplished by a tapping mechanism which causes two rigid wheels with steel rims to chatter against the concrete at the rate of 34 times each second. When either of these wheels taps at a point beneath which the concrete is delaminated the characteristic vibrations are produced in the material.
- 2.2 A pair of liquid-filled acoustic receiving wheels, inside each of which a receiving transducer is mounted in nonrotating proximity to the concrete surface, receive the vibrations from the concrete surface a few inches away from the points at which the tapping force is applied. The transducers are piezoelectric hydrophones (basically similar to crystal microphones) which are coupled to the concrete surface through the soft tires and the liquid within the wheels. They generate electrical signals proportional to the pressure fluctuations within the wheels, which are produced by vibrations of the concrete surface beneath the wheels.

In order to distinguish between solid and delaminated concrete it is necessary for the apparatus to respond as little as possible to the vibrations that are received when solid concrete is being tapped and as much as possible to those that occur when delaminated material is tapped. It has been found that the distinction between these two conditions is enhanced by preventing the instrument from responding to those portions of the vibrations which continue longer than 5 milliseconds (0.005 seconds) after each tap. The distinction is further enhanced by preventing those frequency components of the vibrations which fall below 300 Hz or above 1200 Hz from affecting the record. Accordingly, the electrical signals generated by the receiving transducers are processed as described in paragraph 2.4 below, before being applied to the recorder.

- 2.3 Since a receiving wheel, as well as a tapping wheel must be above a delaminated area in order to detect its presence, the device surveys a pair of approximately 3-in. wide paths, separated by a space of 6 in., while it traverses a bridge deck. An absolutely complete survey of a bridge would necessitate making a large number of parallel traverses, but generally a lesser number is sufficient. Adequate sampling to designate areas to be broken out and repaired can be done by a set of traverses spaced approximately 3 ft apart. Suggested locations for the traverses are: in each wheelpath, midway between

wheelpaths, midway between the outer wheelpath and the curb, and along each curb. A less time-consuming survey, for evaluating the extent of delamination or for determining its growth by comparing successive surveys, comprises traversing only in the outer wheelpaths and along the curbs. If there is any appreciable accumulation of gravel or other debris on the deck it is desirable to sweep it off before making the survey.

- 2.4 The electrical signals developed by the acoustic receivers are processed in the Electronics Unit by time-gating, which accepts only those portions of the signal which occur during the first 5 milliseconds after the occurrence of a tap, and by filtering, which further limits the recorder to respond only to those frequency components of the signal which lie in the range of 300 to 1200 Hz. The processed signals are then rectified and integrated to produce a visual record on the respective channels of the record chart. The chart is driven in proportion to the distance traversed. Thus, a succession of traverses produces a set of records which may be placed side by side to provide a 'map' of the delaminated areas of a bridge.

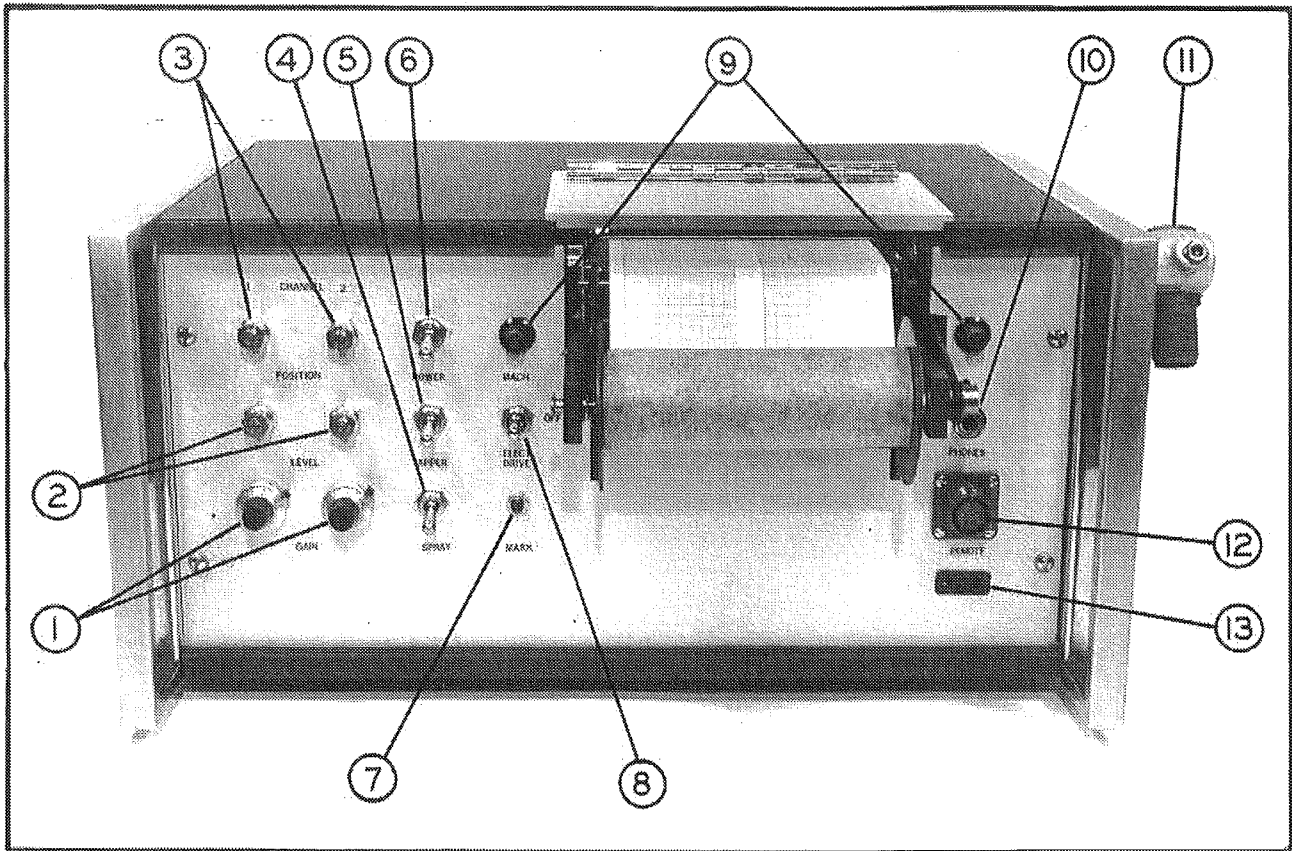
Since the length of chart produced during each successive traverse may vary slightly, it is desirable on long bridges to mark the record, not only at the beginning and end points of each traverse, but also at intermediate control points, such as expansion joints, along the bridge. An event marker system is provided for this purpose, upon pressing a button on the handle.

A further aid for visual detection is provided as an option in the form of a light indicator (Fig. 1 (9)).¹ The lights come on at a pre-set signal level. The light has been adjusted to come on at two divisions above the background signal. Different surfaces may give slightly different background signals so that it may be necessary to readjust the light to come on at another signal level. This can be done by adjusting the adjustment screws on front panel (Fig. 1 (2)). The light responds to both channels and each channel should be adjusted separately. Included in the light indicator is an ability to automatically spray the delaminated area. An audible signal is detected through the earphones and is tied directly to the light indicator and is automatically adjusted when the light is adjusted.

SECTION 3 OPERATING INSTRUCTIONS

- 3.1 After assembling the major components and connecting all the cables, the system is turned on by throwing (upward) the Power switch (Fig. 1 (6)).

¹ The circled numerals refer to the corresponding numbers on the figures.



- ① L - R Channel Transducer Amplifier Signal Gain
- ② L - R Automatic Spray Level Adjust
- ③ L - R ELECT Pen Position Adjust
- ④ On-Off, Spray Inable
- ⑤ On-Off, Tapper Power
- ⑥ On-Off, Main 12 v.d.c. Battery Power
- ⑦ Event Marker
- ⑧ Chart Paper Drive (Up - MACH, Center-Off, Down - ELECT)
- ⑨ Lamp Indicators - L - R Delamination Spray Level
- ⑩ Earphone Jack
- ⑪ Mechanical Chart Paper Drive Adaptor
- ⑫ Remote Spray and Chart Event Marker
- ⑬ Spray Attachment Connector

Figure 1. Front Panel Control

- 3.2 To check the recorder, first make sure the chart drive roller (at the front of the recorder) is in contact with the recorder paper. Allow approximately 15 seconds before turning the Chart Drive switch to the ELEC position (Fig. 1 (8)). This is to allow time for the heat writing pens to warm up. After turning on the Chart Drive switch, adjust the Trace Width controls (the two black controls in the recessed area at the front of the recorder (Fig. 2 (1)), which actually vary the temperature of the heat writing pens, to secure acceptably dark traces.

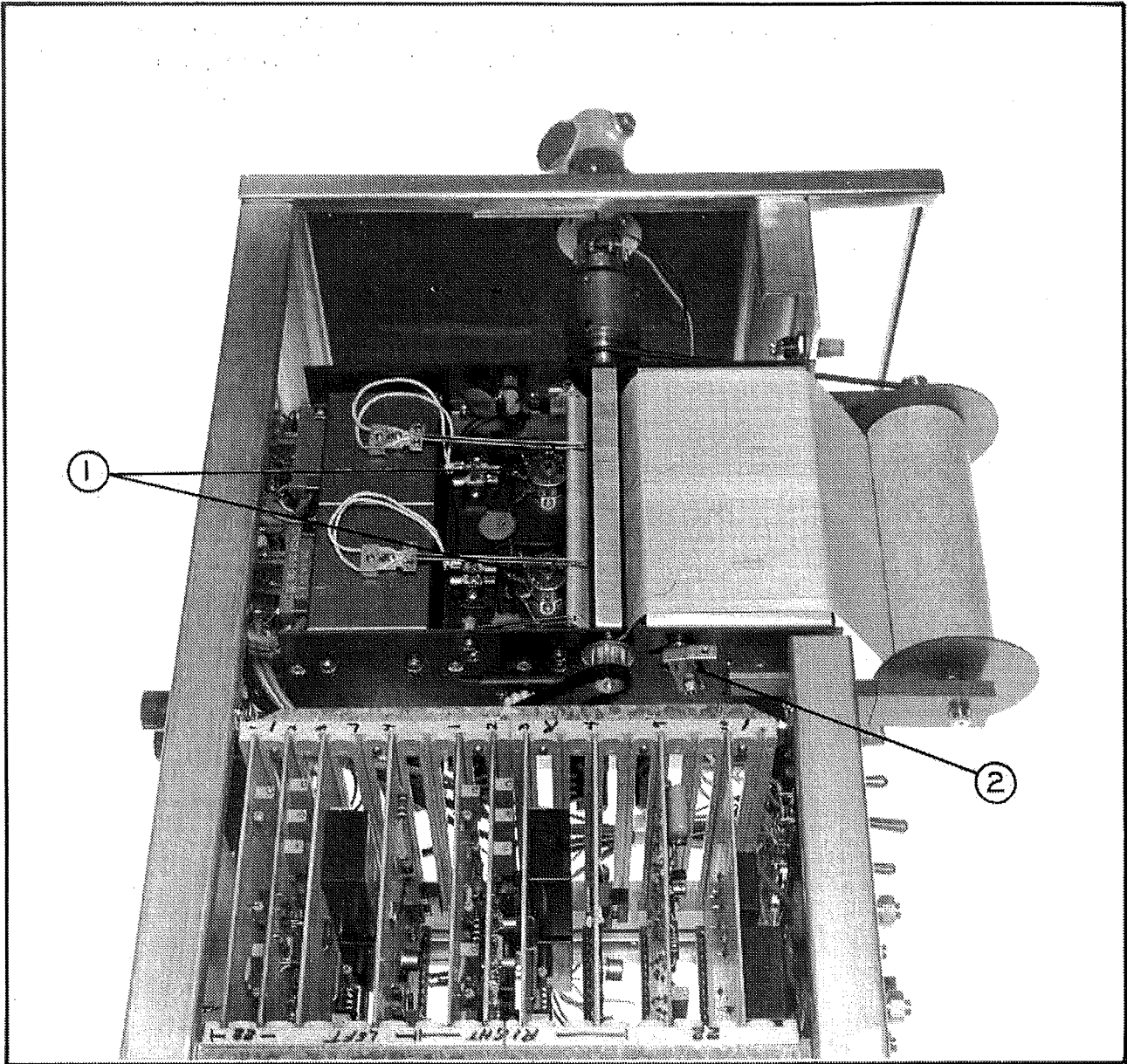
The electrical zero is that point that represents no (or zero) signal response from the Detector sensor system. The electrical zero adjustment screws are mounted on front panel (Fig. 1 (3)).

The electrical zero (on each channel) should be just slightly above the mechanical zero. To achieve this, simply turn the appropriate zero adjustment screw until the base line is seen to move--then turn the screw in the opposite direction until the pen is drawing a straight line at mechanical zero. Now once more reverse the direction of the screw adjustment until the electrical zero line is seen to depart one minor chart division from what had been the mechanical zero.

Turn the Tapper Switch to on (Fig. 1 (5)). The pens should show some response (above electrical zero) which will vary in amplitude depending on the type and thickness of the surface on which the Delamination Detector is resting. This background response can be misleading if the Instrument is on relatively thin asphalt, e. g., parking lot, bridge approach, etc. True background response should be on the bridge deck or a good, solid concrete slab.

The sensitivity of the Detector is increased or decreased by adjusting the Gain controls (Fig. 1 (1)). These are provided to enable the sensitivity (gain) of either or both channels to be adjusted in the field and yet returned to the lab settings. It should be emphasized, however, that normal operation of the Delamination Detector should be at the lab sheetings.

- 3.3 Turn the Chart Drive switch to MACH and start the traverse (Fig. 1 (8)). At the end of each traverse it is desirable to turn off the Tapper switch (leaving the Power switch on--to keep the pens warm) and turn it on again only after turning about or after returning to the starting end of the deck. This will produce a distinctive marking on the record which can be recognized later as representing the start of another traverse.
- 3.4 When not in use, turn off all power switches in order to conserve battery energy. While the unit will operate for 10 hours or more on a fully charged battery, frequent charging and discharging can shorten battery life.



- ① Trace Width Adjust Controls
- ② Chart Paper Load Release

Figure 2. Electronics - Top View

- 3.5 Avoid rolling the acoustic wheels across sharp edges or points which might puncture their thin tires (which are made from commercial inner tubes).

SECTION 4 CALIBRATION

- 4.1 The Delamination Detector should be calibrated periodically to ensure its operation at proper sensitivity, and to maintain equal sensitivity for its two channels. Calibration is accomplished by placing the device on the Calibrator. The Power and Tapper switches are put in the ON position and the Power Chart Drive switch turned on. Each of the two recorder pens should trace a rather erratic line approximately full scale. This line may vary one or two major divisions due to normal variations in the response of the system to the aluminum bar. If the response line does not fall as per above, then each channel should be adjusted by the front panel gain adjustment controls.

SECTION 5 CHART RECORD INTERPRETATION

- 5.1 The Delamination Detector produces a two-channel strip chart record indicating the presence or absence of delamination in the two paths traversed by the pairs of receiving and tapping wheels. When viewed from the operating position, the right and left channels are for the right and left paths, respectively.

Solid concrete is indicated by a smooth base line near zero. A lateral pen excursion of at least two minor chart divisions above the base line has been found to indicate a delaminated area. Generally, the pen excursion will be less for small and/or deep areas of delamination than for shallow and/or large areas.

If the chart recorder drive is operated in the 'distance mode,' (Fig. 1 (8) in MACH, or 'up' position) one can traverse a series of distinct paths on the bridge deck to produce a map of the bridge delamination. By this technique, the extent of delamination in the traverse direction along the traversed paths and the approximate extent of delamination laterally can be determined. Alternatively, the Detector's recorder can be operated in the 'time drive mode' (Fig. 1 (8) in the ELEC or 'down' position) for probing or searching particular areas.

SECTION 6 COMPONENT DESCRIPTIONS

- 6.1 This section contains descriptions of the construction and functions of the several major components of the Delamination Detector. This

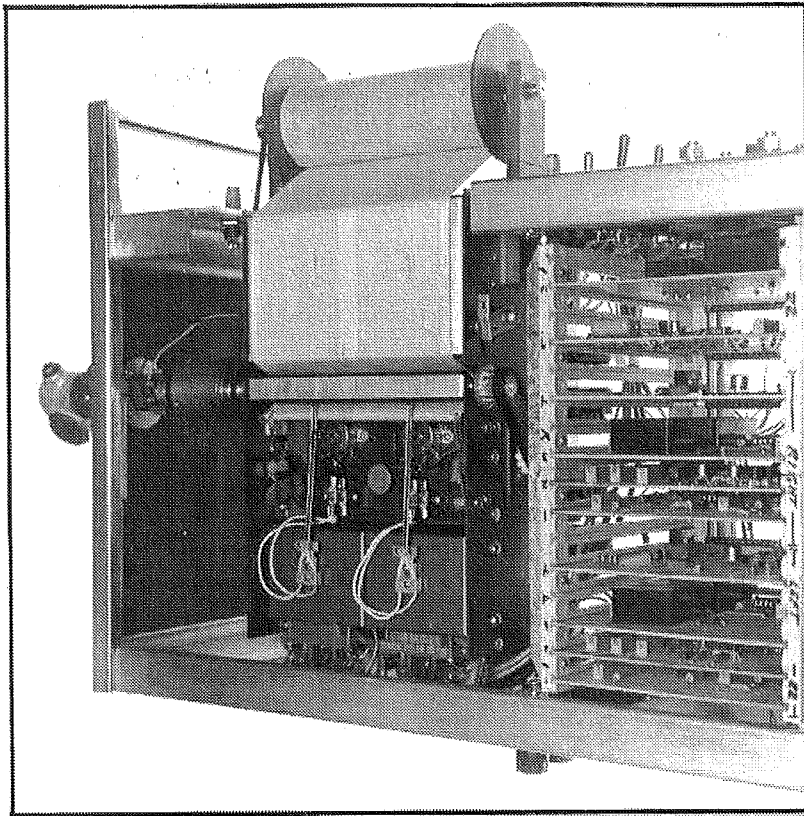


Figure 4

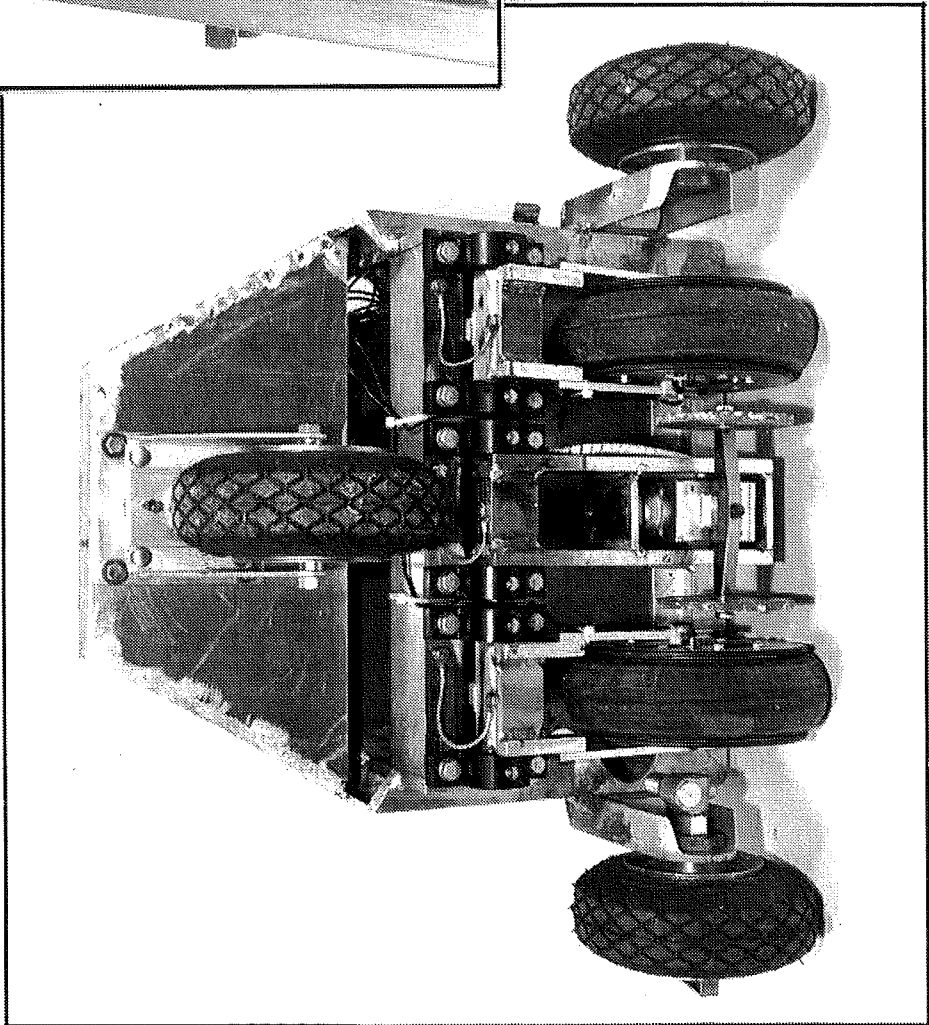


Figure 3

information is presented to aid in understanding the operational requirements of the equipment and to facilitate the recognition and diagnosis of malfunctions of the apparatus.

- 6.2 Tapping Assembly (Fig. 3) - Two rigid tapping wheels are caused to chatter against the concrete surface by the oscillation of a plunger moving up and down between two solenoid coils. This plunger strikes a sharp blow at the end of its 0.050 in. travel. Oscillation is maintained by alternatively energizing the two coils with direct current at an approximate rate of 34 Hz. The frequency is maintained by a uni-junction oscillator. The output from this drives a bi-stable flip-flop that alternately applies a signal to the power circuits that in turn applies the d. c. to the drive coils. Thus, 34 times in each second, first one coil, and then the other, attracts the plunger. This produces a tapping rate of 34 blows per second.

Upon reaching either end of its travel a sharp blow is struck by the plunger. This blow, transmitted through the rigid frame and axle, causes the tapping wheels to momentarily lose contact with the concrete surface. The wheels should be seen to rotate slowly, or at least be free to rotate with the addition of a slight finger pressure applied to their rims, when the cart is motionless. This action indicates that the tapping mechanism actually overcomes the downward force of approximately 35 pounds which the spring applies to the pair of tapping wheels. Wear of the mechanism, which permits the plunger to travel more than the proper amount (0.050 in.), may cause the tapping to become weak or irregular. Thin metal shims can be inserted behind the solenoid coil frames to adjust the plunger travel to the correct amount. Weak batteries may also produce weak or irregular tapping. Always check the batteries for proper charge before disassembling the tapper mechanism for repair.

The tapping assembly, with its axle and wheels, is softly shock mounted, to permit it to tap equally with both wheels on irregular surfaces which may raise one wheel more than the other, as well as to prevent the vibrations which it produces from reaching the acoustic receivers through the frame of the cart.

- 6.3 Acoustic Receiving Transducer Wheel Assembly (Fig. 3) - The receiving transducer inside the liquid-filled tire is rigidly attached to the nonrotating axle. In order to have the transducer pointed downward and maintained in close proximity to the concrete surface, the axle must be maintained in correct orientation. A scribe mark on the axle indicates the approximate angular location of the transducer hidden within the wheel. This mark can be used as a guide in directing the transducer downward.

Proper positioning of the transducers is best obtained by inverting the Detector's base and manually adjusting the position of the transducers. Prior to the adjustment, the Acoustic Wheels should be propped up until the bottom (that portion that would normally contact the surface of a bridge deck) of the Acoustic Wheels rims are in a level position with the bottom of the pneumatic riding wheels. After loosening the allen-head set screws (which clamp the wheel mounting bracket to the axle), the transducer can be adjusted by pressing the thumb and fore-finger into the wheel until both ends of the transducer are grasped between them and the transducer moved to the proper position (centered and aligned with the axles of the riding wheels). After adjustment, the allen set screws must be tightened.

The height of the transducer above the surface is kept constant by adjusting the oil pressure within the Acoustic Wheel until the rubber O-ring on the wheel rim is approximately 1/8-in. above the surface.

The acoustic transducer is a small, sealed piezoelectric hydrophone designed to operate while continuously submerged. Normally, its electrical resistance is many megohms, as measured across its cable terminals or at the corresponding electrical connector which is mounted on the deck of the cart. Leakage of fluid into the transducer will impair its acoustic response and will generally diminish its resistance to the vicinity of 100,000 ohms or less.

The rubber seal provided by the transducer manufacturer is maintained under compression by the mounting arrangement which attaches it to the axle, in order to further prevent entry of moisture into its case.

- 6.4 Power Supply System - An automotive-type, lead-acid storage battery provides the basic power. A heavy duty, 12-v battery with a minimum rating of 60 amp-hours is needed for eight hours of operation of the Detector. As with all storage batteries, proper ventilation should be provided when undergoing charge. Allowance should also be made for expansion of the electrolyte to avoid contamination of the battery box with acid.

Power from the storage battery is utilized in the tapper solenoids by a transistor switching circuit that alternately applies power to one then the other at a 34 Hz rate. The unit has a d.c. to d.c. converter that supplies ± 15 v and $+ 5$ v to the Electronics Unit.

- 6.5 Electronics Unit (Fig. 4) - The tapper driver unit consists of a uni-junction oscillator operating at 68 Hz. The output from the oscillator goes to a bi-stable flip-flop or half-adder that has an output of 34 Hz and supplies the signal to the power transistor switching circuit. The switching circuit drives the tapper assembly.

A sync signal is taken from the driver circuit and goes to the control board and triggers a delay circuit that in turn drives a gate. The gate is opened to permit passage of signals from the acoustic transducers during only the first 5 milliseconds after the occurrence of each tap. An adjustment for gate width is provided. The time of occurrence of the gate is determined by the delay circuit which is adjustable.

To adjust these circuits would require a dual beam scope with one input connected to the sync signal, the other to the gate circuit. The delay circuit would be adjusted to make the leading edge of the signal caused by the down stroke of the tapper to fall within the time the gate circuit is open. The Filter Amplifier is the signal processing circuit that contains the bandpass filter and signal integrator. The signal then goes to the Recorder and Automatic Spray and Lamp Indicator Drive.

- 6.6 Recorder - The two-pen chart recorder is manufactured by Astro-Med. The chart paper is Type No. A0000-86-1 and available from Astro-Med.
- 6.7 Automatic Spray Unit - The Detector is equipped with a spray unit to mark delaminated areas. One spray unit is provided for each acoustic receiver which is independently controlled. The sprayer mechanism can be made to operate at different thresholds or lateral excursions of the recorder pen.

SECTION 7 MAINTENANCE

- 7.1 Dirt is the enemy of all small mechanisms such as the recorder mechanism and the tapping assembly. Keep these items free of grit and dirt by frequent applications of compressed air, or appropriate use of mild solvents. Take care to avoid damage to the parts being cleaned. Use paint remover to keep the paint release mechanism clean.
- 7.2 The distance drive for the recorder can be adjusted slightly by altering the inflation pressure of the right supporting wheel of the base.

A check of the distance drive can be made by marking a 10-ft test section and determining the number of major divisions of the chart that the chart paper travels when traversing the 10 ft.

Normal pressure for the support wheels is 35 lb/sq in.

- 7.3 Keep in mind that the recorder pens, and especially their heating elements, are delicate assemblies which cannot withstand bending or abuse.

7.4 Tests for Normal Operation

- a) Without Calibrator - With the Detector turned on, traverse a bridge deck or concrete floor until a strong indication of delamination is observed on at least one channel of the recorder. Halt the Detector at a selected spot which provides a given large deflection in, say, the right channel. Mark the concrete between the right tapper wheel and the right acoustic wheel. Move the Detector to position the mark in the space between the left wheels. The indication of the left channel should now be approximately equal to that previously observed for the right channel. If not, move the machine slightly and repeat the observations several times before deciding that one channel has a weaker response than the other. When certain, increase the gain in the weaker channel as outlined in paragraph 4.1, 'Calibration,' until further testing indicates that equal response has been attained.

Check the position of the transducer (see paragraph 6.3) to determine whether the inequality is partly or wholly due to the transducer shifting and not pointing straight down. Change the position of the transducer, if required, as per paragraph 6.3

- b) With Calibrator Available - See Section 4.