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TECHNICAL REPORT

72-72-GP

THE DROP HEIGHT RECORDING SYSTEM
A USER'S GUIDE

by

Clive L. Nickerson

Project Reference:

1J662709D552

February 1972

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UNITED STATES ARMY
NATICK LABORATORIES
Natick, Massachusetts 01760

General Equipment & Packaging
Laboratory

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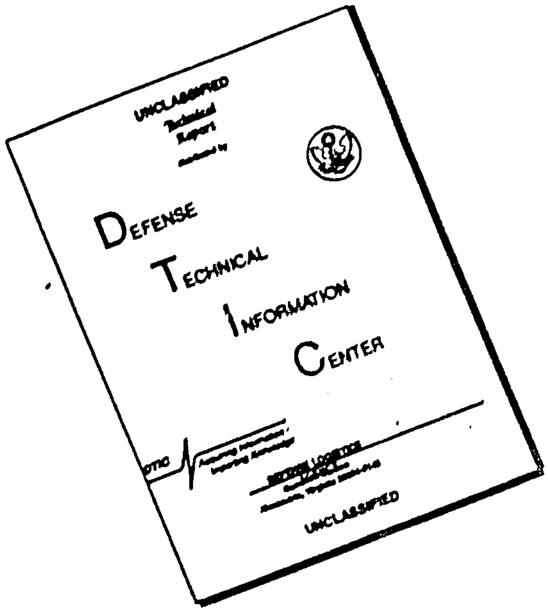

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FOREWORD

The original investigations that resulted in the drop height recording system were conducted under Contract DA19-129-QM-2082 (OI 6150) by the Shock and Vibration Division of Mitron Research and Development Corporation with Mr. Maurice Gertel as Principal Investigator and Mr. David Franklin as Project Engineer.

Project Officer and Alternate Project Officer for the U. S. Army Natick Laboratories were Mr. Matthew A. Venetos and Mr. Denis J. O'Sullivan, both formerly of the Engineering Sciences Division of the General Equipment & Packaging Laboratory.

This contract was originally funded under Project 7X91-03-015 and later transferred to Project 1M643324D587.

Subsequent investigations funded under Project 1J662708D552 were conducted by the Engineering Sciences Division, General Equipment & Packaging Laboratory, to develop the described drop height recording system configuration.

THE DROP HEIGHT RECORDING SYSTEM

A USER'S GUIDE

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13. ABSTRACT A small lightweight battery-operated tape recording system for gathering data on shipping and handling shocks experienced by containers has been developed.

A specialized magnetic tape recorder is used with six magnetoelectric velocity sensors mounted so as to sense impact velocity components in both polarities of the three principal axes of a container. By means of a four-channel recording head, the sensor outputs are magnetically stored on three tracks of 1/4-inch recording tape. The fourth track is used for time reference marks.

Retrieval of data requires the use of a separate playback deck and means of monitoring the playback signal. Peak amplitudes of playback pulses are related to impact components and heights of intransit drops thus determined.

The system is prepared for shipment by installation of the necessary batteries, mounting the sensors on a suitable supporting structure, and electrically interconnecting sensors and recorder. The complete system should fit inside a standard-size carton with the recorder cushioned as much as possible within. A thorough check-out of recorder functions should be conducted before shipment to insure reliable readings. Response to known inputs should be included in the check-out. Calibration drop series should precede and follow system shipment to provide a "same reel" reference for intransit drops.

Many recorder malfunctions may be corrected by the user by trouble shooting and repair procedures. The system may be tailored to the user's specific required recording range or ranges by minor recorder modifications.

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Height	9,4		9			
Drop	9,4		9			
Impact	9,4		9			
Measurement	4		8			
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ABSTRACT

A small lightweight battery-operated tape recording system for gathering data on shipping and handling shocks experienced by containers has been developed.

A specialized magnetic tape recorder is used with six magneto-electric velocity sensors mounted so as to sense impact velocity components in both polarities of the three principal axes of a container. By means of a four-channel recording head, the sensor outputs are magnetically stored on three tracks of 1/4-inch recording tape. The fourth track is used for time reference marks.

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THE DROP HEIGHT RECORDING SYSTEM

A USER'S GUIDE

1. General Information

a. Introduction

This manual describes a drop height recording system for the instrumentation of shipping containers. The system consists of a four channel magnetic tape recorder using 1/4-inch tape, a set of six velocity sensors for the generation of inputs associated with the three principal axes of a container, and a supporting structure. This system has the capability of measuring the height from which a package was dropped and the time of the drop within one hour for all package impacts of 6- to 48-inch drop height occurring in a shipment of six months' duration or less. Package orientation at time of impact may also be determined. Three mutually perpendicular drop height components are recorded upon every impact of an instrumented package and one timing mark is recorded for every hour of shipment. The recorder's tape contains a handling history of the instrumented package upon completion of the shipment.

This recording system was developed to obtain reliable information on conditions normally encountered by military supplies during world-wide distribution and storage. Handling histories determined by this system will provide the package designer with expected values for the maximum and average drop height and for the frequency of drops for particular routes and modes of transportation.

Efficient package design can result from this knowledge; the waste of overpackaging and the damage resulting from underpackaging can be avoided and exact duplication of the shipping environment can be realized in the laboratory.

This guide was written to provide users of this system with the information necessary to most effectively utilize the data gathering capabilities of this instrumentation. Step by step procedures for preparation, check-out, and calibration are included. Read-out techniques and system optimization are also described. A detailed theory of operation, schematics of all electronic circuits, and troubleshooting procedures should enable the user to isolate and correct system malfunctions. This guide can educate those unfamiliar with the system and can serve as a reference to those more experienced.

b. Specifications

	Recorder Only	Recorder with Exterior Box	System (Minimum)
Dimensions: (inches)	7 x 6 x 4-1/2	9-1/2 x 8-1/2 x 6-1/4	9-3/8 x 12-3/16 x 16-1/4
Weight:	8 lb max	11 lb max	25 lb

Recording Medium: 1/4-inch magnetic instrumentation tape, 1.0- or 1.5-mil thickness, Ampex 738 or 748

Mode of Recording: Stationary, no bias, stepping after recording approximately 1/16 inch

Tape Capacity: 100 ft (1.0 mil), 70 ft (1.5 mil)

Recording Head: Nortronics 5651, 4-channel, 0.5-mil gap, 220 ohms d.c.

Recording Channels: 3 drop height components, 1 time

Maximum Unattended Operation (Battery Life Limitation): 6 months

Maximum Unattended Operation (Tape Length Limitation): 2 years

Input Range: 6 inches to 48 inches

Minimum Sequential Recording Interval: 2 seconds

Maximum Shock Pulse Duration (Sinusoid): 28 milliseconds

Maximum Shock Intensity: 250 g

Temperature Range: -25° to 150°F (excluding timer), see par. 1c1, page 3
-13° to 150°F (timer power cell), see par. 1c3, page 6

Accuracy (2-inch Cushion): ±25% maximum average error for 4-foot drops; ±10% average error below 3 feet

Accuracy (Infinite Cushion): ±10% maximum average error for complete recorder/playback system

Power Requirements: +45v, -7.5v, -1.3v, +1.32v

Sensor Connector: Winchester XMRE-18P-C-1306X

c. System Components

1) Recorder (Figure 1). The recording unit for the drop height system is a special battery-operated portable magnetic tape deck upon which are mounted coaxial supply and take-up reels, the recording head, stepping motor, batteries, timer and potted electronic assemblies for controlling stepping and signal cutout. (See Appendix, Figure D1.) This assembly is inclosed in a protective aluminum box.

Recording is done on motionless magnetic tape with one-sixteenth-inch stepping after each record. No sensor signal conditioning is included other than resistive attenuation and a two-second cutout after recording. The timer is an Accutron device which has a contact closure once each hour. (An additional set of contacts is available for a six-hour option.) Sensor signals and the time pulse cause tape advancement by triggering the rotary stepping motor. The stepping motor (Ledex 213229-029) has a operating limit of -25°F. Replacement of the stepping motor with Ledex No. 216020-026 would extend the lower limit to -67°F but would require modification to the tape deck and repositioning of the motor with respect to the tape reels.

2) Sensors (Figure 2). Inputs to the drop height recorder are generated by six velocity sensors mounted so as to monitor the shock components felt by respective faces of an instrumented package. A sensor consists of a bar magnet resting on a helical compression spring within an aluminum tube about which is wound a sensing coil. A magnetic shielding sleeve surrounds the aluminum tube and coil. A voltage proportional to the impact velocity component in the direction of the velocity sensor's longitudinal axis is induced when the instrumented package strikes a surface with sufficient force.

The compression spring and bar magnet comprise a spring-mass system designed to have a natural frequency of about 10 Hz. This frequency allows accurate sensing of impact velocities for impact (deceleration) pulse widths up to 28 milliseconds, provided the supporting structure is rigid (see Section 1c4).

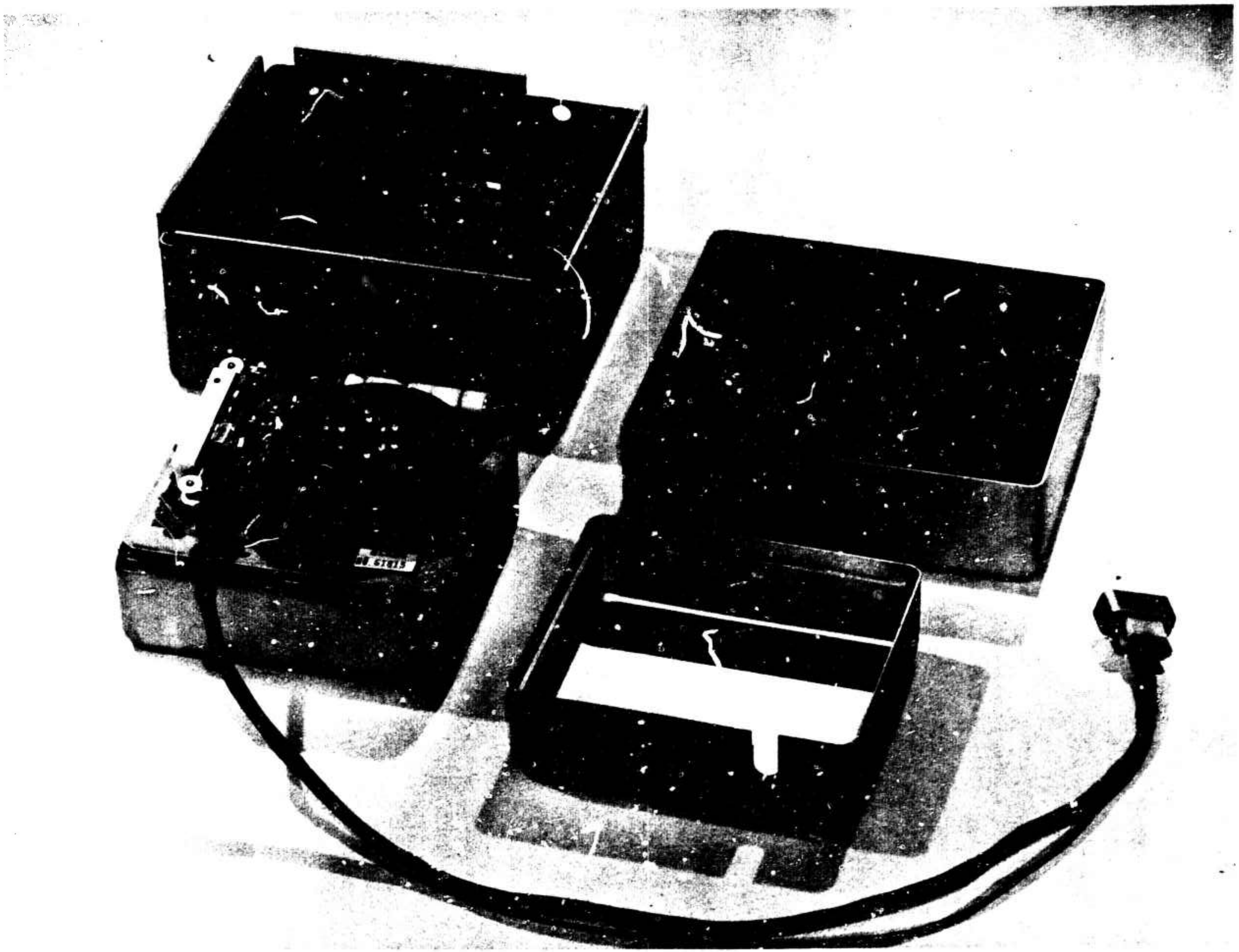


Figure 1. Drop Height Recorder.

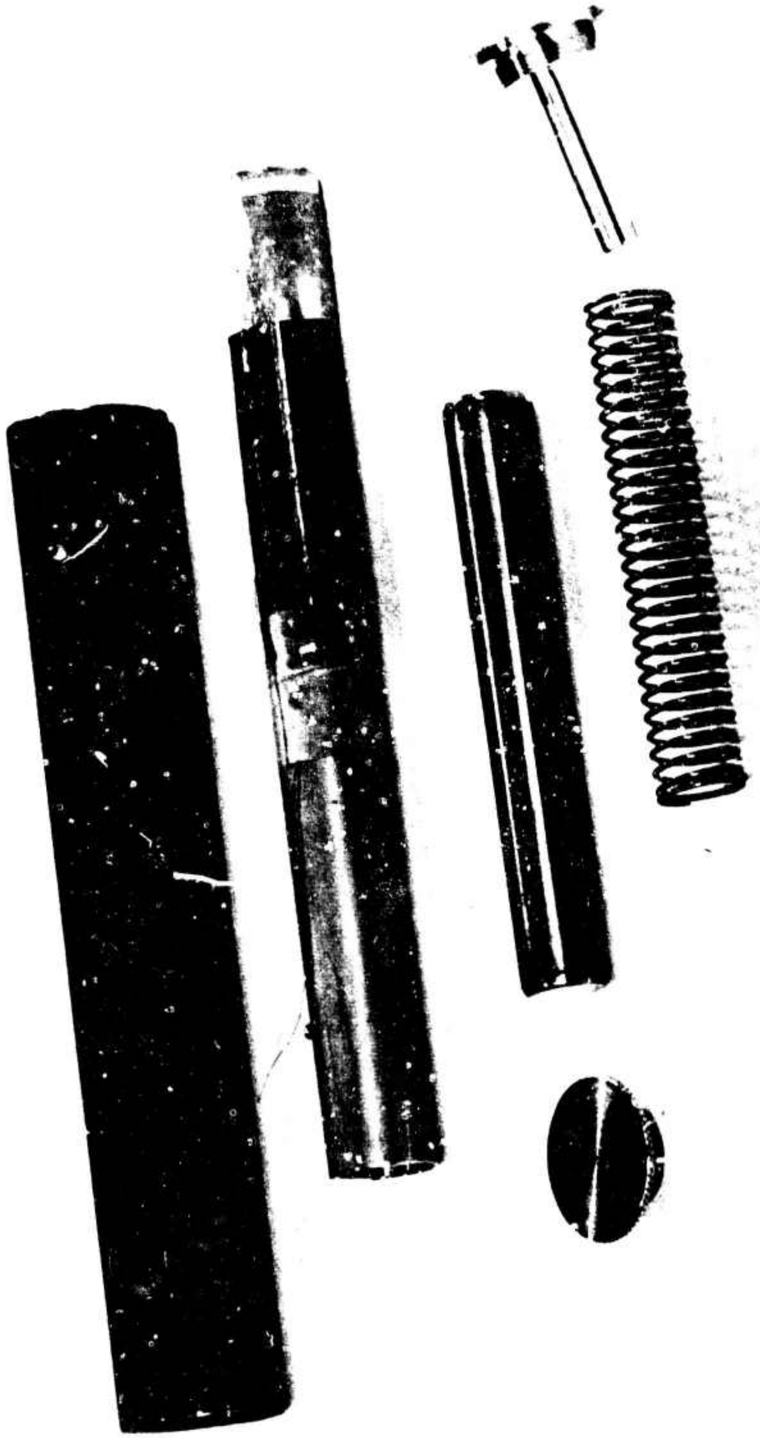


Figure 2. Velocity Sensor.

3) <u>Batteries</u> (Figure 3). Alkaline cells are used where possible to achieve operation over as wide a temperature range as can be obtained with commonly available energy sources.

The primary power supply needed by this system is a +45 volt battery. A -1.5 volt source is also needed for biasing in the advance trigger circuit. Union Carbide can supply an alkaline power pack Y1520 including both these voltages that can be mounted within the recorder. A -7.5 volt source is needed for the recorder electronic cutout switch. Five 1.5 volt cells of the same type as is in the Mallory Mn1306 4.5 volt battery can be placed in a series and then inclosed in a polyethylene sleeve to produce the required -7.5 volt source.

The power cell for the Accutron timer is a 1.32 volt mercury cell commonly used to power the Bulova Accutron No. 214 electric watch and may be obtained at most jewelers. This cell, however, cannot be counted upon to power the timer reliably below -13°F. External alkaline power must be used for timer operation below this temperature. Alkaline cells may be used down to -50°F.

External batteries may be used in place of the internal +45 volt, -1.5 volt, or 7.5 volt batteries. The input connector has terminals available for such a use. (See Installation of Batteries.) Alkaline batteries are recommended.

4) <u>Supporting Structure and Packaging</u>

<u>Frame</u> - The velocity transducers should be securely mounted to a suitable rigid frame. Rigidity should be sufficient to limit the duration of the impact deceleration pulse to 28 milliseconds maximum when subjected to a drop on a surface of softness equivalent to the softest expected during shipment. The frame both protects the drop height recorder and transmits the impact shock to the transducers. Frame design becomes especially important in edge and corner drops. A typical frame is the number 2-1/2 can case frame (Figure 4). It is made of 1" x 1" x 1/8" 6061 T6 aluminum angles welded together and weighs approximately 3.5 pounds. Dimensions are 12-3/16" x 16-1/4" x 9-3/8".

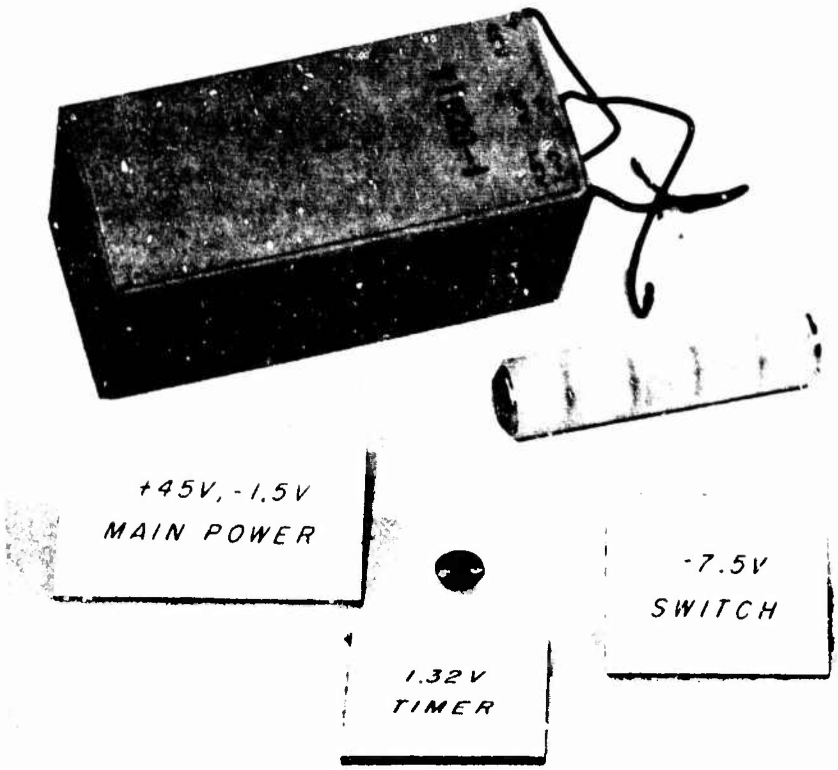


Figure 3. Batteries.

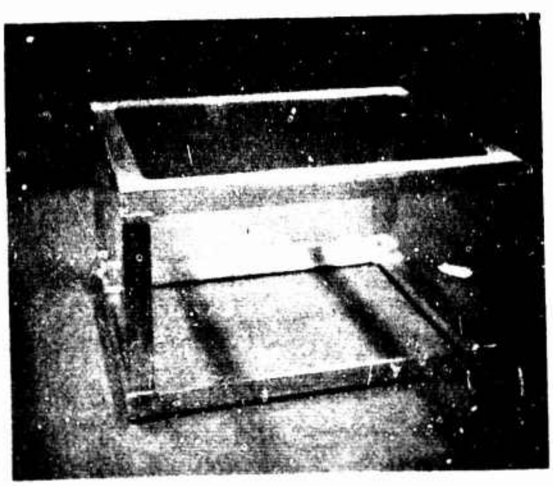


Figure 4. Typical Frame.

This type frame has been found suitable for normal shipment. However, if repetitive frame failures occur due to shipping hazards, the frame can be easily strengthened through the addition of cross members or stress panels or redesigned using heavier angles.

Cushioning - The recommended cushioning medium is a minimum of 2" of low density (2#/FT^3) polyether polyurethane foam. The resilience of this foam is essentially constant over the temperature range of -20°F to +150°F. At -50°F, the foam is approximately three times as rigid as at -20°F and, therefore, a greater cushioning thickness is recommended for expected exposure to this temperature. The optimum static stress level for urethane foams is 0.15 to 0.50 psi. If the recorder is cushioned in a number $2\frac{1}{2}$ can case without the use of load spreaders, the resulting static stress is in this range and satisfactory peak decelerations result. The use of other shipping containers and various cushioning thicknesses may require the use of load spreaders. User experience is the best guide on this point.

5) Magnetic Tape. A high quality black oxide polyester (mylar) $\frac{1}{4}$-inch instrumentation tape is recommended for use with this recorder. Tape with a 1.0-mil backing will allow a 100-foot load on the recorder supply reel. Tape with 1.5-mil backing will provide for more reliable operation because it is less subject to damage (wrinkling, stretching, etc.); however, only 70 feet of it can be loaded on the recorder.

6) Playback Instrumentation. The following equipment (See Appendix A) is required to retrieve information recorded on tapes used by this system:

(a) A quality tape deck with a constant playback speed and a four-channel playback head similar to the recording head. A playback speed of 1-7/8"/sec has successfully been used but a somewhat higher speed (up to 9"/sec) may improve the S/N ratio.

(b) Low noise amplification sufficient to drive display devices.

(c) A high speed display and storage device such as a recording oscillograph or storage oscilloscope. Printout instrumentation such as described in Appendix, Section A2 could alternatively be used.

d. Theory of System Operation (Figure 5)

Drop height and timing information is recorded on magnetic tape by means of a four-channel recorder head. The three drop height channels are identical in operation and are activated

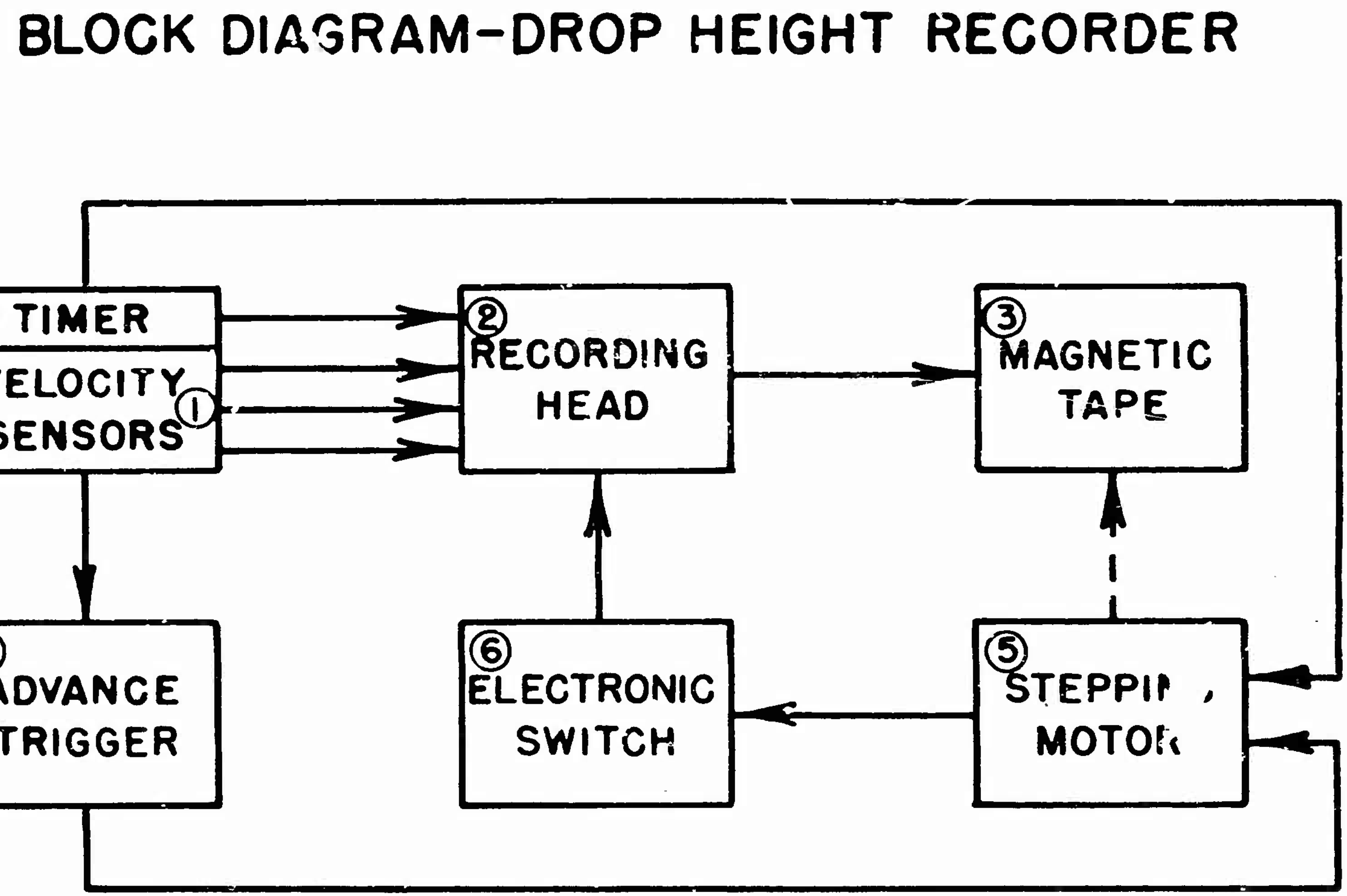


Figure 5. Block Diagram — Drop Height Recording System.

by voltage pulses from two velocity sensors per channel.

Velocity sensor (1) signals are fed to the recording head (2) which records on stationary magnetic tape (3). The magnitude of current through the recording head is limited to the linear range of recording tape by a resistor in series with the sensors, and the direction of current flow corresponds to the polarity of the active sensor. During recording, signals also go to the advance trigger (4) which activates the stepping motor (5) on the trailing edge of the sensor signal. Stepping motor activitation turns on the electronic switch (6) which cuts out signals to the head (2) for a period of two seconds to prevent recording during tape advancement and partial erasure of recorded signal by reverse current flow through the recording head from magnet rebound. Stepping motor (5) advances magnetic tape (3) approximately 1/16 inch.

Once each hour the timer contacts (7) close causing a signal through the time channel of the recording head (2) putting a saturation level timing mark on the tape (3). At the same time, contacts (7) activate stepping motor (5) which acts as above. Detailed operation, schematics, and component functions may be found in Appendices C, D, and E.

e. Operating Instructions

The following sections (2 and 3) contain a detailed description of system preparation, check-out, and calibration. Prior to initial shipment use, all of these procedures should be followed. For subsequent shipments, less preparation will be necessary and check-out procedures may be abbreviated; however, the calibration procedure should remain intact.

A system that has been correctly prepared and has passed the checks outlined in Sections 2 and 3 may be used for shipment. The system may be sent out after the recorder is loaded with tape (Section 2e) and packaged (Section 3b) and an initial calibration series is made (Section 3c). At the conclusion of a shipment, a second calibration series, as in Section 3c, is recommended. The tape may then be removed from the recorder and played back into a suitable display device (Appendix A).

2. Recorder Preparation and Checkout

a. Installation of Batteries

1) Tape Stepping Motor Circuit Battery (+45v) and Advance Trigger Battery (-1.5v).

(a) Place Union Carbide Y1520 or similar power pack on underside of recorder's base plate in space available (Appendix Figure D1, Item 4).

(b) Secure power pack to reco by wire, strapping or other means.

(c) Splice power pack +45v lead to a ble green lead.

(d) Splice power pack -1.5v lead to availa own lead.

(e) Solder power pack common to a ground termina the terminal board (7, 8, 17 or 20 in Figure 6a).

2) <u>Electronic Switch Battery (-7.5v) (Appendix Figure D1, Item 23)</u>

(a) Check battery holder No. 135 on top of base plate for corrosion of terminals. Remove small accumulations of corrosion by sandpaper. If corrosion is extreme, replace holder.

(b) Insert -7.5v battery (See Section 1c3) into holder making certain that positive side of battery is toward ground (black lead).

(c) Secure battery in holder by wire or other means.

3) <u>Accutron Timer (1.32v) (Appendix Figure D1, Item 8)</u>

(a) Remove eight screws holding timer case and advance electronics case.

(b) Remove timer from case and cushioning.

(c) Open cell compartment on rear of timer by removing screw-type cover and remove and discard old cell, if any.

(d) Insert fresh cell as indicated.

(e) Replace cover, timer, cushioning, case, eight screws.

4) <u>External Batteries</u> - If external batteries are used in place of the batteries in Sections 2a1) and 2a2) above, they may be connected to the recorder through the sensor cable connector. The following connections are appropriate for such an implementation. (See Figure 6b)

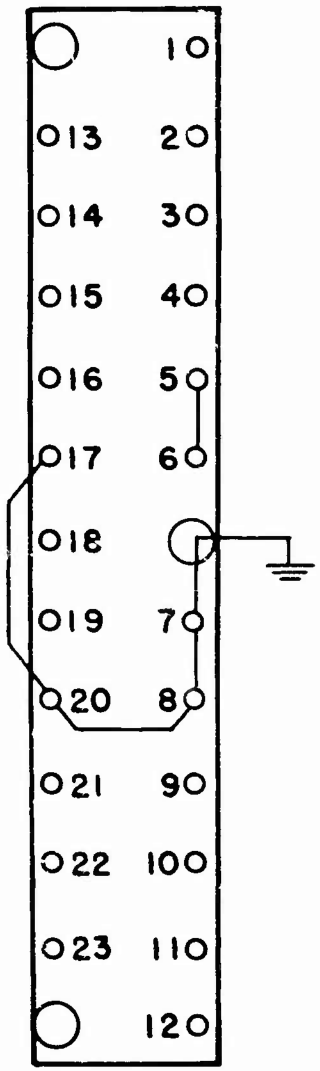


Figure 6a. Terminal Board.

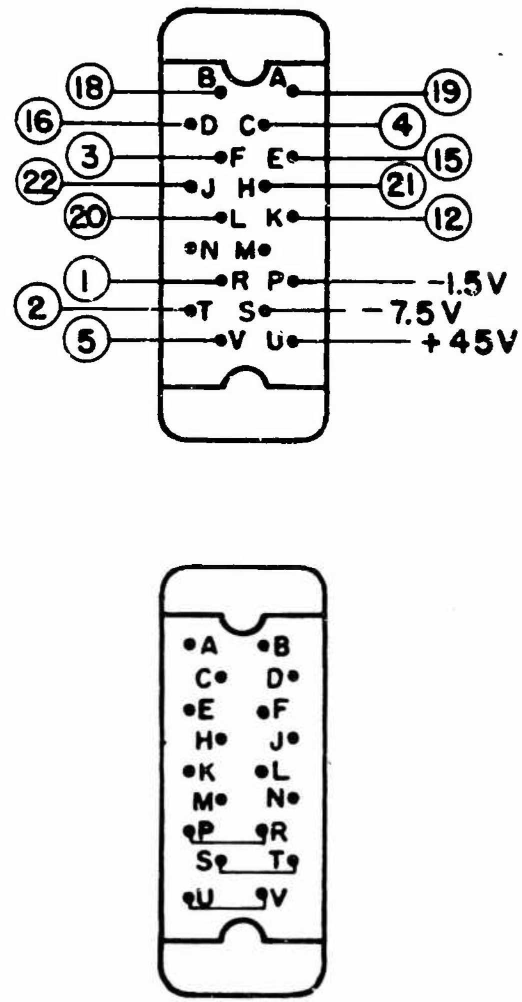


Figure 6b. Sensor Cable Connector.

Table I
External Battery Connections

BATTERY	Connections	
	+	-
+45v	V	L(ground)
-1.5v	L(ground)	R
-7.5v	L(ground)	T

b. Sensor Cable Preparation (Figure 6b)

1) Attach equal lengths of #22 insulated stranded copper wire to terminals A, B, C, D, E, F, H, J, K, on rear of sensor cable connector XMRE18P-C-1306X and label each lead. Length should be suitable for package size (at least three feet for a small package).

2) Attach three equal lengths (same as above) of wire to terminal L (grd.) and label.

3) Insert short between terminals U and V, P and R, and T and S, if not already done.

4) Tie leads into wire bundle and protect by sleeve or wrap if desired. These leads will be attached to sensors as indicated in Section 3a.

c. Reel Advance and Timer Checkout (Figure 6)

1) Simulating Trigger. Momentarily short terminal No. 23 to ground (nearby mounting screw, recorder case, or terminal No. 7, 8, 17 or 20). Caution: Avoid electrical contact with any terminal other than that specified in conducting this and any of the following procedures.

(a) If digimotor indexes and recycles every two seconds (approximately) if short is maintained, go to step 2.

(b) Otherwise, go to troubleshooting procedure 1. (See Section 4b)

2) Simulating Timer. Short terminal No. 13 to No. 14 momentarily.

(a) If digimotor indexes as above and will do so if step 2 is repeated after a wait of at least 10 seconds, go to step 3.

(b) Otherwise, go to troubleshooting procedure 2. (See Section 4b.)

3) Checking Timer. Check movement of tape reel retainers (see Appendix D1, Item 3) over a dozen hours or more, or movement of loaded tape (See Section 2e, below) by marking tape deck and reel retainer and checking relative positions of marks before and after.

(a) If check indicates recorder steps once each hour, go to 2d.

(b) Otherwise, go to troubleshooting procedure 3. (See Section 4b.)

d. Response to Voltage Input Checkout (Figure 6) (Use Sensor Cable)

1) Reel Advance. Connect terminal A to terminal C and feed 4.5 volts d.c. into terminals B(+) and L(-) on sensor cable connector by means of battery, capacitor discharge, or pulse generator. Remove input within one second.

(a) If recorder indexes upon removal of input, go to step 2.

(b) Otherwise, go to troubleshooting procedure 4. (See Section 4b.)

2) Head Voltage. Repeat step 1 checking the voltage across terminals 19 and 20.

(a) If voltage is proportional to the input but at a different level, go to step 3.

(b) Otherwise, go to troubleshooting procedure 5. (See Section 4b.)

3) Two-Second Cutout. Within a two-second interval after indexing as in d1(a) feed another input in.

(a) If voltage as in d2(a) appears on terminals 19 and 20, go to troubleshooting procedure 6. (See Section 4b.)

(b) If tape indexes in the two-second interval, go to troubleshooting procedure 7. (See Section 4b.)

(c) If both (a) and (b), above, are negative, go to step 4.

4) Reruns of Above Checks. Repeat steps 1 through 3 with the following inputs and terminal check points:

Connect	+input	-input	Terminals for d2(a) and d3(a)	
B to L	C	A	19 and 20*	
F to L	E	D	16 and 20*	
E to D	F	L	16 and 20	*Inverted
K to L	J	H	21 and 20*	Waveform
J to H	K	L	21 and 20	

e. Tape Loading and Unloading (Figures 7a and 7b)

1) Tape and Head Preparation

(a) Clean tape head and guides with commercial tape head cleaner or isopropyl alcohol.

(b) Check head alignment with small strip of tape for parallelism with head channels and centering of the tape on the recording area of the head; if misaligned, adjust.

2) Tape Loading (Figure 7)

(a) Remove supply reel (upper reel) from recorder by removing small locking screw on reel retainer (Appendix D1, Item 3).

(b) Attach magnetic tape to supply reel by pressure sensitive tape and wind onto supply reel until capacity is reached with care to avoid touching dull (oxide) surface of the tape.

(c) Demagnetize tape head using commercial head demagnetizer and demagnetize loaded supply reel by use of a bulk tape eraser.

(d) Unroll about one foot of tape from supply reel.

(e) Place supply reel on recorder so that tape unwinds in counter-clockwise direction.

(f) Remove pressure pad from front of tape head.

(g) Thread through tape guides and over front of tape head.

(h) Attach end of magnetic tape to take-up reel (lower reel) with pressure-sensitive tape.

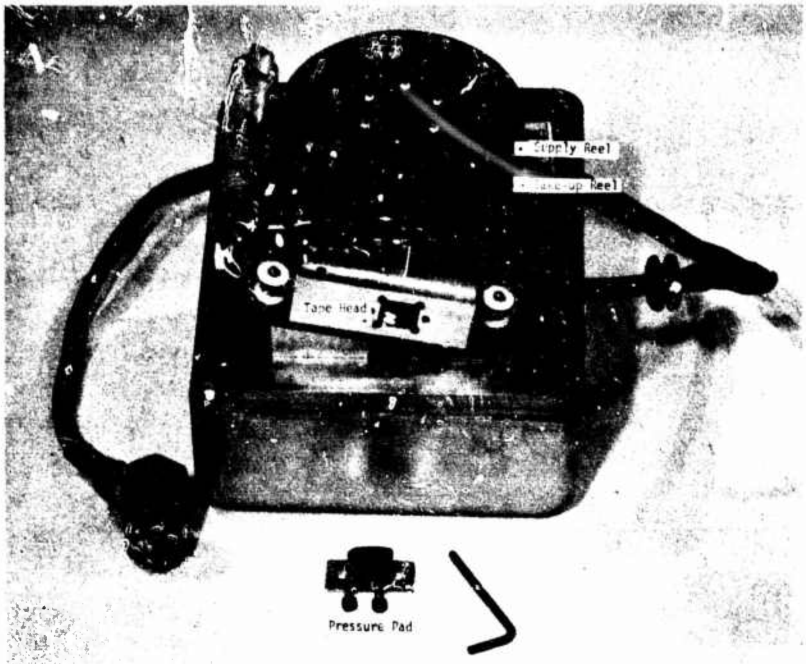


Figure 7a. Tape Loading (Front View).

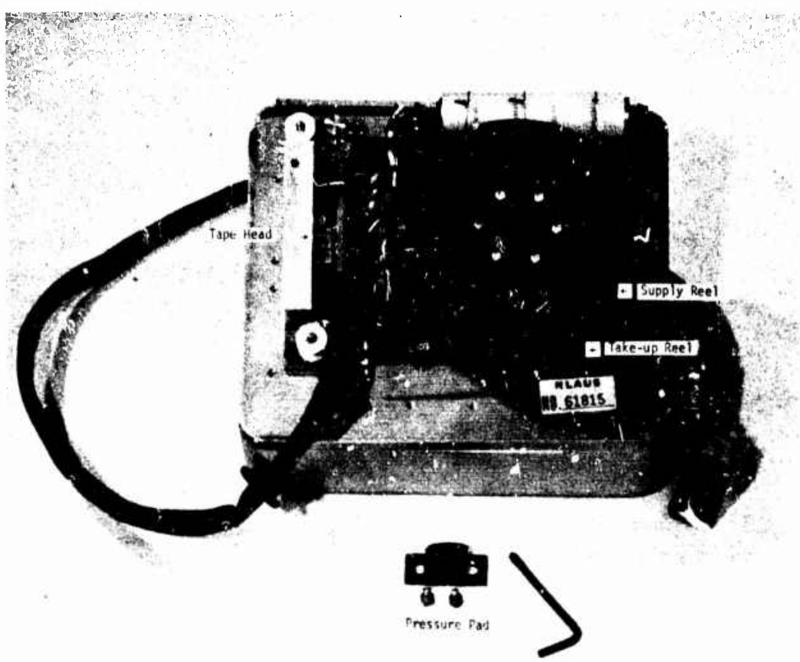


Figure 7b. Tape Loading (Side View).

(i) Remove slack from tape by rewinding excess back onto supply reel.

(j) Attach supply reel to upper reel retainer by small locking screw.

(k) Turn reel retainers counter-clockwise at least one full turn to make at least one loop of tape around take-up reel.

(l) Replace pressure pad.

3) Tape Unloading.

(a) Turn reel retainers counter-clockwise two full turns by hand.

(b) Cut magnetic tape at point of arrival on take-up reel.

(c) Remove supply reel by removing small, locking screw, turning and lifting. (Tape may remain threaded, if desired.)

(d) Remove take-up reel by removing small locking screw, turning and lifting.

f. Recording Function and Range Check

1) Load a short length of tape on the recorder (2 feet to 5 feet).

2) Feed in a series of five 5.0 volt d.c. inputs for each of the following input terminal pairs in succession waiting a minimum of two seconds between inputs. This simulates five successive impacts of equal drop height.

	d.c. Input		Connect		d.c. Input		Connect
(a)	B(+)	L(-)	A to C	(d)	C(+)	A(-)	B to L
(b)	F(+)	L(-)	D to E	(e)	E(+)	D(-)	F to L
(c)	K(+)	L(-)	H to J	(f)	J(+)	H(-)	K to L

3) Let the recorder sit for at least three hours to obtain time marks.

4) Repeat F2 with 2 volt d.c. to simulate a lower drop height.

5) Unload the tape.

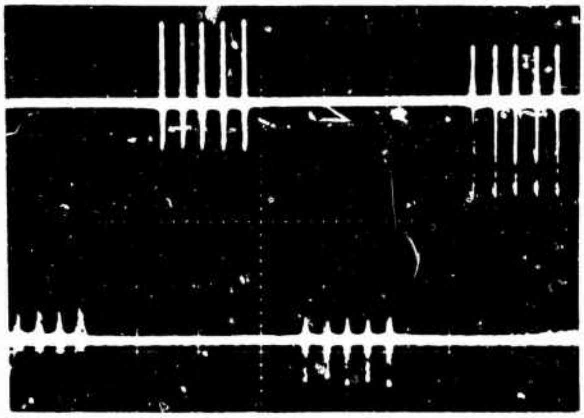
6) Check each drop height channel for an output as in Figure 8a. (See Appendix A.)

7) If the recorder has passed the tests outlined in par 2c1 and section 2d and there is no output, go to troubleshooting procedure 10. (See Section 4b.)

8) Check the timing channel for an output as in Figure 8b.

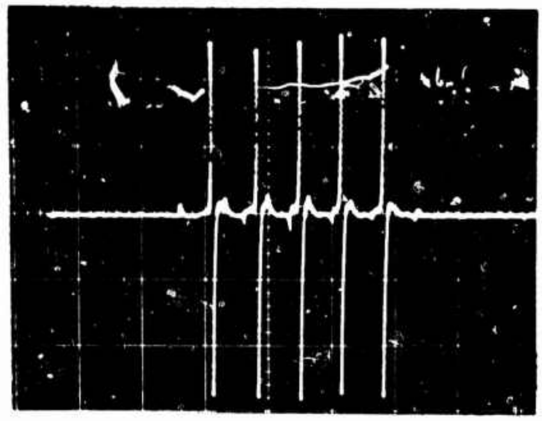
9) If there is no output, go to troubleshooting procedures 2, 3 or 10. (See Section 4b.)

10) Once corrections have been made, repeat above procedures if deemed necessary.



a. Drop Height

Top Vert 1V/Div Horiz 0.1 sec/Div
Bottom Vert 0.2V/Div Horiz 0.1 sec Div



b. Time

Vert 0.2V/Div Horiz 50 msec/Div

Figure 8. Typical Output-Function Check.

3. System Mounting and Calibration

a. Transducer Mounting Procedure

The six velocity transducers shall be rigidly mounted to a suitable support structure such as an aluminum frame. It is very important that the transducers are rigidly mounted to minimize the introduction of extraneous vibrations or unwanted shock damping. Stiffening of the frame may also be necessary to prevent error due to frame ringing.

Two transducers shall be aligned along each of the three major axes of the container. One transducer shall be so oriented that it is sensitive in the positive direction and the other transducer oriented so that it is sensitive in the negative direction. A simple but effective transducer mounting method is shown in Figure 9.

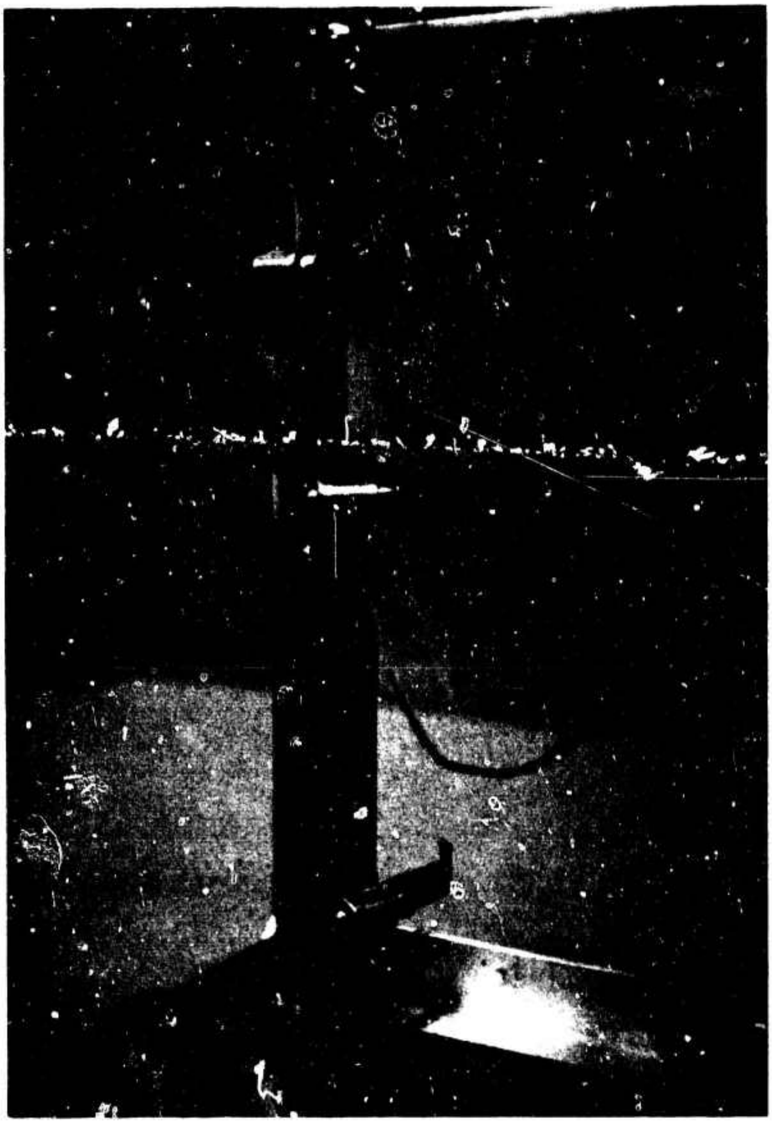


Figure 9. Transducer Mounting Method

The transducers are held rigidly in place by a combination of 1" x 1" wooden blocks and standard screw type hose clamps. More refined methods can be designed to suit the particular application and container.

The table below indicates the proper transducer to sensor cable connection. Wire pairs from transducers to the cable connector may be shielded to prevent cross-talk.

Table II
Transducer-Recorder Interconnections

Transducer	CONNECTIONS	
	Signal High*	Signal Low
Y Positive	B	L
Y Negative	C	A
X Positive	F	L
X Negative	E	D
Z Positive	K	L
Z Negative	J	H

*At impact, initial potential of signal high will be positive with respect to signal low

b. Cushioning

Polyurethane foam of 2#/ft^3 density may be used to cushion the recorder within its package. The recorder may be used with or without its exterior $9\frac{1}{2}$" x $8\frac{1}{2}$" x $6\frac{1}{4}$" case. If the exterior case is used, one inch of cushioning must be used between the inner and outer case. If the exterior case is not used, a maximum amount of cushioning may be used. In either case, the recorder should be located as close to the center of the instrumented package as possible and all the remaining space in the package should be filled with cushioning (excluding space used by sensors, structure, batteries, etc.). The minimum recommended package size allows approximately three inches of cushioning on the least protected side of the recorder (Figure 10).

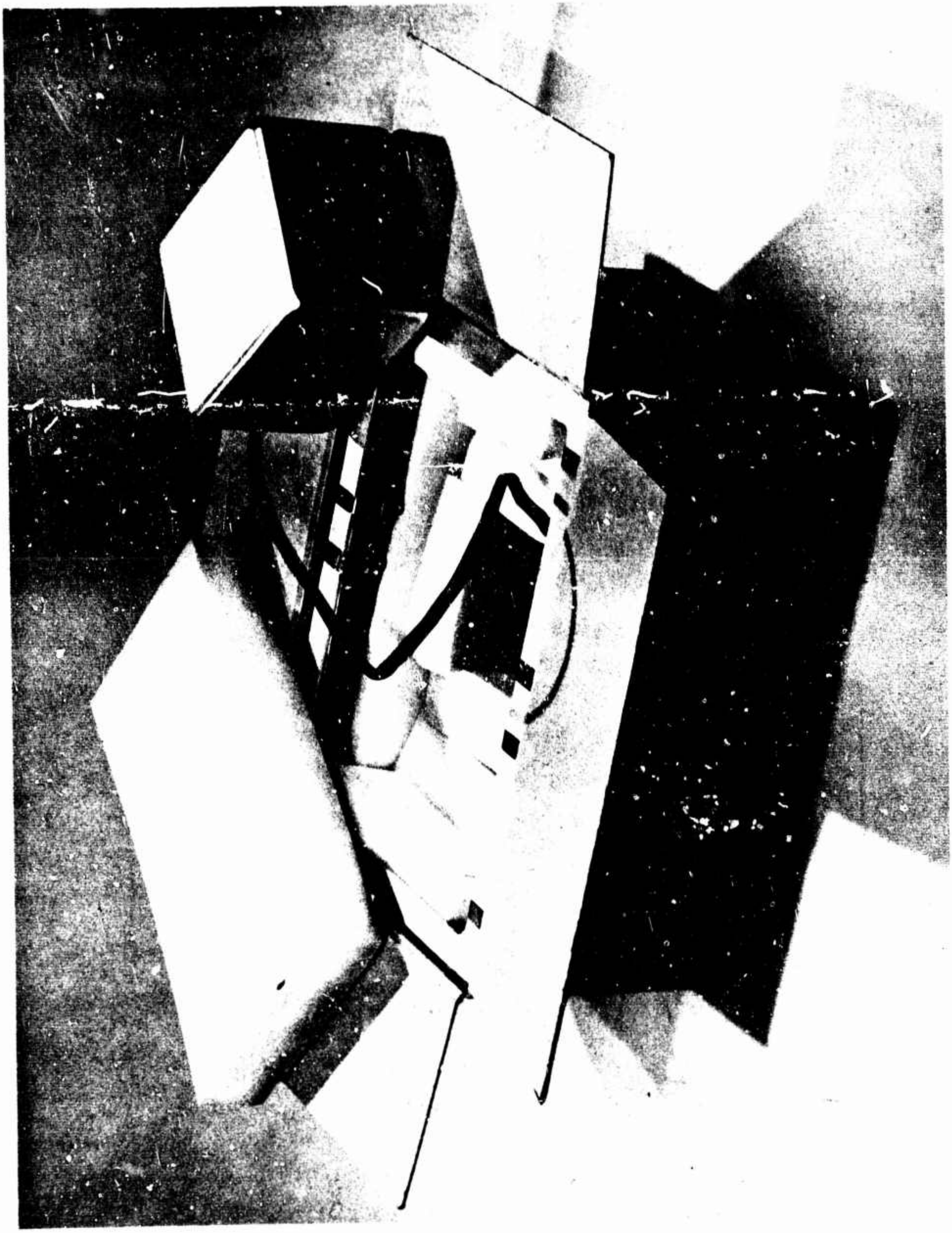


Figure 10. Cushioned System.

c. Calibration Series

Both before and after test shipments the instrumented container should be subjected to a series of calibration drops. The results of the calibration drops are used to interpret the data recorded during shipment. The following is a suggested calibration drop test plan:

Calibration Drop Test

1) Drops shall be made from a free fall drop tester, if available, onto a rigid impact surface such as a concrete floor, steel plate, or hard-packed sand.

2) Drops shall be as near to flat as possible.

3) A minimum of four seconds shall be allowed between drops.

4) The container faces are designated in Figure 11.

5) The drop sequence shall be as follows:

Table III
Calibration Series

Drop Height (inches)	No. of Drops per Face	Drop Face Sequence					
12	3	2	3	5	4	1	6
24	3	2	3	5	4	1	6
36	2	2	3	5	4	1	6
48	2	2	3	5	4	1	6

For Example: Start at height of 12" and make 3 drops on Face #2, followed by 3 drops on Face #3, etc. When all the 12" drops are complete, go to 24" and make 3 drops on Face #2, followed by 3 drops on Face #3, etc.

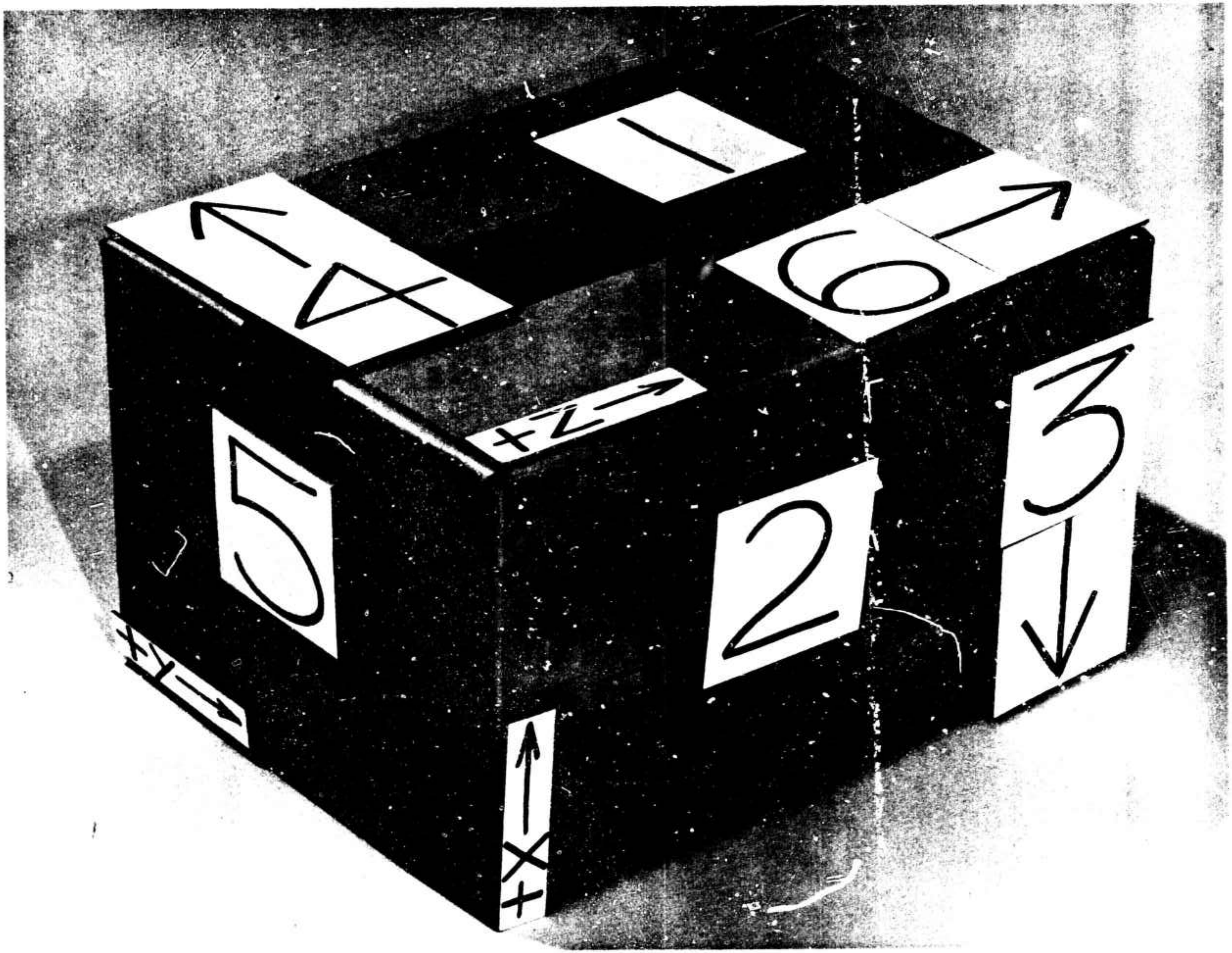


Figure 11. Container Face Designations.

4. Maintenance and Troubleshooting

a. Routine Maintenance

1) Batteries. The 45-volt power pack normally will require replacement after six months of use. The electronic switch battery (-7.5 volts) will last longer; however, its voltage should be checked periodically and if it has discharged to six volts or less, replace the battery. The Accutron power cell normally will operate the timer accurately for a year or more.

When the sensor cable is disconnected, the 45 and -7.5 volt batteries are removed from the recorder circuitry and their discharge characteristics become those of a battery on the shelf. In this case, batteries may go up to two years between replacements. For replacement procedures, see Section 2a.

2) Parts Repair and Replacement. Before and after shipment check for damaged parts or wiring. Repair or replace as required. Checks should also be made for corrosion of recorder parts. Expecially susceptible are the terminals of the 7.5 volt battery holder. Removal of oxide buildup where detected is called for except where excessive buildup may require replacement of parts.

b. Troubleshooting Procedures

Before any of the listed troubleshooting procedures are undertaken, check for the following minimum acceptable voltages with respect to recorder ground: +40 volts at terminal board point 5, -6 volts at point 2, and -1.2 volts at point 1. If any of these voltages are not available, the probable cause is either a battery or wiring problem (possibly at the connector). Make sure the connectors are securely mated.

A low voltage normally indicates a low battery. Disconnect the battery from the recorder and check its voltage; if it is still low, replace the battery.

No voltage indicates an open or short in the wiring or connector. Disconnect the connector and check wiring with a resistance meter for continuity and shorts. Repair or replace any wiring or connector found faulty.

If neither battery nor wiring is at fault, a circuitry problem is indicated. The appropriate circuit should be investigated for shorts or faulty components (check transistors first).

If all required voltages are available to the recorder, the procedures listed in Table IV may be used to locate and eliminate recorder malfunctions.

Operation and voltage checking procedures will require power; thus, when undertaking such procedures either the recorder connector must be mated to the sensor cable connector or the following connections must be made on the recorder connector: U to V, P to R, and T to S.

When conducting continuity and resistance checks or when making repairs, power must be removed from the recorder by disconnecting the recorder connector from the sensor cable connector and discharging the 100μf capacitor (C5) through a resistor (1K or larger).

Repair of circuits in this recorder requires removal of the potted circuit board from its potting case and the cutting away of potting compound around the defective component, desoldering and removal of the component, replacement and resoldering, and return of the potted board to its case. The cavity left in the potting compound may be filled by the addition of fresh compound (Dow Corning SYLGARD 184).

5. References

Gertel, M. and Franklin, D., "Determination of Container Design Criteria," U. S. Army Natick Laboratories Report 67-50-GP, January 1967.

O'Sullivan, D., "NLABS Shipping Hazards Recorder Status and Future Plans," The Shock and Vibration Bulletin 39, Part 6, pp. 19, March 1969.

Venetos, M. A., "Development of Velocity Shock Recorder for Measurement of Shipping Environments," The Shock and Vibration Bulletin 36, Part 6, pp. 173, February 1967.

Table IV

TROUBLESHOOTING

Malfunction Procedure	Test	Abnormal Indication	Repair Method	Dwgs. (See Appendices) Electrical Schematic	Location in Recorder
1. Digimotor does not index when point 23 is shorted to ground.	a. Check continuity from terminal board to digimotor and capacitor C5	Open	Repair wiring	Figure: D2a	Figure: D1, Items 10, 13, 5
	b. Check C5 when disconnected from circuit	Short, leaking, or open	Replace C5 (1000 µf)	D2a	D1, Item 13
	c. Check resistance from point 11 to recorder ground	Less than 3K ohms, both directions	Replace TR1 (2N3054)	D2a	D1, Item 7 D3a
	d. Remove TR1 and short point 23 to ground	Motor steps	Replace TR1 (2N404A)	D2a	D1, Item 7 D3a
2. Digimotor does not index when point 13 is shorted to point 14 but will index if point 23 is shorted to ground.	Remove SCR and check	Cathode to anode short or other defect	Replace SCR (2N1595)	D2a	D1, Item 7 D3a
3. Digimotor does not index once each hour but will index if 13 is shorted to 14.	Remove timer and examine	Timer not running.	Replace power cell.	D2a	D1, Item 8
		Timer does not run with fresh cell or contacts do not close with running timer.	Replace timer	D2a	D1, Item 8
4. Digimotor does not index in response to d.c. input on removal of input but will index if 23 is shorted to ground.	a. Check continuity from electronics to terminal board.	Open	Repair wiring	D2c	D1, Items 12, 5 D3b
	b. Disassemble appropriate sensor	Deformed spring	Replace spring.	-	-
	c. Check resistances of junctions of Q7 and Q6	Short or open	Replace Q7 or Q6 (2N2484)	D2c	D1, Item 12 D3b

Table IV, Continued

TROUBLESHOOTING

Malfunction Procedure	Test	Abnormal Indication	Repair Method	Dwgs. (See Appendices) Electrical Schematic	Location in Recorder
5. Digimotor indexes in response to d.c. input on removal of input but no voltage appears across head terminals.	a. Check continuity from connector to head terminals on terminal board.	Open or intermittent open	Repair wiring	Figure: D2a	Figure: D1, Item 5
	b. Disassemble appropriate sensor	Deformed spring	Replace spring	-	-
	c. Remove head leads from terminal board and check head resistance	Resistance > > 200 ohms	Replace head (#5651)	D2a	D1, Items 5, 6
	d. Check resistance across head terminals with head leads removed.	Short. (Electronic Switch failure)	Replace Q3, Q4, or Q5 (2N404A)	D2b	D1, Item 12; D3b
6. Voltage cutout does not work in the two-second interval following tape advance.	a. Check continuity from terminal board to electronic switch circuit board	Open	Repair wiring	D2b	D1, Item 12; D3b
	b. Check resistance of across head terminals with head leads removed.	Open (Resistance much greater than normal; check good channel for normal)	Replace Q3, Q4, or Q5 (2N404A)	D2b	D1, Item 12; D3b
	c. Check Q1 and Q2	Opens or shorts	Replace Q1 (2N1132) or Q2 (2N2484)	D2b	D1, Item 12; D3b
7. Tape indexes within two seconds of a previous indexing.	Check TR1, then D2	Short	Replace TR1 (2N404A) or D2 (1N705)	D2a	D1, Item 7; D3a

Table IV, Continued

TROUBLESHOOTING

Malfunction Procedure	Test	Abnormal Indication	Repair Method	Dwgs. (See Appendices) Electrical Schematic	Location in Recorder
8. Signal cuts out before peak signal is reached.	a. Disassemble appropriate sensor.	Deformed spring.	Replace	-	-
	b. Monitor signal.	Spike where signal cuts out.	Remove source of noise or shield leads.	-	-
9. Tape indexes every two seconds, spontaneously.	Check resistance from terminal point 23 to recorder ground.	Short circuit. (Either wiring or bad Q7)	Repair wiring or replace Q7. (2N2484)	D2c	D1, Item 12 D3b
10. No tape output on playback.	Check resistance across head terminals.	Resistance $\gg$ 200 Ω Resistance $\gg$ 200 Ω & wiring O.K.	Repair wiring or connections. Replace head.	D2a	D1 Item 6
11. Noisy head signal.	Disassemble appropriat sensor.	Deformed spring.	Replace spring.	-	-
12. Decreased head signal amplitude.	Disassemble appropriate sensor.	Deformed spring.	Replace spring.	-	-
13. Weak tape advance signal (digimotor gets pulse but does not advance).	Check D3	Short or Zener voltage much lower than 36v.	Replace D3. (1N974A)	D2a	D1 Item 7 D3a

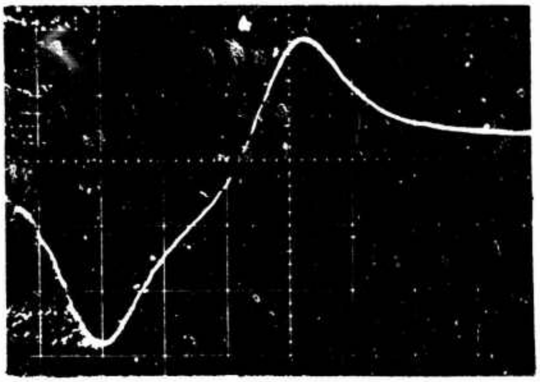
APPENDICES

APPENDIX A

Data Retrieval Techniques

1. Manual Techniques

The playback of a pulse recorded on motionless magnetic tape will appear as a pulse doublet (Figure A1) on a display device. The polarity and peak amplitude of the doublet prior to polarity reversal is related to the polarity and peak amplitude of the original signal. Provided that the playback instrumentation is not changed, similarly polarized inputs will yield similarly polarized outputs and a change in input polarity will cause a change in output polarity. If input circuitry is properly matched to other system characteristics, the output peak amplitude may be assumed to be directly proportional to the height from which the instrumented package was dropped to generate the input pulse. (See Appendix B.)



Vert 2.0V/Div Horiz 0.1 msec/Div

Figure A1. Typical Playback Waveform

Shipment information tapes should be played back on a suitable four-channel tape deck at constant speed and amplified sufficiently to drive a display device for visual records. A four-channel recording oscillograph is desirable for simultaneous tracing of all channels; however, channels may be traced separately and then related to one another. If calibration series have been run, peak amplitudes

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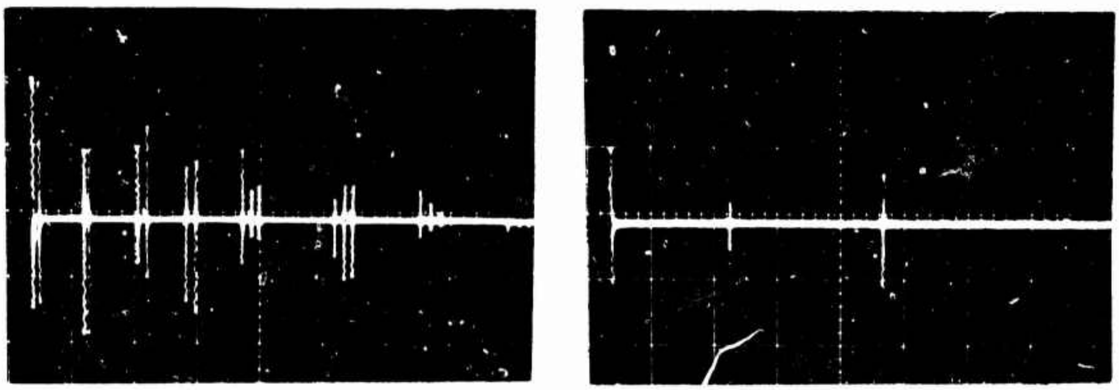
of pulse doublets in the series should be measured and average values calculated for groups of equal drop height. A calibration curve for each sensor can then be determined relating playback pulse amplitude to drop height. Shipment shock drop height estimation can then be made by measurement of playback amplitude of shipment drop pulses and referral to the calibration curve for the corresponding sensor. Simultaneous playback pulses from all three drop height channels indicate a corner drop, pulses from two out of three channels indicate an edge drop, and a pulse from only one channel indicates a flat drop. In any event, the indicated package drop height will be the summation of the indicated drop heights for the individual channels (see Appendix B). The timing channel record provides a means of determining the exact hour of a shock relative to the start of the shipment. Gaps in the timing record correspond to drop height data. A count of the timing pulses from start of shipment to the data equals the hour of data occurrence.

The oscilloscope traces (Figures A2a and A2b) show the single channel playback of a representative calibration drop series and shipment data from the same recorder.



a. Calibration

b. Shipment

Vert 1V/Div Horiz 0.2 sec/Div

Vert 0.5V/Div Horiz 50 msec/Div

Figure A2. Calibration and Shipment Playback

A calibration curve can be drawn from this data (Figure A3) using average values of playback pulse amplitude. (Table A1) Pulse amplitudes of shipment data pulses may then be measured and estimated of drop height made by referral to the calibration curve.

This example is for one channel only. Drop height estimates derived from simultaneous pulses in other drop height channels must be added to yield an estimate of package drop height. The drop height record must be compared to the time channel record to determine the time of occurrence from which it may be possible to determine the locale of the package when it was subjected to the shock.

The accuracy of drop height estimates using this recording system was tested with the following findings:

The average percent error of the complete recorder/playback system during static tests (recorder not subjected to impact) has been measured in the range of ±10% for a pulse input accuracy of ±2%.

The average percent error of the recorder/playback system during dynamic test (recorder subjected to impacts ranging from 20 to 300 g's) under laboratory conditions has been measured to be in the range of ±3% to ±18%. The average percent error increases with increasing "g" level to the recorder.

The average percent error of the recorder/playback system during actual field shipment has been measured in the range of ±10% to ±25% with the average error increasing with drop height. The error increase is most significant above a three-foot drop height.

At the four-foot drop height the maximum expected error is ±25% for the minimum recommended cushioning and approaches ±10% as cushioning is increased.

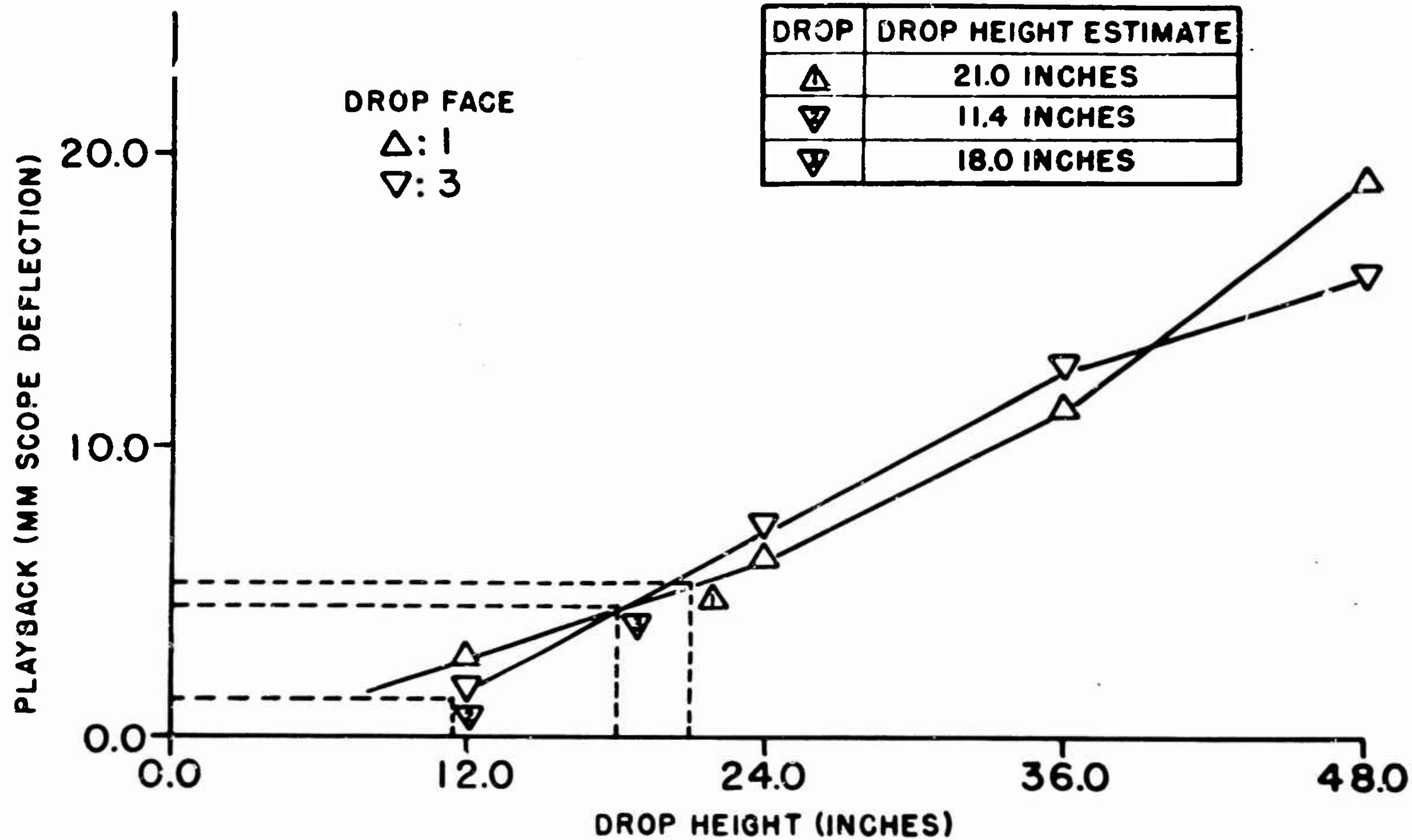


Figure A3. Typical Calibration Curves.

Table AI

Calibration Data (Figure A2a)

Drop Height (Inches)	MM Scope Deflection			
	Drop #1	Drop #2	Drop #3	Average
+48	19.7	19.0	--	19.35
-48	-16.0	-15.8	--	-15.9
+36	10.3	12.8	--	11.55
-36	-11.3	-12.9	--	-12.1
+24	9.8	4.5	4.8	6.36
-24	- 5.4	- 8.5	-8.0	- 7.3
+12	4.4	2.6	1.6	2.86
-12	- 2.0	- 1.4	-1.4	- 1.6

"+" indicates drop face #1

"-" indicates drop face #3

Table AII

Shipment Data (Figure A2b)

Drop* No.	MM Scope Deflection	Equivalent** Calibration MM	Drop Height*** Estimate (Inches)
1	10.7	5.35	21.0
2	- 2.8	-1.4	11.4
3	- 9.0	-4.5	18.0

*Counting from left of photo.
**Shipment playback sensitivity setting was twice that of calibration playback.
***See Figure A3.

2. Automated Techniques

Automated systems may be devised for read-out of data on shipping information tapes. Such a system is in operation at USANLABS. A separate report is planned describing in detail the operation of that system.

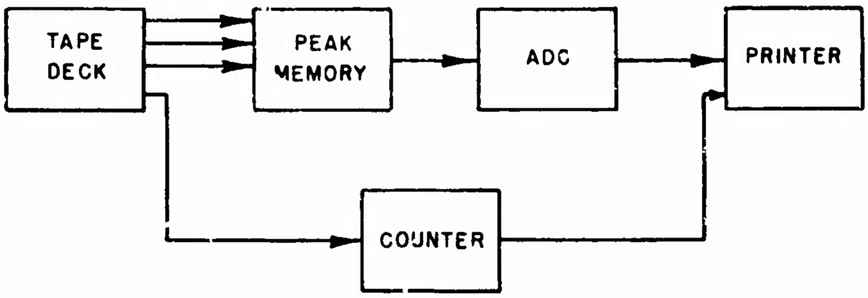


Figure A4. Simplified Block Diagram

NLABS Read-out Instrumentation

Timing pulses are counted and the total is available for print-out with drop height data. When drop height data occurs, pulse peak amplitude is temporarily stored for all three drop height channels. Analog to digital conversion is performed on the data for each channel in turn. The data initiates a line of printout which consists of the time pulse total, drop height components in the three directions, and the computed package drop height.

The output of the A. D. C. could conceivably input a digital recorder for generating input tapes for a digital computer. Programs could then be written for the analysis of raw drop height data.

APPENDIX B

Recording-Playback Theory and Curves

1. Recording

Recording on unbiased motionless magnetic tape results in a magnetized area of tape approximately the size and shape of the recording head gap for each input pulse. The amplitude of the residual magnetism on that area after removal of the input is a nonlinear function of peak input current provided there is no polarity reversal of input current during recording. The function (tape magnetization curve) is dependent upon both tape and head characteristics.

Premagnetization of tape at the saturation level and subsequent recording in the opposing direction will result in a tape input-output curve similar to that for non-magnetized tape but with a useful dynamic range approximately one and one-half times as great; however, use of premagnetization precludes bidirectional recording.

Amplitude errors at record time can result from a variation in tape magnetization due to non-uniformity of particle density, dispersion of particles, or particle size in the tape emulsion. Surface smoothness variations along the tape can affect head to tape positioning during recording. Amplitude errors can also result from tape tracking errors and tape to tape head distance fluctuations.

Amplitude errors can be reduced by using a tape head with a large head gap, by use of a pressure pad at the tape head, and by precision in the guidance and positioning of the tape during recording. The use of a head with a longer gap produces longer signals impressed on the tape increasing the volume of oxide contributing to the recorded signal tending to decrease errors due to non-uniformity of the emulsion. The larger head gap also decreases the error due to fluctuations in tape to tape head distance since this is a function of the ratio of tape to tape head distance and wave length. The use of a pressure pad at the recording head reduces error resulting from random tape motion and surface smoothness variations.

2. Playback

When recorded data is passed over a suitable playback head, a voltage is induced in that head proportional to the rate of change of magnetic flux associated with the recorded pulse. The resulting output pulse doublet will have an initial polarity corresponding to that of the recorded pulse and its peak amplitude in that polarit will be proportional to the amplitude of the recorded pulse. The overall recording-playback characteristic curve is a function of the head and tape used in recording, the playback head, playback speed and tape premagnetization used, if any. (See Table BI.) Curves relevant to NLABS recording systems are shown in Figure B1. Ampex #748 Instrumentation tape was used as the recording medium.

Table B I
Characteristic Curves

Curve	Recording Head (Nortronics)	Gap Length (mils)	Premagnetization	System
1	5651	0.5	No	Drop Height
2	5651	0.5	Yes	Acceleration
3	5653	0.1	No	-
4	5653	0.1	Yes	Combination

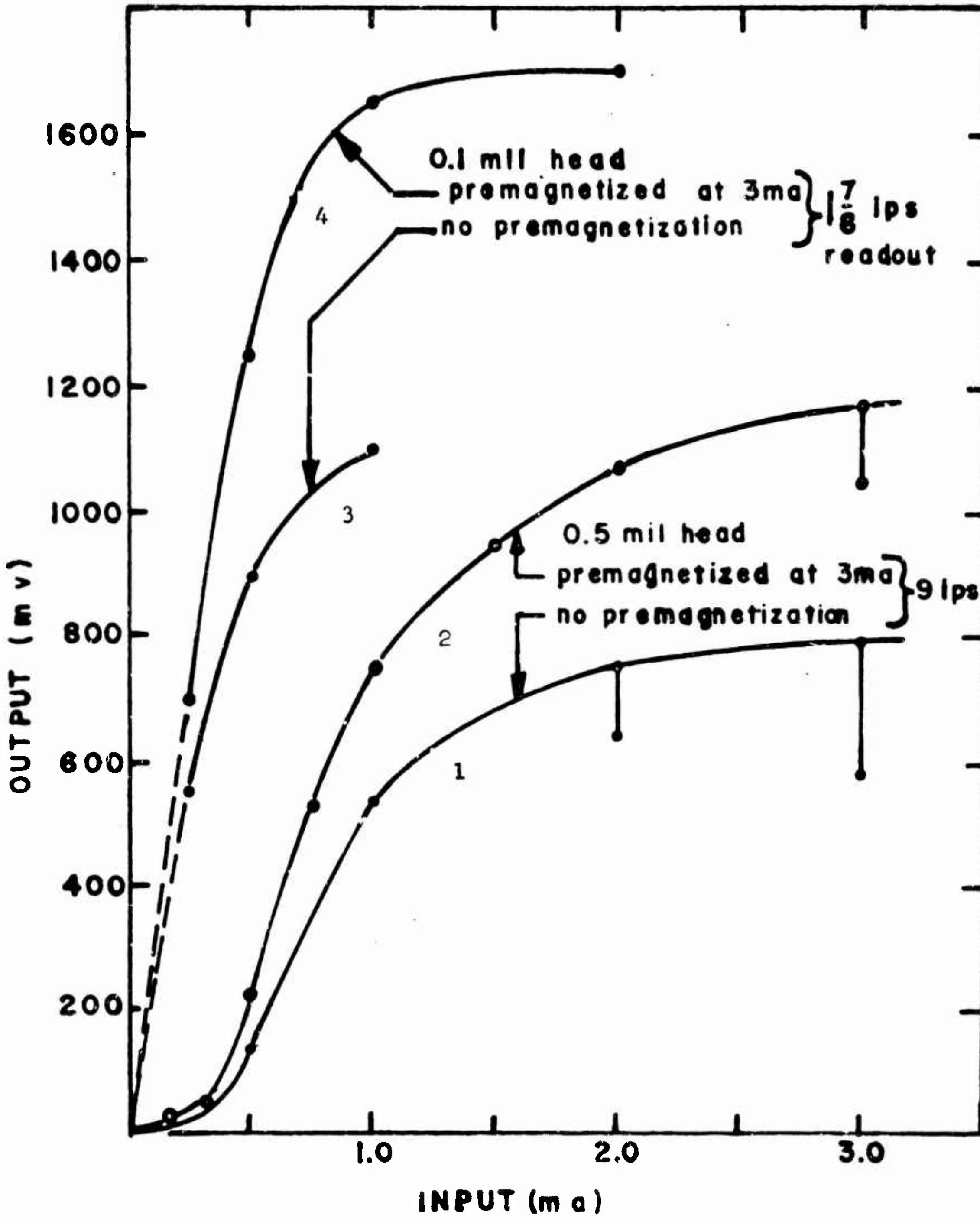


Figure B1. Recording Characteristic Curves.

The lower part of Curve #1 can be used for the drop height recording system to take advantage of its similarity to a squaring characteristic in this region. (See Section 3.) Transducer inputs are proportional to velocity and the square of velocity is proportional to drop height; therefore, tape outputs should be proportional to drop height. For edge and corner drops $V_x^2 + V_y^2 + V_z^2 \propto h$; therefore, indicated drop heights for separate channels should be added to yeild resultant drop height. Polarity sensing is desired for drop height and input (transducer) range is only four to one, thus premagnetization is not used. The drop height system is susceptible to shock-related scatter of data. The wide-gap head is selected to keep scatter to a minimum.

Curve #2 is used from the origin up to near saturation level for the acceleration recording system. The wide-gap head is used because of the shock environment, and premagnetization is used with special electronic linearization to obtain a 200 to 1 dynamic range with a uniform error or uncertainty over the entire range.

Curve #3 was formerly used for the drop height system; however, the narrow-gap head resulted in excessive scatter.

Curve #4 is used for the combination recorder system. A narrow-gap head may be used because this system has little shock-related error and the narrow gap yields a greater linear dynamic range. Premagnetization is used to further extend that range since the recording is done in only one polarity.

3. Input-Output Curve Adjustments

The nominal value for the current limiting resistors mounted on the terminal board (Figure D1, Item 5) in the three drop height recording channels is 4.75K. This value was selected to yield a nearly linear relation between drop height and playback amplitude. The following procedure is recommended if a characteristic tailored to the user's particular needs is desired (if, for example, the user is interested in a drop height range other than six to 48 inches or wants to use a special record head, sensor, or tape) or the user wants to adjust for channel to channel differences in the recording head or differences in sensor sensitivity between axes.

The recording head/playback channel characteristic should be determined by feeding in a series of known d.c. input currents to the head of a recorder with the tape loaded. Input amplitude changes should be in small enough increments to adequately cover the range from zero to near saturation. The playback of the series allows a channel characteristic curve to be plotted.

The sensor output characteristic may be determined by monitoring the output of the sensor mounted in the package as it would be in shipment. The package should be dropped at a number of heights to cover the desired range. The sensor output voltage should simultaneously be monitored by means of a flexible cable. The sensor characteristic may then be plotted.

The overall drop height/playback characteristic may be determined for each data channel from the above two curves and the value of the current limiting resistor. Head current (I_H) may be found from transducer voltage by

$$I_H = \frac{V_T}{R_H + R_S}$$

where

V_T = sensor output voltage

R_H = d.c. resistance of the recording head (220 ohms for #5651 recording head)

R_S = given current limiting resistor

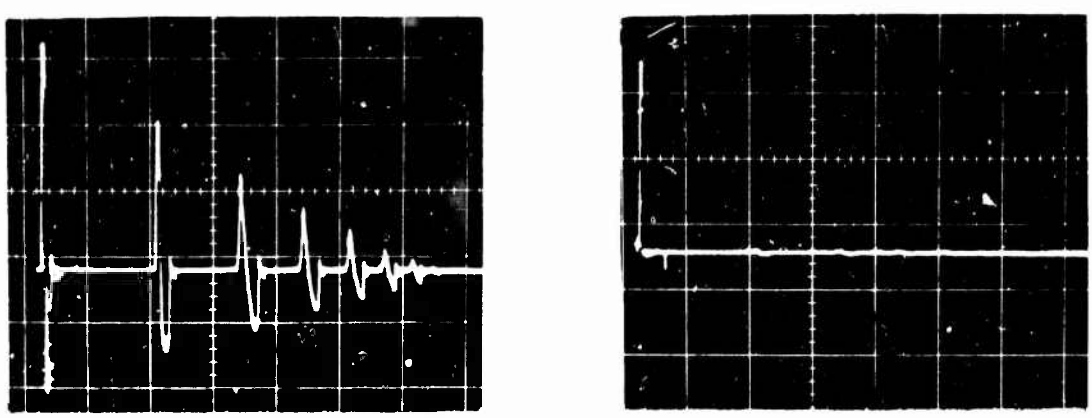
A family of curves may be generated by varying R_S, and optimum R_S may be determined by selection of the best overall drop height/playback curve. The range of R_S for Nortronics #5651 recording head and Ampex #748 tape would normally be from 12K to 2K ohms.

APPENDIX C

Operation of Drop Height Recorder Electronic Circuitry (Refer to Drawings, Figures D2a, D2b, and D2c.)

Drop height and timing information is recorded on magnetic tape by means of a four-channel recorder head. The three drop height channels ("Y" axis, "X" axis, and "Z" axis on Dwg D2a) are identical in operation and are activitated by voltage pulses from two velocity sensors per channel. There is one velocity sensor for each impact surface. Taking the "Z" axis channel as an example, the +Z surface velocity sensor is connected between terminal points 12 and 20 so that, upon impact on the +Z surface, point 12 will experience a positive voltage pulse with respect to point 20. (Figure C1a) Likewise, the -Z surface sensor is connected between points 22 and 21 so that, upon impact on the -Z surface, point 22 will be pulsed positive with respect to point 21. The magnitude of current through the recording head is limited to the lower portion of the recording characteristic by a resistor in series with the sensors, and the direction of current flow corresponds to the polarity of the activated sensor.

After sensor voltage reaches peak, head current is terminated by electronic switching and then the tape advances (Figure C1b).



a. Sensor — Vert 1V/Div Horiz 0.2 sec/Div

b. Head — Vert 20mV/Div Horiz 0.2 sec/Div

Figure C1. Sensor Signal and Record Signal

Termination of head current is necessary to prevent recording during tape advancement and partial erasure of recorded signal by reverse current flow through the head from magnet rebound. Tape advancement and electronic switching work off the sensor signal. The sequence of events, using as an example, a signal from the +Z surface sensor follows:

NOTE:

Specific functions of individual components are tabulated later.

1. Potential at point 12 rises with respect to ground. (Current through the recording head rises.)

2. Current from point 12 through D9, R14, base-emitter junction of Q6, D10, D11, and 1.5 volt battery of Advance Trigger (Figure D2c) to ground (point 17) increases until Q6 goes into saturation.

3. Collector of Q6 goes from +45 volts to near ground producing a negative pulse at the base of Q7. Both junctions of Q7 are then reverse biased, thus Q7 stays off.

4. Potential at point 12 reaches peak. (Current through recording head reaches peak.)

5. Potential at point 12 drops. (Current through recording head drops.)

6. Current through base-emitter junction of Q6 drops until Q6 comes out of saturation.

7. Collector of Q6 goes from near ground to +45 volts producing a positive pulse at the base of Q7.

8. Q7 momentarily goes into saturation producing a momentary near-ground potential at point 23.

9. The grounding of point 23 results in current through R5, D1, and R7 (Figure D2a) biasing the base of TR2.

10. TR2 goes on, biasing TR3. TR3, in turn, biases TR4.

11. TR4 goes on, effectively grounding point 11.

12. The grounding of point 11 (a voltage step from +45 volts to ground) is differentiated by C2 in the electronic switch (Figure D2b). The resulting negative pulse biases the base of Q1, turning it on.

13. Q1 turns Q2 on.

14. Bias on the base of Q1 is maintained by conduction through Q2, R3, R4, and C1, for a period of time determined by time constant (R4 + R5) C1.

15. Q2 allows Q3, Q4, and Q5 to be biased into saturation by the -7.5-volt battery.

16. Q5 acts like a closed switch, shorting point 21 to ground.

17. Current through the Z channel of the recording head is terminated (shunted by Q5). (See Figure 1b.)

18. Advance trigger goes off. (Point 23 goes back to +45 volts).

19. Capacitor C2 (Figure D2a) maintains bias on TR2, keeping TR3 and TR4 on long enough for C5 to discharge through the digimotor.

20. When the potential at point 10 drops sufficiently, Zener Diode D2 fires, biasing TR1 into conduction.

21. TR1 maintains +45 volts at its collector, preventing further triggering from the advance trigger until the potential at point 10 has risen again to nearly +45 volts.

22. Tape advances.

23. When C2 discharges sufficiently, TR2 turns off.

24. TR3, TR4 turn off.

25. C5 charges.

26. TR1 turns off.

27. After about two seconds, capac or C1 in electronic switch (Figure D2b) has charged sufficiently urrent through C1 decayed sufficiently) to cut off Q1.

28. When Q1 goes off, so does Q2.

29. Bias is removed from the base of Q5, shutting off Q5.

30. Short from point 21 to ground opens.

31. Recorder is ready for next pulse.

NOTE: Digimotor circuitry will recycle if point 23 is held at ground potential.

The timing channel records one pulse every hour. The sequence of events in the timing channel is as follows (refer to Figure D2a):

1. Once each hour, contacts of electric watch close, shorting point 13 to 14.

2. SCR is gated by current from +45 volt battery through resistor R1.

3. Capacitor C4 discharges through SCR and the parallel combination of R11 and time channel of the recording head.

4. Current through time channel puts timing mark on tape.

5. Rapid drop in potential at junction of SCR and C6 pulses the digimotor circuitry through C3 in the same manner as does the advance trigger.

6. Digimotor circuitry acts as above, advancing tape.

7. As C6 discharges, current through SCR drops to low level and SCR shuts off.

8. C6, C4 charge.

9. Contacts of watch open.

NOTE: Capacitor C6 was added after test shipment data showed extra time marks caused by contact bounce in the Accutron timer. Accutron contacts close for a period of 30 seconds. The original timer circuit reset time was only 8 seconds, thus permitting retriggering of time marks from contact bounce. Addition of C6 increased the reset time to approximately one minute thus eliminating the contact bounce effect.

APPENDIX D

Electrical Schematic

Drawings

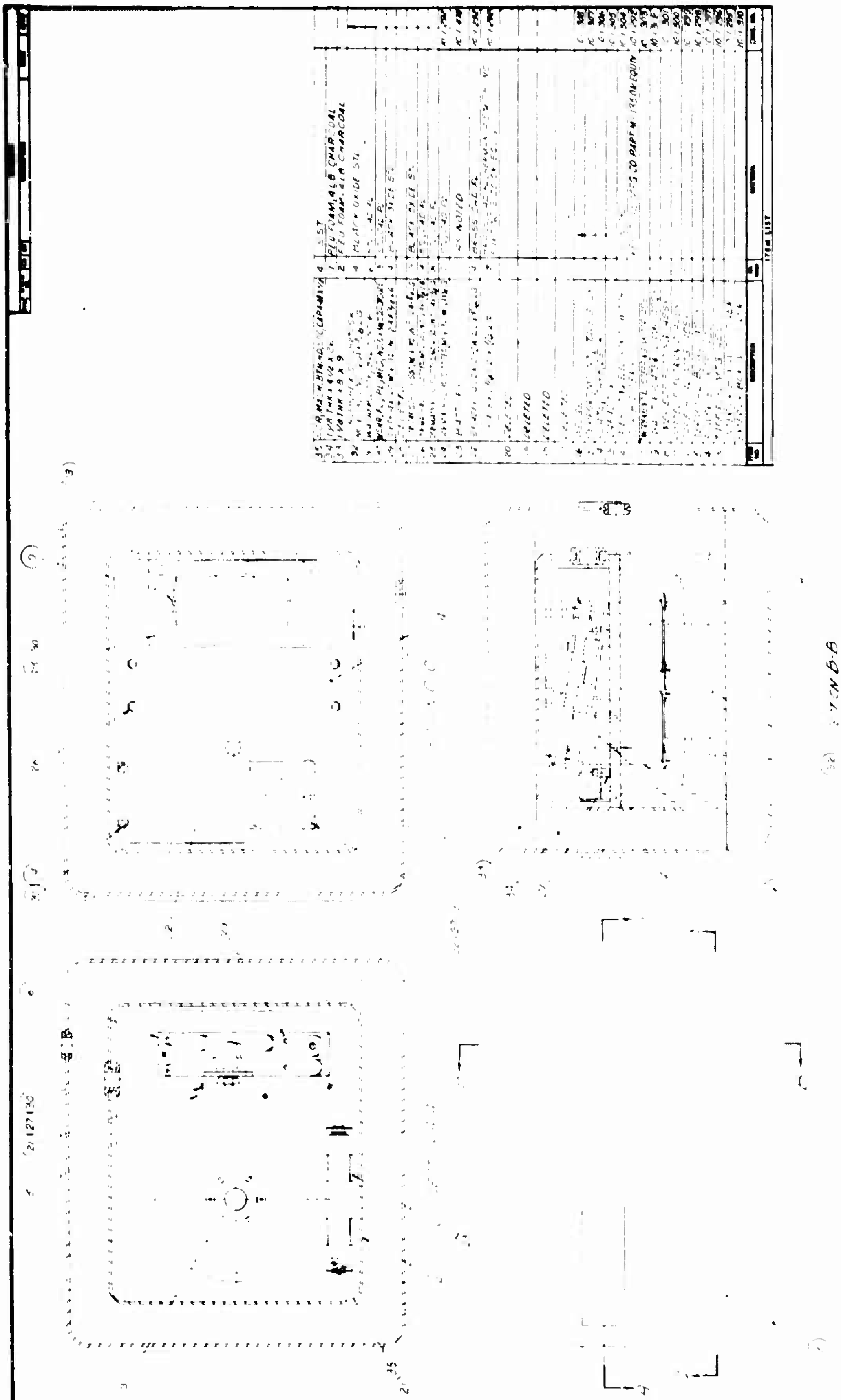


Figure D1. Tape Recorder Assembly.

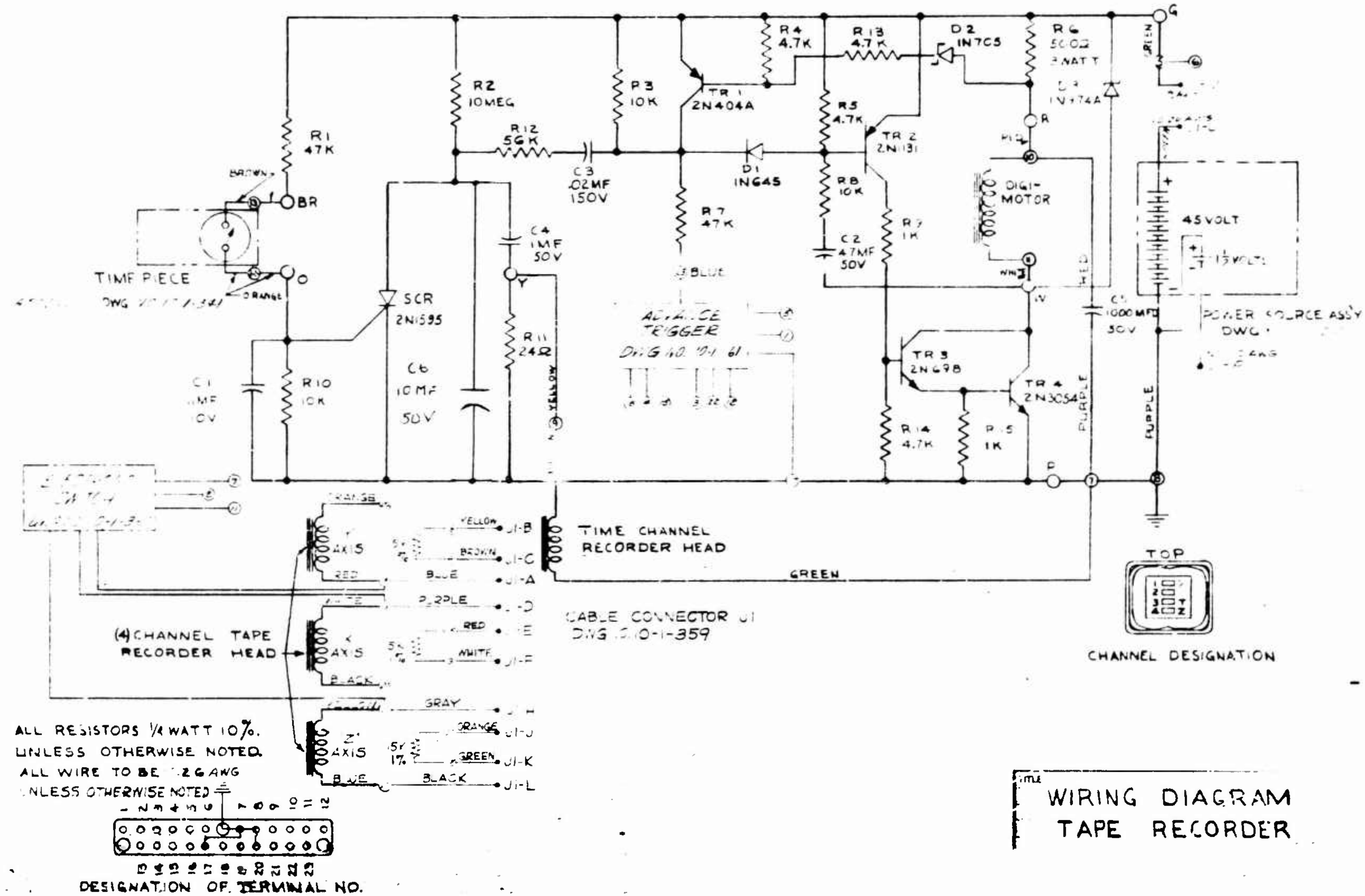


Figure D2a. Schematic--Motor and Timing Circuits.

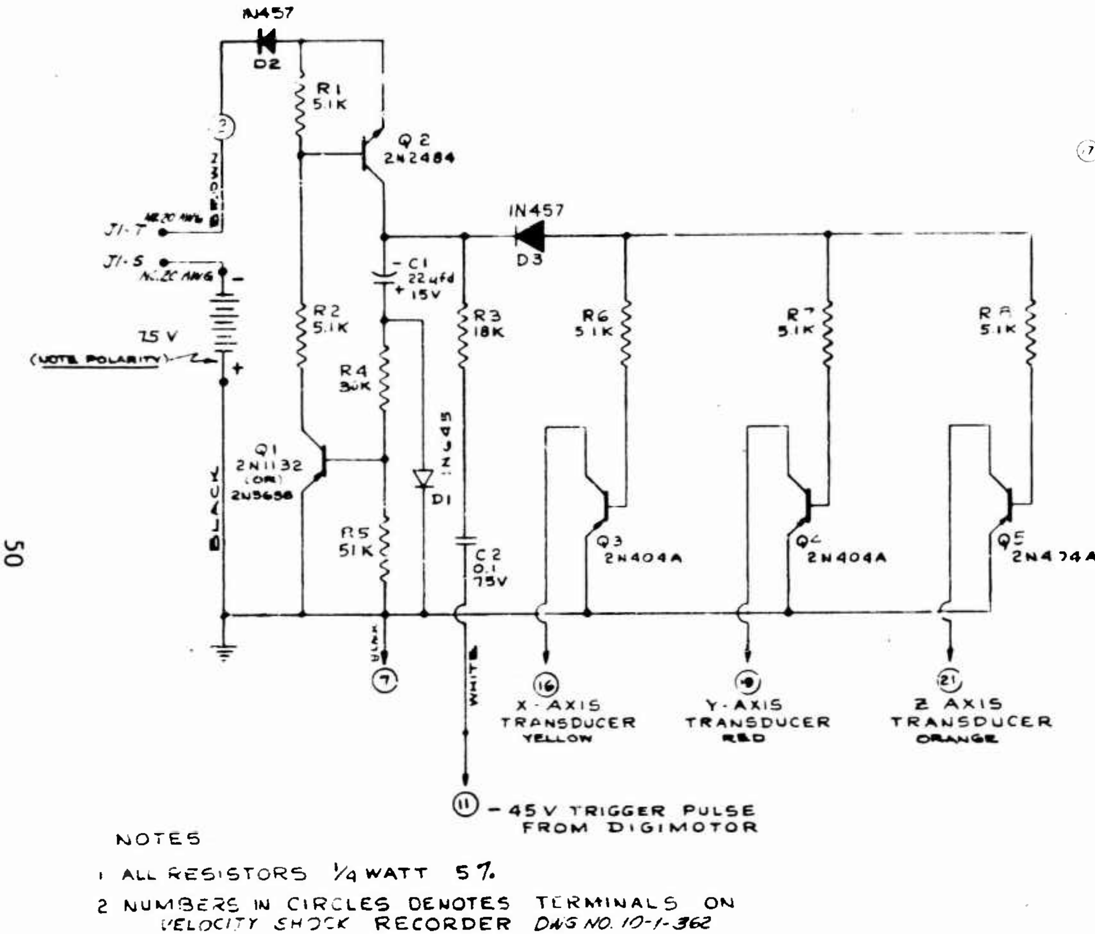


Figure D2b. Schematic--Electronic Switch.

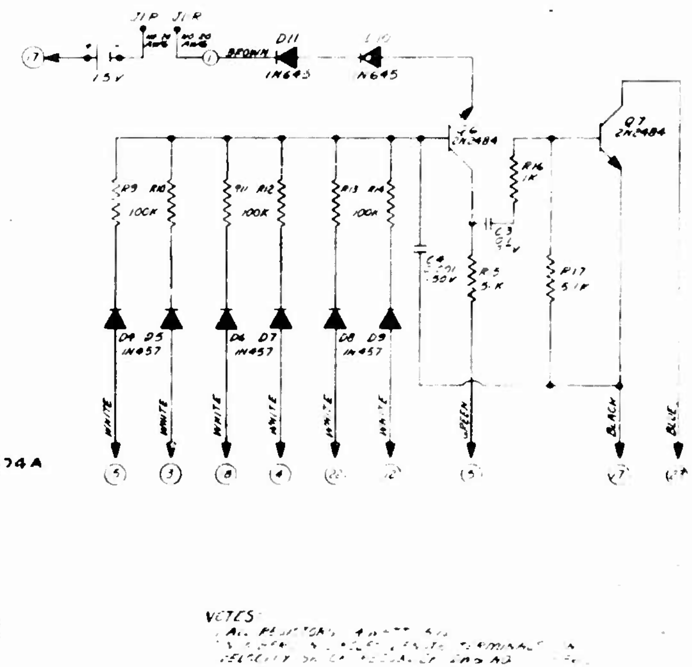


Figure D2c. Schematic--Advance Trigger.

PRINTED CIRCUIT BOARD ASSEMBLY

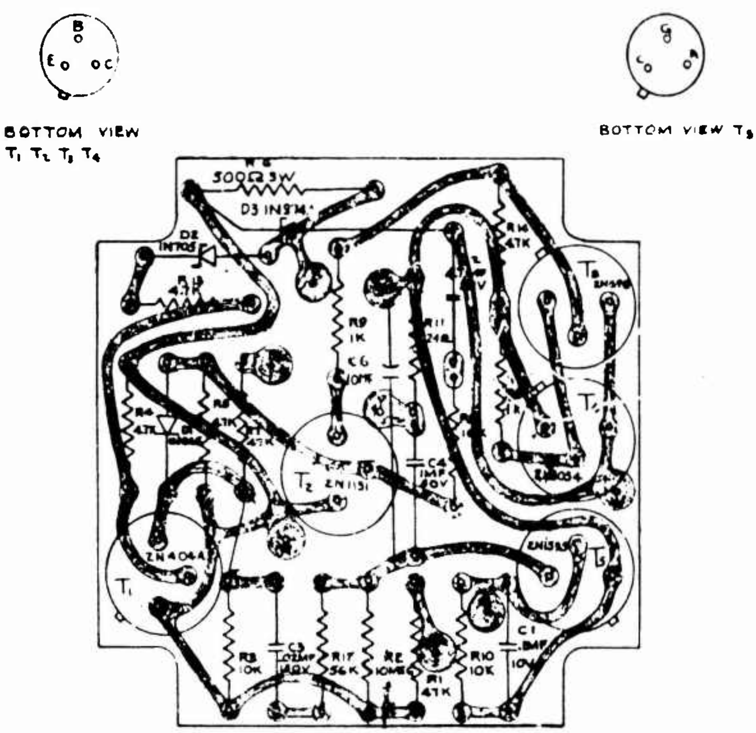
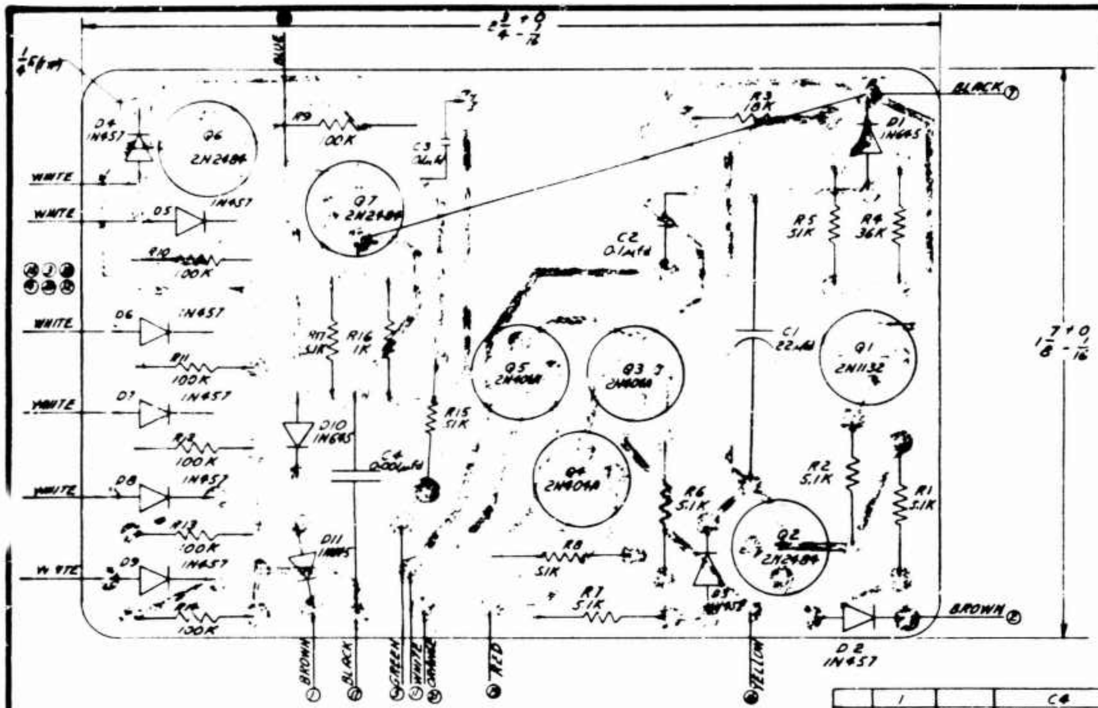


Figure D3a. Component Layout--Motor and Timing Circuits.



NOTES:

1. PRINTED CIRCUIT SIDE OF BOARD SHOWN
2. CONNECT POINT "P" TO POINT "P" ON PRINTED CIRCUIT SIDE OF BOARD WITH #26 INSULATED WIRE

FIGURE- 1

THIS FIGURE IS A MINIATURE COPY OF ARMY NATICK LABORATORIES DRAWING NUMBER 02-10-1-361 REVISION NUMBER ——, DATED 11 NOV 71. THIS COPY IS FOR INFORMATION ONLY; THE DRAWING REFERENCED IN PARAGRAPH 2.1 GOVERNS.

LIST OF MATERIALS

ITEM NO.	QTY REQD	CODE IDENT	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL SPECIFICATION	REMARKS
	1		C4	.001 UFD 150V CAPACITOR CERAMIC		
	8		D2,D3,D4,D5,D6,D7,D8,D9	IN457 DIODE		
	1			BOARD MATERIAL VECTOR 85624EP OR EQUIV		
	1		R16	1K RESISTOR 1/4 WATT 5%		
	1		R3	18K RESISTOR 1/4 WATT 5%		
	6		R9,R10,R11,R12,R13,R14	100K RESISTOR 1/4 WATT 5%		
	2		R5,R15	51K RESISTOR 1/4 WATT 5%		
	1		R4	36K RESISTOR 1/4 WATT 5%		
	6		R1,R2,R6,R7,R8,R17	5.1K RESISTOR 1/4 WATT 5%		
	2		C2,C3	.1 UFD 75V CAPACITOR CERAMIC		
	1		C1	22 UFD 15V CAPACITOR ELECTROLYTIC		
	3		D1,D10,D11	IN645 DIODE		
	1		Q1	2N1132 TRANSISTOR 7-541		
	3		Q2,Q6,Q7	2N2484 TRANSISTOR - C.D.C.		
	3		Q3,Q4,Q5	2N404A TRANSISTOR - G.E.		

DRAWN: R. P. WHITTY
CHECKED: C.L.N.

U. S. ARMY NATICK LABORATORIES
NATICK, MASS.

MECHANICAL LAY-OUT
ELECTRONIC SWITCH
AND ADVANCE TRIGGER

CODE 81337 | SIZE C | DWG NO. 02-10-1-361
SCALE NONE
DRAFTING WORK ORDER NO. D-1882
DATE 11 NOV 1971
SUPERSEDES DRAWING 01-10-1-361 DATED 5 DEC 1967

Figure D3b. Component Layout--Electronic Switch and Advance Trigger.

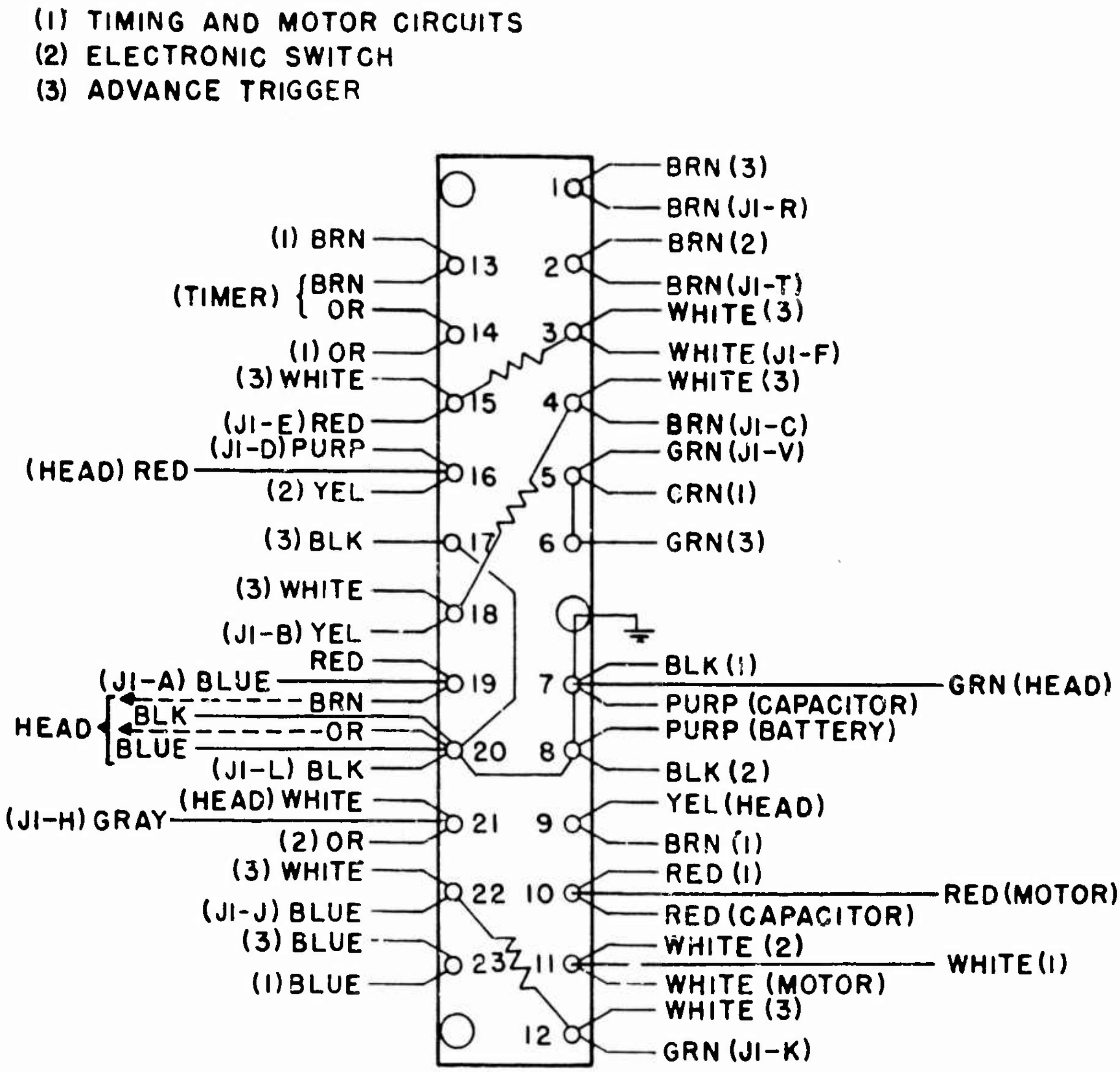
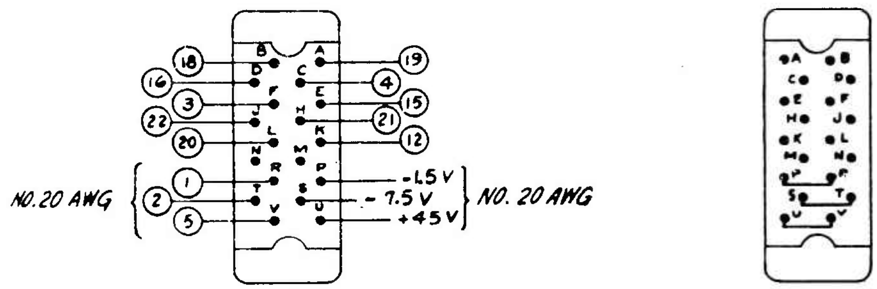


Figure D4. Terminal Board.

WIRE DIAGRAM FOR CABLE CONNECTOR



CABLE CONNECTOR J1
WINCHESTER PART NO. XMRE 18S-F-2506
REAR VIEW SHOWN

TERMINATION OF RECORDER CABLE

CABLE CONNECTOR J2
WINCHESTER PART NO. XMRE 18P-C-1306X
REAR VIEW SHOWN

MATE OF J1

NOTES:

1. NUMBERS IN CIRCLES DENOTE TERMINALS ARE DESIGNATED IN DWG 10-1-362
2. LENGTH OF LEAD FROM TERMINAL STRIP TO WINCHESTER PART NO. XMRE 18S-F-2506 SHOULD BE A MINIMUM OF 35 INCHES LONG.
3. ALL WIRE TO BE NO. 26 UNLESS OTHERWISE NOTED

Figure D5. Connector.

APPENDIX E

Component Function Tables

Table E I	Advance Trigger
Table E II	Electronic Switch
Table E III	Digimotor Circuitry
Table E IV	Timing Circuitry

APPENDIX E

Component Function Tables

Table EI
Advance Trigger (Figure D2c)

Designation	Description	Function
D4, D5,. . .D9	Diode	Prevents channel crosstalk
R9, R10,. . . R14	Resistor	Prevents loading by advance trigger
C4	Capacitor	Noise filter
D10, D11, 1.5v	Diodes, Battery	Fixes threshold voltage of circuit.
R15	Resistor	Limits current through Q6
Q6	Transistor	Produces high level rectangular pulse at its collector from low level sinusoidal sensor pulse at its base.
C3	Capacitor	Differentiates high level rectangular pulse
R16, R17	Resistors	Voltage divider
Q7	Transistor	Driven into saturation by differentiated trailing edge of high level rectangular pulse, effectively grounding point 23.

Functions of Individual Components

Table E II
Electronic Switch (Figure D2b)

Designation	Description	Function
D2	Diode	Blocks reverse polarity power
D3	Diode	Reduces "active" operation of Q3, Q4, Q5 before switch triggers
C2	Capacitor	Differentiates voltage step from point 11
R3	Resistor	Current limiter
C1	Capacitor	Establishes, along with R4 and R5, "on" time of electronic switch.
R4, R5	Resistors	Bias elements for Q1
R2, R1	Resistors	Bias elements for Q2
Q1	Transistor	Turns Q2 on and off
Q2	Transistor	Turns Q3, Q4, and Q5 on and off
R6, R7, R8	Resistors	Current limiters
Q3, Q4, Q5	Transistors	Blanking elements for the three drop height channels
D1	Diode	Provides quick discharge path for C1

Functions of Individual Components

Table E III
Digimotor Circuitry (Figure D2a)

Designation	Description	Function
TR1	Transistor	Prevents digimotor circuitry from triggering at low voltage across C5
R4, R13	Resistors	Bias elements for TR1
D2	Zener Diode (4.8 v)	Establishes trip point of TR1
D1	Diode	Prevents TR1 from removing bias TR2
R5, R7	Resistors	Bias elements for TR2
R8, C2	Resistor, Capacitor	Maintain bias on base of TR2
R6	Resistor	Current limiter
TR3, TR4	Transistors	Provide discharge path for C5
R14, R15, R9	Resistors	Bias elements for TR3, TR4
C5	Capacitor	Current source for digimotor
D3	Zener Diode (36 v)	Regulates voltage across digimotor
TR2	Transistor	Turns TR3, TR4 on and off
Digimotor	Rotary Stepping Motor	Indexes tape

Functions of Individual Components

Table E IV
Timing Circuitry (Figure D2a)

Designation	Description	Function
R1, R10	Resistors	Establish gate current and gate voltage for SCR
Timepiece	Electric Watch	Pulses gate once each hour
C1	Capacitor	Helps prevent noise triggering of SCR
SCR	Silicon Controlled Rectifier	Provides path of discharge for C4 and triggers digi-motor circuitry
C4	Capacitor	Current source for time channel
R11	Resistor	Reduces discharge time of C4
R2	Resistor	Charge path for C4
R12, R3	Resistors	Voltage divider
C3	Capacitor	Differentiates voltage step at SCR, pulsing digimotor circuitry. Also d.c. isolates timing circuitry from advance trigger.
C6	Capacitor	Increases timing reset to prevent extraneous advances.

APPENDIX F

REFERENCE LIST

DROP HEIGHT RECORDER DRAWINGS

NLABS DRAWING NUMBER	TITLE
D-01-10-1-291	VSR Assembly Complete
D-02-10-1-292	Tape Recorder Assembly
D-01-10-1-295	Interior Box and Cover
D-01-10-1-296	Tape Reel Mounting Assembly
B-01-10-1-298	Terminal Board Assembly
C-01-10-1-299	Tape Head Mounting Assembly
C-00-10-1-300	Potted Electronic Assembly
B-00-10-1-301	Time Piece Potting Assembly
B-00-10-1-302	Capacitor Plate and Clamp Assembly
C-00-10-1-303	Incremental Stepping Motor Assembly
B-01-10-1-304	Case Potting, Electric Switch and Advance Trigger
B-01-10-1-305	Capacitor
D- -10-1-306	Plate, Deck Tape
B-01-10-1-307	Mount Support Tape Guide
B-01-10-1-308	Wedge
D-01-10-1-310	Exterior Box and Cover
B-00-10-1-311	Center Post
B-00-10-1-312	Thrust Ball Bearing Assembly
B-01-10-1-313	Spur Gear

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DROP HEIGHT RECORDER DRAWINGS - Continued

NLABS DRAWING NUMBER	TITLE
B-00-10-1-314	Tape Reel
B-01-10-1-315	Upper Reel Retainer
B-00-10-1-316	Lower Reel Retainer Assembly
B-00-10-1-317	Upper Reel Hub Assembly
B-01-10-1-318	Spiral Spring
B-00-10-1-319	Spring Retainer Disc
B-01-10-1-320	Lower Reel Retainer
B-00-10-1-321	Bronze Bearing
B-01-10-1-322	Upper Reel Hub
B-00-10-1-323	Truarc Ring
B-00-10-1-327	Tape Head, Unshielded Leads
B-01-10-1-327	Tape Head, Shielded Leads
B-00-10-1-328	Head Mounting Bracket
B-00-10-1-329	Fixed Tape Guide
B-00-10-1-330	Tape Roller
B-00-10-1-331	Tape Roller Post
B-00-10-1-332	Truarc Ring
B-01-10-1-333	Potting Case
C-00-10-1-334	Printed Circuit Board Assembly
B-00-10-1-335	Potting Compound
C-00-10-1-336	Printed Circuit Board
B-00-10-1-338	Time Piece

DROP HEIGHT RECORDER DRAWINGS - Continued

NLABS DRAWING NUMBER	TITLE
B-00-10-1-342	Capacitor Mounting Plate
B-00-10-1-343	Capacitor Clamp
B-00-10-1-344	Motor
B-00-10-1-345	Pinion Shaft
B-01-10-1-359	Cable Connector
C-01-10-1-360	Schematic, Electronic Switch
C-01-10-1-361	Mechanical Layout, Electronic Switch and Advance Trigger
C-01-10-1-362	Wiring Diagram, Tape Recorder
D-00-10-1-477	Advance Trigger
C-00-10-1-478	Battery