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On..... CARDIOVASCULAR EFFECTS OF VIBRATION

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TABLE OF CONTENTS

		<u>Page</u>
SECTION I	Studies Made So Far to Determine the Underlying Mechanism of Some Cardiovascular Changes Brought About by Vibration	1
SECTION II		
Part I	Magnetic Tape Recording and Playback Technique for: At Will, Coincident Monitoring, and Computer Averaging of ECG and Other Similar Repetitive But Not Necessarily Periodic Phenomena	3
Part II	Body Vibration and the Electrocardiograph	8

SECTION I

STUDIES MADE SO FAR TO DETERMINE THE UNDERLYING MECHANISM OF SOME CARDIOVASCULAR CHANGES BROUGHT ABOUT BY VIBRATION

During previous investigations described in the accompanying paper,¹ an increase in heart rate was found to be an almost constant feature of immediate cardiovascular response to the vibration profiles used. This increase was seen even when a change in blood pressure would be expected to bring about a reflex bradycardia. The question arose whether the vibration interfered with normal cardiovascular reflex mechanisms either by its direct effect on the baroreceptors, the cardiac centers, or on the heart itself.

A series of experiments was planned to investigate these possibilities and this report covers the work done so far.

This series includes experiments on dogs anesthetized with morphine, chloralose, and urethan in which left ventricular pressure and dp/dt max. of left ventricular pressure were obtained during vibration at 7 cps and 1/2-inch total displacement (horizontally) and further experiments in which, in addition, cardiac outputs were measured (using the dye dilution technique) together with mean arterial blood pressure measurements from the thoracic aorta.

During all experiments so far, atropine and/or propranolol were used to block either the parasympathetic and/or sympathetic pathways, respectively, to the heart.

RESULTS

Results of these experiments so far show that the marked transient tachycardia brought about by vibration is accompanied by a drop in peripheral vascular resistance and an increase in cardiac output. Arterial blood pressure rises if the cardiac output more than compensates for the fall in peripheral vascular resistance. More often, however, the blood pressure shows a transient drop.

The above changes appear not to be caused by sympathetic efferent activity because the transient changes described above are virtually unaltered after the administration of propranolol.²

However, atropine abolishes the tachycardia, brought about by vibration both when given alone or after propranolol. As a consequence of this unchanging heart rate, a fall in arterial blood pressure is seen as a transient response within 30 seconds of the onset of vibration. That the heart rate remains fixed during vibration when atropine is given alone provides further evidence that sympathetic activity to the heart is not stimulated by vibration.

Results seem to indicate that changes in dp/dt max. of the left ventricle tend to follow the changes in heart rate, but very careful measurements are now being attempted to monitor changes in both left ventricular end-diastolic pressure and dp/dt max., together with mean peripheral arterial pressure.

COMMENT

Interest regarding the origin of the tachycardia is heightened by the findings reported by Glick and Braunwald³ that a tachycardia induced by a lowered blood pressure was mediated via the sympathetic nervous supply to the heart. In their experiments this response to hypotension was blocked by pronetholol (nethalide), which is said to be a beta-adrenergic blocking agent. Using propranolol as a blocking agent and vibration as a hypotensive agent, we are unable to confirm the findings of these authors.

Possible answers to the dilemma produced by the work of Glick and Braunwald are (a) that the tachycardia of vibration is entirely mediated via the vagus or (b) that pronetholol, although a beta blocking agent, also has a vagolytic effect. (This action of pronetholol has been suggested by some experimenters). We hope that further experiments will answer these questions.

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2. Hamlin, R. L., Smith, R., and Smetzer, D. L., "Sinus Arrhythmia in the Dog," Am. J. Physiol., February 1906, Vol. 210, pp 321-328.
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SECTION II - PART I

MAGNETIC TAPE RECORDING AND PLAYBACK TECHNIQUE FOR: AT WILL, COINCIDENT MONITORING, AND COMPUTER AVERAGING OF ECG AND OTHER SIMILAR REPETITIVE BUT NOT NECESSARILY PERIODIC PHENOMENA

The method described is an extension of the on-line method of signal averaging (random noise cancellation) described by Hon.¹

Refer to Fig. 1 which represents the tape and head of a four-channel instrument tape recorder with separate record and play heads. The signal to be studied (assume for the present one signal only) is recorded on channel one of the tape which moves from left to right in the figure. The recorded signal, on reaching the play head, is reproduced and transmitted through the jumper wire connecting channel 1 play to channel 3 of the record head and there recorded. Thus, two identical signals are recorded on the tape spaced at a distance equal to the head spacing and therefore displaced in time, the time necessary for the tape to move the head spacing distance for the tape speed being used. Multiple signals can be recorded as is illustrated in the third strip of figure .

If the magnetic tape with signals recorded as above described is reversed end for end, as illustrated in Fig. 2, and played back, channel 1 of the tape will now play back on channel 4 play of the recorder, tape channel 3 will play back on channel 2 play. Note that the signal will play backward, i.e., in an ECG the T wave will appear before the R wave.

Any distinctive positive or negative portion of a signal can be used as a trigger for starting an electrical event such as the starting of an oscilloscope sweep as illustrated in the figure. If the leading signal from recorder channel 2 play is connected to the external trigger of an oscilloscope and the oscilloscope adjusted to trigger on a fixed point of the R wave, the oscilloscope sweep is started when the vertical signal amplitude reaches this point. If the lagging signal (the originally recorded signal) which will appear at recorder channel 4, is connected to the vertical input it will appear on the scope screen provided the oscilloscope sweep speed is greater than time t_1 , the time for a point on the tape to move from the record head to the play head at the tape speed being used. By adjusting the sweep speed, the position adjustment, and the vertical amplitude the complete signal, or any selected portion of it, can be displayed for study on the oscillograph screen. Register of sequential complexes is assured regardless of pulse intervals. The advantage of this method of display is that it permits pre-trigger information to be studied and allows noise cancellation and detailed interrelated physiological signals to be studied at will.

Averaging computers, such as the Mnemontron 400A CAT, which was used in this study, requires a signal and trigger as just described. Figure 3 shows the equipment and schematic wiring used for noise averaging of recorded ECG signals recorded before and during vibration of the subject.

The trigger signal from recorder channel 2 is fed to the external trigger circuit of the oscilloscope, the original signal is connected from channel 4 of the recorder to the scope vertical amplifiers, thus the scope can be used for monitoring as previously described. The scope (Tektronix 503) has been modified to obtain a square wave output each time the scope sweeps. (Other model scopes have such a signal available without modification.) This square wave trigger ST is fed to a time delay circuit (the internal delay of the CAT can be used) and thence to the CAT external trigger. The signals to be averaged are fed directly sweep by sweep, through suitable amplifiers or attenuators to the CAT.

Analog information is read out after passing through amplifier to (AD) a suitable paper recorder. Digital readout DO is used for time study analysis (pulse velocities; see Part III).

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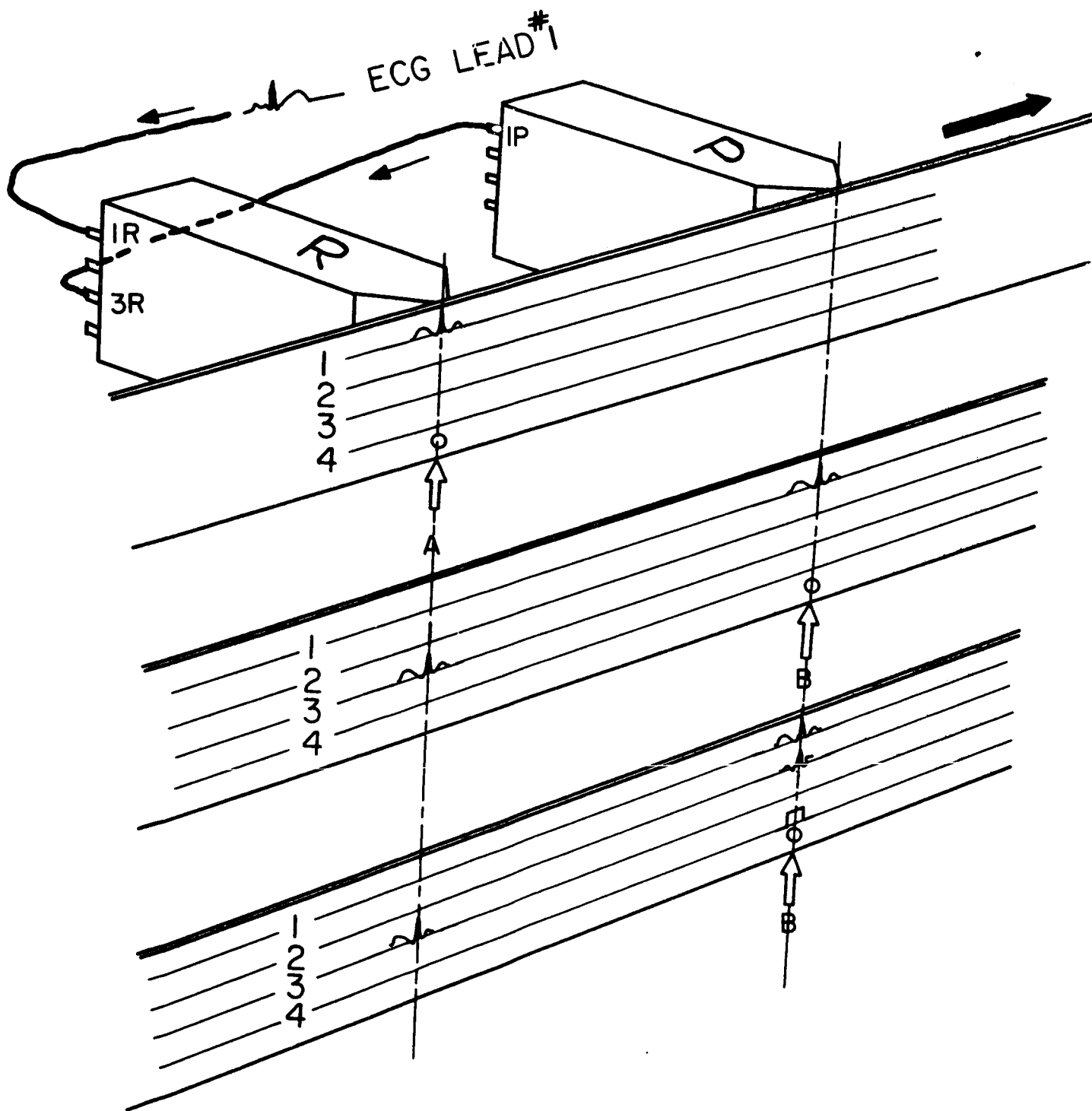


Figure 1

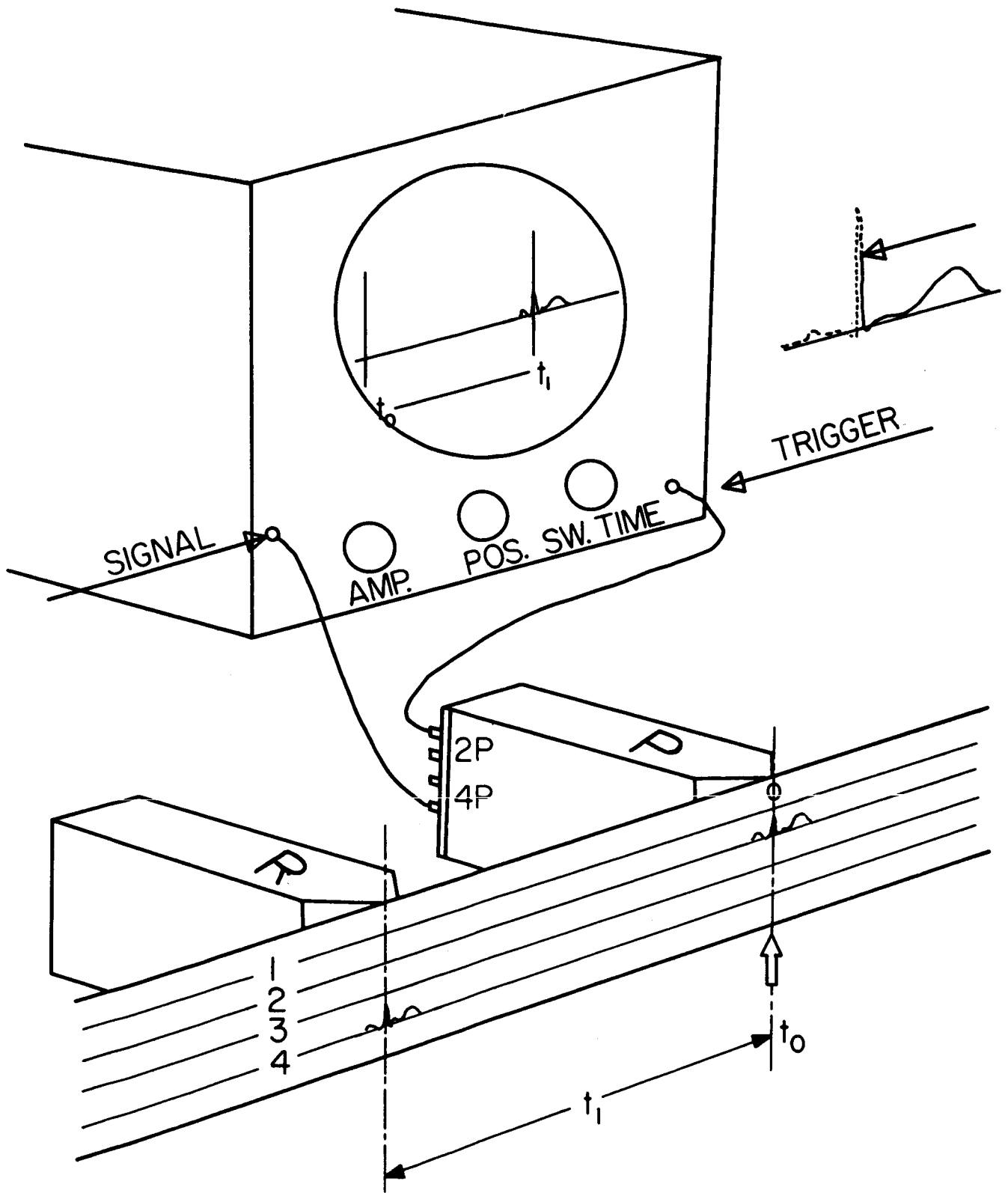


Figure 2

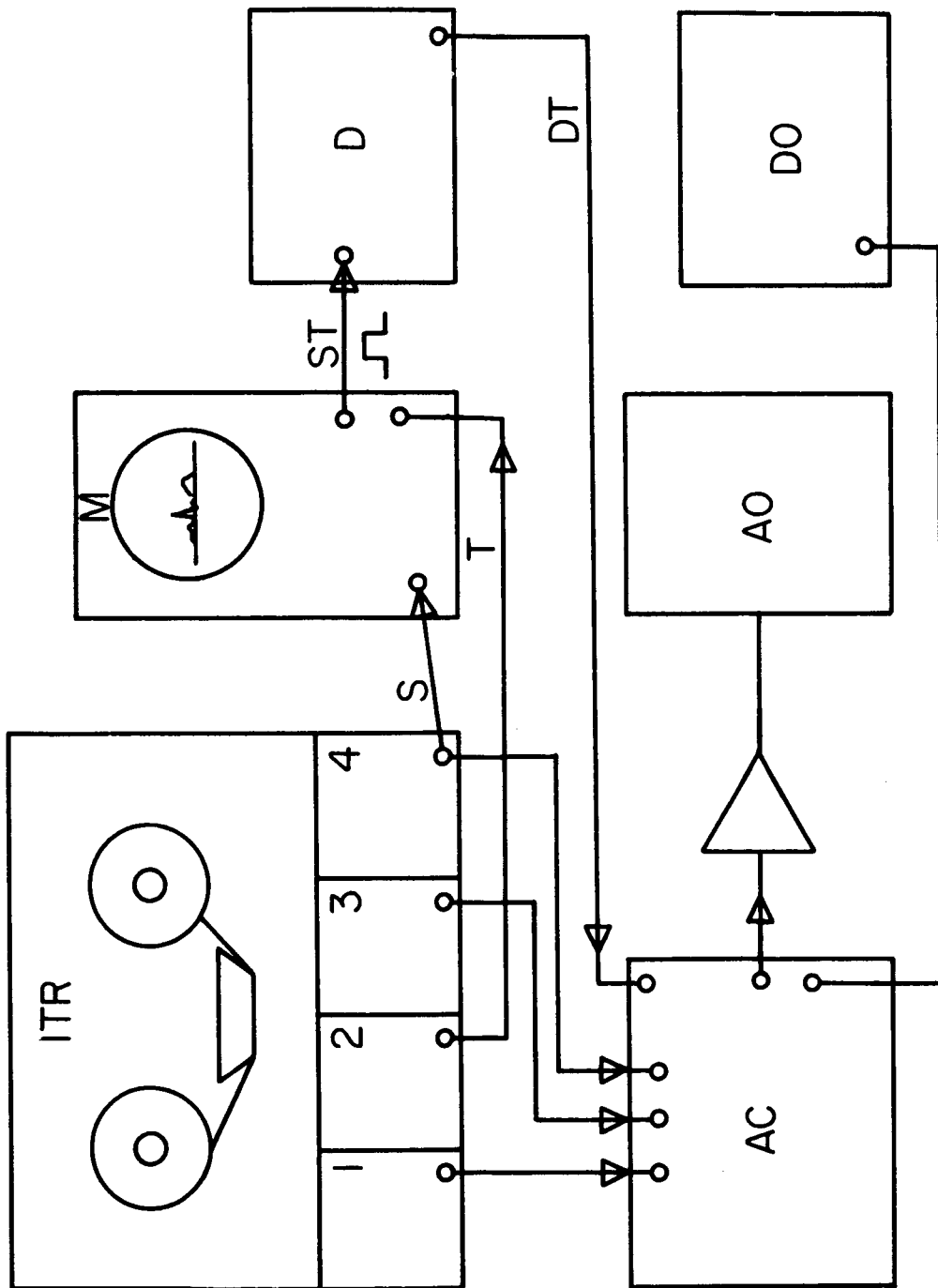


Figure 3

SECTION II - PART II

BODY VIBRATION AND THE ELECTROCARDIOGRAPH

PROBLEM

The fundamental problem is to obtain, if possible, clinically useful ECG traces from subjects exposed to vibration intensities within the range they can tolerate.

PROTOCOL

The research protocol on which we are now working includes: (1) a study of the origin and nature of the noise associated with vibration, (2) a study of ways to remove the noise in an attempt to recover the underlying ECG trace, (3) a study of the traces for evidence of heart movement or electrical center shifts, and (4) clinical interpretation and evaluation of any real ECG changes elicited by vibration.

EXPERIMENTAL PROCEDURE

Multiple ECG traces are recorded on magnetic tape from animals and man during nonvibration and various vibration conditions and during gross body movement.

The tracings are examined for noise, random distortion, cyclic distortion, clinical readability, and evidence of associated resonance.

Employing the special recording and playback technique (described in Part I) and utilizing computer averaging, attempts are made to remove the random noise associated with the recording. The results are compared with the original traces to evaluate the efficiency of noise removal, estimate limitations of the method, and suggest development necessary to improve the technique.

TENTATIVE OBSERVATIONS AND CONCLUSIONS

1. Generally, acceptable ECG tracings can be obtained during moderate vibration by the technique described, providing that an unambiguous trigger can be obtained from at least one lead; that the signal noise is sufficiently random; and that the recording time is long enough. The limiting factor is generally vibration intensity, i.e., the R wave for some lead will stand out above the general noise for moderate vibration intensities or a lead can be found (not necessarily one of clinical interest) which will give a satisfactory trigger wave even under rather severe vibration.

2. Electrode weight, placement, and anchoring is of obvious importance.

3. Variations attributable to body build vary in importance with vibration intensity and depend on the lead under study.

4. Wandering ECG base line may be a problem under vibration conditions particularly when accompanied by gross body movements. Moderate exaggerated ac coupling for the trigger signal helps control this variable.

5. When the subject's pulse is quite regular and the vibration is regular at a fixed frequency and the two frequencies are harmonically related, the vibration signal in the ECG will persist even after many averaging sweeps, and is displayed as an ECG riding on the vibration wave form.

6. Additional research is required.

COMPUTER ANALYSIS

We have subjected certain of our animal's data to digital computer analysis. This analysis was made in order to develop techniques and programs for future data handling. Leads I, AVF, and V_3 were recorded on magnetic tape from an anesthetized dog. Recordings were made using the technique described for computer averaging analysis. Standardization signals for each lead were recorded as reference. Recordings were taken before vibration and during vibration at four and fifteen cycles per second. Using reverse-tape playback, tape recorder delay circuit, and computer of average transients, and average of five sweeps was obtained for each lead at each condition. The average data were recovered as a digital print-out of 400 points for a one-quarter second portion of ECG shown. Thus, each point represented one sixteen-hundredth of a second. Cards (IBM) were punched with this data together with a correction factor for amplitude.

The program used for computation is a modification of a program developed by Dr. Robert Hamlin and the computer-system programming staff for computing vector velocity, vector angles, and vector magnitude. The data was recovered from the IBM computer in plotted and digital readout form.

Vector cardiograms assuming leads I, AVF, and V_3 to be mutually orthogonal were calculated and plotted with time markings. Later a method of three-point averaging to smooth angle data was programmed.

The potential value of the combined computer approach to ECG analysis of this type is apparent and will, we believe, serve as an important tool in future research. We plan to employ this technique extensively.

