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LABORATORY FACILITIES EMPLOYED IN PSYCHOPHYSICAL MEMORY EXPERIMENTS

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ABSTRACT

Equipment and operating procedures used in psychophysical memory experiments at Electronic Defense Group are described and illustrated. This equipment gives precise control of signal parameters and enables one to efficiently collect the large quantities of data required for specification of the parameters of the human hearing mechanism.

LABORATORY FACILITIES EMPLOYED IN PSYCHOPHYSICAL MEMORY EXPERIMENTS

1. INTRODUCTION

To utilize all of the information available in a signal, an observer must have a perfect memory. That is to say, the ideal observer must be able to store exactly information about the starting time, frequency, phase, duration, and amplitude of the input waveform. This information is used by the ideal observer during the observation interval to determine if the signal occurred. Any imperfection in the way in which this information about the signal is stored will lead to a decrement in the performance of the observer.

In order to study the memory-for-signals of the human observer, we have devised procedures that permit us to introduce into the experimental procedure substitutes for some aspects of memory. For example, as a substitute for memory of frequency and phase, we can introduce into the noise background a sine wave of constant amplitude at the same frequency and phase as the signal. In this situation, the signal actually appears as an increment in the sine wave. This increment starts at some time, t_o, and lasts for T seconds. The observer is asked to state whether the increment did, in fact, occur at the specified time. In another experimental situation, a pulsed carrier can be introduced. The signal, an increment of amplitude, is superimposed on the pulsed carrier. Since the pulsed carrier is of the same frequency, phase, starting time, and duration as the signal, only memory for amplitude is required of the observer. Experiments such as these require that signal parameters be controlled precisely.

In addition to precise control of starting time, frequency, phase, duration, and amplitude of the input waveform, it is necessary to control several other aspects of the experiments. Since detection theory is based on statistical probabilities, it is necessary to obtain large numbers of observations from each observer, and it is necessary that the sequence of inputs be random. In experiments of a forced-choice type, it is necessary also to control precisely the intervals between observation periods. This time interval between observation intervals is especially relevant in experiments dealing with memory.

This report describes the equipment used to generate, control, and program the presentation of signals.

2. LABORATORY FACILITIES

2.1 General Description

The equipment used to generate, control, and program input waveforms for the psychophysical experiments on memory is pictured in Fig. 1. As can be seen from this photograph, all of the equipment is mounted in three-inch I beams rather than in conventional relay racks. The heavy duty mountings are used to minimize fluctuations in the performance of the equipment attributable to shock and vibration. Of the equipment shown in Fig. 1, the middle column is comprised of the instruments used to generate noise and input waveforms and those used to measure and control both signals and noise. The equipment mounted in the column on the right is that used to program the experiments. That mounted in the upper left is a second programmer, which will be described later in this report.

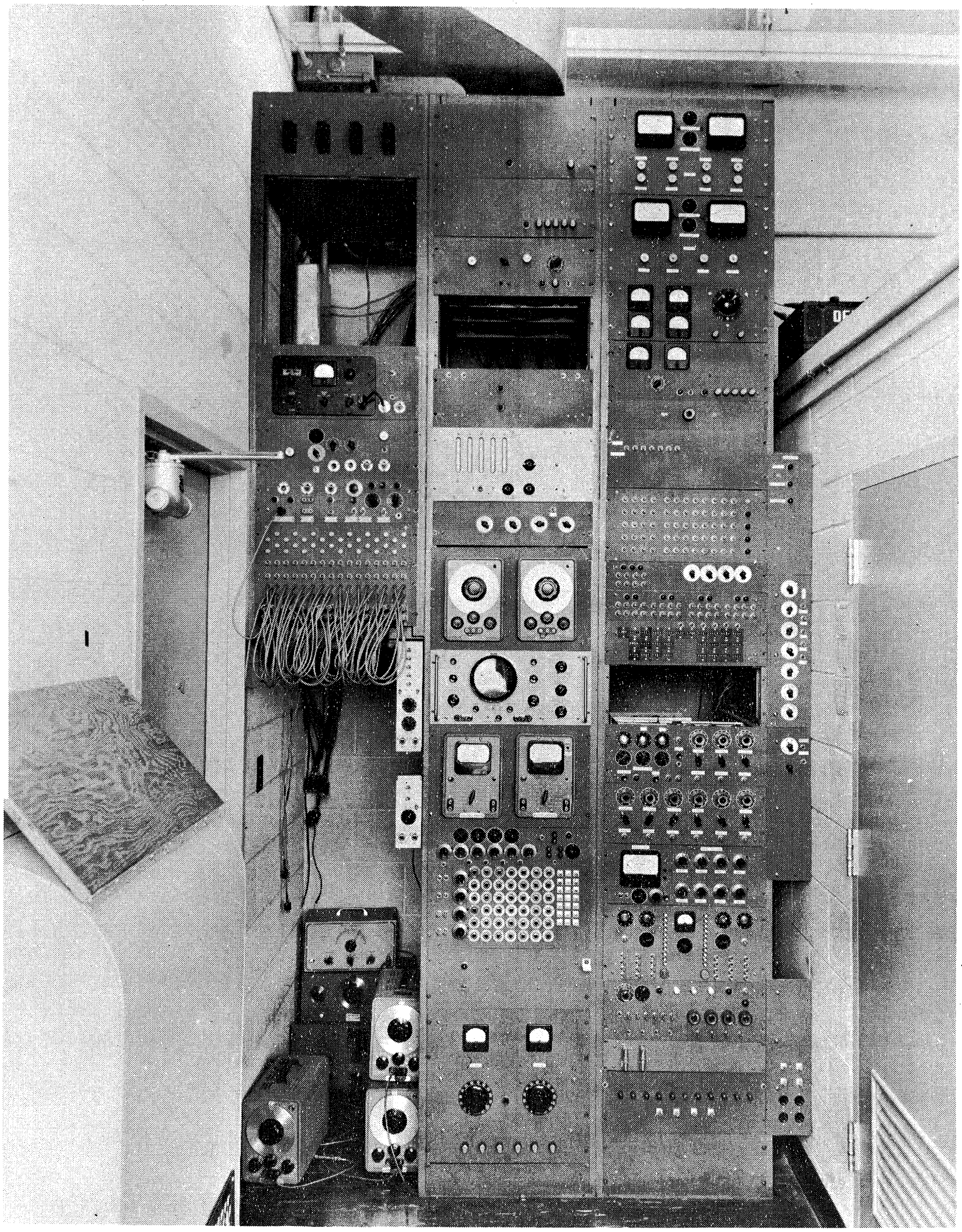

FIG. 1. OVERALL VIEW OF N.P. PSYTAR

In describing this equipment and its purpose, the center column, that equipment used to generate and measure signals and noise, will be described first. Next, the nature and operation of PSYTAR (PSYchological Testing And Recording), the programming equipment, will be described. Finally, ROMPAR (Random Orthogonal Message Presenter and Recorder) will be described.

2.2 Noise and Signal Inputs

The noise used in these experiments is generated by a commercially available noise generator. Noise voltages are measured with a true-rms vacuum-tube voltmeter. In addition, a set of four filters with equivalent rectangular bandwidths of 105 cps and center frequencies of 500, 1000, 2,000 and 4,000 cps is available to measure the noise spectrum.

Two commercial audio-oscillators are used as sources of sine wave signals in experiments involving two different frequencies. For experiments that require sine wave inputs of exactly the same frequency, however, the voltage output of one oscillator is divided and the two voltages are amplified independently. The sine wave voltages are measured with the true-rms vacuum-tube voltmeter. The frequency of the sine wave inputs is measured to the nearest 0.1 cps by means of an electronic counter capable of counting 10^6 events per second. The counter and an oscilloscope are used to monitor the signal voltages throughout every experimental session.

An electronic gate, which allows precise control of the starting phase of the input signals, is used to turn on the sine wave voltages. After appropriate amplification and attenuation the noise and the sine wave signals are added together electrically and fed into four parallel-wired headsets. These headsets are PDR-8 earphones, wired in series to have a

600-ohm impedance. The impedance of the four headsets in parallel is therefore 150 ohms. This 150-ohm load impedance is driven by an amplifier having an output impedance of 1/2-ohm. The damping which results from this intentional mismatch of impedances greatly improves the frequency-response characteristics and transient response of the earphones.

The photographs in Figs. 2, 3, and 4 show the input waveform to the phones and the acoustic output of the phones. This acoustic output was obtained by placing one earphone on a standard 6 cc coupler and photographing the electrical output of the Western Electric, 640 AA, condensor microphone used in the coupler as that output was reflected on an oscilloscope. Figure 2 shows the input-output relation for four different frequencies. Distortions that appear at 2600 and 4800 cps are associated with resonant peaks in the response of the phone. Figure 3 shows how well the earphones in this mismatch follow the relatively complicated flipped-phase operation and cosine waveform. Figure 4 shows the response to damped sinusoidal waveforms.

2.3 PSYTAR

The random selection of input waveforms, the rate at which signals are presented, and the observers' responses are programmed by PSYTAR (right-hand column in Fig. 1). PSYTAR provides a nine-interval program for use in conducting psychophysical experiments. The nine intervals are used as follows: (1) random selection of input; (2) warning signal to observer; (3), (4), (5), and (6) available observation intervals; (7) answer interval; (8) correct-answer feedback and IBM recording of input and of observers' responses; and (9) erase and recycle.

Interval 1. During the first interval of the program the

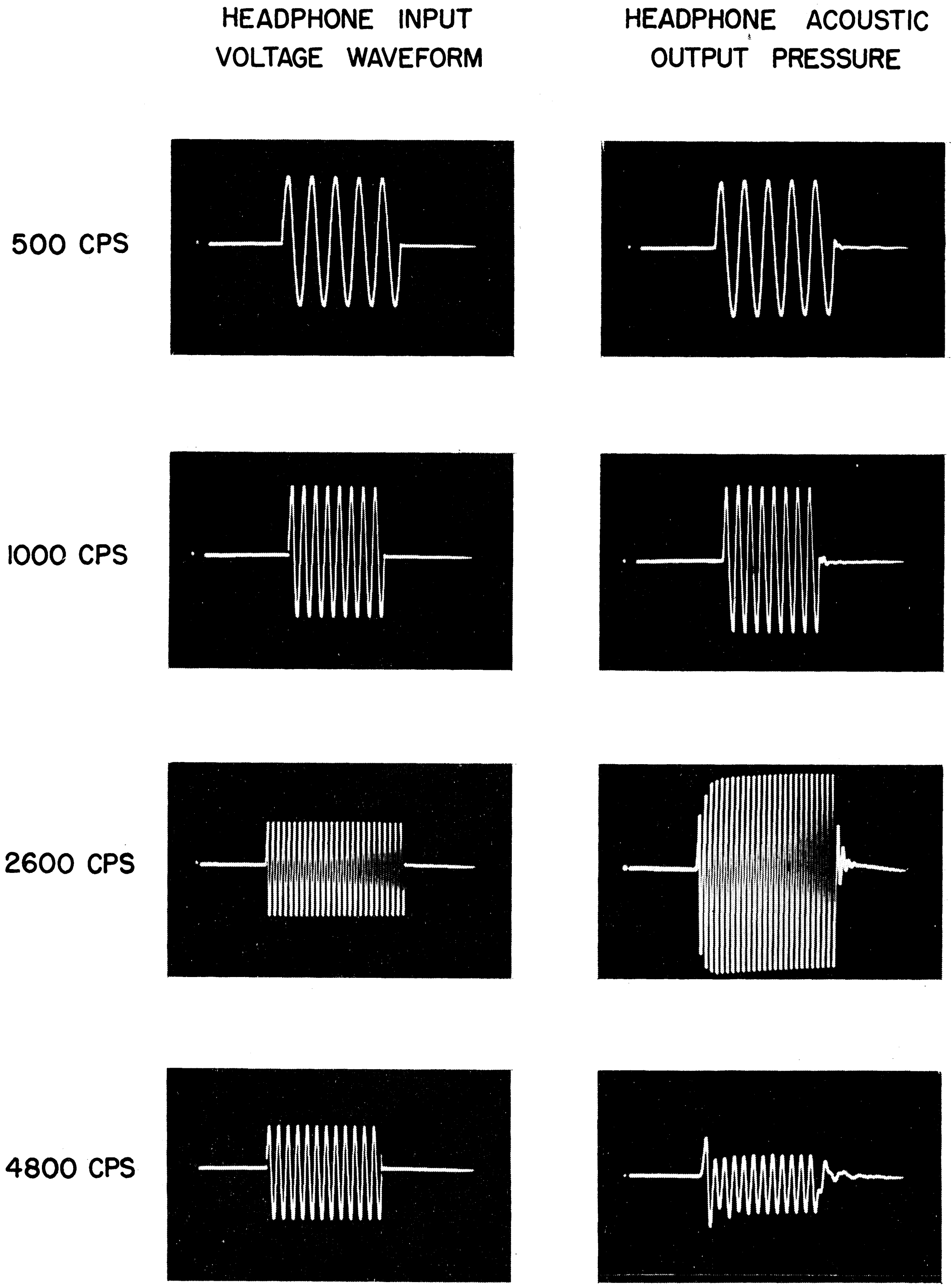

FIG. 2. WAVEFORM FROM N.P. PSYTAR AUDITION SIGNAL PRESENTATION EQUIPMENT

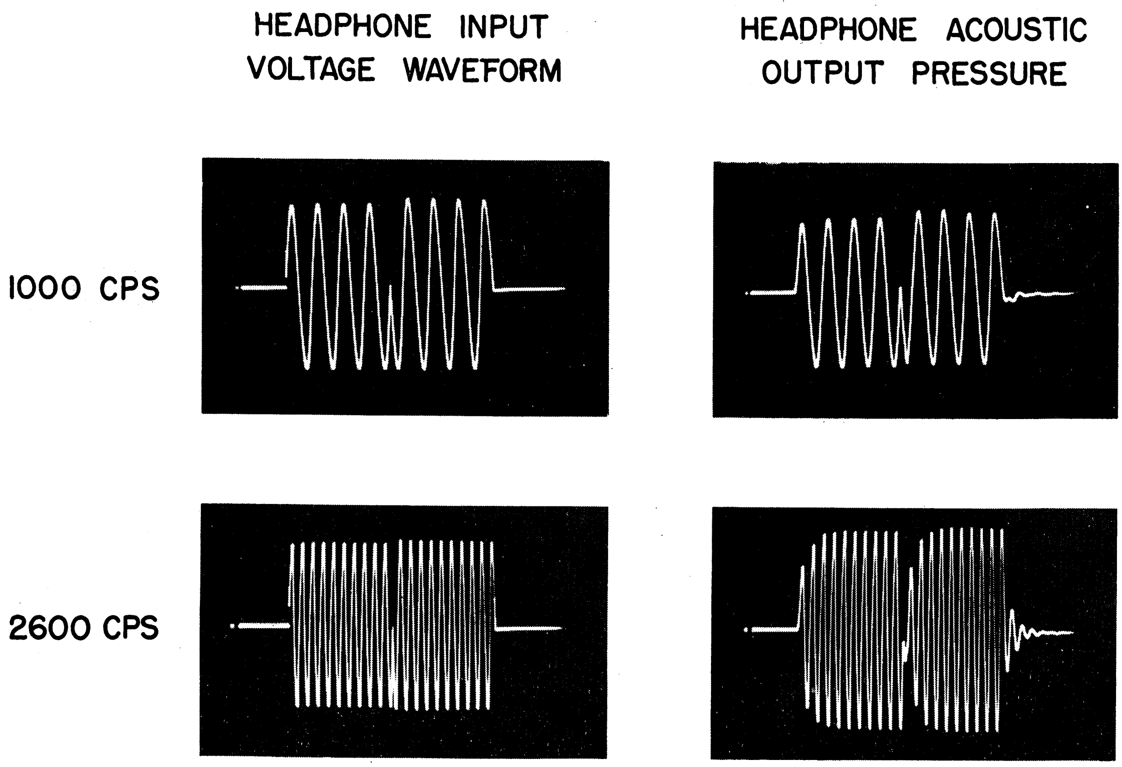

FIG. 3(a). FLIPPED PHASE OPERATION

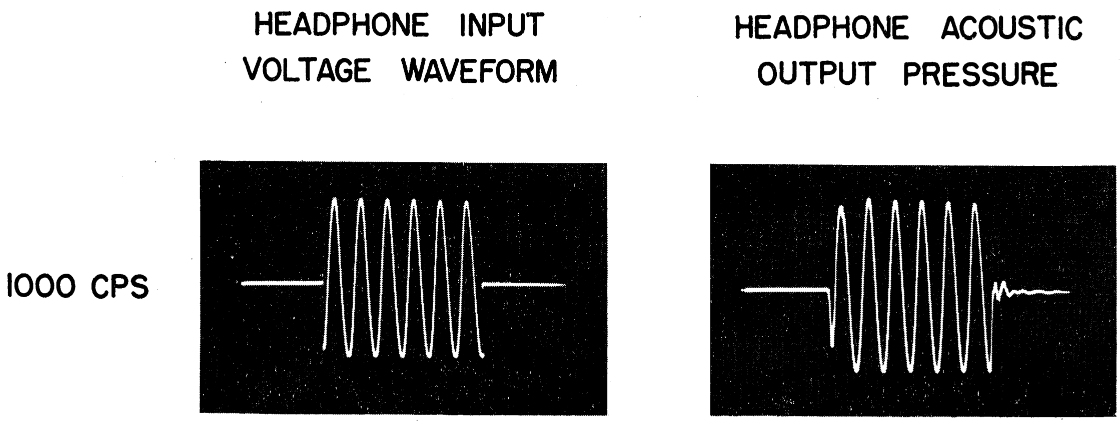

FIG. 3(b). COSINE WAVEFORM

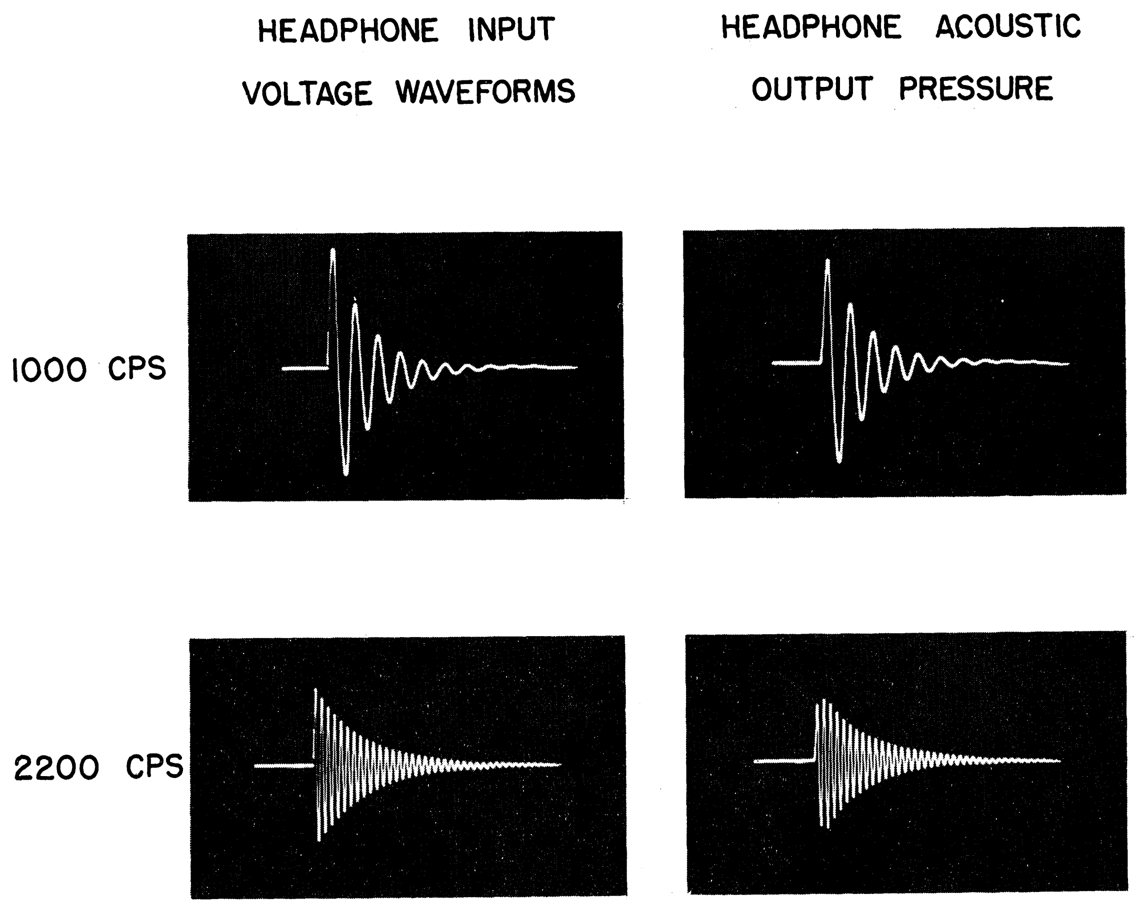

FIG. 4. DAMPED SINUSOIDAL WAVEFORMS

random-number generator[1,2] selects an input waveform from the available array of signals. The block diagram of the random-number generator, shown in Fig. 5, is divided into three main units: (1) the random delay unit; (2) the driver, which programs each selection; and (3) the selection unit, which coordinates the random delay and driver units to select and store the random selection.

The sequence of operations of this circuit for one random selection is as follows: First, examine the stable states of the circuit. The driver flip-flop is in its off condition, which means that: (1) the Geiger-Muller (G-M) tube is cut off; (2) the input from the radiation counter to the G-M tube is blocked; and (3) the oscillator, which drives the spinning disk, is inoperative. The delay, single-shot multivibrator is in its stable state. Both decade counter tubes have a stationary glow, which means they are not counting; and the storage thyratrons are in their non-conducting state waiting to be fired. The driver flip-flop now receives a "question" pulse from the associated programming equipment, asking for a random selection. The driver flip-flop immediately does three things: (1) it connects the radiation-counter tube to the G-M tube; (2) it turns on the G-M tube; and (3) it turns on the oscillator, which in turn starts the spinning disk. The radiation-counter tube counts ten pulses from the G-M tube and then shuts off the driver flip-flop with its random delay output selection pulse. This, in turn, disconnects the radiation-counter tube from the G-M tube and then shuts off the G-M tube. The gated oscillator is turned off, thus stopping the spinning disk in a random position. This position is the random-number selection.

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1 G. A. Roberts, "Spinning Disk Random Selectors," Technical Memorandum No. 39, Electronic Defense Group, University of Michigan, Ann Arbor, Michigan, 1957.

2 J. A. Lauder, "An Electronic Random Number Generator," Electrical Engineering, 78, 1959.

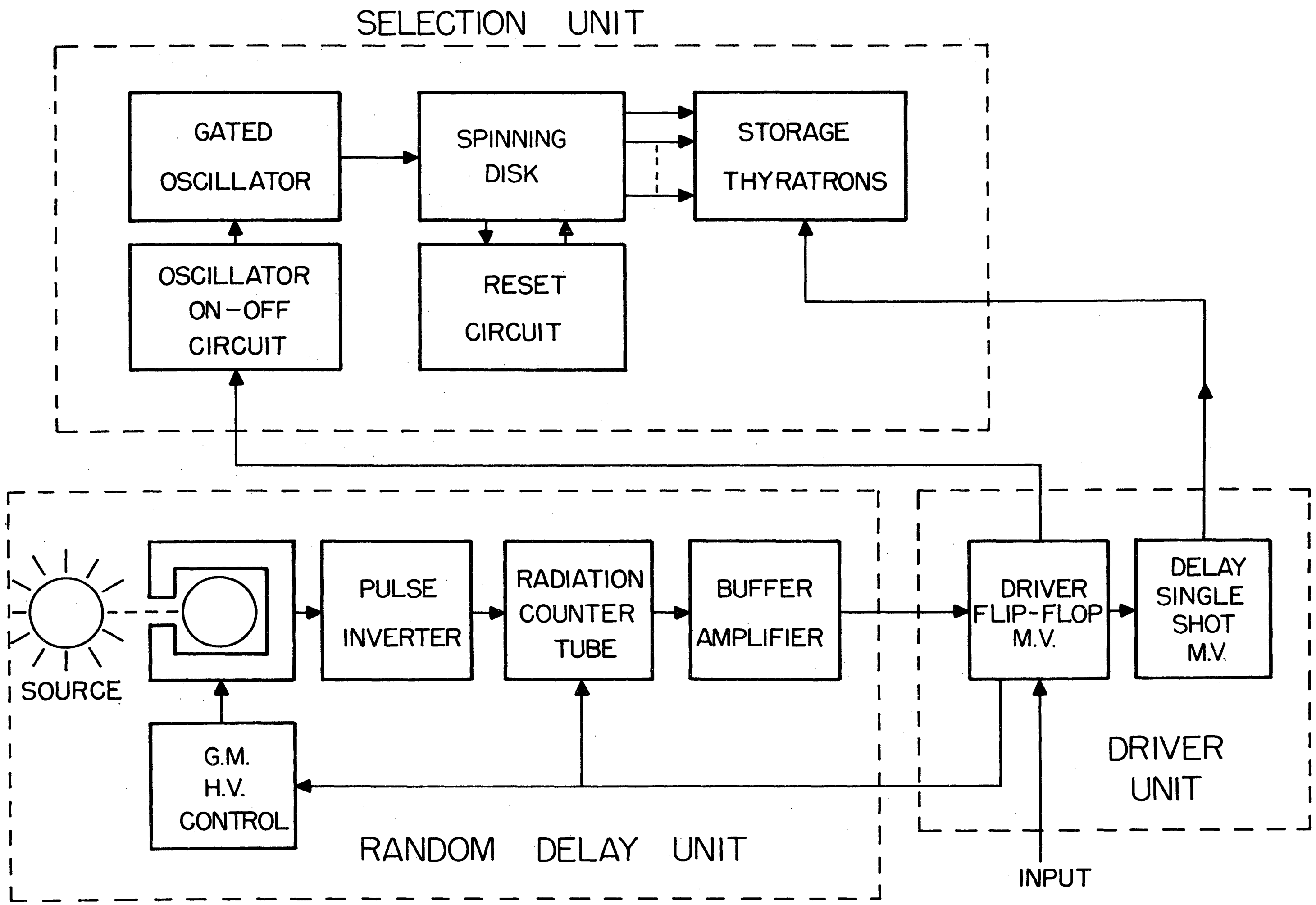

FIG. 5. BLOCK DIAGRAM OF RADIATION DELAY ELECTRONIC SPINNING DISK RANDOM SELECTOR

There is a storage thyratron for each position of the spinning disk, and the thyratron corresponding to the position in which the spinning disk stops is triggered by the coincidence of two impulses, one from the spinning disk and one from the delay, single-shot multivibrator. After a selection has been made and the spinning disk is stopped in its selected random-number position, only the thyratron connected to that random-number position can receive a pulse. When the driver flip-flop is turned off by the random delay output selection pulse, it triggers the delay, single-shot multivibrator, which in turn sends pulses to all ten thyratrons. Only the thyratron receiving two pulses will be fired. The random-number selector can be adjusted to select randomly from among 2 to 10 input waveforms. A photograph of the complete Radiation Delay Electronic Spinning Disk Random Selector is shown in Fig. 6.

Interval 2. At this point in the program, the Warning Information Generator begins to operate the warning lights that pace the observers during the experiment. Interval 2 involves turning on the observers' "get-ready" lights. The Warning Information Generator, shown in Fig. 7, also turns on the warning lights for the observation interval (3-6) and the answer interval.

Intervals 3-6. The Warning Lights for the observer are shown in Fig. 8. The "Trial Warning" light, which is red, turns on to let the observers know that the observation intervals are about to begin. The "Coincidence Warning," which is white, lights up only during an observation interval, and its on- and off-goings mark the beginnings and ends of the observation intervals.

The durations of all 9 intervals of the PSYTAR program can be controlled. This control feature is particularly relevant for the observation intervals since three of these intervals are turned to zero in

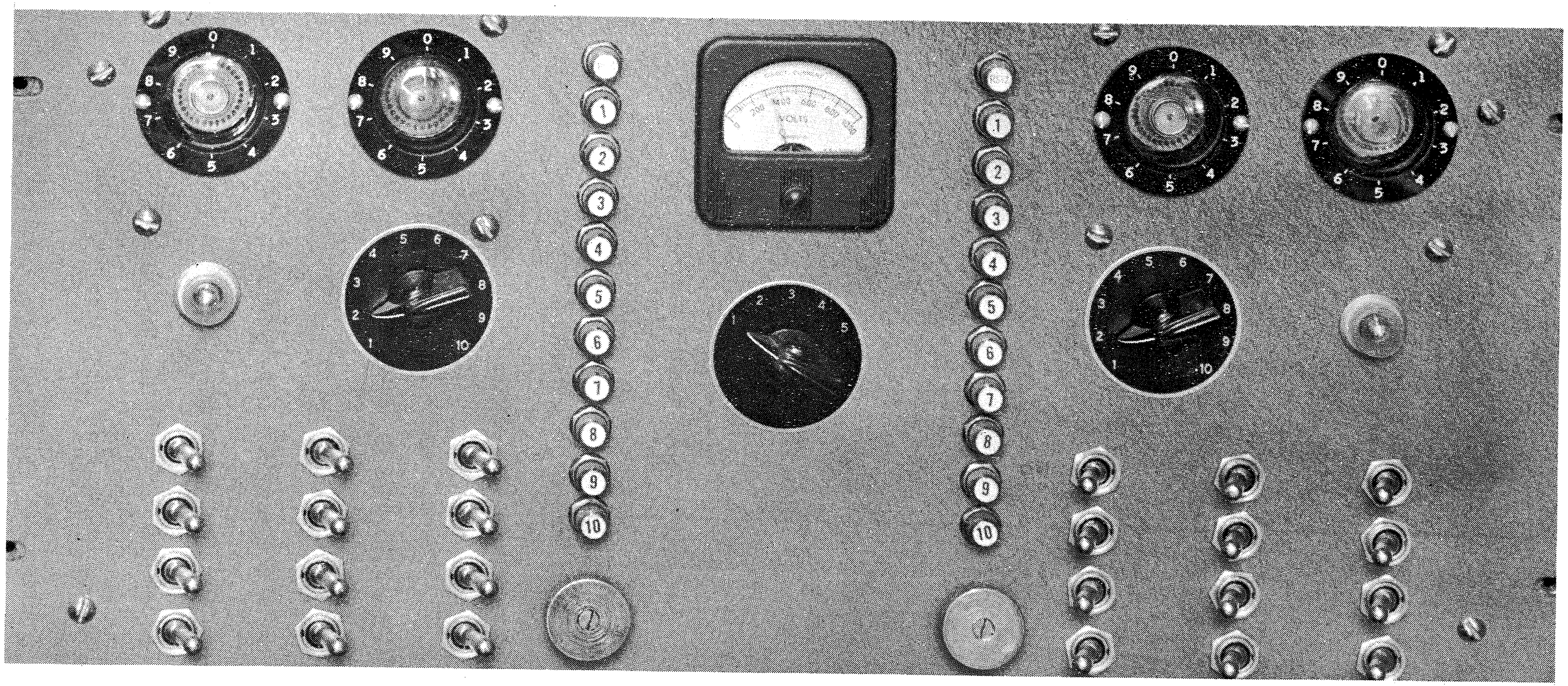

FIG. 6. FRONT PANEL OF RADIATION DELAY
ELECTRONIC SPINNING DISK RANDOM SELECTOR

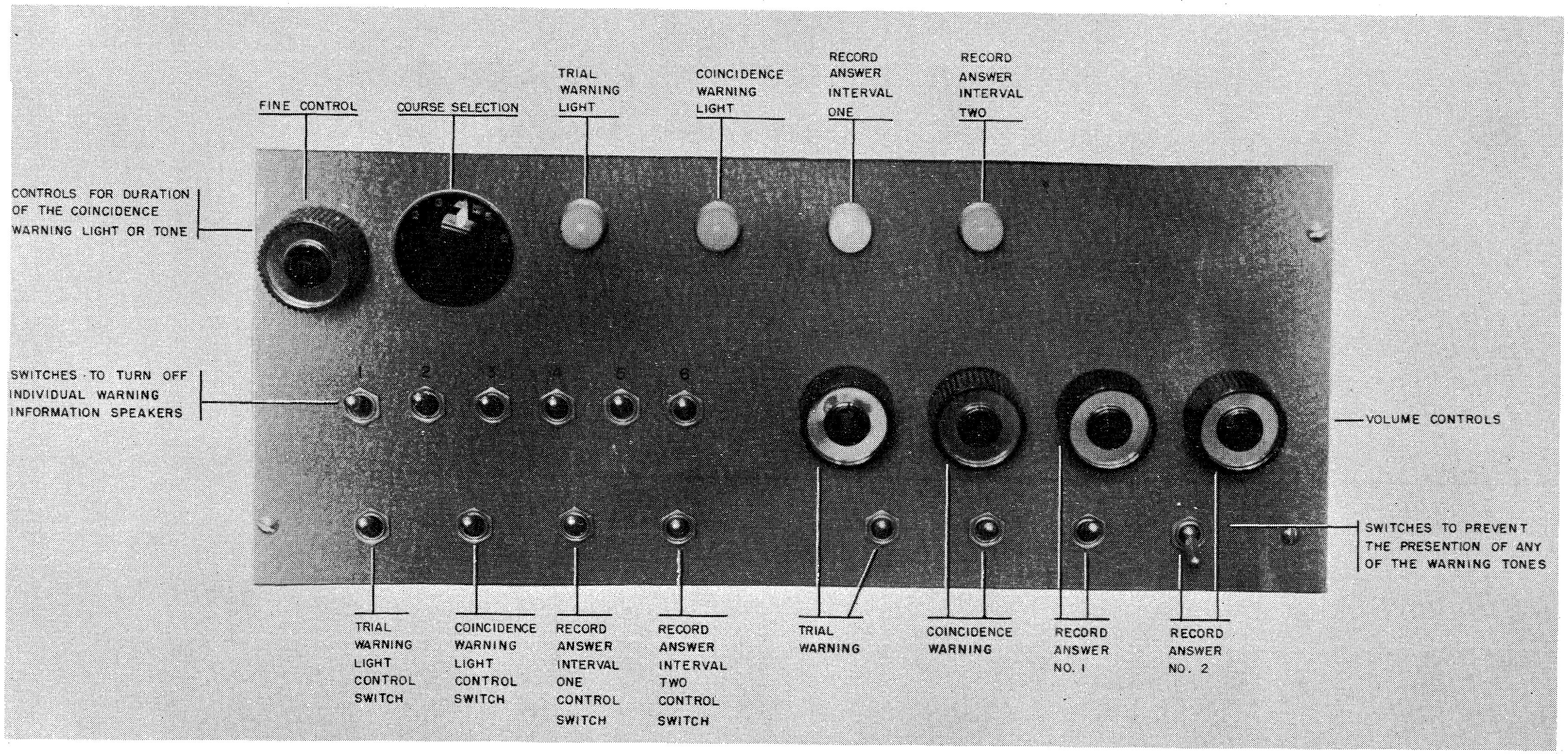

FIG. 7. WARNING INFORMATION GENERATOR FOR N.P. PSYTAR MODEL 2

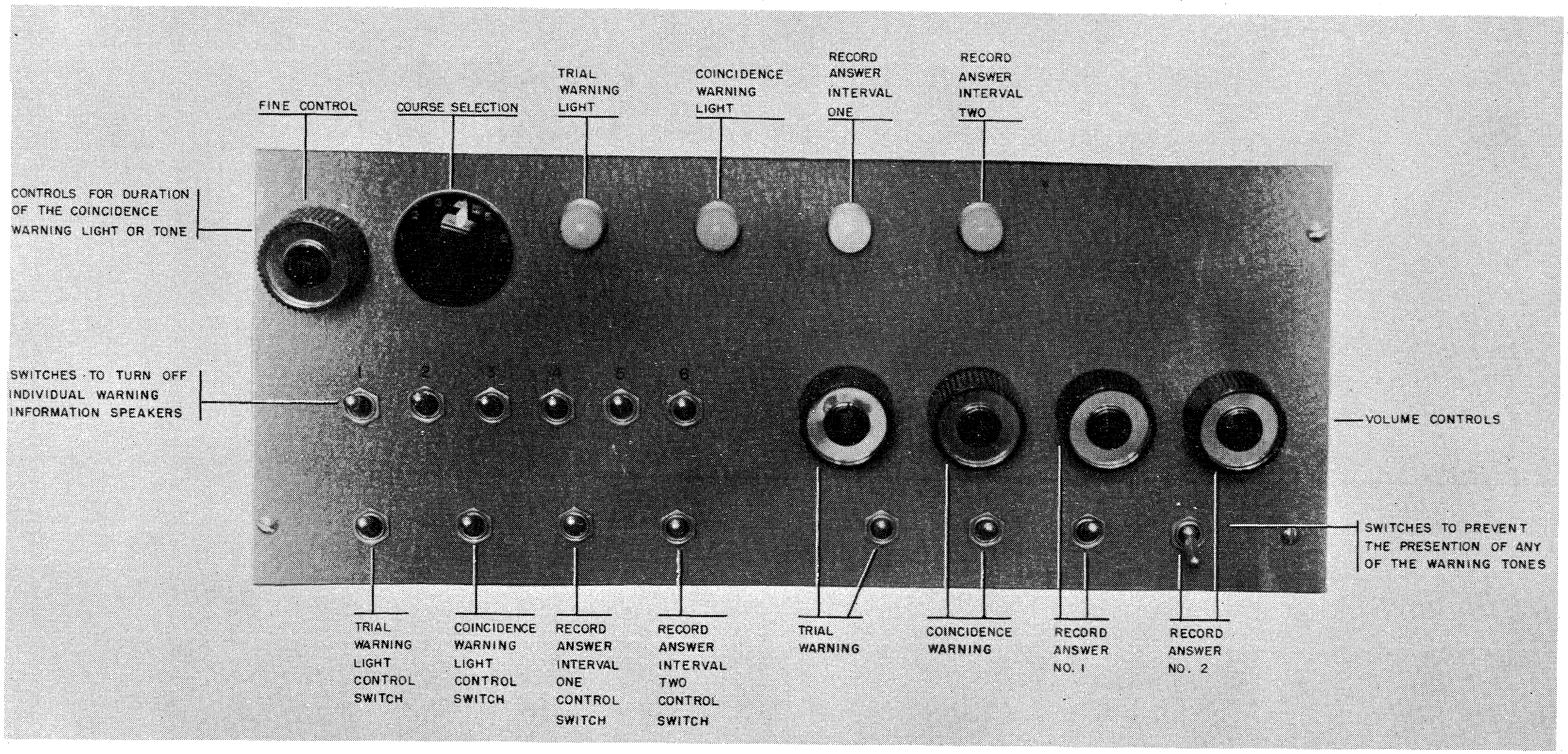

FIG. 7. WARNING INFORMATION GENERATOR FOR N.P. PSYTAR MODEL 2

"Yes-No" type experiments and two are turned off in two-alternative forced-choice procedures. It should be noted that all 9 intervals can be varied continuously from 0 to 50 seconds.

Interval 7. At this point in the program the warning light marked "Record Answer Interval No. 1" in Fig. 8 is turned on (a green light), and the subject records his answer by depressing the button corresponding to his answer. The second answer interval is used only in four-alternative forced-choice procedures in which the observers are sometimes asked to record a second choice (this is a white light).

The arrangement of the observers' listening booth is shown in Fig. 9. The warning lights, as shown in Fig. 8, appear at the top of the observers' bench, and each of the observers has her right hand poised over the buttons which record her answer. (The red buttons on the bench and the array of lights on the wall are part of ROMPAR and will be described later.)

It should be noted that during actual experimentation partitions are placed between the four positions occupied by observers to eliminate the possibility of one observer copying his answer from another. An additional anti-cheat feature is that only the first button pushed during the answer interval records.

Interval 8. During the eighth interval of the PSYTAR program three things occur: (1) a description of the input event and the answer of each of the observers are punched onto an IBM card; (2) a mechanical counter tabulates the correct answers; and (3) the observer is notified of a correct answer by means of another light.

Interval 9. In the last interval of the program, the storage thyratrons of the Selection Unit of the Radiation Delay Electronic Spinning Disk Random Selector are erased and PSYTAR is ready to begin again.

FIG. 9. ARRANGEMENT OF OBSERVERS' LISTENING BOOTHS

It was noted earlier that the duration of each of the nine intervals which make up the PSYTAR program can be varied from 0 to 50 seconds. Although there are calibrated controls on PSYTAR to set the durations of these intervals and to set the time between intervals, these durations are measured accurately before each experiment. Two measuring instruments are available to check these durations: (1) the cathode-ray oscilloscope, which has sweep rates from 1 millisecond to 60 seconds available; and (2) the electronic counter, which can be set to measure intervals from 1 microsecond to 1 second.

2.4 ROMPAR

ROMPAR is a message-storage device that is used in conjunction with PSYTAR. The program of PSYTAR is not changed in using ROMPAR, and the 9 intervals proceed as described above. During Interval 1, a random selector chooses one message from among the 32 stored in ROMPAR. This message is presented during the observation interval. The Warning Lights are used to pace the observer as described above.

The 32 possible messages are displayed for the observer on the lighted panel, shown mounted on the wall of the booths in Fig. 9. The 4 x 8 matrix of response buttons is placed on the bench in front of the observer. To record his answer the observer must depress two buttons, the ones corresponding to the row and column of the answer upon which he decides. Correct answer information is fed back to the observer in two ways: (1) the upper light on the left indicates correct answers and the lower one errors; and (2) the row and column lights (which are matched to the answer buttons) corresponding to the correct answer light up.