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A RAPID TIMING SEQUENCER FOR TOXIC GAS SAMPLING

By

G. L. Hody, CPT., MC
H. W. Huffman

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U. S. ARMY AEROMEDICAL RESEARCH UNIT
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13. ABSTRACT

As part of a study of toxic hazards it is necessary to obtain samples of gases given off by rapid fire weapons and fast burning rocket motors. A solid state instrument was designed which can program solenoid valves for this purpose. The configuration chosen provides three individually adjustable interval timers. Each can be delayed from 25 to 5,000 milliseconds after firing of weapons, and can remain on for 30 to 4,000 milliseconds.

The very short sampling times which are available enable acquisition of gas samples at pressures considerably below ambient, if this is desired to protect analytical instruments or to minimize chemical interactions in the sample. By adjustment of R-C time constants the timer range can be extended or reduced further to provide a versatile tool for future timing applications. Circuit details and performance data are presented.

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APPROVED: Robert W. Bailey

ROBERT W. BAILEY
LTC., MSC
Commanding

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A RAPID TIMING SEQUENCER FOR TOXIC GAS SAMPLING

INTRODUCTION

A study of chemical composition of exhausted gases and particles from machine guns and rockets has been initiated in cooperation with the Air Force Rocket Propulsion Laboratory near Edwards Air Force Base, California. The exhaust composition is needed becuase significant quantities of gun gas may be breathed by aircrews of armed helicopters. Sampling of the gases is complicated by the rapid fire characteristic of the machine guns (about 10 rounds per second) and by the short burning time of the solid propellant rockets (about one second). Remote control of the sampling system is also essential to insure personnel safety.

To collect the gases, evacuated steel cylinders closed by solenoid valves can be used. In order to control the solenoid valves, an interval timer is required.

Samples maintained at low absolute pressures are acceptable for some tests because they are destined for mass spectrometer analysis. In these cases the low partial pressure of each component of the gas mixture might serve to minimize interactions among components or with container walls during the time between collection and analysis.[1] Rapid cycling of the solenoid valves is necessary to keep the contents of the sampling cylinders below ambient pressure.

SPECIFICATIONS

In the intended application, the timing interval and weapons firing are simultaneously initiated from the sequencer. Suitable safety features to prevent accidental discharge of the weapons are incorporated in the sequencer circuit. Desired characteristics include:

Input: 24 - 28 volts DC, about 0.5 amp in addition to the requirements of the controlled circuits.

Controls: a) Three individual channels with independent controls.

b) Control of "on time" and "delay time" for each channel, without interaction.

c) Guarded switch, with two hand operation required for weapons firing.

d) Initiation of timing cycle simultaneous with weapons firing.

e) Lockout to prevent recycling if "firing" switch remains depressed (required on fast timing cycles).

Outputs: a) 24 - 28 volts DC is furnished for operation of the solenoid valves. Either 24 - 28 volts DC or contact closure can be provided to fire the weapon.

b) Provisions for oscilloscope calibration of timing intervals.

c) Pilot light monitoring of each channel output.

GENERAL CIRCUIT DESIGN

A simplified diagram of the sequencer (figure 1) shows how the basic timer circuits are functionally interconnected. Only the first and last sets of timer circuits are shown. If more than two channels are used the others are connected in the same way as the first channel shown. In operation the weapon is fired by depressing switches on the control box. This action simultaneously applies power to a relay connected to be self latching (RY 1, figure 1), and to the "DELAY" timers through RY 1 contacts. When the delay period is over, RY 2 and RY 4 close applying power to the "ON" timers and to the outputs through the normally closed contacts of RY 3 and RY 5. When the first channel's "ON" period is complete RY 3 pulls in and latches, disconnecting the output from the power. RY 5 performs the same action in the last channel but performs two other functions as well: The spare contacts (designated RY 5B in figure 1) are holding RY 1's coil grounded when RY 5 is off. At the ending of the "ON" period for the last channel, RY 5 pulls in and opens the ground circuit to RY 1 causing it to drop out. This removes power from all timer circuits and normally turns them effectively off. However, if the firing buttons have not been released, power will still be furnished to RY 1 from the control box and the timing cycle would repeat. This would fire the solenoids again and might destroy the samples. However, the RY 5A contacts prevent this by keeping the "ON" timer circuit in the last channel energized (independent of RY1) as long as power is supplied from the control box (i.e., as long as the firing switches are depressed). Keeping the last "ON" timer energized keeps RY 5 pulled in thus keeping RY 1 locked out and preventing recycling. D1, a silicon diode, limits this action to RY 5. The firing switch must be released to cause RY 5 to drop out and prepare the entire circuit for a new cycle. This feature is particularly needed to prevent recycling following short (fast) sequences.

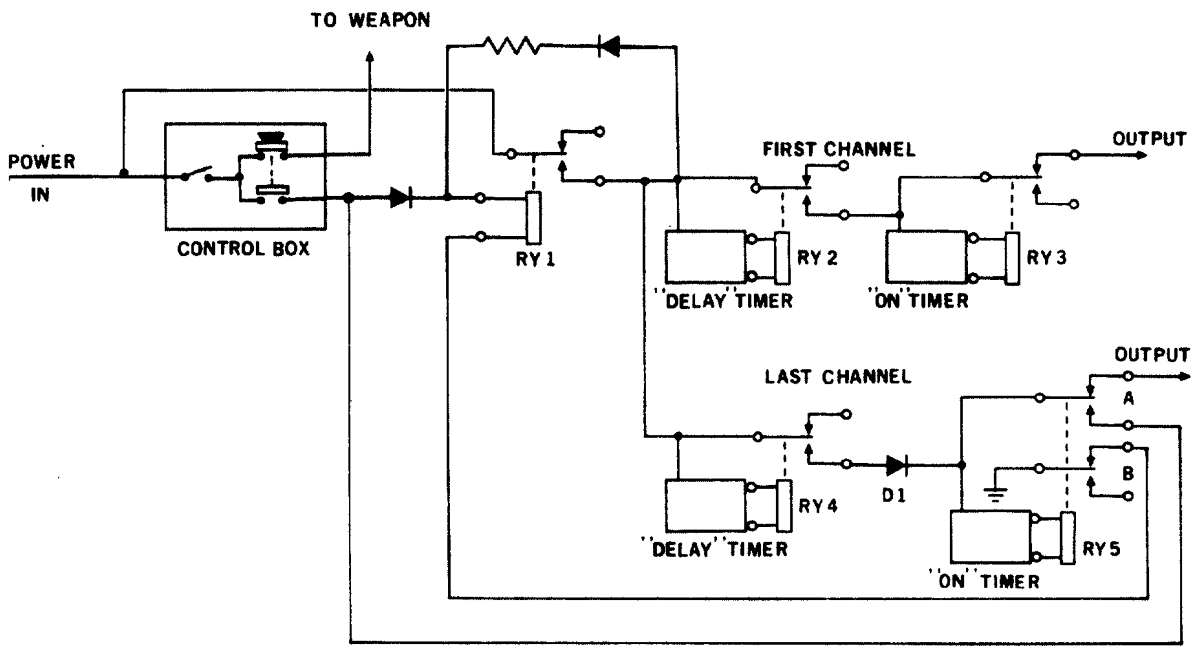

Figure 1. Functional Diagram of Sequencer

TIMING UNIT

The first half of the timing circuit is a standard unijunction timer[2] (figure 2). A 400 KΩ ten turn linear potentiometer (R 2) and a 50 microfarad capacitor (C 1) are used to set the timing. A 1 KΩ resistor (R 1) is placed in series with R 2 to prevent full supply voltage from being applied directly to the emitter of the unijunction transistor (V 1) in case the timing potentiometer is reduced to zero value. Capacitor C 1 charges through R 1 and R 2 until the emitter voltage applied to V 1 is high enough to make it conduct.

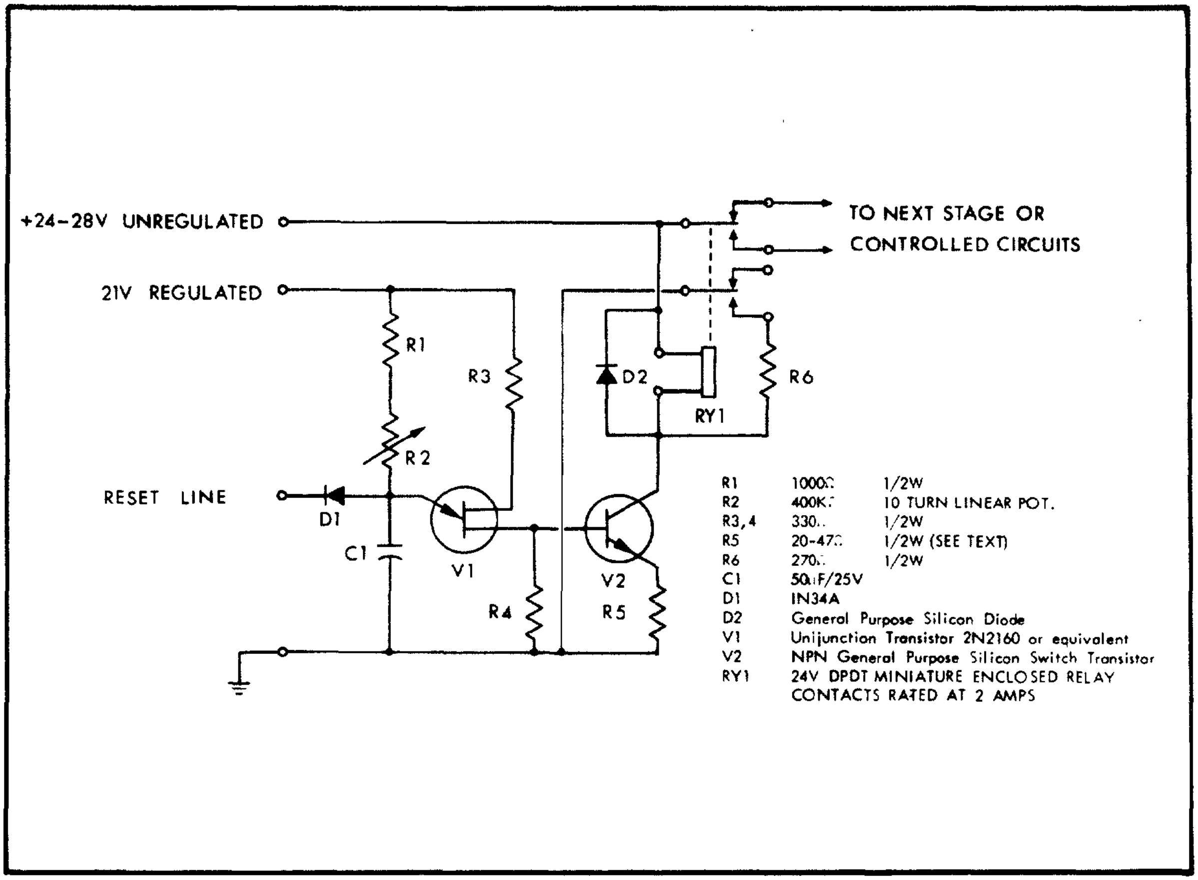

Figure 2. Timing Unit Schematic

The resulting positive pulse from Base 2 of V 1 is coupled to the base of a relay driver transistor (V 2) which is normally biased below the drop out current of the relay. V 2's emitter resistor is selected to keep the collector current well below the dropout current of RY 1 with V 1 not conducting. This value is usually between 20 and 47 ohms. When V 1 conducts, the positive pulse on the base of V 2 is sufficient forward bias to make it conduct also, causing RY 1 to pull in. D 2 suppresses the back EMF across the relay coil. D 1 grounds C 1 through a reset circuit (see figure 3) to discharge it rapidly after completion of the timing cycles. This feature permits rapid recycling without changes in timing accuracy (about 20 seconds between operations are sufficient) and is useful when calibrating the timing intervals.

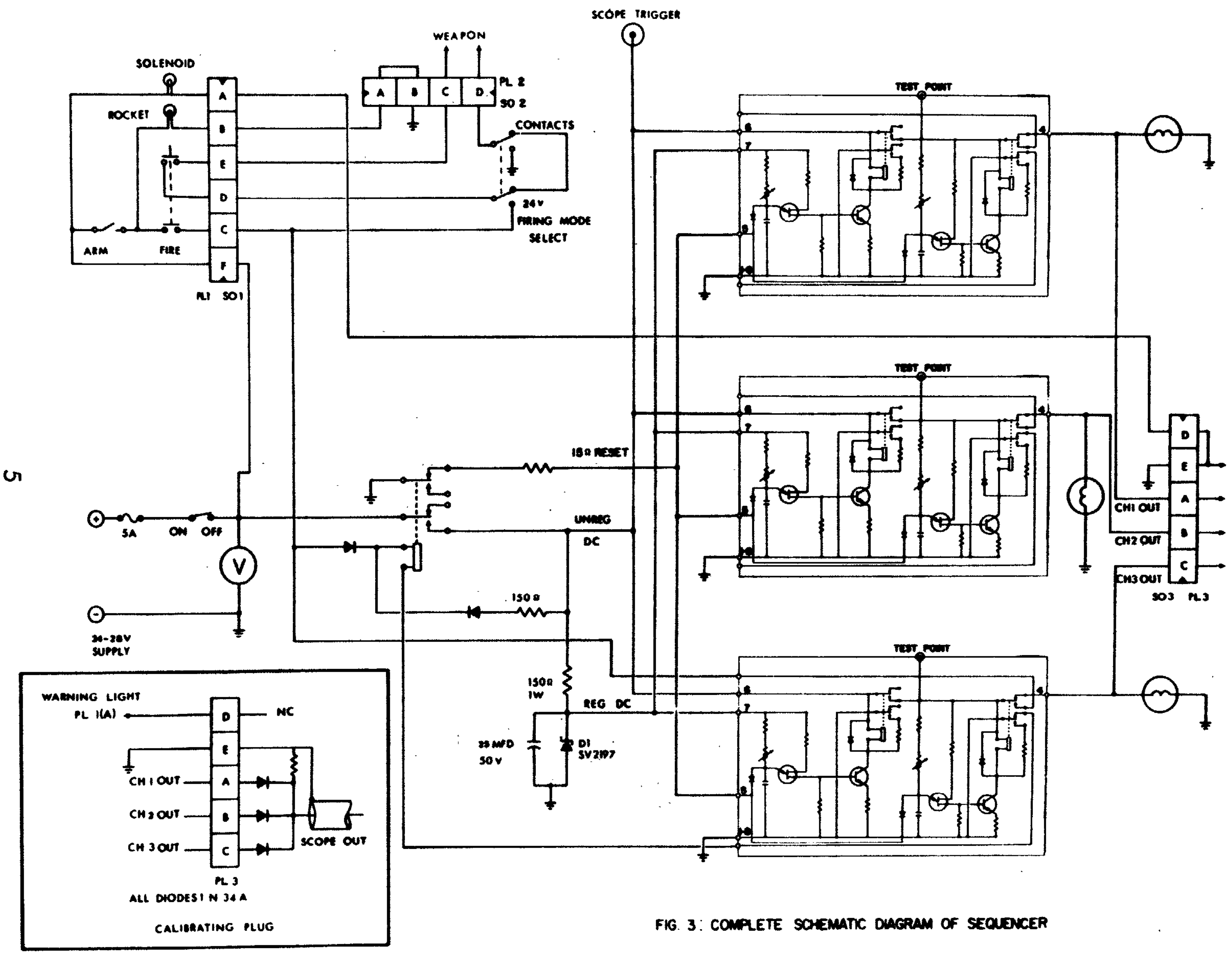

FIG. 3: COMPLETE SCHEMATIC DIAGRAM OF SEQUENCER

PRACTICAL CIRCUIT

A complete schematic of a timer used in weapons exhaust sampling shows some special features such as series guarded switches and warning lights for foolproof operation (figure 3). A 21 V zener diode (D 1 in figure 3) provides a regulated supply for "delay" timer units. A "firing mode selector" assigns the weapon's electrical terminals either to a 24 V firing voltage or to a contact closure. A fuse and voltmeter have been inserted in the power line and pilot lights monitor the output of each channel separately.

CONSTRUCTION

The instrument was assembled inside a commercial chassis enclosure (Bud #WA-1540). Each channel was built up on a clad board using conventional printed circuit technique (figure 4). Front panel mounting of timing potentiometer was provided for convenience (figure 5) and all external connections were brought out to the rear panel (figure 6).

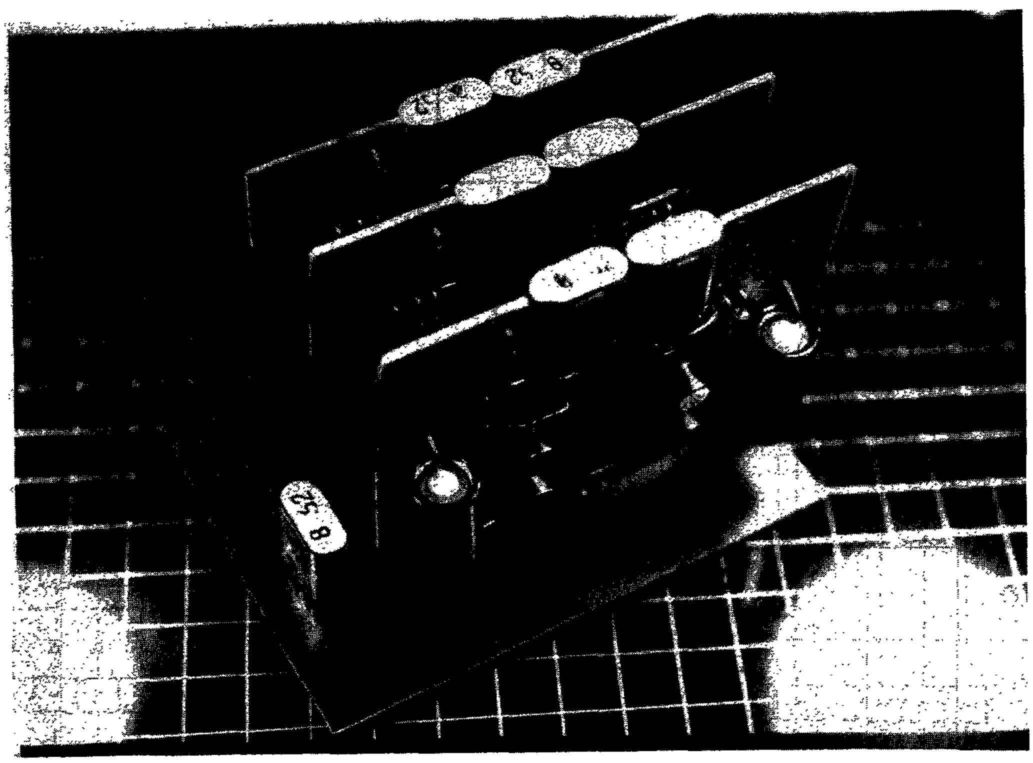

Figure 4. Three Channel Circuit Board

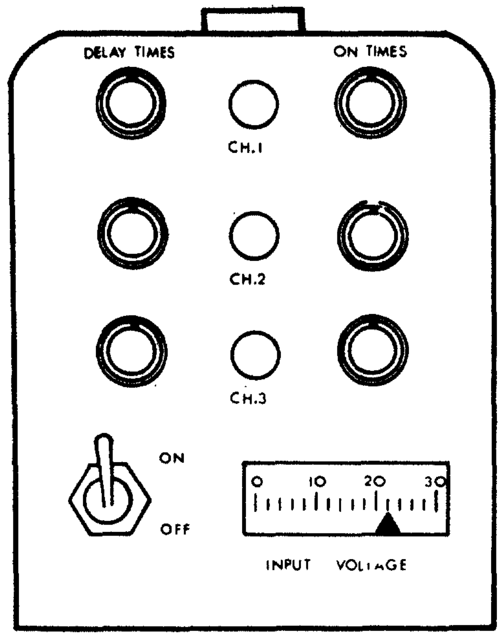

FIG 5 : FRONT LAYOUT

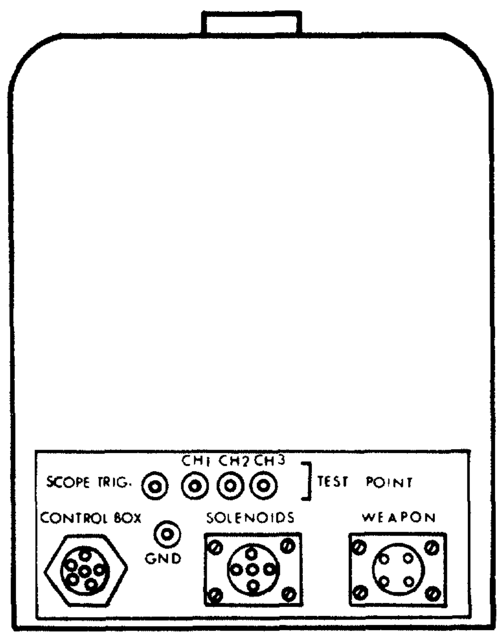

FIG.6 : REAR LAYOUT

OPERATION

Short term stability of the timer is excellent but voltage and temperature changes will cause errors. Calibration of time intervals with an oscilloscope is done before each experiment. Any good oscilloscope equipped with calibrated and triggered sweep is suitable. The input of the scope is connected to the solenoid output socket through a special plug (figure 3) and the "on time" is set first. In order to display the trace from each channel separately, the delay times are set arbitrarily to provide adequate separation. The delay times desired are adjusted last. For this test the scope's external trigger is connected to the "scope trigger" jack on the sequencer and the input of the scope is connected to each channel test point in turn.

PERFORMANCE

The timing intervals obtained are linearly related to potentiometer settings as shown for a typical case in figure 7. For existing circuit constants, 25-30 msec is the minimum available delay and about 4-5 seconds is the maximum. Other values are obtainable by variation of the R-C components (R 1, R 2 and C 1 in figure 2).

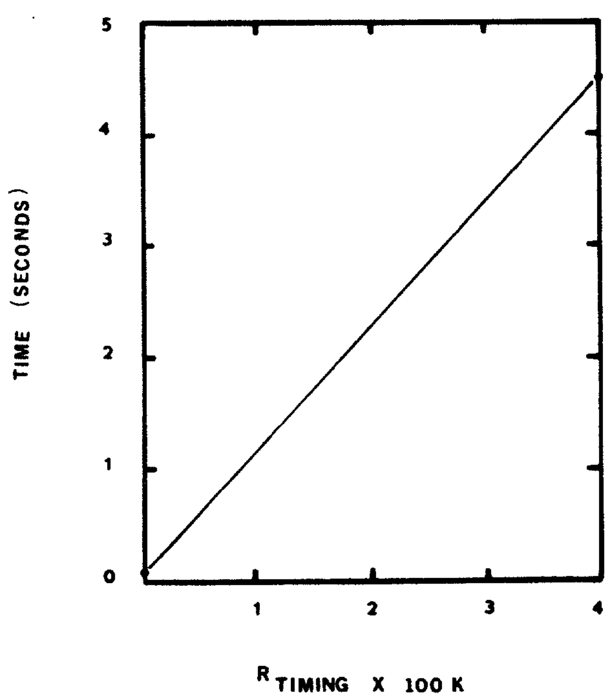

Figure 7. Timing Period vs. Timing Resistor Value

SAMPLING ACCESSORIES

The sequencer was tested with an evacuated cylinder and valve arrangement shown in figure 8. The solenoid valve was a Hoke #S90D 380 HV chosen for rapid operation with a 28 volt DC supply. The manufacturer claims that a complete closed-open-closed cycle requires 20 msec or less (this was not tested). Final pressure (reported as inches of Hg below atmospheric pressure) is shown on the ordinate in figure 9 as a function of "on time" settings. Note that essentially complete equilibration with the ambient atmosphere occurred in less than two seconds in the system tested. Further tests of the sequencer under field conditions have demonstrated its usefulness and reliability.

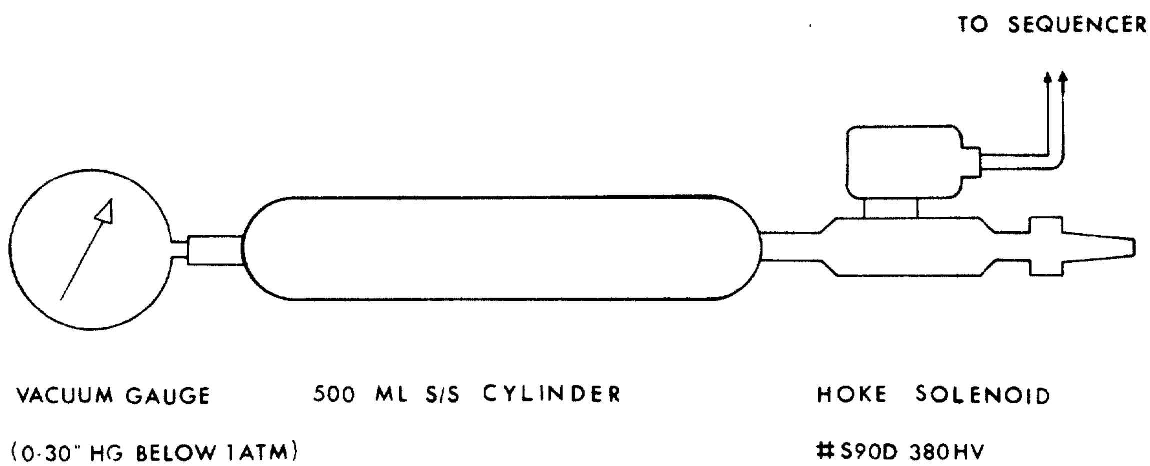

Figure 8. Typical Sampling Apparatus

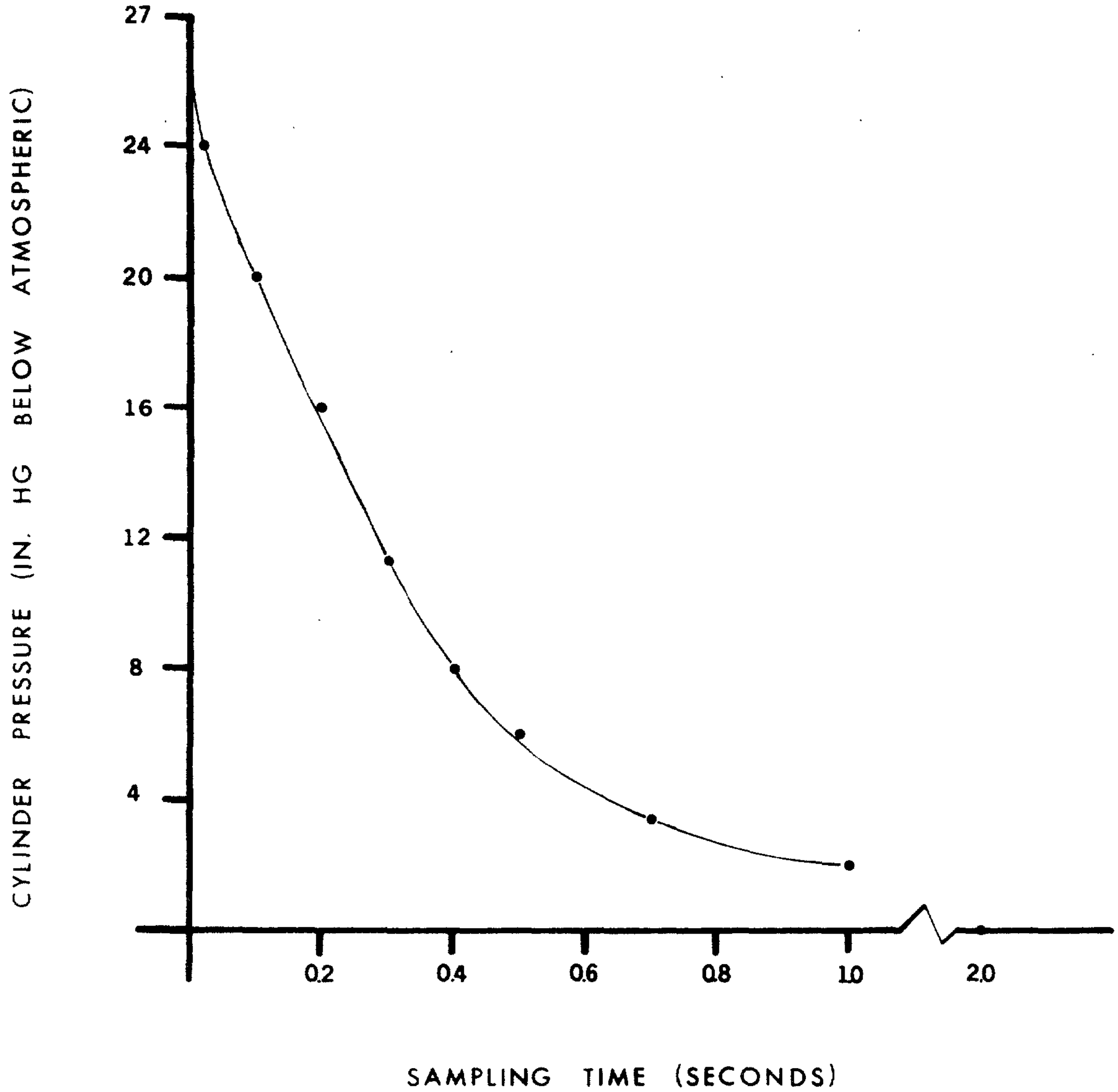

Figure 9
Final Pressure vs. Sampling Time in Typical Apparatus

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1. King, E. L. How Chemical Reactions Occur, Benjamin 1964.

2. General Electric Transistor Handbook, 7th Edition, Chapter 13.