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THE ARM SAFE DEVICE DUD LOCK TESTER (AN APPLICATION OF FLUIDIC TIMING AND CONTROL TO TEST EQUIPMENT.)

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Dover, New Jersey

April 1972

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THE ARM SAFE DEVICE DUD LOCK TESTER

(AN APPLICATION OF FLUIDIC TIMING AND CONTROL TO TEST EQUIPMENT)

BY
J. RAYNER

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The Arm Safe Device Dud Lock Tester (An Application of Fluidic Timing and Control to Test Equipment)

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13. ABSTRACT

A tester controlled by a fluidic logic system has been constructed to test the safety functions of missile safe and arm devices. The tester mechanically sequences the acceleration sensing elements of a safe and arm device with forces applied through air cylinders. The air cylinders are controlled by a fluidic logic and timing circuit with continuously variable time sequences programmable. The tester has been successfully demonstrated to meet extremely accurate time requirements (/ 20 milliseconds over one second intervals) and plans are being made for its use in production acceptance testing.

Details of illustrations in this document may be better studied on microfiche

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THE ARM SAFE DEVICE

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(AN APPLICATION OF FLUIDIC TIMING AND CONTROL OF TEST EQUIPMENT)

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PICATINNY ARSENAL
DOVER, NEW JERSEY

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

PURPOSE

The purpose for designing and constructing this piece of test equipment was to provide a unique in-process bench testing capability of the safety function performed by a safe and arm device. The adequacy of the safety feature of every production unit can now be verified prior to final sealing of the device. After sealing, access to the "g" weights is not possible; testing must then be performed in an actual acceleration environment.

The test equipment needed to simulate flight acceleration levels and times as closely as possible in a bench test. Both the reset function of the safe and arm device and the end lock function were required to be tested. To realistically test the device, two acceleration force levels needed to be applied to the acceleration sensing components of the device with accurately controlled time durations and with the capability to simulate various missile failure modes. Due to the high acceleration levels and short time durations involved it had proven infeasible to accomplish an accurate simulation of certain failure modes on a centrifuge.

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INTRODUCTION

The arm safe device is a missile component which is designed to sense minimum acceleration levels in flight for a minimum period of time. If the proper acceleration-time profile is seen electrical switch contacts should close. If the proper acceleration-time profile is not sensed by the device the timer mechanism is mechanically stopped, the switch contacts do not close, and other missile components do not receive an arm signal.

A typical arm safe device contains two spring-mass combinations, a mechanical timer and a set of electrical switches. When the initial launch acceleration level is sensed, one or both of the "g" weight masses is forced down against its spring. As the "g" weight is forced down, timer sequence begins.

A normal flight curve for a multistage missile contains coast period (a period of zero acceleration) after the initial acceleration pulse and before ignition of the next stage. The "g" weights return to their initial positions during the coast period.

After the coast period in a normal flight, a second acceleration pulse is sensed. One or both of the "g" weights is again forced to move against its spring and the timer runs out closing switch contacts.

If either acceleration pulse does not occur at the proper time or for the proper duration the timer will be stopped and switch closures will not occur.

The Dud Lock Tester was designed to simulate various missile failure modes through forces applied to the "g" weight masses for a controlled time sequence. The forces applied are equivalent to "g" force loadings experienced in flight.

Through proper time-force sequencing the Dud Lock Tester can simulate a shock pulse of time duration less than the first acceleration period, resulting in momentary timer start and stop. The tester can also sequence the Arm Safe Device through a normal initial acceleration period and a second acceleration period of insufficient duration simulating premature engine shutdown. In either case the timing mechanism should be mechanically stopped and final switch closures should not occur in a properly operating arm safe device.

The tester thus provides a unique static bench test capability for testing safe and arm device safety functions. Due to the short time intervals and high acceleration levels involved, it has proven infeasible to test some of the design safety features of the safe and arm devices on standard acceleration testing equipment. The tester thus fills an important void in safety and reliability testing of safe and arm devices.

THE DUD LOCK TESTER CONCEPT

It was stated in the purpose that a bench test was desired that would closely simulate acceleration force levels and time intervals experienced in flight. The ability to simulate various missile failure modes was necessary to test dud lock mechanism performance.

A method was required to sequence the "g" weights against their springs with the appropriate forces applied in the proper time sequence. It was decided that air cylinders could be connected to the "g" weights with a flexible cable. By applying the proper series of pressure pulses to the air cylinders, a series of force pulses could be transmitted to the "g" weights through the cable. The use of a flexible cable allows forces to be applied to the "g" weights in one direction only (i.e., the "g" weight masses are forced to return to their initial positions during the coast period only by their springs; this accurately simulates the flight conditions.) Double acting air cylinders are used to allow the cylinder pistons to be rapidly returned to their initial positions where no force is applied on the "g" weights.

The problem of force level control and pulse duration was thus translated to a problem of pressure level control and pressure pulse duration. The pressure level control problem was solved using a series of pressure regulators connected to the air cylinders through a series of valves. When the valves were opened, the air cylinders saw accurately controlled pressure pulses either to apply a force to the arm safe device "g" weight or to rapidly return the cylinder piston to its rest position.

Due to the short time intervals involved in "g" weight sequencing, an extremely quick acting valve was required. One of the fastest acting was a pilot controlled fluidic valve. A pilot pressure pulse was required for valve actuation. One of the best methods to generate the pilot pressure pulse was with a fluidic control system. Several fluidic control systems were investigated and found to be cost competitive with electronic control systems with an electrical to pneumatic interface at the pressure control valve. As a result, a pure fluidic control system was designed and built.

The Fluidic Control System

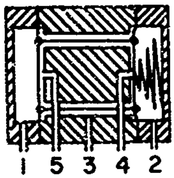
The basic building block of the control system is the "Genicon Logic Gate" (manufactured by the General Fluidics Corporation of Paterson, New Jersey). The gate is shown in figure I with its mechanical layout, drawing symbol and truth table. Ports 1 and 2 are control ports; ports 4 and 5 are supply or exhaust ports; port 3 is the output port. If a signal is applied to port 5 an output will be seen at port 3. If a signal is then applied at port 1 the diaphragm is forced to move against the bias spring and port 5 is closed. Port 4 is now open to port 3. If a signal pressure equal to the signal pressure previously applied at port 1 is now applied at port 2 the gate will suddenly snap back to its original state (this is due to the force applied by the bias spring) and an output will once again be seen at port 3.

By connecting an appropriate series of "Genicon Gates" in combination with fluidic capacitors and variable restrictors (a restrictor will impede a pressure rise on its down stream side), various timing and logic functions can be performed. The "Genicon Logic Gate" and a dual variable restrictor can be seen in figure 2.

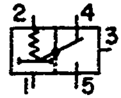
It will be seen that if the "Genicon Gate" is used as shown in part 1 of figure 3 a timed step function output will be obtained. When a signal is applied to the gate it quickly reaches port 1 opening the path between port 4 (where a constant supply pressure is present) and port 3 at time t_1. The pressure at port 2 slowly rises through the restrictor and capacitor until it is equal to the pressure at port 1; when this occurs the gate returns to its original state at time t_2 and a pulsed output has been obtained. By varying the restrictance, pulses of varying duration can be obtained.

The circuit shown in part 2 of figure 3 yields an on time delay. In this circuit the third gate output is held off due to the pressure applied at port 1 by the output from the first gate. When an input pressure is applied the output from the first gate is shut off and the pressure in the line slowly leaks off to atmosphere through port 4 of gate 1. As the pressure is lowered, gate three will snap to its natural biased position opening port 5 and an output will be seen at port 3. Thus a variable time delay has been constructed.

MECHANICAL DESIGN



DRAWING SYMBOL



PORTS 1 AND 2 ARE CONTROL SIGNAL PORTS
PORT 3 IS THE OUTPUT PORT
PORTS 4 AND 5 ARE SUPPLY OR EXHAUST PORTS

PRESSURE TO PORTS 1 AND 2 ACTUATE A DIAPHRAGM ASSEMBLY ALLOWING EITHER PORT 4 OR PORT 5 TO INTERCONNECT WITH PORT 3. WITH NO INPUT ON EITHER PORT 1 OR 2, PORTS 5 AND 3 INTERCONNECT. A PRESSURE PULSE AT PORT 1 CAUSES THE DIAPHRAGM ASSEMBLY TO SWITCH, CLOSING PORT 5 AND INTERCONNECTING PORT 4 WITH PORT 3. IF EQUAL PRESSURES ARE APPLIED ON BOTH PORT 1 AND PORT 2 THE SPRING BIAS CAUSES THE DIAPHRAM TO RETURN TO ITS INITIAL POSITION INTERCONNECTING PORT 5 WITH PORT 3.

TRUTH TABLE

PORTS	CONTROL		SUPPLY		OUTPUT
	1	2	4	5	3
	0	0	0	0	0
	1	0	0	0	0
	0	1	0	0	0
	0	0	1	0	0
	0	0	0	1	1
	1	1	0	0	0
	1	0	1	0	1
	1	0	0	1	0
	0	1	1	0	0
	0	1	0	1	1
	1	1	1	0	0
	1	1	0	1	1
	1	1	1	1	1

0= NO PRESSURE
1= PRESSURE

FIGURE 1
GENICON LOGIC GATE

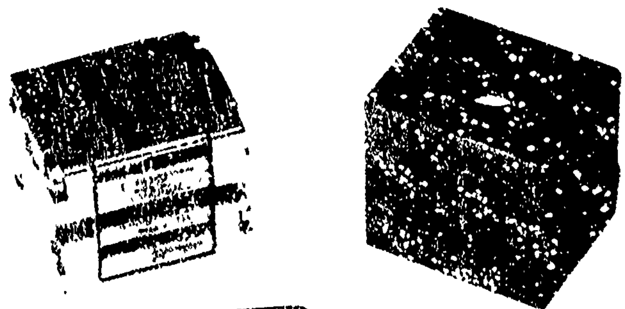


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FIGURE 2
GENICON GATE AND FLUIDIC RESTRICTOR

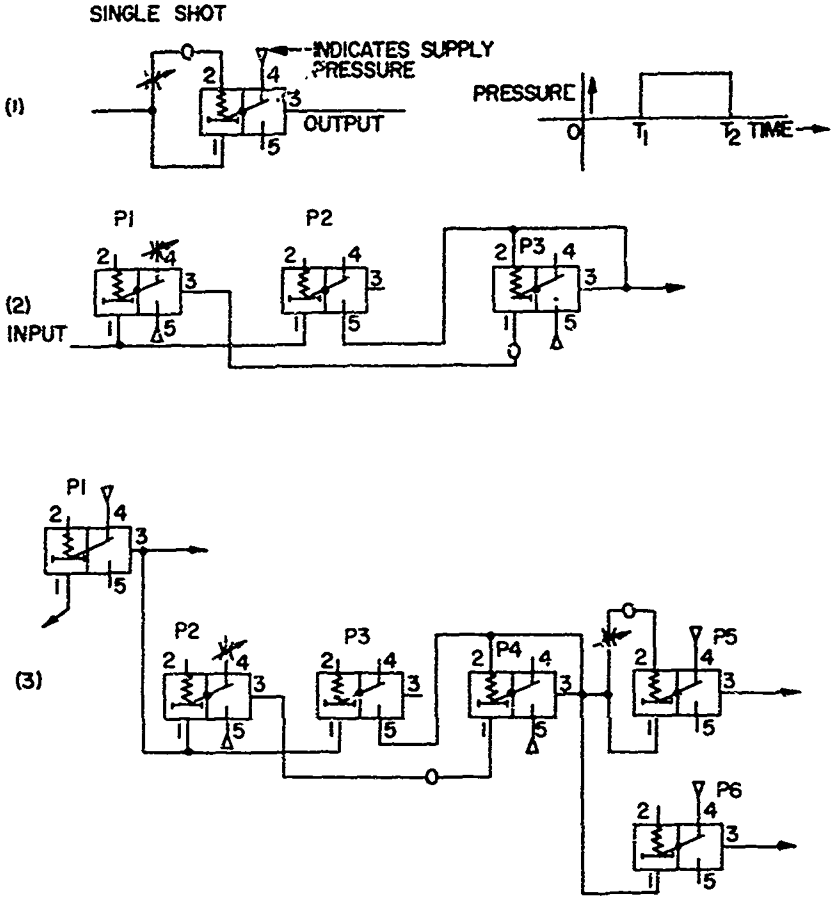

FIGURE 3

LOGIC CIRCUITS

By putting these two circuit elements together (as seen in part 3 of figure 3) the control circuit for the reset test of one safe and arm device has been constructed. The first gate is a push button switch. Its output goes to two valves and gate 2. Each of the valves connected to gate 1 switches a working pressure to each air cylinder (the forces obtained approximate a specific acceleration load of the device "g" weights). These valves are left open until the push button switch is released.

The input to gates 2 and 3 occurs simultaneously with valve actuation and the application of a load on the "g" weights. This starts a time delay function. At the end of the time delay a pulsed output is obtained from gate 5. The output from gate 5 goes to a valve which switches a high pressure to both cylinder piston return ports. Thus a simulated acceleration force pulse has been applied for a short time and then switched off. Zero "G's" is maintained for the duration of the pressure pulse from gate 5. When the pulse from gate 5 initially switched on, gate 6 also switched on yielding an output which opened two other valves. These valves switched working pressures to the actuating ports of each cylinder which result in a larger acceleration force pulse being applied when the trailing edge of the pressure pulse from gate 5 is reached. The higher acceleration load on the "g" weights is then maintained until safe and arm device arming is obtained. The load is released by releasing the push button switch. Control circuits for the dud lock tests are constructed in a similar manner although they are somewhat more complex.

The breadboarded version of the Safe and Arm Device Dud Lock Tester can be seen in figures 4 and 5. The breadboard version has successfully performed required testing activities demanding highly accurate timing ($\pm$ 20 milliseconds over one second intervals) and force control. The tester timing accuracy is continuously monitored for each test run using an oscillograph record to measure "g" weight sequencing times and safe and arm device switch closures. The tester timing functions are continuously variable and various control sequences can be programmed.

SAFE AND ARM DEVICE DUD LOCK TESTER (BREADBOARD)

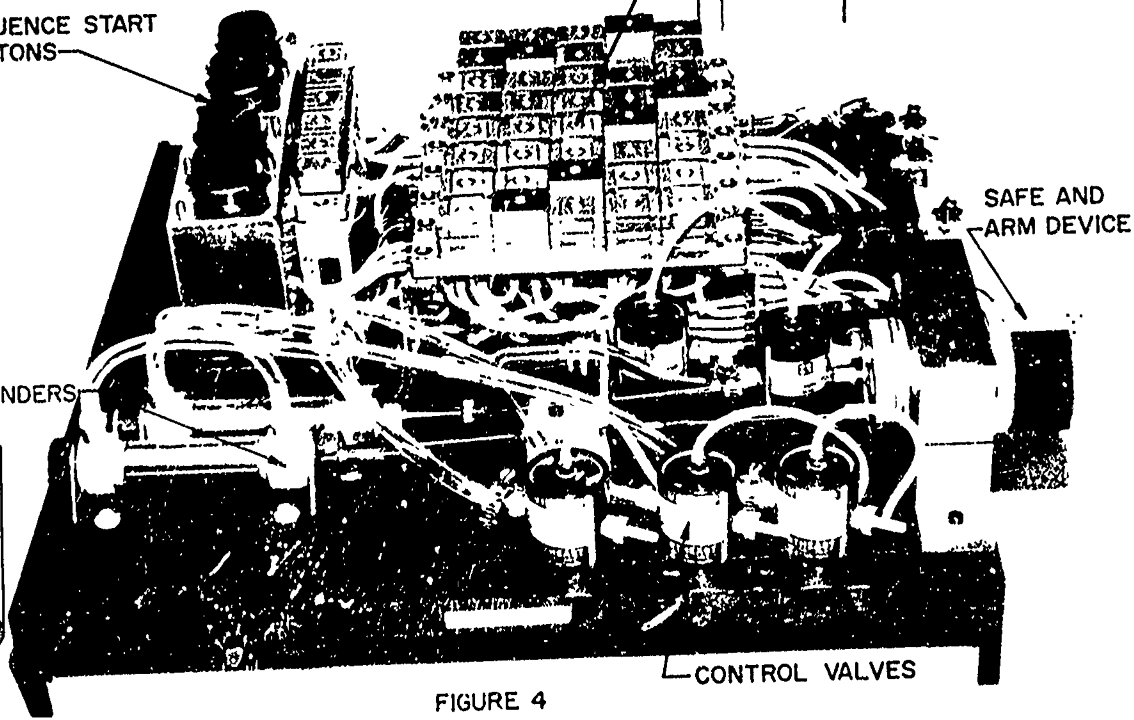

FIGURE 4

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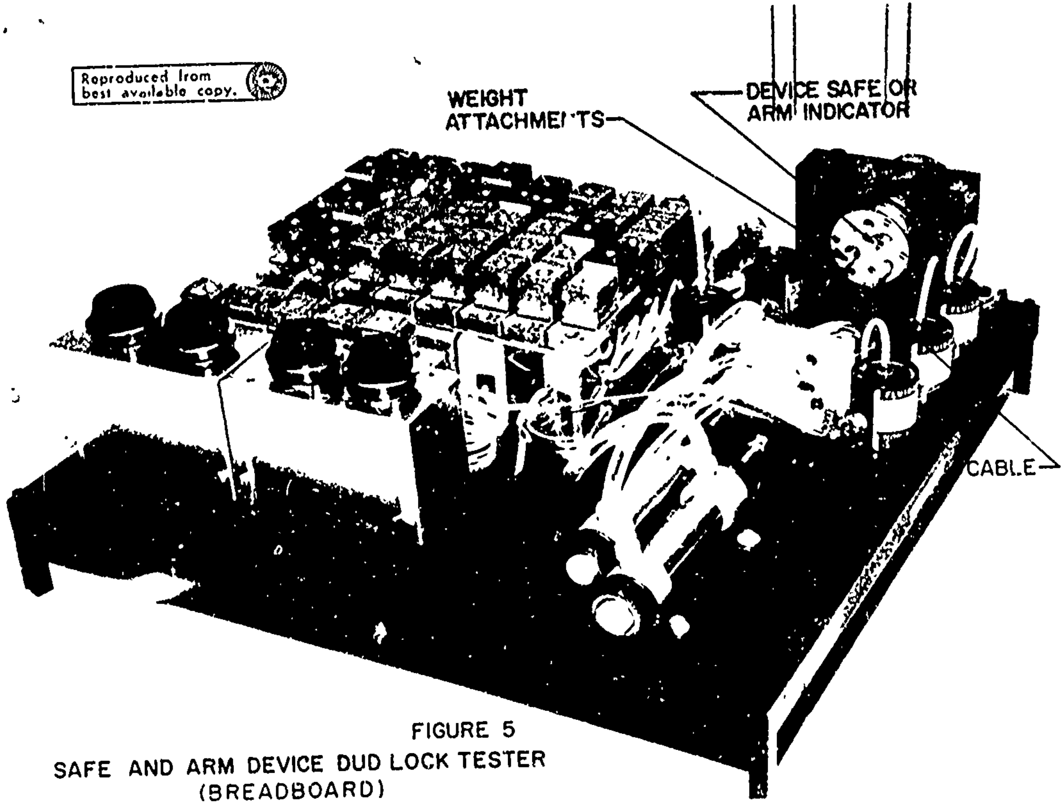

FIGURE 5
SAFE AND ARM DEVICE DUD LOCK TESTER
(BREADBOARD)

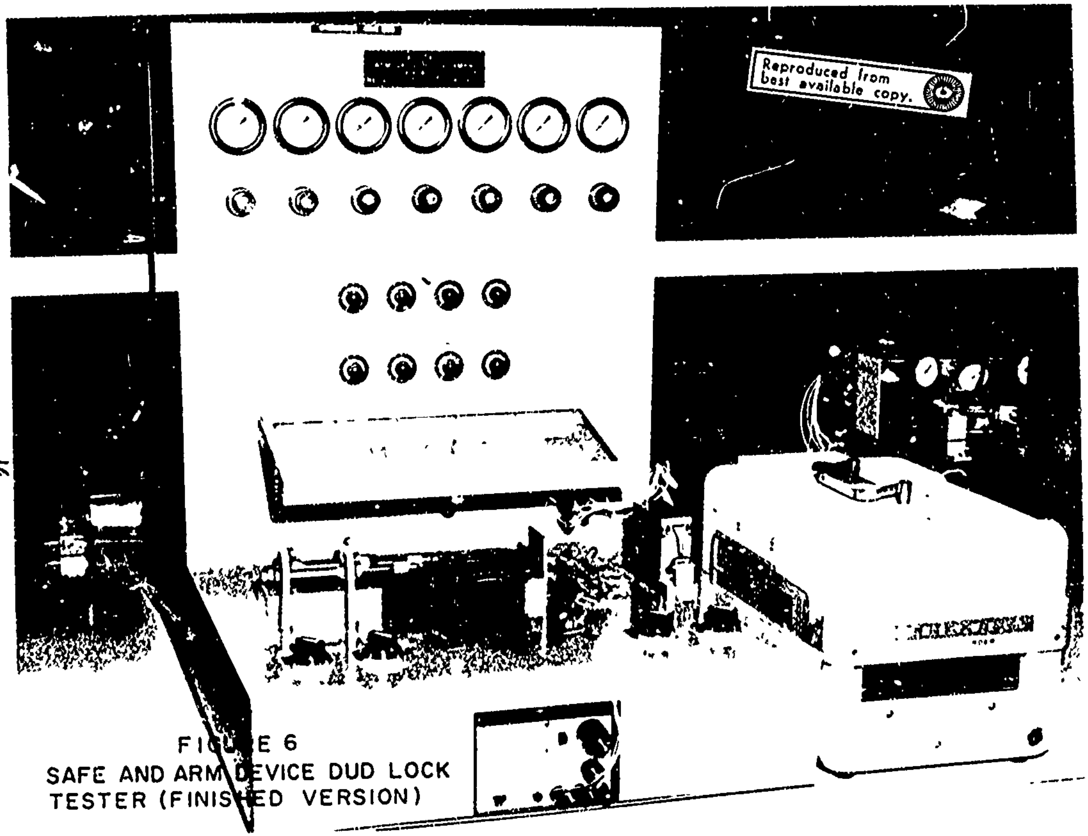

FIGURE 6
SAFE AND ARM DEVICE DUD LOCK
TESTER (FINISHED VERSION)

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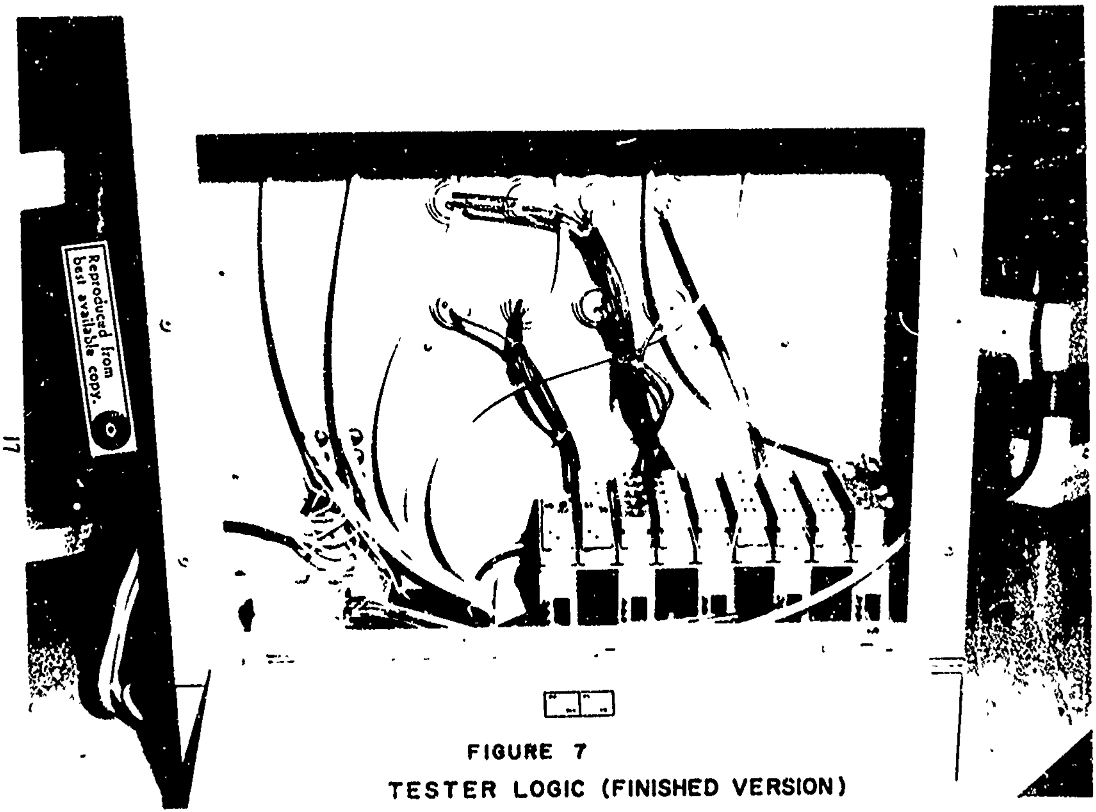

FIGURE 7

TESTER LOGIC (FINISHED VERSION)

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