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AUTOMATIC SATURN V PAGE TEST SYSTEM

W. D. Wylie

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IBM FEDERAL SYSTEMS DIVISION
SPACE GUIDANCE CENTER
OWEGO NEW YORK

ABSTRACT

This paper describes the Automatic Saturn V Page Test System. The system is used to evaluate microminiature Unit Logic Device (ULD) circuits. A page is an assembly consisting of a magnesium-lithium frame, an input-output connector, test points, and multilayer printed circuit boards that interconnect the ULD's into logic circuits. The test system automatically performs tests for shorted voltages and shorted diodes, static logic function, and pulse function.

The advantages of this test system include the reduction of operator error, repetitive testing, error print-out of test failure, and reduction of test time.

The mechanical packaging design considerations include the high density logic card packaging, human factored control panels, cam controlled thermal test, miniaturized test point adapter, and common page adapter design.

The factors involved in the design of the test system and mechanical packaging considerations are discussed.

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AUTOMATIC SATURN V PAGE TEST SYSTEM

W. D. Wylie

International Business Machines Corporation
Space Guidance Center
Owego, New York

SUMMARY

This paper describes the Automatic Saturn V Page Test System and the mechanical packaging features employed to automatically test Saturn V Logic pages. This test system has been in service for over eight months, testing logic page assemblies which form a part of the Saturn V Space Guidance Computer. The factors which were considered in the design of the Automatic Saturn V Page Test System are discussed.

INTRODUCTION

The Saturn V Computer employs a microminiature circuit device in which separate component parts are deposited on a ceramic substrate. To interconnect components, a metallic line and land pattern are screened on to the substrate, after which diode and transistor chips are added. Metal clips are installed on two sides to provide the input and output connections. This assembly (Figure 1) is called a Unit Logic Device (ULD). The ULD's are soldered to a multilayer circuit board to form specific logic functions. Interconnecting feed through pins, test points, and a ninety-eight pin input and output connector are assembled to a magnesium-lithium frame. This completed assembly is called the Saturn V Logic Page (Figure 2). Extensive testing is required to assure that only pages of extremely high reliability are placed in the Saturn V Computer.

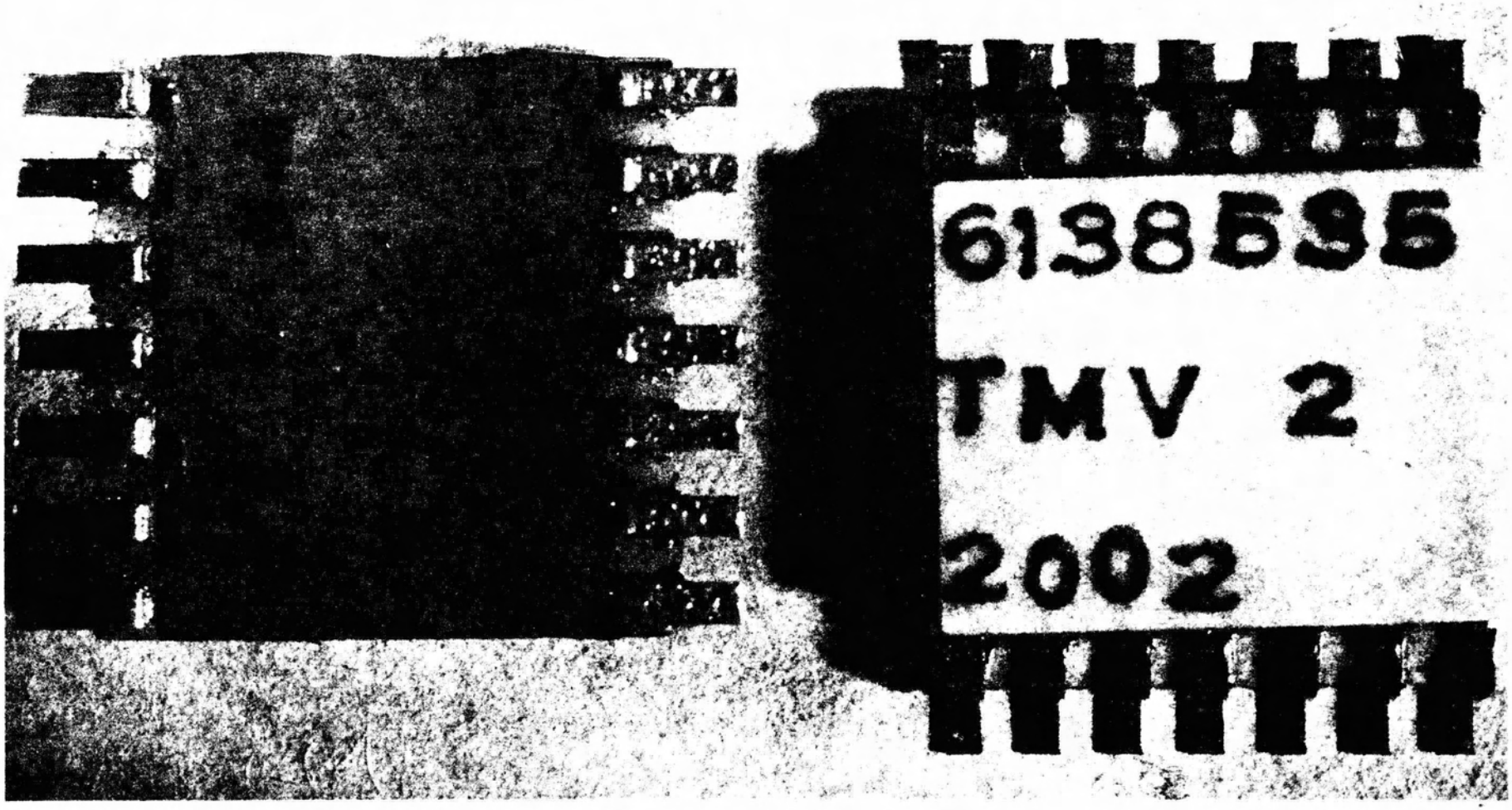

Figure 1. Unit Logic Device (ULD)

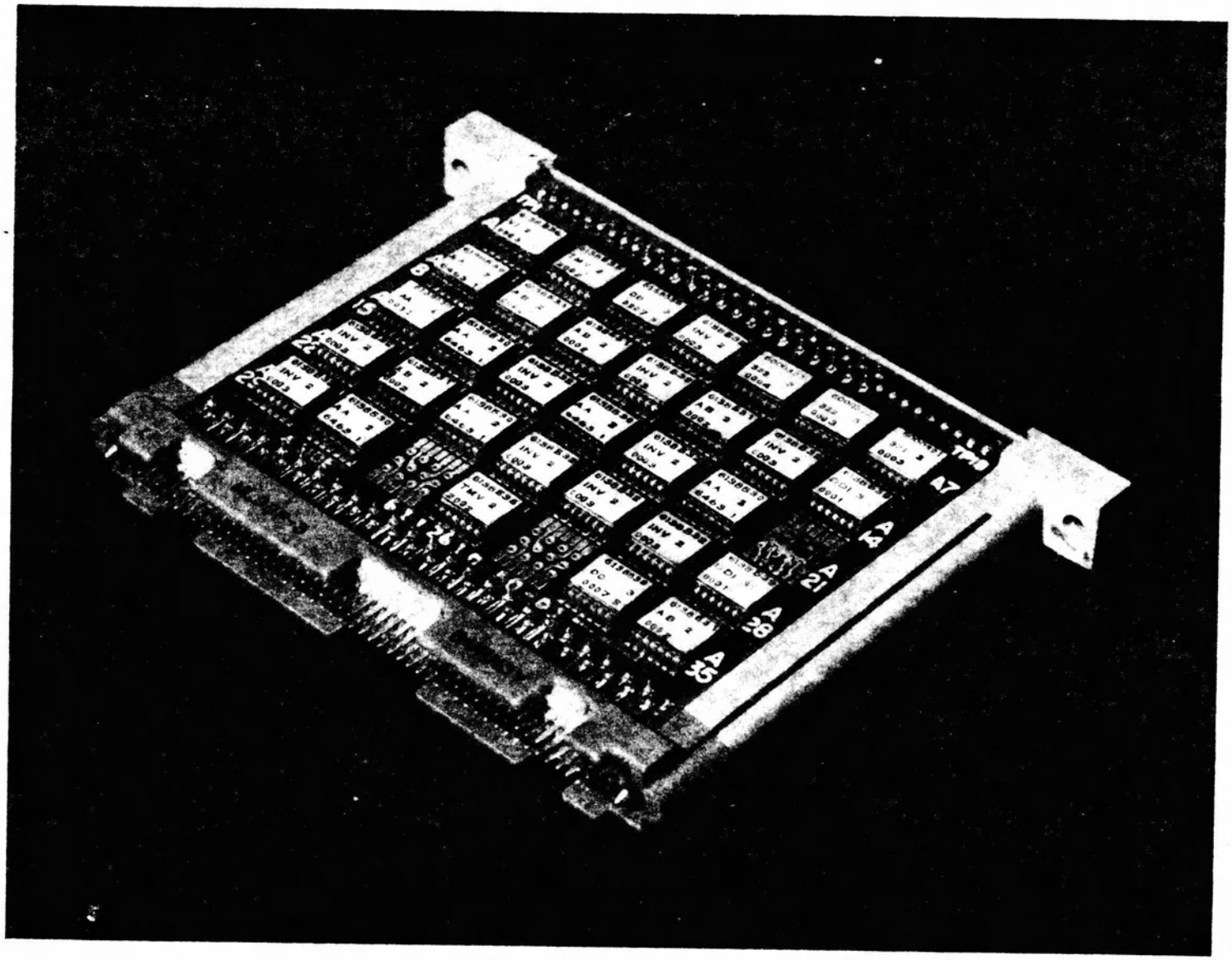

Figure 2. Saturn V Logic Page

AUTOMATIC TEST SYSTEM DESIGN CONSIDERATIONS

The consideration of design philosophy and packaging technique places a major challenge on the design engineer. He must be aware of schedules, cost, and, most important, the function of the device being designed. The test system must perform to meet all test specifications prescribed and still be maintainable, reliable, and easily operated. Automatic test systems are more expensive than manual testers and the preparation of an automatic test program is more complex than the preparation of a manual test procedure. Therefore, these facts place a greater challenge upon the design engineer to be more creative and flexible in order to produce a test system to meet the accuracy demanded.

TESTS PERFORMED

The test system performs four main tests (Figure 3):

- Dynamic Pulse Test
- DC Logic Test
- Shorted Voltage Test
- Shorted Diode Test

Each page circuit output is tester analyzed to assure that it meets predetermined test limits. The failure of a page to meet any test requirement is cause for rejection. Dynamic pulse tests on selected page inputs are pulsed 100 times (as required by specifications) while the associated outputs are continuously analyzed for failure. One pulse failure is cause to reject the page.

DC logic inputs are tester supplied to the page under test and the outputs are checked by a high speed digital voltmeter under simulated output loads.

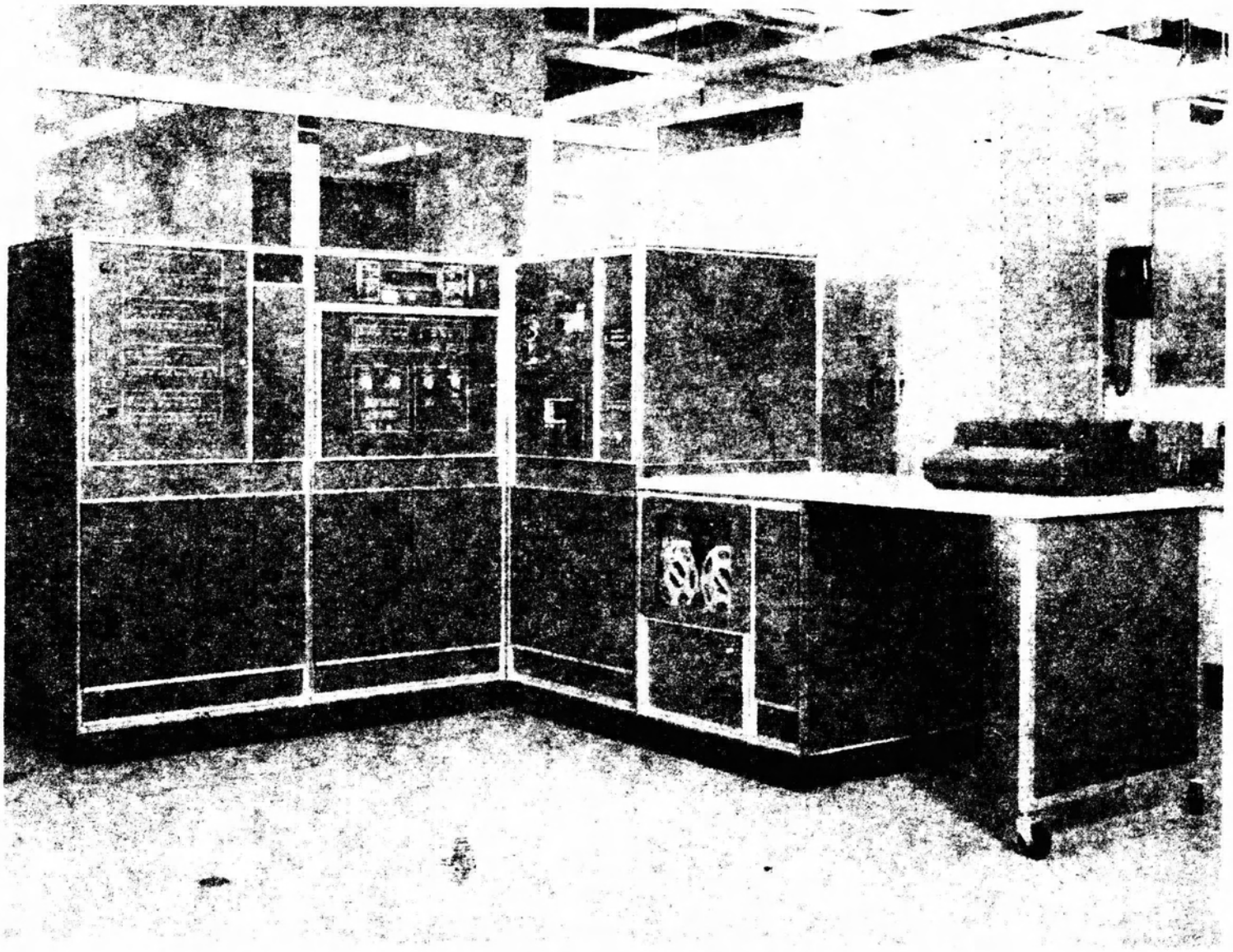

Figure 3. Automatic Saturn V Page Test System

Each output is compared against programmed test limits in a parallel comparator, and a Go-No-Go output is given. Test outputs not normally available at the input-output 98-pin page connector are brought out to the 36 test points for testing purposes. DC logic tests are performed a minimum of 18 times on each circuit during a thermal cycle, which is discussed later in the paper.

Shorted voltage tests are performed on the logic pages prior to the pulse and DC logic tests to prevent damage to the page when power is applied during these tests. The input voltage lines are resistance tested against each other to assure that no shorts exist. If the resistance between voltage lines is less than the predetermined resistance test value an indicator light indicates that a short exists. In this case the operator can not accidently apply power to the page; thus, he must reject it.

Each diode on the page is tested for two types of shorts. The first test is for an actual short across the diode. Few shorts of this nature occur. The second test is for solder shorts acorss the ULD contacts, which would cause a shorting out of the diode. Power is supplied to the diode under test through a current limiting resistor to prevent damage to other components during the test. The voltage across the diode is monitored by a digital voltmeter and the output is compared against the test limits. A shorted diode is indicated by a low voltage reading across the diode which is cause for rejection of the page. If a page is rejected due to voltage or diode shorts, it must be repaired and retested before the pulse and DC logic tests are performed.

When errors are detected during any of the above tests, automatic error print out is made on an IBM input-output Selectric® typewriter. This feature relieves the operator of the task of hand writing rejection sheets plus the fact that such print outs are accurate.

AUTOMATIC TEST SYSTEM ADVANTAGES

Although the expense for the development and manufacture of an automatic test system normally is more than for a manual type, several factors warrant the use of an automatic system.

Normally, test programs have a life span of three to five years. During this span an operator spends a minimum of eight hours a day, and during peak production periods he will spend as much as twleve hours a day at the test console. Therefore, operator fatigue would be a cause for error. The automatic functions of the tester greatly reduce the possibilities of such error. The main functions of the operator are reduced to the following:

- Select the proper program tape and install the tape in the Tape Reader Unit.
- Slect and load the proper page to be tested in the Page Test Adapter.
- Place the Page Test Adapter in the oven in test position.
- Start the test and observe the control panels and IBM Selectric Typewriter for indication of error of the page under test.

Since the functions of the operator are held to a minimum and the functions of the tester are automatic, operator error and test time are held to a minimum.

The automatic page test system employs an eight-channel Mylar* tape which is used in conjunction with the tape reader (Figure 4). This tape automatically provides specific test input data for testing a specific page type. The generation of the test starts with a programmer who manually generates the test program. This data is transmitted to an IBM 1401 computer which in turn produces a card deck, which is later used for change reference, and a Mylar program tape. Thus, by using a program tape for test programs, repetitive testing is assured. This eliminates possible human error or omissions which may occur when the test operators are relied on to perform repetitive testing.

The Mylar tape provides the automatic test data to the test system while the IBM Selectric Typewriter provides the manual input to meet random requirements such as serial numbers or special test data. This test system includes the advantage of a complete thermal cycle test which provides the same environment for all pages. Normal thermal cycles are conducted in a temperature range from 10° C to 85° C through three cycles. Features relative to thermal testing are discussed later in this paper.

Further advantages of using the automatic system include common page test adapters, common usage of existing hardware items, and standard packaging and safety, all of which were utilized in the development of this test system.

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* Trademark of E. I. duPont deNemours Company

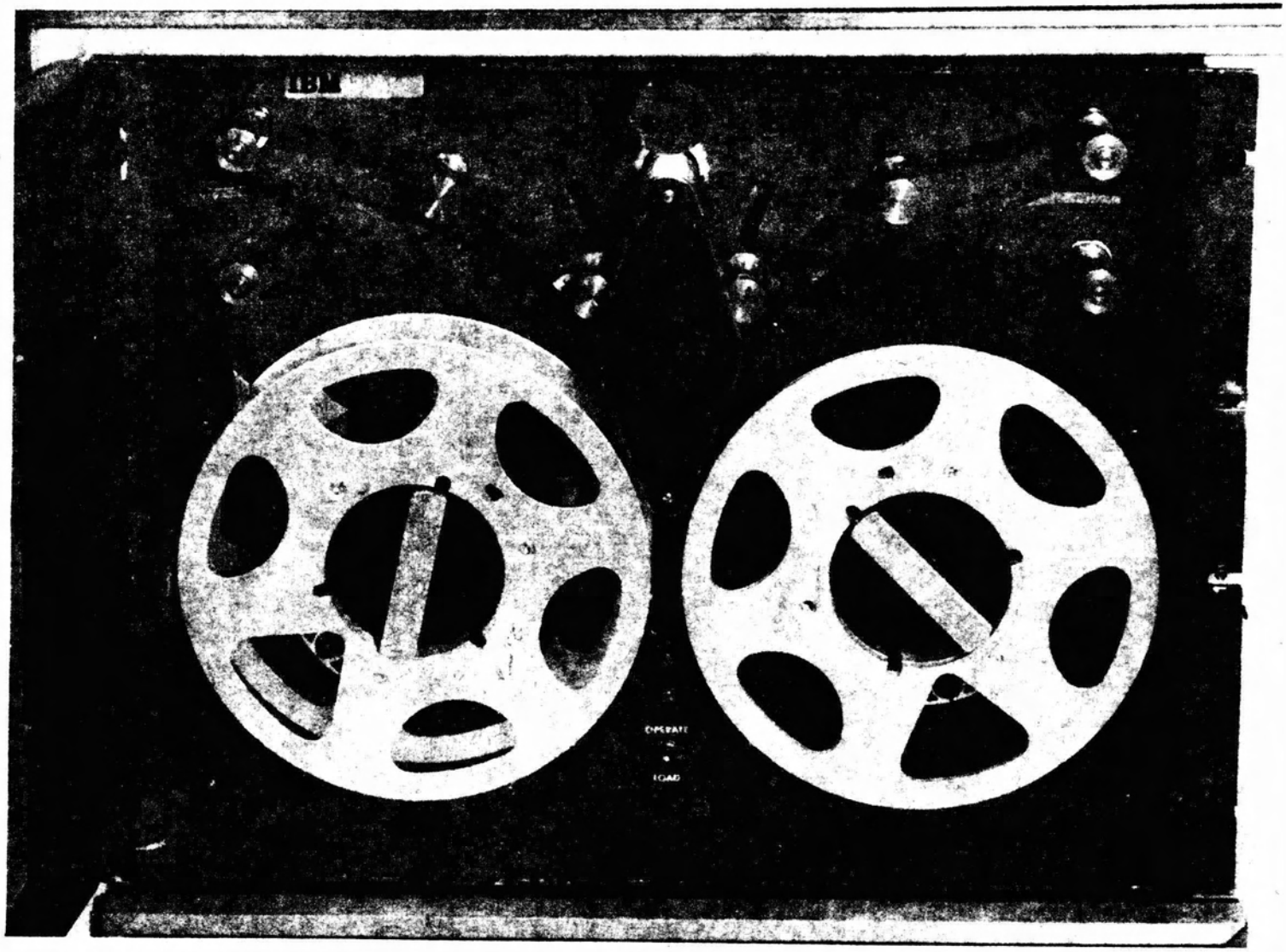

Figure 4. Tape Reader

MECHANICAL DESIGN AND PACKAGING

Mechanical design considerations for a tester of this size require a considerable amount of planning to keep cost at a minimum while at the same time provide the necessary displays, reliability, maintainability, and function.

The main housing for this tester utilizes three standard IBM modular double cube frames, each of which are 30 inches wide, 60 inches high, and 30 inches deep, and one single cube frame which is 30 inches high, together with standard modular components for mounting logic printed circuit cards and modular power supplies. The selection of standard modular parts was made due to low cost, fast delivery, and compatability with the general packaging requirements.

The tester configuration is an angular shape which resulted from placing two double cubes at right angles to the one remaining double cube and one single cube. A special Formica* topped extension table projecting from the end of the single cube, holds the IBM Selectric Typewriter and serves as a work and writing surface. This configuration also provided the following two important accommodations for this tester:

- An "in-reach" arrangement of all controls for the operator which would not have been so if the design were in-line. Thus, the operator has good accessibility to all controls.
- The 90 wedge opening at the rear of the tester provides a convenient housing for storing the CO_2 bottles which are required for

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* Trademark of the Formica Company

thermal testing (Figure 5). The wedge opening is covered with a perforated top plate to which is attached a sliding curtain which completely encloses the wedge section. The right-angled tester is constructed in two sections so that it may be easily separated and reassembled for moving purposes. Special tie bars mounted to the frame corners, the CO_2 bottle mounting brackets, and the perforated wedge cover provide sufficient strength to hold the angular structure in a rigid position.

LOGIC PACKAGING

Approximately 2,300 printed circuit logic cards are employed to provide the functional circuits for this tester. The major part of such circuits provide the capability for the buffer storage, latches, and/or circuits drives, etc. The greater part of discrete circuit components are assembled on standard IBM Standard Modular System (SMS) printed circuit cards. Special printed circuit cards were designed to meet unique circuit requirements.

Each group of functional logic cards are assembled in card gates. Each card gate holds approximately 120 cards mounted in six rows of receptacle. The receptacles are then mounted in a cast aluminum frame, to provide 0.500-inch spacing for each card. This assembly is then mounted to an outer frame assembly consisting of a cooling fan, outer panel, stop assembly, and frame mounting hinge. This total assembly is mounted to the tester frame at the hinge point to provide a 90° swing of the gate for complete accessibility to both cards and wiring (Figure 6).

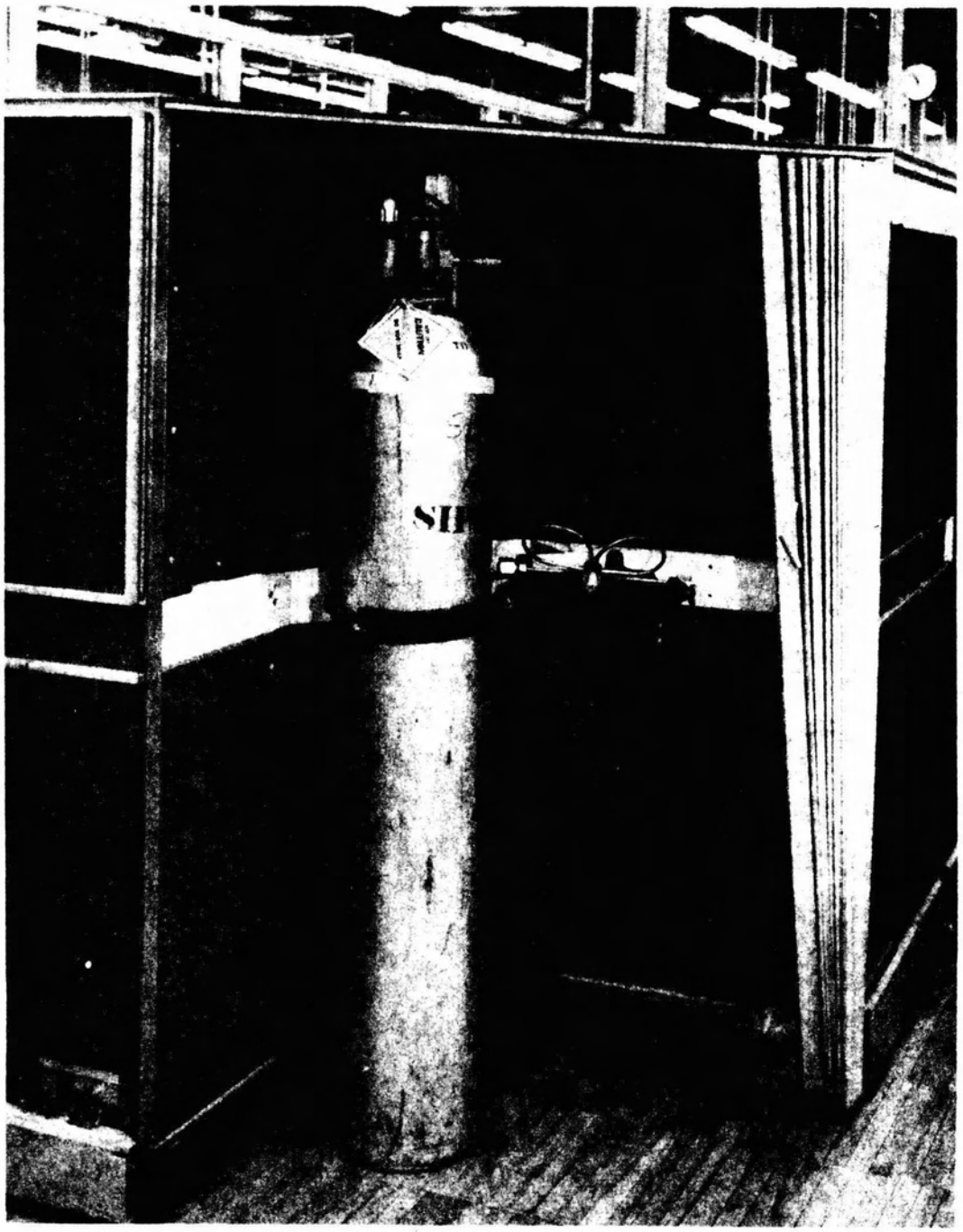

Figure 5. Pie-shaped CO_2 Storage Area

Figure 6. Logic Gate Assembly

HUMAN FACTORED CONTROL PANELS

There are two main control panels used on this system (Figure 7). Each of the panels displays systematic test functions of the test being conducted. Therefore, each test function is set in engraved brackets to correspond with the normal step of the test. This provides the test operation ease of detection in case of an error or malfunction.

During design, each step function was analyzed and placed in sequence with the related function.

The control panels consist of a 0.125-inch thick aluminum plate which is hinged on one side and framed with a 0.375-inch wide brushed and anodized aluminum strip providing a picture frame effect. All characters and bracket lines are engraved and white filled while the main panel is painted with a charcoal color to follow the color scheme of the total tester. The charcoal color was selected because its low reflection quality relieves glare, thus reducing operator fatigue.

SPECIAL PRINTED CIRCUIT CARDS

A tester the size of the Automatic Saturn V Page Tester more often requires special circuits to perform the special functions required over a range of tests. Some 80 different pages are tested by the tester. This tester falls into this category in that many special printed circuit cards were designed. For example, special sense amplifier cards, special load cards for simulation, relay switch cards, and others were developed (Figure 8).

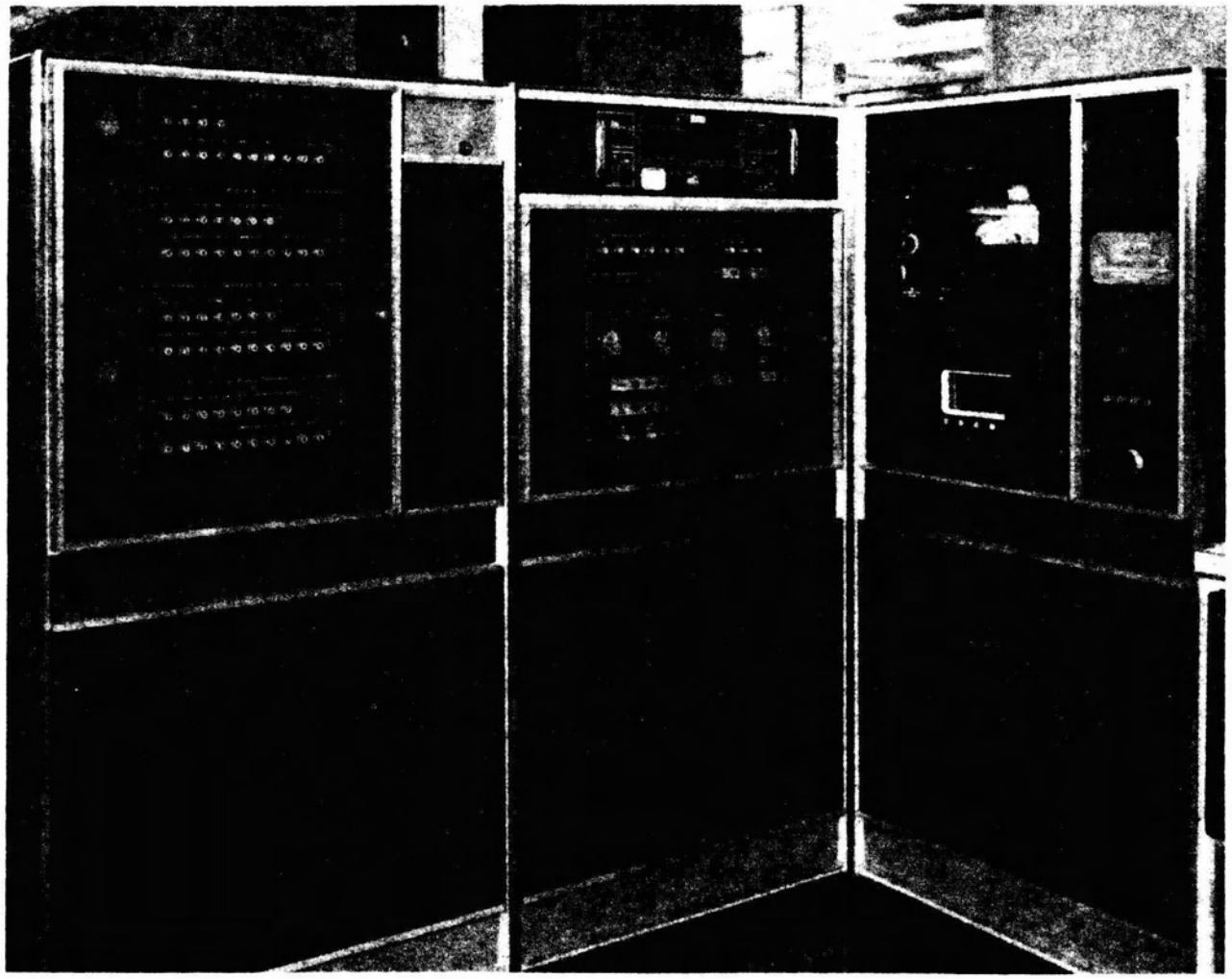

Figure 7. Human Factored Control Panels

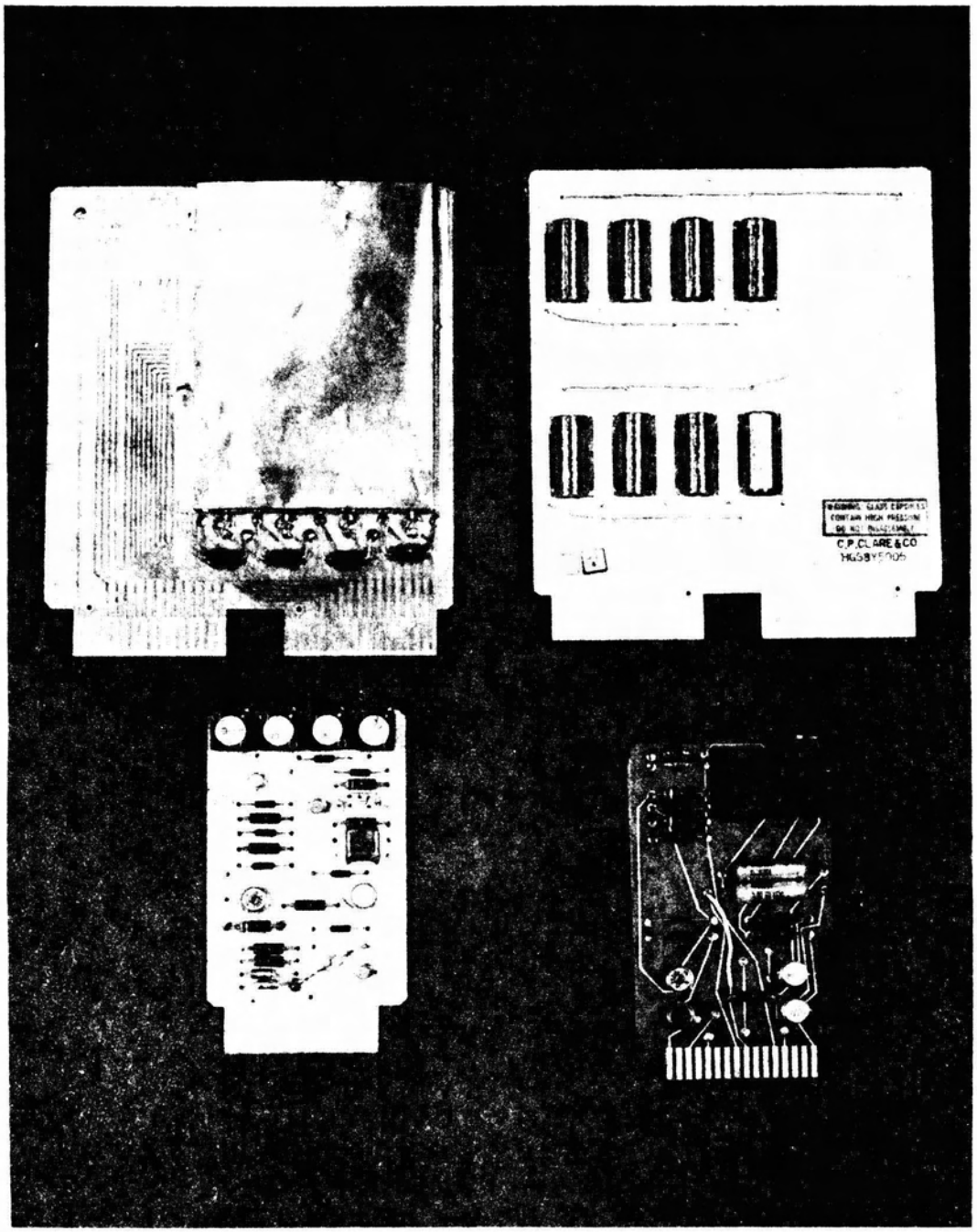

Figure 8. Special Printed Circuit Cards

In general, the special cards were designed to mount on 0.500-inch centers and were fabricated from 0.062-inch thick copper clad epoxy board. The lines and lands were centered to meet the requirements for mounting specific discrete components and input-output requirements.

The special relay cards were unique due to the fact that they were double width to provide space for mounting a total of eight mercury wetted relays and still maintain the standard 0.500 mounting requirements. To eliminate relay dropout, a special mumetal shield 0.005-inch thick was placed over the relays to provide shielding of the magnets which would have caused relay malfunction. Almost all special cards were employed in a special relay matrix located adjacent to the page test fixture in order to relieve the capacitance problem encountered.

TEMPERATURE TEST CONTROL

A space computer is subjected to many degrees of temperature variation. Each page is tested over the temperature range that the computer will be operated.

An oven controlled by a cam operated controller is provided in the page tester (Figure 9). The cam was cut to provide three complete temperature cycles from 10°C to 85°C with a rise and fall time of 10°C per minute. At both high and low temperature, the cam stabilizes the temperature for a period of 4 minutes during which time a complete test iteration is run. Tests are also conducted during the rise and fall times to ensure that each page provides the maximum reliability and function under various temperature ranges.

Figure 9. Thermal Oven and Controller

This tester has also been used for page screen testing. By using special cams, a controlled low temperature of -10°C could be maintained for 30 minutes and high temperature of 100°C for 1 hour. Other combinations of page temperature testing have been conducted by merely cutting a new cam to meet the test temperature requirement.

TEST POINT ADAPTER

Each standard page assembly has a total of 36 test points which are divided into four groups of nine test points. The primary requirement for special page test points is to eliminate probing which may cause solder chips to raise or flake from the multilayer printed line or land, thus causing a short. Two groups of nine test points are assembled to the multilayer board on one side of the page and the remaining test points are assembled in two groups of nine test points on the opposite side of the multilayer board. Each group of nine test points are soldered to the multilayer board in line on 0.080-inch centers. The test point is made of beryllium copper and surface treated with 0.0001 to 0.0003-inch thick electrodeposited tin. The test point is 0.050-inch diameter × 0.032-inch high after assembly to the MIB. The center of this test point is drilled 0.031-inch diameter to a depth of 0.018-inch thus forming a cup or point of contact.

Design consideration for the page test point adapter (Figure 10) indicated that a material requirement to remain dimensional stable under thermal tests was a necessity. Therefore, it was resolved that a clear polycarbonate resin

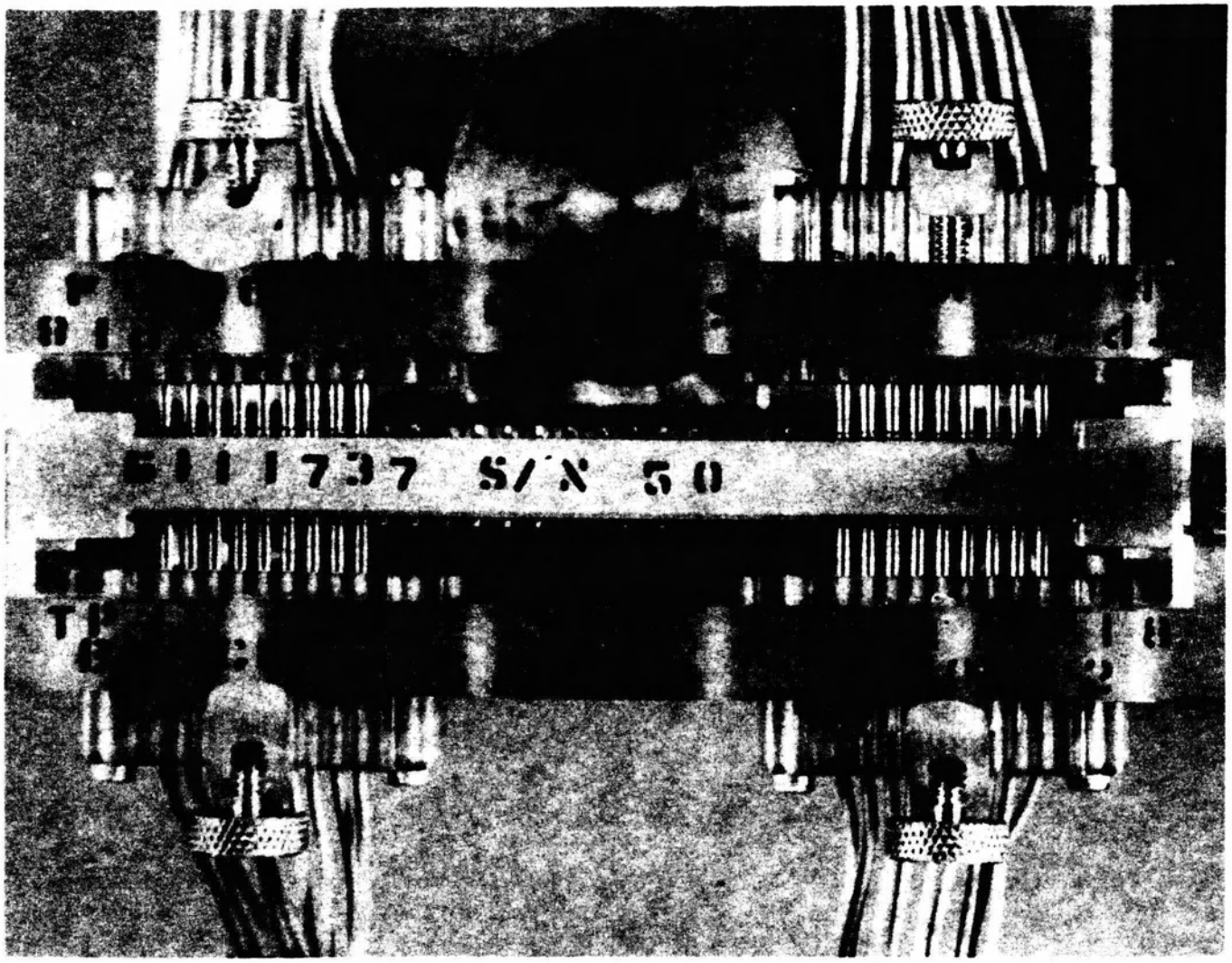

Figure 10. Test Point Adapter

material (Lexan*) would meet this requirement for the main adapter frame and the test point pin blocks. This material has a distortion point of 270 and has good dielectric strength properties. The test point pins are made of beryllium copper 0.047-inch diameter plated gold over nickel with the contact end cone shaped to enter the page test point cup. Contact pressure is applied by a spring providing contact pressure of 4 ounces. The contact and spring are assembled in the contact block which is then assembled to the main adapter frame. The four contact blocks are retained to the main frame by clip jacks which regulate the tension of the contacts mating with the page test points. The main adapter frame is retained to the page assembly by one screw on each end of the page frame. The screws provide the centering ability for the matching of the contacts to the test points. One advantage of using clear material for the frame and contact blocks is that the operator can visibly determine the spring positions in the event of poor spring action. This test point adapter has been in service for several months with satisfactory work reports.

PAGE TEST ADAPTERS

Each page type provides a different electrical function for the operation of the computer. Therefore, the input-output requirements for a page type will vary from one page to another. Simulated loads may be required for

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* Trademark of the General Electric Company

certain page types and not others. In view of this, separate Page Test Adapters are required to provide the isolated test requirements for each page type.

The Page Test Adapter (Figure 11) consist of a fabricated aluminum break-away box, to permit ease of wiring. Assembled to the box is a 152-pin interconnection connector with screw assist for connecting purposes, a 98-pin connector to mate with the page connector, and designated point-to-point wiring and load components which interconnect the two connectors. The box size remains constant, therefore, the fabricated aluminum parts were made on a bulk order basis to reduce cost.

The page is assembled to the Page Test Box by a page guide. This guide is assembled to the test adatper by two thumb screws. The guide provides the alignment of the page connector to the Page Test Adapter connector.

After the page is assembled to the Page Test Adapter the Test Point Adapter is assembled. This assembly is then placed in the thermal chamber (Figure 12) and the page is now in test position.

CONCLUSION

The automatic page test system performs four types of tests: the dynamic pulse test, DC logic test, shorted diode test, and the shorted voltage test. The main purpose of this tester is to provide logic circuit pages to the Saturn V Computer with extremely high reliability.

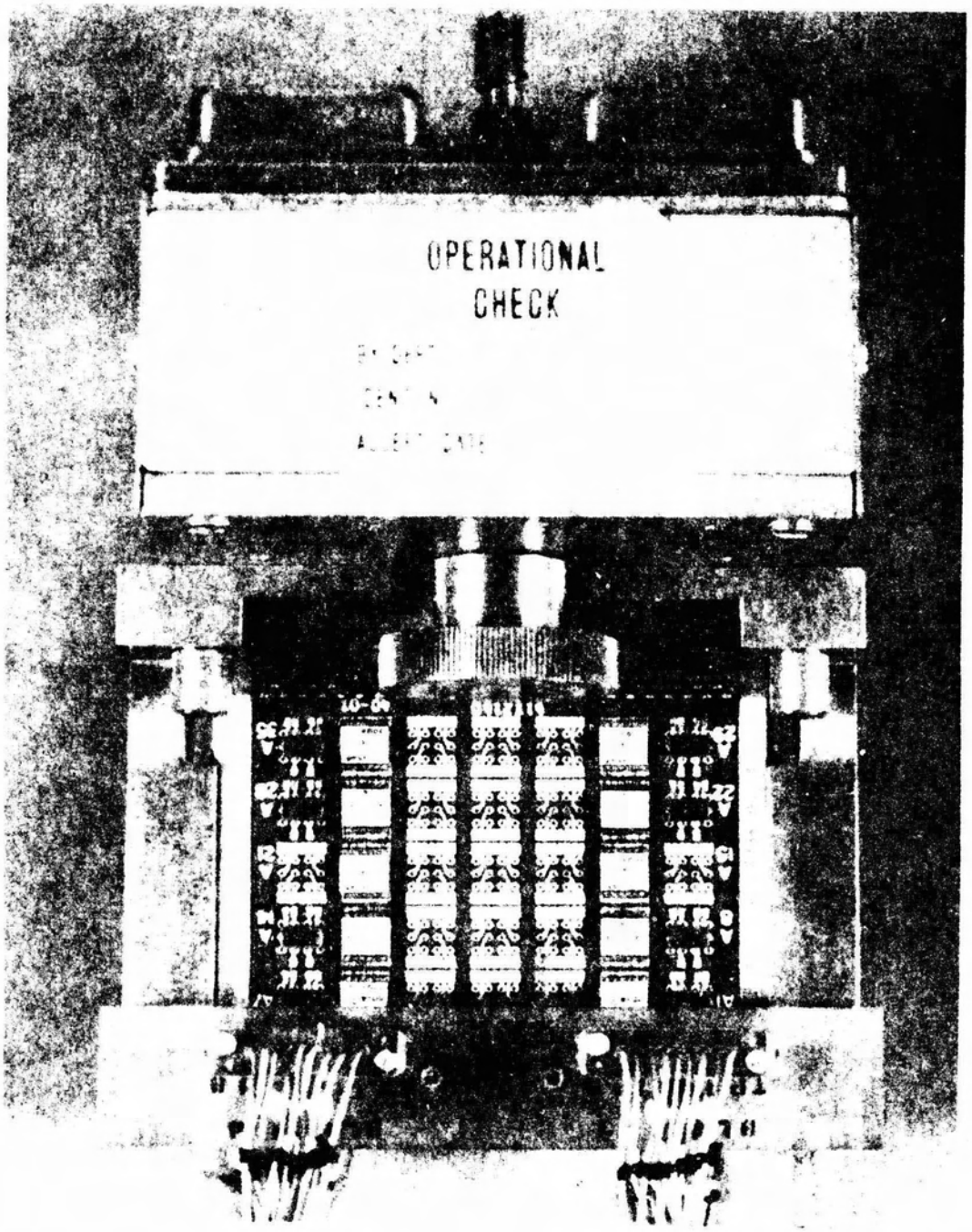

Figure 11. Page Test Adapter

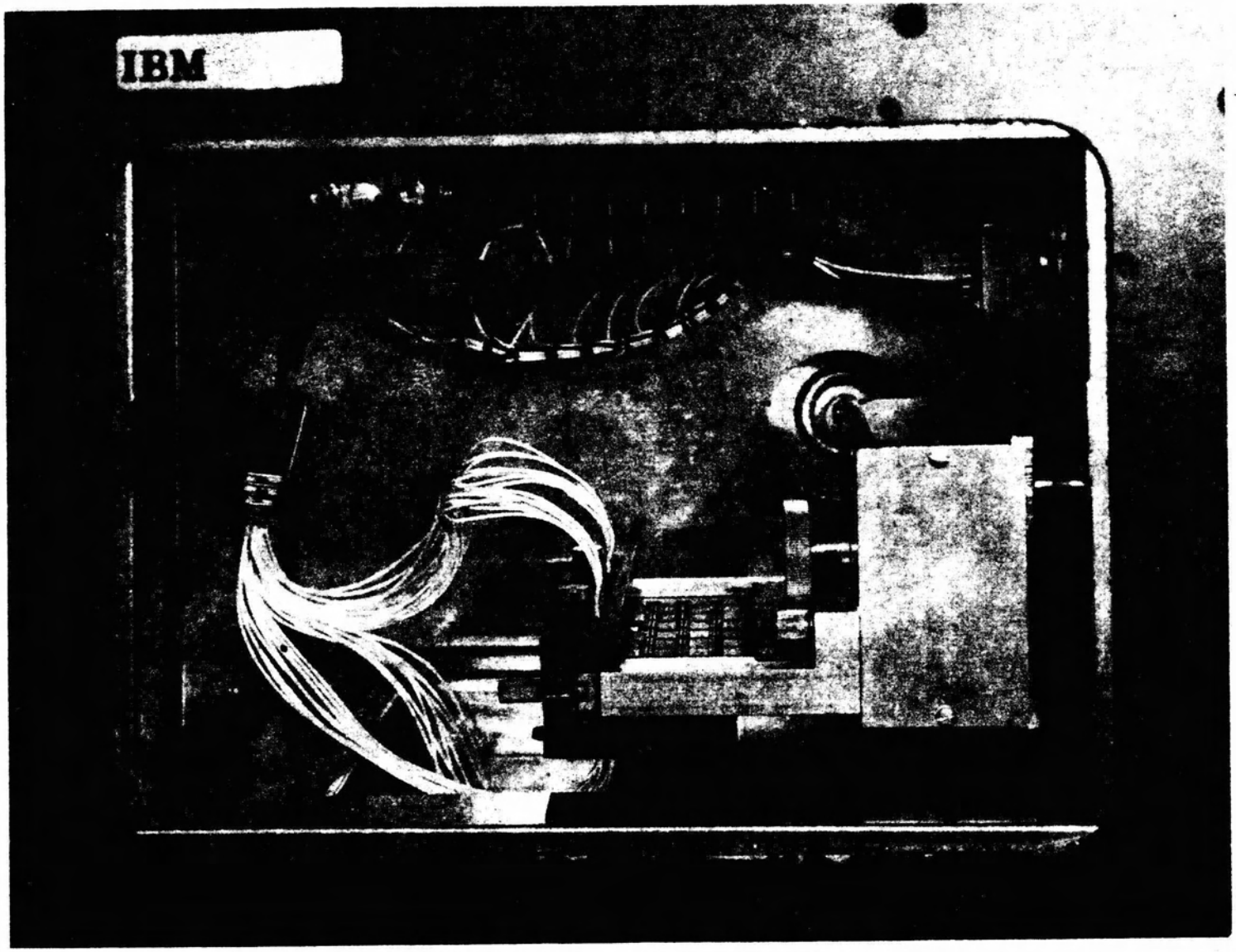

Figure 12. Page Thermal Oven

The advantages of an automatic test system include:

- Reduction of operator error
- Capabilities for repetitive testing using Mylar tape.
- Error print-out defines test failure
- Test time is reduced.

Mechanical design and packaging features describe the configuration of the test system and the mechanical components used for the general assembly. Human factors design considerations were employed to ease operator functions.

Approximately 2, 300 printed circuit cards were employed for the circuit function of this tester. The majority of these cards were standard circuit card; the balance consisted of special cards specifically designed to meet specific circuit functions.

The control panels provide human factored displays on a systematic step function to relieve operator fatigue.

Temperature test control of page functional testing in a thermal range from 10 C to 85 C is conducted by a cam controller unit.

A miniature page Test Point Adapter contacts 36 page cup type test points. Thermal stable materials were used to withstand the test thermal range from 10 C to 85 C. Gold plated spring loaded contacts provides the low resistance necessary to meet test specifications.

A Page Test Adapter is employed for each page type. The adapter box is a break-away construction to permit ease of wiring. Each adapter is wired to meet specific page test function. Load components are wired within the box to provide simulated test loads.

An automatic test system is generally more costly than a manual type system; however, the cost per test is much less due to the speed of test, the capability of repetitive testing, and the elimination of human error.