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DEVELOPMENT AND TESTING OF THE RHO SIGMA INCORPORATED MICROPROCESSOR CONTROL SUBSYSTEM--FINAL REPORT

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TECHNICAL MEMORANDUM

DEVELOPMENT AND TESTING OF THE RHO SIGMA INCORPORATED MICROPROCESSOR CONTROL SUBSYSTEM-- FINAL REPORT

SUMMARY

The intended use for this report is to provide product development information as an aid to the solar heating and cooling systems manufacturing industry in their effort to determine the products adaptability for use in a specifically configured total solar heating and/or cooling system for residential and commercial applications.

This report will also serve as an aid to those who desire to remain abreast of the state-of-the-art of solar energy heating and cooling projects.

The Rho Sigma Controller as developed under this contract had its beginning from a multi-loop system which was implemented as part of a microcomputer based data acquisition system (Fig. 1) as a demonstration of the system's capability. The microprocessor system, because of the data acquisition functions which were included, was larger than needed for the control task and would not sell commercially due to the higher cost. However, it easily controlled several loops and demonstrated what could be done with a programmable controller.

In October 1976, Rho Sigma entered into a contract with the National Aeronautics and Space Administration (NASA)/George C. Marshall Space Flight Center (MSFC) to upgrade the controller to satisfy certain additional requirements to assure that the product could be classified as a marketable product and suitable for public use.

The deliverable end item under this contract was three identical microprocessor control subsystems which could be used in heating, heating and cooling, and/or hot water systems for single family, multi-family or commercial applications. The controller incorporates a low cost, highly reliable, all-solid-state microprocessor which can be easily reprogrammed.

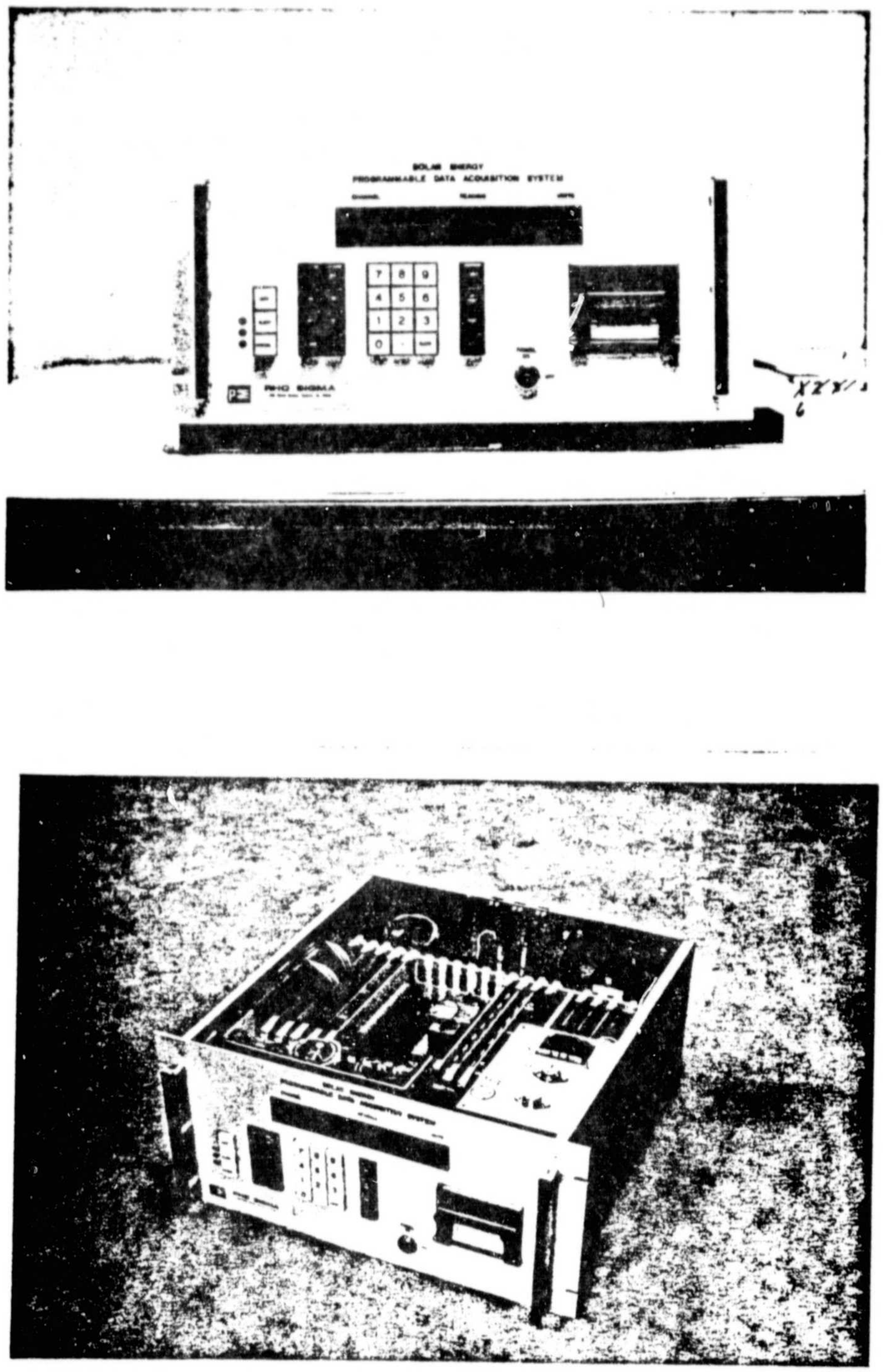

Figure 1. Existing solar heating and control subsystem was implemented in a solar energy data acquisition system.

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At contract completion, three subsystems passed qualification and acceptance test, and were delivered to MSFC. These subsystems are classified marketable for public use.

INTRODUCTION

The problems of energy availability and increasing costs have led to a major national effort to develop alternate energy sources. One such source is the energy in solar radiation, which can be used for heating and cooling buildings, domestic hot water, and other applications. The National Energy Policy, as established in the Solar Heating and Cooling Demonstration Act of 1974 (PL93-409), of which the effort described in this final report is part of, provided for the demonstration within a 3-year period of the practical use of solar heating technology, and demonstration within a 5-year period of the practical use of combined heating and cooling technology. Responsibility for implementing the Demonstration Act was given to the Energy Research and Development Administration (now the Department of Energy). NASA/MSFC manages a large part of this work.

PURPOSE OF THIS PRODUCT DEVELOPMENT CONTRACT

The purpose of this contract was to provide funding to Rho Sigma, Inc. to do additional design, development, fabrication, and test work on their existing subsystem so that each subsystem can be classified as a reliable marketable product for public use.

This second generation system was designed for use with commercial, multi-family dwelling, and complex residential heating, ventilating, and air conditioning (HVAC) systems. Its versatility allows it to be programmed to control any type system where multiple sensor inputs and control outputs are needed.

Contract performance period was from October 18, 1976, through July 29, 1979.

DESCRIPTION OF PROJECT DEVELOPMENT REQUIREMENTS AND CRITERIA

During the development of the microprocessor controller, the contractor was required to:

a) Meet the applicable parts of the interim performance criteria for solar heating and cooling systems.

b) Meet the subsystem performance specifications.

c) Provide test data/analysis to verify that hardware meets the subsystem performance specification.

d) Provide drawings and specifications in sufficient detail to define the configuration and to ensure manufacturing repeatability.

e) Provide installation, operation and maintenance manuals.

f) Provide subsystems and/or component hardware certification by an independent test laboratory (such as Underwriters Laboratory and American Gas Association) to meet nationally recognized standards and codes (such as American Society of Heating, Refrigeration and Air Conditioning Engineers; American Society for Mechanical Engineers; American Standards Institute and American Refrigeration Institute).

DESCRIPTION OF THE RS 600 PROGRAMMABLE CONTROL SYSTEM

The RS 600 Programmable Control System (PCS) (Fig. 2) is a highly versatile, programmable controller. It accepts inputs from a wide variety of sensors and converts them to engineering units. Control equations, customer designated, are then solved and the appropriate outputs occur. Typical of the equations are those used in a solar heating system which include: differential temperature measurement to turn the appropriate pumps on, turning back-up systems on when solar is not enough, and off-peak control for back-up systems.

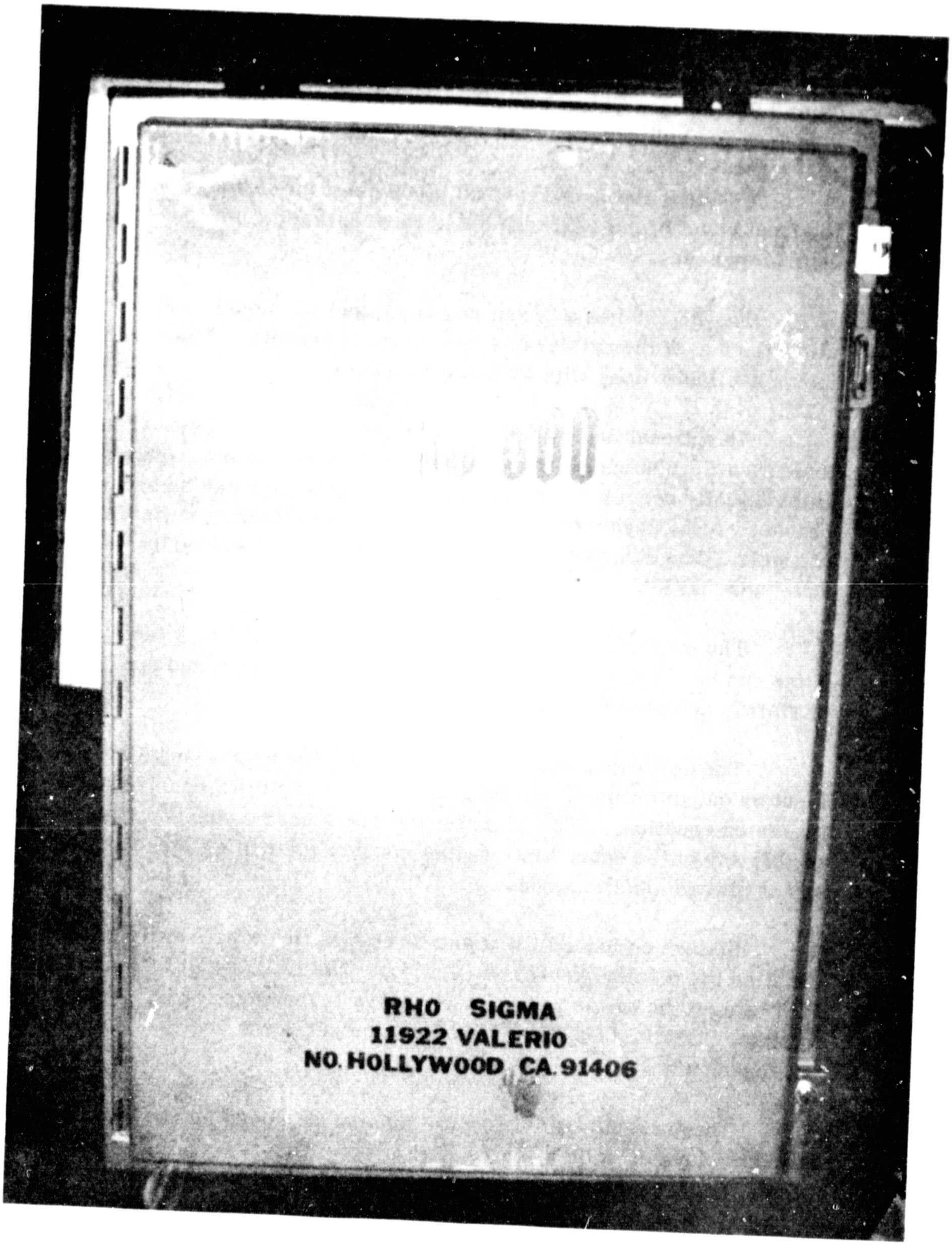

Figure 2. Controller Front with Cover Closed.

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The Control System utilizes a Fairchild F8 microprocessor to perform all timing, control and calculation functions. The microprocessor follows a program which is stored on plug-in, UV eraseable Programmable Read Only Memories (PROM's). These PROM's are changed to customize the system's performance for individual control requirements.

Figure 3 shows the general block diagram of the PCS. Figure 4 shows the front panel of the PCS with the keyboard/display and the output monitor and control switches.

The RS 600 has a "front end conditioning" module which is designed to allow the use of thermistors as temperature sensors. There are 16 such analog inputs available along with 16 discrete inputs.

An optional 5-digit LED display and the 16-key keyboard are mounted inside the RS 600 enclosure as shown in Figures 5 and 6. This display will automatically sequence through all input channels or can be set to monitor one channel via the keyboard. The display is in engineering units for the analog channels. The discrete input channels will be represented by "HI" or "LO" for "ON" and "OFF".

The display also will show the time by day of year, hour, and minute. Time can be changed via the keyboard for initialization and updating in the event of startup and power outage.

The keyboard, in addition to allowing the user to monitor a particular input or output channel, can be used to change up to 52 constants used in the programmed equations. The program constants can be changed via the keyboard to modify any of the equations. In this manner system changes can be tried without any hardware modifications.

Sixteen optional LED's and three-position toggle switches are on the same panel as the display/keyboard (Fig. 4). The LED's will indicate an output in the "ON" stage; the toggle switches will allow the user to manually turn each output to either "ON" or "OFF", or to put the output in the "AUTO" state which is then under computer control (Fig. 7).

There are 16 output control signals which can be used either to drive contact relays or solid state relays for operating pumps, blowers, dampers, valves, etc.

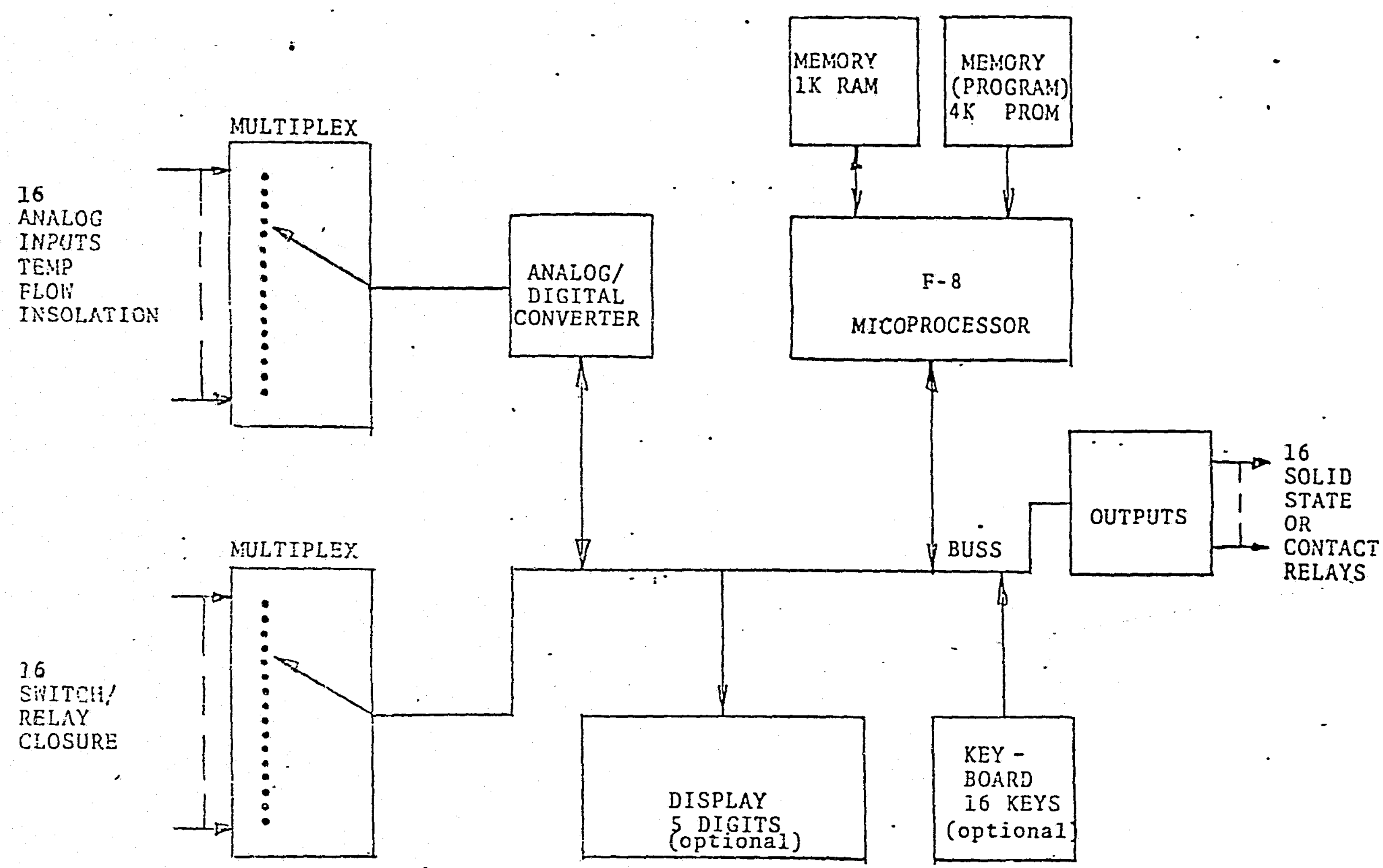

Figure 3. Programmable Control System.

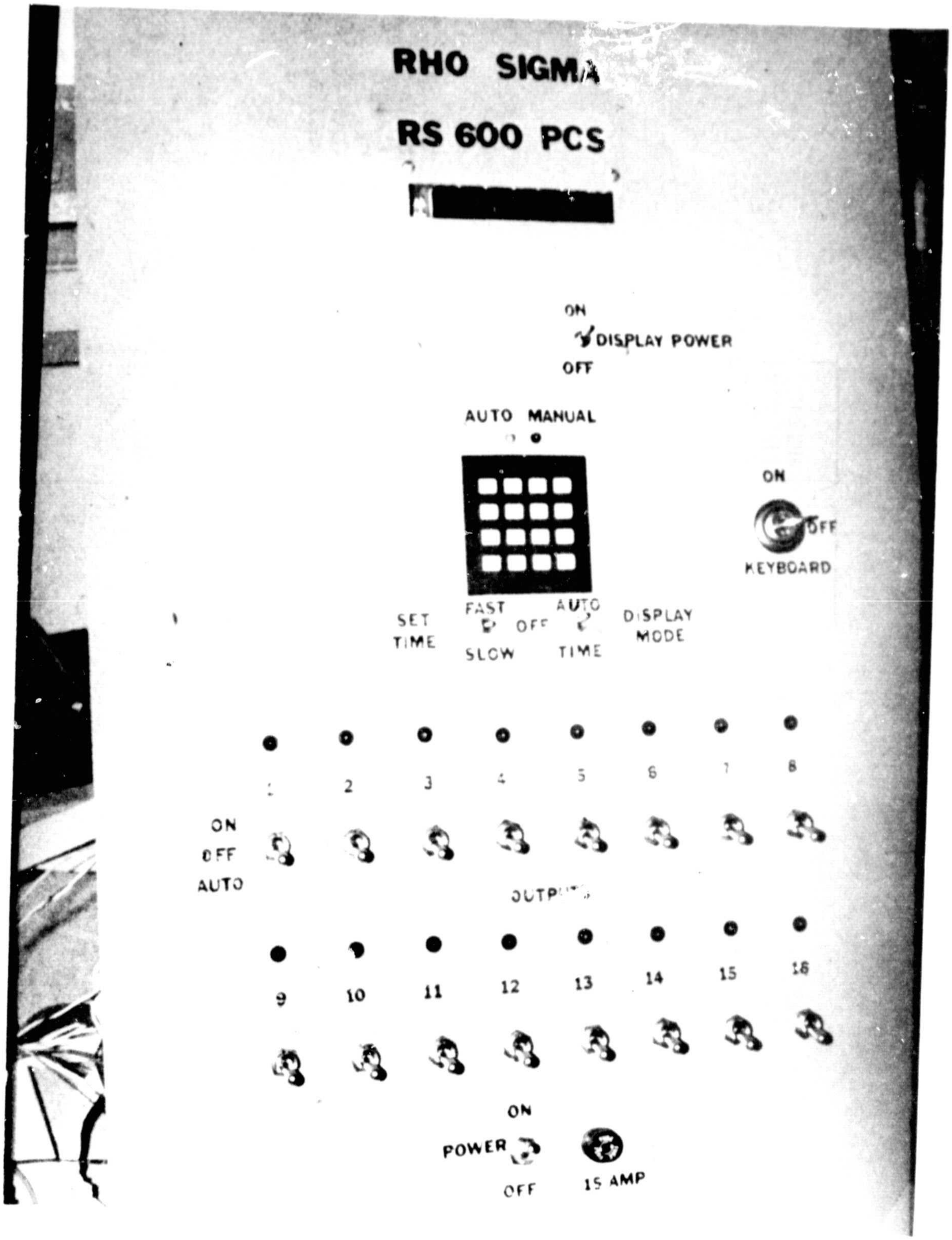

Figure 4. Front Panel of the Controller.

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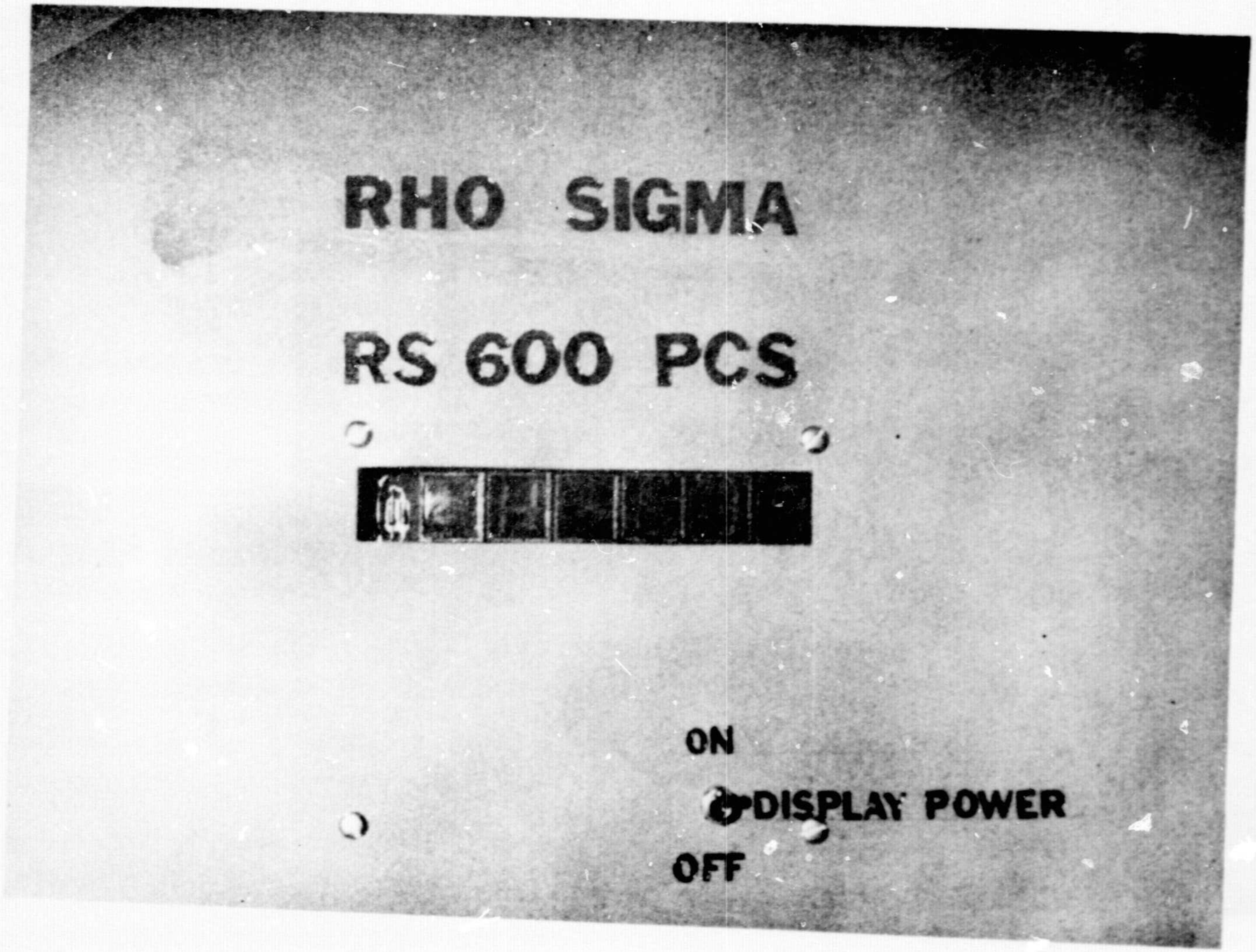

Figure 5. Five Digit LED Display.

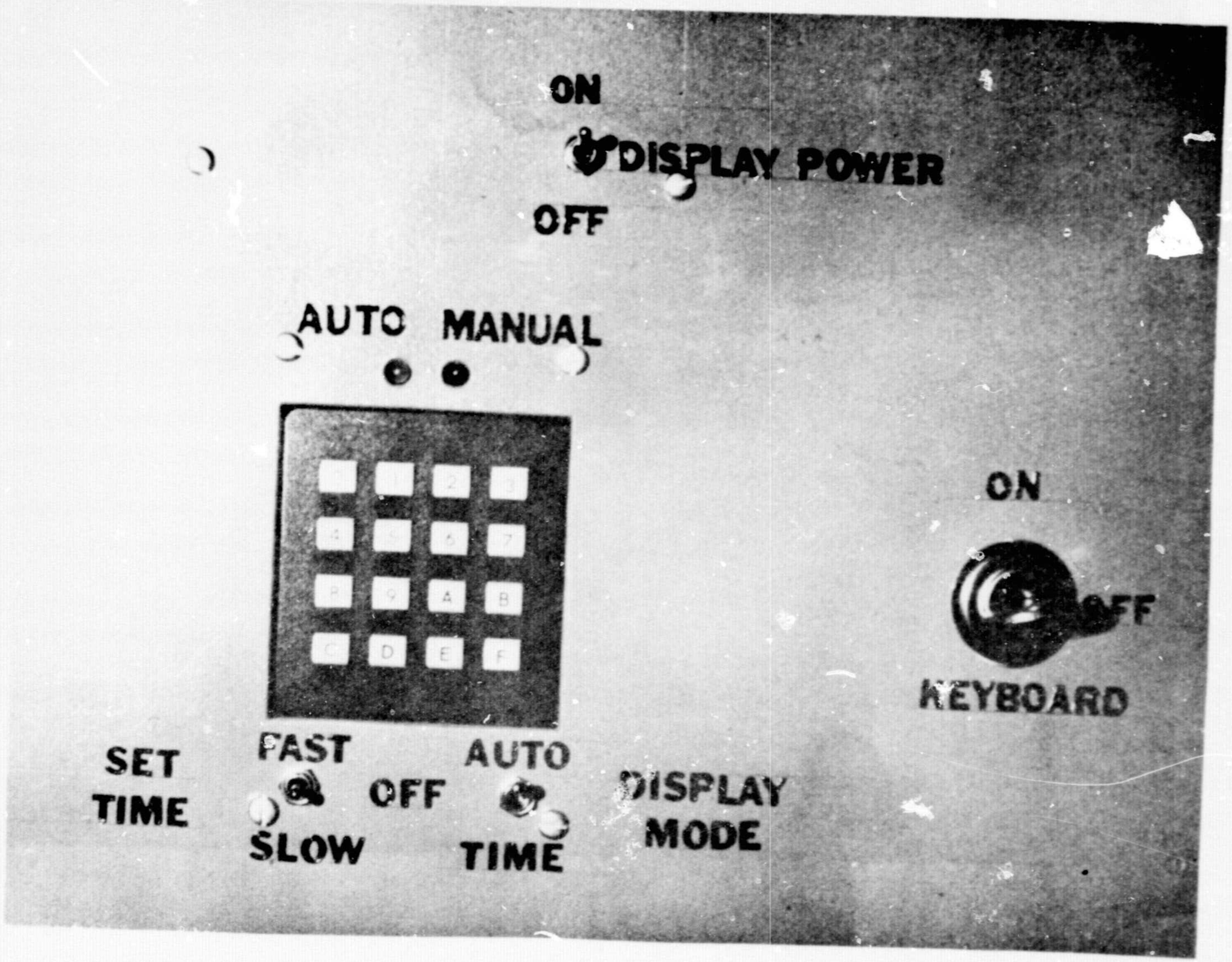

Figure 6. 16 Key Keyboard.

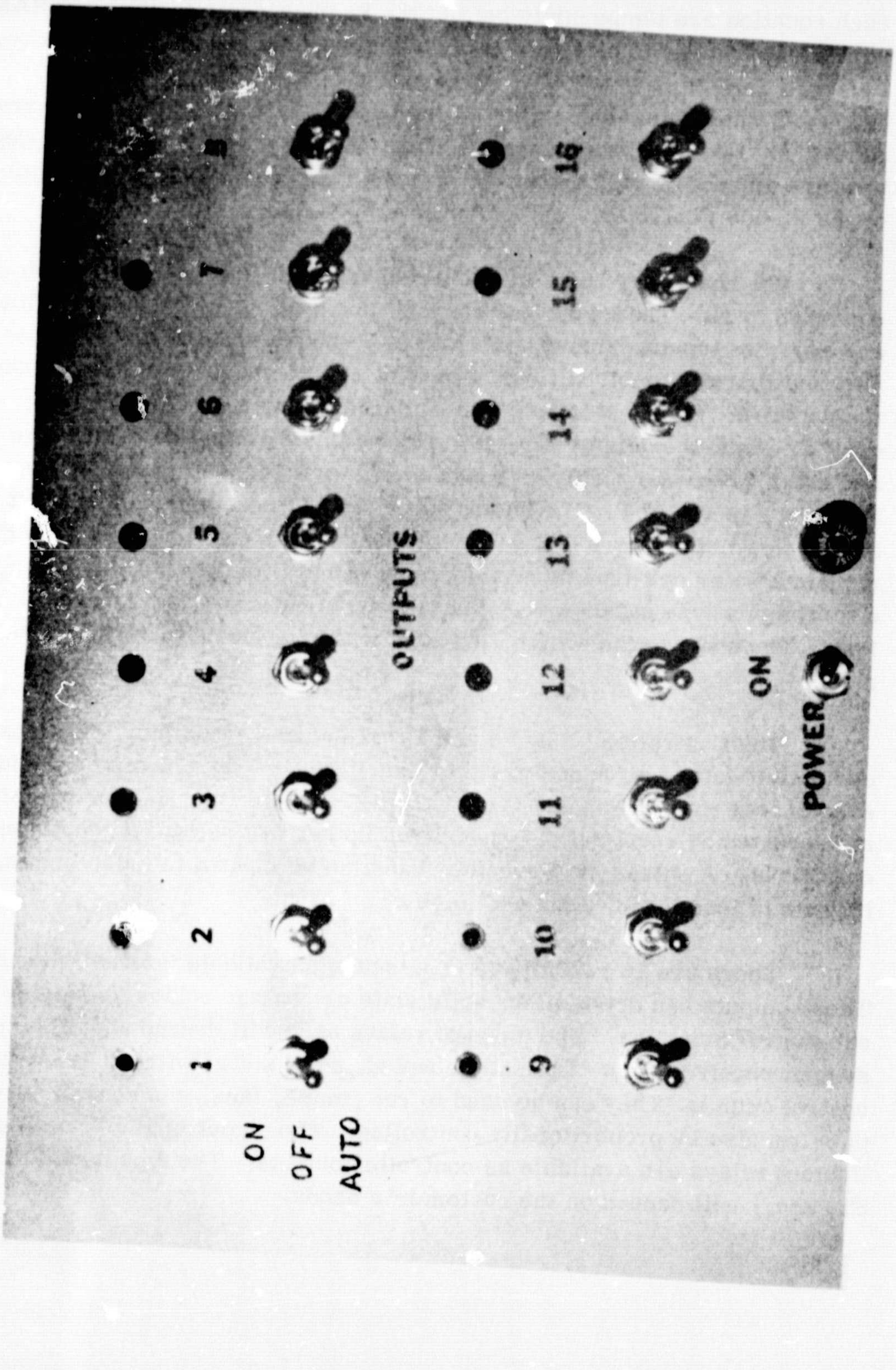

Figure 7. Manual Override Switches.

The controller is programmed to solve a set of logical/arithmetic equations. The equations are contained in PROM's. The associated constants for each equation are temporarily held in the Random Access Memory (RAM) which will allow the user to alter and experiment with the constants via the keyboard.

The following description of the control system applies in general to all RS 600's. However, the exact specifications for any unit may vary, depending upon the amount of customizing or options. Figure 8 presents the basic layout of the RS 600 Controller.

The controller has 8 single ended analog input channels, which can be expanded to 16. The inputs are used for thermistor, pyranometer, flowmeters and switched inputs. Conversion rate is 8 channels/2 sec or 0.25 sec/channel. Optional thermistor circuit cards provide reference resistors for 10000 ohm thermistors. Standard thermistor output is linearized over a range of -40° to +300°F. Each thermistor circuit card contains 8 thermistor reference resistors and a 1.7 reference supply. Power supply drift is 0.2%° C maximum. Linearization error is ± 1.0° F. The analog input can (1) accommodate an input from an analog flowmeter where 0-2 V is representative of the flow, (2) directly accommodate a solar cell type pyranometer input and with optional amplifier, (3) handle a thermopile type pyranometer, and (4) be utilized to handle a switch closure input. To debounce the switch, its input will be scanned twice separated by 200 msec.

The Controller (Figs. 9 and 10) also has 8 transistor transistor logic compatible inputs expanded to 16. Logic 0 is 0+0 V at 1.6 mA or a contact closure of less than 300 ohms. Logic 1 is +2.4 to + 5 V or an open circuit. Debounce is prevented by requiring 2 consecutive inputs, 0.3 sec apart, to act upon new conditions. A pulse type flowmeter can also be inputed to these inputs, provided its rate is less than 240 pulses/minute.

There are 16 relay driver type outputs available internally to the PCS. These outputs can drive either solid state or contact relays to provide 16 different control functions. The types of relays used will depend upon the customer's system requirements. Optically coupled, solid state switches are available as control outputs. They can be used to run pumps, fans, and control valves. Outputs can also be proportionally controlled. The output is 120 V at 10 amps. Contact relays are available as controlled outputs. The type used (DP/DT, SP/ST, etc.) will depend on the customer's needs.

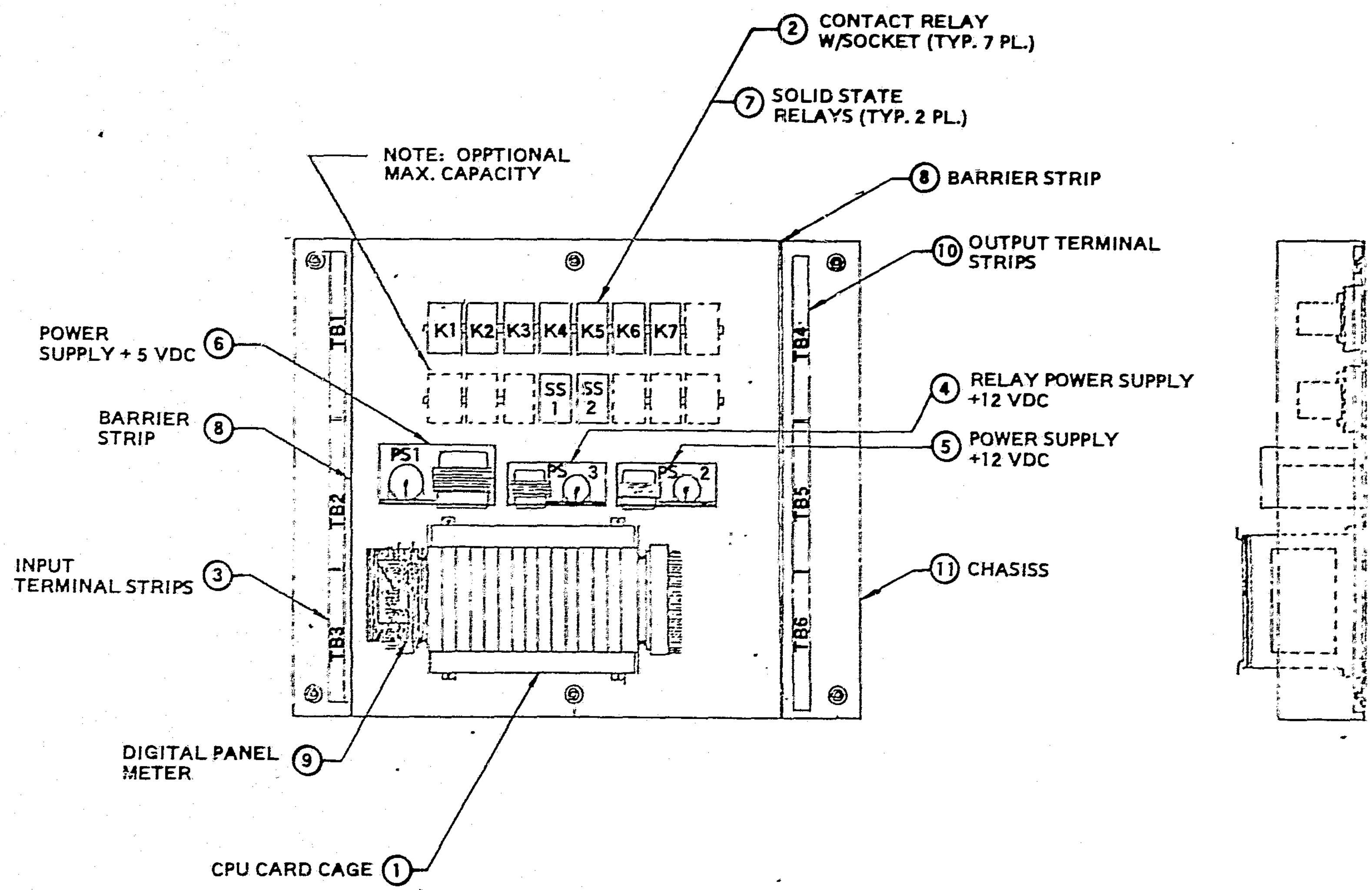

Figure 8. Controller Basic Layout.

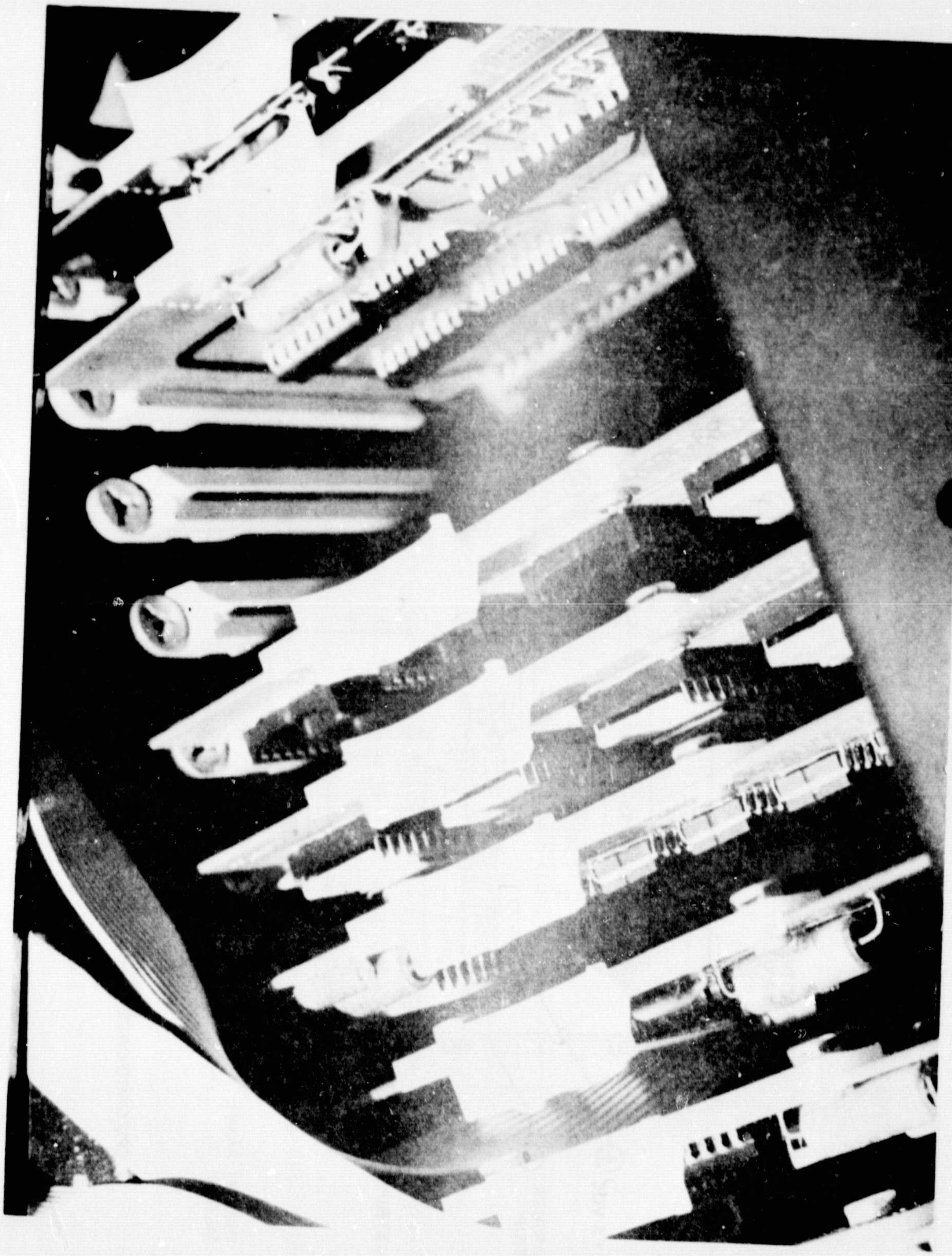

Figure 9. Plug-In Printed Circuit (PC) Board Assembly.

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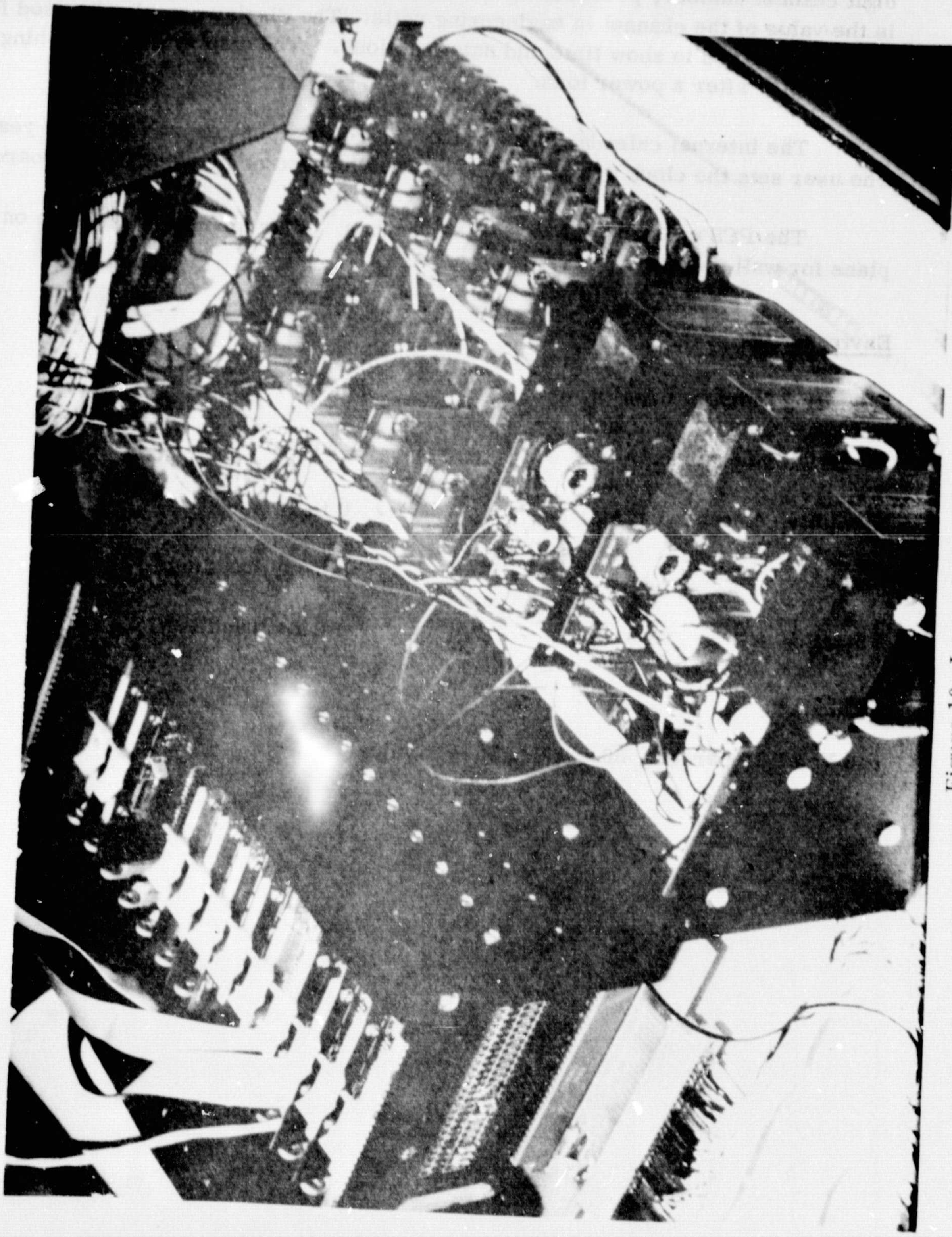

Figure 10. Internal Controller Box.

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The multifunction display of the Controller uses large, 0.6 in. high LED's for good visibility at 25 ft. For each input channel, the display shows the two-digit channel number, proceded by the channel designator. The sequential display is the value of the channel in engineering units. The display can also be used for date entering and to show time and date functions. The display shows flashing time display after a power loss.

The internal calendar clock of the Controller operates on a 365-day year. The user sets the clock with a switch at power turn-on or by using the keyboard.

The PCS enclosure is 20 x 10 x 30 inches. Four mounting holes are on rear plane for wall mounting.

Environment

Operating temperature	0° to + 50° C
Storage temperature	-20° to + 70° C
Humidity (no condensation)	0 to 95 percent
Shock	normal handling
Vibration	normal handling

Power

115 Vac ± 10 percent, 60 ± 3 Hz, 50 W nominal.

CONCLUSIONS AND RECOMMENDATIONS

No major problems were encountered during this contract, and the objective of the contract was successfully accomplished; the delivered Controller passed all acceptance testing and criteria, and are ready for the market.

The developed microprocessor Controller is not an off-the-shelf item and must be customized to each user's requirement.

The obvious application for the Controller is very complex residential, commercial, and industrial solar systems. A not so obvious, but cost effective use is during the prototype and early operational phase of solar systems, which after debugging, checkout and operational verification, would perform efficiently with less sophisticated Controllers. Another very cost effective application, which is extremely desired with solar, is energy management.

Rho Sigma, Incorporated, North Hollywood, California, should be contacted for additional information concerning the RS-600 Programmable Control System.

APPLICABLE DOCUMENTS

1. Preliminary Design Package for RS 600 Microprocessor Control Subsystem, DOE/NASA CR 150628, Contract NAS8-32256, Rho Sigma, Incorporated, North Hollywood, California, January 1976.

2. System Design and Installation for RS 600 Programmable Control System for Solar Heating and Cooling, DOE/NASA CR 150535, Contract NAS8-32256, Rho Sigma Incorporated, North Hollywood, California, January 1978.

3. Quarterly Reports for RS 600 Programmable Controller Solar Heating and Cooling, DOE/NASA CR 150744, Contract NAS8-32256, Rho Sigma Incorporated, North Hollywood, California, July 1978.

4. Proceedings of the First Workshop on The Control of Solar Energy Systems for Heating and Cooling, 1978, pages 193-195, "Government Role in Development of Microprocessor Control Systems for Solar Heating and Cooling," by James D. Hankins, Marshall Space Flight Center, Huntsville, Alabama.

Documents 1, 2, and 3 can be obtained from the Department of Energy, Technical Information Center (TIC), Oak Ridge, TN. Document 4 was published by the Publishing Office of the American Section of the International Solar Energy Society, Inc., McDowell Hall, University of Delaware, Newark, Delaware 19711.

APPROVAL

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The information in this report has been reviewed for technical content. Review of any information concerning Department of Defense or nuclear energy activities or programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

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