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MIUS INTEGRATION AND SUBSYSTEM TEST (MIST)  
DATA SYSTEM

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**MODULAR INTEGRATED UTILITY SYSTEMS**  
improving community utility services by supplying  
electricity, heating, cooling, and water/ processing  
liquid and solid wastes/ conserving energy and  
natural resources/ minimizing environmental impact



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION  
LYNDON B. JOHNSON SPACE CENTER  
HOUSTON, TEXAS 77058

NASA TM X-58201

MIUS INTEGRATION AND SUBSYSTEM TEST (MIST)  
DATA SYSTEM

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## PREFACE

The Department of Housing and Urban Development (HUD) is conducting the Modular Integrated Utility System (MIUS) Program, devoted to development and demonstration of the technical, economic, and institutional advantages of integrating the systems for providing all or several of the utility services for a community. The utility services include electric power, heating and cooling, potable water, liquid-waste treatment, and solid-waste management. The objective of the MIUS concept is provision of the desired utility services consistent with reduced use of critical natural resources, protection of the environment, and minimized cost. The program goal is to foster, by effective development and demonstration, early implementation of the integrated utility system concept by the organization, private or public, selected by a given community to provide its utilities.

Under HUD direction, several agencies are participating in the HUD-MIUS Program, including the Energy Research and Development Administration, the Department of Defense, the Environmental Protection Agency, the National Aeronautics and Space Administration, and the National Bureau of Standards (NBS). The National Academy of Engineering is providing an independent assessment of the program.

This publication is one of a series developed under the HUD-MIUS Program and is intended to further a particular aspect of the program goals.

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# MIUS INTEGRATION AND SUBSYSTEM TEST (MIST) DATA SYSTEM

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## SUMMARY

A historical survey of the development of a data system for use in testing integrated subsystems of a modular integrated utility system (MIUS) is presented. The MIUS integration and subsystem test (MIST) data system is reviewed from its conception through its checkout and operation as the controlling portion of the MIST facility. The efforts of the author and the support contractor in designing, procuring, installing, and operating the system are described chronologically. The main text is not a detailed design description; however, the appendixes are detailed analysis reports that serve as the basis for the MIST data system design.

The MIST data system was intended to provide a real-time monitoring and control function that would allow for complete evaluation of the performance of the mechanical and electrical subsystems, as well as control the operation of the various components of the system. In addition to the aforementioned capabilities, the MIST data system provides computerized control of test operations such that minimum manpower is necessary to set up, operate, and shut down subsystems during test periods.

## INTRODUCTION

The purpose of this report is to document the development of the data system used in testing integrated subsystems of a modular integrated utility system (MIUS) - the MIUS integration and subsystem test (MIST) data system - and to describe the system as it was made operational as a controlling portion of the MIST facility. The acquisition plan for the MIST data system is presented in appendix A; the requirements for the MIST data system are presented in appendix B, written by J. W. Goebel; and the requirements for the MIST controls subsystem are presented in appendix C, written by the Hamilton Standard Division of the United Technologies Corp.

As an aid to the reader, where necessary the original units of measure have been converted to the equivalent value in the Système International d'Unités (SI). The SI units are written first, and the original units are written parenthetically thereafter.

## BACKGROUND

In 1972, a special team of 35 engineers and scientists from the National Aeronautics and Space Administration (NASA) Lyndon B. Johnson Space Center (JSC) was assembled to pursue the design of an integrated utilities system. The purpose of this effort was to determine the overall efficiency of such an integrated system, one in which the waste product of one utility function served as an energy source for another utility function. It was anticipated that fossil fuel consumption, as well as air, water, and thermal pollution, could be minimized through such an integration. The design effort was sponsored by the U.S Department of Housing and Urban Development (HUD) through a memorandum of understanding that specified managerial and financial coordination between the two governmental agencies (the JSC and the HUD).

The initial engineering design studies, prepared during the first year of effort, indicated that favorable results could be obtained within the technical design constraints imposed by the sponsor, the HUD. The most significant of these constraints was the requirement for commercially available hardware in the design. This constraint meant that no major portion of the utilities hardware should require a unique development program. All concepts of accommodating these utilities had to be in terms of "articles of commerce." In addition to this primary ground rule or design constraint, there was at least one other requirement that limited the engine hardware selection to a diesel-powered prime mover.

With these ground rules and the results of studies from the previous year, a competitive procurement effort was begun for the design and demonstration of a test article in which various configurations of utilities concepts could be integrated and tested. The Hamilton Standard Division of the United Technologies Corp. was awarded a fixed-price contract (NAS -13458) and undertook the test article development. The design of the MITS test article (fig. 1) incorporated several utility subsystems, which included the functions of heating, cooling, power supply, liquid-waste processing (sewage), solid-waste processing (garbage), and hot and cold storage. These subsystems were to be integrated, and the working interrelationships were to be controlled and monitored by using a systematic approach to data gathering and automatic readout. However, the costs of the hardware and the integration of the various subsystems did not leave sufficient contractor funds for the monitoring and control functions. Hence, the decision was made in the early stages of the contract to implement only enough instruments to manually operate and control the test article. These instruments would provide the plant operators with an indication of the overall safety and basic configuration status, but manual manipulation and observation of gages and meters in the equipment bay were required to ascertain specific subsystem configuration and status.

It was decided that equipment costs for automation of the plant monitoring and control function should not exceed the costs of manpower that could perform the same job for a test period of only 6 months. For automation of process control and monitoring functions in petrochemical and similar industries, a 5- to 10-year payback on manpower costs as compared to system costs is normally allowed. Obviously, there was little that could be done with the

6 months of equivalent manpower costs; and, therefore, the plant was designed and built for manual operation.

Levied upon the NASA team, however, was the task of evaluating overall performance of the project. This evaluation involved the determination of system integration efficiencies in thermal and energy conservation. Additional instruments were procured by the Government and installed in the various subsystems. These instruments were standard, commercially available process control and monitoring equipment and are described more fully in reference 1. They provided instrumentation output data for flows, temperatures, pressures, and levels. The sensors were installed throughout the system such that the information provided would indicate the energy distribution throughout the plant.

To use the sensor data, it was necessary either to display it on individual meters and readouts (to allow the operators to manually record it for post-test analysis) or to record it automatically on tape and process the tape to provide the post-test analysis data. Because there existed a data acquisition and tape-recording device that could be made available at no procurement cost (Government property) (fig. 2), it was decided to use tape rather than procure the displays and perform the manual recording.

The data acquisition recording device had been used in the thermal-vacuum-testing laboratories in previous test programs. It was more than 10 years old, and the mechanical and electronic components were unreliable.

In addition to the failures of the data-recording device and the resulting loss of test time, another principal problem with the system was discovered. The unit's data scan rate was too slow. The unit was capable of accessing 175 parameters every 1.5 minutes. Hence, only slowly changing data on a few measurements could be monitored in real time. This slow rate did not allow the system to serve as a real-time aid in locating failed sensors. As a result, failed sensors went unnoticed until the test tape had been sent to the NASA Computing Center, processed, and distributed back to the test engineers. This procedure invariably took 1 to 2 weeks. Tests would then have to be rescheduled to make up for the lost data. During a 6-week testing period, many tests had to be repeated because of data system malfunctions or undetected sensor failures.

It now became evident that a reliable data-monitoring system was needed to evaluate the MIUS concept.

#### INITIAL INSTALLATION

From the experiences described in the previous section, it was determined that the data system needed in the MIST should meet the following objectives.

1. Provide real-time display of all instrumented measurements
2. Record data for post-test analysis

(3) Automatically control temperature, flows, and levels so that minimal operational manpower would be necessary

The automatic monitoring and control system in the baseline MIUS design was centered around the use of a minicomputer, with data-gathering interface hardware in the engine room or equipment bay and operator displays in the control room. The baseline MIUS design also specified standard process-control/monitoring instruments and dedicated subsystem monitoring and control equipment for certain portions of the MIUS. Hence, satisfying the MIST test facility data system requirements allowed the demonstration of principal aspects of the MIUS design. In addition, the operating experience that had been gained with the inadequate data system proved valuable in working out the subsystem interrelations with the new data system.

Discussions with vendors of various hardware components that would make up the MIST data system indicated that the minicomputer, its peripherals, the displays, and the data interface units were all competitively priced and available within reasonable delivery times (45 to 120 days). The development of the computer programs that were required was discussed with several companies that provide systems engineering and software development for applications in the NASA complex. It was extremely important that these companies understand the nature of the MIUS Program with respect to economy.

As previously mentioned, the philosophy of initial investment dollars being compared to potential return was very rigid in the test program. This procurement would be of the same type that one would expect in the petrochemical industry, one wherein maximum return on minimum investment is essential.

Another important factor in procurement of the data system for the MIST was the overall time required for the contractual arrangements. There were two contractors who supported the MIST test program and were capable of providing the data system within the allotted time. Their contracts allowed for an additional amount of work sufficient for completion of the data system. The General Electric Co. was selected as the MIST data system contractor.

When a computer system is being procured for a Government installation, there are several formalities that must take place before the computer is contracted for. For example, an acquisition plan must be prepared. This plan briefly outlines the activity and provides sufficient information to the Government management so that a decision can be made as to whether the system merits approval. Various NASA representatives must review and approve the plan. The final approval for the MIST data system was given by the Center Director. A copy of the MIST data system acquisition plan is attached as appendix A.

#### SYSTEMS REQUIREMENTS

The MIST data system effort was awarded to the General Electric Co. under their existing contract (NAS 9-10260), which provides data systems and support to the JSC building 32 test facilities. Justification for the noncompetitive

nature of the contract modification was provided to the NASA management, and the aforementioned effort was awarded as a separate portion of the contract for costs-reporting purposes.

Additional technical discussions were held after the contract was awarded, and the results of these discussions were documented as the basic systems requirements for the MIST data system. A copy of this document is included as appendix B of this report.

#### EQUIPMENT CONFIGURATION

The General Electric Co., in accordance with negotiated agreements, placed the orders for the hardware. Anticipated deliveries were not to exceed 120 days. The hardware items and corresponding suppliers were as follows.

Item	Vendor
Model 716 computer	Interdata, Inc.
Desk drive unit	Diablo Systems, Inc.
Magnetic tape unit	Pertec Corp.
Model 300 card reader	Documentation, Inc.
Model 101 printer	Centronics Data Computer Corp.
Model 400 cathode ray tube (CRT) display	TEC, Inc.
Model 1400 CRT terminal	TEC, Inc.
Data acquisition units	Analog Data, Inc. (ADEC)

The first seven items were delivered within 60 days, and the system was made operational to support the software development (computer programming). Hardware interface programs were developed to allow for communications between the units using the Interdata-computer-supplied real-time operating system. The programs were then developed to meet the objectives of the requirements document.

During the factory checkout of the data acquisition units (fig. 3), a series of component failures occurred and the supplier of the units (ADEC) exceeded the 120-day schedule by 2 weeks.

Further problems were experienced during the field checkout of the data acquisition units. The units were designed to operate under remote control in an equipment bay in order to minimize sensor wire lengths. It was found that the components in the data acquisition units could not withstand the

high relative humidity experienced in the Houston, Texas, area without some conditioning of the air within the equipment <sup>1</sup>NEMA-12 enclosures. Successful operational conditions were achieved by installing a 150-watt light bulb within each enclosure and leaving it on at all times. This procedure raised the inside temperature to a maximum of 310.93 K (100° F) and prevented any internal damage from the local high humidity (fig. 3).

#### SYSTEM DEMONSTRATION

The MIST data system was operated to demonstrate that it met the objectives and satisfied the requirements outlined in appendix B.

The capabilities of the data acquisition hardware were as follows.

1. 64 thermocouples
2. 64 thermocouples
3. 128 analog measurements, 0 to 5 volts, direct current, or 4- to 20-milliampere current

Full use of the 256-measurement signal acquisition equipment capability was not intended initially. Approximately 150 measurements were connected to the computer through these three units.

The operational programs were then checked out with the hardware components, and the system was demonstrated. Figures 4 to 7 illustrate the control room equipment, the basic hardware configuration, a sample data screen display, and a sample printout of the log data, respectively.

The advantages of the data system over the manual observation and recording methods used previously were immediately obvious. A measurement that had gone out-of-limits or that had failed was easily recognized when it was displayed by the computer. A warning light was flashed coincidentally with the failed measurements so that the operator could locate the measurement on its respective page if it was not being displayed at the time. Hence, the condition of all sensor equipment and the data acquisition equipment was evident during the operation. Proper action could then be taken to correct the malfunction, as necessary. Acknowledgment of the malfunction would suffice if the operator wished to ignore the failed measurement.

The utilization of such a real-time monitoring system was the primary objective of the initial phase of the MIST data system. The development of this system was achieved with no major problems other than the previously mentioned component failures and their resultant schedule delays. The software development was accomplished on schedule and within the original estimates of required manpower.

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<sup>1</sup>National Electrical Manufacturers Association.

## SUBSYSTEM CONTROLS

The MIST subsystem hardware, as described previously, was designed to be operated in a manual mode. Central controls (fig. 8) - i.e., pushbuttons, etc. - were available in the control room for the operator's use in many instances. However, several primary valves and motors were manually operated in the equipment bay (fig. 9) so that proper operating ranges could be controlled. To automate the subsystems' overall operation, a rework of several heating, cooling, and electrical energy distribution loops was required. The Hamilton Standard Division of the United Technologies Corp., the original designer of the MIST, was contracted for the modification of the MIST hardware. This effort involved the design of the automatic control loops; the installation of the required valves, relays, controllers, and additional pumps; and the specification of the computer programing requirements for automation.

The analysis required to specify the automation program is documented in appendix C, entitled "Requirements Document MIST Controls Subsystem." This documentation is a very thorough treatise on each of the control requirements and serves as the complete discussion of the overall MIST automatic operations. It is this study that details the extent to which the automation of the MIST operation has been brought. The following three types of automation in the MIST are demonstrated.

1. For the functions wherein several variables were present, direct digital control was used. As an example, the heating and cooling loads, which vary on the basis of outside air temperature, water flow rates, and supply and return water temperatures, were designed to be controlled by special algorithms in the computer. The computer outputs the necessary signal to the valve on the basis of its anticipated result.

2. For those functions that varied because of a single factor (such as temperature), a supervisory control concept was used to relate the automatic operation to the overall process. In these cases, the computer establishes a desired operating value and adjusts a setpoint on a panel-mounted analog controller. The controller then interfaces with the valve and performs the automatic operation as required. This concept is widely used in petrochemical plants, wherein a central authority requires knowledge and control of the various operations.

3. In the study of subsystem controls, the computer was not required to be a part of all levels of automation. In some applications, no changes in the correlation with the computer for a controlled item are necessary. For example, in the case of the cooling-tower water temperature, a conventional analog controller controls the condenser water to the temperature required for proper operation of the various pieces of equipment. This temperature control is not varied during different phases of the operation; and should a particular test specify a different condenser water return temperature, it can be achieved by a manual setpoint adjustment and manual balancing of flow through the tower. Again, this concept is one of augmented automatic control used extensively in industry.

The "MIST Controls Subsystem Requirements Document" was provided by Hamilton Standard to the General Electric Co. so that their second-phase effort could be initiated. Then, Hamilton Standard installed the equipment required and demonstrated that the hardware interfaces met the description of the requirements document. The General Electric Co. then tested all the required software (computer program) modules and demonstrated their operation in an integrated test.

## CONCLUSIONS

The MIUS integration and subsystem test (MIST) data system, featuring computerized monitoring and control, was specified, designed, installed, and made operational in the MIST facility. The system was based on the concepts shown in the modular integrated utility system (MIUS) design studies. It provides the operator with all the measurement information on each parameter, and the information is updated once each second. The capability for recording the information is included in the system; so operator logging of data is unnecessary. Automatic control of subsystems based upon the measured variables has been implemented and demonstrated. This system allows for minimum settling time of processes, with little operator manipulation.

Because of the basic features of the MIST data system and because it is comprised of commercially available equipment, its application to other facilities is direct. Instrumentation found in conventional utility plants or industrial complexes interfaces readily with the remote-data-gathering units. Should there be a greater or lesser number of a specific type of measurement (e.g., thermocouples), the units can be configured accordingly. Additionally, the monitoring, alarm, display, recording, and logging functions are available to be used for performance evaluation purposes.

The MIST data system was demonstrated to the engineers and architects associated with MIUS development at the St. Charles, Maryland, site. In the discussions that followed, it was resolved that the real-time status monitoring and control of the various functions that were demonstrated here are directly applicable to the MIUS site equipment.

Lyndon B. Johnson Space Center  
National Aeronautics and Space Administration  
Houston, Texas, April 29, 1977  
386-02-00-00-72

## REFERENCE

1. Beckham, W. S., Jr.; and Keune, F. A.: The MIST (MIUS Integration and Subsystems Test) Laboratory: A Testbed for the MIUS (Modular Integrated Utility System) Program. Chamber of Commerce Proceedings of the 1st 1974 Technology Transfer Conference, 1974, pp. 107-120.



Figure 1.- Hamilton Standard test article for the MIST, showing piping and integrated hardware (NASA S-74-23335).

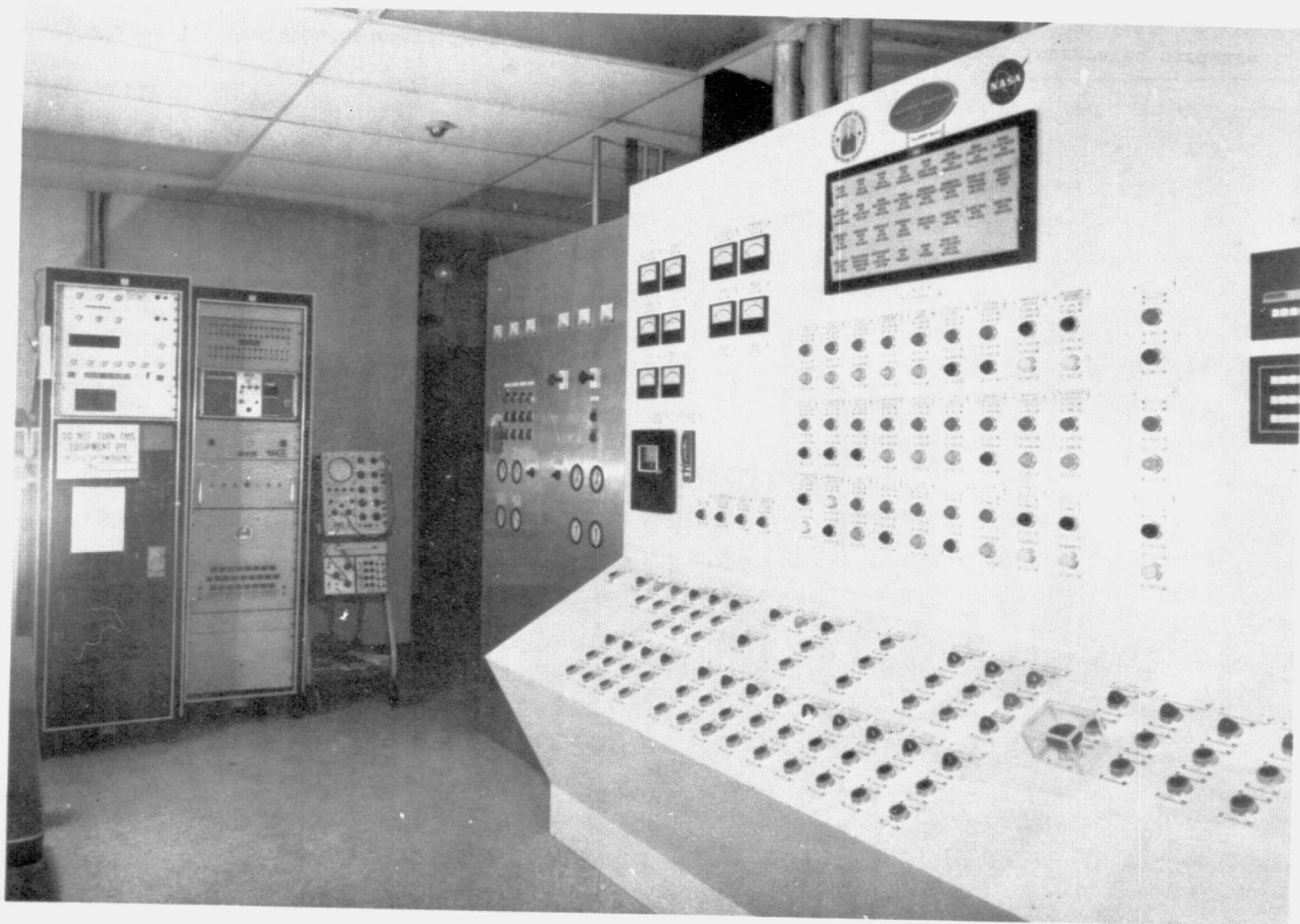


Figure 2.- Data acquisition and tape-recording device (left) originally used for the MIST; original central controls partially shown at right (NASA S-74-21057).

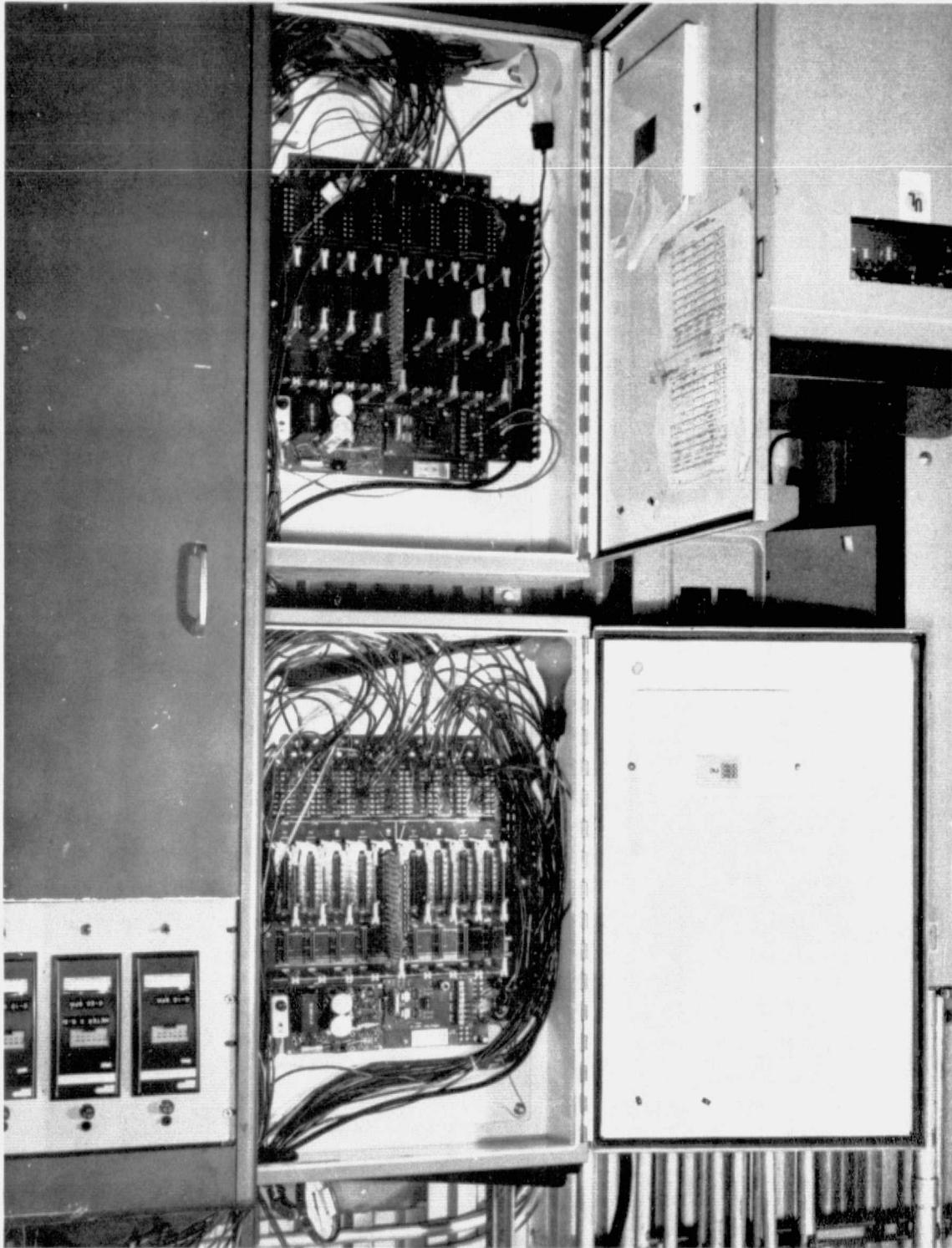


Figure 3.- Interior view of operational data acquisition units. Heat from one 150-watt bulb in each enclosure is used to decrease relative humidity (NASA S-76-32488).

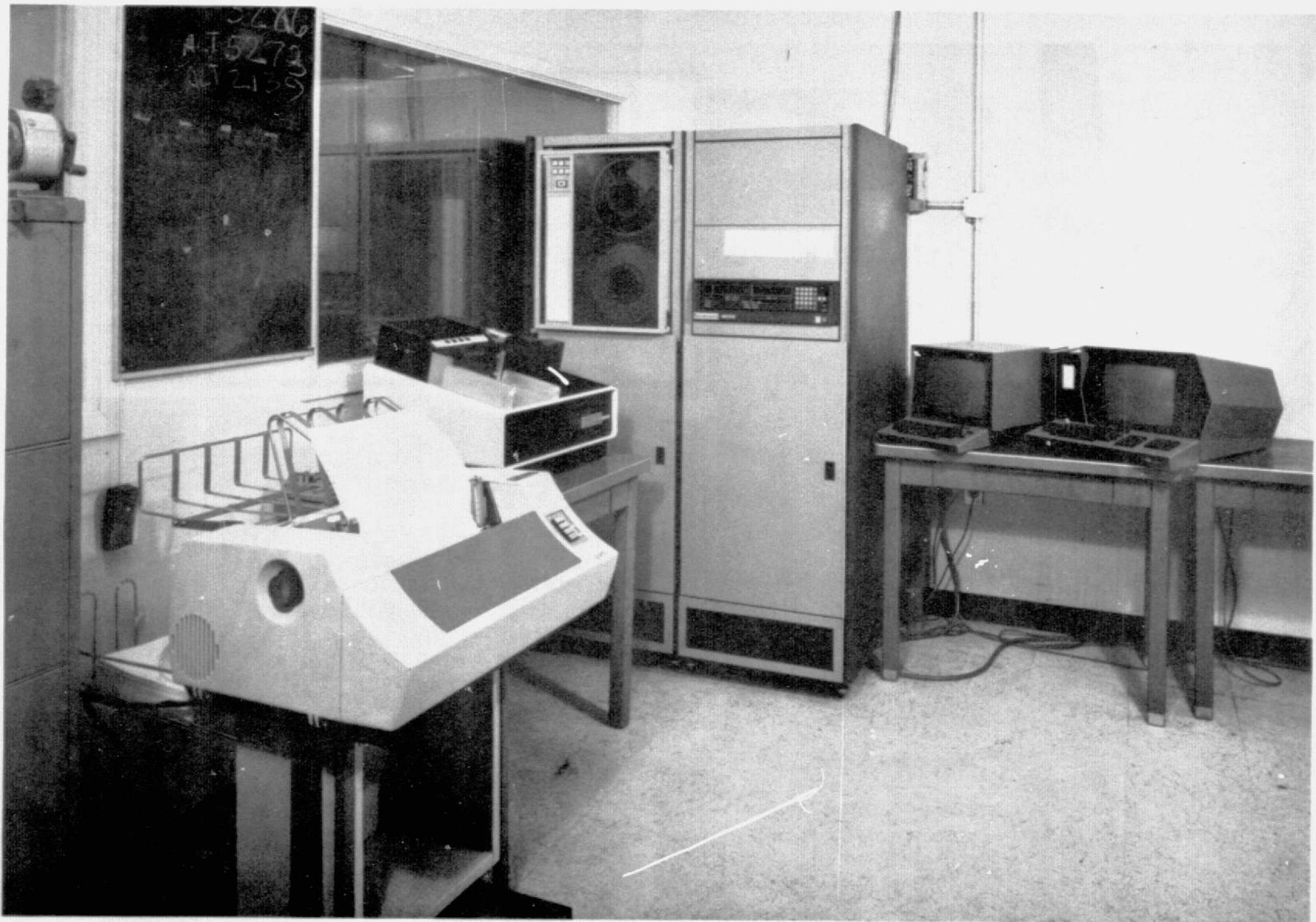


Figure 4.- Improved central control room showing (left to right) line printer, card reader, magnetic tape drive, minicomputer, CRT display, and CRT terminal (NASA S-76-32486).

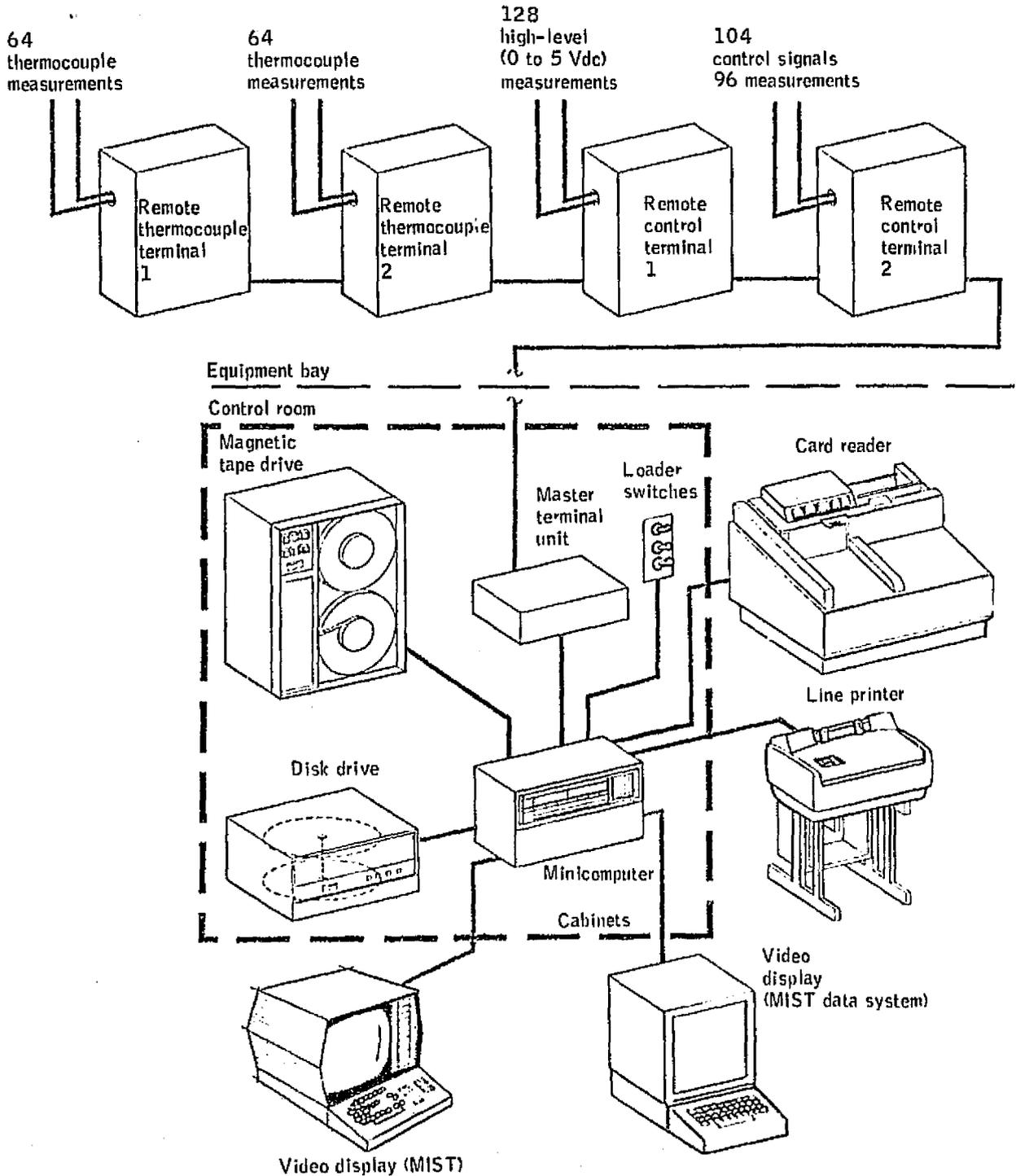


Figure 5.- Basic hardware configuration for the MIST data system.

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PAGE 4    TIME XX:XX    POWER GENERATION SUBSYSTEM    MM/DD/YY    HH:MM:SS
      JACKET WATER ENGINE COOLING LOOPS FORCED AND EBULLIENT MODES
F3    INTERCHANGER OUT    S .XXX UNTS*+T6    JKT H2O INTER OUT    S .XXX UNTS
F2    JACKET WATER RETURN    S .XXX UNTS*TP29    JKT H2O PUMP IN    S .XXX UNTS
PI3   ENGINE IN    S .XXX UNTS*+T53    ENGINE OIL TEMP    S .XXX UNTS
TP3   ENGINE OUT    S .XXX UNTS*P32    ENGINE OUT    S .XXX UNTS
TP6   ENGINE IN    S .XXX UNTS*P33    PUMP INLET    S .XXX UNTS

      ****ENGINE EXHAUST****
      ****HEAT RECOVERY UNIT****
F4    FEED WATER    S .XXX UNTS*P3    PRESSURE ENGINE OUT    S .XXX UNTS
PI2   BACK PRESSURE    S .XXX UNTS*P4    PRESSURE HRU OUT    S .XXX UNTS
P5    FEED WATER    S .XXX UNTS*T4    TEMP ENGINE OUT    S .XXX UNTS
TP5   STEAM TEMP    S .XXX UNTS*T5    TEMP HRU OUT    S .XXX UNTS
T7    FEED WATER    S .XXX UNTS*F39    FLOW    S .XXX UNTS

      ****GENERATOR OUTPUT****
      ****AIR TEMPERATURE****
E1    VOLTAGE    S .XXX UNTS*T2    AMB AIR AT ENGINE    S .XXX UNTS
E2    CURRENT PHASE 1    S .XXX UNTS*T3    ENGINE AIR INTAKE    S .XXX UNTS
E3    CURRENT PHASE 2    S .XXX UNTS*T1    FUEL TEMPERATURE    S .XXX UNTS
E4    CURRENT PHASE 3    S .XXX UNTS*T54    WET BULB    S .XXX UNTS
E5    LOAD SIM TOTAL PWR    S .XXX UNTS*T55    DRY BULB    S .XXX UNTS
E6    GEN TOTAL POWER    S .XXX UNTS*

```

Figure 6.- Sample data screen display from the MIST.

MIST DATA LOG

DATE 05/26/76

TIME 13:08:14

TEST TIME XX:XX

PAGE 1

T1 DEGF 76.88	T2 DEGF 76.36	T3 DEGF 74.56	T4 DEGF 66.58	T5 DEGF 822.8	T6 DEGF 73.40	T7 DEGF 79.20	T9 DEGF 73.40	T10 DEGF 84.32	T11 DEGF 91.70	T12 DEGF 92.26	T13 DEGF 73.14	T14 DEGF 109.0	T15 DEGF 88.86	T16 DEGF 90.56	T17 DEGF 78.04	T18 DEGF 86.02	T19 DEGF 132.1	T20 DEGF 73.98
T21 DEGF 74.62	T22 DEGF 77.46	T23 DEGF 72.40	T24 DEGF 72.82	T25 DEGF 96.24	T26 DEGF 79.20	T28 DEGF 74.56	T30 DEGF 86.59	T31 DEGF 77.46	T32 DEGF 71.08	T33 DEGF 74.56	T34 DEGF 74.56	T35 DEGF 73.40	T36 DEGF 53.50	T37 DEGF 77.46	T38 DEGF 76.30	T40 DEGF 75.14	T44 DEGF 75.72	T51 DEGF 76.30
T52 DEGF 76.36	T53 DEGF 79.78	T54 DEGF 73.98	T55 DEGF 82.05															
TP1 DEGF 73.40	TP2 DEGF 72.69	TP3 DEGF 72.24	TP4 DEGF 70.72	TP5 DEGF 80.35	TP6 DEGF 86.80	TP7 DEGF 70.72	TP8 DEGF 76.62	TP9 DEGF 95.10	TP10 DEGF 78.91	TP11 DEGF 79.20	TP12 DEGF 77.46	TP13 DEGF 76.30	TP14 DEGF 78.62	TP15 DEGF 73.11	TP16 DEGF 81.48	TP17 DEGF 77.46	TP18 DEGF 75.24	TP19 DEGF 75.72
TP20 DEGF 79.49	TP21 DEGF 78.15	TP22 DEGF 76.36	TP23 DEGF 70.14	TP24 DEGF 73.47	TP25 DEGF 75.72	TP26 DEGF 74.56	TP27 DEGF 76.01	TP28 DEGF 159.5	TP29 DEGF 84.89	TP30 DEGF 74.56	TP31 DEGF 75.58	TP32 DEGF 76.88	TP33 DEGF 64.34	TP34 DEGF 79.20	TP35 DEGF 74.05	TP36 DEGF 73.04	TP50 DEGF 609.1	
TS1 DEGF 116.7	TS2 DEGF 87.16	TS3 DEGF 69.76	TS4 DEGF 97.37	TS5 DEGF 97.72	TS6 DEGF 87.16	TS7 DEGF 71.66	TS8 DEGF 71.66	TS9 DEGF 76.88									TD1 DEGF 1.796	TD2 DEGF -8.03
P3 "H2O" -0.14	P4 "H2O" -0.16	P5 PSIG -0.15	P6 PSIG -0.15	P12 PSIG -1.47	P18 PSIG -0.12	P19 PSIG 12.53	P20 PSIG 10.09	P21 PSIG -0.64	P22 PSIG 0.136	P24 PSIG 0.380	P25 PSIG -0.54	P27 PSIG -1.01	P28 PSIG 0.208	P31 PSIG -2.35	P32 PSIG 0.631	P33 PSIG 7.451		
PI1 PSIG 5.063	PI2 PSIG -0.00	PI3 PSIG 2.282	PI4 PSIG -0.17	PI5 PSIG 1.611	PI6 PSIG -0.00	PI7 PSIG 9.749	PI8 PSIG 11.86	PI9 PSIG 10.56	PI10 PSIG 12.59									
F2 GPM 1.269	F3 GPM 38.76	F4 GPM 16.88	F6 GPM -1.01	F8 GPM -0.01	F9 GPM -0.13	F10 GPM 2.399	F11 GPM 0.302	F12 GPM 0.068	F13 GPM -3.39	F14 GPM 0.031	F15 GPM 2.226	F16 GPM 0.607	F17 GPM 1.417	F18 GPM 31.25	F19 GPM 29.39	F20 GPM -1239	F23 GPM 4.914	F24 GPM -0.70
F25 GPM 6.965	F27 GPM 27.52	F28 GPM -2.52	F31 GPM 4.840	F32 GPM -0.01	F33 GPM -0.01	F35 GPM -1.25	F36 GPM -1.25	F38 GPM -2.17	F39 PPM -7.24	F40 GPM -23.4	F41 GPM -2.72	F42 GPM -5.06						
E1 VAC 0.000	E2 AMPS -0.19	E3 AMPS -0.00	E4 AMPS -0.37	E5 KN 0.000	E6 KN -0.11													C11 MCMS 800.7
SV01 STATUS OPEN	SV02 STATUS OPEN	SV06 STATUS OPEN	SV09 STATUS CLOSED	SV56 STATUS CLOSED	SV8 STATUS COOLIN	SV11 STATUS COOLIN	SV30 STATUS PRIMAR	SV58 STATUS PARALL	SV59 STATUS PARALL	SV801 STATUS STORAG	SV802 STATUS DEGF 228.8	SV804 STATUS COMPUT	NO804 STATUS OVERRI	CM804 STATUS COMPUT	ID804 STATUS DIRECT	SV806 STATUS HEATIN	SV807 STATUS CLOSED	
SV808 STATUS CLOSED	SV809 STATUS NORHAL	SV811 STATUS LOAD	SV812 STATUS STORAG	SV813 STATUS LOAD	SV821 KATU 0.000	NO823 STATUS OPERAT	SV823 KBTU 0.000	501A STATUS OFF	502 STATUS OFF	503A STATUS OFF	503B STATUS OFF	508 STATUS OFF	510A STATUS OFF	510B STATUS OFF	514A STATUS OFF	514B STATUS OFF	M999 STATUS OFF	
MDSMOD STATUS MONITO	HEAT2 STATUS OFF	WATER2 STATUS OFF	AIRC2 STATUS OFF	ACHIL2 STATUS OFF	CCHIL2 STATUS OFF	HTS2 STATUS NOHTS	CTS2 STATUS NOCTS											

Figure 7.- Sample MIST data log printout.

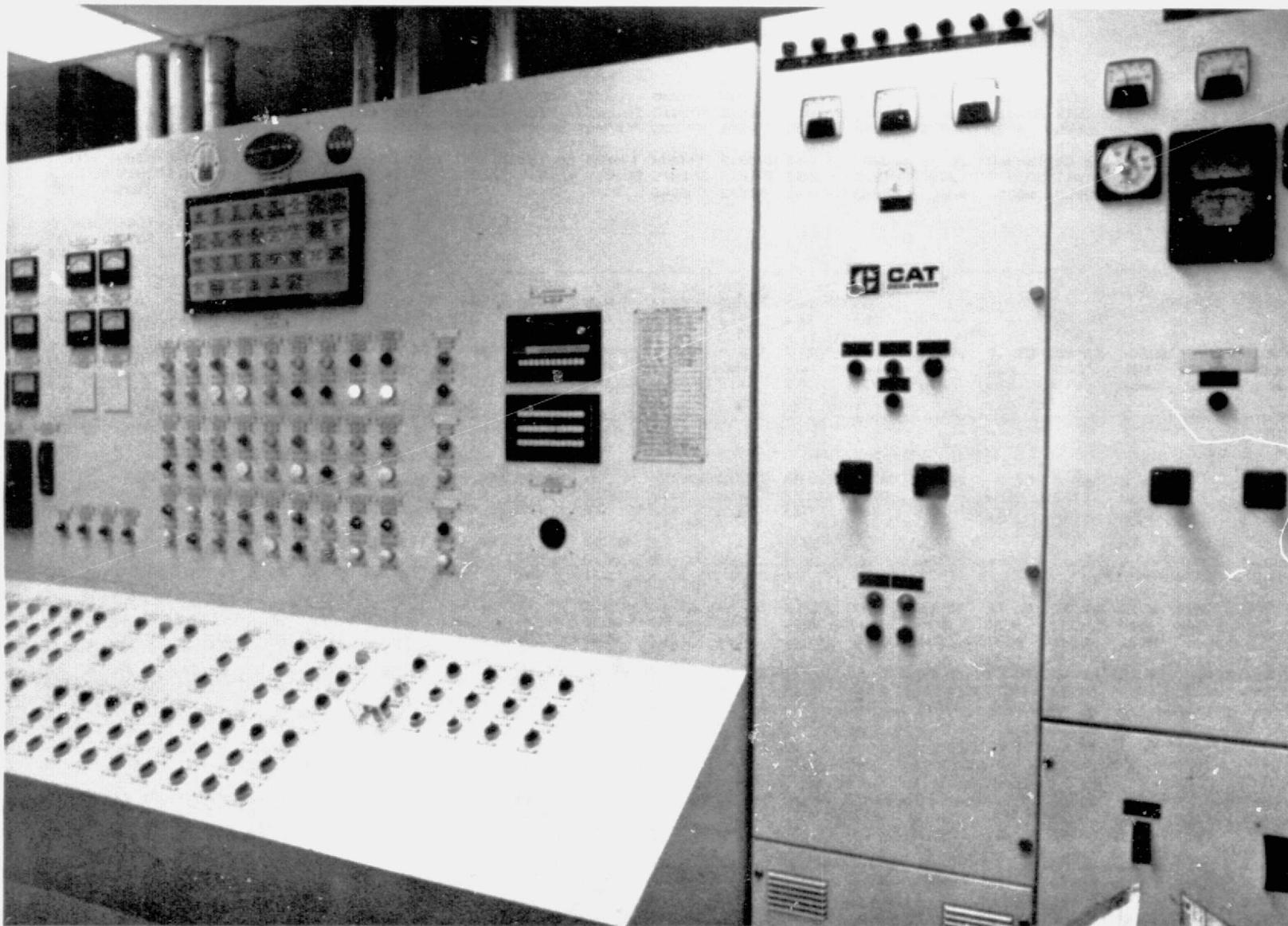


Figure 8.- Original central controls for the MIST (power controls at right).

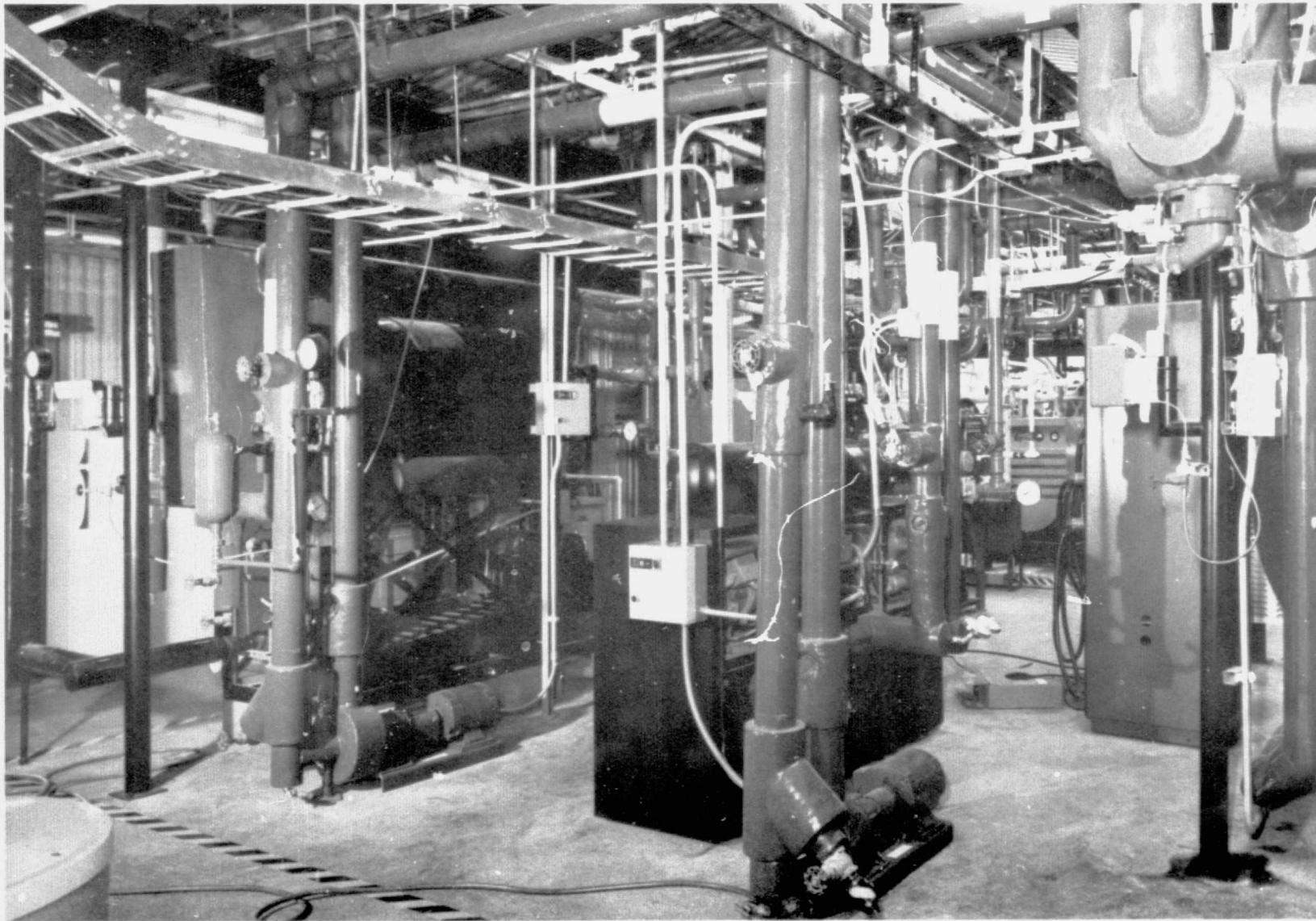


Figure 9.- Original manual controls located in the equipment bay for the MIST (valves, gages, and pushbutton panels) (NASA S-74-23340).

## APPENDIX A

### AUTOMATIC DATA PROCESSING EQUIPMENT ACQUISITION PLAN, MIST MINICOMPUTER DATA AND CONTROL SYSTEM

#### INTRODUCTION

The demonstration of energy conservation and optimized performance of installed utility equipment is a goal of the overall MIUS Program and of the MIST testing effort specifically. The Urban Systems Project Office at the JSC has tested the aspects of hardware integration useful for optimum energy utilization in the MIST facility. The transfer of energy in the form of heat from a utility such as power generation to another such as air-conditioning or sewage processing has proven to be a viable method of minimizing fuel consumption.

The validation of the baseline concepts of the MIUS has been achieved over a testing period of several months. Performance data on equipment in the integrated configurations have been compiled and are currently under detailed analysis. This testing effort has accomplished the immediate objectives of the MIST Program. Future objectives include the testing, in the MIST facility, of automated control to achieve optimized performance and to demonstrate the resulting energy savings attributable to a MIUS design.

The DEXTIR data acquisition system, used during this initial MIST testing period, provided for the recording of all data in digital counts and for display of a single parameter in real time. Paper tape printout (adding machine tape) of the data in digital counts also was provided. All these data outputs were converted to engineering units by table-lookup procedures. In addition to the cumbersome operational techniques for monitoring and recording the data, the DEXTIR does not contain any capability for control signal outputs. Valves and switches were manually adjusted to control the equipment during testing.

Implementation of a minicomputer data acquisition and control system is planned in order to demonstrate the monitoring and control concepts of a MIUS. In addition to the control aspects of a MIUS, the system will provide sufficient capability for monitoring other subsystems that are to be tested in the JSC MIST facility. For example, the water-monitoring unit, which contains sensors of standard process-level output, will interface with the planned data acquisition system. Also, solar energy concepts and pyrolysis hardware are anticipated. The incorporation of the proposed system will allow evaluation of each future subsystem as it applies to the MIUS.

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## REQUIREMENT

The techniques of automated monitoring and control of individual subsystems are well demonstrated in the utility and petrochemical industries. The computerized real-time display of operational parameters and, through use of the preprogrammed decisions in the computer, the automatic control of equipment are proven state-of-the-art. The MIST facility is comprised of several such individual subsystems that have been physically integrated. This integration is now to be operationally optimized. No longer can a manual observance and manipulation of subsystem hardware be depended upon for reaching predetermined operating ranges. The DEXTIR system has served to record the operational parameters so that the data could be processed and printouts and plots made available for evaluation by the interested test engineers. The fact that the display and data output of the DEXTIR is limited has, however, resulted in extensive problems in lost testing man-hours. Failed sensors or improper calibrations could not be identified until the data had been processed by the JSC Data Center. This delay necessitated rerunning the test. This factor alone justifies the real-time engineering-units display offered by a mini-computer data system. The optimization of control aspects, however, is a significant portion of MIUS development activities and is only possible with a computerized system.

## SYSTEM CONFIGURATION

Figure A-1 outlines the proposed minicomputer data system. Figure A-2 depicts the DEXTIR configuration currently being used.

## ALTERNATIVES

The MIUS demonstration tests require the automatic functions provided by a minicomputer data system. An objective of the MIST is to develop and demonstrate these automatic functions. The Interdata model 70 computer and associated equipment have been demonstrated to be an effective tool for utility monitoring and control systems. There are other minicomputer systems that could also demonstrate the automatic functions. However, no more-cost-effective alternative is available within a time frame to support MIUS development. The system is required to be operational within 90 days to support the MIUS development schedule. Other sources have estimated operability in no less than 180 days.

## ESTIMATED COSTS

The costs of the system implementation are to be spread over two phases. The initial effort - installation and operation of the monitoring, display, and recording functions - will cost \$96 000 for hardware and \$31 000 for software,

a total of \$127 000. The second phase, which is to be funded after demonstration of the first phase, adds \$15 000 for the control hardware and \$35 000 for the control software, or a total of \$50 000. A total system cost of \$177 000 provides all hardware and programming. These costs also include the operation of the equipment for the 1-year implementation period. Continuing costs after that time should be minimal, less than \$1000 yearly.

#### METHOD OF ACQUISITION

A proposal has been made that this system be installed by the General Electric Co., Houston Operations, under their existing contract NAS 9-10230, Task Agreement for JSC-SESL<sup>2</sup> Data Systems Support. There are several companies at the JSC that have experience in minicomputer data system design and programming. However, a sole source procurement is being recommended as the most cost effective approach and in the best interest of the Government. The aforementioned proposal and recommendation are based on the following rationale.

The General Electric Co. has developed and demonstrated a computerized data acquisition and control system utilizing the Interdata Model 70 computer and its associated peripheral gear. (The system was based upon requirements for automatic monitoring and control of mass-transit vehicles to be used in New York City.) The General Electric Co. proposed the effort on the basis of their experience with the computer and has since delivered and made operational the overall system. The company pursued this area of technology as a result of their prior experience in the design and development of monitoring and control systems for manned spacecraft.

The General Electric Co., Houston Operations team that will provide the Interdata Model 70 computer is the same group that has designed and developed the spacecraft checkout equipment for the Apollo, Skylab, and Shuttle Programs, as well as for the Apollo-Soyuz Test Project. The company has demonstrated, in the mass-transit endeavor, their ability to also relate to smaller scale data systems. Their proposal of approximately 0.5 to 0.75 man-year of programming and analysis is consistent with NASA estimates of the task. The delivery schedule of 90 days after receipt of order is based upon their experience with the programming requirements and upon the relationships of their original equipment manufacturers with the hardware suppliers. No other contractor company is willing to propose such a delivery because of their uncertainties associated with the software tasks.

Prices and delivery schedules for hardware only from various companies (including the General Electric Co.) are approximately the same. However, it is very important that a contractor understand the software task in order to fulfill a contract with such a short schedule. The cost estimates for the software made by other contractors were higher than the estimates made by NASA

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<sup>2</sup>Space Environment Systems Laboratory.

and the General Electric Co. This difference is attributed to a lack of understanding of the task by the other contractors.

As mentioned earlier, the General Electric Co. is currently maintaining the data system for the MIST in JSC building 32J. The proposed additional work of adding the minicomputer data system is within the general scope of the current contract. Funding will be provided for this added effort. A system provided by any other contractor and then turned over to the General Electric Co. to operate and maintain would necessitate the use of extra time for familiarization and, hence, would not be a practical expenditure of Government resources.

#### IMPACT OF NONAPPROVAL

The demonstration of automatic control to achieve optimized performance of the MIUS equipment is an essential part of the future Urban Systems Project Office efforts. The possible savings in operating manpower and the increased efficiencies in the energy distribution are highly significant to the comparisons of MIUS equipment configurations with those of conventional utilities.

The cost of implementing the minicomputer data system is offset by the savings in operational manpower and by the elimination of current techniques that require the data processing of sometimes useless data before test results can be produced. Should this new system not be implemented, operating costs will be misallocated and even the basic MIUS objectives will be compromised. (This document was written before the minicomputer system had been approved.)

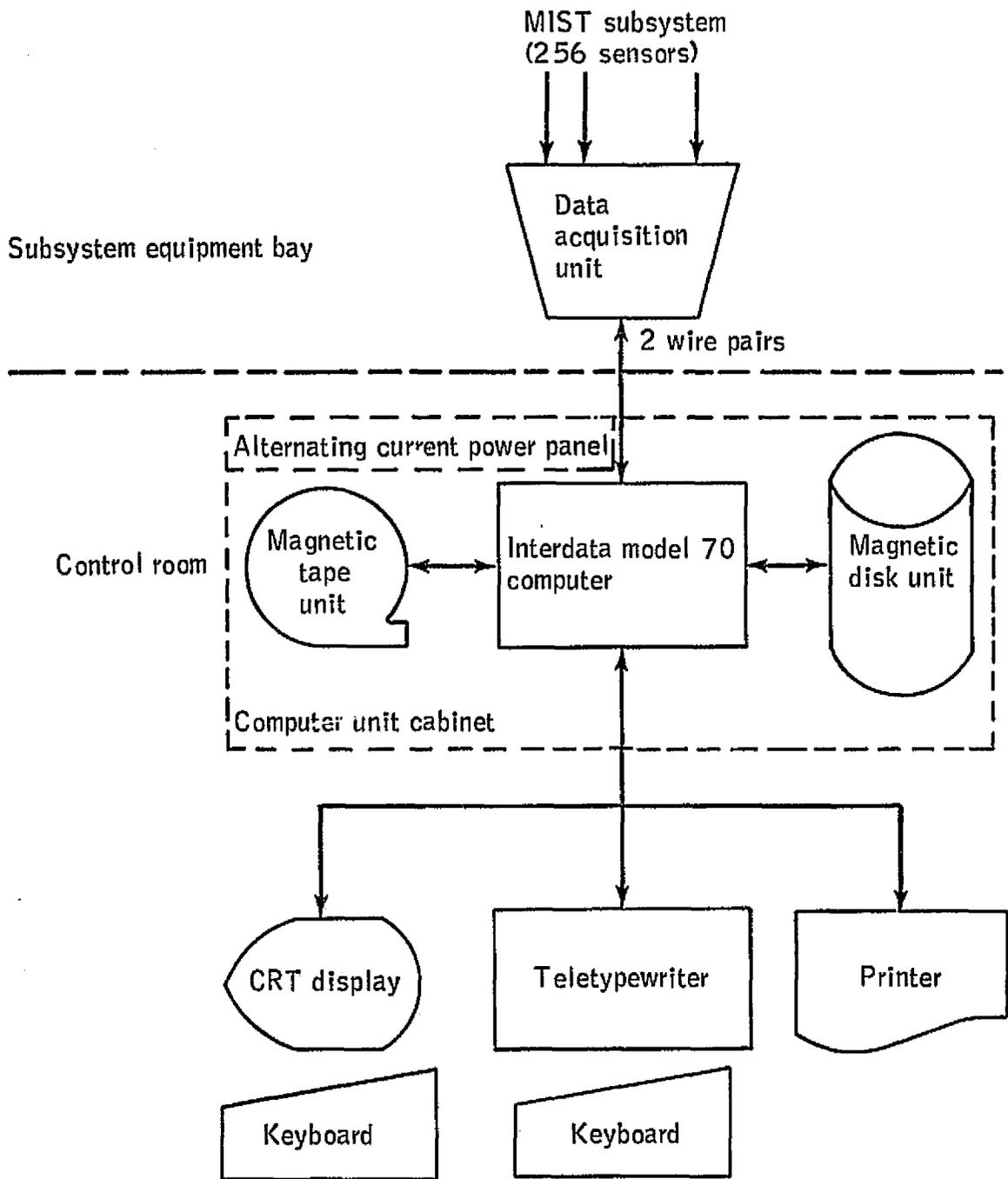


Figure A-1.- The proposed minicomputer data system.

MIST subsystem  
analog submultiplexing

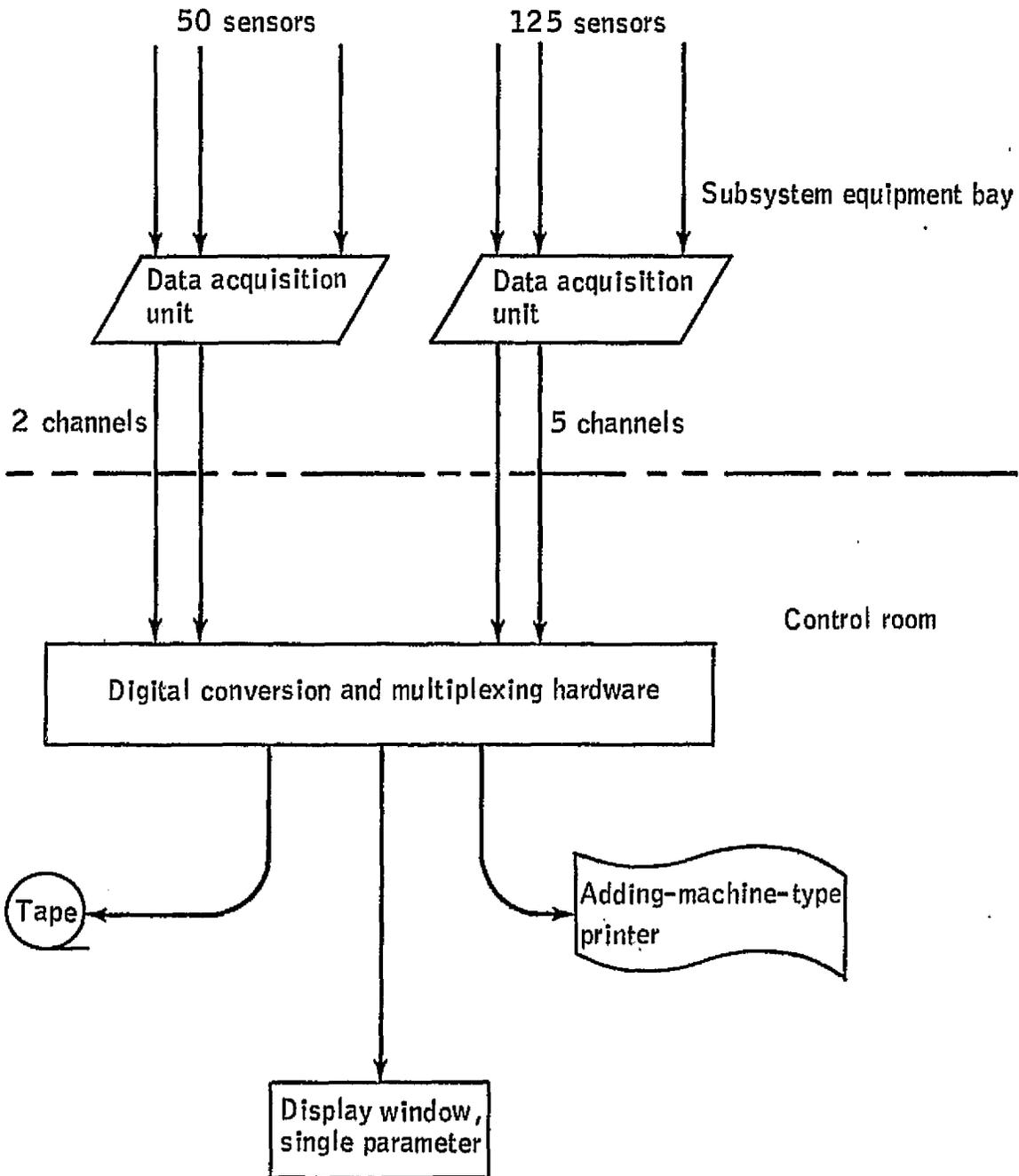


Figure A-2.- The DEXTIR data system configuration.

## APPENDIX B

### MIST DATA SYSTEM REQUIREMENTS\*

By J. W. Goebel<sup>†</sup>

#### INTRODUCTION

The demonstration of energy conservation and optimized performance of installed utility equipment is a goal of the MIST effort. The ability to test and integrate new types of energy-related equipment, such as solar and pyrolysis equipment, is also a goal of the MIST. These goals cannot be met effectively without the assistance of a modern data monitoring and control system. Thus, the MIST data system (MDS) has been developed to meet the MIST data needs.

The MDS is composed of a minicomputer, standard minicomputer peripheral devices, and remote data acquisition/control units. All MDS equipment is proven effective by field tests in process control systems for petrochemical applications, as well as utility applications. The computer programs of the MDS apply the equipment to the specific needs of the MIST.

This document provides a general description of the MDS and a detailed description of MDS equipment, operation, computer programs, and maintenance. System requirements contained in this document are written in the form of description so that a top-level training document is provided, as well as a system requirements document. The descriptive nature of the requirements does not discount their authority. The document defines MDS performance requirements, and interfaces and identifies all end items (hardware and software).

#### GENERAL DESCRIPTION

The current MDS design is limited to the acquisition, limit checking, alarming, display, recording, and later tabulation of as many as 256 MIST measurements. The number of measurements monitored can be increased by adding additional data acquisition equipment and minor software modifications. Supervisory control capability can also be added as an extension of the current design.

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\*This report was originally dated March 10, 1975.

<sup>†</sup>Project Engineer, General Electric Co.

## EQUIPMENT

The MDS functional equipment configuration is shown in figure B-1.

### Capability

A brief summary of the MDS equipment capability follows.

Remote thermocouple terminals (RTT's).- These units operate under the control of the master terminal unit (MTU). Each RTT can sample as many as 64 thermocouple measurements. Unit 1 can sample 64 copper-constantan-type thermocouples. Unit 2 can sample 48 copper-constantan-type thermocouples and 16 chromel-alumel-type thermocouples.

Remote control terminal (RCT).- This unit also operates under control of the MTU. It can sample as many as 128 analog (4 to 20 milliampere) measurements. The unit will accommodate a maximum of 16 data/control cards. The current complement is eight. Thus, eight data or control cards can be added to the unit. A wide range of cards for process control applications is available.

Master terminal unit (MTU).- This unit controls all remote units over a party line (two twisted pairs). It will accommodate up to 31 remote units of any mix currently being used. The MTU communicates with the remote units in full duplex at rates as high as 19 200 bps. Each sample of each measurement point requires one 32-bit interrogation word from the MTU and one 32-bit response word from the addressed remote unit. Thus, the maximum communication rate is 600 points/sec (line delay being neglected). The rate is selectable by a strap in the modems of each unit. The MDS operates at 9600 baud (bps); each of the 256 measurement points is sampled approximately once each second.

Minicomputer.- The minicomputer includes a processor, 64 000 bytes (65 536 actual) of memory, an interface for each peripheral device, and a display panel. The processor includes 16 hardware accumulators (15 can be used for indexing); 122 instructions implemented through solid-state read-only memories (ROM's) and including floating point, list (stack), and high-speed multiply and divide; 16-bit parallel processing; 4 direct memory access channels; and automatic interrupt vectoring to 255 service routines. The memory is 750-nanosecond-cycle core, organized in 32 000 16-bit words with all 64 000 bytes directly addressable. The disk drive interface and magnetic tape drive interface share a direct memory access channel. The MTU interface uses one address for data interrogation and response and a second address for control interrogation and response. This response requires minimum program attention during data/control operation.

Loader switches.- These switches, in conjunction with the loader storage unit (LSU) in the processor, provide for initial processor loading from ROM's located on the LSU. The LSU also provides a "watch dog timer" that can be used to reload and restart the system in the event of a processor or programming fault.

Magnetic tape drive.- This unit provides a 9-track, 315-character/cm (800 character/in) read/write capability. Tape speed is 114.3 cm/sec (45 in/sec) for read and write, and 508.0 cm/sec (200 in/sec) for rewind. Transfer rate is 36 000 characters/sec. The unit accepts a 26.7-centimeter (10.5 inch) tape reel and conforms to American National Standards Institute (ANSI) standards.

Disk drive.- This unit consists of two disks on the same drive shaft. One disk is fixed (not removable), and the other disk is a disk cartridge, compatible with IBM 5440. Each disk accommodates 5 000 000 bytes of storage. The transfer rate is 310 000 characters/sec.

Card reader.- This unit provides the capability to read 300 punched cards/min. The hopper/stacker capacity is 1000 cards.

Line printer.- This unit prints at a rate of 165 characters/sec. As many as 132 characters/line can be used; hence, the speed range is 50 to 150 lines/min.

MIST video display.- This unit consists of a CRT screen, a fixed message display panel, and a keyboard. The CRT screen has a capacity of 1920 characters (24 lines of 80 characters). The screen size is approximately 22.9 by 17.8 centimeters (9 by 7 inches). The fixed message display panel can individually display 16 messages under processor control. The keyboard has a full complement of American Standard Code for Information Interchange (ASCII) characters and editing characters, as well as 16 special-function keys.

MIST data system (MDS) video.- This unit serves as a teletype replacement. It consists of a CRT screen and a keyboard. The screen has a capacity of 1920 characters (24 lines of 80 characters each). The keyboard layout is the same as a teletype keyboard.

#### Location

The remote data units are located in the MIST equipment bay, as shown in figure B-2. The remainder of the MDS equipment is located in the MIST control room, as shown in figure B-3. The layout of the two MDS equipment cabinets is shown in figure B-4.

#### OPERATION

The MDS is designed to be operated by a single MIST operator in supporting MIST testing operations. The system will display real-time MIST data in engineering units, log the data hourly in engineering units, record the data continuously in compressed form, and direct the operator to situations that require his attention. The operator can control MDS testing support operations through eight simple control keys.

An MDS operator uses the system to selectively search, display, and tabulate previously recorded MIST data. This task can be accomplished regardless of whether or not the MDS is directly supporting MIST testing operations.

Each operator (MIST and MDS) has his own video display station. However, it is not necessary for the MDS operator to be present during system operation except to process previously recorded data and to analyze system faults called to his attention by the MIST operator.

The MDS detects errors within itself and reports them to the MIST operator. The nature of the errors is reported in detail on the MDS video display.

### General Considerations

There are several other matters useful in operation of the MDS.

System power.- The MDS minicomputer is equipped with two power supplies that furnish all power required for its operation. Each peripheral device contains its own power supply; power may be removed from such a device when the device is not in use. Power is not to be removed from the processor except for maintenance purposes.

Processor display panel.- The processor display panel is to be kept in the locked position except for maintenance.

Mass storage devices.- The magnetic tape drive is used to record MIST data. A tape should be mounted and positioned before a MIST test run is begun. The magnetic tape drive is also used for recorded-data tabulation. When data tabulation is in progress, real-time test data are temporarily recorded on the disk cartridge formatted for that purpose. This disk cartridge should be mounted in the disk drive before a test run is started. The fixed disk contains data files accessed by the software during operations. The disk drive must be in the run mode with the write protect switch off before test or data tabulation operations are started and must not be taken out of the run mode while either of these operations is in progress.

### MIST Testing

All MIST testing operations are controlled through the MIST video display. This device is equipped with 16 special-function keys and 16 fixed message displays that are dedicated to MIST testing functions. The CRT screen is used to display MIST data. The operation of the controls, messages, and displays is coordinated to produce a simple, understandable MIST operating station.

Test controls.- The special MIST test control keyboard is located on the far right on the keyboard assembly. The legends of the keys (plus a later variation of key controls) are illustrated in figure B-5. A description of the basic function of each key follows.

The begin test key is used to start test operations. Data acquisition is started, the data page index is displayed, and the testing message is illuminated.

The end test key is used to stop test operations. When this key is depressed, the testing message will blink and the keyboard bell will sound for 10 seconds. Then, testing will be terminated by stopping data acquisition, terminating data recording (if not previously terminated), clearing the screen, and extinguishing all messages. Should the begin test key be depressed during the 10-second interval after the end test key is depressed, testing operations will continue as if the end test key had not been depressed.

The record on key is used to start test data recording. Test data are recorded in a compressed form on the magnetic tape mounted on the magnetic tape drive. The first time the record on key is depressed during a test run (after depression of the begin test key), the tape will be rewound and recording will be started at the beginning of the tape. Each successive time this control is used, recording will restart from the position on the tape where it last stopped. When recording is actually started, the recording message is illuminated.

The record off key is used to stop recording. When this key is depressed, the recording message will blink and the keyboard bell will sound for a 10-second interval. Then the recording operation terminates. If the record on key is depressed during the 10-second interval after the record off key is depressed, recording will continue uninterrupted as if the record off key had not been depressed.

The page index key is used to cause the index of data pages to be displayed on the screen.

The page number key is used to select a data page for display. Before this key is depressed, one or two numeric keys on the main keyboard are depressed to select a data page by number. Data pages 0 through 99 can be selected in this manner. However, in the MDS, only pages 0 through 5 are active. Any other number will result in an error. Only the last two numbers entered are recognized. For example, if the keys "1," "7," "5," "0," "2," and "PAGE #" are depressed in that order, page 2 will be displayed; depression of keys "1" and "PAGE #" - in that order - will result in the display of page 1.

If no numeric keys are depressed before the page number key is depressed, the next sequential page will be displayed. For example, if page 1 is being displayed, a new page will be displayed in the page number order 2, 3, 4, 5, 0, 1, 2, etc., each time the page number key is depressed.

The rescan key is used to put all measurement points currently in the range error or the data error back into normal-measurement-point scan. This control is used after action has been taken to correct hardware faults associated with range and data errors. (See paragraphs on range error and data error messages in subsequent subsection "Messages.")

The acknowledge key is used to acknowledge all alarm-type messages (alarm, range error, or data error). When this key is depressed, the keyboard bell is cancelled and the respective message is extinguished.

The remainder of the special-function keys are not currently used in the MDS. Depressing these keys or any other key on the keyboard assembly (except the numeric keys and terminal control keys) will have no effect on system operation.

Messages.- Eight messages are used to direct the MIST operator to situations requiring his attention. The basic meaning of each message is described in the following paragraphs. The layout of the fixed message panel is illustrated in figure B-6.

The alarm message is illuminated, the keyboard bell sounded, and the alarm display page displayed whenever an alarm measurement point initially has a value in the alarm range. This message is extinguished and the bell silenced when the operator depresses the acknowledge control key. The value of an alarm measurement point will blink on the screen as long as the value is in the alarm range.

The range error message is illuminated and the keyboard bell sounded when the value of a measurement point goes out of its normal operating range. This message is extinguished and the bell silenced when the acknowledge key is depressed. The value field on the display will contain H's or L's that blink for the out-of-range measurement. An "H" indicates an out-of-range high, and an "L" indicates an out-of-range low. The measurement point is taken out of scan; that is, it will not be updated until the operator rescan key is depressed. An out-of-range value will normally be due to a failed or open sensor.

The "DATA ERROR" message is illuminated and the keyboard bell sounded when a remote data unit response contains an error or is not received. The value field of the respective data display page will contain I's (interrogation) or R's (response) that blink. The message will be extinguished and the bell silenced when the acknowledge control key is depressed. The measurement point is taken out of scan until the operator rescan key is depressed.

The MDS fault message is illuminated whenever the MDS detects an internal error. The MIST operator should request the MDS operator to determine the extent of the problem by interpreting the detailed message displayed on the MDS video display. This message is extinguished by the MDS operator through the MDS video display keyboard.

The control error message is illuminated when the MIST operator depresses a control key that is illogical or out of sequence, such as the BEGIN TEST key when testing is in progress or the acknowledge key when no alarms are sounding. This message will be extinguished when the next executable control is received or 5 seconds after it is illuminated.

The recorder full message is illuminated when the magnetic tape end is sensed. The MDS automatically begins to record data in a special file on the

fixed disk when this sensing occurs. A new magnetic tape must be mounted within 5 minutes after this message is illuminated. The MDS will rewind the old tape. When the new tape is mounted by the operator (MIST or MDS), the MDS will automatically copy the data from the fixed-disk file to the new tape, then continue to record on the new tape. The message will be extinguished when data are being recorded normally on the new tape.

If data tabulation is in progress when this message is illuminated, the tabulation process must be terminated and a tape for data recording mounted or the recorded data will be lost. (See subsequent subsection entitled "Recorded Data Processing," subsection "Tabulation.")

The testing message is illuminated at all times that testing is in progress (from depression of the begin test key to depression of the end test key).

The recording message is illuminated during all times that recording of test data is in progress. If this message is extinguished while the recorder full message is illuminated, the file on the fixed disk has filled before the new tape was mounted, and additional data are lost.

Data display.— The MIST data are displayed on the screen of the MIST video display. Six different data pages and a page-index page may be displayed, one at a time. The format of each page, including the page-index page, is illustrated in figure B-7. When a new data page is called for display, with the "PAGE #" control, the annotation information is first written on the screen. Then, the value in engineering units (degrees F, etc.) of each measurement point is written on the page. The values will be updated approximately once each second when there is a significant change in value, for as long as the page is displayed.

The alarm page (page zero) will automatically be called by the MDS when a measurement point passes from the normal range to the alarm range. The value of any alarm measurement point will blink as long as the value is in the alarm range.

The value field of measurement points in the range error and data error conditions will have blinking H's, L's, I's, or R's to indicate the specific condition.

Data log.— The data log is printed on the line printer once each hour while testing is in progress. The format of the log is shown in figure B-8. The data log provides a test history in hard-copy form that can be used to identify areas of recorded test data requiring detailed evaluation.

Should the line printer be in use for data tabulation when the time arrives for a data log output, the data log will be filed. All unprinted data logs will go to the line printer the next time a log output is due and the tabulation (tab) task is not using the line printer. A maximum of eight logs can be filed. Either the MIST operator or the MDS operator can request a log output at any time. If logs from previous hours are filed when a log is requested, they will be printed first.

## Recorded-Data Processing

The MDS operator controls the processing of previously recorded data from the MDS video display keyboard. The operator uses the facility of the MDS command language to communicate with the MIST tab task.

Data tabulation considerations.- The MIST data tabulation format is illustrated in figure B-9. One page of tabulated data contains 1 column of time data and 17 columns of MIST measurement point data in engineering units. Each column contains 56 data values. Approximately 1 minute is required to print one data page.

Data are recorded approximately once each second, and therefore it is possible to tabulate data in 1-second increments. To do so for 255 of the 256 measurement points requires a 16:1 ratio; that is, 16 times longer to tabulate the data than the time span they represent. To tabulate the data with the use of 1-minute intervals requires about one-fourth of the recorded time span.

The MDS provides facilities to isolate the time span of interest and tabulate only the data in that span. These facilities are as follows.

1. Hourly data log
2. Selective, recorded, compressed data processing
3. Data search mode
4. Data display mode

Setup.- Recorded data can be processed regardless of whether or not testing is in progress. The operation is started by starting the tab task, with use of an MDS command. If data are being recorded during a test in progress, the record task will write an "end of file" (EOF) on the magnetic tape, start it rewinding, and begin to record on the disk cartridge. The MDS operator will remove the current data tape and mount the tape containing the data of interest. The operator is now ready to use the tab task command set to edit, search, display, and tabulate the data.

Edit.- The tab task has as many as 20 lists of measurement identifications (ID's) stored on a file. Each list contains as many as 17 measurement ID's. Using the tab task command set, the operator can print (line printer) or display (MDS video display, see fig. B-10) any or all of these lists. The operator can also replace the contents of these lists from the keyboard. One of these lists is used by the tab task during search, display, and tabulation. The operator reviews the contents of the list(s) and makes any needed adjustments before proceeding.

Search.- The operator enters the search mode by typing the command. Before typing this command, the operator enters a measurement list number and a search parameter. This information may be a date and time of day or a

measurement ID and value. The measurement ID must be in the selected measurement list. When the search command is entered, the tab task will sequentially search the tape for the parameter. Should it not be found before the end of the recorded data, the tab task will display "EOF" and start rewinding the tape. The operator will redefine the search parameter and retype the search command. When the parameter is found, the tab task will display the recorded date, time of day, and each measurement ID with an engineering-unit value and halt the search. The tab task is now in the display mode.

Display.- The operator uses the display mode to frame the time slice of data desired for tabulation. The operator can enter the tab task commands to back up, go forward, or stop. When such a command is entered, the tab task will update and display the data values from each record for a minimum of 5 seconds. The tab task will continue to operate on these commands until the operator exits the display mode.

Tabulation.- When the time slice of data has been framed by the operator, the tabulation start time, the tabulation end time, and the time increment for tabulation are entered. Next, the tabulation command is entered. The tab task reads data recordings (forward or backward) to the start time and then tabulates the data to the end time with use of the time increment specified. All the measurements in the specified list are tabulated. When tabulation is complete, the tab task rewinds the tape. The operator can tabulate more measurements from the same time slice by entering a new measurement list number followed by the tabulation command. The tab task will read to the start time and tabulate to the end time.

If the operator knows the time slice of interest, he may skip the search and display modes. After starting the program, he enters the start and end times, the time increment, the measurement list number, and the tabulation command.

Exit.- When all required tabulations have been obtained, the operator removes the recorded-data tape from the drive and replaces the current tape. He then enters the "tab done" command. The tab task notifies the record task, which repositions the current record-data tape and begins to transfer data from the disk cartridge to the tape while it continues to record on the disk cartridge. When all recorded data have been transferred from the disk cartridge to the tape, the record task begins to record data on the tape in the normal manner.

### Error Diagnosis

The MDS is designed to detect errors within itself. These errors are categorized and described in the following subsections.

Range error.- A range error, indicated on the MIST video display message panel, is usually caused by a sensor failure or open sensor circuit. The circuit, including the sensor, should be checked and the rescan control used to put the measurement point back in scan. Testing need not stop to troubleshoot a range error.

Data error.- This type of error is indicated on the MIST video display message panel and in the value field of each affected measurement display. The grouping of the affected measurement points can be correlated with the cards in the remote data units to pinpoint the failure. The cards can be replaced without removing power from the remote units. Testing need not stop to troubleshoot data errors.

Peripheral device error.- This type of error is reported on the MIST video display as an MDS fault, with a detailed error message logged on the MDS video display. If either of these two devices fails, one error message will be present without the other. If the MDS message indicates that the peripheral device is unavailable, a check should be made to see if power has been applied to the device. If it has not, then power should be applied and system operation continued. Whether data will have been lost depends on which device was found unavailable. Any other type of device error will require that system operation be discontinued and that system maintenance be performed.

Processor and memory errors.- These types of errors result in a variety of errors being logged on the MDS video display but no indication on the MIST video display. If any of the following types of errors are logged, it is necessary to discontinue system operations and perform system maintenance.

1. Memory parity
2. Queue overflow
3. Task aborted

Power failure.- The processor is equipped with power failure detection and restart capability. When a power failure occurs, the processor shuts down in an orderly fashion and the contents of memory are not disturbed. When power is reapplied, the MDS initializes test support operations if they were in progress before the power failure - as if the begin test control had been exercised. The time-of-day clock should be reset if power has been off for more than an instant. Any data tabulation in progress must be restarted.

## COMPUTER PROGRAMS

The MDS performs under the control of the MIST real-time operating system (MRTOS). The MRTOS is a flexible tool for implementation of current and future MIST operations. It consists of system-level programs and a group of "task" programs. The system-level programs create an environment that allows all tasks to share MDS resources according to priority. The MRTOS and the tasks are described in the following subsections.

### The MIST Real-Time Operating System

This program package consists of an executive, an input-output (IO) set, device drivers, and a scheduler. The basic communication paths within the

MRTOS are illustrated in figure B-11. The tasks use the MDS resources, with the MRTOS functions being activated only to serve the tasks.

Executive.- The executive handles all processor interrupts (internal and external) and task service requests (supervisor calls). It provides routing of these functions.

Input-output set.- The IO set services all task requests for data transfers with peripheral devices. Initially, the selected peripheral device is linked to the data area designated by the task through the respective device driver.

These data transfers occur on a byte-by-byte (word by word) basis between the peripheral device and the data area. Each byte (word) is transferred by using an interrupt that is serviced directly by the device driver until the data area is exhausted or a terminating character is recognized. Then the device driver terminates the IO operation with a queue termination interrupt.

The executive services the queue termination interrupt and notifies the task of IO completion. In this way, IO is overlapped with task execution; so tasks can execute instructions while several IO operations are also in progress.

External interrupts (from peripheral devices) are ignored unless they have been activated by the executive because of a task service request or an executive function, such as time-of-day timekeeping.

Device drivers.- These programs contain the unique coding required to transfer data with their respective peripheral device. They have three parts, as follows.

1. The initialize routine
2. The device interrupt service routine
3. The termination routine

The IO set calls the initialize routine. The interrupt service routine handles each byte-by-byte (word by word) transfer directly. The termination routine interrupts the executive when the transfer is complete.

Scheduler.- The scheduler is responsible for task activation upon exit from the executive. The state and priority of tasks are parameters in the task control block of each task. The scheduler activates the highest priority task that is in the ready state. A task exists in one of four states, as follows.

1. Active
2. Ready

3. Suspended

4. Dormant

The active task is the one currently executing instructions. Only one task may be in the active state at any given instant. Task states change dynamically. A task in the suspended state will progress to the ready state when the event it awaits occurs. Typical suspended states are as follows: time wait, task wait, and IO wait. A dormant task can be made ready at the request of another task or as the result of an operator command.

### Tasks

There are currently seven tasks, as follows.

1. Task loader task
2. MDS command task
3. MIST control task
4. MIST data task
5. MIST display task
6. MIST record task
7. MIST tab task

All tasks are loaded with the MRTOS and remain memory resident.

Four tasks (control, data, display, and record) and the common data area (CDA) are used to support MIST testing with real-time data processing. The tab task is used to tabulate recorded MIST test data. The MDS command task provides a command language for use by the MDS operator. The task loader task is used by the other tasks to load overlays. The MIST test data flow is illustrated in figure B-12. The tasks and the CDA are described in the following subsections.

Common data area (CDA).- This area of memory is accessible by all tasks. Its purpose is to provide a single area for data required by more than one task. It contains a real-time data base (RTDB) and other data and parameters used by tasks. All MIST tasks are table driven; i.e., they contain no data within themselves. In this way, the reconfiguring of MIST measurements requires no changes to the tasks but only to the data in the CDA.

MIST data task.- This task performs checks on all incoming MFU status bytes and response words. Data stored in the RTDB are used for checks. Results of the checks are stored in the RTDB. Parameters are passed to the other MIST tasks for further processing.

This task accomplishes the following actions on each status byte and response word from the MTU driver.

1. Performs measurement error, state, and value checks
2. Stores results in the RTDB for the respective measurement point
3. Passes parameters to other tasks as indicated by the results of the checks and the process flags in the RTDB
4. Awaits the next status and response word

Time of day is read from the MRTOS clock. If the time has increased by 1 second, the new value is stored in the RTDB and the change is treated as a changed data value, described subsequently. The new time is also checked to see if it has "wrapped" (passed midnight). If so, the new day is read from the MRTOS, stored in the RTDB, and treated as a changed data value.

All measurement points are classified as being in one of the following seven states.

- |                        |   |             |
|------------------------|---|-------------|
| 1. Interrogation error | } | Data error  |
| 2. Response error      |   |             |
| 3. Out-of-range high   | } | Range error |
| 4. Out-of-range low    |   |             |
| 5. Alarm high          | } | Alarm       |
| 6. Alarm low           |   |             |
| 7. Normal              |   |             |

The current state of each measurement point is stored in the RTDB. All measurement points can be in any one of the seven states at any given time except the alarm states. Only measurement points designated as alarm points can be in the alarm states. State changes, as well as data value changes, are used to trigger further processing.

Once a measurement point is classified as being in the data error or range error states, it is taken out of scan (processing of data from that point is suspended) because it may be unreliable. All measurement points in the data error and range error states can be put back into scan by use of the rescan operator control. Measurement points are classified as being in the data error state only when two consecutive errors of the same type (interrogation or response) are detected. The data from a measurement point are not processed the first time a data error is detected. A range error state is declared the first time an out-of-range condition is detected.

The MIST data task performs checks to determine if a measurement point has changed state and if the current value is significantly changed from the value stored in the RTDB. If either condition exists, the RTDB is updated (new state and/or value stored) and other MIST tasks are alerted for further processing. The further processing required is as indicated in a process word stored in the RTDB. The conditions and responses for further processing are as follows.

1. Display data if the measurement is on the page selected and
  - a. The page is being initialized (page call) or
  - b. The state or value has changed.
2. Record the measurement if recording is on and
  - a. The record is being initialized or
  - b. The state or value has changed.
3. Display message if
  - a. A data error has been declared or
  - b. A range error has been declared or
  - c. An alarm has been declared.
4. Notify control task if time is on the hour (data log time interval).

MIST display task. - This task performs the display processing of MIST measurements. It operates on the state and value of a measurement when it is alerted by the data task.

When the state of the measurement being processed for display is normal or alarm, the value is converted to engineering units by using a reentrant subroutine in the reentrant library. The specific routine is indicated by a parameter in the RTDB associated with the measurement being processed. Then the engineering-unit value is converted into ASCII characters and stored in the display buffer, together with the screen location parameters and other characters required by the MIST video display driver.

When the state of the measurement is other than normal or alarm, alpha characters replace the numerical characters in the value field of the display in accordance with the following code.

Interrogation error	- I's
Response error	- R's
Range error high	- H's
Range error low	- L's

All characters in the value field (alpha or numeric) are blinked if the state of the measurement point is other than normal.

MIST record task.- This task processes MIST data for recording. It operates on the measurements flagged for recording by the data task. The record task stores the current value of the measurement in the record buffer, together with the ID of the measurement. When the record buffer is full, the task outputs the buffer contents to the mass storage device with a service request to the executive. When the task senses an end of media, it notifies the control task. The mass storage device used for recording is determined by a parameter in the CDA.

MIST tab task.- This task operates interactively with the MDS operator. It reads recorded MIST data from a magnetic tape and then edits, searches, converts, formats, displays, and tabulates that data. The task data flow is illustrated in figure B-13.

The tab task performs selective data processing. As many as 17 measurements plus date and time of day can be processed at one time. The ID's of the measurements being processed are stored in a buffer within the task. The current raw-data value of each of these measurements is maintained by the task during operation in any mode. The task accesses a file on the fixed disk to obtain 1 of 20 lists. The file can be edited under MDS operator control.

The task operates in one of three modes as selected by the operator. A measurement list must be specified by the operator before any mode is entered. When a new list is specific, the task rewinds the tape, reads the new list measurement ID's from the file, initializes the values from the tape, cancels any previously selected mode, and outputs "Ready" to the MDS video display. The modes are as follows.

1. Search
2. Display
3. Tabulate

With a single command, the operator can specify the search mode and a search parameter. The parameter is a date and time of day or a measurement ID and value. The parameter is converted to the same representation as that used by the recorded data. The tape is searched for a parameter match. For a measurement value, the significant-change tolerance stored in the RTDB for the measurement is applied to the search parameter value. When a match is found, the values in the measurement list are converted to ASCII engineering units (decimal) and displayed on the MDS video display, followed by a "Ready." The display mode is entered.

While in the display mode, the task accepts operator commands to advance, back up, and stop. When the task is advancing, the next sequential record is read and measurement list values are updated, converted, and displayed. The task delays 5 seconds and then repeats the process. This action continues until a stop command is received or another mode or measurement list is selected.

The backup process is similar except that the tape is backspaced three records and then reads two records.

With a single command, the operator can specify the tabulation mode, start time, end time, and print interval. The task moves the tape to the start time (forward or backward), keeping the measurement list current. Then, it reads, converts, and prints the initial measurement values. Then, records are read, the measurement list is updated with conversion, and output to the printer occurs at specified intervals. When the tabulation is complete, the task rewinds the tape but does not destroy the operator-entered parameters. These parameters will be used if a subsequent tabulation command is received without parameters.

The tab task is started by the control task, and it notifies the control task when it is terminating.

MIST control task.- This task provides for MIST operator communications and task coordination. The task operates out of a first-in-first-out queue, receiving inputs from the MIST video display driver, from the other tasks, from the MFU driver, from the MDS video display driver, and from itself. The task consists of a queue and a group of relatively independent routines (sequences). The task is started when an entry is made in its queue. It executes the queued sequence; checks the queue; and, if the queue is empty, proceeds to "End of job."

Operator controls are enabled and disabled by the sequences. Operator messages are illuminated (on) and extinguished (off) by the sequences. One sequence may queue other sequences. When the task is loaded, the begin test control is the only operator control enabled. Any message operation is always the last operation performed. The major operator-control-key sequences are summarized as follows.

1. Begin test

a. Message

- (1) If on, means testing
- (2) If off, means all other modes

b. Controls

- (1) If enabled, can use controls for record on, end test, or  
page index
- (2) If disabled, use begin test control

c. Process

- (1) Starts MFU driver
- (2) Queues page index

## 2. End test

a. Message: if off, means all tasks are off

### b. Controls

(1) If enabled, can use begin test control

(2) If disabled, can start any others

### c. Process

(1) Allows testing panel light to blink and bell to sound for 10 seconds

(2) If recording is on, turns queue record off

(3) Terminates the MTU driver

(4) Writes an end-of-test mark on recording, if used

(5) Initializes CDA

## 3. Page index

### a. Controls

(1) If enabled, can use page number control

(2) If disabled, use page index control

### b. Process

(1) Clears all display flags in RTDB

(2) Disables display task

(3) Clears display screen

(4) Loads page-index file

(5) Annotates screen

## 4. Page number

### a. Controls

(1) If enabled, can use page index control

(2) If disabled, use page number control

b. Process

- (1) Clears all display flags
- (2) Disables display task
- (3) Clears screen
- (4) Loads page file
- (5) Annotates screen
- (6) Loads location table
- (7) Sets display and first-display flags
- (8) Clears page-number buffer
- (9) Enables display task

5. Record on

a. Message: if on, recording

b. Controls

- (1) If enabled, can use record off control
- (2) If disabled, use record on control

c. Process

- (1) If first recording of this test run, rewinds
- (2) Otherwise, sets record and first-record flags

6. Record off

a. Message: if off, recording

b. Controls

- (1) If enabled, can use record on control
- (2) If disabled, use record off control

c. Process

(1) Allows recording panel light to blink and bell to sound for 10 seconds

- (2) Resets all record flags in RTDB

(3) Writes "End of file" in record buffer

(4) Writes "Record buffer to record media"

7. Acknowledge process

a. Stops bell

b. If alarm panel message lit, extinguishes alarm message

(1) To enable, use page index and page number keys

(2) To disable, use acknowledge key if "range error" and "data error" are off

c. If range error panel is lit (alarm panel message off), extinguishes range error message

(1) To disable, use acknowledge key if data error panel is off

(2) To enable, use rescan key

8. Rescan

a. Control: if disabled use rescan key

b. Process: changes the state in the RTDB of all measurements in the range error and data error states to the normal state

The major sequences beginning with operator messages are summarized as follows.

1. Alarm (from data task)

a. Message: if on, alarm

b. Controls

(1) If enabled, can use acknowledge key

(2) If disabled, use page index key and page number key

c. Process

(1) Queues page number zero

(2) Sounds bell

2. Control error
  - a. Message: if on, means control error
  - b. Process: extinguishes control error panel light when an enabled control is processed or after 5 seconds
3. Data error (from data task)
  - a. Message: if on, data error
  - b. Control: if enabled, can use acknowledge control
  - c. Process: sounds bell
4. Range error (from data task)
  - a. Message: if on, range error
  - b. Control: if enabled, can use acknowledge key
  - c. Process: sounds bell
5. MDS fault (IO error from all tasks)
  - a. Message: if on, MDS fault
  - b. Process: IO error code outputted to MDS video display
6. MDS fault cancel (from MDS video display): message saying "Off"
7. Recorder full (end of media, from record task)
  - a. Message: if on, recorder full
  - b. Process
    - (1) Sets all first-record flags in RTDB
    - (2) Directs record-task output to record file on fixed disk
    - (3) Rewinds tape
    - (4) Queues tape check
8. Recorder full (tape back)
  - a. Message: if on, recorder full
  - b. Process

- (1) Buffers from record file to magnetic tape
- (2) Directs record-task output to magnetic tape

Three other major sequences are summarized as follows.

1. Tape check: process
  - a. Checks magnetic tape status every 5 seconds
  - b. Notes progress through following sequence
    - (1) Not ready (rewinding)
    - (2) Ready (rewound)
    - (3) Not ready (removed)
    - (4) Ready (new tape mounted)
  - c. Then queues tape back
2. Data log (from data task or MIST video display): process
  - a. Outputs all measurement identifications and values to file on fixed disk
  - b. If tab task not running
    - (1) Reads all measurement identifications and values from oldest log on file, converts, and prints
    - (2) Repeats for any remaining logs on file
3. Tab on (from MDS video display)
  - a. Starts MIST tab task
  - b. Notes line printer busy

MDS command task.- It is the function of this task to interpret and act upon directives received from the MDS operator through the MDS video display. The MDS video display is left in the read mode, and characters are read as typed and passed in a queue to the MDS command task. A large variety of commands and modifiers are available to the MDS operator to provide a high degree of MDS control. Included are commands that allow tasks to be started, stopped, and modified. These types of commands are useful when new tasks are being developed. A command is also available to "protect" the system from control commands; i.e., lock out the MDS keyboard from all commands except those that provide information. The task is loaded in the protected mode and used in the unprotected mode only for software maintenance. The categories of commands provided are as follows.

1. System initialization
2. Disk file control
3. Task option control
4. Task execution control
5. Task communication
6. System status interrogation
7. Peripheral device control
8. Debug aids

The MRTOS automatically reports MDS errors on the MDS video display. The types of errors detected and reported are as follows.

1. IO errors
2. Illegal instruction
3. Memory protect violations
4. Privileged mode violation
5. Arithmetic faults
6. Memory parity
7. Power failure (during recovery)
8. Queue overflow (IO hardware failure)

Task loader task.- This task is called by the MDS command task or by other tasks. It loads tasks and overlays from the MDS library. It is used for software maintenance.

## MAINTENANCE

The MDS has provisions for equipment and software maintenance.

### Equipment

Equipment maintenance is classified as scheduled and unscheduled.

Scheduled.- Scheduled maintenance should be performed once each month. It should be scheduled to coincide with the resetting of the date maintained

by the MDS. The clock within the MRTOS updates each day of the date at midnight but does not update the month and year. The month and year are set with a command of the command task when the MDS is in the unprotected mode.

Scheduled maintenance is performed by individually loading and executing the MDS diagnostic programs. These are stand-alone programs; i.e., they do not run under the MRTOS. There is a diagnostic program for the processor, the memory, and each peripheral device. The peripheral-device diagnostic programs test the device interface logic board in the minicomputer, as well as the device. These diagnostic programs can be loaded from magnetic tape or from a disk cartridge. Each program is controlled and communicates with the operator through the processor display panel and/or the MDS video display. The diagnostic programs are sequenced in the normal order of use. The processor boot loader is hand-loaded from the display panel to load from tape or cartridge. Care must be taken not to write on the fixed disk when the disk drive diagnostic program is used, or the operational software will be destroyed.

As a part of each diagnostic procedure, consumables are replenished as necessary. This operation includes replacing the disk drive filter, as well as ensuring that supplies (ribbons, printer paper, magnetic tape, etc.) are adequate for the next month's operation.

When all diagnostic procedures are completed, the system is reloaded with the operational software, and the system date and time-of-day clock is set. The system is put into the protected mode, and the processor display panel is locked.

Unscheduled.- Unscheduled maintenance is performed when testing operations cannot be continued because of an MDS failure. The failure is detected through the MDS video display. (See "Operation" section, "Error Diagnosis" subsection.) The respective diagnostic program is loaded and executed to pinpoint the failure. Then the failed component is replaced. The diagnostic program is used to confirm the repair, and the system operational software is reloaded. The date and time-of-day clock is reset before MIST operations are continued.

## Software

There are two basic software maintenance operations that can be performed - rebuilding of the fixed disk and modification of the RTDB. Each of the operations is described in subsequent subsections - following a description of system loading.

System loading.- The MDS is capable of automatic loading from the fixed disk, disk cartridge, and magnetic tape. The operational software resides on the fixed disk, and the processor will normally load from it. To load from the disk cartridge or magnetic tape, the display panel data switches are used.

Automatic loading is performed by sequencing two of the three loader switches. This procedure causes a loader program stored in the ROM's of the LSU to be loaded into memory and executed. This loader program will check the contents of the display panel switch register. One unique setting will cause the loader program to load from the magnetic tape, and another unique setting

will cause the loader program to load from the disk cartridge. All other settings cause the loader program to load from the fixed disk. The loader program loads data in core image form, performs a check-sum check, and executes the loaded program at a fixed location. Check-sum errors are indicated on the display panels.

The system can be loaded manually by loading and executing a boot loader through the display panel. This method is used for the processor and memory diagnostic programs.

To reload the operational software after maintenance operations have been performed, the following steps are accomplished.

1. Set display panel on; clear switch register.
2. Lock display panel.
3. Exercise the loader switches.
4. Set date and time of day (command through the MDS video display).
5. Protect the system (command through the MDS video display).

The entire 64 000 bytes of memory are loaded, including the 7 tasks and the CDA. No tasks are active. The begin test control is armed. The tab task is ready for use. The system status commands of the command task are also ready for use.

Fixed-disk rebuilding.- This process is necessary only after the data on the fixed disk have been destroyed by a disk drive malfunction or a maintenance operation error.

A magnetic tape containing a complete copy of all data on the fixed disk is provided. The fixed-disk data on the magnetic tape are preceded by a program capable of copying the data from the magnetic tape to the fixed disk and from the fixed disk to the magnetic tape.

To rewrite the fixed disk, the system is loaded from the magnetic tape. A set of operator commands is used to copy the data from the magnetic tape to the fixed disk. Just before this operation, the disk-drive diagnostic program should be run in both the test and format modes to ensure that the fixed disk is operational and properly formatted to receive the operational software.

Certain data on the fixed disk are dynamic in nature, such as the measurement lists used by the tab task. When the fixed disk is rebuilt, these data will be in the form last copied on the magnetic tape. Therefore, it is wise to copy the fixed-disk data to the magnetic tape when significant changes are made to the data. This procedure is particularly important after the data base is modified.

Data-base modification.- The MIST Data Base is a complete list of characteristics of each of the 256 MDS measurement points. The RTDB and the data-display-page formats were generated from this data base. Currently, all 256

measurements are not used; thus, their characteristics are not completely defined.

Modifications to MDS measurement points (additions, deletions, or changes in characteristics) require corresponding changes to the "MIST Data Base," the RTDB, and all affected data-display-page formats. These changes are implemented individually.

The "MIST Data Base" is a controlled document. Any changes to measurement points are first redlined in the master copy of this document.

The RTDB is modified to reflect all redlined "MIST Data Base" changes applicable to it. This process is started with the operational software loaded, no tasks active, and the system unprotected. The MDS command set is used to cancel all tasks except the MDS command task and the task loader task and to load the edit task by using an eight-task control block provided for this purpose. The command set of the edit task is used to operate on the RTDB and make the required modifications.

Next, any changes to data display pages are made. This step is also accomplished with the edit task. The data file on the fixed disk that controls the data page format of the affected page is modified by using the edit task. It is then written back to its location on the fixed disk. This process is repeated for each affected page.

The edit task is deleted, and the five MIST tasks are started. These tasks are put in the ready (not active) state by the start command. The "Begin test" control must not be utilized at this point because it would result in tasks being activated.

Now the system is initialized by using the processor display panel. This procedure causes the entire core contents to be copied on the fixed disk. The operational software backup tape is mounted and loaded. The fixed disk is copied to the magnetic tape. Finally, the operational software is loaded in the normal manner, the date and time-of-day clock is set, and the system is protected. It is now configured in accordance with the master redlined copy of the "MIST Data Base" and is ready for use.

There are some limitations on the amount of modification that can be made in this way. No more than the original 256 measurement points can be accessed. No more than 10 data pages can be used. (Currently, six pages are defined, and the other four pages are spares that can be added.)

System generation.- To implement system capabilities beyond those that can be added by data-base modification, a new system must be generated. This process is not considered to be within the scope of software maintenance and thus is not described in this document.

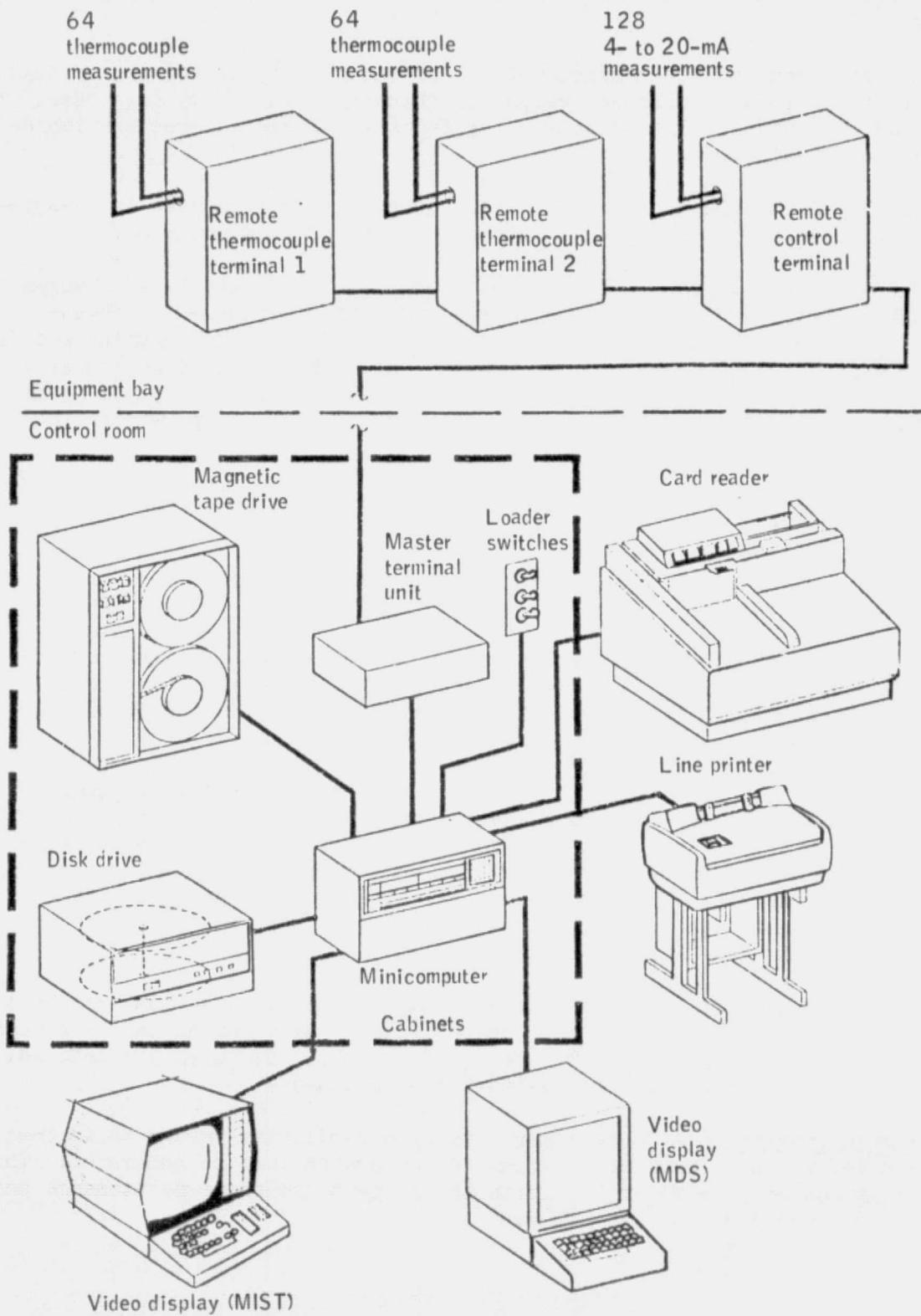
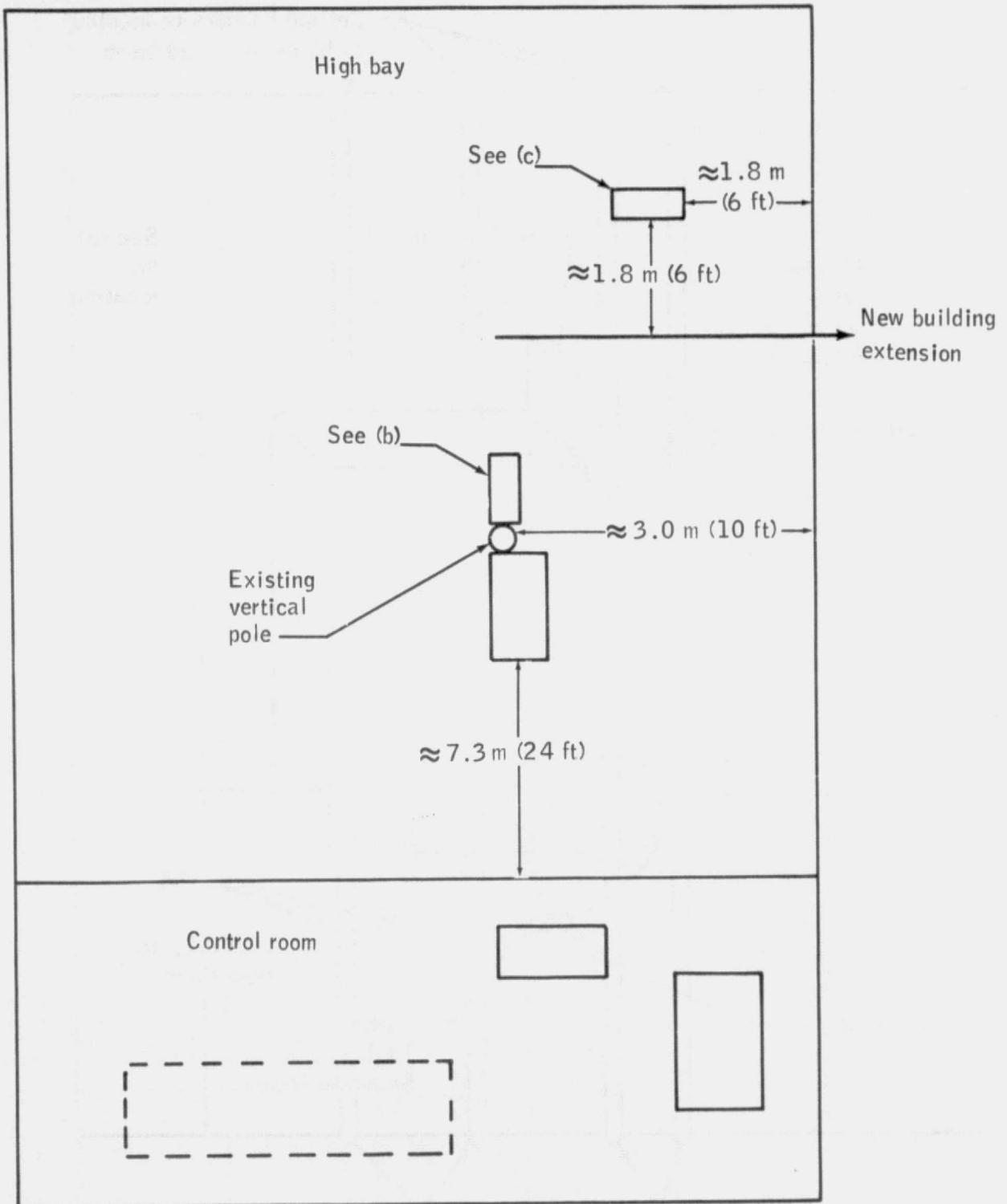
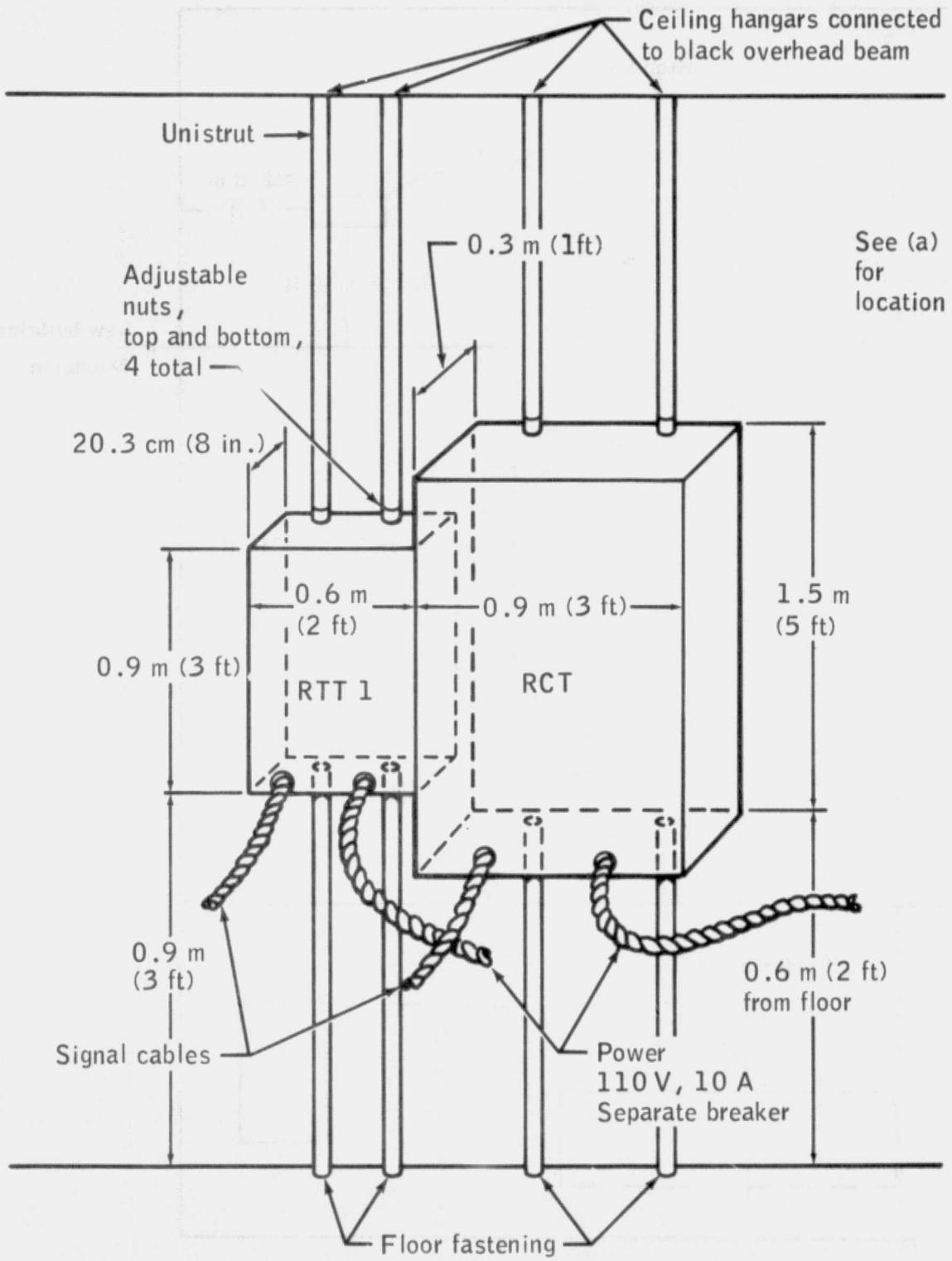


Figure B-1.- Equipment configuration for the MDS.



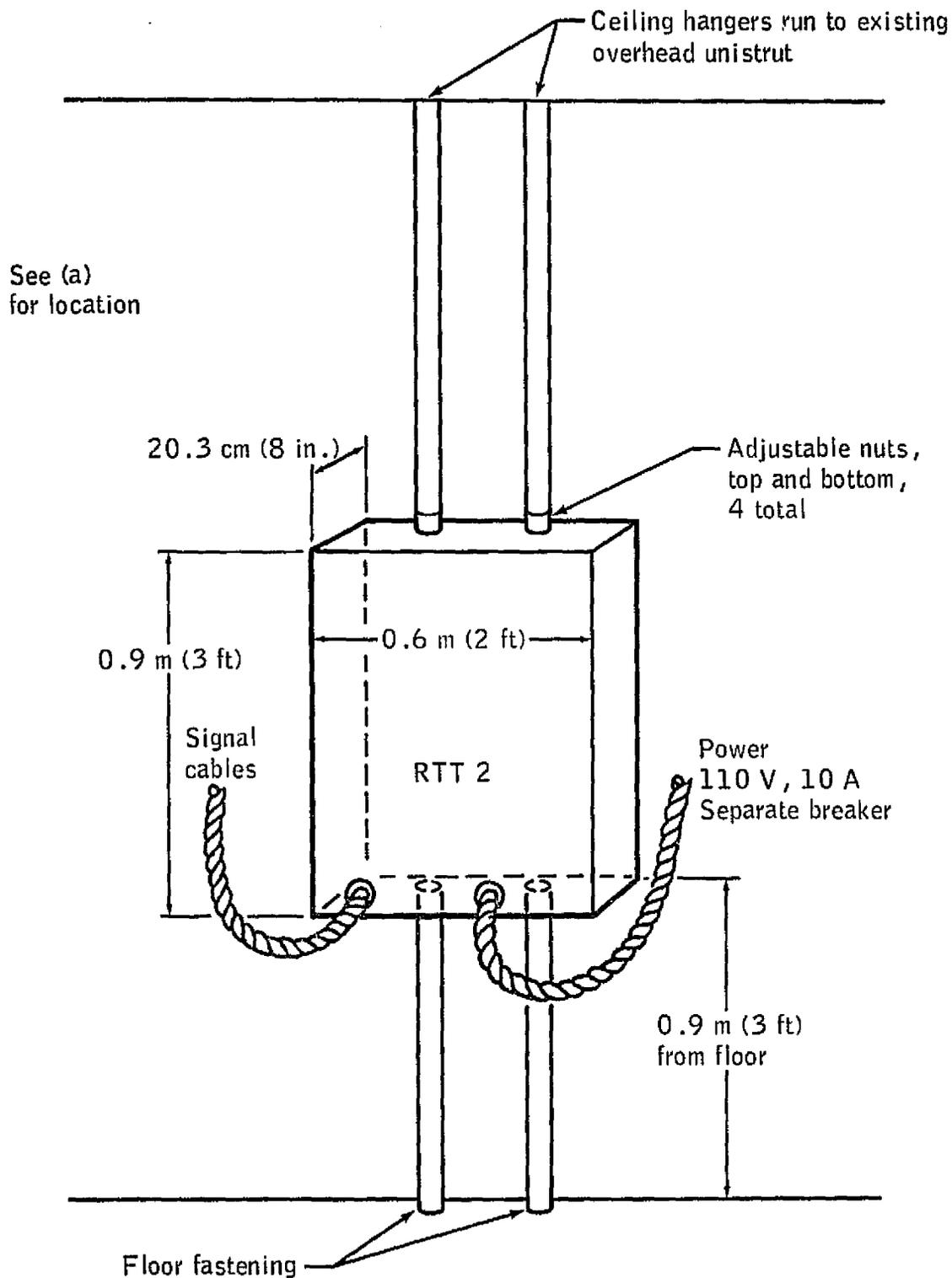
(a) Location of data acquisition units (supplied by ADEC) in building 32J of the JSC.

Figure B-2.- MDS module.



(b) Positioning of remote control terminal and remote thermocouple terminals  
 Note: power and signal cables to be routed overhead.

Figure B-2.- Continued.



(c) Positioning of box containing remote thermocouple terminals.

Figure B-2.- Concluded.

Equipment bay

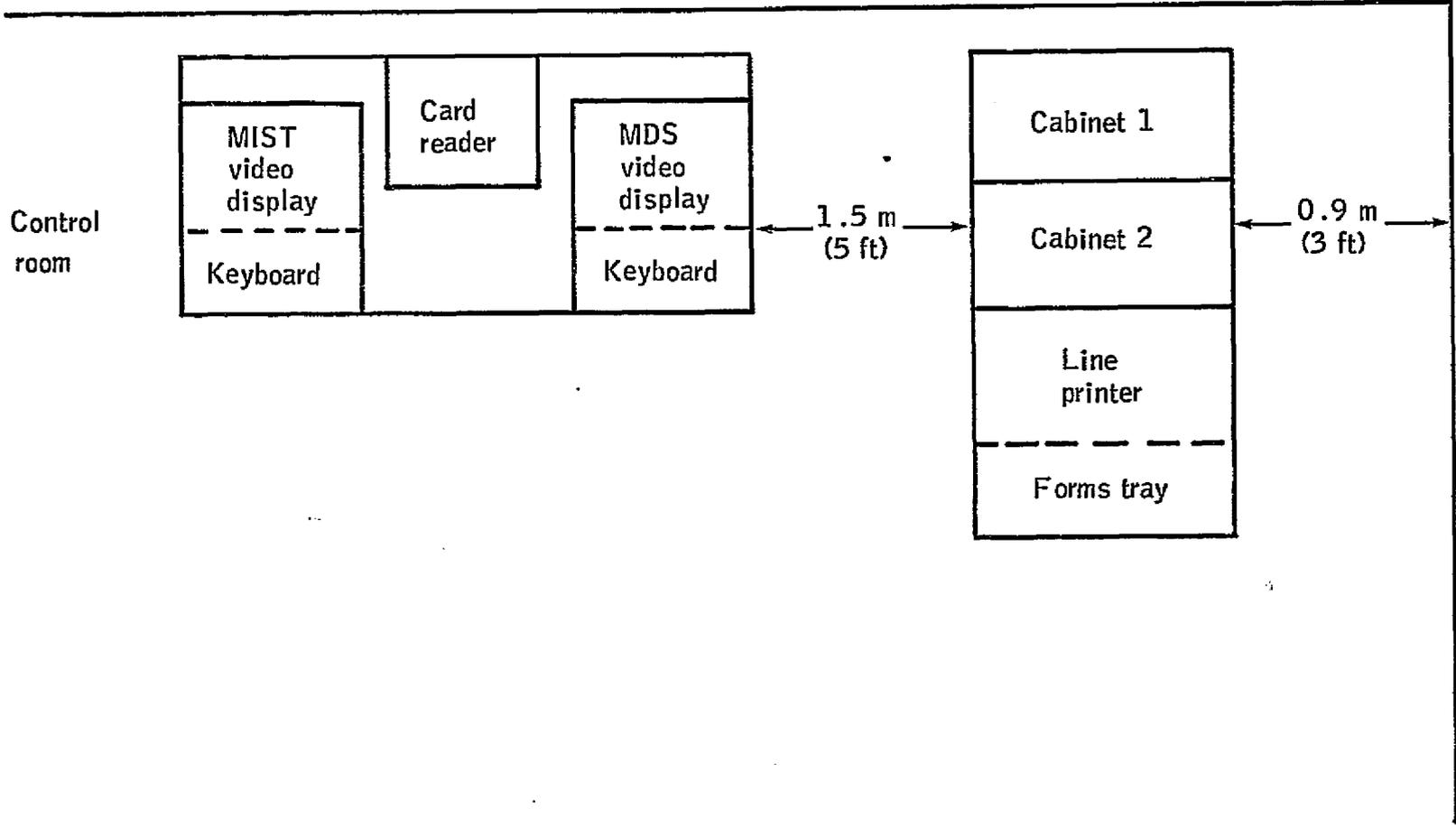
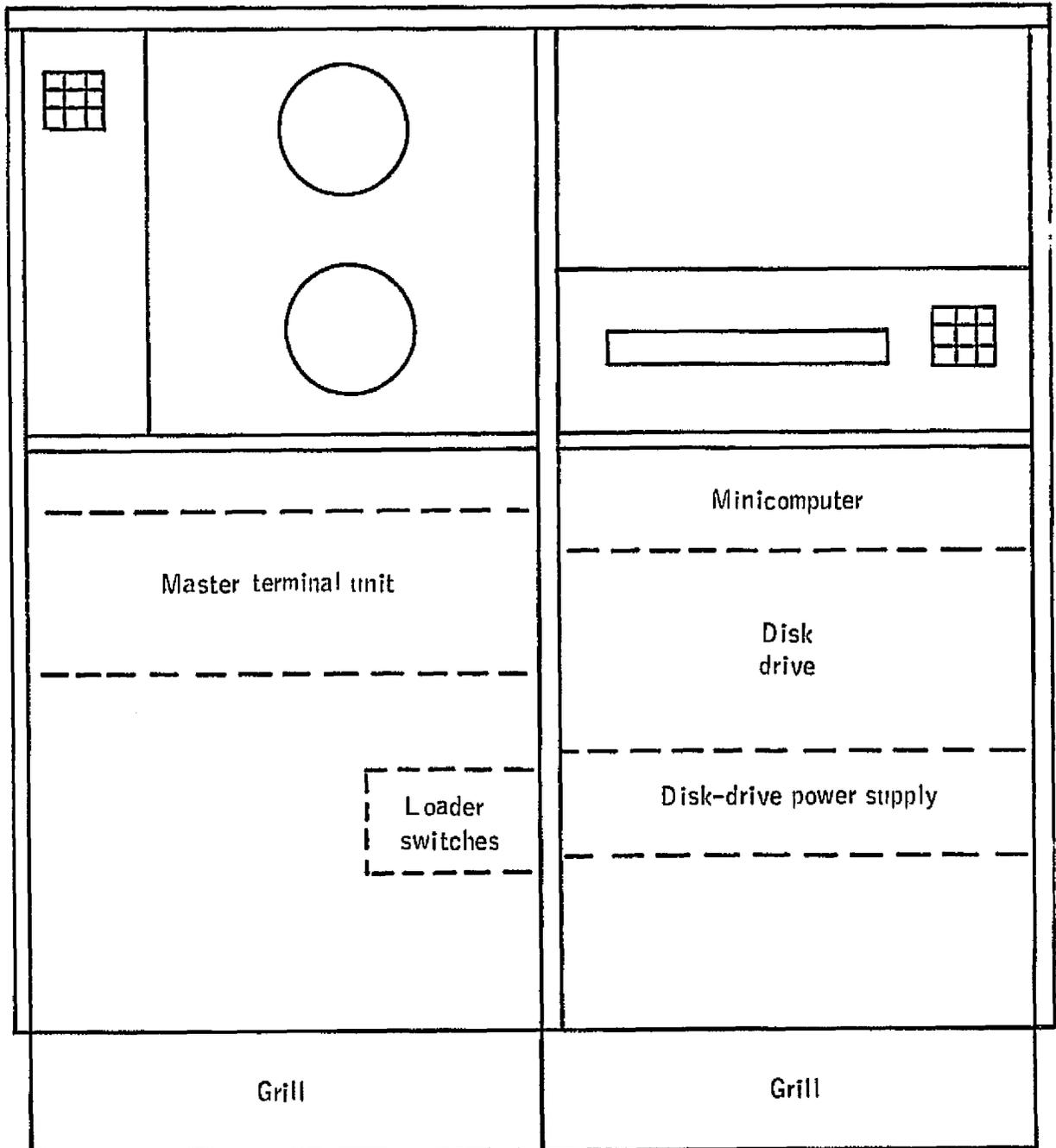


Figure B-3.- MDS equipment in MIST control room.



Cabinet 1

Cabinet 2

Figure B-4.- Layout of MDS equipment cabinets.

Begin test	End test	Record on	Record off
Page index	Page number	Rescan	Acknowledge

(a) System described in appendix.

Figure B-5.- MIST operator control keys. (Empty keys are not presently used in the MIST system.)

Page index	Page number		Acknowledge
Record on	Record off	Log	
Set up	Pretest	Begin test	End test
Manual	Auto		

(b) Later variation being developed.

Figure B-5.- Concluded.

ALARM	Red
RANGE ERROR	Red
DATA ERROR	Red
MDS FAULT	Yellow
CONTROL ERROR	Yellow
RECORDER FULL	Yellow
TESTING	Green
RECORDING	Green

Figure B-6.- MIST operator message panel (colors in legend to right).

PAGE INDEX

MM/DD/YY HH:MM:SS

PAGE 0 ALARMS  
PAGE 1 ENGINE PARAMETERS  
PAGE 2 SEWAGE TREATMENT PARAMETERS  
PAGE 3 HEAT RECOVERY (STEAM)  
PAGE 4 COLD STORAGE/COOLING LOAD  
PAGE 5 HEAT RECOVERY (HOT WATER), STORAGE AND LOAD

(a) Page index.

Figure B-7.- Sample computer printouts of MIST data display format pages.

PAGE 0		A L A R M S			MM/DD/YY HH:MM:SS	
LOW	VALUE	HIGH				
TEMPERATURES						
TAS1	LLL.L	XXX.X	UUU.U	TP6	ENGINE WATER JACKET INLET	
TAS2	LLL.L	XXX.X		TP12	STERIL. REGEN. HX - WATER INLET	
?	LL.LL	XX.XX		TP2	OIL/AFTER-COOLER INLET	
PRESSURES						
PAS1	LL.LL	XX.XX	UU.UU	PI6	STEAM MANIFOLD	
PAS3	LL.LL	XX.XX	UU.UU	P5	CONDENSATE PUMP OUTLET	
CONDUCTIVITY						
CAS1		XXX.X	UUU.U	CI830	COOLING TOWER OUTLET	
PYROMETERS						
		XXXX.	UUUU.	TP101	INCINERATER EXHAUST	

(b) Alarms.

Figure B-7.- Continued.

PAGE 1		ENGINE PARAMETERS					MM/DD/YY		HH:MM:SS	
FUEL	LEVEL	%	TEMP	DEGF.		* EXHUAUST				
DAY TANK	L2	XXX	T1	XXX.X		* STACK GAS	IN	OUT		
						* TEMP	T4	XXXX.	T5	XXX.X DEGF
AIR	TEMP	DEGF	PRESS	INHG		* PRESS	P3	XX.XX	P4	XX.XX "H2O
AMBIENT	T2	XXX.X	P2	XX.XX		* FLOW		F39	XX.XX	LBPM
INLET	T3	XXX.X				* OIL/AFTER-COOLER	IN	OUT		
WATER JACKET			IN	OUT		* TEMP	TP2	XXX.X	TP1	XXX.X DEGF
TEMP	TP6	XXX.X	TP3	XXX.X DEGF		* PRESS	PI1	XX.XX		PSIG
PRESS	PI3	XX.XX	P32	XX.XX PSIG		* FLOW	F38	XX.XX		GPM
						* WMS HEATER	IN	OUT		
AUX. FACILITY HX			IN	OUT		* TEMP	TP1	XXX.X	T28	XXX.X DEGF
TEMP	TP3	XXX.X	TP29	XXX.X DEGF		* FRESH H2O PREHEAT	IN	OUT		
PRESS	P32	XX.XX	P33	XX.XX PSIG		* TEMP	T28	XXX.X	TP21	XXX.X DEGF
FLOW			F3	XXX.X GPM		* FLOW		F13	XX.XX	GPM
INTERCHANGER			IN	OUT		* OIL/A-C INTERCHNG	IN	OUT		
TEMP	TP29	XXX.X	T6	XXX.X DEGF		* TEMP	TP21	XXX.X	T40	XXX.X DEGF
FLOW			F3	XXX.X GPM		* FLOW		F40	XX.XX	GPM

(c) Engine parameters.

Figure B-7.- Continued.

PAGE 2		SEWAGE TREATMENT PARAMETERS				MM/DD/YY HH:MM:SS		
REGEN SEWAGE HEATER				*MET-PRO UNIT				
PROCESS WATER	IN		OUT					
TEMP	TP9	XXX.X	T17	XXX.X	DEGF	* BIO-DISC OUTLET TEMP	T20	XXX.X DEGF
SEWAGE SUPPLY	IN		OUT			* BRINE RETURN FLOW	F8	X.XXX GPM
TEMP	T25	XXX.X	T14	XXX.X	DEGF	* INLET FLOW	F10	X.XXX GPM
						* OUTLET FLOW	F34	XXX.X GPD
BIO-DISC UNIT				*STERIL. REGEN. UNIT				
SEWAGE IN (WMS HX)		T15	XXX.X	DEGF	* PRE-HEAT INLET FLOW	F32	X.XXX GPM	
REGEN. HEATER BYPASS		T16	XXX.X	DEGF	* PRE-HEAT OUTLET TEMP	T18	XXX.X DEGF	
BIO-SURF WATER INLET		TP4	XXX.X	DEGF	* STERIL HX OUTLET TEMP	TP12	XXX.X DEGF	
	FLOW	F35	XX.XX	GPM	* R.O. BYPASS FLOW	F33	X.XXX GPM	
BIO-DISC SLUDGE OUT		F31	XX.XX	GPM?	* R.O. WATER OUT TEMP	T19	XXX.X DEGF	
					* WASTE H2O OUTLET TEMP	TP7	XXX.X DEGF	
					* COOLING TOWER MAKE-UP	F36	X.XXX GPM	
					* SAND FILTER INLET	F9	X.XXX GPM	
					*			
					*			
					*			
					*			
					*			

(d) Sewage treatment parameters.

Figure B-7.- Continued.

PAGE 3	HEAT RECOVERY (STEAM)				MM/DD/YY	HH:MM:SS			
INCINERATOR HEAT EXCHANGER	IN TEMP	OUT	DEGF	IN	PRESS	OUT	PSIG	FLOW	LBPH
WATER/STEAM	T12	XXX.X		P6	XX.XX	PI4	XX.XX	F6	XXX.X
	EXHAUST PYROMETER	TP101	XXXX.	DEGF					
	FUEL FLOW	F11	XX.XX	GPM					
	STEAM MANIFOLD	TP11	XXX.X	DEGF	PI6	XX.XX	PSIG		
ABSORPTION CHILLER	IN TEMP	OUT	DEGF	IN	PRESS	OUT	PSIG	FLOW	GPM
STEAM/CONDENSATE		T35	XXX.X	P26	XX.XX	P23	XX.XX		
CHILLED WATER	T33	XXX.X	TP19	XX.XX	PI8	XX.XX	P20	XX.XX	F24
CONDENSER WATER	T34	XXX.X	T13	XXX.X	P21	XX.XX	P22	XX.XX	F25
FACILITY HEAT EXCHANGER									
STEAM/CONDENSATE		T36	XXX.X	P27	XX.XX	P13	XX.XX		
HOT WATER	TP30	XXX.X	T21	XXX.X					
WATER STERILIZATION HX									
STEAM/CONDENSATE		T37	XXX.X	P28	XX.XX	P18	XX.XX		
STERILIZED WATER	TP23	XXX.X	T13	XXX.X					
EXCESS STEAM CONDENSER									
STEAM/CONDENSATE		T31	XXX.X			P18	XX.XX		
COOLING TOWER WATER	TP16	XXX.X	TP22	XXX.X					
EXHAUST SILENCER HX							"H2O	FLOW	LBPM
EXHAUST GAS	T4	XXX.X	T5	XXX.X	P3	XX.XX	P4	XX.XX	F39
							PSIG		LBPH
WATER/STEAM	T7	XXX.X	TP5	XXX.X	P5	XX.XX	PI2	XX.XX	F6
									XXX.X

(e) Heat recovery (steam).

Figure B-7.- Continued.

PAGE 4	COLD STORAGE/COOLING LOAD				MM/DD/YY HH:MM:SS					
COLD THERMAL STORAGE				*COOLING LOAD		SUPPLY		RETURN		
STORAGE TEMPERATURE	TP33	XXX.X	DEGF	#	H2O TEMP	T46	XXX.X	T47	XXX. DEGF	
COMBINED CHILL. OUT	TP31	XXX.X	DEGF	*		TP35	XXX.X	TP36	XXX. DEGF	
STORAGE OUTLET	TP15	XXX.X	DEGF	*						
BYPASS FLOW	F41	XXX.X	GPM	*						
CHILLED H2O SUPPLY	TP32	XXX.X	DEGF	*						
*****										
COMPRESSION CHILLER	IN	TEMP	OUT	DEGF	IN	PRESS	OUT	PSIG	FLOW	GPM
CHILLED WATER	T32	XXX.X	TP26	XXX.X	P110	XX.XX	P19	XX.XX	F32	X.XXX
CONDENSER WATER			TP25	XXX.X	P24	XX.XX	P25	XX.XX	F27	XXX.X
WET COOLING TOWER										
WATER	T30	XXX.X						F18	XXX.X	
PUMP OUTLET			TP10	XXX.X			P15	XX.XX		
BYPASS								F20	XXX.X	

(f) Cold storage or cooling load.

Figure B-7.- Continued.

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PAGE 5		HEAT RECOVERY (WATER), STORAGE AND LOAD					MM/DD/YY	HH:MM:SS			
HOT THERMAL STORAGE		*HEATING LOAD					SUPPLY	RETURN			
STORAGE TEMPERATURE	TP23	XXX.X	DEGF	*	H2O TEMP	T43	XXX.X	T44	XXX.X	DEGF	
FACILITY HX HOT H2O	TP30	XXX.X	DEGF	*		TP27	XXX.X	TP34	XXX.X	DEGF	
PUMP OUTLET	PI9	XXX.X	PSIG	*	FLOW	F17	XX.XX			GPM	
STOR/FAC HX SUPPLY	F16	XX.XX	GPM	*	PUMP TEMP			TP18	XXX.X	DEGF	
FRESH WATER HEATER	IN			*	PRESS			PI7	XX.XX	PSIG	
	OUT										
HOT H2O	T24	XXX.X	T21	XXX.X	DEGF	*FRESH H2O PRE-HEAT	IN		OUT		
FLOW	F15	XX.XX			GPM	* OIL TEMP	T28	XXX.X	TP21	XXX.X	DEGF
H2O TEMP	TP8	XXX.X	T23	XXX.X	DEGF	* FLOW	F13	XX.XX		GPM	
FLOW	F14	XX.XX			GPM	* H2O TEMP	T22	XXX.X	TP3	XXX.X	DEGF
*****											
OIL/A-C INTERCHANGER	IN	TEMP	OUT	DEGF	IN	PRESS	OUT	PSIG	FLOW	GPM	
OIL LOOP	TP21	XXX.X	T40	XXX.X					F40	XX.XX	
COOLANT WATER	T26	XXX.X	TP14	XXX.X	P12	XX.XX			F25	XXX.X	
AUXILIARY FACILITY HEAT EXCHANGER											
JACKET WATER	TP3	XXX.X	TP29	XXX.X	P32	XX.XX	P33	XX.XX	F3	XXX.X	
COOLANT WATER	T9	XXX.X									
JACKET WATER INTERCHANGER											
JACKET WATER	TP29	XXX.X	T6	XXX.X					F3	XXX.X	
COOLANT WATER	TP14	XXX.X	TP16	XXX.X	P12	XX.XX			F28	XX.XX	
WYS HEATER											
OIL LOOP	TP1	XXX.X	T28	XXX.X							
SEWAGE	T10	XXX.X	T11	XXX.X							

(g) Heat recovery (water), storage, and load.

Figure B-7.- Concluded.

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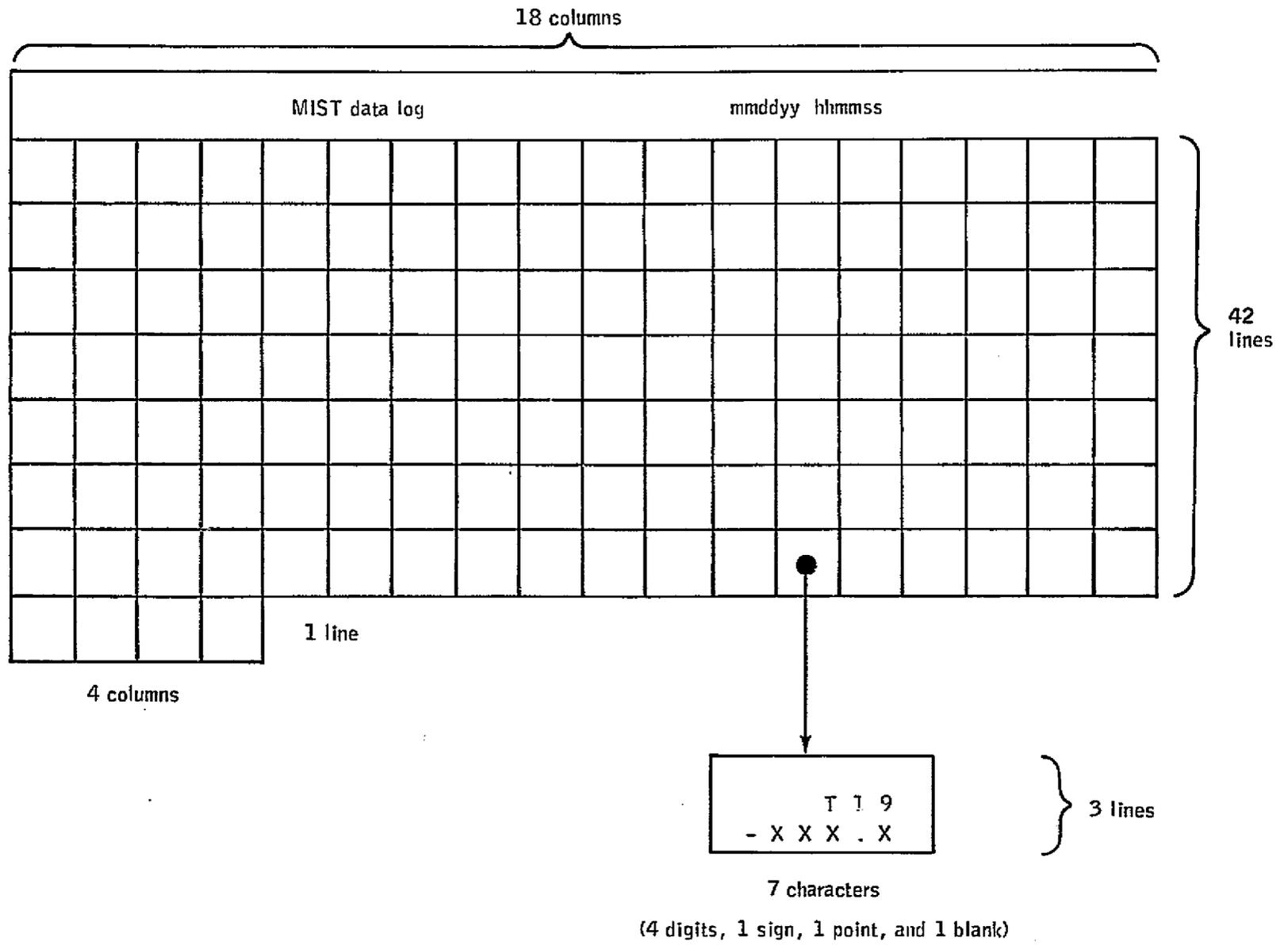
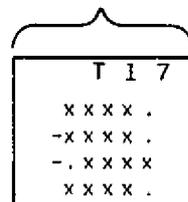
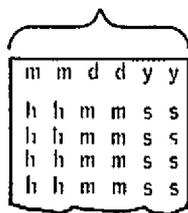
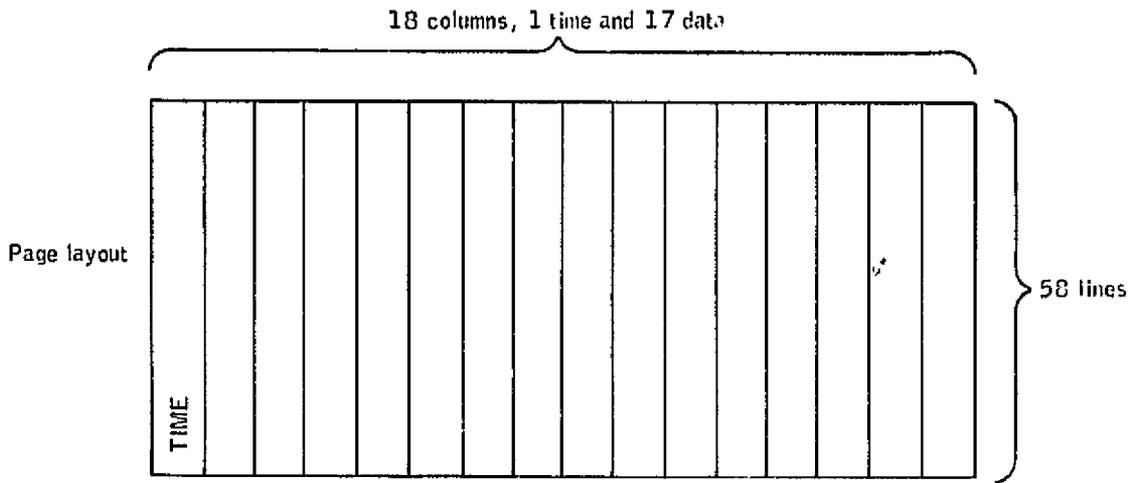
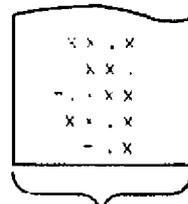


Figure B-8.- Data log format for the MIST.



-Measurement ID  
-Blank



56 data lines

7 characters  
4 digits maximum  
1 sign, if negative  
1 decimal point  
Last blank

Any arrangement

Figure B-9.- Data tabulation format for the MIST.

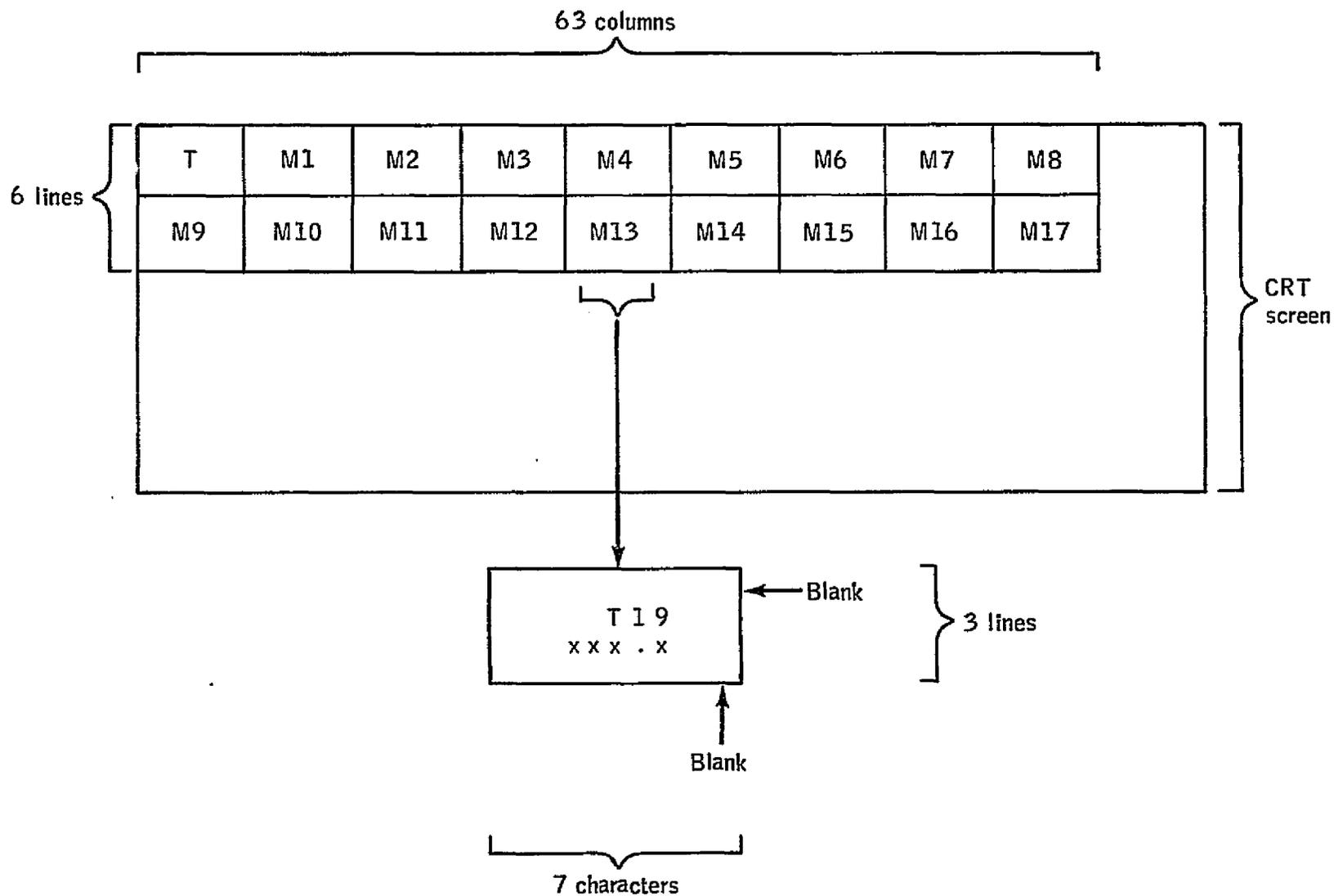


Figure B-10.-- Recorded data display format for the MIST. (T is time of day, and M is measurement.)

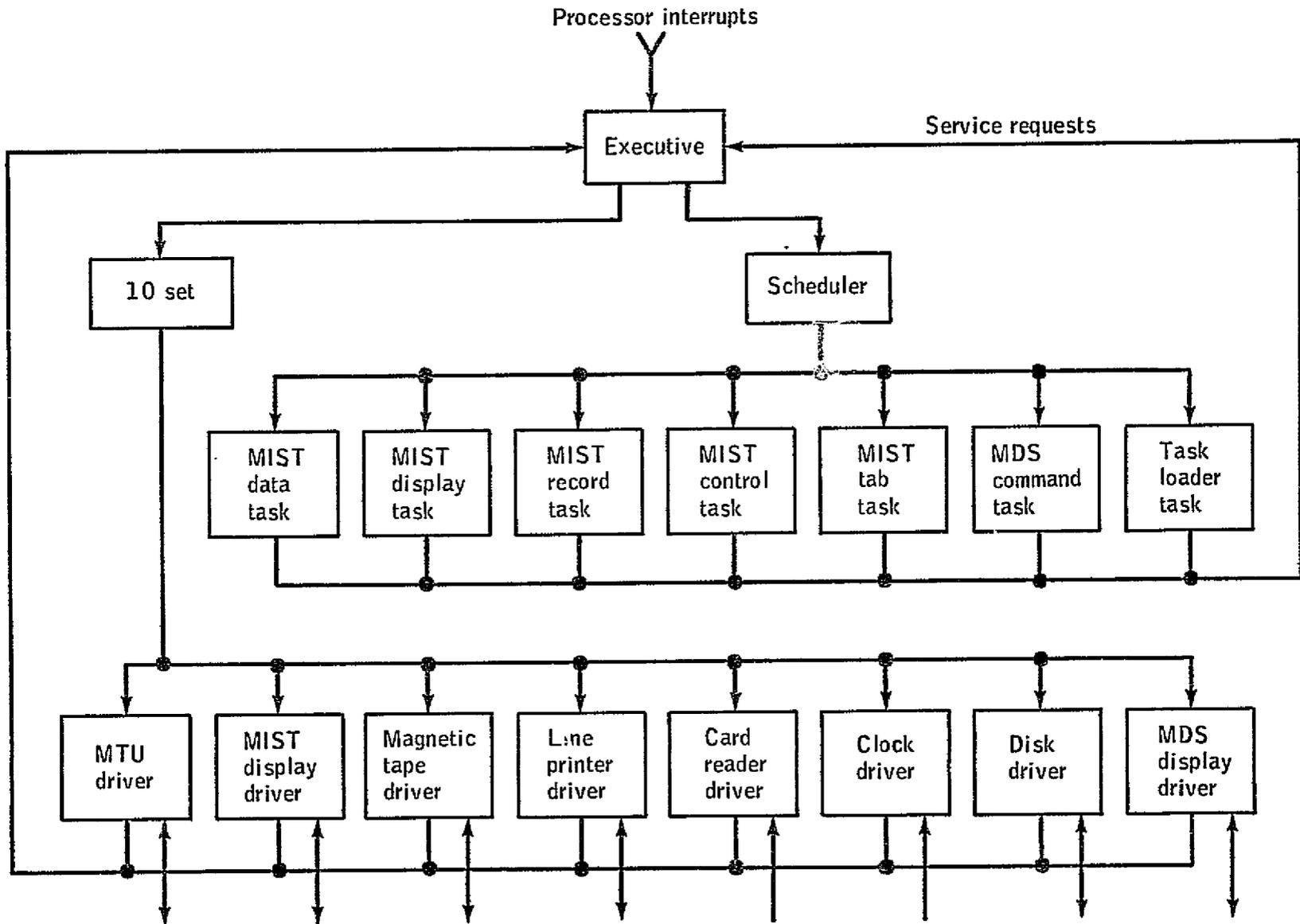


Figure B-11.- Configuration of the MRTOS.

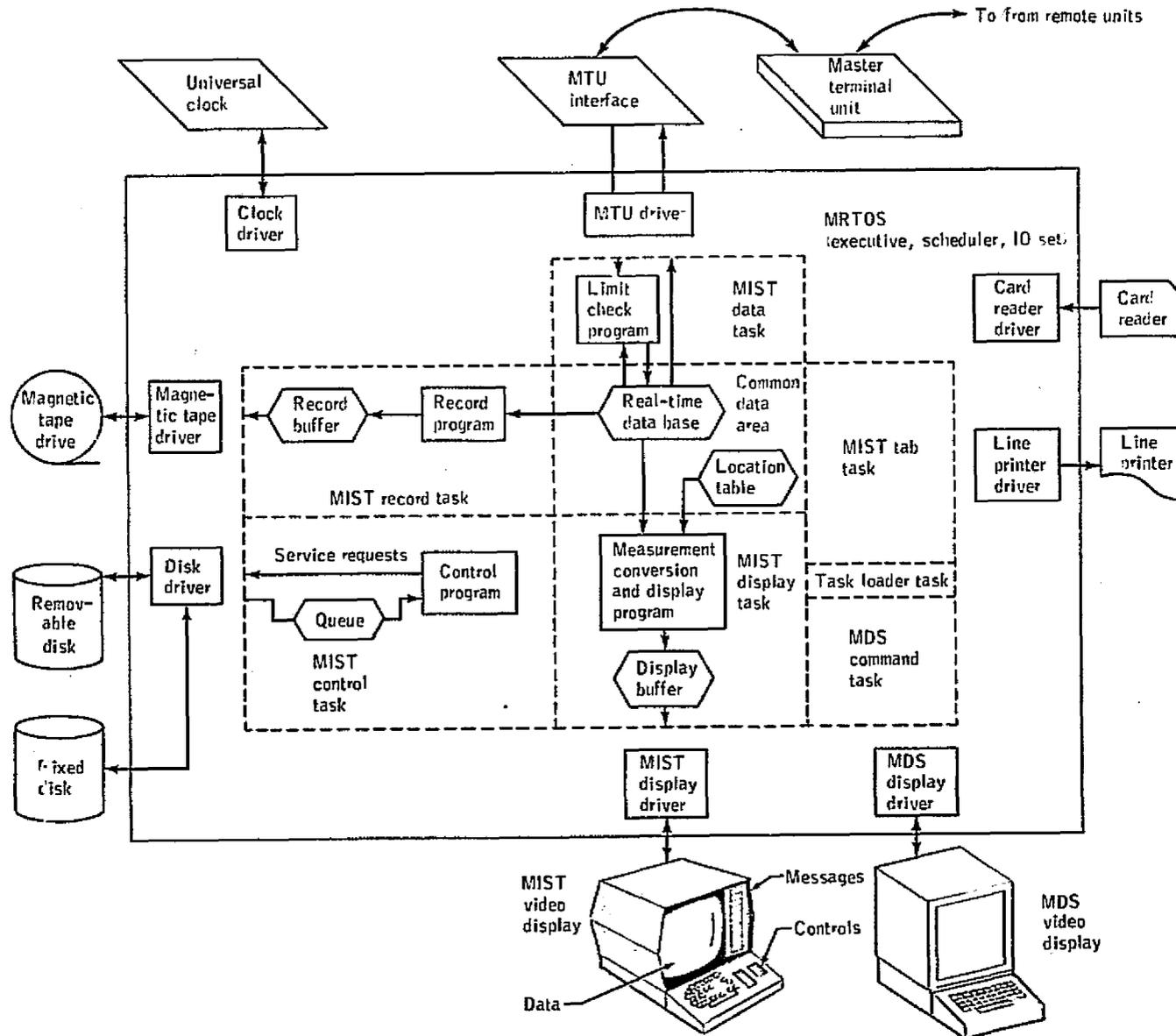


Figure B-12.- Measurement processing flow for the MIST.

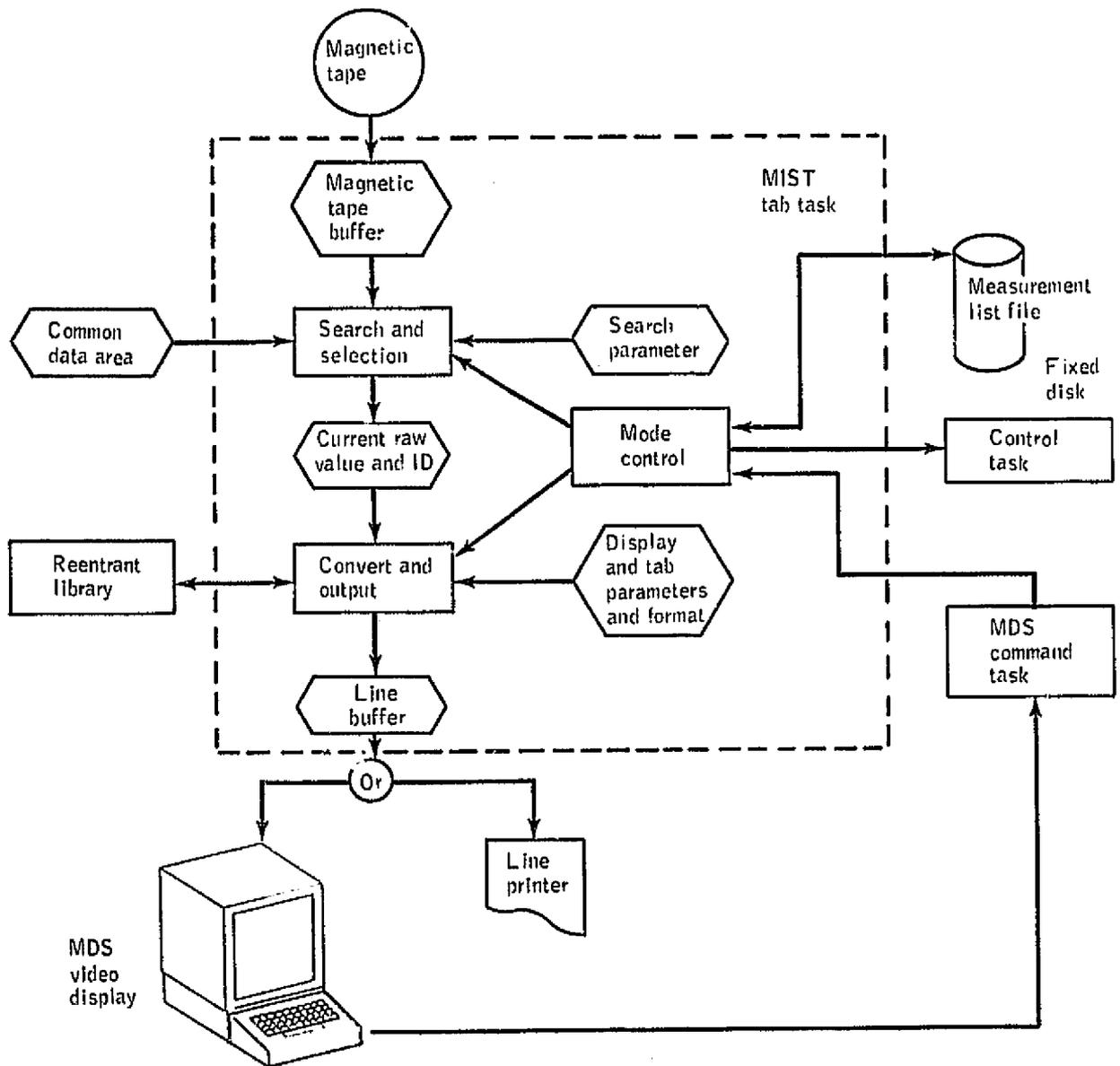


Figure B-13.- Tab task data flow for the MIST.

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## APPENDIX C

### REQUIREMENTS DOCUMENT, MIST CONTROLS SUBSYSTEM

By the Hamilton Standard Division of the United Technologies Corp.

#### INTRODUCTION

This appendix provides the technical data required for computerized control and/or monitoring of selected MIST subsystems. Specific computerized functions to be performed are as follows.

1. Control of the MIST power load simulator and monitoring of the diesel engine generators' cooling systems
2. Control of the MIST heating-load simulator and MIST heating subsystem including the heating-load simulator
3. Control of the MIST air-conditioning load simulator subsystem and the MIST air-conditioning subsystem, including cold thermal storage and condenser water flows

Accomplishment of the aforementioned computerized control functions is enabled as follows.

1. By installation of the control hardware that is defined in the section of this appendix entitled "Control Elements"
2. By definition of the system operating modes and configurations that are defined in the section of this appendix entitled "Operating Modes"
3. By definition of the software requirements and controls logic that are described in the sections of this appendix entitled "Software Requirements" and "Control Logic"

The control logic for controlling the electrical, heating, and air-conditioning load simulators is provided by the NASA and is not part of this appendix.

#### CONTROL PHILOSOPHY

The philosophy used in the preparation of this appendix is to provide the computer with the same capability as that of a test operator in the MIST

control room - i.e., with the capability to start and stop equipment, verify system configurations, control simulated loads, and monitor data. This capability includes all control room functions except (1) engine stop, start, and control and (2) water management and solid-waste management.

The capability to shed automatic computer control is to be provided; this capability will allow for manual operations or direct computer input for the operation of each control element.

## CONTROL ELEMENTS

The control elements consist of various valves and switches that control operation of the MIST simulated loads.

### Identification

All control elements to be controlled and/or monitored by the computer are identified in table C-I. The possible states of each control element and the indicators for showing the specific states of the control elements are also identified.

The terminal board, terminal number, and control relay for each control element operated by the computer are identified in tables C-II and C-III, which are extensions of table C-I.

### Description

This section provides a technical description of all control hardware to be added to the MIST. The hardware included is as follows.

1. Control valves for:
  - a. Heating-water temperature (SV802)
  - b. Domestic-water temperature (SV803)
  - c. Absorption-chiller-firing water (SV806)
  - d. Cooling-tower temperature (SV805)
  - e. Condenser water on-off (SV807 and SV808)
  - f. Chilled-water temperature (SV804)
  - g. Chilled-water mode (SV811, SV812, and SV813)

2. Motor stop/start controls for:
  - a. Absorption chiller (item 501)
  - b. Compression chiller (item 502)
  - c. Tower water pumps (items 510A and 510B)
  - d. Chilled-water pumps (items 503A and 503B)
  - e. Heating-water pumps (items 514A and 514B)
  - f. Cooling-tower fan (item 508)
3. Valve controls for:
  - a. Thermal-storage diverter valve (SV801)
  - b. Firing-water diverter valve (SV806)
  - c. Condenser water shutoff valve, absorption (SV807)
  - d. Condenser water shutoff valve, compression (SV808)
  - e. Diverter valve, compression chiller (SV811)
  - f. Diverter valve, chiller inlet (SV812)
  - g. Diverter valve, chiller outlet (SV813)
  - h. Chilled-water-temperature control (SV804)
  - i. Heating-load-simulator control (SV823)
4. Level controls for:
  - a. NASA surge tank (item 140)
  - b. Sludge tank (item 130)
  - c. Processed-water surge tank (item 175)
  - d. Cooling-tower blowdown tank (item 182)
5. Simulator controls for:
  - a. Air-conditioning-load simulator (SV821)
  - b. Power load simulator
  - c. Heating-load simulator (SV823)
  - d. Boiler water temperature control (SV824)

Heating-water-temperature control.-- The heating-water-temperature control, SV802, is shown schematically in figure C-1. This controller will maintain a temperature of 355.37 K (180° F) for heating loads and a temperature of 377.59 K (220° F) for the firing-water input to the absorption chiller during air-conditioning loads. Temperature control is accomplished by mixing heated water from the facility heat exchanger (item 513) or the hot-thermal-storage tank (item 512) with the cooled return water from the absorption chiller and/or the heating-load simulator to obtain the desired supply temperature. When heating loads only are being simulated, the temperature controller and valve will maintain a setpoint temperature of 355.37 K (180° F), with a flow of 265.0 liters/min (70 gal/min). A portion of this flow (75.7 liters/min (20 gal/min)) will be directed through the heating-load simulator, whereas 189.3 liters/min (50 gal/min) will be bypassed around the heating-load simulator. The lower flow directed through the heating-load simulator will require, approximately, a 27.78-K (50° F) differential temperature at maximum load.

When air-conditioning loads or combined air-conditioning and heating loads are simulated, a controlled delivery temperature of 377.59 K (220° F) is required for the absorption chiller. System flow, as well as the flow of heated water for the absorption chiller, is at 265.0 liters/min (70 gal/min). The flow of water to the heating-load simulator remains at 75.7 liters/min (20 gal/min); the balance of 189.3 liters/min (50 gal/min) is bypassed around the heating-load simulator and returned to the hot-facility-water pump (item 514B).

The control system provided to accomplish the previously described requirements is defined in the control system listing (fig. C-2). An electronic temperature controller and resistance-type temperature sensor with a range of 310.93 to 388.71 K (100° to 240° F) senses the hot-water delivery temperature, compares it to the setpoint of 355.37 or 377.59 K (180° or 220° F), and sends a proportional 4- to 20-milliampere signal to the electropneumatic positioner mounted on the control valve, SV802. The input electrical signal causes air pressure to act on the diaphragm of the control valve to position the valve until the mechanical feedback force generated by the valve is equal to the force generated by the incoming electrical signal in a magnetic coil. The temperature controller can operate in three modes: a supervisory mode, in which the operation is in conjunction with the digital acquisition and control computer; a remote/automatic mode, as a stand-alone controller; and a manual mode, in which the valve can be positioned from the central control panel. In the supervisory mode, the controller receives an input of the required setpoint from the computer and maintains this setpoint until it is updated again by the computer. The signal input and output by the controller is defined in the interface definition (fig. C-3).

Accessory equipment includes a power supply for the controller and temperature sensor and an air-filter regulator for the electropneumatic positioner.

Domestic water temperature control.-- The domestic water temperature control will automatically control the temperature of domestic hot water at 344.26 K (160° F) by mixing water heated by the freshwater heater (item 517) with cool water input from the domestic supply or preheated by the freshwater preheater (item 520). This automatic temperature control system replaces the present manual control. The control system consists of a bulb-filled local pneumatic

temperature control and a diaphragm control valve as defined in the control system list (fig. C-4). The controller to be used is the temperature controller presently installed as the hot-facility-water-temperature controller. The temperature range is 283.15 to 394.26 K (50° to 250° F). The design delivery temperature is 344.26 K (160° F). The domestic water is preheated by the oil cooler/aftercooler circuit in the freshwater preheater (item 520). Final heating occurs in the freshwater heater (item 517). Temperature control is accomplished in bypassing a part of the domestic water around the freshwater heater.

The control valve is a 1.27-centimeter (0.50 inch) three-way diaphragm mixing valve as defined in the control system listing. This control system is a local, self-contained unit with no computer interface.

Absorption-chiller-firing-water control.- The absorption-chiller-firing-water control, SV806, shown schematically in figure C-1, is a diverter valve that can be actuated by an electrical signal from the computer or manually actuated from a pushbutton switch on the central control panel. The diverter valve directs hot facility water to the absorption chiller or to the heating-load simulator.

The equipment provided is defined in the control system listing (fig. C-5) and includes a 5.1-centimeter (2-inch three-way diaphragm-operated diverter valve, an air-filter regulator, switches, and valve-position indicator lights.

The computer interface definition is shown in figure C-6.

Cooling-tower-temperature control.- The cooling-tower-temperature control is shown schematically in figure C-7. The cooling-water-supply temperature to the MIST is automatically controlled by allowing the cooling-water return to flow through the evaporative-cooling tower (item 508) or directly to the tower basin, and bypassing the cooling tower. Mixing of the return water flowing through the cooling tower and the hot water that is bypassed around the cooling tower occurs in the cooling-tower basin. This mixture of cooled and hot water is then delivered to the MIST. The temperature control would normally be from 288.71 to 305.37 K (from 60° to 90° F). When the water-fired absorption chiller is operating, the cooling water used for condensing and absorption cooling must be set at 297.04 K (75° F) minimum. Maintaining this minimum temperature requires bypassing water around the cooling tower on cool days so that the condensing-water temperature remains at 297.04 K (75° F) or higher. On warm days (302.59 K (85° F) dry bulb, 297.04 K (75° F) wet bulb, or higher), the return cooling water will be directed through the cooling tower to obtain maximum cooling. An override is provided to enable all the water to be directed through the cooling tower. This override is actuated from the central control panel by a pushbutton switch; an indicator light will show the override position.

The equipment provided is defined in the control system listing (fig. C-8) and includes a 10.2-centimeter (4 inch) three-way-balanced mixing diaphragm-operated valve, an electropneumatic positioner, an air-filter regulator, and a sensing well for the thermocouple probe. The temperature controller,

thermocouple probe, and transmitter are presently installed as the chilled-water-temperature controller; these items will be relocated as required and used on this control system. There is no computer interface for this control system.

Condenser water on-off controls.- Condenser water on-off controls are shown schematically in figure C-7. These two valves control condensing-water flow to the absorption and compression chillers. The valves are either opened or closed upon a signal from the computer or manually from a switch located on the central control panel. The primary purpose of these valves is to facilitate the automatic startup and shutdown of the chiller from a computer signal. When the chillers are not operational, the valves will be closed and the need for cooling water for the MIST will be reduced. At this time, one of the condenser-water-circulating pumps may be shut down.

The equipment provided is defined in the control system listing (figs. C-9 and C-10) and includes 5.1- and 6.4-centimeter (2 and 2.5 inch) diaphragm-operated solenoid-actuated on-off valves, complete with position-indicating switches and an air-filter regulator. Central control panel material includes switches and position-indicating lights for the open and closed positions. Computer input and output for these valves are defined in the interface definition (figs. C-11 and C-12).

Chilled-water-temperature control.- The chilled-water-temperature controller, SV804, shown schematically in figure C-13, will perform the following functions: (1) control chilled-water temperature within the range of 278.71 to 280.93 K (42° to 46° F) when it is hydraulically located downstream of the chillers, (2) control chilled-water temperature within the range of 282.04 to 285.93 K (48° to 55° F) when it is hydraulically located upstream of the chillers, and (3) change between direct-acting and reverse-acting according to whether the thermal-storage tank is charging or discharging, respectively. When the chilled-water-temperature controller is located downstream of the chillers, temperature control is accomplished by mixing water from the chillers with water from the thermal-storage tank to obtain the desired delivery temperature of 278.71 to 280.93 K (42° to 46° F).

Temperature control in other modes is accomplished in a similar manner; however, the thermal-storage tank is located in the flow stream before the chillers. This configuration reduces the actual load on the chillers because the returning chilled water is being cooled by the thermal-storage tank. The temperature controller is set at 282.04 to 285.93 K (48° to 55° F), and the mixing valve controls the inlet temperature to the chillers by mixing cold water stored in the thermal-storage tank with the warm water returning from the cooling-load simulator.

The control system provided is defined in the control system listing (fig. C-14). The temperature controller is an electronic, supervisory type similar to the heating-water-temperature control previously described. The control range is from 255.37 to 310.93 K (0° to 100° F). A resistance-type temperature probe, transmitter, sensor well, controller power supply, and reversing relay are included. The existing three-way diaphragm mixing valve, SV804, with electropneumatic positioner, and the override solenoid valve will be used.

The computer input and output are defined in the interface definition (fig. C-15).

Chilled-water-mode controls.— The chilled-water-mode controls consist of three diverter valves that establish the operating mode of the chilled-water circuit. The system, shown schematically in figure C-13, has three basic operating modes, all associated with the use of thermal storage.

1. Downstream mode — The thermal-storage tank is charged or discharged while it is located downstream from the chillers.

2. Upstream mode — The thermal-storage tank is charged or discharged while it is located upstream from the chillers.

3. Compression chiller/thermal storage — In this mode, the thermal-storage tank is located between the load and the compression chiller. The absorption chiller is not directly influenced by thermal storage.

Each of the three operating modes can be selected manually from the control room or automatically by the computer.

The equipment provided in this control system, defined in the control system listing (figs. C-16 to C-18), includes three 7.6-centimeter (3 inch) three-way pneumatically operated valves with integrally mounted four-way latching-type solenoid valves and position-indicating switches to indicate valve position. The solenoid valves can be operated in the automatic mode through actuation from the digital acquisition and control computer. The valves can also be actuated by a manual switch on the central control panel.

Computer input and output are defined in the interface definitions (figs. C-19 to C-21).

Motor stop/start control.— Computer-operated stop/start functions are incorporated for the following nine power-consuming items.

1. Absorption chiller (item 501)
2. Compression chiller (item 502)
3. Tower water pumps, two (items 510A and 510B)
4. Chilled-water pumps, two (items 503A and 503B)
5. Heating-water pumps, two (items 514A and 514B)
6. Cooling-tower fan (item 508)

The control concept, shown schematically in figure C-22, adds two computer-operated control relays (CR's) (i.e., CR-1 and CR-2) for each motor-control circuit. This concept provides computer operability while maintaining the manual control capability. Starting or stopping of a pump is initiated by a signal pulse from the computer.

The computer input and output for each of the motor controls are defined in the interface definitions (figs. C-23 to C-30).

Valve controls.- Computer-operated valve function is provided for the following valves.

1. Thermal-storage diverter valve (SV801)
2. Firing-water diverter valve (SV806)
3. Condenser water shutoff valve, absorption (SV807)
4. Condenser water shutoff valve, compression (SV808)
5. Diverter valve, compression chiller (SV811)
6. Diverter valve, chiller inlet (SV812)
7. Diverter valve, chiller outlet (SV813)
8. Chilled-water-temperature control (SV804)
9. Heating-load-simulator control (SV823)

The control concept, shown schematically in figure C-31, adds two computer-operated control relays to each valve function. This approach maintains the manual override capability in the system. Valve operation is initiated upon receipt of a signal pulse from the computer.

The interface definition for the thermal-storage diverter valve is shown in figure C-32. The computer input and output for the remaining valves are defined in the interface definition attached to the specific control system description (fig. C-33).

Level controls.- Level controls for the NASA surge tank, sludge tank, processed-water tank, and cooling-tower blowdown tank are shown schematically in figures C-34 to C-37, respectively. These level-control systems start and stop pumps that fill or discharge their respective tanks. The NASA surge tank level control starts the sewage pump to fill the tank from the main sewage supply tank. When the tank is filled to the high level, the pump is stopped by the level control. High- and low-level alarms will be fitted to the tank as a safety measure to alarm at the central control panel that a failure of the control or pumping system has occurred.

The sludge and processed-water tanks are controlled in a similar manner. The level-control sensor starts the pump when the tank content reaches the high-level point. The tank is pumped down to the preset low-level point, where the pump is stopped. The cycle is repeated when the tank is filled from the connected process. High- and low-level alarms that exist in the present tanks will sound the panel alarm system in the control room.

The equipment provided includes a level sensor with high- and low-level setpoints, control relays for actuation of the pump, and the necessary conduit, wire, and fittings with which to install the aforementioned items.

There is no computer interface for these level controllers.

Air-conditioning-simulator temperature control valve.- The air-conditioning-simulator temperature control valve is shown schematically in figure C-38. Control of the differential temperature is accomplished by mixing the chilled-water supply from the MIST with the warmer water produced in the cooling-load simulator in the air-conditioning-simulator temperature control valve. This control valve receives a proportional electronic signal from a direct digital controller within the computer. The equipment provided is defined in the control system listing (fig. C-39) and includes a 5.1-centimeter (2 inch) three-way diaphragm mixing valve with an electropneumatic positioner and air-filter regulator.

The computer input and output are defined in the interface definition (fig. C-40).

Power simulator control.- The power simulator control, shown schematically in figure C-41, will accept a signal from the digital acquisition and control computer to start the motor on the power simulator to raise or lower the probe in the simulator bath. This action decreases or increases the electrical load on the MIST. The electrical load sensors, controller for the simulator control, necessary control logic, and software programming will be provided by the NASA.

The equipment provided includes control relays, wire, panels, and terminal strips required for installation. The signals required for actuation of the control relays are defined in the interface definition (fig. C-42).

Heating-load-simulator control.- The heating-load-simulator control is shown schematically in figure C-43. It is similar in concept to the cooling-load-simulator control. The digital acquisition and control computer monitors the inlet and outlet temperature of the heating-load simulator and generates a proportional output signal that is used to position a three-way mixing valve. The control valve mixes the hot facility water delivered from the MIST with the cooler water generated by the heating-load simulator to obtain the desired differential temperature.

The equipment provided is defined in the control system listing and includes a 1.91-centimeter (0.75 inch) three-way diaphragm mixing valve with an integrally mounted electropneumatic positioner, a latching solenoid valve for override control, and an air-filter regulator. Equipment mounted in the central control panel includes pushbutton switches and lights for indicating normal and override positions.

Computer output is defined in the interface definition (fig. C-44).

Boiler water temperature control.- The boiler water temperature control is shown schematically in figure C-45. This control system is part of an

addition that includes a hot-water boiler, a pump, and circulating piping. This system provides heating capability for the cooling-load simulator that is independent of the outside air temperature. This provision allows operation of the MIST with air-conditioning loads when the outside air temperature is not high enough to heat the chiller water to the level required. The boiler circulating pump provides a constant flow from the boiler to the cooling-load simulator. The boiler is fitted with an on-off control for maintaining outlet water temperature in the range of 333.15 to 377.59 K (140° to 220° F). The boiler water temperature control senses the air temperature between the coils of the cooling-load simulator and positions a three-way mixing valve to heat the air to the desired temperature. The valve mixes the hot water from the boiler with the cooler water returning from the cooling-load simulator to obtain the desired temperatures.

The equipment provided is defined in the control system listing (fig. C-46). The system includes a local, pneumatic, bulb-filled temperature controller, a 6.4-centimeter (2.5 inch) three-way mixing valve, and an air-filter regulator. There is no computer interface for this control system.

#### OPERATING MODES

This section describes the operating modes of the MIST that are controlled by the computer and defines the configuration requirements for each operating mode, the configuration instructions, and the configuration constraints.

#### Description

Figure C-47 illustrates the functions that may be performed by the MIST with computer control and monitoring. With the engine operating, the system can perform space heating (HEAT), domestic water heating (WATER), air-conditioning (AIRC), or any combination of these three functions.

The HEAT function can be performed with hot thermal storage (HTS) or without hot thermal storage (NOHTS). Similarly, the WATER function can be accomplished with or without hot thermal storage.

The AIRC function includes several modes of operation, as illustrated in figure C-47. The cooling-tower section can be operated in the series mode (SER) or the parallel mode (PAR). The number of chillers operating establishes three additional modes: ACHILL for absorption chiller operation only, CCHILL for compression chiller operation only, and ACHILL, CCHILL for both chillers operating. Whenever the absorption chiller is operating, the HTS or the NOHTS may be used. Cold thermal storage (CTS) may also be used in any air-conditioning mode. If one of the chillers is to be operated with cold thermal storage, there are four operating modes of the cold thermal storage for a complete charge/discharge cycle. When both chillers are operating (ACHILL, CCHILL), two additional modes are available wherein thermal storage affects the compression chiller only. The following list provides additional descriptions of these operating modes.

1. POWER - This operating mode controls and monitors system performance with the engine operating with forced-circulation cooling or with forced ebullient cooling. This operating mode must exist in order for the system to perform any of the other operating modes.
2. HEAT - This mode controls and monitors the MIST heating subsystem during the heating-load or air-conditioning-load simulation. It analyzes system load conditions and determines if hot thermal storage should be used. It also determines the required setting for SV802 and SV806.
3. WATER - This mode monitors the system configuration and will alert the operator if the configuration changes such that water cannot be heated.
4. AIRC - This operating mode establishes the specific mode(s) in which the air-conditioning system is to operate. These modes include SER, PAR, ACHILL, and CCHILL.
5. SER - This mode monitors the cooling-tower section of the MIST during operation in the series mode. It alerts the operator if the temperature conditions are such that the parallel mode should be used.
6. PAR - This mode monitors and controls the cooling-tower section during operation in the parallel mode. It alerts the operator to start or stop the second cooling-tower pump on the basis of load conditions.
7. ACHILL - This operating mode controls and monitors the MIST air-conditioning section when the absorption chiller only is operating. It includes load sensing to start the compression chiller if this action is permitted by test conditions.
8. CCHILL - This operating mode controls the MIST air-conditioning section when the compression chiller only is in operation. It includes load sensing to alert the operator that the load is too high or nonexistent. It does not provide for startup of the absorption chiller.
9. ACHILL, CCHILL - This operating mode monitors and controls the MIST air-conditioning section when both chillers are operating. It includes load sensing to start up or stop the compression chiller on the basis of load conditions.
10. HTS - This operating mode monitors and controls the MIST hot thermal storage. If the hot-thermal-storage temperature is too low, the hot thermal storage will be isolated from the system.
11. NOHTS - This operating mode maintains the hot thermal storage in isolation from the system until the load conditions permit it to be charged.
12. CTS - This operating mode monitors and controls the use of cold thermal storage. It analyzes data and directs cold-thermal-storage operation in one of its seven operating modes, a description of which follows.

a. NOCTS -- This is an operating mode of CTS wherein SV804 is placed in the override position to remove CTS from the system.

b. UP:C:C -- This is an operating mode of the air-conditioning system that locates the cold thermal storage in the hydraulic flow upstream (UP) from the compression chiller (C) and configures SV804 for charging (C) of the cold thermal storage.

c. UP:C:D -- This operating mode of the air-conditioning system locates the cold thermal storage in the hydraulic flow upstream (UP) from the compression chiller (C) and configures SV804 for discharging (D) the cold thermal storage.

d. UP:CA:C -- This operating mode of the air-conditioning system locates the cold thermal storage in the hydraulic flow upstream (UP) from the compression and absorption (CA) chillers and configures SV804 for charging (C).

e. UP:CA:D -- This operating mode is the same as UP:CA:C except that SV804 is configured for discharging (D).

f. DWN:CA:C -- This operating mode of the air-conditioning system locates the cold thermal storage in the hydraulic flow downstream (DWN) from the compression and absorption (CA) chillers and configures SV804 for charging (C).

g. DWN:CA:D -- This operating mode is the same as DWN:CA:C except that SV804 is configured for discharging (D).

#### Configuration Requirements

For each operating mode, the system must establish and maintain specific valve position and motor status in order to perform the specific function. The required control element states for each operating mode are defined in table C-IV. The PRETEST mode may be considered the basic system configuration and is to be maintained unless this configuration is changed by a required operating mode. For example, the potable-water shutoff valve (S013) should be closed unless an instruction is received for the operating mode of WATER (domestic water heating).

Because it is not allowable to perform any of the operating modes unless POWER exists (engine running), the cooling tower (item 508) and one of the cooling-tower pumps (item 510A or 510B) will be on during all operating modes.

When configurations are being changed, the computer should perform the following tasks.

1. Determine the existing configuration
2. Determine the new configuration
3. Execute the differences

In other words, the computer is not to establish the PRETEST mode from any operating mode except for POWER. The PRETEST mode can only exist when the engine is stopped. During engine shutdown, the operator advises the computer that he is going to shut down the engine. If no other functions (HEAT, WATER, or AIRC) exist, the computer will shut down the cooling tower (item 508) and the pump (item 510). Thereafter, the computer will immediately instruct the operator to depress the engine STOP button. If the operator does not stop the engine within 20 seconds, the computer will restart the cooling tower and pump.

### Configuration Instructions

To obtain the desired operating mode or modes, the operator provides an input to the computer that defines the required configuration and the control logic to be followed. (Control logic is presented in the last section of this appendix.) For example, HEAT, HTS, SER, and ACHILL may be an operator input for space heating with the use of hot thermal storage, air-conditioning with the absorption chiller using hot thermal storage, and use of the cooling tower in the series (SER) mode. In providing these inputs, the following rules apply.

1. POWER does not have to be specified unless it is the only operating mode to be run.
2. If HTS or NOHTS is not specified, the system will operate in NOHTS.
3. If SER or PAR is not specified, the system operates in PAR.
4. If ACHILL; ACHILL, CCHILL; or CCHILL is specified, AIRC does not have to be specified.
5. If AIRC is specified, the system will operate in ACHILL, CCHILL. If the load analysis of this mode shows that ACHILL can satisfy the load, it will change to ACHILL. If the load conditions then become such that ACHILL is exceeded, it will change to ACHILL, CCHILL.
6. SER is to be specified only with ACHILL or CCHILL.
7. If CTS or NOCTS is not specified, the system will operate in NOCTS.
8. If CTS is specified, operating modes UP:CA:C, UP:CA:D, DWN:CA:C, and DWN:CA:D will be used.
9. If the CTS UP:C is specified, only UP:C:C and UP:C:D will be used.

### Configuration Constraints

There are certain combinations of operating modes that are physically impossible and not allowed. These constraints are identified in the following list.

1. It is not allowable to specify HTS for one function and NOHTS for another function. The HTS (hot thermal storage) mode is designed to serve HEAT, WATER, and/or AIRC. When it is used for one operating mode, it must also be used for any other operating mode specified.

2. It is not allowable to specify CTS for one chiller and NOCTS for another chiller.

3. It is not allowable to operate the cooling tower in the series mode (SER) when both chillers are operating. The reduced cooling-water flow may be detrimental to the engine and/or chillers.

4. If the cold thermal storage is operated to affect the compression chiller only (UP:C:C and UP:C:D), it can be accomplished if the aforementioned modes are specified with ACHILL, CCHILL. When these modes are specified, then UP:CA:C, UP:CA:D, DWN:CA:D, and DWN:CA:C cannot be performed.

5. If water heating (WATER) is to be the only operating mode, then HTS must also be specified. The system must have hot thermal storage on in order to heat water when space heating or absorption chilling is not operating.

The following list is a summary of the allowable operating modes.

1. POWER
2. HEAT
3. HEAT (HTS)
4. WATER (HTS)
5. AIRC - same as ACHILL, CCHILL
6. ACHILL
7. ACHILL, SER
8. ACHILL, HTS
9. ACHILL, HTS, SER
10. ACHILL, CTS
11. ACHILL, CTS, SER
12. ACHILL, HTS, CTS
13. ACHILL, HTS, CTS, SER
14. CCHILL
15. CCHILL, SER

16. CCHILL, CTS
17. CCHILL, CTS, SER
18. ACHILL, CCHILL
19. ACHILL, CCHILL, HTS
20. ACHILL, CCHILL, CTS
21. ACHILL, CCHILL, HTS, CTS
22. ACHILL, CCHILL, CTS, UP:C
23. ACHILL, CCHILL, HTS, CTS, UP:C
24. HEAT, WATER
25. HEAT, WATER, HTS
26. HEAT, AIRC
27. HEAT, ACHILL
28. HEAT, ACHILL, SER
29. HEAT, ACHILL, CTS
30. HEAT, ACHILL, CTS, SER
31. HEAT, CCHILL
32. HEAT, CCHILL, SER
33. HEAT, CCHILL, CTS
34. HEAT, CCHILL, CTS, SER
35. HEAT, ACHILL, CCHILL
36. HEAT, ACHILL, CCHILL, CTS
37. HEAT, ACHILL, CCHILL, CTS, UP:C
38. HEAT, AIRC, HTS
39. HEAT, ACHILL, HTS
40. HEAT, ACHILL, HTS, SER
41. HEAT, ACHILL, HTS, CTS

42. HEAT, ACHILL, HTS, CTS, SER
43. HEAT, ACHILL, HTS
44. HEAT, CCHILL, HTS, SER
45. HEAT, CCHILL, HTS, CTS
46. HEAT, CCHILL, HTS, CTS, SER
47. HEAT, ACHILL, CCHILL, HTS
48. HEAT, ACHILL, CCHILL, HTS, CTS
49. HEAT, ACHILL, CCHILL, HTS, CTS, UP:C
50. WATER, AIRC
51. WATER, ACHILL
52. WATER, ACHILL, SER
53. WATER, ACHILL, CTS
54. WATER, ACHILL, CTS, SER
55. WATER, ACHILL, CCHILL
56. WATER, ACHILL, CCHILL, CTS
57. WATER, ACHILL, CCHILL, CTS, UP:C
58. WATER, AIRC, HTS
59. WATER, ACHILL, HTS
60. WATER, ACHILL, HTS, SER
61. WATER, ACHILL, HTS, CTS
62. WATER, ACHILL, HTS, CTS, SER
63. WATER, CCHILL, HTS
64. WATER, CCHILL, HTS, SER
65. WATER, CCHILL, HTS, CTS
66. WATER, CCHILL, HTS, CTS, SER
67. WATER, ACHILL, CCHILL, HTS

68. WATER, ACHILL, CCHILL, HTS, CTS
69. WATER, ACHILL, CCHILL, HTS, CTS, UP:C
70. HEAT, WATER, AIRC
71. HEAT, WATER, ACHILL
72. HEAT, WATER, ACHILL, SER
73. HEAT, WATER, ACHILL, CTS
74. HEAT, WATER, ACHILL, CTS, SER
75. HEAT, WATER, ACHILL, CTS, SER
76. HEAT, WATER, ACHILL, CCHILL, CTS
77. HEAT, WATER, ACHILL, CCHILL, CTS, UP:C
78. HEAT, WATER, AIRC, HTS
79. HEAT, WATER, ACHILL, HTS
80. HEAT, WATER, ACHILL, HTS, SER
81. HEAT, WATER, ACHILL, HTS, CTS
82. HEAT, WATER, ACHILL, HTS, CTS, SER
83. HEAT, WATER, CCHILL, HTS
84. HEAT, WATER, CCHILL, HTS, SER
85. HEAT, WATER, CCHILL, HTS, CTS
86. HEAT, WATER, CCHILL, HTS, CTS, SER
87. HEAT, WATER, ACHILL, CCHILL, HTS
88. HEAT, WATER, ACHILL, CCHILL, HTS, CTS
89. HEAT, WATER, ACHILL, CCHILL, HTS, CTS, UP:C

#### SOFTWARE REQUIREMENTS

The software should accommodate all facets of the plant operation. However, it provides capabilities for and requires operator setup and intervention during various phases of testing.

## Override Functions

The controls software shall include the following capabilities.

1. Allow the operator to manually control the operation of the control functions described in the last section of this appendix.
2. Allow the operator to establish the state of each computer-controlled element by means of computer input. This method would be employed while the system is under manual control.
3. Allow the operator to instruct the computer to ignore the state of a control element that is under manual control and monitoring. This method would be used when the system is under computer control. An example of this capability is the case in which the control logic requires two chillers to be operating and the operator wants to determine the effect of one chiller operating.

## Operator Responsibilities

The installation and operation of the computerized control system in the MIST does not relieve the operator of his responsibilities. He uses existing procedures to prepare for startup of the system and the engine and for directing control to the computer. When the operator takes manual control of a function or control element, he is responsible for monitoring and control.

## CONTROL LOGIC

### CENTRAL CONTROL Mode

CENTRAL CONTROL is the supervisor of all control functions, with the primary purpose of starting or stopping the HEAT and AIRC when loads are applied or removed (fig. C-48). Specific tasks performed by CENTRAL CONTROL are as follows.

1. To ensure that no other functions are performed during a test unless a power load exists
2. To direct the operation of HEAT and AIRC in response to input loads
3. To establish pretest conditions of hot- and cold-thermal-storage temperatures

4. To inform the operator that the system is ready for test when the hot- and cold-thermal-storage conditions are satisfied and when the steam pressure exceeds  $82.7 \text{ kN/m}^2$  (12 psig)

5. To sequence the shutdown of chillers and chilled-water pumps when no air-conditioning load exists

6. To direct the position of the SV823 to "Override" if the absorption chiller is operating and there is no heating load

#### PRETEST Mode

The PRETEST mode is the mode in which the operator informs the computer of the system configuration desired for a particular test (fig. C-49). Specific inputs required before engine start are as follows.

1. Valve SV30 position
  - a. Primary - ebullient engine
  - b. Auxiliary - forced-circulation engine
2. Valve S01 position
  - a. Open - incinerator on
  - b. Closed - incinerator off
3. Pump 510
  - a. 510A - pump 510A to be on at all times
  - b. 510B - pump 510B to be on at all times

After the computer has received the aforementioned information, it is ready for the operator to start the engine. The operator's responsibilities for starting the engine are unchanged with the installation of this control system.

If the engine is running (POWER mode exists), the operator will instruct the computer to go to PRETEST. The computer verifies that loads are off, informs the operator, shuts off the cooling tower and cooling-tower pump, and signals the operator to depress the engine STOP button. If the flow in the oil/aftercooler (A-C) circuit is not significantly reduced within 20 seconds, the cooling tower and pump will be restarted.

#### POWER Mode

In the POWER mode, the control system monitors engine cooling systems and alerts the operator of any out-of-specification conditions. Also during this

mode, the operator informs the computer of the test conditions required (fig. C-50).

The following data requirements are specified for monitoring of the engine cooling systems.

1. Oil/A-C coolant flow (F38), 265.0 liters/min (70 gal/min) minimum
2. Oil/A-C coolant temperature (TP2), 330.37 K (135° F) maximum
3. Cooling-water flow (F28), 567.8 liters/min (150 gal/min) minimum
4. Condensate return pressure (P5), 103.4 kN/m<sup>2</sup> (15 psig) minimum

If the engine is operating with forced-circulation cooling, the following additional data verification is included.

1. Jacket water flow (F2), 530.0 liters/min (140 gal/min) minimum
2. Jacket water temperature, less than the setting of SV802 (THW)

If any of the aforementioned conditions are violated, the operator is to be advised.

If the system in the PRETEST mode is ready for engine start as part of that mode, it will wait for an input from the operator that he has started the engine, closed the main breaker, and wants the computer to control the POWER mode. When this instruction is received, the control system sequences the startup of the cooling tower and the pump selected by the operator as part of the PRETEST mode.

While operating in this mode, the operator should specify one of the allowable operating modes and provide inputs of the following specific control parameters.

1. Power simulator load (kilowatts) in contrast to test time
2. Heating-simulator load (J/hr (Btu/hr)) in contrast to test time
3. Air-conditioning-simulator load (kilowatts (tons)) in contrast to test time
4. THW (kelvins (degrees F)), the hot-water-temperature setting of SV802 that is TABS and/or THTG
5. TABS (kelvins (degrees F)), control setting of SV802 for temperature of firing water to the absorption chiller (nominal, 377.59 K (220° F))
6. THTG (kelvins (degrees F)), control setting of SV802 for heating loads (nominal, 355.37 K (180° F))

7. TCW (kelvins (degrees F)), the chilled-water-temperature setting of SV804 that is TCWR and/or TCWS

8. TCWR (kelvins (degrees F)), control setting of SV804 when cold thermal storage in any (UP: : ) mode is used; controls the chilled-water return to the chillers (nominal, 284.26 K (52° F))

9. TCWS (kelvins (degrees F)), control setting of SV804 when cold thermal storage in any (DWN: : ) mode is used; controls the chilled-water supply to the load (nominal, 280.37 K (45° F))

10. THTS (kelvins (degrees F)), the desired temperature of hot thermal storage at the start of the test

11. TCTS (kelvins (degrees F)), the desired temperature of cold thermal storage at the start of the test

#### HEAT Mode

In the HEAT mode, the control system establishes and verifies the system configuration, positions SV806, and sets SV802 at the proper setting (either TABS or THTG) on the basis of which operating modes exist. It also calculates the heat available and the heat load and will alert the operator if the heat load exceeds the heat available or else start up hot thermal storage if it is allowed (fig. C-51).

#### WATER Mode

The WATER mode verifies that the system configuration and operating modes allow the system to heat potable water. If the hot-water temperature exceeds  $338.71 \text{ K} \pm 5.55$  ( $150^\circ \text{ F} \pm 10^\circ$ ), the operator will be alerted. This mode also directs the use of hot thermal storage if it is allowed (fig. C-52).

#### HTS Mode

The instruction "Go to HTS" originates from any of the operating functions that use hot thermal storage; namely, HEAT, WATER, AIRC, and/or ACHILL (fig. C-53). When this instruction is received, the control system first determines whether the thermal storage can be used in the system by calculating the heat loads and checking the temperature of the thermal storage. If thermal-storage and load conditions do not permit use of thermal storage, it will not be used and the operator will be advised. If it is usable, it will be actuated and monitored until load and temperature conditions are such that it is no longer usable. At this time, it will be isolated from the system and the operator will be advised.

When the hot thermal storage is operating, the control system will inform the operator that it is charging or discharging.

#### NOHTS Mode

The instruction to enter the mode of NOHTS (no hot thermal storage) originates from the HTS mode and only exists when HTS is specified and its temperature conditions require that it be isolated from the system. The logic diagram (fig. C-54) isolates it from the system and then directs the load analysis of the HEAT mode so that HTS may be used when proper conditions exist.

#### AIRC Mode

The AIRC mode includes several modes of operating the MIST air-conditioning system. The control logic diagram (fig. C-55) directs the control system to the proper operating mode.

#### SER Mode

The SER operating mode originates only from operator input (fig. C-56). When operating in this mode, the operator is warned if the temperature and flow conditions are such that the parallel mode should be used or the manual setting of SV805 should be readjusted.

#### PAR Mode

Control in the PAR operating mode ensures that the following conditions will exist.

1. Both tower water pumps are on whenever both chillers are on.
2. Both tower water pumps are on when the engine is cooled by forced circulation and any chiller is on.

The control system monitors the system flows and temperatures and starts or stops the second cooling-tower pump as required (fig. C-57). Before shutting down one of the cooling-tower pumps, the control system predicts the cooling-water-supply temperature with one pump operating, on the basis of data received with two pumps operating.

#### ACHILL Mode

In the ACHILL operating mode, the control system establishes the configuration, monitors the performance, and directs the use of cold thermal storage (CTS) (fig. C-58) if it is allowed. If the control system finds that the load conditions are excessive for the absorption chiller, it will direct a mode change to ACHILL, CCHILL if this transition is allowed.

### ACHILL, CCHILL Mode

Control in the ACHILL, CCHILL operating mode is illustrated in figure C-59 and includes the following capabilities.

1. Startup and operation of both chillers, the chilled-water pumps, and the cooling-tower pumps
2. Direction of the use of cold thermal storage if it is allowed
3. Data monitoring of the air-conditioning subsystem
4. Load analysis to determine if the absorption chiller can satisfy the load by itself

### CCHILL Mode

Control in the CCHILL operating mode includes startup of the compression chiller and its chilled-water pump, as well as data monitoring to alert the operator if the temperatures, flows, and/or load conditions exceed specified limits (fig. C-60). There is no load analysis as part of this control mode.

### CTS Mode

The control of CTS (cold thermal storage) consists of monitoring the various temperature conditions and directing one of the seven operating modes of the cold thermal storage (fig. C-61).

The control logic illustrated in figures C-62 to C-66 uses thermal storage to apply a fixed load to the chillers. This approach simplifies the complexity of the control function and causes the thermal storage to charge during low loadings and to discharge during high loadings. The load applied to the chillers by the cold thermal storage is a function of TCWR and TCWS, which are operator inputs.

The control modes of cold thermal storage (CTS) are as follows: (1) NOCTS, (2) UP:C:D, (3) UP:C:C, (4) DWN:CA:D, (5) DWN:CA:C, (6) UP:CA:D, and (7) UP:CA:C.

Each of these operating instructions originates from the CTS mode and requires that the chilled-water system establish a specific configuration. The control logic diagrams (figs. C-62 to C-66) require that the system establish the specific mode, wait 60 seconds, and then go to the CTS control diagram to reconfirm or to change its operating mode.

TABLE C-I.- CONTROL ELEMENT STATES AND INDICATORS

Element	Name	Computer function	State	Input for change of state	Indicator, light number	Feedback, power on or off
S01	Incinerator steam valve	Monitor	Open	--	71	On
			Closed		72	On
SV8	Facility water outlet valve	Monitor	Cooling	--	83	On
			Facility		84	On
SV58	Combined-chiller outlet valve	Monitor	Series	--	85	On
			Parallel		86	On
SV59	Oil/A-C interchanger inlet valve	Monitor	Series	--	87	On
			Parallel		88	On
SV11	Facility water inlet valve	Monitor	Cooling	--	89	On
			Facility		90	On
S013	Potable-water shutoff valve	Monitor	Open	--	92	On
			Closed		93	On
S026	Compression chiller outlet shutoff valve	Monitor	Open	--	124	On
			Closed		125	On
S029	Compression chiller bypass valve	Monitor	Open	--	126	On
			Closed		127	On
SV30	Heating-mode-selector valve	Monitor	Primary	--	117	On
			Auxiliary		123	On
S056	Facility heat exchanger steam shutoff valve	Monitor	Open	--	76	On
			Closed		77	On
SV801	Hot-thermal-storage diverter valve	Control	Normal	Pulse	3	On
			Storage		4	On
SV802	Heating-water-temperature control	Control	--	Pulse train	(a)	
SV804	Chilled-water-temperature control	Control	Direct acting	Pulse	(b)	On
			Indirect acting	Pulse		
			Override	Pulse		
			Normal	Pulse train		
SV806	Absorption-chiller firing-water control	Control	Chilling	Pulse	201	On
			Heating		200	On
SV807	Shutoff valve, compression chiller condenser	Control	Open	Pulse	202	On
			Closed		203	On
SV806	Shutoff valve, absorption chiller condenser	Control	Open	Pulse	204	On
			Closed		205	On

<sup>a</sup>Control interface defined in subsection "Heating-Water-Temperature Control."

<sup>b</sup>Control interface defined in subsection "Chilled-Water-Temperature Control."

TABLE C-I.- Concluded

Element	Name	Computer function	State	Input for change of state	Indicator, light number	Feedback, power on or off
SV809	Oil/A-C heat-transfer-temperature control valve	Monitor	Override Normal	--	135	On
SV811	Diverter valve, compression chiller inlet	Control	From thermal storage (T/S) From load	Pulse	207 206	On On
SV812	Diverter valve, chiller inlet	Control	From T/S From load	Pulse	209 208	On On
SV813	Diverter valve, chiller outlet	Control	To T/S To load	Pulse	211 210	On On
SV823	Heating-load-simulator control valve	Control	Operating Override	Direct digital Pulse	14	On
I-501A	Absorption chiller	Control	On Off	Pulse	12	On Off
502	Compression chiller	Control	On Off	Pulse	11 11	On Off
503A	Chilled-water pump, absorption chiller	Control	On Off	Pulse	28 28	On Off
503B	Chilled-water pump, compression chiller	Control	On Off	Pulse	30 30	On Off
508	Cooling tower	Control	On Off	Pulse	38 38	On Off
510A	Tower water-coolant pump	Control	On Off	Pulse	51 51	On Off
510B	Tower water-coolant pump	Control	On Off	Pulse	30 30	On Off
514A	Hot-water pump (storage)	Control	On Off	Pulse	55 55	On Off
514B	Hot-water pump	Control	On Off	Pulse	57 57	On Off

TABLE C-II.- COMPUTER INTERFACES FOR TERMINAL BOARD NUMBER 20 OF THE MIST SYSTEM

Term	Assignment	Control signal	Control component	Control element		
				State	ID	Name
1	+	+24 Vdc	CR 10	Heating	SV806	Absorption-chiller-firing-water control
2	-	128 msec				
3	Shield					
4	+	+24 Vdc	CR 11	Chilling	SV806	
5	-	128 msec				
6	Shield					
7	+	+24 Vdc	CR 12	Open	SV807	Shutoff valve, compression chiller condenser
8	-	128 msec				
9	Shield					
10	+	+24 Vdc	CR 13	Closed	SV807	
11	-	128 msec				
12	Shield					
13	+	+24 Vdc	CR 14	Open	SV808	Shutoff valve, absorption chiller condenser
14	-	128 msec				
15	Shield					
16	+	+24 Vdc	CR 15	Closed	SV808	
17	-	128 msec				
18	Shield					
19	+	+24 Vdc	CR 16 (latch)	Direct acting	SV804	Chilled-water-temperature control
20	-	128 msec				
21	Shield					
22	+	+24 Vdc	CR 16 (release)	Indirect acting	SV804	
23	-	128 msec				
24	Shield					
25	+	+24 Vdc	CR 17	Normal	SV804	
26	-	128 msec				
27	Shield					
28	+	+24 Vdc	CR 18	Override	SV804	
29	-	128 msec				
30	Shield					
31	+	+24 Vdc	CR 19	From load	SV811	Diverter valve, compression chiller inlet
32	-	128 msec				
33	Shield					
34	+	+24 Vdc	CR 20	From T/S	SV811	
35	-	128 msec				
36	Shield					

TABLE C-II.- Concluded

Term	Assignment	Control signal	Control component	Control element		
				State	ID	Name
37	+	+24 Vdc	CR 21	From load	SV812	Diverter valve, chiller inlet
38	-	128 msec				
39	Shield					
40	+	+24 Vdc	CR 22	From T/S	SV812	
41	-	128 msec				
42	Shield					
43	+	+24 Vdc	CR 23	To load	SV813	Diverter valve, chiller outlet
44	-	128 msec				
45	Shield					
46	+	+24 Vdc	CR 24	To T/S	SV813	
47	-	128 msec				
48	Shield					
49	+	+24 Vdc	CR 25	On	I-501A	Absorption chiller (power)
50	-	128 msec				
51	Shield					
52	+	+24 Vdc	CR 26	Off	I-501A	
53	-	128 msec				
54	Shield					
55	+	+24 Vdc	CR 27	On	I-502	Compression chiller (power)
56	-	128 msec				
57	Shield					
58	+	+24 Vdc	CR 28	Off	I-502	
59	-	128 msec				
60	Shield					
61	+	+24 Vdc	CR 29	On	I-510A	Tower water-coolant pump (power)
62	-	128 msec				
63	Shield					
64	+	+24 Vdc	CR 30	Off	I-510A	
65	-	128 msec				
66	Shield					
67	+	+24 Vdc	CR 31	On	I-510B	
68	-	128 msec				
69	Shield					

TABLE C-III.- COMPUTER INTERFACES FOR TERMINAL BOARD NUMBER 21 OF THE MIST SYSTEM

Term	Assignment	Control signal	Control component	Control element		
				State	ID	Name
1	+	+24 Vdc	CR 32	Off	I-510B	Tower water-coolant pump (power)
2	-	128 msec				
3	Shield					
4	+	+24 Vdc	CR 33	On	I-503A	Chilled-water pump, absorption chiller (power)
5	-	128 msec				
6	Shield					
7	+	+24 Vdc	CR 34	Off	I-503A	
8	-	128 msec				
9	Shield					
10	+	+24 Vdc	CR 35	On	I-503B	Chilled-water pump, compression chiller (power)
11	-	128 msec				
12	Shield					
13	+	+24 Vdc	CR 36	Off	I-503B	
14	-	128 msec				
15	Shield					
16	+	+24 Vdc	CR 37	On	I-508	Cooling tower (power)
17	-	128 msec				
18	Shield					
19	+	+24 Vdc	CR 38	Off	I-508	
20	-	128 msec				
21	Shield					
22	+	+24 Vdc	CR 39	On	I-514A	Hot-water pump (storage) (power)
23	-	128 msec				
24	Shield					
25	+	+24 Vdc	CR 40	Off	I-514A	
26	-	128 msec				
27	Shield					
28	+	+24 Vdc	CR 41	On	I-514B	Hot-water pump (power)
29	-	128 msec				
30	Shield					
31	+	+24 Vdc	CR 42	Off	I-514B	
32	-	128 msec				
33	Shield					
34	+	+24 Vdc	CR 43	Increase electrical load		Electrical load simulator
35	-	On as required				
36	Shield					
37	+	+24 Vdc	CR 44	Decrease electrical load		
38	-	On as required				
39	Shield					

TABLE C-III.- Concluded

Term	Assignment	Control signal	Control component	Control element		
				State	ID	Name
40 41 42	+ - Shield	+24 Vdc 128 msec	CR 45	Operating	SV823	Heating-load-simulator control valve
43 44 45	+ - Shield	+24 Vdc 128 msec	CR 46	Override	SV823	
91 92 93	+ - Shield	1 to 5 Vdc continuous from control	M18	Feedback	SV802	Heating-water-temperature control
94 95 96	Switch closure Return (RTN) Shield	Switch closure (computer), 3-msec pulses	M18	Increase setpoint	SV802	
97 98 99	Switch closure RTN Shield	Switch closure (computer), 3-msec pulses	M18	Decrease setpoint	SV802	
100 101 102	Switch closure RTN Shield	Switch closure (computer)	M18	Computer shed	SV802	
103 104 105	Switch closure RTN Shield	Switch closure (computer)	M18	Station status	SV802	
106 107 108	+ - Shield	1 to 5 Vdc from control (continuous)	M19	Feedback	SV804	Chilled-water-temperature control
109 110 111	Switch closure RTN Shield	Switch closure (computer), 3-msec pulses	M19	Increase setpoint	SV804	
112 113 114	Switch closure RTN Shield	Switch closure (computer), 3-msec pulses	M19	Decrease setpoint	SV804	
115 116 117	Switch closure RTN Shield	Switch closure (computer)	M19	Computer shed	SV804	
118 119 120	Switch closure RTN Shield	Switch closure (control)	M19	Station status	SV804	
121 122 123	+ - Shield	4 to 20 mA continuous from computer		Valve control	SV821	Air-conditioning-load-simulator control valve
124 125 126	+ - Shield	4 to 20 mA continuous from computer	823	Valve control	SV823	Heating-load-simulator control valve

TABLE C-IV.- REQUIRED CONTROL ELEMENT STATES FOR EACH OPERATING MODE

Control element	State	Operating mode																	
		PRETEST	POWER	HEAT	WATER	SER	PAR	ACHILL	CCHILL	ACHILL, CCHILL	HTS	HOHTS	NOCTS	UP:C:C	UP:C:D	UP:CA:C	UP:CA:D	DWN:CA:C	DWN:CA:D
S01 <sup>a</sup>	Open Closed																		
SV8 <sup>b</sup>	Cooling Facility	X																	
SV58	Series Parallel	X				X	X			X									
SV59	Series Parallel	X				X	X			X									
SV11 <sup>b</sup>	Cooling Facility	X																	
S013	Open Closed				X														
S026	Open Closed	X								X	X								
S029	Open Closed	X								X	X								
SV30 <sup>c</sup>	Primary Auxiliary					X													
S056	Open Closed	X		X	X			X		X	X								

<sup>a</sup>The required position of this valve is an operator input depending on whether or not the incinerator is to be operated.

<sup>b</sup>For computer operation, "COOLING" is the only allowable position.

<sup>c</sup>The required position of this valve is an operator input depending on whether the engine is operating with forced-circulation cooling or ebullient cooling.

TABLE C-IV.- Continued

Control element	State	Operating mode																	
		PRETEST	POWER	HEAT	WATER	SER	PAR	ACHILL	CCHILL	ACHILL, CCHILL	HTS	NOHTS	NOCTS	UP:C:C	UP:C:D	UP:CA:C	UP:CA:D	DWN:CA:C	DWN:CA:D
SV801	Normal Storage	X									X	X							
SV802 <sup>d,e</sup>	Tabs Temperature for heating	X						X		X									
SV804 <sup>f</sup>	Direct acting	X																	
	Indirect acting	X											X	X	X	X	X	X	X
	Override	X																	
	Temperature of cold water return												X	X	X	X			
	Temperature of cold water supply																	X	X
SV806 <sup>d</sup>	Chilling Heating	X						X		X									
SV807	Open						X		X	X									
	Closed	X																	
SV808	Open						X		X	X									
	Closed	X																	
SV809	Override Normal	X																	
SV811	From thermal storage													X	X				
	From load	X														X	X	X	X

<sup>d</sup>The required position of this control element is determined by the computer and depends upon the functions being performed.

<sup>e</sup>SV802 is for temperature control of hot water.

<sup>f</sup>SV804 is for temperature control of cold water.

TABLE C-IV.- Concluded

Control element	State	Operating mode																	
		PRETEST	POWER	HEAT	WATER	SER	PAR	ACHILL	CCHILL	ACHILL, CCHILL	HTS	NOHTS	NOCTS	UP:C:C	UP:C:D	UP:CA:C	UP:CA:D	DWN:CA:C	DWN:CA:D
SV812	From thermal storage	X														X	X		
	From load	X											X	X				X	X
SV813	To thermal storage																	X	X
	To load	X											X	X	X	X			
SV823	Operating Override	X																	
501	On							X		X									
	Off	X																	
502	On								X	X									
	Off	X																	
503A	On							X		X									
	Off	X																	
503B	On								X	X									
	Off	X																	
508	On		X																
	Off	X																	
510A <sup>g</sup>	On									X									
	Off	X																	
510B <sup>g</sup>	On									X									
	Off	X																	
514A	On										X								
	Off	X										X							
514B	On			X				X		X									
	Off	X																	

<sup>g</sup>One of these cooling-tower pumps is selected by the operator as the base pump and is to be on for all modes of operation.

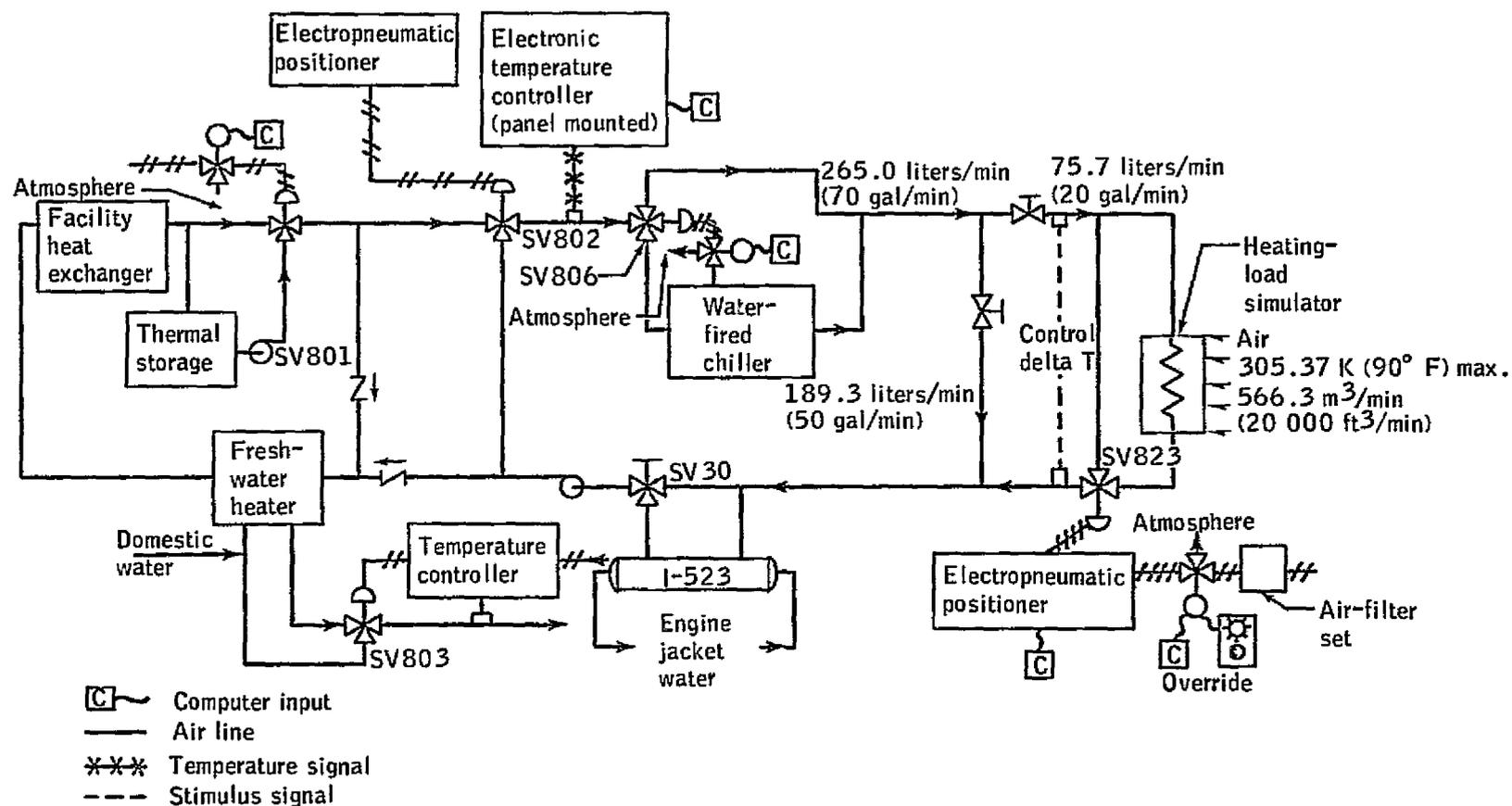
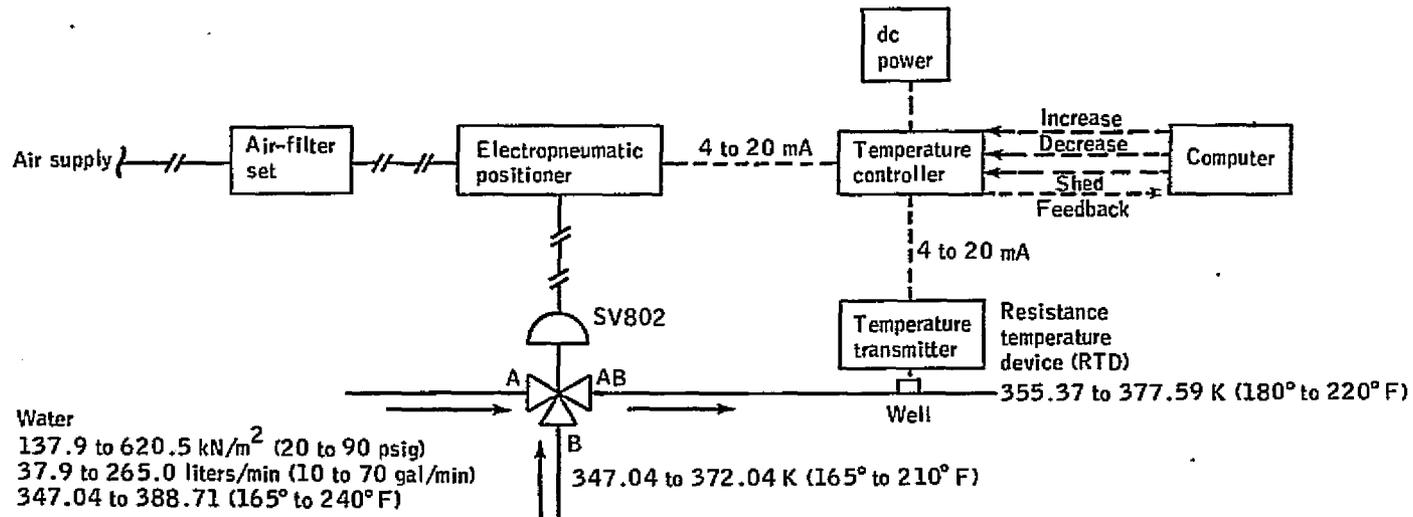


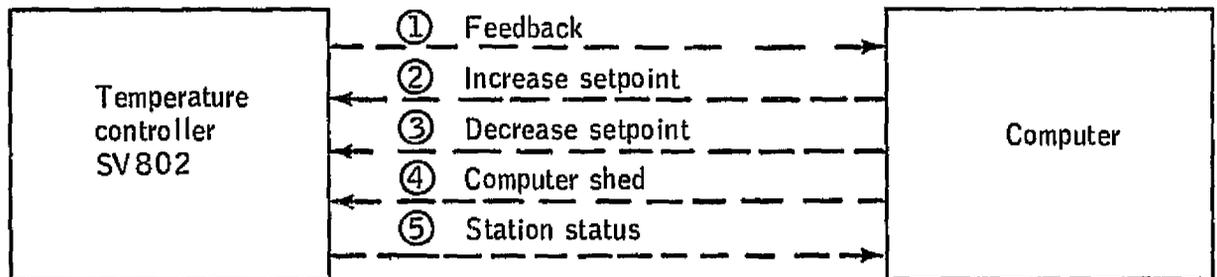
Figure C-1.- Controls for chiller-firing water, domestic water temperature, heating-load simulator, and heating-water temperature.



## Equipment List

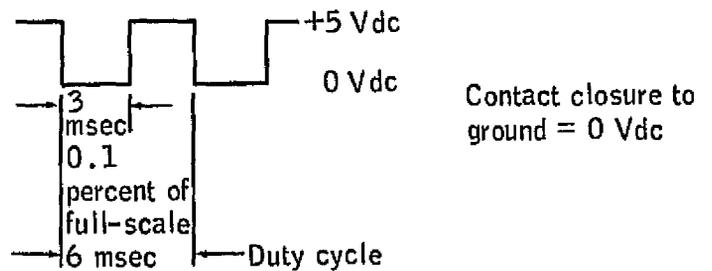
1. Electropneumatic positioner with gages and field installation kit  
 Input, 4 to 20 mA  
 Output, air signal
2. Air-filter set
3. Electronic temperature controller  
 Proportional band; range, 310.93 to 388.71 K (100° to 240° F)  
 Automatic reset; setpoint, 355.37 to 377.59 K (180° to 220° F)  
 Reverse/direct acting  
 Input/output, 4 to 20 mA  
 Computer  
     5 Vdc, 3-msec pulse train, increase setpoint  
     5 Vdc, 3-msec pulse train, decrease setpoint  
     1 to 5 Vdc, feedback continuous  
 Input power, 24 Vdc (310.93 to 388.71 K (100° to 240° F))
4. Transmitter with RTD probe  
 Input, RTD resistance  
 Output, 4 to 20 mA
5. Well for above RTD probe, stainless steel
6. Power supply, 24 Vdc (for each electronic 1-A controller)

Figure C-2.- Control system listing for heating-water-temperature control SV802.



Computer input 1. 1- to 5-Vdc continuous setpoint feedback  
 1 to 5 Vdc linear and proportional from  
 310.93 to 388.71 K (100° to 240° F)  
 250-ohm source resistance

Computer output 2. Increase setpoint pulse - switch closure  
 3-msec pulses, 0 or 5 Vdc  
 1000 pulses = 0 to 100 percent of full scale  
 1 pulse = 0.1 percent of full-scale incremental change

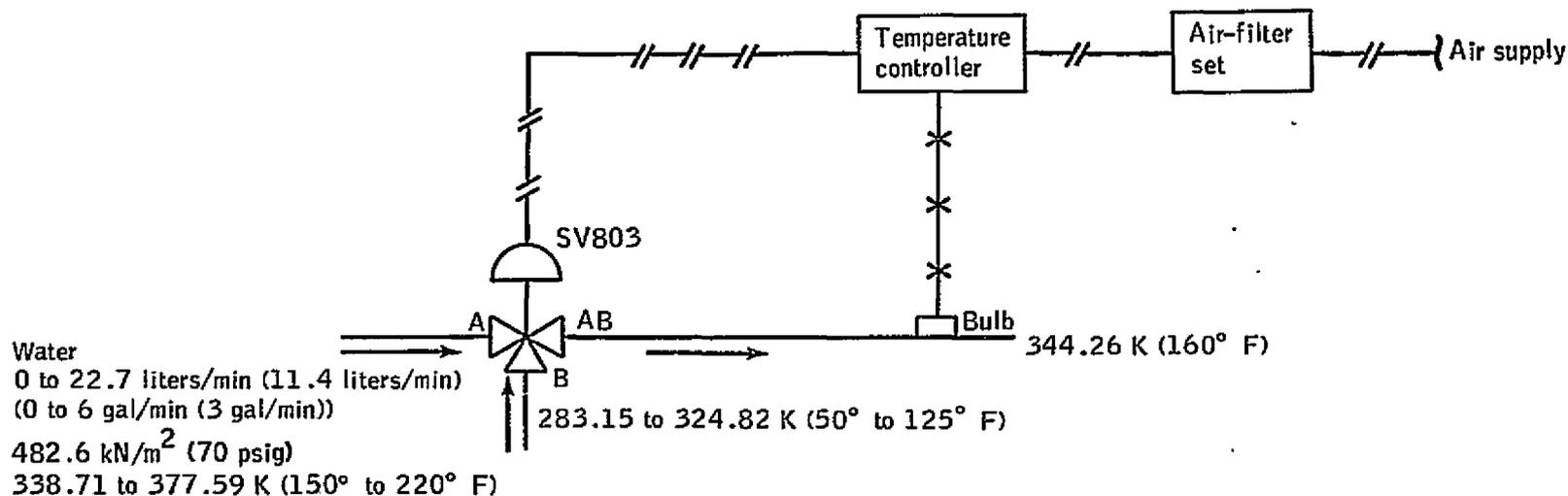


Computer output 3. Decrease setpoint pulse - same as "2."

Computer output 4. Computer shed - contact closure to ground, computer to manual control transition

Computer input 5. Station status - contact closure (continuity) when station control mode is in computer position (not manual mode)

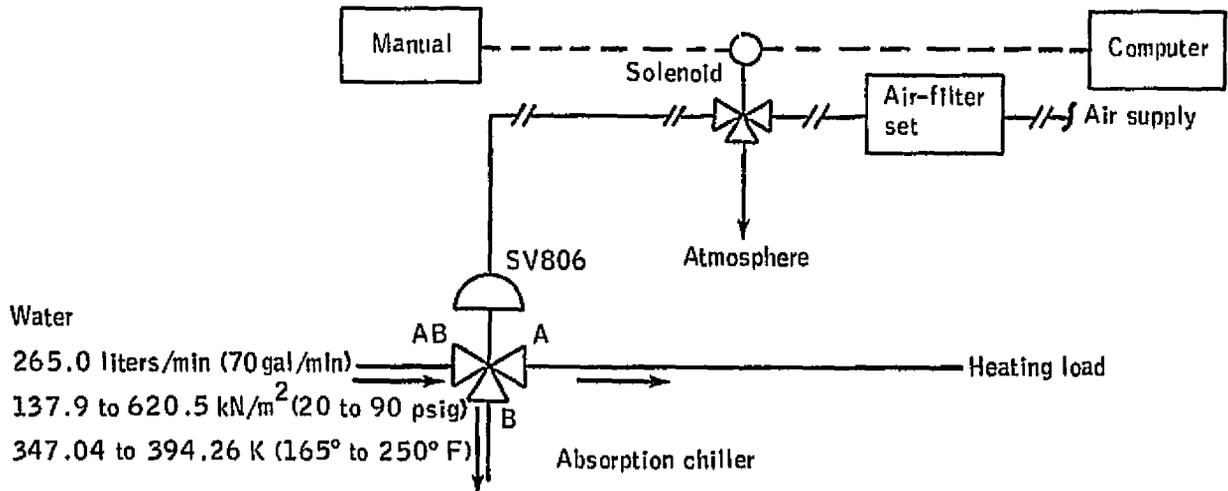
Figure C-3.- Interface definition for heating-water-temperature control SV802.



#### Equipment List

1. SV803 - mixing valve, diaphragm actuator  
 1.3-cm (0.5 in.) three-way valve  
 Stainless steel trim  
 Cast-iron screw connections 861.8 kN/m<sup>2</sup> (125 psig) American Standards Association (ASA)  
 Air-failure port, A, closed  
 Direct acting  
 Teflon/asbestos packing
2. Air-filter set
3. Local pneumatic controller - reverse acting  
 Proportional band, 283.15 to 394.26 K (50° to 250° F) (use existing temperature controller SV802)  
 Automatic reset  
 Input, bulb (3.0-m (10ft) minimum lead length)  
 Output, 20.7 to 103.4 kN/m<sup>2</sup> (3 to 15 psig)
4. Well for above bulb

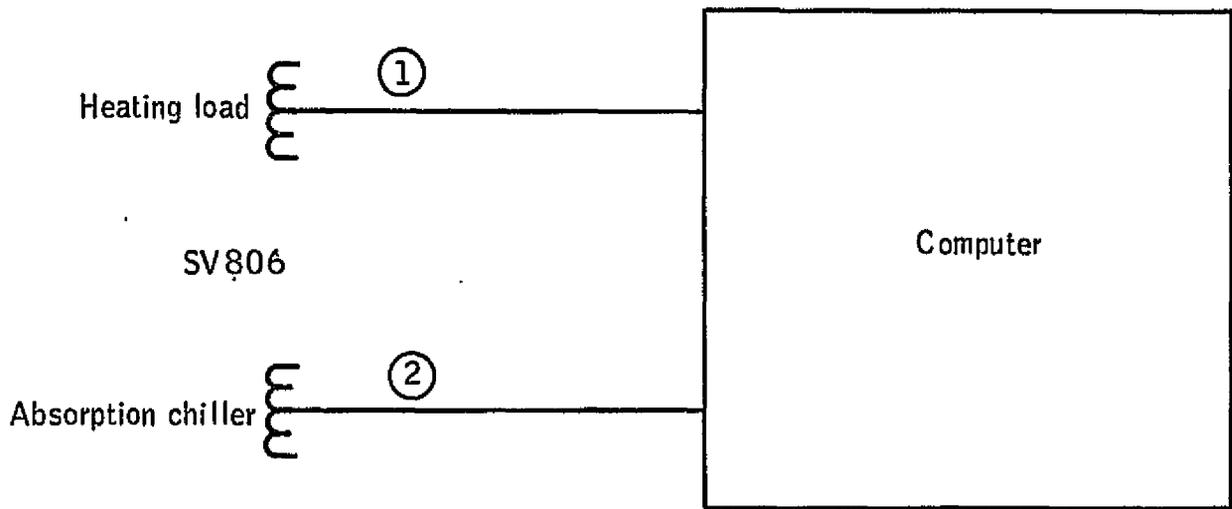
Figure C-4.- Control system listing for domestic water temperature control SV806.



#### Equipment List

1. SV806 - diverter valve, diaphragm operator
  - 5.1-cm (2 in.) three-way valve
  - Stainless steel trim
  - Carbon steel flanged connections, 1034.2 kN/m<sup>2</sup> (150 psig) ANSI
  - Teflon/asbestos packing connections
  - Air-failure port, B, closed
  - Reverse acting
  - Latching solenoid, 110 Vac
  - Microswitch (two each)
2. Air-filter set
3. Manual control
  - Heating-load switch
  - Absorption chiller switch
  - Valve position indicator (VPI) light (two; amber, green)
4. Computer control
  - Relay, 24 Vdc (two)

Figure C-5.- Control system listing for absorption-chiller-firing-water control SV806.



Computer output 1. Heating-load position, SV806  
 +24 Vdc pulse, 128 msec  
 Nominal coil power = 1.2 W

Computer output 2. Absorption chiller position, SV806  
 +24 Vdc pulse, 128 msec

Note: Single pulse for actuation

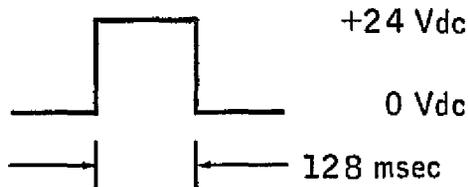


Figure C-6.-- Interface definition for absorption-chiller-firing-water control SV806.

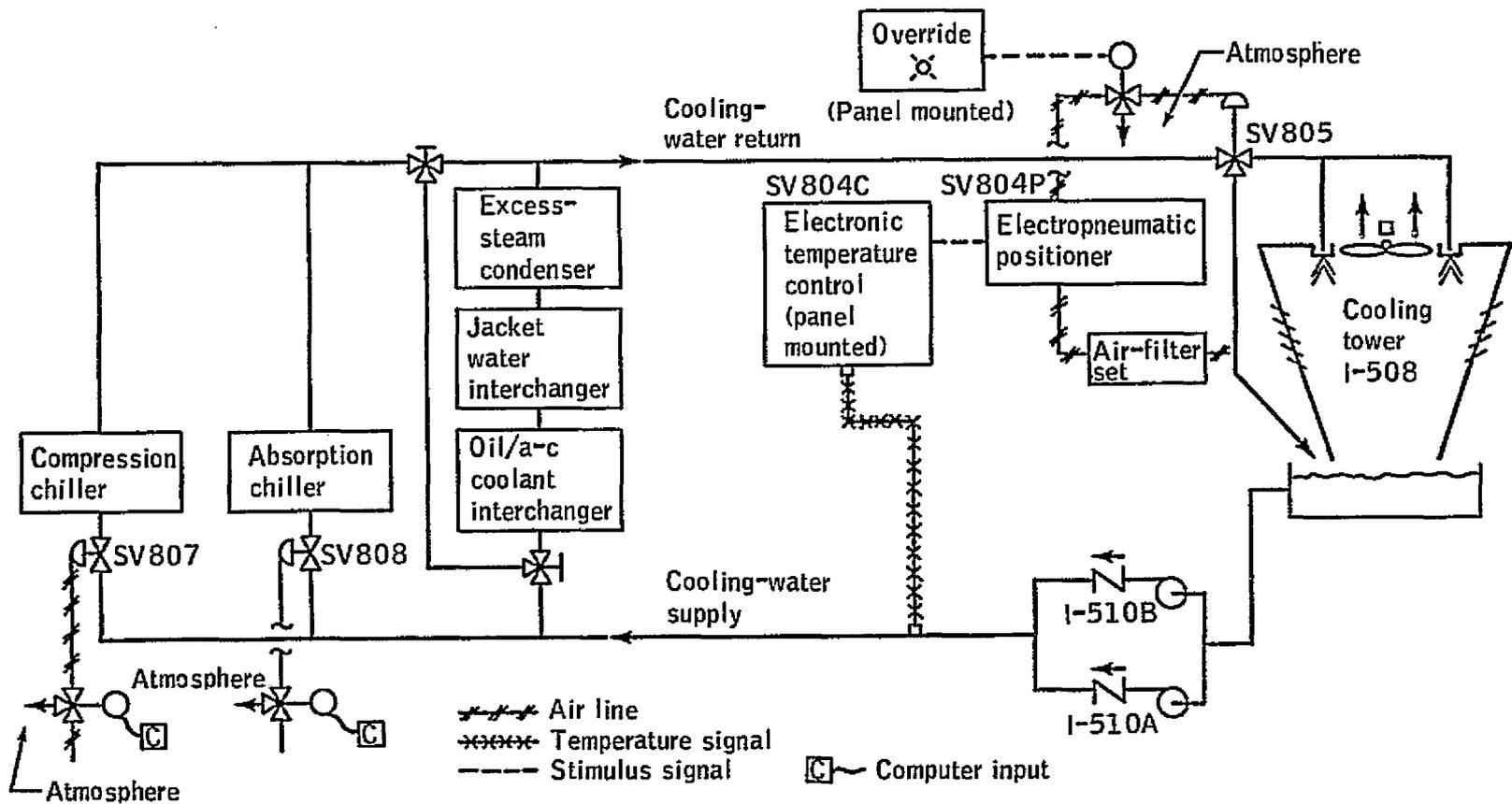
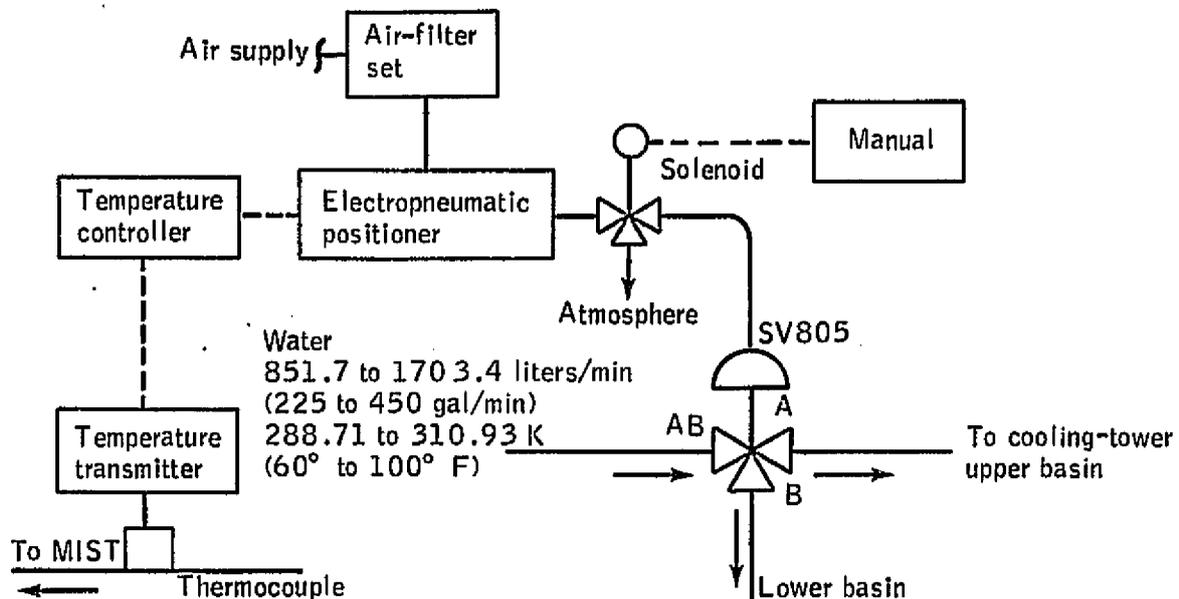


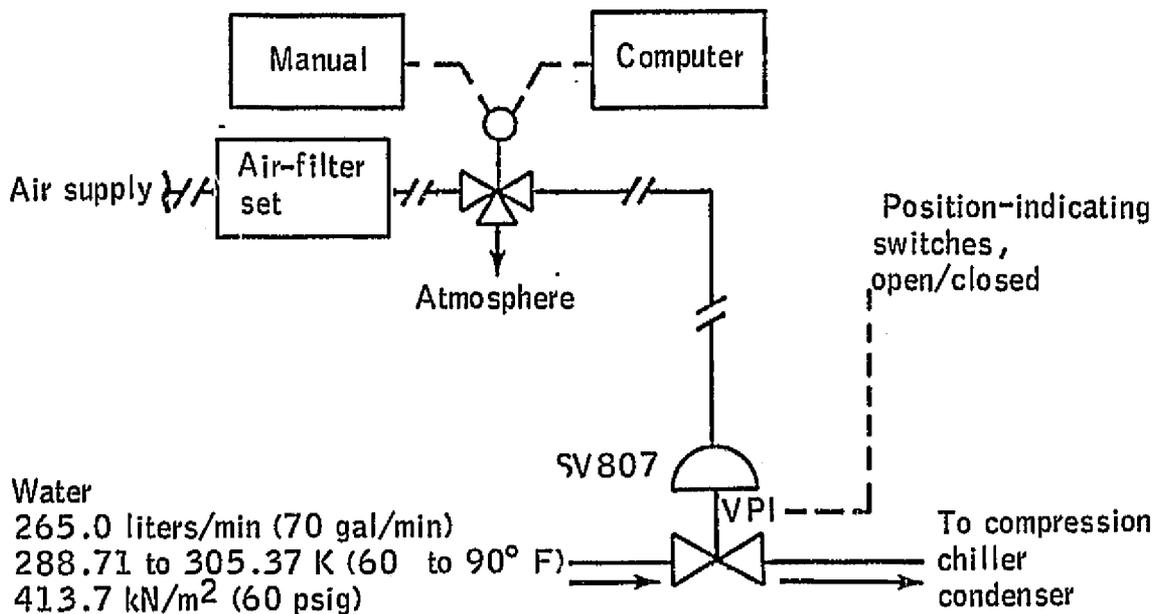
Figure C-7.- Cooling-tower-temperature control and condenser water on/off controls.



#### Equipment List

1. SV805 - mixing valve, diaphragm operator  
 10.2-cm (4 in.) three-way valve  
 Stainless steel trim  
 Cast-iron body  
 Flanged connections,  $861.8 \text{ kN/m}^2$  (125 psig) ASA  
 Microswitch, port B, closed position  
 Air-failure port, B, closed  
 Reverse acting  
 Latching solenoid valve, 110 Vac  
 Teflon/asbestos packing
2. Electronic controller (existing SV804 255.3 to 310.93 K (0° to 100° F))
3. Transmitter (existing SV804 255.37 to 310.93 K (0° to 100° F))  
 Thermocouple probe
4. Well
5. Electropneumatic positioner with gages  
 Input, 4 to 20 mA  
 Output, air signal
6. Air-filter set
7. Manual control  
 Normal switch  
 Override switch  
 Override VPI light (one, amber)

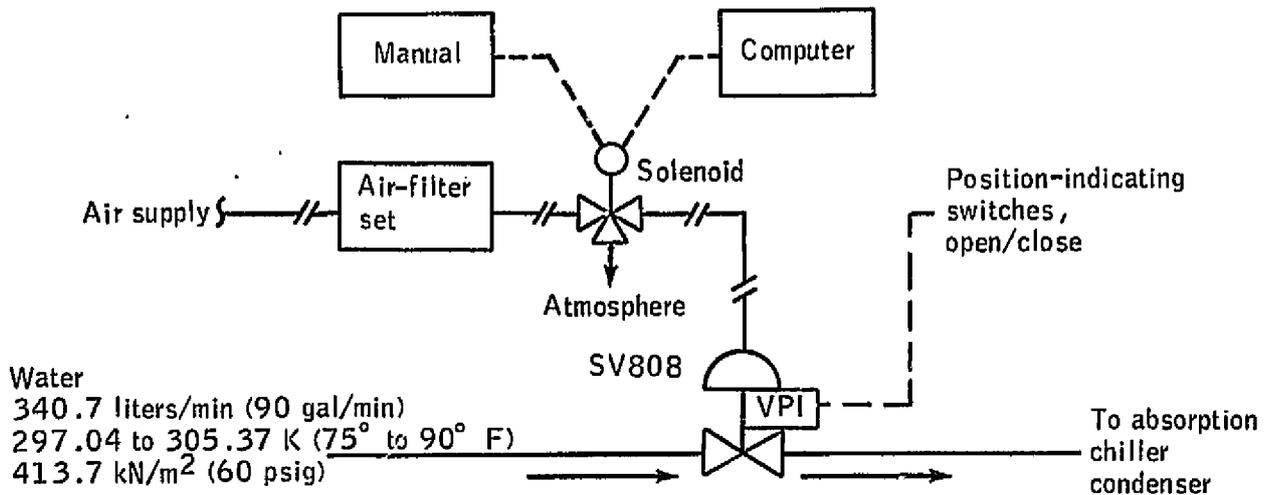
Figure C-8.- Control system listing for cooling-tower-temperature control SV805.



#### Equipment List

1. SV807 - 5.1-cm (2 in.) cage-type operator control valve  
 Normally open  
 Flanged connections,  $861.8 \text{ kN/m}^2$  (125 psig) ASA  
 Cast-iron body  
 Stainless steel trim  
 Teflon/asbestos packing  
 Latching solenoid valve (mounted and piped)  
 Position-indicating switches (two)
2. Air-filter set
3. Manual control  
 Open switch (one)  
 Close switch (one)  
 VPI light (two; green, amber)
4. Computer control relay, 24 Vdc (two)

Figure C-9.- Control system listing for shutoff valve for compression chiller condenser, SV807.

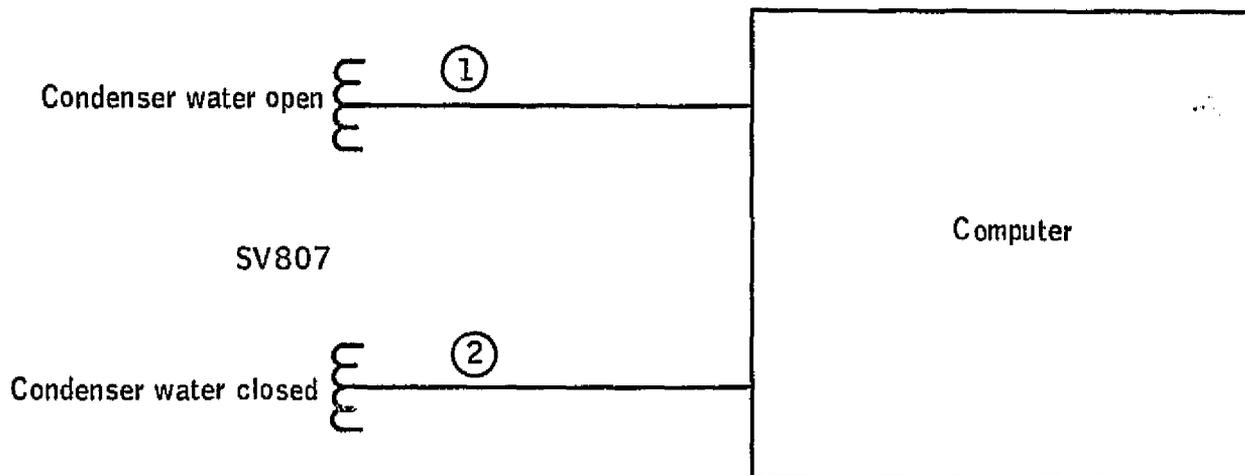


#### Equipment List

1. SV808 - 6.4-cm (2.5 in.) cage-type operator control valve  
Normally open  
Flanged connections, 854.9 kN/m<sup>2</sup> (124 psig) ASA  
Cast-iron body  
Stainless steel trim  
Teflon/asbestos packing  
Latching solenoid valve (mounted and piped)  
Position-indicating switches (two)
2. Air-filter set
3. Manual control  
Open switch (one)  
Closed switch (one)  
VPI light (two; green, amber)
4. Computer control relay, 24 Vdc (two)

Figure C-10.- Control system listing for shutoff valve for absorption chiller condenser, SV808.

Relay control



Computer output 1. Compression chiller condenser water, open SV807  
+24-Vdc pulse, 128 msec  
Nominal coil power = 1.2 W

Computer output 2. Compression chiller condenser water, closed SV807  
+24-Vdc pulse, 128 msec

Note: Single pulse for actuation

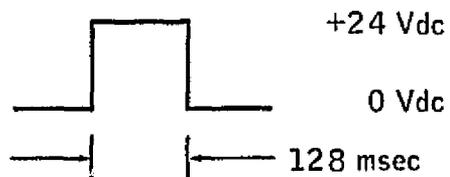
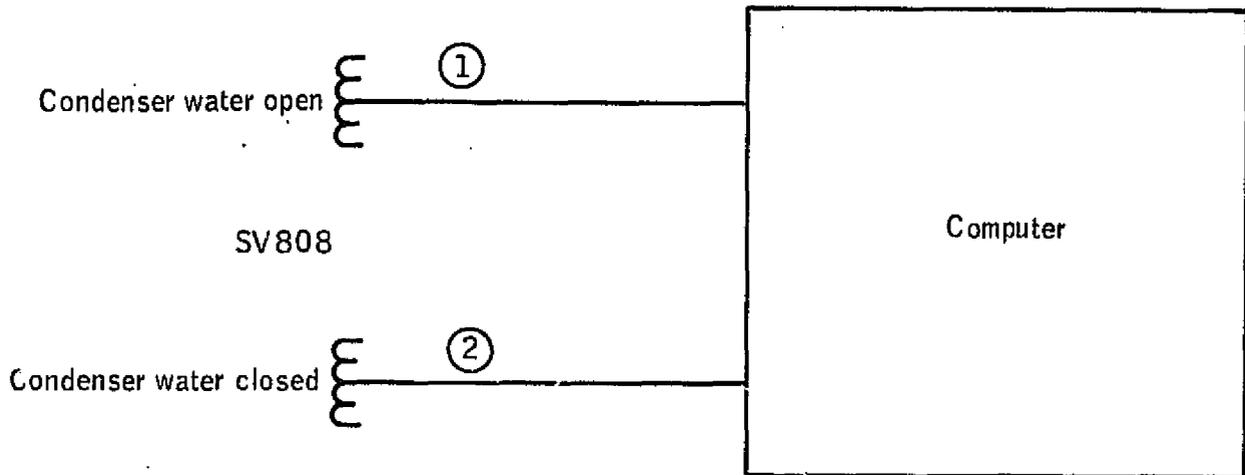


Figure C-11.- Interface definition for condenser water on/off control SV807.

### Relay control



Computer output 1. Absorption chiller condenser water, open SV808  
+24-Vdc pulse, 128 msec  
Nominal coil power = 1.2 W

Computer output 2. Absorption chiller condenser water, closed SV808  
+24-Vdc pulse, 128 msec

Note: Single pulse for actuation

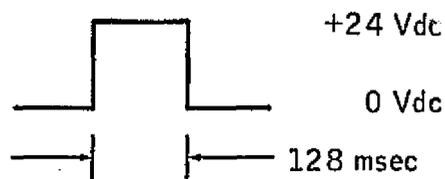


Figure C-12.- Interface definition for condenser water on/off control SV808.

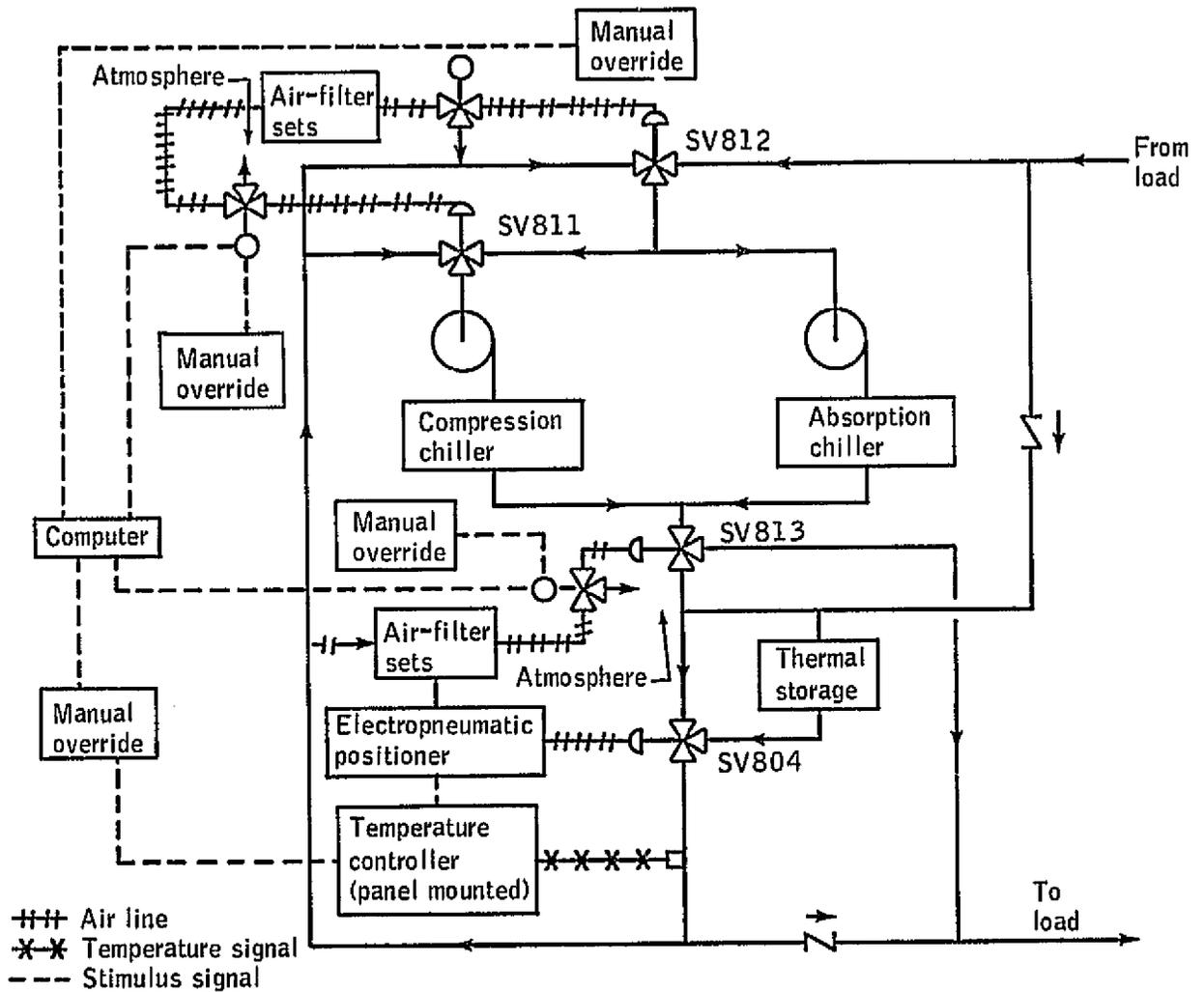
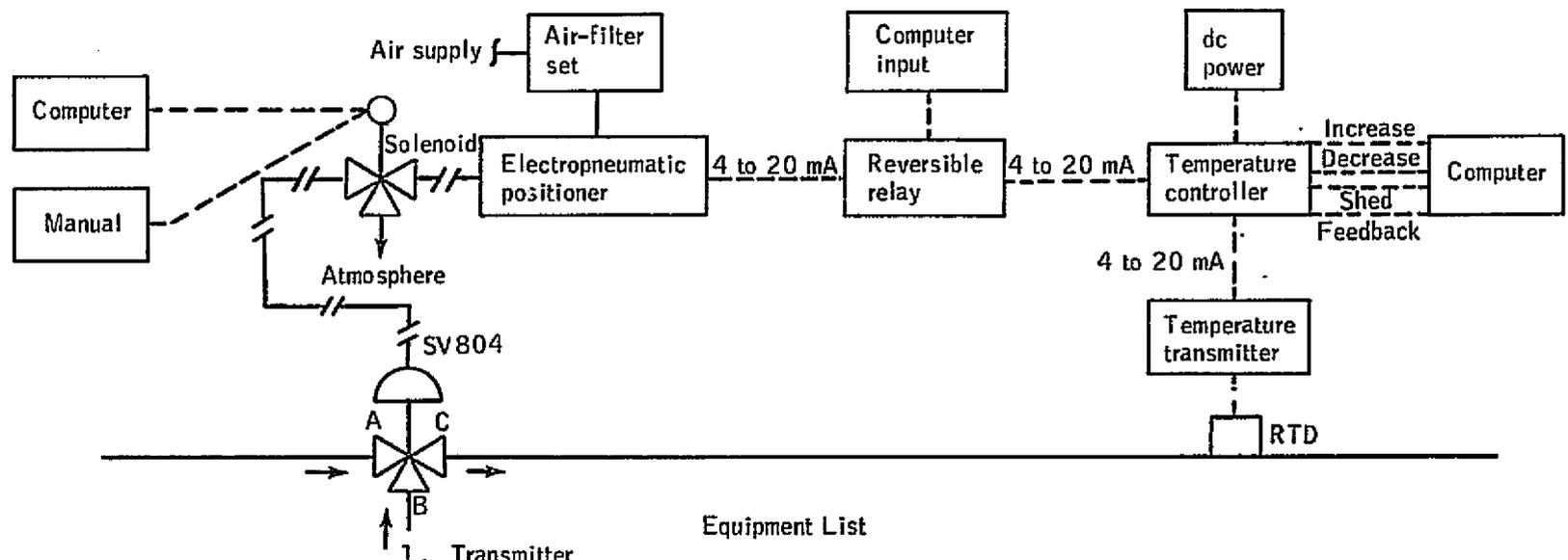


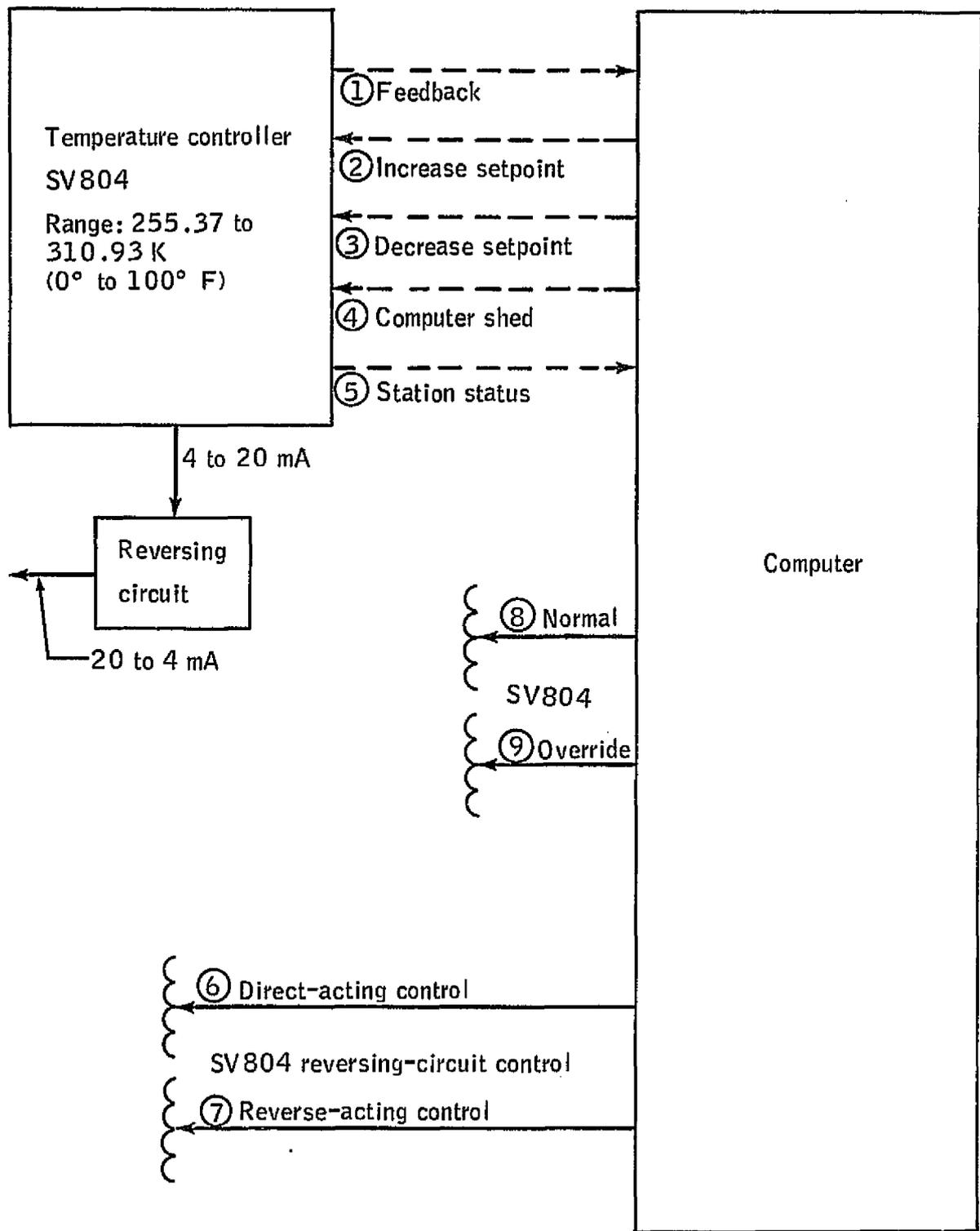
Figure C-13.- Chilled-water mode and temperature control.



## Equipment List

1. Transmitter  
+RTD probe  
255.37 to 310.93 K (0° to 100° F)  
Output, 4 to 20 mA
2. Well for above probe, stainless steel
3. Electronic temperature controller  
Proportional band; range, 255.37 to 310.93 K (0° to 100° F)  
Automatic reset; setpoint input/output, 4 to 20 mA  
Computer  
5 Vdc, 3-msec pulse train, increase setpoint  
5 Vdc, 3-msec pulse train, decrease setpoint  
1 to 5 Vdc continuous feedback  
Input power, 24 Vdc
4. Computer  
Override control (2 relays)  
Reversing/direct (2 relays)
5. Power supply, 24 Vdc at 1 A

Figure C-14.- Control system listing for chilled-water-temperature control SV804.

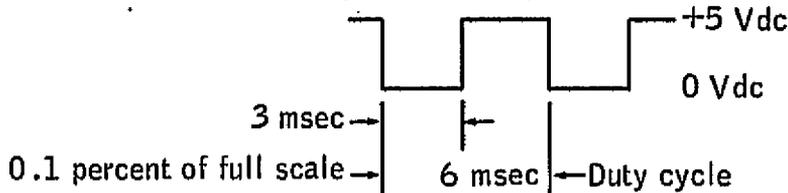


(a) Schematic.

Figure C-15.- Interface definition for chilled-water-temperature control SV804.

Computer input 1. 1- to 5-Vdc continuous feedback  
1 to 5 Vdc linear and proportional from  
255.37 to 310.93 K (0° to 100° F)  
250-ohm source resistance

Computer output 2. Increase setpoint pulse-switch closure  
3-msec pulses, 0 or 5 Vdc  
1000 pulses = 0 to 100 percent of full scale  
1 pulse = 0.1 percent of full-scale incremental change

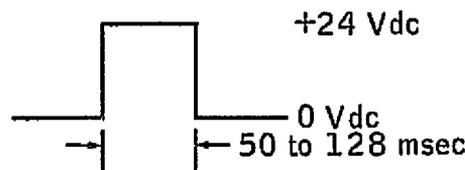


Computer output 3. Decrease setpoint pulse (same as "2.")

Computer output 4. Computer shed - contact closure to ground, computer  
to manual control transition

Computer input 5. Station status - contact closure (continuity) when station  
control mode is in computer position (not manual mode)

Computer output 6. Direct-acting control SV804  
+24-Vdc pulse, 50-msec minimum to 128-msec maximum  
Nominal coil power = 2.7 W



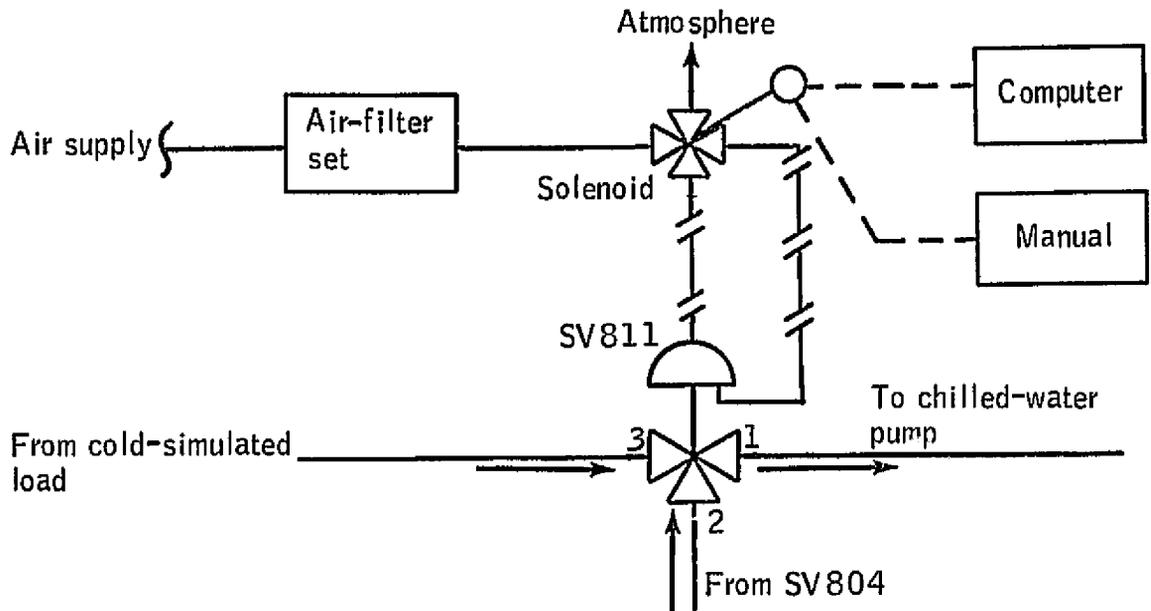
Computer output 7. Reverse-acting control SV804  
+24-Vdc pulse, 50-msec minimum to 128 msec maximum

Computer output 8. SV804 control  
+24-Vdc pulse, 128 msec  
Nominal coil power = 1.2 W

Computer output 9. SV804 override  
+24-Vdc pulse, 128 msec  
Nominal coil power = 1.2 W

(b) Computer inputs and outputs.

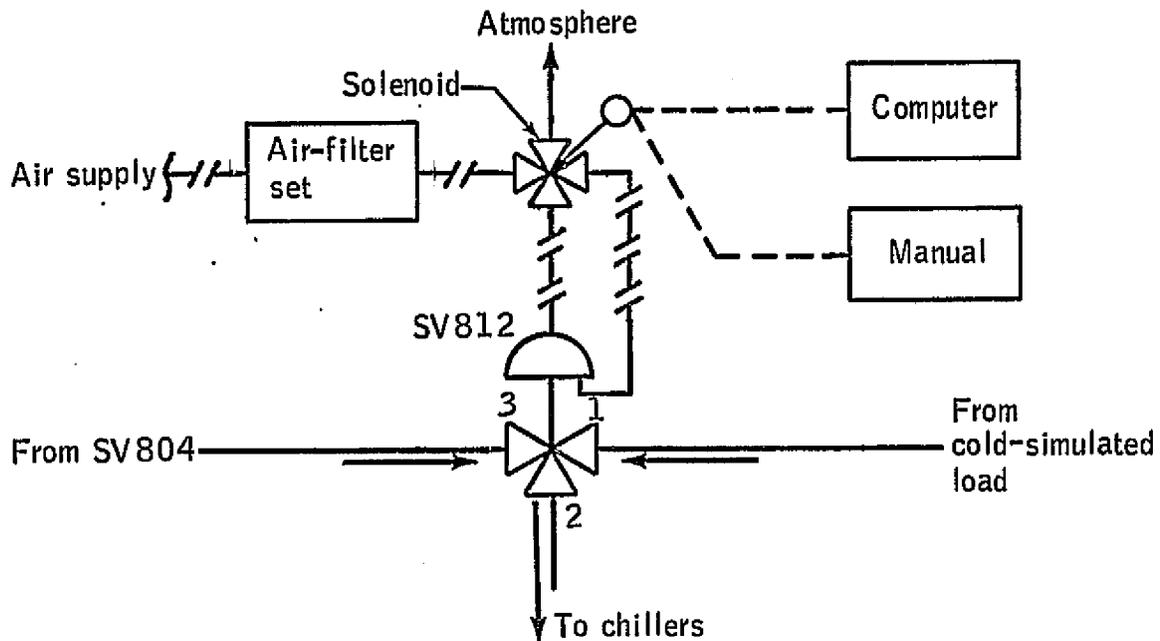
Figure C-15.- Concluded.



#### Equipment List

1. SV811 - 7.6-cm (3 in.) tapered three-way plug valve
  - Semisteel body and plug
  - Metal-to-metal seat
  - Flanged connections,  $861.8 \text{ kN/m}^2$  (125 psig) ASA
  - Double-acting pneumatic cylinder operator
  - Four-way latching solenoid valve (mounted and piped), 110 Vac
  - Single-pole double-throw position-indicating switches (two)
  - Combination-1-type valve (valve to remain in set position if air failure occurs)
2. Air-filter regulator
3. Manual control
  - From load switch
  - From thermal-storage switch
  - VPI lights (two)
4. Computer control relay, 24 Vdc (two)

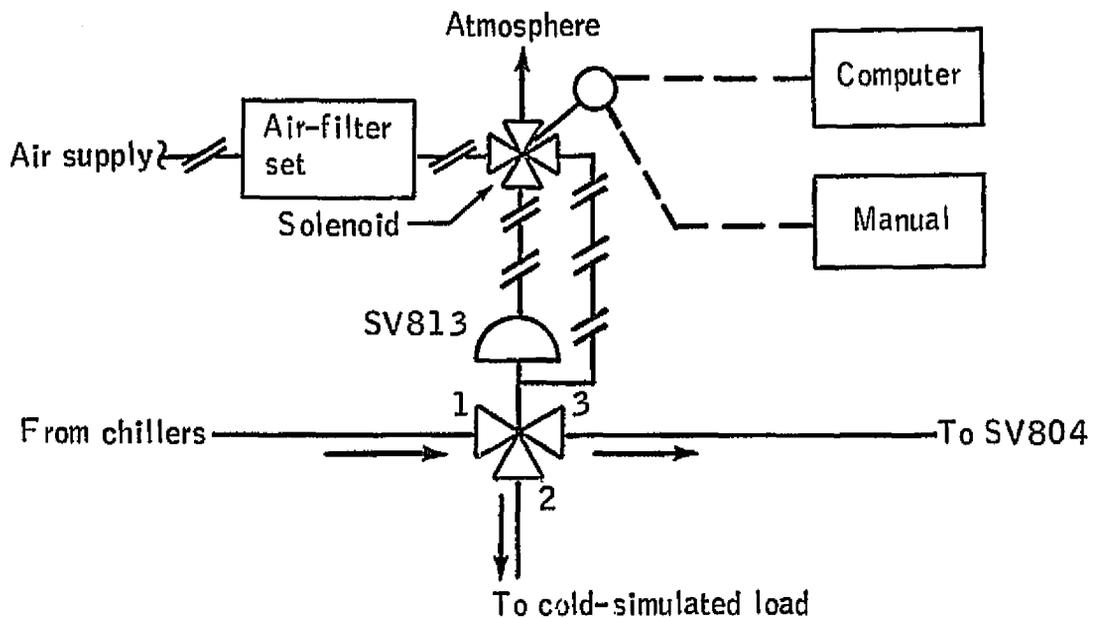
Figure C-16.- Control system listing for diverter valve for compression chiller inlet, SV811.



#### Equipment List

1. SV812 - 7.6-cm (3 in.) tapered three-way plug valve  
 Semisteel body and plug  
 Metal-to-metal seat  
 Flanged-end connections,  $861.8 \text{ kN/m}^2$  (125 psig) ASA  
 Double-acting pneumatic cylinder operator  
 Four-way, latching-type solenoid valve (mounted and piped)  
 Single-pole, double-throw position-indicating switches, 110 Vac (two)  
 Combination-2-type valve (valve to remain in set position if air failure occurs)
2. Air-filter regulator
3. Manual control  
 From load switch  
 From thermal-storage switch  
 VPI lights (two) (existing)
4. Computer control relay, 24 Vdc (two)

Figure C-17.- Control system listing for diverter valve for chiller inlet, SV812.

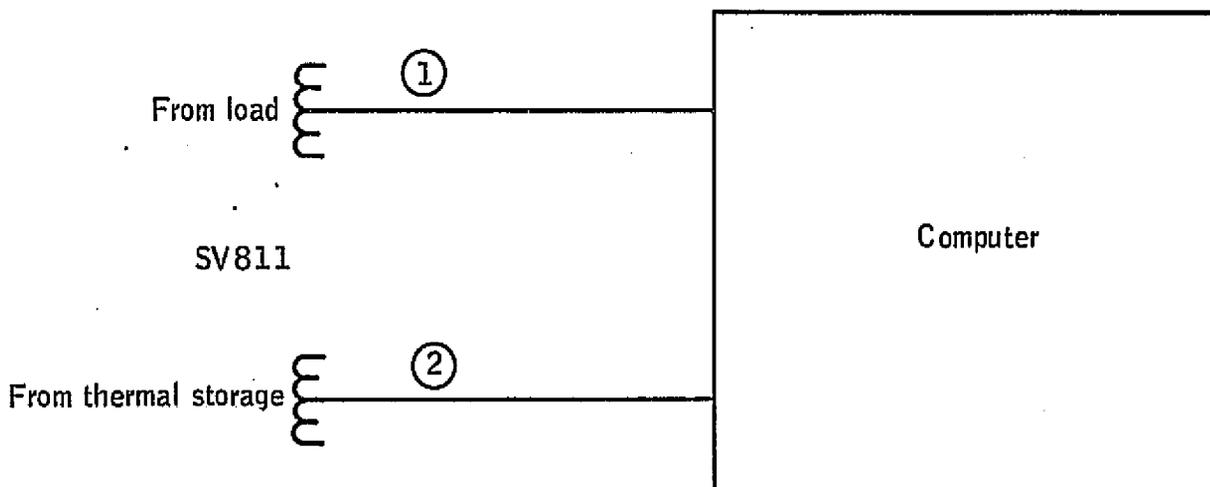


#### Equipment List

1. SV813 - 7.6-cm (3 in.) tapered three-way plug valve  
 Semisteel body and plug  
 Metal-to-metal seat  
 Flanged-end connections,  $861.8 \text{ kN/m}^2$  (125 psig) ASA  
 Double-acting pneumatic cylinder operator  
 Four-way, latching-type solenoid valve (mounted and piped)  
 Single pole, double-throw position-indicating switches, 110 Vdc (two)  
 Combination-1-type valve (valve to remain in set position if air failure occurs)
2. Air-filter regulator
3. Manual control  
 To load switch  
 To thermal-storage switch  
 VPI lights (two) (existing)
4. Computer control relay, 24 Vdc (two)

Figure C-18.- Control system listing for diverter valve for chiller outlet, SV813.

### Relay control



Computer output 1. From load, SV811  
+24-Vdc pulse, 128 msec  
Nominal coil power = 1.2 W

Computer output 2. From thermal storage, SV811  
+24-Vdc pulse, 128 msec

Note: Single pulse for actuation

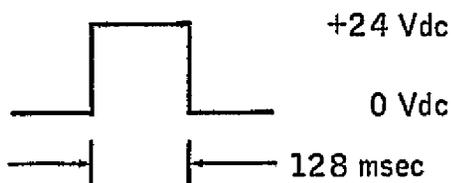
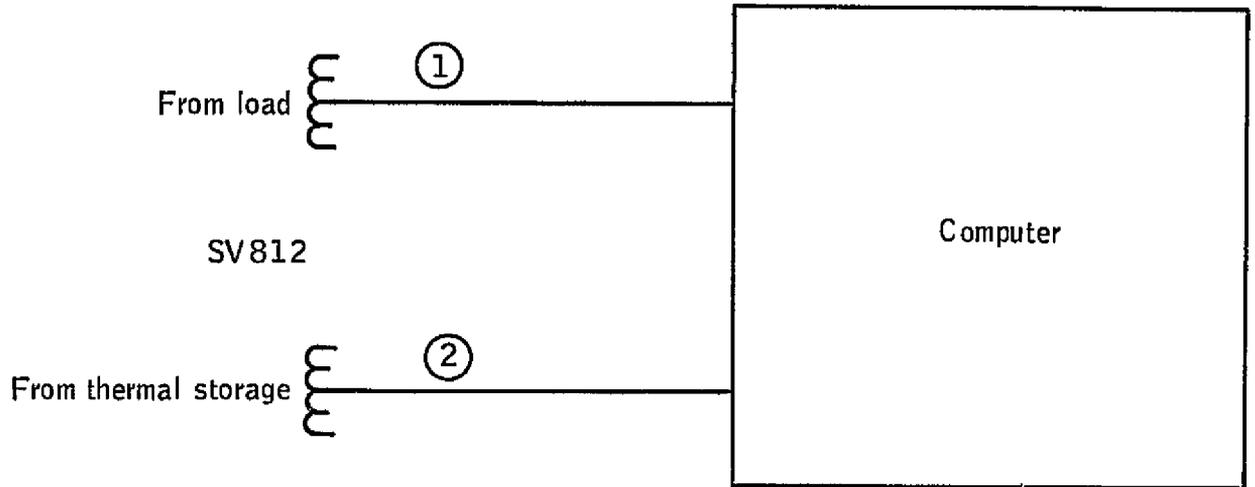


Figure C-19.- Interface definition for chilled-water-mode control SV811.

Relay control



- Computer output 1. From load, SV812  
+24-Vdc pulse, 128 msec  
Nominal coil power = 1.2 W
- Computer output 2. From thermal storage, SV812  
+24-Vdc pulse, 128 msec

Note: Single pulse for actuation

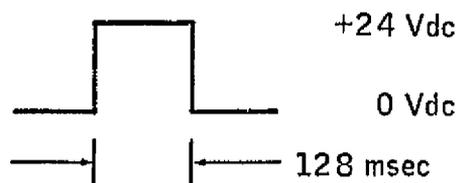
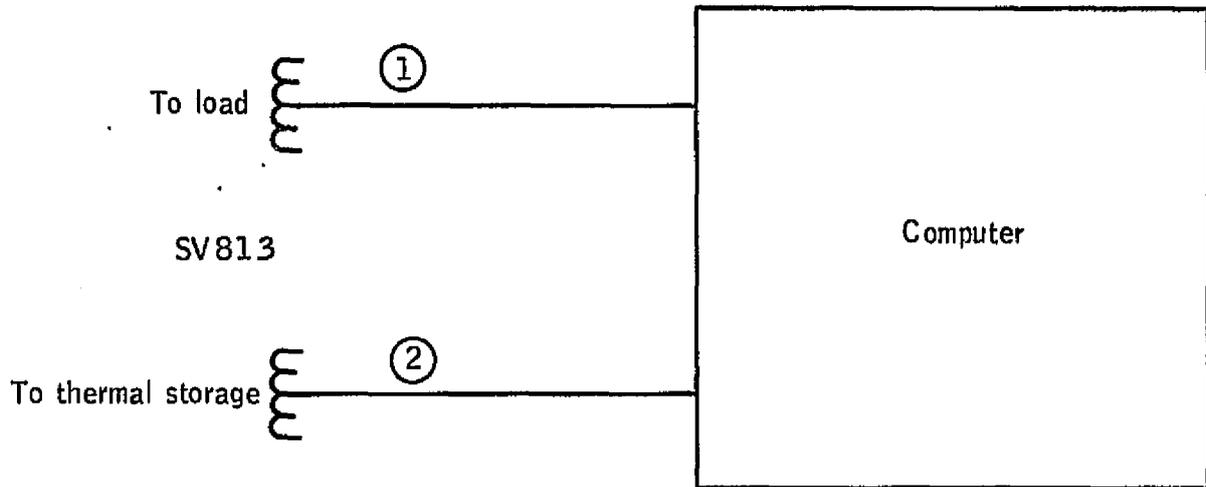


Figure C-20.- Interface definition for chilled-water-mode control SV812.

### Relay control



Computer output 1. To load, SV813  
+24-Vdc pulse, 128 msec  
Nominal coil power = 1.2 W

Computer output 2. To thermal storage, SV813  
+24-Vdc pulse, 128 msec

Note: Single pulse for actuation

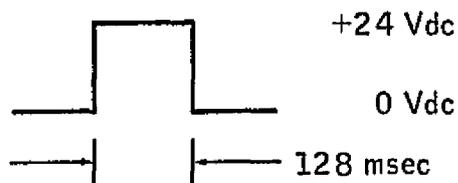


Figure C-21.- Interface definition for chilled-water-mode control SV813.

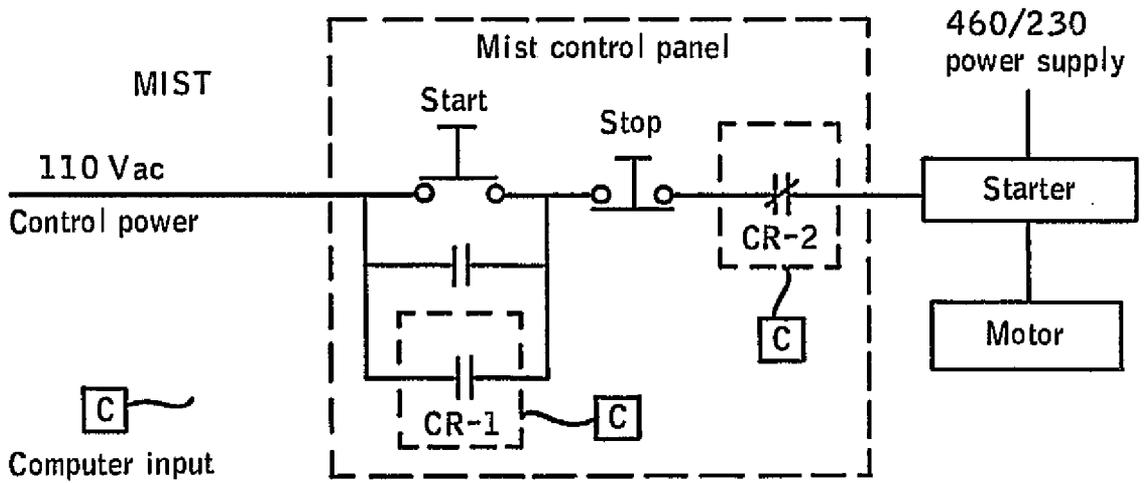
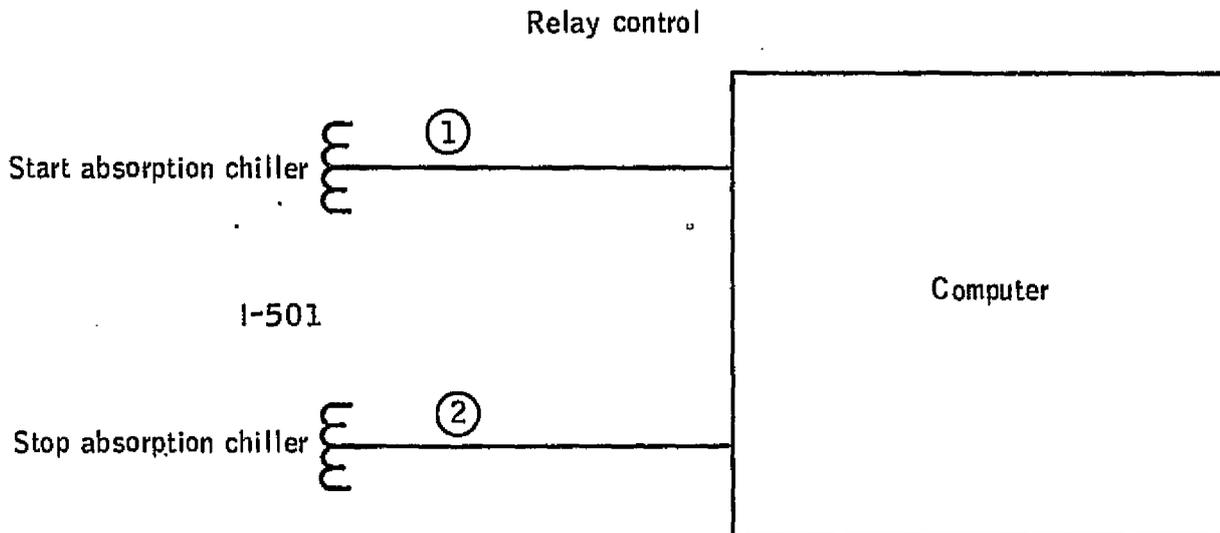


Figure C-22.- Typical motor stop/start controls.



Computer output 1. Start absorption chiller I-501  
 +24-Vdc pulse, 128 msec  
 Nominal coil power = 1.2 W

Computer output 2. Stop absorption chiller I-501  
 +24-Vdc pulse, 128 msec

Note: Single pulse for actuation

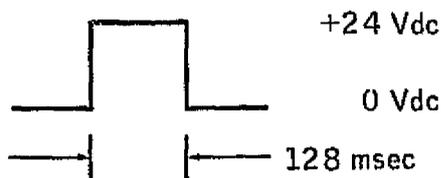
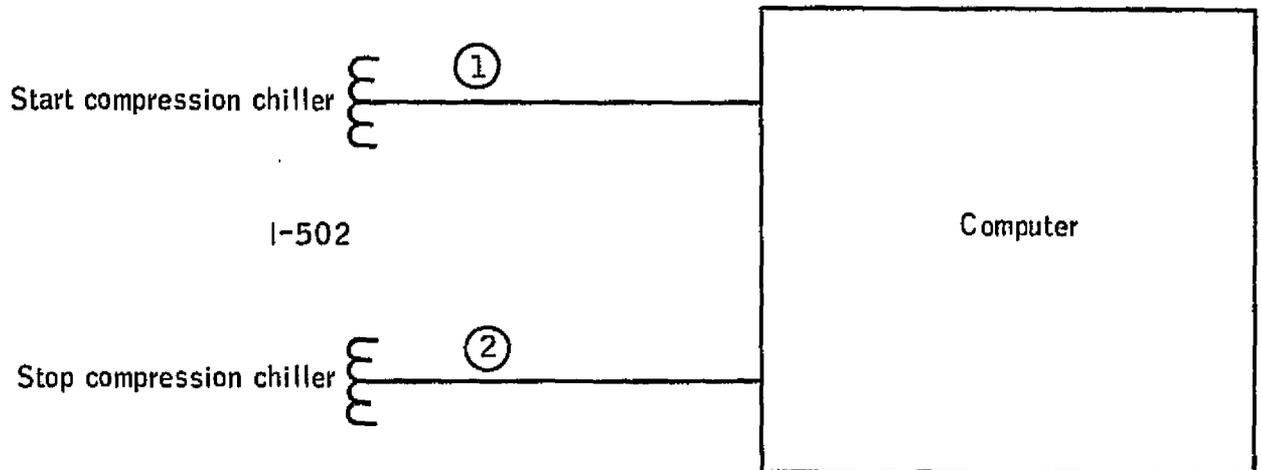


Figure C-23.- Interface definition for motor control, absorption chiller I-501.

Relay control



Computer output 1. Start compression chiller I-502  
+24-Vdc pulse, 128 msec  
Nominal coil power = 1.2 W

Computer output 2. Stop compression chiller I-502  
+24-Vdc pulse, 128 msec

Note: Single pulse for actuation

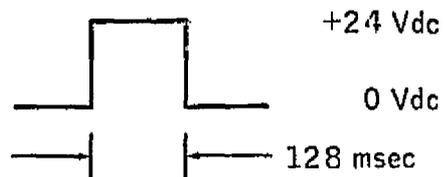
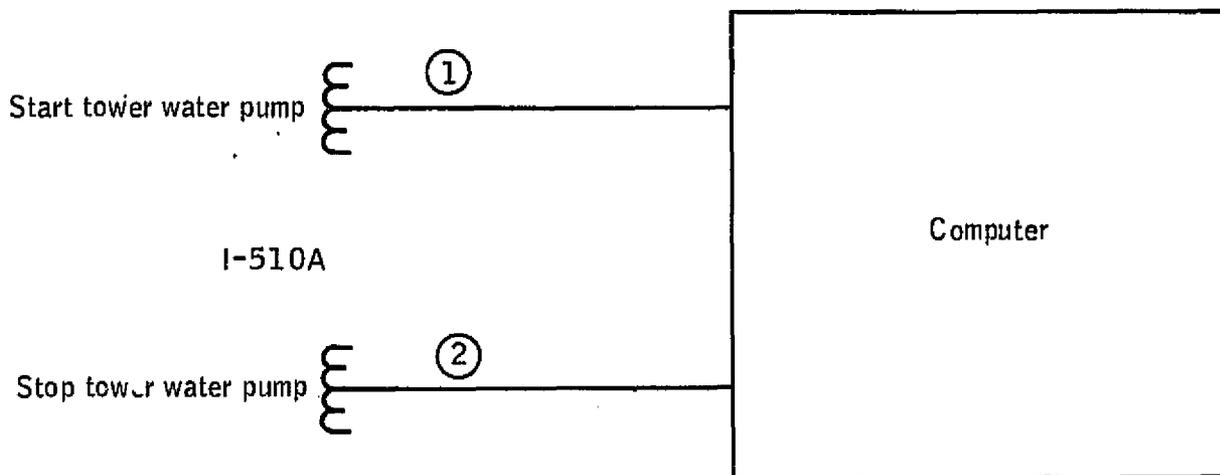


Figure C-24.- Interface definition for motor control, compression chiller I-502.

Relay control



Computer output 1. Start tower water pump I-510A  
+24-Vdc pulse, 128 msec  
Nominal coil power = 1.2 W

Computer output 2. Stop tower water pump I-510A  
+24-Vdc pulse, 128 msec

Note: Single pulse for actuation

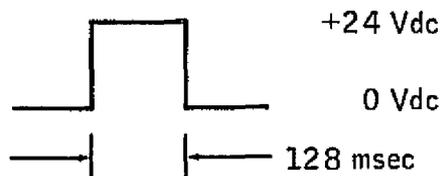
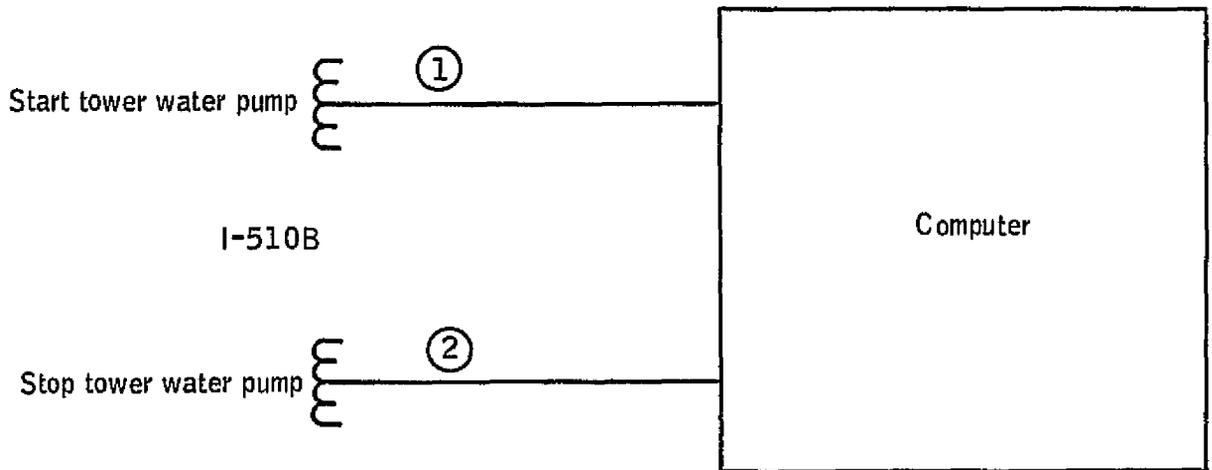


Figure C-25.- Interface definition for motor control, tower water pump I-510A.

Relay control



Computer output 1. Start tower water pump I-510B  
+24-Vdc pulse, 128 msec  
Nominal coil power = 1.2 W

Computer output 2. Stop tower water pump I-510B  
+24-Vdc pulse, 128 msec

Note: Single pulse for actuation

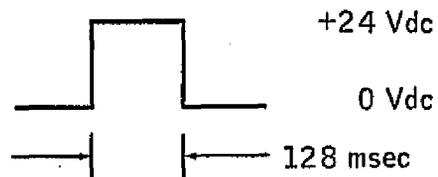
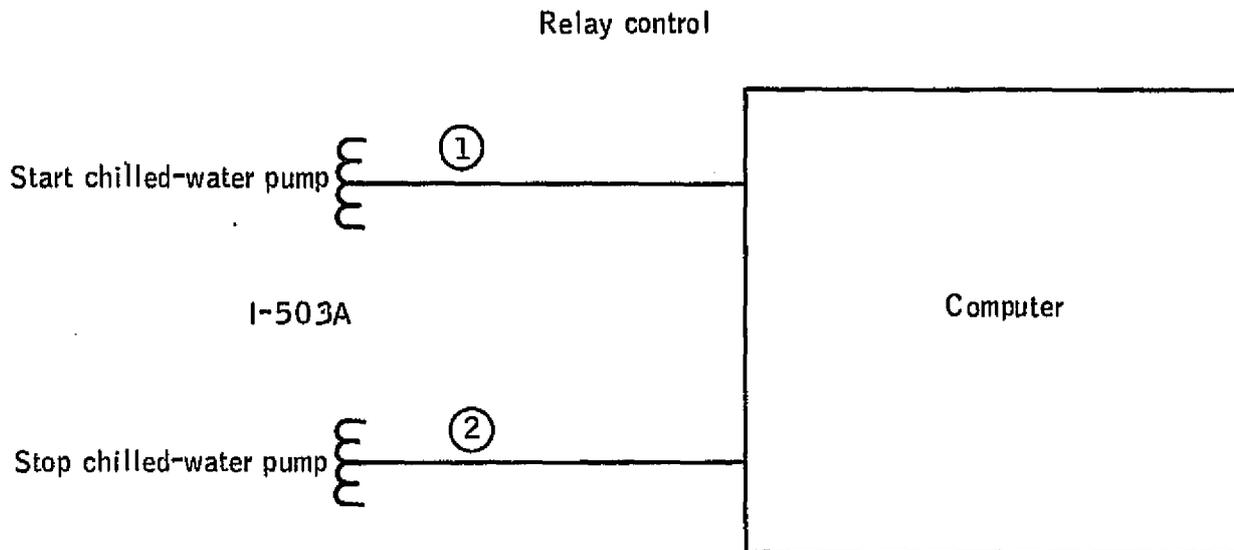


Figure C-26.- Interface definition for motor control, tower water pump I-510B.



Computer output 1. Start chilled-water pump I-503A,  
absorption chiller  
+24-Vdc pulse, 128 msec  
Nominal coil power = 1.2 W

Computer output 2. Stop chilled-water pump I-503A,  
absorption chiller  
+24-Vdc pulse, 128 msec

Note: Single pulse for actuation

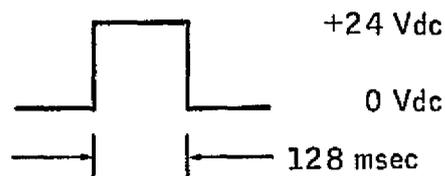
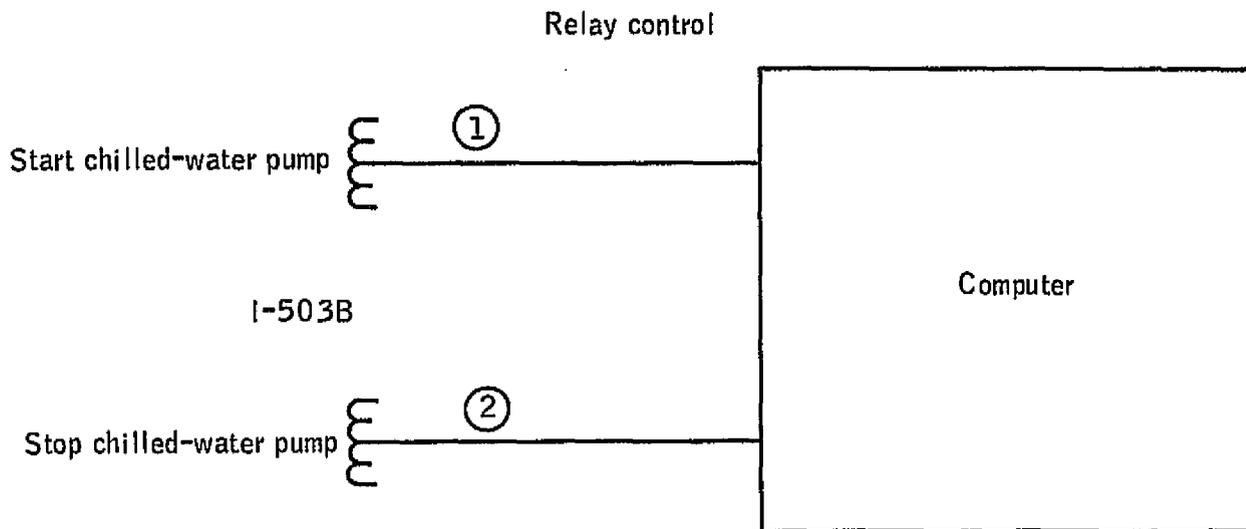


Figure C-27.- Interface definition for motor control, chilled-water pump I-503A, absorption chiller.



Computer output 1. Start chilled-water pump I-503B,  
compression chiller  
+24-Vdc pulse, 128 msec  
Nominal coil power = 1.2 W

Computer output 2. Stop chilled-water pump I-503B,  
compression chiller  
+24-Vdc pulse, 128 msec

Note: Single pulse for actuation

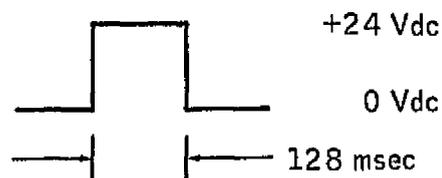
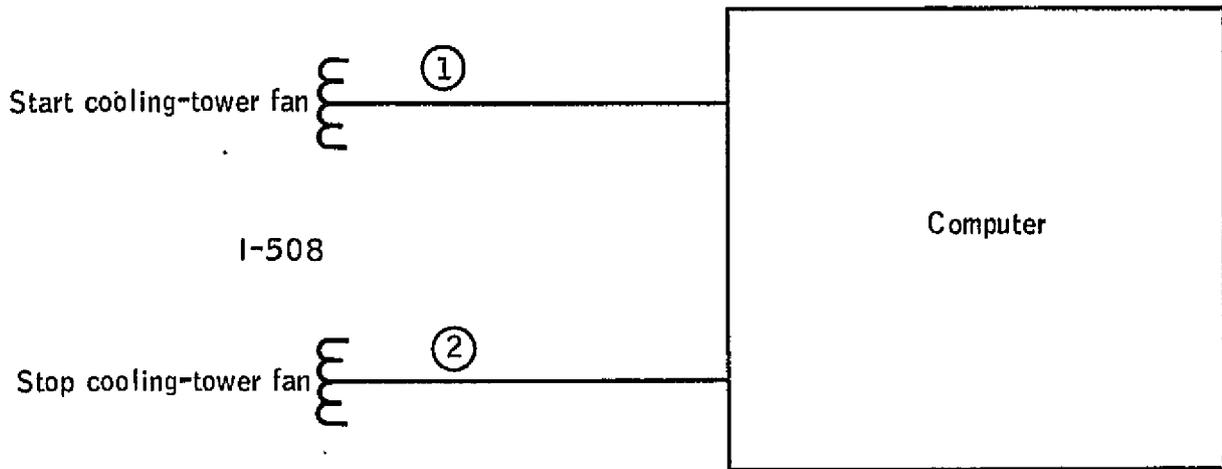


Figure C-28.- Interface definition for motor control, chilled-water pump I-503B, compression chiller.

### Relay control



Computer output 1. Start cooling-tower fan I-508  
+24-Vdc pulse, 128 msec  
Nominal coil power = 1.2 W

Computer output 2. Stop cooling-tower fan I-508  
+24-Vdc pulse, 128 msec

Note: Single pulse for actuation

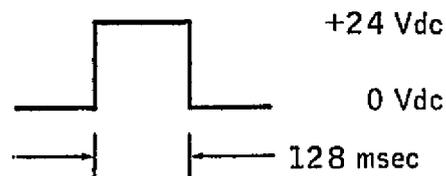
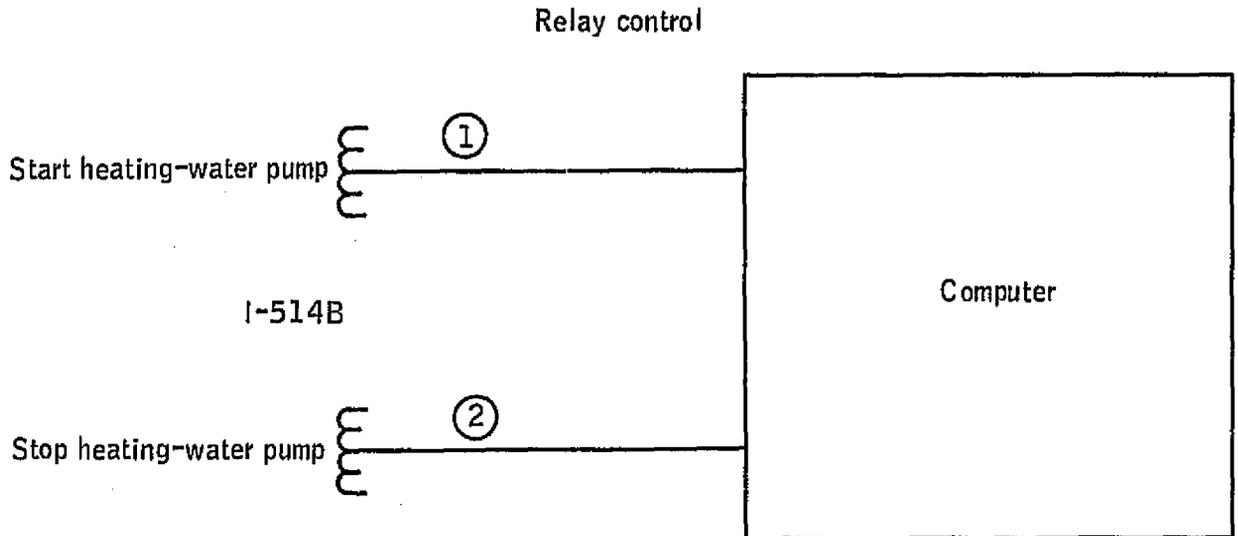


Figure C-29.- Interface definition for motor control, cooling-tower fan I-508.



Computer output 1. Start heating-water pump I-514B  
 +24-Vdc pulse, 128 msec  
 Nominal coil power = 1.2 W

Computer output 2. Stop heating-water pump I-514B  
 +24-Vdc pulse, 128 msec

Note: Single pulse for actuation

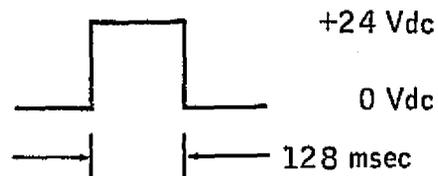


Figure C-30.- Interface definition for motor control, heating-water pump I-514B.

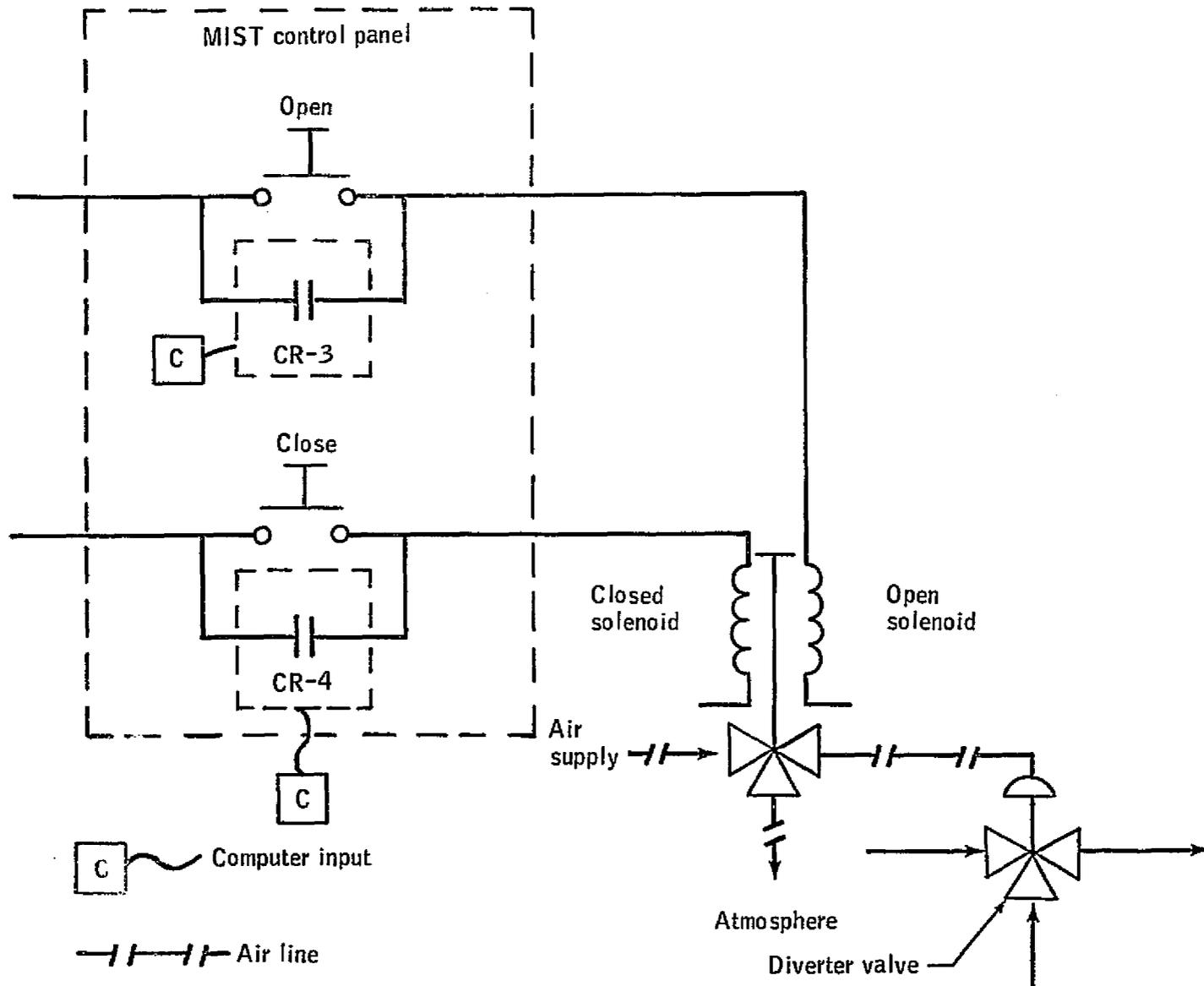
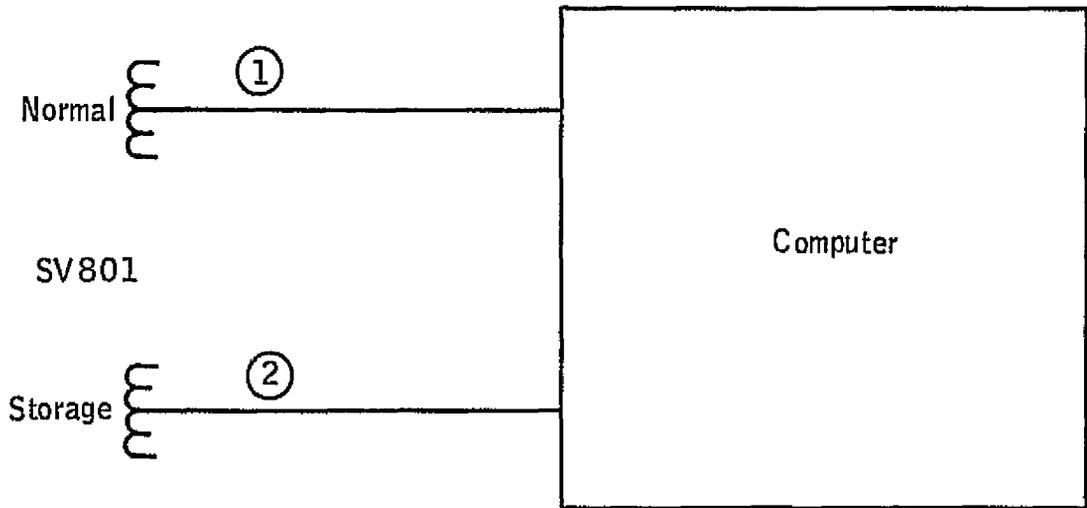


Figure C-31.— Typical valve controls.

Relay control



Computer output 1. Normal, SV801  
+24-Vdc pulse, 128 msec  
Nominal coil power = 1.2 W

Computer output 2. Storage, SV801  
+24-Vdc pulse, 128 msec

Note: Single pulse for actuation

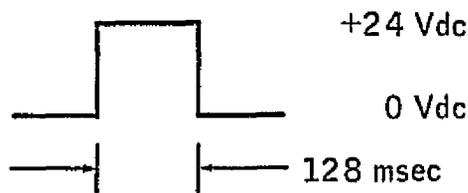
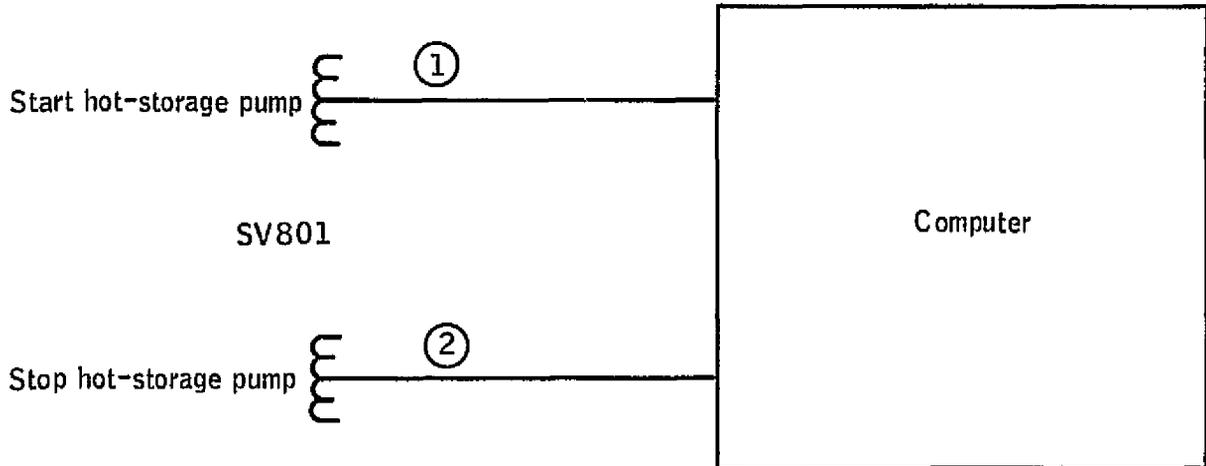


Figure C-32.- Interface definition for thermal-storage diverter valve SV801.

### Relay control



Computer output 1. Start heating-water pump I-514A  
(storage through SV801)  
+24-Vdc pulse, 128 msec  
Nominal coil power = 1.2 W

Computer output 2. Stop heating-water pump I-514A  
(normal SV801)  
+24-Vdc pulse, 128 msec

Note: Single pulse for actuation

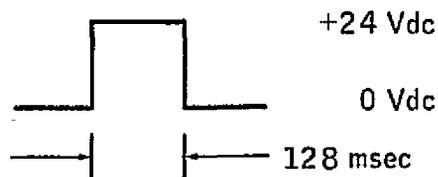


Figure C-33.- Interface definition for motor control, heating-water pump I-514A (storage through SV801).

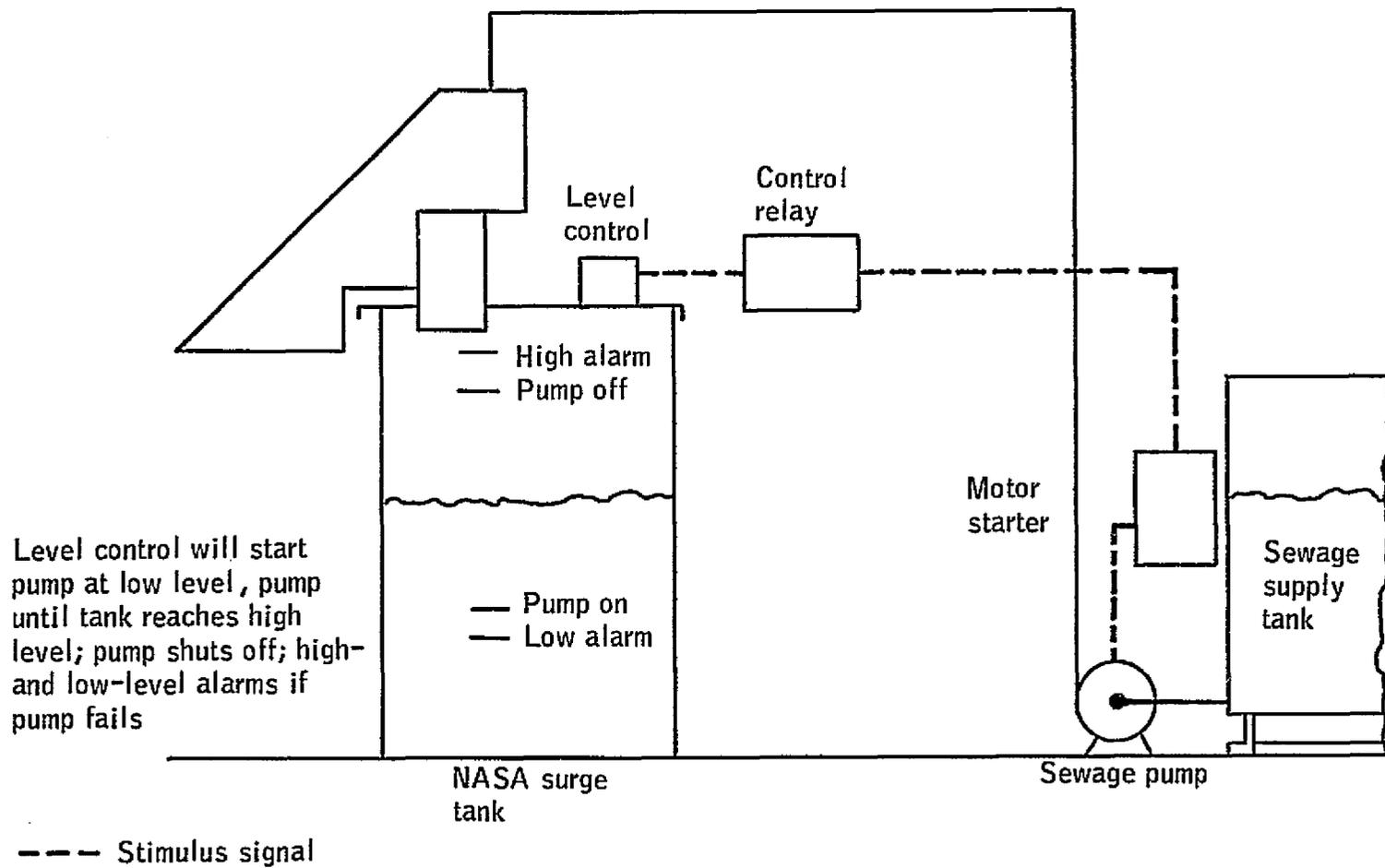


Figure C-34.- NASA surge tank level control.

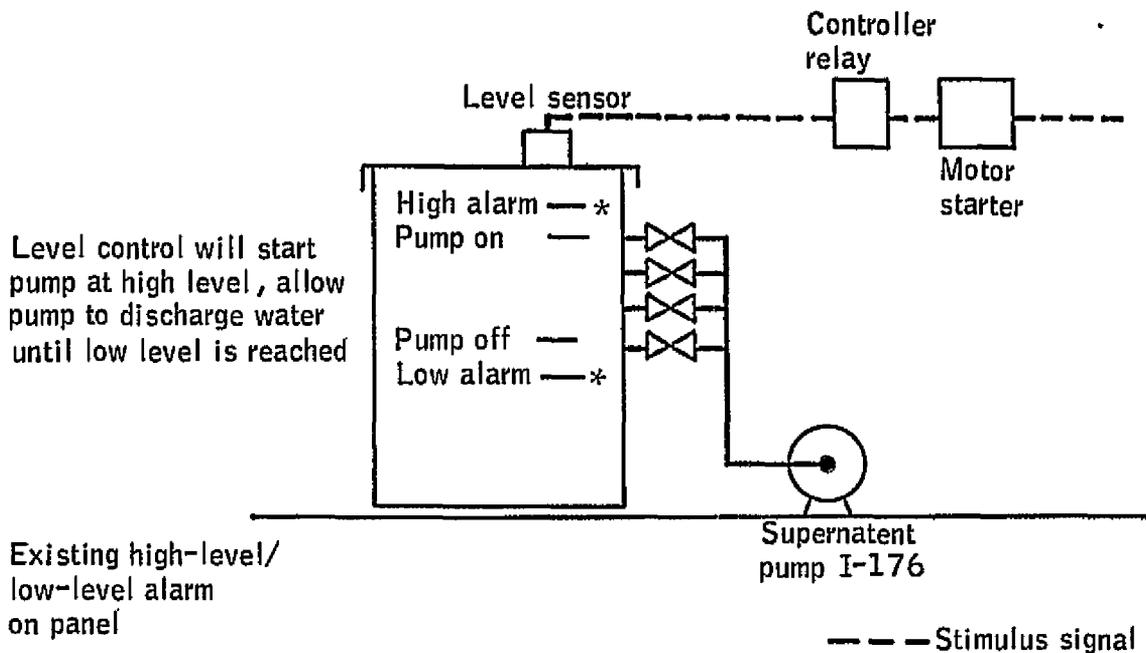


Figure C-35.- Supernatant pump level control.

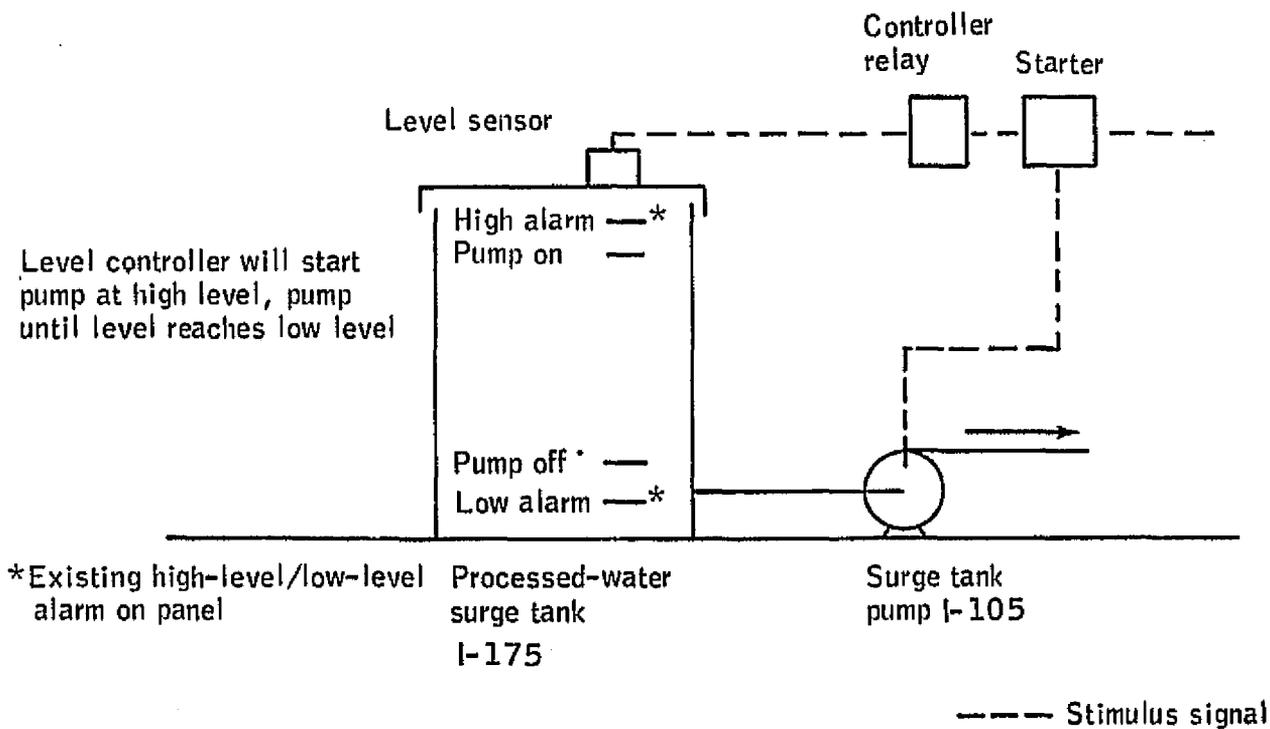


Figure C-36.- Processed-water-surge-tank level control.

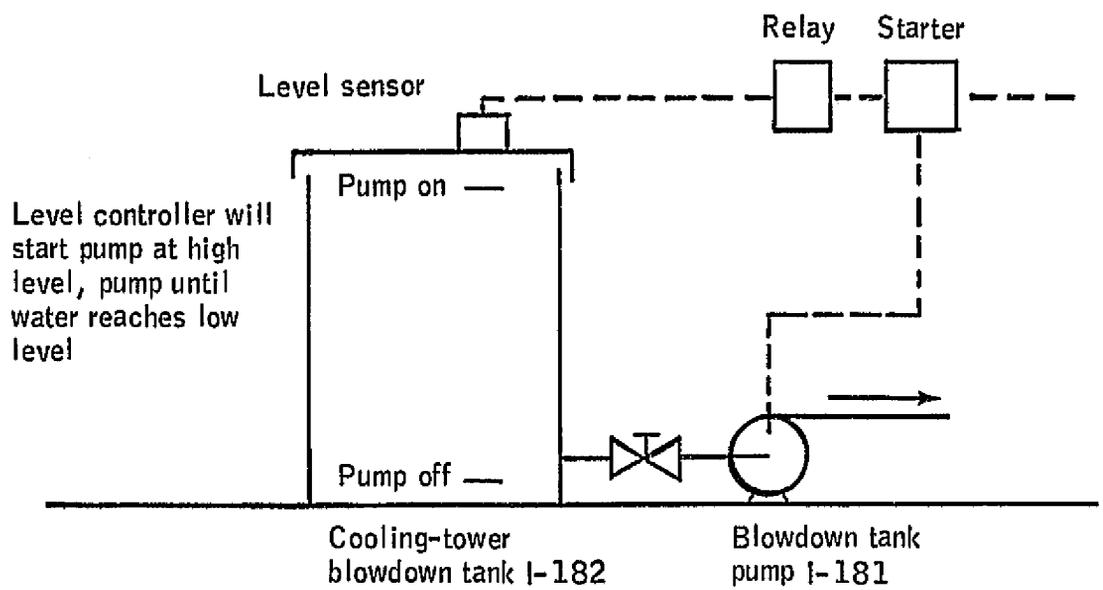


Figure C-37.- Blowdown tank level control I-825.

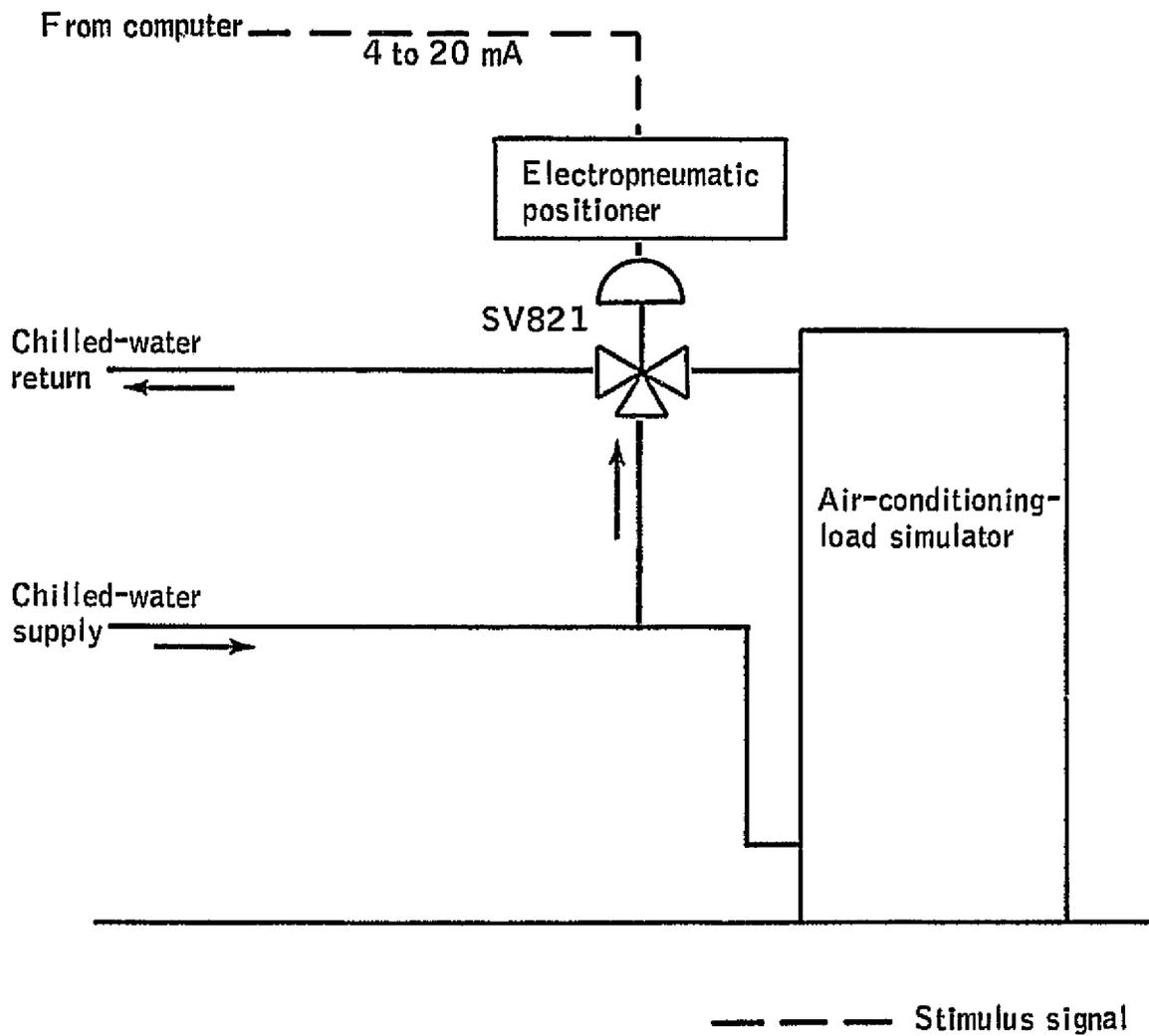
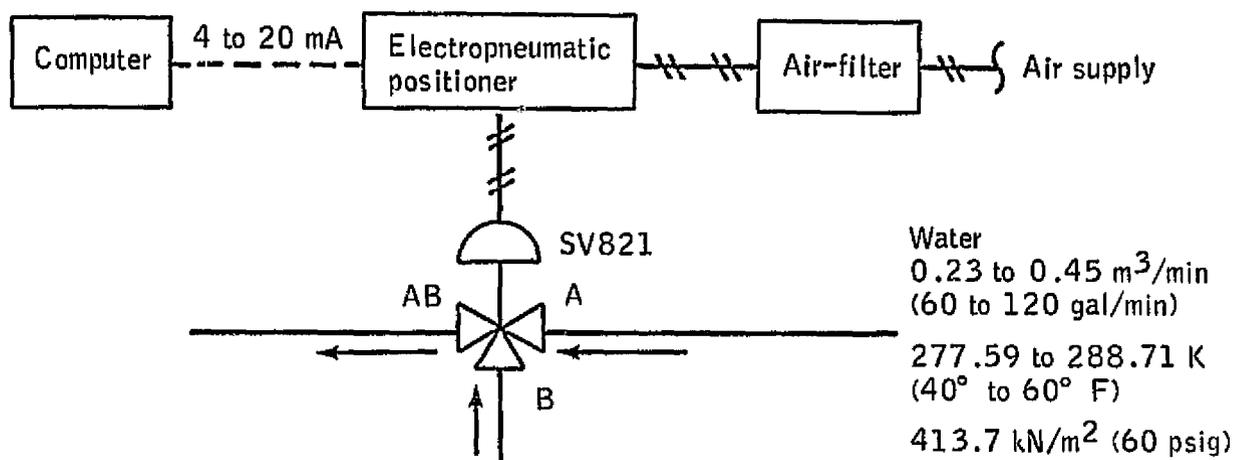


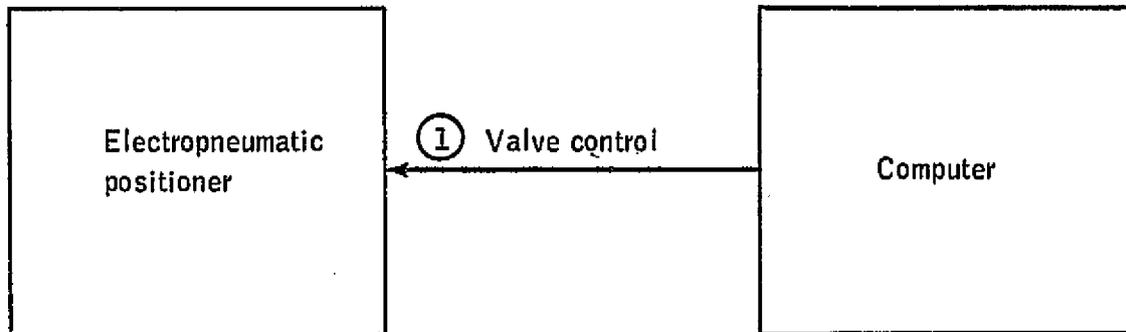
Figure C-38.— Air-conditioning-simulator temperature control valve.



#### Equipment List

1. SV 821 - 5.1-cm (2 in.) three-way diaphragm mixing valve  
 Stainless steel trim  
 Cast-iron flanged connections, 861.8 kN/m<sup>2</sup> (125 psig) ASA  
 Air failure, port B closed  
 Teflon/asbestos packing
2. Electropneumatic positioner  
 Input, 4 to 20 mA (1 to 5 Vdc)  
 Output, air signal
3. Air-filter set

Figure C-39.- Control system listing for air-conditioning-simulator temperature control valve SV821.



Computer input 1. Valve control signal  
 4 to 20 mA  
 270 ohms

Figure C-40.- Interface definition for air-conditioning-simulator temperature control valve SV821.

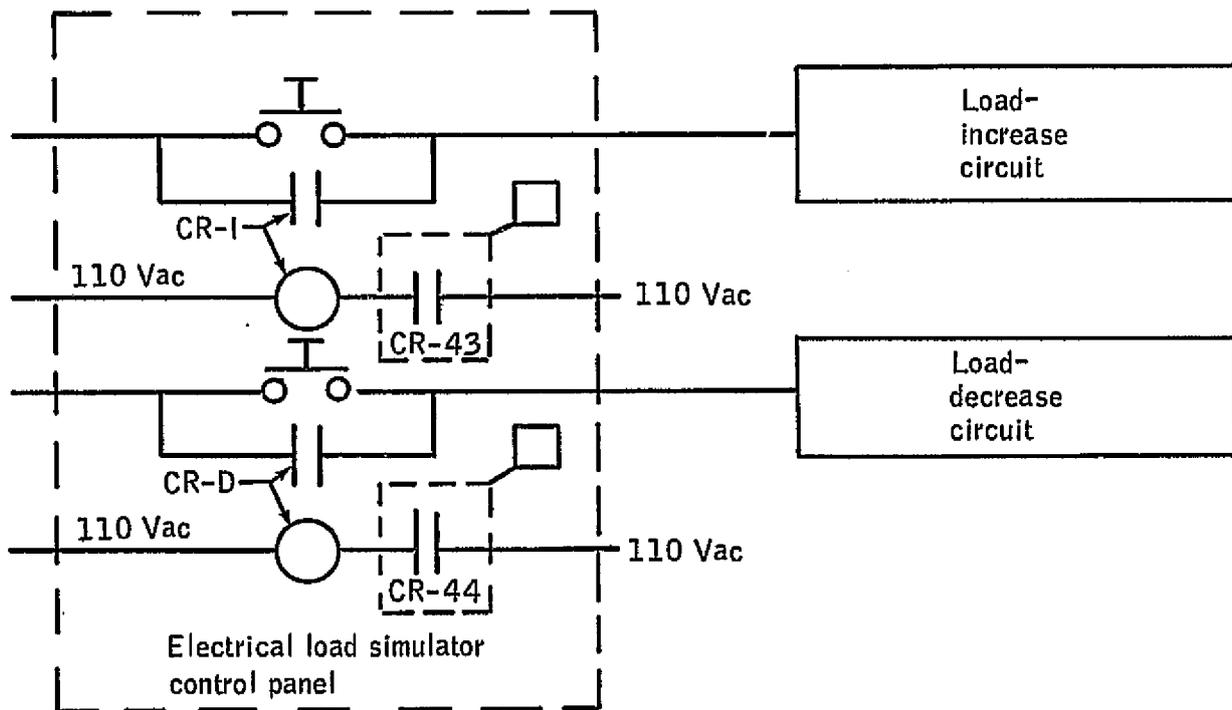
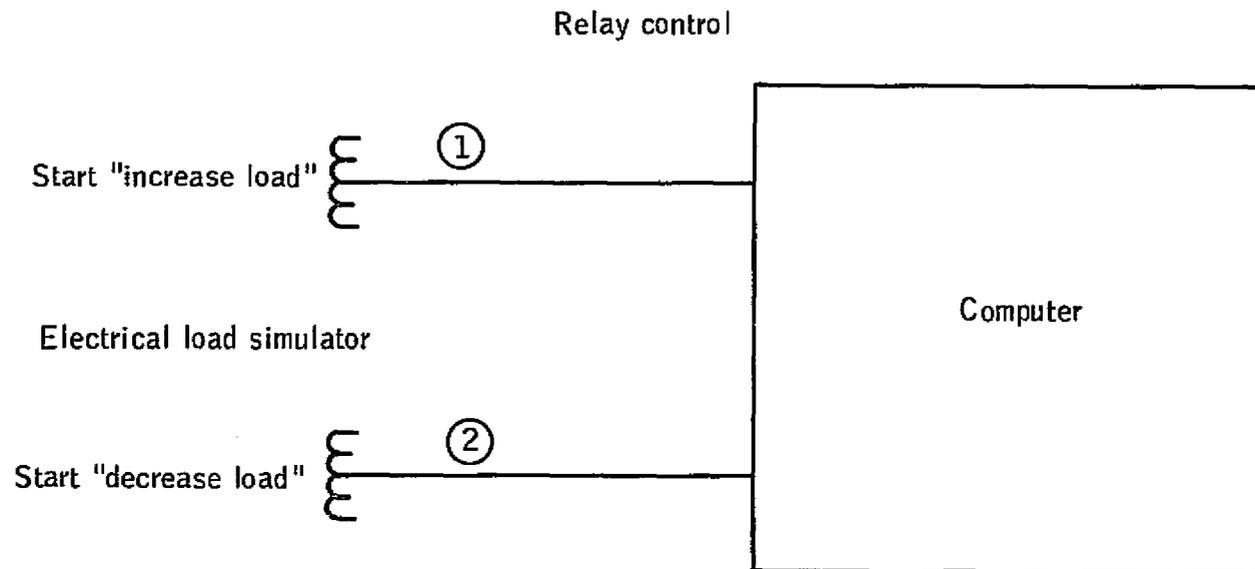


Figure C-41.- Power simulator control.



Computer output 1. Start "increase load," electrical load simulator  
 +24-Vdc period proportional signal,  
 50-msec minimum  
 Nominal coil power = 1.2 W

Computer output 2. Start "decrease load," electrical load simulator  
 +24-Vdc period proportional signal, 50-msec  
 minimum

Figure C-42.- Interface definition for electrical simulator power control,  
 motor control.

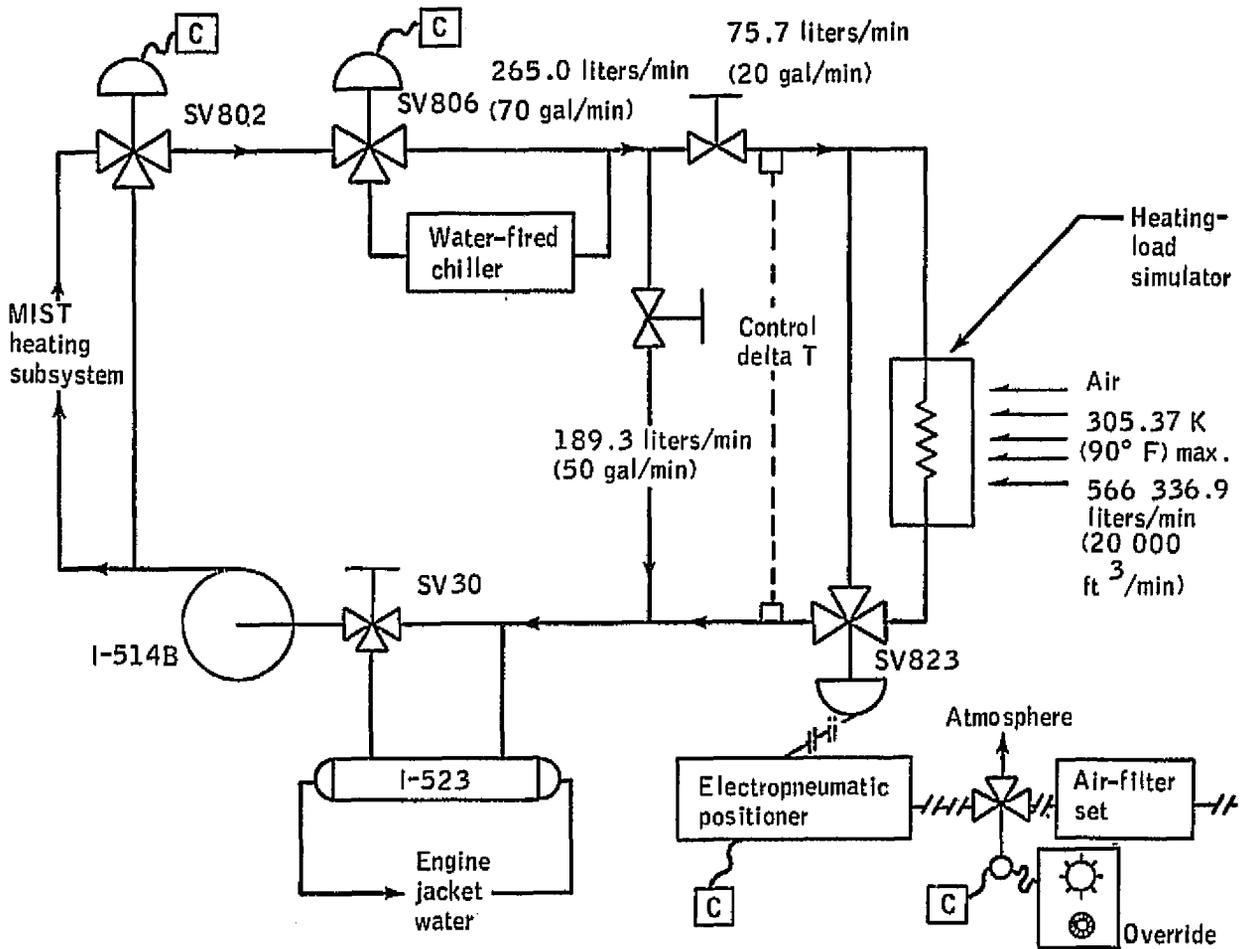
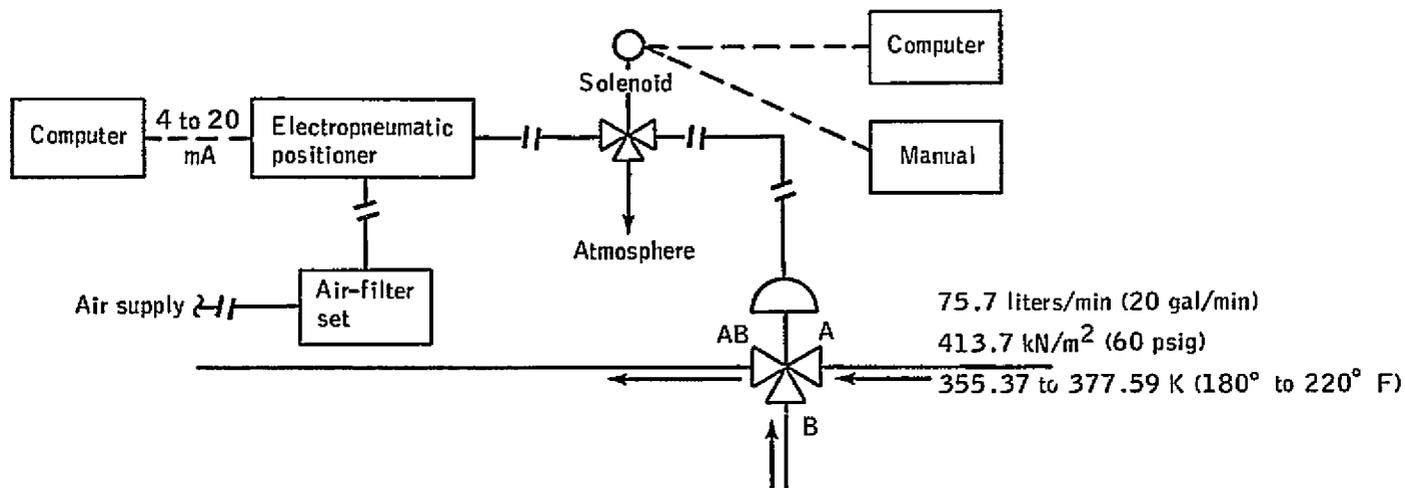


Figure C-43.- Heating-load-simulator control.

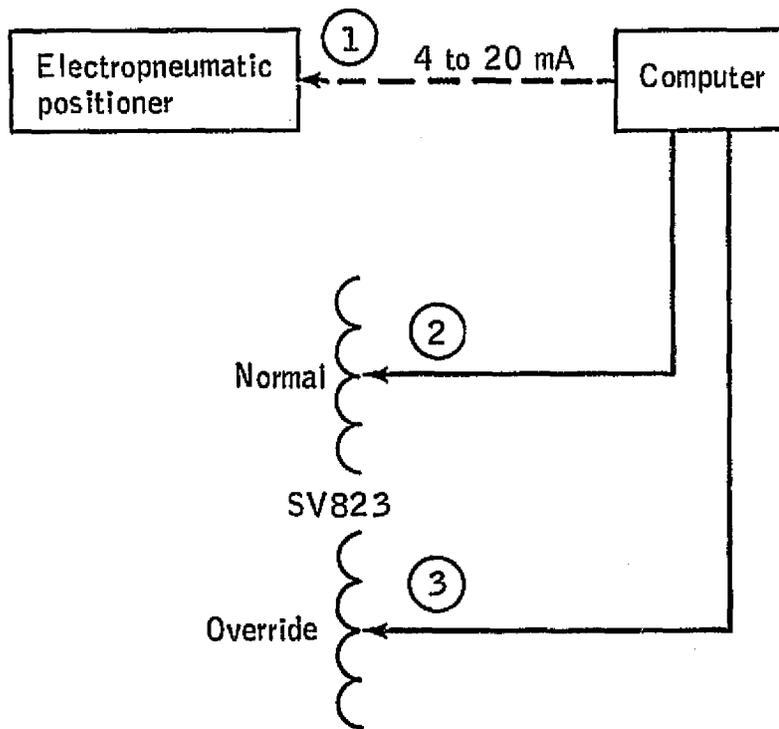


#### Equipment List

1. SV823 - 1.91-cm (0.75 in.) three-way diaphragm mixing valve  
 Carbon steel  
 Stainless steel trim  
 Screwed connections  
 Teflon/asbestos packing  
 Latching solenoid valve (mounted and piped)  
 Position-indicating switch (one)  
 If air failure occurs, port A closes (indicator switch to indicate this position)
2. Electropneumatic positioner, 4- to 20-mA signal input, positioner mounted and piped to valve
3. Air-filter regulator
4. Manual control  
 Operational switch (one)  
 Override switch (one)  
 Override light (two)
5. Computer control relay, 24 Vdc (two)

(a) Entire system.

Figure C-44.- Control system listing for heating-load-simulator control SV823.



- |                 |  |
|-----------------|--|
| Computer output | 1. 4- to 20-mA (dc) signal for valve (SV823) position                        |
| Computer output | 2. Operating, SV823<br>+24-Vdc pulse, 128 msec<br>Nominal coil power = 1.2 W |
| Computer output | 3. Override, SV823<br>+24-Vdc pulse, 128 msec                                |

(b) Computer-electropneumatic positioner interface.

Figure C-44.- Concluded.

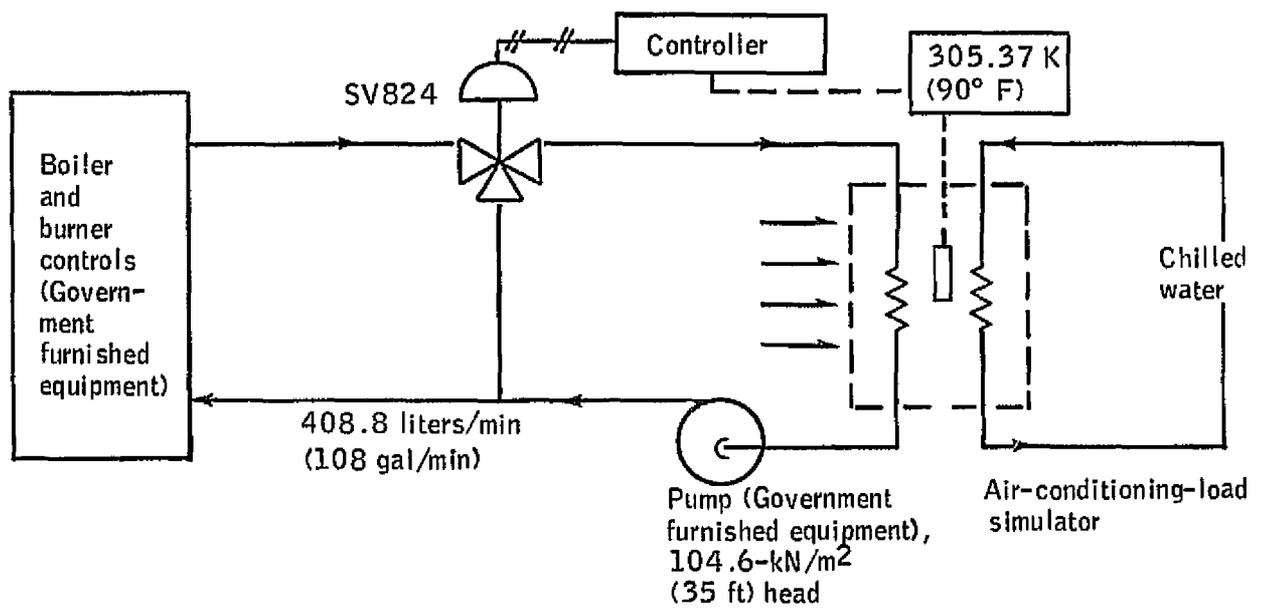
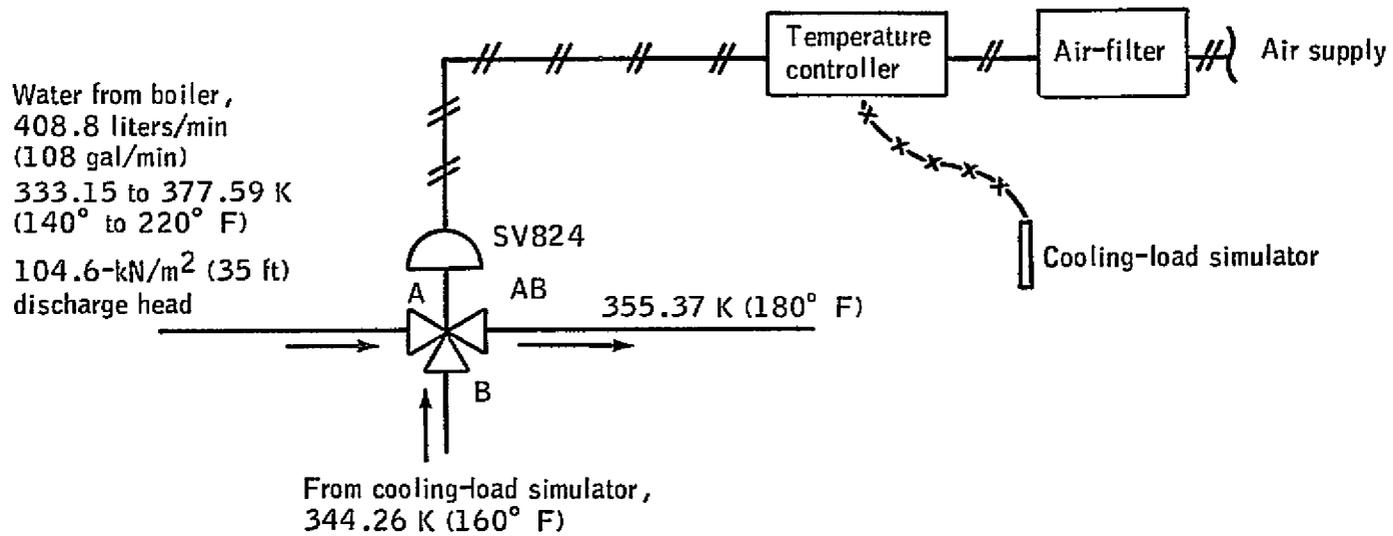


Figure C-45.- Boiler water temperature control.



#### Equipment List

1. SV824 - 6.4-cm (2.5 in.), three-way diaphragm mixing valve  
 Flanged connections, 861.8 kN/m<sup>2</sup> (125 psig) ASA  
 Cast-iron body  
 Stainless steel trim  
 Air signal, 20.7 to 103.4 kN/m<sup>2</sup> (3 to 15 psig)  
 Air failure closes port A  
 Teflon/asbestos packing
2. Air-filter regulator
3. Local pneumatic, bulb-filled temperature controller; range,  
 6.1 m (20 ft) at 283.15 to 338.71 K (50° to 150° F);  
 sensing bulb suitable for atmospheric air

Figure C-46.- Control system listing for boiler water temperature control SV824.

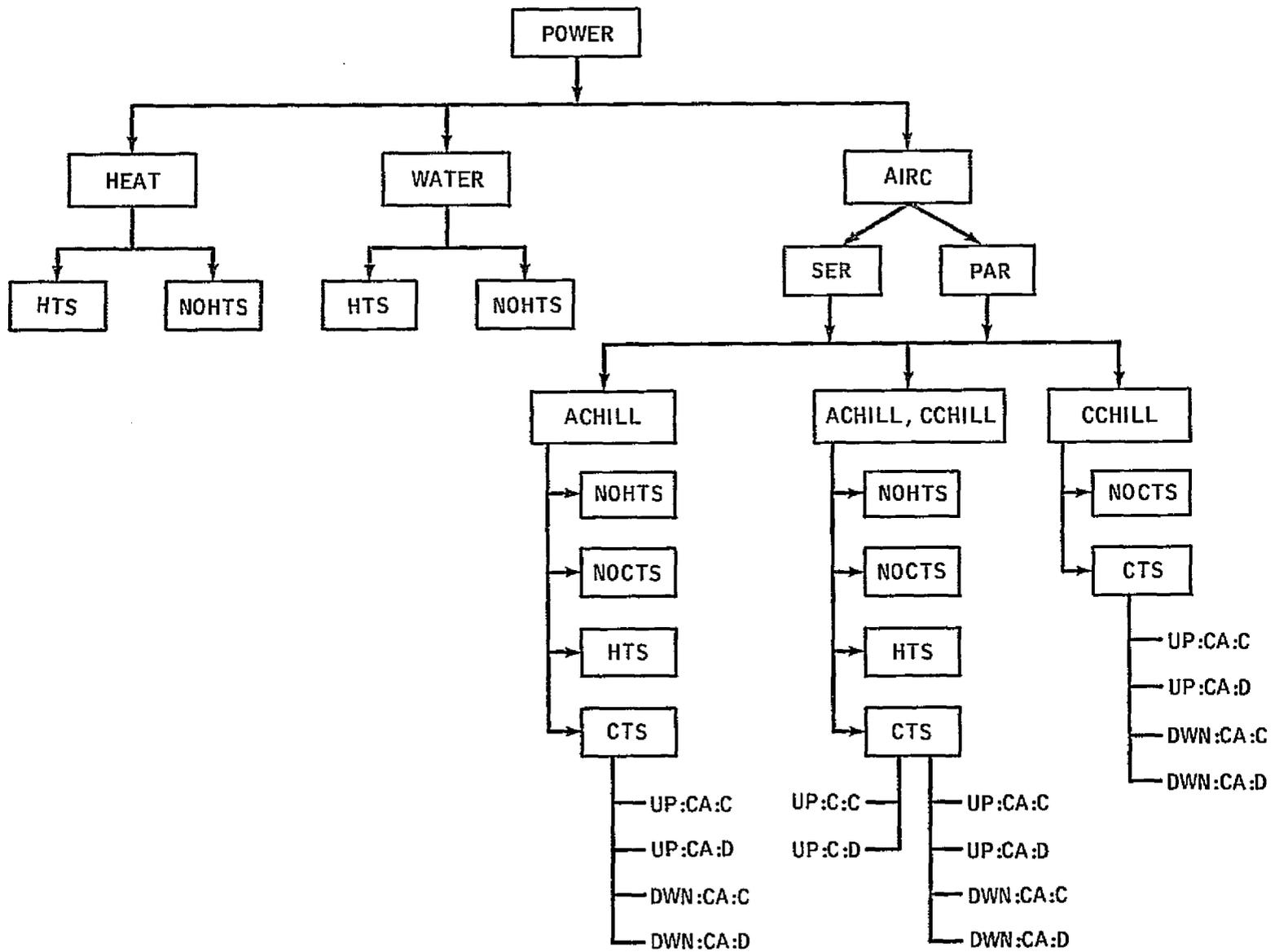
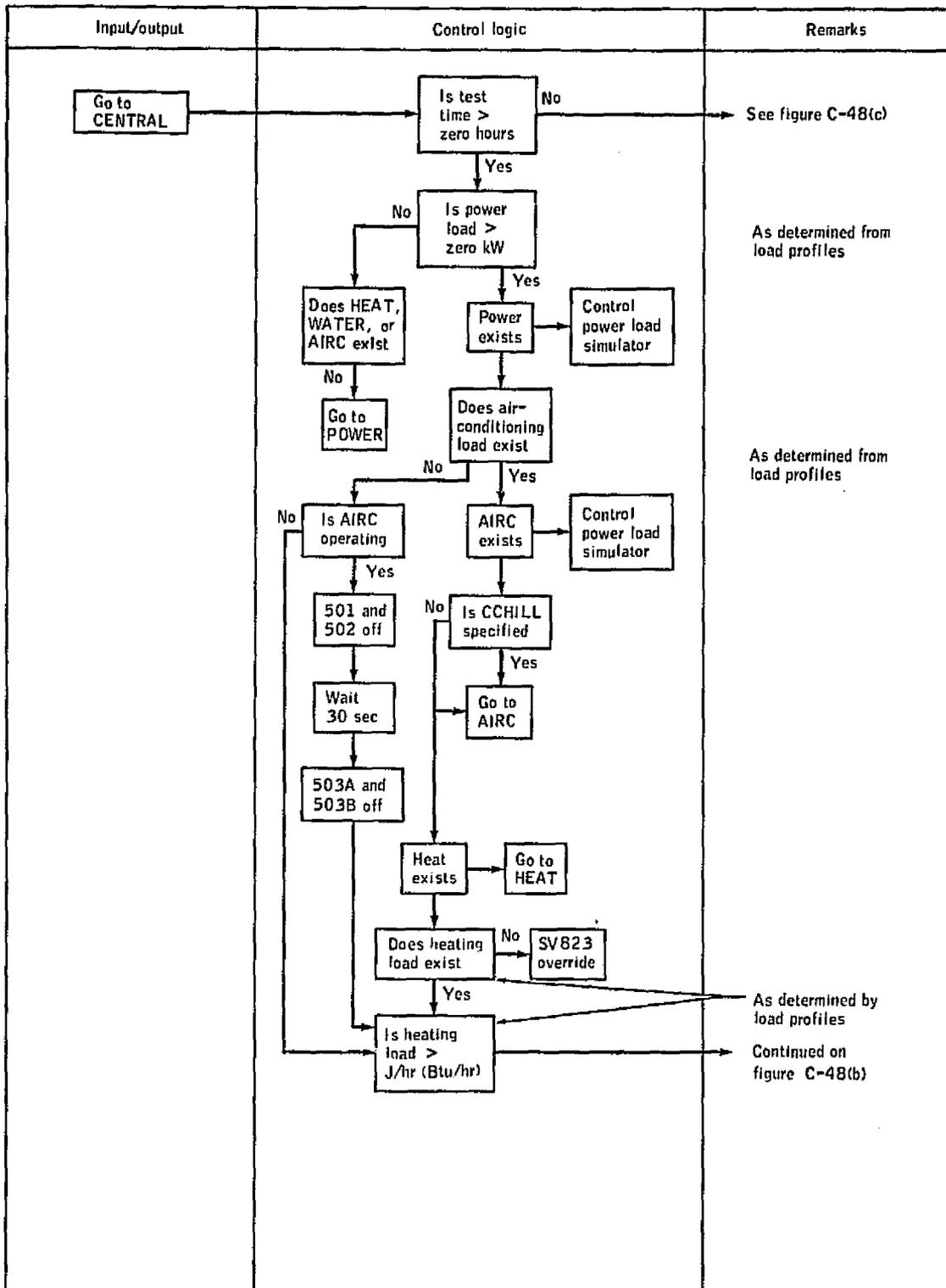
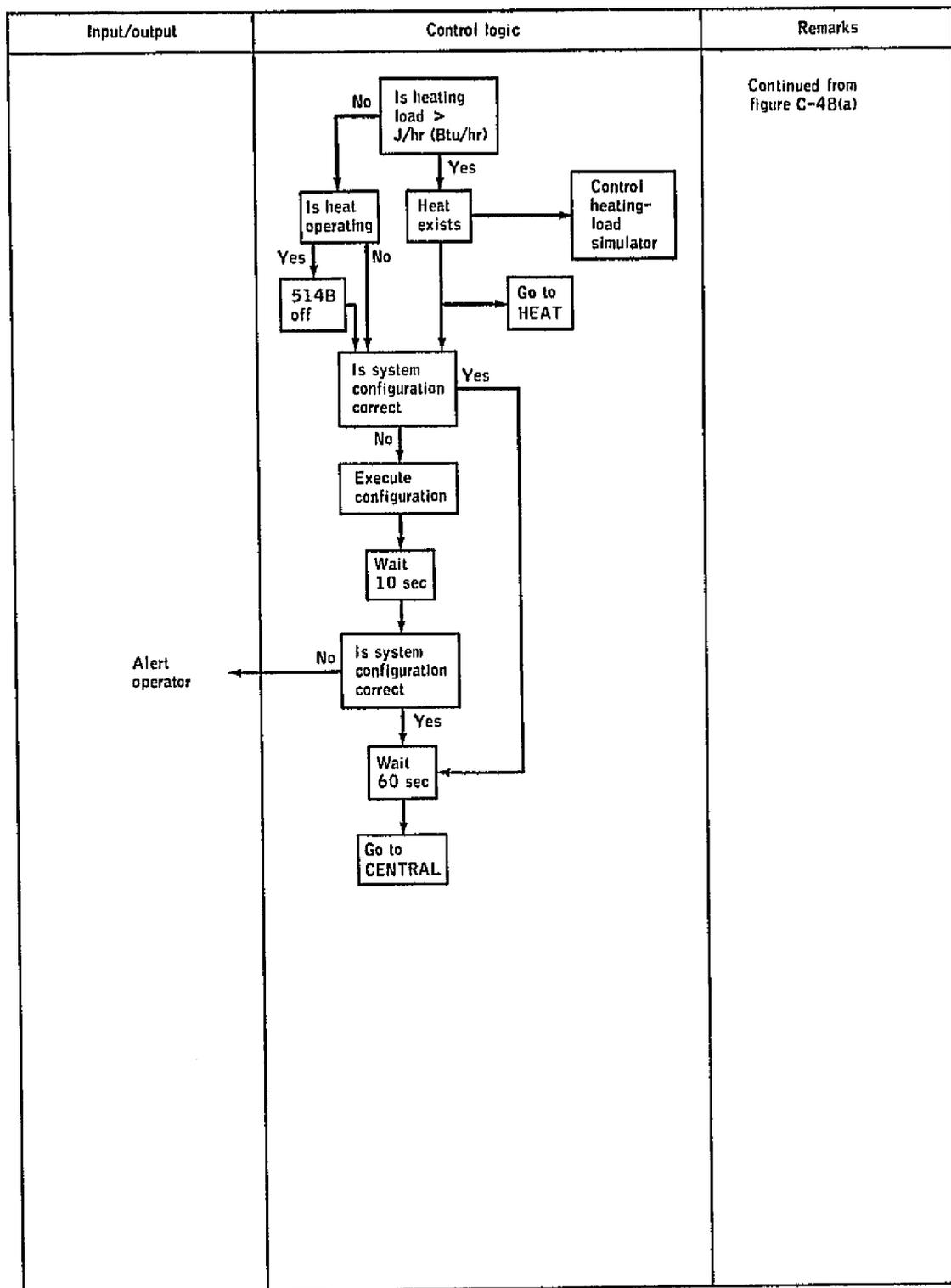


Figure C-47.- System operating modes.



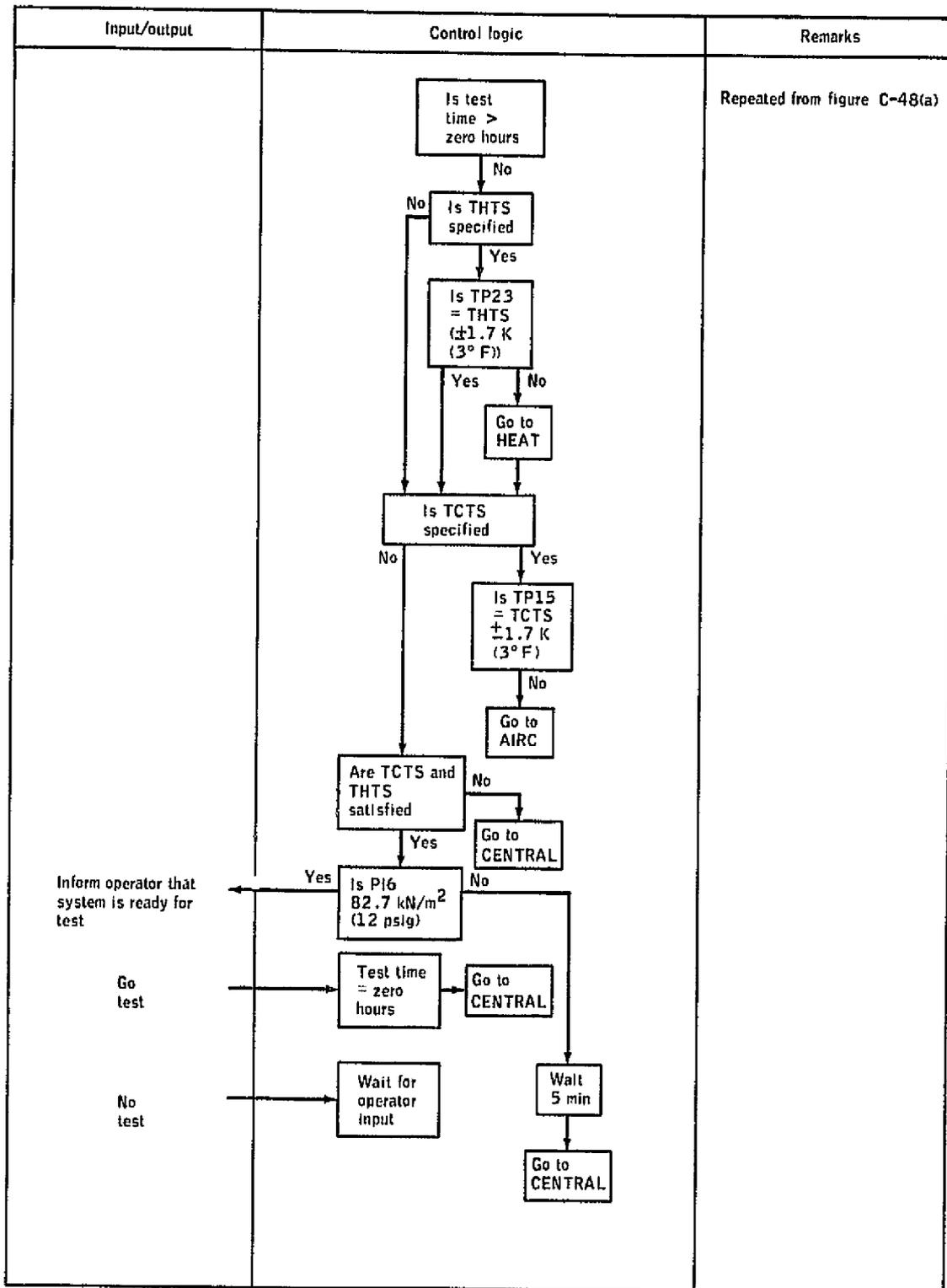
(a) Beginning of diagram.

Figure C-48.- Logic diagram for CENTRAL CONTROL mode.



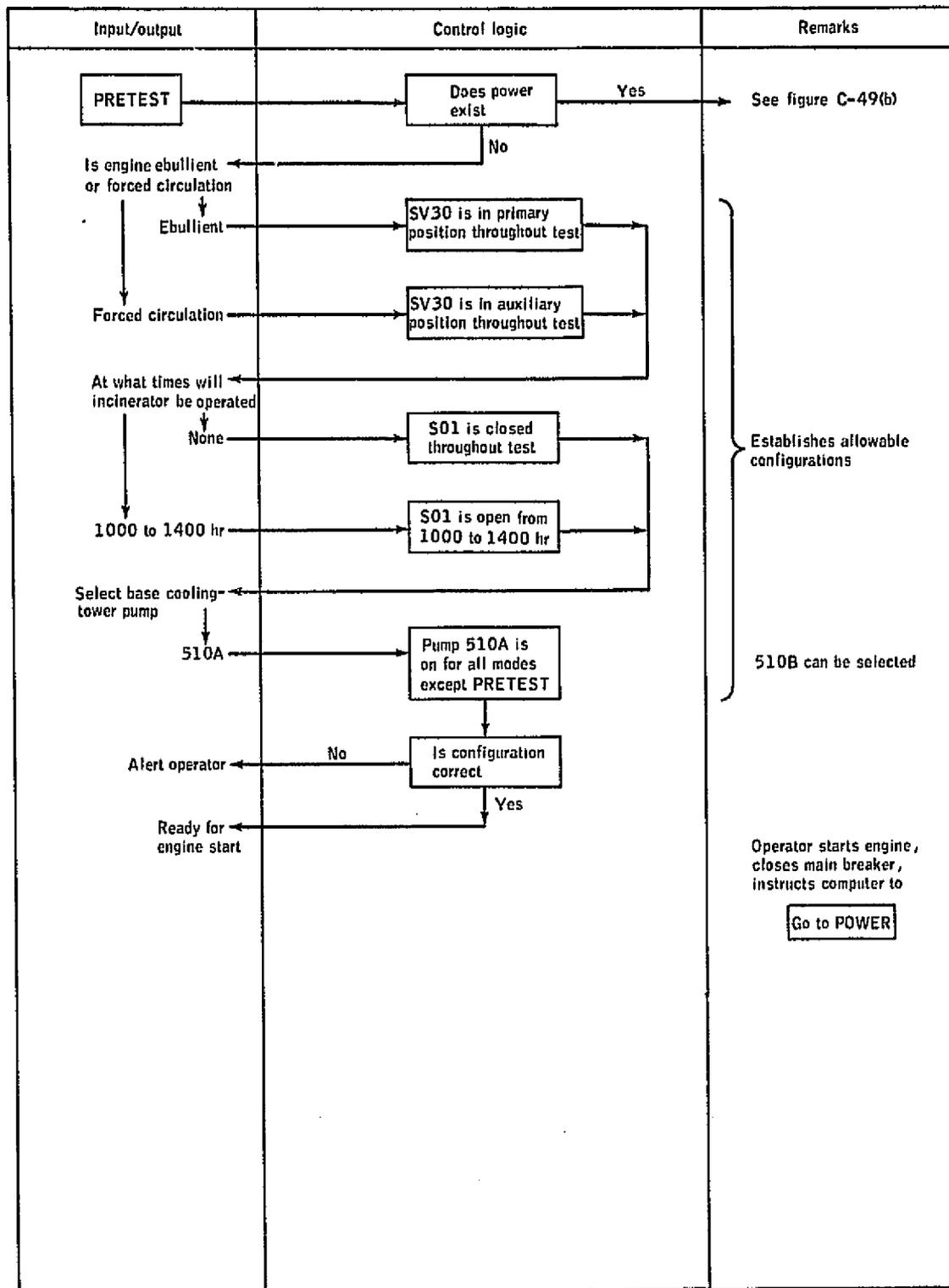
(b) Middle of diagram.

Figure C-48.- Continued.



(c) Conclusion of diagram.

Figure C-48.- Concluded.



(a) Beginning of diagram.

Figure C-49.- Logic diagram for PRETEST mode.



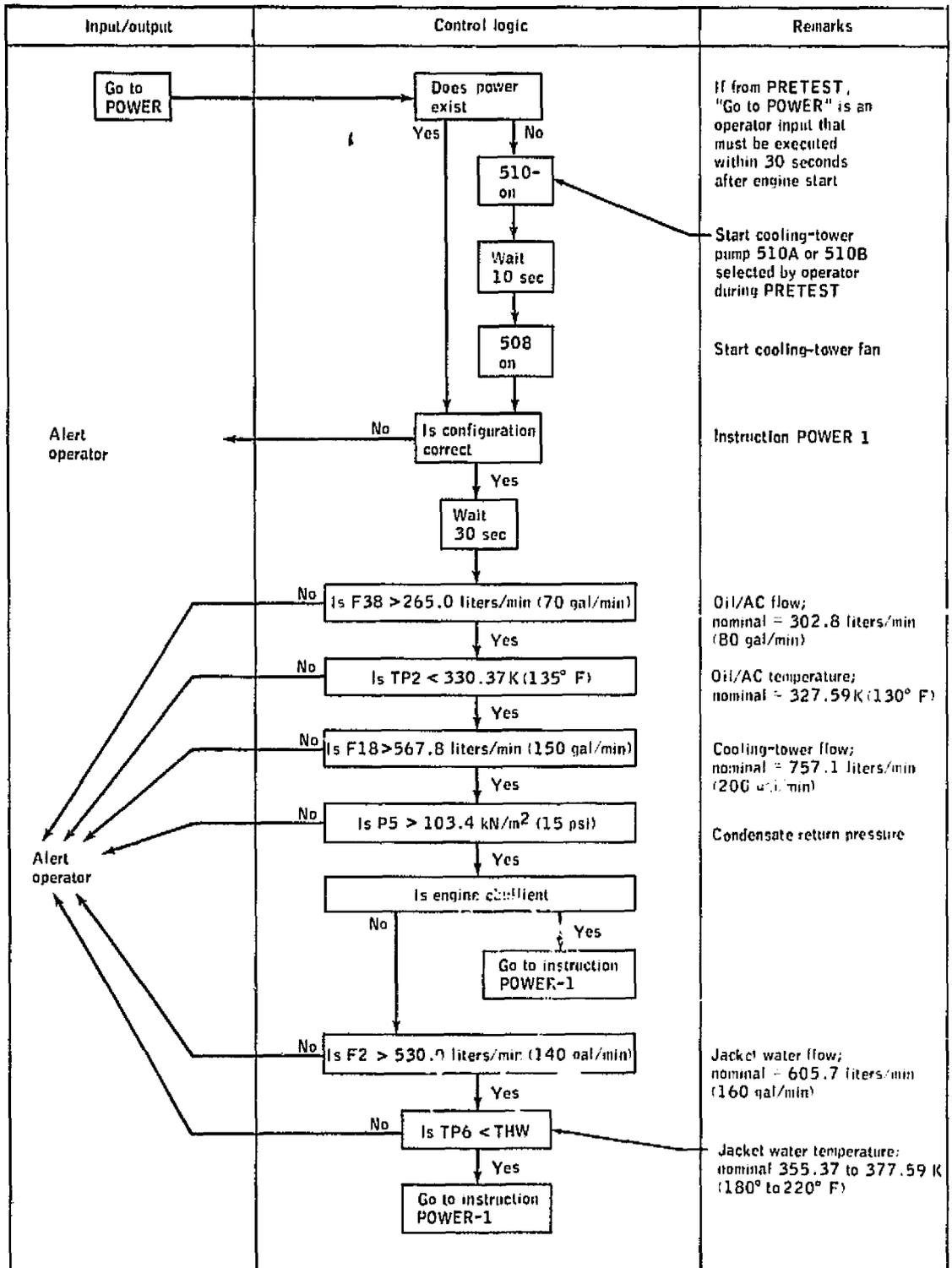
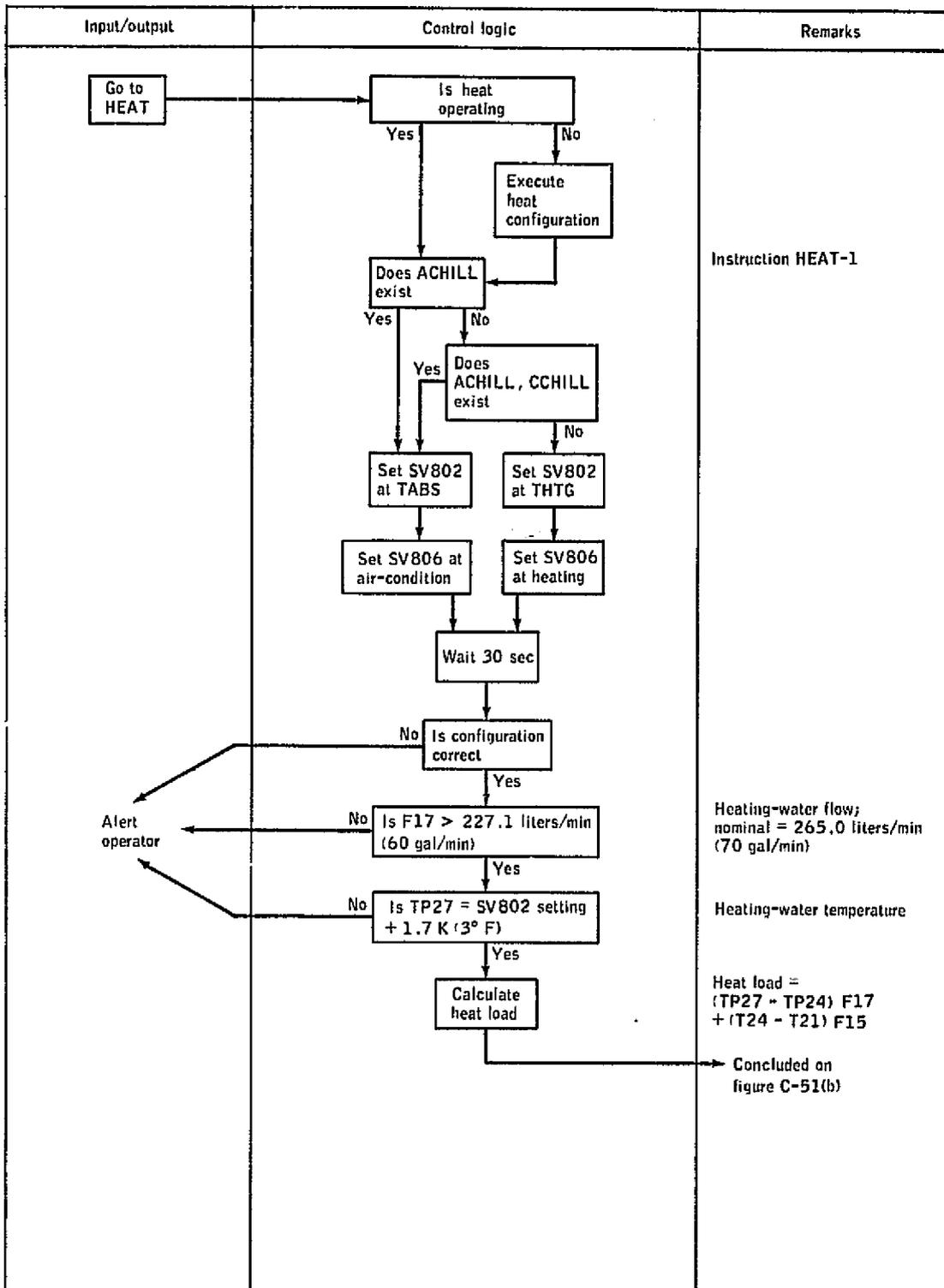


Figure C-50.- Logic diagram for POWER mode.



(a) Beginning of diagram.

Figure C-51.- Logic diagram for HEAT mode.

Input/output	Control logic	Remarks
<p data-bbox="381 1100 558 1188">Advise operator that insufficient heat for load HTS is not allowed</p>	<pre> graph TD     A[Calculate heat load] --&gt; B{Is heat load &gt; zero}     B -- No --&gt; C{Is test time &gt; zero}     C -- Yes --&gt; D[Go to CENTRAL]     B -- Yes --&gt; E{Is engine ebullient}     E -- Yes --&gt; F[Calculate available heat]     E -- No --&gt; G[Calculate available heat]     F --&gt; H{Is heat available &lt; heat load}     G --&gt; H     H -- Yes --&gt; I{Is HTS specified}     I -- No --&gt; J[Go to instruction HEAT-1]     I -- Yes --&gt; K{Is HTS specified}     K -- No --&gt; J     K -- Yes --&gt; L[Go to HTS]     </pre>	<p data-bbox="1172 348 1434 373">Continued from figure C-51(a)</p> <p data-bbox="1172 590 1381 674">Heat load is gone CENTRAL will establish required mode</p> <p data-bbox="1172 726 1392 772">Ebullient heat available = (TP30 - TP24) F15</p> <p data-bbox="1172 810 1373 894">Forced-circulation heat available = (TP18 - TP34) F17 + (TP30 - T24) F15</p>

(b) Conclusion of diagram.

Figure C-51.- Concluded.

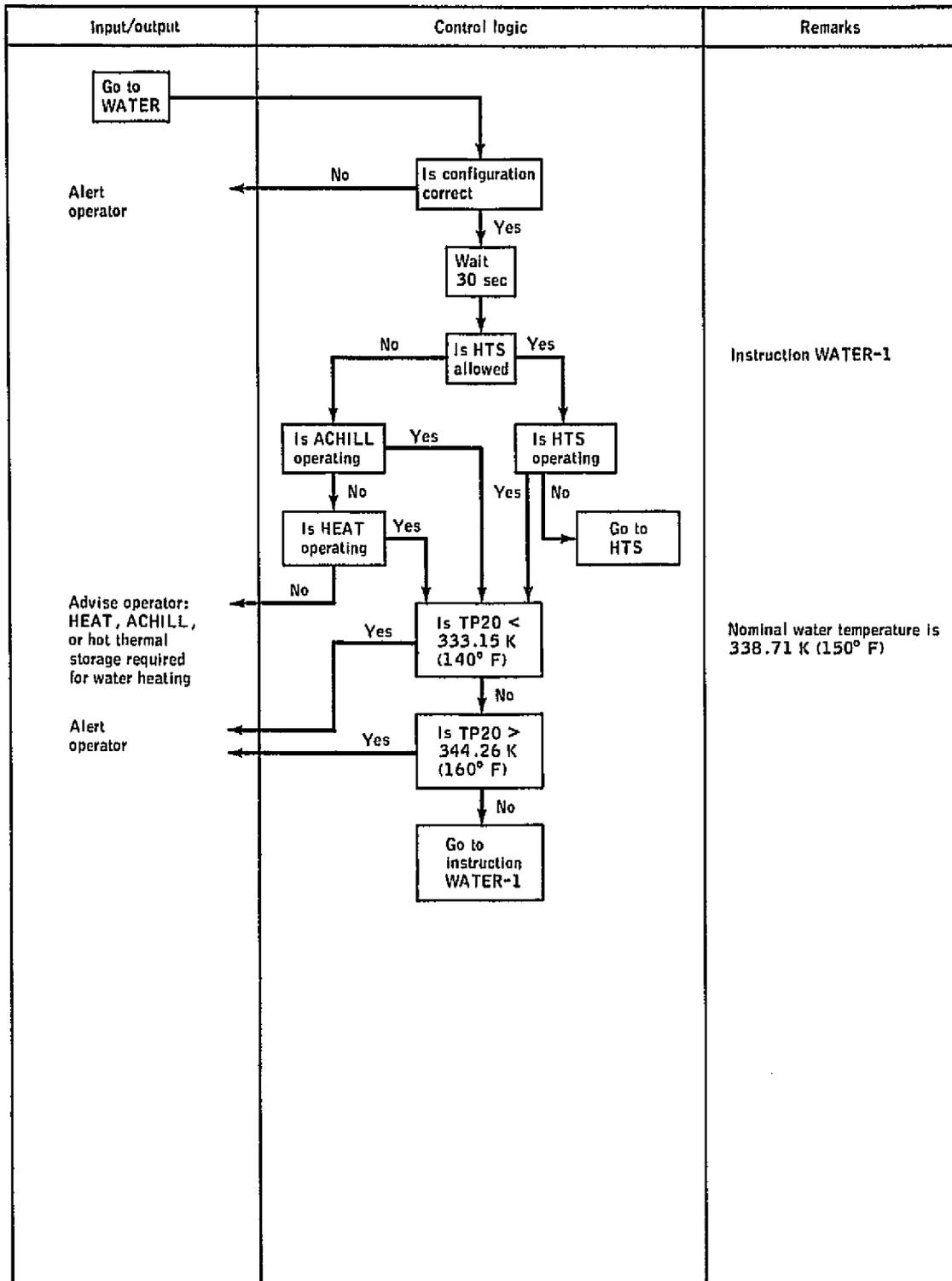
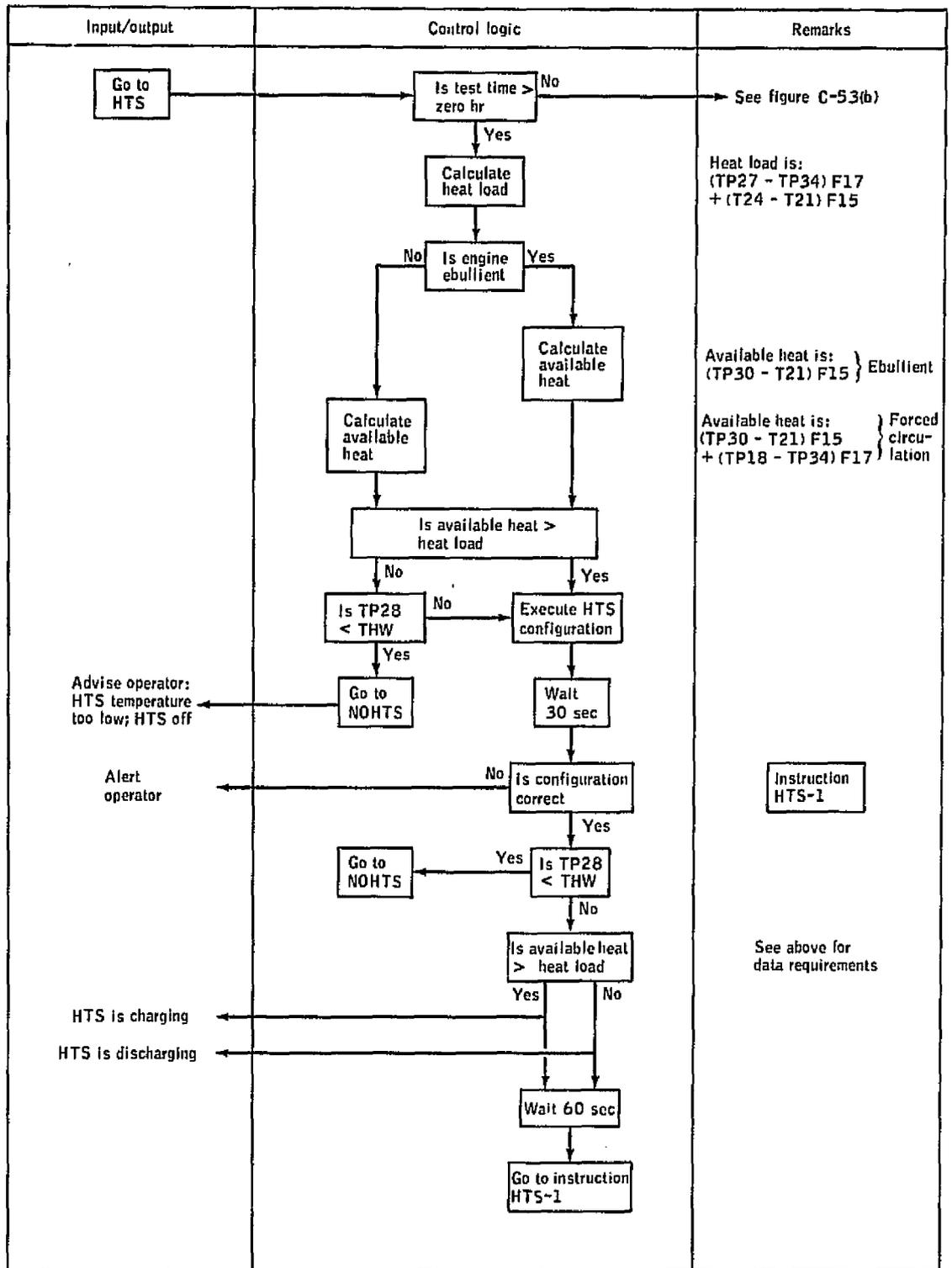
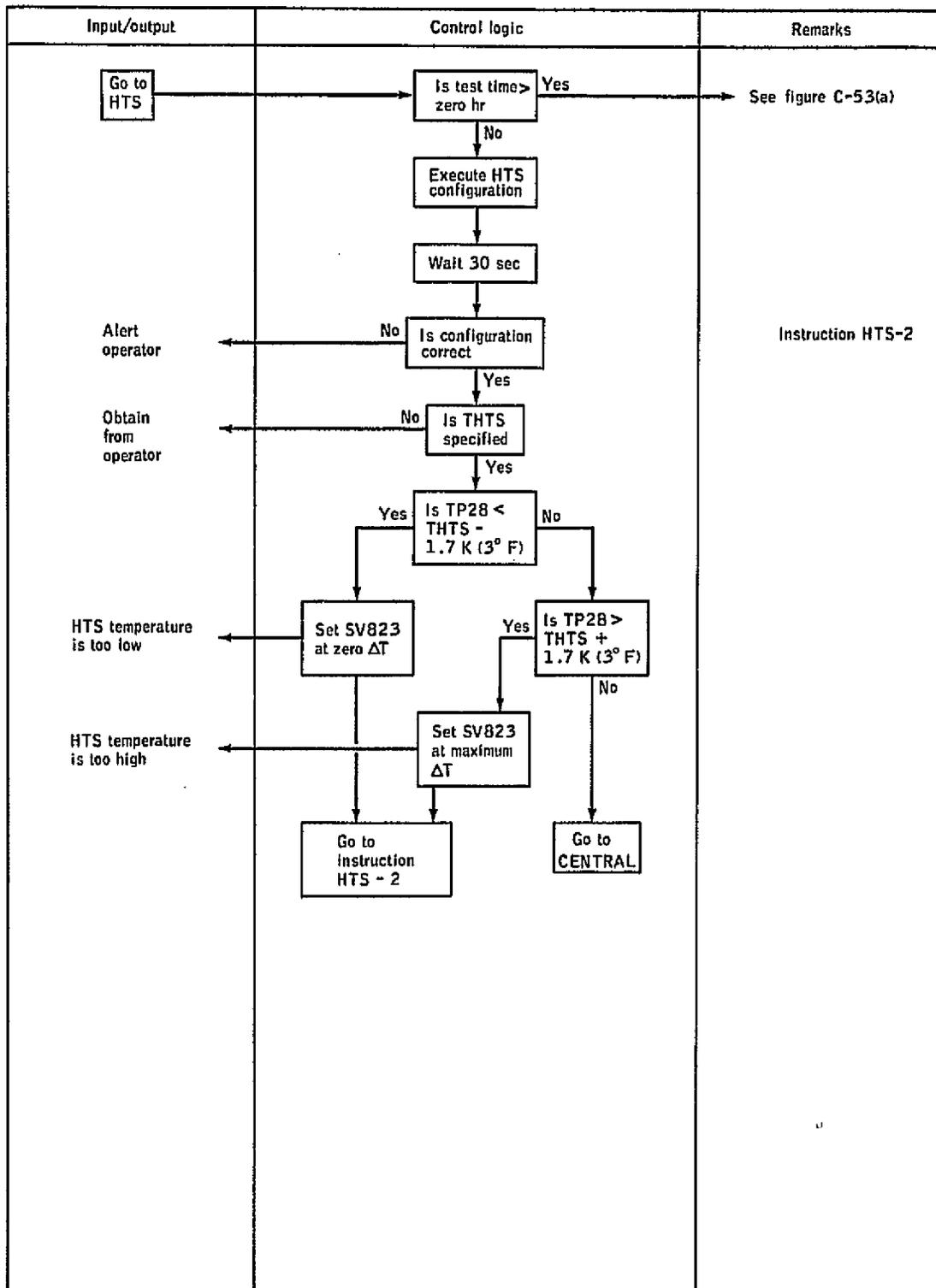


Figure C-52.- Logic diagram for WATER mode.



(a) Beginning of diagram.

Figure C-53.- Logic diagram for HTS mode.



(b) Conclusion of diagram.

Figure C-53.- Concluded.

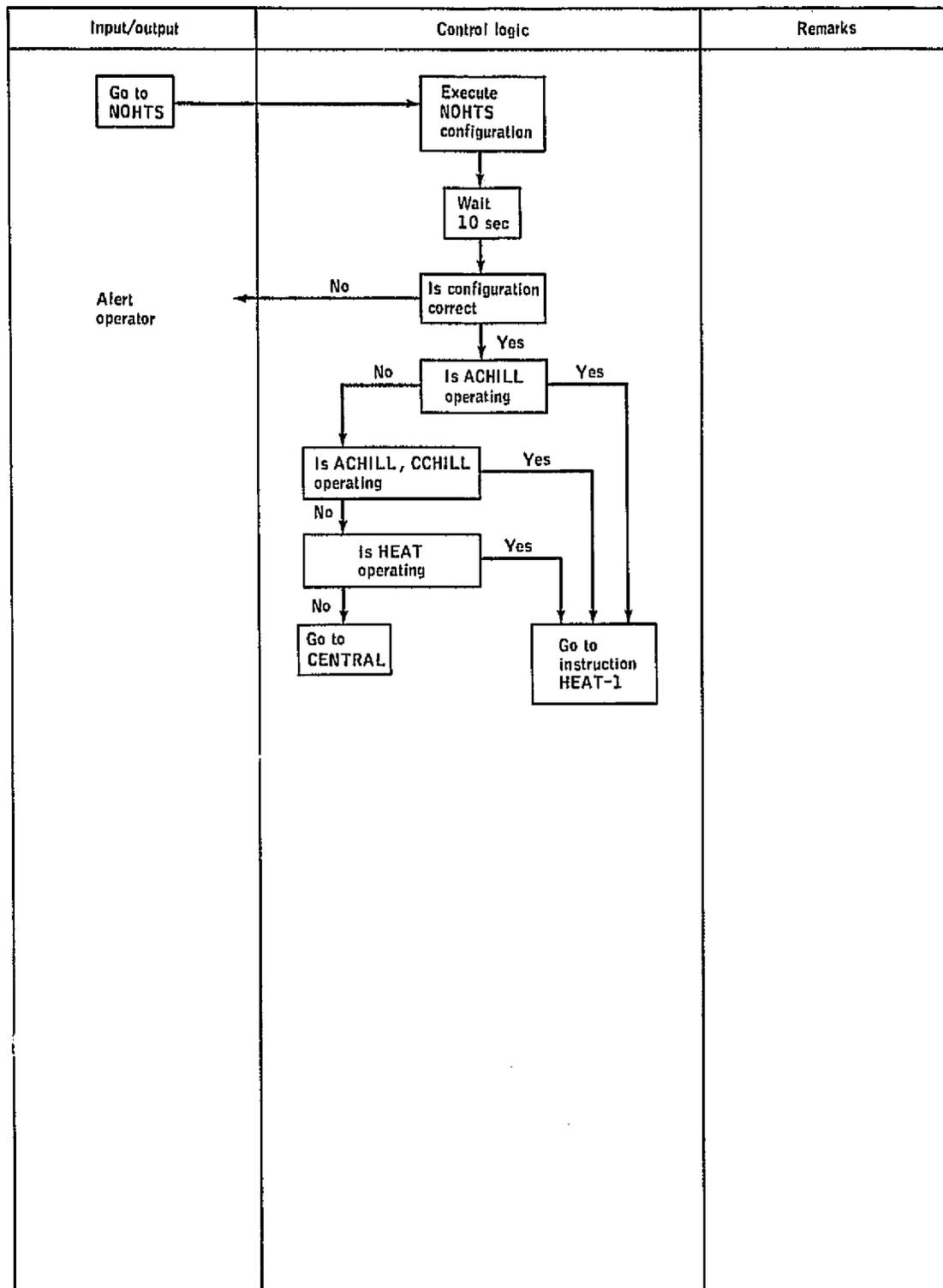


Figure C-54.- Logic diagram for NOHTS mode.

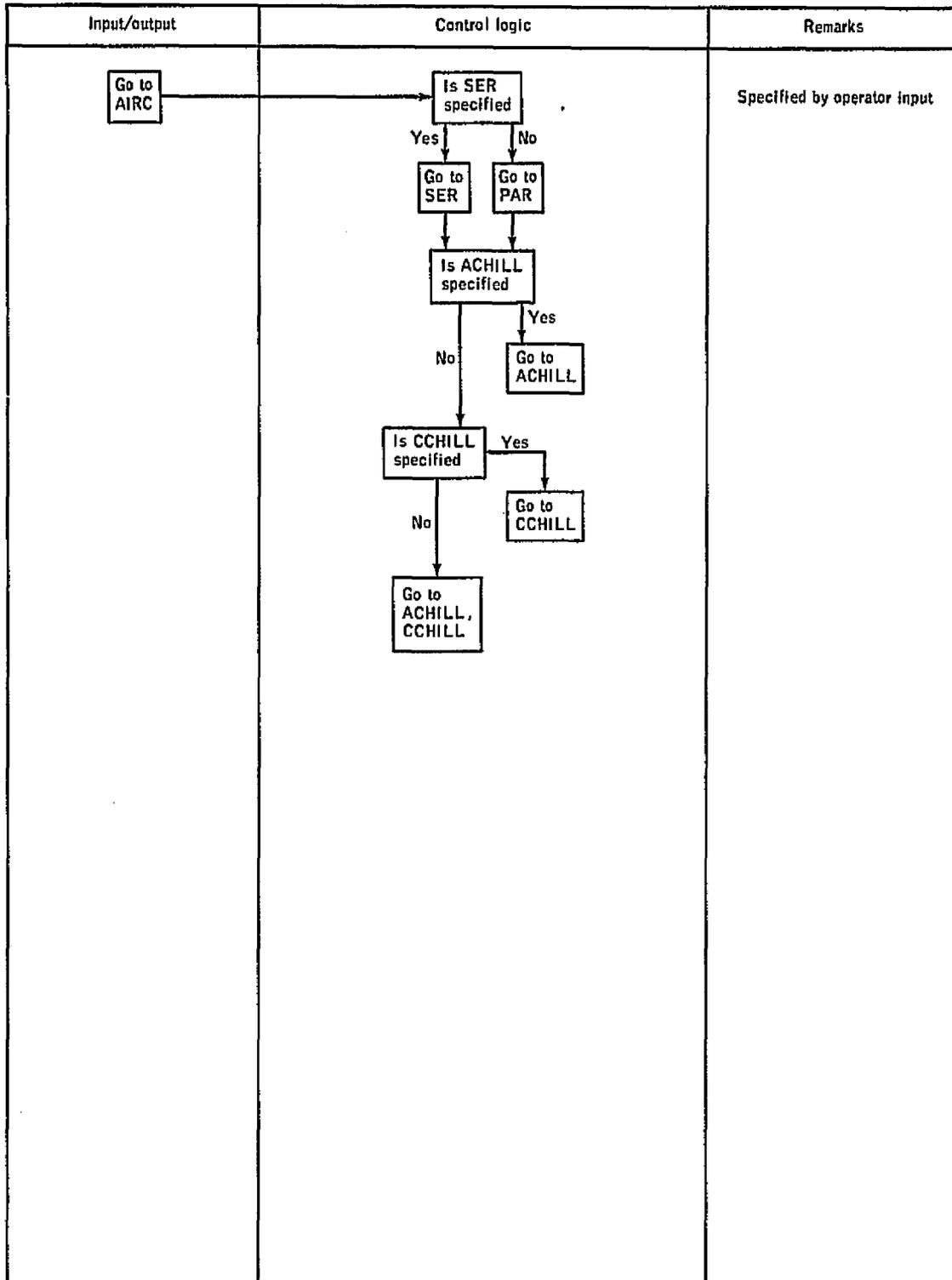


Figure C-55.- Logic diagram for AIRC mode.

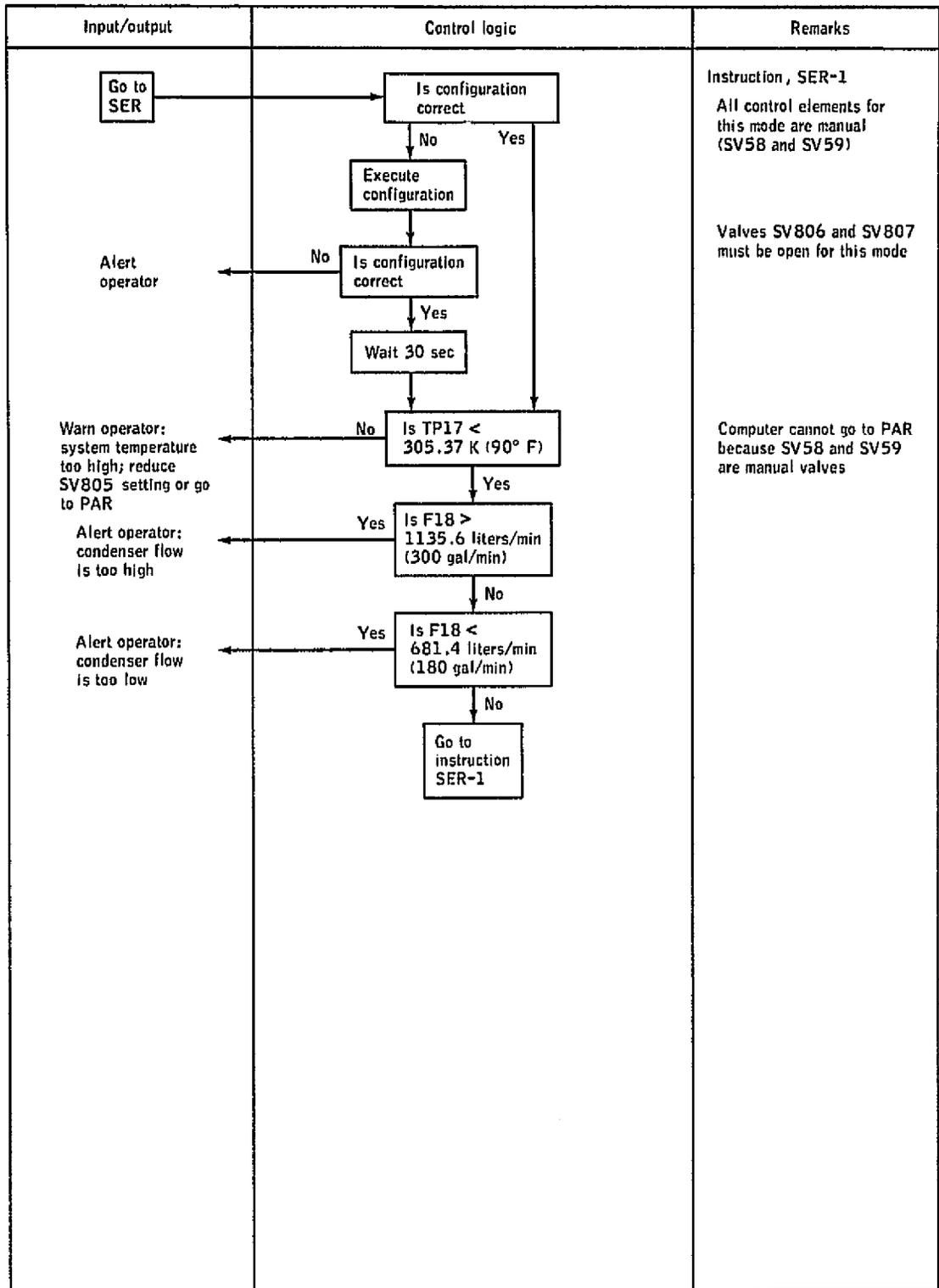
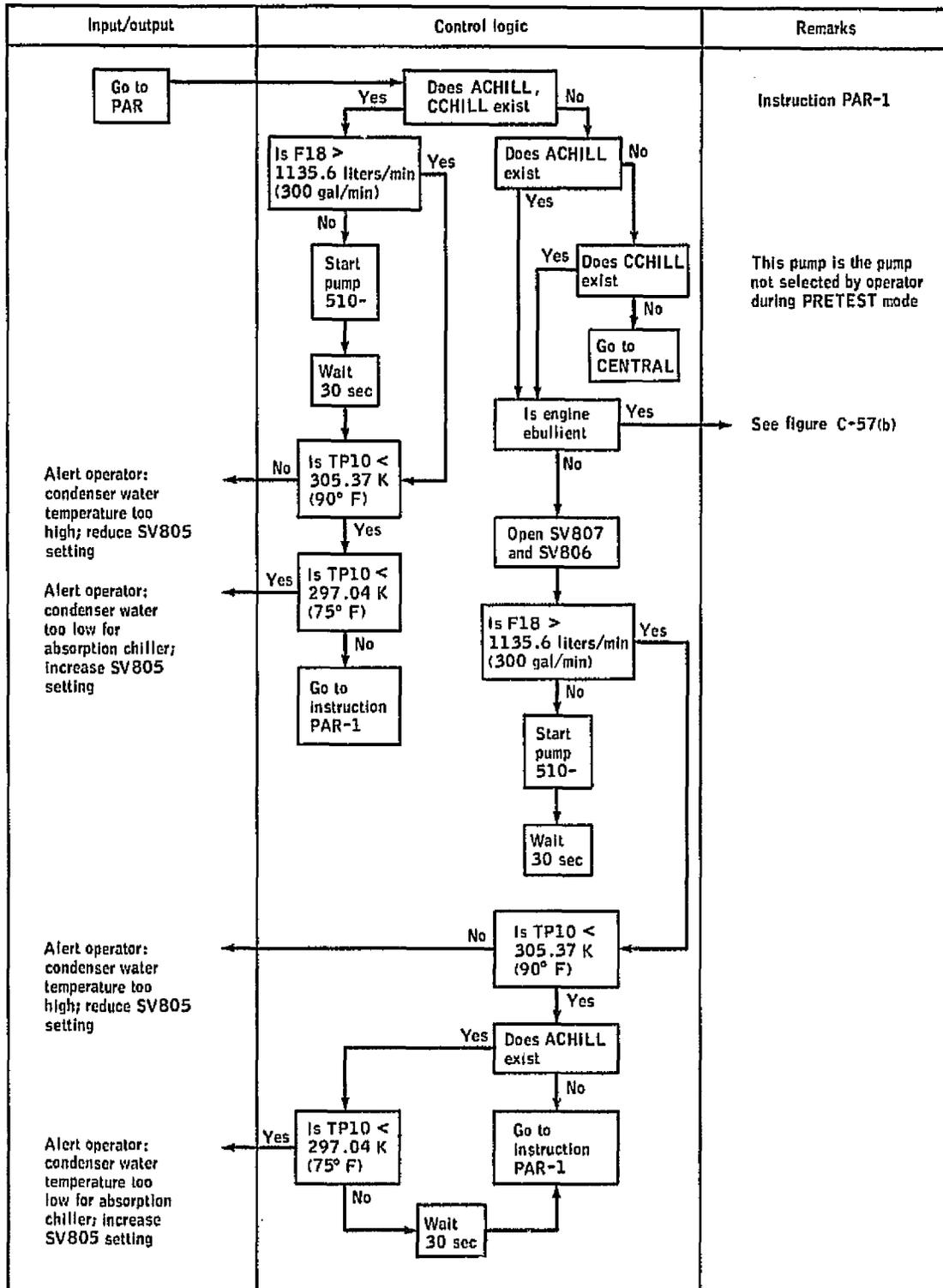
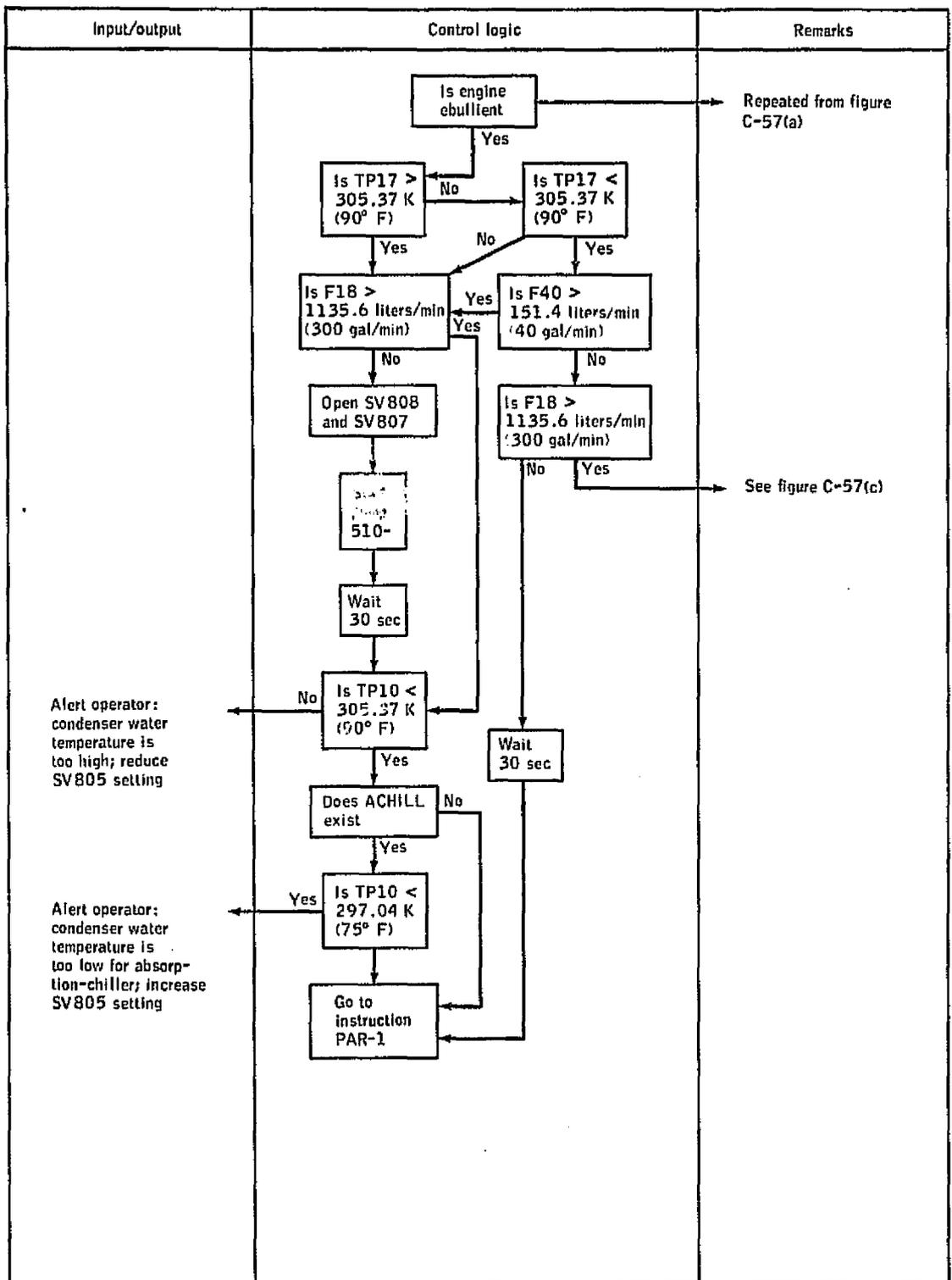


Figure C-56.- Logic diagram for SER mode.



(a) Beginning of diagram.

Figure C-57.- Logic diagram for PAR mode.



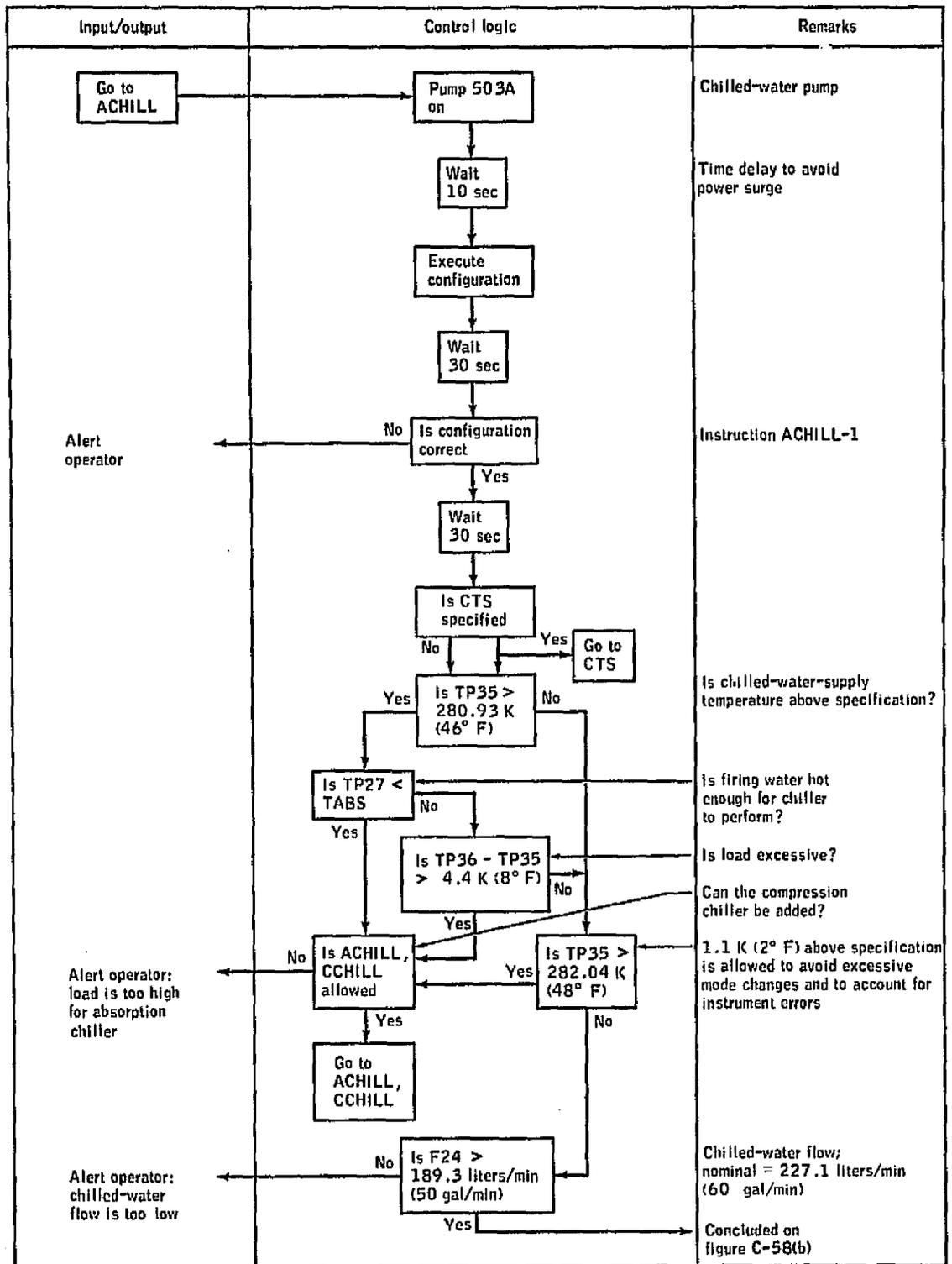
(b) Middle of diagram.

Figure C-57.- Continued.

Input/output	Control logic	Remarks
	<pre> graph TD     A[Is F18 &gt; 1135.6 liters/min (300 gal/min)] -- Yes --&gt; B["[(TP17 - TP10) (1.35) + TP10] &lt; 305.37 K (90° F)"]     A -- No --&gt; C[Go to instruction PAR-1]     B -- No --&gt; C     B -- Yes --&gt; D[Is F40 &lt; 151.4 liters/min (40 gal/min)]     D -- No --&gt; C     D -- Yes --&gt; E[Stop pump 510-]     E --&gt; F[Does ACHILL exist]     F -- Yes --&gt; G[Close SV807]     F -- No --&gt; H[Close SV808]     G --&gt; I[Wait 30 sec]     H --&gt; I     I --&gt; J[Go to instruction PAR-1]   </pre>	<p data-bbox="1041 384 1298 411">Repeated from figure C-57(b)</p> <p data-bbox="1086 705 1244 793">This pump is the pump not selected by operator during PRETEST mode</p>

(c) Conclusion of diagram.

Figure C-57.- Concluded.



(a) Beginning of diagram.

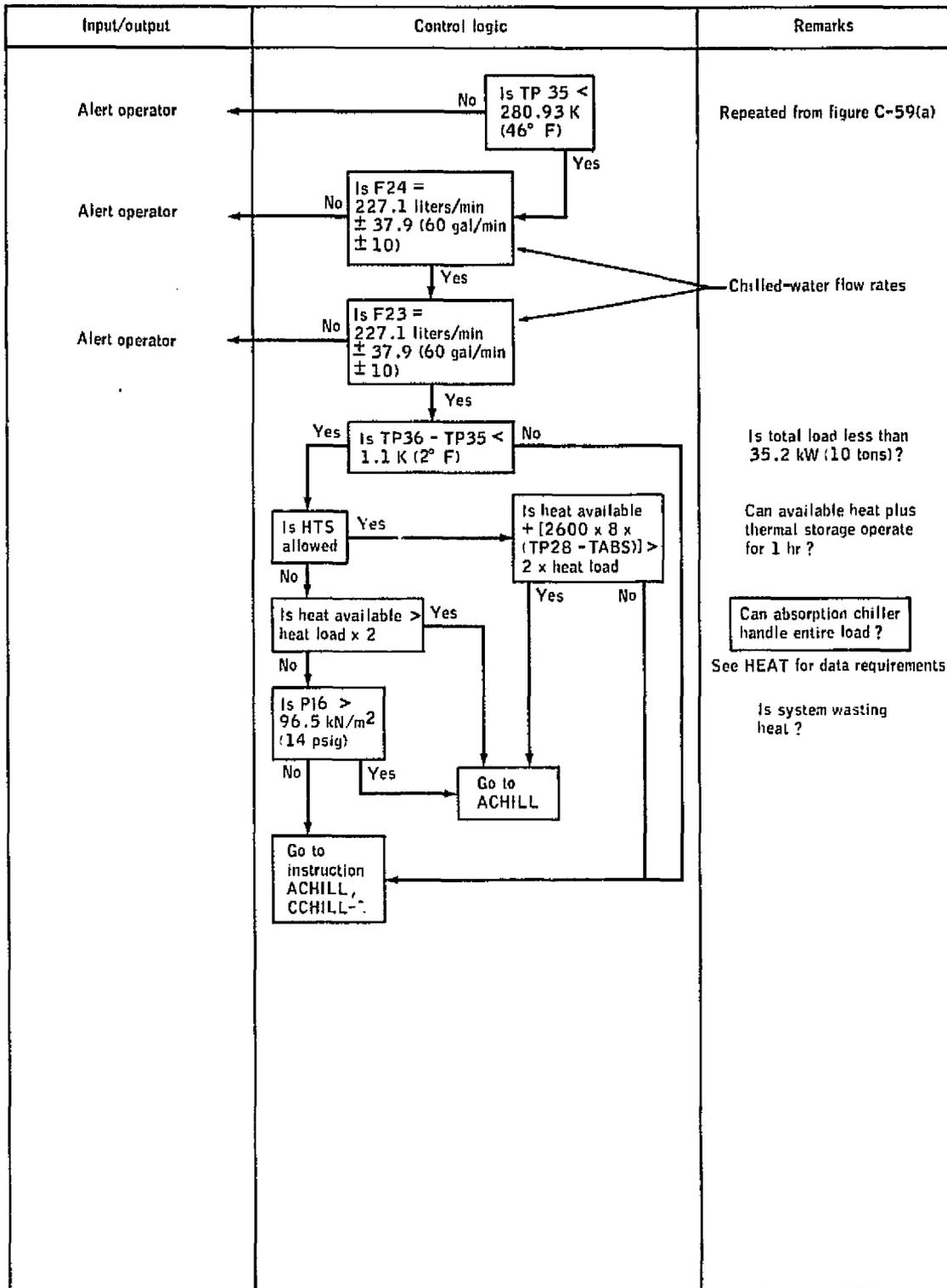
Figure C-58.- Logic diagram for ACHILL mode.

Input/output	Control logic	Remarks
<p>Alert operator</p> <p>Alert operator: chilled-water flow is too high</p>	<pre> graph TD     A[Is F24 &gt; 189.3 liters/min (50 gal/min)] -- No --&gt; AO1[Alert operator]     A -- Yes --&gt; B[Is F24 &lt; 265.0 liters/min (70 gal/min)]     B -- No --&gt; AO2[Alert operator: chilled-water flow is too high]     B -- Yes --&gt; C[Is TP36 - TP35 &lt; 0 K (0° F)]     C -- No --&gt; D[Go to instruction ACHILL-1]     C -- Yes --&gt; E[Go to CENTRAL]           </pre>	<p>Repeated from figure C-58(a)</p> <p>Is load zero?</p>

(b) Conclusion of diagram.

Figure C-58.- Concluded.





(b) Conclusion of diagram.

Figure C-59.- Concluded.

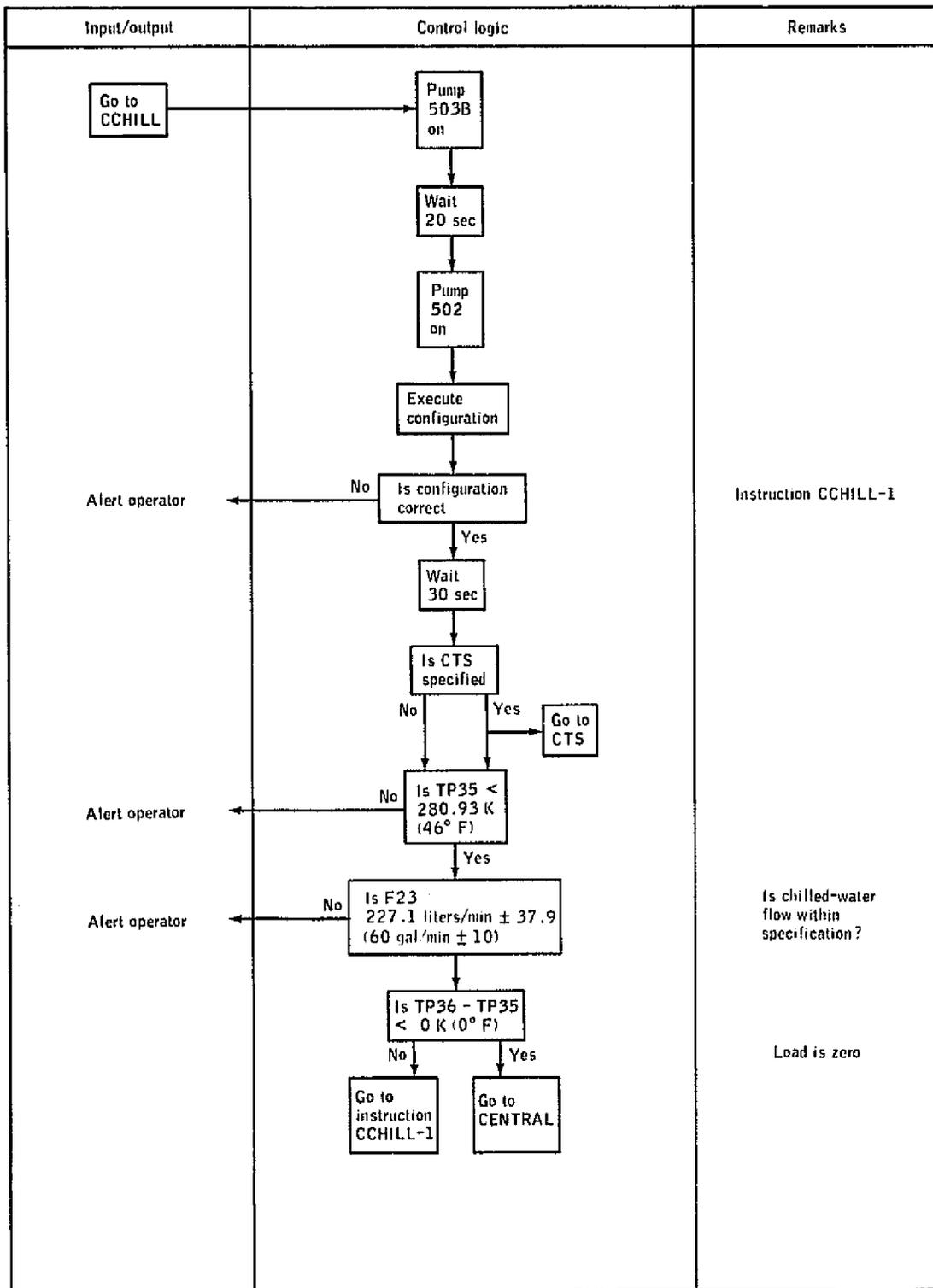
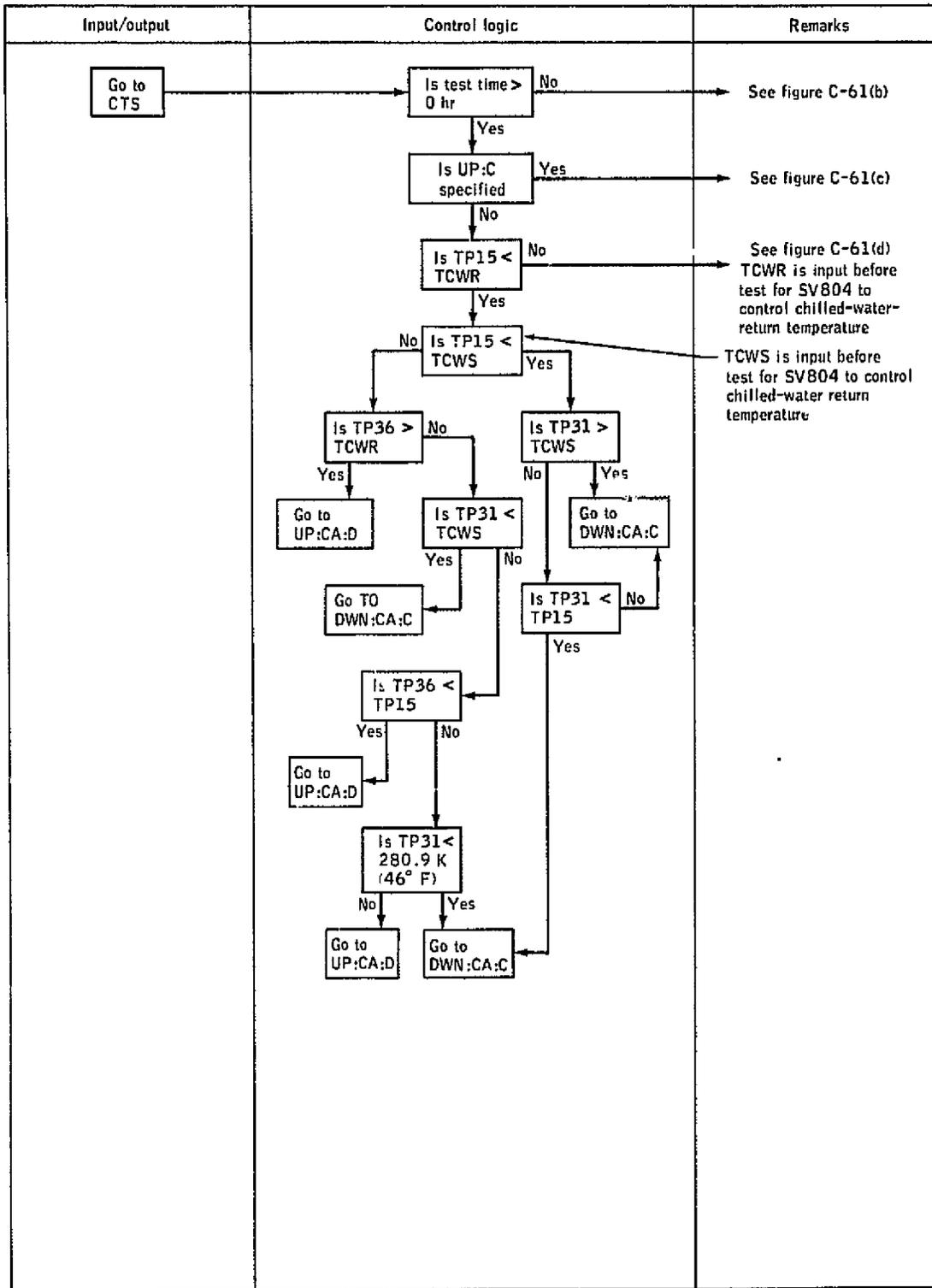


Figure C-60.-- Logic diagram for CCHILL mode.



(a) Beginning of diagram.

Figure C-61.- Logic diagram for CTS mode.

Input/output	Control logic	Remarks
<p data-bbox="386 879 566 989">Alert operator: cold-thermal-storage temperature too low; establish conditions manually</p>	<pre> graph TD     A[Is test time &gt; 0 hr] -- No --&gt; B[Is TP15 = TCTS ± 1.7 K (3° F)]     B -- Yes --&gt; C[Go to CENTRAL]     B -- No --&gt; D[Is TP15 &gt; TCTS]     D -- Yes --&gt; E[Go to DWN:CA:D]     D -- No --&gt; F[Alert operator: cold-thermal-storage temperature too low; establish conditions manually]   </pre>	<p data-bbox="1179 365 1305 411">Repeated from figure C-61(a)</p> <p data-bbox="1191 464 1367 527">TCTS is the desired temperature for CTS before test</p>

(b) Continuation of diagram.

Figure C-61.- Continued.

Input/output	Control logic	Remarks
	<pre> graph TD     A[Is UP:C specified] -- Yes --&gt; B[Is TP36 &gt; TCWR]     B -- Yes --&gt; C[Is TP15 &lt; TCWR]     B -- No --&gt; D[Is TP15 &lt; TCWR]     C -- Yes --&gt; E[Is TP36 &gt; TP15]     C -- No --&gt; F[ ]     E -- Yes --&gt; G[Go to UP:C:D]     E -- No --&gt; F     D -- No --&gt; F     D -- Yes --&gt; H[Is TP36 &lt; TP15]     H -- Yes --&gt; F     H -- No --&gt; I[Go to UP:C:D]     F --&gt; J[Go to UP:C:C]   </pre>	<p>Repeated from figure C-61(a)</p>

(c) Continuation of diagram.

Figure C-61.- Continued.

Input/output	Control logic	Remarks
	<pre> graph TD     A[Is TP15 &gt; TCWR] -- No --&gt; B[Is TP15 &lt; TP36]     B -- Yes --&gt; C[Is TP31 &lt; 280.93 K (46° F)]     B -- No --&gt; D[Go TO NOCTS]     C -- Yes --&gt; E[Go to UP:CA:C]     C -- No --&gt; F[Go to UP:CA:D]   </pre>	<p>Repeated from figure C-61(a)</p>

(d) Conclusion of diagram.

Figure C-61.- Concluded.

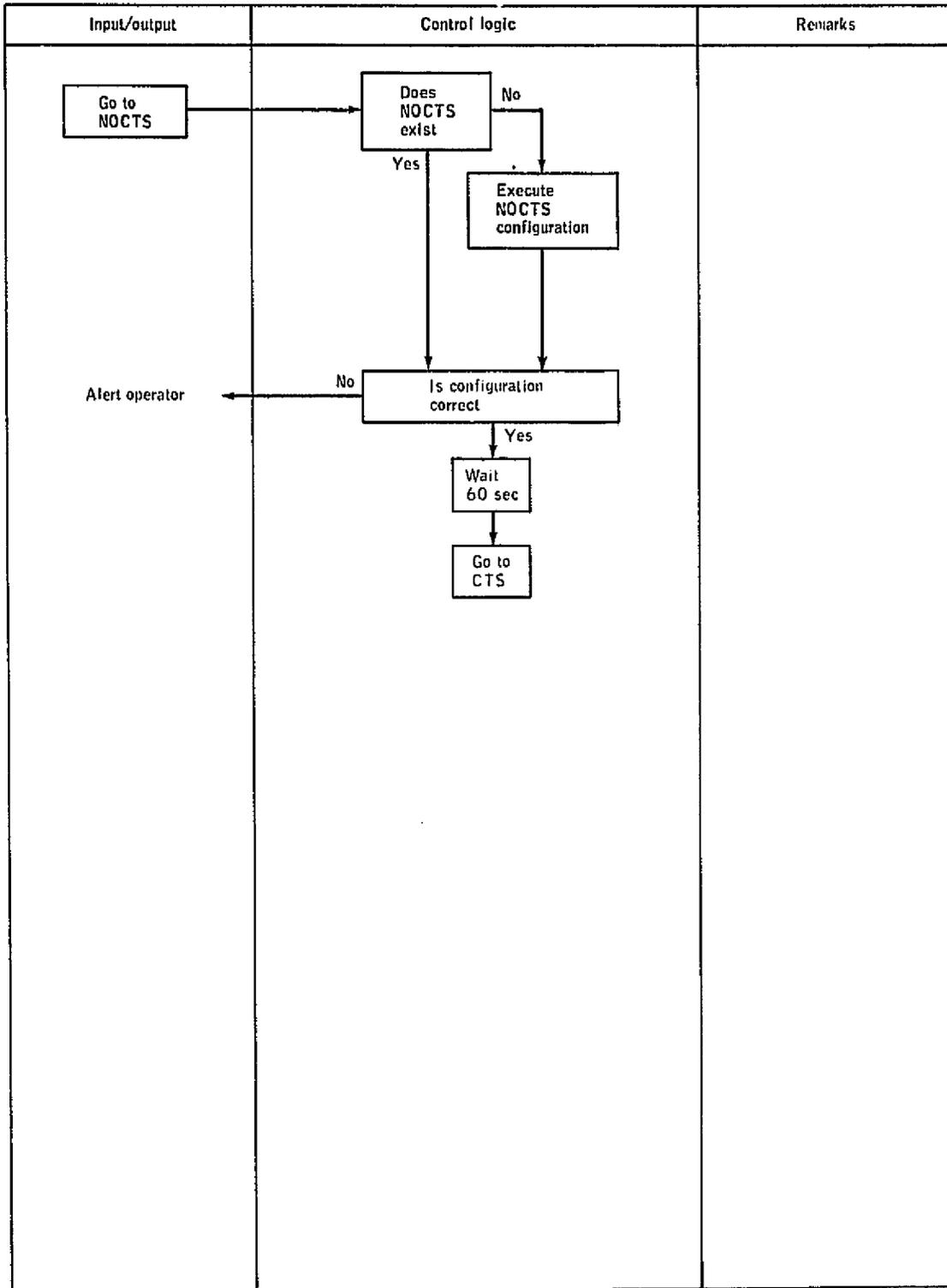
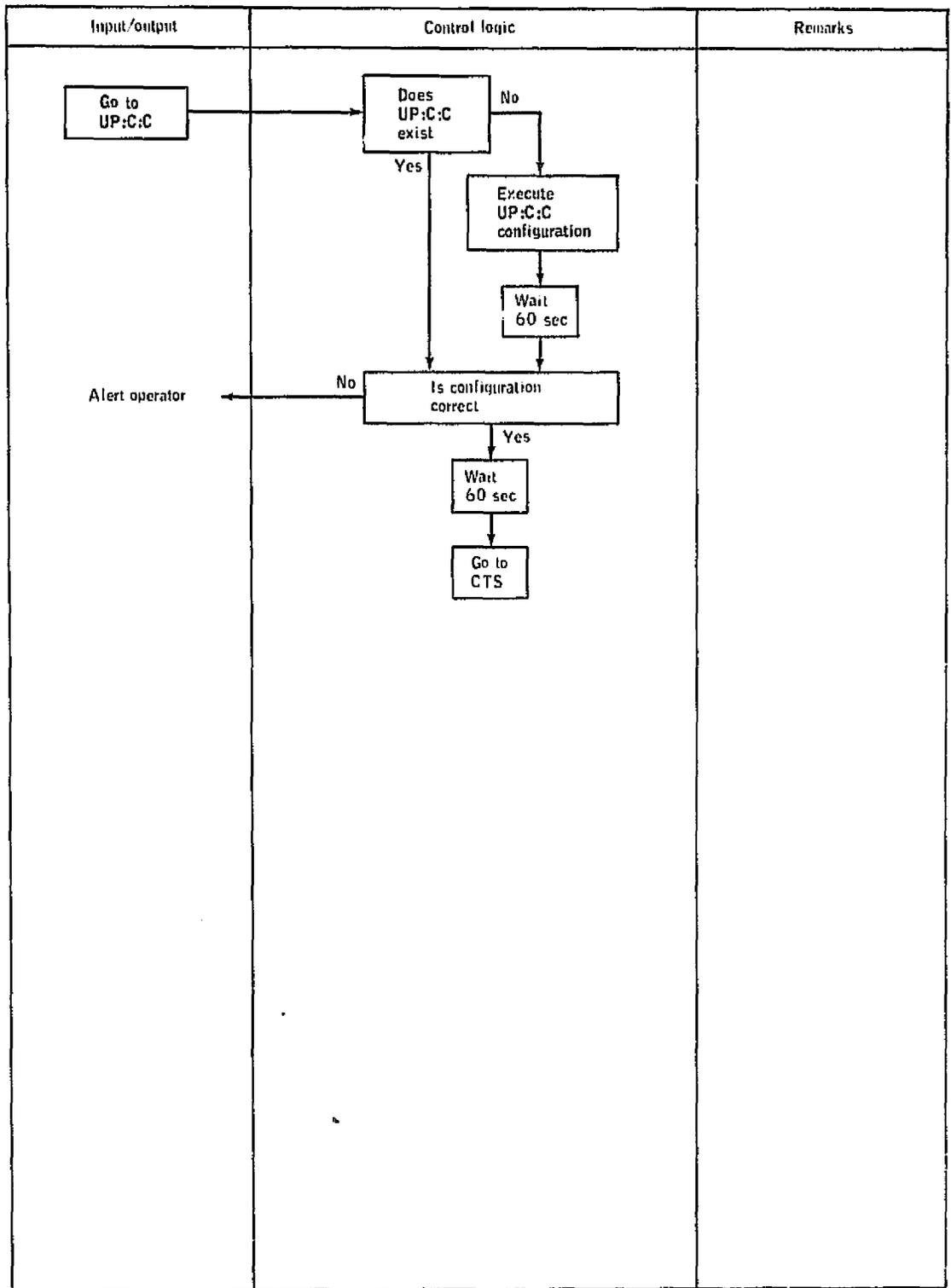


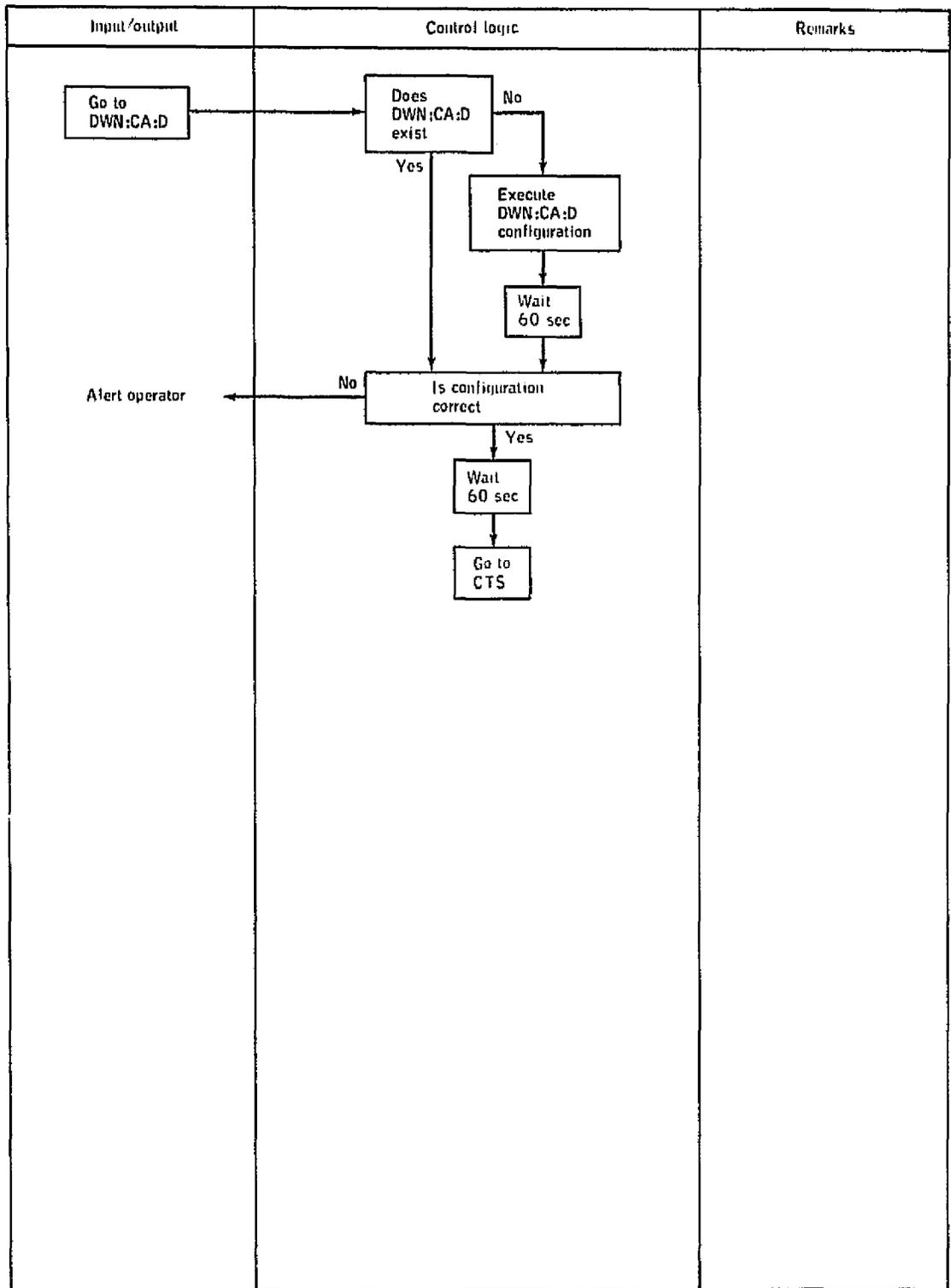
Figure C-62.- Logic diagram for NOCTS mode.



(a) Beginning of diagram.

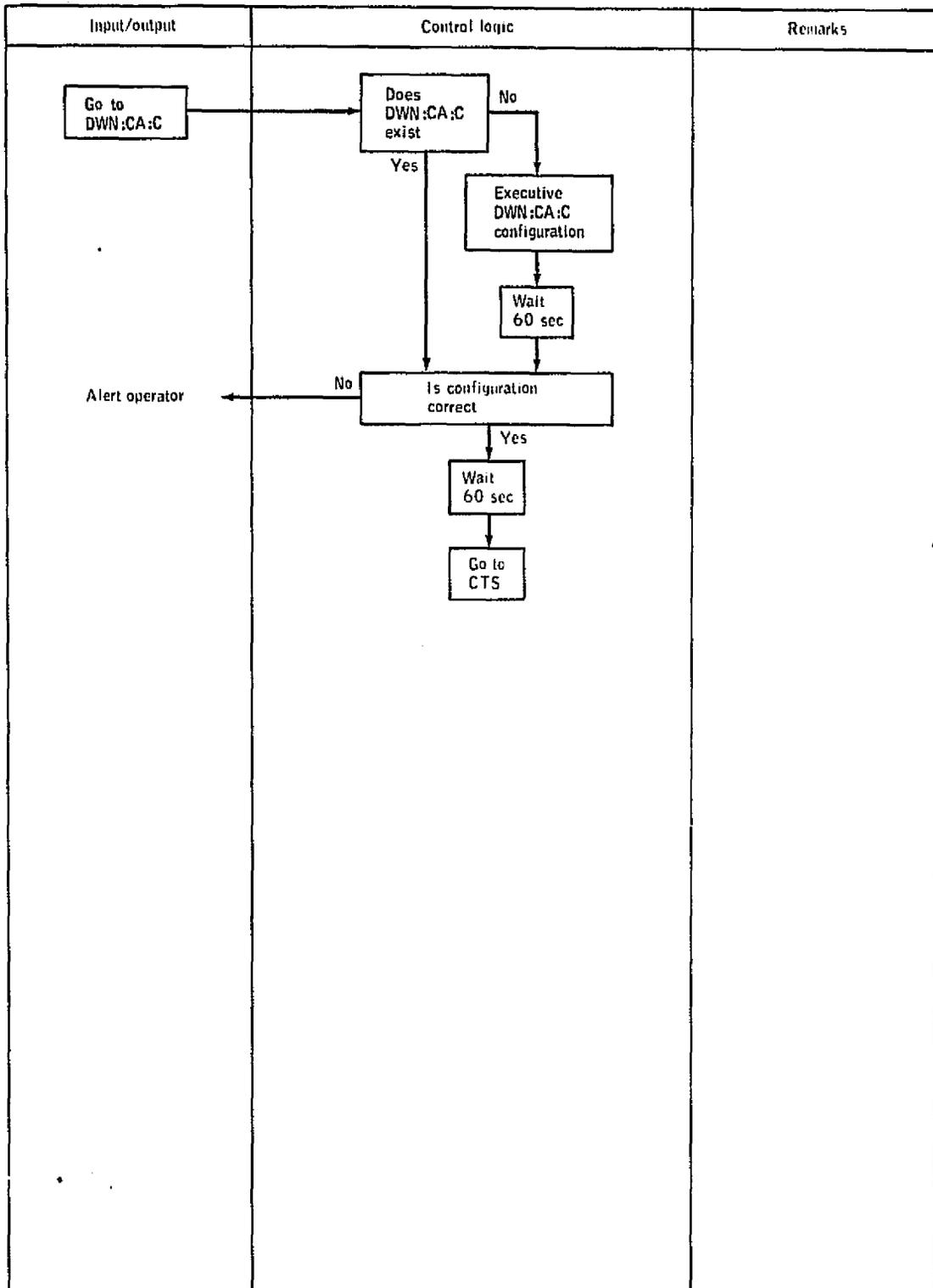
Figure C-63.- Logic diagram for UP:C:D mode.





(a) Beginning of diagram.

Figure C-64.- Logic diagram for DWN:C:D mode.



(b) Conclusion of diagram.

Figure C-64.- Concluded.

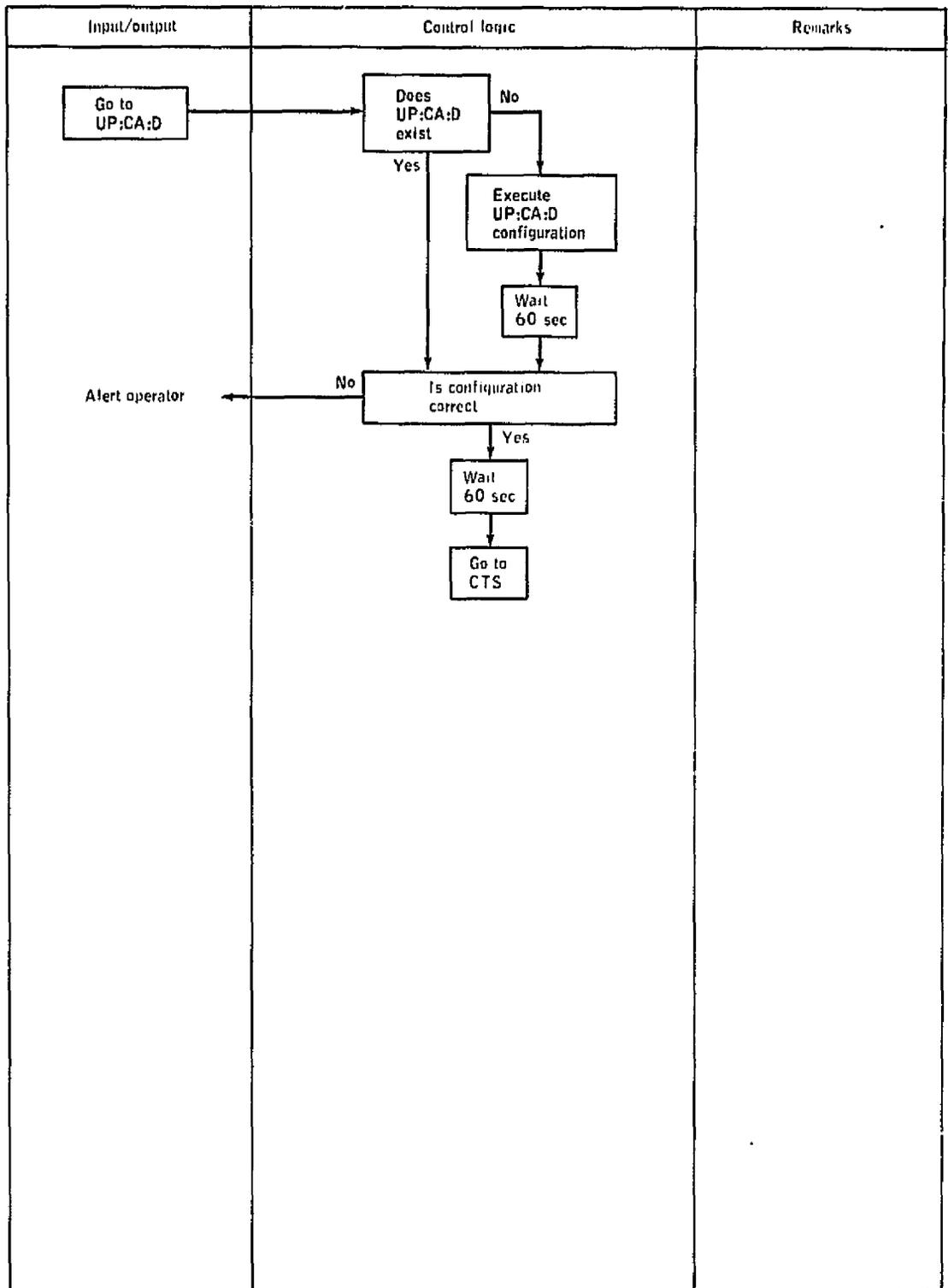


Figure C-65.- Logic diagram for DWN:CA:D mode.

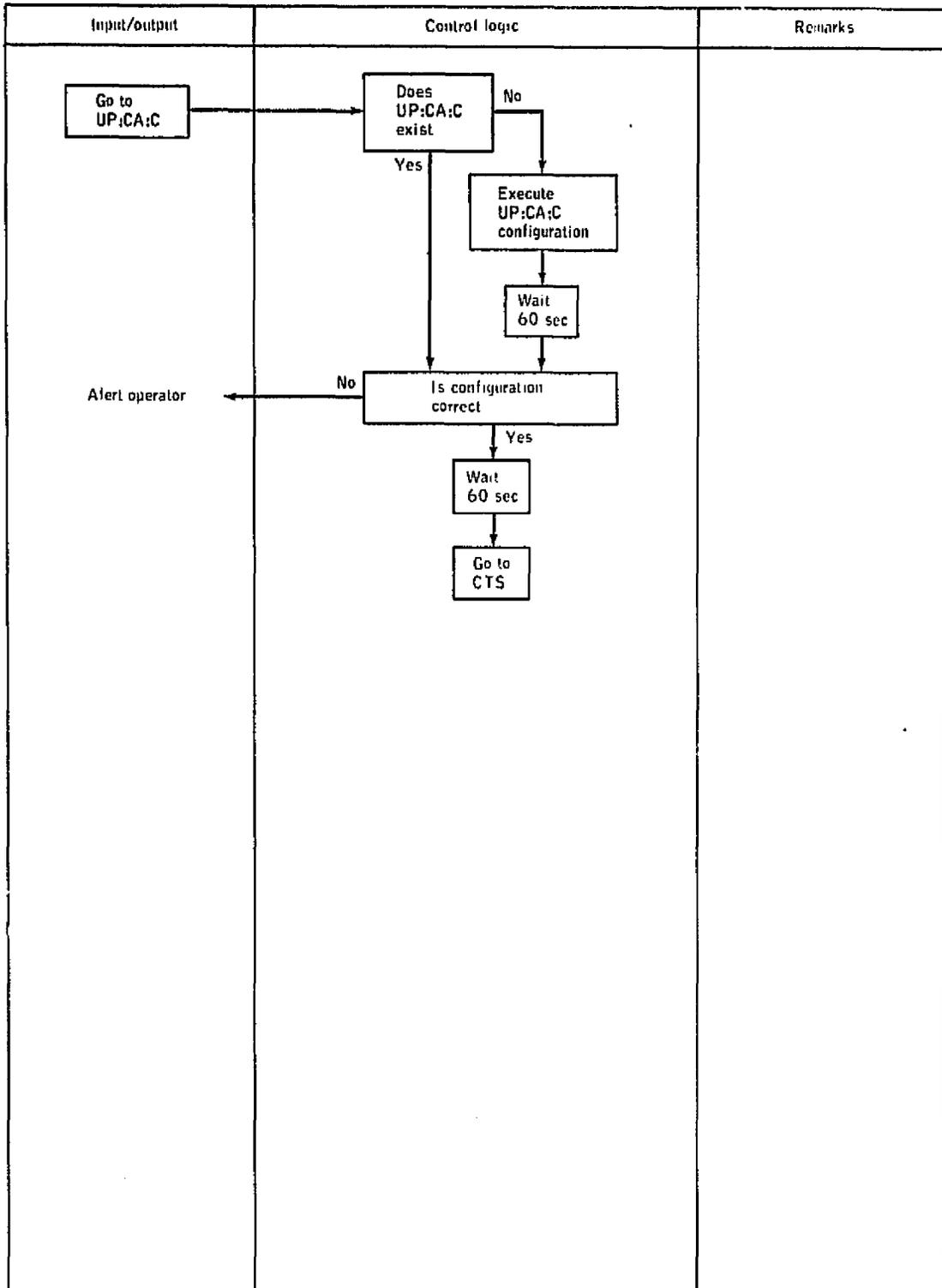


Figure C-66.- Logic diagram for UP:CA:C mode.