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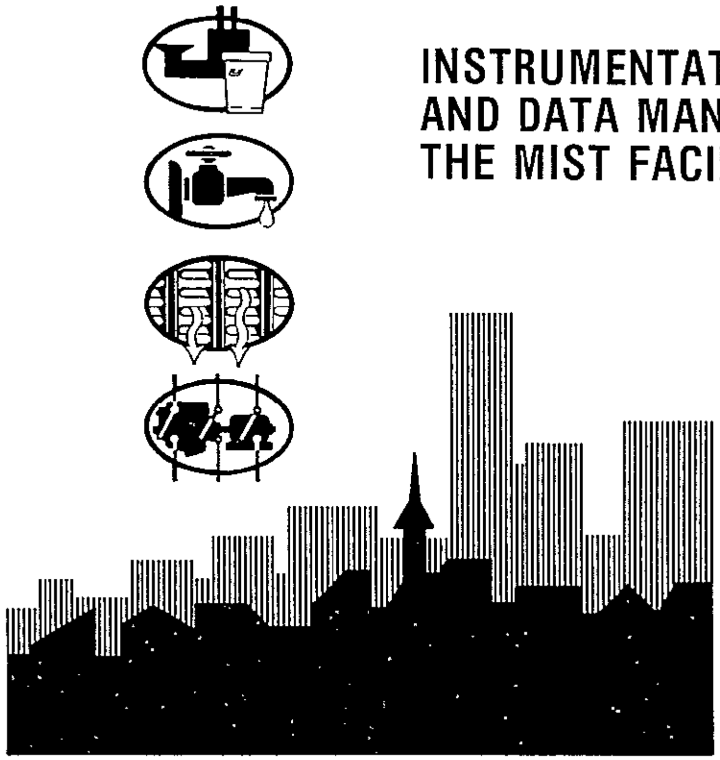
MODULAR INTEGRATED UTILITY SYSTEM

MIUS



INSTRUMENTATION, CONTROL AND DATA MANAGEMENT FOR THE MIST FACILITY

MIUS INTEGRATION AND SUBSYSTEM TEST

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Instrumentation, Control and Data Management for the MIST Facility

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1. PREFACE

The Department of Housing and Urban Development (HUD) is conducting the Modular Integrated Utility System (MIUS) Program, to integrate 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 to provide the utility services with reduced consumption of critical natural resources, protection of the environment, and minimized cost. The program goal is to encourage early acceptance of the integrated utility system concept.

Under HUD direction, several agencies are participating in the 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.

NASA has been a major participant in the MIUS program since the origin of the Urban Systems Program Office (USPO) in 1972. The NASA effort has been directed toward the MIUS Integration and Subsystem Test (MIST). The purpose of the MIST has been to evaluate overall performance benefits of various configurations of utilities integration concepts. The results of these tests have been adequately documented in the MIST Final Report (Reference 1) for the performance of subsystems and overall energy conservation and environmental benefits.

Budget constraints during the early stages of the MIST program, however, necessitated a compromise from a fully automated instrumentation, controls and data system to the minimum required for manual operation. Provisions were made in the initial design, however, for upgrading this instrumentation, control and data subsystem at a future date. Testing of the MIST has demonstrated its technical value to the overall MIUS program, but the limitations of manual data gathering, reduction and control imposed a severe limitation for effective utilization. As a result, the MIST has been retrofitted with complete instrumentation and automated data gathering and control. This system has proven itself efficient, convenient, and reliable in providing data for evaluation of subsystems and systems performance in MIST testing to date.

Because of the basic features of the MIST data system and because it is comprised of commercially available equipment, the data system and the methodology of its implementation are directly applicable to other facilities where system evaluation is required. The conventional instrumentation interfaces readily with remote data gathering units and the data system's monitoring, alarm, display, recording, and logging functions to satisfy the needs for complete performance analysis. Reference 2 provides a complete technical description of the data system as installed. It is the purpose of this document to record the methodology by which the successful implementation was accomplished; to emphasize the requirement to include a thorough instrumentation and control task early in the system design stages; and to suggest the means by which such an installation could be duplicated.

2. BACKGROUND

In 1972, the National Aeronautics and Space Administration (NASA) Lyndon B. Johnson Space Center (JSC) assembled the Urban Systems Program Office (USPO) to pursue the design of an integrated utilities system. The purpose of this effort was to determine the overall efficiency of an integrated system where the waste product or energy of one utility function serves 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).

The initial engineering design studies, prepared during the first year of effort, indicated that favorable results could be obtained within the technical design constraint imposed by HUD that equipment should be limited to commercially available hardware. This 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".

With this ground rule and the results of the initial engineering design studies, Hamilton Standard, Division of United Technologies Corporation was contracted for the design and demonstration of a test article in which various configurations of utilities concepts could be integrated and tested. The design of the MIUS test article incorporated several utility subsystems, which included the functions of heating, cooling, electrical power, liquid-waste processing (sewage), a 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. As budget constraints and the costs of hardware and integration of various subsystems became evident, however, it was decided that the initial MIST should include instrumentation for manual operation and control of the test article. These instruments were to 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 further decided that additional 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 six months. For automation of process control and monitoring functions in petrochemical and similar industries a five to ten year payback through manpower cost savings is normally allowed. The six months of equivalent manpower costs savings for the MIST testing would not offset costs of the fully automated system. Therefore, the plant was designed and built for manual operation with the only automatic operation being accomplished by local devices selected to control functions such as heating water maximum temperature and cooling water minimum temperature (automatic mixing valves) and steam line maximum pressure (automatic dump valve).

A primary objective of the MIUS program was the task of evaluating overall performance of the project. Beyond operation and control, this evaluation involved the determination of system integration efficiencies related to thermal and energy conservation. During the plant design phase particular attention was paid to determining the proper instrumentation and locations to provide data feedback for complete performance evaluation and a fully automated system which made a subsequent retrofit feasible. Instruments were procured and installed in the various subsystems to meet the requirements for the initial test article. These instruments were standard, commercially available process control and monitoring equipment, and provided instrumentation output data for flows, temperatures, pressures, and levels. Sensors were installed throughout the system such that the information provided would indicate the energy distribution throughout the plant.

An automatic data acquisition and tape recording device was made available by the government. Processing of the tape was required for post test analysis, but significant cost savings were made in the reduced quantity of individual readout equipment.

Early testing exposed several problems with the use of the data acquisition system. In addition to failures of the data-recording device, the tape processing and distribution of reduced data to the test engineers characteristically took one to two weeks. Failed sensors and the resultant lost data went unnoticed during that time. The number of test conditions which had to be repeated due to data system malfunctions and failed sensors during the initial six weeks of the test program made it evident that a reliable direct reading data acquisition recording and monitoring device was required to evaluate the MIUS concept.

3. METHODOLOGY

The engineering process which defined the original instrumentation, controls and data system was the key factor which made subsequent automation feasible. This basic process began in the early MIST definition stages and may be characterized as shown in Figure 1. Although the exact details of this procedure may be varied in any MIUS definition phase, it is essential to establish the instrumentation and controls requirements and define the equipment prior to the preparation of system layout and construction drawings. Failure to do this will lead to unsatisfactory compromise in the instrumentation at a later time.

Definition of Control and Evaluation Requirements

A critical step necessary for the successful operation and evaluation of the MIST or any MIUS installation is a thorough system level analysis of the proposed installation that must be performed at the start of the design effort.

Virtually all of the functions performed by the system require some sort of automatic control to regulate the operation of the function, and feedback of operational data to evaluate the level of performance. In order to accomplish this, it is necessary to project all anticipated parameters of interest together with the projected sensitivity of each measurement.

In many cases, two or more indirect parametric measurements and associated computations are required to produce the intelligence to control and/or evaluate the function under consideration. Further, a practical means of sensing the parameter must be identified and the sensor output form (analog voltage, electrical resistance, digital, pulse count, etc.) determined. Signal conditioning equipment must be selected to convert the signal to an acceptable form. Since most of the evaluation is conducted at the subsystem and system level, and the parametric measurements are made at the component level, an error analysis must be performed to determine the sensitivity of the anticipated control function to the accuracy of each measurement. Substantial error buildup may occur in signal transfers or small differences between large numbers may lead to unacceptable errors in certain parameters.

An example of this may be a heat load calculated by a delta temperature reading and a fluid flow rate reading. Commercially available process equipment for temperature measurement typically has a quoted accuracy of $\pm$ 2°F or $\pm$ 3°F at the conditioned signal. The computation of thermal load based on a delta T measurement may have a 10% error due to the accuracy of the delta temperature reading alone for a typical delta of 30F°. This error is then compounded by the error in the flowmeter signal and the thermal load computation device.

Sensor Location

Integral with the successful control and evaluation of a system is the task of physical location of the sensor required for measuring the various parameters

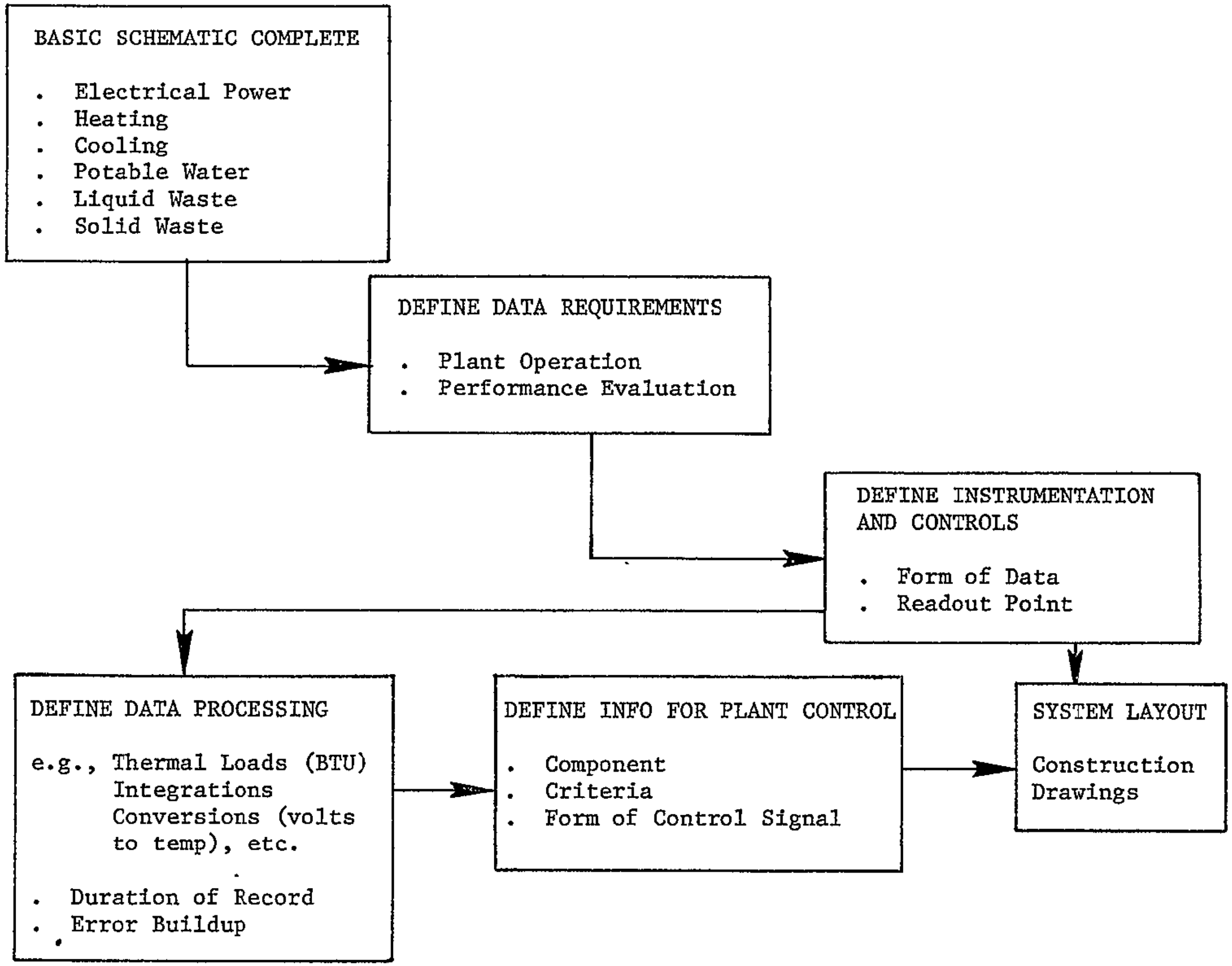


FIGURE 1. PROCEDURE FOR ESTABLISHING MIST INSTRUMENTATION AND CONTROLS

of interest. No matter how comprehensive the system level analysis and design, the installation cannot operate properly if the sensors provide inaccurate and/or improperly phased data.

Numerous problems in system operation arise from mislocated sensors. For example, the mislocation of a temperature sensor used to control a water temperature resulting from the automatic mixing of hot and cold water supplies can result in erroneous readings if the sensor is located too near the mixing point of the hot and cold supplied, and can result in control instabilities if the sensor is located too far from the mixing point. Further, annubar flow meters must be located in lines that have the prescribed minimum straight sections upstream and downstream of the sensor to insure accurate readings. Sensors for numerous other parameters exhibit similar location problems. Additionally, the output signal from may sensors is a low level voltage, requiring isolation of these signal lines from power lines to prevent induction of faulty signals.

It becomes obvious from the extreme criticality of sensor location that the instrumentation design must be accomplished in parallel with the system layout design.

4. MIST IMPLEMENTATION

The considerations outlined in Section 3 along with the definition of required form of the data, the acceptable degree of automation and location of readout were performed for the MIST system. The results are illustrated in the requirements document reproduced in the appendix. This document transmitted the logic and all necessary information required to define a computerized data management and control system described in Reference 2 which was retrofit to the MIST system. As stated earlier in this report, the MIST was originally built without the computerized data system. The equivalent steps were taken in the original definition stage, but on a less formal basis and without a separate requirements document. The fact that the equivalent steps were taken during the original definition stage made the adequate automation by retrofit possible without substantial rebuild of the MIST system.

The appendix reflects the preliminary systems evaluation tasks which must be performed prior to the preparation of construction drawings or the definition of a data management system necessary for plant control and performance evaluation.

REFERENCES

1. "MIST Facility Final Report", USPO 5274, June 1974.

2. "MIUS Integration and Subsystem Test (MIST) Data System", NASA Technical Memorandum X-58201, April 1977.

APPENDIX

REQUIREMENTS DOCUMENT, MIST CONTROLS SUBSYSTEM

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 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 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 II and III, which are extensions of Table 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 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 (figure 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° of 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 diaphram 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 (figure 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 (figure 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 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 (figure 5) and includes a 5.1-centimeter (2-inch three-way diaphram-operated diverter valve, an air-filter regulator, switches, and valve-position indicator lights.

The computer interface definition is shown in figure 6.

Cooling-tower-temperature control - The cooling-tower-temperature control is shown schematically in figure 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 (figure 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 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 (figures 9 and 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 (figures11 and 12).

Chilled-water-temperature control - The chilled-water-temperature controller, SV804, shown schematically in figure 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 (figure 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 (figure 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 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 (figures 16 to 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 (figures 19 to 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. Chiller-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 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 (figures 23 to 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 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 32. The computer input and output for the remaining valves are defined in the interface definition attached to the specific control system description (figure 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 34 to 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 present 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 set-points, 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 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 (figure 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 (figure 40).

Power simulator control - The power simulator control, shown schematically in figure 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 programing 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 (figure 42).

Heating-load-simulator control - The heating-load-simulator control is shown schematically in figure 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 (figure 44).

Boiler water temperature control - The boiler water temperature control is shown schematically in figure 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 (figure 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 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 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) 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 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 from 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 of 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 (figure 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 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 (figure 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/after-cooler (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 (figure 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^2 (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 to 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 (figure 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 K ± 5.55 (150°F ± 10°), the operator will be alerted. This mode also directs the use of hot thermal storage if it is allowed (figure 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 (figure 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 (figure 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-conditioned system. The control logic diagram (figure 55) directs the control system to the proper operating mode.

SER Mode

The SER operating mode originates only from operator input (figure 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 (figure 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) (figure 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 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 (figure 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 (figure 61).

The control logic illustrated in figures 62 to 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 (figures 62 to 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 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 Closed	—	71 72	On On
SV8	Facility water outlet valve	Monitor	Cooling Facility	—	83 84	On On
SV58	Combined-chiller outlet valve	Monitor	Series Parallel	— —	85 86	On On
SV59	Oil/A-C interchanger inlet valve	Monitor	Series Parallel	—	87 88	On On
SV11	Facility water inlet valve	Monitor	Cooling Facility	—	89 90	On On
S013	Potable-water shutoff valve	Monitor	Open Closed	—	92 93	On On
S026	Compression chiller outlet shutoff valve	Monitor	Open Closed	—	124 125	On On
S029	Compression chiller bypass valve	Monitor	Open Closed	—	126 127	On On
SV30	Heating-mode-selector valve	Monitor	Primary Auxiliary	—	117 123	On On
S056	Facility heat exchanger steam shutoff valve	Monitor	Open Closed	—	76 77	On On
SV801	Hot-thermal-storage diverter valve	Control	Normal Storage	Pulse	3 4	On On
SV802	Heating-water-temperature control	Control	—	Pulse train	(a)	
SV804	Chilled-water-temperature control	Control	Direct acting Indirect acting Override Normal	Pulse Pulse Pulse Pulse train	(b) 137	On
SV806	Absorption-chiller firing-water control	Control	Chilling Heating	Pulse	201 200	On On
SV807	Shutoff valve, compression chiller condenser	Control	Open Closed	Pulse	202 203	On On
SV806	Shutoff valve, absorption chiller condenser	Control	Open Closed	Pulse	204 205	On On

[a]Control interface defined in subsection "Heating-Water-Temperature Control."
[b]Control interface defined in subsection "Chilled-Water-Temperature Control."

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

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

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

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

TABLE 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 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 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 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	NOHTS	NOCTS	UP:C:C	UP:C:D	UP:CA·C	UP:CA:D	DWN:CA.C	DWN:CA:D
SO1[a]	Open																		
	Closed																		
SV8[b]	Cooling	X																	
	Facility																		
SV58	Series					X													
	Parallel	X					X			X									
SV59	Series					X													
	Parallel	X					X			X									
SV11[b]	Cooling	X																	
	Facility																		
SO13	Open				X														
	Closed																		
SO26	Open	X							X	X									
	Closed																		
SO29	Open																		
	Closed	X							X	X									
SV30[c]	Primary					X													
	Auxiliary																		
SO56	Open			X	X			X		X	X								
	Closed	X																	

[a]The required position of this valve is an operator input depending on whether or not the incinerator is to be operated.

[b]For computer operation, "COOLING" is the only allowable position.

[c]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 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	X										X							
	Storage										X								
SV802[d,e]	Tabs							X		X									
	Temperature for heating	X																	
SV804[f]	Direct acting	X													X		X		X
	Indirect acting													X		X		X	
	Override	X											X						
	Temperature of cold water return													X	X	X	X		
	Temperature of cold water supply																	X	X
SV806[d]	Chilling							X		X									
	Heating	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

[d]The required position of this control element is determined by the computer and depends upon the functions being performed.

[e]SV802 is for temperature control of hot water.

[f]SV804 is for temperature control of cold water.

TABLE 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[g]	On									X									
	Off	X																	
510B[g]	On									X									
	Off	X																	
514A	On										X								
	Off	X										X							
514B	On			X				X		X									
	Off	X																	

[g]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.

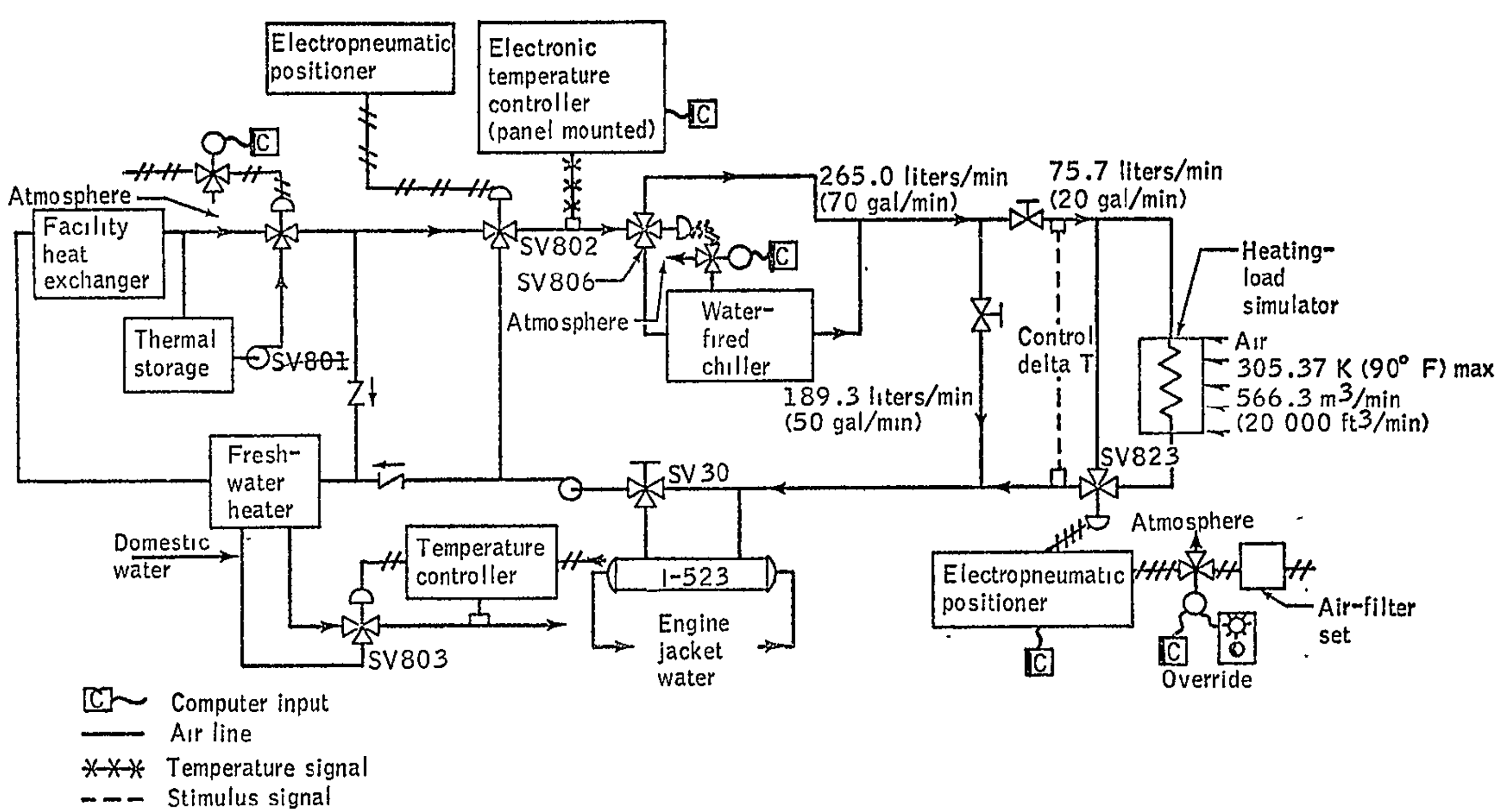
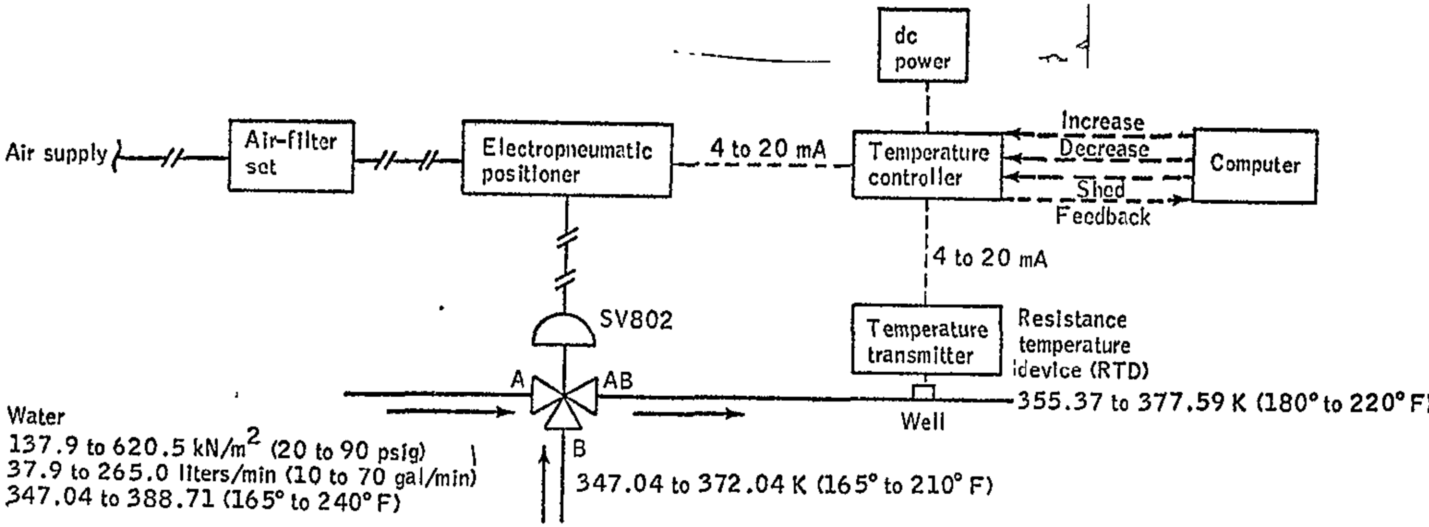


Figure 1. Controls for chiller-firing water, domestic water temperature, heating-load simulator, and heating-water temperature



Equipment List

1. Electropneumatic positioner withe gages and field installation kit
   Input, 4 to 20 mA
   Output, air signal

2. Air-filter set

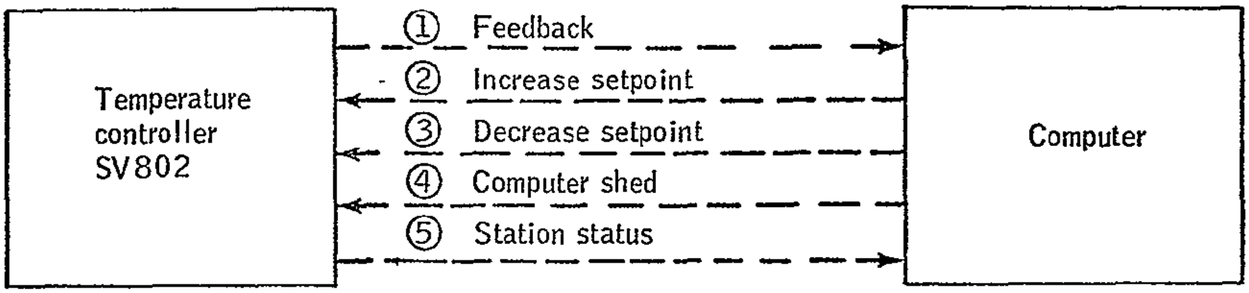
3. Electronic temperature controller
   Proportional band; range, 310.93 to 388.71 K (100° to 240° F)
   Automatic reset; setpoint, 355.37 to 377.59 K (180° to 220° F)
   Reverse/direct acting
   Input/output, 4 to 20 mA
   Computer
      5 Vdc, 3-msec pulse train, increase setpoint
      5 Vdc, 3-msec 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

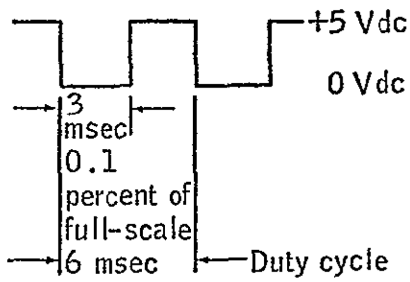
6. Power supply, 24 Vdc (for each electronic 1-A controller)

Figure 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



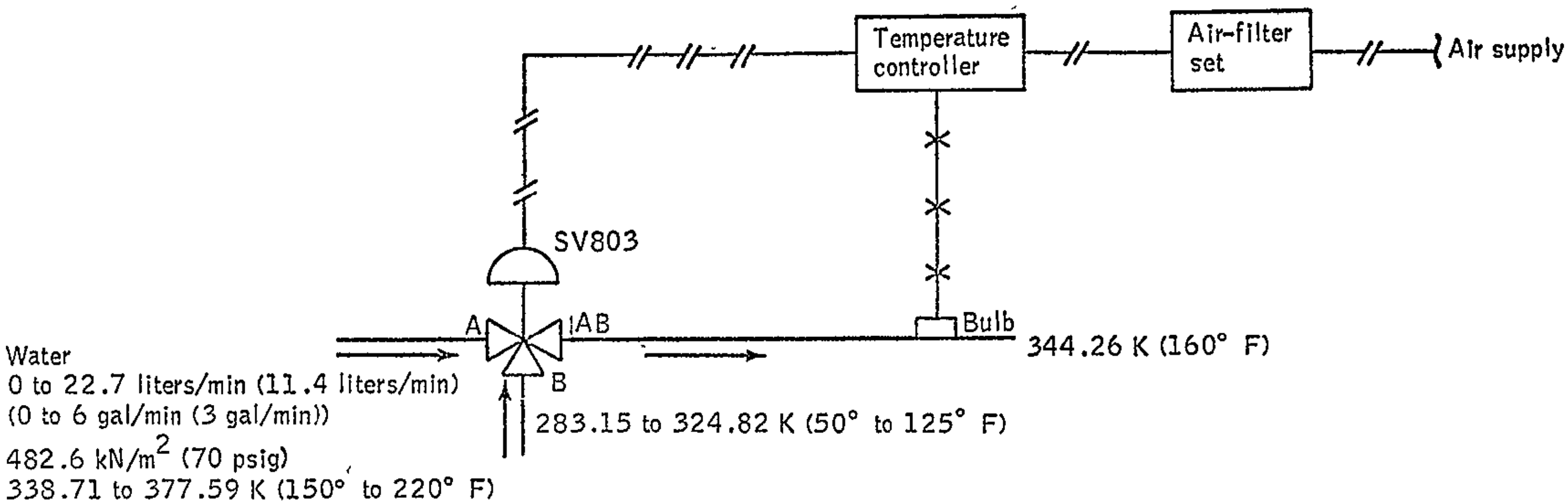
Contact closure to ground = 0 Vdc

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



Equipment List

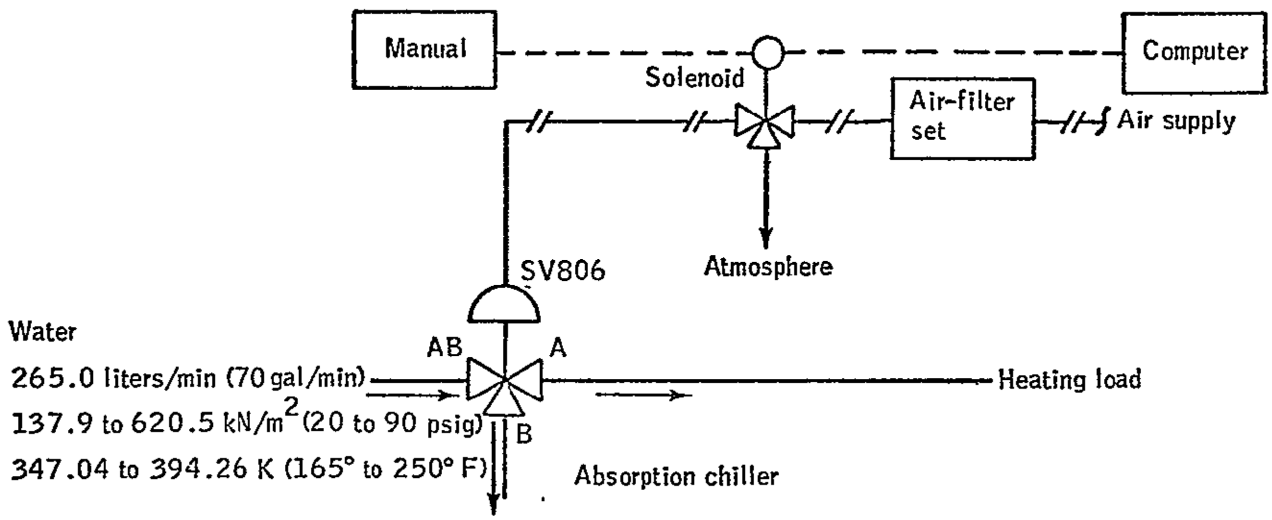
1. SV803 - mixing valve, diaphragm actuator
   1.3-cm (0.5 in.) three-way valve
   Stainless steel trim
   Cast-iron screw connections 861.8 kN/m^2 (125 psig) American Standards Association (ASA)
   Air-failure port, A, closed
   Direct acting
   Teflon/asbestos packing

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^2 (3 to 15 psig)

4. Well for above bulb

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



Equipment List

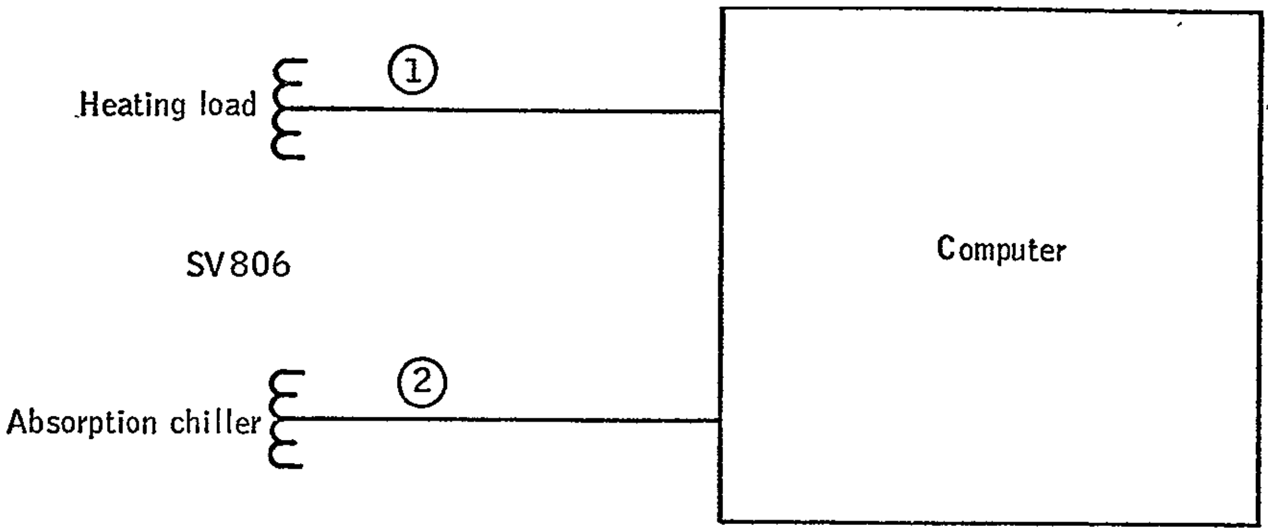
1. SV806 - diverter valve, diaphragm operator
   5.1-cm (2 in.) three-way valve
   Stainless steel trim
   Carbon steel flanged connections, 1034.2 kN/m^2 (150 psig) ANSI
   Teflon/asbestos packing connections
   Air-failure port, B, closed
   Reverse acting
   Latching solenoid, 110 Vac
   Microswitch (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 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

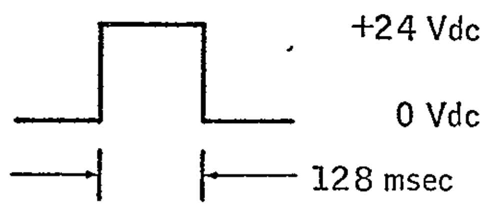


Figure 6. Interface definition for absorption-chiller-firing-water control SV806

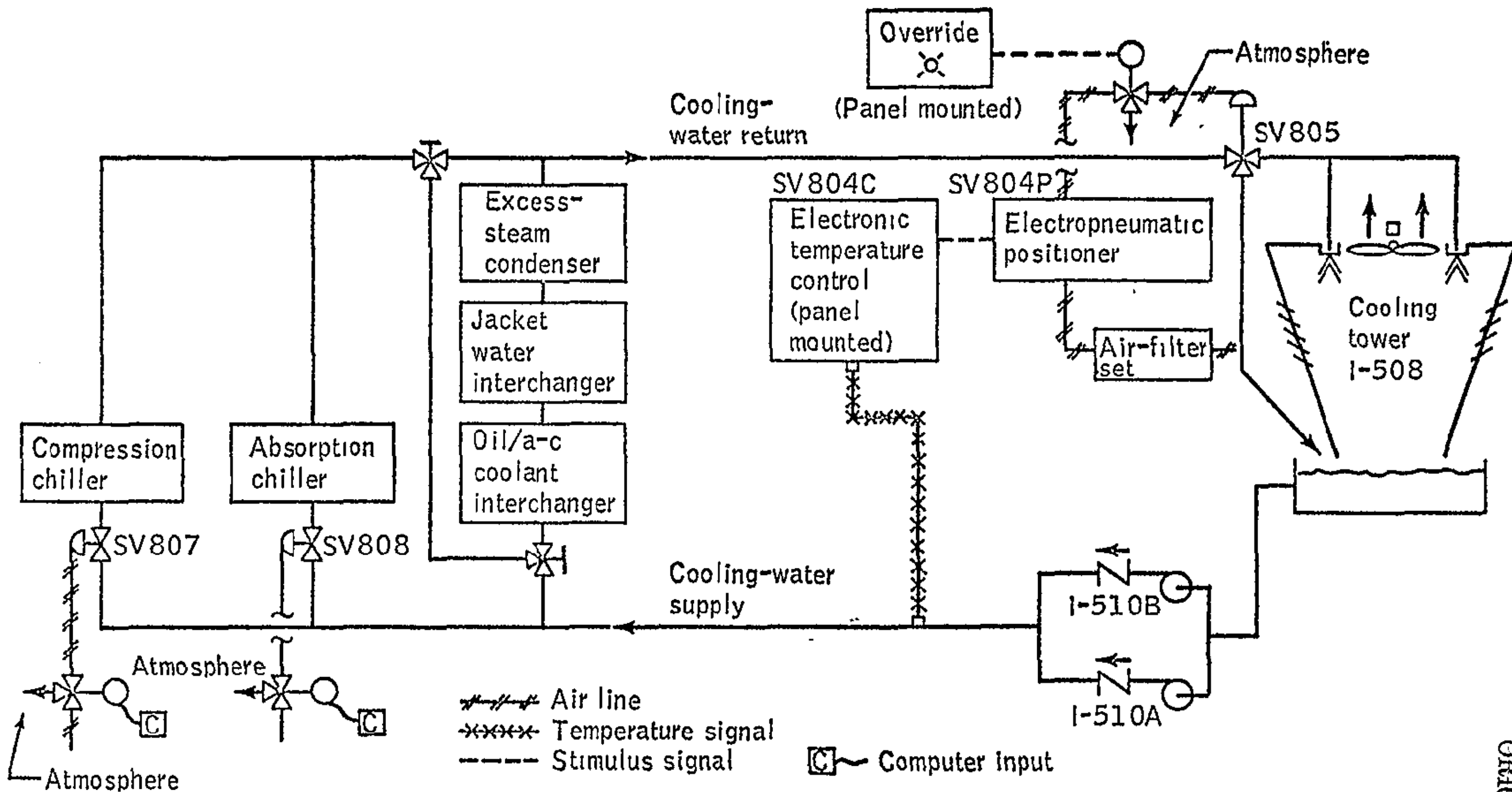
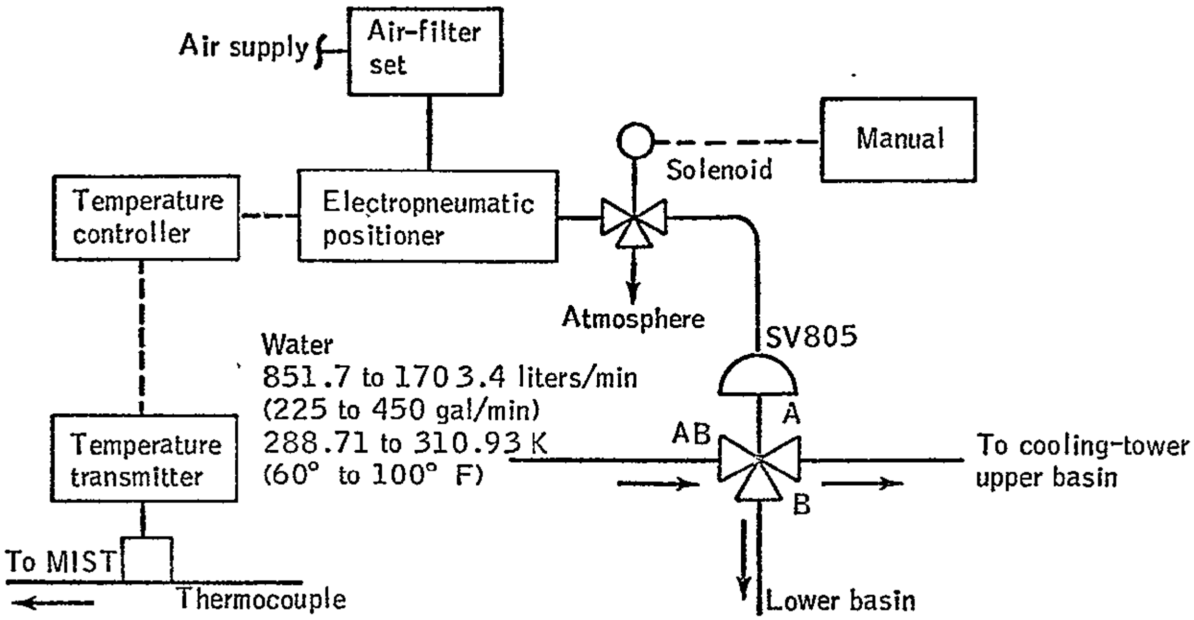


Figure 7. Cooling-tower-temperature control and condenser water on/off controls



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 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

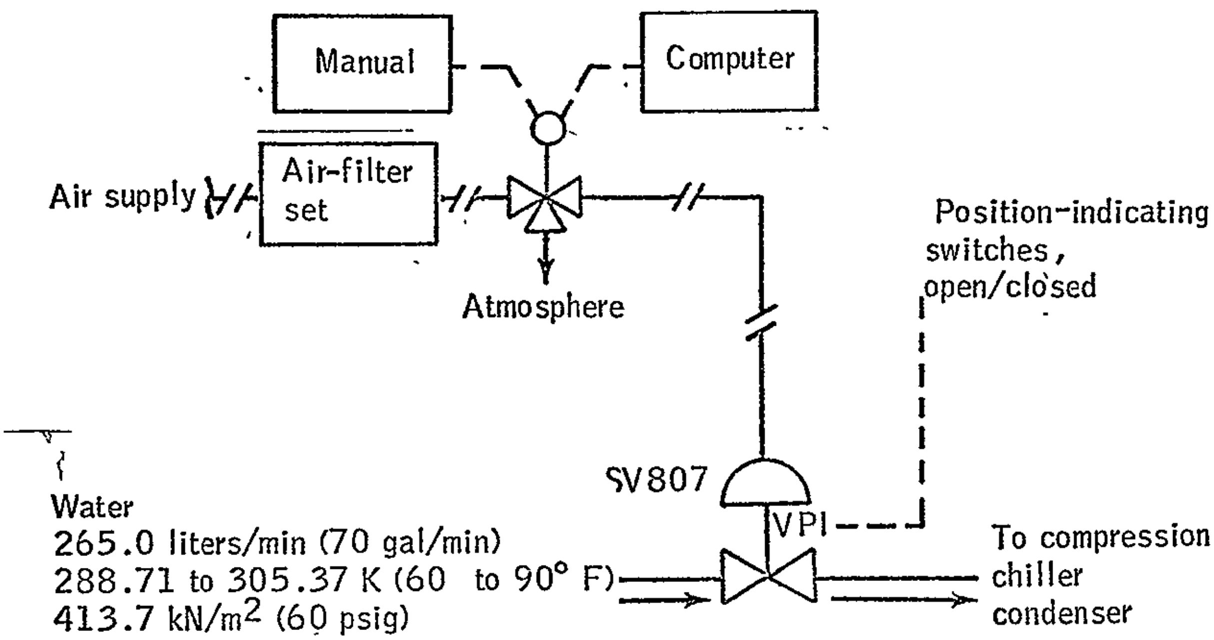
4. Well

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



Equipment List

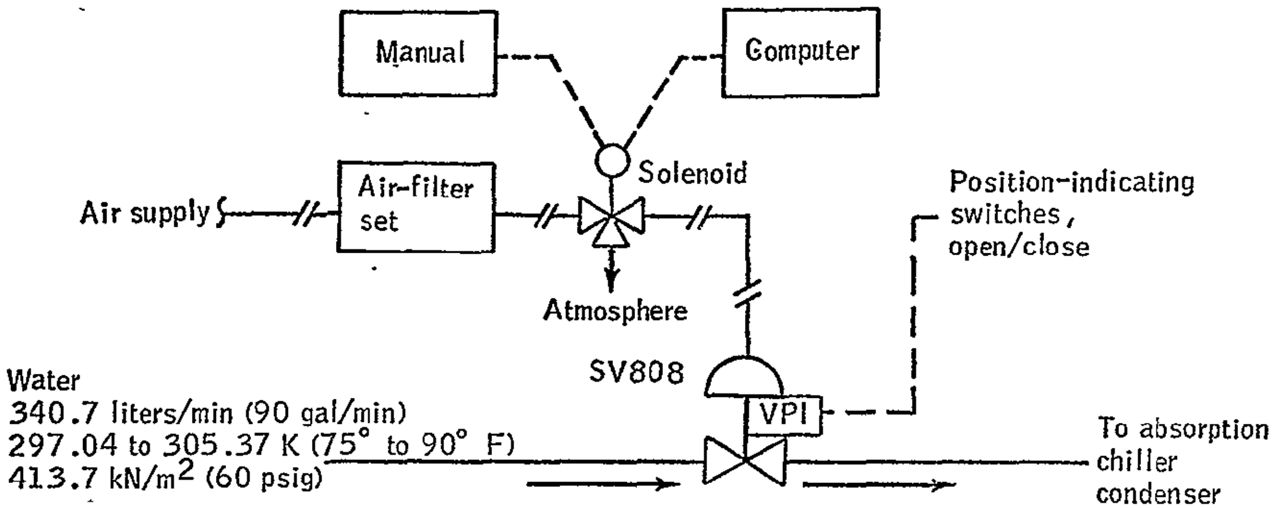
1. SV807 - 5.1-cm (2 in.) cage-type operator control valve
   - Normally open
   - Flanged connections, 861.8 kN/m^2 (125 psig) ASA
   - Cast-iron body
   - Stainless steel trim
   - Teflon/asbestos packing
   - Latching solenoid valve (mounted and piped)
   - Position-indicating switches (two)

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)

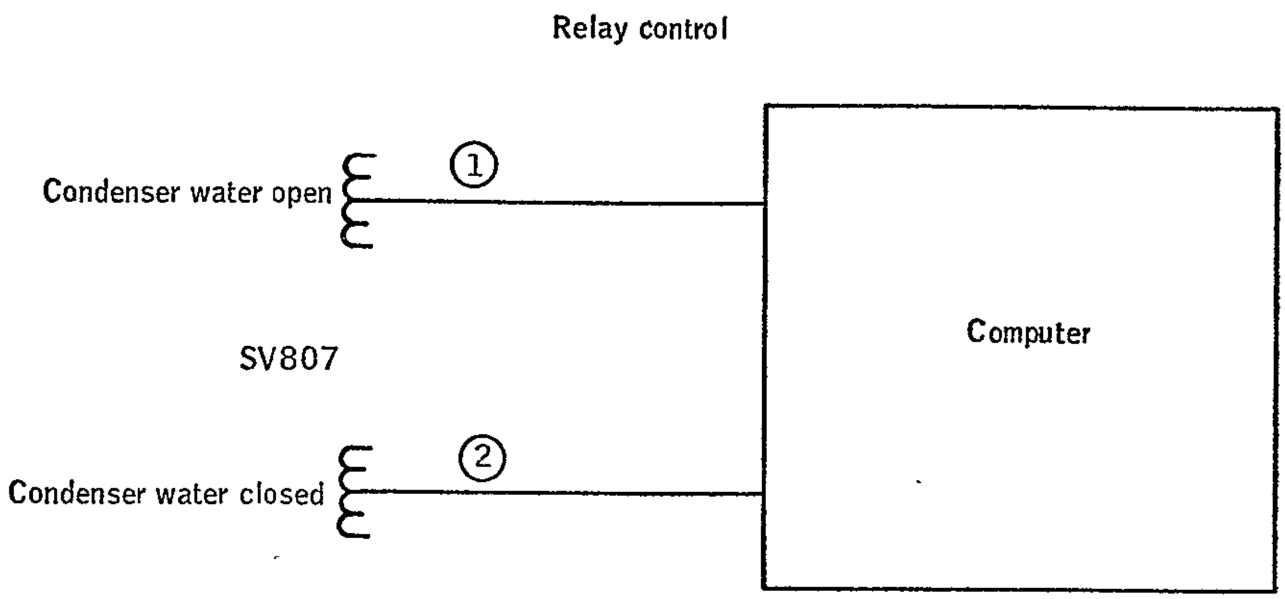
Figure 9. Control system listing for shutoff valve for compression chiller condender, SV807



Equipment List

1. SV808 - 6.4-cm (2.5 in.) cage-type operator control valve
   - Normally open
   - Flanged connections, 854.9 kN/m^2 (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 10. Control system listing for shutoff valve for absorption chiller condenser, SV808



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

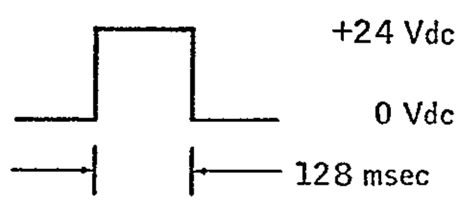
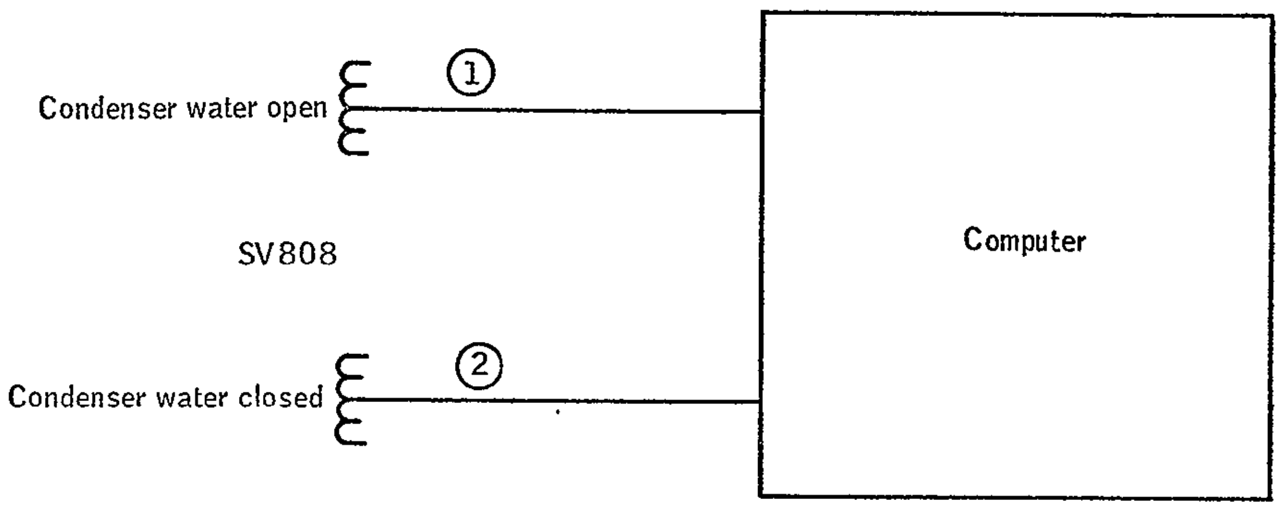


Figure 11. Interface definition for condenser water on/off control SV807

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

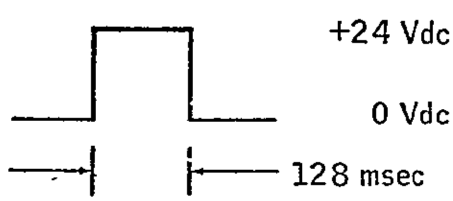


Figure 12. Interface definition for condenser water on/off control, SV808

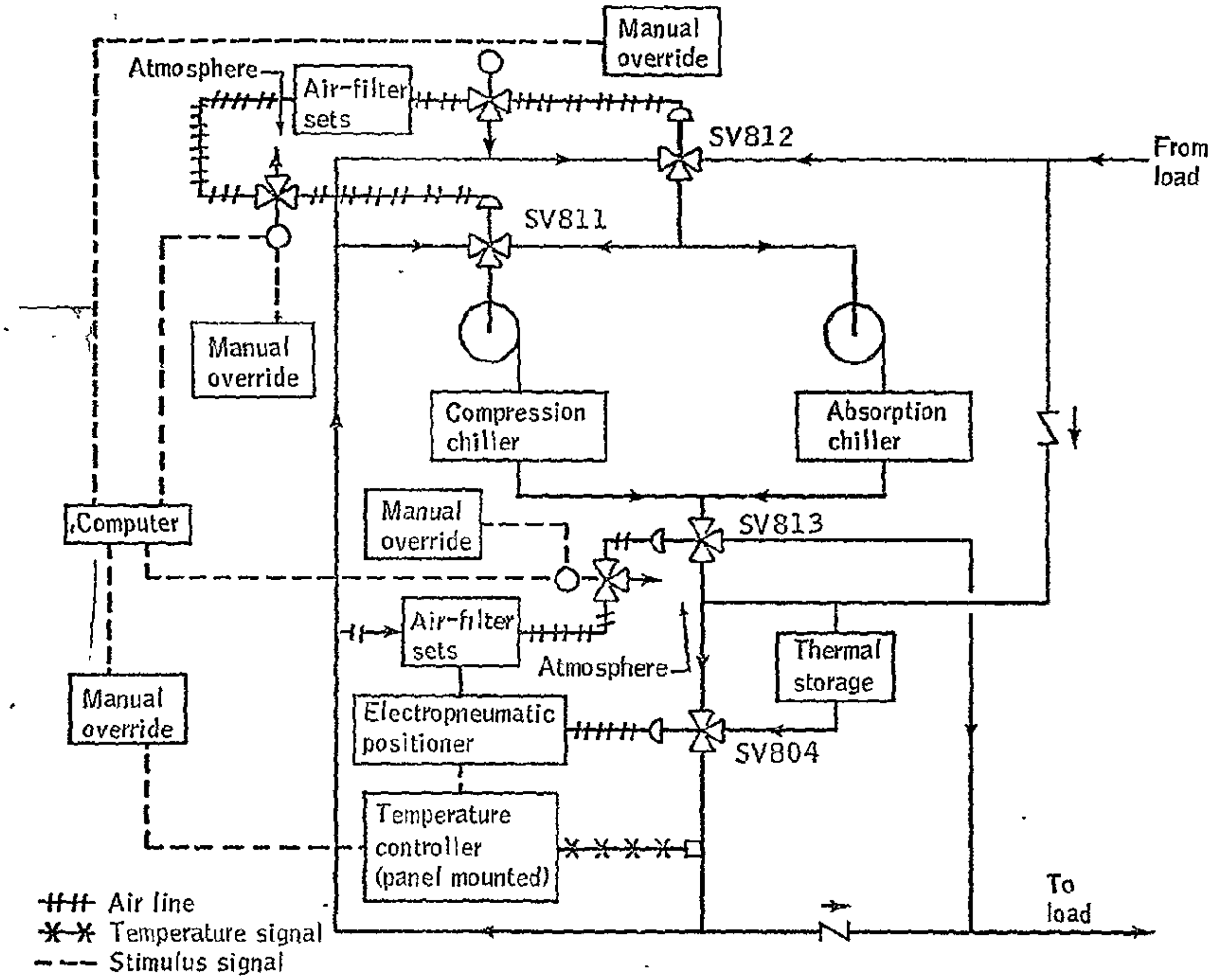
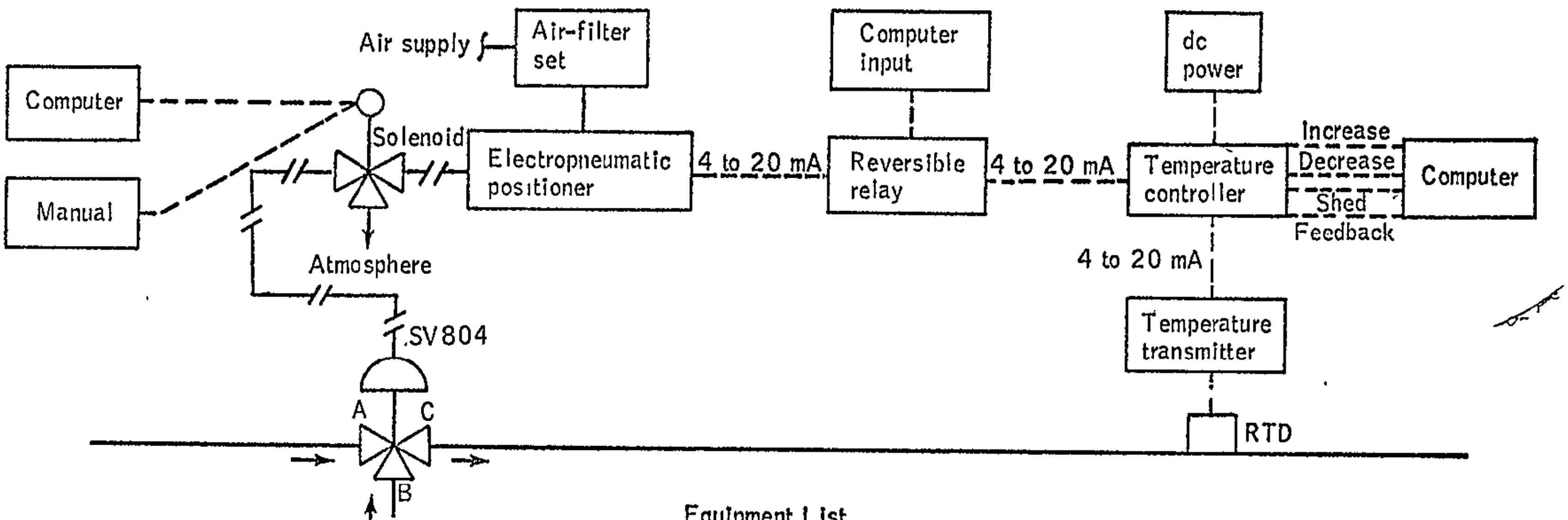


Figure 13. Chilled-water mode and temperature control



Equipment List

1. Transmitter
   +RTD probe
   255.37 to 310.93 K (0° to 100° F)
   Output, 4 to 20 mA

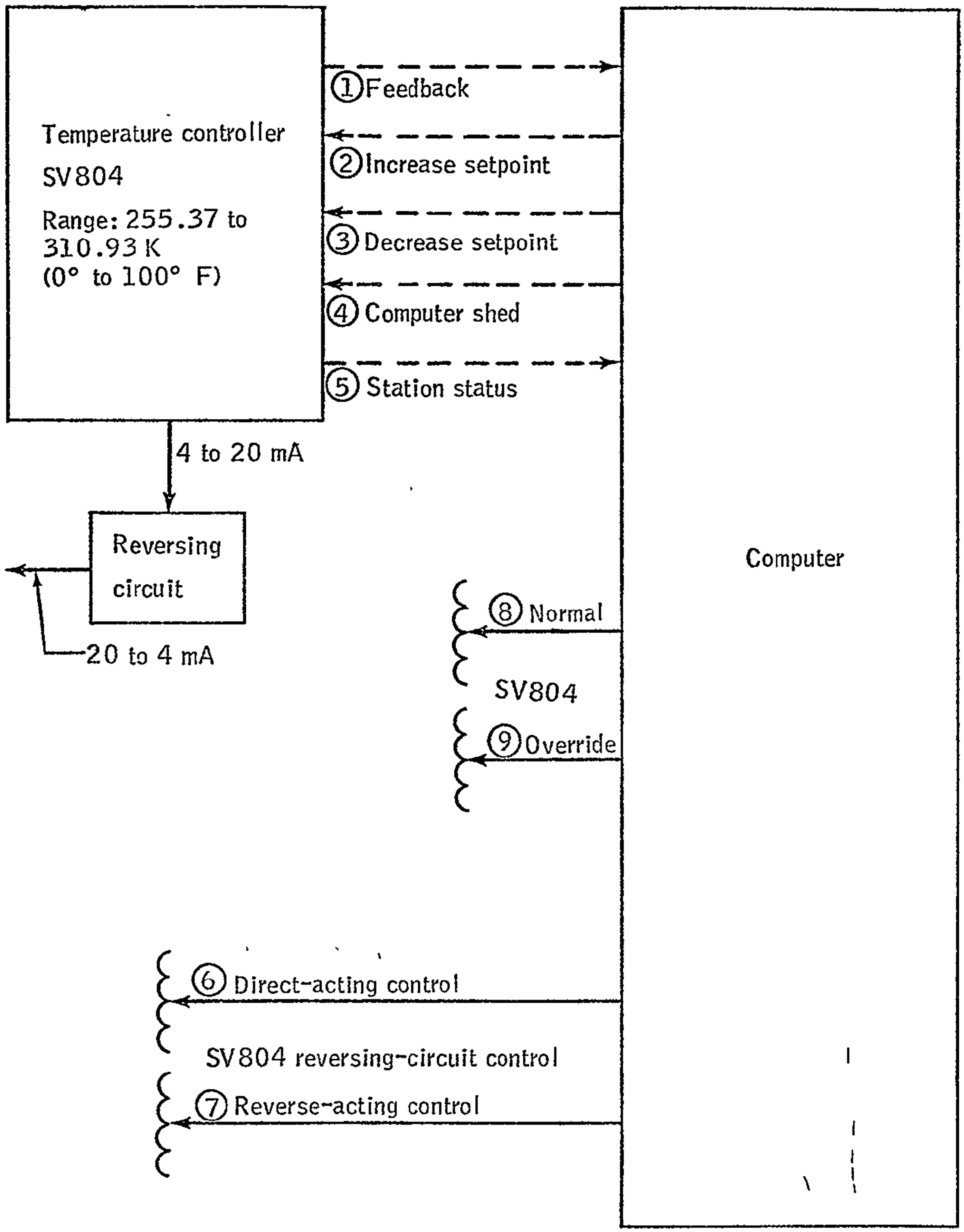
2. Well for above probe, stainless steel

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

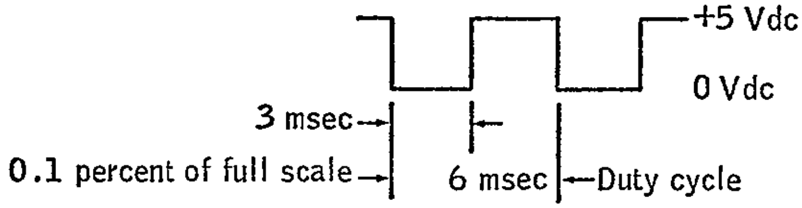


(a) Schematic.

Figure 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

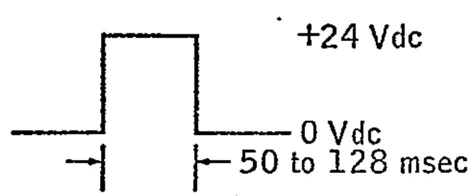


Computer output — 3. Decrease setpoint pulse (same as "2.")

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



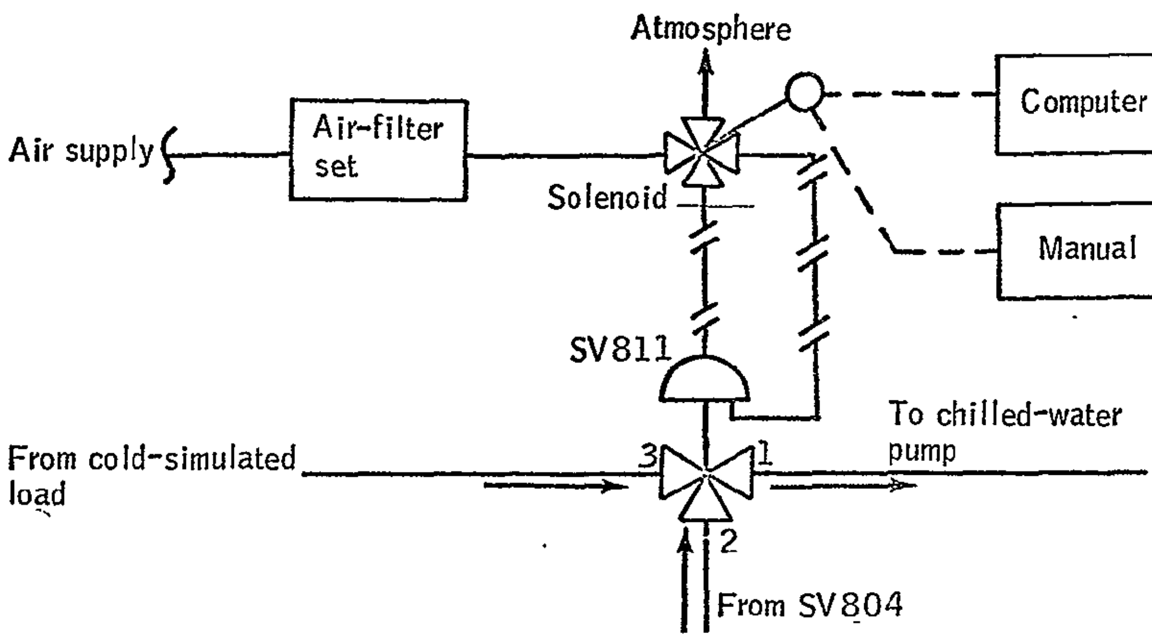
Computer output — 7. Reverse-acting control SV804
+24-Vdc pulse, 50-msec minimum to 128 msec maximum

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 15. Concluded



Equipment List

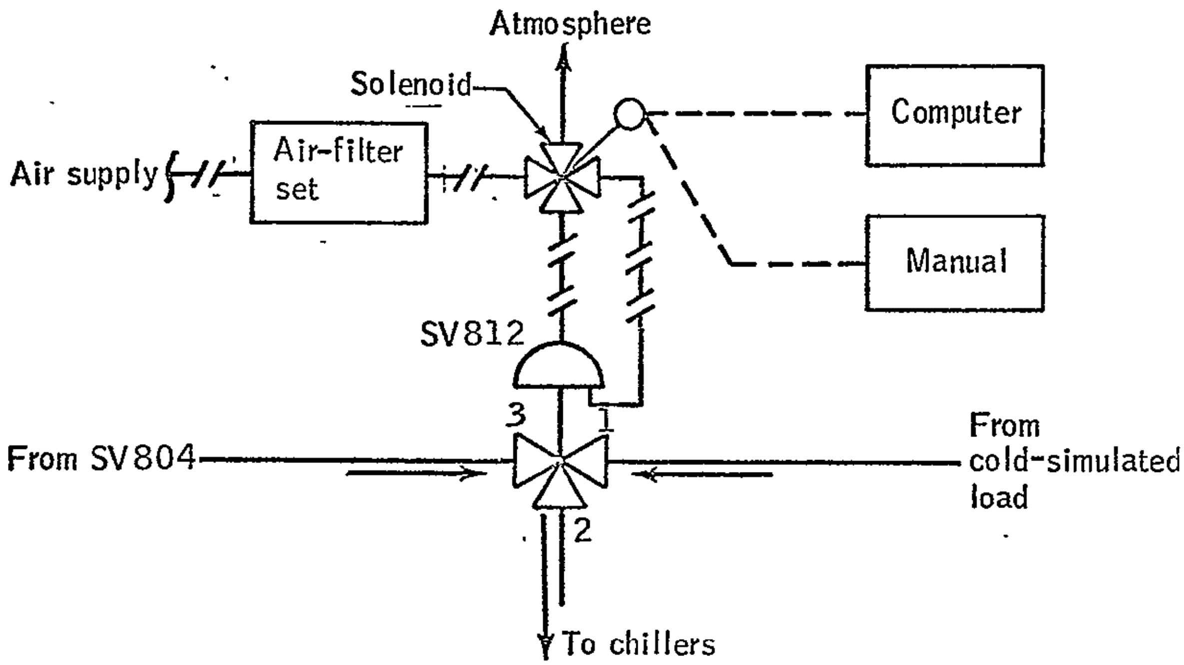
1. SV811 - 7.6-cm (3 in.) tapered three-way plug valve
   - Semisteel body and plug
   - Metal-to-metal seat
   - Flanged connections, 861.8 kN/m^2 (125 psig) ASA
   - Double-acting pneumatic cylinder operator
   - Four-way latching solenoid valve (mounted and piped), 110 Vac
   - Single-pole double-throw 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 16. Control system listing for diverter valve for compression chiller inlet, SV811



Equipment List

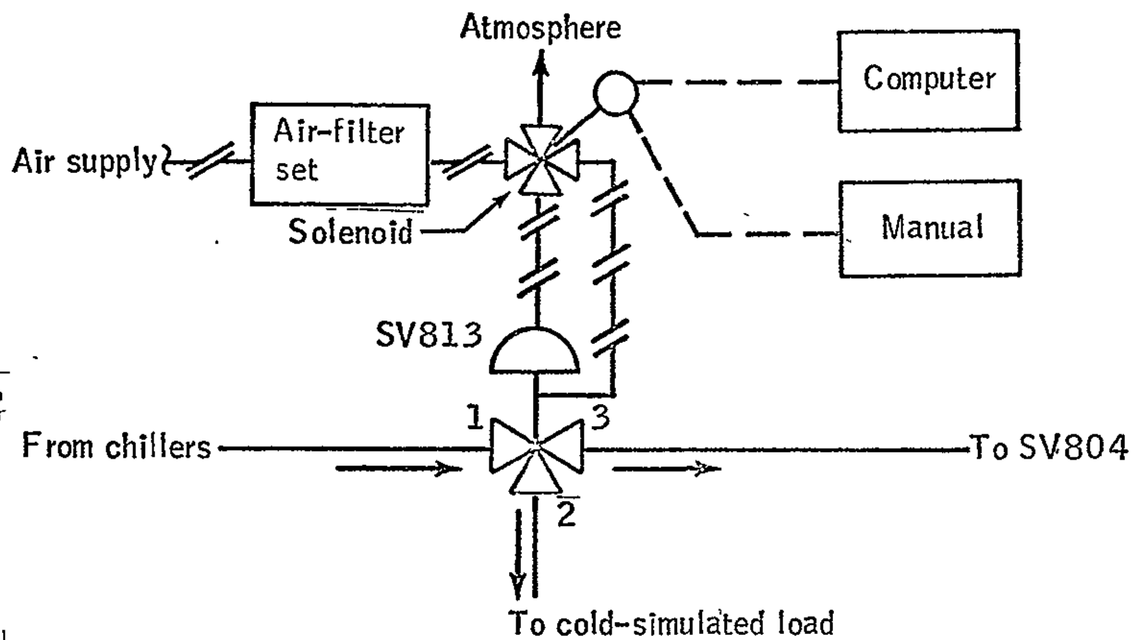
1. SV812 - 7.6-cm (3 in.) tapered three-way plug valve
   Semisteel body and plug
   Metal-to-metal seat
   Flanged-end connections, 861.8 kN/m^2 (125 psig) ASA
   Double-acting pneumatic cylinder operator
   Four-way, latching-type solenoid valve (mounted and piped)
   Single-pole, double-throw position-indicating 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 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 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)

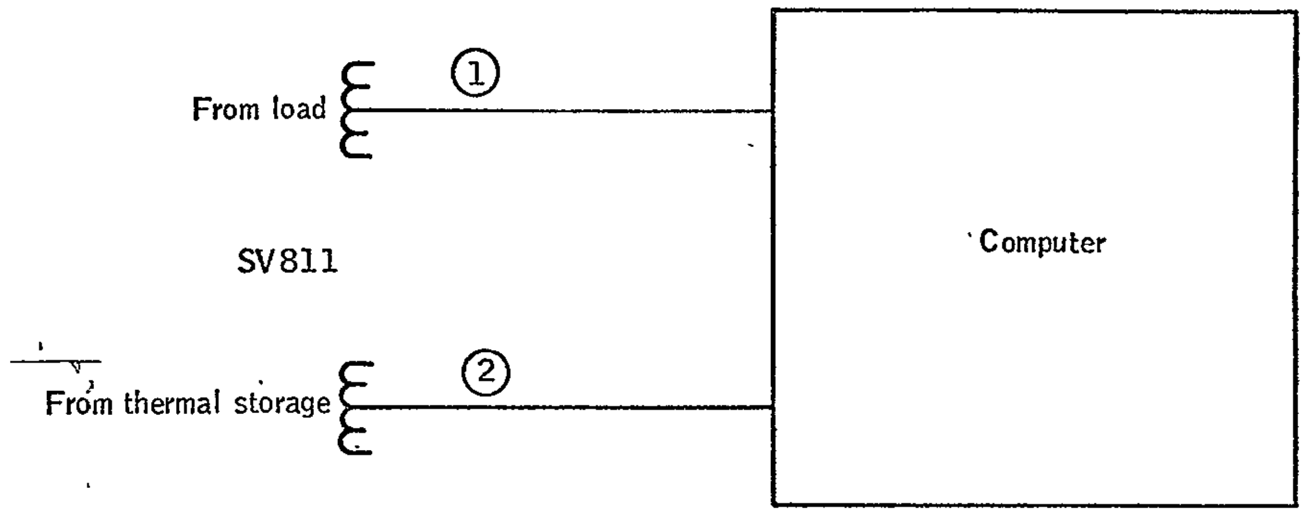
2. Air-filter regulator

3. Manual control
   To load switch
   To thermal-storage switch
   VPI lights (two) (existing)

4. Computer control relay, 24 Vdc (two)

Figure 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

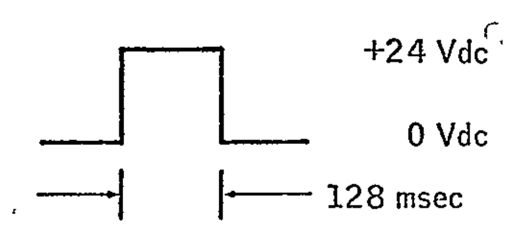
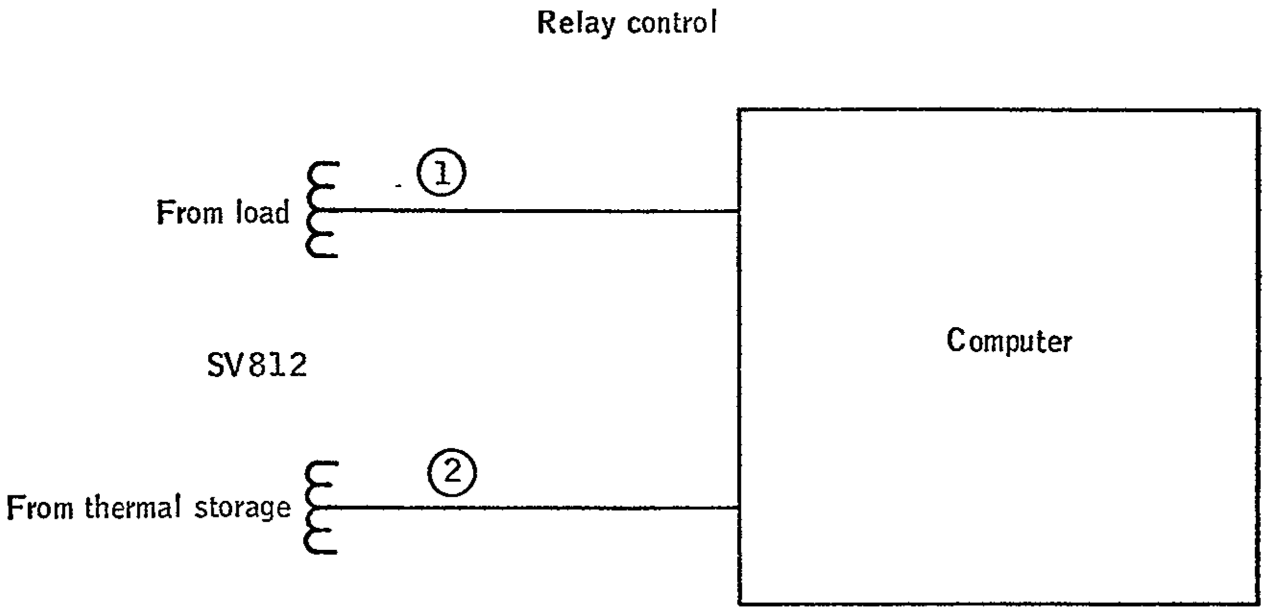


Figure 19. Interface definition for chilled-water-mode control, SV811



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

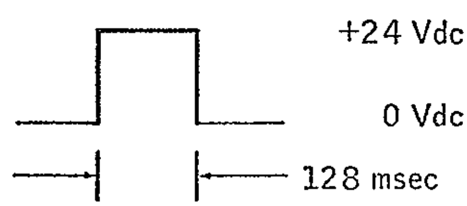


Figure 20. Interface definition for chilled-water-mode control, SV812

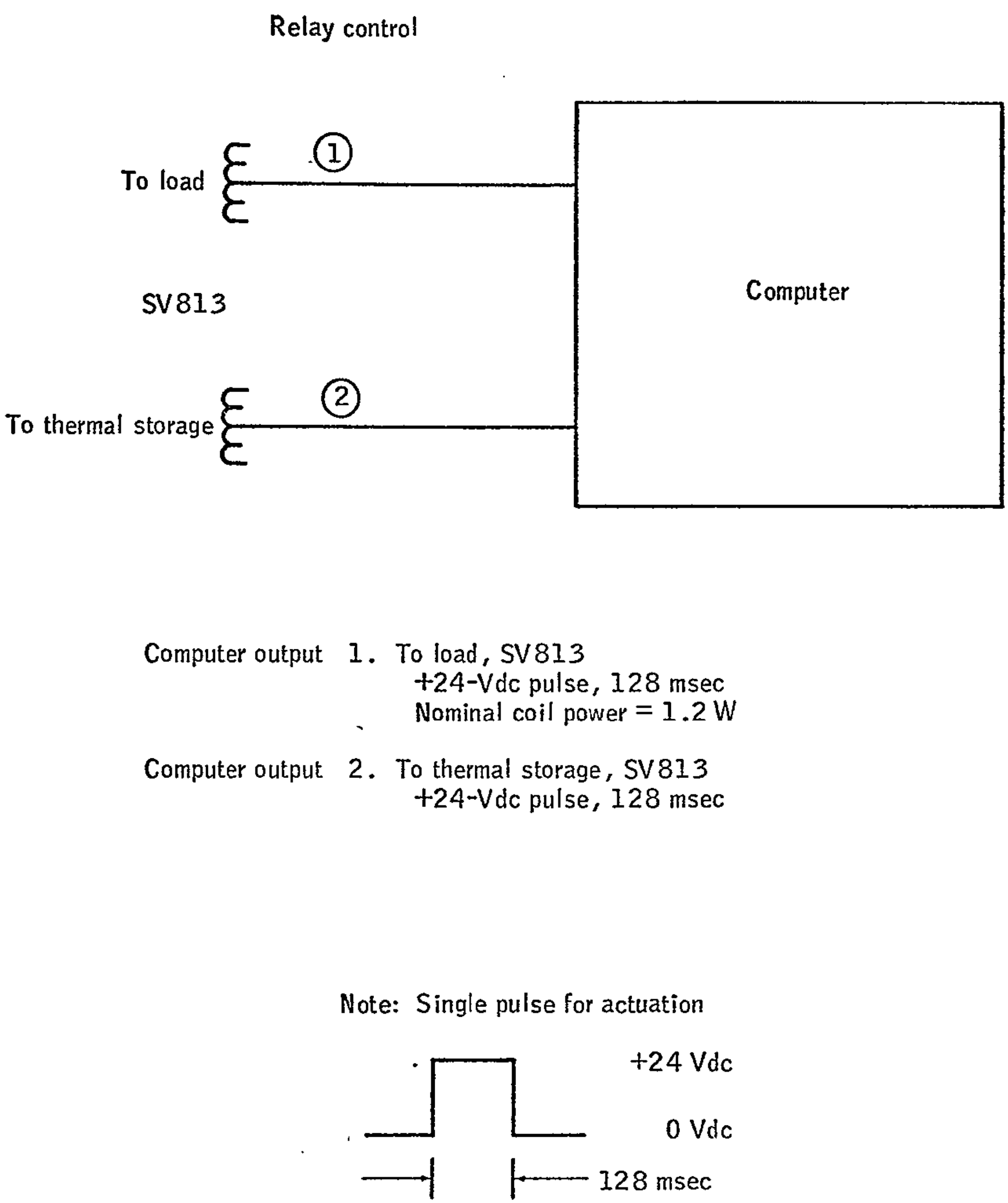


Figure 21. Interface definition for chilled-water-mode control SV813

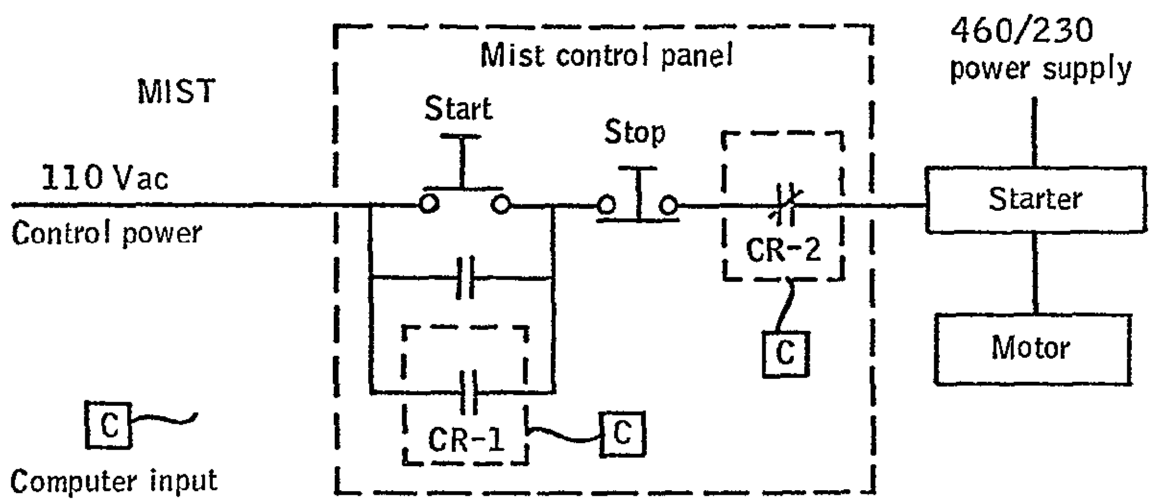
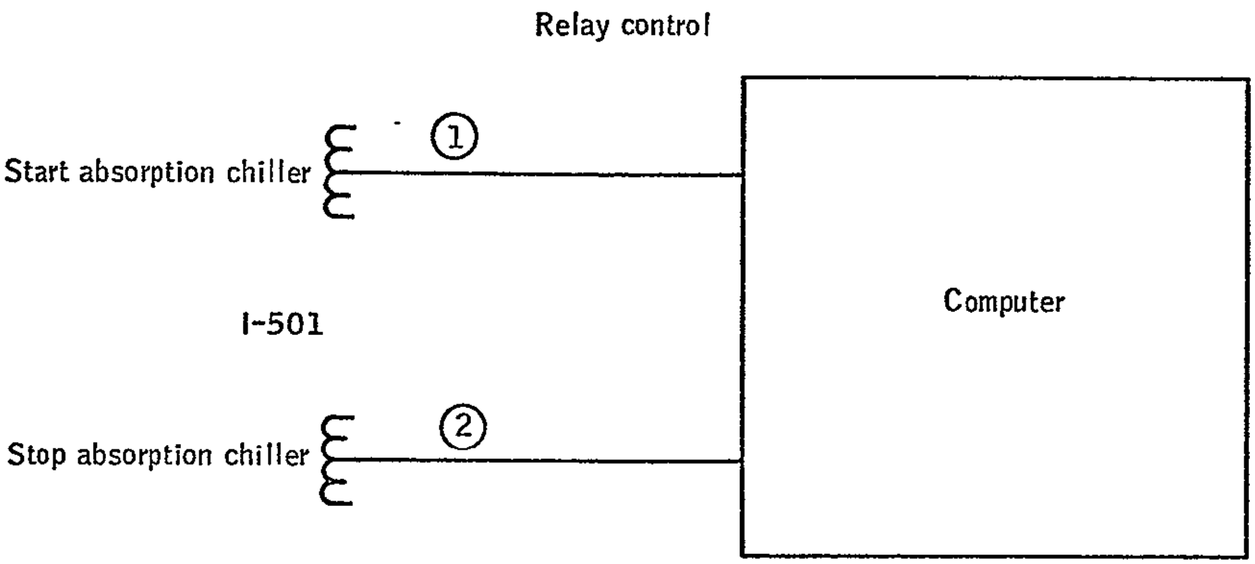


Figure 22. Typical motor stop/start controls



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

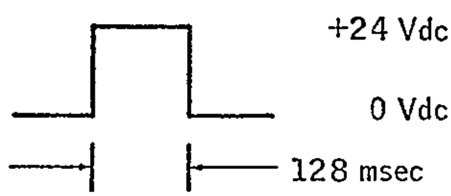
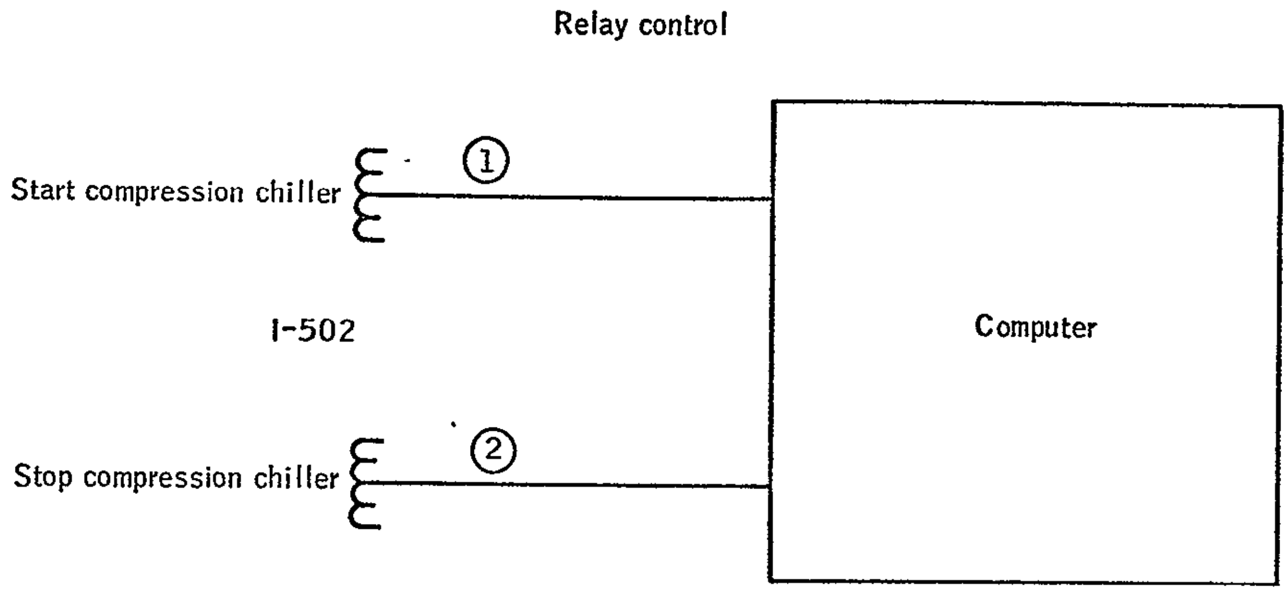


Figure 23. Interface definition for motor control, absorption chiller I-501



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

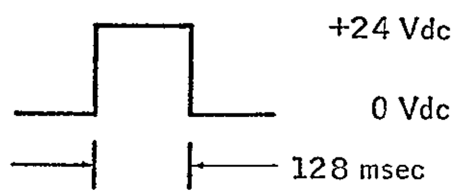
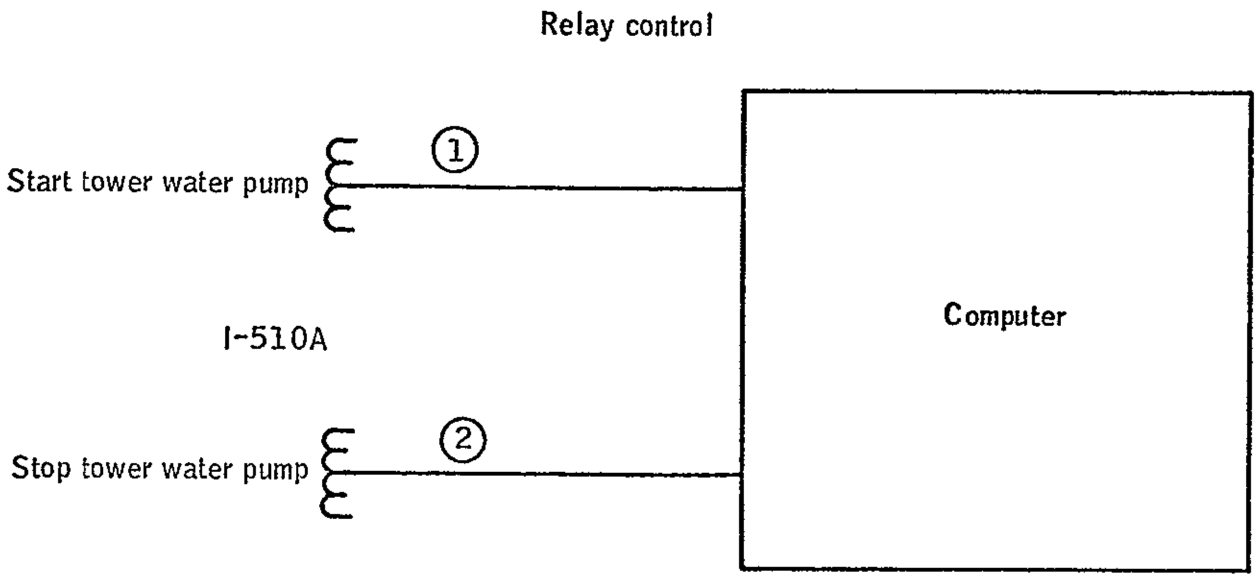


Figure 24. Interface definition for motor control, compression chiller I-502



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

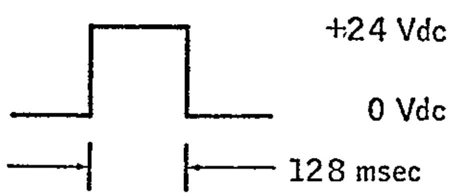
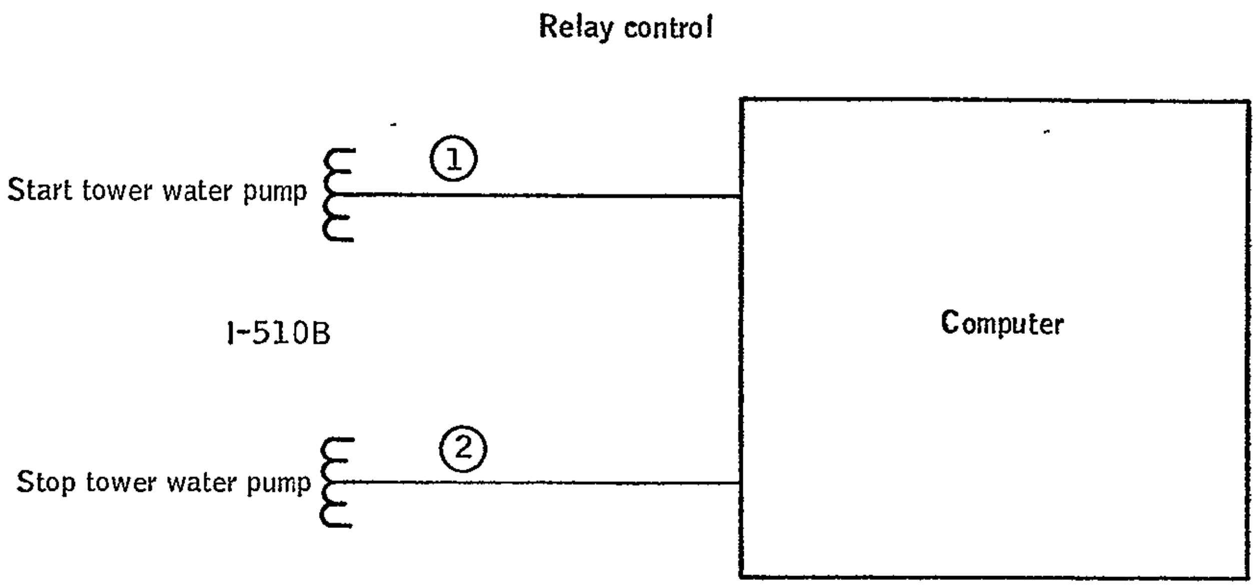


Figure 25. Interface definition for motor control, tower water pump I-510A



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

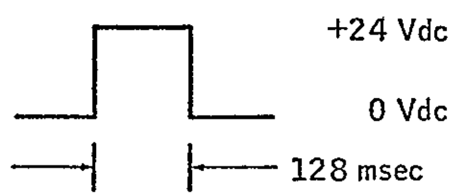
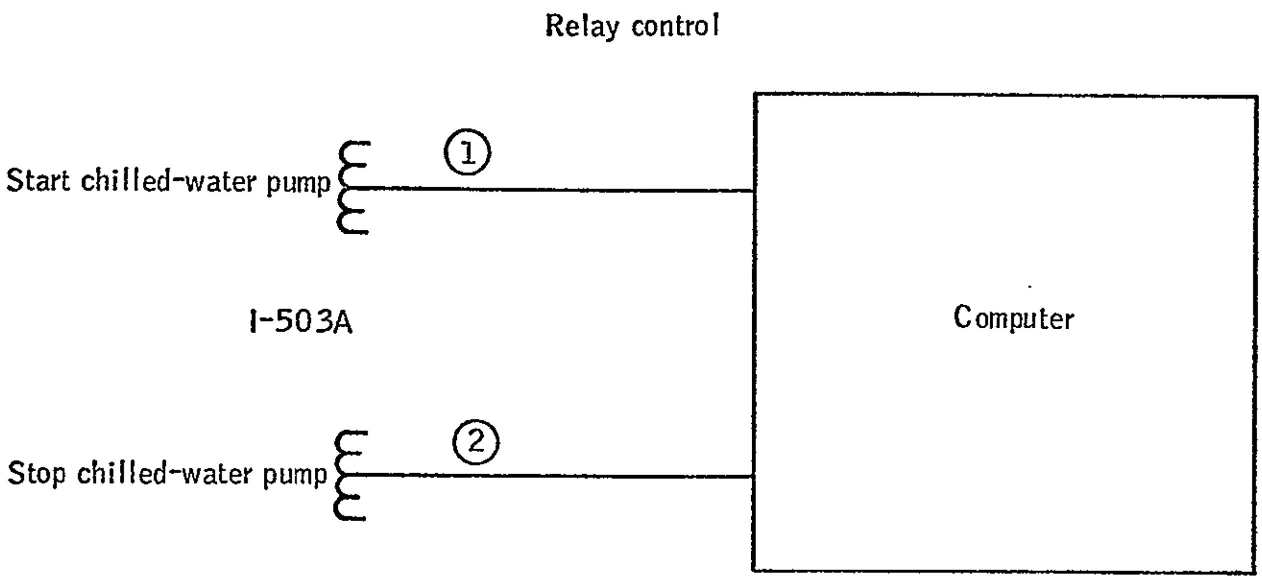


Figure 26. Interface definition for motor control, tower water pump I-510B



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

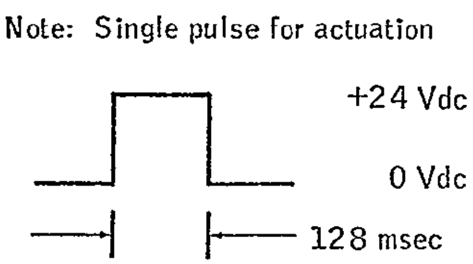
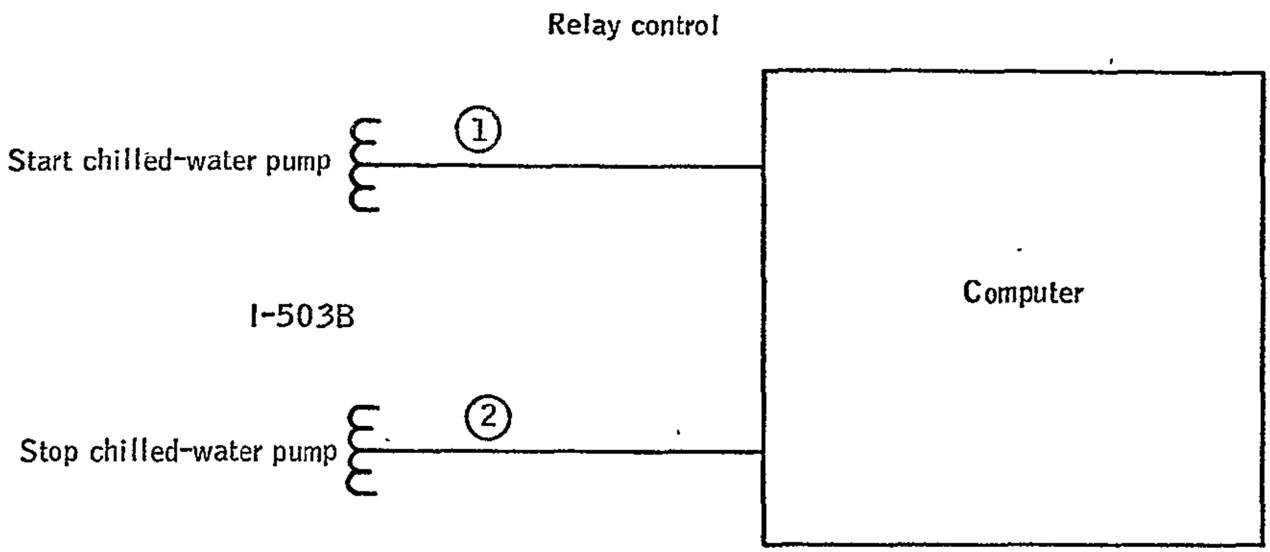


Figure 27. Interface definition for motor control, chilled-water pump I-503A, absorption chiller



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

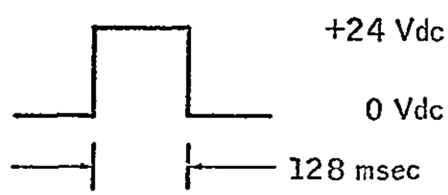
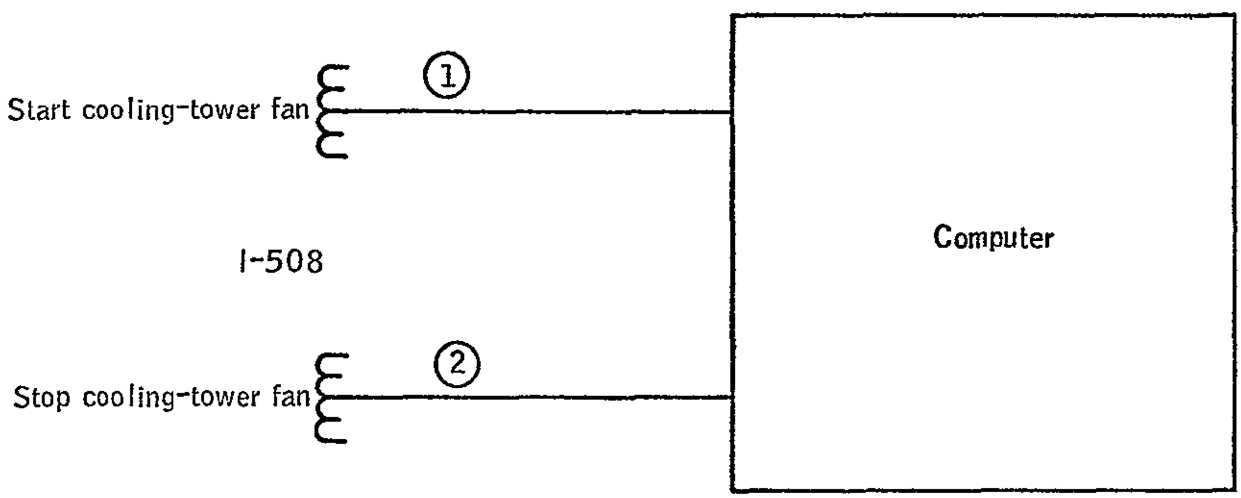


Figure 28. Interface definition for motor control, chilled-water pump I-503B, compression chiller

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

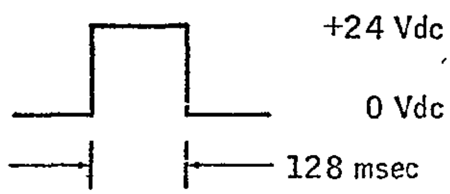
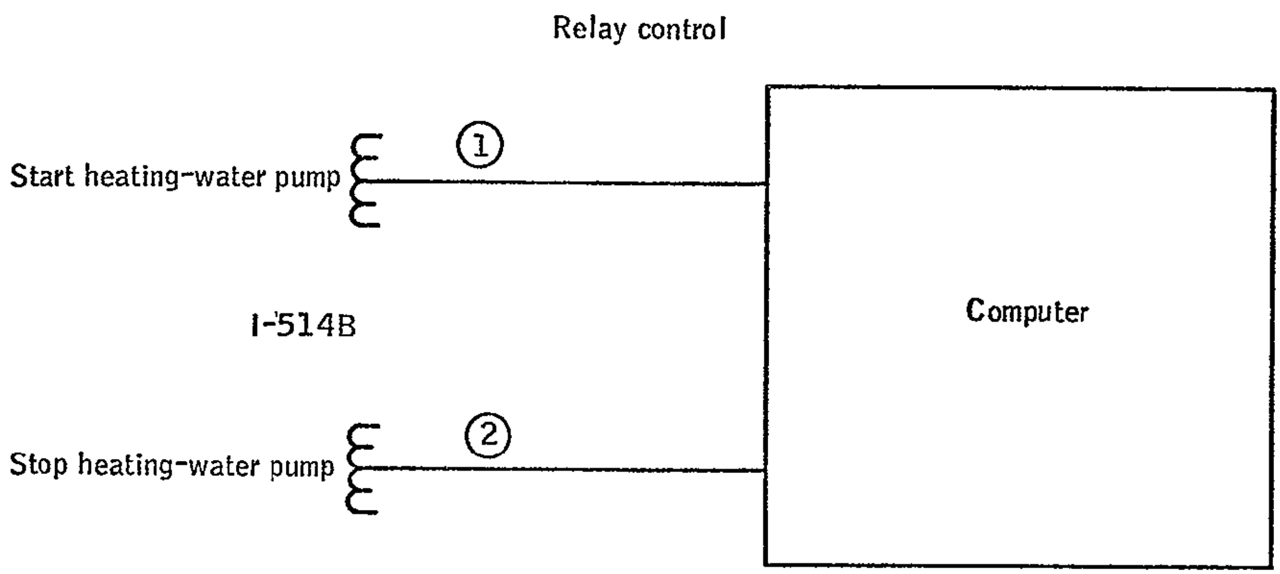


Figure 29. Interface definition for motor control, cooling-tower fan I-508



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

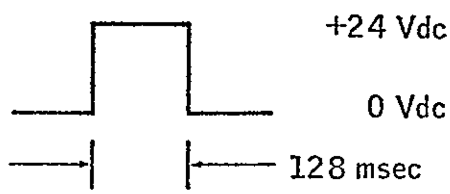


Figure 30. Interface definition for motor control, heating-water pump I-514B

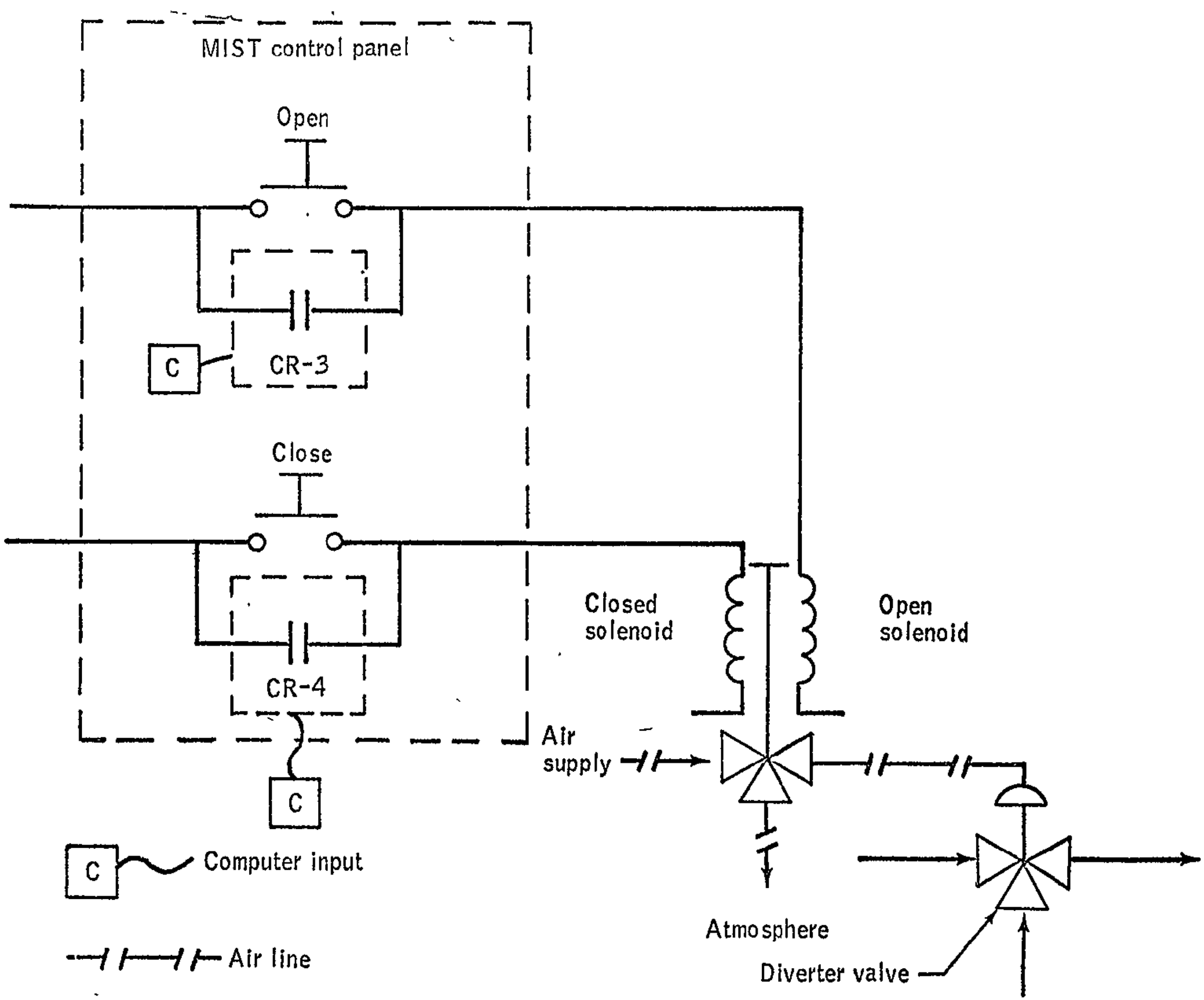
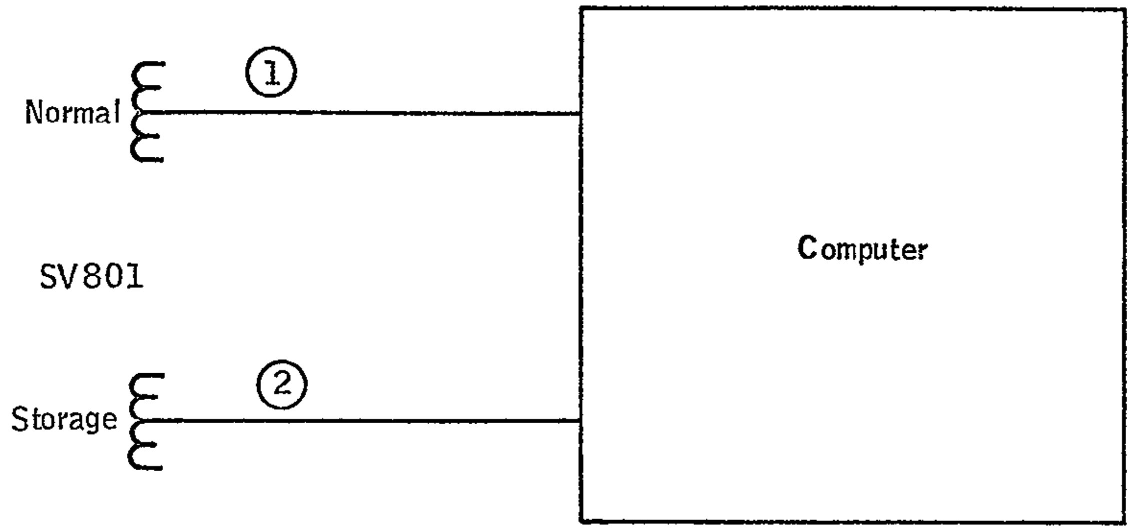


Figure 31. Typical valve controls

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

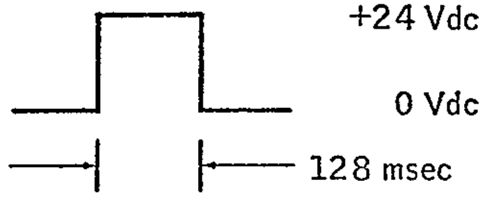
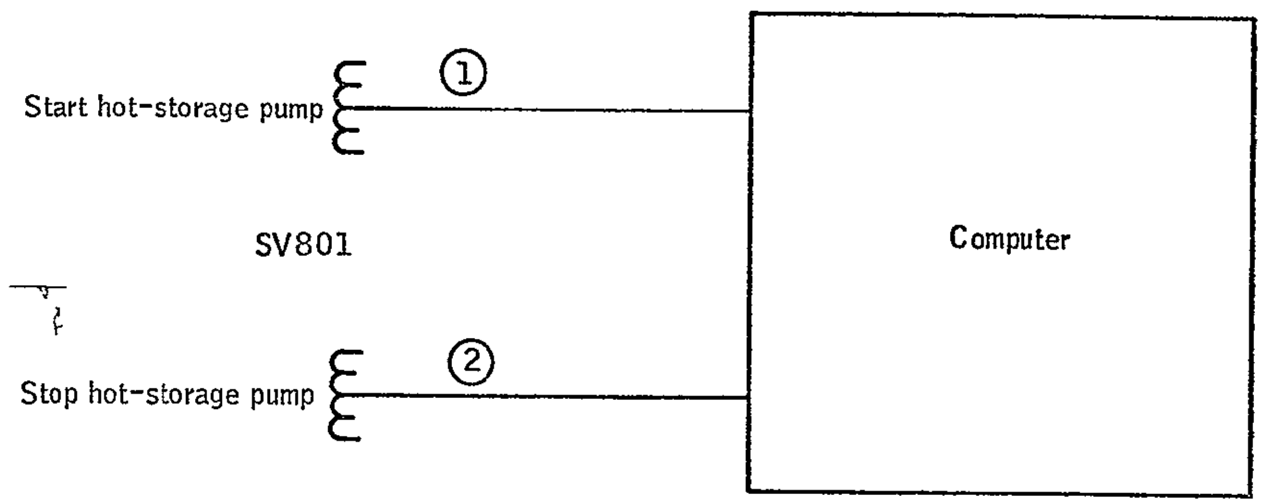


Figure 32. Interface definition for thermal-storage diverter valve SV801

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

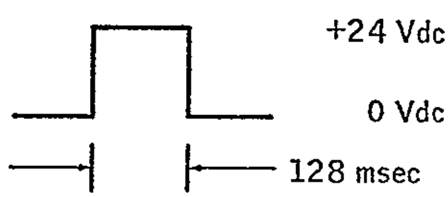


Figure 33. Interface definition for motor control, heating-water pump I-514A (storage through SV801)

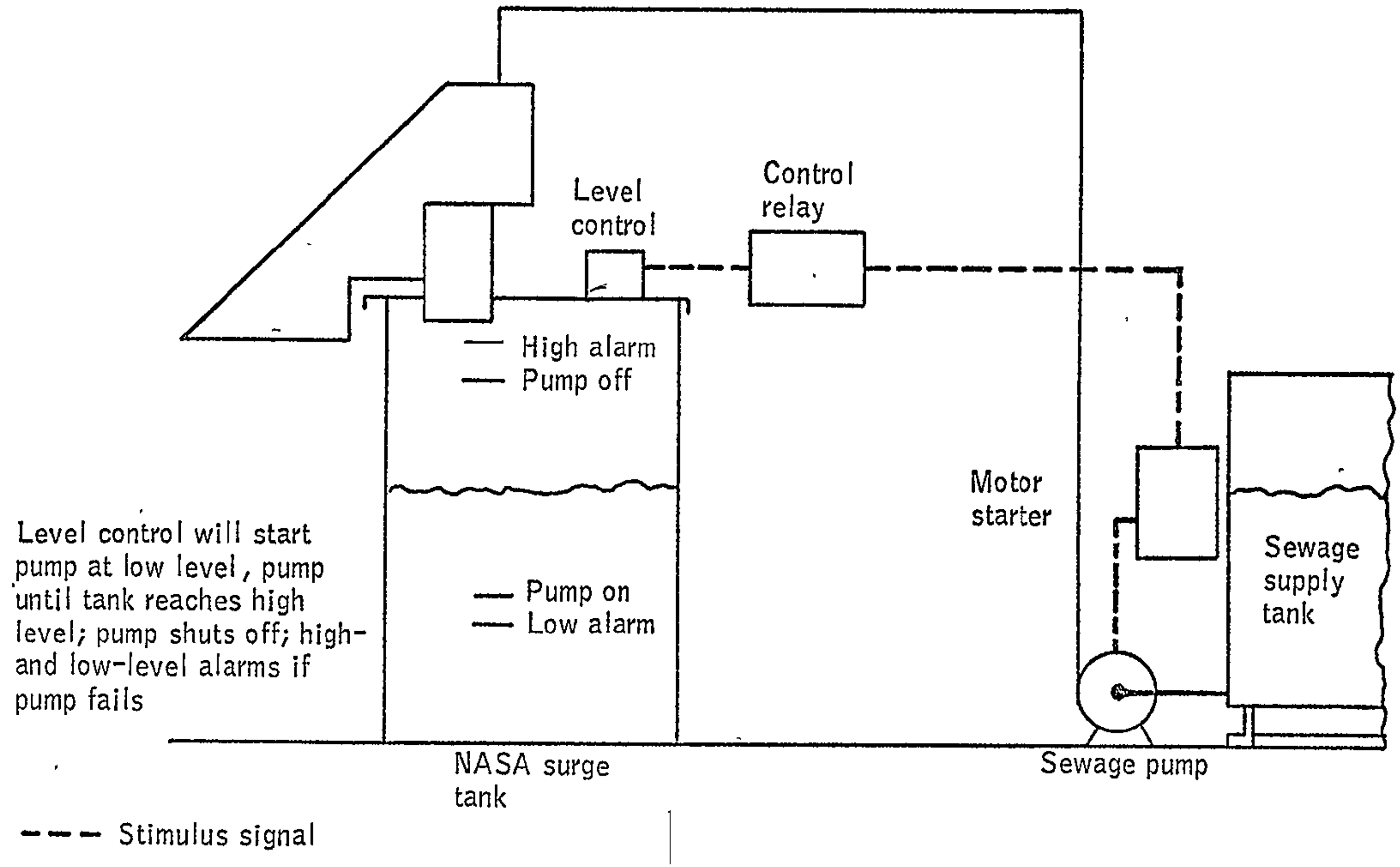


Figure 34. NASA surge tank level control

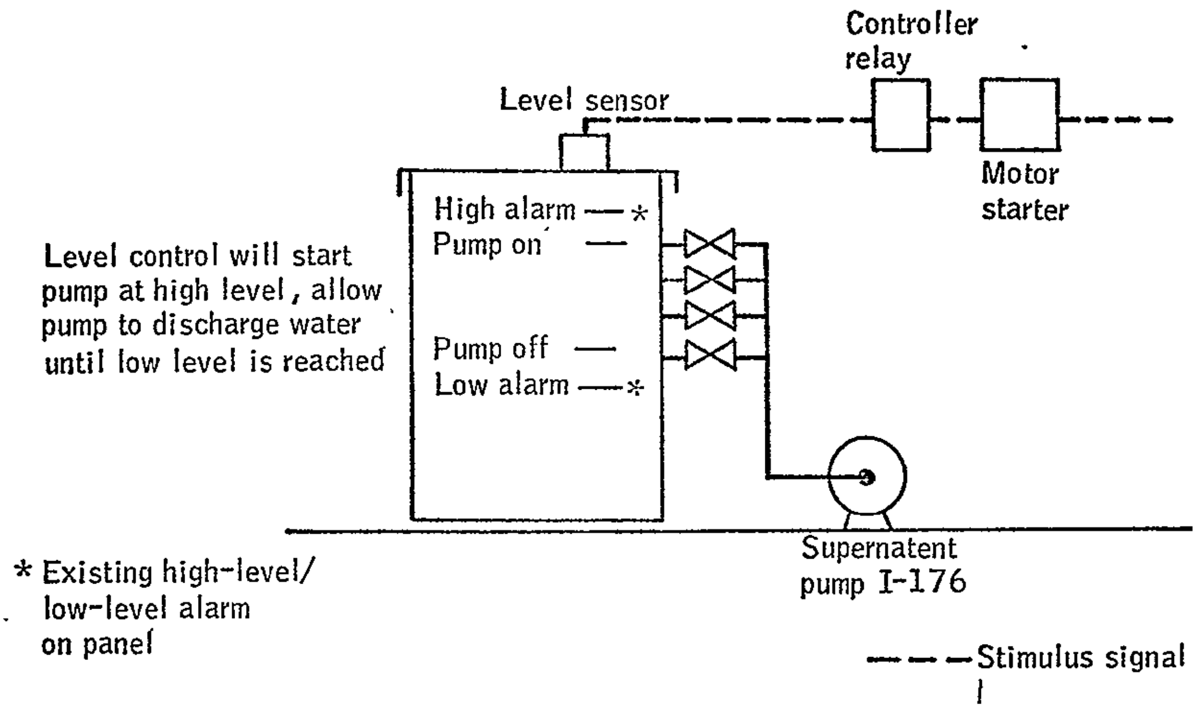


Figure 35. Supernatent pump level control

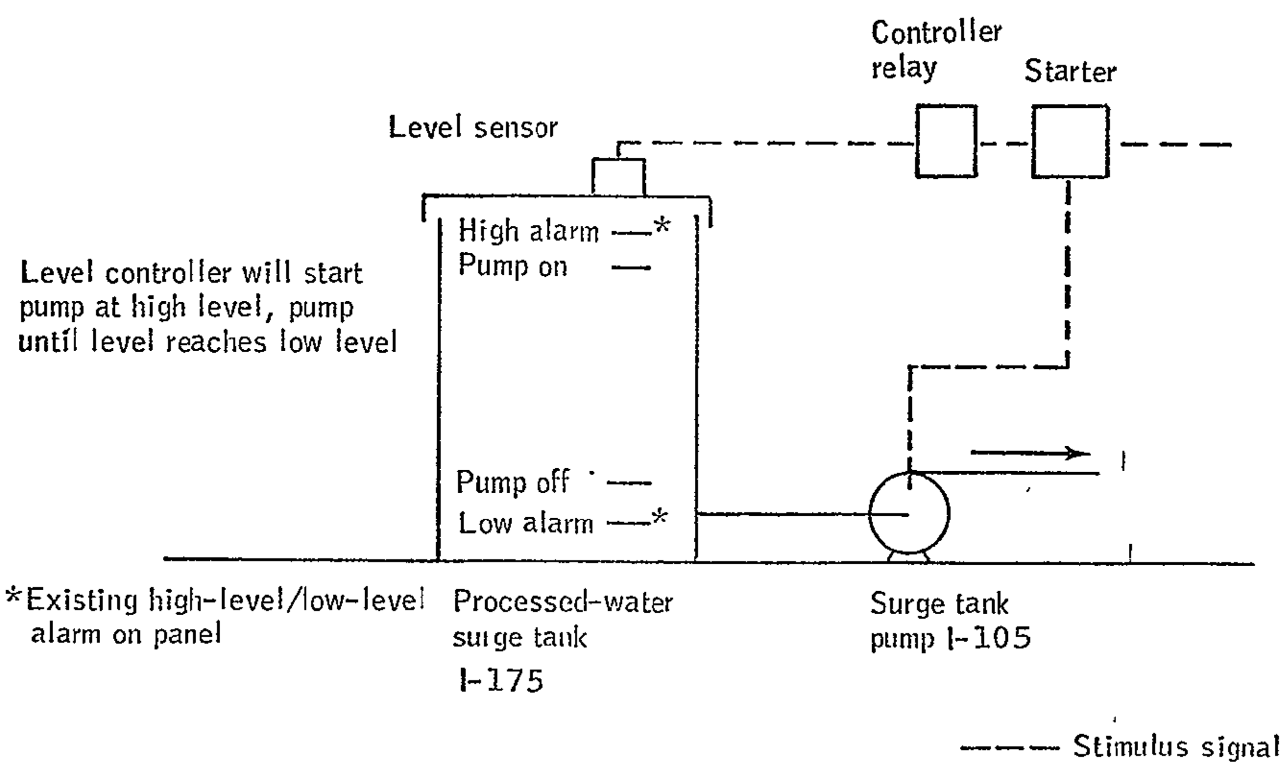


Figure 36. Processed-water-surge-tank level control

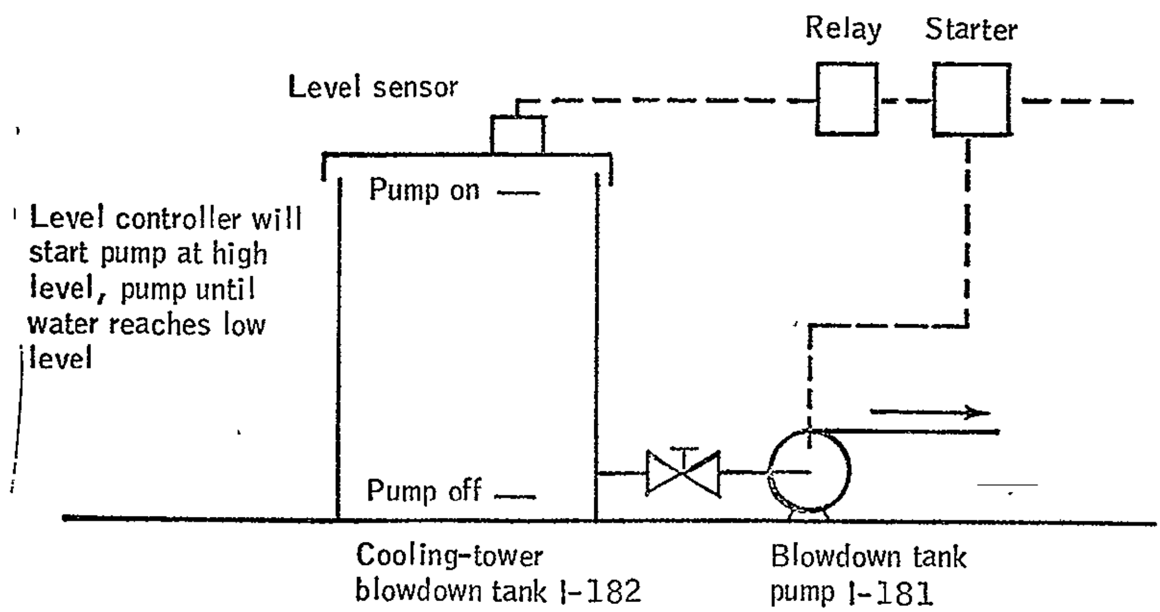


Figure 37. Blowdown tank level control I-825

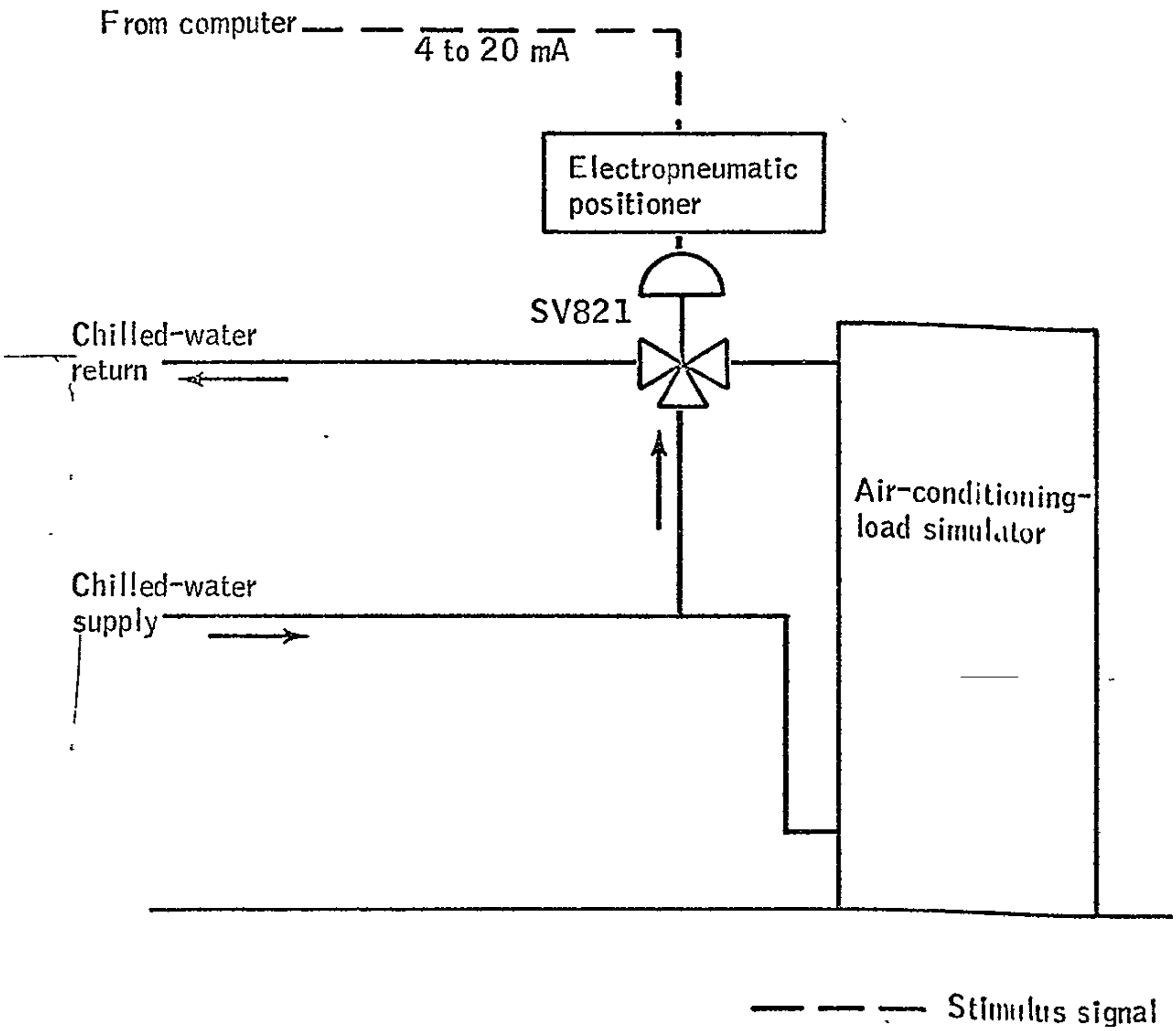
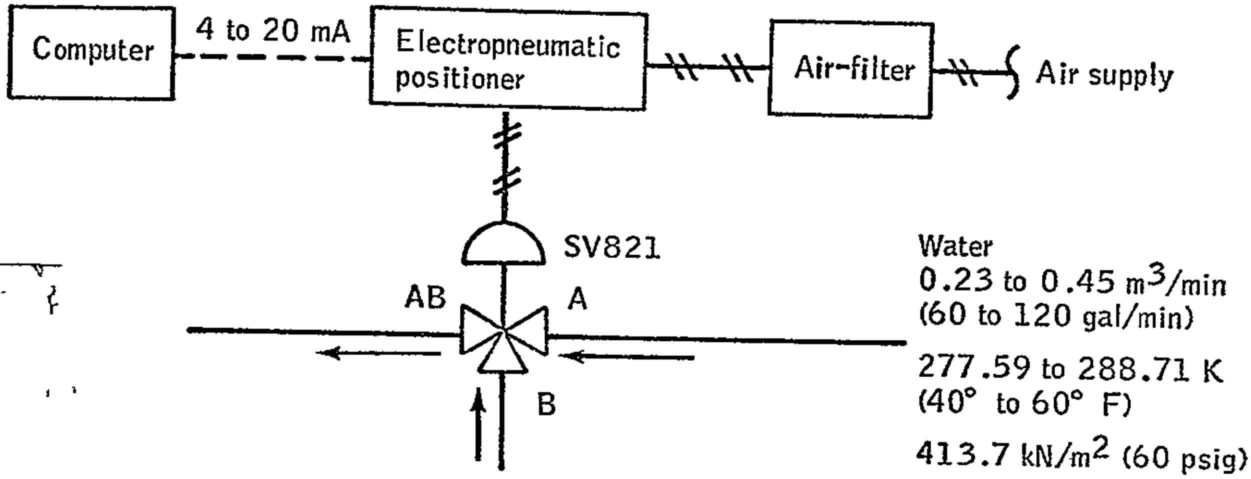


Figure 38. Air-conditioning-simulator temperature control valve



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^2 (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 39. Control system listing for air-conditioning-simulator temperature control valve SV821

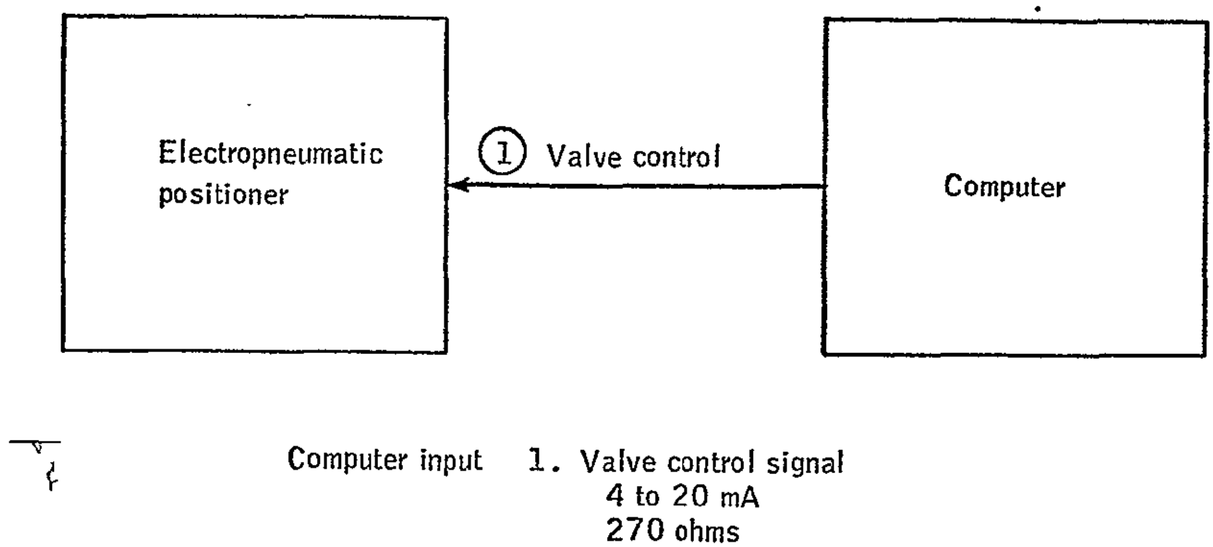


Figure 40. Interface definition for air-conditioning-simulator temperature control valve SV821

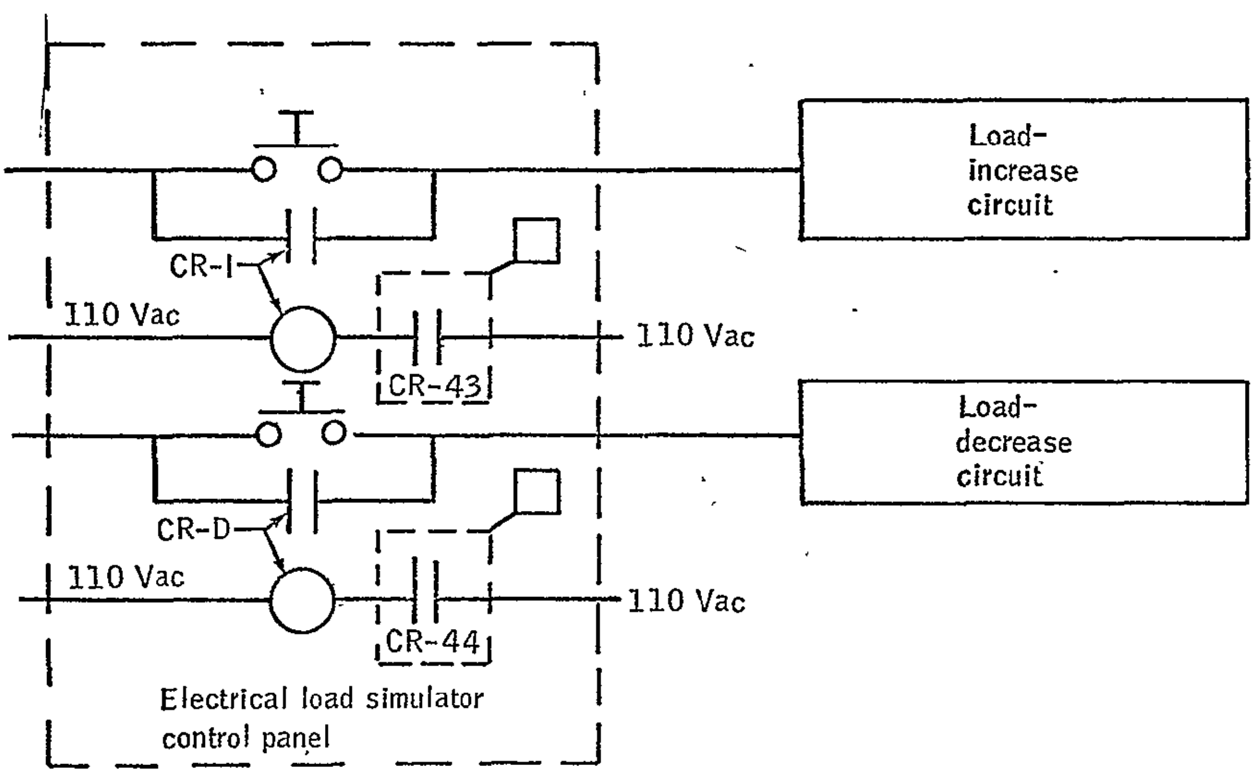
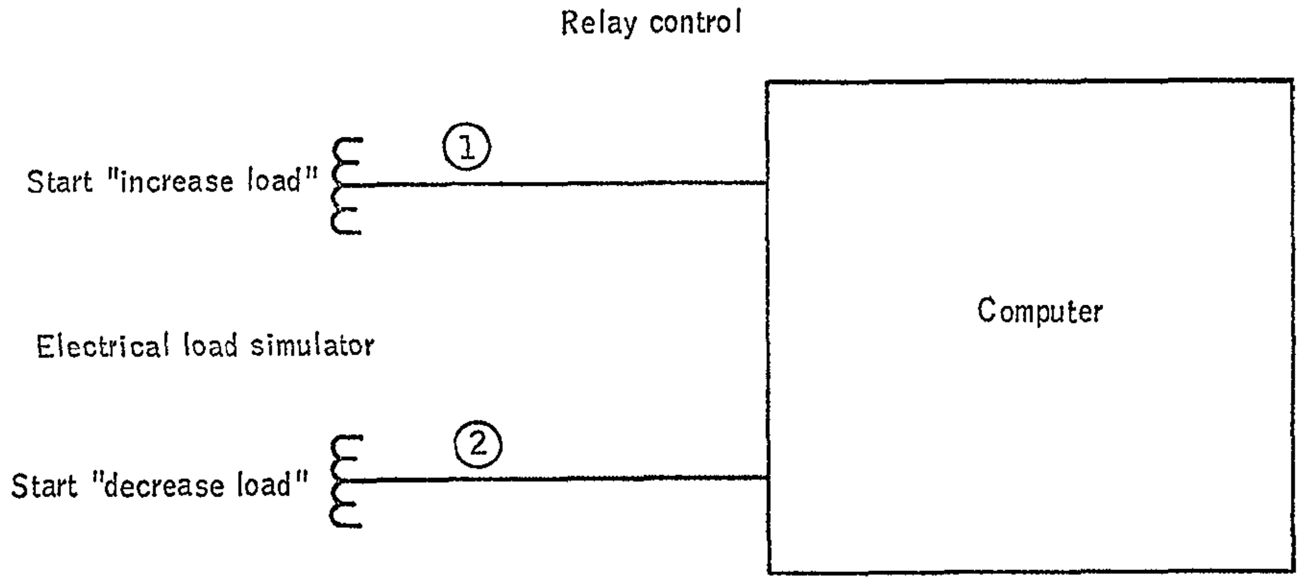


Figure 41. Power simulator control



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 42. Interface definition for electrical simulator power control, motor control

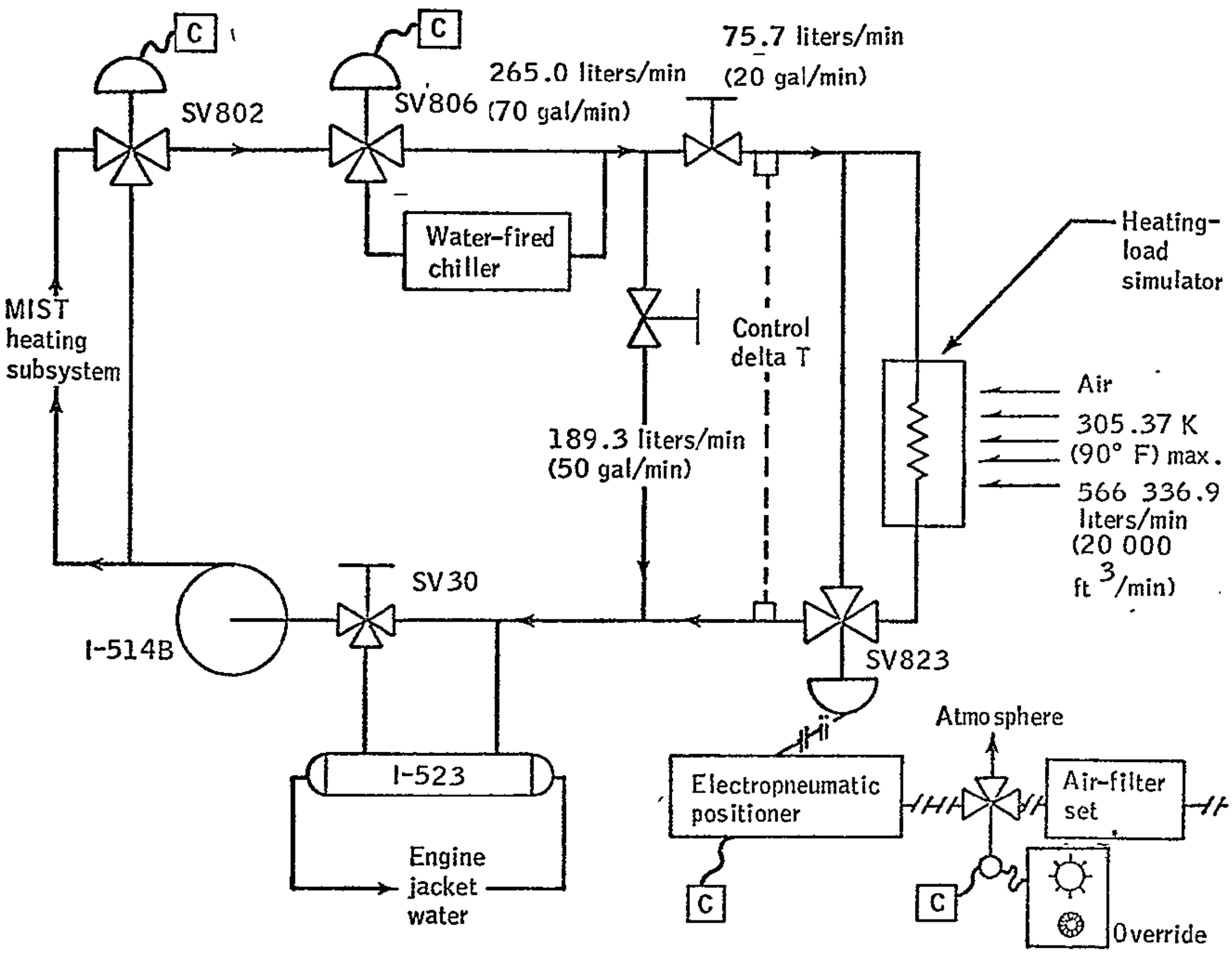
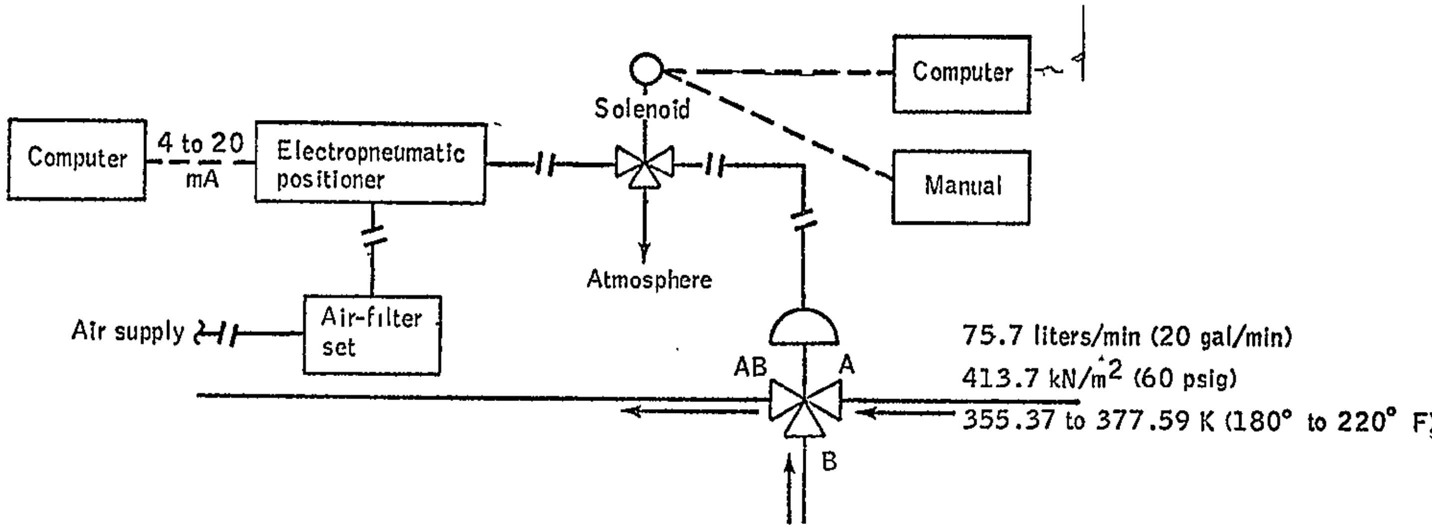


Figure 43. Heating-load-simulator control



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)

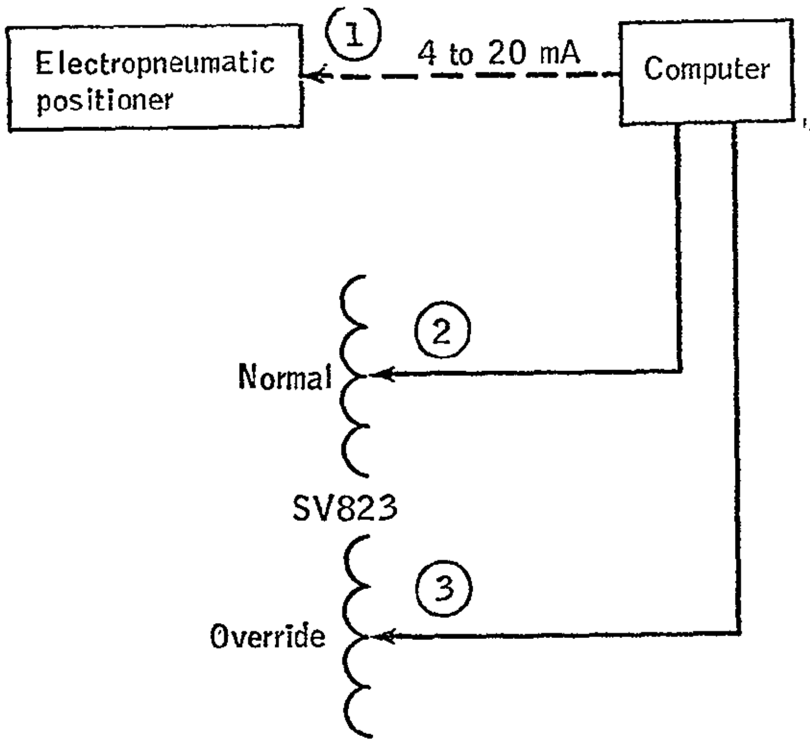
2. Electropneumatic positioner, 4- to 20-mA signal input, positioner mounted and piped to valve

3. Air-filter regulator

4. Manual control
   Operational switch (one)
   Override switch (one)
   Override light (two)

5. Computer control relay, 24 Vdc (two)

Figure 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 +24-Vdc pulse, 128 msec Nominal coil power = 1.2 W
Computer output	3. Override, SV823 +24-Vdc pulse, 128 msec

(b) Computer-electropneumatic positioner interface.

Figure 44. Concluded

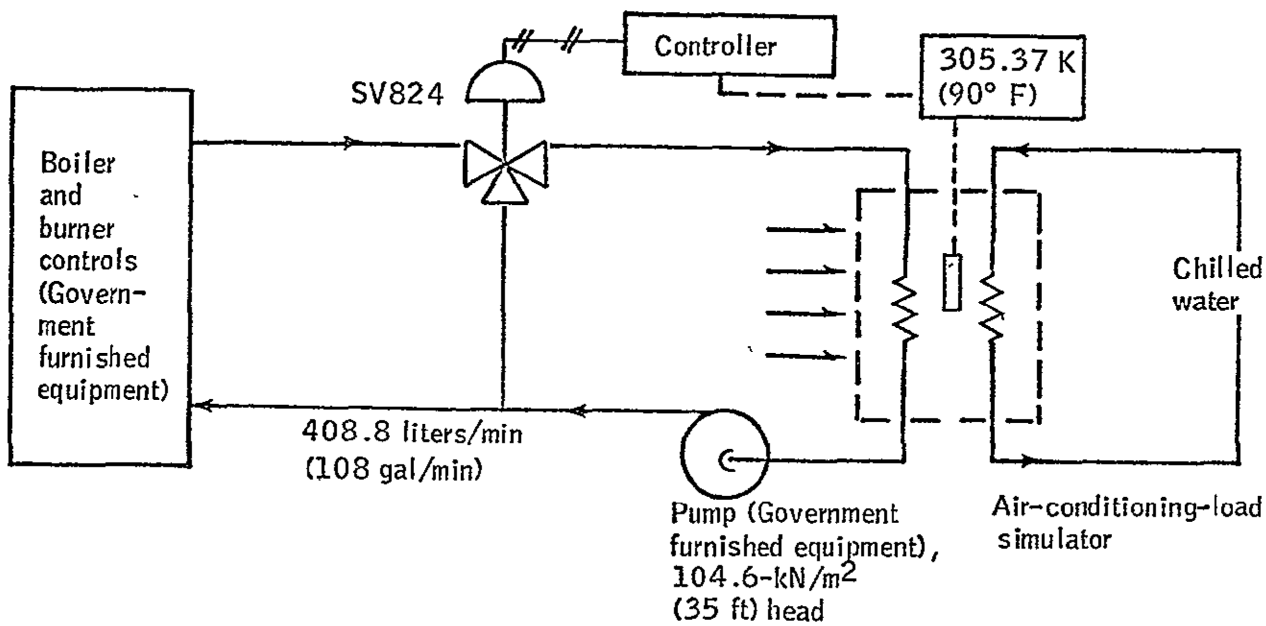
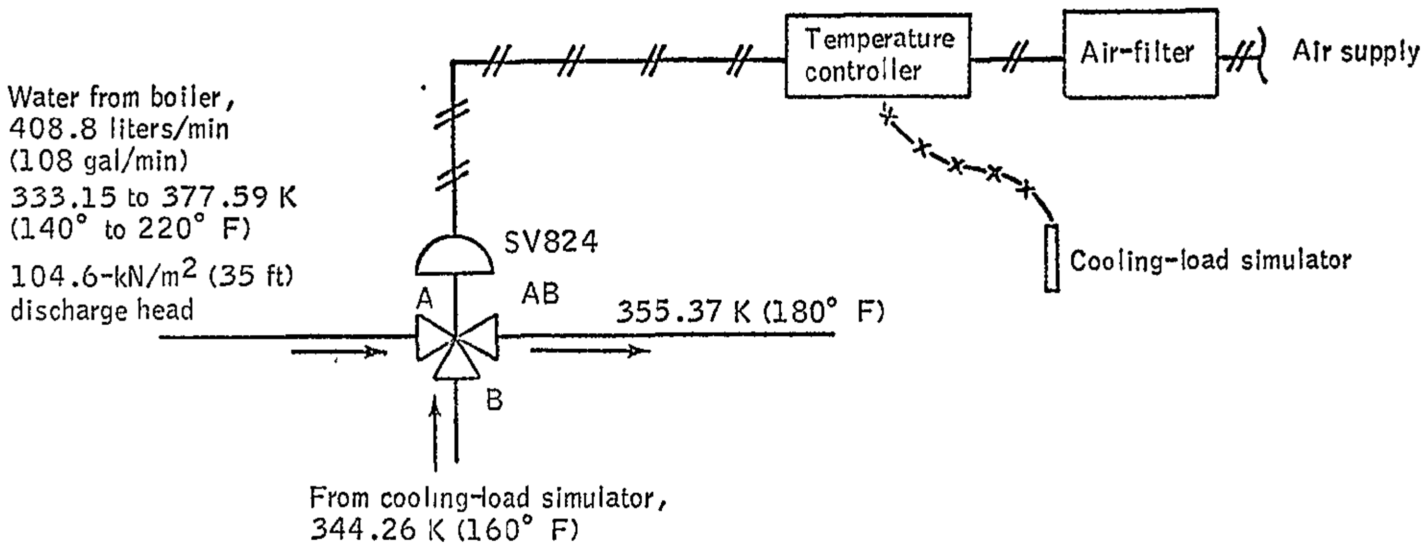


Figure 45. Boiler water temperature control



Equipment List

1. SV824 - 6.4-cm (2.5 in.), three-way diaphragm mixing valve
   Flanged connections, 861.8 kN/m^2 (125 psig) ASA
   Cast-iron body
   Stainless steel trim
   Air signal, 20.7 to 103.4 kN/m^2 (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 46. Control system listing for boiler water temperature control SV824

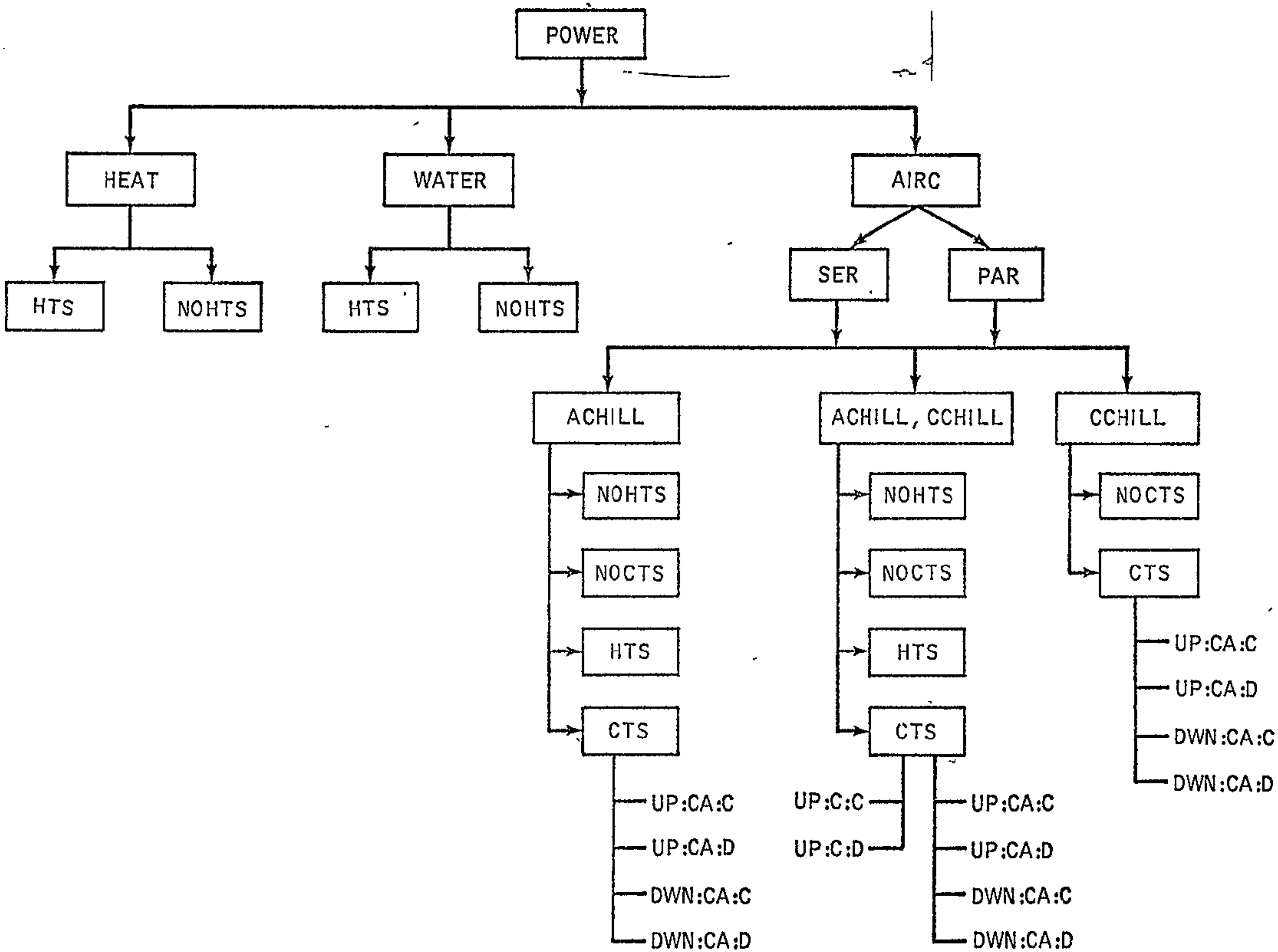
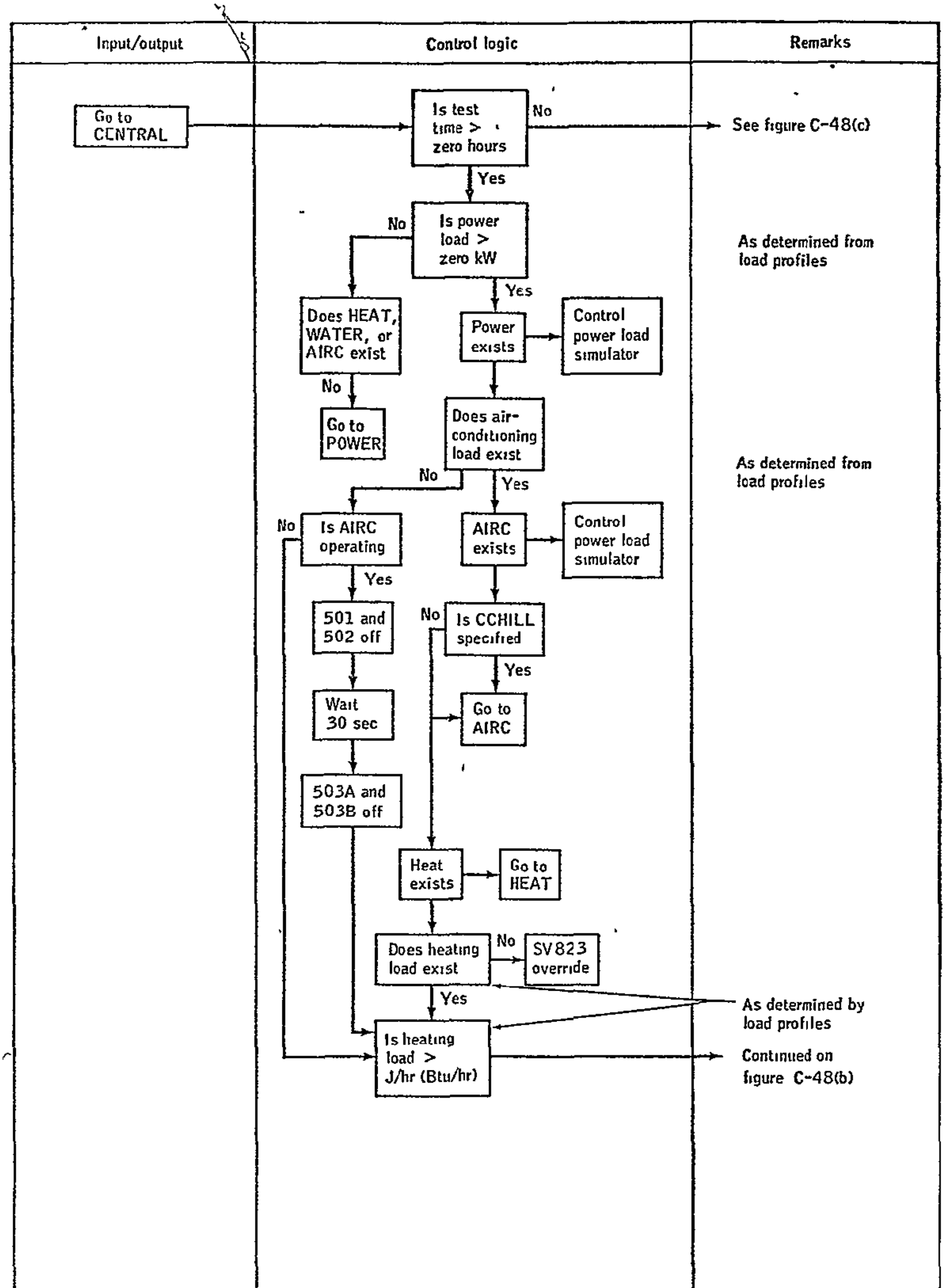
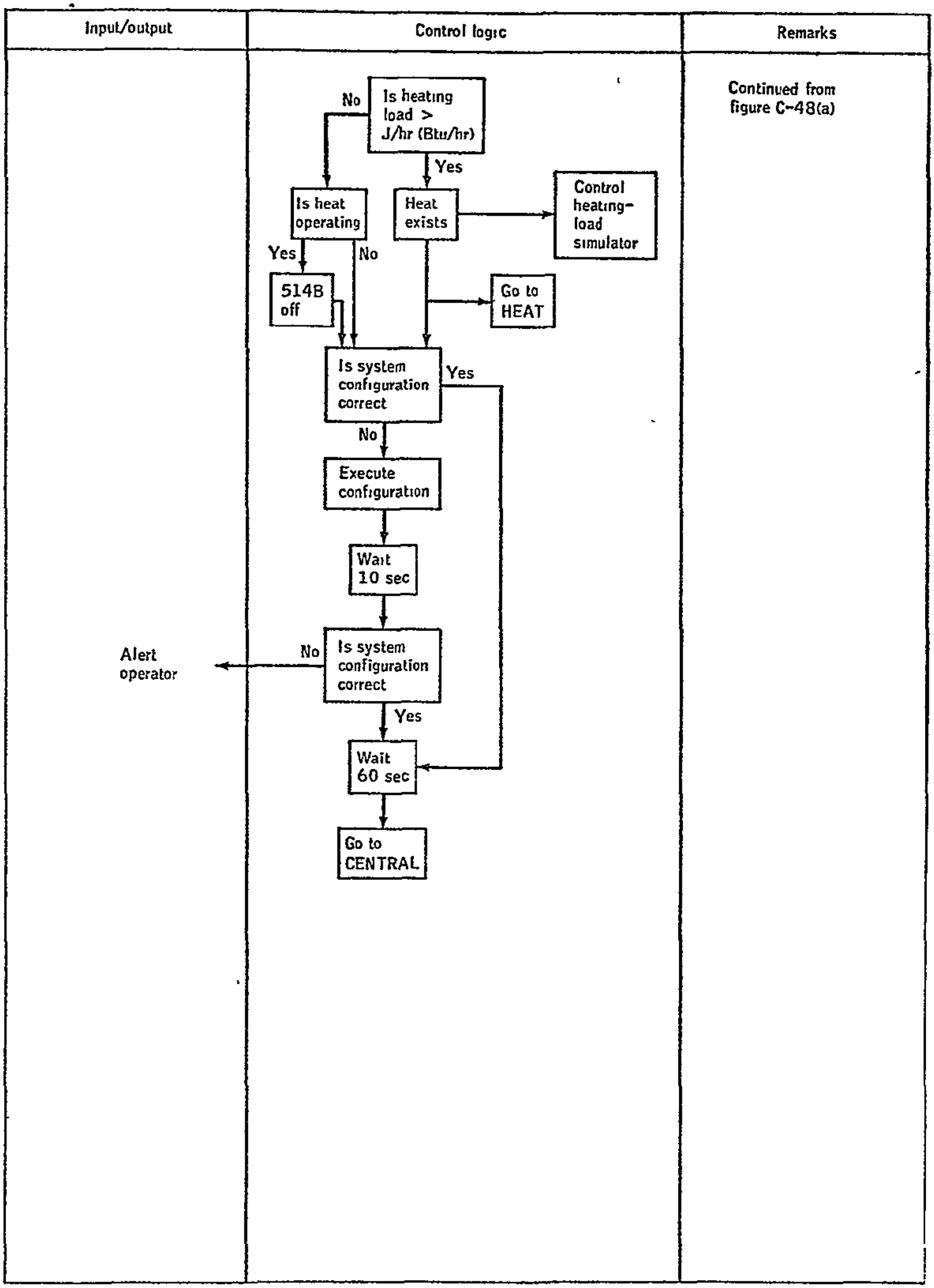


Figure 47. System operating modes



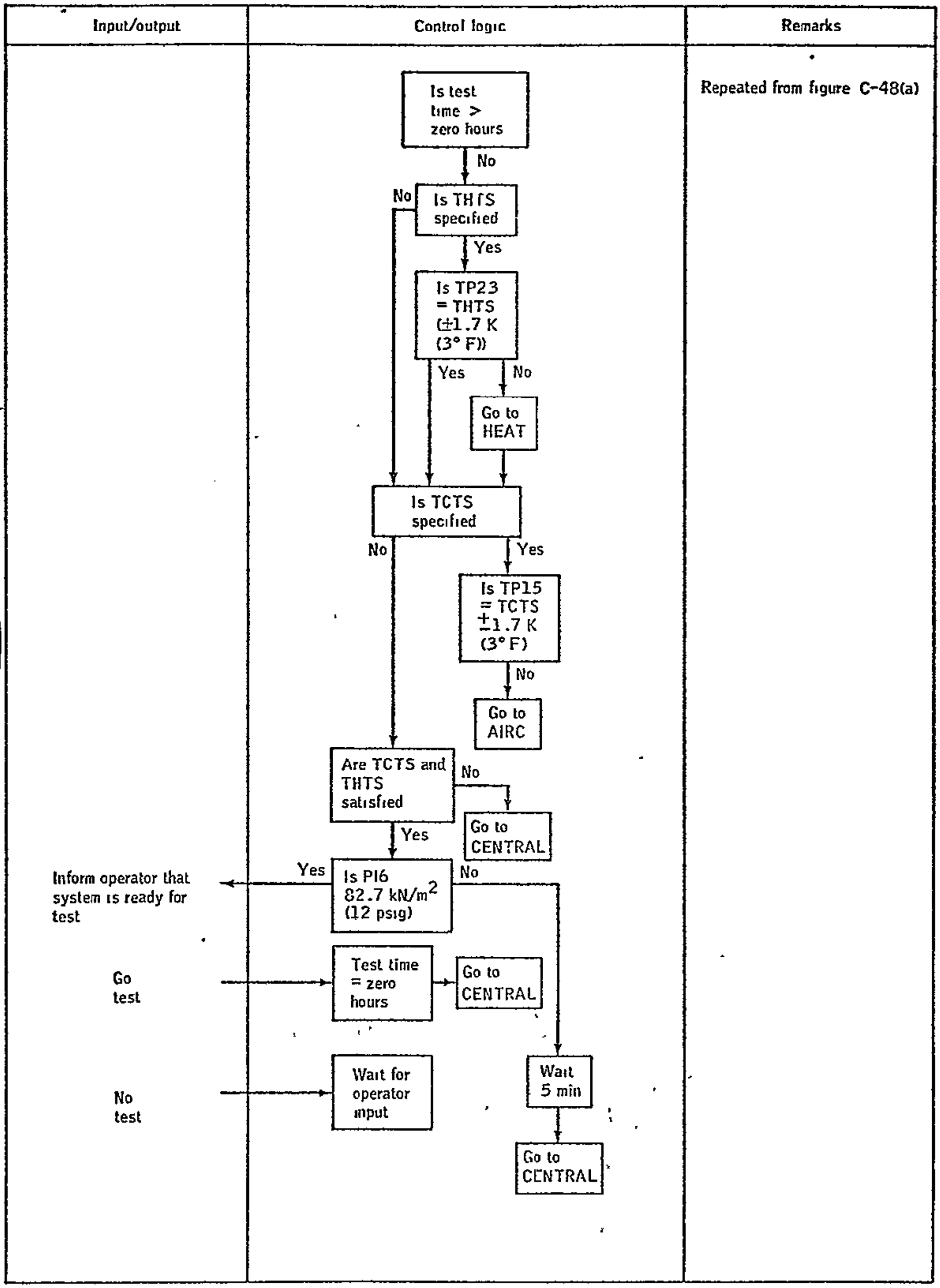
(a) Beginning of diagram.

Figure 48. Logic diagram for CENTRAL CONTROL mode



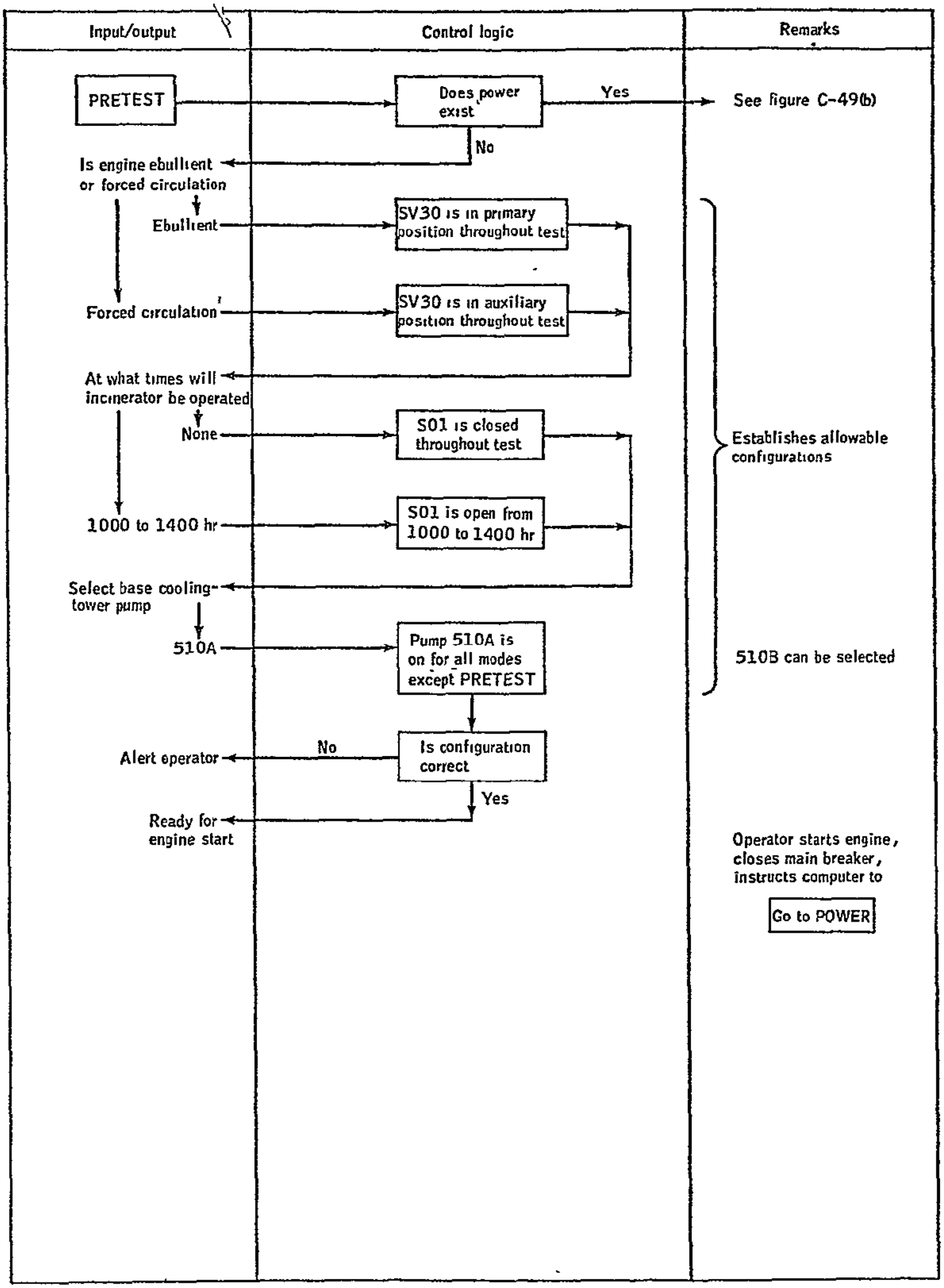
(b) Middle of diagram.

Figure 48. Continued



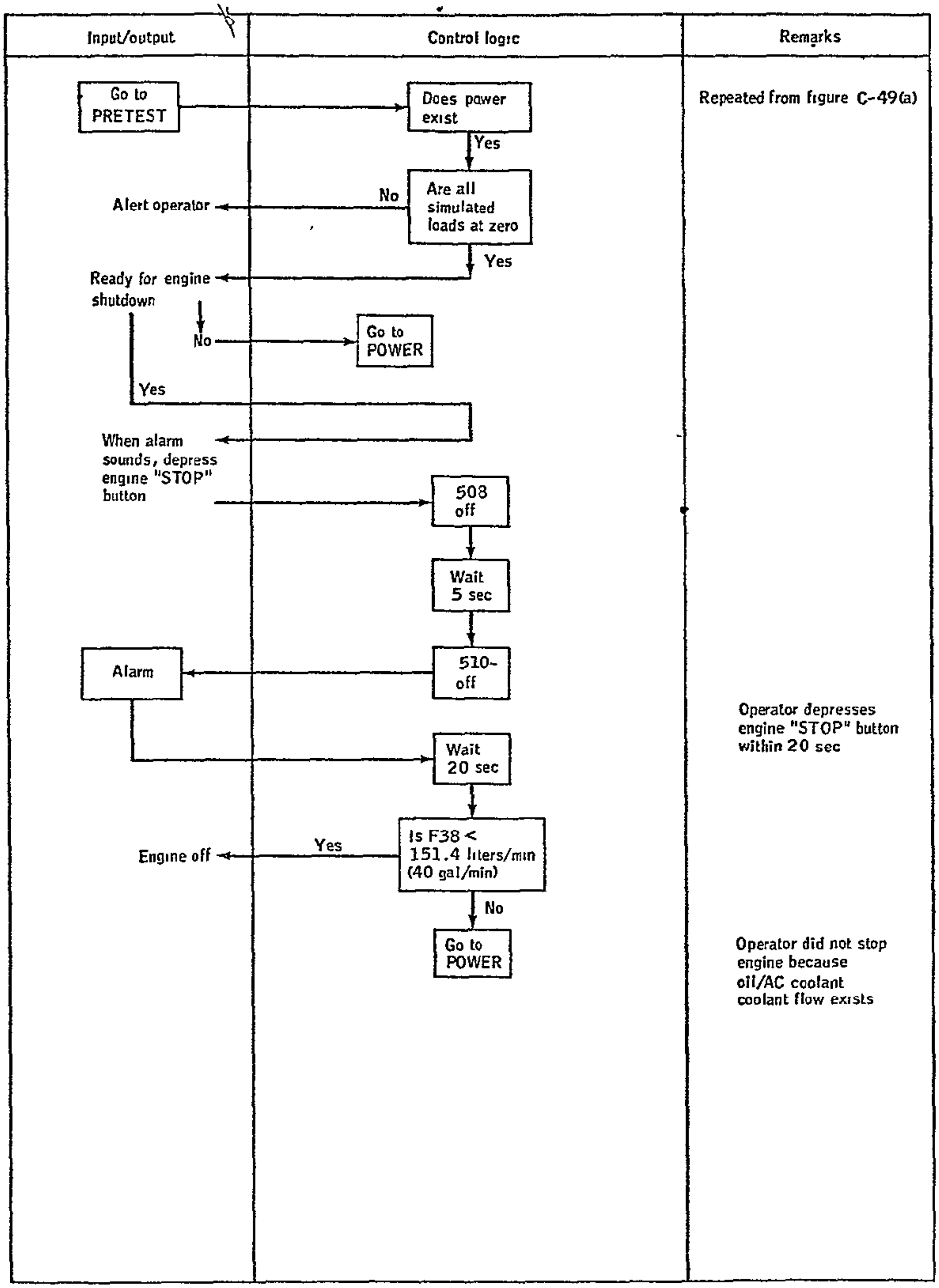
(c) Conclusion of diagram.

Figure 48. Concluded



(a) Beginning of diagram.

Figure 49. Logic diagram for PRETEST mode



(b) Conclusion of diagram.

Figure 49. Concluded

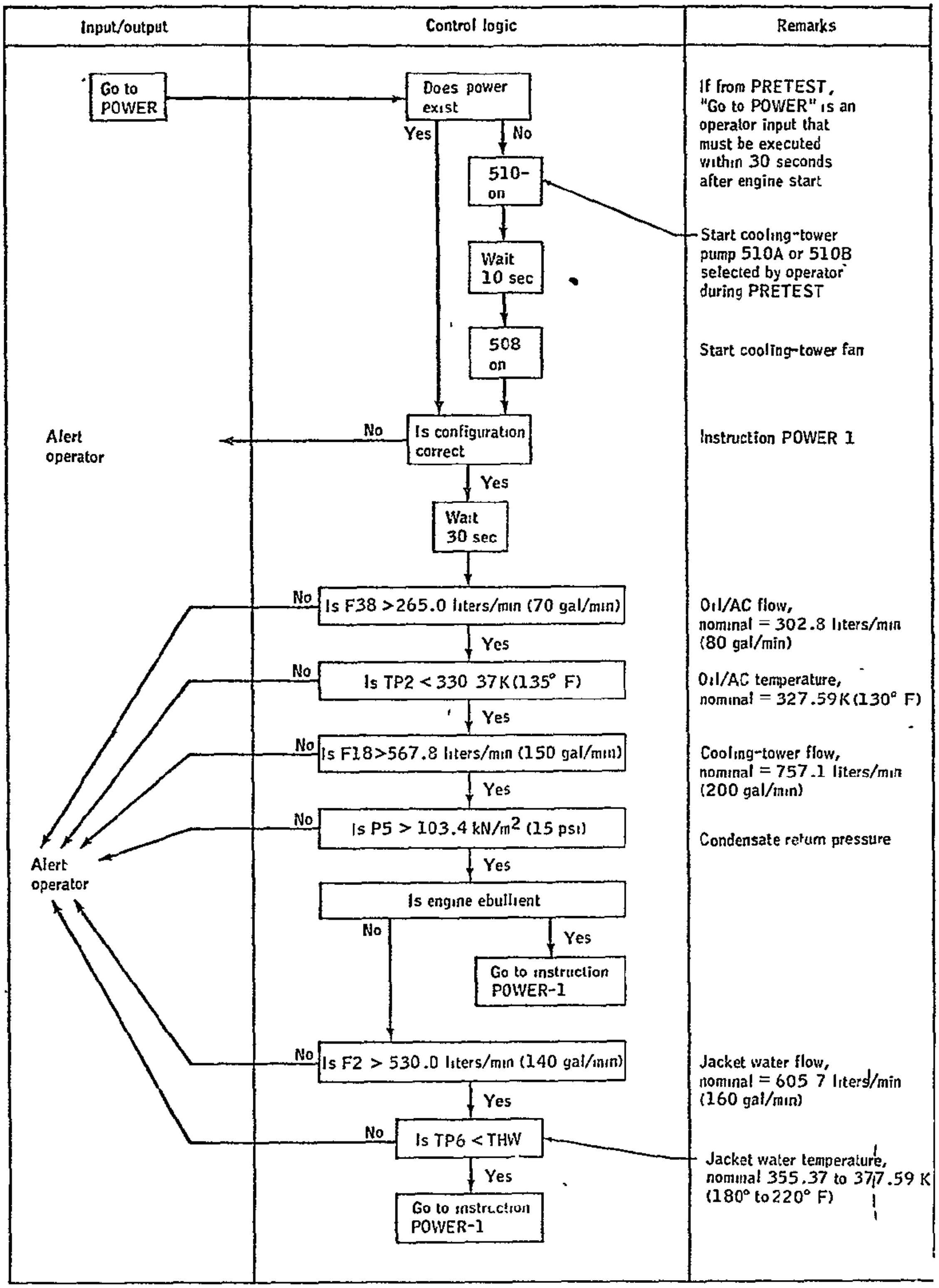
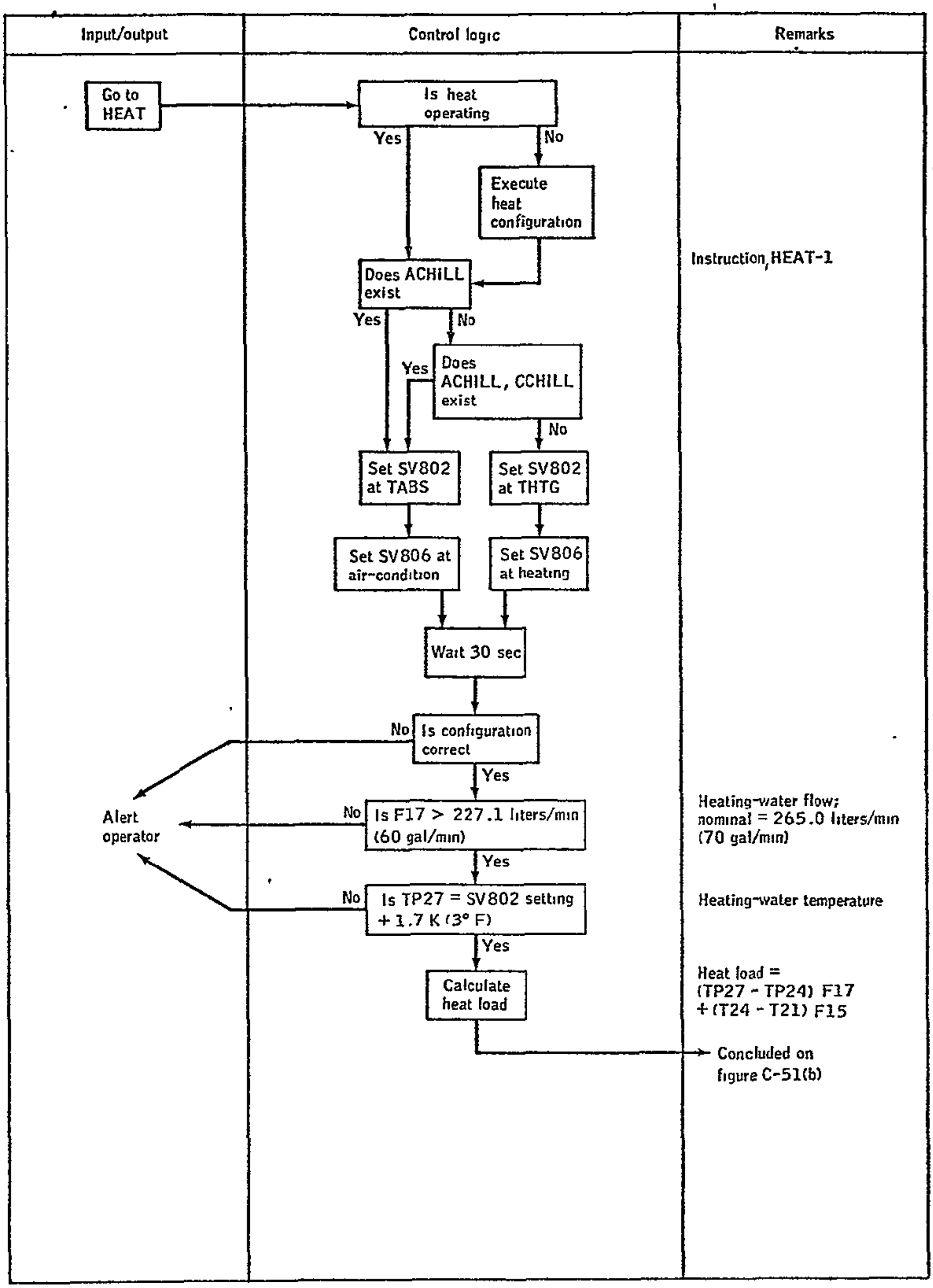
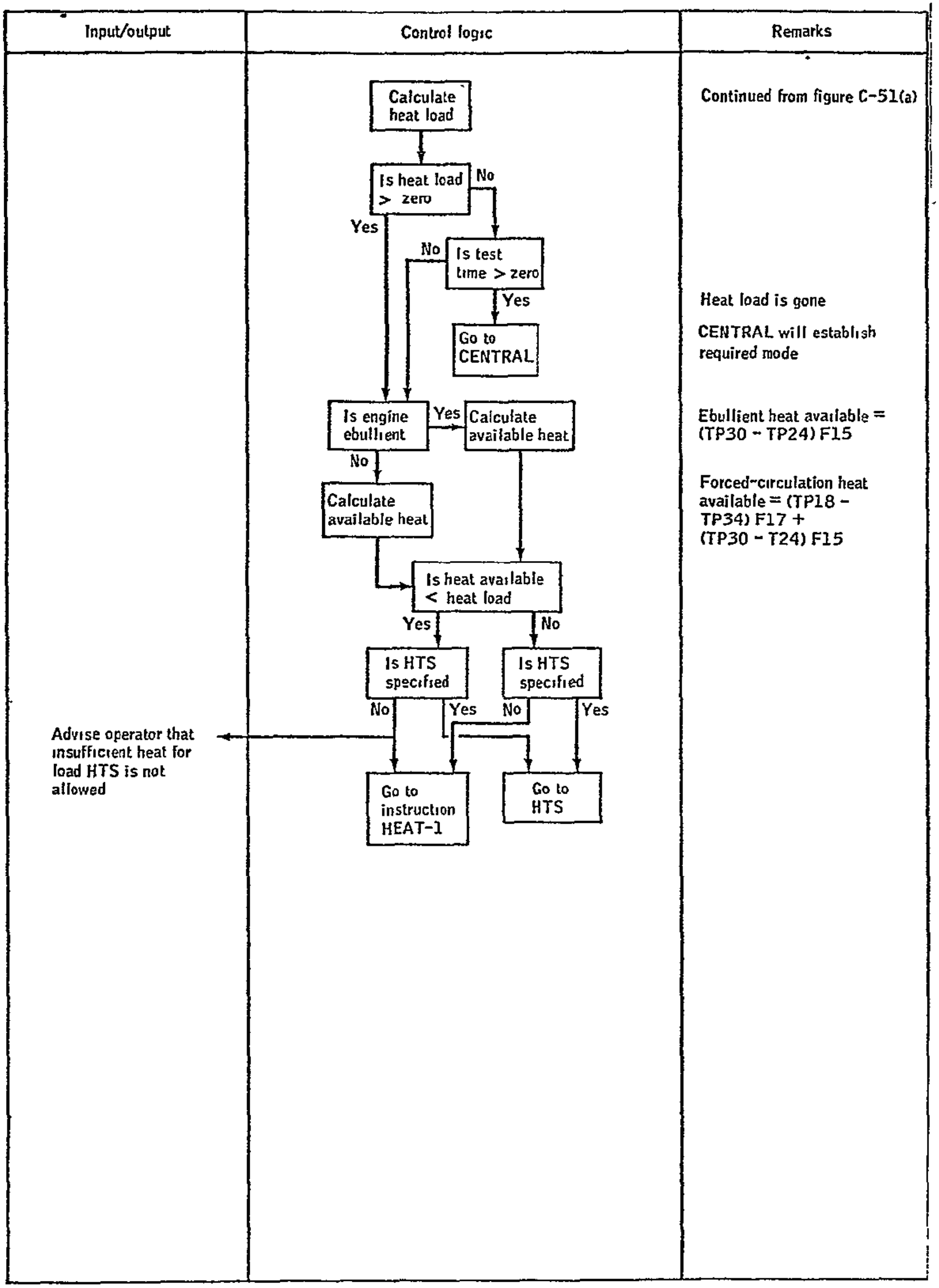


Figure 50. Logic diagram for POWER mode



(a) Beginning of diagram.

Figure 51. Logic diagram for HEAT mode



(b) Conclusion of diagram.

Figure 51. Concluded

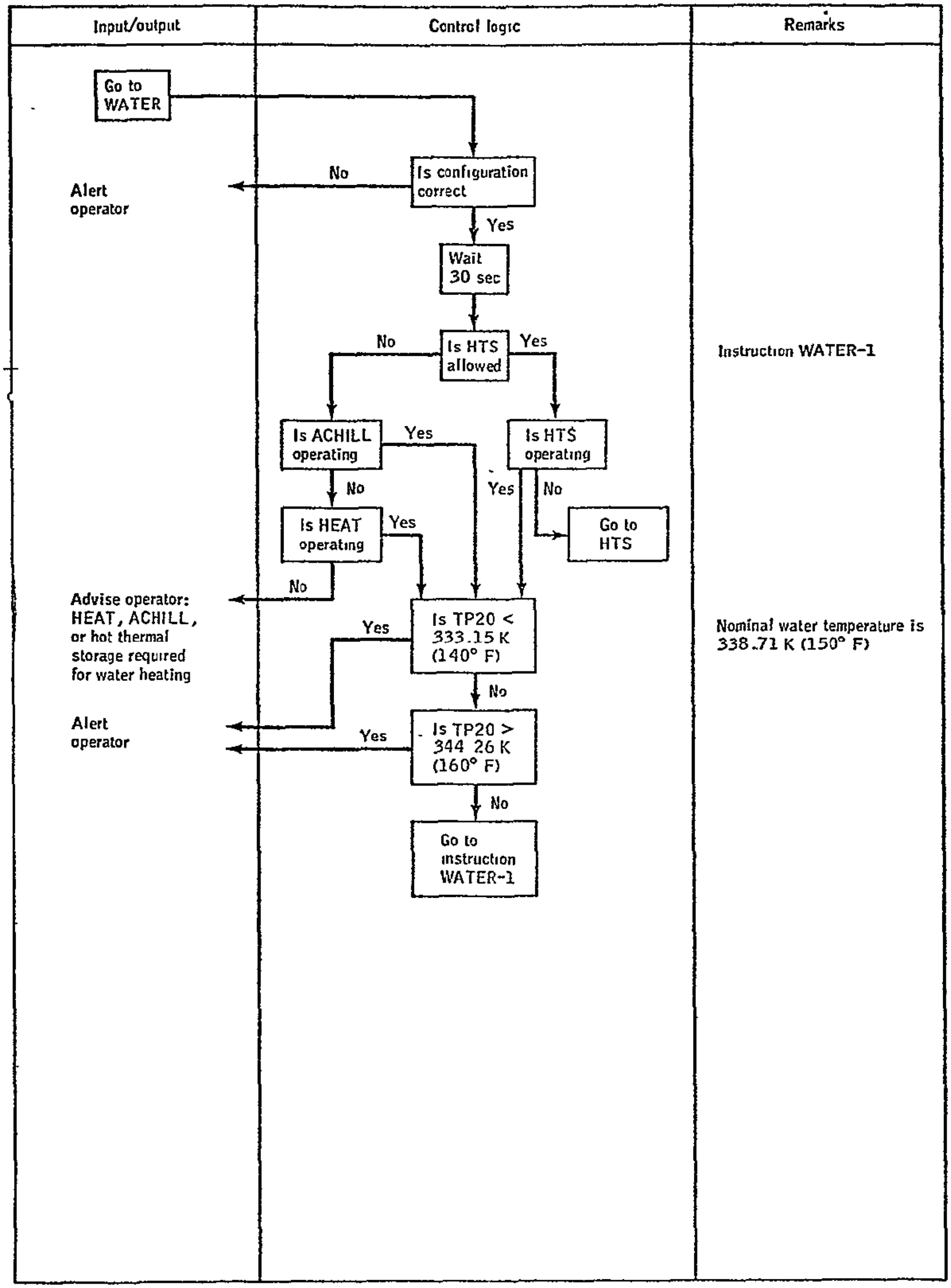
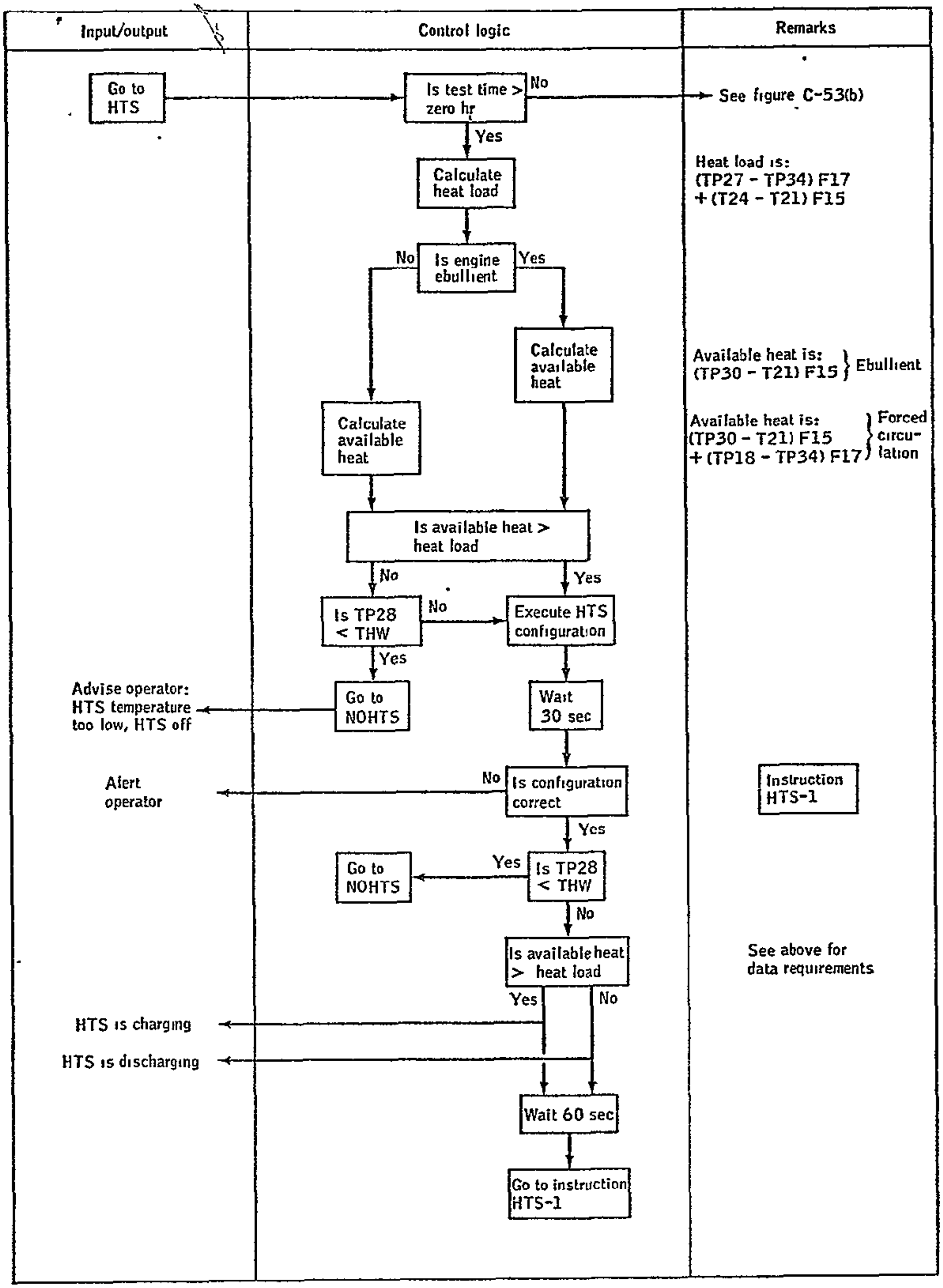
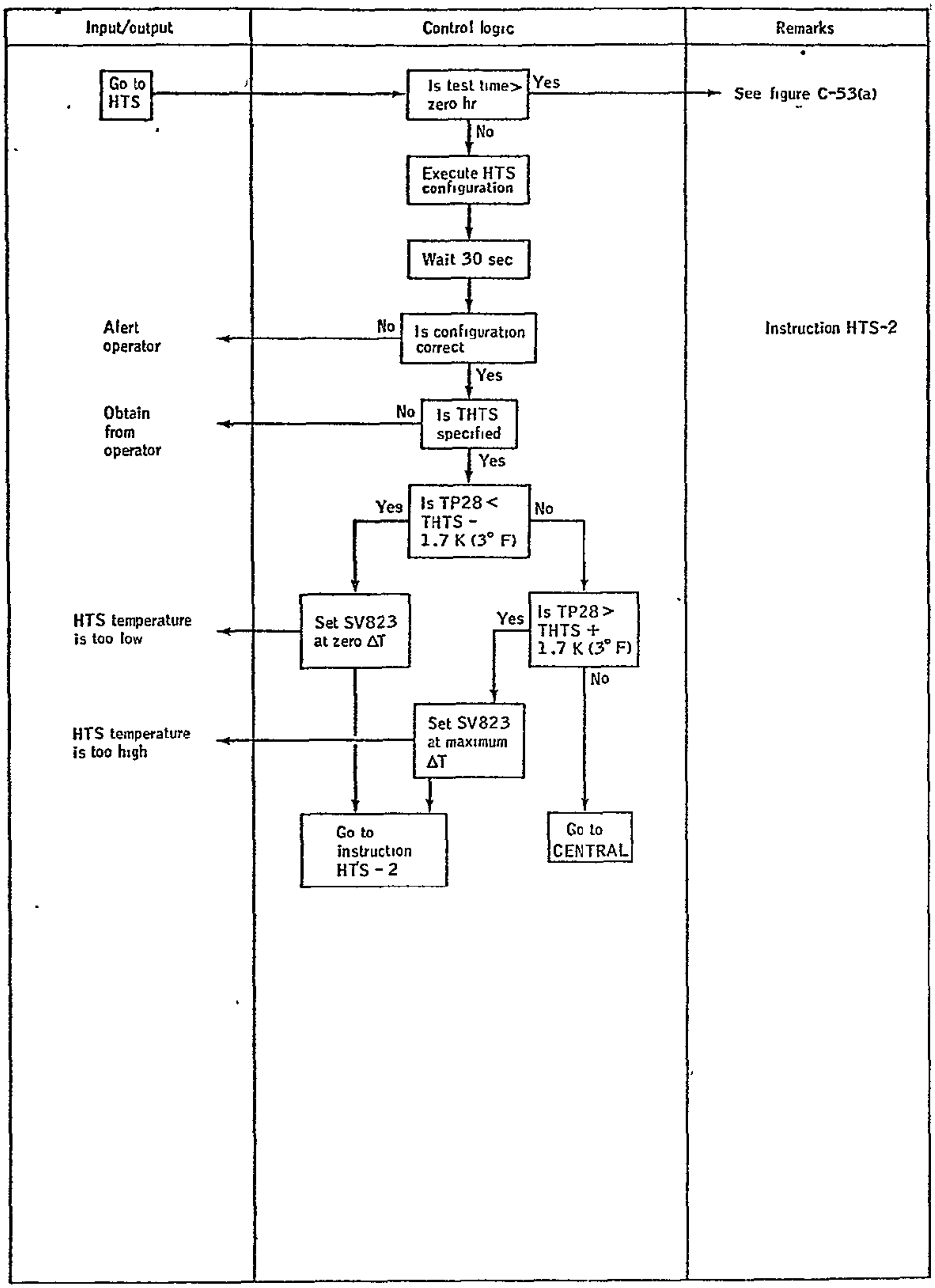


Figure 52. Logic diagram for WATER mode



(a) Beginning of diagram.

Figure 53. Logic diagram for HTS mode



(b) Conclusion of diagram.

Figure 53. Concluded

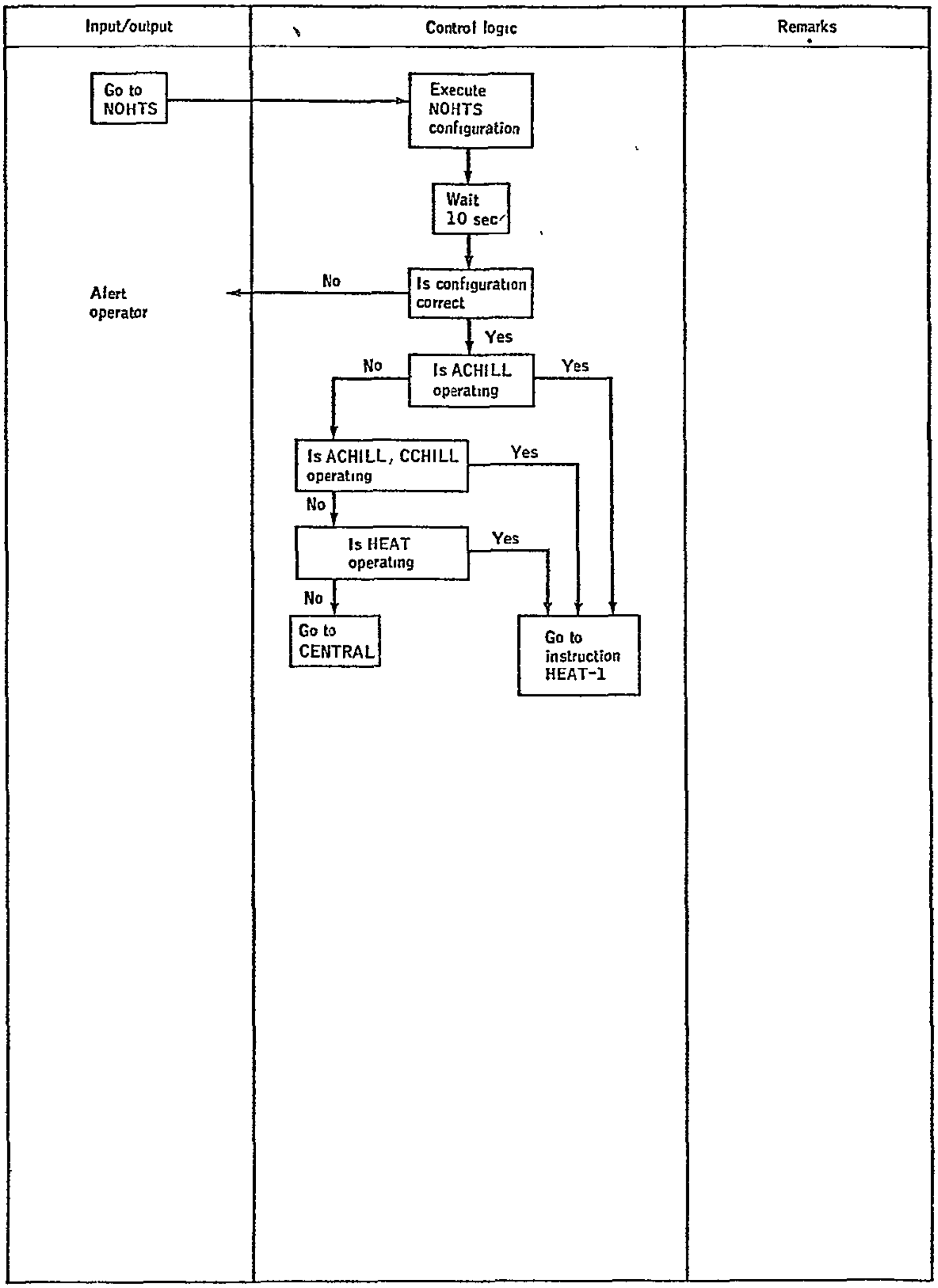


Figure 54. Logic diagram for NOHTS mode

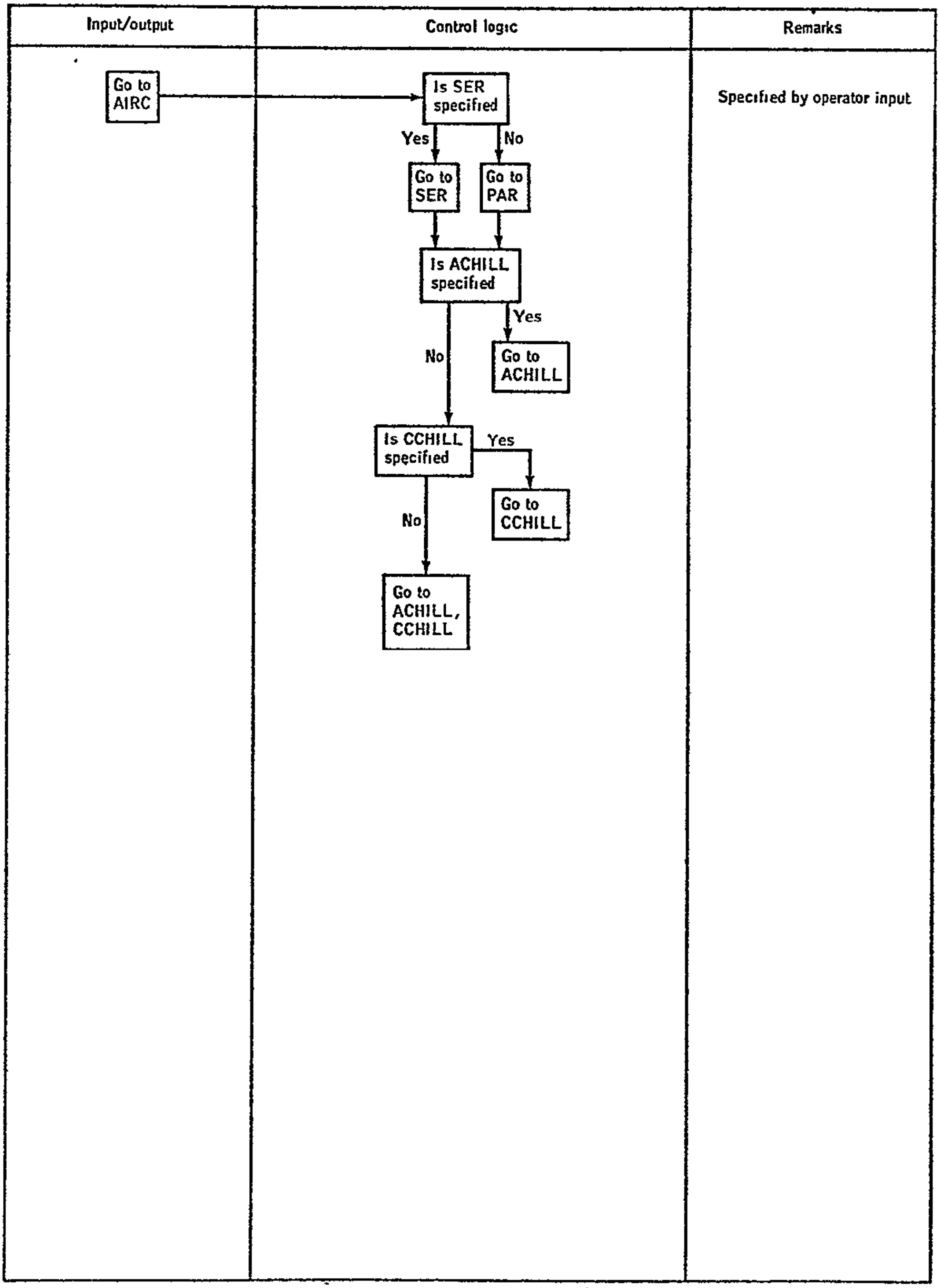


Figure 55. Logic diagram for AIRC mode

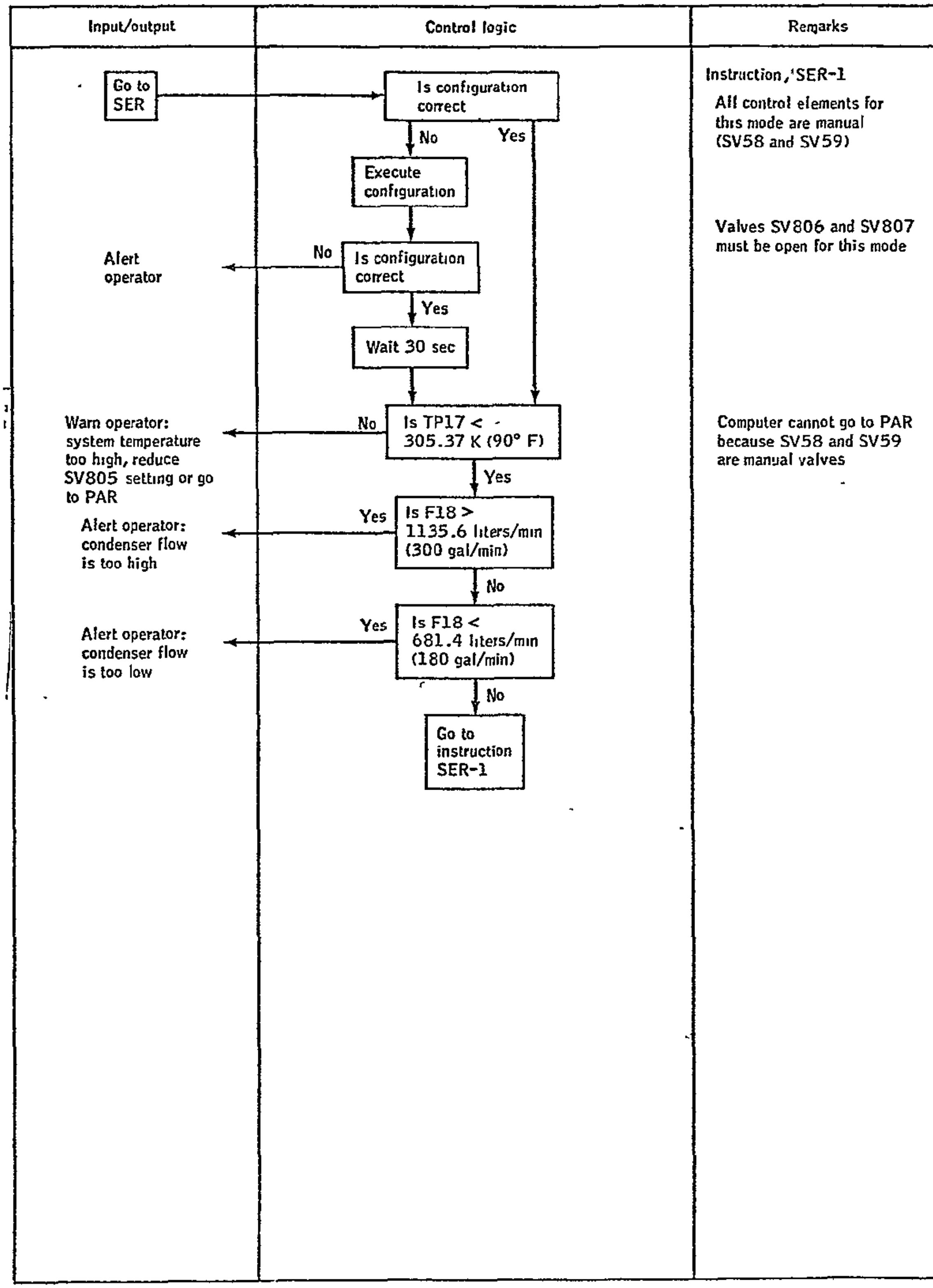
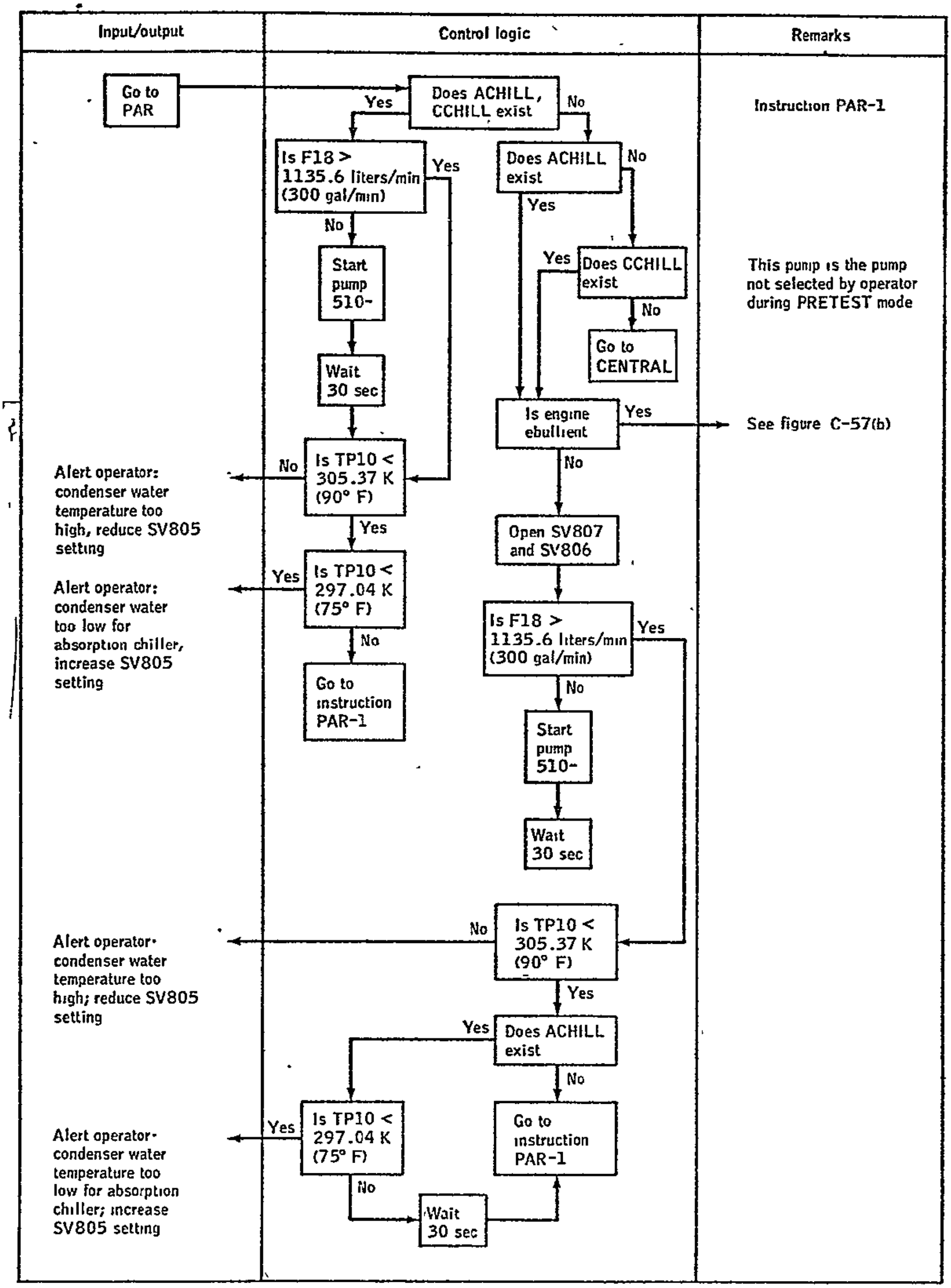
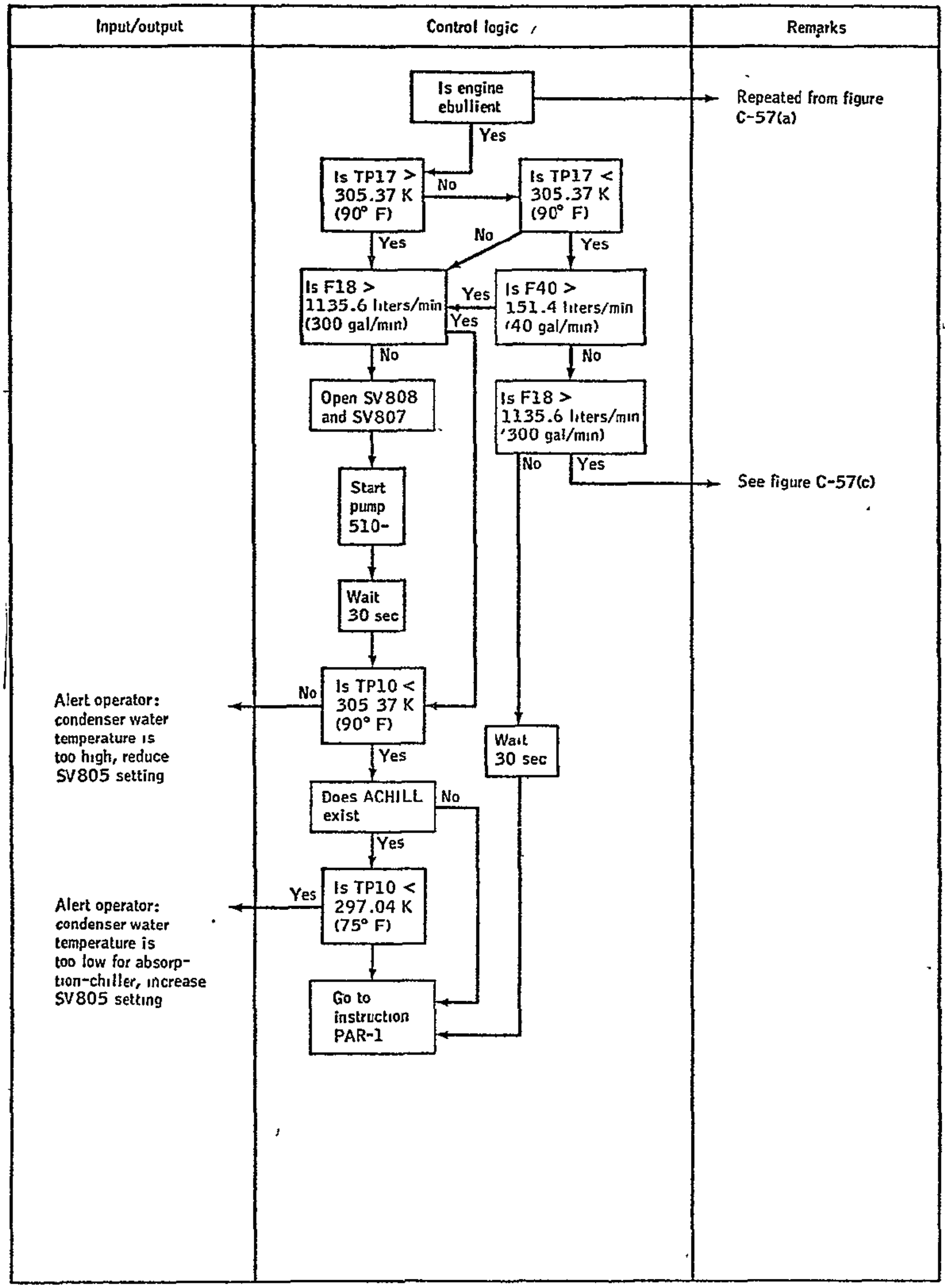


Figure 56. Logic diagram for SER mode



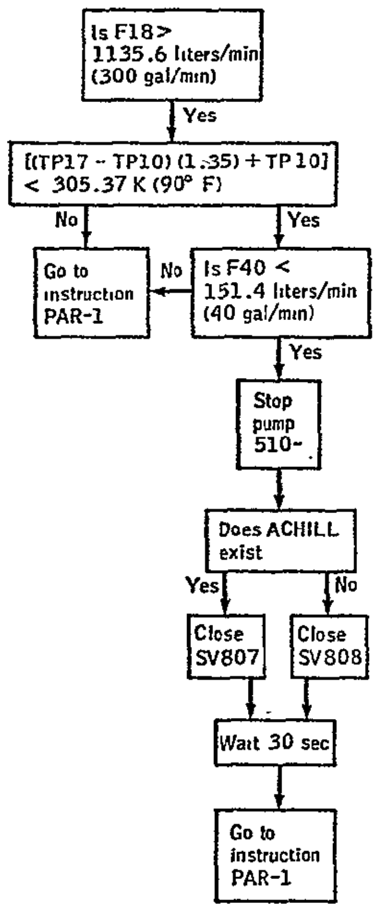
(a) Beginning of diagram.

Figure 57. Logic diagram for PAR mode



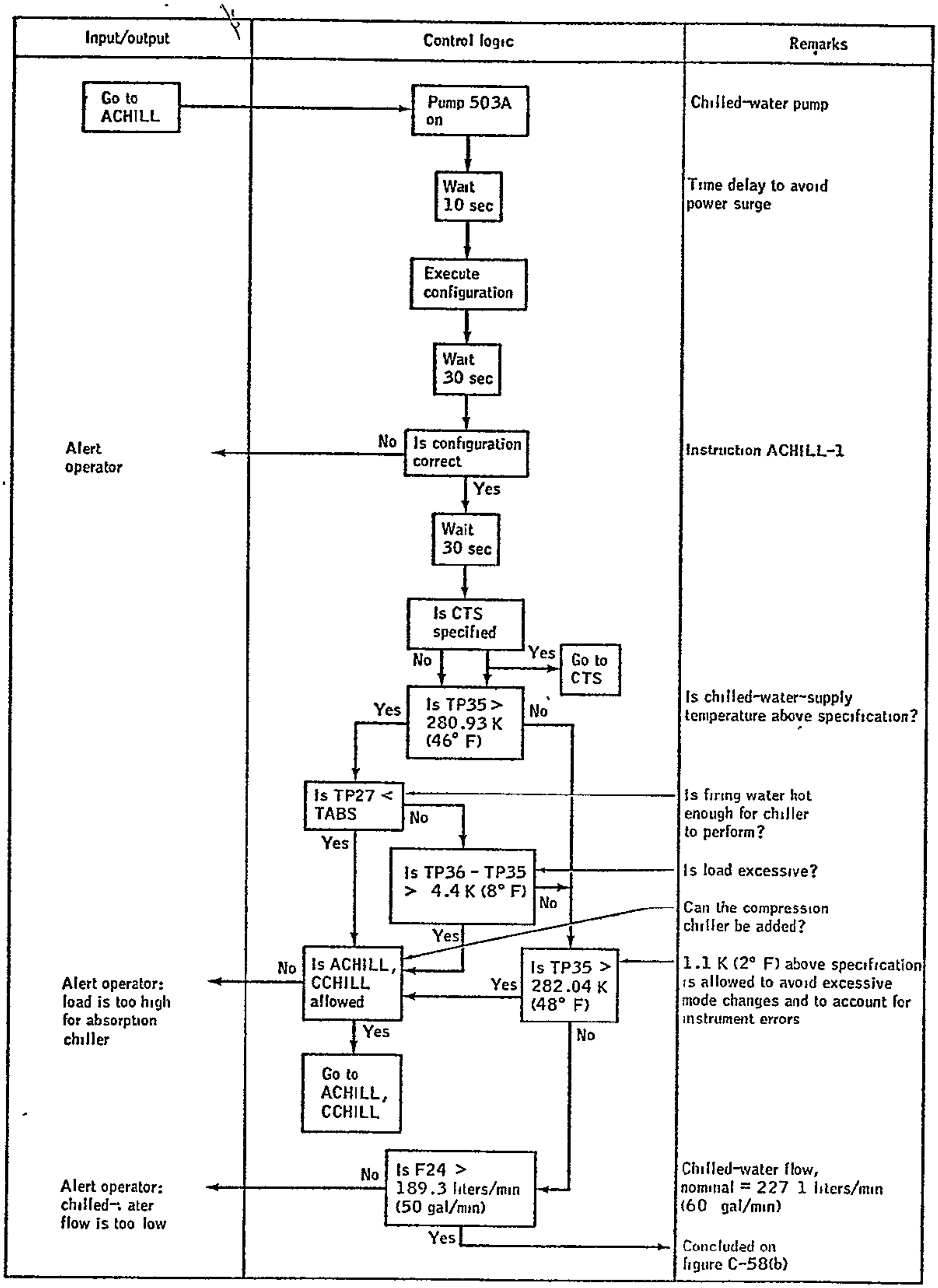
(b) Middle of diagram.

Figure 57. Continued

Input/output	Control logic	Remarks
		Repeated from figure C-57(b) This pump is the pump not selected by operator during PRETEST mode

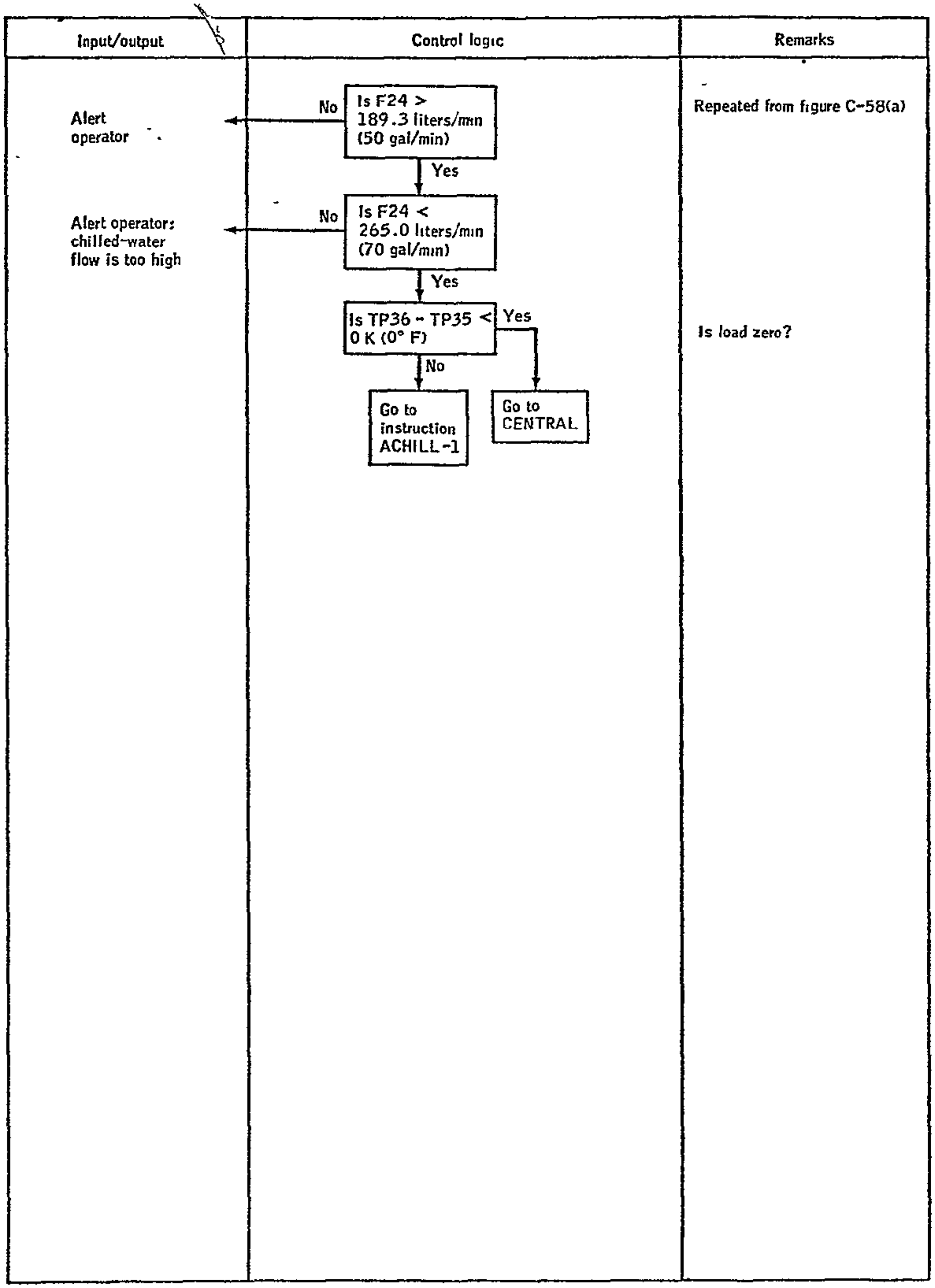
(c) Conclusion of diagram.

Figure 57. Concluded



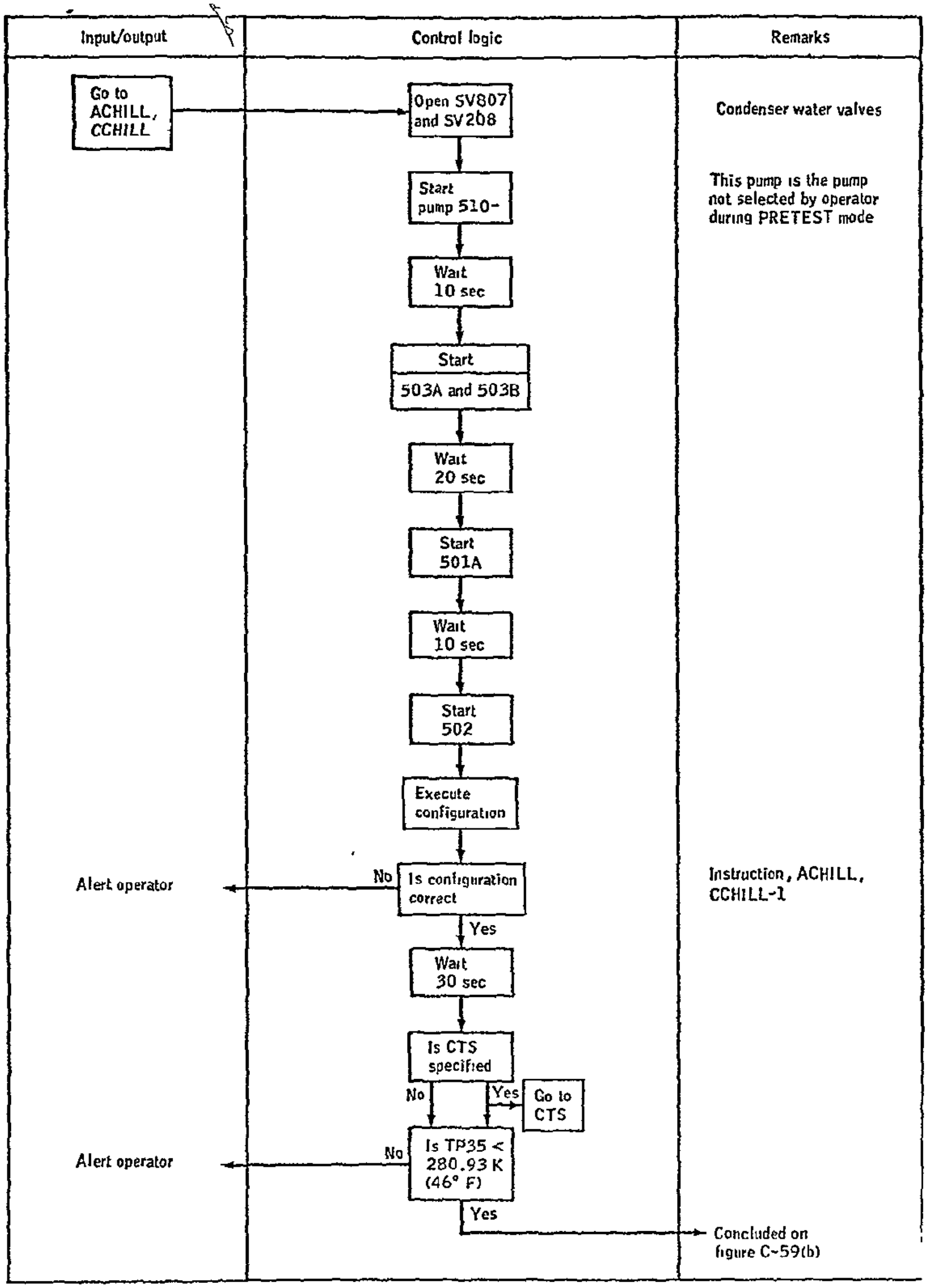
(a) Beginning of diagram.

Figure 58. Logic diagram for ACHILL mode



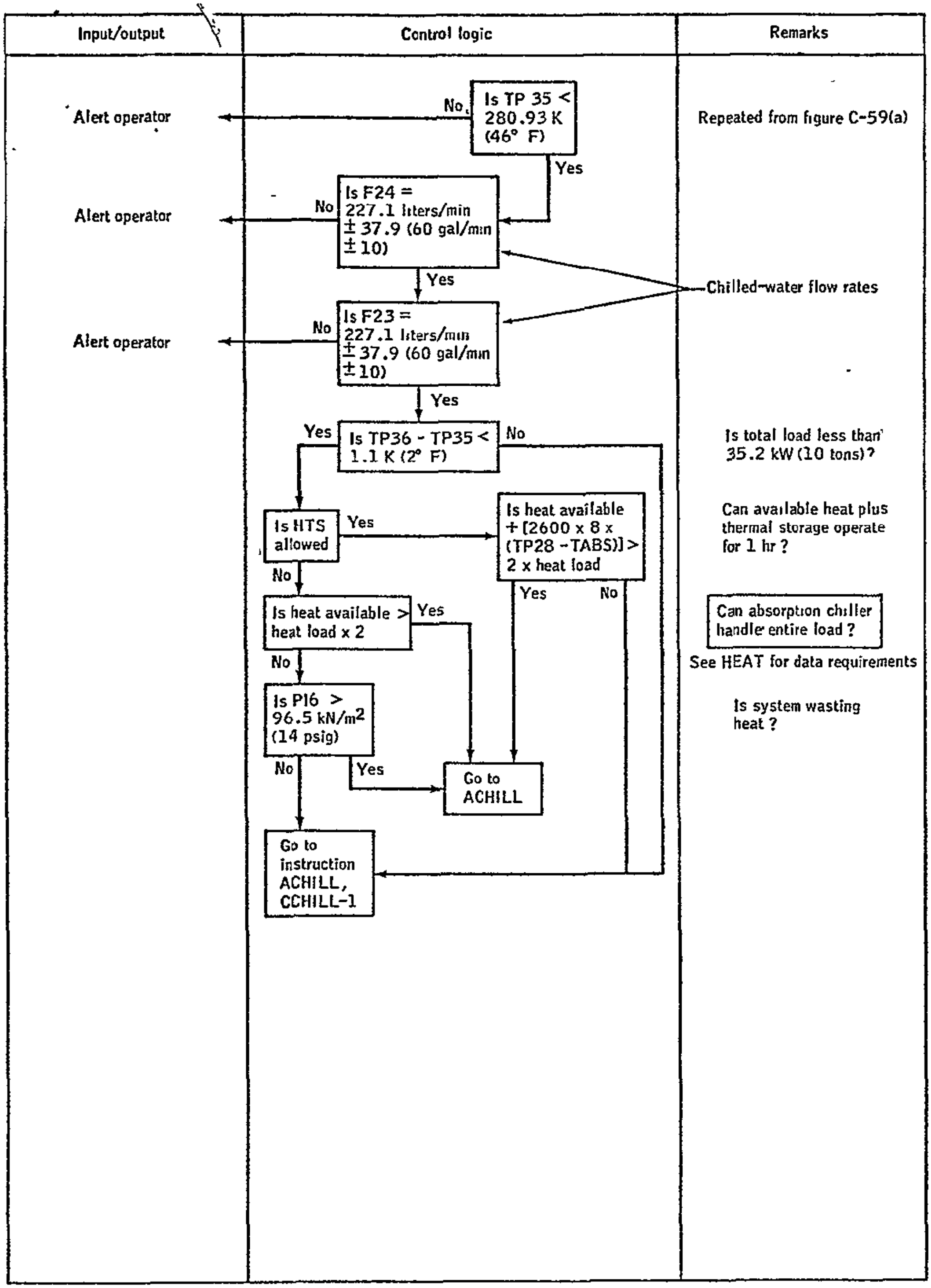
(b) Conclusion of diagram.

Figure 58. Concluded



(a) Beginning of diagram.

Figure 59. Logic diagram for ACHILL, CCHILL mode



(b) Conclusion of diagram.

Figure 59. Concluded

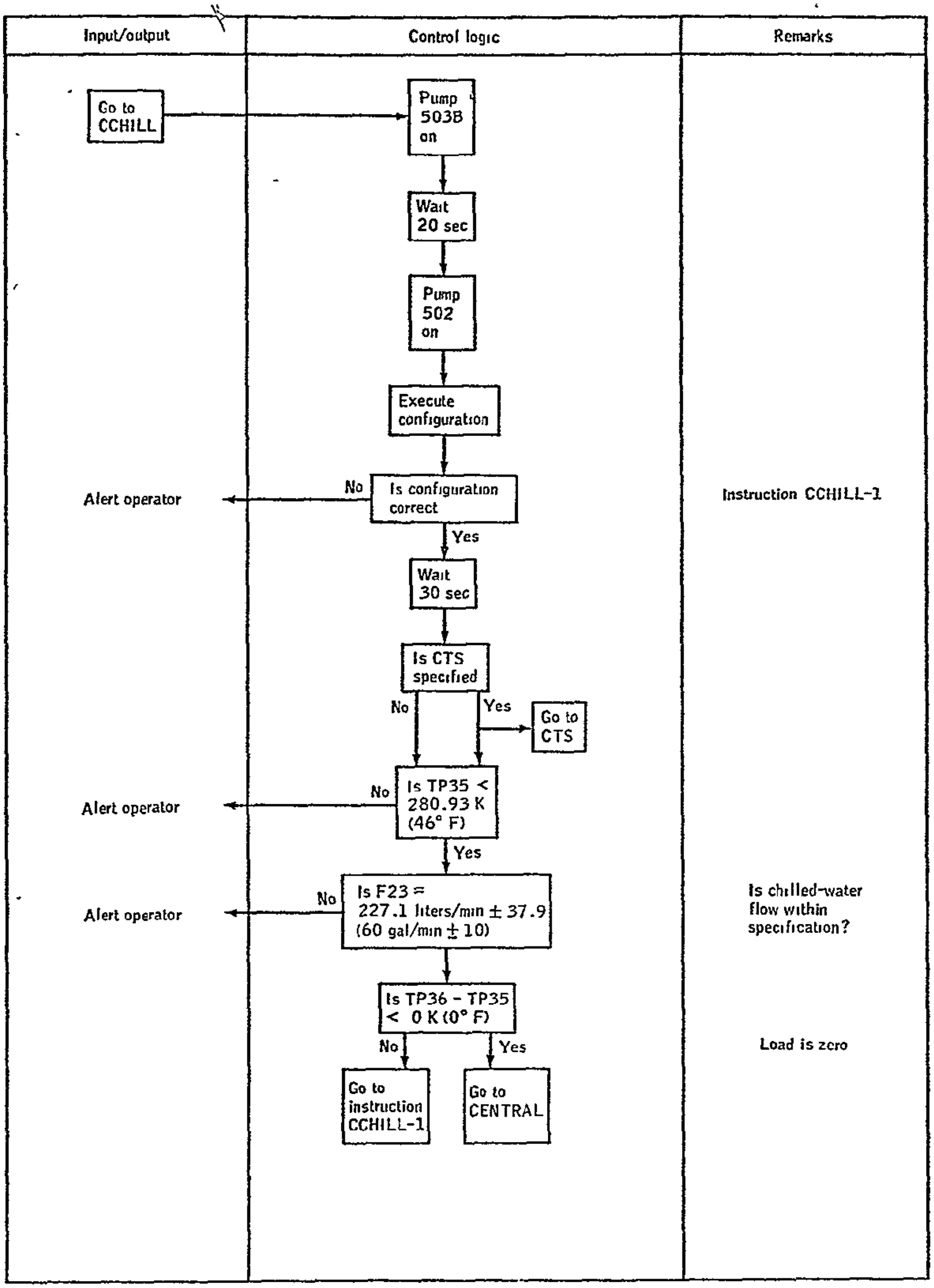
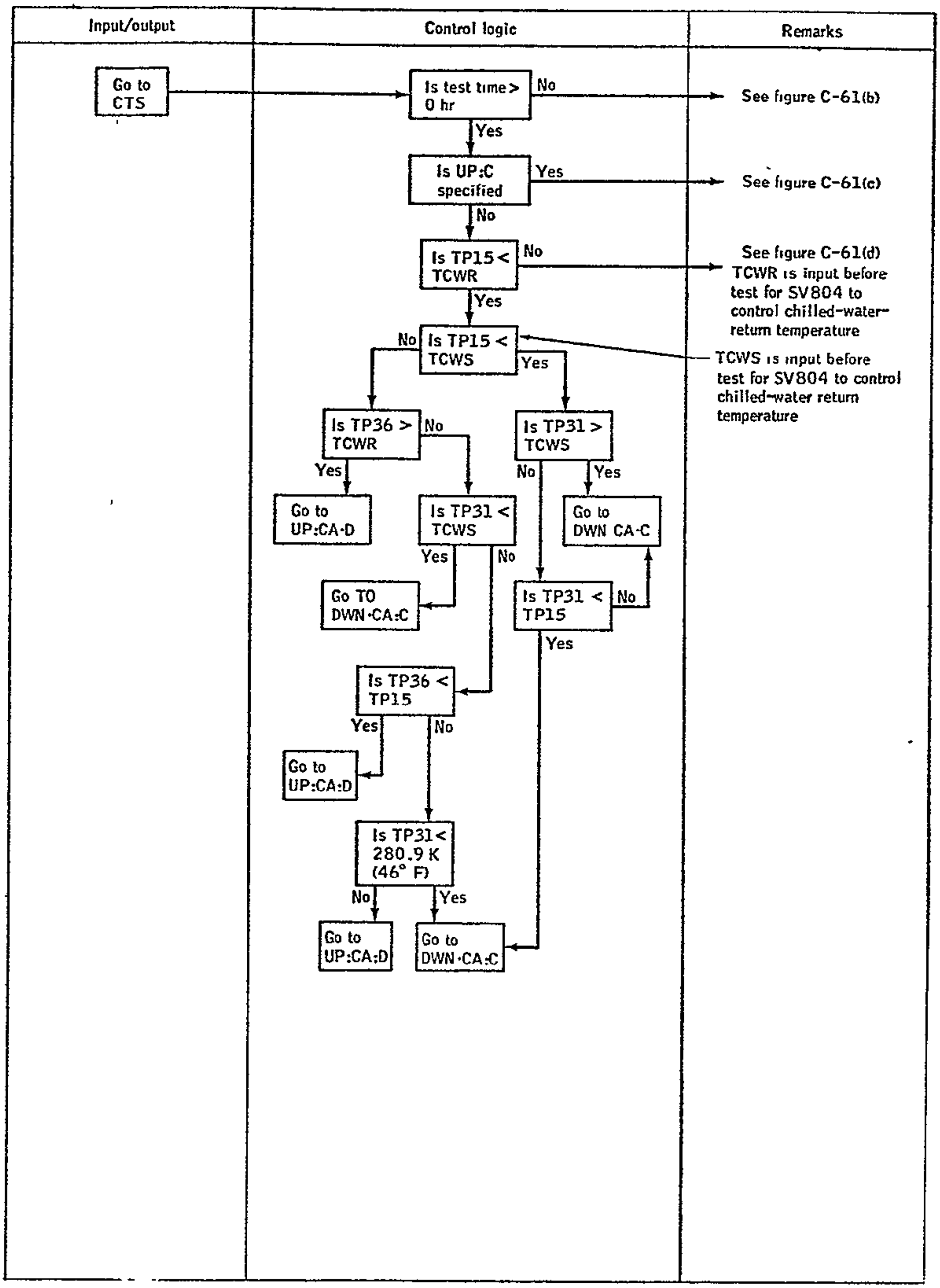
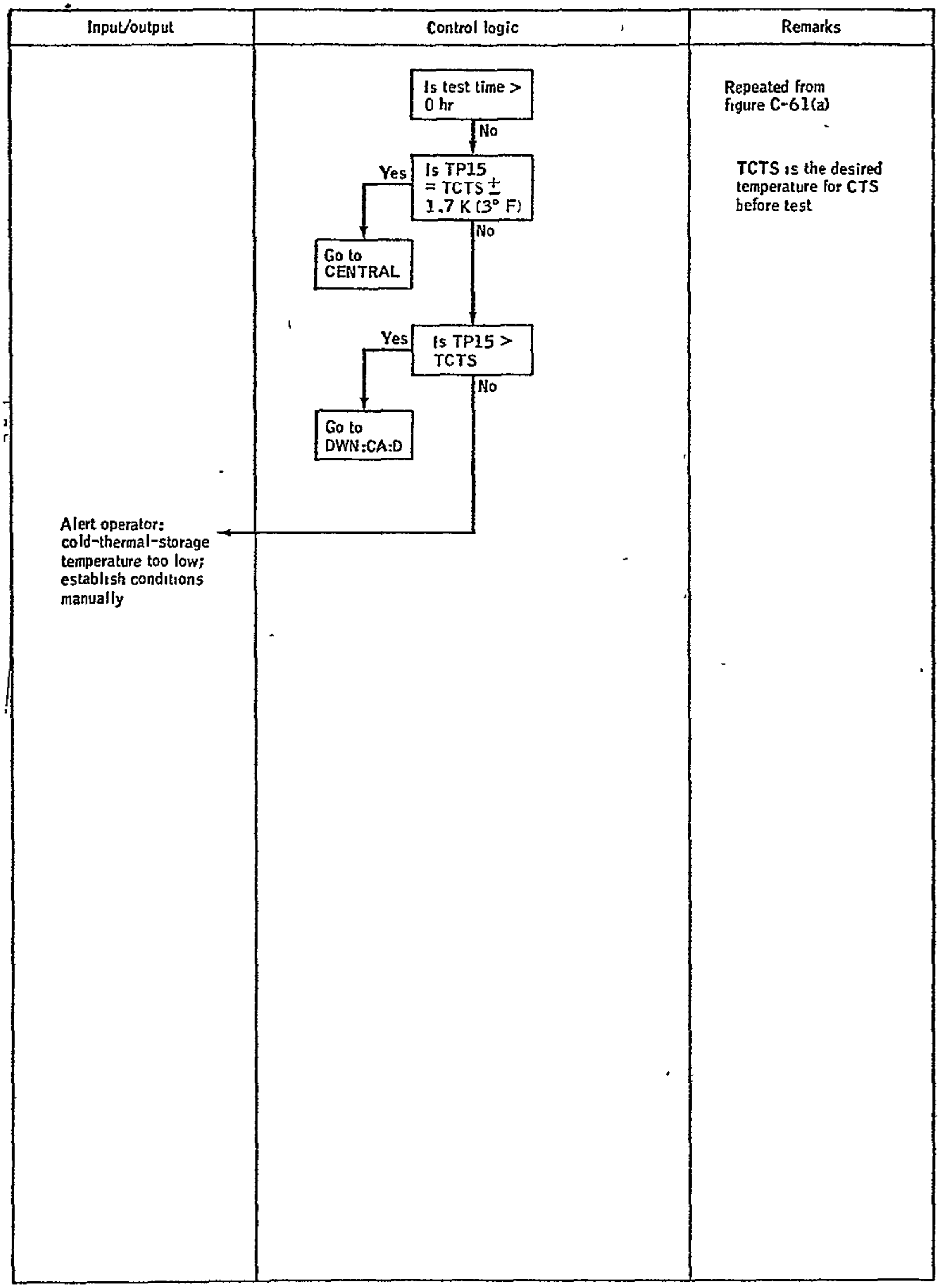


Figure 60. Logic diagram for CCHILL mode



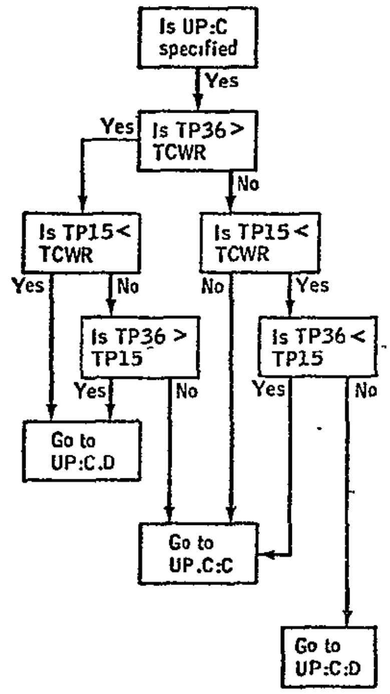
(a) Beginning of diagram.

Figure 61. Logic diagram for CTS mode



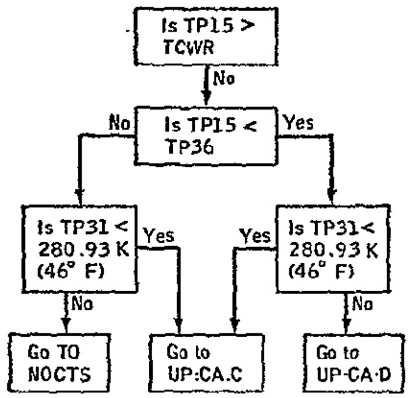
(b) Continuation of diagram.

Figure 61. Continued

Input/output	Control logic	Remarks
		Repeated from figure C-61(a)

(c) Continuation of diagram.

Figure 61. Continued

Input/output	Control logic	Remarks
		Repeated from figure C-61(a)

(d) Conclusion of diagram.

Figure 61. Concluded

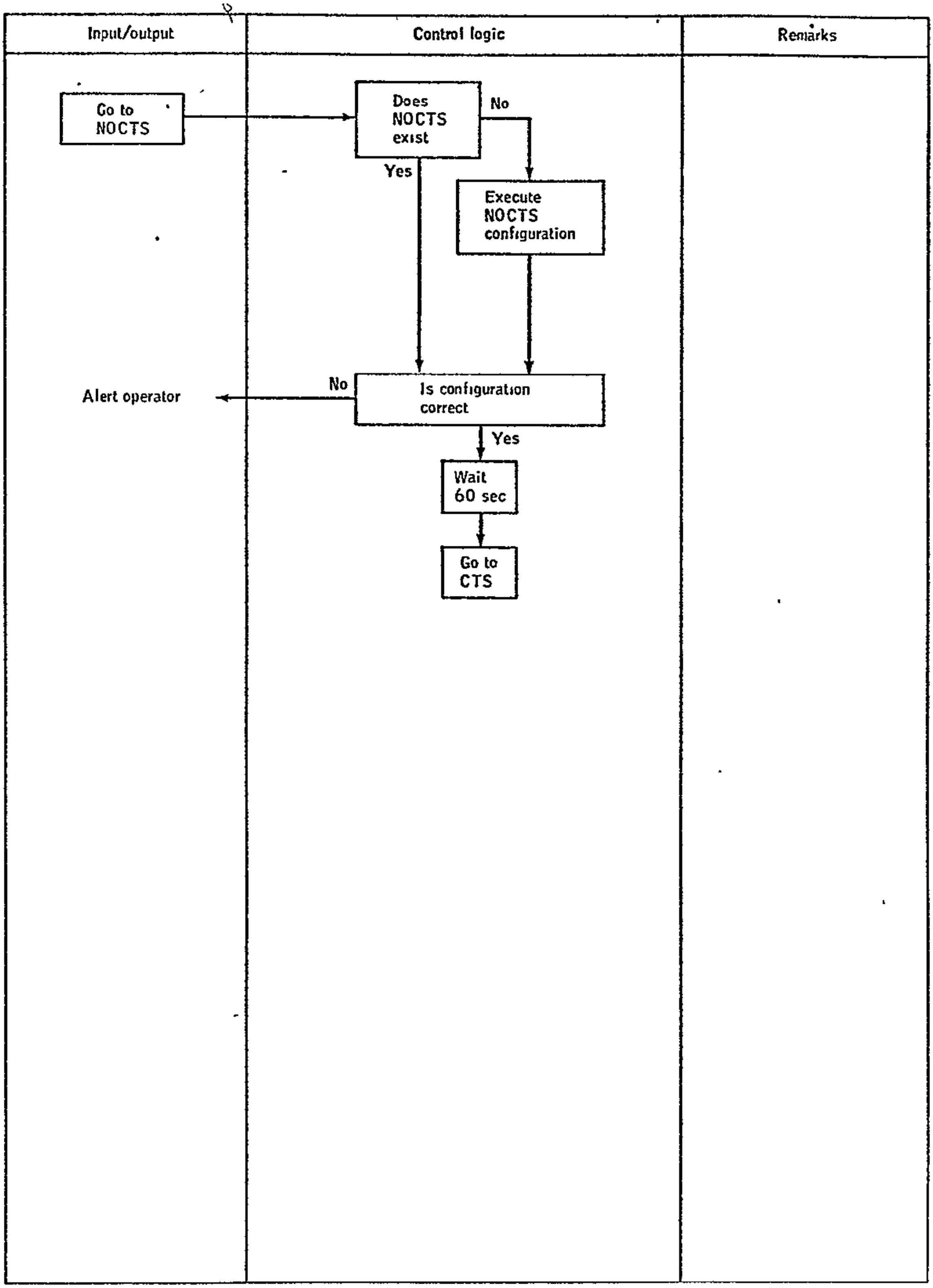
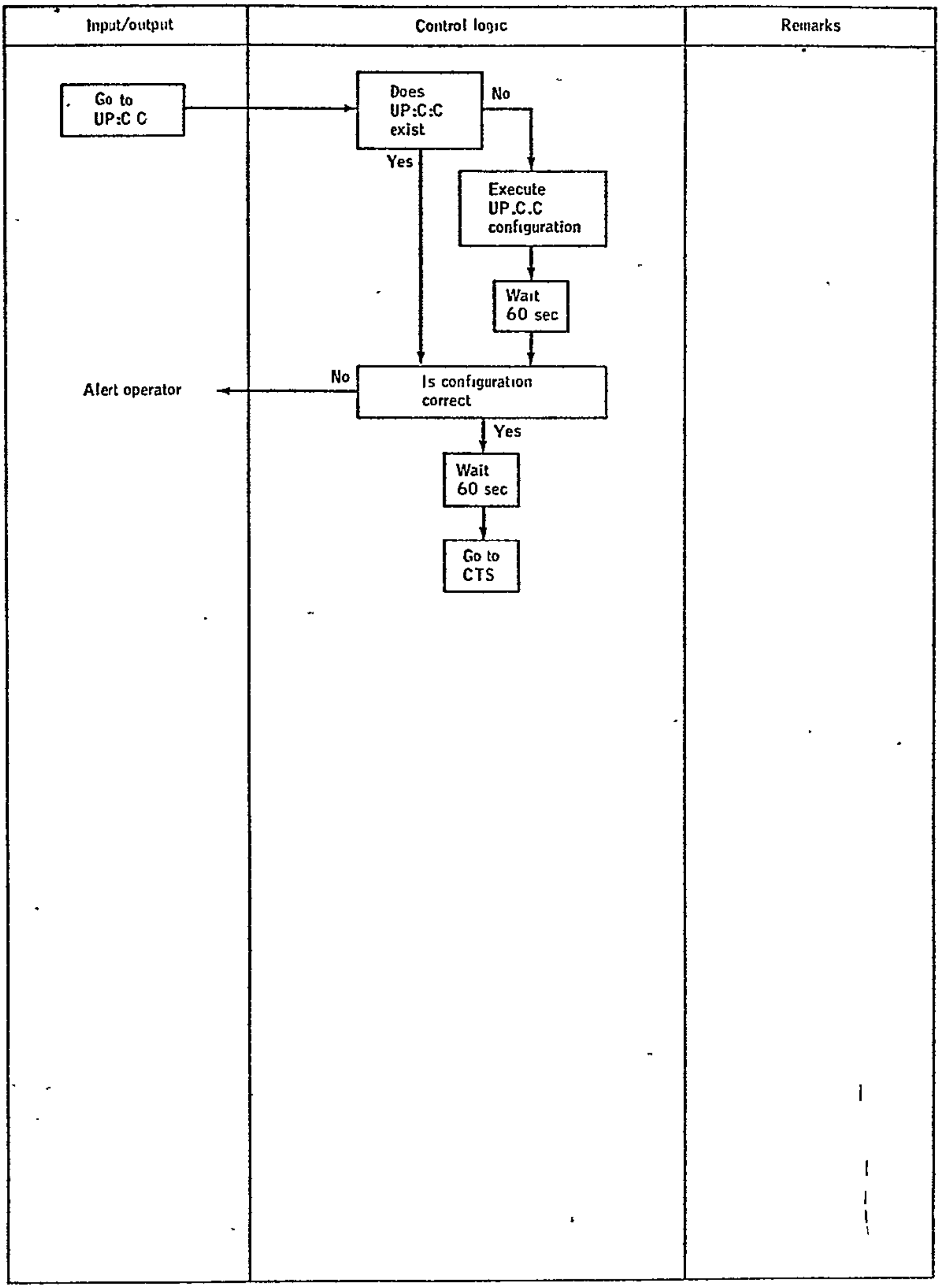
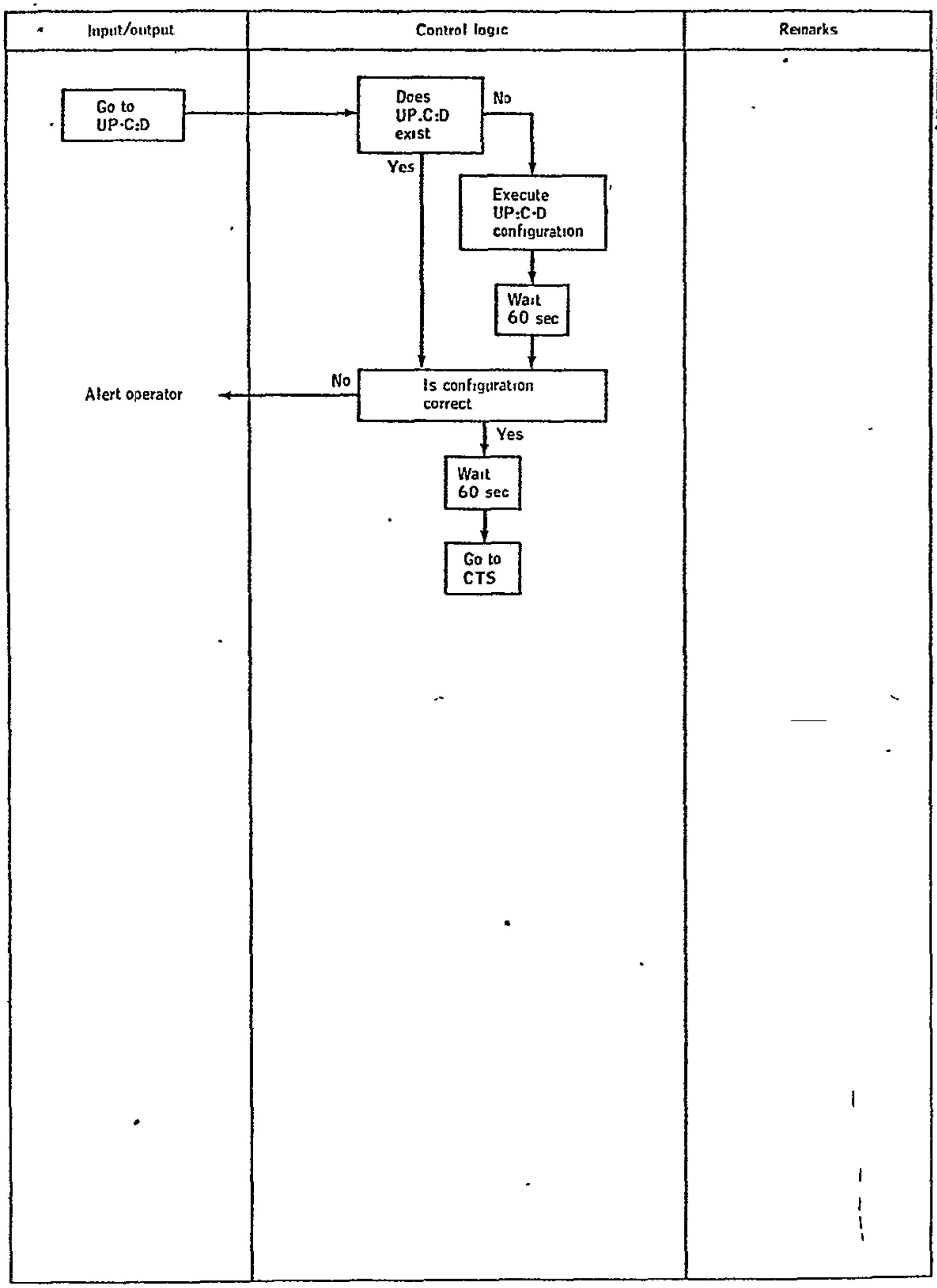


Figure 62. Logic diagram for NOCTS mode



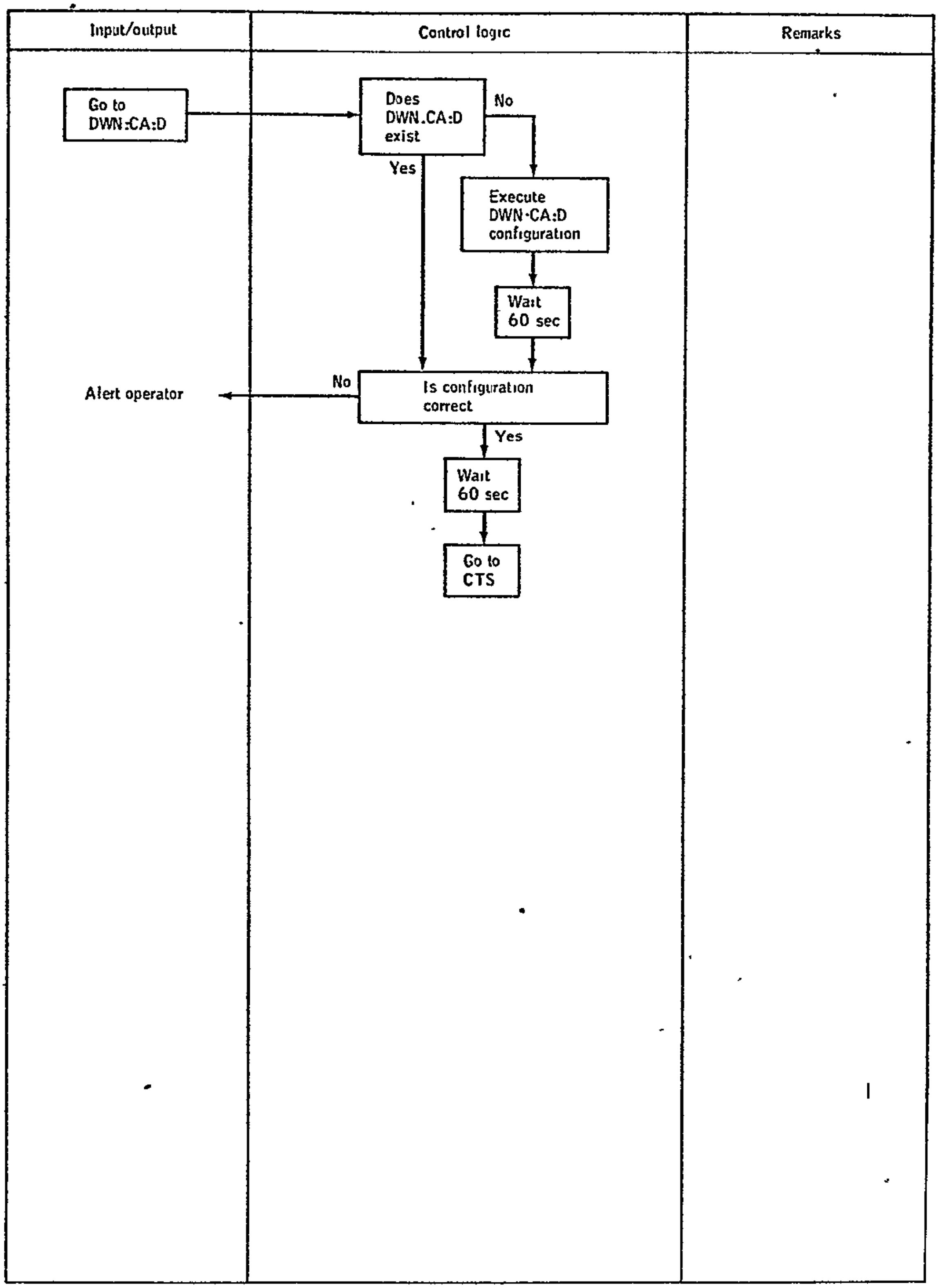
(a) Beginning of diagram.

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



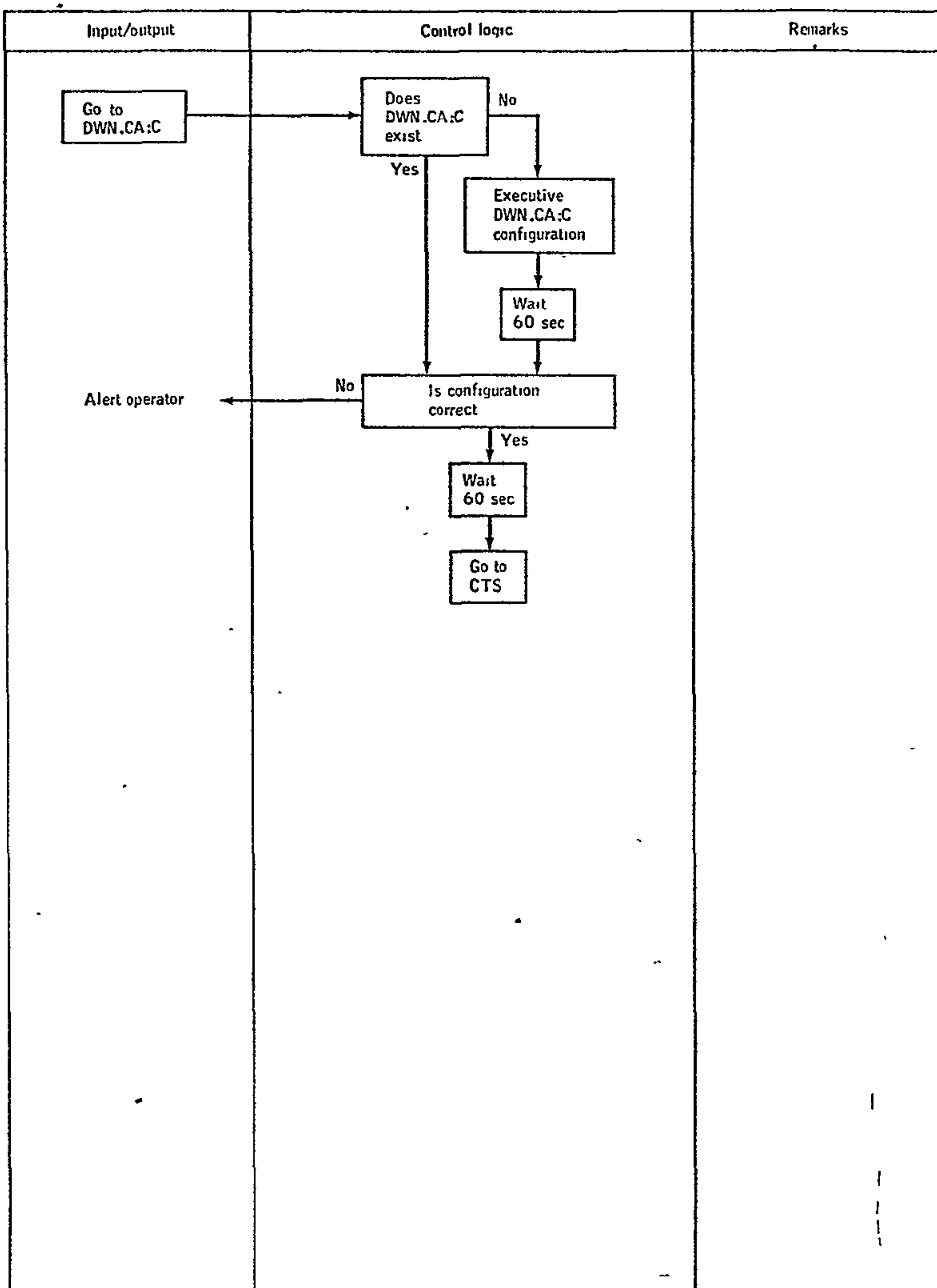
(b) Conclusion of diagram.

Figure 63. Concluded



(a) Beginning of diagram.

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



(b) Conclusion of diagram.

Figure 64. Concluded

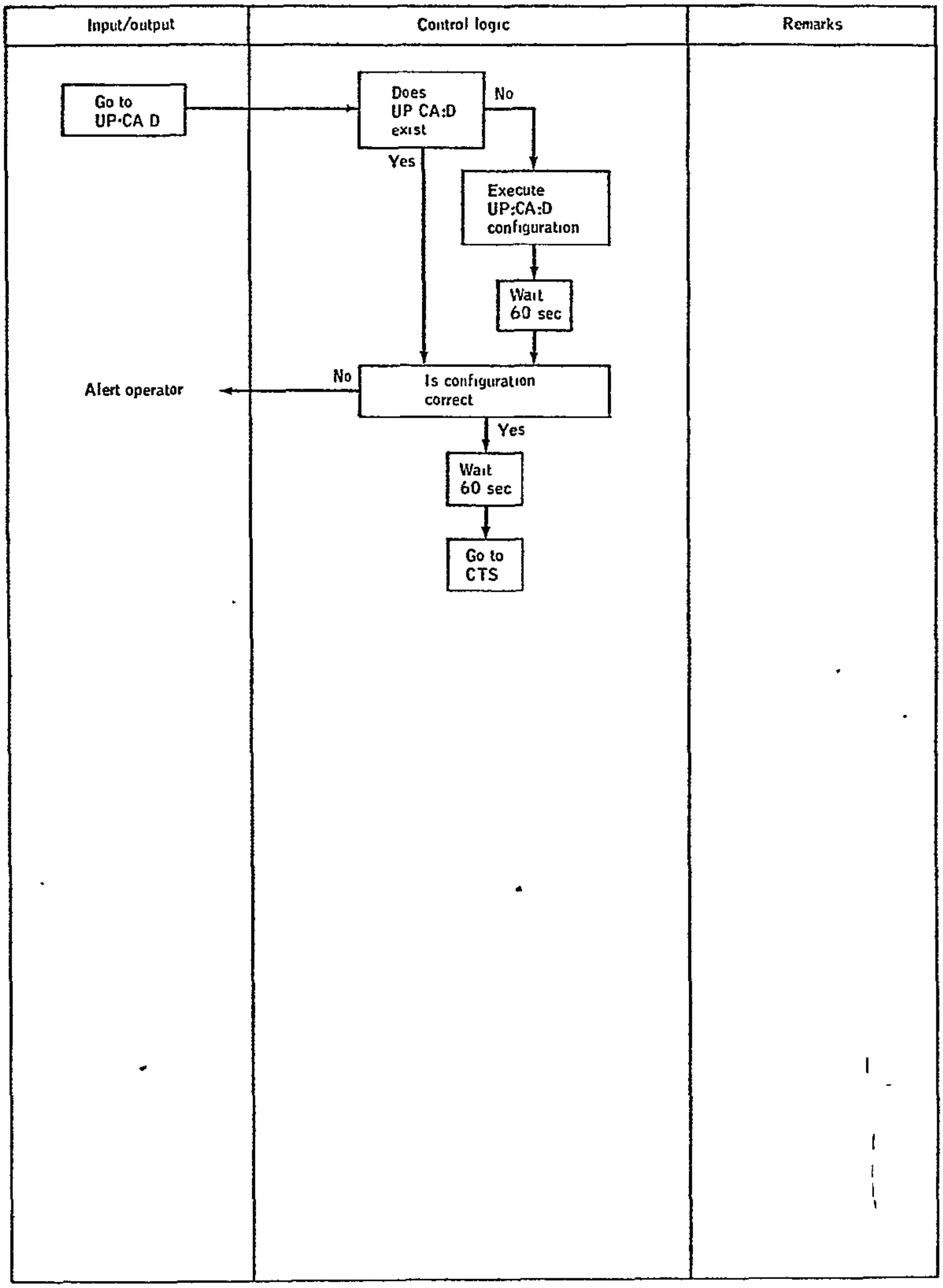


Figure 65. Logic diagram for DWN:CA:D mode

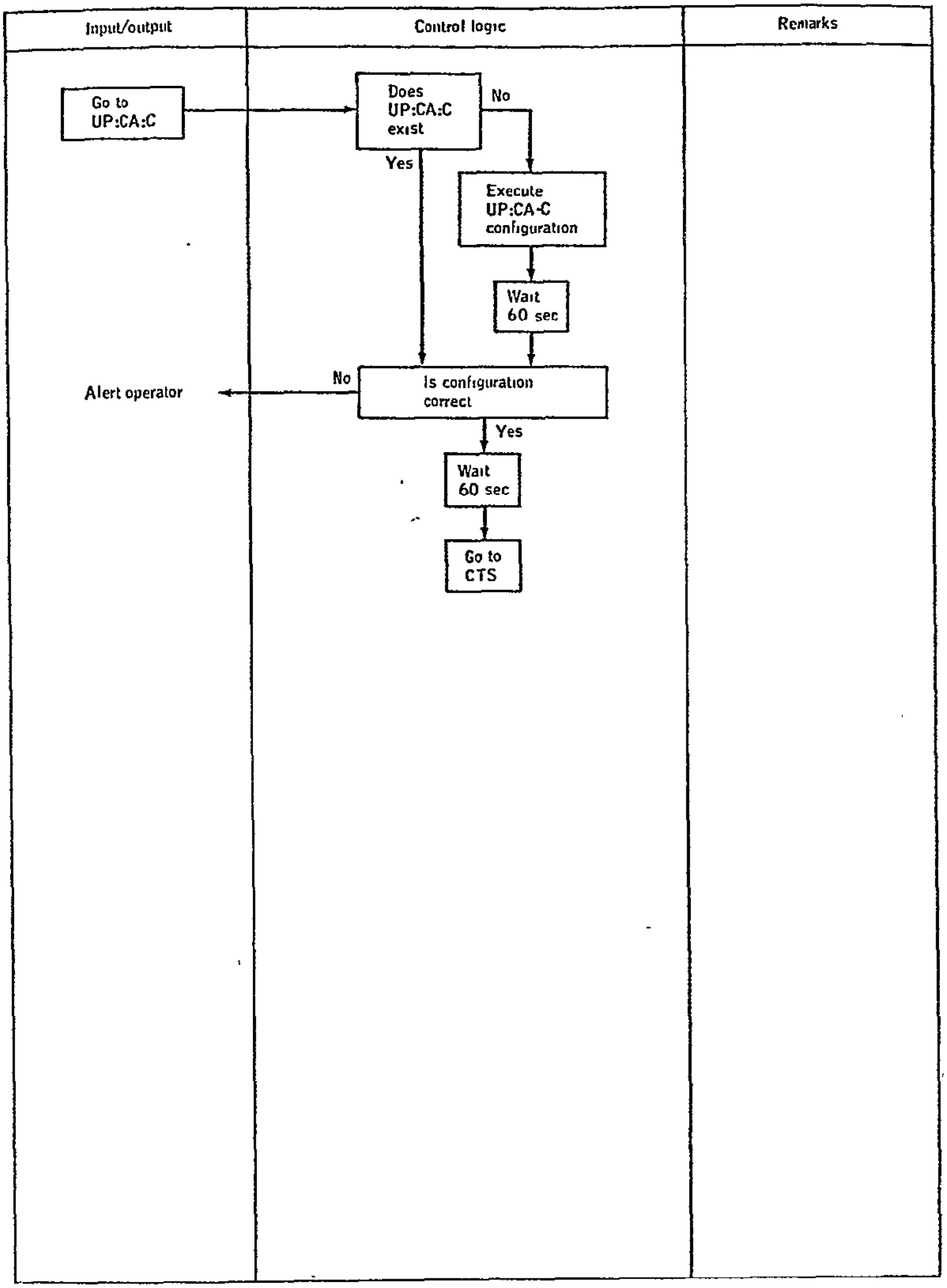


Figure 66. Logic diagram for UP:CA:C mode