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SYSTEM DESCRIPTION DOCUMENT

COLLECTOR SUBSYSTEM FOR THE 10MWe SOLAR THERMAL CENTRAL RECEIVER PILOT PLANT

PHASE II

AUGUST 1980

Martin Marietta Corporation
Denver Division
Denver, Colorado 80201

Prepared for the U.S. Department of Energy
Under Contract No. DE-AC03-80SF10539

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Subj: Contract DE-AC03-80SF10539, Transmittal of Documentation, System Description Document

Encl: (1) MCR-80-1362, System Description Document

1. Enclosure (1) is transmitted herewith for your use and information. Any questions regarding this transmittal may be directed to Mr. Melvin Frohardt, (303) 789-1781.

Very truly yours,

MARTIN MARIETTA CORPORATION

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M2. COLLECTOR SUBSYSTEM

M2.1 DRAWING REFERENCES

A. Mechanical and Civil

40M5005132720 - Heliostat Assembly

40M5005132721 - Drive Mechanism Assembly

40M5005132711 - Drive Mechanism

40M5005132722 - Pedestal Interface Adapter

40M5005132723 - Control Arms

40M5005132725 - Pedestal

40M5005132727 - Encoder Brackets

40M5005132730 - Reflective Assembly

40M5005132719 - Mirror Assembly

40M5005132732 - Rack Assembly

40M5005132733 - Bar Joists

(Continuation of M2.2 - General Description)

Each heliostat consists of 1) the mirror assembly, 2) the mirror support or rack assembly, 3) the drive mechanism, 4) the main support pedestal, 5) the pedestal foundation, and 6) associated instrumentation, controls, and signal cabling; see Figure M2-2. The components are designed to be transported by highway and railroad carriers using standard transport vehicles and materials handling equipment and within applicable Federal and State regulations. The heliostats are designed for a 30-year life.

The maximum heliostat weight is governed by cost, transportation, and structural requirements. Reflector shape limitations are imposed by the array layout, shadowing and blocking constraints, and servicing requirements. The heliostats are spaced to permit access by service vehicles and maintenance personnel. The collector subsystem is designed to provide malfunction indication and fault isolation information on critical components. Critical components are those components that, because of failure risk, downtime, or effect on overall pilot plant performance, materially affect collector subsystem availability, or safety with respect to the reflected beam in the surrounding air space or on the ground within the collector field.

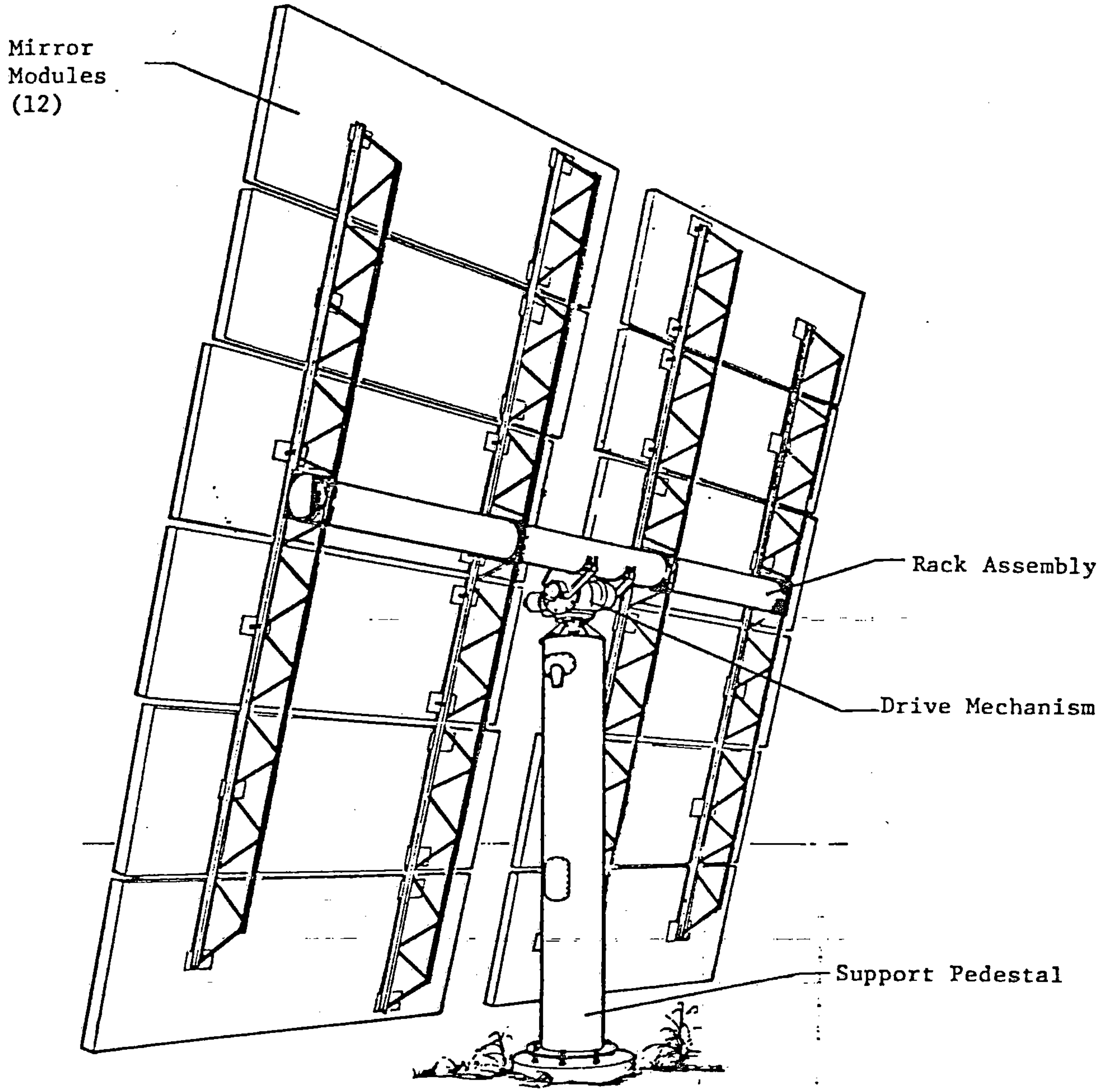

Figure M2-2 Heliostat Assembly

M2.3 HELIOSTAT CHARACTERISTICS

A. Mirror Panels

Each heliostat has 12 mirror panels, 120.3 in. long by 43.3 in. wide mounted as shown in Figure M2-2. Each panel consists of a second surface glass mirror bonded to an aluminum honeycomb core. This core is bonded to a steel enclosure pan and sealed with an environmental edge seal.

B. Mirror Supports

The mirror modules are mounted on a rack structure consisting of four bar joists riveted to a 12-in. diameter torque tube, which constitutes the heliostat elevation axis. Each mirror module is mounted to the bar joists in three places. This mounting (shown in Figure M2-3) allows the mirrors to be canted so that the centroid of the reflected beam from each of the 12 mirrors falls on the heliostat aiming axis.

C. Drive Mechanism

The torque tube is connected to the drive mechanism by two control arms. The drive mechanism, mounted on a pedestal, provides the driving force for positioning the heliostat's azimuth and elevation axes. Each axis is driven by a DC motor and the axis position is identified by a 13-bit incremental encoder, as shown in Figure M2-4. Limit switches prevent the heliostat from being driven beyond its mechanical limits.

D. Pedestal and Foundation

The drive mechanism is mounted on the main support pedestal which is in turn bolted to the foundation. The pedestal also houses the electronic controls for the heliostat. See Figure M2-5.

E. Heliostat Performance Performance, Specifications, and Operational Limits

Mechanical Limits - The mechanical constraints for the heliostats are as follows:

Heliostat Reference Position	Mirror normal horizontal, pointing east
Stow Position	Mirrors face down

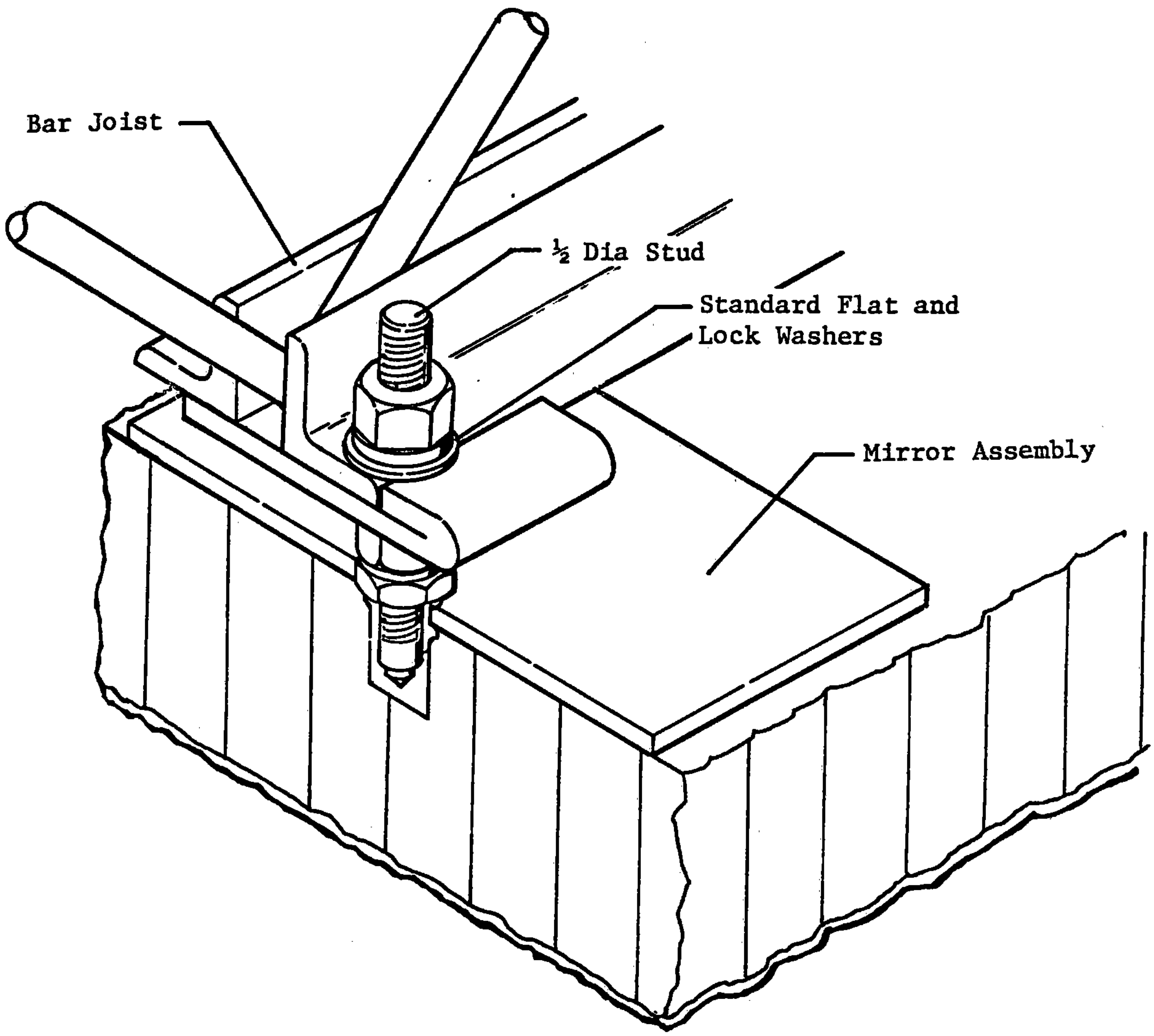

Figure M2-3 Mirror Assembly/Rack Assembly Interface

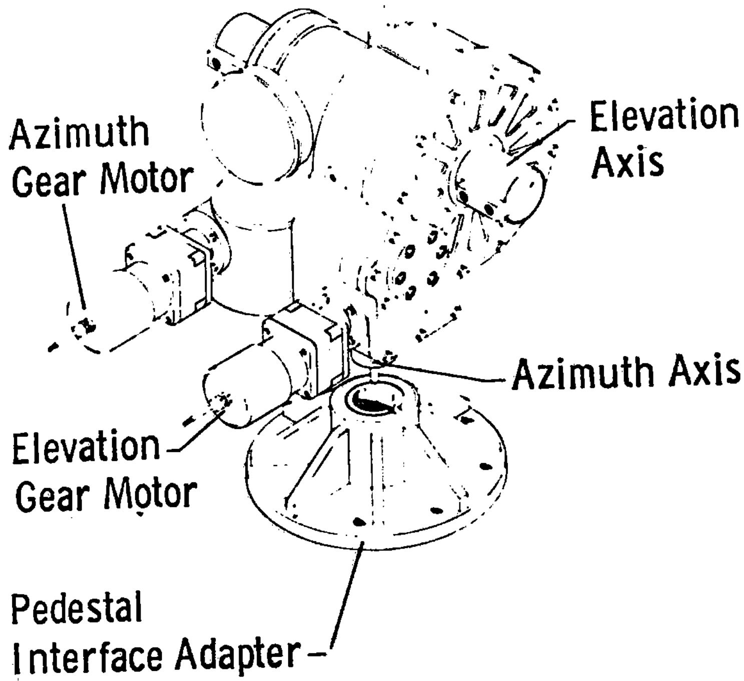

Figure M2-4 Heliostat Drive Mechanism

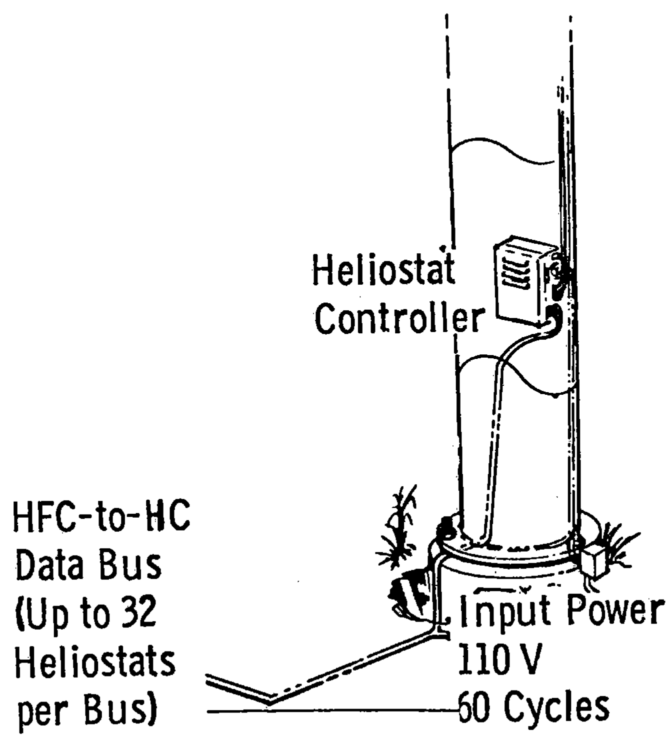

Figure M2-5 Pedestal Showing Heliostat Controller

Gimbal Rotation	Azimuth, ±270° from reference
	Elevation, ±95° from reference
Gimbal Drift	During power-off modes, the drive mechanism locks both axes
Stowage*	15 minutes from any position (270° maximum travel)
Over-the-Shoulder Resolution*	10 minutes (180° maximum travel
Maximum Slew Rate	≤18°/min

*Depending on wire-walk requirements

Weight Breakdown - The weight breakdown for the heliostat's major subassemblies are shown in Table M2-1

Table M2-1 Heliostat Weights

PART DESCRIPTION	TOTAL WEIGHT IN LBS
HELIOSTAT RACK ASSEMBLY	2546
Mirror Assembly	
Bar Joists	
Torque Tube	
Support Arms	
Mounting Hardware	
DRIVE UNIT ASSEMBLY	923
Drive Mechanism	
Support Base	
Oil	
Motors/Gearheads	
Encoders	
Mounting Hardware	
PEDESTAL ASSEMBLY	601
Pedestal	
Cover (Access Hole)	
Mounting Hardware	
CABLE AND ELECTRONICS	62
Cable	
Heliostat Cont. Electronics	
Mounting Hardware	
HELIOSTAT TOTAL	4132

Reflectivity - Average reflectance of clean heliostat mirrors exceeds 91% over an air mass 2 solar spectrum within a 1 mrad cone.

Beam Quality & Tracking Accuracy - Beam quality errors are less than 2 mrad (1 sigma) in azimuth and elevation over the operating temperature range under no-wind conditions. The heliostat structural supports limit reflective surface deflections to 1.7 mrad (1 sigma) in a 27 mph wind. The beam pointing error is less than 1.5 mrad (1 sigma) for each gimbal axis under no-wind conditions.

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CI10. <u>COLLECTOR SUBSYSTEM</u>

CI10.1 DRAWINGS REFERENCES

40E5005132735 - Installation Assembly

40E5005132739 - Wiring Harness

40E5005132712 - Azimuth and Elevation Gearmotors

40E5005132713 - Encoder

40E5005132751 - HAC to HFC Interface

40E5005132740 - HC/HFC Electrical Unit

CI10.2 GENERAL DESCRIPTION

Control of the field of heliostats is accomplished by means of a distributed computer control system consisting of a minicomputer located in the plant control room and a network of data buses and microcomputer-based controllers located at the heliostats.

The reflective surface on each heliostat is rotated about azimuth and elevation axes by means of a gear-drive unit and electric motors. The actual azimuth and elevation angles are determined by means of incremental optical encoders and a microcomputer, and the microcomputer provides the logic to turn the drive motors on and off as required.

A. Collector Control System

The collector control system is a distributed computer control system (Fig CI10-1) consisting of a Heliostat Array Controller (HAC), 64 Heliostat Field Controllers (HFC), and 1,818 Heliostat Controllers (HC). The HAC, HFCs, and HCs are connected by data buses as shown in the figure. The HAC is a dual-redundant minicomputer located in the control room. The HFC consists of a microcomputer and data-bus input/output circuits on a single printed wiring board. Each HFC can control up to 32 HCs. The HFC is installed in the electronics package that houses the HC. One HC (or a combination HC/HFC) is installed inside the pedestal of each heliostat. The HC consists of a microcomputer, data bus input/output circuits, motor control circuits, and power supplies.

The HAC consists of two identical minicomputers with automatic switchover to the backup computer should the prime computer fail. Each computer has 512 k bytes of memory. Peripheral equipment includes two 10-megabyte discs (one associated with each computer), a color CRT terminal, a status printer, an alarm printer, two color graphics CRTs, and a magnetic tape unit and a card reader. A WWV receiver is used to provide the accurate time base that is required for calculating sun position.

The plant operator controls the field of heliostats by typing commands into the CRT console. Capability is also provided for completely automatic control using time-sequenced commands stored on the disc.

Color graphic displays provide capability for the operator to display the status of either the complete field or selected segments of the heliostat field. Each heliostat is represented by a small circle on the screen and different colors are used to indicate the operating mode of that heliostat, e.g., track, standby, or stow.

The HFC provides the interface between the HAC and the HC. It receives commands from the HAC and transmits commands to the HCs, receives status information from the HCs, and transmits status to the HAC. Once each second, the HAC transmits the current sun vector to all HFCs. These data are transmitted to the HCs for use in the pointing algorithm to determine necessary encoder positions for each heliostat to direct its reflected beam at the desired target. The HFC also calculates a new target once each second during a corridor walk, and transmits the target to the HC.

B. Individual Heliostat Control System

Figure CI10-2 is a block diagram of the control system for an individual heliostat. The microcomputer calculates required gimbal angles based on sun vector and target vector data received from the Heliostat Field Controller. The required gimbal angles are compared to the actual gimbal angles; if there is a difference, the microcomputer sends an output to turn on the appropriate drive motor. The microcomputer determines actual gimbal angles by counting changes in the state of the encoder outputs.

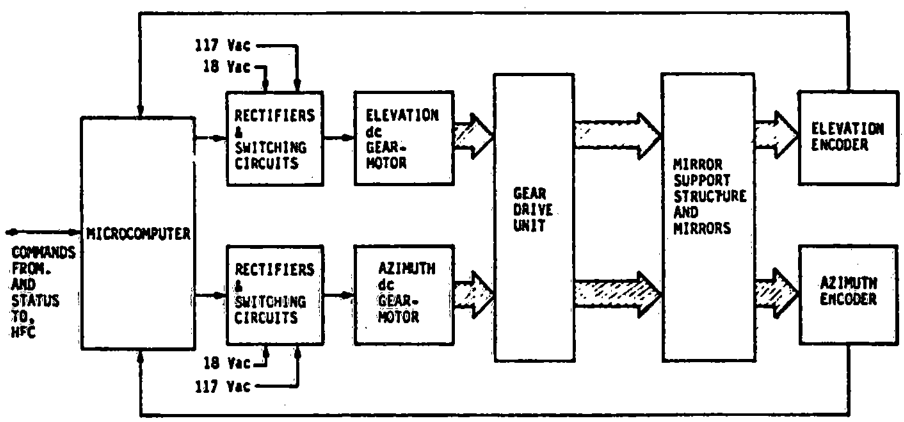

Figure CI10-2 Control System for Individual Heliostat

The heliostat control system is an on-off system that operates at two different speeds--slew and track. The motors are turned on at slew speed if the error is large or at track speed for small errors. Slew speed is approximately 20 deg/min and is required to meet time requirements on positioning the heliostat. Track speed is less by about a factor of ten.

CI10.3 HELIOSTAT ARRAY CONTROLLER

The configuration of the Heliostat Array Controller (HAC) computer system is shown in Figure CI10-1. The HAC computer system consists of a set of identical, dual-redundant MODCOMP CLASSIC computers, with a set of peripheral and input/output equipment needed to satisfy the HAC computer system requirements.

The HAC computer system includes two identically configured MODCOMP CLASSIS 7861 CPUs with 512k bytes of memory. Each computer has the MODCOMP 3109 Communications Processor Option and a 3771 Dual Bus Memory Processor. One of the dual buses is dedicated to input/output initiation and termination with the field, and the other bus handles all other input/output of the CPU (e.g., disc, graphic displays). The HAC has a dedicated 10M byte disc unit on each computer, along with a TI-820 KSR terminal for the computer console.

A single set of peripheral equipment is connected to MODCOMP 4906 Peripheral Control Switch units. With control of the switch under software control, with manual control override, this concept allows one set of peripheral equipment to be used, and switched to the backup computer if the prime computer fails. The HAC console is an Intelligent Systems Corporation 8001G color CRT terminal. To provide emergency backup to this unit, command input can be switched to the computer console. Hardcopy log of commands entered and alarms generated is furnished through a MODCOMP 4228 Serial Matrix Printer, capable of 150 characters per second printing. This is sufficient for the low-volume traffic of commands and alarms. To achieve the higher-volume capability required for status requests, a MODCOMP 4227 Serial Matrix Line Printer is provided, capable of output up to 280 lines per minute. In case of failure of either printer, its output is automatically rerouted to the other printer. To provide the color graphics required, two Chromatics 1999 Intelligent terminals are interfaced to the computers. These terminals have integral keyboards for interactive requests of display formats. They are also equipped with function keys for emergency field command entry. To maintain the accuracy of the time base, a Tru-Time Model 60 DC WWVB Receiver/Clock is interfaced to the computers. For long-term data storage capability, and for transportability of software programs and data to/from other computer systems, a nine-track magnetic tape unit (MODCOMP 4148) is included in the system. To facilitate software maintenance/development when the computer is not controlling the field of heliostats, a MODCOMP 4411 Card Reader is included in the system.

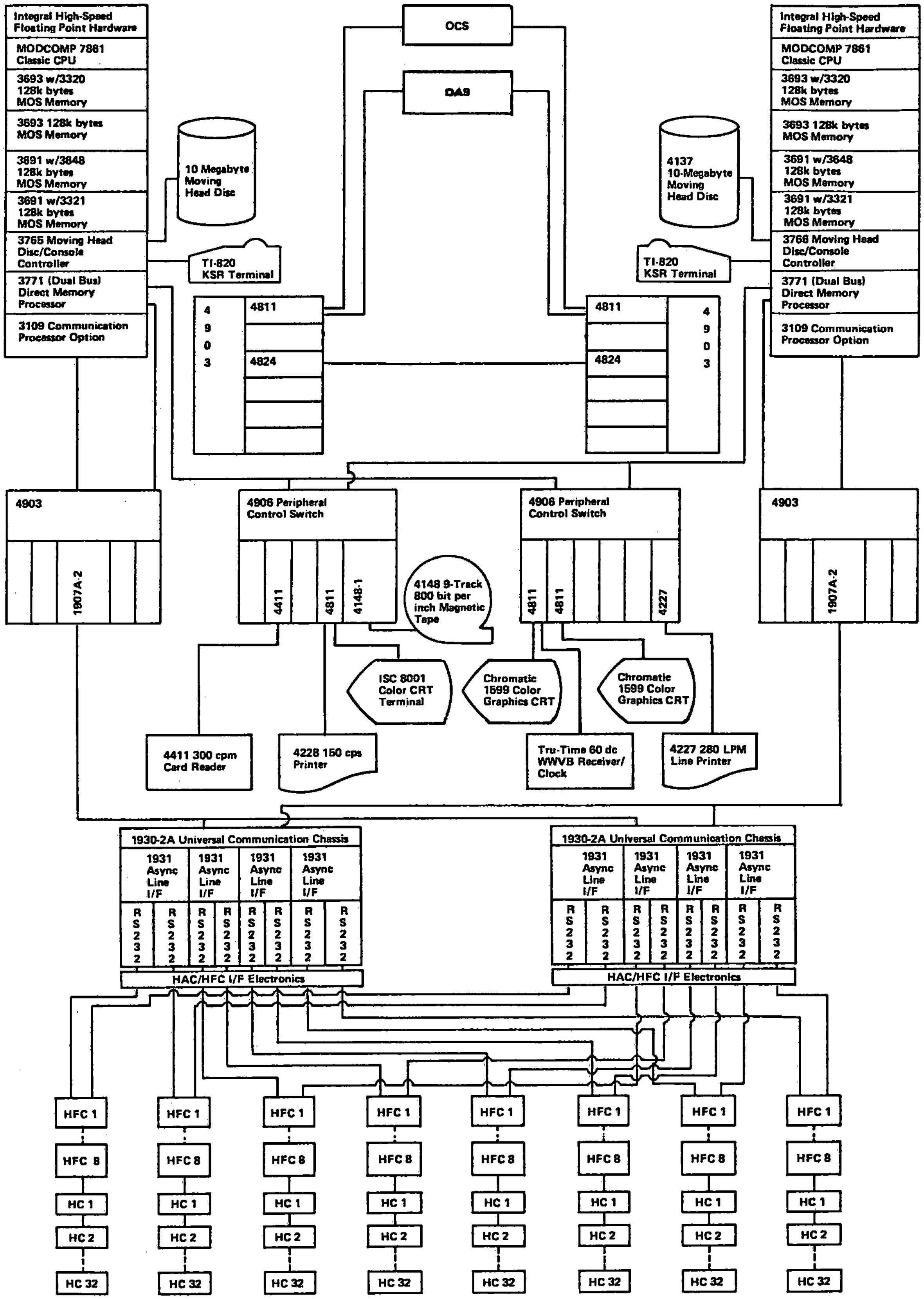

Figure CI10-1 Collector Control System

The HAC computers must communicate with the field of heliostats, with the external subsystems, and with each other. To communicate with the field, two MODCOMP 1930 Universal Communications Chassis are used. Each unit is equipped with four MODCOMP 1931 Asychronous Line Interface Modules to communicate over the eight data buses to the field, through a special Martin Marietta-designed and -built interface. These 1931 Universal Communications Chassis are dual-ported, so that either computer can communicate to the field through either unit. Thus, switchover of communications from "prime" to "backup" unit is software controlled, and does not require a full computer switchover. Communications with the external subsystems is through the MODCOMP 4811 Asynchronous Communications Interface with each computer. These units are configured to operate at 19.2k baud. Communications between prime and backup HAC computers is over two MODCOMP 4824 High-Speed Serial Coax Link Controllers.

CI10.4 HELIOSTAT FIELD CONTROLLERS

The HFC provides the interface between the HAC and the HC. It receives commands from the HAC and transmits commands to the HCs, receives status information from the HCs, and transmits status to the HAC. Once each second, the HAC transmits the current sun vector to all HFCs. These data are transmitted to the HCs for use in the pointing algorithm to determine necessary encoder positions for each heliostat to direct its reflected beam at the desired target. The HFC also calculates a new target once each second during a corridor walk, and transmits the target to the HC.

Figure CI10-3 is a block diagram of the HFC, which includes a microcomputer and input/output electronics. The optically coupled isolation prevents excessive voltage from entering or leaving the HFC, and provides limited lightning protection and isolation from ground loops and noise.

The HFC has 4096 bytes of read-only memory (ROM) and 1152 bytes of random-access memory (RAM).

CI10.5 HELIOSTAT CONTROLLER

Figure CI10-4 is a block diagram of the HC, which is positioned at each heliostat, receives commands, and controls beam position with a digital control system. The heliostat can be manually controlled through the HC by connecting a manual control unit. The HC has a self-check system and can automatically signal the control room in case of failure. These functions are implemented by a microcomputer controller in the HC. The microcomputer receives data from the bus, transmits data back when required,

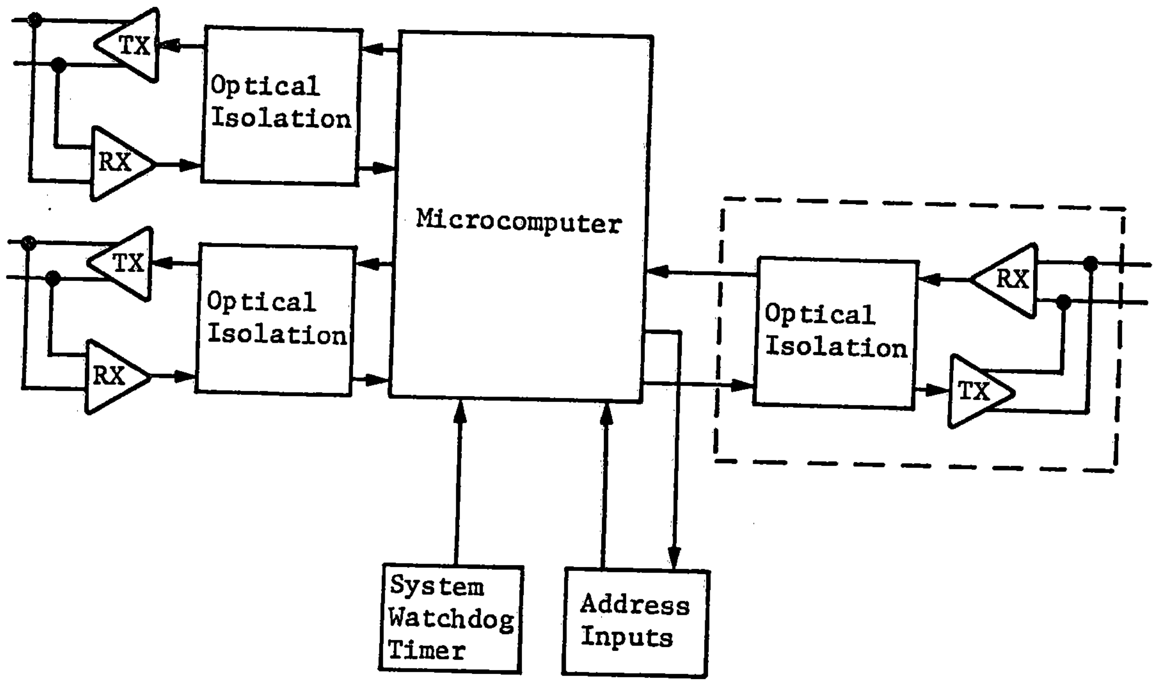

Figure CI10-3 Heliostat Field Controller

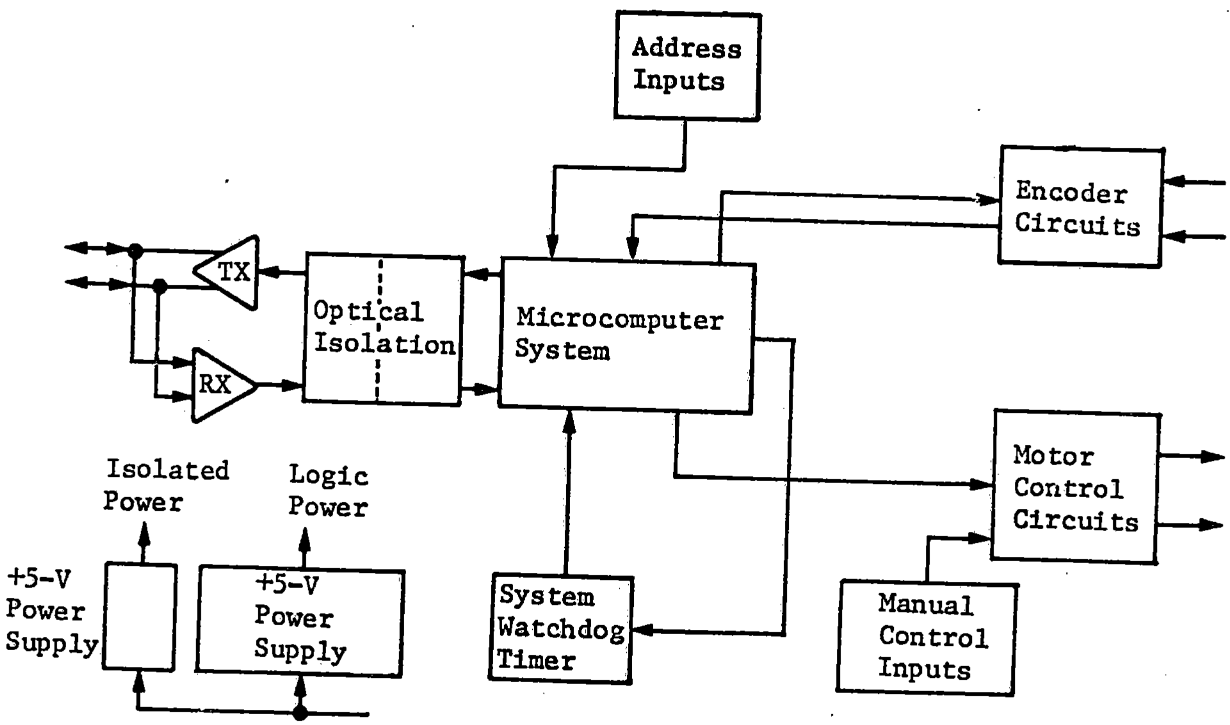

Figure CI10-4 Heliostat Controller

calculates gimbal angle commands, determine actual gimbal angles from encoder outputs, and services the motor control loop.

Electrical isolation is provided by optically-coupled isolators, that prevent excessive voltages from entering or leaving the HC.

The HC operates so that the line transmitter is enabled only when required for transmission. At all other times, it presents a high output impedance to the data bus. Thus, although all line transmitters are tied to the same bus, only one is active at any time. The line receivers are always enabled for reception of a message.

Motor control is set up by the microcomputer software that provides slew, track, or off commands to the motor control circuit.

The microcomputer performs the necessary functions based on commands supplied by the HFC. It provides motor control based on comparison of the commanded position and gimbal position, and formats the data for status information.

The microcomputer provides automatic reset during power-up, and the clock section provides the crystal-controlled operating frequencies for the system. The time section serves as a watchdog, giving automatic reset and initialization during any error.

The HC has 2048 bytes of ROM and 256 bytes of ROM.

CI10.6 DATA BUS COMMUNICATIONS

Communications between the HAC minicomputer and the HFC microcomputer, as well as the communications between the HFC and the HC microcomputer, are maintained over data buses.

The HAC minicomputer maintains communications with the 64 HFCs over eight data buses, with eight HFCs connected to each data bus. Each HFC maintains communications with up to 32 HCs over a single data bus.

The data transmitted over the HAC/HFC data buses include sun position data, status poll requests to each of the HFCs, status response from each of the HFCs, and operational commands to the HFCs as required. The data transmitted over the HFC/HC data buses include sun position data, operational commands, status poll requests, and status poll responses.

Each data bus consists of a single pair of wires, and data are transmitted in both directions over that wire pair. The timing is set up so that there is no interference between the units communicating over the same bus.

The HAC-to-HFC data buses are dual redundant; if a failure makes a bus inoperable, the HAC and HFCs will automatically switch over to the backup bus.

CI10.7 GEARMOTORS AND MOTOR CONTROL

Bodine Electric Company dc gearmotors are used to drive the heliostat. The gearmotors operate at two significantly different speeds--slew and track. The slew speed is necessary to meet time requirements for stowing the heliostats and for resolving the south-field singularity. The track speed is required to provide stable operation when the heliostat is in the fine track mode.

Slew operation is obtained by applying full voltage (rectified) to the motor. Track or slow operation is obtained by supplying a reduced voltage to the motor. Figure CI10-5 is a block diagram of the motor controller. Solid-state relays are used to turn the motor on and off at either slew or track speed. The solid-state relays turn on as the voltage wave form is going through zero and turn off as the current wave form is going through zero. This type of operation minimizes switching transients and noise generation.

The mechanical relay is used to change the direction of motor rotation. Logic in the microcomputer permits operation of the mechanical relay only when the motor is turned off, so that the mechanical relay never breaks the motor current.

The limit switches are mechanically actuated at the limits of gimbal travel (approximately ±270 degrees in azimuth and ±95 degrees in elevation) to prevent any damage to the heliostat that could result from driving it too far.

The diodes around the limit switches provide the capability of driving the heliostat back in the opposite direction after it has been driven into the limit switches.

CI10.8 GIMBAL ANGLE ENCODERS

BEI Electronics, Inc. optical encoders are used to determine the heliostat gimbal angles.

The gimbal-angle encoders are 11-bit, self-contained, totally enclosed optical encoders for each axis, directly coupled to the

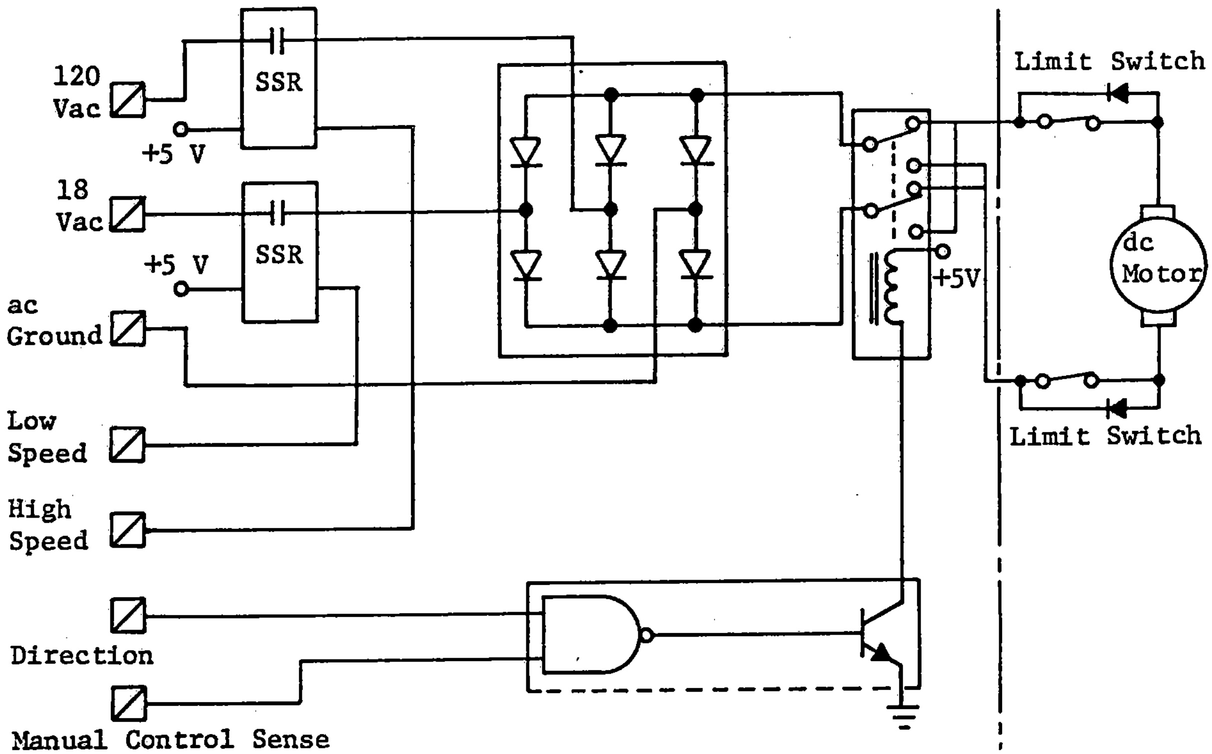

Figure CI10-5 Motor Controller

azimuth and elevation output shafts. The encoders have two optical tracks with outputs that are 90 degrees out of phase and provide 13-bit resolution. The encoder outputs are fed into the micro-computer in the Heliostat Controller, the microcomputer detects all incremental changes in the encoder output and stores a count that is the gimbal angle position.