SAN/0499-57
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10 MWe Solar Thermal
Central Receiver Pilot Plant

SOLAR FACILITIES DESIGN INTEGRATION

PILOT PLANT SYSTEM DESCRIPTION (RADL ITEM 2-1)

December 1980

WORK PERFORMED UNDER CONTRACT
DE-AC03-79SF10499

MCDONNELL DOUGLAS ASTRONAUTICS COMPANY
5301 BOLSA AVENUE
HUNTINGTON BEACH, CA 92647

U.S. Department of Energy

McDonnell Douglas Corporation | Rockwell International Rocketdyne Division | Stearns-Roger | Solar Energy

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PREFACE

This document is provided by the McDonnell Douglas Astronautics Company (MDAC) in accordance with Department of Energy Contract No. DE-AC03-79SF10499, Report and Deliverables List, Item 2-1.

The document is a description of the complete pilot plant which includes the SFDI, SCE, and Martin Marietta areas of design responsibility. For presentation purposes, the document is divided into seven major sections, as follows:

- Plant Requirements (OPDD Section I)
- Plant Operating Concepts
- Mechanical
- Electrical Power
- Control and Instrumentation
- Civil - Structural
- Architectural

Each major section in turn is further divided into subsections which treat specific systems or portions of the overall plant.

Due to the lack of detailed hardware data in many areas, some sections are missing or incomplete in this document. As additional information becomes available, and as revisions are made, sections will be prepared or revised and submitted for inclusion in this document.

Questions concerning this document should be directed to R. G. Riedesel at (714) 896-3357.

TABLE OF CONTENTS

PLANT REQUIREMENTS (PR)

Table of Contents

PLANT REQUIREMENTS SECTION

(to be supplied)

PLANT OPERATING CONCEPTS (OC)

Table of Contents

PLANT OPERATING CONCEPTS SECTION

(to be supplied)

MECHANICAL (M)

Table of Contents

MECHANICAL SECTION

Table of Contents (Continued)

MECHANICAL SECTION

Table of Contents

M1. SOLAR PLANT GENERAL DESCRIPTION

M1. SOLAR ONE GENERAL DESCRIPTION

M1.1 Drawing References

40C1005133911 - Site Plot Plan Layout

40C1005133900 - General Arrangement Plot Plan

40C1005133901 - General Arrangement Core Area

40C1005133903 - General Arrangement Receiver Tower

40E1005133904 - Electrical Plot Plan (Core Area and Area Lighting)

40E7005133234 - Grounding - Core Area

40E7005133120 - Overall Plant Trip Logic

40I7002133078 - Solar One Overall Plant Trip Logic Design Criteria

M1.2 General Plant Description

Solar One is a 10MWe Solar Thermal Central Receiver Pilot Plant which generates electricity exclusively from solar energy. The pilot plant is a joint undertaking between the U.S. Department of Energy and the Utility Associates composed of the Southern California Edison Company, the Los Angeles Department of Water and Power, and the California Energy Resources Conservation and Development Commission.

Since this pilot plant is the first large scale demonstration of the generation of electricity using a solar central receiver, the pilot plant design, construction, and operation activities are intended to support the primary and secondary program objectives as defined by the Department of Energy and the Utility Associates. These primary and secondary program objectives are:

(primary objectives)

1) To establish the technical feasibility of solar thermal power plants of the central receiver type, including collection of data for retrofit applications of solar boilers to existing power plants fueled by oil or natural gas.

2) To obtain sufficient development, production, and operating and maintenance data to identify potential economics of commercial solar plants of similar design, including retrofit applications on a comparable scale.

3) To determine the environmental impact of solar thermal central receiver plants.

(secondary objectives)

1) To gather operational data that can be analyzed to determine system operating and safety characteristics.

2) To develop both utility and commercial acceptance of solar thermal central receiver systems.

3) To stimulate industry to develop and manufacture solar energy systems.

4) To enhance public acceptance and familiarity with solar energy systems.

The pilot plant is located on a 130-acre site of Southern California Edison property near the Coolwater Generating Station which is located east of Daggett, California and approximately 12 miles east of Barstow, California. The site is at a latitude of 34.87°N and longitude of 116.83°W The site is contained in the western half of Section 13, Township 9N - Range 1E, San Bernardino County: San Bernardino Meridian. The reference location for the pilot plant is the receiver tower vertical centerline with coordinates N 501, 260 and E 2, 349, 950. The nominal elevation of the site is 1,946 feet above mean sea level.

The plant is designed to produce at least 10MWe of electrical power to the utility grid (after supplying the plant parasitic power requirement) for a period of 4 hours on the plant "Worst Design Day" (Winter solstice) and for a period of 7.8 hours on the plant "Best Design Day" (Summer solstice). The "Worst" and "Best Design Days" are based on assumed insolation (solar intensity) conditions which have been developed from actual site insolation measurements. During actual plant operation, the plant capability and electrical output will depend on the current sun and atmospheric conditions. During certain periods of the year (near noon from March through September), the plant energy collection capability can exceed the 12.5MWe turbine-generator rating.

M1.3 Plant Systems

The pilot plant, represented schematically by Figure M1-1, consists of seven systems: (1) the collector system - designed to focus incoming solar radiation, (2) the receiver system - designed to absorb the redirected solar energy from the collector system and convert feedwater into superheated steam, (3) the thermal storage system - designed to minimize energy transients and to store thermal energy for use during transient or nonsunshine periods, (4) the electrical power generating system (or Turbine-Generator Facility - designed to convert the collected thermal power into electrical power delivered to the busbar, (5) the plant control system - used to control the plant and gather data in an integrated fashion, (6) the plant support system - which

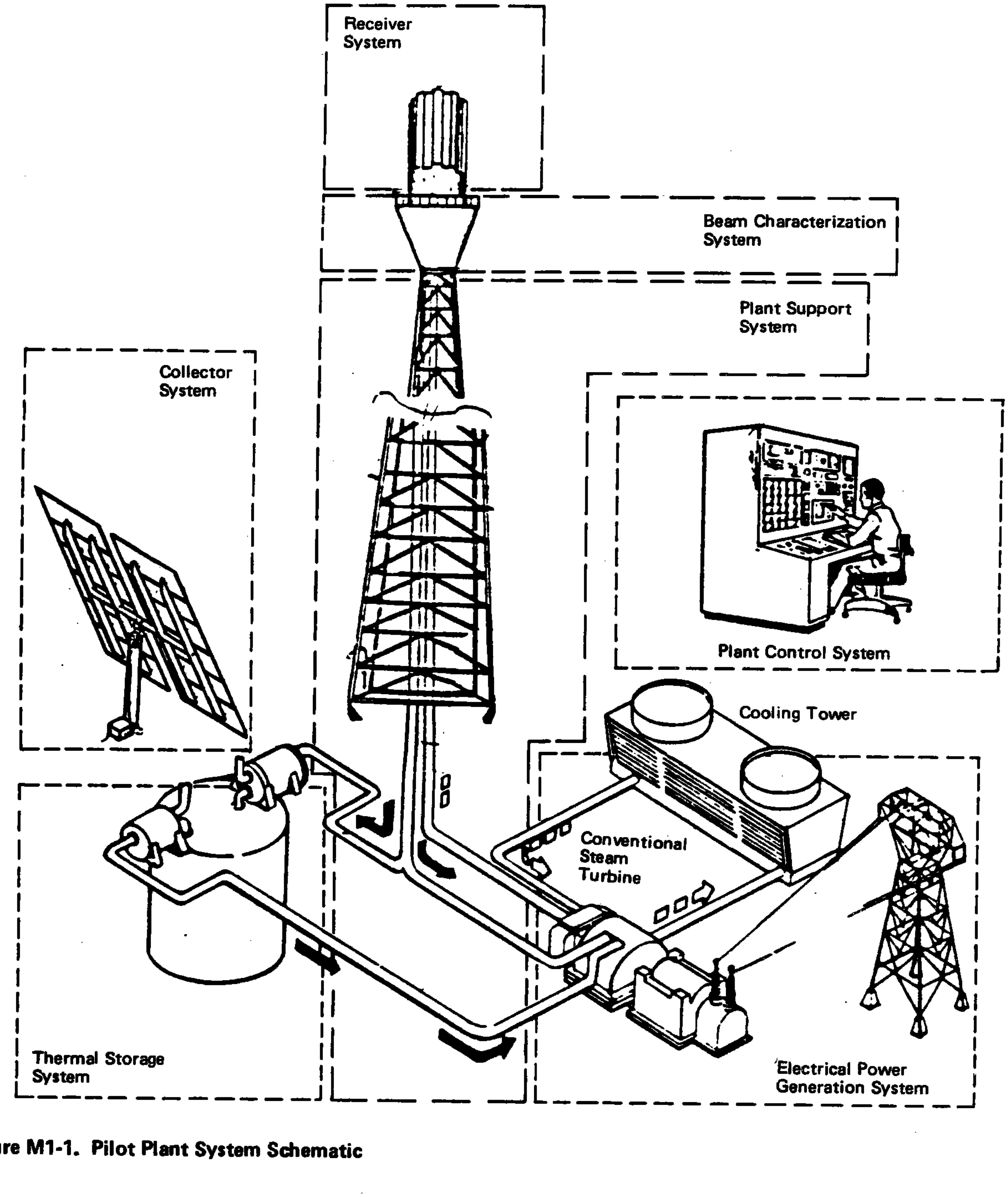


Figure M1-1. Pilot Plant System Schematic

includes piping and wiring interconnections, miscellaneous site facilities and support equipment, and (7) the beam characterization system - designed to calibrate the collector system equipment.

A. Collector System (CS)

The CS is a 360-degree array of sun tracking mirrors (heliostats), made up of 1818 heliostats which reflect the sun's incident radiation to an energy absorbing receiver mounted on top of a tower located inside the heliostat field. The CS includes the reflective surface, support structure, drive mechanisms, pedestals, local controllers, and a system control console remotely located in the centralized plant control room. The heliostat foundations as well as power and instrumentation wiring are included in the plant support system. The collector field layout which shows the location of the individual heliostats relative to the central tower is shown in Figure M1-2.

B. Receiver System (RS)

The RS is composed of the tower-mounted energy absorbing receiver unit consisting of 24 energy absorbing surfaces (panels), a steam manifold, piping, support structure, and instrumentation and controls required for RS operation and monitoring. Equipment to collect, distribute, and assure that dry superheated steam is delivered to the balance of the plant is also included in this system.

During operation, feedwater is pumped through a riser pipe to the receiver unit where it is first heated in the receiver preheat section and then evaporated and superheated in the boiler/superheater section. Heat is transferred to the receiver unit absorbing surfaces by reflection of solar radiation from the surrounding CS heliostat field. Steam produced in the receiver unit is routed through a main steam downcomer to the base of the tower where it is subsequently routed directly to a turbine-generator to produce electricity, or to the thermal storage system or both simultaneously.

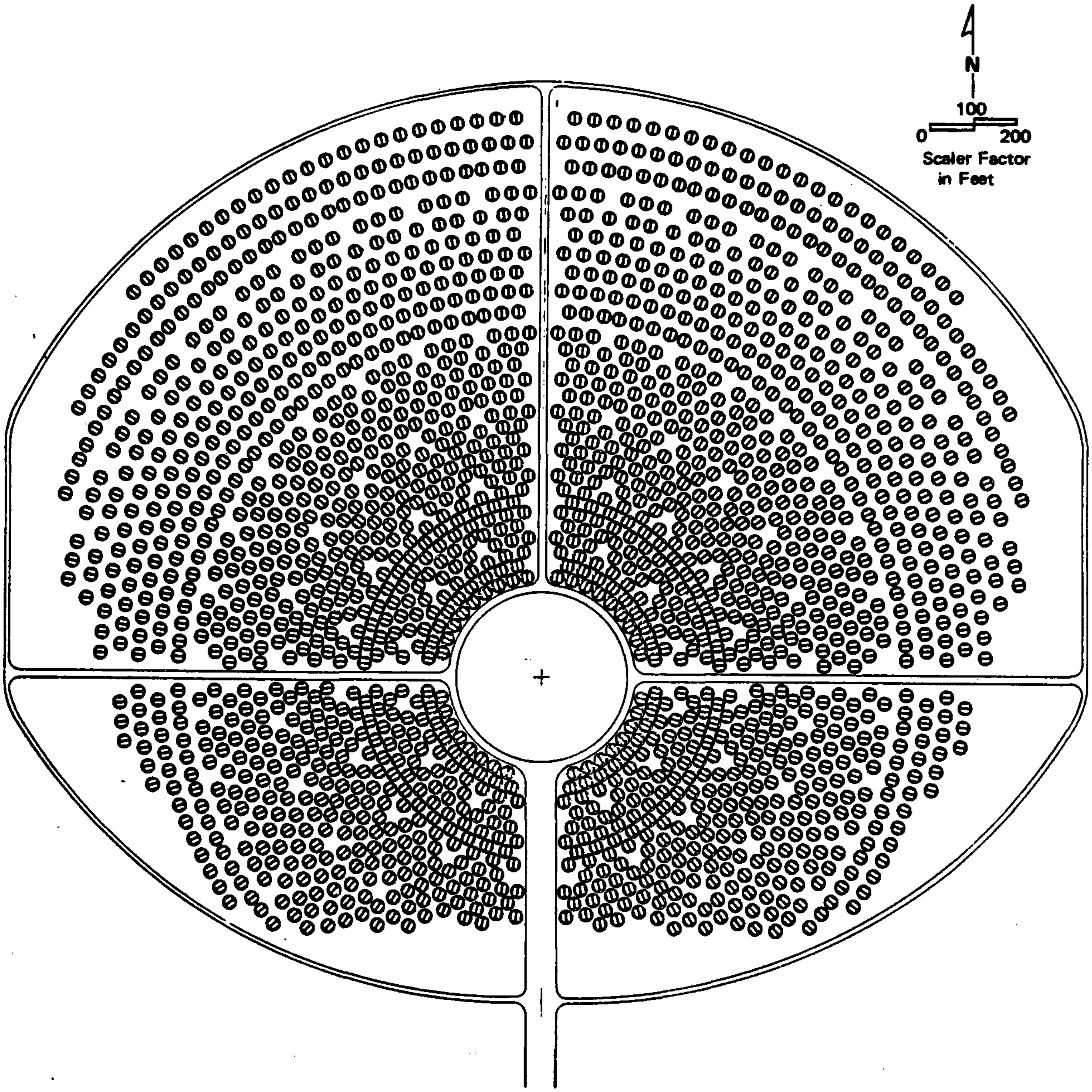


Figure M1-2. Collector Field Layout

During operation, the steam temperature leaving the receiver is controlled to a value between 660 and 960°F depending on downstream equipment requirements. The 960°F temperature is required when the turbine is operating from receiver generated steam while a 660°F steam temperature is sufficient to charge the thermal storage system. An intermediate temperature setpoint may be used to provide control margin during cloud passage events. Steam pressure is controlled by downstream components (except during receiver startup) causing the receiver discharge pressure to vary from 1510 to 1580 psia (nominal values). The total receiver steam flow range is 31,800 to 135,000 lb/hr. Figure M1-3 shows a simplified version of the receiver system.

C. Thermal Storage System (TSS)

The TSS is a reservoir of heat tranfer thermal capacitance medium which serves as a heat sink for receiver steam. Energy is stored as sensible heat, providing a heat source to generate admission steam for the turbine, thus allowing electric power generation in the absence of sunlight.

The TSS also isolates the turbine from receiver or insolation-induced transients by absorbing part or all of the receiver output during the transient event and providing a steady-state source of steam for turbine operation on an as required basis. The TSS consists of tanks, heat exchangers, piping valves, pumps, and instrumentation and controls required for TSS operation and monitoring.

During charging operation, the TSS is capable of accepting up to 105,000 lb/hr of receiver steam at a temperature of 950°F[1] (or up to 130,000 lb/hr of receiver steam at a temperature of 650°F[1]). During extraction, the TSS is capable of producing up to 110,000 lb/hr of steam at a temperature and pressure of 525°F[2] and 385 psia[2]. During the charging and extraction processes, the TSS fluid and rock is exercised over a temperature range from 425 to 575°F.

(1) temperature measured at inlet to thermal storage system.

(2) measured at the inlet to the turbine admission port.

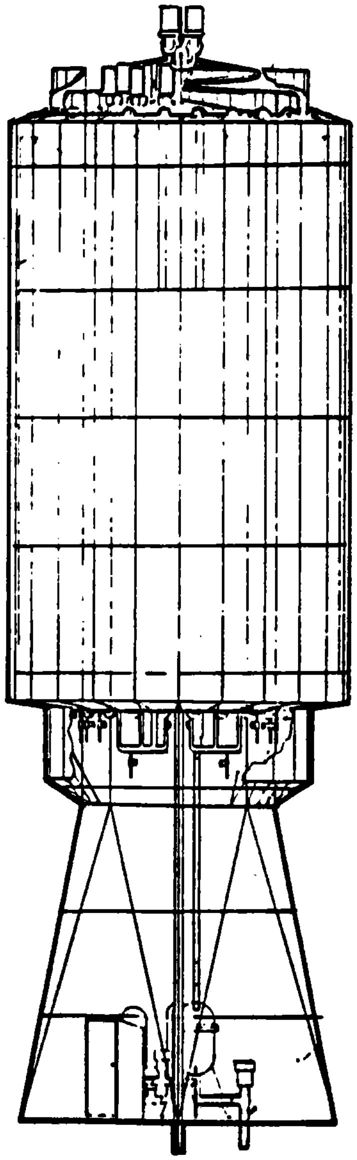


Figure M1-3. Simplified Receiver System Configuration

Figure M1-4 depicts a simplified diagram of the TSS which shows the overall relationships between the major system components.

D. Electrical Power Generation System (EPGS)

The EPGS consists of convention or near conventional steam Rankine cycle power plant equipment including the turbine-generator, condensate and feedwater equipment, circulating and cooling water systems, auxiliary steam system, and electrical distribution network. The principal process flow paths and major process interfaces with the EPGS are shown in Figure M1-5.

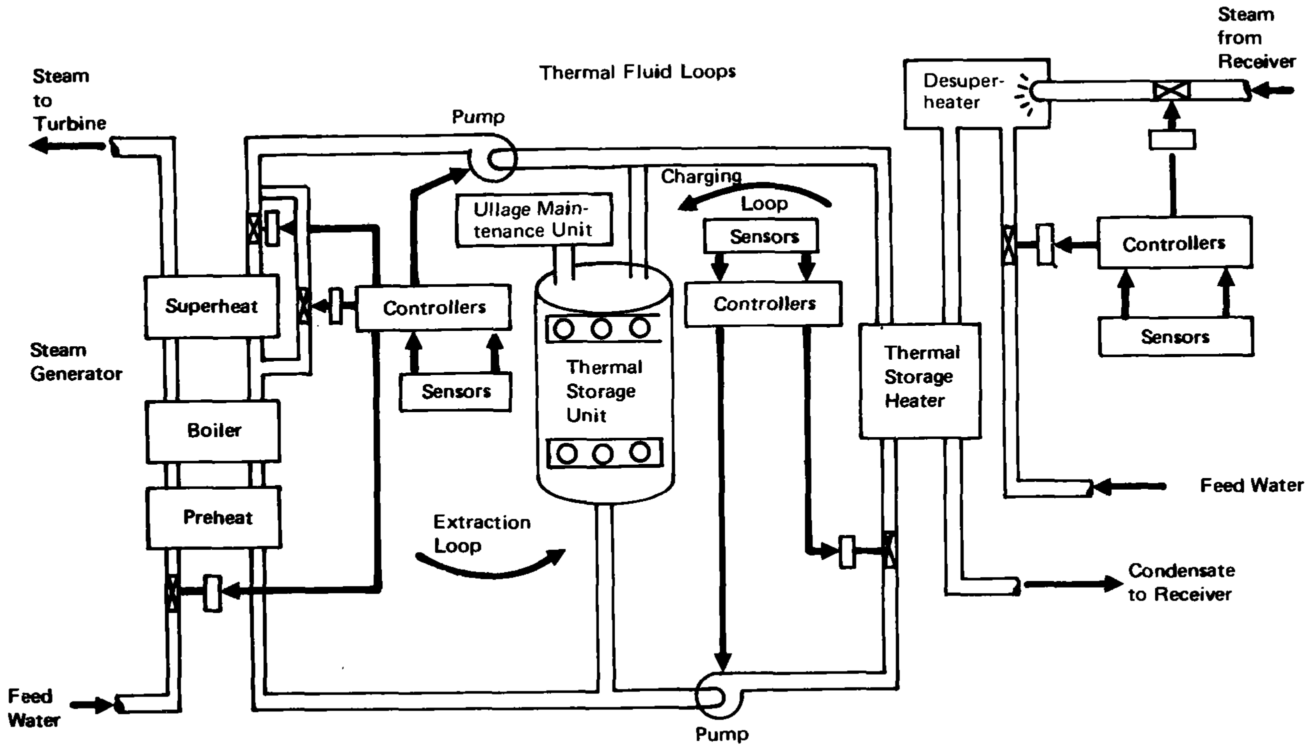
The turbine is a tandem-compound, single-flow, automatic admission, condensing unit produced by General Electric. It is rated at 12.5MWe at a 2.5 in. Hg back pressure when operating with inlet steam conditions (from the receiver) of 1465 psia and 950°F. When operating on admission steam at 385 psia and 525°F, the turbine will generate 7.8MWe at a 2.5 in. Hg back pressure.

The cycle includes four feedwater heaters for regeneration purposes and three major pumps; the condensate pump which draws from the hotwell, the receiver feed pump, and the thermal storage feed pump both of which draw from the dearator.

Heat rejection is accomplished by means of a wet cooling tower located beyond the southern edge of the collector field. Circulating water flows between the cooling tower and the condenser and cooling water heat exchanger to reject waste heat. The heat rejection equipment is designed to dissipate $95X10^6$ BTU/HR.

E. Plant Control System

The plant control system includes the master control (MCS) equipment, system distributed process control (SDPC) equipment, and interlock logic system (ILS). The equipment is located in the control room and at four distributed sites throughout the plant.



M1-4. Simplified Thermal Storage Diagram

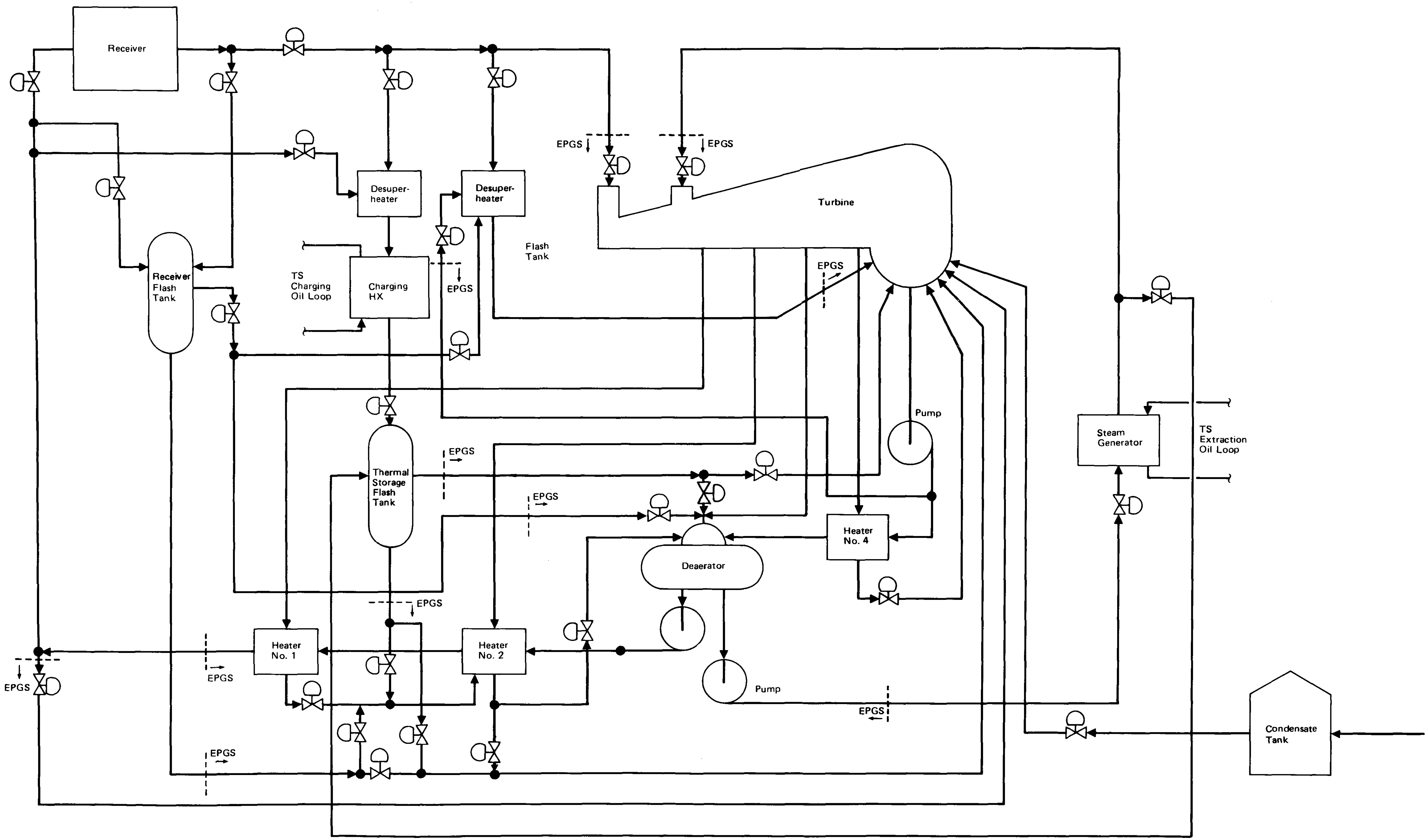


Figure M1-5. EPGS Process Flow Paths and Principal Process Interfaces

The MCS is an overall command, control, and data acquisition system (DAS) that performs control management, and supervision functions as well as data collection and display functions. Its purpose is to integrate the independent controls of the other four primary operating systems (CS, RS, TSS, EPGS) with the balance of plant to achieve effective single-console control and evaluation capability. Plant operating commands can be initiated either from the operator or directly from plant operating software contained in the operational control system computer.

The SDPC is a Beckman MV-8000 distributed digital control system with a portion located in the control room and the balance of the hardware located in the remote stations. The SDPC allows the operator to manually control subsystems on an independent basis.

The ILS, which is independent of the MCS and SDPC contains the interlock logic and plant permissives required to safely operate the plant. This computer will verify the plant and/or selected equipment status prior to executing a command. The ILS will also shutdown equipment in the event certain permissives are not satisfied.

Principal elements of the plant control system and its interfaces with otherplant elements are shown schematically in Figure M1-6.

F. Plant Support System (PSS)

The PSS consists of most of the balance of plant hardware including site structures, buildings and facilities, and facility services. The following site structures are provided:

1. The receiver support tower including receiver piping, supports, personnel access equipment, and safety equipment.
2. Pipe racks and equipment foundations required for component support.

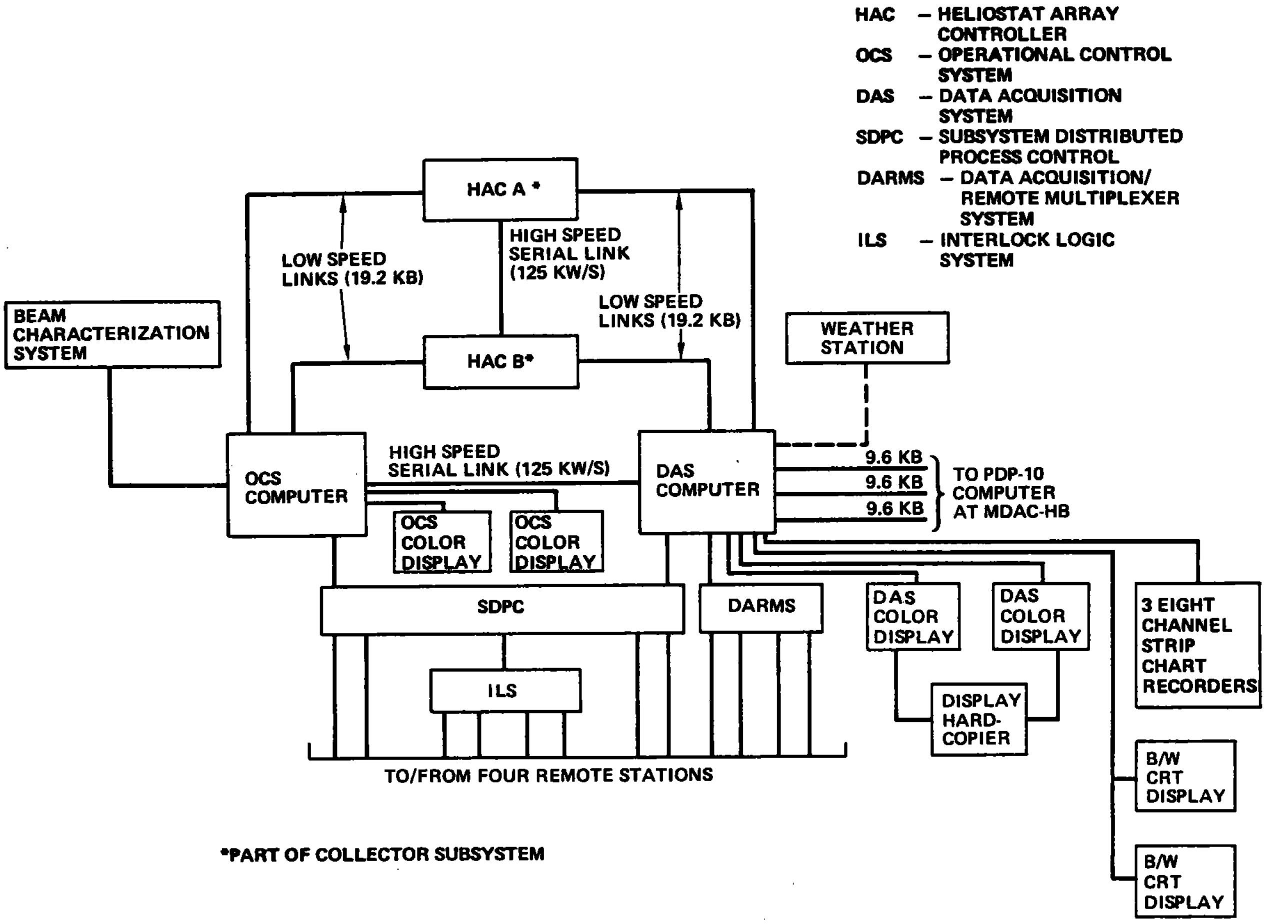


Figure M1-6. Plant Control System Elements

The following major buildings and facilities are provided with design and construction responsibility as indicated:

A. An administration building, which contains areas and facilities for plant management, visitor control, and technical support for the pilot plant (provided by SCE*).

B. A turbine-generator building, which contains the turbine-generator, associated steam, feedwater and electrical equipment, and a control building which contains the necessary consoles and electronic equipment to permit centralized control of the plant through the MCS. (Buildings will be provided by SCE; equipment for the master control room are provided by SCE and SFDI**.)

C. Electronic termination shelters and electrical equipment building.

D. A warehouse building for the receiving and storage of equipment, spare parts and materials for plant servicing (provided by SFDI).

E. A guardhouse for plant security (provided by SCE).

F. Weather monitoring equipment used for operating information and to supply data for historical records (provided by SFDI).

G. A pump house, which contains the primary fire pump, water treatment pumps, a motor control center, and foam tanks (provided by SFDI).

H. A tower on which the receiver is mounted. The tower shall contain a small environmentally controlled rooms at the uppermost working levels for electronic equipment (provided by SFDI).

I. A visitors center near the plant site (provided by SCE).

J. A heliport near the plant site (provided by SCE).

* Southern California Edison as an agent of the Utility Associates

** Solar Facility Design Integrator as an agent of DOE

PSS facility services include support systems such as raw water, fire protection, demineralized water, cooling water, nitrogen, compressed air, liquid waste, oil supply, and lightning protection. The responsibility for many of these facilities and services are shared between the SCE and the SFDI.

G. Beam Characterization System (BCS)

The BCS consists of a tower-mounted target(s), video camera(s), heat flux sensors, and supporting electronic and display equipment which permits measurement of flux delivered by an individual heliostat. The BCS also includes (as a part of the MCS capability) the software which controls the ordering, processing, and storing of the measurement data. The resulting data is used for heliostat alignment, updating the heliostat tracking equation constants, and the detection of heliostat anomolies. Figure M1-7 shows the interrelationships between the principal system elements.

M1.4 Plant Operating Modes

The plant is capable of being operated in 8 steady-state operating modes and 2 special operating modes used during startup, transitions, or emergency conditions. The 8 steady-state operating modes are shown in block diagram form in Figure M1-8.

A. Steady-State Operating Modes

Mode 1: Basic Normal - All of the thermal power collected by the collector and receiver systems flows to the turbine for the purposes of generating electrical power. This mode of operation requires the plant to be operated in a sun-following manner since the generator output must match the energy input as modified by the cycle efficiency. During periods of high thermal power collection, the available power can exceed the ability of the turbine-generator to accept input thermal power. In this event, a portion of the collector field must be removed from the receiver by an operator command to prevent a trip condition. No automatic collector field defocus capability is provided.

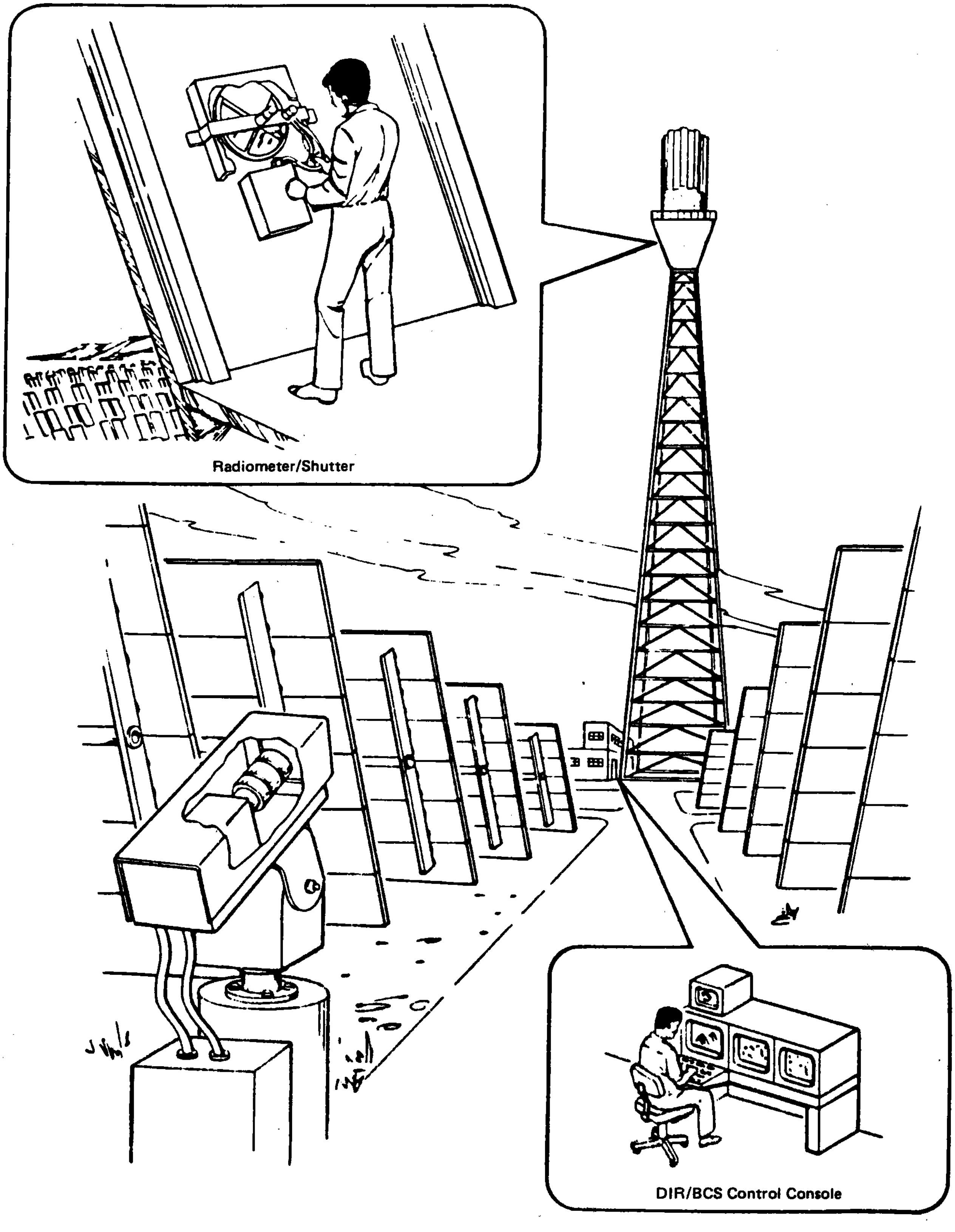
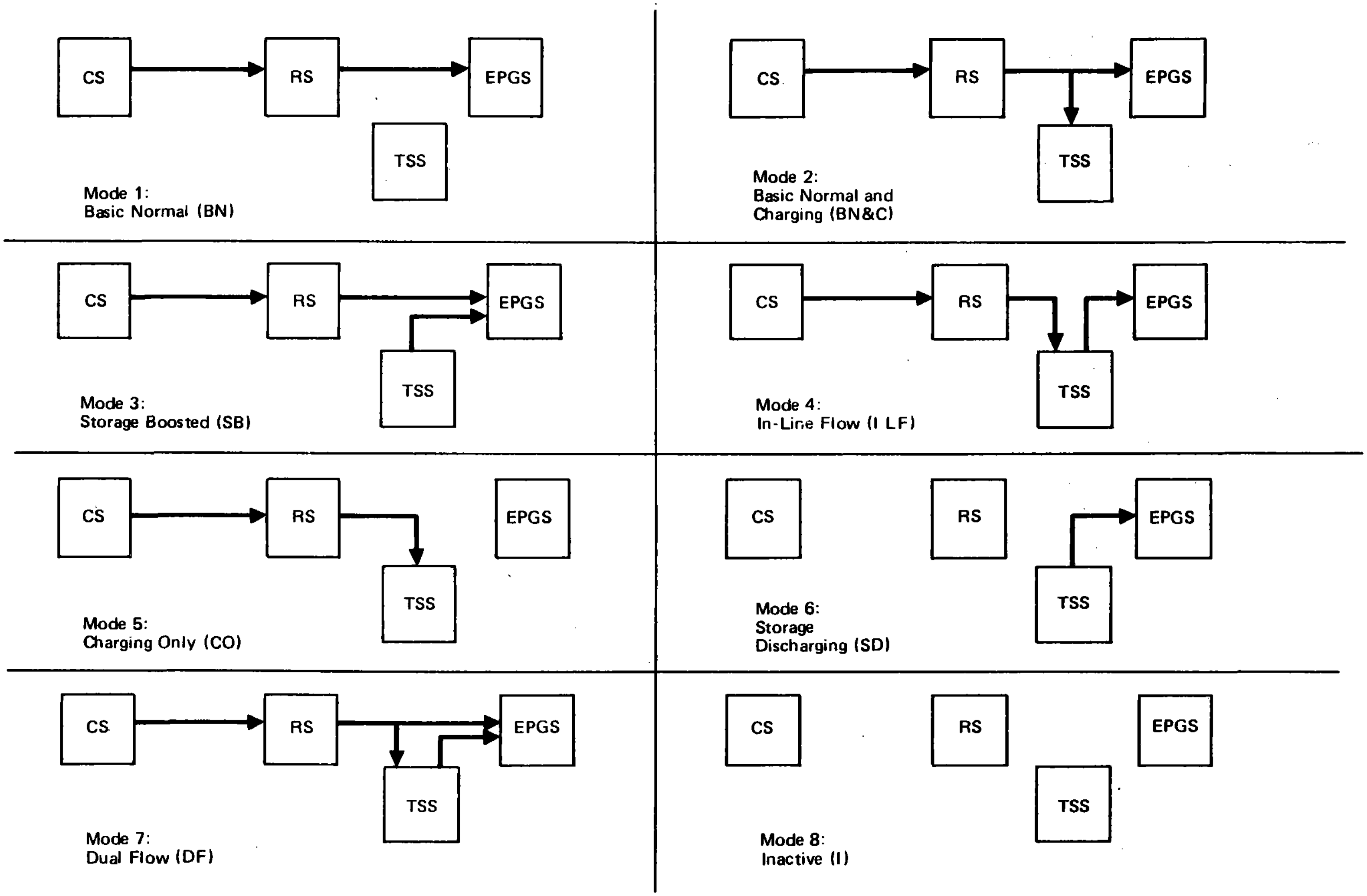


Figure M1-7. Digital Image Radiometer Beam Characterization System



M1-8. Steady-State Operating Modes

Mode 2: Basic Normal and Charging - The thermal power collected by the collector and receiver systems is split between the turbine-generator and the thermal storage charging heat exchangers. The combination of turbine and charging heat exchangers are capable of accepting all available collected power unless the operation of the equipment is inhibited by operator setpoint commands. During this mode, the plant can be operated in two ways; 1) the generator output can satisfy a fixed power demand with the thermal storage charge rate being modulated to accept variation in the thermal power collection rate (load following) or 2) fix the steam flowrate to the thermal storage while allowing the turbine flowrate (and electrical generation rate) to vary with variations in input power (sun following).

Mode 3: Storage Boosted - This mode of operation is used when the available thermal power from the collector subsystem is insufficient to produce the required electrical output. During this mode, all thermal power collected by the collector and receiver systems flows to the turbine through the main steam system. Supplemental steam is provided to the turbine through the admission steam system which is produced by extracting energy from the thermal storage system. The rate of admission steam flow is modulated to offset variations in collected power to produce a constant turbine-generator output. The range of operation permitted in this mode is limited on the low side by minimum flow capabilities of the receiver (≈31,800 lb/hr) and the thermal storage steam generator (5,500 lb/hr) and on the high side by the maximum allowable turbine (combined) steam flow (≈115,000 lb/hr). Efforts to exceed these limits may result in a plant trip condition.

Mode 4: In-Line Flow - This mode is used when transients in collected energy because of cloud passage or other conditions are more severe than can safely be accommodated by the turbine through the main steam network. During these periods, all collected thermal power is diverted to the thermal storage charging heat exchangers which operate in a sun-following manner. At the same time, energy is extracted from the thermal storage at a fixed rate to satisfy the turbine-generator load requirement.

Receiver steam temperature during this mode may be reduced to 660°F or any level below the normal 960°F control point to provide additional control margin and reduce receiver heat loss by reducing receiver surface temperature. The 660°F valve (650°F at the inlet to the charging heat exchangers) is the minimum acceptable level required to charge thermal storage. The operation of the energy collection and charging equipment is limited by the maximum charge rate capability for thermal storage (105,000 lb/hr at 950°F steam or 130,000 lb/hr at 650°F steam). The thermal storage steam generation equipment is capable of producing admission steam over the range of 5,500 to 110,000 lb/hr at a turbine inlet condition of 525°F and 385 psia. Due to the quantity of process equipment operating in this mode, a parasitic power load of up to 2.4 MWe will occur when all primary process equipment is operating.

<u>Mode 5: Charging Only</u> - During this mode, all thermal power collected by the collector and receiver systems flows to the thermal storage charging heat exchangers which operate in a sun-following control strategy. This mode is used whenever it is desired to charge thermal storage while a plant electrical power output is not required. Since it is not necessary to provide high temperature steam for the charging process, the receiver steam temperature can be controlled to a 660°F outlet condition or higher (as required) to provide additional control margin. As in the case of Mode 4, the energy collection process is limited by the capability of the charging heat exchangers to absorb energy. Also, as the thermal storage system becomes fully charges, the capability of the equipment to absorb energy goes to zero. An operator action is required to reduce the level of energy input or initiate operation in another operating mode to prevent a plant trip from occurring.

<u>Mode 6: Storage Discharge</u> - This mode of operation is used to generate electrical power after sunset or during other non-sunshine periods, when thermal energy is available in the thermal storage subsystem. The thermal storage extraction rate is set to provide admission steam to the turbine at a level required so satisfy the electrical demand. The thermal storage steam generation equipment is capable of producing admission steam over the range identified above for Mode 4. As the

thermal storage subsystem becomes fully discharged, the steam generator (steam) temperature and pressure will gradually decay until an admission steam condition trip occurs unless the operator transitions the plant into another operating mode.

Mode 7: Dual Flow - This mode can be used to transition between other operating modes or as a means of anticipating and/or operating through transients in collected energy. During this mode, the collected energy flows through the main steam line and is split between the turbine main steam port and the thermal storage charging heat exchangers. The thermal storage in turn produces admission steam which is introduced into the turbine admission port. The operation of the main steam system can control either a fixed flow to the turbine or thermal storage charging heat exchanger while the admission steam flow can be adjusted to a fixed rate or modulated to satisfy an electrical load demand. Operating limits for this mode are set by the maximum thermal storage charge rate and the combined turbine steam flowrate. Since all major process equipment may operate during this mode, a plant parasitic power demand of up to 2.4 MW will occur. Operation in this mode will require modification or termination as the thermal storage reaches a fully charged or fully discharged condition.

Mode 8: Inactive - The inactive operating mode is used during non-operating periods when the plant is being maintained at some level of thermal conditioning. Process equipment requiring thermal conditioning will be blanketed with auxiliary steam produced either by low grade thermal energy contained in the thermal storage or from the auxiliary electric boiler. During this period, condenser vacuum may be broken and portions of the system back filled with GN_2.

B. Special Operating Modes

Receiver Startup - This mode is used to start the receiver by diverting all receiver discharge flow into the receiver flash tank which is capable of accommodating all condensate, a two-phase water/steam mixture, or all steam. This flow path may be used when other steam flow paths are inactive or when the turbine is operating on admission steam (Mode 6). During this period, receiver pressure is controlled by the flash tank control system while temperature is controlled by the receiver. The limits to this operating mode are the pressure rating of the receiver flash tank (500 psia nominal control point) and the steam and condensate flowrate limit, each at a maximum of 40,000 lb/hr. For operation above these pressure and flowrate limits, dry superheated steam must exist which can be passed down the main steam downcomer.

Steam Dump - Receiver produced steam which passes through the main steam system may be diverted directly to the condenser through the steam dump network. This network is capable of assuming upstream (receiver) steam pressure control and is used to increase receiver steam pressure from the flash tank control level (500 psia) to the operating pressure required for turbine and/or thermal storage charging heat exchanger operation (1505 psia at the pressure control point). This network is used as part of the normal receiver startup or as an emergency steam diversion path in the event of a turbine or thermal storage charging loop trip. Steam flow through the steam dump is possible when no other steam flow paths are active or when the main and/or admission steam systems are supplying steam to the turbine. Flow through this network is limited when an excessive (>5 in. Hg) condenser back pressure is produced because of simultaneous flow from the turbine exhaust (during Mode 6 operation). In this case, excessive upstream steam pressures may be produced resulting in the opening of the steam safety valves.

Table of Contents

M2. COLLECTOR SYSTEM

M2. COLLECTOR SYSTEM

M2.1 Drawing References

A. Mechanical and Civil

40C1005133912 - Collector Field Plot Plan Northeast Quadrant
40C1005133913 - Collector Field Plot Plan Southeast Quadrant
40C1005133914 - Collector Field Plot Plan Southwest Quadrant
40C1005133915 - Collector Field Plot Plan Northwest Quadrant
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

B. Control Logic

C. Electrical

40E1005133927 - Electrical Plot Plan Collector Field Power and Lighting

M2.2 General Description

The collector system is composed of 1818 individually tracking heliostats that redirect the incoming insolation on to a central tower mounted receiver. Each heliostat has a nominal reflector area of 425 sq. ft. The heliostats are arranged in the field layout shown in Figure M1-2. The collector system also includes the control system hardware and software required to operate, control, and monitor the heliostats. These items include the heliostat controller, heliostat field controller, and heliostat array controller.

For operational purposes, the collector field is divided into 54 control segments as shown in Figure M2-1 which are the basic elements for field control. With these segments, the field can be controlled in the following ways:

1) as a complete field
2) by control rings (groups of segments surrounding the receiver)
3) by control wedges (groups of segments in a radial direction from the central core to the edge of the field)
4) by individual heliostats

When tracking the receiver, individual heliostats are capable of having up to 20 individual aim points that can be used to create favorable heat flux distributions over the surface of the receiver such that incident flux is ≤ 0.35 MW/M^2 and the maximum metal temperature is $\leq$ 1150°F. Since the receiver flux distribution is created by superimposing the individual heliostat images, a change in aim strategy will simultaneously affect all heliostats in the field to maintain distributional limits defined above. During periods of beam movement other than tracking the receiver, beam movement constraints exist to prevent unsafe conditions from being produced by the reflected beams.

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.

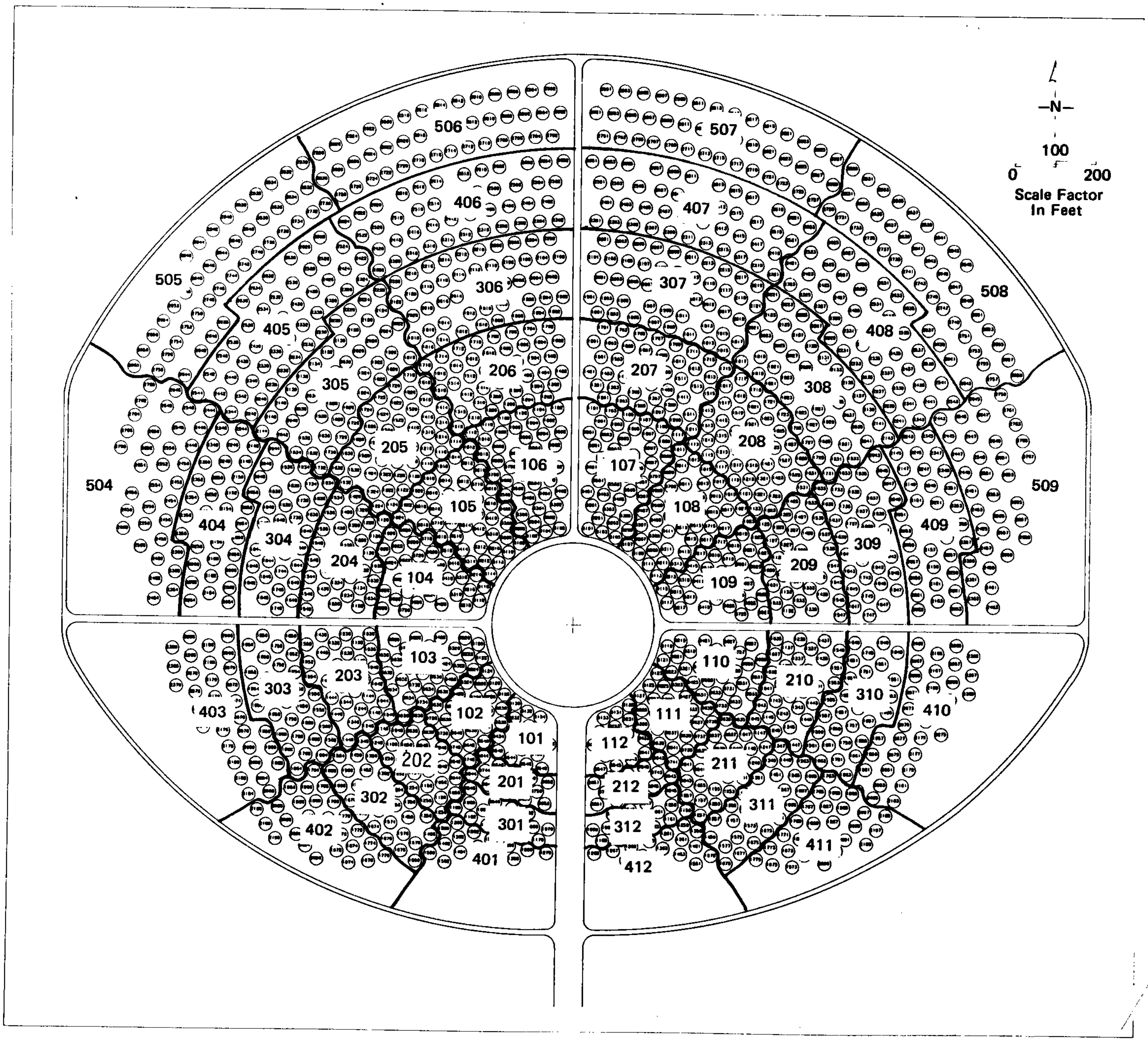


Figure M2-1. Collector Field Segmentation

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 system 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 system availability, or safety with respect to the reflected beam in the surrounding air space or on the ground within the collector field.

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

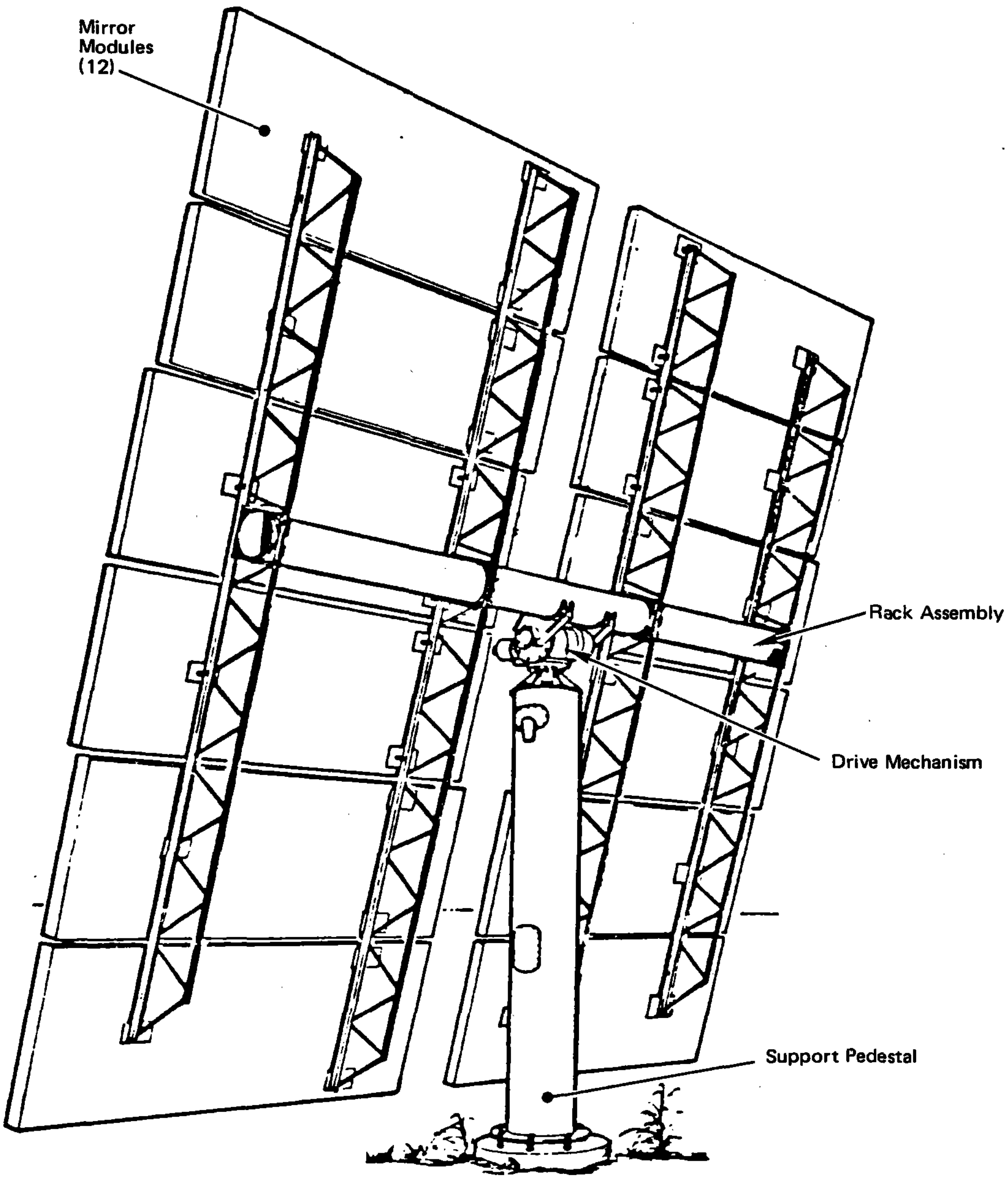


Figure M2-2. Heliostat Assembly

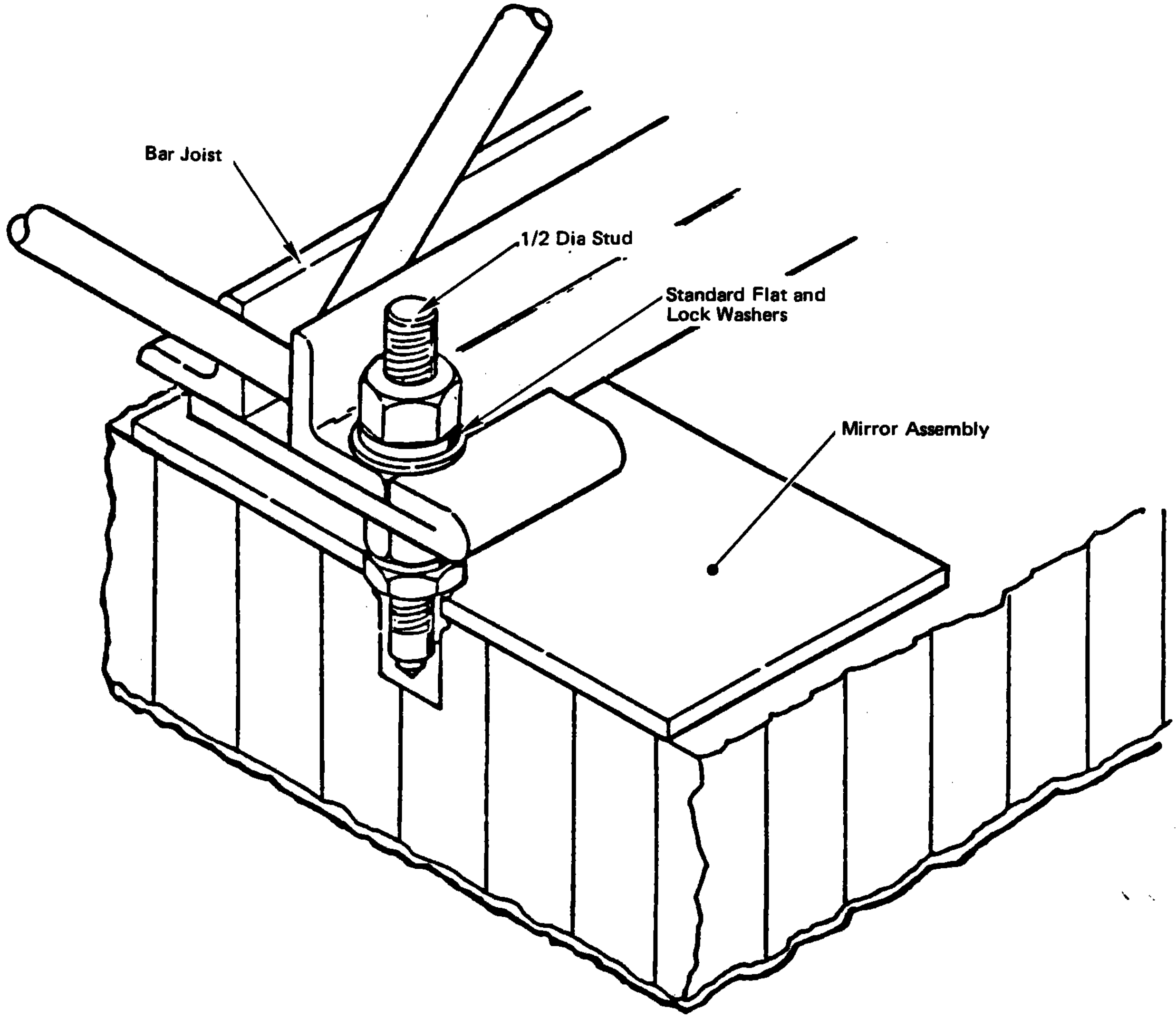


Figure M2-3. Mirror Assembly/Rack Assembly Interface

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, 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
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.

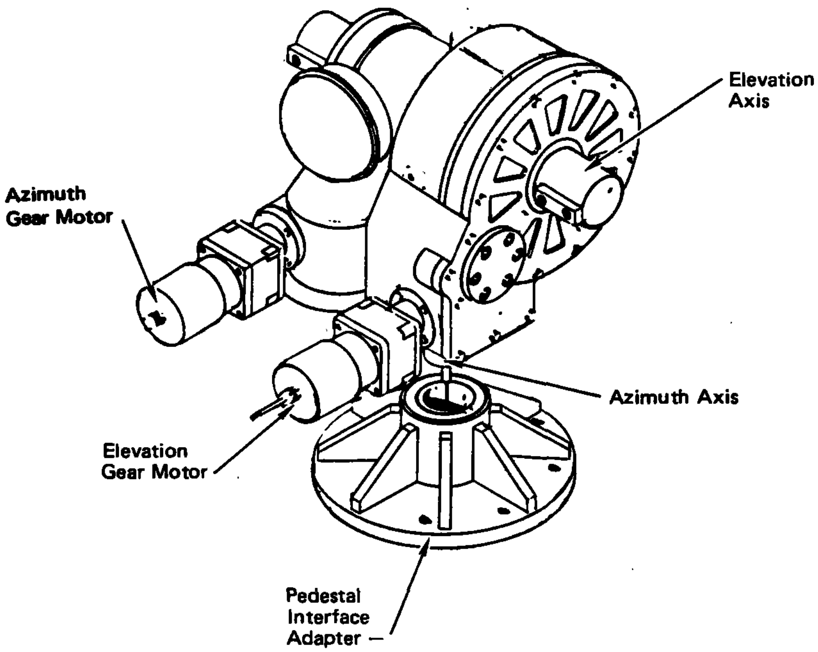


Figure M2-4. Heliostat Drive Mechanism

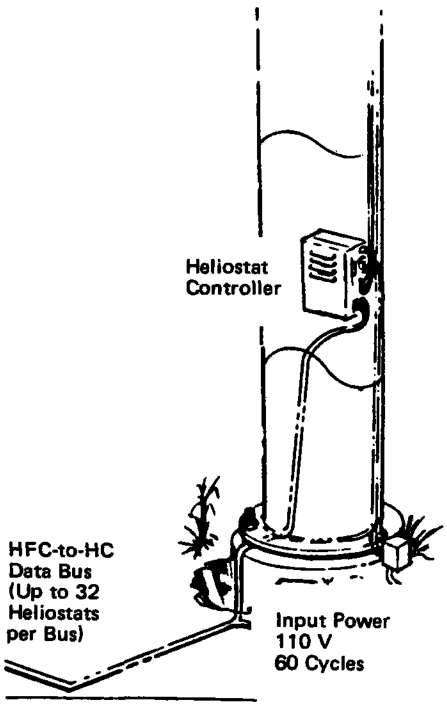


Figure M2-5. Pedestal Showing Heliostat Controller

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.

M2.4 System Operation

All collector field operations are initiated manually either through the collector system or operating computer system console or through prestored commands that can be loaded directly into the heliostat array controller (HAC). No automatic software exists that controls the system independent of the operator.

Control of the collector system can be accomplished by addressing (1) a segment, ring, or wedge of heliostats; (2) all heliostats controlled by a single field controller (HFC); (3) by an individual heliostat; (4) by a contiguous grup of heliostats on a radial arc; (5) by a number of heliostats within a segment.

The operation of the collector field is in terms of 9 heliostat operating modes as defined below.

Stow

This mode has the heliostats faced mirror down, with each heliostat having its own specific azimuth/elevation orientation (it should be noted that if the heliostats are to be "referenced" via the encoder mark, they must be stowed due east). This position would be used normally for storage at night or during extended non-operating periods. This mode may be reached from stow-alternate 1, track, standby, directed positioning, initialization, and mark with the transitions being applicable to an individual heliostat, a collector field control segment, arc, or the entire collector field.

Stow - Alternate 1

This mode has the heliostats at a near-vertical position, with each heliostat having its own specific azimuth/elevation orientation. This position can be used as an alternate to stow to save power or to take advantage of frost or dew for cleaning. This mode may be reached from stow, track, standby, and directed positioning. The transition command may be applied to an individual heliostat, segment, wedge, ring, field controller, arc, or the entire field.

Stow - Alternate 2

This mode has the heliostats faced mirror up, with each heliostat having its own specific elevation orientation (azimuth may be the azimuth the heliostat was at, at the time of the mode change command). This position can be used to take advantage of rain for cleaning or for other purposes such as to eliminate blocking and shadowing to do beam characterization measurements. This mode may be reached from standby, and directed positioning. The transition command may be applied to an individual heliostat, control segment, arc, or the entire field.

Wash

In this mode, the heliostats are approximately at 20 degrees from vertical (with mirrors facing above horizon) and with each heliostat having its own specific azimuth pointing away from the tower. This mode may be reached from all modes except offline. The transition command may be applied to an individual heliostat or contiguous heliostats on a layout circle.

Offline

This mode leaves a heliostat in whatever position it was just prior to commanding it to "offline." It is a mode for maintenance or testing on a specific heliostat. Specific manual operator command action is required to get a heliostat out of this mode. This mode may be reached from stow, stow-alternate 1, stow-alternate 2, and directed positioning. The transition command may be applied to an individual heliostat, segment, wedge, ring, field controller, or arc.

Track

This mode results in each heliostat tracking a designated aim point on the receiver (unique aim point for each heliostat) and is used during periods of plant power production from receiver steam. This mode can only be reached by heliostats originating in the standby mode. The transition command "track" can be applied to individual heliostats, a segment, wedge, ring, field controller, or arc. The transition command "increase" may be applied to a number of heliostats in a segment, complete segment, wedge, or ring. This command can be initiated by the operator through either the OCS or collector subsystem console.

Standby

In this mode, heliostats track standby points located adjacent to the receiver surface. The standby points correspond to the tops of the imaginary wires used to move the heliostat images to the vicinity of the vicinity of the receiver in a safe manner. The standby mode can be reached by heliostats originating in stow, stow-alternate 1, stow-alternate 2, and track. The transition can apply to individual heliostats, segments, wedges, rings, arc, field controller, and the entire field as it involves wire-walking to the vicinity of the receiver. In the event of an emergency condition, all heliostats can be moved from track to standby with a single operator "defocus" command.

BCS

In this mode, an individual heliostat tracks the BCS target located below the receiver with up to 4 heliostats being in the BCS mode at any one time (one per target). This mode can be reached by heliostats originating in either the standby mode on the basis of pre-stored commands contained in the HAC or from an operator command through the CS console. It should be noted that some heliostats adjacent to the heliostat in the BCS mode may have to be commanded to a stow-alternate 2 mode to prevent blocking and shadowing which can distort the reflected image on the BCS target.

Directed Positioning

In this mode, the commanded heliostat or heliostat group moves to a commanded gimbal axis position. The primary purpose of this mode is to facilitate maintenance and testing. Depending on the operator command, the directed positioning mode can be reached by heliostats in some or all of the following mode; stow, stow-alternate 1, stow-alternate 2, standby, wash, offline, or other directed positioning orientation. In addition, directed positioning can be reached when a "hold" command is issued during a heliostat mode transition period. The directed positioning mode can be applied to individual heliostats, segments, rings, wedges, field controllers, arc and the entire field.

Initialization

This is the default mode into which the heliostat is placed after being powered on and prior to its being initialized by the HAC.

Mark

The heliostat is placed into the mark mode when it is commanded to establish the reference marks for each axis. The reference marks for the azimuth and elevation axes are located at a face down, due east orientation. These reference marks are used to provide an absolute reference from which the relative position encoders can be calibrated.

M2.5 Beam Safety

Because of potential hazards associated with reflected beams for on-site and off-site equipment and personnel, a series of operating constraints in terms of operator guidelines and software limitations have been defined and implemented into the pilot plant design. These constraints are sufficient to allow maintenance personnel into the collector field during periods of collector field operation. Under no conditions however, are maintenace personnel permitted to be in the vicinity of the receiver (above the 15th tower level corresponding to the top of the BCS targets) during receiver operation.

The following limitations apply to the movement of groups of heliostats (note that the reflected beam from an individual heliostat is safe from both an equipment and personnel standpoint).

Stow to Standby Movement

The normal stow position of the heliostats is in a face down position which is safe from a reflected beam standpoint. In moving to standby, the reflected beams must be moved to a position which is located near the receiver. Once the beams are at standby, they can be moved on to the receiver as operational requirements dictate.

In general, the standard procedure is to move the reflected beams from the stow to standby position before sunrise, thus eliminating any beam hazard problem. However, because this movement could occur during the day, a procedure has been developed and implemented into the HAC software which permits this movement to be accomplished in a safe manner.

The procedure involves moving the reflected beams from ground level to the standby point by following an invisible "wire", employing a procedure known as the "wire walk". This procedure uses the HAC software to describe a path which the heliostats must follow in moving from stow to standby. The path starts near ground level and moves upward until it reaches the standby point. This procedure utilizes the fact that if all of the beams are pointed at a point on the wire they will diverge beyond that point, and will then reach safe intensity level at the minimum distance beyond the wire.

Standby to Stow Movement

A reverse wire-walk procedure is used to safely stow the heliostats which involves moving images simultaneously from the standby point, down the wire, to the wire termination point in the collector field. During any wire-walk sequence, personnel should not be near the bottom of the wire termination point because of potential high reflected beam intensity levels.

Multiple Commands Involving Wire Walks

For commands involving wire walks, the HAC software is designed to prevent anymore than one group of images from occupying a wire at a given time.

Target Pointing Beam Safety

The HAC provides software "inclusion volume" to screen all heliostat aim-point array positions for beam safety. The inclusion volume in general allows beams to point only in the receiver area. Aim-point arrays with inclusion volume violations will not be accepted by the HAC. The inclusion volume will be defined in terms the volume of the receiver as truncated ±17 ft from the horizontal centerline of the cylinder.

Directed Positioning and Stow - Alternate 2

These commands will use beam safety constraints imposed on the CS console operator by operational procedures. The movement of beams from Standby to Stow - Alternate 2 and return will be free of software restraints on the path traveled other than exclusion areas such as the tower, core area, etc.

Loss of Communications

If any HFC loses communication with the HAC, the HFC will delay (to allow for a possible HAC failover), then move all heliostats in the Track or BCS mode to the Standby mode while leaving all other heliostats in the mode that they were in. Following completion of this maneuver, all heliostats in the standby mode will be moved to the stow mode using the wire-walk method described previously. Loss of communications during an unstow movement will allow for completion of the wire-walk to standby, a time delay, and then the coordinated wire-walk down to stow.

Field Power Loss

A condition exists under which the prime power to the heliostat field may be lost for a period of time up to 30 seconds before a backup power source is switched on through operator action in the control room. Since the HAC's and their peripherals are powered via an uninterruptible power supply, they will stay on-line during this interruption. Because of the need to slew the field off of the receiver after power is restored, special requirements on the field initialization shall apply as follows:

A. The collector system will sense a field power loss through receipt of a power loss signal. This will create an audio alarm at the active HAC and will not cause a failover to the backup HAC.

B. Following the restoration of power to the field, the collector system is allocated a total of 60 seconds to reach a state where the field may be commanded again. This time period is for the purpose of reloading and initializing HC and HFC memories.

C. At the end of 60 seconds, the heliostats in either the track mode or transitioning between the track and standby modes before power loss must be moved to the standby mode in as short a time as possible; however, the backup power source will only allow a portion of the field to be moved at a time (backup power approximately 1/5 of normal power source). This movement is accomplished through the ESTANDBY commands, one ring at a time. The HAC will allow the movement of heliostats from the initialization mode directly to the standby mode in order to accomplish this. The heliostats should be commanded to the mark mode as soon as possible following power loss. The wire walk will be used to move the heliostats gathered in the standby mode to the stow mode. As a result of the power failure, the heliostat azimuth/elevation locations as initialized in the HC's by the HAC will only be accurate within the 8 second update cycle for HC status in the HAC.

Table of Contents

M3. BEAM CHARACTERIZATION SYSTEM

M3. BEAM CHARACTERIZATION SYSTEM

M3.1 Drawing References

A. Mechanical

40M6005132902 Receiver Tower BCS Target Elevations, Sections, and Details
40M6005132903 Receiver Tower BCS Target Section and Details
40M6005132904 Receiver Tower BCS Target Sensor/Shutter Locations and Details

B. Control Logic Diagrams

C. Electrical

M3.2 General Description

The beam characterization system (BCS) includes the hardware and software required to permit rapid and automatic characterization of the reflected beams delivered to the receiver by any single heliostat. The data available from the BCS includes beam size and shape, beam centroid, flux distribution, and total beam power. BCS data is gathered by four vidicon cameras (each dedicated to a separate target) which view tower-mounted targets located below the receiver and through radiometers located in each target. The cameras are located as shown in Figure M3-1 to be near-perpendicular to their respective targets. The physical characteristics of targets are shown in Figure M3-2 along with the locations of the radiometers (shutter locations).

Data gathered by the BCS equipment is digitized, calibrated, processed to characterize the image, and stored. This data can then be used to align and evaluate the heliostats during plant operation. The system is designed to evaluate reflected images on an individual heliostat basis. No capability exists to calibrate multiple heliostat images superimposed on a single target. Simultaneous operation of the 4 targets and cameras for the calibration of individual heliostats is possible.

The major BCS hardware elements are the video equipment, the data processing and control equipment, and the target. Detailed descriptions of each of these elements are presented in the following 3 sections.

M3.3 Video Equipment

The video equipment consists of:

- Low light, self-contained video cameras (4) with camera lenses and sunshields.
- Remote camera control system with interconnecting cables to the video switching system and the operating control system (OCS) computer and a remote control panel

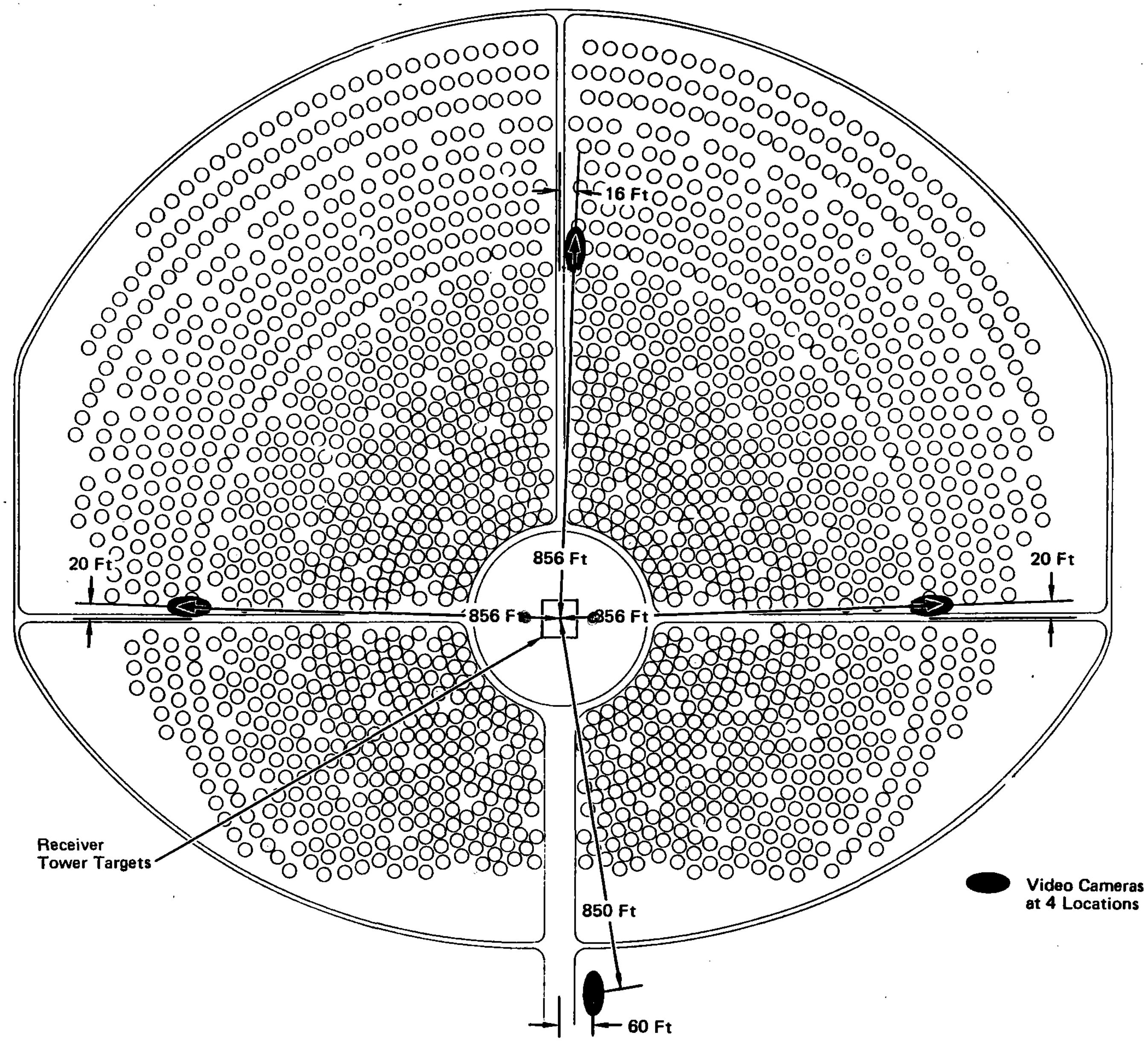


Figure M3-1. MCS Camera Orientation

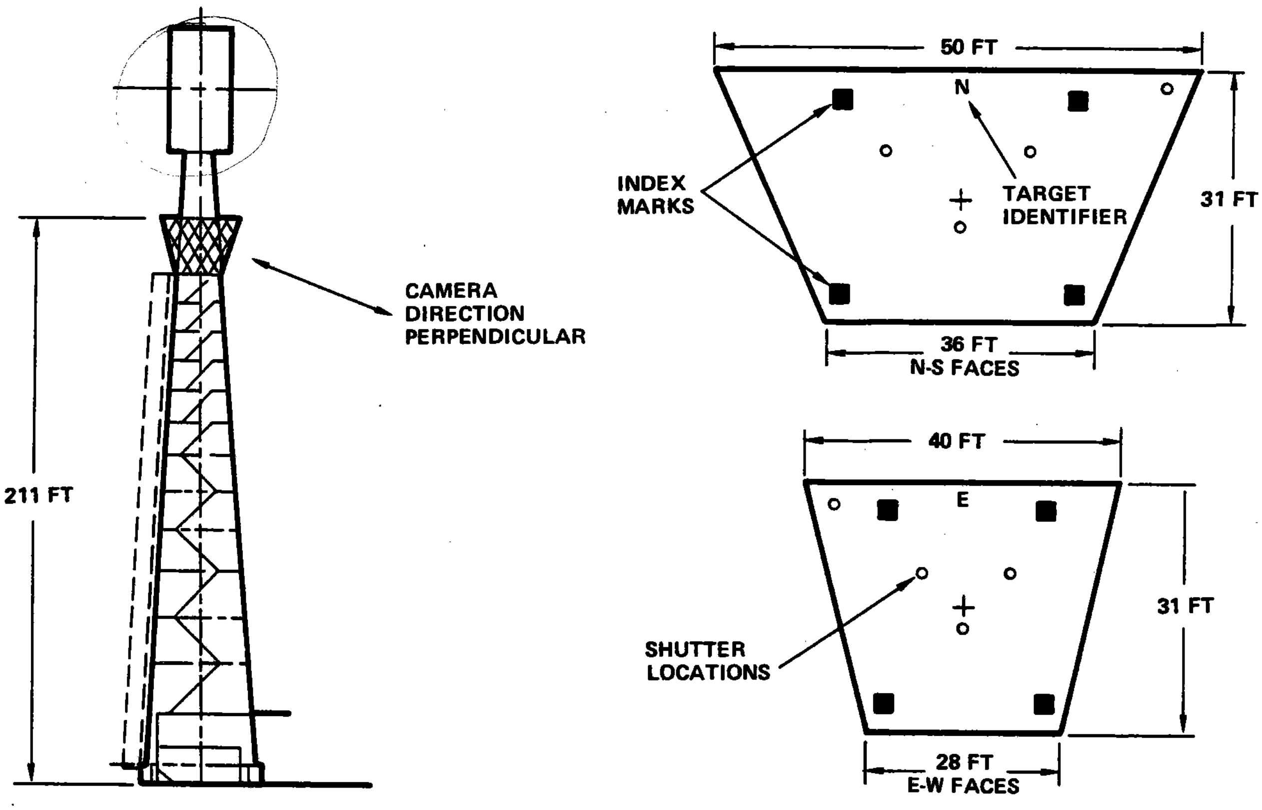


Figure M3-2. BCS Targets

- Video switching system
- Video monitor
- Cabinet for rack mounting the remote camera control system, the video switcher, and video monitor
- Mounting bases for the video cameras with sunshields

A. Video Camera

The video camera exhibits the characteristics of the COHU Model 2850C-207 low light television camera. The camera is self contained and enclosed in an environment-resistant housing and is equipped with an RCA Model 4532 B/H silicon vidicon tube. It does not require external cooling for operation between -40°C to 60°C (-40°F to 140°F).

The camera is designed for reliable, unattended, continuous-duty operation in day and night monitoring or surveillance applications. The camera can operate automatically in light levels ranging from bright sunlight to moonlight. It can be aimed at direct sunlight, without damage to the tube target, and then aimed at a low light level area and produce a clear, crisp picture.

A bright light limiter circuit allows full camera performance under conditions where blooming from intense scene highlights would otherwise make the picture unsatisfactory. The level and amount of scene highlights affected are adjustable. Highlight level can be set from black to maximum white for best contrast and resolution.

The zoom lens used on the camera is a 16 mm to 160 mm focal length f:1.8 with a 2X extender. It is manufactured by Fujinon and is contained in the COHU Camera (Model 2820C-204).

B. Remote Camera Control System

The remote camera control system exhibits characteristics of the COHU DTMF remote camera control system. The camera control unit provides a means to remotely control the operation of the four (4) video cameras located in the collector field. The following functions are controlled by the camera control unit from the local control panel or the OCS computer:

- iris
- focus
- camera switching
- camera power

The basic system consists of a transmitter at the control station, with the capability of 40 different commands, and a receiver at each television camera location. The system includes: (1) a computer interface unit with a remote control interlock and remote status feedback; (2) a switcher control; (3) pre-select automatic standby or automatic off. Communications between the transmitter and each receiver are over a standard twisted-pair wire.

When a new camera location is addressed, the previously addressed location goes to Automatic Light Control Mode (ALC) regardless of the mode it was in when last controlled. This feature serves to automatically protect the camera image tube by preventing accidental exposure to excess light.

Camera locations are addressed with a 12-key telephone-type touchpad and displayed on a 2 two-digit LED readouts labeled "SELECT" and "CONTROL." The address codes are two-digit Binary Coded Decimal and the camera control codes are 4 bit. Control codes are divided into four subgroups with each subgroup capable of ten commands, this allows transmission of forty different commands.

C. Video Switching System

The Video Switching System provides a means for connecting the four video camera inputs to a single video digitizer and video monitor. The characteristics of the switching system are similar to the COHU Model 9151 switching matrix unit. This device will provide for up to seven camera inputs to be switched to up to five output devices (i.e., the video digitizer and video monitor are the only two outputs required).

The unit consists of a standard 19-inch, rackmountable chassis which includes an integral power supply. Each unit is equipped with a circuit interconnection board; wiring; connectors; and plug-in, etched-circuit cards as required to perform the specified functions. Units may be used individually or interconnected to form large systems.

D. Video Monitor

A single nine (9) inch video monitor is provided with the BCS and is rack mounted in the master control console. The video monitor has the characteristics of the COHU Model DM-9R unit and connects to the video digitizer or the video switcher.

The monitor has three modes of operation: 1) automatic video level control with dc restoration, 2) dc restoration only, and 3) manual operation only. The operational mode is selected by a three position switch. In the automatic video level control mode, the blanking level and the contrast level are held constant. The dc restoration mode maintains a constant blanking level, however and contrast level will vary as a function of input signal. The manual operation mode (OFF position) allows viewing of changes in both the blanking level and the contrast level as a function of input signal variation.

The monitor uses cathode-ray tube that has a P4 phosphor (9300K) with a gray filter glass, and 800-line center resolution. The monitor also incorporates a differential video input in which long line/interference pickup on the cable shield is reduced by 25 dB with up to 4V p-p maximum hum component. It accepts composite or noncomposite video inputs and external sync, when required, with all inputs having loop-through capability. The monitor operates at a scan rate of 525 lines/fram (60 Hz/sec) with input signals that meet EIA RS-170 specifications.

E. Video Equipment Cabinets

The video equipment, with the exception of the video cameras, is rack-mounted in cabinets or the master control console. The video monitor is mounted in the master control console. The video control unit, video switcher, video digitizer and OCS computer interface (IEEE 488) are mounted in an EMCOR Model SFR-727A equipment cabinet.

F. Video Camera Foundations and Mounts

The video cameras are mounted in the field in the orientation shown in Figure M3-1. An adjustable camera mount bolted to a reinforced concrete pedestal and mounting plate form the camera mount.

The mount, COHU Universal Camera Mount, Model UCM-2, is of an adjustable pan and tilt design which can be adjusted manually. It can be installed in any orientation on a flat surface with a single bolt.

The camera can be locked in any desired panning orientation (360°) by tightening the 5/16" panning bolt; it can be tilted ± 50° as required and locked in position by tightening the tilt axis socket head bolt.

M3.4 Data Processing and Control Equipment

The data processing and control equipment consists of:

- Video digitzer
- OCS computer interface
- CRT/Keyboard Terminal

A. Video Dizitizer System

The video digitizer system is a Quantex Model DS-12 Digital Image Memeory/Processor. This system: 1) accepts the video signal from the video camera (conforming to the EIA RS-170 standard; 2) converts the signal to a digital form 3) stores the digital data; and 4) transmits these data to the OCS computer upon command over an IEEE 488 interface.

B. OCS Computer Interface

The Quantex Model DS-12 Video Digitizer interfaces with the OCS computer through an IEEE 488 bus controller interface. This interface connects the digitizer to a direct memeory access channel of the computer and allow block data tranfers to 210,000 bytes per second.

C. CRT/Keyboard Terminal

A CRT/keyboard terminal, Tektronix Model 4025, is provided with the BCS and connected to the OCS computer to: 1) view data processed by the BCS software, and 2) allow the operator to enter data and control the BCS activities via the keyboard. This equipment is a black and white storage tube type display table mounted and located in the data evaluation room. The unit also connects to a hard copy unit, Tektronix Model 4631. The hard copy unit uses a 3M Corporation Brand 7770 dry silver paper and produces a copy in approximately 18 seconds.

M3.5 BCS Target

The target equipment consist of the

- Target
- Radiometers
- Target Shutters

A. BCS Target

Each target consists of 20 individual panels hoisted and assembled in place on each side of the tower. Accurately located horizontal frames are permanently attached to the side of the tower. The panels are of 6061-T6 aluminum and .125 inches thick. Panel flatness criteria is established at ± 1' per 10'. Each panel is attached horizontally and anchored. Panel installation begins at the target bottom and progresses to the top using ten panels covering 36" each. Ten more panels are installed adjacent to the first ten. The largest panels are 3' X 20'; the rest are shortened to accommodate the shape of the target. An extrusion is riveted to the top edge of each panel and is hooked over a leg of the 3" channel. The bottom edge of each panel has a continuous aluminum angle riveted to it. To the horizontal flange of the angle a clevis and compression spring are tensioned to hold the top edge of the under panel secure. Each of the targets is erected in place with a 1/4" spacing between adjacent targets to accommodate expansion.

The paint to be used for the BCS target is a high temperature, lamertain, flat white and has a flat spectral reflectance. The 3M corporation Nextel paint is representative of a paint that is suitable for covering the target surface. This paint has the following characteristics:

Color	flat white
Directional Reflectance	constant out beyond 65°
Spectral Reflectance	flat from .4 μ to .7 μ
Temperature	stable at 250°F to 300°F
Life Time	>1 year
Chalking	none

B. Radiometers

Four radiometers are located on each target in the patterns as shown in Figure M3-8. The radiometers are Medtherm Corp. Model FDTW-2.5-20020. The radiometers measure the light intensity incident on the surface of the sensor and provide an analog signal proportional to the light intensity to the MODCOMP MODAC III Analog Input Circuitry. The measurements are digitized and subsequently transmitted to the OCS computer where the values are used in beam characterization computations.

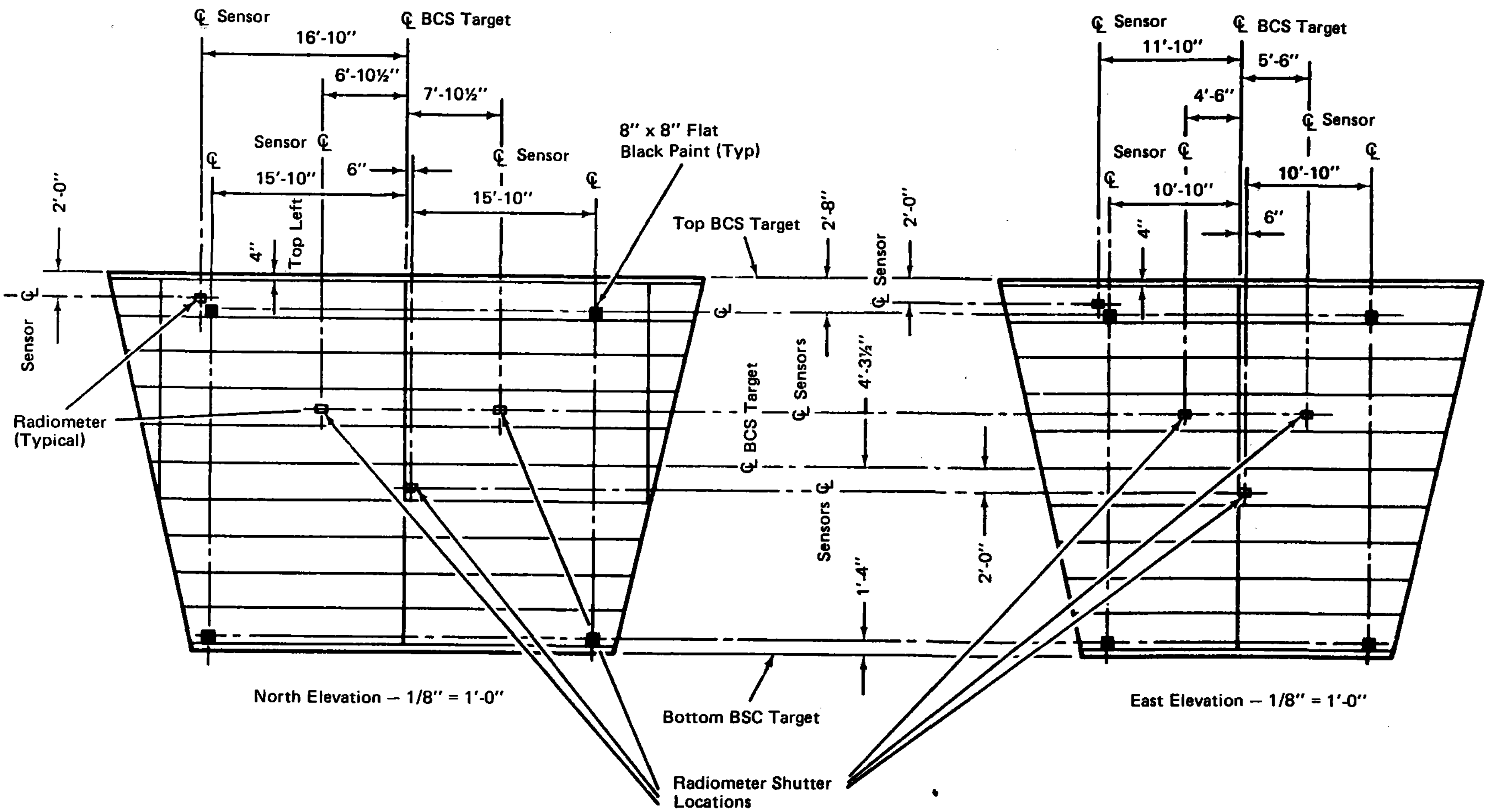


Figure M3-3. Radiometer and Radiometer Shutter Orientation

The radiometers are water cooled to protect the sensor below and above the temperature range of 45°F to 130°F. A thermocouple is provided in the sensor; however, this measurement is not counted or used by the BCS.

C. Target Shutters

Three target shutters are provided on each target. The shutters allow the total blocking of the light source impinging at the radiometer apertures located closest to the target center. The three shutters on each target are pneumatically controlled by a single solenoid operated valve that is activated from the MODACS III digital output circuitry. The location of the shutters are shown in Figure M3-3.

M3.6 Operation

The BCS is used periodically to align and calibrate individual heliostats. It can be used to analyze heliostats that are in "standby" operating mode in which the heliostat images are tracking a standby point adjacent to the receiver.

The BCS is operated in a near automatic fashion and interfaces with the heliostat array controller (HAC), OCS, and the plant operator. Movement of an individual heliostat on to the tower-mounted target and calibration of the heliostat is possible during the normal steady-state operating modes of the total system.

The BCS operations can be divided into the following phases; initiation, calibration, calculation, and transfer/display. During the initiation phase, three lists of heliostats to be measured are created. In addition, any neighboring heliostats which will cause blocking and shadowing are also identified. These lists are transferred to the HAC while the initialization of the BCS software and hardware is carried out. This initialization involves the selection of start time, alarm thresholds, and sample rates.

During the calibration phase, the heliostats are brought on target, the background is determined and subtracted from the data, and a calibration curve results. The calibration curve relates gray level digital valves to watts/cm^2.

During the calculation phase, centroids are determined and averaged, beam powers are calculated and compared to theoretical values. Finally the centroids and beam powers are tested against alarm thresholds and error messages (if any) are sent to the HAC.

In the transfer/display phase, the digital data is stored on disk file, results are sent to the HAC, and if necessary power profiles are displayed at a graphics terminal.

Table of Contents

M4. RECEIVER SYSTEM

M4. RECEIVER SUBSYSTEM

M4.1 Drawing References

A. Mechanical

40P2005131763 - P&ID Receiver Preheat Panel Feedwater
40P2005131764 - P&ID Receiver Boiler Panels RB-204 Thru RB-209
40P2005131765 - P&ID Receiver Boiler Panels RB-210 Thru RB-215
40P2005131766 - P&ID Receiver Boiler Panels RB-216 Thru RB-221
40P2005131767 - P&ID Main Steam Manifold, GN_2, & Drain Systems

B. Control Logic Diagrams

40I7002133054(I15-50) - Receiver Nitrogen Pressure Valves
40I7002133055(I15-52) - Flash Tank Steam Inlet Valve (AOV-2911)
40I7002133056(I15-53) - Valves AOV 2901 and AOV 2902
40I7002133061(I15-54) - Preheat Panel Feedwater Inlet Valve AOV 2004
40I7002133039(I5-50) - RS N_2 Valves - SOV 2019 A&B SOV 2016 A&B
40I7002133040(I5-52) - Flash Tank Steam Inlet Valve - AOV 2911
40I7002133041(I5-53) - Valves AOV 2901 & PSV 2902 Control
40I7002133060(I5-54) - AOV 2004 Control

C. Electrical

M4.2 General Description

The receiver system is a tower-mounted single pass to superheat boiler with the heat absorbing surfaces (panels) configured to form a vertical cylinder 45 feet high by 23 feet in diameter. The total of 24 receiver panels are subdivided into two groups; preheat panels which comprise the 6 southern most panels and boiler panels which consist of the remaining 18 panels that face in a west, north, or easterly direction. Incident radient energy is distributed over the outside surface of these panels by means of aim points assigned to the individual heliostats in the collector field.

The receiver subsystem also includes the feedwater distribution circuits to the individual preheat and boiler panels, the steam collection manifold, the receiver flash tank, GN_2 distribution network, and moisture separation and drain equipment. In addition, it includes all of the structure and attachments required to support the piping and panels as well as to allow for thermal expansion and contraction over the entire operating temperature range.

During receiver operation, feedwater enters the receiver at the top of the tower through the riser line. The feedwater first passes through inline filter PF-FW-2-201 with a 100 micron equivalent mesh size and isolation valve AOV-2004 and then to the preheat panel inlet headers. These headers distribute the total flow in an uncontrolled fashion between preheat panels RP-201, 202, and 203. The feedwater passes vertically upward through each of the panels and exits at the top of the respective panels. The flow from each of the three panels is separately routed back to the bottom of the panels where it enters preheat panels RP-222, 223, and 224 followed by a second vertical preheat pass. The routing of panel RP-201 into RP-222, RP-202 into RP-223, and RP-203 into RP-224 is designed to result in similar energy input into each of the three parallel preheat flow streams.

Preheated feedwater leaving panels RP-222, 223, and 224 flows into a common downcomer line and into a ring distribution manifold which in turn provides feedwater to each of the 18 boiler panels (RP-204 through RP-221). Flow to each boiler panel is controlled by a flow control valve (TV-2301 thru 2303, TV-2401 thru 2403, TV-2501 thru 2503, TV-2601 thru 2603, TV-2701 thru 2703, and TV-2801 thru 2803) which adjusts flow to produce the setpoint steam temperature at the outlet of each boiler panel. Flow in each boiler panel is upward during which the feedwater is converted into superheated steam.

Steam flow leaving each boiler panel passes through a moisture separator (a separator is dedicated to each panel) which removes entrained water droplets. The steam is then manifolded together with adjacent three panel groupings being combined first to form six steam lines that finally combine into the 6 inch main steam line. Depending on the conditions of the steam or the state of the rest of the plant, the steam can be either directed to the main steam downcomer line (down the tower) through valve UV-2905 or into the receiver flash tank through valve AOV-2911.

The receiver flash tank V-201 is used primarily during receiver startup when all water or a water/steam mixture is flowing from the boiler panels. The tank allows the water and steam components to be separated with each passing down the tower through dedicated steam and water downcomer lines. The tank is rated for a pressure of 600 psig and 950°F. The pressure during startup will be limited to 500 psia.

Note that the flash tank pressure rating is well below the nominal receiver operating pressure range of 1510-1570 psia. The 950°F design temperature is slightly below the normal receiver steam temperature control point of 960°F and 60°F below the maximum temperature excursion valve of 1010°F. These lower tank pressure and temperature conditions were selected to limit the flash tank wall thickness to a reasonable value which can accomodate the thermally cyclic environment associated with daily startup and shutdown as well as periodic cloud passage without requiring extended heatup and cooldown cycles. Because of the pressure and temperature incompatibility between the receiver and flash tank, valve AOV-2911 must be interlocked to receiver steam pressure and temperature to prevent its opening when the steam pressure and/or temperature are above the allowable limit of the flash tank.

The gaseous nitrogen network is used to provide a source of nitrogen during receiver draining operation to prevent the inflow of oxygen into the system and to prevent the cavitation of the boiler panel inlet water control valves during periods of initial water circulation (prior to applying heat to the receiver) by pressurizing the flash tank to a level above the local saturation pressure. During draining operation, a 25 psia nitrogen pressure is supplied to the receiver water and steam lines. During initial circulation, a nitrogen pressure of 415 psia is supplied to the receiver flash tank.

M4.3 Receiver Panels

The receiver absorbing panels are composed of an inlet water manifold, 70 vertical tubes, and an outlet manifold. For the 18 boiler panels, inlet water control valves are included upstream of the inlet water manifold to provide for outlet steam temperature control.

The panel tubes are made of Incoloy 800 and have an outside diameter of 0.5 inch (ID = 0.269 inch). Each panel has a vertical dimension of 45 feet and a width of 35 inches. Adjacent tubes are welded together to form a "light tight" absorbing surface. The exposed panel surface is coated with Pyromark (α = .95) to enhance the absorption of incident energy. The back surface of the panels is insulated to minimize heat loss and prevent excessive temperatures from occurring in the receiver core area.

The receiver panels are fixed at the top of the receiver and allowed to expand vertically downward when raised to operating temperature. Each panel is also free to expand in the transverse direction.

Each tube in the 18 boiler panels is orificed to distribute the water flow between the 70 tubes of each panel. North facing panels have identical orifices in each tube to provide a uniform flow distribution. This is required since these panels may experience a transverse gradient in incident power that reverses during the course of a day. During the morning, the left side of the panel will be exposed to a greater flux than the right side. By noon, the left to right distribution will be nearly uniform while in the afternoon, the high flux region will move to the right side of the panel.

The boiler panels facing the easterly and westerly directions experience a transverse power gradient which varies in intensity but is consistent in direction. On these panels, the north portion of each panel always experiences a higher flux than the southern portion. In these panels, graded orifices are used to produce a perferential flow through the northern tubes.

Each panel is instrumented with thermocouples to monitor metal temperature. The maximum permitted metal temperature is 1150°F with the actual metal temperature being influenced by the panel outlet steam temperature and distribution of incident energy over the receiver surface.

M4.4 Feedwater Circuit

Feedwater enters the receiver through the riser line at an interface point at the top of the tower. Prior to receiver startup, the feedwater flow can be diverted into the receiver flash tank through PV-2902 to allow feedwater circulation (for loop cleanup purposes) without requiring flow through the panels which would reject a substantial amount of the thermal energy contained in the feedwater (feedwater temperature must be maintained in the deaerator at a level greater than or equal to 228°F to permit adaquate deaeration during clean up operation).

During normal receiver operation, the feedwater is routed through the 6 preheat panels (3 parallel paths of two panels each). No control valves or tube orificing is used to control flow in these panels. The mix feedwater temperature leaving the final preheat panels and entering the boiler panel distribution manifold must be at least 50°F below the local boiling point (function of the local water pressure). If the final feedwater is less than 50°F subcooled, distructive cavitation may occur across the boiler panel inlet control valves. Increased subcooling can be achieved by reducing the incident power on the preheat portion of the receiver through selective heliostat defocus or by reducing inlet feedwater temperature through setpoint adjustment in the feedwater heater circuit.

M4.5 Steam Manifold

Steam leaving each of the 18 boiler panels passes through a moisture separator which is designed to remove small quantities of entrained moisture. The condensate is routed to a separator drain manifold which in turn drains to the flash tank. Steam leaving the moisture separators combine into three panel groupings and then flows into a common collection manifold.

During startup or in the event dry superheated steam is not available at a condition compatible with the operation of the rest of the plant, the flow may be diverted to the flash tank subject to the flash tank temperature and pressure limitations. During this period, receiver steam pressure will be under the control of the receiver flash tank vent valve (PV-2906).

When adaquate steam conditions exist and downstream components are properly conditioned, the steam flow can be diverted to the main steam downcomer. During this period, receiver steam pressure control will be maintained by either the steam dump valve (PV-1001), the turbine inlet valve, or the thermal storage inlet valve (UV-3102). The steam collection manifolding is capable of accepting a steam temperature transient of 60°F/min.

M4.6 Drains and Vents

In order to prevent receiver freeze up during subfreezing non-operating periods or to permit receiver maintenance, provisions are incorporated in the receiver to drain each of the panels. The drain operation is controlled by 24 remotely operated solenoid valves placed in each panel (AOV2101-2103, AOV2201-2203, AOV2313-2315, AOV2513-2515, AOV2613-2615, AOV2713-2715, and AOV2813-2815).

Upon command, these valves open and allow each panel to drain into a common collection line which in turn passes down the tower to the condenser. During the draining operation, low pressure (10 psig) nitrogen gas in introduced into the top of the preheat panels to backfill the receiver.

Since the drain lines downstream of the solenoid valves are rated for low temperature/low pressure service (230 psig, 300°F), the operation this drain loop is interlocked to receiver pressure to prevent inadvertent activation during normal receiver operation. Approximate receiver drain time is 15 min.

Two receiver vents (AOV-2902 and AOV-2903) are available for receiver venting required during initial filling operation or as a pressure relieving device which can be activated during normal receiver operation or during trip conditions to prevent the need to lift the safety relief valves on a "routine" basis.

Valve AOV-2902 provides the main receiver venting function which can be activated either manually or automatically as a receiver protective device once receiver trip conditions have been detected. The valve is capable of passing 40,000 lb/hr of steam at its design operating condition. This is approximately 1/4 of the maximum design flow of the receiver feed pump. As a result, any effort to use this valve to vent full receiver flow without opening the receiver safety valves will require the pump speed to be reduced to a value substantially below the 3550 RPM maximum operating speed.

Valve AOV-2903 is a low flow valve which is used to vent nitrogen during receiver filling operation. This valve is opened by the operator and will normally remain open until water flows from the valve indicating the upsteam portion of the receiver is filled.

M4.7 Receiver Nitrogen Service

Gaseous nitrogen is provided in the receiver at two pressure levels to be used during draining operation and during periods of feedwater circulation prior to directing heliostat images on to the receiver. The points of low pressure (10 psia) nitrogen injection and its use during draining operation is as discussed in Section M4.6. Maximum nitrogen supply rate at 10 psig is 75 SCFM.

High pressure nitrogen (up to a maximum pressure of 400 psig) is used to pressurize the receiver to a level above the local vapor pressure to prevent cavitation from occuring across flow control valves. When the receiver has been drained and AOV-2004 and AOV-2911 are closed, the initial feedwater circulation during cleanup will be through the flash tank. The flash tank will be pressurized with nitrogen to ensure that a condition of at least 50°F subcooling exists in the feedwater entering PV-2002.

To prevent the nitrogen from flowing to the downstream components (deaerator and condenser), the flash tank vent valves PV-2906 and AOV-2914 must be closed during this period. Also to prevent high pressure nitrogen back flow into the drained receiver, valves AOV-2911 and AOV-2915 must be closed.

When it is required to fill the receiver, assuming initial feedwater circulation was provided through PV-2002 to the flash tank, valve AOV-2004 and vent valve AOV-2007 shall be opened first. The receiver panels must be allowed to fill completely (feedwater flowing from the vent valve) prior to opening valve AOV-2911 and allowing the panel flows to enter the flash tank. This is required to prevent high pressure nitrogen from filling the partially filled receiver panels and steam collection piping.

In order to prevent the nitrogen bubble from migrating from the flash tank to the receiver high point and filling the steam piping network, a minimum feedwater flow of 4000 lb/hr is required. With this flow, the downflow feedwater velocity in the main steam line will exceed the maximum nitrogen bubble rise rate and the nitrogen charge will be retained in the flash tank.

With feedwater flow circulating through the entire receiver, flash tank pressure must be adjusted to ensure that a condition of at least 50°F subcooling exists at the inlet to each of the panel control valves. Since any nitrogen introduced into the receiver must be removed through either the deaerator noncondensible vent or the condenser vacuum pump, it is important to minimize the quantity of nitrogen to only that amount required to prevent valve cavitation. Since the nitrogen charge will be the first flow leaving the flash tank through valve PV-2906 when initial steaming operation begins, an excessive nitrogen charge may lead to a plant trip because of excessive deaerator and/or condenser pressure.

M4.8 Operation and Control

A. Startup

Receiver startup is initiated by filling the receiver and providing sufficient circulation (both in quantity of flow and time) to allow for initial feedwater cleanup. During this period, all feedwater flowing through the panels is routed through the receiver flash tank and then down the tower to the feedwater loop and/or condenser. During this period, feedwater flow through the flash tank is limited to 40,000 lb/hr which is the design capacity of the flash tank and tank drain equipment.

Once satisfactory water chemistry levels have been achieved, heliostat images may be directed on to the receiver surface. During this period, the receiver feed pump speed is adjusted to establish a constant startup flow of ≈30,000 lb/hr while receiver pressure is maintained by the nitrogen pressurization equipment describe in M4.7. Individual panel control valves are set to preassigned positions. Because the valves have different trim characteristics depending on the panel location, the preassigned positions will create a flow distribution among the boiler panels.

Heliostats are directed on to the receiver per established procedures. Note that since the local performance of the collector field varies as a function of time of day and time of year, unique collector field startup procedures depending on the time of startup are required. Also, the thermal power directed toward the receiver must be accomplished in such a manner as to maintain at least 50°F subcooling in the mix water temperature leaving the preheat panels.

With the heat addition in the receiver, water temperature entering the flash tank rises and the boiling process is initiated. When the flash tank pressure reaches 500 psia, the flash tank pressure valve PV-2906 opens and maintains the tank pressure at 500 psia. At this point, the panel control valves are commanded to regulate individual panel flows to produce a 500°F panel outlet steam condition. During this period, the receiver feed pump speed must be modulated to match the receiver flow requirements while maintaining required inlet water pressure.

Steam temperature setpoint is maintained at 500°F until all boiler panels are satisfying the required steam temperature. At that point, the main steam downcomer valve (UV-2905) is slowly opened allowing steam to flow to the downcomer and downstream equipment for preheating purposes. Once proper downstream conditions have been established, the receiver flash tank is taken out of service (valve AOV-2911 is closed) and receiver pressure control is maintained by main steam dump valve PV-1001.

During periods of receiver flash tank operation, the maximum condensate or steam flow leaving the flash tank is 40,000 lb/hr based on outlet piping and control valve flow limitations. During a morning starup (rising sun), the performance of a fixed "startup" portion of the collector field may increase significantly in a short period of time due to the apparent sun motion. Care must therefore be exercised by the operator to recognize this condition and prevent overloading of the flash tank. Some defocus of previously contributing heliostats may be required to prevent the situation of continuously rising power in excess of the flash tank capability.

With the receiver flash tank out of service and receiver pressure control being maintained by the steam dump valve, receiver steam conditions are ramped to the appropriate value required to initiate plant operation. Steam temperature is ramped by adjusting receiver panel control valve setpoint while pressure is ramped by adjusting the steam dump valve setpoint. All temperature ramps should be initiated prior to pressure ramps to prevent the formation of a two-phase condition at the receiver outlet. During all ramping operation, the speed of the receiver feed pump must be adjusted to maintain required feedwater pressure and flow.

B. Normal Operation

Once the receiver steam is under pressure control by the steam dump valve and the individual panel control valves maintain steam temperature, considerable flexibility exists regarding the steam temperature and pressure setpoint conditions. These conditions are determined by the ultimate use of the receiver steam. Unique steam conditions are required for turbine startup (differing for a cold, warm, or hot turbine initial condition), normal turbine operation, and thermal storage charging. Typical steam conditions as measured at the turbine inlet are:

	Temperature	Pressure
Turbine startup		
• Cold	585°F	≈590 psia
• Warm • Hot	per GE turbine specifications	
Turbine operation	950°F	1465 psia
Thermal storage charging	650-950°F (derated-rated)	1465 psia

Receiver operation from a steam temperature and pressure standpoint is permitted for any of these conditions. Total steam flow leaving the receiver is closely coupled to the amount of thermal power incident on the receiver which may be incompatible with flow limits required by a downstream component (for example the turbine during startup). During these periods, course modulation of steam flow can be accomplished by modulating heliostats on to or off of the receiver. Fine flow control to a flow limiting component must be controlled by providing an alternate (non-limiting) flow path for the receiver steam such as the steam dump valve.

C. Shutdown

The receiver shutdown process is in general the reverse of the startup process described in Section M4.8A. Receiver steam pressure control is shifted from the turbine inlet or thermal storage charging inlet control valve (depending on mode of plant operation) to the steam dump valve PV-1001. Receiver steam pressure is reduced through the coordinated operation of the steam dump valve and the receiver feed pump. Steam temperature is reduced by ramping the temperature setpoint for the panels downward.

Steam flow passing through the downcomer and steam dump valve during this period must at all times be maintained with at least 50°F of superheat. Failure to maintain sufficient superheat may result in two phase flow entering the downcomer which could flash and damage piping and/or downstream flow control components.

When the steam pressure at the receiver is less than or equal 500 psia and the steam temperature is less than 950°F, the main steam downcomer inlet valve UV-2905 can be closed while the flash tank inlet valve AOV-2911 is opened diverting flow to the flash tank. The total steam flow at this point must be below the 40,000 lb/hr maximum steam flow limit. Reduced steam flow can be accomplished by defocusing operating heliostats. At this point, the receiver is decoupled from the rest of the system and the heliostats powering the receiver can be removed causing a natural deterioration in steam conditions. With the heliostats removed from the receiver, the feed pump can be shut down and draining and/or blanketing provisions can be initiated.

TABLE OF CONTENTS

M5. MAIN STEAM SYSTEM

M5. MAIN STEAM SYSTEM

M5.1 Drawing Reference

A. Mechanical

40P2005131767 - P&ID Main Steam Manifold, GN_2, and Drain Systems

40P7005133140 - P&ID Electrical Power Generation Subsystem (EPGS) Steam

40P9005133306 - P&ID Steam

40P3005132193 - P&ID Thermal Storage Subsystem (TSS) Charging Steam and Condensate

B. Control Logic Diagrams

40I7002133008 (I5-6) Steam Atomizing Value FV-1006

40I7002133018 (I5-7) MOV Control (MOV-1030, -1031, -1132)

40I7002133021 (I15-6) FOV-1006 Control

40I7002133029 (I15-17) MOV Control MOV-1030, MOV-1031, MOV-1132

40I7002133024 (I15-9) SOV-1002 Control

40I7002133011 (I5-9) SOV-1002 Control

C. Electrical

40E7005133192 - One Line Diagram 480 Volt MCC-B

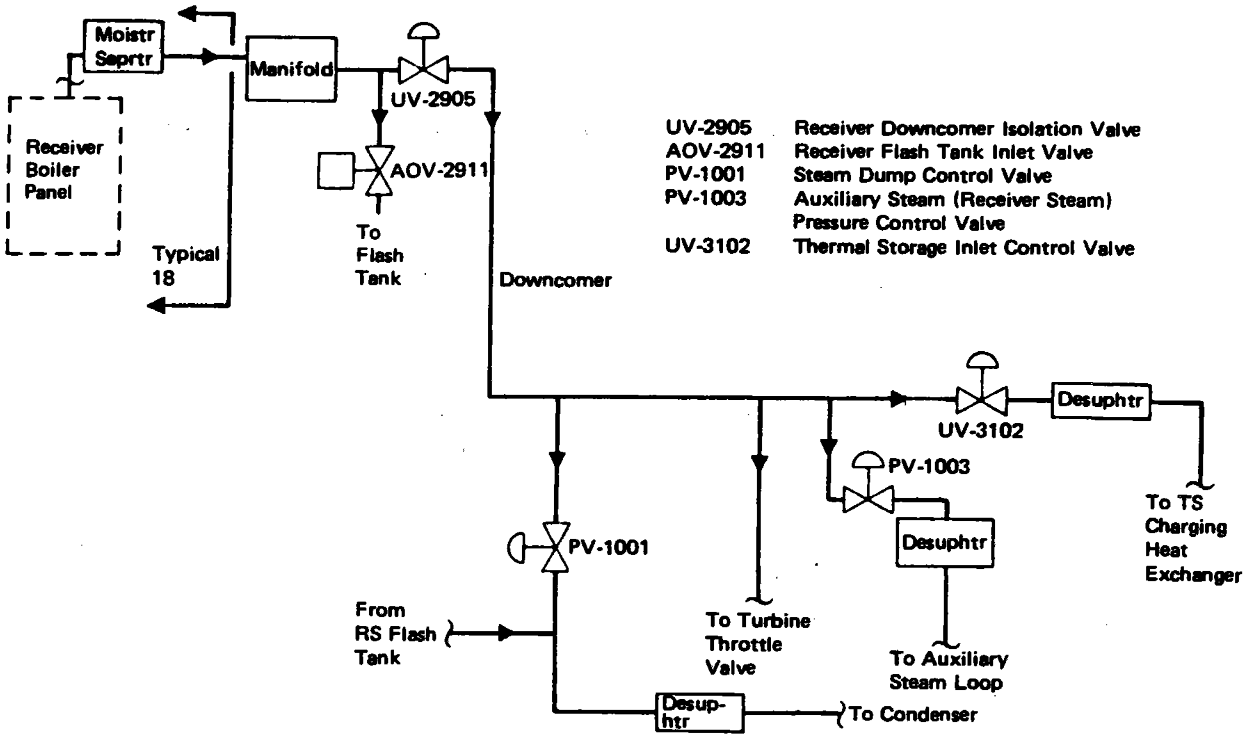


Figure M5-1. Main Steam System

M5.2 General Description

The main steam system consists of the piping network and control valves required to transport receiver steam from the receiver outlet (defined by the downcomer isolation valve UV-2905) to:

(i) the turbine throttle valve.

(ii) the thermal storage charging inlet control valve (UV-3102) and desuperheater (DS-301).

(iii) the condenser through the steam dump pressure control valve (PV-1001) and downstream desuperheater (DS-901)

(iv) the auxiliary steam loop through the pressure control valve (PV-1003) and downstream desuperheater (DS-902).

The downcomer and main horizontal steam piping is constructed of 6 inch double-extra strong pipe of material 2-1/4Cr-1Mo ASTM A335 Grade P22. It is capable of accommodating a steam temperature of 1010°F at a pressure of 1765 psig which is established by the receiver relief valve setting. The piping network and valves are designed to ANSI B 31.1 (Power Piping Code). Pipes located downstream of desuperheaters are designed for lower temperature service with the exact requirement depending on the service involved.

During normal receiver operation when superheated steam is available at the receiver outlet, the particular flow path followed by the steam depends on the plant operating mode or transition through which it is currently passing. Flow passing to the turbine must be within specified temperature and pressure limitations as specified by the turbine supplier. These conditions vary between turbine startup and normal operation. Steam flow passing directly to the condenser through the steam dump line after being reduced in pressure by PV-1001 is desuperheated (by DS-901) to a condition of 10°F superheat which can be introduced into the condenser without creating an unacceptable condenser back pressure. Flow passing to the thermal storage charging equipment first passes through a low pressure drop control valve (UV-3102) required to apportion flow to thermal storage and then through a desuperheater which is required to reduce steam temperature to a level compatible with the Caloria HT-43 maximum temperature limit. Flow passing to the auxiliary steam loop passes through a downstream pressure control valve (PV-1003) and desuperheater which are designed to produce steam on a demand basis at 75 psia and 345^{o}F.

The main steam syscem is designed for steam service only with trips and interlocks provided which close the main downcomer inlet valve in the event that water or two-phase flow is entering the downcomer. The principal trip parameter is degrees of steam superheat which must be maintained or exceeded at the inlet to the downcomer with 50^{o}F being the minimum acceptable valve. Because of the relatively small steam pipes involved in this plant, steam temperature transients as high as 60^{o}F/min can be tolerated on a repeated basis during daily startup, mode transitions requiring changes in receiver steam temperature, and shutdown. Low point drains and bootlegs are placed in the steam lines to trap and remove condensed moisture which could be introduced into the turbine or other control component causing damage to the equipment. Information regarding drain control valves is contained in Section M12.

Depending on the operating mode, the turbine throttle valve, steam dump valve, or thermal storage inlet control valve will be responsible for maintaining pressure control in the main steam system. The principal control point is in the steam line at sensor PIT-1001 which is located approximately 150 ft upstream of the turbine throttle valve at the split point for the steam dump and thermal storage charging steam line. By controlling pressure at this control point, steam pressure at the inlets to the turbine and thermal storage and at the receiver outlet float as a function of total flow and the flow split. A minimal control point pressure of 1505 psia ensures that the inlet steam pressure to the turbine and thermal storage is always greater than or equal to 1465 psia independent of the flow split between the two flow paths. This is critical for the successful operation of the thermal storage charging heat exchangers in which the condensing pressure determines the condensing temperature and overall heat exchanges operating capability. At low flows to either the turbine or thermal storage charging equipment, the inlet pressure will approach the 1505 psia control point valve.

M5.3 Steam Dump Network

The purpose of the steam dump network is to provide an alternate flow path for receiver steam which is used during startup and shutdown periods and in the event of a flow upset or component trip. Valve PV1001 is capable of maintaining or controlling upstream steam pressure while allowing flow to pass through the downstream desuperheater (DS-901) and on to the condenser.

The flow capacity of PV-1001, DS-901, and the associated piping network to the condenser have been sized to accomodate (i) steam flow of 112,300 lb/hr at nominal conditions of 950°F and 1465 psia associated with a turbine trip while producing 12.5 MWe or (ii) steam flow of 130,000 lb/hr at nominal conditions 650°F and 1465 psia associated with a thermal storage charging equipment trip. The steam dump network is capable of operating and maintaining upstream pressure control at inlet steam conditions as low as 6500 lb/hr, 380 to 1505 psia, and 440-950°F.

Since PV-1001 is required to open in the event of a turbine or thermal storage charging loop trip and assume the main steam pressure control function an actuation time of 0.8 sec to full open is specified for the valve to prevent opening of receiver safety valves in the event of a trip at or near full flow operation. The desuperheater and water injection equipment is designed with a comparable response to ensure that the desuperheating function can be initiated immediately thus preventing a plant wide trip that would occur if non-desuperheated steam were introduced into the condenser.

Since the condenser can experience large steam flows from the turbine which originate from turbine admission steam, the simultaneous injection of large steam flows from the steam dump network and turbine can over load the condenser causing a trip due to high condenser pressure. The operation of PV-1001 is therefore limited by a condenser pressure override function which limits condenser pressure to 5 in Hg absolute (low vacuum alarm point). When the condenser pressure override function is initiated, PV-1001 will be restricted from opening to its normal control position. This will result in a buildup of upstream steam pressure and opening of receiver safety relief valves unless some other corrective action is taken. This condition could occur in either Mode 4 or 7 operation which experience high turbine admission steam and thermal storage charging flows followed by a trip of the thermal storage charging equipment.

During the operation of PV-1001 and desuperheater DS-901, an additional atomizing steam flow is required for proper desuperheater operation. This steam flow is drawn directly from the main steam system and introduced into the desuperheater through FV-1006. This valve is interlocked directly to PV-1001 to ensure simultaneous opening of both valves.

M5.4 Auxiliary Steam System Inlet

The auxiliary steam system draws steam from the main steam system on a demand basis through the pressure reducing valve PV-1003 and desuperheater DS-902 (DS-902 is also used to desuperheat admission steam entering the auxiliary steam system).

Valve PV-1003 is designed to reduce main steam pressure to a downstream control valve of 82 psia which is required to produce a 75 psia steam condition downstream of the desuperheater. The valve is designed to operate over the following range of conditions:

	Flow (lb/hr)	Inlet Temp (°F)	Inlet Pressure (psia)
(i)	13554	650	1465
(ii)	9880	950	1465
(iii)	368	950	1465

The first two conditions correspond to high auxiliary steam flow requirements associated with receiver "stand alone" operation in which all receiver output flows through the steam dump network to the condenser. The last condition corresponds to the low flow limit anticipated for normal "on demand" service.

The desuperheater (DS-902-Copes Vulcan V076) reduces the steam temperature to 345°F which is the downstream components receiving the auxiliary steam. No atomizing steam is required for this desuperheating function.

Table of Contents

M6. THERMAL STORAGE SYSTEM (TSS)

M6. THERMAL STORAGE SYSTEM (TSS)

M6.1 Drawing References

A. Mechanical

40P3005132192	P&ID	Thermal Storage System (TSS) Charging Oil
40P3005132193	P&ID	Thermal Storage System (TSS) Charging Steam and Condensate
40P3005132194	P&ID	Thermal Storage System (TSS) Extraction Oil
40P3005132195	P&ID	Thermal Storage System (TSS) Extraction Steam and Condensate
40P3005132196	P&ID	Thermal Storage System (TSS) Thermal Storage Unit and Ullage Maintenance Unit

B. Control Logic Diagrams

40I7002133046	(I15-30)	Thermal Storage Fluid Auxiliary Pump P305 (TFAP) Control
40I7002133047	(I15-31)	TSS Fluid Oil Pump Control (Charging and Extraction Pumps P301, P302, P303, and P304)
40I7002133048	(I15-33)	AOV Valves: -3220, -3320, -3209, -3309, -3905, -3906, -3708, -3808, -3707, -3807, -3218, -3318, -2903
40I7002133049	(I15-34)	Thermal Storage Hot Standby Fluid Control Valve - AOV 3005
40I7002133050	(I15-35)	Valves AOV 3001, AOV 3002, AOV 3003, AOV 3004, AOV 3907
40I7002133051	(I15-36)	Valves AOV 3717, and AOV 3817
40I7002133052	(I15-37)	TSS Steam Generator Bleed Control Valves AOV 3117 and AOV 3118.
40I7002133053	(I15-38)	Thermal Storage Heater Steam Inlet Control AOV 3206 and AOV 3306
40I7002133031	(I5-30)	Thermal Storage Fluid Auxiliary Pump Control (P-305)
40I7002133032	(I5-31 & I5-31a)	TSS Fluid Oil Pump Control (Charging - P301 and P302: Extraction - P303 and P304) and TSS Fluid Oil Pump Control Table
40I7002133033	(I5-33 & I5-33a)	AOV Valves: -3220, -3320, -3209, -3309, -3905, -3906, -3708, -3808, -3707, -3807, -3218, -3318, -2903 and I5-33 Valves-Control Table

40I7002133034	(I5-34)	Thermal Storage Hot Standby Fluid Control Valve AOV 3005
40I7002133035	(I5-35) & I5-35a)	AOV Valves: -3001, -3002, -3003, -3004, -3907 and I-35 Valves-Control Table
40I7002133036	(I5-36)	Superheater Steam Outlet Control Valves AOV 3717 and AOV 3817
40I7002133037	(I5-37 & I5-37a)	TSS Steam Generator Bleed Control Valves AOV 3117 and AOV 3118 and I5-37 Valves-Control Table
40I7002133038	(I5-38)	Thermal Storage Heater Steam Inlet Control Valve AOV 3206 and AOV 3306

C. Electrical

40E7005133192	One-Line Diagram 480 Volt MCC-B
40E3005132029	One-Line Diagram Load Center "A" and Receiver F.W. Pump
40E7005133187	Electrical Equipment - General Arrangement Bldg. 712 and 709 and 710

M6.2 General Description

The thermal storage system is designed to absorb and store thermal energy by condensing receiver generated steam and to serve as a source of thermal energy for a simultaneous or subsequent steam generation process. The thermal energy is absorbed into the subsystem (charging process) by circulating low temperature (nominally 425°F) Caloria HT-43 (heat transfer oil) through charging heat exchangers which condense receiver steam and exits from the heat exchangers at an elevated temperature (580°F). The high temperature Caloria flows to either the storage tank (thermal storage unit) or on to the inlet of the steam generating heat exchangers.

The thermal storage unit (TSU) is a vertical cylindrical tank filled with a sand/rock mixture through which the Caloria passes. Hot Caloria is introduced at the top of the TSU through a distribution manifold and passes downward through the tank. As the oil passes through the rock/sand mixture, it transfers its heat to the sand and rock and is cooled to the low temperature

(425°F) condition. The zone of heat transfer within the tank (thermocline) occurs over a small fraction of the entire tank height. As energy is added to the TSU, the thermocline moves downward thereby increasing the thermal charge of the system.

During the energy extraction process, high temperature Caloria is circulated to the steam generators either flowing directly from the outlet of the charging heat exchangers or from the top manifold in the TSU. The steam generators produce steam at a nominal condition of 420 psia and 530°F. Caloria leaves the steam generators at a nominal temperature of 425°F and flows to either the TSU bottom manifold where it is reintroduced into the tank or directly to the charging heat exchangers where it absorbs additional charging energy.

The Caloria introduced into the TSU bottom manifold flows upward through the sand/rock mixture. As the Caloria passes through the thermocline region, it absorbs heat from the high temperature rock and continues to flow upward until it passes out of the top of the tank at a nominal temperature of 575°F During this period, the thermocline is moving toward the top of the TSU which results in a net energy extraction from the TSU. Charging and extraction functions for the TSU must be terminated when the thermocline begins to pass out of the bottom or top manifold respectively.

The ullage maintenance unit (UMU) controls the pressure in the TSU to a safe level and removes volatile degradation products generated by the Caloria at high temperature. The UMU also controls nitrogen flow to the TSU. At all times, the TSU is maintained at a slightly positive pressure to prevent air from leaking into the tank. The presence of oxygen in the tank will significantly increase the degradation rate of the Caloria and could produce a combustible mixture if sufficient free oxygen existed inside the TSU.

M6.3 Charging Loop (Steam and Condensate)

The steam and condensate portion of the charging loop is composed of a single inlet control valve (UV-3102) which has responsibility upstream pressure or flow control depending on the plant operating mode, a steam desuperheater (DS-301), two identical parallel charging heat exchanger trains complete with drain tanks, and a condensate flash tank (V-304). For discussion purposes, the flash tank along with its outlet steam and condensate flow control equipment are treated in Section M9.

By design, the inlet control valve and desuperheater are capable of accepting from 5000 to 105,000 lb/hr of rated steam (950°F at the TSS inlet) and from 6300 to 130,000 lb/hr of derated steam (650°F at the TSS inlet). As the rated steam or any steam flow with a temperature greater than 650°F passes through the desuperheater, spray water is added to the steam to reduce the steam temperature to a nominal control level of 650°F. Steam conditions leaving the desuperheater and flowing toward the charging heat exchangers during normal operation will have a nominal temperature of 650°F and be within the derated flow rate limit of 6300 to 130,000 lb/hr. Steam pressure upstream of UV-3102 will vary from 1505 psia at 5000 lb/hr rated steam flow to 1465 psia at 105,000 lb/hr steam flow.

For plant operating modes in which all receiver steam flows to the thermal storage (Modes 4 and 5) valve UV-3102 is responsible for upstream pressure control which establishes pressure control for the receiver. During operating modes when steam is simultaneously flowing to the turbine main steam valve (Modes 2 and 7), UV-3102 responds to either a fixed flow rate or turbine generator load command while the turbine main steam valve controls main steam line pressure.

For successful operation of the charging heat exchangers at maximum design flow, it is necessary to maintain a high heat exchanger steam pressure (nominally 1400 psia). As a result, total steam flow pressure drop through UV-3102, DS-301 and the interconnecting pipes and valves to the charging heat exchangers must be limited to ≈ 65 psia. By maintaining a high steam pressure in the heat exchangers, steam condensation will occur at a high temperature thereby ensuring an adaquate temperature difference between the condensing steam and the oil being heated in the heat exchanger.

Each charging heat exchanger train is composed of a condenser, surge tank, subcooler, and drain tank. Each condenser is a TEMA type BEU, class R design with 4 tube passes, 1 shell pass and a heat transfer area of 7,583 sq. ft. The condenser is in a horizontal orientation with the steam contained in the tubes because of the high steam pressure. The tubes are 3/4 in. OD, 0.095 in. wall and constructed of material SA-556-A2. The overall shell dimensions are 48 ft. long by 39 in. in diameter. Shell material is SA-515-70. Each of the two condensers are capable of accepting 50% of the maximum design flow.

The condensate surge tank which is placed in each heat exchanger train between the condenser and subcooler provides a location where liquid level may be sensed and used as a control parameter if desired. If the heat exchanger trains are operating under pressure control, liquid level will float and may rise into the condenser tubes or enter the subcooler, depending on pressure control point and the total steam/condensate flow. Control (level or pressure) of the two heat exchanger trains is maintained by the respective drain tank discharge valves UV-3110 and UV-3111 located at the inlet to the thermal storage flash tank.

Condensate leaving the condenser and surge tank enters the subcooler where condensate temperature is further reduced by transfering its energy to the Caloria. Each subcooler is of TEMA type NFU class R design with 8 tube passes and 2 shell passes and a heat transfer area of 1995 sq. ft. The high pressure condensate is contained in the tubes which are 3/4 in OD, 0.095 in wall and constructed of material SA-556-A2. The overall shell dimensions are 33 ft long by 28 in diameter. Shell material is SA-285-C.

The condensate drain tank at the outlet of each subcooler is used as a final level indicating station upstream of the flash tank. At no time during normal heat exchanger operation should a level be detected in the drain tank (tank should always be flooded). If a level exists, either non-condensible gas is trapped in the tank or charging steam has reached this point in the charging train without being condensed. This latter condition would occur as a result of a malfunction in the outlet control valve. If steam is detected, the charging train must be shutdown to protect the flash tank from a possible steam "blow through" which would result in unacceptably hot steam being introduced into the flash tank.

Secondary steam lines exist from the condenser, surge tank, and drain tank which may be used for warmup circulation and as a means of removing non-condensible gases from the trains during operation which would otherwise be trapped in the heat exchangers and reduce unit performance. Vents servicing the condensers are orificed for continuous bleed flow at a rate of 1/2% of maximum design flow. Vents servicing the surge and drain tanks are activated by operator controlled remote valves which are used to vent non-condensibles and/or steam. When the tanks are flooded, the vents remain closed to prevent water flow through the vent lines.

An additional steam line enters each of the charging trains through valves AOV-3218 and AOV-3318. These lines provide a source of blanketing steam to pressurize the steam side of the heat exchangers during non-operating periods. At all times, steam side pressure must be maintained higher than Caloria side pressure to prevent Caloria leaks into the steam side.

M6.4 Charging Loop (Oil)

The oil portion of the charging loop is designed to provide the necessary Caloria flow through the charging heat exchangers as required to carryout the steam condensation process. In this loop, cold Caloria (≈ 425°F) is drawn from the bottom of the thermal storage unit (TSU) and/or from the outlet of the steam genrators and is circulated through the two parallel 50% capacity heat exchangers. Flow to each heat exchanger is controlled by a separate variable speed Caloria pump and control valve. Two parallel 100% capacity filters are located upstream of the pumps to protect them from any entrained sand or dirt that was picked up by the Caloria as it left the TSU. Caloria flow is regulated through each heat exchanger to an outlet Caloria temperature of 580°F. The high temperature Caloria is routed back to the top of the TSU or directly to the thermal storage steam generators.

Each of the parallel 50% capacity pumps (Dean Brothers Model 6X8X15 1/2, R84) is capable of circulating 533,500 lb/hr of Caloria with a maximum head rise of 350 feet. Each pump is driven by a GE (Model No. GEP-1087) 200 HP electric motor complete with an AF-400 adjustable frequency type control.

The Caloria flow leaving each pump passes through a control valve (TV-3410 and TV-3411) which provides a trim control function which is used in conjunction with a coarse flow control provided by the pump speed control. The normal control approach is to maintain the control valves at a nearly wide open condition while reducing pump speed to the minimum acceptable level. In this way, pumping power and the corresponding electrical power consumption are minimized.

A cross-over connection between the outlets of the two pumps is provided to allow one pump to provide Caloria circulation to either heat exchanger train. The cross-over flow can be established by opening the hand operated cross-over valve. In order to provide automatic flow control when the cross-over branch is used, the proper temperature and pressure control signals must be input manually to the operating pump. No automatic switchover of control signal inputs to the pumps is available.

The pumps are protected by two parallel 20 mesh size filters which are operated on an alternating basis. Excessive dirt buildup in the filter is indicated by an alarm which is activated by a high differential pressure measurement across the operating filter. Waste Caloria which is present at the pumps and filters as a result of leakage or filter cleaning is diverted to the liquid waste drain and on to the oil/water separator.

M6.5 Extraction Loop (Steam and Feedwater)

The purpose of the extraction loop (steam and feedwater) is to provide a continuous and controlled source of steam which can be used to start and run the turbine, thermally condition system components during plant operation, and provide a source of low grade blanketing steam to be used during inactive periods.

The principal elements of the loop are two parallel 50% capacity steam generator trains with the interconnecting piping and flow control equipment. Each train is composed of a preheater, boiler, and superheater with flow through each train being controlled by an inlet feedwater control valve (LV-3505 and LV-3605) which responds primarily to changes in boiler feedwater level. Each train is designed to produce 530°F, 420 psia (nominal/pressure) steam over a flow range of 5500-55000 lb/hr.

Each preheater (E-303 and E-304) is a horizontal (TEMA type AFU, class R) heat exchanger with 8 tube and 2 shell passes. The tubes are 3/4 inch OD with a 0.095 inch wall thickness and have an overall heat transfer surface area of 1433 sq. ft. The tubes and shell are constructed of carbon steel SA-515-70) and a double tube sheet is provided to minimize the possibility of Caloria leakage into the feedwater.

Each boiler (E-305 and E306) is a horizontal (TEMA type AKU, class R) heat exchanger with 4 tube and 1 shell pass. The preheated feedwater and steam are on the shell side while hot Caloria circulates through the tube side. The shell is rated for a design pressure of 472 psig (designed to ASME Section VIII) while the tubes are 1 inch in OD with a 0.95 inch wall thickness. Each steam generator includes a mist eliminator at the steam outlet port to minimize the possibility of moisture carryover which could be detrimental to the turbine. Each boiler has a heat transfer surface area of 7919 sq. ft. while both the tubes and shell are constructed of carbon steel (SA-515-70). Double tube sheets are provided for leakage control.

Each superheater (E-307 and E-308) which is mounted directly on top of the respective steam generators is a horizontal (TEMA type AEU, class R) heat exchanger with 2 tube passes and 1 shell pass. Superheated steam is the tube side fluid while high temperature Caloria is contained in the shell. Each superheater uses 3/4 inch OD tubes with a 0.095 inch wall thickness and has a heat transfer surface area of 670 square feet. Both the tubes and shell are constructed of carbon steel (SA-515-70). Each unit is provided with a double tube sheet for leakage control.

The concentration of dissolved solids built up in each of the steam boilers is controlled by a blowdown system which allows a small flow of boiler water to flow to the blowdown tank. The flow occurs on an intermittent basis with the opening of valves AOV-3708 and AOV-3808. The blowdown tank uses service water to condense any steam formed during the blowdown process and diverts the resulting flow to the plant drains. Due to the high degree of feedwater purity entering the boiler, the buildup of dissolved solids occurs at a very slow rate dictating an infrequent blowdown operation. The actual blowdown frequency shall be as specified in the Plant Operating Procedures.

M6.6 Extraction Loop (Oil)

The oil portion of the extraction loop is designed to provide the necessary Caloria flow through the extraction heat exchangers to carryout the required steam generation and thermal conditioning processes. In this loop, high temperature Caloria (≈ 575°F) is drawn from the top of the thermal storage unit (TSU) and/or directly from the outlet of the charging heat exchangers and is circulated through the two 50% capacity steam generator trains.

The Caloria circulation rate through each steam generator (which is a measure of heat input to the steam generators and related to steam generation rate) is controlled by pump speed and the operation of two parallel control valves upstream of the superheater and boiler. The oil control valve pairs (PV-3702/PV-3710 and PV-3802/PV-3810) also adjust the hot oil flow split between the superheater and boiler portion of the respective steam generator trains which trim the final superheated steam temperatures produced by the steam generators.

Caloria which has been circulated through the steam generator trains exits from the respective preheaters at low temperature (≃ 425°F) and is reintroduced into the bottom of the TSU or routed to the inlet of the charging heat exchangers.

Each of the parallel 50% capacity pumps, P-303 and P-304, (Dean Brothers Model 6X8X15 1/2, R84) is capable of circulating 588,000 lb/hr of Caloria with a maximum head rise of 350 feet. Each pump is driven by a GE (Model No. GEP-1087) 200 HP electric motor complete with an AF-400 adjustable frequency type control.

The oil extraction loop includes an auxiliary extraction oil pump, P-305, which can draw Caloria from the top or auxiliary manifold for preheating the steam generator equipment or producing low grade steam for nightime blanketing and sealing duty. The auxiliary extraction oil pump is capable of circulating Caloria at a rate of 108,000 lb/hr at an oil temperature of 575°F. Caloria flow through the auxiliary extraction loop is controlled by Valve PV-3910 which repsonds to a steam generator (steam side) pressure command.

The piping network downstream of the main extraction and auxiliary extraction pumps is configured to permit any of the three pumps to circulate Caloria through either of the two steam generator trains. When cross over circulation is desired for the main extraction oil pumps (P-303 and P-304), the controller input signals must be reversed to allow the proper control signals to operate the pump.

M6.7 Thermal Storage Unit (TSU)

The TSU consists of the thermal storage tank and piping and valves required to complete the Caloria flow paths between the tank and the charging and extraction loops.

The thermal storage tank is a vertical cylindrical carbon steel (ASTMA537 Class 2) tank with a height of 48 feet. It has a total volume of 118,800 cubic feet and contains 6860 tons of granite rock and coarse silica sand in an approximately 2:1 (rock:sand) volume ratio. The tank also contains 1,700,000 lbs of Caloria which is ciculated through the rock/sand bed during charging and extraction operations and permits the establishment of a sharp temperature transition (thermocline) in the tank. Thermocouples are located throughout the rock bed to permit the thermal status of the bed to be continuously monitored by the operator. The tank is mounted on a special foundation which is designed to minimize heat loss from the tank bottom to the surrounding ground.

Three Caloria manifolds are contained in the tank which are used to create a uniformly distributed Caloria flow through the bed. The top and bottom manifolds are sized to distribute maximum charging and extraction Caloria flows while the auxiliary manifold located 8 feet above the bottom manifold is sized to accomodate the lower Caloria flows associated with thermal conditioning, startup, and blanket steam generation operations. Each manifold contains 0.332 inch diameter holes for flow distribution which are sized to prevent the coarse sand from being carried into the manifold by the Caloria.

6.8 Ullage Maintenance Unit (UMU)

The purpose of the UMU is to maintain a slightly positive pressure environment within the thermal storage tank and prevent oxygen entry that would cause the high temperature Caloria to oxidize and create a potential combustion hazard.

The UMU normally utilizes n-heptane as the ullage make-up fluid at times when the Caloria volume is contracting due to a lowering of the temperature experienced during an extraction or normal cooldown period. As the n-heptane enters the top of the tank and contacts the hot oil, it vaporizes and expands to fill the ullage space, thus maintaining ullage pressure. At times when the oil volume is expanding because of an increasing bed average temperature or when the ullage gas pressure begins to rise because of the liberation of degradation products, a portion of the gas flows back to the UMU. This gas passes through a long uninsulated line which allows the "high boilers" (fraction of the gas mixture with a high boiling point temperature) to be condensed and stored in the accumulator tank for later reintroduction into the tank during a period of Caloria contraction. "Low boilers" (fraction of the gas mixture with a low boiling point temperature) which do not condense are diverted to the burn stack where they are burned prior to release to the atmosphere. To ensure an oxygen free thermal storage tank and UMU, gaseous nitrogen is available to provide the necessary positive pressure in the event the hydrocarbon pressures are insufficient.

M6.9 Operation and Control

The thermal storage system Caloria piping is designed to permit a wide variety of circulation options that allows substantial operational flexibility especially when operating both the charging and extraction loops simultaneously. The following discussion describes these options (reference Figure M6-1).

A. Blanketing Steam Generation

Valve Status	Pump Status
AOV-3001 - Closed	P-301 - Off
AOV-3002 - Closed	P-302 - Off
AOV-3003 - Closed	P-303 - Off
AOV-3004 - Open	P-304 - Off
AOV-3005 - Closed	P-305 - On
AOV-3907 - Open to aux. manifold	

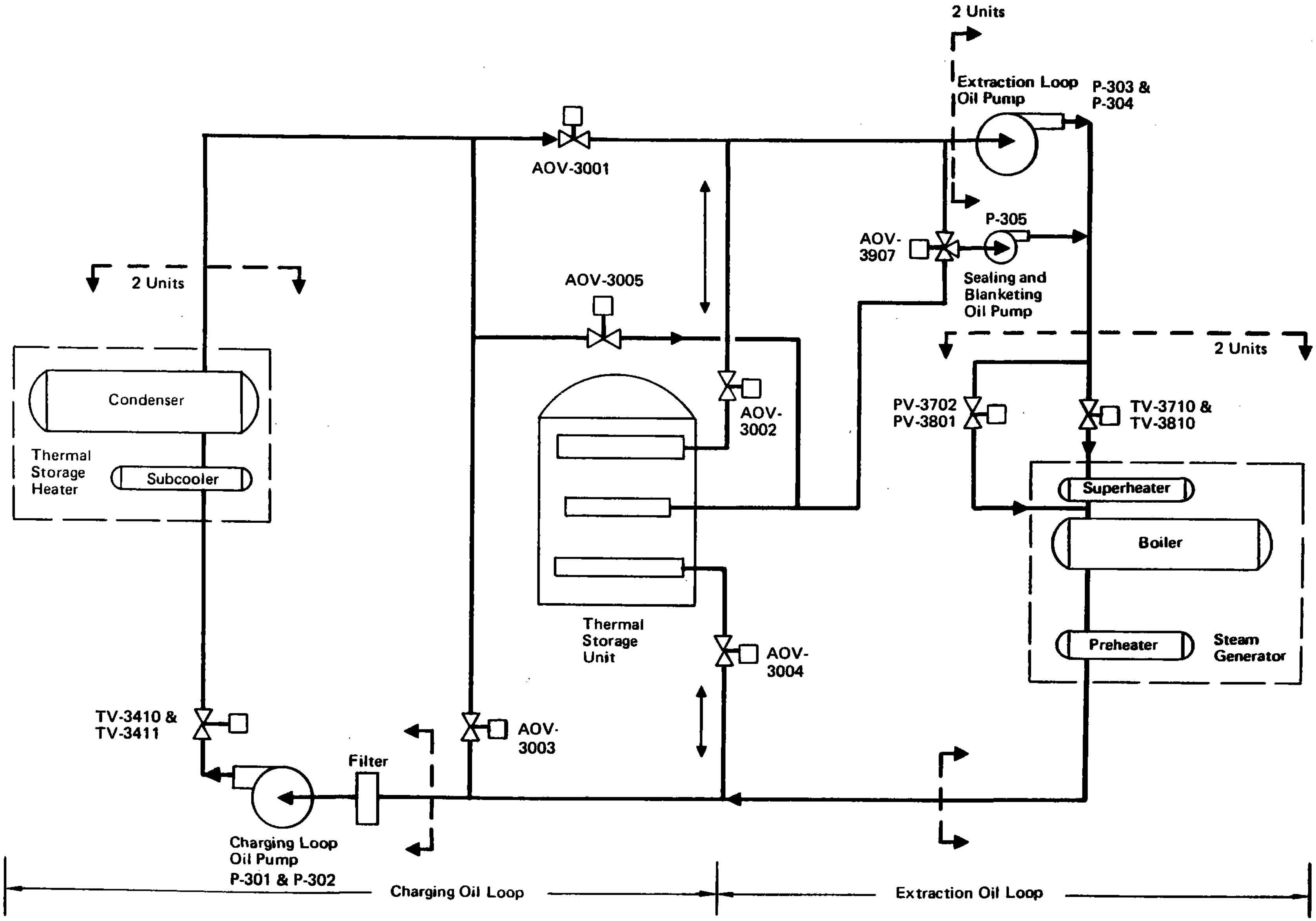


Figure M6-1. Thermal Storage Subsystem Oil Loops

This mode allows Caloria to be extracted from the auxiliary manifold and flow through one of the steam generator trains. The steam temperature depends on the temperature of the Caloria available at the auxiliary manifold. Steam generated during this mode flows to the auxiliary steam system and to inactive portions of the plant (including inactive thermal storage heat exchangers) to maintain a blanketing steam pressure in those elements. Steam pressure of ≈ 120 psia (saturated) would be maintained in the active steam generator during this operation with the Caloria flow to the unit being modulated by valve PV-3910 to maintain the desired pressure. Steam flow will be supplied to the balance of the system on a demand basis.

B. Blanketing Steam Generation and Charging Heat Exchanger Warm Up

Valve Status	Pump Status
AOV-3001 - Closed	P-301 - On(1)
AOV-3002 - Closed	P-302 - On(1)
AOV-3003 - Open	P-303 - Off
AOV-3004 - Open	P-304 - Off
AOV-3005 - Closed	P-305 - On
AOV-3907 - Open to aux. manifold	

(1) Can also be operated with only one of the two charging oil pumps operating.

This mode allows Caloria to flow to one of the steam generator trains in the manner described in (A) while simultaneously warming up the charging heat exchangers with a Caloria flow circulation. The charging heat exchanger Caloria flow is drawn from the TSU bottom header piping network or from the outlet of the steam generator. The Caloria flow is circulated through the heat exchangers and exits from the condenser. This Caloria returns to the vicinity of the tank where it passes through the tank bypass valve (AOV3003) and returns to the bottom header piping network. Since no "charging" steam flow is available during this period, the Caloria is not at a sufficiently high temperature to introduce it back into the tank through the top manifold. If the Caloria flow is inadvertently routed into the tank through the top manifold, the high temperature zone near the top of the tank will be degraded and subsequent extraction operations requiring this high temperature energy may be compromised.

C. Normal Steam Generation (Mode 6) and Charging Heat Exchanger Warm Up

Valve Status	Pump Status
AOV-3001 - Closed	P-301 - On
AOV-3002 - Open	P-302 - On
AOV-3003 - Open	P-303 - On (alt - off)
AOV-3004 - Open	P-304 - On (alt - off)
AOV-3005 - Closed	P-305 - Off (alt - on)
AOV-3907 - Closed	

(Alternate: open to top manifold)

In this mode, high temperature Caloria is drawn from the top of the TSU and circulated through the steam generator trains (the "pump status" information assumes both trains operating) producing admission steam at the desired temperature and pressure conditions which will vary between turbine startup and normal turbine operation on admission steam.

As an alternate flow scheme, the two extraction pumps may be turned off and high temperature Caloria can be circulated through one train with the auxiliary extraction oil pump. In this case, the "alternate" valve and pump status comments apply.

Simultaneous to the steam generator operation, low temperature (≃ 425°F) Caloria is circulated through the charging heat exchangers to continue the warmup function. Caloria leaving the charging heat exchangers is diverted to the bottom header piping of the TSU by flowing it through valve AOV-3003.

D. Simultaneous Charging and Extraction Operation

Valve Status	Pump Status
AOV-3001 - Open	P-301 - On
AOV-3002 - Open	P-302 - On
AOV-3003 - Closed	P-303 - On
AOV-3004 - Open	P-304 - On
AOV-3005 - Closed	P-305 - Off
AOV-3907 - Closed	

This mode involves the normal operation of the charging and extraction loops. High temperature Caloria, drawn from the top of the TSU and/or the output of the charging loop is circulated through one or both steam generator trains producing admission steam at a nominal condition of 530°F, 420 psia.

Low temperature Caloria leaving the steam generators flows either to the inlet of the charging heat exchangers or to the bottom of the TSU. Caloria entering the charging heat exchangers is heated to 580°F by the charging process and returned to the top tank header where it is either reintroduced into the tank or allowed ot flow to the steam generators.

The net Caloria flow direction inside the TSU depends on the relative energy charging and extraction rates. When the charge rate exceeds the extraction rate, a net flow of hot Caloria will enter the TSU through the top manifold while low temperature Caloria will be withdrawn from the bottom manifold. This will create a net positive charging condition for the TSU. When the extraction rate exceeds the charge rate, hot Caloria will be withdrawn through the top TSU manifold while cold Caloria will enter the TSU through the bottom manifold creating a net discharging condition.

This case represents the general situation of both the charging and extraction loops (and all four major Caloria pumps) operating. The non-simultaneous operation of both the charging and extraction loops or the operation of a single charging or extraction pump represents an operating variation about this general case.

E. Charging Heat Exchanger Startup and Normal Steam Generation

Valve Status	Pump Status
AOV-3001 - Closed	P-301 - On
AOV-3002 - Open	P-302 - On
AOV-3003 - Open (alt - Closed)	P-302 - On
AOV-3004 - Open	P-303 - On
AOV-3005 - Closed (alt - open)	P-304 - On
AOV-3007 - Closed	P-305 - Off

The mode of operation is used during charging heat exchanger startup to prevent high temperature Caloria which is below the minimum Caloria control temperature of 560°F from entering the top tank manifold. Charging Caloria flow bypasses the tank and is recirculated back to the inlet of the charging heat exchangers.

As the Caloria temperature leaving the charging heat exchangers approaches the minimum acceptable temperature of 560°F, simple recirculation of the Caloria may be undesirable because the high temperature (<560°F) Caloria will be fed directly back to the inlet of the charging heat exchanger which could cause potential control and transition problems. During this period, the alternate flow routing may be selected (see "alternate" Valve Status) which diverts high temperature Caloria into the auxiliary manifold while "constant temperature" desired for the inlet of the charging heat exchangers is drawn from the bottom manifold or cold side piping network.

A variation to this mode involves the non-operation of the steam generation loop and/or the use of single charging and extraction Caloria pumps. Corresponding changes in the Valve Status list would be required to establish the desired flow paths into and around the TSU.

Table of Contents

M7. ADMISSION STEAM SYSTEM

M7. ADMISSION STEAM SYSTEM

M7.1 Drawing References

A. Mechanical

40P3005132193 - P&ID Thermal Storage System (TSS) Charging Steam and Condensate

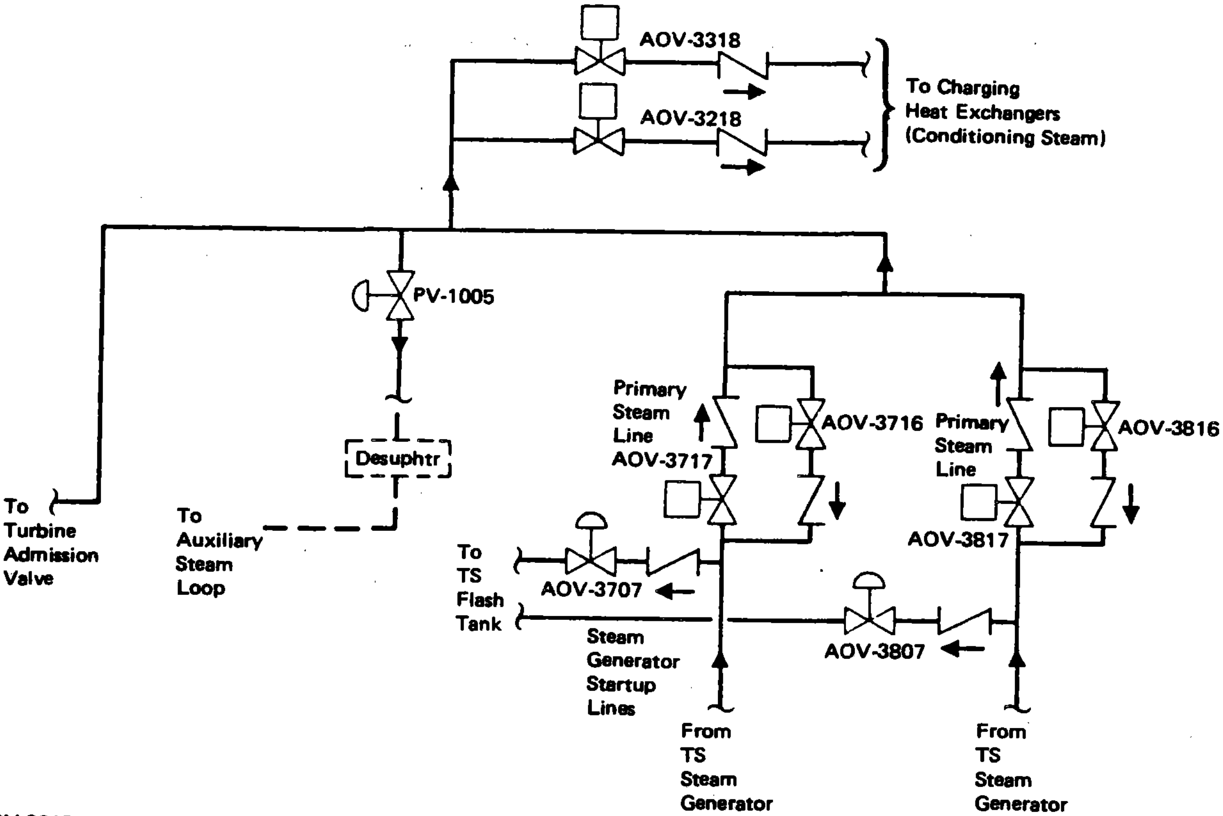
40P3005132195 - P&ID Thermal Storage System (TSS) Extraction Steam and Condensate

40P7005133140 - P&ID Electrical Power Generation System (EPGS) Steam

40P9005133306 - P&ID Steam

B. Control Logic

C. Electrical



AOV-3218 & 3318	Conditioning Steam Valve
PV-1005	Auxiliary Steam (TSS) Pressure Control Valve
AOV-3707 & 3807	Steam Generator Startup Valve
AOV-3717 & 3817	Admission Steam Valve
AOV-3716 & 3816	Conditioning Steam Bypass Valve

Figure M7-1. Admission Steam System

M7.2 General Description

The admission steam system consists of the piping network and control valves required to transport admission steam produced by the thermal storage steam generators to

(i) the turbine admission valve
(ii) the auxiliary steam system through the pressure control valve PV-1005
(iii) the thermal storage flash tank through valves AOV-3716 and AOV-3816
(iv) the charging heat exchangers (blanketing steam flow) through valves AOV-3218 and AOV-3318
(v) A non-operating steam generator through valves AOV-3707 and AOV-3807.

The main portion of the admission steam system (connection between the steam generators and the turbine admission port) is constructed of 8 inch schedule 40 carbon steel pipe (ASTM A106 Grade B) and compatible fittings and valves which are rated for a maximum service of 750°F at 505 psig. The entire piping network is designed to ANSI B31.1 (Power Piping Code).

During the operation of one or both of the steam generator trains, admission steam is available at the inlet to the admission steam system with the steam conditions and flow routing depending on the plant operating mode and/or status of the equipment. Prior to flowing steam into the turbine admission valve, the admission steam is allowed to flow through the network and through the drains (to the condenser) to preheat and dry the admission steam piping. With the lines conditioned, the turbine may be started and operated directly from admission steam. The scheduling of steam temperature and pressure during turbine startup from admission steam shall be in accordance with the General Electric turbine startup procedures. During periods when the turbine operates on admission steam, nominal steam conditions of 525°F, 385 psia (at the turbine over a flow range of 5500- 110,000 lb/hr will be delivered through the admission steam system. System pressure control is maintained by the turbine admission steam valve while steam temperature and flowrate are controlled by the operation of the steam generation (oil side) equipment.

M7.3 Auxiliary Steam System Inlet

The auxiliary steam system draws steam from the admission steam system on a demand basis through the pressure reducing valve PV-1005. The flow is then passed through the desuperheater (DS-902) which was described as part of the Main Steam System (see Section M5.4). Valve PV-1005 is designed to reduce admission steam pressure to a downstream value of 72 psia which is required to produce a 65 psia steam condition downstream of the desuperheater. The valve is designed to operate over the flow range of 270 - 3765 lb/hr at an inlet steam condition of 525°F, 385 psia. This flowrate is sufficient to ensure that the deaerator pressure can be pegged at $\geq$ 20 psia during low power Mode 6 operation.

During nighttime or other inactive periods, the conditions upstream of valve PV-1005 will be reduced to 120 psia saturated steam. The valve will continue to control the downstream pressure setpoint condition. During some plant operations such as feedwater circulation for water cleanup prior to startup from admission steam, an insufficient steam flow can be passed through PV-1005 at an upstream pressure of 120 psia to satisfy the required deaerator energy demand. In these cases, flow from the steam generators through the thermal storage flash tank and on to the deaerator can be initiated by opening valves AOV-3716 and AOV-3816. See Section M7.4 for additional information regarding this flow scheme.

M7.4 Thermal Storage Flash Tank Admission Steam Flow

A portion of the admission steam network is designed to divert steam generator outlet steam flow to the thermal storage flash tank. An individual flow path is dedicated to each of the two steam generator trains and is activated by opening the appropriate valve (AOV-3716 or AOV-3816) located near the flash tank. These paths are used for the following three purposes:

(i) Provide a steam circulation path for the steam generator to establish a controlled temperature and pressure condition prior to opening the main stop valves (AOV-3717 and AOV-3817) at the inlet to the admission steam network. This operation is most useful when one of the trains is already producing admission steam for turbine operation and it is desired to activate the second train and establish steam conditions prior to mixing the two flows.

(ii) Provide a steam pressure relieving path which can be activated when the steam generators are first shutdown and the residual thermal energy contained in the Caloria is sufficient to cause the steam pressure to build until the safety valves lift.

(iii) Provide a steam flow path that can be used to pass additional steam to the deaerator (through the thermal storage flash tank) over that provided by the auxiliary steam system. This is used when the required deaerator input steam for pegging purposed (deaerator pressure $\geq$ 20 psia) exceeds the capability of the auxiliary steam system. This will occur during periods of feedwater circulation prior to plant startup from admission steam when the steam generator is operating at a blanket steam pressure of 120 psia.

Steam flow through each of these bypass lines is limited by design to 5500 lb/hr at a steam generator pressure and temperature of 420 psia and 530°F.

M7.5 Charging Heat Exchanger Blanketing Steam

During periods when the thermal storage charging heat exchangers are inactive, it is necessary to maintain a positive water/steam side pressure at all times to prevent any Caloria leakage into steam and condensate circuit. It is also desirable to have a source of thermal energy which can be used to condition the heat exchangers prior to their operation.

This function is accomplished through a 1 1/2 inch line that connects the admission steam system to each of the charging heat exchanger trains. By opening valves AOV-3218 and/or AOV-3318, the steam conditions which exist in the admission steam system can be introduced into the charging heat exchanger trains. These valves are interlocked to charging heat exchanger steam pressure to prevent their opening when the charging heat exchangers are operating at normal conditions (1400 psia and 650°F).

M7.6 Steam Generator Blanketing Steam

During inactive periods where blanketing steam is provided from one of the steam generator trains (or form the auxiliary electric steam generator), blanketing steam pressure can be maintained in the non-operating steam generator(s) by opening the blanketing steam bypass valves (AOV-3707 and AOV-3807). With this action, steam conditions which exist in the admission steam system will be imposed directly on the water/steam side of the steam generators. This operation is required during non-operating periods to maintain a positive water/steam side pressure to prevent Caloria leaks into the water/steam circuit.

Table of Contents

M8. STEAM TURBINE AND ASSOCIATED EQUIPMENT

M8. STEAM TURBINE AND ASSOCIATED EQUIPMENT

M8.1 Drawing References

A. Mechanical

40P9005133306 - Steam P&ID

40P9005133309 - Turbine P&ID

B. Control Logic Diagrams

N3221 SH.2 Extraction Valves

N3221 SH.4 Motor Operated Valves

N3221 SH.15 Gland Steam Exhauster

N3221 SH.18 Generator

N3221 SH.19 Steam Turbine

C. Electrical

M8.2 General Description

The principal steam turbine and associated equipment elements are the:

- Steam Turbine
- Hydraulic System
- Lubrication Oil System (Section M19)
- Turning Gear System
- Gland Steam Seal System
- Turbine Control System
- Turbine Supervisory Instrumentation
- Turbine Performance and Monitoring

The turbine and associated equipment is provided by General Electric as part of the overall turbine procurement. They are located in the northwest portion of the EPGS building close to the receiver and thermal storage steam sources, thereby minimizing the lengths of the hot steam piping.

M8.3 Steam Turbine

The steam turbine is an automatic admission, single flow, extraction, condensing unit capable of accepting and admitting steam either through its main throttle (primary inlet) valve or through the automatic admission (secondary inlet) valve or through both valves simultaneously.

The unit is rated and guaranteed at 12.5 MWe gross electrical output at a 2.5 in. Hg condenser back pressure at a throttle steam inlet condition of 950°F, 1465 psia, and flowrate of 112,140 lb/hr (Mode 1 operation). The unit is also guaranteed to produce 8.0 MWe gross at a 2.5 Hg condenser back pressure at an admission steam inlet condition of 525°F, 385 psia and flowrate of 105,000 lb/hr (Mode 6 operation).

The nominal steam flow ranges for the main and admission steam systems for the power producing modes are as follows:

Mode	Main Steam Flow (lb/hr)	Admission Steam Flow (lb/hr)
1	30,000 - 115,000	------
2	30,000 - 115,000	------
3*	30,000 - 109,500	5,500 - 85,000
4	------	45,000 - 110,000
6	------	45,000 - 110,000
7*	5,000 - 109,500(2)	5,500 - 110,000(2)

(*) the sum of the main and admission steam flow entering the turbine simultaneously is limited to the range from 35,500 to 115,000 lb/hr.

Other turbine steam flow limits are:

(1) the maximum permissible main steam flowrate is 120,750 lb/hr with zero admission steam flow.

(2) the maximum permissible admission steam flowrate is 115,200 lb/hr with zero main steam flow.

The unit is configured with four steam extraction ports for feedwater heating. The state point conditions at each port for the 12.5 MWe guaranteed operating condition are:

Extraction Point #1 (H.P.) 270 psia, 633°F
Extraction Point #2 (H.P.), 128 psia, 820°F (from end packing leakage)
Extraction Point #3 (Deaerator), 40 psia, 297°F
Extraction Point #4 (L.P.), 12 psia, 205°F

The steam turbine is designed for continuous operation from main steam when the steam pressure rises to but does not exceed 105% rated pressure. During abnormal transient conditions, the steam pressure may exceed rated pressure briefly by as much as 20%, but the aggregate duration of such brief swings beyond 105% of rated pressure is limited to 12 hours per month per 12 month operation period.

Steam temperatures into the steam turbine are not to exceed rated steam temperatures by 15°F during normal operations. During abnormal operating conditions, the steam temperature is limited to:

1) 25°F above rated steam temperatures for a maximum accured time of 400 hours per 12 month operating period; or

2) 50°F above rated steam temperature for a transient swing of 15 minutes duration or less aggregating to not more than 80 hours per 12 month period.

M8.4 Turbine Operation and Control

During normal turbine operation, the main and admission steam valves are used to control major process parameters. During operation in modes 1, 2, 3, and 7, the main steam valve is responsible for controlling upstream steam pressure to 1505 psia as measured by PIT-1001. During operation in modes 3, 4, 6, and 7, the admission steam controls upstream pressure to 385 psia as measured by PT-1024.

Turbine startup can be accomplished from either main (receiver) steam or admission (thermal storage) steam but in either case, it will be carried out as a manual operation by the operator. During these periods, the appropriate steam inlet valve is controlled by a speed-load signal while steam pressure is maintained by some other system element. Separate startup sequences and procedures exist depending on the initial state of the turbine (hot, cold, or warm) and the startup steam source being used. These startup sequences are based on the General Electric startup and operating procedures.

From an operational standpoint, transitions between main and admission steam can be made as fast as the turbine inlet valves will permit based upon their normal stroke rates. During operation in modes 4 and 6 (operating exclusively on admission steam), approximately 9600 lb/hr of admission steam is routed through a bypass line to the high pressure turbine stages to ensure adequate cooling of that portion of the turbine.

Turbine protection is provided through a series of alarms and trips that include the following parameters:

- main steam enthalpy (degrees of superheat)
- admission steam enthalpy (degrees of superheat)
- turbine speed
- hydraulic oil pressure
- loss of 125 V DC electrohydraulic controller power
- turbine vibration
- turbine bearing oil pressure
- loss of turbine speed signals
- turbine electrohydraulic controller master trip

M8.5 Associated Turbine Equipment

(Information to be supplied by SCE)

Table of Contents

M9. FLASH TANK CIRCUITS

M9. FLASH TANK CIRCUITS

M9.1 Drawing References

A. Mechanical

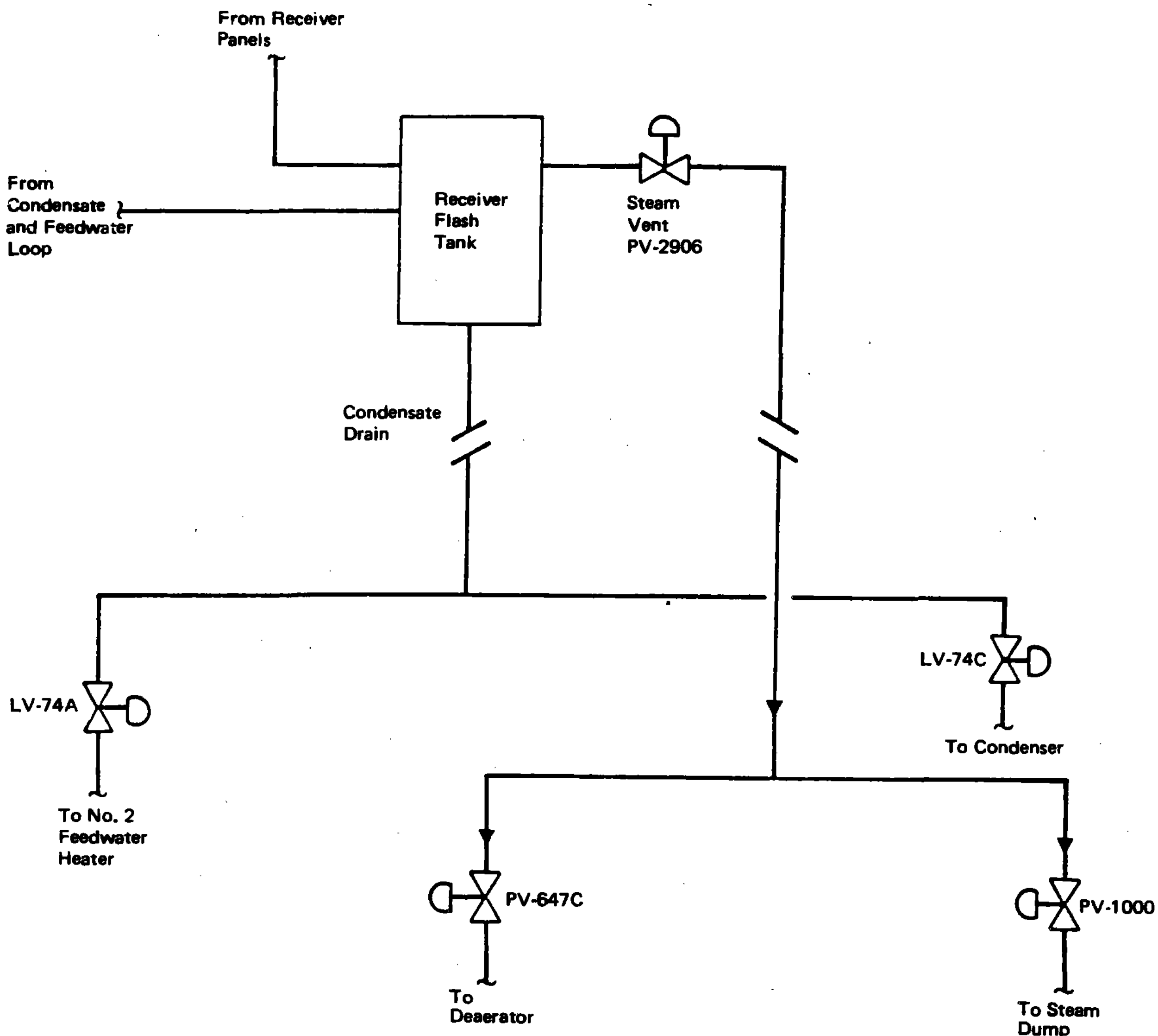
40P2005131767	- P&ID	Receiver System (RS) Main Steam Manifold, GN_2, and Drain Systems
40P7005133140	- P&ID	Electrical Power Generation System (EPGS) Steam
40P9005133306	- P&ID	Steam P&ID
40P7005133141	- P&ID	Electrical Power Generation System (EPGS) Condensate and Feedwater
40P3005132193	- P&ID	Thermal Storage System (TSS) Charging Steam and Condensate

B. Control Logic Diagrams

40I7002133022	(I15-7)	FV-1007 Control
40I7002133023	(I15-8)	SOV-1000 Control (PV-1000 Close Interlocks)
40I7002133030	(I15-20)	TSS Flash Tank Drain Pump P-307
40I7002133009	(I5-7)	FV-1007 (Atomizing Steam to DS-901 When PV-1000 Is Open)
40I7002133010	(I5-8)	SOV-1000 Control (PV-1000 Close Interlocks)
40I7002133019	(I5-20)	TSS Flash Tank Drain Pump P-307

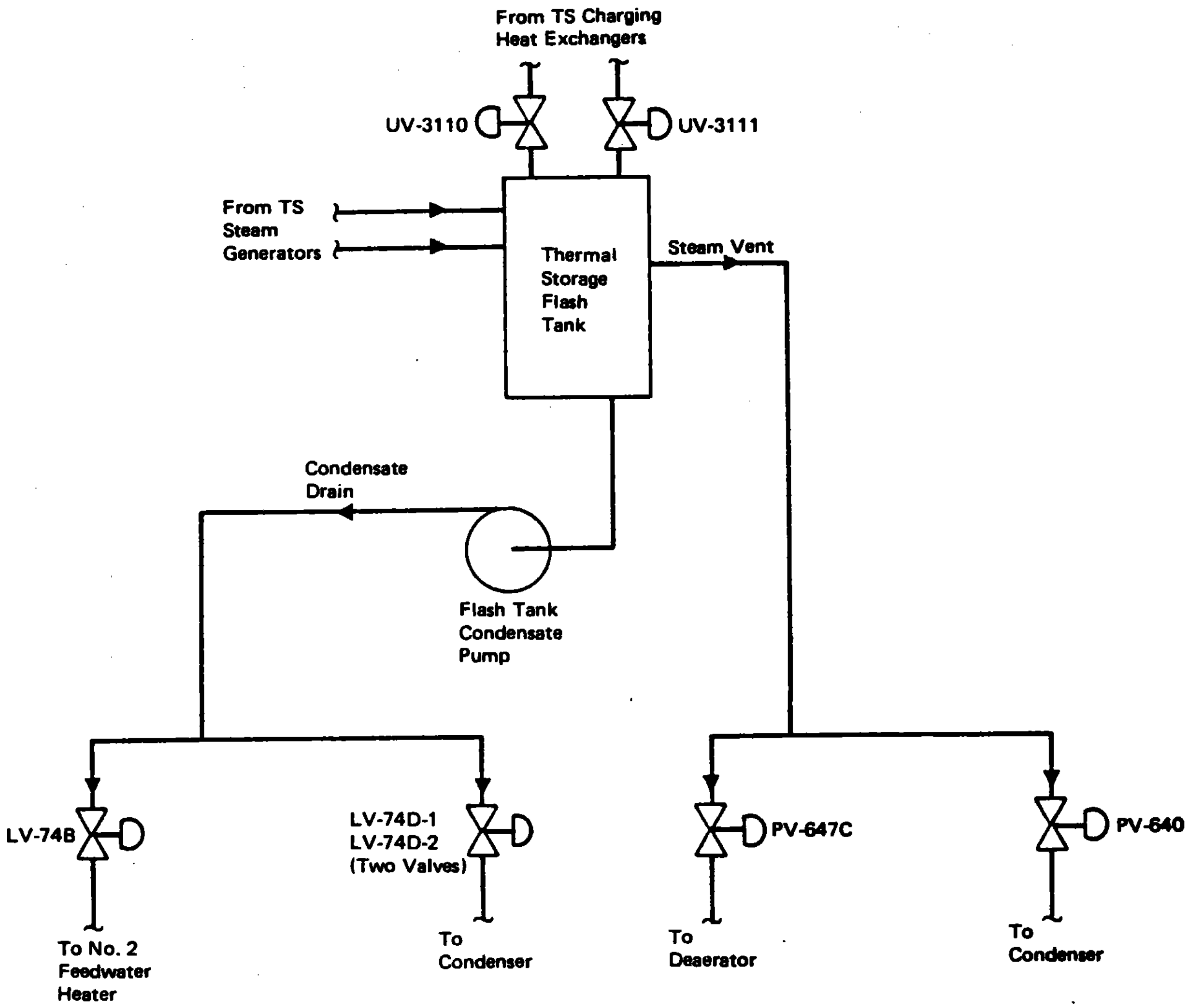
C. Electrical

40E7005133192 One-Line Diagram 480 Volt MCC B



PV-2906	Flash Tank Pressure Control Valve
PV-647C	Deaerator Pressure Valve
PV-100	Upstream Pressure Valve
LV-74A	Flash Tank Level Control Valve (Primary)
LV-74C	Flash Tank Level Control Valve (Secondary)

Figure M9-1. Receiver Flash Tank Loop



UV-3110, UV-3111	Charging Heat Exchanger Outlet Control Valves
PV-647C	Deaerator Flow Control Valve (Primary)
PV-640	Condenser Flow Control Valve (Secondary)
LV-74B	Flash Tank Level Control Valve (Primary)
LV-74D-1, LV-74D-2	Flash Tank Level Control Valves (Secondary)

Figure M9-2. Thermal Storage Flash Tank Loop

M9.2 General Description

The two flash tank circuits in the system include the tanks themselves plus condensate and steam distribution piping and control valves which are required to route the tank outlet flows to the feedwater and condensate systems. In both cases, the condensate and steam distribution piping and control valve operating logic is designed to route the flows directly into the feedwater system in order to retain the maximum amount of heat in the cycle.

In the event the feedwater system is unable to accept the flash tank flows, alternate flow paths for the steam and condensate from each flash tank are available to the condenser. These alternate paths are capable of passing all of the available flows to the condenser which will result in a rejection of the flash tank energy and a reduction in plant efficiency.

For both of the flash tanks, the primary condensate flow path is into the shellside of the No. 2 feedwater heater while the primary steam path is to the deaerator. Condensate flows into the No. 2 heater are controlled by level control valves (LV-74A and LV-74B) which maintain condensate levels in their respective flash tanks. In the event the condensate flow (thermal energy flow) exceeds the capability of the heater to absorb the energy input, the shellside pressure will rise and cause the level valves to modulate closed (part of the controller logic). This pressure override function will begin when the shellside pressure reaches 120 psia and cause the valves to reach a fully closed position when the shellside pressure reaches 130 psia. With the override function active, the condensate levels in the respective flash tanks will rise, activating the alternate level control valves (LV-74C, LV-74D-1, and LV-74D-2) which allow excess condensate (up to 100% flow) to be diverted to the condenser.

The primary path for steam flowing from the flash tanks is to the dearator. However, deaerator pressure overrides are used in a manner similar to that described for the No. 2 heater to prevent an over pressure condition. In the case of the deaerator, the pressure and override is initiated at 40 psia shell pressure and completely closes the inlet valves (PV-647B and PV-647C) when the deaerator pressure reaches 50 psia. In the case of the receiver flash tank steam flow, an additional override on valve PV-647B prevents steam from entering the deaerator if the steam temperature is in excess of 660°F. Whenever the deaerator is unable to accept all of the flash tank steam flows, either because of the override function on the control valves or the flow limits of the valves themselves, the upstream steam pressure will rise causing the alternate steam control valves (PV-640 and PV-1000) to open and allow steam flow to pass to the condenser.

The flow routing selection in which condensate is routed to the No. 2 heater and steam flows to the deaerator is based on deaerator considerations. If the flash tank condensate flows were routed directly to the deaerator while the steam flows were introduced into the shellside of the No. 2 heater (more efficient operation of the No. 2 heater), a deaerator shell pressure would be easily reached through the introduction of a portion of the condensate which would be sufficient to shutoff all steam flow to the deaerator. Since steam is required for the deaeration function, this approach to flow routing would compromise the ability of the deaerator to function properly.

In general, the two flash tank circuits will not be operating simultaneously since the receiver must be started (requiring the receiver flash tank) before receiver steam is available for the purposes of charging thermal storage. Exceptions can occur if the thermal storage flash tank is accepting steam flow from the thermal storage steam generator through valves AOV-3716 and AOV-3816 at the same time a receiver startup is being executed.

M9.3 Receiver Flash Tank

The receiver flash tank is the primary circulation path through which the receiver startup, shutdown, or low flow standby conditions. This flow path is maintained during a startup operation until dry superheated steam at a condition compatible with downcomer and downstream component operation is created. Flash tank pressure is maintained by a GN_2 pressurization system which prevents flow cavitation across control valves during all-water flow. When sufficient thermal power has been added to the receiver to create steam (i.e., the vapor pressure is above the tank control pressure), tank pressure is maintained by PV-2906 which controls pressure to 500 psia.

The flash tank is 26 inches OD, 116 inches long and made of 2 1/4 CR - Mo (SA-335, P22) steel. It is rated for a maximum pressure of 600 psig and 950°F. To prevent over pressurizing or an excessive temperature condition in the tank, the inlet valve AOV-2911 is interlocked to upstream (receiver) steam pressure and temperature. Upstream steam pressure $\geq$ 650 psig or steam temperature $\geq$ 950°F will inhibit operation of valve AOV-2911.

These flash tank restrictions in temperature and pressure are required to minimize flash tank wall thickness which enhances the ability of the flash tank to accept rapid temperature changes which can occur on a nearly instantaneous basis as the flash tank is brought into service during a receiver shutdown.

During periods of receiver operation (steam flowing to the main steam downcomer) and the flash tank is out of service, the flash tank is maintained at a temperature of 465 - 675°F by means of a steam bleed flow which is introduced into the flash tank through a bleed orifice. With this temperature conditioning constraint, any fluid condition from 300°F feedwater to 950°F steam could be introduced into the flash tank on an instantaneous basis. The bleed flow lines (inlet and outlet) are equipped with remote isolation valves which are interlocked to the main steam downcomer valve so that they all open and close together. The purpose of these orifice block valves is to isolate the flash tank and prevent undesirable GN_2 flows back into an unfilled receiver or downstream into the deaerator and condenser that might occur during receiver prestart, filling, and startup periods.

The steam leg of the receiver flash tank circuit passes down the tower and splits into two paths with the primary path flowing to the deaerator through PV-647C. The secondary flow which passes through valve PV-1000 continues to the desuperheater DS-901 and on to the condenser. The total flow capability of the steam leg is limited to 40,000 lb/hr.

As discussed in Section M9.2, the primary steam path is to the deaerator. This allows a method of ensuring adaquate deaeration during receiver startup and results in startup energy being retained in the cycle. Valve PV-647C which responds to downstream pressure signals (deaerator shell pressure) has a flow limit of 6285 lb/hr at 375 psia and 660°F upstream conditions. This flow is sufficient to peg the deaerator at maximum pressure (50 psia) during receiver startup. In the event deaerator pressure exceeds 50 psia or inlet temperature exceeds 660°F, an override control function will modulate PV-647C closed.

The steam path through PV-1000, DS-901, and to the condenser is designed to accept the full 40,000 lb/hr flash tank steam flow at temperatures up to 950°F. Valve PV-1000 controls upstream pressure to 380 psia. During most low flow periods, all steam flow will be accepted by the deaerator resulting in a steam line pressure < 380 psia. During high flows or when PV-647C is closed by an override function, the pressure in the steam line builds until the 380 psia control pressure is reached. At that point, valve PV-1000 will open and allow flow to the condenser while maintaining upstream pressure at 380 psia.

Since it is possible for PV-1000 to pass steam at temperatures of up to 950°F, the desuperheater (DS-901) must be active to reduce the degree of superheat prior to its injection into the condenser. Because atomizing steam is required to operate the Graham desuperheater (DS-901), a parallel steam path to DS-901 through valve FV-1007 is provided. This valve operates in a simple open-closed fashion and is sized to pass 1300 lb/hr of atomizing steam.

Valve FV-1007 is also left in an open position any time the flash tank is being conditioned by receiver steam which flows through the flash tank temperature control orifices. The steam flow (≃ 900 lb/hr) passes down the steam vent downcomer, through FV-1007 and on to the condenser. Since DS-901 is incapable of operating at steam flow rates down to 900 lb/hr, no attempt will be made to desuperheat this small bleed flow. Piping downstream of DS-901 is capable of accommodating the high temperature steam. This steam, when introduced into the condenser, will have a negligible effect on condenser operation since it represents ≈ 1% of maximum condenser flow.

Condensate from the receiver flash tank flows, on a first priority basis to the 2nd point heater (shellside) through valve LV-74A and as an alternate to the condenser through valve LV-74C. The logic applied to the control of these valves is as described in Section M9.2. The maximum flash tank condensate rate is 40,000 lb/hr with valve LV-74A flow limited to 23,800 lb/hr. Valve LV-74C is designed to pass the full flash tank flow of 40,000 lb/hr.

M9.4 Thermal Storage Flash Tank

The primary function of the thermal storage flash tank is to accept flashing condensate which is expanded across the drain tank outlet control valves (UV-3110 and UV-3111) and to separate the resulting flow into its condensate and steam components. The flash tank also accepts startup steam from the thermal storage steam generators through valves AOV-3716 and AOV-3816, and assorted vents and warmup steam flows from the charging heat exchangers.

Steam leaving the flash tank passes through a steam piping network which splits with the primary flow leg going through valve PV-647C and into the deaerator while the secondary flow path routes steam through valve PV-640 and into the condenser. Valve PV-647C is responsible for maintaining flash tank pressure at a setpoint value of 135 psig. Valve PV-640 is activated by deaerator pressure as it approaches 50 psia to prevent an over pressure condition from occuring in the deaerator. This scheme allows steam to flow to the deaerator until it becomes saturated with energy (as measured by a high deaerator pressure), excess steam flow (thermal energy) is then diverted to the condenser.

The maximum steam flow leaving the flash tank is 30822 lb/hr assuming all inputs to the flash tank occur at their maximum levels simultaneously. By design, valve PV-647C is flow limited to 12,500 lb/hr which is sufficient to saturate the deaerator with energy. Valve PV-640 is sized to accommodate the full flash tank steam flow. No steam desuperheating is provided upstream of the condenser inlet due to the low steam temperatures involved ($\leq$ 480°F).

Condensate leaving the flash tank passes through the flash tank drain pump (P-307) and then on to the No. 2 heater (shellside) through LV-74D and/or to the condenser thru LV-74D-1 and LV-74D-2 (parallel level control valves to provide adaquate control range). The flash tank drain pump increases the condensate pressure by 15 psi which is adaquate to prevent flashing in the downstream piping and upstream of the level control valves. Flashing will occur across the level control valves.

The primary condensate flow path is to the No. 2 heater where the thermal energy contained in the hot water can be retained in the cycle. Valve LV-74B is sized to accommodate the maximum condensate flow available from the TS flash tank (117,500 lb/hr). A pressure override function as described in Section M9.2 is provided to prevent LV-74B from over pressurizing the No. 2 heater.

The secondary flow path to the condenser is also sized to accommodate the full condensate flow. Two valves are provided (LV-74D-1 and LV-74D-2) since normal (excess condensate) flow through this leg will be near zero which creates an excessive operating range for a single valve.

Table of Contents

M10. AUXILIARY STEAM SYSTEM

M10. AUXILIARY STEAM SYSTEM

M10.1 Drawing References

A. Mechanical

40P7005133140 - P&ID Electrical Power Generation Subsystem (EPGS) Steam

40P9005133306 - P&ID Steam

B. Control Logic

40I7002133012 (I5-10) AOV 1009 Control
40I7002133013 (I5-11) AOV 1008 Control
40I7002133025 (I15-10) AOV 1009 Control
40I7002133026 (I15-11) AOV 1008 Control

C. Electrical

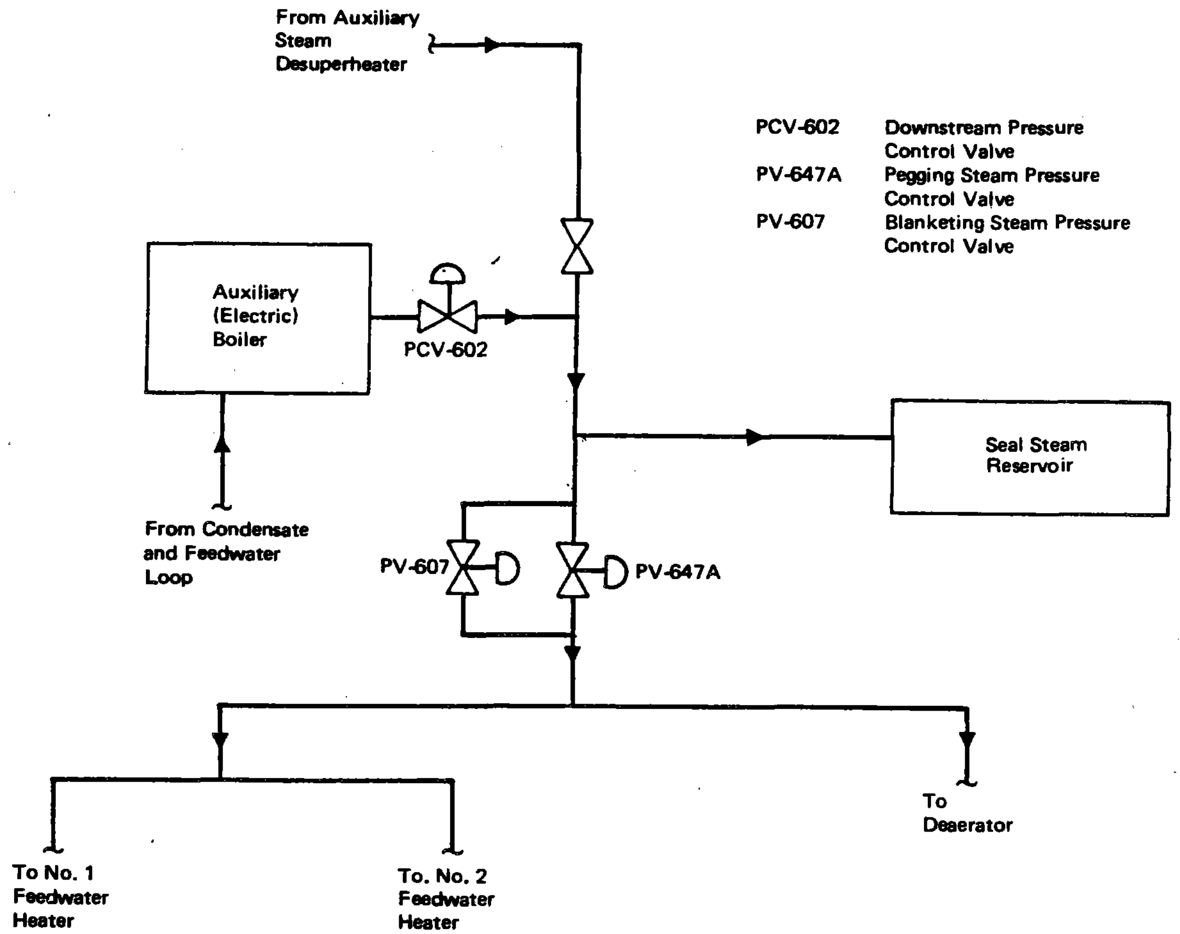


Figure M10-1. Auxiliary Steam System

M10.2 General Description

The auxiliary steam system accepts "low grade" steam at the outlet of the auxiliary steam desuperheater (DS-902) or from the auxiliary electric boiler and distributes it on an as required basis to the turbine seal steam reservoir, high pressure feedwater heaters (No. 1 and 2), deaerator, and to steam pipes and components requiring a blanketing steam pressure during non-operating periods. The auxiliary steam system also interfaces with the plant nitrogen system which allows the heaters and deaerator to be inerted in a nitrogen environment.

The auxiliary steam system is designed to accept steam from three sources in the following order of priority:

1. Steam drawn from the main steam system through pressure control valve PV-1003.
2. Steam drawn from the admission steam system through pressure control valve PV-1005.
3. Steam produced by the auxiliary electric boiler.

The auxiliary steam system pressure is maintained at 75, 65, or 55 psia respectively, depending on which of the above sources is providing the auxiliary steam. Prior to distribution to the downstream components, the steam pressure is further reduced to 20 psia by pressure regulating valves PV-607 and PV-647A (parallel valves).

M10.3 Auxiliary Electric Boiler

The auxiliary electric boiler is used as a second backup source of auxiliary steam behind the main steam and admission steam systems. It will be required to operate during the initial plant startup when the plant is completely "cold" and during periods when steam from the main and admission steam systems is not available.

The boiler is rated to produce 5000 lb/hr of saturated steam at 55 psia maximum pressure. The boiler draws its feedwater from the auxiliary boiler/thermal storage feedwater pump. The boiler startup is a manual operation carried out by the plant operator. Feedwater flow to the boiler is controlled to maintain boiler level.

(Detailed boiler characteristics TBD pending SCE selection and procurement)

M10.4 Operation and Control

The auxiliary steam system is designed to allow blanketing steam flow to inactive elements of the system. The following tabulation identifies the combinations of source steam and supplied components permitted by the design of the auxiliary steam system piping network.

Steam Source	Auxiliary Steam Service To: TS Heat Exchangers	Receiver Downcomer Piping	Turbine Seals and/or Feedwater Heaters
Main Steam System	✓		✓
Admission Steam System		✓	✓
Auxiliary Electric Boiler	✓	✓	✓

For any of the steam sources listed, the auxiliary steam may be supplied to each "checked" item individually or to any combination of the "checked" items indicated. The actual auxiliary steam flow path(s) for any configuration is determined by opening and closing the appropriate isolation valves.

A. Auxiliary Steam Supplied From Main Steam System

When steam is supplied from the main steam system, all steam passes through DS-902 where it is desuperheated prior to its introduction into the auxiliary steam system. When the incoming steam temperature is greater than 660°F and the receiver downcomer valve is full open, valve AOV-1008 will be closed (interlock function) to prevent high temperature, high pressure steam from entering the admission steam system. From the outlet of the desuperheater, flow will be routed as required to the turbine and feedwater heaters and automatically to the thermal storage heat exchangers (by opening AOV-1009) in the event that the admission steam system pressure is < 90 psia.

B. Auxiliary Steam Supplied From Admission Steam System

When steam is supplied from the admission steam system, valve AOV-1008 is opened which allows the steam to pass through DS-902 and be desuperheated (if required) prior to its introduction into the auxiliary steam system. Prior to passing through DS-902, a portion of the steam may back flow into the receiver downcomer piping thereby maintaining a blanketing steam pressure on these elements. Note that desuperheating of this steam is not required since the receiver downcomer piping is rated for temperature and pressure conditions for in excess of the thermal storage steam generator capabilities.

In the event that the auxiliary steam demand exceeds the capability of either the main or admission steam systems to supply the steam (because of flow limits on PV-1003 and PV-1005), both steam sources can be drawn from simultaneously in the quantities required to maintain the auxiliary steam pressure at the 65 psia control point. Both steam sources will mix upstream of DS-902 and be desuperheated as required. This combined flow operation will commonly occur during routine plant startups.

C. Auxiliary Steam Supplied From the Electric Boiler

Auxiliary steam can be supplied to all plant components indicated in the previous tabulation by opening valves AOV-1009 and AOV-1008 as well as allowing auxiliary steam to flow to the turbine and feedwater heaters in the normal fashion.

Table of Contents

M11. FEEDWATER SYSTEM

M11. FEEDWATER SYSTEM

M11.1 Drawing References

A. Mechanical

40P9005133301	- P&ID	Feedwater and Condensate System
40P7005133141	- P&ID	Electrical Power Generation Subsystem (EPGS) Condensate and Feedwater
40P2005131763	- P&ID	Receiver Subsystem (RS) Receiver Preheat Panel Feedwater
40P2005131767	- P&ID	Receiver Subsystem (RS) Main Steam Manifold, GN_2 and Drain Systems
40P3005132193	- P&ID	Thermal Storage Subsystem (TSS) Charging Steam and Condensate

B. Control Logic

40I7002133005	Receiver Feedwater Pump - P917 (RFP)
40I7002133020	Receiver Feedwater Pump (P917) and Disch/Recirc. Valves Design Criteria
40I7002133006	P-917 Lube Oil System
40I7002133007	P-917 Discharge MOV Control
N3221 SH.4	Motor Operated Valves
N3221 SH.5	Thermal Storage Feedwater Pump
N3221 SH.6	Pump Control - S.D.P.C.

C. Electrical

40E7005133192	One-Line Diagram 480 Volt MCC-B
40E3005132029	One-Line Diagram Load Center "A" and Receiver F.W. Pump

M11.2 General Description

The feedwater system includes all of the pumps, heat exchangers, control valves and piping between the deaerator outlet and the termination points in the receiver system, the thermal storage system, and the auxiliary steam system. Flow leaving the deaerator is drawn through one of the three feedwater pumps which provide the necessary feedwater circulation to various parts of the system. A deaerator liquid level elevation of 28 feed (minimum) provides adaquate head to satisfy the inlet pressure requirements of the feedwater pumps during all operating conditions. Descriptions of the dearator and No. 4 feedwater heater are contained in the condensate system (Section M12.)

M11.3 Receiver Feedwater Network

The receiver feedwater network supplies high pressure feedwater to the receiver and thermal storage charging desuperheater (DS-301). Flow is provided by the variable speed receiver feed pump (Bingham-Williamette - 4X6X9E CP) with a design operating speed of 3450 rpm. At the design point, the pump is able to produce a discharge pressure of 2176 psig at a flowrate of 164,400 lb/hr.

The pump is capable of operating at speeds as low as 720 rpm. The speed reduction is supplied through an American Standard fluid drive (Type VS Class 6) which in turn is powered by an 800 HP, 3600 rpm, Reliance motor. Minimum feedwater flowrates of 70 and 30 GPM are required at pump speeds of 3450 and 720 rpm respectively. A minimum flow circulation loop is included in the feedwater network which discharges back to the deaerator.

The discharge flow from the receiver feed pump passes through the No. 2 and No. 1 (high pressure) feedwater heaters where it is heated prior to flowing to the receiver or thermal storage desuperheater. The No. 2 heater is a horizontal U-tube design containing dedicated desuperheating, condensing, and subcooling sections. The heater has a total surface area of 462 sq. ft. and is made up of 54 - 3/4 inch U-tubes. Steam enters the shell from normal turbine extractions while condensate enters the shell from the receiver and thermal storage flash tanks and the drains from the No. 1 heater. Drain flow from the shell side flow to the deaerator and/or condenser depending on the ability of the deaerator to accept the condensate flow.

The No. 1 heater is a horizontal U-tube design containing dedicated desuperheating, condensing, and subcooling sections. The heater has a total surface area of 440 sq. ft. and is made up of 54 - 3/4 inch U-tubes. Steam enters the shellside from the first point turbine extraction port. All condensate draining from the shell is cascaded into the No. 2 heater.

During the operation of this network, the majority of the feedwater flows up the riser to the receiver inlet where it is split into 3 parellel flow paths through the preheat panels and then mixed in a common manifold prior to being distributed to the 18 receiver boiler panels. Prior to receiver startup, the main receiver inlet valve AOV-2004 may be closed while the bypass valve PV-2002 is open allowing feedwater to circulate directly into the flash tank. This flow path is used on a daily (or as required) basis to allow for the necessary circulation during water cleanup periods. Feedwater flow through the bypass valve (PV-2002) is limited to 30,000 lb/hr while system pressure (< 400 psia). Close control of receiver feed pump speed is required during this recirculating period to prevent excessive feedwater flow or pressure.

During initial startup of the receiver feedwater network, flow leaving the No. 1 heater may be diverted directly back to the condenser by opening valve MOV-110. This flow path would be used to cleanup the feedwater heater portion of the feedwater and condensate systems prior to initiating flow through the riser line to the receiver. This flow path is limited to a flowrate of 28,000 lb/hr.

During periods of plant operation in which all or a portion of the receiver steam is used to charge thermal storage, feedwater is supplied to the thermal storage charging desuperheater (DS-301) by the receiver feedwater network. Flow to the desuperheater is controlled by the temperature control valve (TV-3105) which maintains a desuperheater outlet steam temperature of 650°F.

M11.4 Thermal Storage Feedwater Network

The thermal storage feedwater network supplies feedwater to the thermal storage steam generators in sufficient quantity to satisfy the steam generation demand rate. The flow is provided by the thermal storage feedwater pump (P-903) and controlled by inlet control valves (LV-3505 and LV-3605) located upstream of the steam generators.

The feed pump (P-903) is a 150 HP single speed centrifugal pump capable of a 500 psia discharge pressure at 110,000 lb/hr flow. A recirculation path to the deaerator is provided to maintain a minimum required pump flow rate. (Details of the pump and drive shall be provided by SCE).

M11.5 Auxiliary Steam Feedwater Network

The auxiliary steam feedwater network is responsible from providing feedwater to either thermal storage steam generator(s) or auxiliary electric boiler during periods when blanketing steam is required. Feedwater flow is provided by the auxiliary boiler/thermal storage feedwater pump (P-904). This pump is capable of circulating 4880 lb/hr of feedwater at a discharge pressure of 120 psia. The pump is operated in a cyclic fashion as required to provide the necessary makeup flow.

Flow to the steam generators is initiated by opening remote valve LV-1. Flow continues until the steam generator(s) is filled to its maximum level at which point the pump is shutdown. The pump is restarted when the steam generator level falls to its minimum level.

Flow to the auxiliary boiler is initiated by opening the boiler inlet (manual) valve and closing LV-1. Flow to the boiler is controlled by the on/off operation of the pump in response to boiler level signals.

(Details of the auxiliary boiler/thermal storage feedpump and drive shall be provided by SCE)

Table of Contents

M12. CONDENSATE SYSTEM

M12. CONDENSATE SYSTEM

M12.1 Drawing References

A. Mechanical

40P9005133301 - P&ID	Feedwater and Condensate System
40P7005133141 - P&ID	Electrical Power Generation System (EPGS) Condensate and Feedwater
40P7005133140 - P&ID	Electrical Power Generation System (EPGS) Steam

B. Control Logic

40I7002133027	(I15-15)	Steam Line Drain Pots (Single Level Switch)
40I7002133028	(I15-16)	Steam Line Drain Pots (Dual Level Switches)
40I7002133014	(I5-15)	Drain Pot Level Control (Single Level Switch)
40I7002133015	(I5-15a)	I5-15 Control Table
40I7002133016	(I5-16)	Drain Pot Level Control (Dual Level Switches)
40I7002133017	(I5-16a)	I5-16 Control Table
N3221	SH.4	Motor Operated Valves
N3221	SH.6	Pump Control - S.D.P.C.
N3221	SH.7	Condensate Pump
N3221	SH.8	Polishing Demineralizer Sump Pumps
N3221	SH.21	Pump Start

C. Electrical

M12.2 General Description

The condensate system refers to the liquid portion of the electrical power generation subsystem bounded by (and including) the condenser and deaerator as well as the condensate supply (and drainage) equipment. Major elements of the system in addition to the condenser and deaerator are the condenser vacuum pump, condensate pump, inline demineralizer, No. 4 heater, and condensate storage tank. These elements of the system are functioning anytime feedwater is required to support plant operation (excluding blanketing periods during Mode 8 operation).

During operation, condensate is drawn from the hotwell portion of the condenser and circulated through the inline demineralizer and No. 4 feedwater heater before entering the deaerator. Circulation is provided by the condensate pump which is capable of flowing 218,000 lb/hr with a discharge pressure of 140 psia. A portion of the condensate is diverted from the main flow path to the steam dump and auxiliary steam desuperheaters (DS-901 and DS-902) to satisfy the desuperheater condensate requirements. Additional condensate is drawn into the condenser from condensate storage tank through level valve LV-146A in response to a low hotwell level. Excess condensate is routed back to the condensate storage tank from the discharge of the condensate pump in response to a high hotwell level signal. Flow back to the condensate storage tank is through level valve LV-146B.

Flow entering the deaerator is heated to a temperature level of 228-281°F (20-50 psia saturated) to allow for adaquate deaeration of the condensate. The heated condensate accumulates in the deaerator reservoir where it serves as a source of feedwater for the rest of the system. Excess condensate, as defined by a high deaerator level signal from LIT-83, is routed back to the condenser through valve LV-83A. Depending on the status of the hotwell level, the condensate may be subsequently diverted back to the condensate storage tank.

The inline demineralizer is located upstream of the No. 4 feedwater heater to allow it to function with the coolest water available in the cycle. In order to prevent damage to the demineralizer bed, the condensate temperature entering the demineralizer should be maintained below 135°F.

M12.3 Condenser

The condenser is a tube and shell heat exchanger which accepts the waste heat from the plant and rejects it to the circulating water system (flowing through the tubes). The condenser has a steady state heat rejection capacity of $95X10^6$ BTU/HR while maintaining the condenser pressure at $\leq$ 2.5 inches Hg. During transient conditions, the condenser is capable of rejecting in excess of $142.5X10^6$ BTU/HR. Separate water and steam injection points are provided into the condenser to properly accommodate the external steam and condensate flows. The steam injection point uses a sparging tube to distribute the steam inside the condenser.

Condenser vacuum is maintained at 2.5 inches Hg with a Nash vacuum pump which is rated at 7.5 SCFM at 2.5 inches Hg. During "hogging" operation, the vacuum pump is rated at 170 SCFM at a pressure of 10 in. Hg. The pump is driven by a 1200 rpm 25 HP (460V) motor.

(Detailed design, performance, and construction information involving the condenser and vacuum system shall be as provided by SCE)

M12.4 Inline Demineralizer

The inline demineralizer consists of two parallel full flow devices which are operated on an alternating basis while the off line unit is being regenerated. Each device is required to maintain the discharge condensate water quality to the following maximum specification:

Total dissolved solids	50 ppb
Silica	20 ppb
Iron	10 ppb
Copper	2 ppb
Sodium	2 ppb
Chloride	2 ppb
Cation Conductivity at 77°F	0.3 μmho/cm

For regeneration purposes, a separate regeneration tank along with acid and caustic storage and feed systems are provided.

(Details involving the design, construction, and operation of the inline demineralizers and supporting equipment shall be as provided by SCE).

M12.5 No. 4 Feedwater Heater

The No. 4 feedwater heater (E-904) is a horizontal U-tube heat exchanger which is designed to raise the condensate temperature from 108°F to 197°F at a flowrate of 92,200 lb/hr. It is also designed to pass a maximum condensate flow of 218,600 lb/hr.

The heat exchanger is divided into a condensing and drain cooling section. It is made up of 97-5/8 inch OD U-tubes with an effective surface area of 711 sq. ft. The tubes are constructed of 304 stainless steel while the shell is made of carbon steel (ASTM-106 Grade B). During heater operation, all shell side condensate is routed to the condenser through level valve LV-104 which modulates to maintain a preset heater condensate level. No provisions are made to provide blanketing steam to the No. 4 heater.

M12.6 Deaerator

The deaerator (A-901) is responsible for removing dissolved and non-condensible gases from the system. It is operated at saturated temperature between 20 and 50 psia and vents directly to the atmosphere. The deaerator also includes an elevated (28 ft. level) reservoir that provides a source of feedwater to the 3 feedwater pumps. The reservoir is sized for a 7 min. capacity as measured from the condenser hotwell pump discharge. During blanketing operation, this reservoir serves as the only source of feedwater for the blanketing steam generation process. If the condenser vacuum is not maintained, condensate can not be transferred to the reservoir from the hotwell without contaminating the system.

(Details involving the design, performance, construction, and operation of the deaerator shall be as provided by SCE).

M12.7 Condensate Storage Tank

The condensate storage tank is a 24,000 gallon reservoir for excess condensate. The tank is located in the central core area, due east of the turbine generator area.

When a low condensate level occurs in the condenser hotwell, makeup condensate is drawn from the storage tank to the hotwell by the natural pressure difference that exists between the two vessels. Excess condensate is diverted back to the condensate storage tank from the discharge of the condensate pump in response to a high condensate level in the hotwell.

Makeup condensate is supplied to the condensate storage tank from the makeup demineralizer. The makeup flow is provided by the demineralizer. The makeup flow is provided by the demineralized water transfer pump (P-710) and is controlled by condensate tank level valve LV-162. The design condensate makeup flowrate is 75 GPM.

The tank also provides a source of condensate flow required for the operation of the condenser vacuum pump (P-910). It is equipped with overflow and drain ports which discharge to the plant drains system.

Table of Contents

M13. COOLING WATER SYSTEM

M13. COOLING WATER SYSTEM

M13.1 Drawing References

A. Mechanical

40P9005133303 - P&ID Cooling Water System
40P9005133302 - P&ID Circulating Water System
40P9005133301 - P&ID Feedwater and Condensate System

B. Control Logic Diagrams

N3221 SH.6 Pump Control - S.D.P.C.

C. Electrical

M13.2 General Description

The cooling water system consists of the piping network, pumps, heat exchangers, and tanks necessary to provide cooling water circulation to the major plant rotating equipment and water sample chillers and to reject the waste heat to the circulating water system. The cooling water is drawn directly from the outlet of the condensate pump (P-907) and stored in the cooling water surge tank (TK-901).

Cooling water is drawn from the surge tank and circulated to the rest of the system by the cooling water pump (P-901). The discharge flow then passes through the cooling water heat exchanger (E-905) where heat is transferred to the circulating water system. The low temperature cooling water is then distributed to the thermal storage Caloria pumps (4), thermal storage feedwater pump, receiver feed pump lube oil cooler, turbine lube oil coolers (2), generator air cooler, and the feedwater sample chillers where waste heat is absorbed. The high temperature cooling water is then returned to the cooling water surge tank where the process is repeated.

M13.3 Pumps

The cooling water system utilizes two pumps to provide cooling water circulation. The cooling water pump (P-901) provides the principal flow circulation. It is a horizontal centrifugal pump with a flow capacity of 700 GPM. The pump has a discharge head of 120 feet and is driven by a 40 HP, 460V electric motor. The pump speed is 1800 rpm.

A secondary flow loop within the cooling water system is used to cool sample coolers SC-907, 908, 909, 910, and 911. Flow through these coolers is provided by the sample chiller pump (P-925). This pump is a small centrifugal unit rated at less than 1 HP. This secondary cooling water loop interfaces with the primary cooling water system through the sample chiller (CR-907).

M13.4 Surge Tank and Heat Exchangers

The surge tank serves as the water source for the cooling water pump. It is a vertical 1200 gallon storage tank located on the upper level of the turbine area. Makeup water is provided by the condensate system which enters the tank through level valve LV-307. This valve responds to the tank level signal LC-307. The tank is equipped with an overflow and drain which route the cooling water to the plant drain system.

The cooling water heat exchanger (E-905) is the interface element between the cooling water and circulating water system. The heat exchanger is rated to transfer $7X10^6$ BTU/HR between the two water flows. The unit is capable of passing 700 GPM of cooling water (shellside) and 560 GPM of circulating water (tubeside).

(Details regarding the design and construction of this heat exchanger shall be.as provided by SCE).

Heat exchangers for the individual pieces of rotating equipment are as provided by the equipment suppliers. These include lube oil coolers for the receiver feed pump and turbine and direct flow through the pumps in the case of the thermal storage Caloria and feedwater pumps.

Table of Contents

M14. CIRCULATING WATER SYSTEM

M14. CIRCULATING WATER SYSTEM

M14.1 Drawing References

A. Mechanical

40P9005133302 - P&ID Circulating Water System

B. Control Logic

N3221	SH.3	Cooling Tower Fans
N3221	SH.4	Motor Operated Valves
N3221	SH.10	Circulating Water Pumps
N3221	SH.13	Sodium Hypochlorite Pump
N3221	SH.14	Cooling Tower Acid Pump
N3221	SH.20	Circulating Water Pump Discharge Valve

C. Electrical

M14.2 General Description

The circulating water system is responsible for absorbing waste heat from the condenser, cooling water heat exchanger, and vacuum pump heat exchanger and rejecting it to the atmosphere through the cooling tower. Flow through the system is provided by two vertical circulating water pumps which draw water from the cooling tower basin. The design inlet water temperature is 78°F.

The circulating water then flows in a parallel fashion to the condenser, cooling water heat exchanger, and vacuum pump heat exchanger after which it is recombined and returned to the cooling tower. The design point return water temperature is 103°F. The design flow through the system with both pumps operating is 8300 GPM.

Circulating water pH is automatically maintained at a level of with an acid feed system which responds to a pH measurement (AE-207) located upstream of the cooling tower. The acid is mixed with service water prior to its injection into the cooling tower basin. A sodium hypochlorite system is used to control slime-forming bacteria by injecting a mixture of sodium hypochlorite and service water into the cooling tower basin.

Circulating water conductivity is monitored at the discharge of the circulating water pumps and the blowdown rate is adjusted to maintain the conductivity at a value ≤ . The blowdown flow is controlled by control valve CV-241 which discharges to the evaporation pond.

Cooling tower makeup water is supplied through two connections with the service water system, one which introduces service water at the inlet to the condenser and heat exchanger and the second which works with the acid and sodium hypochlorite feed systems. Additional chemicals (scale inhibitors) are introduced directly into the cooling water basin by the duplex chemical feed pump. This pump is controlled exclusively with a local hand switch.

M14.3 Cooling Tower Unit

The cooling tower unit consists of the cooling tower, cooling fans, basin, and miscellaneous supporting equipment. The cooling tower is made up of three cells and is of wood construction. The dimensions of the cooling tower are X X and it is located outside of the collector field, immediately adjacent to the southern access road. Each cell is designed to reject $34.3x10^6$ BTU/HR with a supply water temperature of 103°F and a design wet bulb temperature of 62°F. Because of its wooden construction, each cell is protected by a sprinkler system which uses service water to maintain the structure in a moistened state during non-operating periods to prevent a fire hazard.

Each cooling tower cell is equipped with a 2-speed 60 HP fan which is powered by a 460V motor. Each of these fans is activated through the keyboard of the SDPC. Each fan is in turn interlocked to fan oil pressure and fan vibration both of which can activate alarm conditions in the control room and cause the fan to trip.

The basin is a rectangular concrete structure which collects the circulating water run off from the cooling towers and provides the input water reservoir for the circulating water pumps and Diesel driven fire pump. The basin has dimensions of X and contains 45,000 gallons of circulating water.

M14.4 Circulating Water Pumps

The two circulating water pumps (P-905 and P-906) are mounted in the cooling tower sump located at the west end of the cooling tower basin. Each pump is a 200 HP, 1800 rpm vertical unit with a head rise capability of 85 feet at a 4150 GPM flowrate.

Each pump can be activated through either the SDPC keyboard or a dedicated hand switch located on the control console. As the pump starts, the discharge motor operated valve (MOV-222 or MOV-243) will open automatically. Note that if the discharge valve is open, the circulating water pump startup logic will be inhibited.

M14.5 Miscellaneous Chemical Systems

A. Acid System

The acid system includes the acid tank (TK-904), the acid pump (P-912), and the interconnecting piping and is responsible for maintaining pH control in the circulating water. The acid tank is a 3000 gallon container located in a basin adjacent to the cooling tower.

The cooling tower acid pump delivers a discharge head of 30 feet at a flowrate of 10 GPM. It is powered by a 3600 rpm, 460V motor rated at less than 1 HP. The acid pump is activated either from the SDPC keyboard, by local hand switch, or by a high pH indication as measured by AE-207. The pump is interlocked with the circulating water pumps so that the acid pump cannot operate unless one or both circulating water pumps are operating. The operation of the acid pump is interlocked with flow valve FV-264 which is opened to provide service water when the pump is activated to be mixed with the discharge of the acid pump prior to flowing into the cooling tower basin.

B. Sodium Hypochlorite System

The sodium hypochlorite system includes the storage tank (TK-922), the pump (P-930), and the interconnecting piping and is responsible for maintaining an adequate chlorination level to control the formation of algae and other slime-forming bacteria. The sodium hypochlorite storage tank is a 500 gallon container located adjacent to the cooling tower basin. The tank includes fill, drain, and overflow connections and is vented to the atmosphere.

The sodium hypochlorite pump is capable of producing a discharge head of 30 feet at a flowrate of 2 GPM. It is powered by a 3600 rpm, 460V motor rated at less than 1 HP. The pump is activated either from a local handswitch or by a programmed timer input from KC-204. The operating schedule established by the timer defines a sequence with injections per day for a duration minutes per injection. The pump is stopped as a result of either an operator command from the keyboard, timer input, or a motor overload condition. In the event of an overload, a manual reset is required before a subsequent start can be accomplished.

C. Chemical Feed System

The chemical feed system is used to introduce additional chemicals into the circulating water system. The chemicals are drawn from two 55 gallon day tanks (TK-905 and TK-907). The chemicals are injected into the circulating water system with a duplex chemical feed pump (P-923). The pump is rated at 50 GPM with a discharge head of 230 feet. It is driven by a 3600 rpm, 460V motor which is rated at less than 1 HP. The duplex pump is operated through a local hand switch.

(Details regarding this system shall be as specified by SCE).

Table of Contents

M15. WATER TREATMENT FACILITIES

M15. WATER TREATMENT FACILITIES

M15.1 Drawing References

A. <u>Mechanical</u>

40P7005133145 - P&ID Plant Support System (PSS) Water Treatment
40P9005133301 - P&ID Feedwater & Condensate System

B. <u>Control Logic</u>

N3221 SH.9 Pump Control - Local

C. <u>Electrical</u>

40E7005133193 One-Line Diagram 480V MCC-C

M15.2 General Description

The water treatment facilities include all of the equipment necessary to convert raw water into demineralized and polished water and supply it as required to the condensate storage tank and to the heliostat washing equipment. The equipment includes a make-up package demineralizer (D-701), demineralized water storage tank (TK-702), demineralized water transfer pump (P-710), and two polishing demineralizers (DE-701 and DE-702).

The overall water treatment facility is designed to convert raw water into polished-demineralized water with the following water analysis characteristics:

	Raw Water Analysis	Polished Water Analysis
Calcium	400 ppm	0
Magnesium	94 ppm	0
Sodium	286 ppm	2 ppb
(Total Cations)	780 ppm	
Bicarbonate Alkalinity	339 ppm	0
Sulfates	208 ppm	0
Chlorides	185 ppm	2 ppb
Nitrates	48 ppm	0
(Total Cations)	780 ppm	
Silica	35 ppm	20 ppb

During operation, raw water passes through the makeup package demineralizer and is stored in the demineralized water tank. On demand, the demineralized water transfer pump would draw demineralized water from the storage tank and circulate it through a downstream polishing demineralizerbefore introducing it into the condensate storage tank. Heliostat wash water would be drawn directly from the discharge of the demineralized water transfer pump upstream of the polishing demineralizers.

M15.3 Make-Up Package Demineralizer

The make-up package demineralizer is a mobile unit which includes a primary cation exchanger, a primary anion exchanger and one or two mixed bed polishers, all mounted on a trailer. The unit will be rented from a commercial water treatment equipment supplier. When demineralizer regeneration is required, the unit will be replaced with a fresh system by the rental supplier. No on site regeneration equipment is provided.

(Details pertaining to the design, performance, and operation of this unit shall be as provided by the rental supplier).

Water conductivity is monitored at the discharge of the demineralizer by CE-1207. This parameter is displayed in the control room for operator monitoring and includes a high conductivity alarm.

M15.4 Demineralized Water Storage Tank

The demineralized water storage tank (TK-702) is an 18,000 gallon welded aluminum vessel constructed of alloy ASTM B209. It has a diameter of 14 feet and height of 16 feet and is located due north of the Raw Service Water Pump Building (BL-702).

Flow into the tank is controlled by the inlet level valve LV-1203 which responds to the water tank level switch (LS-1203). The tank is equipped with drain and overflow connections which route the flow to the plant drains. The tank itself is vented to the atmosphere. The main inlet and outlet lines are trace heated to protect against possible freeze-up.

M15.5 Demineralized Water Transfer Pump

The demineralized water transfer pump (P-710) transfers water from the demineralized storage tank to the condensate storage tank or mirror washing equipment. It is a horizontal centrifugal pump driven by a 5 HP, 480V motor.

The design flow is 75 GPM with a head rise of 80 feet.

Pump operation is initiated by a low condensate storage tank level signal from LC-162 which simultaneously opens the condensate tank inlet level valve LV-162. The pump can also be activated by a locally mounted hand switch (HS-1202).

M15.6 Polishing Demineralizers

The polishing demineralizers are provided as part of the rental water treatment equipment and are designed to supplement the demineralizer equipment described in Section M15.4 in the event that equipment is unable to completely satisfy the final demineralized water analysis requirements. This equipment will be portable and will be exchanged by the rental supplier as necessary to satisfy the regeneration requirements.

(Details pertaining to the design, performance, and operation of this equipment shall be as provided by the rental supplier).

Table of Contents

M16. RAW AND SERVICE WATER SYSTEM

M16. RAW AND SERVICE WATER SYSTEM

M16.1 Drawing References

A. Mechanical

40P7005133150 - P&ID Plant Support System (PSS) Service Water

B. Control Logic

C. Electrical

40E7005133193 One-Line Diagram 480V MCC-C

M16.2 General Description

The raw and service water system is the source for all plant water and supplies directly the fire protection system, water treatment facilities, restroom and sanitary facilities, service to the EPGS, TSS, and RS areas, cooling towers, and the raw/service water pump building sump. The water is supplied from Well "A" located outside of the plant security fence, southeast of the collector field. Water is supplied from the well by an existing pump which can deliver 1000 GPM at a 250 psig discharge pressure to the Solar One site. Control of the well water pump is maintained by the operators of the Coolwater Generating Station located adjacent to the Solar One site.

The incoming water is accumulated in the raw water storage tank (TK-701) which serves as the main water reservoir for the plant. Water from this tank supplies the raw/service water pumps (P-703 and P-704), the primary electric fire pump (P-705) and the fire maintenance jockey pump (P-707). The discharge from the raw/service water pumps is routed to the service areas identified above. Service water is also provided directly to the cooling tower basin to support the operation of the secondary Diesel driven fire pump. This flow is routed directly from the well pump and bypasses the raw water storage tank.

M16.3 Raw Water Storage Tank

The raw water service tank is sized to accommodate 151,000 gallons of raw water, 90,000 gallons of which is reserved to supply the primary electric fire pump. The remaining 61,000 gallons is dedicated to the plant service water requirements. The tank is 29.5 feet in diameter and 39.5 feet tall and is constructed of carbon steel (ASTM A283-c) in accordance with the American Water Works Association design standards.

Flow to the tank is controlled by level valve LV-1702 which responds to a water level switch (LS-1702) that monitors tank level. In addition to serving as a water supply to the service and fire pumps, the tank also receives the minimum bypass recirculation flows from each of these pumps. All supply and return lines connected to the tank are trace heated to protect against possible freezeup.

The tank is also equipped with overflow and drain ports that route the raw water onto splash blocks.

M16.4 Raw/Service Water Pumps

The raw/service water pumps (P-703 and P-704) are 2 half capacity pumps each rated at 350 GPM at a discharge pressure of 100 psig. Each pump is a horizontal centrifugal design driven by a 75 HP, 460V motor. A minimum flow bypass loop is provided and shared by both pumps that will open at low flow (high discharge pressure as measured by PS-1703) and provide circulation back to the raw water storage tank. The operation of the pumps is initiated through locally mounted hand switches located in the Raw/Service Water Pump Building. The pump controller is connected to level switch LS-1703 in the raw water storage tank which terminate pump operation in the event of a low water level.

Table of Contents

M17. CHEMICAL FEED SYSTEM

M17. CHEMICAL FEED SYSTEM

M17.1 Drawing References

A. Mechanical

40P9005133301 - P&ID Feedwater and Condensate System
40P9005133304 - P&ID Miscellaneous Systems
40P9005133307 - P&ID Sampling System

B. Control Logic

N3221 SH.16 Hydrazine Feed Pump
N3221 SH.17 Ammonia Feed Pump

C. Electrical

M17.2 General Description

The chemical feed system includes the ammonia and hydrazine equipment required to feed the feedwater and condensate systems to maintain control of the pH and dissolved oxygen in the cycle. The equipment consists of tanks, pumps, piping, instrumentation, and controls required for the chemical injection process. The primary ammonia and hydrazine injection points are downstream of inline polishing demineralizer. The secondary injection points are in the deaerator discharge line which provides feedwater to the receiver and thermal storage feed pumps.

M17.3 Ammonia Feed System

The ammonia feed system consists of the ammonia tank (TK-914), ammonia pump (P-934), the interconnecting piping, and control equipment. The pump is a two speed, fractional horsepower unit rated at 1/6 GPM at a discharge head of 140 feet. It is activated by the operator in the control room through a keyboard command (HS-726). Once operating, the pump speed is automatically selected in response to the deaerator inlet conductivity as measured by CE-726. This parameter gives a direct measure of ammonia level. When a high level is experienced, the low pump speed is selected. When a low ammonia level occurs, the high pump speed is selected. The maximum pump speed is 3600 rpm.

The ammonia tank is a 100 gallon container which supplies the inlet flow to the ammonia pump. The tank is equipped with a local reading level gauge (LG-437) and a level indicating transmitter (LIT-438) which supplies level data to the operator in the control room. The output of this sensor will be used for low level alarming in the control room. No provisions are provided for a low level ammonia pump trip. Makeup ammonia is supplied to the ammonia tank from 100 pound drums which can be attached to the tank fill connection. The tank is also equipped with overflow and drain connections which route the ammonia to the plant drains.

M17.4 Hydrazine Feed System

The hydrazine feed system is used primarily to control the level of dissolved oxygen contained in the condensate system by combining with it to form $H_2O + N_2$. The nitrogen gas produced by the process is subsequently removed from the cycle by the deaerator. Excess hydrazine in the feedwater decomposes at high pressure and temperature to form ammonia and nitrogen gas which then affects the pH level of the cycle.

Hydrazine is supplied to the condensate system by the hydrazine feed pump (P-933) which draws its supply from the hydrazine tank (TK-913). The pump is a 2-speed, fractional horsepower unit which is rated at 1/6 GPM at a discharge head of 140 feet. It is activated by the operator in the control room through a keyboard command (HS-725). Once operating, the pump speed is automatically selected in response to the deaerator inlet hydrazine level as measured by AE-725. A high pump speed is used when measured hydrazine levels are low and a low pump speed is used in response to a high measured level. The maximum pump speed is 3600 rpm.

The hydrazine tank is a 100 gallon container which supplies flow to the hydrazine pump inlet. It is equipped with a level indicating transmitter (LIT-400) which provides routine level and low level alarm information to the operator in the control room. The tank is also equipped with a local level gauge and overflow and rain connections. The tank is filled from a standard 55 gallon hydrazine drum through a fill port connection.

Table of Contents

M18. SAMPLING SYSTEM

M18. SAMPLING SYSTEM

M18.1 Drawing References

A. Mechanical

40P9005133307 - P&ID Sampling System

B. Control Logic

C. Electrical

18.2 General Description

The sampling system is designed to monitor water chemistry in the condensate and feedwater systems on a continuous basis and provide the analysis information to the operator in the control room. The monitored parameters are pH, dissolved oxygen, sodium, conductivity, and cation conductivity. Some or all of these parameters are measured at the following five locations:

- (i) the discharge of the condensate pump, upstream of the inline demineralizers
- (ii) the outlet of the inline demineralizer, upstream of the 4th point feedwater heater
- (iii) the outlet of the 4th point feedwater heater
- (iv) the outlet of the deaerator, upstream of the receiver feed pump
- (v) the outlet of the 1st point feedwater heater (final feedwater condition).

Also included in the sampling system are sampling connections and sample coolers attached to the turbine main and admission steam lines (one each). These ports are operated manually and provide a condensed sample of the steam to the plant chemist for subsequent analysis. The recommended GE standards for steam purity are (i) cation conductivity < 0.2 micromhos/cm and (ii) sodium concentration < 3 ppb. The respective steam purity values may go to 0.5 micromhos/cm and 6 ppb for short periods which do not accummulate to more than 500 hours per year and under emergency conditions (less than 100 hours accummulated over a year) to 1.0 michromhos/cm and 10 ppb.

The sampling system hardware includes the piping (and tubing), isolation and control valves, pressure reducing orifices, sample coolers, and the water analysis instrumentation.

M18.3 Condensate Pump Discharge Analysis

The condensate pump discharge analysis station monitors condensate pH (AE-719) dissolved oxygen (AE-733), conductivity (CE-736), cation conductivity (CE-720), and sodium (AE-733), with the sodium monitoring equipment also being used to measure the sodium levels in the condensate leaving the inline demineralizer. The selection of the source flow for the sodium analysis equipment is made by the three-way solenoid valve KY-733 which cycles based on a timer input.

Prior to conducting the analysis measurements, the condensate which is drawn from the condensate system passes through a pressure regulating valve (PCV-731) and sample cooler (SC-911).

Each of the five measurements are fed to the SDPC which are used to provide display and alarm information to the operator in the control room. In the event of a circulating water system leak in the condenser, the alarms associated with these parameters will provide the operator with the first indication that such an event has occurred.

Condensate which flows through the measuring devices is routed to the plant drain system. Included in the interconnected piping are safety valves and drain connections.

M18.4 Inline Demineralizer Discharge Analysis

The inline demineralizer discharge analysis station monitors pH (AE-729), conductivity (CE-728), cation conductivity (CE-727), and sodium (AE-733). These monitoring elements give a direct measure of the water quality leaving the demineralizer and provide a first indication of contamination break through in the demineralizer. Each sensor provides information to the operator in the control room through the SDPC, and activates an alarm in the event of an anomalous condition.

The sample which is drawn from the condensate system passes through a pressure regulating valve (PCV-709) and sample cooler (SC-910) prior to flowing to the water analysis equipment. Other details regarding this monitoring station are as described in Section M18.3.

M18.5 Fourth Point Heater Discharge Analysis

The circulating water sample taken from the outlet of the fourth point heater is used to control the ammonia and hydrazine injection rates based on conductivity (CE-726) and pH (AE-725) measurements. Condensate drawing from the circulating water system passes through an initial sample chiller (SC-904), a pressure reducing valve (PCV-721), and a final sample chiller (SC-909) to reduce the temperature and pressure of the condensate to a valve compatible with the sensing elements. Measurement signals are fed to the SDPC for display and alarm purposes in the control room.

M18.6 Deaerator Discharge Flow Analysis

The deaerator discharge analysis station monitors cation conductivity (CE-717), pH (AE-716), and dissolved oxygen (AE-715), with the dissolved oxygen monitor being shared with the final feedwater measurement station. The selection of the sample source for the dissolved oxygen measurement is made through a locally mounted hand switch (HS-715) which sets the flow path for the three-way sample solenoid valve (HY-715). These measurements provide a direct indication of state of the deaerator and in particular its functions involving the removal of dissolved oxygen. Dissolved oxygen levels at this point in the feedwater system should be less than 7 ppb during normal operation. Because of the carbon steel used in the feedwater system (downstream of the deaerator), dissolved oxygen levels should not exceed 10 ppb during plant startup. Values above this level may cause corrosion which could result in iron oxide being carried to the receiver where filter and orifice fouling could occur.

The sample drawn from the feedwater system pass through an initial sample cooler (SC-906), a pressure reducing valve (PCV-711), and a final sample cooler (SC-908) before being routed to the measurement equipment. The piping network is equipped with a safety relief and drain valves.

M18.7 First Point Heater Discharge Analysis

Feedwater flow leaving the final feedwater heater must satisfy the following feedwater chemistry requirements:

Total Solids	50 ppb (max)
Dissolved Oxygen	7 ppb (max)
Silica	20 ppb (max)
Iron	10 ppb (max)
Copper	2 ppb (max)
pH at 77°F	9.3 to 9.6
Hydrazine	200 ppb (max)
Cation Conductivity at 77°F	0.3 micromhos/cm (max)
Sodium	2 ppb (max)
Chloride	2 ppb (max)

This final sampling station monitors pH (AE-706), hydrazine (AE-707), conductivity (CE-708), cation conductivity (CE-718), and dissolved oxygen (AD-715). Samples drawn from the feedwater system pass through a set of double isolation valves which are required to ensure a positive sample system shutoff against the full feed pump discharge pressure. The flow then passes through a pressure reducing orifice (FO-713) and two series sample chillers (SC-903 and SC-903A). It then passes through a pressure control valve (PCV-701) and a final sample cooler (SC-907) before entering the water analysis measurement areas. Each of the sensors transmits information back to the control room for monitoring and alarming purposes. Condensate leaving the sample monitoring equipment is routed to the plant drains.

M19. STEAM TURBINE LUBE OIL SYSTEM

(to be supplied)

M20. COMPRESSED AIR SYSTEM

(to be supplied)

M21. NITROGEN SYSTEM

(to be supplied)

Table of Contents

M22. FIRE PROTECTION SYSTEM

M22. FIRE PROTECTION SYSTEM

M22.1 Drawing References

A. <u>Mechanical</u>

40P7005133148 - Piping and Instrument Diagram Plant Support System (PSS), Fire Protection

40P7005133246 - Piping Arrangements - Auxiliary Buildings, Secondary Fire Pump Building Plan and Section

40P7005133247 - Composite Drawing, Fire Protection System

B. <u>Control Logic</u>

C. <u>Electrical</u>

M22.2 General Description

The fire protection system consists of:

- a fire water service system designed to fight both indoor and outdoor fires of a conventional nature
- a foam system designed to be used in the thermal storage area in the event of a Caloria or other hydrocarbon fire
- a Halon system and Halon fire extinguishers for use in enclosed areas and particularly against electrical fires

The entire system is designed to be in compliance with the standards of the National Fire Protection Association (NFPA).

M22.3 Fire Pumps

All fire pumps are supervised locally and remotely via the pump's associated controller. Annunciation is also provided on a local and remote basis. Local control and annunciation functions include "power" (in service) and "loss of power" for the electrical pump and "battery power available," "selector switch in automatic," "loss of AC power," and "trouble" for the diesel pump. Remote control and annunciation functions located at the Fire Protection Supervisory Panel in the control room include "power" (in service), "loss of power," and "pump running" for the electrical pump. The remote diesel pump function is a "trouble" signal which represents any of the local annunciation conditions. In addition, both the electric and diesel fire pumps have remote "start only" pushbutton stations located in the Supervisory Panel.

Each fire pump location is provided with fire extinguishers to provide for local fire protection. Installation of the fire extinguishers is in accordance with NFPA Standards No. 10 "Portable Fire Extinguishers" and No. 20 "Centrifugal Fire Pumps."

Both pumps are equipped with relief valves (electric - 3/4" circulating; diesel - 4" automatic main) and water flow meters discharging back to their stored water sources. These arrangements are designed to help conserve water during pump operation and testing periods.

Fire pumps are installed in accordance with NFPA Standard No. 20 "Centrifugal Fire Pumps," and No. 37 "Stationary Combustible Engines and Gas Turbines" for the Diesel Fire Pump.

A. Primary Electric Fire Pump

In order to ensure reliable fire service water for this facility, an electric driven horizontal shaft centrifugal fire pump taking suction from an aboveground suction tank (described in Section II.B.) is provided.

Site underground fire service system pressure is maintained by an automatic start electric driven horizontal shaft centrifugal pressure maintenance "jockey" pump. This pump is sized at 25 gpm at 125 psi. This small flow capacity is adequate for anticipated makeup demands due to leakage in the fire protection system piping.

B. Backup Diesel Fire Pump

In addition to the electric fire service water fire pump, a 100 percent backup diesel driven vertical shaft centrifugal fire pump is also provided to help ensure reliable fire service water supply to the facility during an impairment of the electric pump. This pump is also sized at 1000 gpm at 125 psi and arranged for automatic start via its associated controller.

This backup pump is located in a separate pump structure in the Construction/Laydown area. The pump will take suction from a wet pit supplied with water (via a concrete pipe) from the cooling tower basin. Due to the potential fire exposure problems presented by the cooling tower, the diesel fire pump structure is located 55 feet away. Sprinkler protection is provided over the diesel fuel tank and all oil supply lines. A 1-1/2 inch fire hose station is also provided within the pump structure adjacent to the entrance doorway. The waterflow switch sprinkler is supervised (local and remote) as described in Section M22.8. Installation will be in accordance with NFPA Standard No. 13 "Installation of Sprinkler Systems."

M22.4 Stored Water Supplies

A. Primary Pumping System

A combined service (site service and fire water) aboveground suction water tank is provided adjacent to the Raw/Service Water Pump Building in the Core area. All fire water supplied by the electric driven fire pump is reserved strictly for fire service via a dual standpipe arrangement within the tank with water for fire service being drawn from the bottom of the tank. The storage water tank is provided with a refill system arranged to fill the tank when normal site service water demand is approximately 50 percent of its normal level. At no time will normal or abnormal site service water demands draw into the fire service water.

NOTE: Tank refill can be accomplished well within the maximum 8 hr. time permitted by NFPA Standard No. 22.

Stored water supplies reserved exclusively for fire service have a capacity of 90,000 gallons. This capacity is based on maximum anticipated water duration requirements of one hour for fire fighting purposes, and has been sized as follows:

One hour operation of the fire pump based on 150 percent of rated fire pump capacity. 150 percent of 1000 gpm = 1500 gpm x 60 min. = 90,000 gallons.

A 4" pumper connection with National Standard threads is provided on the 4" tank drain connection. This connection is available for energizing use by the Barstow Fire Department for pumper truck suction in the event of an impairment to the primary electric pump during a fire.

B. Backup Pumping System

The backup diesel driven fire pump also has the total available water capacity contained in the cooling tower basin which furnishes water to the diesel fire pump's wet pit via a 21 inch concrete supply line. In addition, during actual fire service use, continuous backup water supply makeup to the cooling tower basin is performed via operation of the SCE well pump (2250 gpm). This pump primarily supplies raw water to the Core area.

NOTE: These well pumps are fed electrically from an independent distribution network than that which furnishes power to the site.

Backup water supply makeup is accomplished by opening a normally closed 6 inch post indicator valve located on a 6 inch lateral (teed off the 8 inch supply line from the SCE well pumps) which feeds water to the cooling tower basin. The six inch supply line runs up over the top of the basin wall to discharge water, thereby preventing contamination of the well water source.

With both fire pumps in service, the total combined pumping capacity is a minimum of two hours at 150 percent of the pump's total rated pumping capacity.

Installation of the water storage tank is in accordance with NFPA Standard No. 22 "Water Tanks."

M22.5 Underground Piping

An independent dedicated underground fire service main is provided for this site. All underground fire mains which direct water from the fire pumps to the various laterals supplying fire hydrants, and between the Laydown/Construction area and Core area are 8 inch. This size was selected to keep friction loss low in these major supply lines. An 8 inch line has been provided to the east of the EPGS area which in effect ties in the north and west 8 inch legs in the Core area resulting in a loop around the Raw/Service Water Pump Building and EPGS area. This loop will help ensure added reliability to water distribution in the area.

A single 8 inch lateral extending from the Core area along the roadway back to the Construction/Laydown area has been provided to supply fire water to hydrants in this area. This line will also supply fire service water from the diesel fire pump to the Core area. All laterals supplying fire hydrants in both areas are 6 inch.

A fire department pumper connection tied directly into the 8 inch main is provided near the main entrance to the site at the Construction/Laydown area. The associated check valve is located in a concrete valve pit. This connection will permit the fire department to hook a pumper to one or both 2-1/2 inch connections while taking suction from the 4" Fire Department suction connection standpipe located at the Southwest corner of the cooling tower basin, should the diesel fire pump be impaired. The Fire Department can then pressurize the entire underground loop to help ensure fire service water at effective pressure is available during an emergency. All Fire Department connections will have National Standard threads.

All underground piping material is fiberglass reinforced plastic (FPR) which will offer the least amount of friction loss on water flow. Due to the "C" factor given FRP pipe, the pipe sizes employed are equivalent to one pipe diameter larger for all other piping materials. Installation is in accordance with manufacturer's recommended procedures.

Valving has been provided to ensure proper isolation of the system during an impairment which will enable water to continue to be supplied to all other areas. Valving is accomplished by Post Indicator assemblies (P.I.) which ensures prompt operation and visual status (open/closed) of the valve above grade level.

All P.I. assemblies are provided with Frangible locks to prevent unauthorized valve operation.

With the exception of the two fire hydrants equipped with water spray monitor nozzles, all other hydrants have one 4" pumper and two 2-1/2" butt connections. All connections have National Standard threads.

All fire hydrants are provided with buried controlling gate valves (access via curb box) to permit isolation of the hydrant for repairs without impairing the rest of the system.

All installations are in accordance with NFPA Standard No. 24 "Outside Protection," and any special manufacturer's instructions as covered above.

M22.6 Fire Protection - Outside Areas

Fire hydrants are provided to ensure 100 percent fire hose (2-1/2 inch and/or 1-1/2 inch) coverage of all areas where combustible occupancy or construction exists, both for the Construction/Laydown area and Core area. A total of twelve (12) hydrants provide this coverage. All hydrants are of the standard design, with the exception of a single wall fire hydrant located on the west wall of the Warehouse as described in Section M22.8.

Standard hydrants are equipped with 2 to 2-1/2 inch hose butt connections and controlled by independent gate valves located at the inlet.

Fire hose (both 2-1/2 inch and 1-1/2 inch), combination spray nozzles and all other necessary hardware are located inside hydrant hose houses located at approximately every other fire hydrant. Hose houses have been located at hydrants in close proximity to structures/equipment where fire problems are most likely to occur.

Fire hose is single jacket (synthetic wrap) rubber lined, 300 pound test. Hose nozzles are combination straight stream/spray, except hose houses in the vicinity of electrical equipment which have only non-shock type spray nozzles. Appropriate hose lengths and component quantities are provided.

Fittings for all components are compatible with threads used by the local fire dpeartment.

A fixed mount (portable unit) waterspray monitor nozzle is mounted on the fire hydrants located at the north west corner of the Thermal Storage Tank and to the east of the TSS Heat Exchanger Area. These monitor nozzles aid in providing backup cooling water in the event of a fire at this equipment.

Installations are in accordance with NFPA Standard No. 24.

M22.7 Fire Protection - Thermal Storage Area

A. <u>TSS Equipment Skid Layout</u>

(1) TSS equipment described below is protected by an automatic balanced pressure proportioner foam system using 3 percent floroprotein AFFF concentrate foam. Separate foam systems, each controlled by independent selector valves (one valve associated with each protected area) and supplied by the common foam concentrate tank, provides foam-water spray protection to all equipment and rack piping containing oil in the TSS area. System actuation is by electric rate-compensated thermal detectors and manual pull station at the valves.

(2) Protection is provided for the following equipment:

(a) Charging Pump Skid

(b) Thermal Storage Heater Skid Assembly

(c) Extraction Pump Skid Assembly

(d) Preheater Skid Assembly

(e) Boiler and Superheater Skid Assembly

(f) Ullage Maintenance Skid Assembly

B. <u>TSS Thermal Storage Tank</u>

No fixed internal or external automatic foam system is provided. However, a foam hydrant system consisting of two (2) hydrants located 180 degrees apart, is provided for exterior tank and berm area fire protection.

Foam hydrants ensure 100 percent fire hose (2-1/2 inch and/or 1-1/2 inch) coverage of the berm area and all tank surfaces are supplied from the central foam system. In addition, each hydrant is equipped with a fixed mount monitor nozzle which enables unmanned foam spray coverage of the Thermal Storage Tank and TSS Heat Exchanger Area in the event of a fire.

Actuation of the foam hydrant system's deluge valve is by manual pushbutton station located at the hydrant and mounted on an adjacent post. A manual pull station associated with the hydrant system's deluge valve also actuates the foam system.

A curb is provided around the tank in accordance with NFPA Standard No. 30, "Flammable and Combustible Liquids Code," and designed to contain 150 percent of the tank contents.

Installations are in accordance with NFPA Standards No. 11, "Foam Extinguishing Ssytems," No. 16 "Foam - Water Sprinkler and Spray Systems," Nos. 24, 30, and 70, "National Electrical Code," No. 72A, "Local Protective Signaling Systems" and No. 72E, "Automatic Fire Detectors."

M22.8 Fire Protection - Structures

A. <u>Annunciation</u>

Automatic fire protection systems provided have all functions monitored locally via control panels. Supervision consists of waterflow and pressure switches for water and foam systems; detection circuits; release circuits for Halon, waterspray and foam systems; manual pull stations; and all trouble alarm signals.

Local annunciation consists of jeweled pilot lamps or light emitting diodes (LEDs) on the local control panel (in vicinity system's deluge valve, fire hose station standpipe, or external to Halon protected areas) indicating "Trouble" and "Alarm" conditions on a per zone basis.

When adjacent multiple systems can be served by a single control panel, a multizone panel is used.

Local audible "Trouble" signals originate at a common trouble buzzer in the control panel, while audible "Alarm" signals originate a common "Alarm" horn located outside the protected area or structure in which the valve is located. Simultaneous remote transmission of these signals terminate on the Fire Protection Supervisory Panel (FPSP) located in the EPGS Area Control Room.

A 24 amp/hr built-in battery backup is provided at each panel to ensure uninterruptible operation in the event of power failure.

Installation is in accordance with NFPA Standard No. 72A.

All local fire protection equipment signals described above are annunciated on an individual basis. The following signals are terminated on the Fire Protection Supervisory Panel (FPSP) located in the EPGS Control Room.

(1) Pumps
 (a) Electric - Power (in service) Loss of Power and Pump Running.
 (b) Diesel - Common Diesel Pump "Trouble."

(2) Sprinkler system waterflow switch

(3) Deluge valve pressure switch

(4) Halon System - "Trouble"

(5) Detection Systems - "Trouble" and "Alarm" signals

In addition, the FPSP also contains the manual remote "fire pump start pushbutton" stations. The panel power supply is of an uninterruptible type which ensures continuous operation. All signals received on the FPSP will be manually logged. Surveillance of the panel is carried out as part of normal control room operation.

Installation of signaling equipment is in accordance with NFPA Standard No. 72D "Proprietary Signaling System."

B. Thermal Storage Control Buildings

Thermal storage control buildings (BL-709 and BL-710) are equipped with automatic Halon 1301 systems with a design concentration of 5 to 7 percent by room volume at 70°F. Automatic actuation is by cross-zoned photoelectric detectors, whereas manual actuation is by manual pull stations located inside the protected area, adjacent to the exit doorway(s).

Prior to system discharge, fire dampers are arranged to close automatically along with air handling unit shutdown. This arrangement ensures gas retention within the room.

An audible/visual (strobe light) alarm is located outside the door to these buildings and arranged to operate on system actuation. Instruction signs (engraved phenolic plastic) mounted beneath these alarms state "DO NOT ENTER WHEN HORN/LIGHT OPERATING - HALON DISCHARGE". Halon 1211 portable fire extinguisher (9 lb.) are located inside each building adjacent to the entrance door.

All installations are in accordance with NFPA Standard Nos. 10, 12A, "Halon 1301 Systems," 72A and 72E.

C. Receiver Tower

Protection as described below is provided for the following locations:

(1) 14th Level Primary Electronics Room

(2) 13th Level Overflow Electronics Room

All electrical and electronic equipment installed in these rooms is provided with Total Flooding Halon 1301 systems. Halon 1211 portable fire extinguishers (9 lb.) are provided inside each of the protected areas and located adjacent to the exit doorways.

All installations will be in accordance with NFPA Standard Nos. 10, 12A, 72A and 72E.

D. Raw/Service Water Pump Building

Portable fire extinguishers are provided throughout the Raw/Service Water Pump Building to ensure 100 percent coverage where required. No other protection will be provided.

Installations will be in accordance with NFPA Standard No. 10.

E. Warehouse

A single wall fire hydrant is located at the west wall of this building to insure fire hose streams are available in this area while eliminating the need to route hydrant supply piping beneath the paved area. Water supply to the hydrant is controlled by an automatic fire service self-resetting deluge valve located in a heated enclosure. Actuation of the valve is by an electric pushbutton station located adjacent to the wall hydrant. This automatic valve also supplies water to the interior fire hose stations upon actuation of the pushbutton stations.

Photoelectric (smoke) detectors suitable for building ambient temperature are provided throughout on maximum of 400 square feet spacing predetector. All detectors are arranged for "alarm only". This arrangement helps ensure prompt response during the initial stages of a fire.

Portable fire extinguishers and fire hose stations (1-1/2") are provided to ensure 100 percent coverage where required. Fire hose stations are actuated by pushbutton stations located at each hose station. These pushbuttons actuate the automatic deluge valve described above.

Installations will be in accordance with NFPA Standard Nos. 10, 14, 72A, 72D and 72E.

F. Construction Office and Administration Building

Portable fire extinguishers only are provided throughout the Administration Building to ensure 100 percent coverage where required.

Installation will be in accordance with NFPA Standard No. 10.

G. Cooling Tower

No automatic deluge system fire protection is provided for this cooling tower.

Fire hose ensuring 100 percent coverage of all exterior surface areas is provided by yard area fire hydrants as described in Section M22.6.

H. Cooling Tower Remote MCC Building

Photoelectric detectors are arranged for "alarm only". Halon 1211 portable fire extinguisher (9 lb.) are provided inside this room and located adjacent to doorway.

Installations will be in accordance with NFPA Standard Nos. 10, 72A and 72E.

M22.9 Fire Protection - Electrical Power Generation System Area

A. General

Fire hose stations (1-1/2") and portable extinguishers are provided to ensure 100 percent coverage of all areas in the building requiring such protection.

(1) Fire hose stations are supplied from the interior looped header system. All fire hoses are equipped with non-shock spray nozzles.

(2) Interior header supply risers are provided with fire department connections. Pumper connections will have local fire department threads.

(3) Extinguisher size and type are selected based on area/equipment requiring protection.

Installations are in accordance with NFPA Standard Nos. 10, 14, "Standpipe and Hose Systems," and 72A.

B. Lower Plan Area

Since safety type oil will be provided for the turbine-generator lube oil system, no sprinkler protection is provided over the lube oil reservoir and conditioner located at the underside of the turbine floor area or for the associated piping.

Floor drains are provided throughout this area. All drains tie into an oil/water separator.

C. Upper Plan Area

(1) Turbine-Generator (T-G)

Automatic high pressure CO_2 protection is provided for the Generator enclosure. Actuation is by thermal detectors.

Installation is in accordance with NFPA Standard Nos. 12, "Carbon Dioxide Systems" and 72A.

(2) Equipment Room

Total flooding Halon 1301 system with design concentration of 5 to 7 percent by equipment or sub-floor volume at 70°F provides protection for this room and its associated sub-floor. System is as described for the thermal storage control buildings with the exception; detectors are of "Alarm Only" type and system actuation is manual.

All wall and sub-floor penetrations are sealed with Dow Corning 3-6548 Silicone RTV Foam or equivalent which is listed for 3 hour fire rating.

Installations will be in accordance with NFPA Standard Nos. 12A, 72A, and 72E.

(3) Control Room and DAS (Evaluation) Room

Halon 1211 portable fire extinguishers are provided within this room.

Installation will be in accordance with NFPA Standard No. 10.

M22.10 Miscellaneous Fire Protection

A. EPGS Area Lube Oil Storage

Yard fire hydrants ensuring 100 percent area coverage is provided at this location. A containment berm is provided around the tanks with containment capacity designed for 100 percent contents of one tank.

B. EPGS Main and Auxiliary Transformers

No waterspray protection is provided for these transformers. However, containment basins filled with crushed rock are provided around each of these transformers for small oil spills.

Yard fire hydrants for fire hose coverage are provided.

C. Fire Truck

Due to the above protection being provided and the fact the Barstow Fire Department will respond, no fire truck has been provided.

M23. DRAINS, SUMPS AND WASTE DISPOSAL SYSTEM

(to be supplied)

M24. HEATING, VENTILATING, AND AIR CONDITIONING

(to be supplied)

M25. SATELLITE BUILDINGS

(to be supplied)

M26. RECEIVER TOWER AND CRANE

(to be supplied)

ELECTRICAL (E)

Table of Contents

ELECTRICAL POWER SECTION

Table of Contents

E1. GENERAL ELECTRICAL POWER DESIGN

E1. GENERAL ELECTRICAL POWER DESIGN

E1.1 Scope

The electrical power section of the System Description contains pertinent engineering data and descriptions of the pilot plant electrical features. Aspects of the electrical system to be treated include the

- Generator and steam turbine
- Component protection
- High voltage system
- Auxiliary power system
- 125 V dc system
- Communication system
- Lighting system
- Electrical distribution system control
- Power system grounding

It is intended that this description present the broad engineering design features and the intended operating arrangements. Detailed references to the various vendors' instruction manuals and drawings are included to aid in startup, operation, and maintenance activities.

E1.2 System Elements

A. Generator and Steam Turbine

The steam turbine is an automatic admission, single flow, extraction, condensing unit capable of accepting and admitting steam either through the main throttle valve or through the automatic admission valve or through both valves simultaneously under the operating conditions (modes) defined for the plant. The turbine with a design rating of 12.5 MWe operates at a synchronous speed of 3600 rpm and is directly coupled to a 13.8 KV generator.

The following electrical power devices are required for the operation and control of the tubine:

- AC bearing oil pump (2)
- DC emergency bearing oil pump
- DC starter for emergency oil pump
- Vapor extractor
- Turning gear
- Gland exhauster blower
- Hydraulic fluid pump (2)
- Filter motor
- Hydraulic fluid heater and blower
- Motor valve operators
- Speed-load control motor

The electrical generator is the revolving field, sychronous, cylindical rotor, air cooled type. The housing of the generator is of outdoor design which is compatible with the pilot plant environment.

The generator is designed to operate continuously at maximum required output, at power factors of 0.90 lagging to 0.95 leading without exceeding the guaranteed temperature rise of TBD°F, or causing harmful localized heating or other injurious effect of heating.

The output rating of the generator is referenced to continuous operation at maximum turbine output, 13.8 kv (14.23 MVA), grounded wye-connected, 3 phase, 6 Hz. The short circuit ratio of the generator at maximum output is 0.58 or greater.

B. Component Protection

Electrical protection is provided for all electrical devices through breakers in the power distribution networks. In addition, the interlock logic system (ILS) described in the Control and Instrumentation section (CI) of this System Description document contains permissive logic that must be satisfied to allow component startup and/or operation to continue. Hardwire trip signals are also provided independent of the normal plant control equipment to guarantee complete component protection.

C. High Voltage System

The high voltage system consists of the 13.8 KV network which connects the generator to the main station and auxiliary transformers and the 33 KV section between the main station transformer and the 33 KV main line.

During normal operation, the plant generator, auxiliary transformer, and 33 KV line are interconnected thereby allowing the generator output to accommodate the auxiliary electrical load plus provide a net power production to the grid. In the event that the main transformer breaker opens, the turbine-generator output can accommodate the auxiliary load without a turbine over-speed condition occuring. In this way, a safe plant shutdown can be executed. Prior to turbine startup, power can be drawn directly from the grid as required to supply the plant startup auxiliary load.

D. Auxiliary Power System

The auxiliary power system begins at the auxiliary transformer and supplies all of the 4160, 480, and 120 Vac service required for plant operation. Also included as part of the auxiliary power system is the uninteruptable power supply required to isolate critical control components from grid power fluctuations and to permit continued control system in the event of a loss of primary power.

E. 125 Volt DC System

The 125 volt dc system is a battery powered system designed to provide reliable power to critical components which must be maintained in an operational status even when the primary ac power is lost. Examples of these components include the turbine dc lube oil pump and solenoid operators on control and isolation valves. The capacity of this system is sufficient to safely shutdown the plant in the event of an emergency condition.

F. Communication System

The communication system involves all permanently installed equipment used for intra plant communication and/or warning of operating personnel. This includes telephones, intercoms, and alarms/siren devices. Excluded from this system are the data communication networks.

G. Lighting System

The lighting system includes the indoor and outdoor lighting for the entire site. Outdoor lighting includes area lighting for the main southern access area (warehouse and administration building areas) and in the core area. Collector field lighting is limited to low profile (runway) lights placed along the collector field access roads. No effort is made to light the entire collector field. Tower and receiver lighting includes both general area lighting and safety lighting which complies with Federal Aviation Administration requirements.

H. Electrical Distribution System Control

The electrical distribution system control elements include the remote (located in the control room) and local controls used to activate or deactivate selective portions of the overall electrical system. Control room operations are carried out through a dedicated control panel.

I. Power System Grounding

The power system grounding is provided through a series of grounding networks that service the core area, collector field, and southern equipment areas. Grounding networks that service site buildings and pipeways connect directly to the structural steel members. In the collector field, grounding rods are provided at each heliostat for grounding purposes.

Table of Contents

E2. GENERATOR AND STEAM TURBINE

(To Be Supplied)

Table of Contents

E3. GENERATOR, TURBINE, RECEIVER PROTECTION

(To Be Supplied)

Table of Contents

E4. HIGH VOLTAGE SYSTEMS

(To Be Supplied)

Table of Contents

E5. AUXILIARY POWER SYSTEMS

E5. AUXILIARY POWER SYSTEM

E5.1 Drawing References

40E7005133351 - Main One Line Design
40E7005133353 - One Line Diagram, 4160 Volt System
40E7005133354 - One Line Diagram, 480 Volt System, Switchgear "B01"
40E7005133355 - One Line Diagram, 480 Volt Switchgear, B02 & BOL
40E7005133356 - One Line Diagram, 480 Volt System, MCC - "BOA"

E5.2 General Description

The auxiliary power system begins at the auxiliary transformer (AX1) and supplies all of the 4160, 480, and 120 V ac power required for plant operation. The power for the system is normally drawn from the 33 KV grid or generator output through the auxiliary tranformer. In the event the auxiliary transformer breaker opens, power can be restored on a selective basis by switching to the 4 KV water well power source. The transfer is carried out manually from the control room. This backup power source is sufficient to maintain control system operation and permit a sequential defocus of the collector field to a safe standby point off the receiver followed by a field stowage operation.

E5.3 4160 V Service

The 4160 V portion of the system consists of a 3000 A bus that provides service to the station service transformer (SX1), thermal storage load center transformer, cooling tower transformer (CTX1), and the auxiliary boiler transformer. In addition, the 4160 V service is provided directly to the receiver feed pump and to the two heliostat feeder lines running to the collector field. The 4160 V bus also ties directly to the 4 KV water well line through which backup power can be provided.

Data pertaining to the operation and performance of the 4160 V network are provided through the following measurements:

Location	Power	Current
• Auxiliary transformer (low voltage side)	√	√
• Station service transformer (high voltage side)		√
• Cooling tower transformer (high voltage side)	√	√
• Thermal storage system transformer (high voltage side)	√	√
• Receiver feed pump	√	√
• Heliostat feeders (2)	√	

Current measurements can be displayed by the operator in the control room through the SDPC console while power measurements are transmitted directly to the DAS equipment.

E5.4 480 V Service Systems

The 480 V service is provided throughout the plant by means of the station service transformer, thermal storage system load center transformer, cooling tower transformer and collector subsystem transformers (14) located in the collector field.

A. Station Service Transformer

The station service transformer is located in the vicinity of the control room. The transformer powers the 1200 A 480 V bus which in turn powers:

- Motor Control Center A - Electrical power generation subsystem equipment
- Motor Control Center C - Raw and service water pumps, fire pumps, trace heating, and miscellaneous lighting and HVAC service.
- Power Panel A - Receiver and tower.
- Thermal Storage Feed Pump

Power flow to each of these four areas is recorded by the DAS system for subsequent parasitic load analysis purposes.

B. Cooling Tower Transformer

The cooling tower transformer is located to the north of the cooling towers and powers the 1200 A, 480 V bus. This bus in turn powers the

- Motor Control Center L - Cooling tower miscellaneous loads (lighting, fans, and pumps), warehouses, and the secondary fire pump building.
- Administration Building
- Cooling Tower Circulating Water Pumps

No DAS data is recorded for each of these three service loads individually. The input power to the cooling tower transformer which represents the sum of these services is recorded.

C. Thermal Storage System Load Center Transformer

The thermal storage subsystem load center transformer is located in the northeast corner of the core area adjacent to the thermal storage electrical equipment building (BL-712). This transformer powers the 1600A, 480 V bus which in turn provides power to the thermal storage charging and extraction pumps and other thermal storage loads including trace heating, MOV's, and ullage maintenance equipment. All of these loads combine to form motor control center "B".

E5.5 Uninterruptable Power System (UPS)

The uninterruptable power system consists of a battery charger, a 250 V dc battery, and two inverters which supply power directly to the equipment bus. Equipment powered by the UPS include the heliostat array controllers (HAC), subsystem distributed process control (SDPC), and the data acquisition sytem (DAS). All of these elements are located in the control room and are critical for safe plant operation and shutdown. No attempt is made to maintain power in any of the remote stations in the event of a power failure. These elements will require reinitialization prior to resuming their control functions.

The UPS is designed to supply a 50 KVA Load for a period of up to 30 minutes following the loss of primary power. The two parallel inverters are used to enhance overall UPS reliability. Automatic inverter fail-over occurs in 4 milliseconds in the event of an inverter malfunction. The batteries are standard lead-acid cells. Input power is provided to the UPS from motor control center "A".

Table of Contents

E6. 125 VOLT DC SYSTEM

(To Be Supplied)

Table of Contents

E7. COMMUNICATIONS SYSTEM

(To Be Supplied)

Table of Contents

E8. LIGHTING SYSTEM

E8.1 General Description

Lighting for the various buildings and roadways described hereinafter is provided by high pressure sodium, fluorescent and incandescent type fixtures. The fixtures are arranged in suitable combinations to provide adequate lighting in work areas for the safety, convenience, and comfort of operating and maintenance personnel. General area lighting is provided throughout the plant on catwalks, pipe racks and in non-working areas, including access roads and perimeter roadway lighting in the core area. An emergency lighting system will automatically provide lighting in essential areas, in the event of failure of the normal lighting system. An emergency battery operated unit is employed to provide lighting inside most buildings, for personnel safety, in the event of failure of the normal lighting system. Photoelectric cell controlled lighting circuits are provided for outdoor type lighting to provide adequate illumination from dusk to dawn working hours in essential areas.

Power for lighting and receptacles in the plant buildings and site facilities is obtained from the various electrical distribution systems, as described in the following paragraphs.

E8.2 Drawing References

(TBD)

E8.3 Warehouse Lighting (Building No. BL703)

Two three-phase, 4-wire, 480/277 volt systems furnish power for the warehouse lighting. Control and distribution for these systems is provided by lighting panel LP-6 (East), and lighting panel LP-7 (West) located in the warehouse.

Two single-phase, three wire, 120/240 volt power panels furnish power for receptacles, air condition units and office lighting as required. Control and distribution for these systems are provided by power panel PP-6 (East) and PP-7 (West), located in the warehouse. Power for the power panel PP-6 (East), is supplied from a breaker in the lighting panel LP-6 (East). Power for the power panel PP-7 (West), is supplied from a breaker in the lighting panel LP-7 (West) as shown on drawing No. E19-12.

E8.4 Raw/Service Water Building & Water Storage Tanks

A three-phase, 4-wire, 480/277 volt system furnishes power for lighting in the raw/service water building and for lighting of the cat walks on the demineralized water tank and raw water storage tank. The roadway lighting on the inner perimeter road of the core area including all the lighting for the plant access roads from North, East, South and West entrances.

Control and distribution for these systems is provided by lighting, panel LP-3, located in the raw/service water building (BL-702).

Power for raw/service water building lighting panel is supplied from a 45 KVA, 480-277/480 volt, three-phase, 4-wire, 60 hertz, dry type transformer, located in the raw/service water building and fed from a 70 amp breaker in motor control center, MCC-C located in the building.

E8.5 Building Services

A three-phase, 4-wire, 120/208 volt power panel, PP3, furnishes power for space heaters, receptacles, ventilation fans, fire control panel and fire pump controllers.

Power supply for power panel PP3, is supplied from a 30 KVA, 480-120/208 volt, 3-phase, 4-wire dry type transformer located in the building, and fed from a 50 ampere breaker in motor control center MCC-C.

E8.6 Perimeter And Roadway Lighting

Lighting panel LP3, which controls the perimeter and roadway lighting has 24-circuit capability, and is equipped with single pole 20 amperes molded-case circuit breakers as required. All the perimeter and roadway lighting fixtures are furnished with photo electric controlled circuits for all-night security lighting for the solar plant.

E8.7 Receiver Tower Electronics Rooms (Building Nos. BL708A&B)

The indoor lighting in the electronics rooms, which are located on the 13th and 14th levels of the receiver tower, is furnished from two lighting panels, located at the 1st level of the receiver tower. Lighting panel LP-1 furnishes control and distribution of the normal lighting system, and lighting panel EML1, furnishes control and distribution of the emergency lighting system. All the lighting fixtures in the electronics rooms are local controlled from wall switches.

A three-phase, 4-wire, 480/277 volt system furnishes power for the indoor and outdoor lighting systems as required. Lighting panel LP-1, is designed with a 100 ampere split bus, protected by a 50 ampere, 3 pole circuit breaker at the bottom. A remotely controlled, 60 ampere, 3 pole N.O. contactor separates bus no. 1 and bus no. 2. The bottom section (bus no. 1) has a

12-circuit capability and provides power to the Centaurus III H.I.D. and to lighting in the electric rooms at the 13th and 14th level of the tower. The top section, (bus No. 2) provides the outdoor lighting in the receiver tower and pipe racks.

A single-phase, 3-wire, 277 volt system furnishes power for the indoor and outdoor emergency lighting systems, as described hereinafter. The emergency lighting panel EML1, is a 12-circuit panel, and contains a 25 ampere, 4-pole N.O. Contactor, which furnishes power to the outdoor emergency lighting circuits. The lighting contactors in panel LP-1 and EML1, are remotely controlled from the lighting control panel, described under outdoor lighting.

E8.8 Receiver Tower Structure And Pipe Rack

A. Outdoor Lighting

The outdoor lighting system, can be operated from the lighting control panel, in either of two modes of control using the hand-off-automatic selector switch, on the lighting control panel.

1. In the automatic mode, the outdoor lighting is controlled automatically from a Photo-electric controller (PEC). The PEC is set to turn lighting units "on" at one (1) footcandle and "off" at ten (10) footcandle during the period from dusk to dawn.

2. In the manual mode the outdoor lighting is controlled from the Hand-off-automatic selector switch in the "Hand" or manual position. The manual mode will bypass the Photo-electric controller.

   The outdoor lighting, located on the receiver tower at levels, 1 thru 11 and 15; the pipe racks in the TSS area and receiver tower pipe rack area, is controlled from two lighting panels.

Lighting panel LP-1 described under indoor lighting above, furnishes control and distribution of the "normal" outdoor lighting system, in either the manual or automatic modes as selected at the lighting control panel.

Lighting panel EML1, described under indoor lighting above, furnishes control and distribution of the "emergency" outdoor lighting system, in either the manual or automatic modes as selected.

The outdoor lighting system operates in the "normal" condition, receiving power from the utility source of electrical distribution. Upon loss of utility power, the emergency lighting system will automatically continue to function with power furnished from the centaurus system's battery and inverter, for a minimum period of 1.5 hours. Upon restoration of utility power, the inverter will automatically synchronize with utility power and reconnect the outdoor lighting load to the utility power. During the "normal" condition with power supplied by utility power, all outdoor lighting fixtures will operate in either mode. Upon loss of utility power, only the emergency lighting fixtures will remain in operation, and only for a period of 1.5 hours.

B. Emergency Lighting

The emergency lighting system described above, is known as Centaurus III HID. The Exide/Lightguard Centaurus III HID, is rated, 7500 VA at a power factor from 0.8 lag to 0.8 lead. The system will operate on 277 volts AC, 60 hertz single-phase. The output voltage will be 277 volts AC of 7500 VA, 60 hertz, single-phase, in any combination to the maximum VA capacity of the system. The Centaurus III HID, unit is located in the electrical equipment building BL-712, and is supplied with 277 volts single-phase power from the lighting panel LP-1, located at the receiver tower.

E8.9 Receiver Tower Air Navigation Obstruction Lighting System

(To Be Supplied)

E8.10 Secondary Fire Pump Building (Building No. BL-706)

A single-phase, 3-wire, 120/240 volt, lighting panel LP8, furnishes power for building lights, receptacles, emergency battery pack lighting unit and fire pump controller. The lighting panel, LP8, has a 4-20 ampere circuit breaker capability and is fed by a 25 ampere circuit breaker. The lighting panel is part of a mini-power center with a 5 kva, 480-120/240 volt, single-phase, 3-wire transformer, which is fed from a 20 ampere circuit breaker.

The mini-power center is fed from motor control center MCC4 located in the secondary fire pump building.

The motor control center MCC4, is a Westinghouse Jr. Group unit with a 100 ampere main bus, fed from a 50 ampere circuit breaker. MCC4 furnishes power to heating and ventilating equipment as described under the HVAC system.

The motor control center MCC4, is fed from "SCE" MCC-BOL, with power from circuit breaker no. 42-BOL-16. Ref "SCE" drawing no.________ for the cooling tower substation.

E8.11 Thermal Storage Control Building (Building No. BL709)

A three-phase, 4-wire, 120/208 volt system furnishes power for lights, receptacles, and various power requirements for electronic equipment, fire control panel, etc. Control and distribution for this system is provided by power panel PP4, located in the TSS control building BL-709. Power panel PP4, is fed from a three-phase, 4-wire, 480-120/208 volt, 30 KVA, dry-type transformer, located in the building.

The 30 kva transformer is fed from a 50 ampere circuit breaker in motor control center MCC1, located in building. Generally the motor control center MCC1, furnishes power for building services and the HVAC system which will be described in the HVAC section.

E8.12 Thermal Storage Control Building (Building No. BL 710)

A three-phase, 4-wire, 120/208 volt system furnishes power for lights, receptacles, and various other power requirements for the electronic equipment, fire control panel, etc. Control and distribution for this system is provided by power panel PP5, located in the Thermal Storage Control Building. BL710.

Power panel PP5, is fed from a three-phase, 4-wire, 480 120/208 volt, 30 kva, dry-type transformer, located in this building.

The 30 kva transformer for PP5, is fed from a 50 ampere circuit breaker in motor control center MCC2, located in this building. Motor control center MCC2, provides power for building services and is further described in the HVAC system description herein.

E8.13 Thermal Storage Electrical Equipment Building (Building No. BL 712)

A three-Phase, 4-wire, 120/208 volt system furnishes power for lighting, receptacles and various other power requirements for electronic equipment and building services as required. Control and distribution for this system is provided by Lighting Panel LP4, located in the electrical equipment building BL 712.

A three-phase, 4-wire, 480-120/240 volt, 30 kva, transformer, furnishes power to the lighting panel LP4. The 30 kva transformer is fed from a 50 ampere breaker in motor control center MCC-B, located in the electrical equipment building, BL 712.

The motor control center MCC-B will be described under the auxiliary electrical power distribution section of system description.

Table of Contents

E9. ELECTRICAL DISTRIBUTION SYSTEM CONTROL

(To Be Supplied)

Table of Contents

E10. POWER SYSTEM GROUNDING

(To Be Supplied)

CONTROL AND INSTRUMENTATION (CI)

Table of Contents

CONTROL AND INSTRUMENTATION SECTION

CI 1. GENERAL CONTROL SYSTEM DESCRIPTION

(to be supplied)

CI 3. OPERATIONAL CONTROL SYSTEM

(to be supplied)

CI 4. SUBSYSTEM DISTRIBUTED PROCESS CONTROL

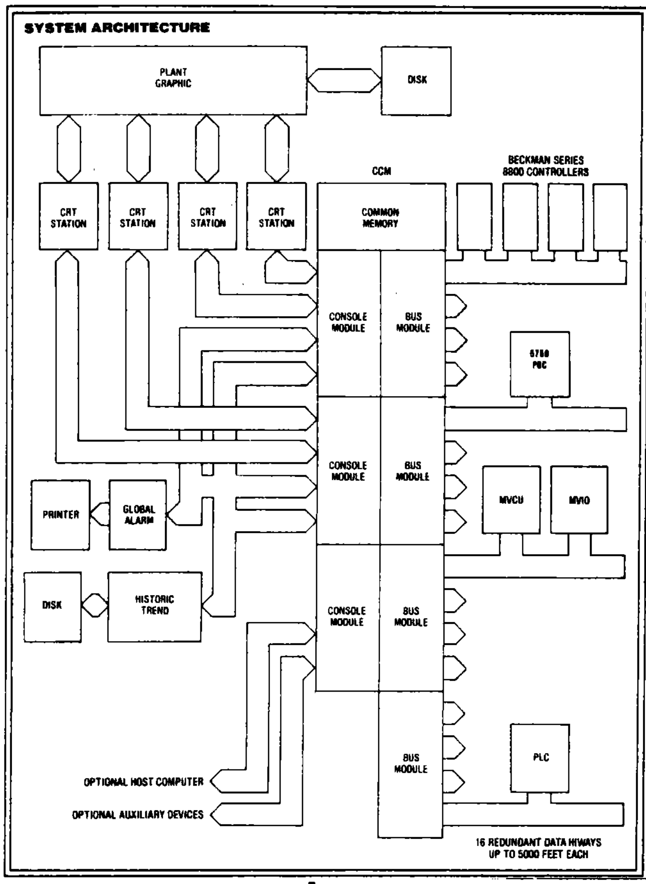
NOTE: Generic data describing the Beckman MV8000 system are included here as interim material for general familiarization with the system. Specific descriptions of the tailored 3-MV8000 system for Solar One application will be supplied later.

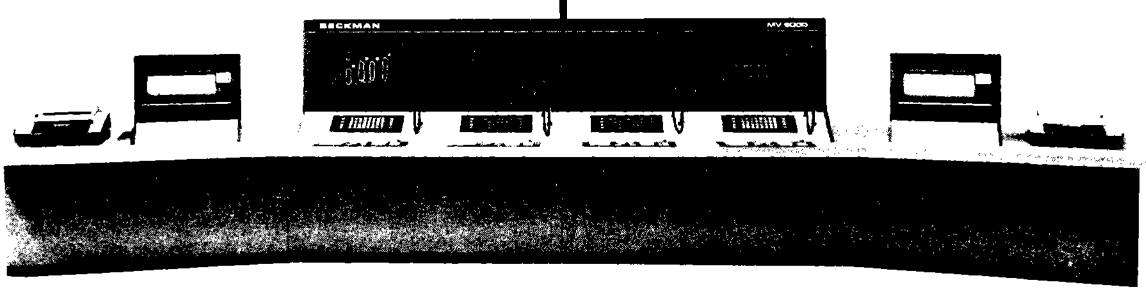
MV8000 PROCESS CONTROL SYSTEMS

DATA SHEET NO: TOP 7-01
EFFECTIVE DATE: 1 NOV. 1979

TECHNICAL DATA

MV8000 System Architecture





MV8000 SYSTEM ARCHITECTURE

This document outlines the architecture of the MV8000 Distributed Control System. This document is broken down into ten main areas:

- I. General Overview
- II. Operator Stations
- III. Communication Control Module (CCM)
- IV. Communication Translator Module (CTM)
- V. Field Hardware
- VI. Historic Trend Processor (HTP)
- VII. Plant Graphic Processor (PGP)
- VIII. Report Generation Processor (RGP)
- IX. Operator Interface Unit (OPIU)
- X. Special Configurations

I. GENERAL OVERVIEW

The MV8000 Process Control System is a distributed control and display system featuring stand-alone field equipment connected to centralized operator consoles via a distributed data highway system. All components are interconnected via serial communication over RS232-C hardware connections utilizing an ASCII character format at a rate of 9600 baud.

A block diagram of a typical MV8000 system is shown in Figure 1.

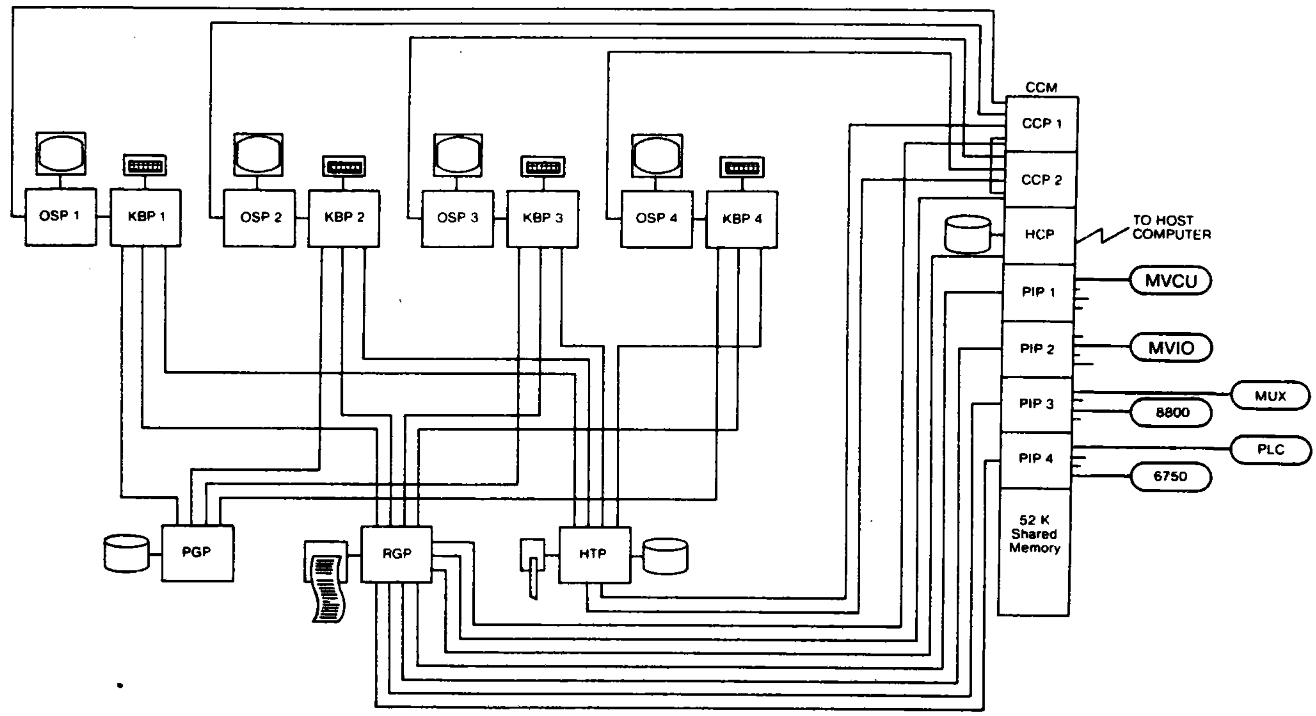


FIGURE 1. MV8000 ARCHITECTURE

II. OPERATOR STATIONS

The Operator Stations are comprised of four basic devices which are interconnected as shown in Figure 2. The devices are described below.

A. Operator Station Processor (OSP)

The OSP is an 8080 based micro-ccmputer resident in the mainframe of an eight color CRT. The OSP communicates to two external devices directly, and has indirect access to all devices within the MV8000 System. The OSP communicates to a Console Communication Processor (CCP) which is one of up to seven processors in the Communications Control Module (see Section III of this description). This RS232-C bit serial link which is ASCII based is used for the following functions:

1. Servicing requests for process data as required for inclusion in the present CRT display.
2. Receiving time messages.
3. Receiving alarm messages for Annunciator Keyboard indication.
4. Initiating the transmission of commands to field equipment for changing setpoints, outputs, and operating modes.
5. Transmission messages for configuring the CCM data base (i.e., loop and group display data).
6. Initiating the transmission of configuration messages to Multivariable Control Units (MVCU's); Programmable logic Controllers, Multiplexors, and Process Analyzers.

The second RS232-C serial link is used to communicate to other devices through the Keyboard Processor (KBP). The following is a list of messages used by this link:

1. Servicing requests from the Operator and Annunciator Keyboards
2. Servicing requests for historic trend information
3. Servicing requests for Alarm Summaries and Diagnostic Summaries from the Report Generation Processor (RGP)
4. Servicing requests for graphic display information from the Plant Graphic Processor (PGP)
5. Configuration of graphic display pages in the Plant Graphic Processor (PGP)

The OSP also interfaces to a lightpen. The lightpen is an operator convenience which allows display selection and manipulation using abbreviated key sequences. All Operator Stations are equipped with lightpens.

Figure 2 is the architecture for an Operator Station and is identical to all other Operator Stations. Each Operator Station within a console has separate RS232-C serial links to all MV8000 devices, thus assuring continued operator access to process information.

B. Keyboard Processor (KBP)

The Keyboard Processor is an 8080 based microcomputer which is resident in the operator console in close proximity to the Operator CRT Station it serves. It has two basic functions:

1. A message center for the exchange of data between the OSP and the Report Generation Processor, Plant Graphic Processor, and the Historic Trend Processor.
2. Decoding of keyboard entries, Annunciator Keyboard lamp illumination and controlling the console mounted horn.

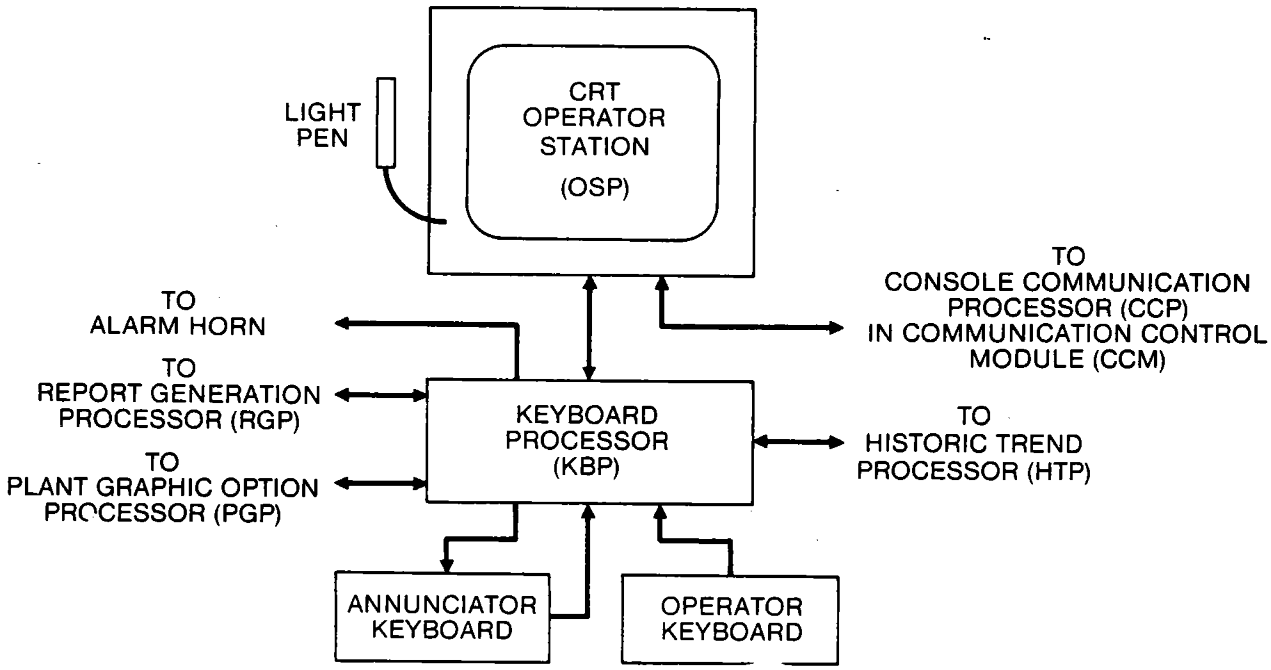


FIGURE 2. OPERATOR STATION ARCHITECTURE

C. Operator Keyboard

The Operator Keyboard is the primary operating keyboard. It is used to perform the following functions:

1. Display selection
2. Loop manipulation
3. System configuration
4. Graphics configuration

The Operator Keyboard is shown in Figure 3. Detailed description of its operations and functions can be found in the MV8000 Operators Manual and the MV8000 Configuration Manual.

D. Annunciator Keyboard

The Annunciator Keyboard is located on a sloped surface immediately above the Operator Keyboard. It provides the following:

1. Indication of Group Alarming through use of color-coded backlit keys.
2. Acknowledge and silence operator action keys.
3. Call-up of Group Status Displays.
4. Annunciation of system hardware diagnostics.

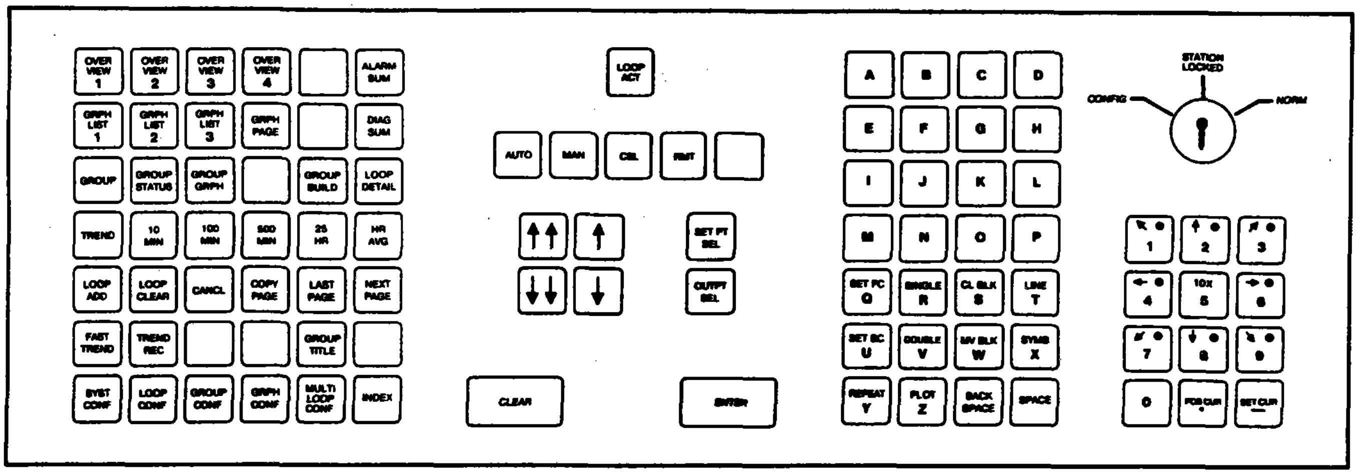


FIGURE 3. OPERATOR KEYBOARD

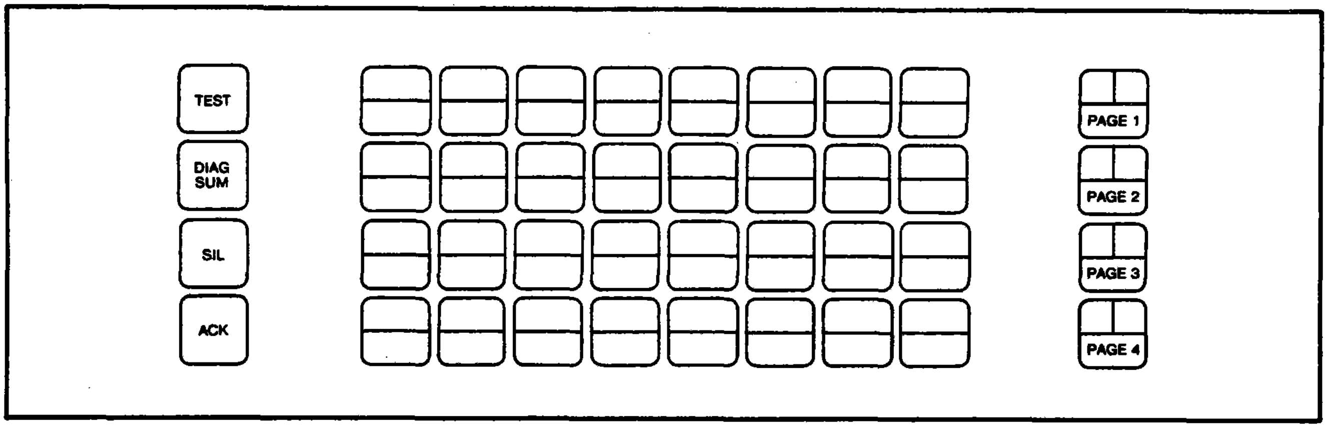


FIGURE 4. ANNUNCIATOR KEYBOARD

III. COMMUNICATION CONTROL MODULE (CCM)

The Communication Control Module is a multiple microcomputer based device responsible for the following tasks:

1. Scanning of field devices for current data and storing this data into a common nonvolatile memory.
2. Providing data to Operator Stations (OSP's) and/or Host Computers upon request.
3. Broadcasting alarm status information to the Operator Stations (OSP) and to the Report Generation Processor (RGP)
4. Broadcasting time messages to all connected devices.
5. Broadcasting trend data to the Historic Trend Processor (HTP)
6. Servicing control commands from the Operator Stations to the field equipment (i.e., setpoint changes, auto/manual changes, etc.)
7. Storing data for Loop, Group, and Multiloop Device configuration.

The CCM is made up of three modules: the CCM mainframe; the CCM power supply; and the Configuration Storage Module.

The tasks of the CCM are divided in the mainframe through the use of individual processors dedicated to particular functions. The three types of processors are:

1. Communication Control Processor (CCP)
2. Plant Interface Processor (PIP)
3. Host Configuration Processor (HCP)

There are two CCP's in each standard system, each having the capability of interfacing with two operator stations. There are up to four PIP's in a standard system, with each PIP utilizing up to four data highways and thus, allowing a total capability of 16 data highways. There is one HCP in each system which allows host computer interfacing as well as the interface to the Configuration Storage Module.

A. CCM Mainframe

A block diagram of the CCM mainframe is shown in Figure 5. This diagram shows the RS232-C links to other processors in the MV8000 system. All ports are used at a 9600 baud transmission speed.

The CCM contains a battery-backed system clock card which keeps operation station time accurate to within ±5 seconds per month. The system time can be initialized from any Operator Station and can ride through a three month power outage. All processors in the MV8000 system are synchronized once an hour by the CCM clock.

All processors in the CCM are directly connected to the RGP. This allows for immediate reporting of diagnostic problems and in the case of the PIP's, allows for the immediate transfer of loop alarm information derived from the servicing of highway based field equipment.

The basic CCM mainframe comes with 4K of common ROM memory for common fixed tables and 48K of battery-backed RAM. This 48K RAM is single bit error correcting and double bit error detecting.

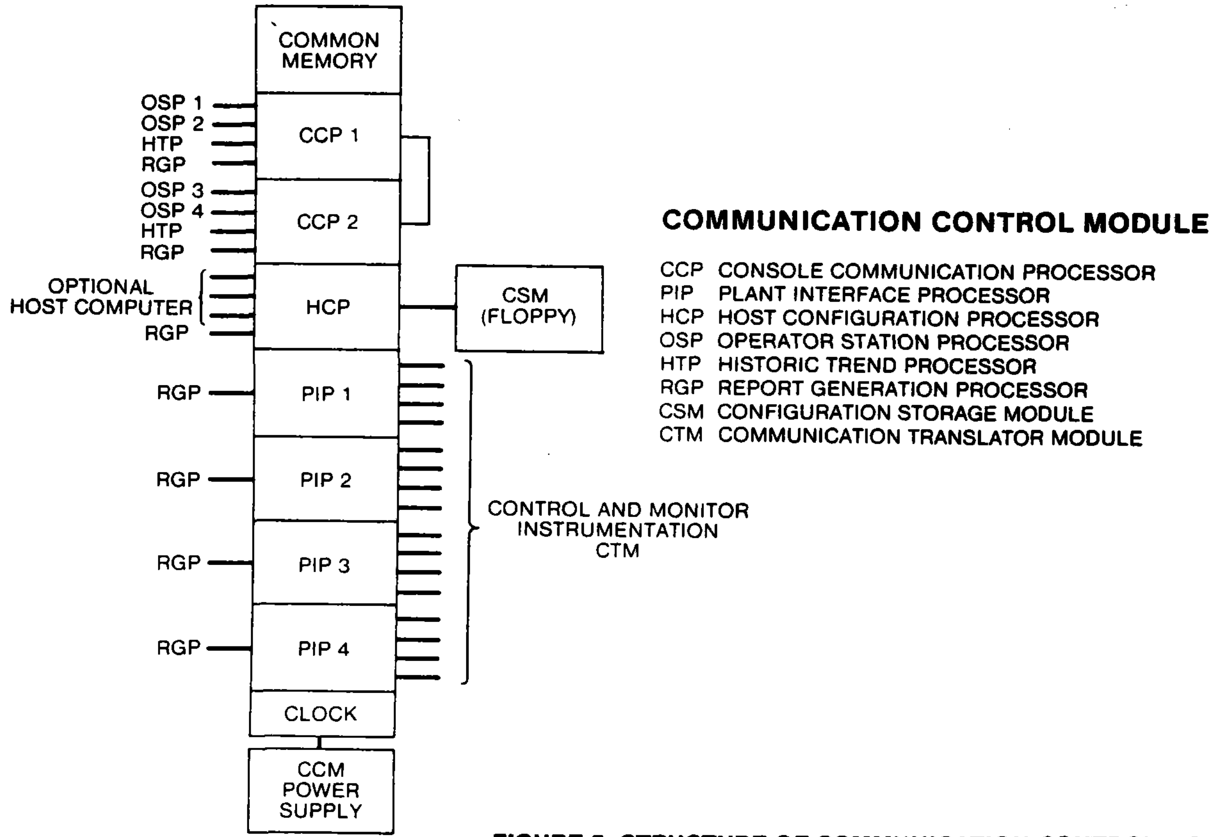


FIGURE 5. STRUCTURE OF COMMUNICATION CONTROL MODULE

The HCP is responsible for enacting configuration changes that are requested from the Operator Stations or the optional host computer, and updating the storage of this data in the Configuration Storage Module.

The PIP interfaces to the control and monitor instrumentation via the Beckman Bus generated by the Communication Translator Module.

Plant Interface Processors (PIP's) are normally supplied in pairs to achieve communications redundancy with field hardware. The system is structured such that PIP #1 is the master processor and PIP #2 is the slave processor. The same relationship applies to PIP #3 and PIP #4. Each PIP supports four data highways, port 1 on PIP #1 is matched with port 1 on PIP #2, port 2 with port 2, port 3 with port 3, and port 4 with port 4.

The operation of this architecture is illustrated in Section V of this specification.

B. CCM Power Supply

The CCM power supply provides the power required to operate the CCM. It provides +5, -5, +12, and -12 DC Voltages.

C. Configuration Storage Module (CSM)

The Configuration Storage Module contains a dual floppy disk drive which is connected via RS232-C to the Host Configuration Processor (HCP) in the CCM. (See Section III.)

IV. COMMUNICATION TRANSLATOR MODULE (CTM)

The CTM is a device which converts RS232-C to 3 wire Beckman Bus. Each card in the CTM converts four RS232-C ports to four Beckman Buses with a total capability of six cards. This unit provides a total input/output capability of 24 channels.

The CTM can be replaced with individual Beckman Bus Switches which provides single-port RS232-C to Beckman Bus conversion.

V. FIELD HARDWARE

The standard equipment which may be interfaced to the MV8000 console, via a Beckman 3-wire bus, are Multivariable Control Units (MVCU's), Multivariable Input/Output Units (MVIO's) and 8800 Analog Controllers. Devices such as Programmable Logic Controllers (PLC's), Beckman 6750 Process Chromatographs, rack mounted multiplexors and other devices which are RS232-C compatible can be interfaced to the system if desired.

The MVCU, MVIO, and 8800 can all be located on the same highway(s), or separately. Up to 63 Model 8800 controllers or any combination of up to 4 MVCU's and MVIO's can be placed on the same highway. In actual practice, however, depending upon the desired access times, it may not be feasible or practical to fully load the data highway. Thus, equipment should be distributed over the 16 possible data highways. As a general rule of thumb, placing 20 Model 8800 controllers or any combination of up to 2 MVCU's or MVIO's on a highway will provide less than two second update on all points in the CCM data base.

A. Model 8800 Controllers

The Model 8800 Controller is a single 3-wire highway device. When connected to a standard MV8000 System, a Beckman Bus Coupler is used to provide redundant communication pathways.

Figure 6 shows the standard connection of the 8800 to the MV8000 system. The Beckman Bus Coupler is basically an "OR" circuit which accepts two 3 wire highway inputs and generates a combined output in both 3 wire Beckman Bus and RS232-C formats. Communications with an 8800 can only take place on one bus at a time. This restriction is managed by the CCM to guarantee non-simultaneous transmission. In this configuration, communication is always done on one of the two highways with the other being reserved for backup. Thus, if PIP-1 fails or if board 1 in the CTM fails, or if the 3 wire highway cable is severed, the CCM automatically transfers communications tasks to PIP-2, CTM Board 2, and the alternate data highway. This switchover is then reported to the operator for maintenance. The Bus Coupler is normally located in close proximity to the 8800's.

B. MVCU/MVIO

The Multivariable Control Unit (MVCU) and the Multivariable Input/Output Unit (MVIO) are interconnected to the MV8000 system as shown in Figure 7. These devices have built-in redundant highways which support simultaneous communication. Because of this, the Bus Coupler used with the Model 8800 Controllers is no longer required and there is no limitation to communicating on both highways at the same time. This allows the scan time for a particular MVCU or MVIO to be halved by obtaining half the data on each bus. However, the automatic switchover ability described earlier still exists. The net effect is that a failure of one of the communication channels causes a communication to be transferred to one highway and the failure to be reported. Thus, the scan time is doubled but communication is not lost.

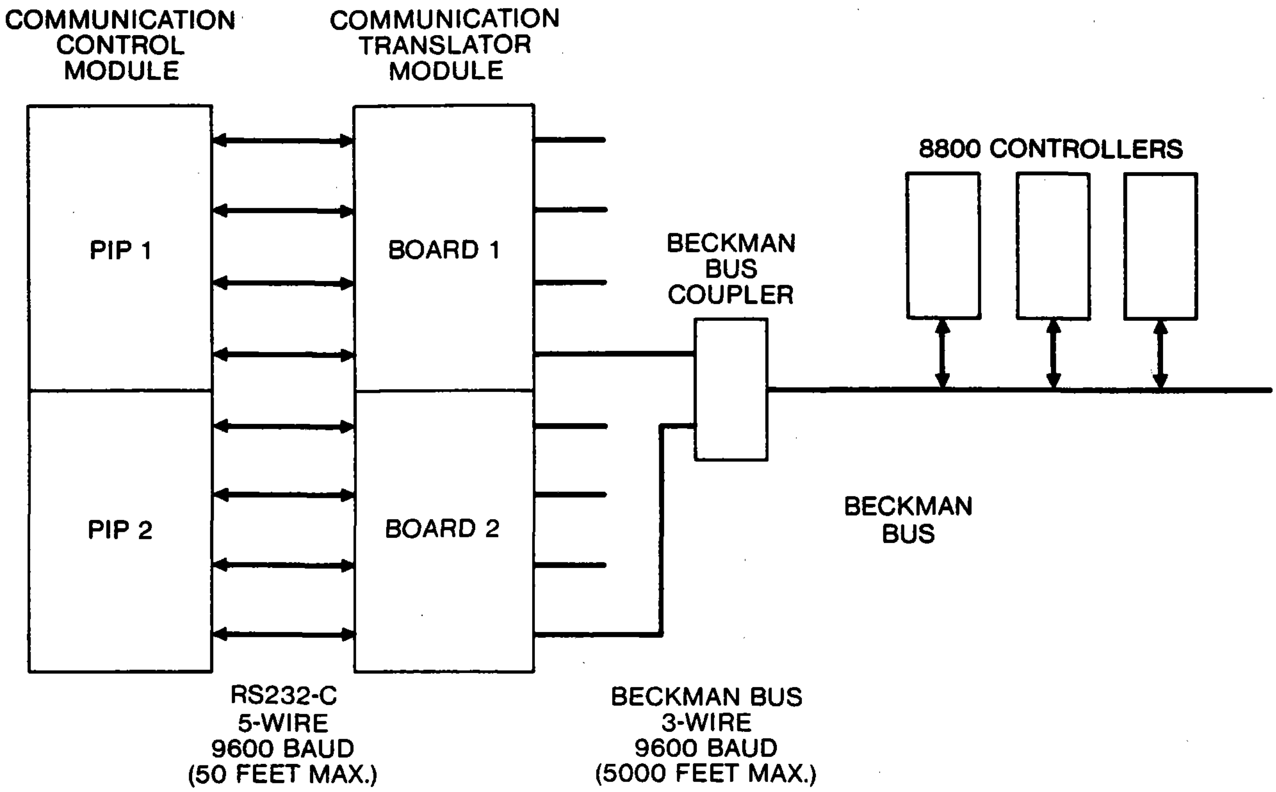


FIGURE 6. MV8000 INTERFACE TO BECKMAN MODEL 8800 CONTROLLERS

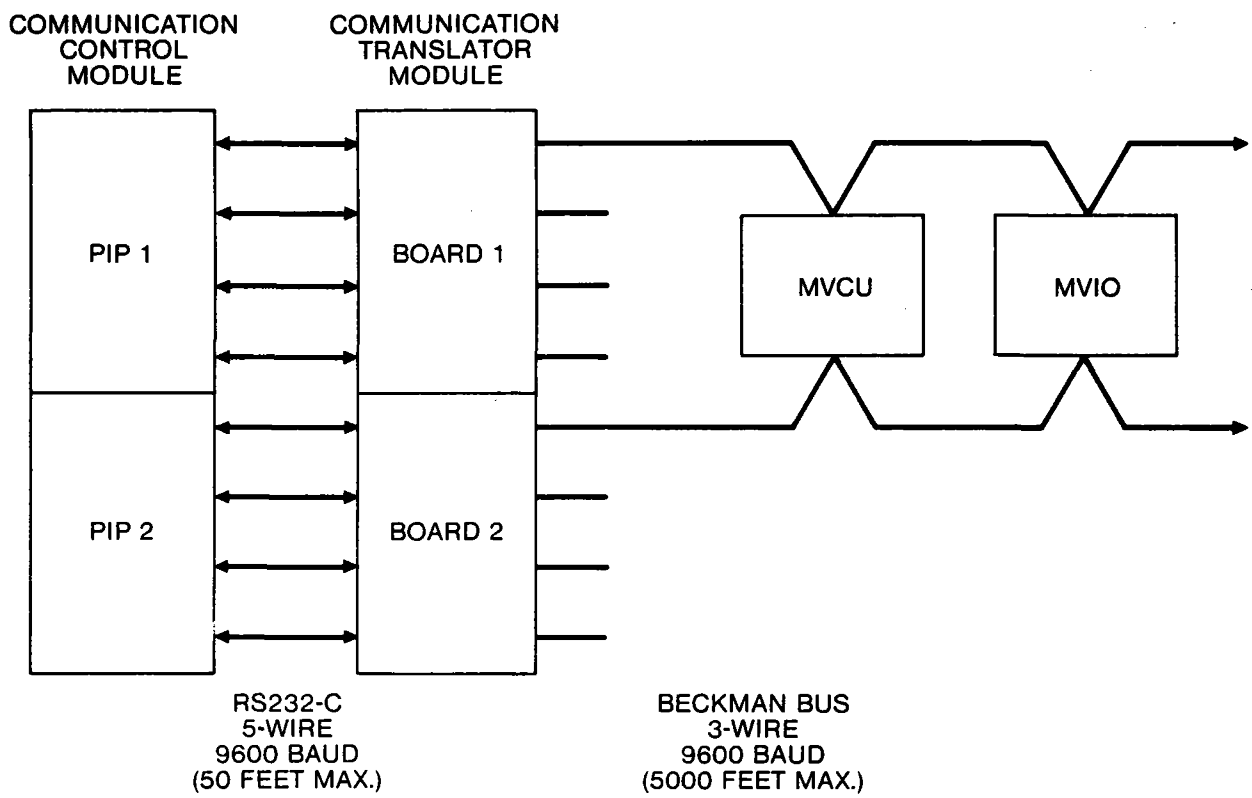


FIGURE 7. MV8000 INTERFACE TO BECKMAN MULTIVARIABLE CONTROL AND INPUT/OUTPUT UNITS

C. Programmable Logic Controllers (PLC)

The ability to interface PLC's to the MV8000 system is accomplished by utilizing a Texas Instruments 5TI PLC. The standard interface of this device is shown in Figure 8. The MV8000 provides complete monitoring and programming capability from the Operator Console by utilizing a 5TI data link which supports RS232. The PLC may also be programmed using Texas Instruments' standard programmer. To provide data highway redundancy a Bus Coupler is used since the 5TI data link only supports a single RS232-C port. The action of the redundant communication link is as described for the Beckman 8800 controller. A single PLC unit can be interfaced per data highway.

D. Beckman 6750 Process Chromatograph

Beckman Model 6750 process chromatographs may also be interfaced to the MV8000 system. The standard interface to these process analyzers is shown in Figure 9. Up to four of these analyzers can be interfaced to a single data highway and can be intermixed with Model 8800 controllers, MVCU's and MVIO's. Data highway redundancy is again maintained through use of a Bus Coupler. The MV8000 system provides complete monitor and programming capability from the operator's console for these analyzers.

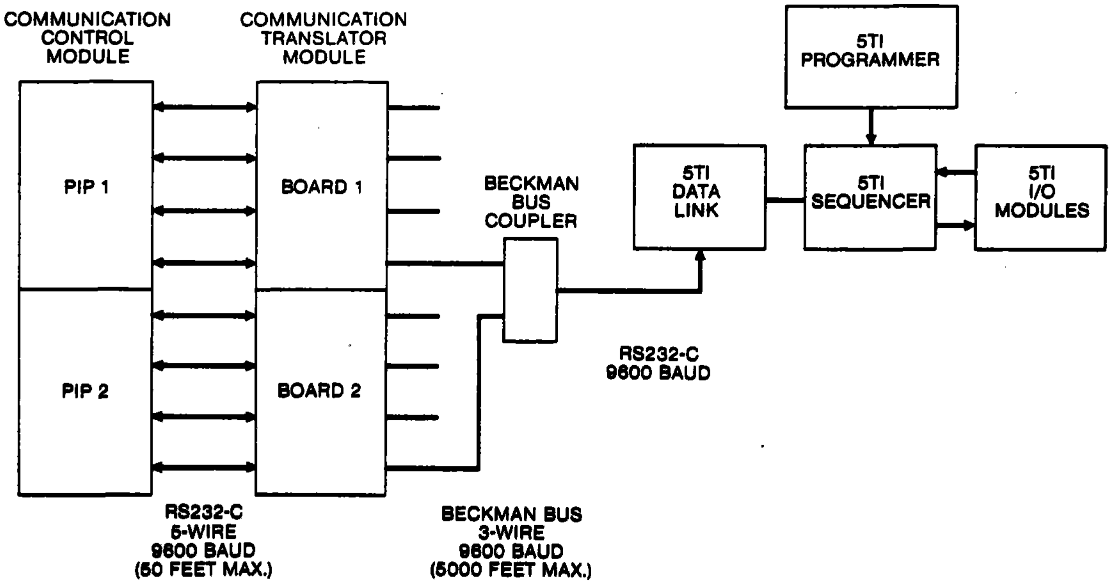


FIGURE 8. MV8000 INTERFACE TO TEXAS INSTRUMENTS 5TI PLC

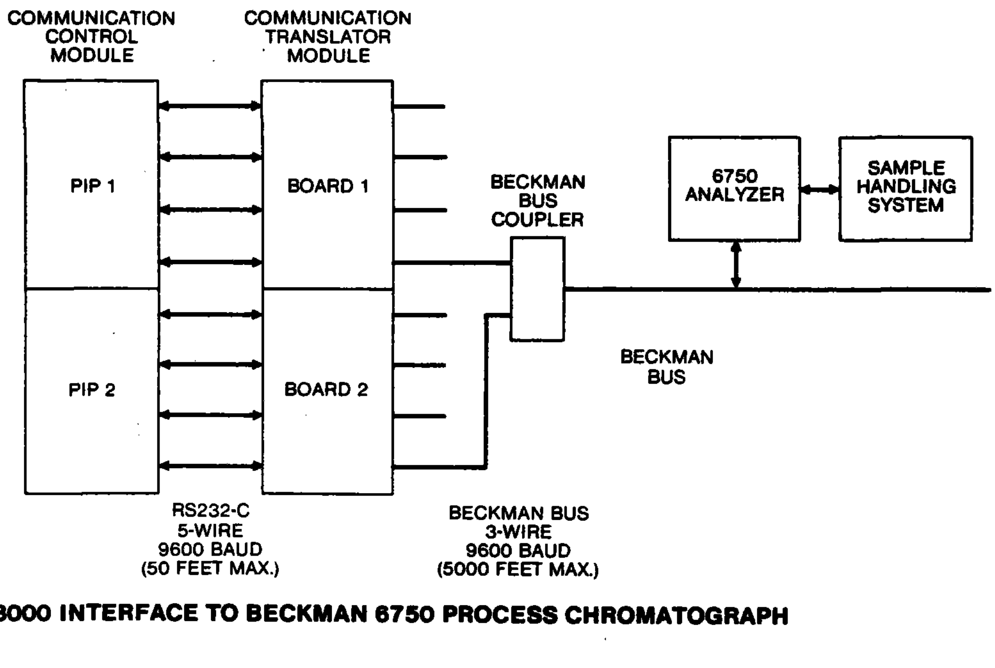


FIGURE 9. MV8000 INTERFACE TO BECKMAN 6750 PROCESS CHROMATOGRAPH

E. Rack Mounted Multiplexors

Beckman Rack Mounted Multiplexors may be interfaced to the MV8000 system structure as shown in Figure 10. Up to fifteen multiplexors can be interfaced using a Serial Line Controller. The redundant bus structure is identical to those described for the 5TI PLC and the Beckman Model 8800 Controller. The MV8000 operator console provides full monitoring and programming capabilities.

F. Other Devices

There are many other devices which support RS232-C communications which can be interfaced to the MV8000. These would typically be interfaced as shown in Figure 11. Consult the factory for details on interfacing these devices.

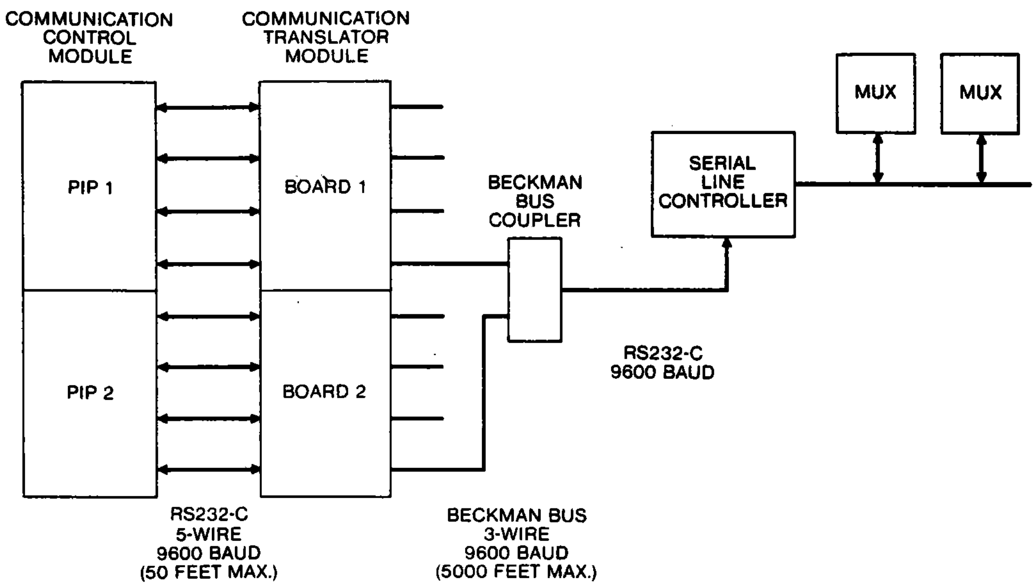


FIGURE 10. MV8000 INTERFACE TO BECKMAN PACK MOUNTED MULTIPLEXER

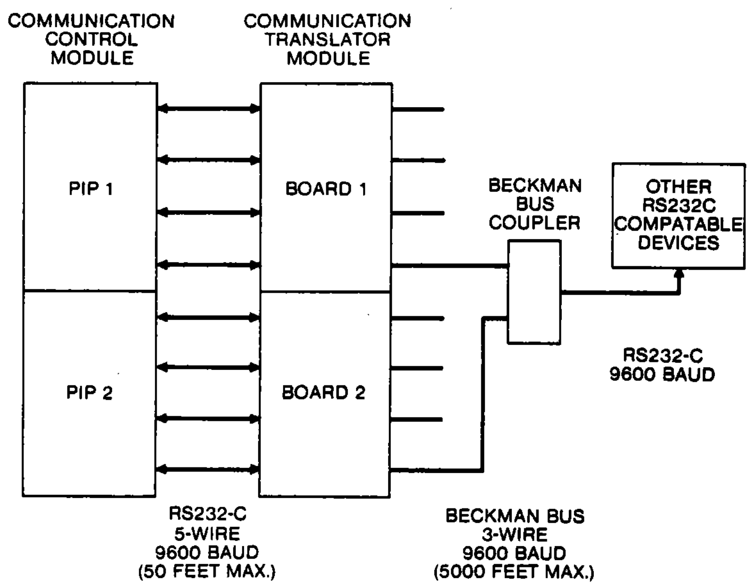


FIGURE 11. MV8000 INTERFACE TO OTHER RS232C COMPATIBLE DEVICES

VI. HISTORIC TREND PROCESSOR (HTP)

The Historic Trend Processor is an 8080 based microcomputer which is located in the operator's console. The module contains 48K of core memory for short term storage of historic trend information and a dual floppy disk unit for long term storage of historic trend information. The connection of the HTP in the MV8000 system is shown in Figure 1 and exploded in Figure 12.

The link to the Console Communication Processors (CCP) in the CCM are RS232-C at 9600 baud. This link has three basic functions:

1. Acquisition of fast trend data for a maximum of 50 analog variables every six seconds.
2. Acquisition of historic trend data for all analog points in the system every minute.
3. Acquisition of trend recorder data for a maximum of 12 analog points for display on console mounted Beckman 8750 Trend Recorders every three seconds.

The links to the Keyboard Processors (KBP) are RS232-C at 9600 baud. This link has five basic functions:

1. Acquisition of hourly average data.
2. Acquisition of historic trend data.
3. Acquisition of the Fast Trend list for the up to 50 analog loop tags on six-second Fast Trending.
4. Acquisition of the Trend Recorder list for the up to 12 analog loop tags on three second digital to analog reconstruction.
5. Configuration commands associated with the HTP.

VII. PLANT GRAPHIC PROCESSOR (PGP)

The Plant Graphic Processor is an 8080 based microcomputer which is located in the operator console. The module contains 32K of core memory for short term storage of graphic display information and a dual floppy disk unit for long term storage of plant graphic displays. The connection of the PGP in MV8000 is shown in Figure 1 and detailed in Figure 13.

The links to the Keyboard Processors are RS232-C at 9600 baud. This link has three basic functions.

1. Acquisition of graphic page display data.
2. Acquisition of the graphic page titles upon request.
3. Graphics configuration commands

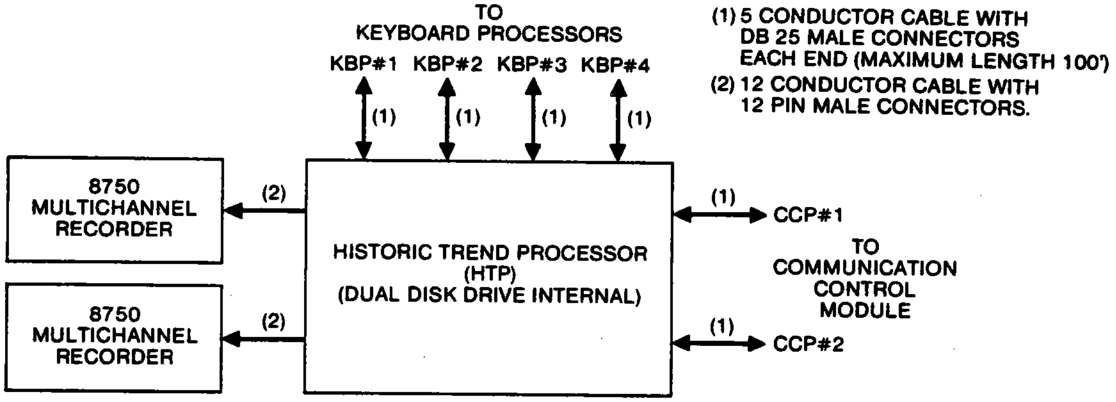


FIGURE 12. MV8000 INTERFACE TO HISTORIC TREND PROCESSOR

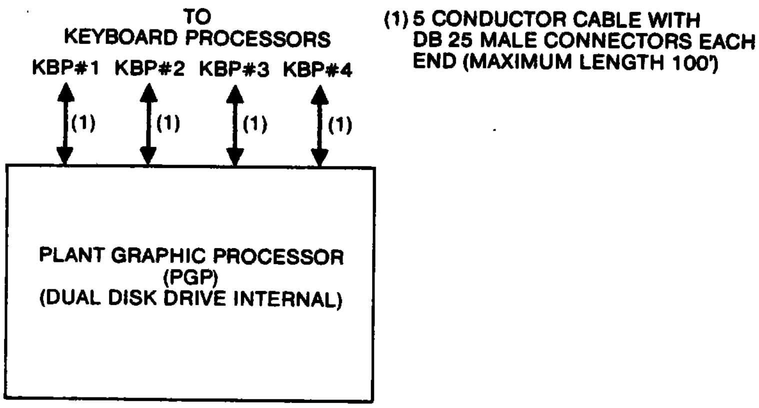


FIGURE 13. MV8000 INTERFACE TO PLANT GRAPHIC PROCESSOR

VIII. REPORT GENERATION PROCESSOR (RGP)

The Report Generation Processor is an 8080 based microcomputer which is located in the operator's console. The module contains 16K core memory for the storage of historic alarm and diagnostic information. The connection of the RGP in the MV8000 is shown in Figure 1 and detailed in Figure 14.

The link to the Keyboard Processor is RS232-C at 9600 baud. These communication links have five basic functions:

1. Acquisition of alarm summary data.
2. Routing of the present OSP screen display for alphanumeric duplication on the Display Printer.
3. Acquisition of Diagnostic Summary information.
4. Receiving system configuration commands for print out on the Alarm Printer.
5. Receiving diagnostic messages.

The links to the Plant Interface Processors (PIP) located in the CCM are RS232-C at 9600 baud. This link is used for two basic functions:

1. Receiving loop alarm messages.
2. Receiving field hardware diagnostics messages.
3. System hardware fault detection and notification.

The link to the Host Configuration Processor (HCP) is RS232-C at 9600 baud. This link is used for two basic functions:

1. Receiving system configuration messages associated with the Configuration Storage Module (CSM).
2. Receiving diagnostic messages.

The links to the two Console Communication Processors are RS232-C at 9600 baud. These links are used for two basic functions:

1. Receiving confirmed operator actions for printout on the Alarm Printer.
2. Receiving diagnostic messages.

The links to the Alarm Printer and the Display Printer are RS232-C at 300 baud. These links are used for two functions:

1. The Alarm Printer link is used for printing alarms, diagnostics, and operator actions.
2. The Display Printer link is used for printing screen displays.

IX. OPERATOR INTERFACE UNIT (OPIU)

The Operator Interface Unit is mounted in a free-standing rack and provides monitoring and configuration capability to the MVCU and MVIO. This device communicates directly to these devices independent of the MV8000 console system. It can communicate to up to 16 data highways by switch selection. The OPIU consists of three devices: The OPIU mainframe; 11-inch black and white CRT; and an ASCII keyboard. Figure 15 shows the interface of this device. Up to 8 MVCU/MVIO combinations can be located on a single bus.

A. OPIU Mainframe

The OPIU Mainframe is a 8080 based microcomputer located in the same rack as the CRT and keyboard. The unit has a self-contained dual floppy disk unit for configuration storage.

The link to the CRT is RS232-C at 9600 baud. The link to the MVCU's and MVIO's is a 3-wire Beckman Bus at 9600 baud. This link is used to monitor individual MVCU/MVIO devices and to configure these devices.

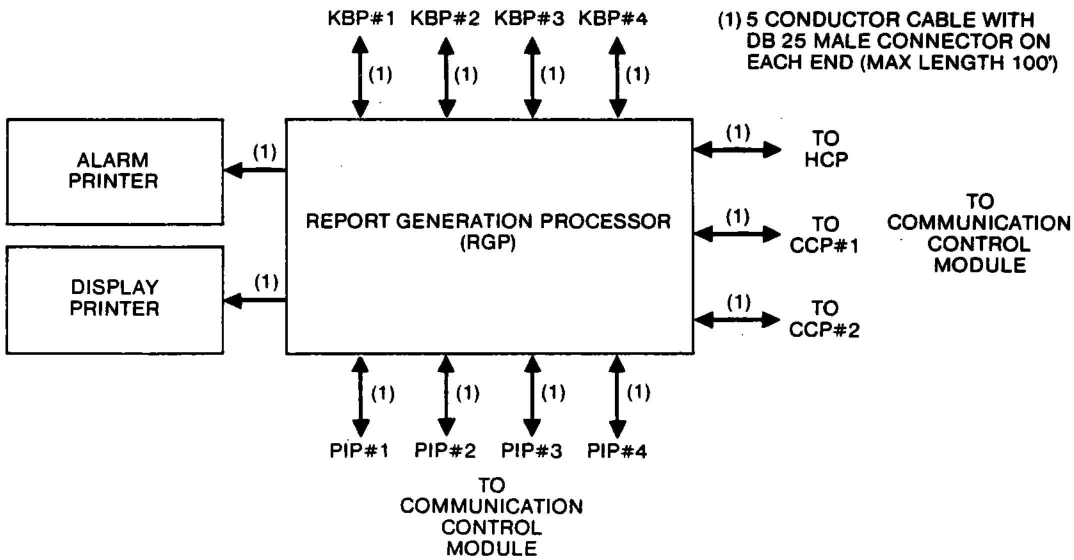


FIGURE 14. MV8000 INTERFACE TO REPORT GENERATION PROCESSOR

X. SPECIAL HARDWARE CONFIGURATIONS

The MV8000 system has inherent to its design, several possible special hardware configurations. Some of the possible combinations are listed below:

1. Remote Operator Stations
2. Expanded Plant Graphics Capability
3. OPIU/MV8000 interconnection

A. Remote Operator Stations

The ability to remote an operator station is inherent in the MV8000 architecture. This is because of the capability of converting any RS232-C link to a 2-wire Beckman Bus. This converts a data link from a 50 ft. maximum length to a data link which has a 5000 ft. maximum length.

From Figure 1, there are four RS232-C 9600 baud links to an operator station (i.e., one to the OSP and three to the KBP) that connect it to the MV8000 console system. To remote this operator station to 5000 ft. requires converting these links to Beckman Bus and then back to RS232-C. Figure 16 shows how this is accomplished.

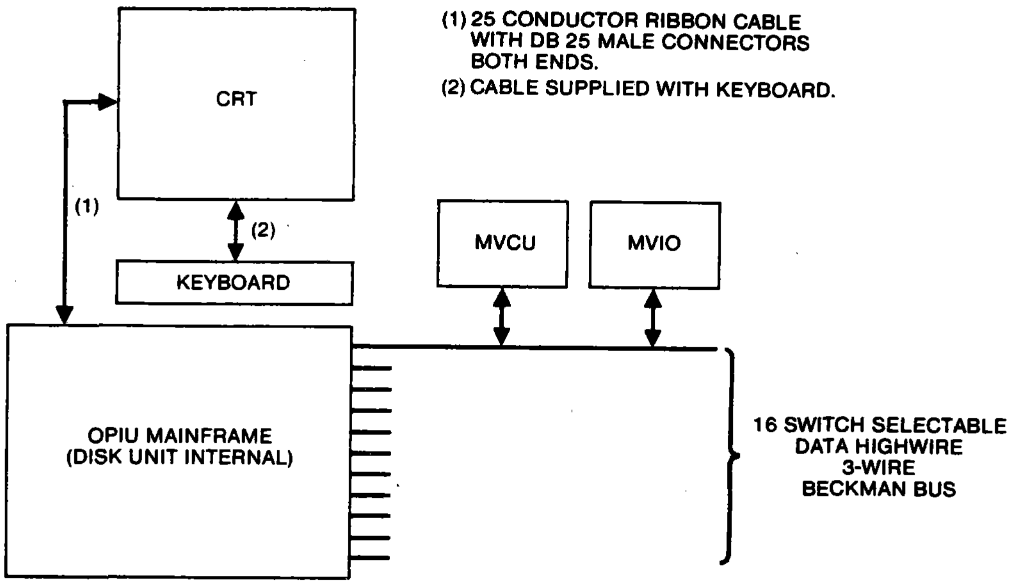


FIGURE 15. OPERATOR INTERFACE UNIT INTERCONNECT

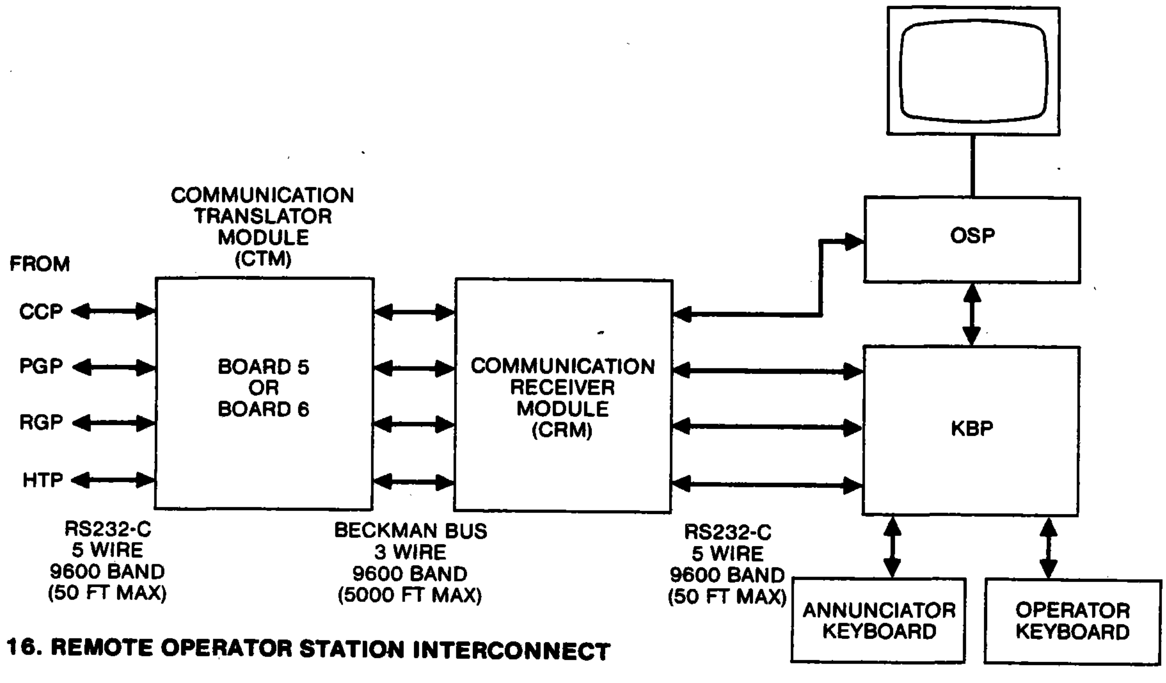


FIGURE 16. REMOTE OPERATOR STATION INTERCONNECT

The Communication Translator Module (CTM) as described in Section IV, has a capability of six boards and each board can convert four RS232-C lines to Beckman Bus. The first four boards are allocated for use with PIP's in the CCM. Thus, board 5 and board 6 can be used as shown to implement a remote CRT. The Communication Receiver Module (CRM) is the inverse of a single CTM board. It converts Beckman Bus to RS232-C for four independent links. The net result is an operator station which is up to 5000 ft. from the main console and has the same response characteristics as one located at the main console.

B. Expanded Plant Graphics Capability

The Plant Graphics Processor which is interconnected to MV8000 as shown in Figure 1 provides for 99 pages of interactive graphics. All that is required to double this capability or for that matter to provide 99 separate pages of graphics for each OSP, is to interconnect more PGP's. Thus, it is possible to provide 396 pages of graphics to a four CRT system, 297 to a three CRT system, and 198 to a two CRT system. Figure 17 shows the architecture for a four CRT system with 198 graphic page capability. The only limitation to this configuration, as well as other configurations, is that no longer do all CRT's have access to all graphics, but only have access to the 99 pages stored in the PGP to which it is interfaced.

C. OPIU/MV8000 Interconnection

There are basically three ways an Operator Interface Unit can be utilized:

1. Standalone
2. Mobile
3. Stationary

1. The stand alone capability was described earlier and interconnection is shown in Figure 15.
2. The Mobile approach provides for the OPIU to be mounted into a roll-around rack to be used randomly on MVCU's and MVIO's for maintenance and local indication purposes. The data highway can then be plugged into one of the two highway connections to provide local monitoring capability. Because of the auto switchover, redundancy in the MV8000 CCM (i.e., PIP redundancy described earlier), this will not effect normal console operations. Figure 18 depicts this arrangement.
3. The stationary approach to interfacing an OPIU to a MV8000 system is shown in Figure 19. As shown in the figure, the MV8000 communication redundancy is kept intact, however, all MV8000 communication must be kept on one bus at a time. With the 16 bus capability available on the OPIU, multiple MVCU/MVIO's can be interfaced.

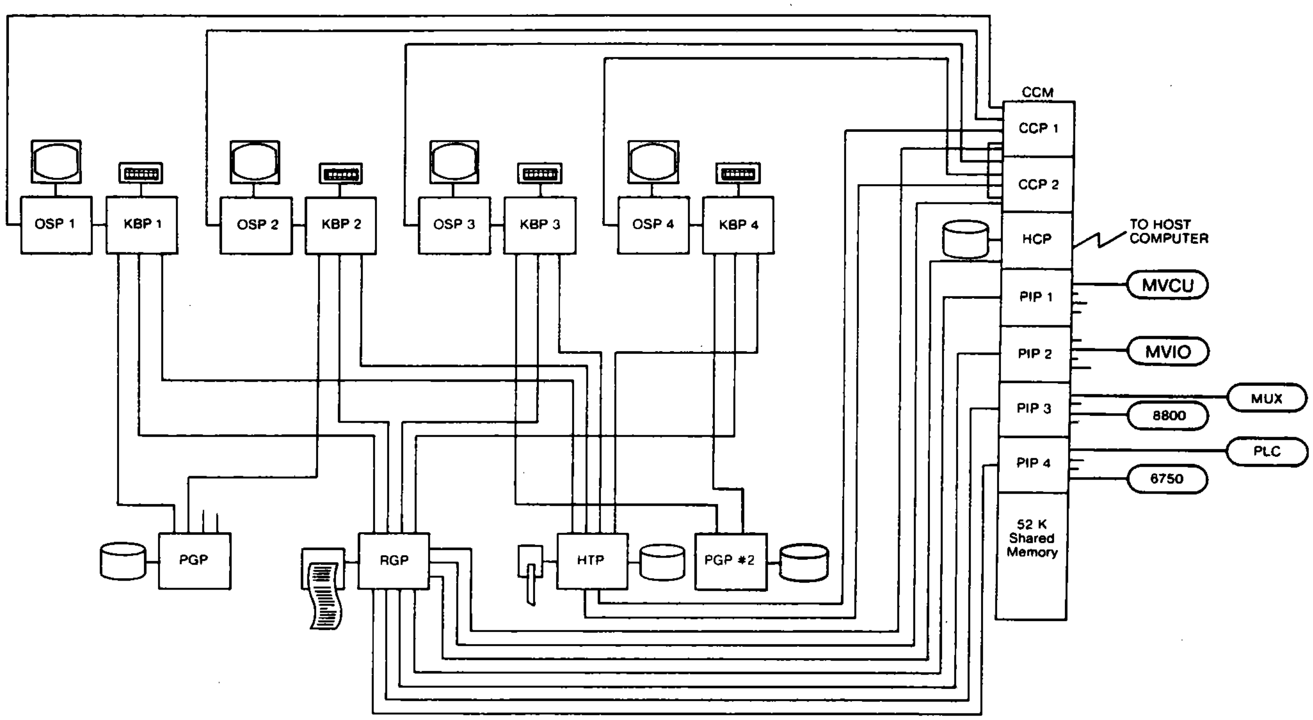


FIGURE 17. EXPANDED PLANT GRAPHICS CAPABILITY

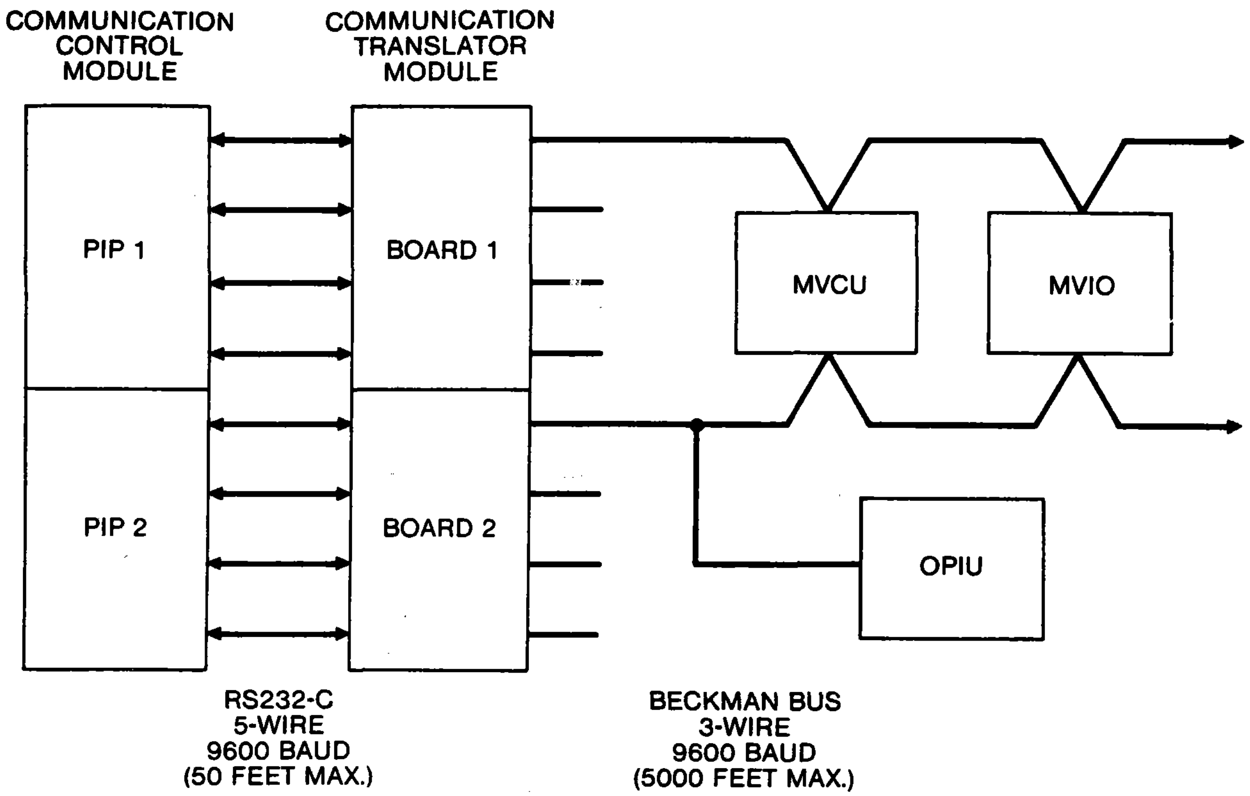


FIGURE 18. PLUG-IN APPROACH TO OPIU INTERFACE

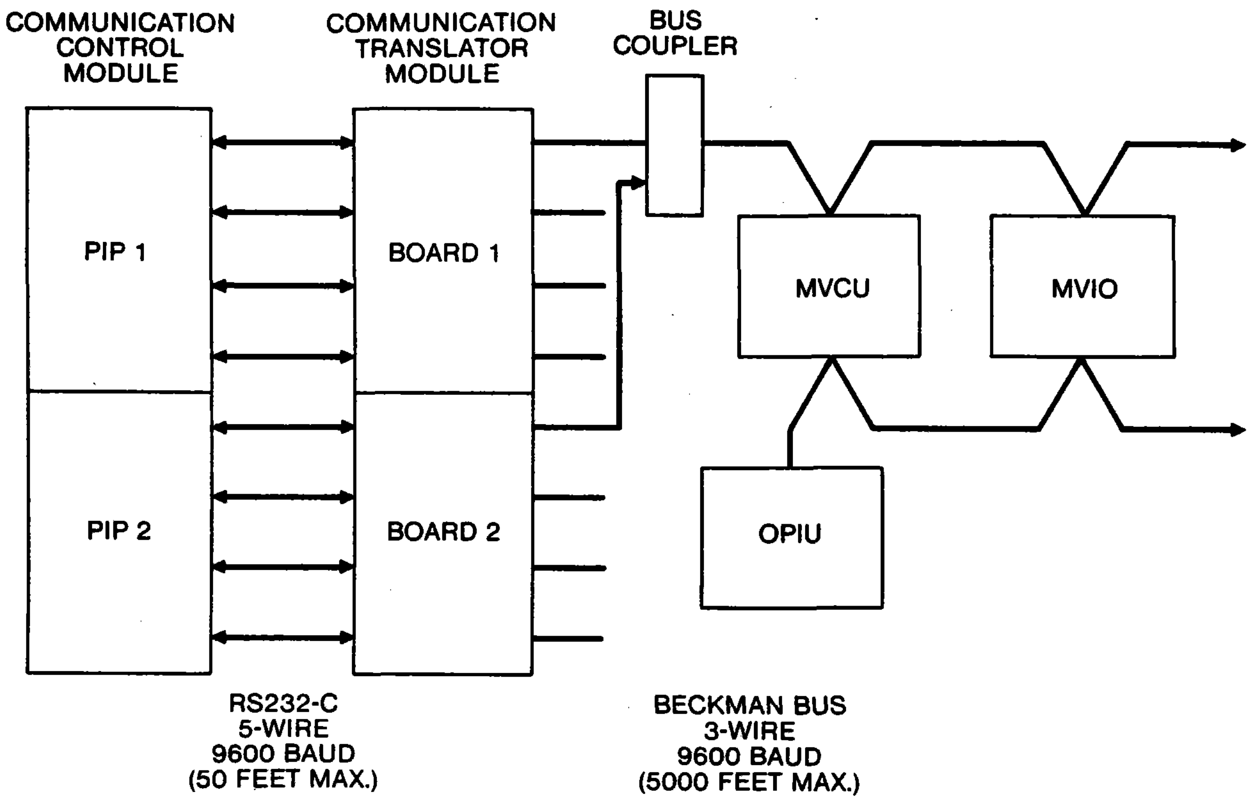


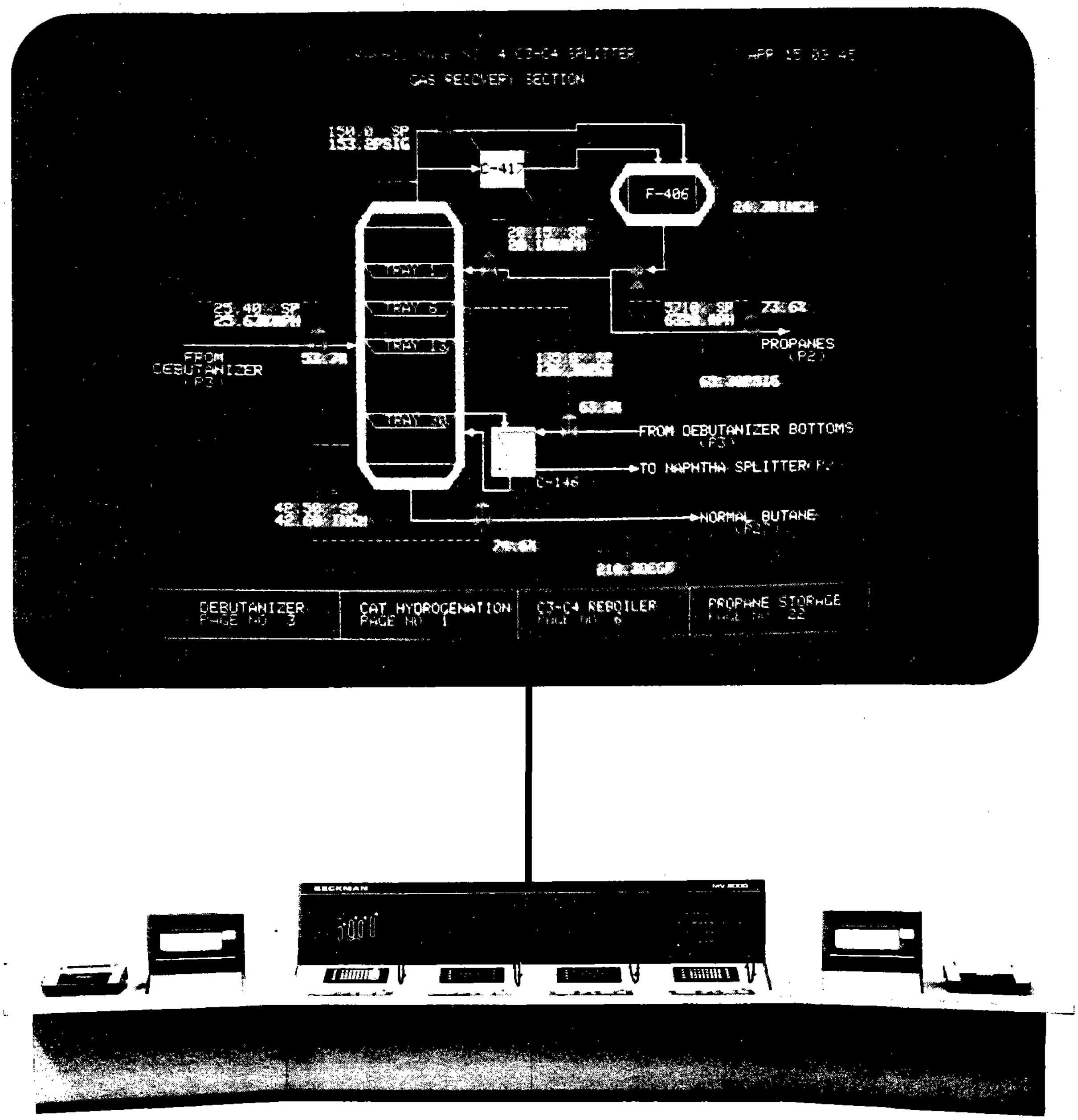
FIGURE 19. OPIU INTERFACE TO MV8000

MV 8000 PROCESS CONTROL SYSTEMS

DATA SHEET NO: TOP 7-11
EFFECTIVE DATE: 1 NOV. 1979

TECHNICAL DATA

MV 8000 CONFIGURATION PROCESS



BECKMAN

BECKMAN MV8000 CONFIGURATION PROCESS

This document outlines the general overview of the configuration process in the MV8000 system. More detailed information can be acquired from the Configuration Manual. The configuration process can be subdivided into the following areas:

I. MVCU Configuration

II. CCM Data Base Configuration

III. System Configuration

IV. Graphics Configuration

I. MVCU CONFIGURATION

The MVCU Configuration has three separate configuration processes:

1. Analog
2. Digital
3. Mode Transfer

The operator initiates the configuration of the MVCU by placing the key-lock in the configure position and depressing the "MULTILOOP CONF." button on the operator keyboard. A "prompt" requesting the device tag appears and after the information is entered, a display comes up on the screen as shown in Figure 1. A "prompt" at the bottom of the display requests the operator to select which action he wishes to take. Upon the selection, a sequence of "prompts" is initiated that will correspond to the action selected (i.e., if #3 is selected, the "prompts" will be for information contained in Figure 3.

MVCU TAG: MVCU ADDRESS CCM PORT:
MVCU FUNCTION SELECT

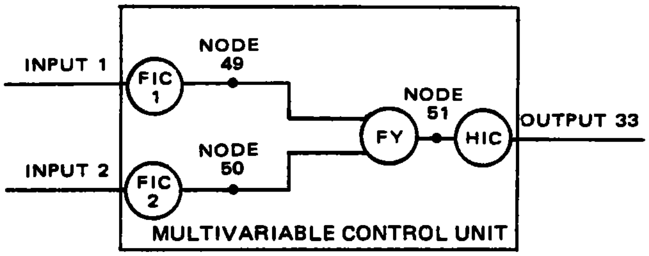
1. Configure/Display Status
2. Display Analog Configuration Table
3. Configure/Display Analog Conf. Line
4. Display Digital Configuration Table
5. Configure/Display Digital Conf. Line
6. Configure/Display Mode Transfer Table

FIGURE 1. MVCU FUNCTION SELECT DISPLAY

1. MVCU Analog Configuration

The MVCU Analog Configuration is based on the addresses of inputs, outputs, and nodes into and out of the MVCU being configured. The first step in the process is the assignment of inputs, outputs, and nodes to the P&ID. For each MVCU the inputs will be addressed from 1 to 32, outputs from 33 to 48, and 49 to 88 are to be used for nodes. Nodes are defined as the input or output of a function that is internal to the MVCU. A node is used to link algorithms together within the MVCU. In the diagram shown, two nodes are linking the controllers to the low selector and a node is used to link the low selector and auto/manual station together within the MVCU. The numbers associated with the inputs, outputs, and nodes are an example of address assignments to a typical P&ID.

Example of Address Assignments



In this fashion, algorithms are linked together *within the MVCU* with the only constraints being the 40 algorithm location capability within each MVCU and the number of inputs, outputs, and nodes that can be used as outlined previously (32 inputs, 16 outputs, and 40 nodes).

The configuration of the analog section will be facilitated by the use of two forms that represent tables within the MVCU. The two forms are:

A1. Analog Configuration Table (Figure 2)

A2. Analog Function Configuration Table (Figure 3)

Form A1 is used for collecting information in a format to easily conceptualize information that is to be combined in form A2. Form A2 is the actual information that will be entered into the MVCU via the operator keyboard at the console.

An MVCU has the capability of performing forty algorithms. Form A1 consists of forty lines each representing the location of a function to be performed.

The information needed for each line is the function code, function code description, and the inputs, outputs and node addresses that are associated with the function. Form A2 incorporates the information of Form A1 into a format suitable for entry into the MVCU via the operator keyboard. Form A2 will be in the same sequence as the "prompts" that will appear on the CRT. With this type of procedure, all information that will be requested from the CRT will be available in front of the operator through the use of the (A2) form. Only information necessary will be requested (i.e., the setpoint limits will not be requested for an adder/subtractor). In this manner the entering of configuration data is a straightforward transfer of information from the form to the CRT console.

2. MVCU Digital Configuration

The Digital Configuration process for the MVCU is very similar to the analog process. Forms that are used are:

D1. Digital Configuration Table (Figure 4)

D2. Digital Function Configuration Table (Figure 5)

FORM A1

ANALOG CONFIGURATION TABLE

MVCU ADDRESS ______________________

CCM PORT ADDRESS ______________________

Line #	Function	Code	Description	Input 1	Input 2	Input 3	Input 4	Output
1	____	____	________	____	____	____	____	____
2	____	____	________	____	____	____	____	____
3	____	____	________	____	____	____	____	____
4	____	____	________	____	____	____	____	____
5	____	____	________	____	____	____	____	____
6	____	____	________	____	____	____	____	____
7	____	____	________	____	____	____	____	____
8	____	____	________	____	____	____	____	____
9	____	____	________	____	____	____	____	____
10	____	____	________	____	____	____	____	____
.								
.								
.								
.								
.								
.								
.								
.								
37	____	____	________	____	____	____	____	____
38	____	____	________	____	____	____	____	____
39	____	____	________	____	____	____	____	____
40	____	____	________	____	____	____	____	____

FIGURE 2. ANALOG CONFIGURATION TABLE

FORM A2

MVCU TAG:________ MVCU ADDRESS: ________ CCM PORT:________

1	ANALOG CONFIGURATION LINE: ___ ___	21	GAIN TERM ENABLED ___ ___ ___
2	FUNCTION CODE: ___ ___	22	RESET TERM ENABLED ___ ___ ___
3	OUTPUT LOCATION: ___ ___	23	RATE TERM ENABLED ___ ___ ___
4	INPUT 1 LOCATION: ___ ___	24	SETPOINT LIMITING ___ ___ ___
5	INPUT 2 LOCATION: ___ ___	25	OUTPUT LIMITING ___ ___ ___
6	INPUT 3 LOCATION: ___ ___	26	BUMPLESS SETPOINT XFR ___ ___ ___
7	INPUT 4 LOCATION: ___ ___	27	BACK CALCULATION ___ ___ ___
8	K1 FACTOR: ___ ___ ___• ___ ___	28	BACK CALCULATION POINTER ___ ___
9	K2 FACTOR: ___ ___ ___• ___ ___	29	SETPOINT LOW ALARM ___ ___• ___ ___
10	K3 FACTOR: ___ ___ ___• ___ ___	30	SETPOINT HIGH ALARM ___ ___• ___ ___
11	K4 FACTOR: ___ ___ ___• ___ ___	31	PV LOW ALARM ___ ___• ___ ___
12	K5 FACTOR: ___ ___ ___• ___ ___	32	PV HIGH ALARM ___ ___• ___ ___
13	AUTO/MANUAL: ___ ___ ___ ___	33	OUTPUT LOW ALARM ___ ___• ___ ___
14	HIGH DYNAMIC LIMIT ___ ___ ___	34	OUTPUT HIGH ALARM ___ ___• ___ ___
15	LOW DYNAMIC LIMIT: ___ ___ ___	35	OUTPUT RAMP RATE ___ ___ ___
16	CONSOLE/NORMAL: ___	36	OUTPUT RAMP VALUE ___ ___• ___ ___
17	CASCADE/LOCAL: ___	37	SET POINT RAMP RATE ___ ___ ___
18	PV INVERTED: ___ ___ ___	38	SET POINT RAMP VALUE ___ ___• ___ ___
19	ERROR INVERTED: ___ ___ ___	39	SEND OUT CONF. LINE AND VERIFY
20	RATE ON PV/ERROR: ___		

FIGURE 3. ANALOG FUNCTION CONFIGURATION TABLE

FORM D1

DIGITAL CONFIGURATION TABLE (PAGE 1 OF 3)

MVCU ADDRESS ________

CCM PORT ADDRESS ________ ________

Line #	Function	Code	Description	Input 1	Input 2	Input 3	Input 4	Input 5	Output
1	____	____	________	____	____	____	____	____	____
2	____	____	________	____	____	____	____	____	____
3	____	____	________	____	____	____	____	____	____
4	____	____	________	____	____	____	____	____	____
5	____	____	________	____	____	____	____	____	____
6	____	____	________	____	____	____	____	____	____
7	____	____	________	____	____	____	____	____	____
8	____	____	________	____	____	____	____	____	____
9	____	____	________	____	____	____	____	____	____
10	____	____	________	____	____	____	____	____	____
11	____	____	________	____	____	____	____	____	____
12	____	____	________	____	____	____	____	____	____
13	____	____	________	____	____	____	____	____	____
.									
.									
.									
.									
.									
.									
.									
.									
149	____	____	________	____	____	____	____	____	____
150	____	____	________	____	____	____	____	____	____

FIGURE 4. DIGITAL CONFIGURATION TABLE

FORM D2

DIGITAL FUNCTION CONFIGURATION

MVCU TAG _ _ _ _ _ _ _ MVCU ADDRESS ____ ____ CCM PORT ____ ____

DIGITAL CONFIGURATION LINE ____ ____ ____

FUNCTION CODE	____	____		AUTO/MANUAL	____
OUTPUT 1 LOCATION	____	____	____	OUTPUT 1 INVERTED	____
OUTPUT 2 LOCATION	____	____	____	OUTPUT 2 INVERTED	____
OUTPUT 3 LOCATION	____	____	____	OUTPUT 3 INVERTED	____
OUTPUT 4 LOCATION	____	____	____	OUTPUT 4 INVERTED	____
OUTPUT 5 LOCATION	____	____	____	OUTPUT 5 INVERTED	____
OUTPUT 6 LOCATION	____	____	____	OUTPUT 6 INVERTED	____
OUTPUT 7 LOCATION	____	____	____	OUTPUT 7 INVERTED	____
NUMBER OF LINES TO SKIP	____	____	____	INPUT 1 INVERTED	____
INPUT 1 LOCATION	____	____	____	INPUT 2 INVERTED	____
INPUT 2 LOCATION	____	____	____	INPUT 3 INVERTED	____
INPUT 3 LOCATION	____	____	____	INPUT 4 INVERTED	____
INPUT 4 LOCATION	____	____	____	INPUT 5 INVERTED	____
INPUT 5 LOCATION	____	____	____		

SEND OUT CONFIG. LINE AND VERIFY

FIGURE 5. DIGITAL FUNCTION CONFIGURATION TABLE

The addressing structure for the digital inputs, outputs, and nodes is as follows:

Digital Inputs	1–32
Digital Outputs	33–64
Digital Nodes	65–192

Selection of Parameter Identification #5 on the MVCU Function Select Display (Figure 1) will initiate the prompting sequence for the digital portion of the MVCU.

3. Mode Transfer Configuration

The Mode Transfer Section of the MVCU gives the device the capability of changing operating parameters of the analog function processor and/or the digital function processor. The mode transfer function is broken up into 36 mode transfer tables which are individually addressable. Each mode transfer table has twenty (20) lines, of which either line can modify a configuration line in either the Analog Function processor or the Digital Function Processor. Therefore, twenty configuration lines can be modified via a single table. The following is a list of the mode transfer functions available in the MVCU.

Analog Function Processor

(a) Manual Transfer (hold output)
(b) Automatic Transfer
(c) Manual Transfer with output select
(d) Automatic Transfer with setpoint select

Digital Function Processor

(a) Manual Transfer (hold output)
(b) Automatic Transfer
(c) Manual Transfer with output select

Mode transfer Table #2 is dedicated to power up. The mode transfer table is shown in Figure 6.

The mode transfer table configuration is initiated by selecting parameter identification #6 (Figure 1) of the MVCU Function Select Display. Once selected, the prompting sequence is initiated for the configuration process.

II. CCM DATA BASE CONFIGURATION

The CCM data base configuration provides the necessary information for displays associated with loop and group information. Figures 7 and 8 show the loop and group forms that should be filled out prior to entry into the system. Loop configuration is initiated by depressing the "Loop Conf" button on the operator keyboard. A prompting sequence is then initiated to acquire the information from the operator that is contained in the form of Figure 7. Group configuration is initiated by depressing the "GROUP CONF" button on the operator keyboard at which time a prompting sequence is initiated to obtain the information on the form of Figure 8. As in the MVCU configuration process, only information for the particular function in question will be requested.

III. SYSTEM CONFIGURATION

The system configuration deals with the configuration of the three different types of processors in the system as follows:

1. HCP (Host Communications Processor
2. HTP (Historic Trend Processor)
3. PGP (Plant Graphics Processor)

MVCU TAG: MVCU ADDRESS: CCM PORT

MODE TRANSFER TABLE ______________ ____________

Line #	Function Code	Description	Detailed Value	Configuration Line #
1				
2				
3				
.				
.				
.				
20				

FIGURE 6. MODE TRANSFER TABLE

LOOP CONFIGURATION

LOOP TAG ____ ____ ____ ____ ____ ____ ____ ____

DESCRIPTOR WORD 1 ____ ____ ____ ____ ____ ____ ____ ____

DESCRIPTOR WORD 2 ____ ____ ____ ____ ____ ____ ____ ____

DEVICE TYPE ____ ____ ____ ____

INTERNAL TYPE ____ ____ ____ ____

ANALOG? ____

CONTROLLED? ____

BUS NUMBER ____ ____

INTERNAL ADDRESS ____ ____

REDUNDANT BUS ALLOWED? ____

CASCADED? ____

HOST CONTROL ALLOWED? ____

CALIBRATION 100% ____ ____ ____ ____ ____

CALIBRATION 0% ____ ____ ____ ____ ____

SCALE ____ ____ ____

SETPOINTS LIMITS HI ____ ____ ____ ____ ____

SETPOINTS LIMITS LO ____ ____ ____ ____ ____

OUTPUT LIMITS HI ____ ____ __.__ ____

OUTPUT LIMITS LO ____ ____ __.__ ____

ALARM TYPE ____ ____ ____ ____

ALARM LIMIT HI/HI ____ ____ ____ ____ ____

ALARM LIMIT HI ____ ____ ____ ____ ____

ALARM LIMIT LO ____ ____ ____ ____ ____

ALARM LIMIT LO/LO ____ ____ ____ ____ ____

OUTPUT ACTION ____ ____ ____

DIGITAL ON DESCRIPTION ____ ____ ____ ____ ____ ____ ____

DIGITAL OFF DESCRIPTION ____ ____ ____ ____ ____ ____ ____

DIGITAL ALARM STATE ____ ____ ____ ____ ____ ____ ____

DIGITAL ALARM PRIORITY ____

FIGURE 7. CCM DATA BASE LOOP CONFIGURATION

GROUP CONFIGURATION

Group Number					___	___	___	___
Group Title Word 1	___	___	___	___	___	___	___	___
Group Title Word 2	___	___	___	___	___	___	___	___
Graphic Page Link						___	___	___
Tag Slot 1	___ ___ ___ ___	___ ___ ___ ___	___ ___ ___ ___	___ ___ ___ ___	___ ___ ___ ___	___ ___ ___ ___	___ ___ ___ ___	___ ___ ___ ___
Tag Slot 2	___ ___ ___ ___	___ ___ ___ ___	___ ___ ___ ___	___ ___ ___ ___	___ ___ ___ ___	___ ___ ___ ___	___ ___ ___ ___	___ ___ ___ ___
Tag Slot 3	___ ___ ___ ___	___ ___ ___ ___	___ ___ ___ ___	___ ___ ___ ___	___ ___ ___ ___	___ ___ ___ ___	___ ___ ___ ___	___ ___ ___ ___
Tag Slot 4	___ ___ ___ ___	___ ___ ___ ___	___ ___ ___ ___	___ ___ ___ ___	___ ___ ___ ___	___ ___ ___ ___	___ ___ ___ ___	___ ___ ___ ___
Tag Slot 5	___ ___ ___ ___	___ ___ ___ ___	___ ___ ___ ___	___ ___ ___ ___	___ ___ ___ ___	___ ___ ___ ___	___ ___ ___ ___	___ ___ ___ ___
Tag Slot 6	___ ___ ___ ___	___ ___ ___ ___	___ ___ ___ ___	___ ___ ___ ___	___ ___ ___ ___	___ ___ ___ ___	___ ___ ___ ___	___ ___ ___ ___
Tag Slot 7	___ ___ ___ ___	___ ___ ___ ___	___ ___ ___ ___	___ ___ ___ ___	___ ___ ___ ___	___ ___ ___ ___	___ ___ ___ ___	___ ___ ___ ___
Tag Slot 8	___ ___ ___ ___	___ ___ ___ ___	___ ___ ___ ___	___ ___ ___ ___	___ ___ ___ ___	___ ___ ___ ___	___ ___ ___ ___	___ ___ ___ ___

FIGURE 8. CCM DATA BASE GROUP CONFIGURATION

The system configuration process is initiated by depressing the "SYSTEM CONF" button on the keyboard. At that time a display will appear with a prompt asking to select one of the following processors:

1. HCP
2. HTP
3. PGP

When the processor is selected, a prompting sequence is initiated for the processor selected. The following information shows the parameters available for each of the processors.

Processor	Parameter	Description
HCP	1	Reset
	2	Primary Disk
	3	Initialize
	4	Copy
	5	Save loops
	6	Restore loops
	7	Save MVCU
	8	Restore MVCU
	9	Lock
	10	Unlock
	11	Clear
HTP	1	Primary Disk
	2	Initialize
	3	Auto Backup
	4	Copy
	5	Delete
PGP	1	Primary Disk
	2	Initialize
	3	Copy

IV. GRAPHICS CONFIGURATION

The graphics configuration process is initiated by depressing the "graph conf." button on the operate keyboard. A display is then provided on the screen as shown in Figure 9.

Graphics Configuration Selection

1. Initialize Disk
2. Backup Disk
3. Configure a New Page
4. Delete an Old Page
5. Update an Old Page

FIGURE 9. GRAPHICS CONFIGURATION SELECTION TABLE

A prompt will appear at the bottom of the page requesting the action to be taken. If parameter I.D. numbers 3 or 5 are selected a page frame with grid coordinates is placed on the screen and the screen is ready for keyboard action. It is advised that a preconfiguration sketch be drawn of the particular display to be configured. The sketch should also contain a grid coordinate frame, (48 x 80 matrix) that will make the actual configuration process a straightforward transfer of information from the sketch to the screen.

The configuring of a new page is initiated by selecting parameter ID #3 in the display shown in Figure 9. A grid coordinate frame and cursor are then displayed on the screen. At this point the display is ready for keyboard action.

Figure 10 is a diagram of the operator keyboard. The following information explains the use of the keyboard for the graphics configuration process. The keyboard has two modes with which to operate in for the graphics configuration process.

They are the single key mode and the function key mode. When the keyboard is in the single key mode the alphanumeric portions of the keys are active. (A thru Z, 0 thru 9). The function key mode activates the following functions that are on the upper section of the keys.

Keys (See Fig. 10)	Description
SET FC	Set Foreground Color
SINGLE	Single key mode
CL BLK	Clear Block
LINE	Draw line
SET BC	Set Background Color
DOUBLE	Double Character Size
MV BLK	Move Block
SYMP	Special Symbols
REPEAT	Repeat last character
PLOT	Plot mode
↖ •	Cursor direction/color selection (Red)
↑ •	Cursor direction/color selection (Green)
↗ •	Cursor direction/color selection (Yellow)
← •	Cursor direction/color selection (Dk Blue)
→ •	Cursor direction/color selection (Lt. Blue)

↙•	Cursor direction/color selection (White)
↓•	Cursor direction/color selection (Black)
↘•	Cursor direction/color selection (Purple)
10X	Repeat a character 10 times
POS CUR	Position Cursor
SET CUR	Set Cursor Direction

The keyboard is in the function key mode when the configuration of a new page is initiated. To access the single key mode the "single" key is depressed. Depression of the "cancel" key will put the keyboard back into the function key mode. The following information gives the key sequences that are to be used for the major functions in the graphics configuration process. The following sequences are with the keyboard in the function key mode.

Character Selection

Figure 11 shows the character set used for building the graphics pages. A character is selected by depressing two keys (A thru P, A thru P) that correspond to the matrix for the particular character selected. For example in Figure 11 the character "Σ" corresponds to keys A and A, the character "╲" corresponds to keys A and B, the character "X" to A and D and so on. By typing in the vertical matrix letter first and horizontal matrix letter second the character will appear on the screen at the position of the cursor.

Set Background Color

The background color represents the space in a character block that is not filled by the character itself. The color of the character itself is represented by the foreground color. For example, the period (C,O) in the character set uses the same character block size as the arrow (A,D) with the period having more background color showing then the arrow. Any of the eight colors can be selected for a background color by depressing "set BC" and then any of the colors associated with the keys numbered 1 thru 9 excluding 5. Typically a background color is used that is the same as the screen color and then only the foreground color (the character) shows up.

Set Foreground Color

The foreground color establishes the color of the actual characters. The foreground color is established by depressing the "Set FC" key and then selecting any of the eight colors on the 1 thru 9 keys. The colors available are:

Key	Color
1	Red
2	Green
3	Yellow
4	Dark Blue
6	Light Blue
7	White
8	Black
9	Purple

Set Cursor, Position Cursor

The cursor can be manipulated in two fashions. One is to hit the "set cur" button and then any of the direction arrows on keys 1 thru 9. Subsequent depressions of the arrow keys (1 thru 9) or any characters will cause the cursor to move in the direction chosen. If the "10X" button is depressed in the middle of the above sequence the cursor will move ten character positions. If the 10X is depressed after the direction arrow the character that is subsequently selected will be repeated ten times in the direction of the arrow. The other way to establish cursor control is to depress "Pos Cur" and then enter an X,Y coordinate. The cursor will then move to that coordinate.

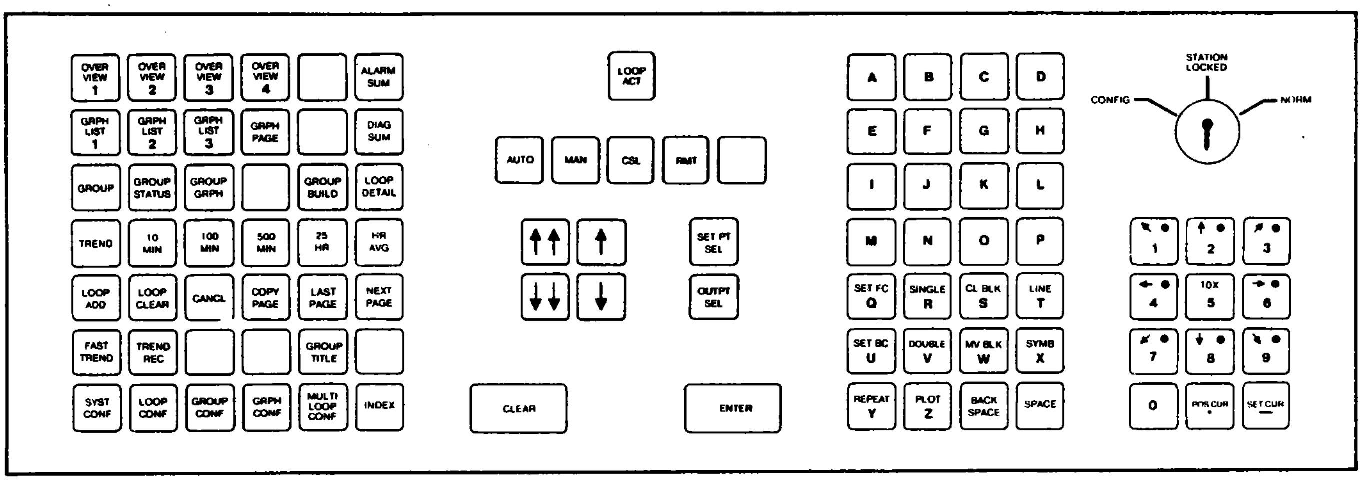


FIGURE 10. OPERATOR KEYBOARD

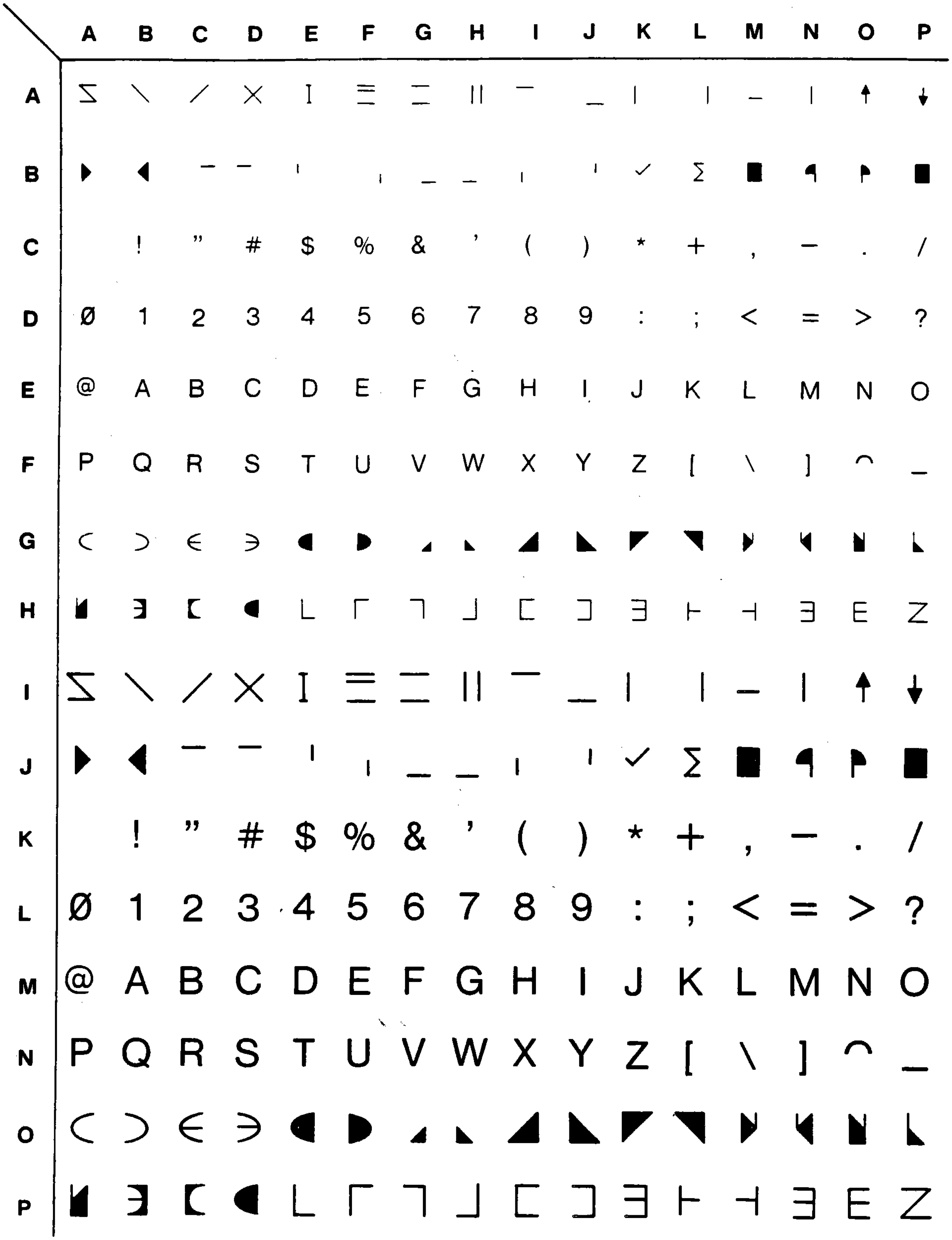


FIGURE 11. CHARACTER SET SYMBOLS

Plot Mode

The graphics configuration can be done in the character mode or the plot mode. The character mode uses the character set in Figure 11. The plot mode gives the user the ability to access the eight different sections that make up the plot character as shown in Figure 12. In this manner symbols and figures can be configured that are not contained in the standard character set.

To access the plot mode the "PLOT" key is depressed. A background color and foreground color would also be selected. Then keys C, D, G, H, K, L, O, and P are toggled to turn on or off any of the eight sections of the plot character with each key corresponding to a specific section as shown in Figure 13.

OFF	ON
ON	OFF
OFF	ON
ON	OFF

FIGURE 12. 8 SECTION CHARACTER

C	D
G	H
K	L
O	P

FIGURE 13. KEYS USED FOR PLOT CHARACTER

Move A Specified Screen Block

This function allows the user to move a specified section of the display that has already been configured on the screen. This function is initiated by depressing the "MV BLK" key. The next step is to place the cursor at the top left corner of the block to be moved and depress "ENTER". Then the cursor is placed down at the lower right corner of the block to be moved and again depress "ENTER". The prompt then requests the operator to enter the upper left and lower right corners coordinates for the new area that the block is to be moved.

Clear A Block

This function allows the user to specify and clear a defined block. This function is initiated by depressing "CL BLK" and specifying the top left and lower right corners of the block to be cleared as done in the "move a block" sequence.

Symbol Library

This function is a future enhancement of the system. It will consist of a library of standard ISA symbols already built from the character set of Figure 11.

A present capability of the system allows for the more common symbols to be built on one or more of the 99 pages. The "symbol page" can then be copied onto the desired page. The move block and clear block functions allow the symbols to be manipulated to the desired locations on the display.

Loop Configuration for Graphics

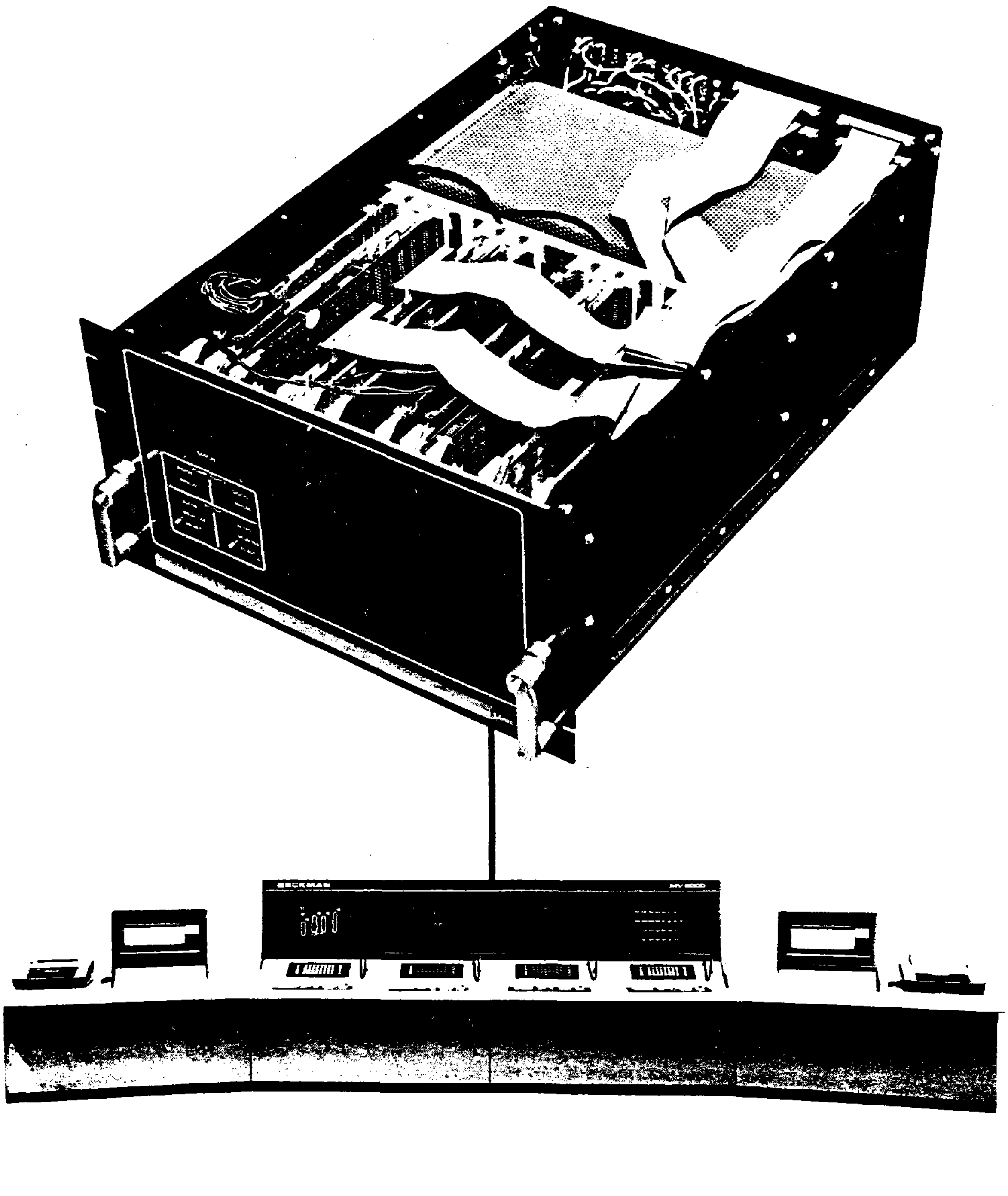
A loop is configured by depressing "loop Add" and entering a tag associated with the loop. (1 to 8 characters). A three line field is associated with the tag (tag, setpoint, and process variable). If a control output is associated with this tag (i.e., controller) a prompt requests the position of the five character wide field used for the output data. The limit of tags per page is twenty.

DATA SHEET NO: TOP 8-05
EFFECTIVE DATE: ~~1 NOV 1979~~
OCT 0 1 1984

MV8000 PROCESS CONTROL SYSTEMS

TECHNICAL DATA

Multi Variable Control Unit



BECKMAN

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BECKMAN MULTIVARIABLE CONTROL UNIT (MVCU)

This document outlines the design of the Beckman Multivariable Control Unit. This document is broken down into eight (8) main areas.

I. General Overview
II. Hardware Architecture
III. Analog Function Processor
IV. Digital Function Processor
V. Communications
VI. Mode Transfer Routines
VII. Executive
VIII. Failure Diagnostics

I. GENERAL OVERVIEW

The MVCU is a microprocessor-based unit that accepts both analog and digital inputs from the process, performs the desired control algorithms and provides both analog and digital outputs to the process. The algorithms are constructed from a library of functions stored in Read-Only-Memory (ROM). Selection of parameterization of these functions, plus routing of inputs and outputs, is accomplished via either of two ASCII bit-serial communication buses. This configuration is held in non-volatile memory (magnetic core).

The MVCU operates as a redundant system consisting of two identical, but separate, microcomputer systems. These are identified by the nomenclature side "A" and side "B". Normally the "A" side is controlling, with the "B" side tracking. In the event "A" becomes non-functional, as determined by hardware/software watchdog, side "B" assumes control and an error flag is set which can be detected via communication buses and LED indication on the hardware itself. Side "A" or "B" controlling can also be commanded by both bus communication and manual switches at the MVCU for maintenance purposes.

The MVCU is made up of three distinct boxes: the MVCU mainframe, an Analog Conditioning Module, and a Digital Conditioning Module.

The MVCU mainframe houses both side "A" and "B" microcomputer systems which are hardware described in Section II of this specification. The Digital Conditioning Module conditions process digital inputs and provides digital drive capability for the MVCU mainframe. The Analog Conditioning Module conditions process analog inputs and provides analog output drive capability for the MVCU mainframe.

To provide manual intervention at the MVCU, two options are available: one is the Digital Manual Operator Panel and the second is the Analog Manual Operator Panel. Both allow the local operator to override output and display all inputs on a continuous basis.

The MVCU software is made up of five (5) functional routines:

a. Analog Function Processor
b. Digital Function Processor
c. Mode Transfer
d. Communication
e. Diagnostics.

Each of these is described in this document.

II. HARDWARE ARCHITECTURE

The Multivariable Control Unit (MVCU) is comprised of seven major assemblies which are interconnected as shown in Figure 1. The assemblies are as listed below.

a. MVCU Mainframe
b. Analog Conditioning Module
c. Analog Manual Operators Panel (optional)
d. Analog Terminal Board
e. Digital Conditioning Module
f. Digital Manual Operators Panel (optional)
g. Digital Terminal Board

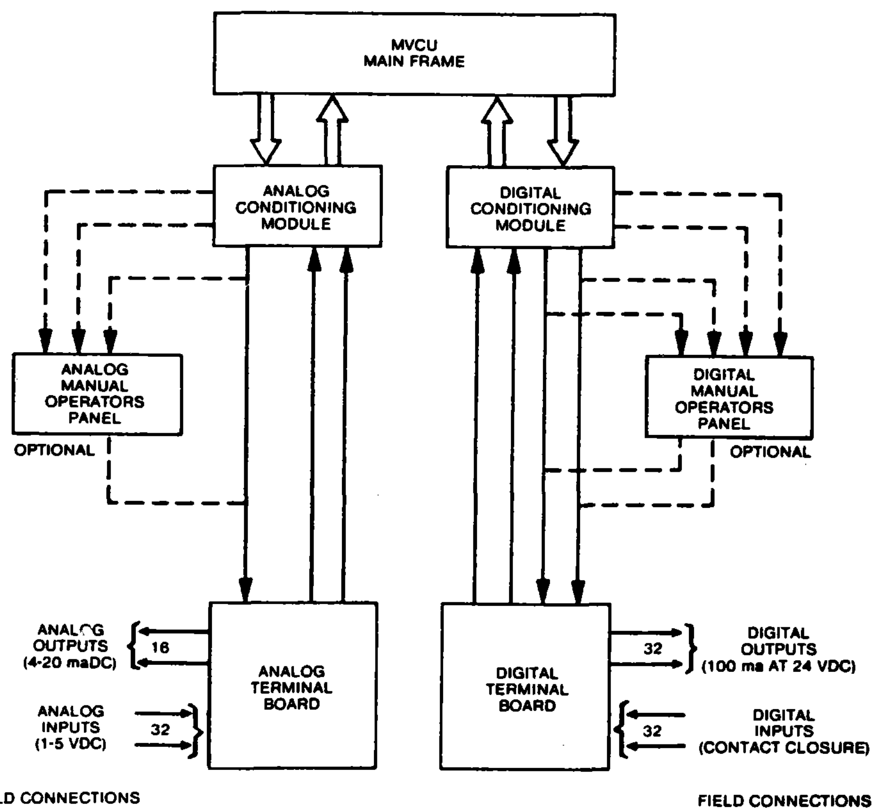


FIGURE 1. MVCU SYSTEM

Each MVCU has the capability to read up to 32 analog input signals. Each analog input is a differential input of 1 to 5 volts D.C. with a common mode rejection of 70 dB, maximum voltage of 30 volts, and an input impedance of one megohm. Each input can accept a current input of 4 to 20 mADC or 10 to 50 mADC by the use of an external load resistor (250 ohm or 100 ohm, respectively) installed on the Analog Terminal Board Assembly.

Each MVCU also has the capability to output up to 16 analog signals. These current outputs are non-isolated 4 - 20 mADC, with a maximum output load of 850 ohms. Each output is diode protected for reverse voltage protection. The Analog Terminal Board Assembly can be remotely installed up to fifty (50) feet as standard.

Each MVCU also has the capability to read up to 32 digital input signals and output 32 digital signals. All inputs and outputs are optically isolated in the digital conditioning module. Each digital input requires a contact closure which will be sensed by the MVCU. The D.C. power for digital inputs, 24 volts at 20 mA for the contact closure, is supplied by the MVCU. The digital outputs are transistor output with the capability of sinking 100 mADC (resistive or inductive) at 24 VDC.

Each input and output are diode protected for reverse voltage protection. The Digital Terminal Board Assembly can be remotely installed up to fifty (50) feet as standard.

A. MVCU Mainframe

The MVCU Mainframe houses redundant microcomputers which provide the computational capability of the MVCU System. Figure 2 is a one-line diagram of the boards, which comprise the MVCU Mainframe. Figure 3 is a pictorial of the MVCU Mainframe.

As shown in Figure 2, the MVCU Mainframe is made up of two identical microcomputer systems which access common conditioning modules. The two computer systems are linked via a 9600

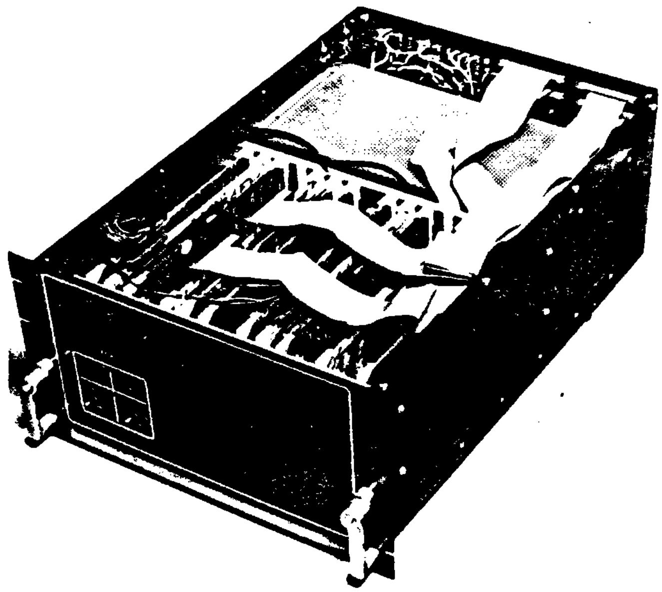


FIGURE 3

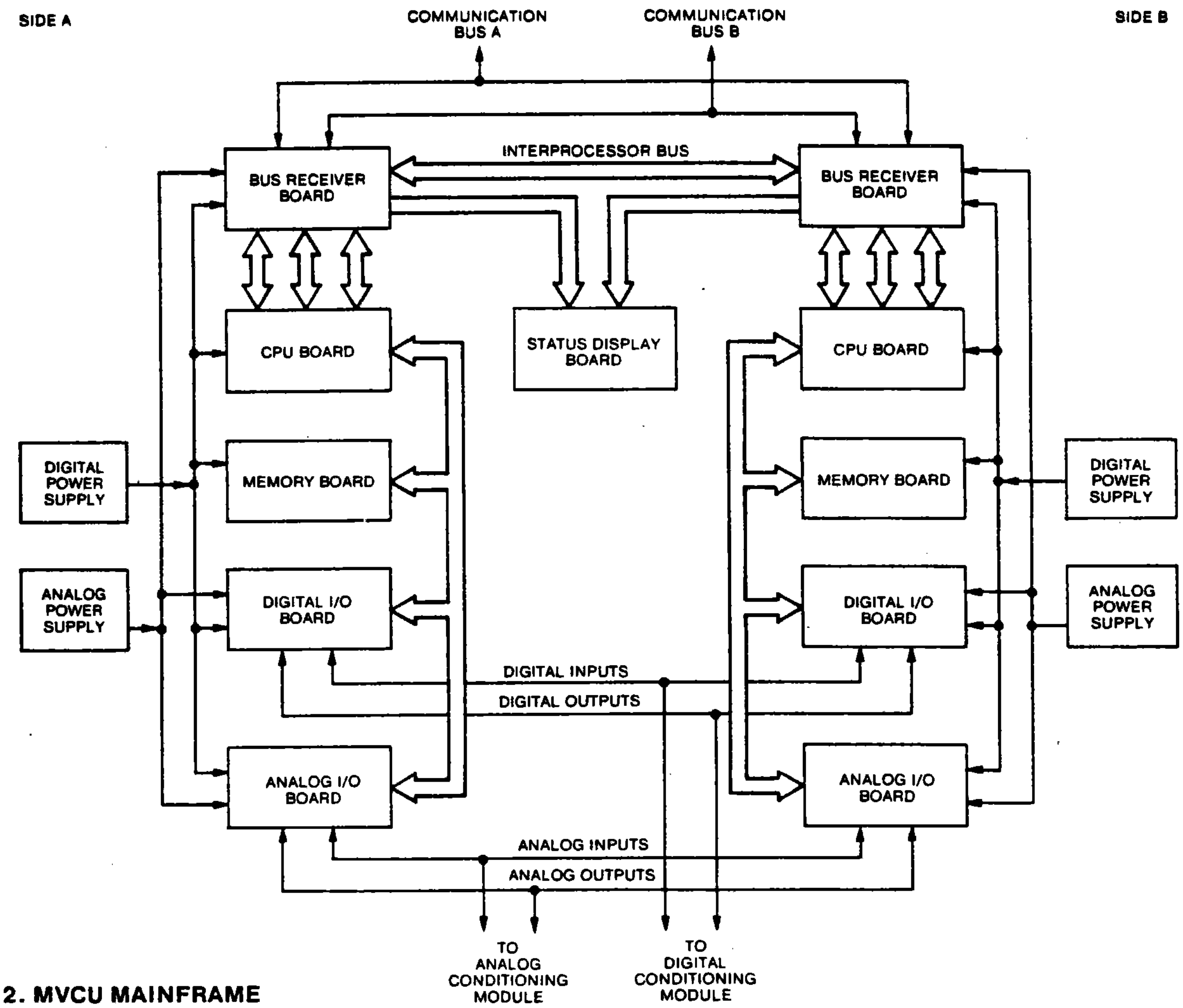


FIGURE 2. MVCU MAINFRAME

baud RS232-C communication link. Both computers are linked to central console systems via dual communication buses which are interfaced via the Bus Receiver Cards. Present status and manual switching are accessed via the Status Display Board. Each component of the MVCU Mainframe is described below.

A.1 Bus Receiver Board, Figure 4. The Bus Receiver Board provides four major functions for the MVCU Mainframe. A simplified line diagram is shown in Figure 4A.

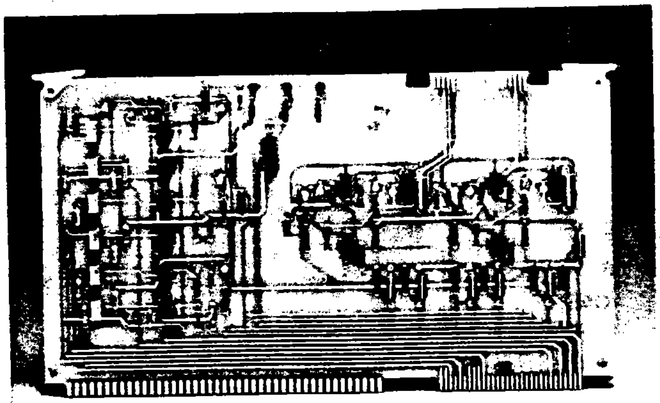


FIGURE 4

a. Communication Bus Interface. Communication Buses A and B are three-wire optically coupled bit serial ASCII communication links to the MVCU, which provide monitor and configuration capabilities to host processors which can be up to 5,000 feet away. Both buses are physically identical and each can be independently hardware strapped for communication rates from 110 to 9600 baud.

b. Interprocessor Bus Interface. Communication between the side "A" and side "B" microcomputers is an RS232-C interface at 9600 baud using ASCII protocol. Although each processor basically runs asynchronously, this link is used for handshaking between systems as described under the diagnostic section of this document.

c. Status Display Board Interface. The Status Display Board provides status indication and manual side "A" to side "B" transfer capability on the front panel of the MVCU as shown in Figure 5. The status indications for the power supplies are generated from the Bus Receiver Board.

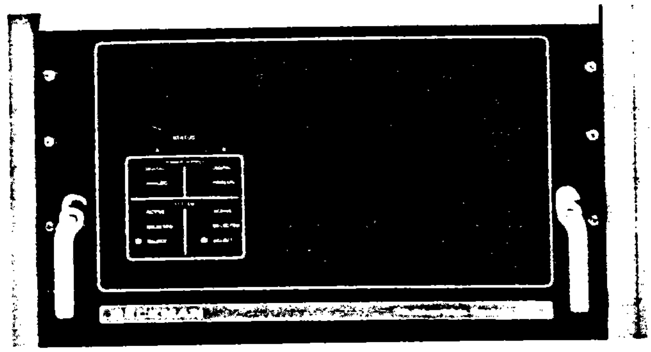


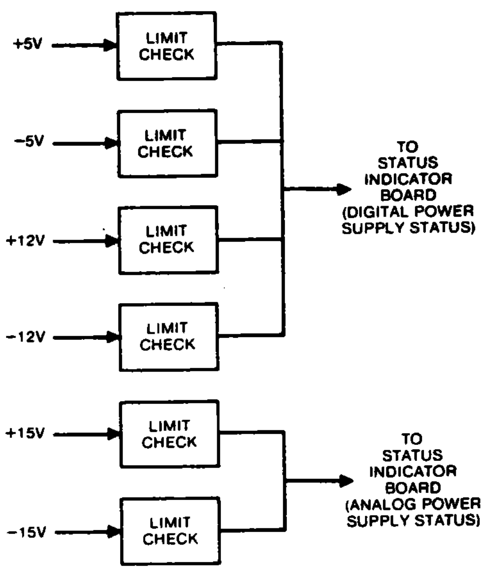
FIGURE 5

The Analog Power Supply Status refers to the ±15 volt supply and the Digital Power Supply Status refers to the ±12 volt and ±5 volt supply. Each voltage is checked to determine whether the voltage is within 6% of normal voltage on the low side. Thus, this is a detection circuit for loss of a power supply.

d. Diagnostic Failure Indication. The board also has three (3) LEDs which are used to indicate the particular software diagnostic routines which caused that particular side of the MVCU to shut down.

The processor lights the LEDs just before shutdown. The octal representation of these three bits are decoded below.

0	No problem
1	Unused
2	Magnetic Core Failure
3	CPU On-Board RAM Failure
4	DAC/ADC Failure
5	CPU On-Board ROM Failure
6	Off-Board ROM Failure
7	CPU Initialization



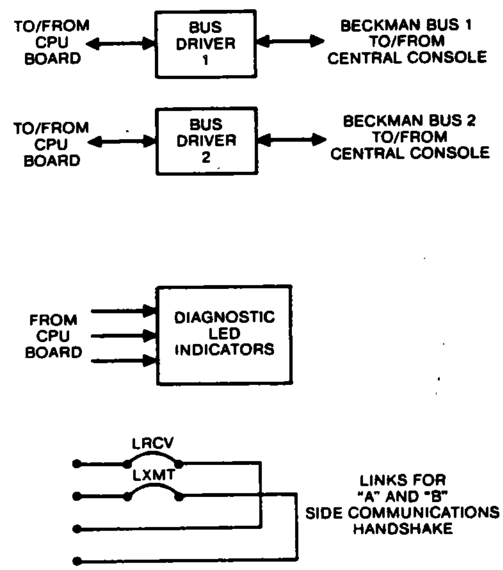


FIGURE 4A. BUS RECEIVER BOARD

A.2 CPU Board, Figure 6. The CPU Board for the MVCU contains the computational power of the device. A one-line diagram of this board is shown in Figure 6A.

FIGURE 6

The board is based on an 8080 processor chip. The board contains 4K of RAM, 8K of ROM, and hardware USARTs to support the two external serial communication buses and one internal serial communication bus for side "A" to side "B" communication.

The board has switch selection for both the baud rate selection and address selection. The baud rate selection can be from 110 to 9600 and the address can be selected from 1 to 256.

The board also interfaces to the Status Indicator Board in that it provides the ACTIVE indication and the SELECTED indication. ACTIVE designates that the CPU is operating with no diagnostic failures and SELECTED designates that this particular side of the MVCU is running the MVCU. The hardware transfer request from the MVCU front panel also interfaces to this board.

The CPU on-board RAM is used for scratch pad memory and the 8K ROM is used for MVCU program storage. The configuration of process oriented software routines are stored in the core memory located on the Memory Board.

A.3 Memory Board, Figure 7. The Memory Board contains two types of memory. It contains 8K of core memory for configuration storage and up to 16K of ROM memory for extended MVCU program storage. The operating system for each microcomputer, i.e., side "A" and side "B", are stored in ROM, which begins on the CPU Board and is extended on the Memory Board.

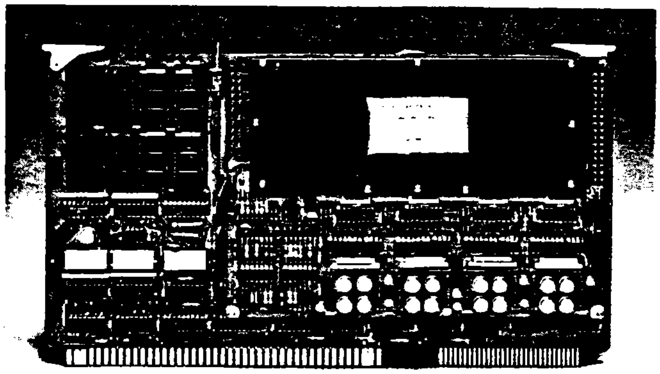


FIGURE 7

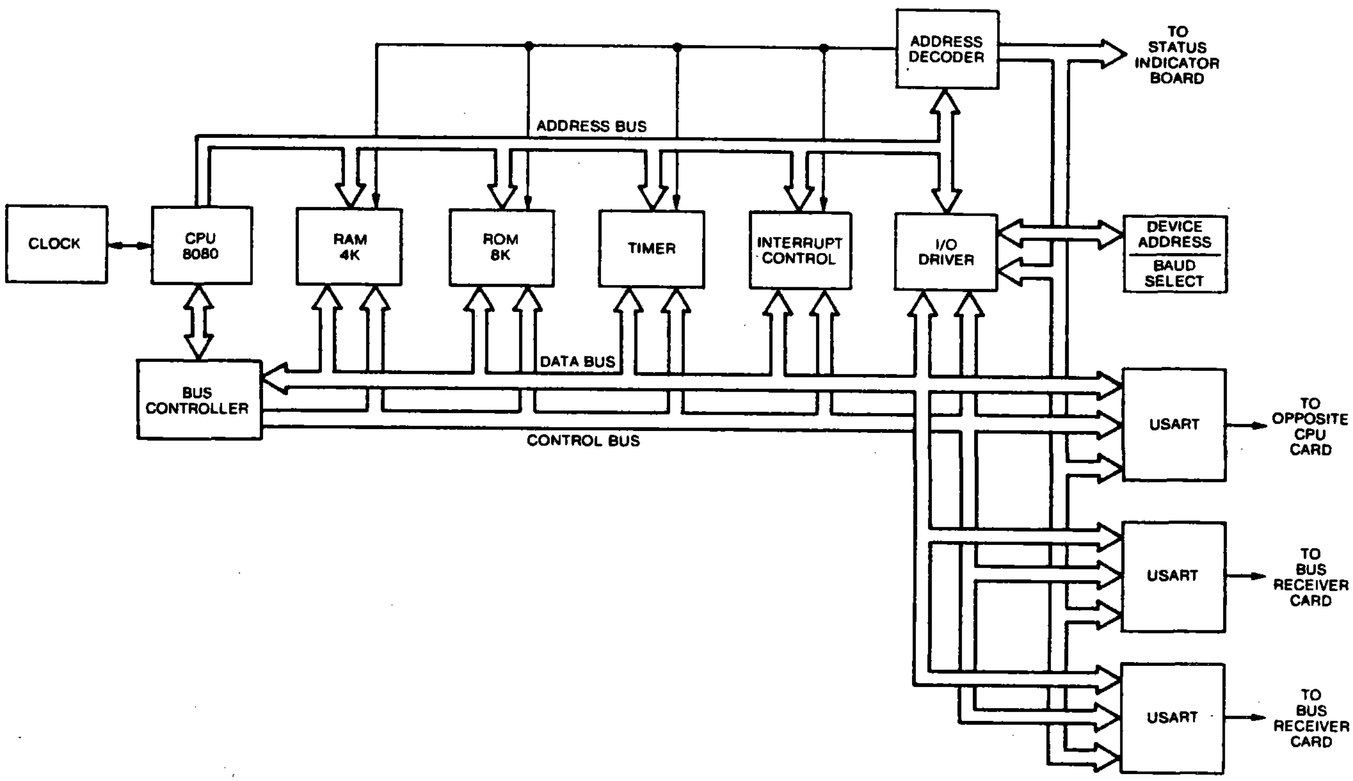


FIGURE 6A. CPU BOARD

A.4 Digital I/O Board, Figure 8. The Digital I/O Board provides the MVCU Mainframe with digital input and output capability. The one-line diagram of the card is shown in Figure 8A.

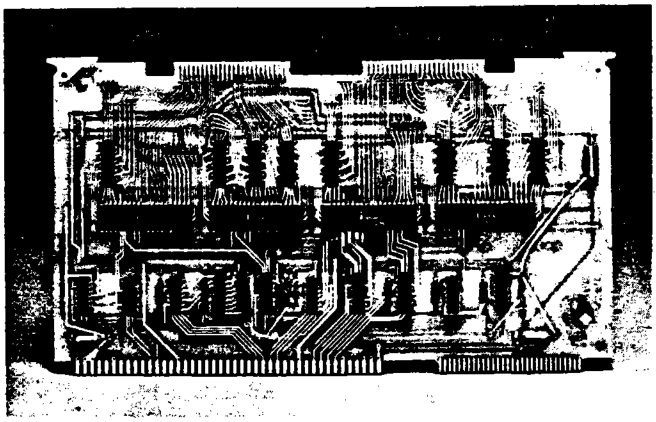


FIGURE 8

This card is used in conjunction with the Digital Conditioning Module. Thus, the card, by itself, does not give the MVCU digital I/O capability. It provides a 5 volt TTL level signal interface to and from the Digital Conditioning Module. The Output Buffers are controlled from the CPU card. These control lines disable the Output Buffer when the opposite side of the MVCU is enabled. The output lines of the Output Buffers from both sides are ored together.

A.5 Analog I/O Board, Figure 9. The Analog I/O Board provides the MVCU Mainframe with the capability of interfacing to an Analog Conditioning Module and, thus, providing the MVCU with analog input and output capability. Figure 9A is a one-line diagram of the Analog I/O Board.

Analog inputs and outputs from this card are 0 to 10 volts D.C., which interface to the Analog Conditioning Module. The

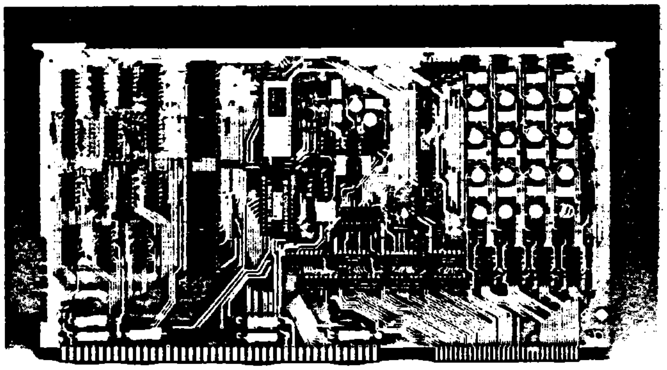


FIGURE 9

input and output multiplexing is software controlled via Control Circuits (2) and (3). Control Circuit (1) is used to route signals directly from the DAC (Digital to Analog Converter) to the ADC (Analog to Digital Converter) for software controlled diagnostic checks of these devices. Control Circuit (4) is the enable/disable analog output function to implement the redundant MVCU strategies.

A.6 Status Display Board. The Status Display Board provides the MVCU with the LED status indication and side "A" to side "B" pushbutton located on the front panel (see Figure 5). This board is interconnected to the Bus Receiver Board described earlier.

A.7 Digital Power Supply. The Digital Power Supply provides the power for the digital components of the MVCU. It is a single unit quad supply which provides +5, -5, +12 and -12 volts D.C.

A.8 Analog Power Supply. The Analog Power Supply provides power for the analog components of the MVCU. It is a single unit dual supply which provides +15 and -15 volts D.C.

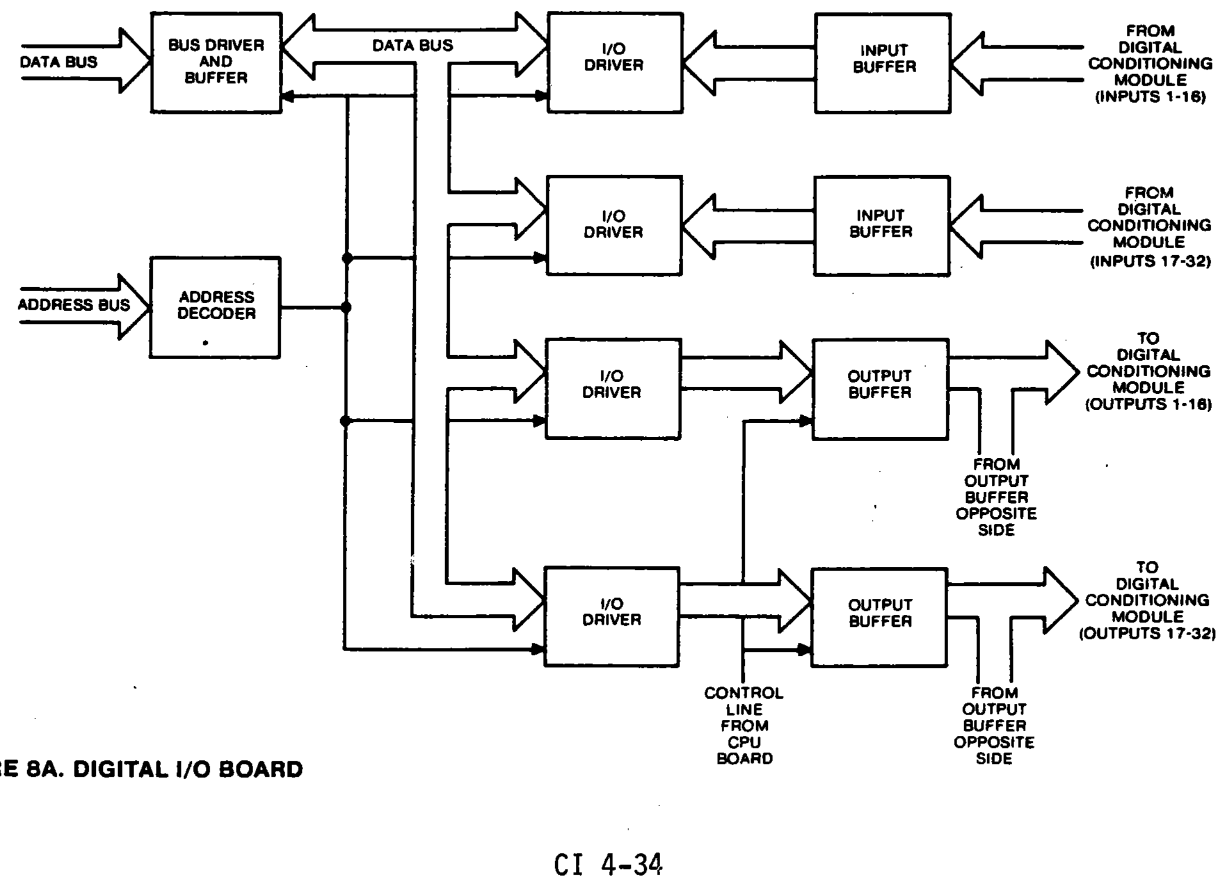


FIGURE 8A. DIGITAL I/O BOARD

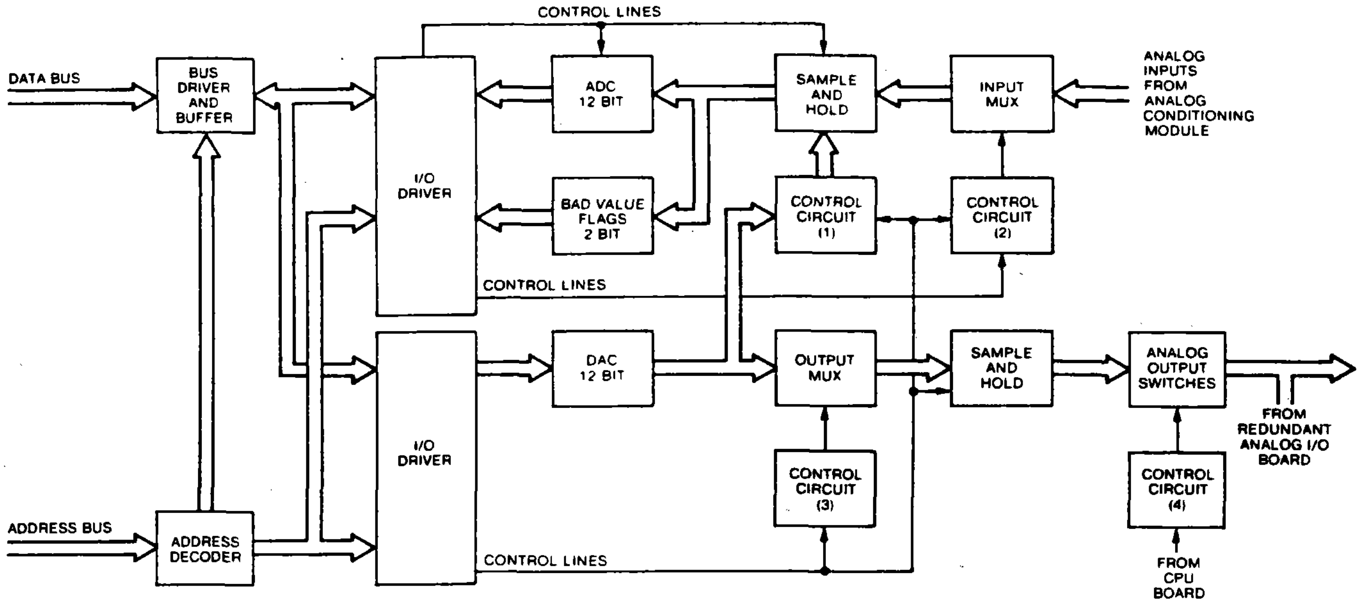


FIGURE 9A. ANALOG I/O BOARD

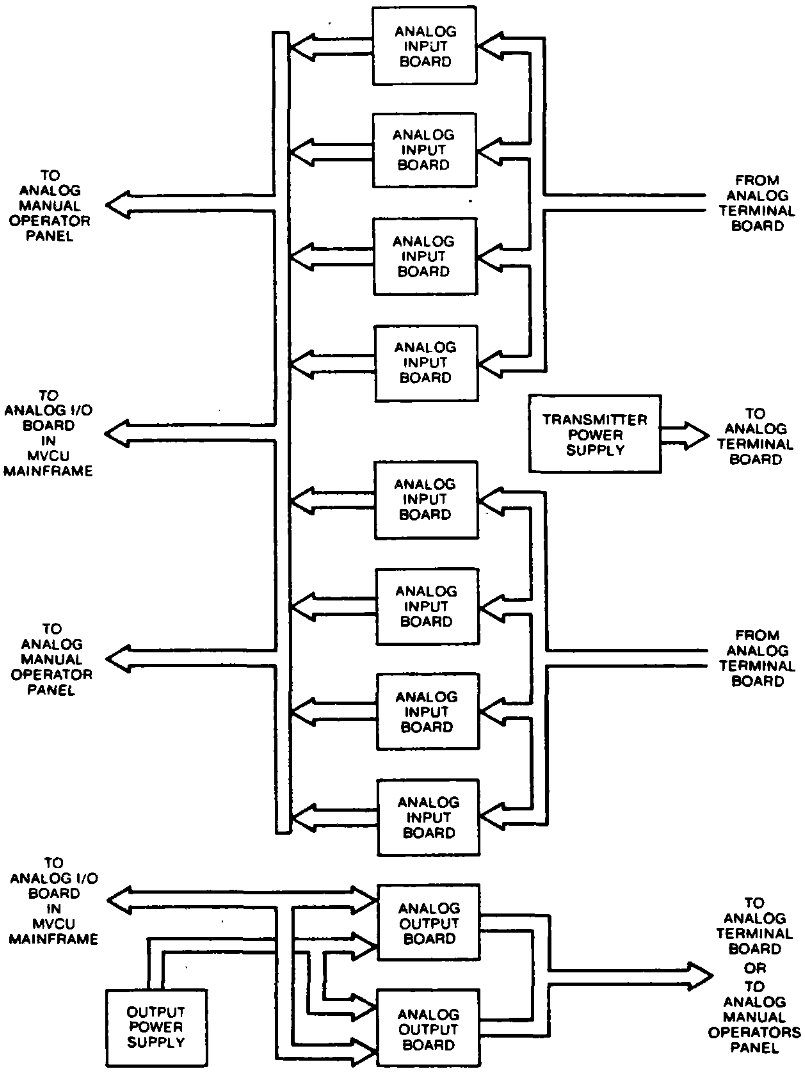


FIGURE 10. ANALOG CONDITIONING MODULE

B. Analog Conditioning Module (ACM)

The Analog Conditioning Module is a separate 19" rack-mounted enclosure which is provided when the MVCU requires analog input/output capability. A line diagram of the ACM is shown in Figure 10 and a photo of the ACM is shown in Figures 11 and 11A.

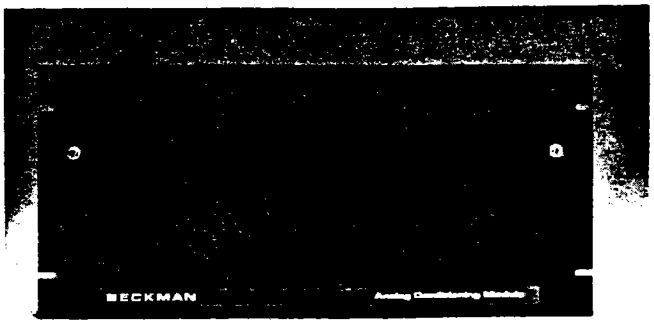


FIGURE 11

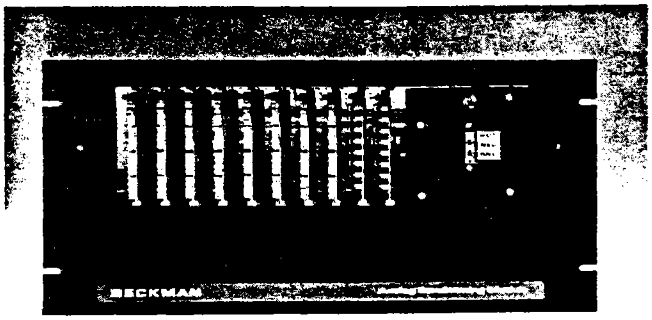


FIGURE 11A

All analog input and output signals are conditioned by the Analog Conditioning Module which is electrically located between the MVCU Mainframe and the Remote Analog Terminal Board. The Analog Conditioning Module consists of:

1. Analog Input Boards (Quantity 8)
2. Analog Output Boards (Quantity 2)
3. 24 Volts Transmitter Supply (Quantity 1)
4. 24 Volts Current Output Supply (Quantity 1)

B.1 Analog Input Board, Figure 12. The Analog Input Board is designed to condition four (4) channels of analog input. Each channel consists of three stages: (1) a Buffer Stage, (2) an Active Filter Stage, and (3) a Voltage Translator Stage (Figure 12A).

The analog input signal (1 - 5 VDC) is initially buffered by a differential input amplifier with a common mode voltage adjustment. The output of the differential amplifier is then filtered by an Active Filter Stage with a corner frequency of 1 HZ and an attenuation of 12 dB at 2 HZ. The filter output of 1 - 5 VDC is then modified by the Translator Amplifier Stage to the required 0 to 10 VDC full-scale signal needed for the Analog I/O card inside the MVCU.

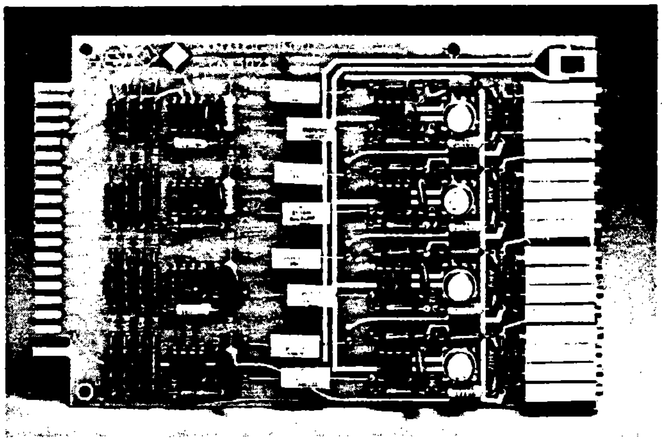


FIGURE 12

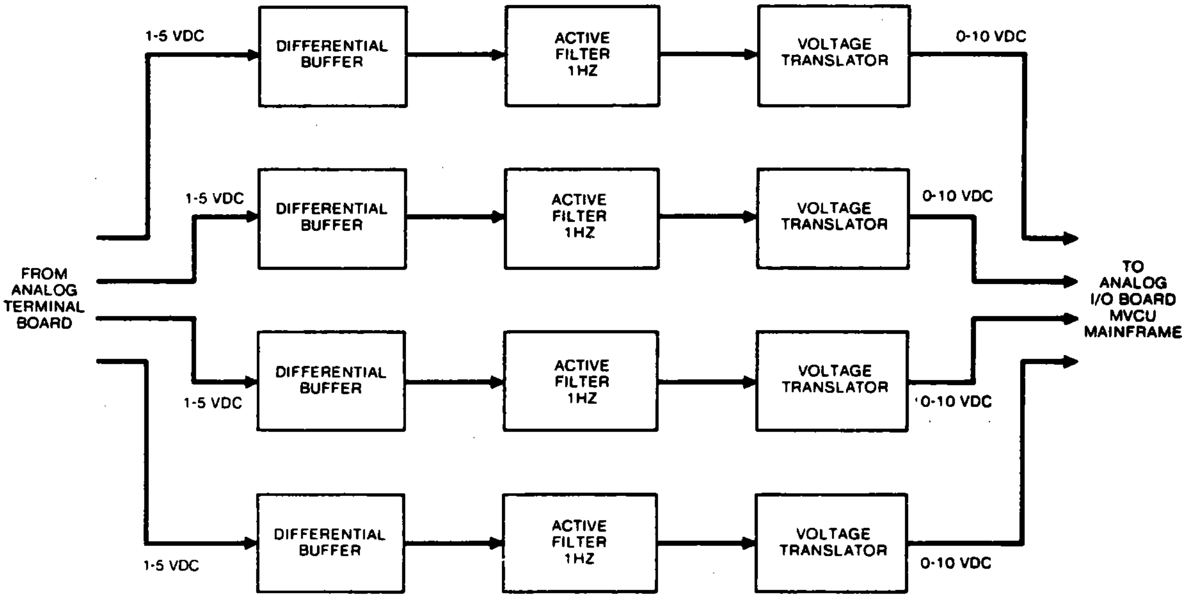


FIGURE 12A. ANALOG INPUT BOARD

B.2 Analog Output Board, Figure 13. The Analog Output Board is designed to translate (0 - 10 VDC) from the MVCU Analog I/O card to a 4 - 20 mADC output as shown in Figure 13A. Each board has the capability to output eight (8) separate channels. Each analog output channel consists of a Hold Stage and a voltage to current translator.

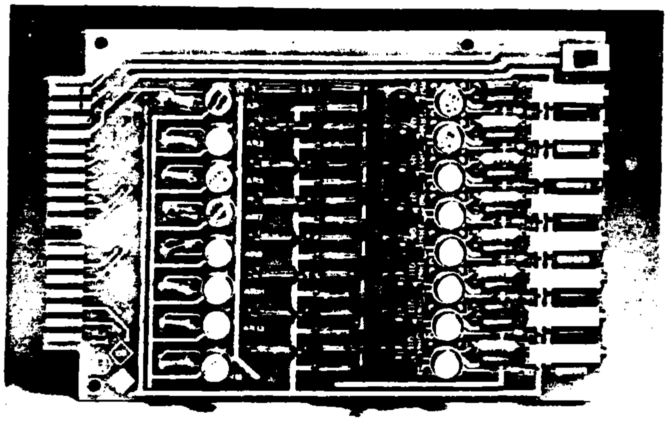


FIGURE 13

The Hold Stage is a circuit which removes transients from the current output when switching from side "A" to side "B". It has no effect during normal operation. The V/I Driver translates the 0 - 10 VDC signal from the MVCU Mainframe to a non-isolated 4 - 20 mADC current loop, which can drive up to 850 ohm output impedance.

Each output is diode protected for reverse voltage protection.

B.3 Transmitter Power Supply. The Analog Conditioning Module has a 24 volt power supply capable of supplying power for 32 4 - 20 mA two-wire transmitter loops. This supply voltage, which is routed to the Remote Analog Terminal Board, is individually fused to protect a complete shutdown of transmitter supply due to a short in a particular loop.

B.4 Output Power Supply. The Analog Conditioning Module has a 24 volt power supply, which provides the power for all sixteen (16) current output loops. All current output loops are non-isolated types.

For maintenance and equipment protection, all conditioning boards power supply (±15 VDC) are fused to protect total system shutdown. Each board also has a power ON/OFF switch for ease of circuit board replacement without total shutdown.

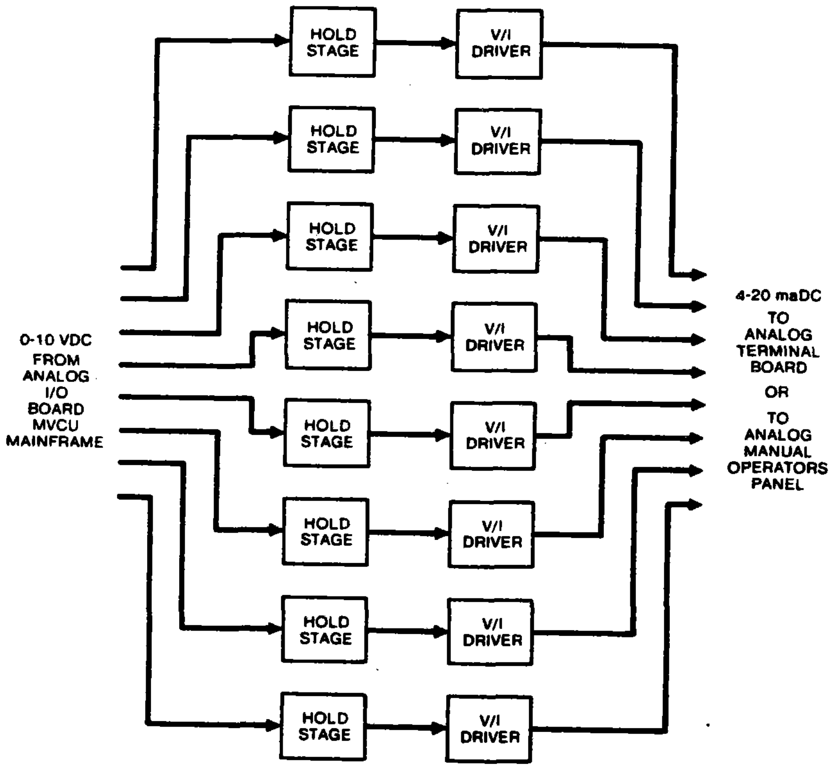


FIGURE 13A. ANALOG OUTPUT BOARD

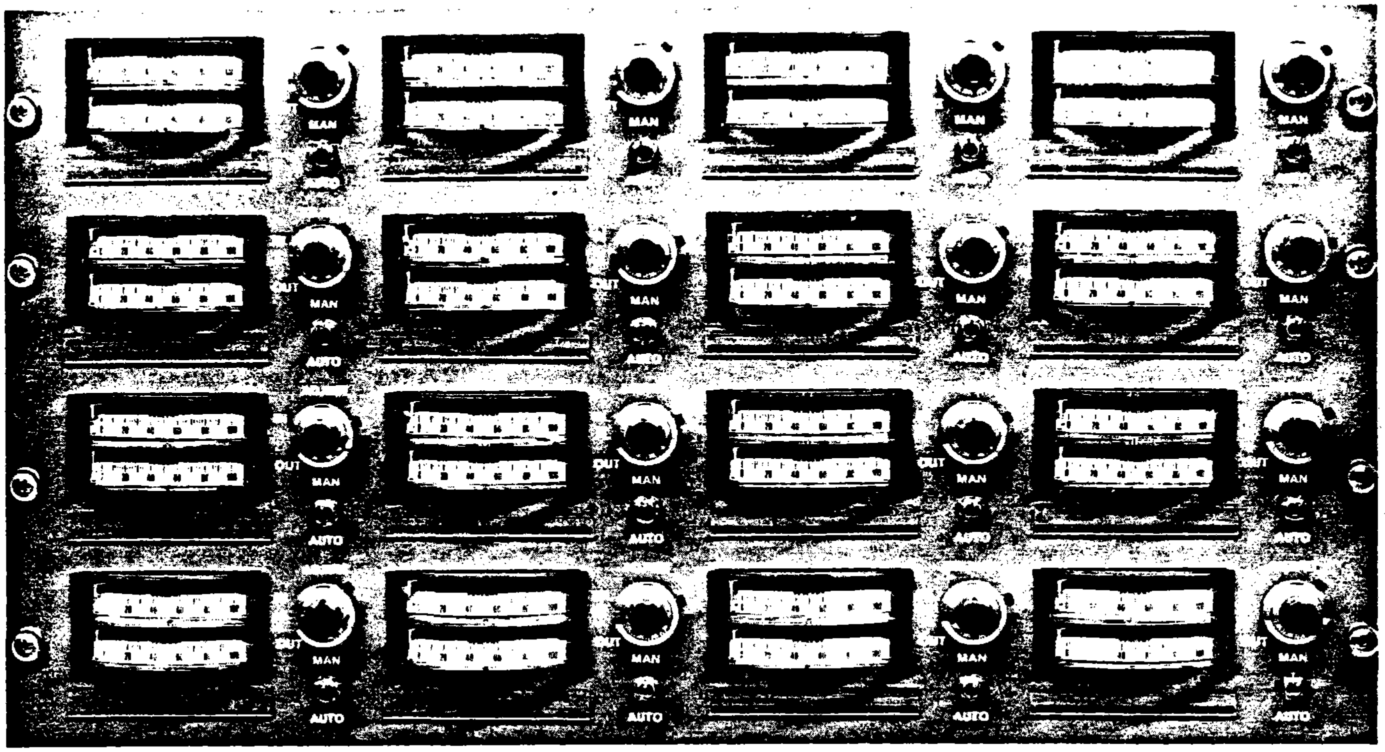


FIGURE 14. ANALOG MANUAL OPERATORS PANEL

C. Analog Manual Operators Panel

The Analog Manual Operators Panel is a 19" rack-mounted device which provides full indication of analog inputs and monitor/manual control of analog outputs. Figure 14 shows the front panel layout. The unit has sixteen (16) sections which have dual meters, (one is dedicated to actual output and the other is wirewrap selectable for any of the 32 analog inputs or 16 MVCU analog outputs), tag information, and auto/manual switch with potentiometer for manual control of the output. The unit has an internal 24 VDC supply for the non-isolated current outputs (4 - 20 mA), which can drive up to 850 ohms. Terminals are provided for a backup 24 VDC power supply which is diode switched to the internal supply.

D. Analog Terminal Panel

The Analog Terminal Panel is a 19" rack-mountable device which is cable connected to the Analog Conditioning Module and/or the Analog Manual Operators Panel. It provides terminal connections for all of the possible 32 analog inputs and 16 analog outputs. The terminal panel is normally mounted within fifty (50) feet of the other devices. A picture of the panel is shown in Figure 15.

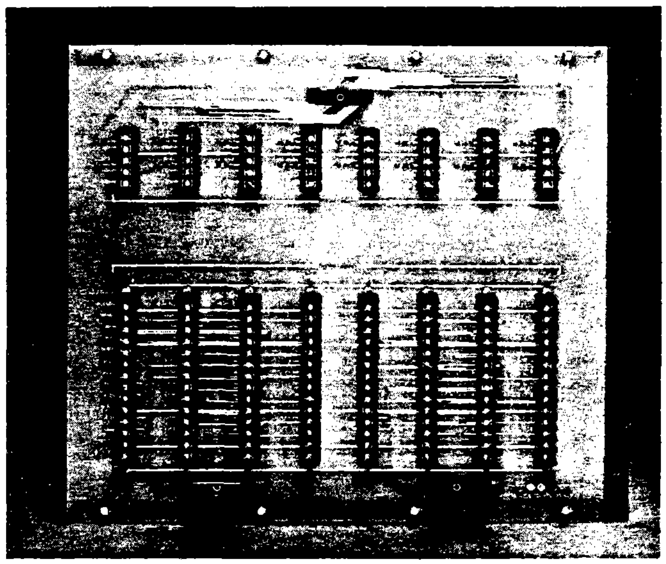


FIGURE 15

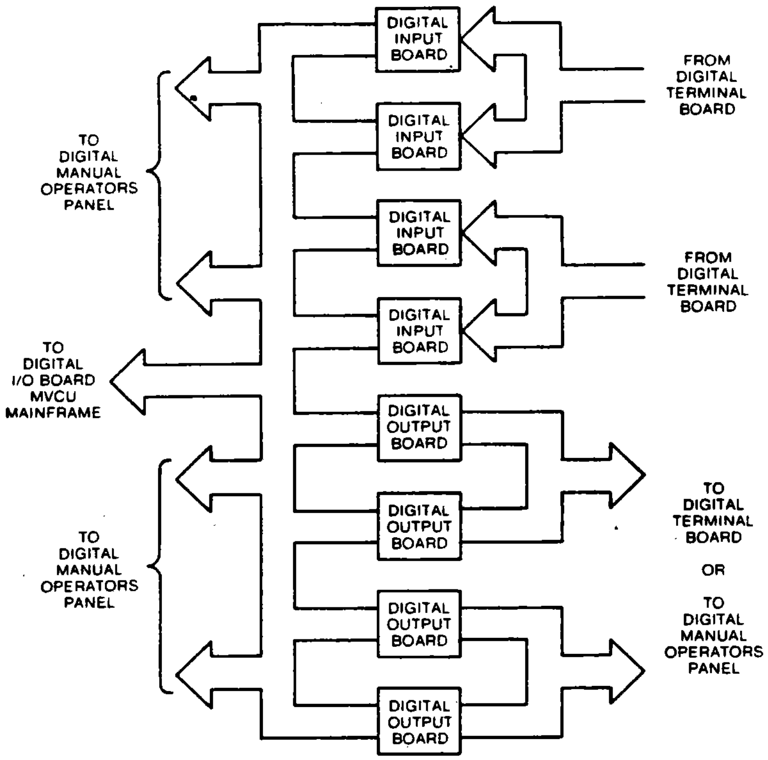


FIGURE 16. DIGITAL CONDITIONING MODULE

E. Digital Conditioning Module (DCM)

The Digital Conditioning Module is a separate 19" rack-mounted enclosure which is provided when the MVCU requires digital input/output capability. A line diagram of the DCM is shown in Figure 16 and a photo of the DCM is shown in Figure 17 and Figure 17A.

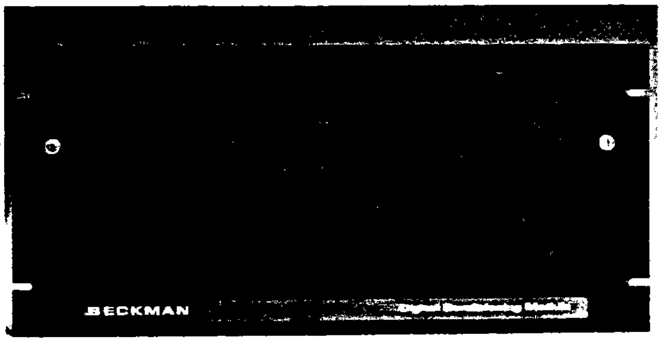


FIGURE 17

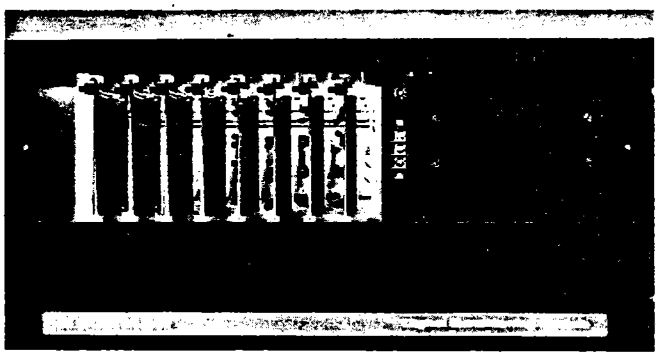


FIGURE 17A

All digital input and output signals are conditioned by the Digital Conditioning Module which is electrically located between the MVCU Mainframe and the Remote Digital Terminal Board. The Digital Conditioning Module consists of:

1. Digital Input Boards (Quantity 4)
2. Digital Output Boards (Quantity 4)
3. 24 VDC Supply

E.1 Digital Input Board, Figure 18. The Digital Input Board is designed to optically isolate eight (8) channels of digital input (Figure 18A). Each channel has a phototransistor opto-isolator for an input to output electrical isolation of 1500 VDC. The input signal consists of a 20 mA current passing through an input diode via the external contact closure. The output voltage is a standard TTL 5 VDC signal to the MVCU Mainframe.

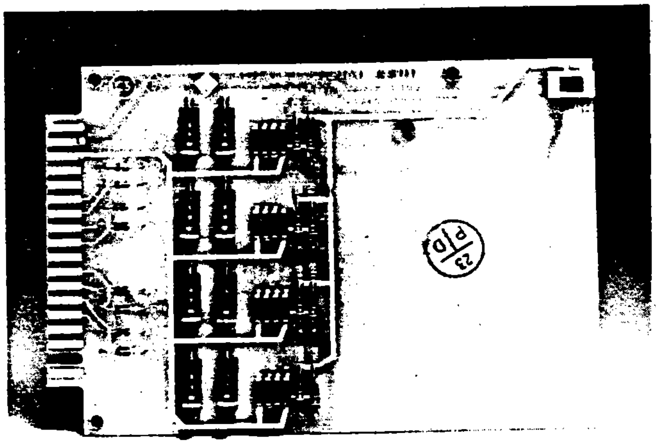


FIGURE 18

E.2 Digital Output Board, Figure 19. The Digital Output Board is designed to optically isolate eight (8) channels of digital outputs (Figure 19A). Each channel has a phototransistor opto-isolator for an input to output electrical isolation of 1500 VDC. The input signal from the MVCU Mainframe is a standard TTL 5 VDC signal input to a buffer driver for the isolation diode. The output stage consists of an open collector transistor that will sink up to a 100 mA from the isolated 24 volt power supply.

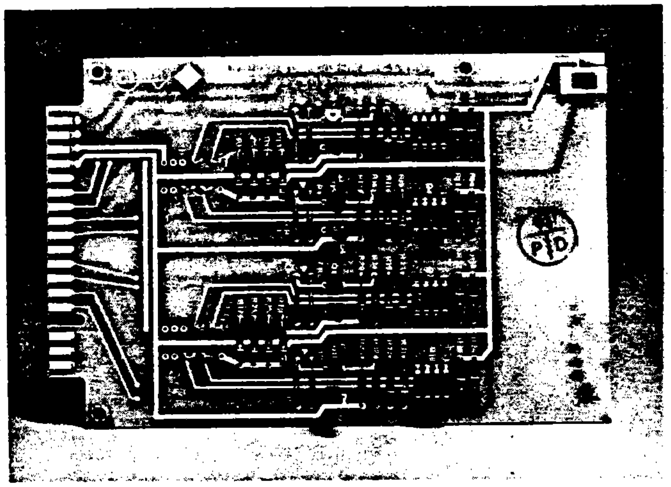


FIGURE 19

E.3 Output Power Supply. The Digital Conditioning Module has a built-in 24 volt power supply capable of supplying power for 32 digital inputs and the source 32 digital outputs.

For maintenance and equipment protection, all the conditioning boards are fused to protect total system shutdown. Each board also has a power ON/OFF switch for ease of circuit board replacement without total shutdown.

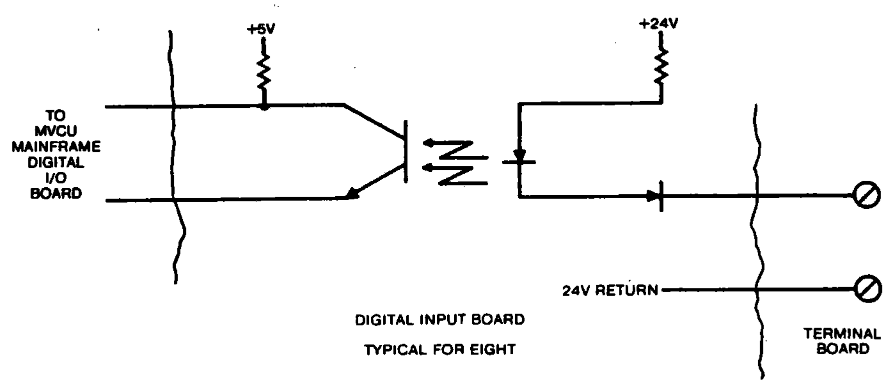


FIGURE 18A. DIGITAL INPUT BOARD

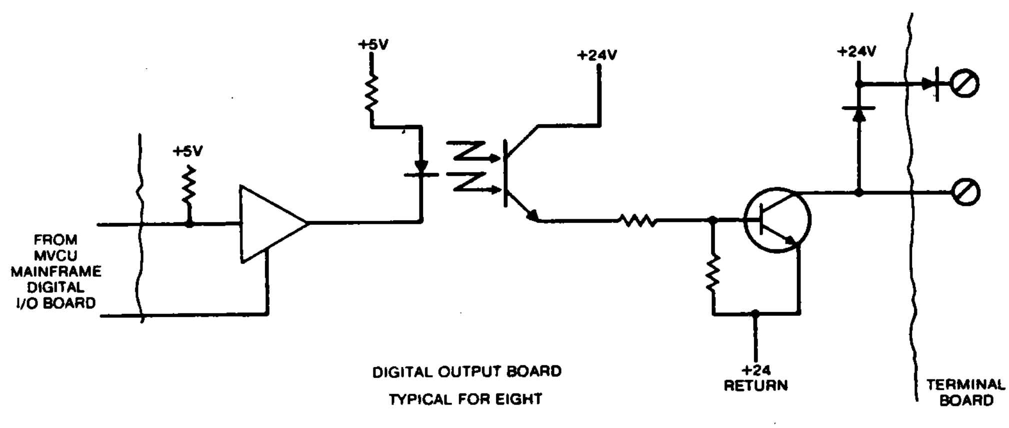


FIGURE 19A. DIGITAL OUTPUT BOARD

F. Digital Manual Operators Panel

The Digital Manual Operators Panel is a 19" rack-mountable device which provides the capability for monitoring all digital inputs to the MVCU System and manual control of the digital outputs. A picture of the panel is shown in Figure 20. The unit has an internal 24 VDC power supply to backup the 24 VDC supply in the Digital Conditioning Module.

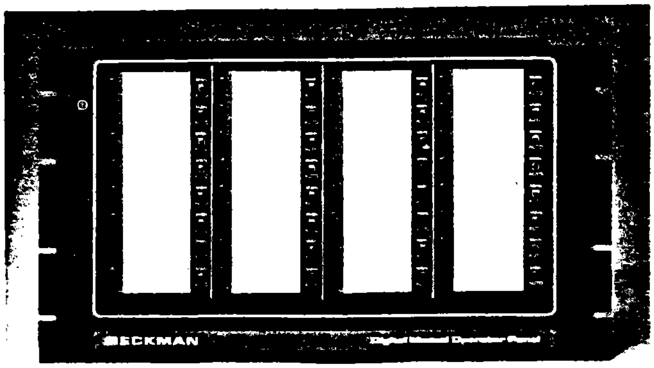


FIGURE 20

The unit also has terminal connections for an external 24 VDC backup supply via diode switching. The front panel is divided into 32 sections that provide an LED for indication of the digital inputs, auto/manual switch, manual output selector switch, and space for tag labeling.

G. Digital Terminal Panel

The Digital Terminal Panel is a 19" rack-mountable device which is cable connected to the Digital Conditioning Module and/or the Digital Manual Operators Panel. It provides terminal connections for all of the possible 32 digital inputs and 32 digital outputs. The terminal panel is normally mounted within fifty (50) feet of the other devices. A picture of the panel is shown in Figure 21.

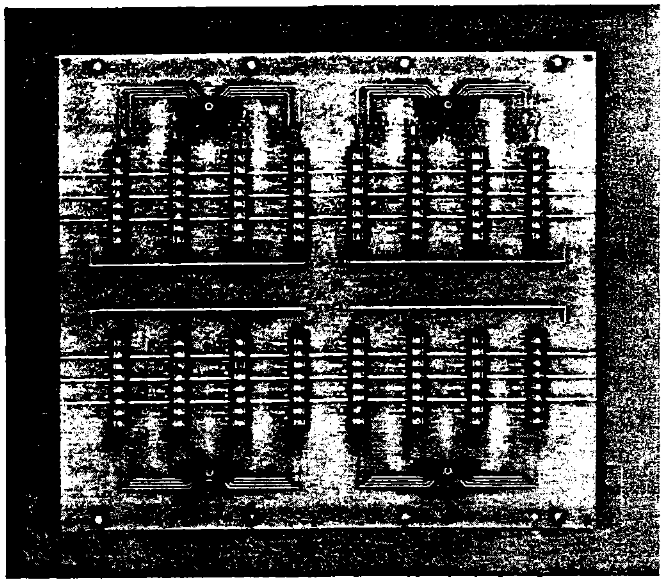


FIGURE 21

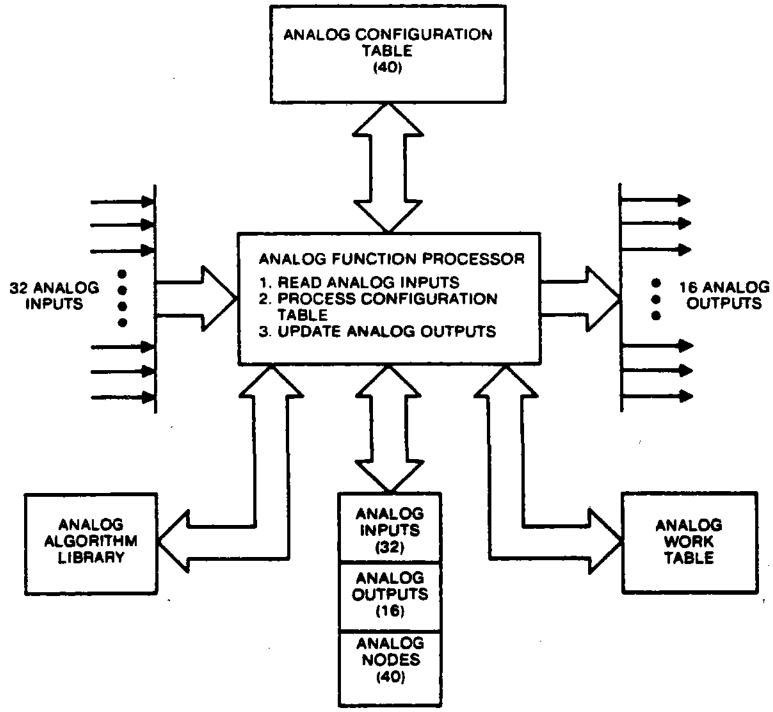


FIGURE 22. ANALOG FUNCTION PROCESSOR

III. ANALOG FUNCTION PROCESSOR

The Analog Function Processor consists of a Configuration Table, an Input/Output/Node Table, a Work Table, and an Analog Algorithm Library.

The Analog Function Processor executes at one-fifth (0.2) second intervals. During this time, 32 analog inputs are sampled and stored into the input section of the Input/Output/Node Table. The Analog Function Processor then begins reading the Configuration Table line by line, operating on each line of the table. The choice of algorithms are described under the Analog Algorithm Library. The output or results of each line is then stored back into the Input/Output/Node Table. After each pass through the Analog Function Processor, the 16 analog outputs held in the Input/Output/Node Table are outputted via digital to analog converter. The Analog Function Processor then waits for the next execution cycle.

All requested analog inputs are checked for bad value flags. If there is a bad value in any input it is reported via the bus communication.

The software structure of the Analog Function Processor is shown in Figure 22.

A. Analog Input, Output and Node Table

As shown in Figure 22, the Analog Input/Output/Node Table is divided into three (3) sections. In the first section is the 32 analog inputs, each of which is comprised of two 8-bit bytes. This creates a storage of 64 bytes of data. Sixteen (16) analog outputs are stored in the second section utilizing 32 total bytes. The third section contains storage area for 40 nodes, resulting in an additional 80 bytes of data.

A node is classified as an intermediary storage location for the output of an algorithm which is to be used by another algorithm as an input.

All analog data stored in the Analog Input/Output/Node Table is a twelve-bit hexadecimal number from 0 to 4095 decimal. The four most significant bits of the two bytes of information used by inputs and outputs are for bad value flags. A bad value is defined as an input which is above or below the standard voltage input range of 1 to 5 VDC.

B. Analog Work Table

The Analog Work Table is used for internal software convenience only. All data from a line in the Configuration Table is temporarily stored into the Work Table and all math functions are computed there so as not to destroy data in the Configuration Table.

C. Analog Configuration Table

The Analog Function Processor accesses the Analog Configuration Table once during each execution cycle. The Configuration Table consists of a 40-line table of which each line represents an algorithm selected from the Analog Algorithm Library. The configuration line is made up of a total of 37 bytes of data per line.

D. Analog Algorithm Library

The Analog Algorithm Library consists of the algorithms which are available for use in the Configuration Table. Below is a list of these algorithms, followed by specific descriptions of their operation and the range of adjustments.

0	No Operation
1	PID Normal
2	PID Error-Squared
3	Ratio Station
4	Auto/Manual Station
5	Manual Loading Station
6	Integrator/Totalizer
7	Adder/Subtractor
8	Multiplier
9	Divider
10	High Select
11	Low Select
12	Square Root
13	Function Generator
14	Lag
15	Mass Flow
16	Dual PV Alarm
17	Dual Deviation Alarm
18	Dual Rate Alarm

D.1 PID Algorithm

$$OUT = \left[K_1\left(E + K_2\int Edt + K_3\frac{dE^*}{dt}\right) + K_5\right] f(K_4)$$

where:

E	=	PV-SP, where PV is the process variable input and SP is the configured set point (either local or cascade)
K_1	=	Gain
K_2	=	Reset in repeats per minute
K_3	=	Rate in minutes
K_4	=	A lowpass digital filter
K_5	=	Bias in percent output

*The rate term can be specified as PV or E. The range of coefficients is as below:

K_1	=	0.01 to 100
K_2	=	0.01 to 100, 0 if no integral term
K_3	=	0.01 to 25, 0 if no derivative term
K_4	=	0 to 0.39 HZ
K_5	=	-400 to +400, 0 if no bias

The possible combinational forms of the PID algorithm are shown below with the adjustable filter K_4 available on all gain and derivative terms.

a. **Proportional Only**

$$OUT = \left[K_1 E + K_5\right] f(K_4)$$

b. **Integral Only**

$$OUT = \left[K_1 K_2 \int Edt + K_5\right] f(K_4)$$

c. **Derivative Only**

$$OUT = \left[K_1 K_3 \frac{dE}{dt} + K_5\right] f(K_4)$$

d. **Proportional + Integral**

$$OUT = \left[K_1\left(E + K_2\int Edt\right) + K_5\right] f(K_4)$$

e. **Proportional + Integral + Derivative**

$$OUT = \left[K_1\left(E + K_2\int Edt + K_3\frac{dE}{dt}\right) + K_5\right] f(K_4)$$

f. **Proportional + Derivative**

$$OUT = \left[K_1\left(E + K_3\frac{dE}{dt}\right) + K_5\right] f(K_4)$$

g. **Integral + Derivative**

$$OUT = \left[K_1 \left(K_2 \int Edt + K_3 \frac{dE}{dt} \right) + K_5 \right] f(K_4)$$

There are limits on both setpoint and output. These limits are returned with the status information (see communication section of this description) when they are reached. The value can then either be clamped or used for print out indication. They can also be used in the Digital Function Processor for interlocking with other inputs and outputs. See Section IV.

There is an option to have the output limits be set by an analog input or node. This option can be specified on high or low or both output limits. This option is labeled "Dynamic Limit High" or "Dynamic Limit Low".

Setpoint and Output Ramping is a configurable item. They are adjustable from 0.125% per second (1000 seconds full scale) to 25.5% per second (4 seconds full scale). The ramping feature applies to setpoint changes or output changes commanded from the communication bus.

All PID Blocks will have the following status capability.

a. **Automatic.** Output calculated via algorithm.

   Manual. Output manipulated from communication buses.

b. **Remote.** Setpoint from analog input or node within the MVCU. This status will be indicated as CASCADE on the console displays of MV8000.

   Console. Setpoint from either bus. This status will be indicated as CONSOLE or COMPUTER dependent upon loop data base when connected to the MV8000 System.

D.2 PID Error Squared Algorithm. This function is identical to Function 1, except for the basic control equation. The equation for this block is:

$$OUT = \left[K_1 \left(E\,|E| + K_2 \int Edt + K_3 \frac{dE}{dt} \right) + K_5 \right] f(K_4)$$

where:

K_1 = Gain

K_2 = Integral Time Constant

K_3 = Derivative Time Constant

K_4 = Low Pass Filter

K_5 = Output Bias

$$|E| = + \frac{\sqrt{E^2}}{100}$$

where: $-100\% \leq E \leq +100\%$

$0 \leq |E| \leq 1$

Example:

E	|E|	E|E|
0%	0	0%
50%	0.5	25%
-50%	0.5	-25%
100%	1	100%
-100%	1	-100%

Note that this normalized value of error is only used on the proportional term.

D.3 Ratio Station

$OUT = K1\ (PV) + K_5$

where:

PV = Input

K_1 = Ratio adjusted from -100 to +100

K_5 = Bias adjusted from -400 to +400

This station has Auto/Manual and Computer/Console capability.

D.4 Auto/Manual Station

$OUT = PV \pm K_5$ (Bias)

with Auto/Manual capability and Computer/Console capability.

D.5 Manual Loading Station

This function allows manual control of an output or node from Computer/Console down the data highways. There is no auto mode.

The algorithms (6) through (18) are not at this time displayed on MV8000, but are configurable from the Operator CRT's. They have Auto/Manual control capability which can be changed from the operator stations in the MVCU configure Mode or via the Mode Transfer function described in Section VI.

D.6 Integrator/Totalizer. The Integrator/Totalizer function is a means of computing a total quantity of a variable which is time-based. A typical example would be a flow measurement. The analog input (1 - 5 VDC) 0 - 100% may represent an actual measured flow of 0 to 200 gallons per minute. The integrator part of the block would basically do a time integration of this signal and the totalizer section would keep a running total. Thus, when the flow is 100% (200 GPM), after one minute the counter may read 200 gallons, or 2000 10th of gallons, or 2 in hundreds of gallons, depending upon the configured scaling. The following specifications apply:

Totalizer	8 decimal digits
Count Adjustment	1 count per minute to 10 counts per second

In Automatic the totalizer runs continually and rolls over to 0 after reaching 99999999. However, a reset of this function can be done via the communication buses by putting the function in Manual.

All of the following computational blocks have the capability of Automatic/Manual Mode transfer. In the Automatic Mode, the output of the function is computed from the configured equation. In Manual the output can be manipulated from the Mode Transfer functions.

D.7 Adder/Subtractor

$$OUT = (K_1)(X_1) + (K_2)(X_2) + (K_3)(X_3) + (K_4)(X_4) + K_5$$

where: $-100 \leq K_1, K_2, K_3, K_4, \leq 100$ $\quad K_5 = \pm 400\%$

Also X_1, X_2, X_3 and X_4 can be either an analog input, an analog output, or an analog node. These specifications apply to all blocks, 7 through 15.

D.8 Multiplier

$$OUT = (K_1)\,[(X_1)(X_2)(X_3)(X_4)] + K_5$$

D.9 Divider

$$OUT = K_1 \left[\frac{(X_1 + K_2)}{(X_2 + K_3)} \right] + K_5$$

D.10 High Select

$$OUT = \text{Max of } (X_1, X_2, X_3, X_4) + K_5$$

D.11 Low Selector

$$OUT = \text{Min of } (X_1, X_2, X_3, X_4) + K_5$$

D.12 Square Root

$$OUT = K_1 \sqrt{X_1 + K_2} + K_5$$

D.13 Function Generator. This is a seven segment straight line adjustable breakpoint algorithm with the X input fixed at the endpoints. Therefore, the specified points are:

$(0\%, Y_0)$ (X_1, Y_1) (X_4, Y_4) (X_6, Y_6)

(X_2, Y_2) (X_3, Y_3) (X_5, Y_5) $(100\%, Y_7)$

where:

X = Input
Y = Output

D.14 Lead/Lag Compensation. This block provides phase lead or phase lag to the processor. Typically used in feedforward applications, the times are adjustable from 0.01 to 50 min.

$$Y(s) = \frac{K_1}{K_2\,s + 1} + K_5$$

where:

s = LaPlace transform operator
K_1 = Gain
K_2 = Lag compensation time constant
K_5 = Bias (±100%)

D.15 Mass Flow Computation

$$OUT = K_1 \left[\sqrt{\frac{(K_2)(X_1)(X_2) + K_3}{X_3 + K_4}} \right] + K_5$$

The following algorithms have to do with alarms on analog inputs, nodes or outputs which drive digital nodes or outputs. Each alarm block has dual alarm capability with each alarm specifiable as high or low and with adjustable deadband of 1 to 50%. Transferring these functions to manual disables these functions.

D.16 Absolute Alarm Block. This function requires:

a. Analog Input Specifier (node, input or output)
b. "A" Alarm Type (high or low)
c. "B" Alarm Type (high or low)
d. "A" Alarm Value (0 to 100%)
e. "B" Alarm Value (0 to 100%)
f. "A" Alarm Deadband (1 to 50%)
g. "B" Alarm Deadband (1 to 50%)
h. "A" Alarm Output function, i.e., trigger digital node or digital output
i. "B" Alarm Output function, i.e., trigger digital node or digital output

This function alarms from absolute values of a single measurement calculation.

D.17 Deviation Alarm Block. This function requires:

a. Analog Input Specifier (node, output, input)
b. Analog Input 2 Specifier (node, output, input, or fixed value)
c. "A" Alarm Mode (high or low)
d. "B" Alarm Mode (high or low)
e. "A" Alarm Value (-100 to +100%)
f. "B" Alarm Value (-100 to +100%)
g. "A" Alarm Deadband (0 to 50%)
h. "B" Alarm Deadband (0 to 50%)
i. "A" Alarm Output function (trigger digital node or digital output)
j. "B" Alarm Output function (trigger digital node or digital output)

This function alarms off the difference between two measurements or calculations. The second input can be a fixed value set during configuration.

D.18 Rate of Change Alarms. This function requires:

a. Analog Input Specifier (node, input, output)
b. "A" Alarm Mode (high or low)
c. "B" Alarm Mode (high or low)
d. "A" Alarm Value (1 to 100% per minute)
e. "B" Alarm Value (1 to 100% per minute)
f. "A" Alarm Deadband (1 to 50% per minute)
g. "B" Alarm Deadband (1 to 50% per minute)
h. "A" Alarm Output function (trigger digital node or output)
i. "B" Alarm Output function (trigger digital node or output)

This function alarms on the change of the input variable with respect to time.

IV. DIGITAL FUNCTION PROCESSOR

The Digital Function Processor consists of a Digital Input Table, a Digital Configuration Table, a Digital Input/Output Node Table, a Digital Output Table, and a Digital Function Work Table. The basic structure of the Digital Function Processor is shown in Figure 23.

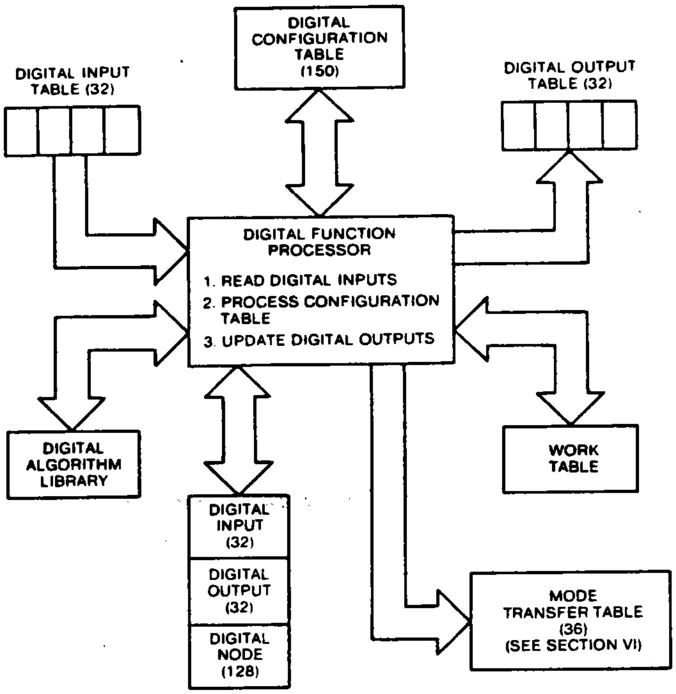


FIGURE 23. DIGITAL FUNCTION PROCESSOR

The Digital Function Processor executes at one second intervals. The Analog Function Processor is responsible for loading the Digital Input Table and driving outputs from the Digital Output Table. This is executed at 0.2 second intervals. Therefore, the Analog Function Processor scans the 32 digital inputs and packs them directly into the Digital Input Table.

The Digital Function Processor unpacks the Digital Input Table into the Digital Input/Output/Node Table, thus putting each digital input into the first 32 bytes of the table. The Digital Function Processor then reads the Configuration Table line by line. During this pass the Digital Function Processor uses the work table for calculations, fills the Digital Input/Output/Node Table, and then packs the Digital Output Table. The Digital Function Processor task then exits and waits for the next execution cycle. Each of the components of the Digital Function Processor is listed below.

A. Digital Input Table

The Digital Input Table is a four-byte, 32-bit table which represents the present state of MVCU digital inputs. This table is loaded by the Analog Function Processor every 0.2 second.

B. Digital Input/Output Node Table

This table contains the unpacked digital inputs (32), the unpacked digital outputs (32), and the digital nodes (128) for internal linking of algorithms. Therefore, the table is 192 entries long.

C. Digital Output Table

This table is loaded by the Digital Function Processor for output of the MVCU. It is four bytes wide and represents the compressed version of the 32 output values in the Digital Input/Output/Node Table. The Analog Function Processor drives the digital outputs every 0.2 second.

D. Digital Work Table

The Digital Work Table is the scratch pad area for the Digital Function Processor for processing each line of the Configuration Table. The configuration lines are temporarily loaded into this work area and operated on one at a time.

E. Digital Configuration Table

The Digital Function Processor accesses the Digital Configuration Table once during each execution cycle (one-second intervals). The Configuration Table consists of a 150-line table of which each line represents a digital function selected from the Digital Algorithm Library.

F. Digital Algorithm Library

The Digital Algorithm Library is made up of 12 possible algorithms which can be used any number of times. These algorithms are listed below, followed by a description of each.

0	No Operation
1	Logical "AND"
2	Logical "OR"
3	Triggered Logical "AND"
4	Triggered Logical "OR"
5	Mode Transfer "AND"
6	Mode Transfer "OR"
7	Jump "AND"
8	Jump "OR"
9	Timer
10	Counter
11	Dual Pulsed Output
12	Analog Function Alarm Status

All input and output states, i.e., "0" or "1", can be inverted to accomplish negative logic. All algorithms have Auto/Manual capability. Automatic allows the algorithm to function normally. Manual disables the function and allows the output to be specified.

For all the algorithms, Y represents algorithm outputs (digital nodes or outputs) and X represents algorithm inputs (digital inputs, nodes and outputs).

F.1 Logical "AND"

$$Y = X_1 \cdot X_2 \cdot X_3 \cdot X_4 \cdot X_5$$

F.2 Logical "OR"

$$Y = X_1 + X_2 + X_3 + X_4 + X_5$$

F.3 Triggered Logical "AND". The function is the same as Logical "AND" except the output is latched when the "true" state is reached. The output must be reset to "untrue" condition by another function line.

F.4 Triggered Logical "OR". The function is the same as Logical "OR" except the output is latched when the "true" state is reached. The output must be reset to "untrue" condition by another function line.

F.5 Mode Transfer "AND"

$$Z = X_1 \cdot X_2 \cdot X_3 \cdot X_4 \cdot X_5$$

When the Z becomes "true", this function enables a mode transfer table request (see Section VI of this specification).

F.6 Mode Transfer "OR"

$$Z = X_1 + X_2 + X_3 + X_4 + X_5$$

When the Z becomes "true", this function enables a mode transfer table request (see Section VI of this specification).

F.7 Jump "AND"

$$Z = X_1 \cdot X_2 \cdot X_3 \cdot X_4 \cdot X_5$$

When the Z becomes "true", a preselected number of configuration lines after this line are skipped.

F.8 Jump "OR"

$$Z = X_1 + X_2 + X_3 + X_4 + X_5$$

When the Z becomes "true", a preselected number of configuration lines after this line are skipped.

F.9 Timer. This timer function has three (3) inputs and one output with a specifiable time range of 1 to 65,534 seconds. The inputs are as described below.

X_1 = Input

X_2 = Reset

X_3 = Hold

The operation is such that, when X_1 is "true", while X_2 and X_3 are "false", the timer continues timing until the preset time range is reached, upon which the output (Y) goes "true". During this operation, driving X_2 "true" will reset to zero the present timer value. Driving X_3 "true", will hold the present timer value until X_3 is driven "false".

F.10 Counter. This counter function has three (3) inputs and one output with a specifiable count range of 1 to 65,534 counts. The inputs are as described below.

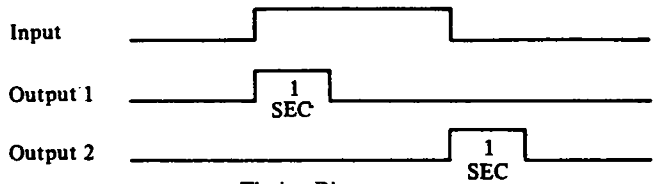
X_1 = Input

X_2 = Reset

X_3 = Hold

The operation is such that, when X_2 and X_3 are "false", the function counts the number of times the X_1 input goes true. X_2, being "true", resets the count register. X_3, being "true", will disable the count register and hold a present state. When the number of counts reaches the selectable preset value, the output drives "true".

F.11 Dual Pulsed Output. This function provides the ability to get a pulsed output based on the rising edge of an input signal, and a separate pulsed output based on the falling edge of the input signal. The pulses are 1 second in length.



Timing Diagram

F.12 Analog Function Alarm Status. This function allows the alarms configured in the Analog Configuration lines to be used in the Digital Function Processor.

V. MVCU COMMUNICATIONS

The MVCU communicates with the outside world via two identical serial buses. The baud rates are selectable from 110 to 9600. The MVCU responds identically to commands received over either bus. Both buses are physically connected to both side "A" and side "B". The MVCU is a passive device in that it only responds to communication commands; it does not initiate commands.

All messages to and from the MVCU start with a left bracket, [, and end with a right bracket,], in ASCII, between the start and end brackets are the message bytes. Each message byte is made up of two ASCII characters. The first character is the most significant hex digit and the second character is the least significant hex digit. The last byte before the right bracket is a checksum of the message string.

The following is a list of all communication requests to the MVCU.

READ MVCU Status
READ All Analog Function Status
READ All Analog Inputs
READ All Analog Nodes
READ All Digital Inputs (block transfer)
READ All Digital Inputs (individual transfer)
READ All Digital Outputs (block transfer)
READ All Digital Outputs (individual transfer)
READ All Digital Nodes (individual transfer)
READ MVCU Time
READ One Analog Function Status (1 to 40)
READ One Line from Analog Configuration Table (1 to 40)
READ One Analog Input (1 to 32)
READ One Analog Output (1 to 16)
READ One Analog Node (1 to 40)
READ One Line from Digital Configuration Table (1 to 150)

READ One Digital Input (1 to 32)
READ One Digital Output (1 to 32)
READ One Digital Node (1 to 128)
READ One Mode Transfer Table (1 to 36)
WRITE Time to the MVCU
WRITE Analog Input Mapping Table
WRITE One Analog Output
WRITE One Analog Node
TRANSFER Analog Function N to Manual
TRANSFER Analog Function N to Auto
TRANSFER PID Loop N to Remote
TRANSFER PID Loop N to Console
TRANSFER Digital Function N to Manual
TRANSFER Digital Function N to Auto
WRITE One Digital Output
WRITE One Digital Node
STOP Ramping Analog Function N Output
STOP Ramping PID Loop N Setpoint
SELECT Side "A" of MVCU
SELECT Side "B" of MVCU
ENABLE Opposite Bus
DISABLE Opposite Bus
WRITE One Line to Analog Configuration Table
WRITE One Line to Digital Configuration Table
WRITE One Mode Transfer Table
RAMP Analog Function N Output to XX
RAMP Analog Function N Setpoint to XX

VI. MODE TRANSFER FUNCTION

The Mode Transfer Section of the MVCU gives the device the capability of changing operating parameters of an analog function and/or a digital function initiated via the Digital Function Processor. The mode transfer function is broken up into 36 mode transfer tables which are individually addressable. Each mode transfer line can modify a single function in the analog or digital configuration table. The following is a list of the mode transfer functions available in the MVCU.

A. Analog Function Processor

1. Manual Transfer (hold output)
2. Automatic Transfer
3. Manual Transfer with Output Select
4. Automatic Transfer with Setpoint Select

B. Digital Function Processor

1. Manual Transfer (hold output)
2. Automatic Transfer
3. Manual Transfer with Output Select

Each mode transfer table has twenty (20) lines of which each can modify a configuration line in either the Analog Function Processor or the Digital Function Processor. Therefore, twenty configuration lines can be modified via a single table.

Mode Transfer Table #2 is dedicated to power up.

VII. MVCU EXECUTIVE

The MVCU Executive is a software routine which controls and prioritizes the functions controlled by the MVCU. The functions are listed below in the order in which they are prioritized by the executive.

A. Analog Function Processor
B. Digital Function Processor
C. Mode Transfer Function
D. Communication Bus "A"
E. Communication Bus "B"
F. Side "A"◄──►"B" Communication
G. Memory Diagnostics

A. Analog Function Processor

The Analog Function Processor is the highest priority and is executed every 0.2 second. The operation is described in Section III.

B. Digital Function Processor

The Digital Function Processor is executed every second. The operation is described in Section IV.

C. Mode Transfer Function

Mode Transfer Functions are operated on when called. The functions are done after the execution of the Analog and Digital Function Processors. Thus, the mode transfers do not bump the algorithms in midcalculation. The Mode Transfer capability is described in Section VI.

D. Communication Bus "A"

Communication Bus "A" is operated on when required. Communication is done when the three higher order tasks listed are not requested.

E. Communication Bus "B"

Communication Bus "B" is operated on when required.

F. Side "A"◄──►"B" Communication

The communication task takes approximately 300 milliseconds. The running side transfers balancing information to the non-running side. The non-running side only does partial algorithm computations. The part that is not done is actual PID integral computations, but the value of this integral term is transferred to the non-running side. This is done to prevent reset windup.

G. Memory Diagnostics

This is the lowest priority task in the MVCU and, therefore, is executed as "free" time is available. These tasks are:

1. Check sum on ROM Memory
2. Read/Write Addressing of RAM
3. Read/Write Addressing of CORE

As part of the Analog Function Processor, diagnostics are performed on the Digital to Analog Converters (DAC) and the Analog to Digital Converters (ADC). This is accomplished by looping the output of the DAC into the input of the ADC and testing the following conditions:

1. Outputting and reading 100% value
2. Outputting and reading a 0% value
3. Outputting and reading a 50% value
4. Outputting and reading two alternating bit patterns.

The result of these tests must fall within an 0.2% accuracy specification or a transfer will be initiated from this side to the other.

VIII. FAILURE DIAGNOSTICS

This section covers the conditions and results of the failure of the selected side of the MVCU and the transfer to the other side.

Side "A" and side "B" are continually communicating to each other as described in Section VII. A failure of this communication will result in a transfer from a non-working side to a working side (if required) in less than a second. All other transfers of control from one side to the other takes four (4) milliseconds. This transfer can be initiated by any of the following modes.

a. Manual Transfer from MVCU Front Panel
b. Transfer initiated via communication bus command
c. Deviation of more than ±6% on all supply voltages. This includes +5, -5, +12, -12, +15, and -15.
d. Memory diagnostic failure (Section VII)
e. ADC and DAC failures or out of spec performance. (Section VII)

The cause of failure of a particular side of an MVCU can be determined in both a hardware and a communication mode as described as follows.

A. Hardware Diagnostics

The operation of the MVCU can be determined at the hardware level via the use of Light Emitting Diodes (LEDs). There are two sets of diagnostic LEDs for each side of the MVCU.

A.1 On the front panel there are four LEDs for each side. These are labeled and described as shown below.

a. Power Supply

Digital	This LED is "ON" when the +5, -5, +12 and -12 voltages are within tolerance.
Analog	This LED is "ON" when the +15 and -15 voltages are within tolerance.

b. System

Active	This LED is "ON" when this side is passing all diagnostic checks, whether it is selected or not.
Selected	This LED is "ON" when this side of the MVCU is actually running the I/O. This LED can only be "ON" for side "A" or side "B", but not both.

NOTE: On the CPU Card internal to the MVCU, the Active and Selected LEDs are duplicated.

A.2 On the bus communication cards internal to the MVCU, the actual diagnostic routine that has caused the failure is encoded into three (3) LEDs. These three LEDs are decoded in octal format as detailed below.

Octal Representation	Description
0	No Problems
1	Unused
2	Magnetic Core Failure
3	CPU Onboard RAM Failure
4	DAC/ADC Failure
5	CPU Onboard ROM Failure
6	Offboard ROM Failure
7	CPU Initialization

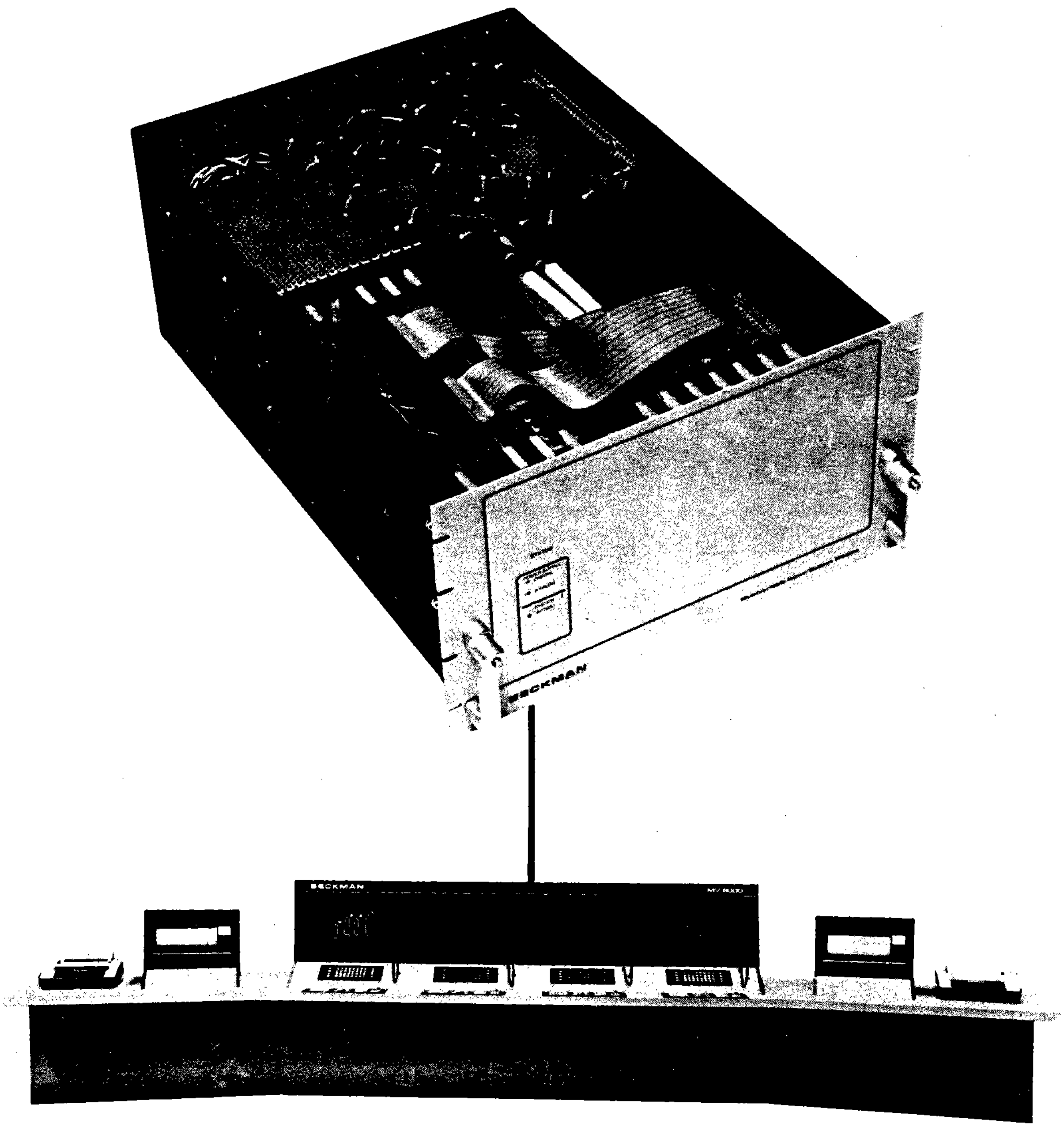
B. Software Diagnostics

All the information detailed under Hardware Diagnostics is also available over the communication buses using the READ MVCU Status Command.

DATA SHEET NO: TOP 8-06
EFFECTIVE DATE: 1 DEC. 1979

TECHNICAL DATA

Multi Variable Input/Output Unit



BECKMAN

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BECKMAN MULTIVARIABLE INPUT/OUTPUT UNIT (MVIO)

This document outlines the design of the Beckman Multivariable Input/Output Unit. This document is broken down into seven main areas:

- I General Overview
- II Hardware Architecture
- III Analog I/O Task
- IV Digital I/O Task
- V Communications
- VI Executive
- VII Failure Diagnostics

I. GENERAL OVERVIEW

The MVIO is an 8080 microprocessor based micro-computer that accepts both analog and digital inputs from the process and provides both analog and digital outputs to the process. The MVIO is housed in a single 19-inch rack mounted enclosure and provides input/output capability of 32 analog inputs, 16 analog outputs, 64 digital inputs, and 64 digital outputs. The unit has two independent bit serial communication links for reading device status, reading all inputs and outputs, and controlling all outputs.

The MVIO is the companion unit to the Multivariable Control Unit.

II. HARDWARE ARCHITECTURE

The Multivariable Input/Output Unit is comprised of three major assemblies which are interconnected as shown in Figure 1. The assemblies are listed below:

1. MVIO Mainframe
2. Analog Terminal Board
3. Digital Terminal Board

Each MVIO has the capability to read up to 32 analog input signals. Each analog input is a differential input of 1 to 5 volts DC with a common mode rejection of 70 dB, maximum voltage of 30 volts, and an input impedance of one megohm. Each input can accept a current input of 4 to 20 mADC or 10 to 50 mADC by the use of an external load resistor (250 ohm or 100 ohm, respectively) installed on the Remote Terminal Board Assembly.

Each MVIO also has the capability to output up to 16 analog signals. These current outputs are non-isolated 4-20 mADC, with a maximum output load of 850 ohms. Each output is diode protected for reverse voltage protection. The Analog Terminal Board assembly can be remotely installed up to fifty (50) feet as standard.

Each MVIO also has the capability to read up to 64 digital input signals and output 64 digital signals. All inputs and outputs are optically isolated. Each digital input requires a contact closure which will be sensed by the MVIO. The DC power for digital inputs, 24 volts at 20 mA for the contact closure, is supplied by the MVIO. The digital outputs are transistor outputs with the capability of sinking 100 mADC (resistive or inductive) at 24 VDC.

Each input and output are diode protected for reverse voltage protection. The Digital Terminal Board Assembly can be remotely installed up to fifty (50) feet as standard. There are two Digital Terminal Boards required for full I/O capability. Each terminal board supports 32 inputs and 32 outputs.

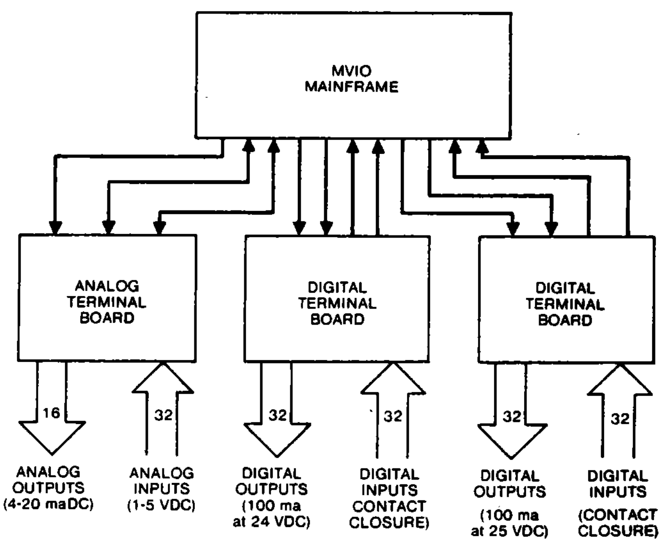


FIGURE 1. MVIO SYSTEM

A. MVIO Mainframe

The MVIO Mainframe houses an 8080 based microcomputer which provides the intelligence for the MVIO system. Figure 2 is a one-line diagram of the boards which comprise the MVIO mainframe. Figure 3 is a pictorial of the MVIO mainframe.

As shown in Figure 2, all of the input/output conditioning is self-contained in the mainframe. This device is directly cabled to the terminal boards. Each component of the MVIO mainframe is described below.

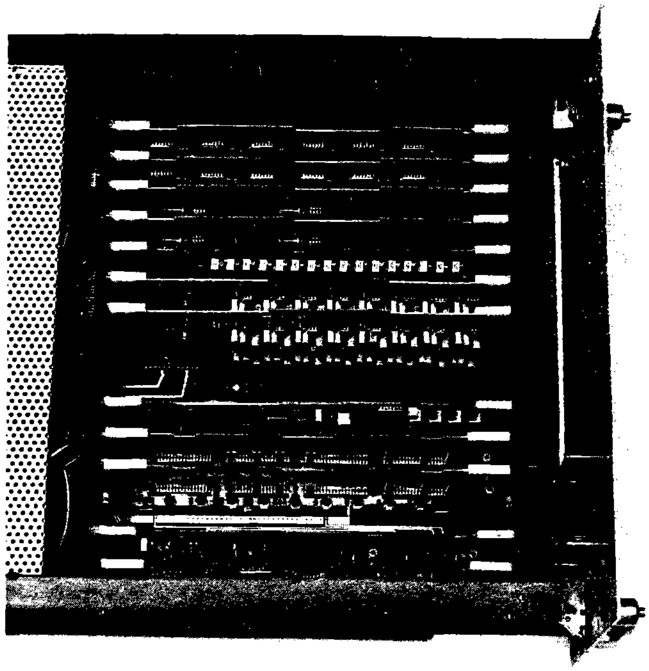
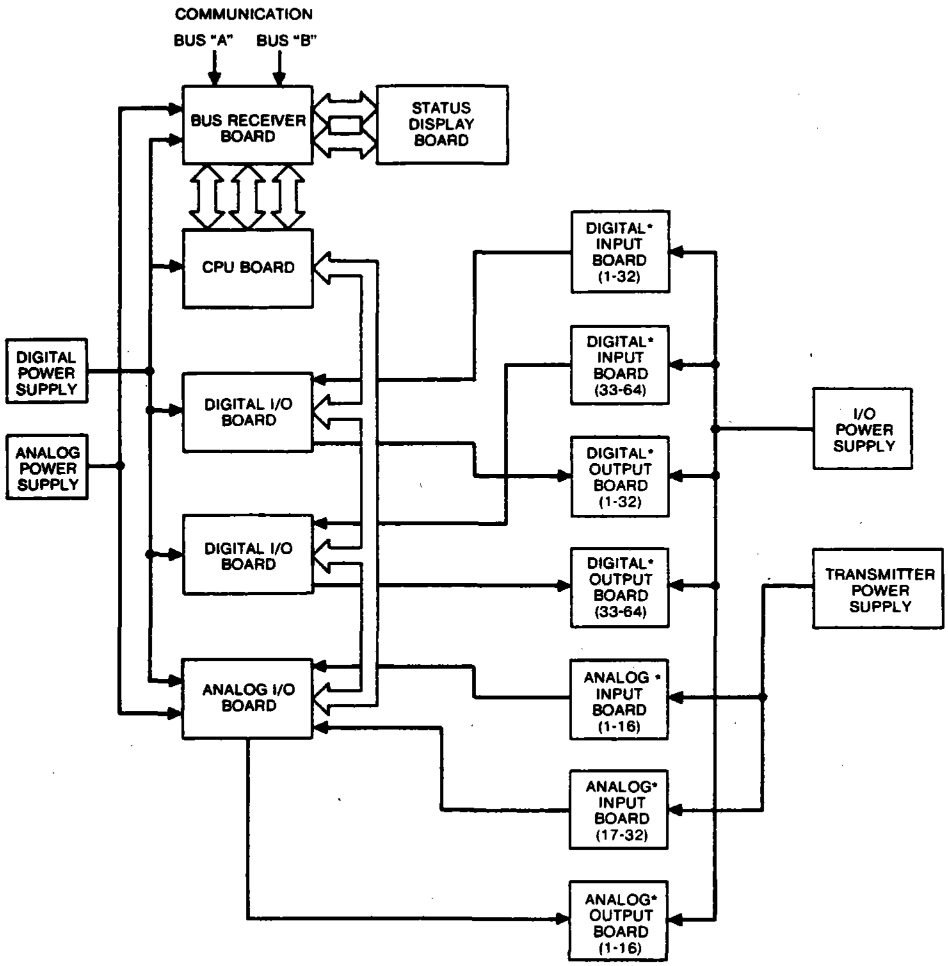


FIGURE 3. MVIO, TOP OFF



*THESE BOARDS ARE DIRECTLY CABLED TO REMOTE TERMINAL BOARDS.

FIGURE 2. MVIO MAINFRAME

1. Bus Receiver Board, Figure 4

The Bus Receiver Board provides three major functions for the MVCU Mainframe. A simplified line diagram is shown in Figure 4A.

a. Communication Bus Interface. Communication Buses A and B are three-wire optically coupled bit serial ASCII communication links to the MVIO, which provides monitor and configuration capabilities to host processors which can be up to 5,000 feet away. Both buses are physically identical and each can be independently hardware strapped for communication rates from 110 to 9600 baud.

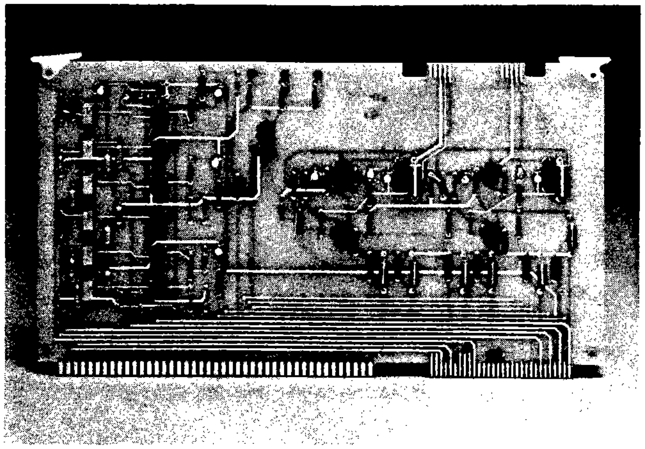


FIGURE 4. BUS RECEIVER BOARD (MVCU DOCUMENT)

b. Status Display Board Interface. The Status Display Board provides status indication to the front panel of the MVIO as shown in Figure 5. The status indications for the power supplies are generated from the Bus Receiver Board.

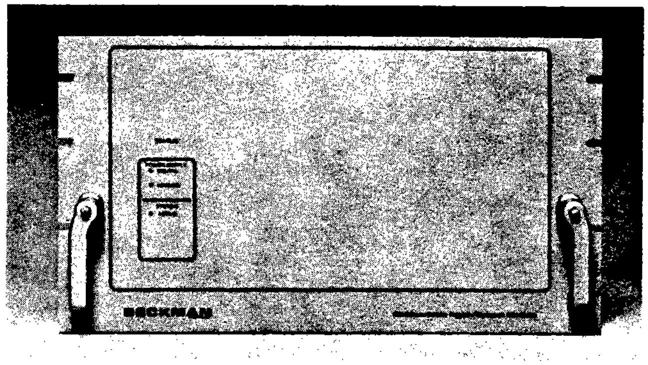


FIGURE 5. MVIO, FRONT PANEL

The Analog Power Supply Status refers to the ±15 volt supply and the Digital Power Supply Status refers to the ±12 volt and ±5 volt supply. Each voltage is checked to determine whether the voltage is within 6% of normal voltage on the low side. Thus, this is a detection circuit for loss of a power supply.

c. Diagnostic Failure Indication. The board also has three (3) LED's which are used to indicate the particular software diagnostic routines which caused the MVIO to shut down. These LED's are coded in octal format.

0	No Problem
1	Unused
2	Unused
3	CPU On-Board RAM Failure
4	DAC/ADC Failure
5	CPU On-Board ROM Failure
6	Unused
7	CPU Failure

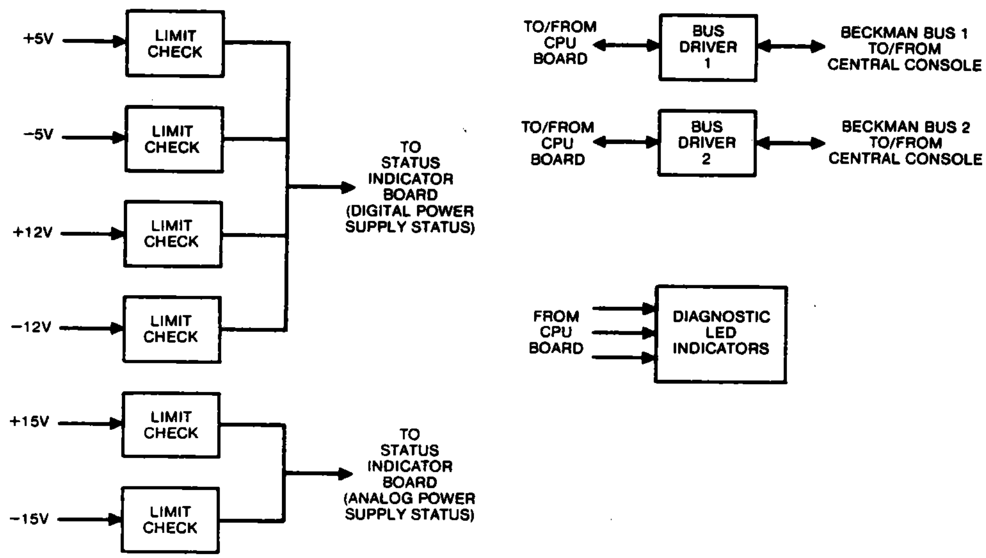


FIGURE 4A. BUS RECEIVER BOARD

2. **CPU Board, Figure 6**

The CPU Board for the MVIO contains the computational power of the device. A one-line diagram of this board is shown in Figure 6A.

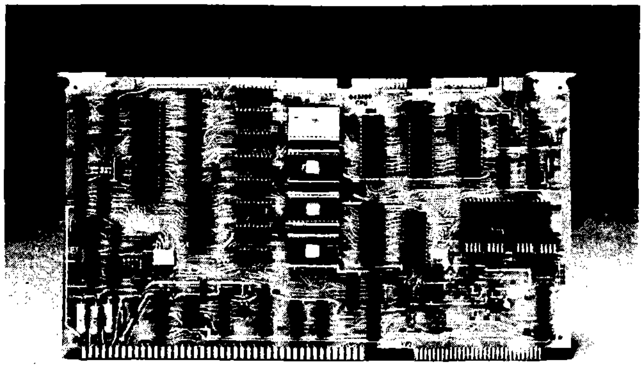


FIGURE 6. CPU BOARD

The board is based on an 8080 processor chip. The board contains 4K of RAM, 8K of ROM, and hardware USARTs to support the two external serial communication buses.

The board has switch selection for both the baud rate selection and address selection. The baud rate selection can be from 110 to 9600 and the address can be selected from 1 to 256.

The board also interfaces to the Status Indicator Board in that it provides ACTIVE indication. ACTIVE designates that the CPU is operating with no diagnostic failures.

The CPU on-board RAM is used for scratch pad memory and the 8K ROM is used for MVIO program storage.

3. **Digital I/O Board, Figure 7**

The Digital I/O Board provides the MVIO with digital input/output capability. There are two of these boards in a fully loaded MVIO with each board capable of 32 inputs and 32 outputs. The one-line diagram of this board is shown in Figure 7A.

This card is used in conjunction with the Digital Input and Output Boards. Thus, the card, by itself, does not give the MVIO digital I/O capability. It provides a 5 volt TTL level signal interface to and from the Digital Input and Output Boards.

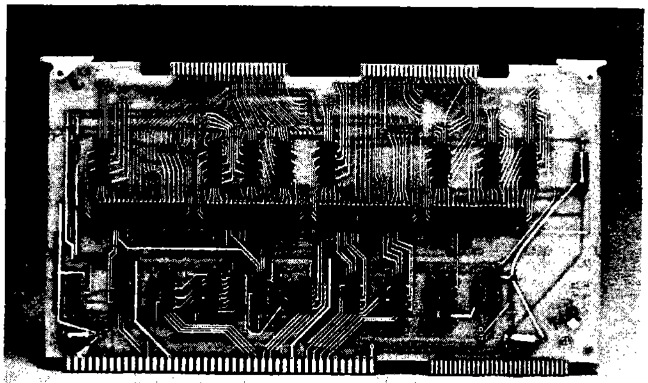


FIGURE 7. DIGITAL I/O BOARD

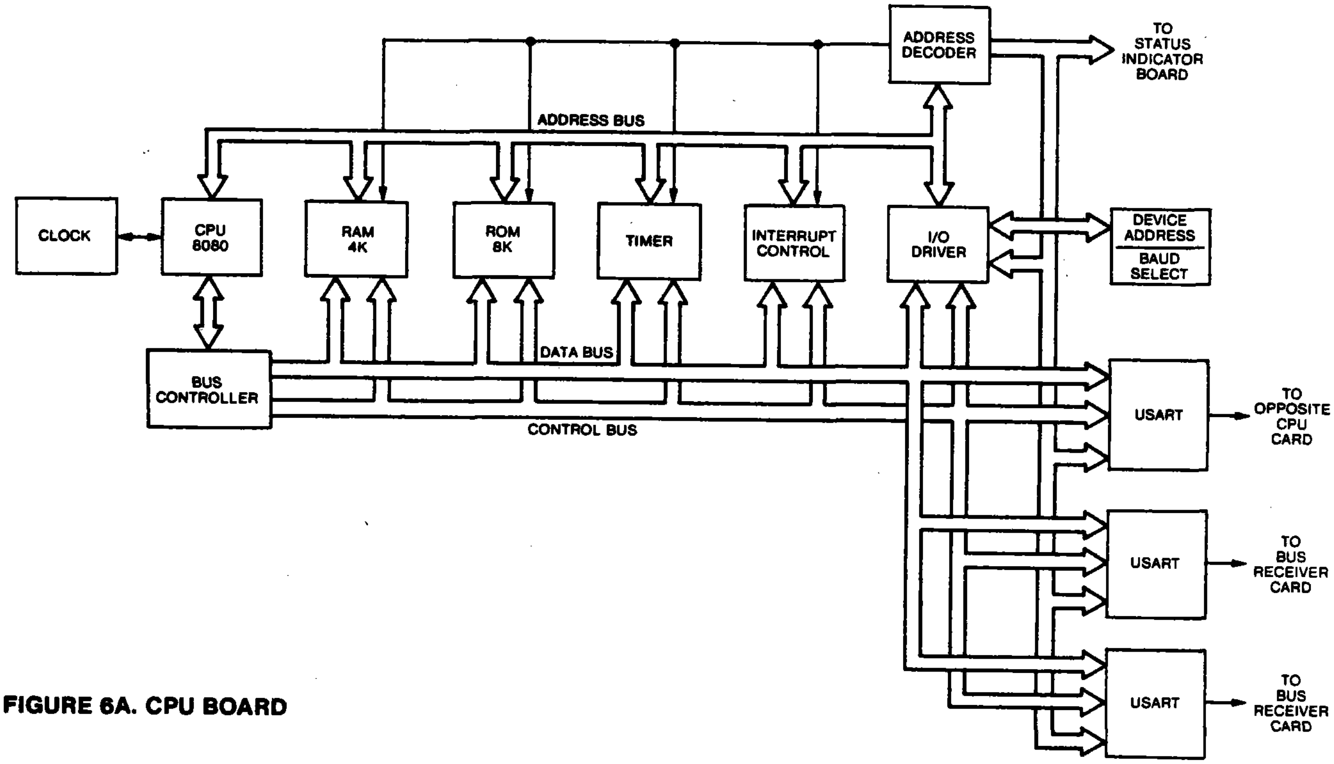


FIGURE 6A. CPU BOARD

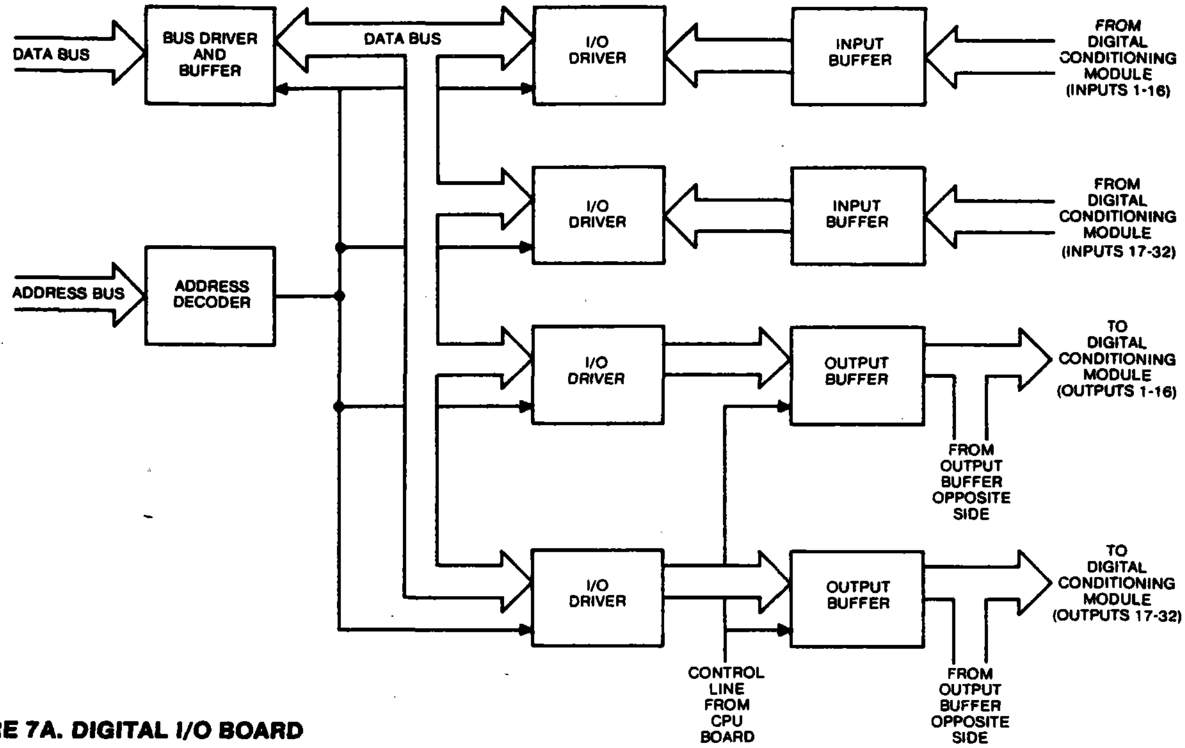


FIGURE 7A. DIGITAL I/O BOARD

4. Analog I/O Board, Figure 8

The Analog I/O Board provides the MVIO Mainframe with the capability of interfacing to an Analog Input and Output Board and, thus, providing the MVIO with analog input and output capability. Figure 8A is a one-line diagram of the Analog I/O Board.

Analog inputs and outputs from this card are 0 to 10 volts DC which interface to the Analog Input and Output Boards. The input and output multiplexing is software controlled via Control Circuits (2) and (3). Control Circuit (1) is used to route signals directly from the DAC (Digital to Analog Converter) to the ADC (Analog to Digital Converter) for software controlled diagnostic checks of these devices.

5. Status Display Board

The Status Display Board provides the MVIO with the LED status indication (see Figure 5). This board is interconnected to the Bus Receiver Board described earlier.

6. Digital Power Supply

The Digital Power Supply provides the power for the digital components of the MVIO. It is a single unit quad supply which provides +5, -5, +12 and -12 volts DC.

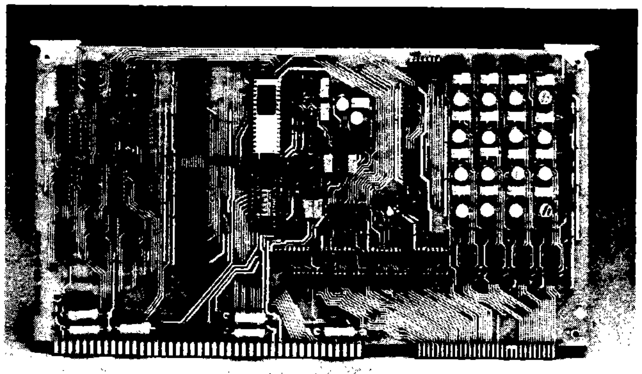


FIGURE 8. ANALOG I/O BOARD

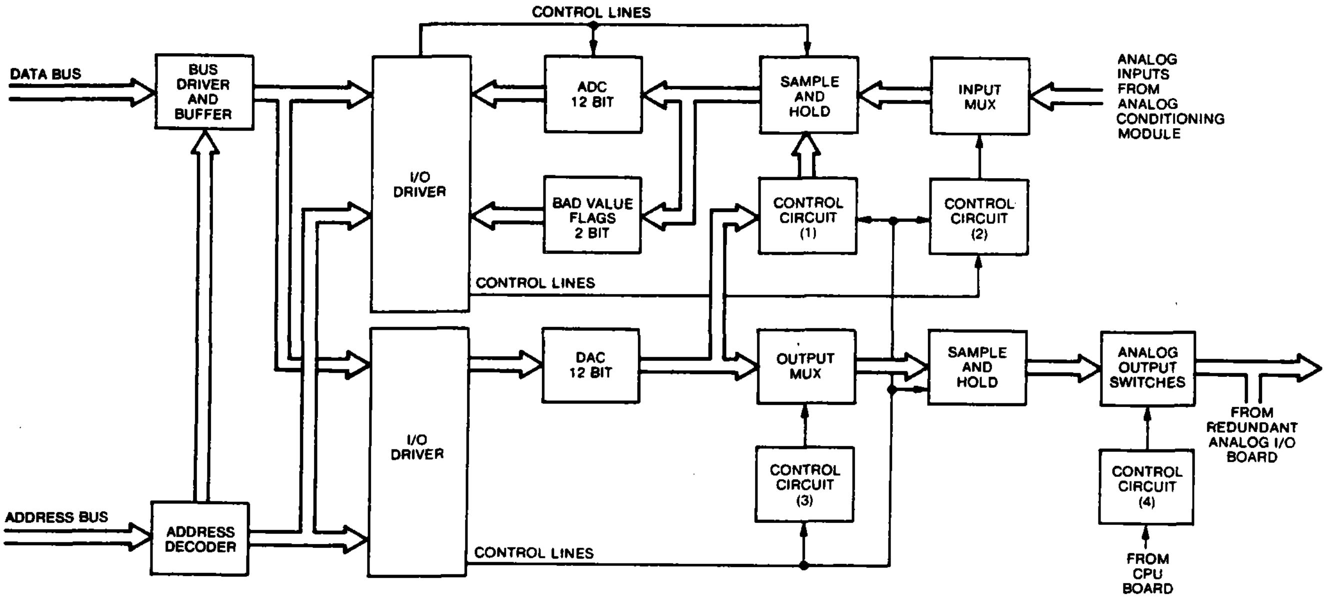


FIGURE 8A. ANALOG I/O BOARD

7. Analog Power Supply

The Analog Power Supply provides power for the analog components of the MVIO. It is a single unit dual supply which provides +15 and -15 volts DC.

8. Digital Input Board, Figure 9

The Digital Input Board is designed to optically isolate thirty-two (32) channels of digital input (Figure 9A). Each channel has a photo-transistor opto-isolator for an input to output electrical isolation of 1500 VDC. The input signal consists of a 20 mA current passing through an input diode via the external contact closure. The output voltage is a standard TTL 5 VDC signal to the MVIO Digital I/O Board. There are two of these boards in a fully loaded MVIO.

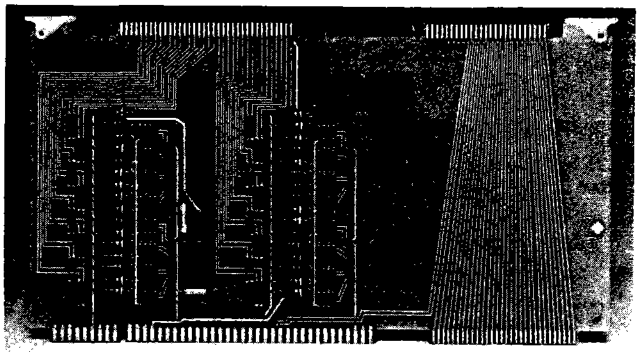


FIGURE 9. MVIO DIGITAL INPUT CARD

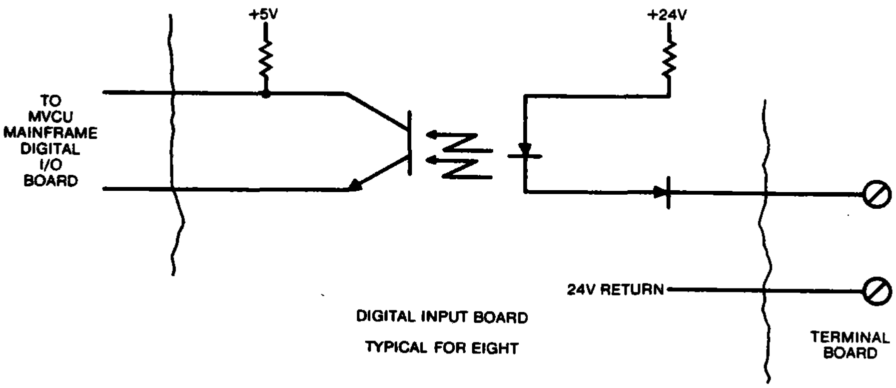


FIGURE 9A. DIGITAL INPUT BOARD

9. Digital Output Board, Figure 10

The Digital Output Board is designed to optically isolate thirty-two (32) channels of digital outputs (Figure 10A). Each channel has a photo-transistor opto-isolator for an input to output electrical isolation of 1500 VDC. The input signal from the MVIO Digital I/O Board is a standard TTL 5 VDC signal input to a buffer driver for the isolation diode. The output stage consists of an open collector transistor that will sink up to 100 mA from the isolated 24 volt power supply. There are two of these boards in a fully loaded MVIO.

10. Analog Input Board, Figure 11

The Analog Input Board is designed to condition sixteen (16) channels of analog input. Each channel consists of a single stage Buffer and Translator (Figure 11A).

The analog signal (1-5 VDC) is buffered by a differential input amplifier with a common mode voltage adjust and translated to a 0 to 10 volt DC signal utilizing a span and zero voltage adjust. There are two of these cards required for a fully loaded MVIO.

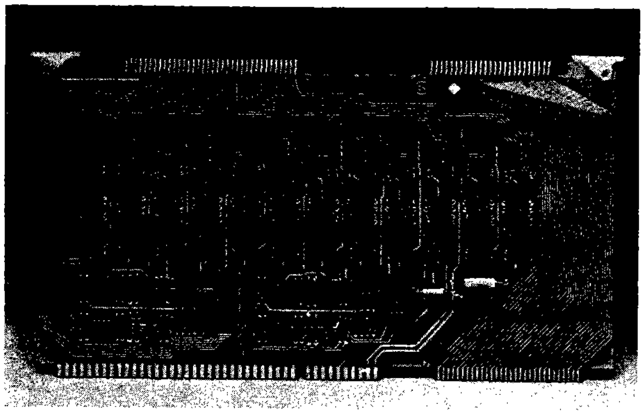


FIGURE 10. DIGITAL OUTPUT BOARD

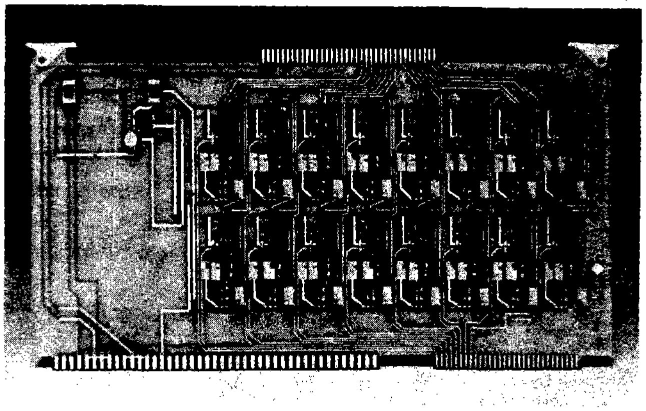


FIGURE 11. MVIO ANALOG INPUT BOARD

11. Analog Output Board, Figure 12

The Analog Output Board is designed to translate (0-10 VDC) from the MVIO Analog I/O Board to a 4-20 mADC output as shown in Figure 12A. Each board has the capability to output sixteen (16) separate channels. Each analog output channel consists of a voltage to current translator. There is one analog output board in a fully loaded MVIO. The analog outputs are non-isolated and can drive up to a 850 ohm load. Each output is diode protected for reverse voltage protection.

12. Transmitter Power Supply

The MVIO has a 24 volt power supply capable of supplying power for 32 4-20 mA two-wire transmitter loops. This supply voltage, which is routed to the Remote Analog Terminal Board, is individually fused to protect a complete shutdown of transmitter supply due to a short in a particular loop.

13. I/O Power Supply

The MVIO has a separate 24 VDC supply which provides power for the sixteen (16) current outputs, the sixty-four (64) digital inputs, and the sixty-four (64) digital outputs.

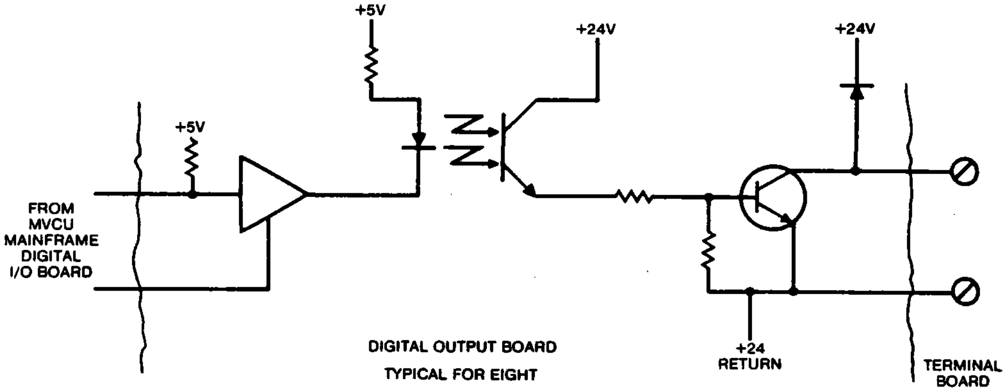


FIGURE 10A. DIGITAL OUTPUT BOARD

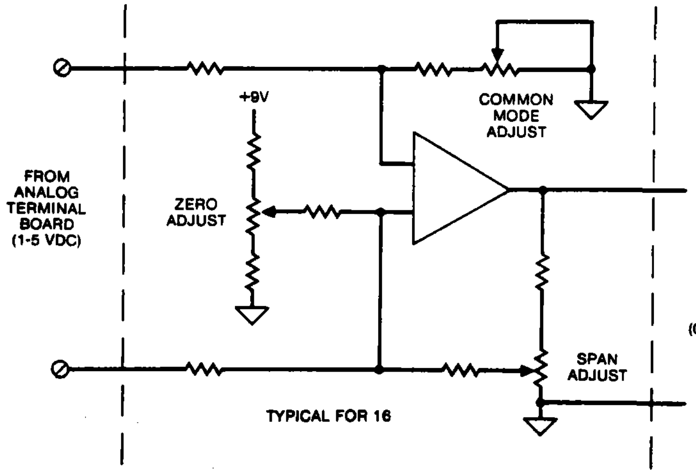


FIGURE 11A. ANALOG INPUT BOARD

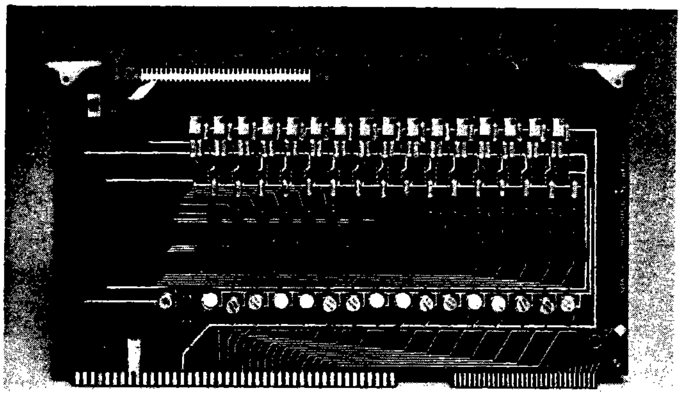


FIGURE 12. ANALOG OUTPUT BOARD

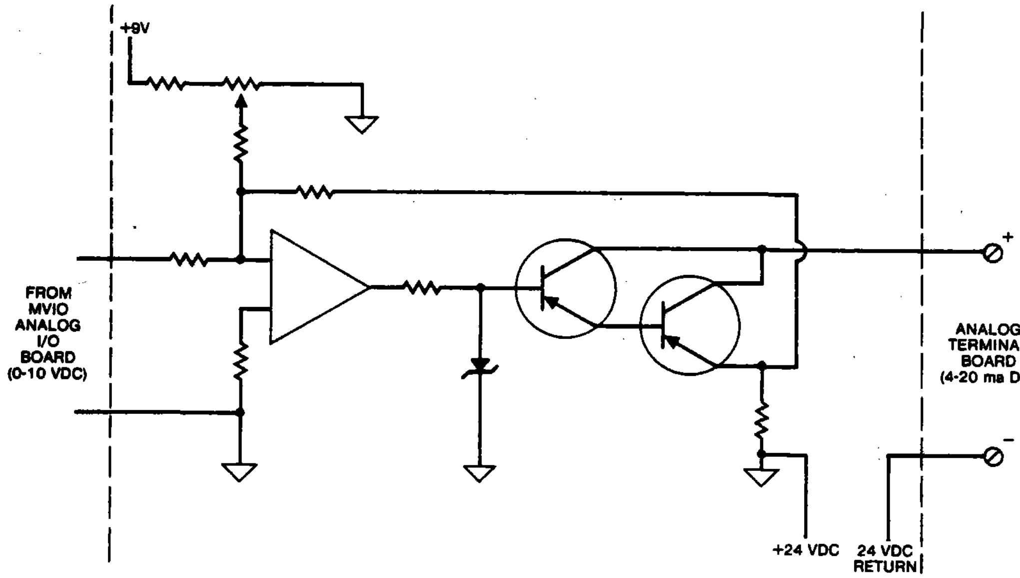


FIGURE 12A. ANALOG OUTPUT BOARD

B. Analog Terminal Panel

The Analog Terminal Panel is a 19-inch rack-mountable device which is cable connected to the MVIO. It provides terminal connections for all of the possible 32 analog inputs and 16 analog outputs. The terminal panel is normally mounted within fifty (50) feet of the MVIO. A picture of the panel is shown in Figure 13.

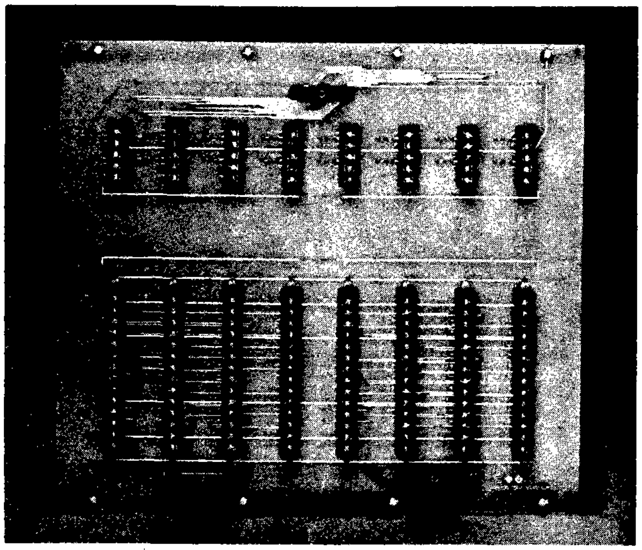


FIGURE 13. ANALOG TERMINAL PANEL

C. Digital Terminal Panel

The Digital Terminal Panel is a 19-inch rack-mountable device which is cable connected to the MVIO. It provides terminal connections for 32 digital inputs and 32 digital outputs. For a fully loaded MVIO, two Digital Terminal Panels are required. The terminal panels are normally mounted within fifty (50) feet of the MVIO. A picture of the panel is shown in Figure 14.

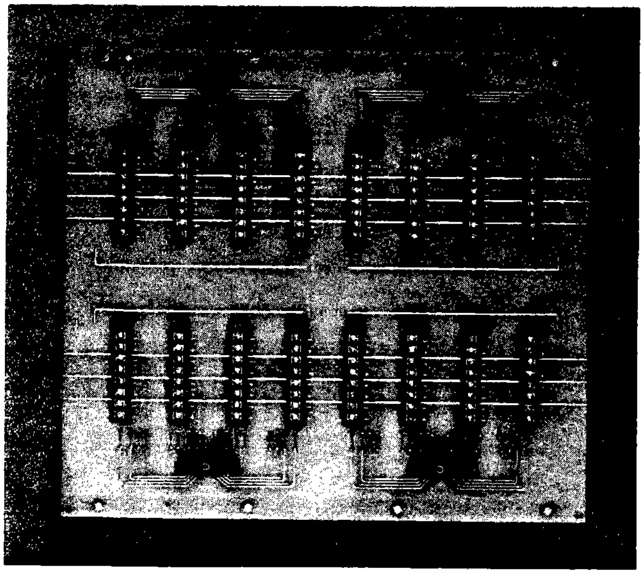


FIGURE 14. DIGITAL TERMINAL PANEL

III. ANALOG I/O TASK

The Analog I/O Task is responsible for the handling of analog inputs and outputs. This is done by managing two tables: The Analog Input Table and the Analog Output Table.

The software structure of the Analog I/O Task is shown in Figure 15.

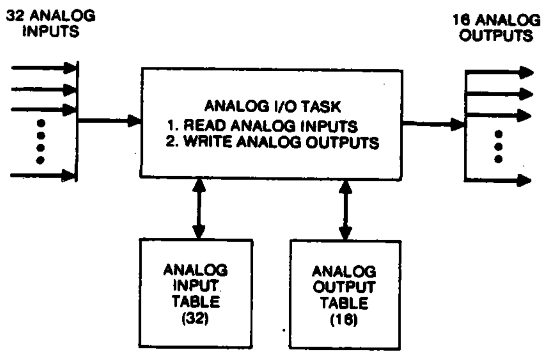


FIGURE 15. ANALOG I/O TASK

The Analog I/O Task executes every 0.1 second. During this time, 32 analog inputs are sampled via the analog to digital converter and stored into the Analog Input Table. Also, the values of the outputs which are held in the Analog Output Table are sent through the Digital to Analog converter to the Analog Terminal Board. The output table entries can only be loaded via the communication buses. All inputs are checked for bad values. A bad value is defined as an input which is either below 1 volt or above 5 volts. These bad value flags are stored and transmitted with the data.

A. Analog Input Table

As shown in Figure 15, the Analog Input Table contains the values of the 32 analog inputs. Each analog input is stored in two bytes (16 bits). This creates a storage of 64 bytes of data. The input data is actually a twelve bit number from 0 to 4095 decimal. Two of the remaining four bits are used for the bad value flags. The structure of the 16 bits is shown in Figure 16.

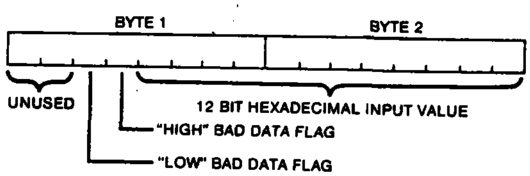


FIGURE 16. ANALOG INPUT DATA STORAGE STRUCTURE

B. Analog Output Table

As shown in Figure 15, the Analog Output Table contains the values of the 16 analog outputs. The values in this table are entered via the Communication Task (see Section V). This table is 32 bytes long and the data is stored as shown in Figure 16 except there are no bad value data flags.

IV. DIGITAL I/O TASK

The Digital I/O Task is responsible for the handling of digital inputs and outputs for the MVIO. This is accomplished by managing four tables: The Packed Digital Input Table; the Unpacked Digital Output Table; the Unpacked Digital Output Table; and the Packed Digital Output Table. The software structure of the Digital I/O Task is shown in Figure 17.

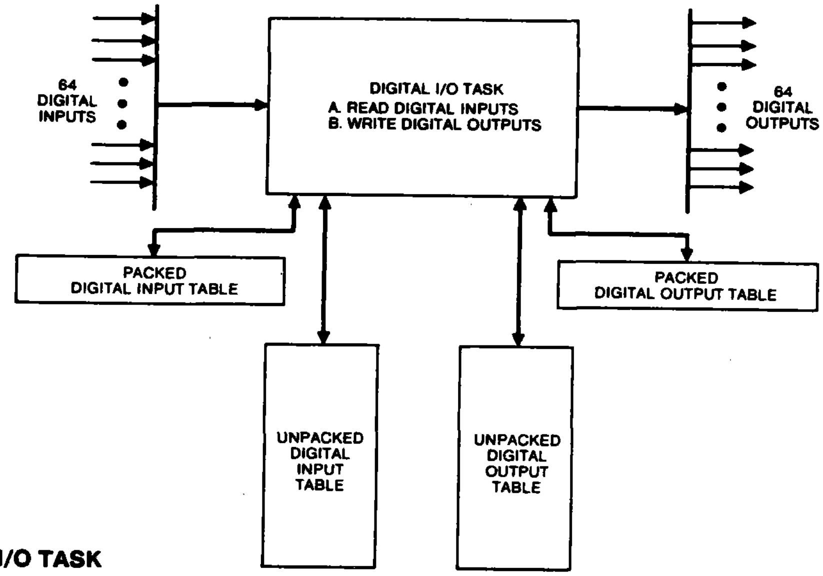


FIGURE 17. DIGITAL I/O TASK

The Digital I/O Task executes every one second. During this time, the 64 digital inputs are read and stored into the Packed Digital Input Table. This table is then unpacked into the Unpacked Digital Input Table. The digital outputs which are commanded by the communication buses are held in the Unpacked Digital Output Table, packed into the Packed Digital Output Table, and then outputted from the MVIO every execution cycle.

A. Packed Digital Input Table

This table is loaded by the Digital I/O Task. The table is 8 bytes long, thus creating a storage of 64 bits with each bit representing an input.

B. Unpacked Digital Input Table

This table is loaded from the Packed Digital Input Table. The table is 64 bytes long with the least significant bit of each byte representing the digital input value.

C. Unpacked Digital Output Table

This table is loaded via the Communication Task (see Section V). This table is 64 bytes long with the least significant bit representing the desired output value.

D. Packed Digital Output Table

This table is loaded from the Unpacked Digital Output Table. The table is 8 bytes long with each of the total 64 bits representing the MVIO desired output. The Digital I/O Task takes this table and drives the MVIO digital outputs.

V. MVIO COMMUNICATIONS

The MVIO communicates with the outside world via two identical serial buses. The baud rates are selectable from 110 to 9600. The MVIO responds identically to commands received over either bus. The MVIO is a passive device in that it only responds to communication commands; it does not initiate commands.

All messages to and from the MVIO start with a left bracket, [, and end with a right bracket,], in ASCII, between the start and end brackets are the message bytes. Each message byte is made up of two ASCII characters. The first character is the most significant hex digit and the second character is the least significant hex digit. The last byte before the right bracket is a checksum of the message string.

The following is a list of all communication requests to the MVIO:

READ MVIO Status
READ All Analog Inputs
READ All Digital Inputs (block transfer)
READ All Digital Inputs (individual transfer)
READ All Digital Outputs (block transfer)
READ All Digital Outputs (individual transfer)
READ MVIO Time
READ One Analog Input (1 to 32)
READ One Analog Output (1 to 16)
READ One Digital Input (1 to 64)
READ One Digital Output (1 to 64)
WRITE Time to the MVIO
WRITE One Analog Output
WRITE One Digital Output
ENABLE Opposite Bus
DISABLE Opposite Bus

VI. MVIO EXECUTIVE

The MVIO Executive is a software routine which controls and prioritizes the functions controlled by the MVIO. The functions are listed below in the order in which they are prioritized by the executive.

Analog I/O Task
Digital I/O Task
Communication Bus "A"
Communication Bus "B"
Memory Diagnostics

A. Analog I/O Task

The Analog I/O Task is the highest priority and it is executed every 0.1 second. The operation is described in Section III.

As part of the Analog I/O Task, diagnostics are performed on the Digital to Analog Converters (DAC) and the Analog to Digital Converters (ADC). This is accomplished by looping the output of the DAC into the input of the ADC and testing the following conditions:

1. Outputting and reading 100% value
2. Outputting and reading a 0% value
3. Outputting and reading a 50% value
4. Outputting and reading two alternating bit patterns

The results of these tests must fall within a 0.2% accuracy specification. If they do not, diagnostic flags will be set as described in Section VII.

B. Digital I/O Task

The Digital I/O Task is executed every second. The operation is described in Section IV.

C. Communication Bus "A"

Communication Bus "A" is operated when requested as long as tasks A and B above are not requested.

D. Communication Bus "B"

Communication Bus "B" is operated when requested as long as tasks A, B, and C above are not requested.

E. Memory Diagnostics

This is the lowest priority task in the MVIO and, therefore, is executed as "free" time is available. These tasks are:

1. Check sum on ROM Memory
2. Read/Write Addressing of RAM

VII. FAILURE DIAGNOSTICS

This section covers the conditions and resulting actions in conjunction with the MVIO. The possible diagnostic failures are listed below:

1. Deviation of more than ±6% on all supply voltages. This includes +5, -5, +12, -12, +15, and -15.
2. Memory diagnostic failure (Section VI).
3. ADC and DAC failures or out of spec performance (Section VI).

These failures can be determined in the hardware as well as by bus communication.

A. Hardware Diagnostics

The operation of the MVIO can be determined at the hardware level via the use of Light Emitting Diodes (LEDs).

On the front panel there are three LEDs. These are labeled and described as shown below:

Power Supply

Digital	This LED is "ON" when the +5, -5, +12, and -12 voltages are within tolerance.
Analog	This LED is "ON" when the +15 and -15 voltages are within tolerance.

System

Action	This LED is "ON" when the MVIO is passing all diagnostic checks.

Note: On the CPU Card internal to the MVIO, the Active and Selected LEDs are duplicated.

On the bus receiver card in the MVIO, the actual diagnostic routine that has caused the failure is encoded into three (3) LEDs. These three LEDs are coded in octal format as detailed below.

Octal Presentation	Description
0	No Problems
1	Unused
2	Unused
3	CPU Onboard RAM Failure
4	DAC/ADC Failure
5	CPU Onboard ROM Failure
6	Unused
7	CPU Failure

B. Software Diagnostics

All the information detailed under Hardware Diagnostics is also available over the communication buses using the READ MVIO Status Command.

CI 5. DATA ACQUISITION SYSTEM

(to be supplied)

CI 6. CONTROL CONSOLE

(to be supplied)

CI 7. INTERLOCK LOGIC

(to be supplied)

Table of Contents

CI10. COLLECTOR SYSTEM

CI10.1 Drawing 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 (Figure 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.

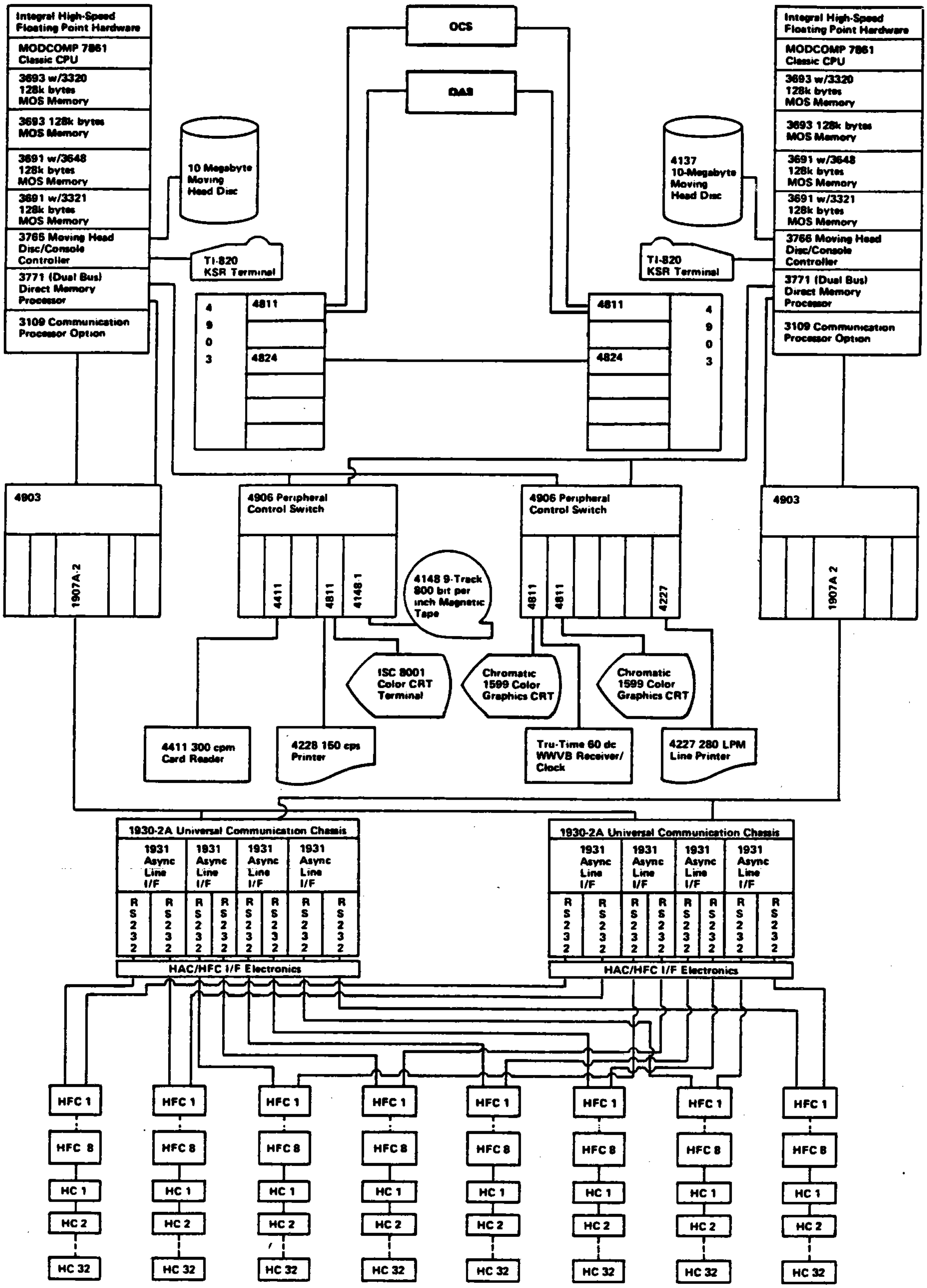


Figure CI10-1. Collector Control System

The HAC consists of two identical minicomputers with automatic switchover to the backup computer should the prime computer fail. Each computer has 512k 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.

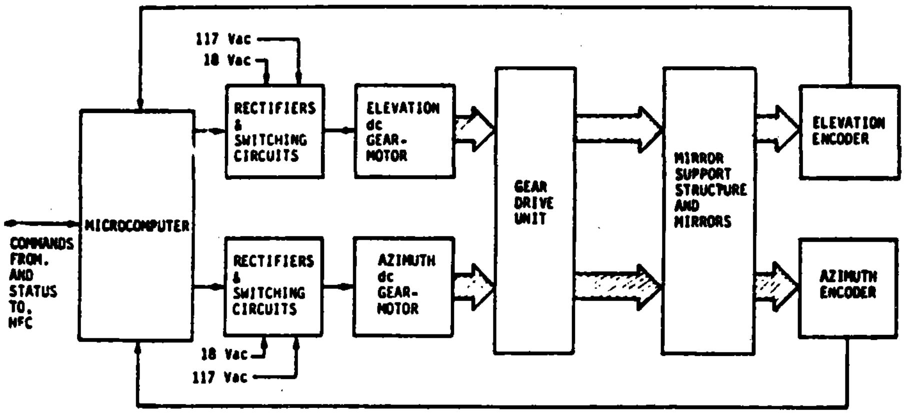


Figure CI10-2. Control System for Individual Heliostat

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 CLASSIC 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.

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 Asynchronous 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 Controller

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

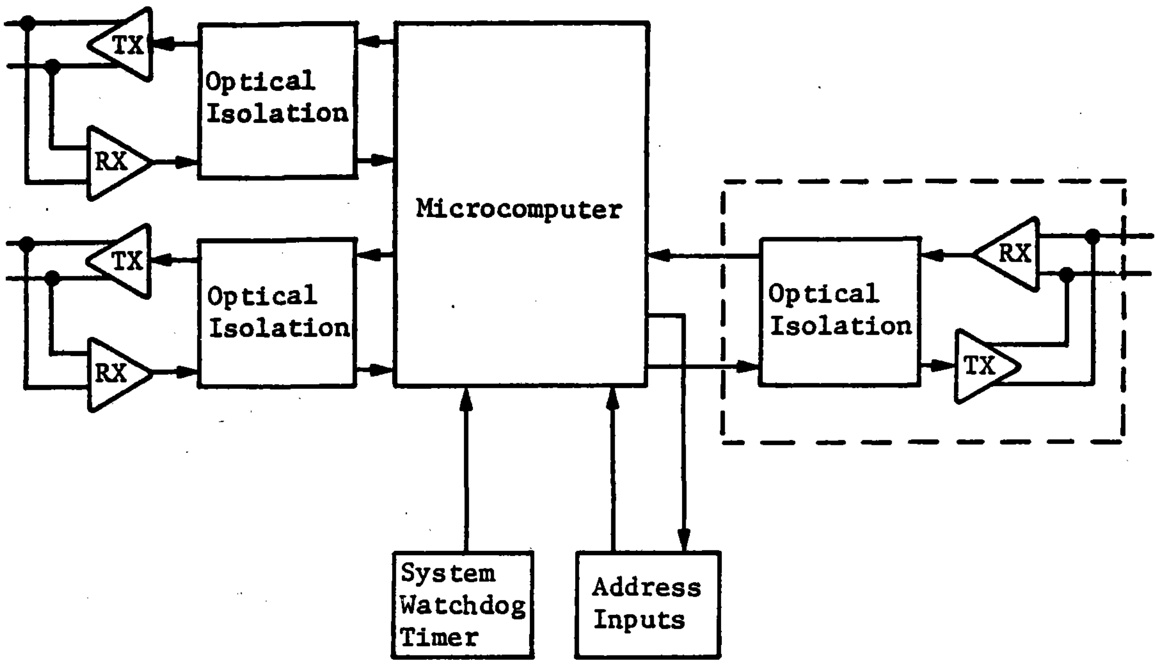


Figure CI10-3. Heliostat Field Controller

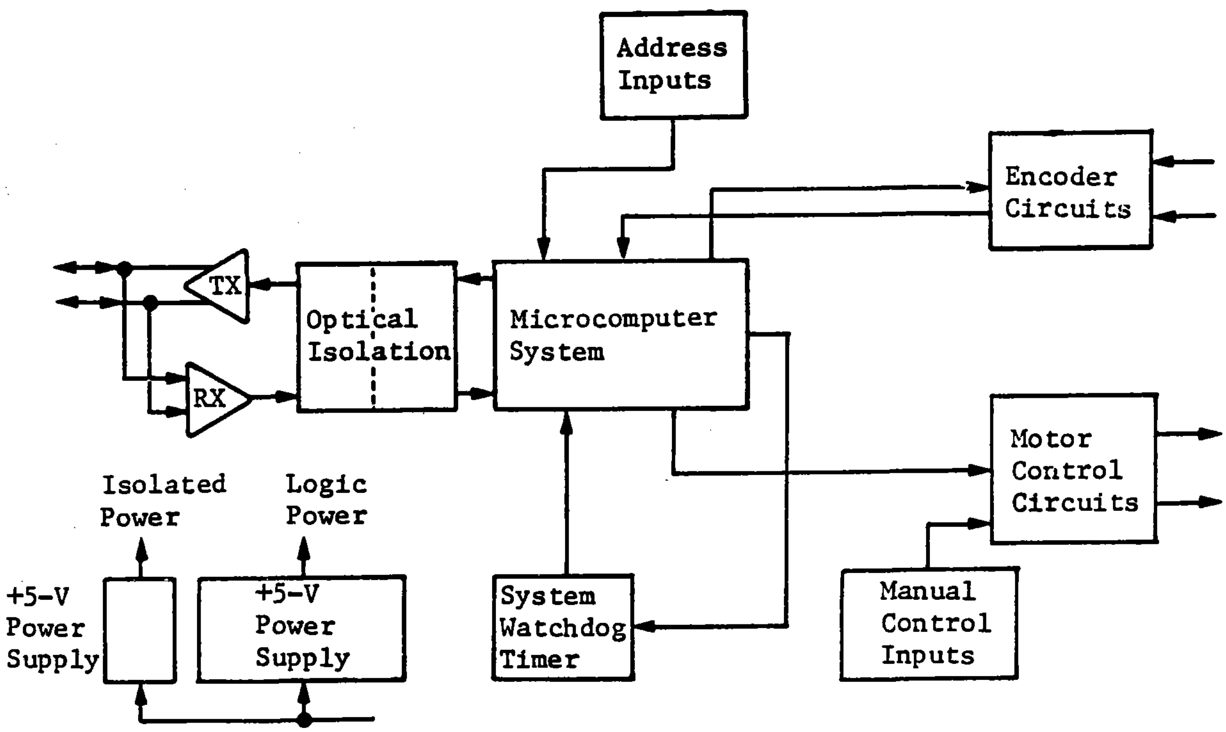


Figure CI10-4. Heliostat Controller

receives data from the bus, transmits data block when required, 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.

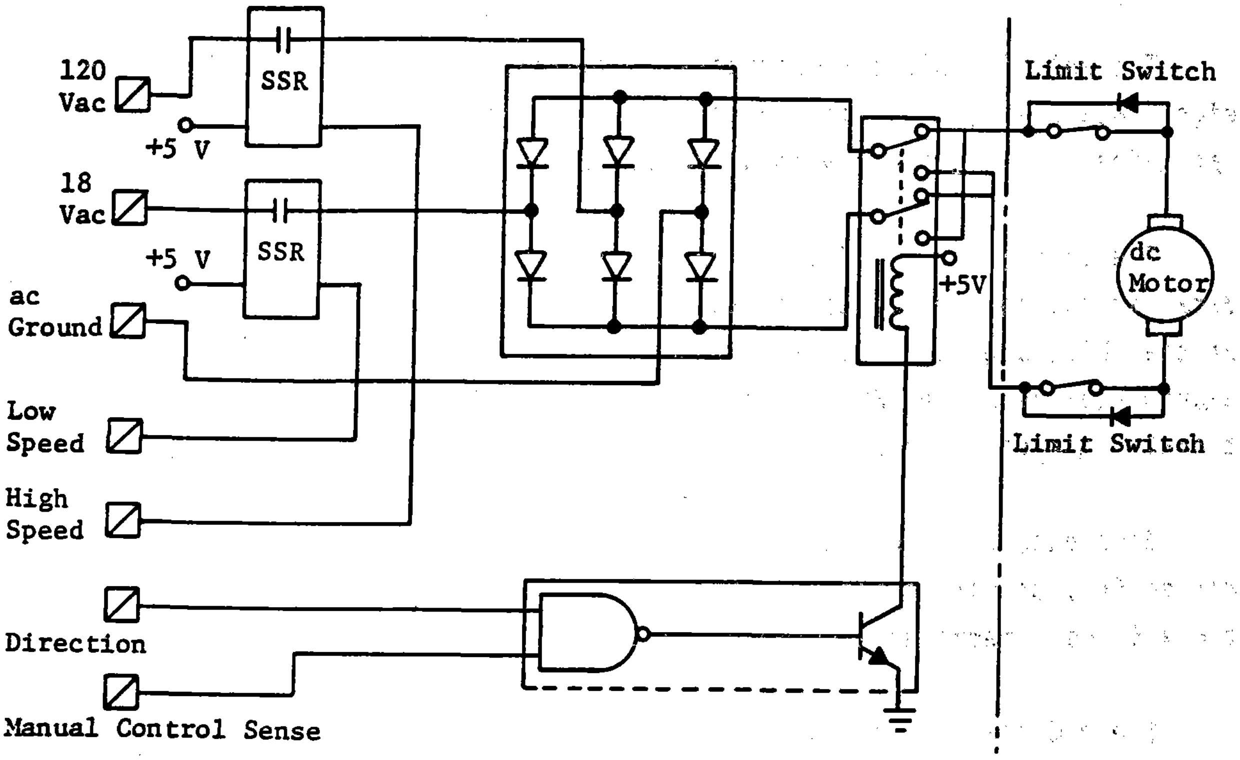


Figure CI10-5. Motor Controller

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 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 microcomputer in the Heliostat Controller, the microcomputer detects all incremental changes in the encoder output and stores a count that is the gimbal angle position.

CI 11. BEAM CHARACTERIZATION SUBSYSTEM

(to be supplied)

CIVIL – STRUCTURAL (CS)

Table of Contents

CIVIL-STRUCTURAL SECTION

(to be supplied)

CIVIL – STRUCTURAL (CS)

CIVIL –
STRUCTURAL

Table of Contents

CIVIL-STRUCTURAL SECTION

(to be supplied)

ARCHITECTURAL (A)

ARCHITECTURAL

Table of Contents

ARCHITECTURAL SECTION

(to be supplied)