CHAPTER 2

SYSTEMS DESCRIPTIONS

Section I. CONFIGURATIONS

2-1. General

a. The large EMCS consists of a CCU, memory, storage devices, I/O devices, a central communications controller (CCC), communications link terminations (CLT), DTM, FIDs, MUXs, instruments, and controls. The primary task of the CCU is to perform monitoring and control functions. The control functions require the execution of programs used to predict environmental conditions and rate of power consumption, calculate equipment operating setpoints, and produce supervisory control signals to operate equipment in the real-time environment. The CCU also accommodates the operator interface required for EMCS operation. Functions of the FID are to collect data and issue control commands to the local control equipment in the FID's data environment (DE). FIDs contain a microcomputer that performs local control, monitoring, and communications functions. Data from the FID is transferred via DTM to the CCU/CCC where it is utilized to perform supervisory control and monitoring functions, calculations, and alarm reporting. Point as referred to in this manual means any connected device such as a temperature sensor.

b. EMCS is classified into four configurations associated with the total number of points connected to the system, system function, and operational requirements. The system functions and operational requirements are factors in system selection, and the classifications will usually fall within the following ranges:

(1) Large EMCS in excess of 2,000 points.

(2) Medium EMCS with 200 to 2,500 points.

(3) Small EMCS with 50 to 600 points.

(4) Micro EMCS with less than 125 points.

c. Special terminology is used for subsystem components. Major components of EMCS consist of the following:

(1) CCU. A minicomputer or microcomputer, with memory for the operating system software, command software, and implementation of application programs. Computations and logical decision functions necessary to perform central supervisory monitoring and control are performed in the CCU. Data and programs are stored or retrieved from the memory or mass storage devices. The CCU contains interfaces for specific equipment, such as printers, cathode ray tube (CRT) consoles, magnetic tape system, and disk systems. During normal operation, the CCU coordinates operation of all other EMCS components, except safety interlocks.

(2) CCC. A second minicomputer identical to the CCU, which performs communications processing and is also required to continue system operation in the event of CCU failure. The CCC is required in large EMCS only.

(3) Communications link termination (CLT). Communications equipment interface between field equipment and Master Control Room (MCR) equipment.

(4) Operator's console. A CRT terminal and keyboard. It is the operator interface that accepts operator commands, displays alarms and data, and in large and medium systems, graphically displays systems connected to the EMCS.

(5) System terminal. An alphanumeric CRT terminal or a printer used by programmers to load the operating system, develop programs, run diagnostics, and support background processing.

(6) Alarm and logging printers. Printers to provide a permanent copy of alarm system operations, and historical data.

(7) Rigid disk system. High density random access mass storage device, with either fixed or removable storage media.

(8) MODEM. Device which allows communications over DTM.

(9) Flexible disk storage system. A medium density random access storage device, with removable storage media.

(10) System real time clock (RTC). A clock with battery backup that is used to synchronize system clocks at regular intervals.

(11) Failover controller. Switches CCU, CCC, and peripherals in the event of CCU or CCC failure into a backup mode of operation. The failover controller is required in large EMCS, to enhance reliability of the system.

(12) Magnetic tape system. A high density serial mass storage device.

(13) FID. A microcomputer based device with memory, I/O functions, communications, and power supply. The FID monitors and controls the DE, performs calculations and logical operations, accepts and processes system commands, and is ca-

pable of stand-alone operation in the event of CCU, CCC, or DTM failure.

(14) Multiplexer (MUX). A device which combines data from a number of points in the DE and communicates with its associated FID. It also performs demultiplexing of commands received from the FID. The MUX is functionally part of the FID and can be in the same enclosure or remotely located.

(15) Memory protect power supply. Independent CCU/CCC back-up power supply to maintain volatile memory contents for at least 20 minutes.

(16) Data Terminal Cabinet (DTC). A device used as the interface point between FID/MUX and the DE.

(17) Dial-Up Telephone MODEM. A MODEM used for auto-answer connection of the EMCS for performing remote diagnostics, and for acquiring data from the system.

(18) Data Transmission Media (DTM). A communications link such as wirelines, fiber optics, coaxial cable, or radio frequency transmission.

(19) FID Test Set. A unit consisting of a FID, MUX, and a DE simulator panel. It is required for installation in the MCR for simulation tests and checkout.

(20) FID/MUX portable tester. A unit for local programming, and bulk loading diagnostic testing of all FID/MUX functions.

(21) Power line conditioner (PLC). A constant voltage transformer used at the MCR, FID and MUX to regulate voltage and provide noise isolation.

2-2 Large EMCS

a. A large EMCS, *in excess of 2,000 points,* consists of the following major components. Refer to figure 2-1 for a typical configuration.

(1) CCU utilizing computer system with 16 bits minimum word size.

(2) CCC utilizing computer system with 16 bits minimum word size.

(3) Color graphics CRT based operator's console (2 required).

(4) Alphanumeric CRT or printer based system terminal.

(5) Alarm printer.

(6) Logging printer.

(7) Rigid disk system for the CCU, and an identical rigid disk system for the CCC.

(8) Magnetic tape system.

(9) System RTC.

(10) Failover controller.

(11) FID, MUX, and DTC.

(12) CLT.

(13) DTM.

(14) PLCs.

(15) Dial-up telephone MODEM.

(16) FID test set.

(17) FID/MUX portable tester.

b. Distributed processing architecture is required.

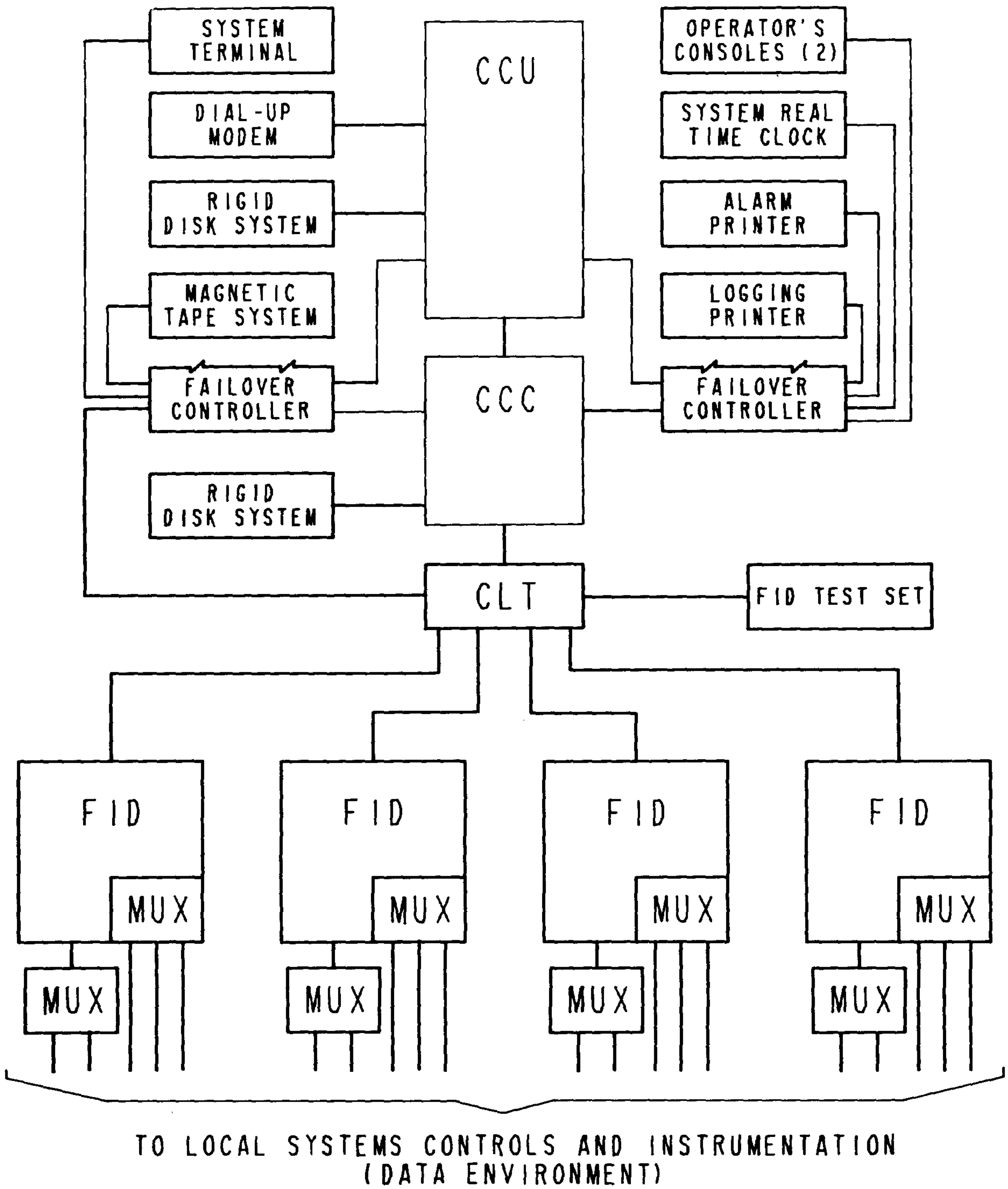

Figure 2-1. Large EMCS block diagram.

2-3. Medium EMCS

a. A medium EMCS, *approximately 200 to 2500 points,* consists of the following major components. Refer to figure 2-2 for a typical configuration.

(1) CCU utilizing computer system with 16 bits minimum word size.

(2) Color graphics CRT based operator's console (2 required).

(3) Alphanumeric CRT or printer based system terminal.

(4) Alarm printer.

(5) Logging printer.

(6) Rigid disk system.

(7) Magnetic tape system.

(8) System RTC.

(9) MUX, and DTC.

(10) CLT.
(11) DTM.
(12) PLCs.
(13) Dial-up telephone MODEM.
(14) FID test set.
(15) FID/MUX portable tester.

b. Distributed processing architecture is required, but no CCC for CCU backup operation is provided.

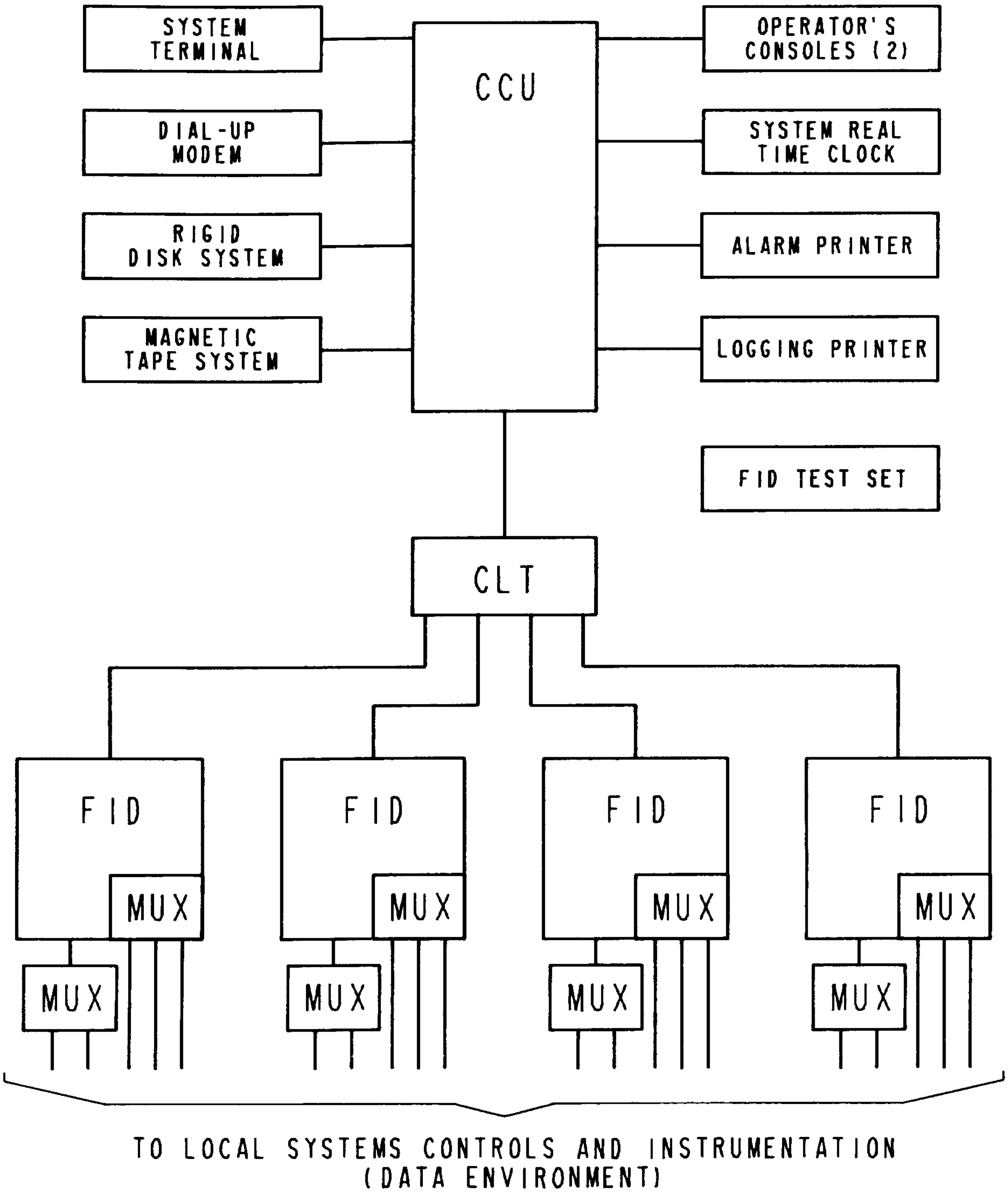

Figure 2-2. Medium EMCS block diagram.

2-4. Small EMCS

a. A small EMCS, *approximately 50 to 600 points*, consists of the following major components. Refer to figure 2-3 for a typical configuration.

(1) CCU utilizing computer system with 16 bits minimum word size.

(2) Alphanumeric CRT based system console.

(3) Alphanumeric CRT or printer based system console.

(4) Alarm printer.

(5) Logging printer.

(6) Rigid disk system.

(7) Magnetic tape system.

(8) System RTC.

(9) MUX and DTC.

(10) CLT.

(11) DTM.

(12) PLCs.

(13) Dial-up telephone MODEM.

b. The system architecture is centralized processing.

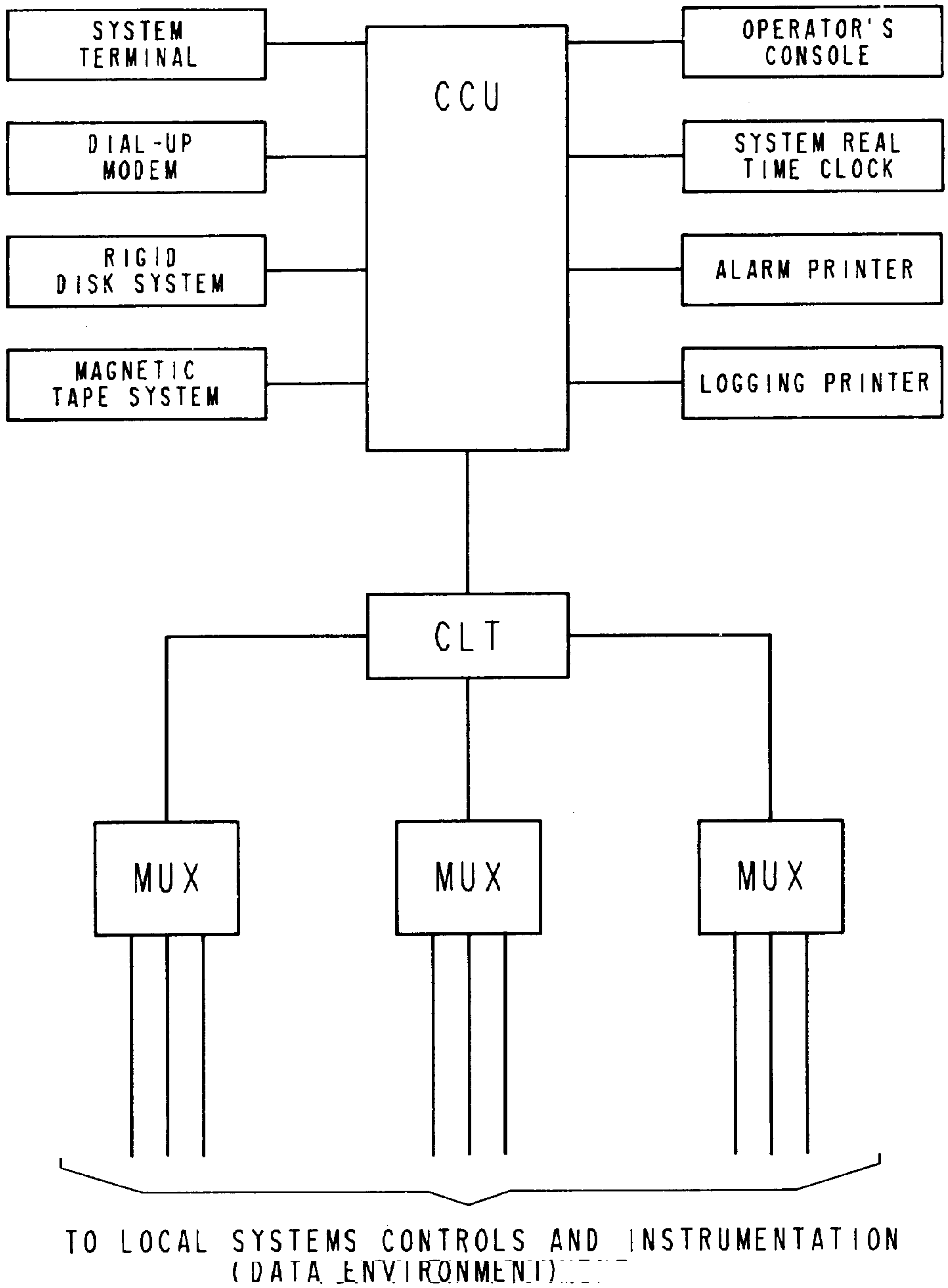

Figure 2-3. Small EMCS block diagram.

2-5. Micro EMCS

a. A micro EMCS, *less than 125 points,* consists of the following major components. Refer to figure 2-4 for a typical configuration.

(1) Microcomputer based remote control unit (RCU).

(2) Alphanumeric CRT based operator 's console.

(3) Printer.

(4) Telephone MODEMs.

(5) Portable tester.

(6) PLCs.

(7) Dial-up telephone circuits for DTM.

b. A single remote operator's console may communicate with multiple RCUs.

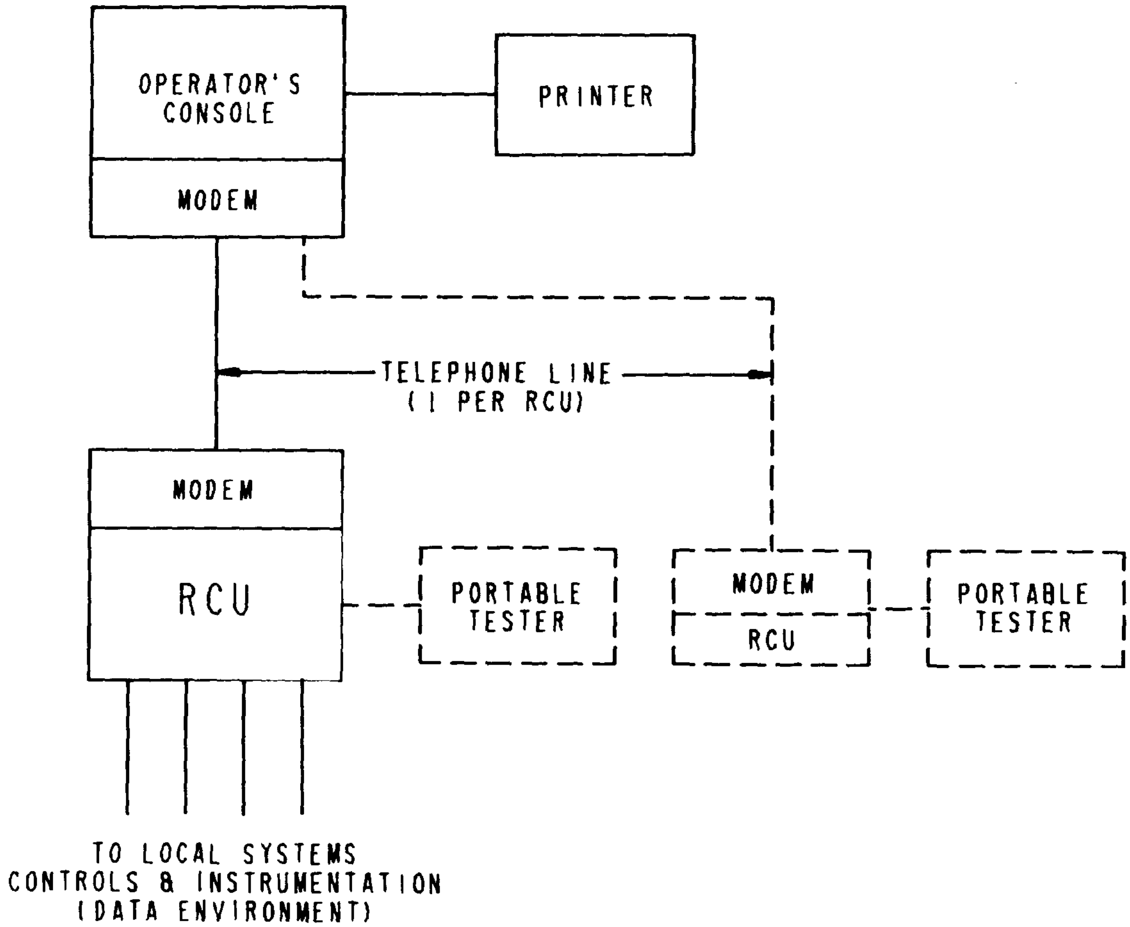

Figure 2-4. Micro EMCS block diagram.

Section II. MASTER CONTROL ROOM (MCR) EQUIPMENT

2-6. General

a. The MCR is an area containing the CCU, CCC, operator's consoles, system terminal, mass storage devices, printers and other peripheral devices required for each EMCS. The MCR location, although site specific, will be in a clean environment near the maintenance, service, and operations center. Environmental conditions in the MCR will be maintained between 70 and 75 degrees F, and between 40 and 60 percent relative humidity. The MCR will be adequately sound- proofed to attenuate noise from printers, equipment fans, and other noise generating devices. Lockable space will be provided for storage of test equipment, spare parts, and other auxiliary equipment. Printers and operator's consoles will be installed separately from the central computer and disk drives for noise control. Adequate space will be provided to allow supplier servicing of the MCR hardware. Typically a clear zone of three feet is required front, rear, and sides of cabinets. Fire protection for the MCR equipment will be provided as required by the agency's current guidelines. The MCR area for the MICRO system consists of tabletop space in an office environment in or near the maintenance, service, and operations center. Figure 2-5 illustrates the type of MCR layout required.

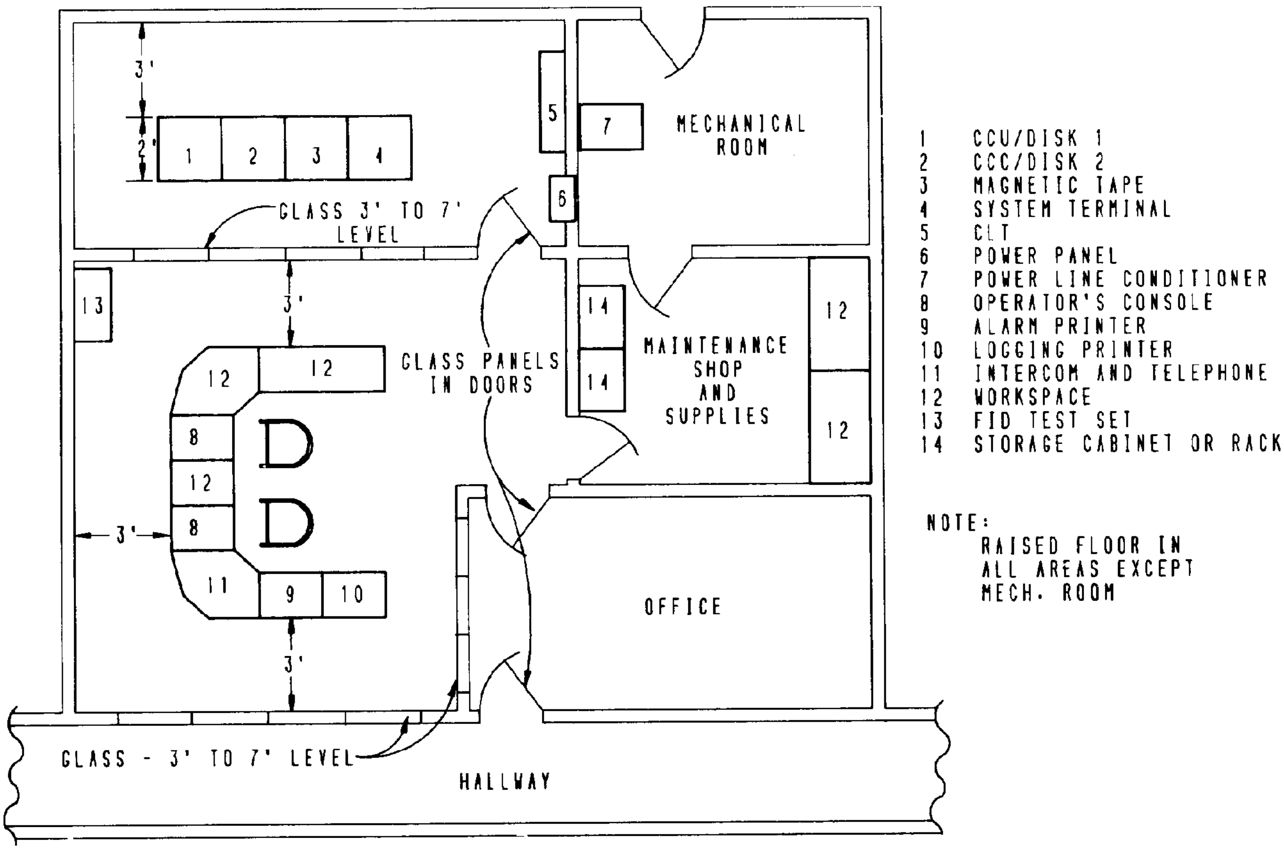

Figure 2-5. Typical MCR layout.

b. A single MCR is adequate for an entire facility. The capabilities of any existing CCU, operational problems, and current state-of-the-art will be analyzed to determine if any existing MCR equipment is to be saved.

c. Where printers and operator's consoles are required to be installed remotely from the CCU/CCC, the data transmission rate will equal or surpass the required data rate for each peripheral, but at a minimum of 1200 baud in order to provide timely data updates.

2-7. CCU

a. The CCU functions as the overall system coordinator, performing automated energy management functions, complex calculations, control of peripheral devices, operator interface, alarm reporting, and events logging.

b. The CCU is a complete computer system consisting of a central processing unit (CPU), main memory, I/O bus, and time base generator (TBG).

c. The CCU's system software handles the tasks of program development, editing, compiling, and providing rapid access to online programs and data. An operator's console must be provided as a part of the system, allowing the operator to interact with the system in a manner not requiring expertise in programming. The system response to operator commands includes error messages, informing the operator of improper commands, and prompting questions and instructions which aid the operator in system operation.

d. When the CCU senses a power failure, it must initiate an orderly shutdown and store essential data in semiconductor memory with battery backup or on mass strorage systems. Programs, CPU status, and register contents are protected against a power outage by the battery backup. Restart after power failure must be accomplished automatically.

e. For initial EMCS startup, a bootstrap program designed to bring the system to an initial ready state is required. After loading a bootstrap program, the operator is able to manually start the system with the proper operator command.

f. In the system configuration of figure 2-1, failure of the CCU results in transfer of most peripherals to the CCC. System operations continue, and all functions normally performed by the CCU are performed by the CCC. Transfer of CCU functions to the CCC (CCU backup mode) must be automatic without requiring operator intervention. Return to the normal mode of operation must be accomplished manually by the operator. The CCU acts as a backup to the CCC in the event of CCC failure. Upon CCC failure, the CCU must perform the CCC communications functions in addition to its usual functions. In each backup mode, system response time may be longer, and applications software programs may be executed at a slower rate.

2-8. CCC

a. The CCC functions normally as a communications device which reformats, buffers, performs error checking and retransmission of data transmitted between the CCU and FIDs, and communicates at high speed with the CCU. In the event of a CCU failure, it provides backup as previously described in 2-7 *f* above.

b. The CCC relieves the CCU of time consuming communications with the FIDs, allowing the CCU to devote its full capabilities to the execution of control and monitoring functions.

c. The CCC is a minicomputer system identical to the CCU.

d. In medium, small, and micro EMCS configurations, the communications functions are handled by the CCU and no separate CCC is required.

2-9. CLT

The CLT includes MODEMs and other line terminations required for interface to the CCC/CCU. Signal conditioning to maintain the required signal quality must be performed at the CLT.

2-10. Memory protect power supply

a. The CCU, CCC, and mass storage devices must have power-fail logic so the MCR equipment will be shut down in an orderly manner upon a power failure. The orderly shutdown "saves" all software and data.

b. All volatile memory in the MCR must have a battery backup of sufficient capacity to maintain memory for 20 minutes when power fails, unless a separate uninterruptible power system is included in the MCR design.

2-11. System real time clock (RTC)

a. A battery backed uninterruptible system RTC will be included in the EMCS. This system RTC coordinates all time and provides information for updating all system clocks at least once a day. Upon start-up of power after a failure, the system RTC provides the data for automatic reset of all system clocks, thus updating all time dependent pro- grams. Clock function in FIDs must also have battery backup.

b. The system RTC must have provisions for resetting to accommodate daylight saving time, extended power outages, and other system or clock failures which may occur.

2-12. Rigid disk systems

a. Cartridge disk systems. Magnetic cartridge disk systems are used to store the EMCS system, command, and applications programs. They are also used to archive data bases, historical data, and reports. Removable magnetic cartridge disk systems provide random access mass storage.

b. Winchester disk systems. Winchester disk systems may be used to store the EMCS command and applications programs. Winchester disk technology is similar to the magnetic cartridge disk, except that is consists of a sealed media, including disk and heads. These disk systems provide large storage capacities at lower cost per byte of storage than the cartridge disk systems. The increased recording density is made possible by advanced head design and new disk coatings, which combine to allow extremely small clearance between the disk and the head. Winchester disks are more reliable than cartridge disks because of manufacturing and component advancements, as well as the sealing of the media. A magnetic tape system must be provided for backup of the disk software and data.

c. Spare cartridge disk. A spare formatted cartridge disk must be readily available at all times containing the system, command, and applications software, including all database information. The spare disk should be updated at regular intervals by the operator, at least monthly, so it will contain all of the current software and database information.

2-13. Magnetic tape systems

a. Nine track magnetic tape systems store data sequentially, typically 2.5 to 15 megabytes on a reel. Data retrieval is slower than from a random access disk system. These systems are useful where large amounts of historical data need to be accumulated, but will only be accessed periodically. The primary reasons for using a magnetic tape system are to store large amounts of historical data which can be used to demonstrate proof of energy savings or cost avoidance, and to provide archival storage for software and data. One of the most important characteristics of nine track magnetic tape is its transportability. Although many different recording formats and densities exist, the 9 track, 45 inches per second, 800/1600 bits per inch, (9 track, 45 ips, 800/1600 bpi) will be specified.

b. Magnetic cartridge tape systems are removable magnetic tape cartridges for data storage. They can typically store 30 to 100 megabytes.

c. Streaming magnetic tapes are high speed magnetic tape media which pass through the system one time only for entering programs and data, and for backup of disks.

2-14. Printers

a. Large, medium, and small systems will be equipped with two printers. One printer is dedicated to alarm reporting, the other to logging of data and report printing. Printers must be capable of being reassigned, providing backup to each other. Should either the alarm printer or the logging printer fail, the other printer, upon reassignment, must assume the duties of both. Since alarms have higher priority and must be printed before any other information, data logging and reports may have to be temporarily stored by the CCU for printout at a later time. Micro systems are equipped with one printer that performs the alarm reporting and logging functions.

b. A character printer prints one character at a time, while a line printer prints an entire line or a block of characters at once. Character printers with minimum speeds of 150 characters per second (CPS) must be used for most EMCS applications because of the volume of data that is printed under normal operating conditions.

2-15. Operator's console

a. In large and medium EMCS, an eight color, microprocessor based graphic CRT terminal is the primary operator-machine interface. The console must be able to graphically display equipment schematics, system status, operating parameters, and equipment operating data. The operator’s console must contain a dedicated keyboard for entry of operator commands. Graphic displays may be brought up automatically when an alarm is activated, or upon operator command. The operator's console is located in the MCR. The operator’s console must be on-line to provide the operator interface to the system at all times.

b. In large and medium EMCS, redundant operator’s consoles are required.

c. In small EMCS, the operator's console is an alphanumeric CRT with no graphics capabilities.

d. In micro EMCS, the operator's console is a personal computer.

2-16. System terminal

The system terminal allows a programmer to perform applications software diagnostics, perform system generation functions, and develop or modify applications programs. The system terminal is physically located with the CCU, and is not intended to be used to enter operator commands. It may be either an alphanumeric CRT or printer, depending on the supplier's requirements.

2-17. Failover controller

a. The failover controller is included for automatic and manual switching of the CCU, CCC, and peripherals to a backup mode of operation in the event of CCU or CCC failure.

b. In the configuration of figure 2-1, the failover controller will transfer the communication link to the CCU as a backup for CCC failure. CCU failure results in the failover controller automatically connecting selected peripherals to the CCC. Return to normal mode operation must be accomplished manually by the operator. Some or all of the failover controller functions may be accomplished by software, depending upon the system manufacturer's standards.

2-18. MCR dial-up MODEM

A dial-up MODEM with auto answer and manual originate capabilities is to be used for remote interface between the CCU and a remote location, such as the EMCS supplier’s diagnostics facility. The MODEM's auto answer capabilities allow the supplier to perform system diagnostic checks and programming from the supplier's facilities. The MODEM's manual originate capabilities allow on-site maintenance personnel to communicate with the supplier's home office to transmit data as required to resolve field problems.

2-19. MCR PLC

The MCR equipment will include a PLC that protects the equipment from power line fluctuation and noise which can result in computation error erratic operation, loss of data, overheating, circuit burnout and in some cases, computer shutdown. The PLC provides attenuation of the power line noise by the use of isolation transformers. The PLC provides a constant voltage source by the use of solid state regulators that provide fast response to changes in incoming voltage or load conditions.

2-20. Intercommunications systems

An intercom system will be used to communicate with field personnel while performing checkout, maintenance, and troubleshooting tasks for EMCS. The intercom system can also facilitate the check-out and acceptance of the EMCS by providing communication between FID locations and the MCR. Implementation of an intercom system will require dedicated circuits between the MCR intercom and each intercom station, or the encoding of voice communications on the DTM. Hand held FM radio units are an alternative to intercommunications systems.

2-21. Interface and future expansion

When specifying the CCU, provision must be made for additional peripherals such as CRTs and printers which may be required in the future when expanding or modifying the EMCS. Additional I/O ports must be provided for a printer and a CRT. Hardware and software communication protocol documentation, required for hardware and software, must be provided by the original system manufacturer. If future planning at the facility indicates an expansion, costs for the larger system can be deferred to the future project by installing a medium or small system; or, depending on agency criteria and cost trade-offs, it may be more prudent to initially procure the MCR equipment for the larger system

2-22. MCR console and accessories

The MCR will contain necessary accessory equipment to support operation of the system, including a metal desk type console, swivel chairs with casters, paper trays for printers, and storage enclosures for test equipment, magnetic disks, magnetic tapes, printer paper and other supplies. The MCR console will contain sufficient surface area for the operator's consoles and work area. Equipment cabinets and accessories must be color coordinated.

2-23. Support equipment

a. A PROM programmer enables operating or service personnel to program the FIDs that utilize PROM with permanent on-line programs.

b. A FID test set, consisting of a FID/MUX and DE simulator, is part of the system to be installed in the MCR, enabling the operator to simulate and display the operation of a FID/MUX. Analog and digital sensor input conditions must be adjustable from the simulator's control panel. The simulator receives a control signal from the FID and returns a feedback signal, simulating the performance of various analog sensors or digital monitors by use of this device, the operator will be able to study system response when new control routines or sensors are implemented, and verify the performance of existing equipment.

c. A FID/MUX portable tester provides for diagnostics, programming, and bulk loading functions for connection to a FID or MUX. The tester must include a keyboard, display, and mass storage device sufficient to perform all required diagnostics and exercise all points.

Section III. FIELD EQUIPMENT

2-24. General

The field equipment consists of FIDs, MUXs, DTCs, PLCs, instrumentation, and controls. The field equipment is located in the vicinity of the DE monitored and controlled by the EMCS.

2-25. FID

a. A FID contains a microcomputer consisting of a Micro-processor, Real Time Clock (RTC), communication interface, digital and analog I/O, controls, indicators, and power supply. Normally, the FID communicates with the CCU/CCC, where the CCU provides updated operational parameters and accepts information for alarm reporting, logging of events, generation of reports, and display. The FID must also function in a non-communicating (standalone) mode performing the same monitoring and control routines using applications software pro-grams and operating parameters stored in the FID's memory.

b. The FID collects data from instruments within its DE and generates commands to control operating devices such as analog controllers, electric motors, valves, and relays. The FID’s capabilities include control of all physical parameters such as space temperature, space humidity, and supply water temperature without requiring data or operating parameters from the CCU. The FID also responds to CCU requests for equipment operating data and status. The FID transmits alarms to the CCU for conditions such as high and low temperatures, pressures, flows, unauthorized equipment operation, or FID malfunction. Commands from the MCR operator's console and the CCU software cause downloading of new or revised parameters to adjust setpoints or change operating parameters of equipment.

c. The FID must include memory of sufficient capacity to contain the operating system and applications software for necessary operation. Volatile memory is required to have backup batteries. Software and data stored in non-volatile memory do not have to be downloaded from the CCU when an interruption of power occurs.

d. The FID must be equipped with a battery backed internal RTC function to provide a time base for implementing time dependent programs. The FID RTC function must be updated by the CCU at least once a day and upon resumption of communications with the CCU after a DTM interruption.

e. A MODEM in the FID converts the digital output of the FID to a signal compatible with the site specific DTM for communications with the CCU/CCC. The MODEM must transmit and re ceive data at rates sufficient to support system re sponse requirements over the DTM.

f. Resumption of power after an outage must cause the FID to automatically restart and estab lish communications with the CCU/CCC. If the FID is unable to establish communications, it must automatically enter the noncommunicating mode of operation. A FID low battery condition must cause the FID to revert to or remain in the required failure mode. FID Shutdown based on a self-diagnosed failure in the power supply, hardware, or software must set the controlled equipment to the required failure mode as defined in the I/O summary tables. FID or MUX failure must generate an alarm message to the CCU.

g. In the relatively unusual situation where the FID will be required to continuously collect data to be transmitted to the CCU, it will be necessary to provide an uninterruptible power supply (UPS) in lieu of the PLC for the entire FID as well as any sensor power required.

h. The FID functionally includes the MUXs associated with it whether in the same enclosure remotely located.

2-26. MUXs

MUXs serve as I/O devices for a FID and for its DE, and are functionally an extension of the FID. The number of remote MUXs connected to single FID is limited only by the maximum number of points addressable by a FID, the number of points allowed on a single DTM, or by the alarm response time. Remote MUXs transmit their data to the FID via MODEM or line drivers. The MUX contains I/O functions to handle digital and analog data, digital data error detection, and message transmission. Failure of a MUX must return the controlled equipment to a predetermined failure mode as defined in the I/O summary tables. MUXs will have an UPS to sustain operation during a power failure, in those unusual situations where their associated FIDs require an UPS for complete operation.

2-27. I/O functions

Electronic circuits enable the EMCS to interface with the DE instrumentation and controls. Instrumentation signals from the DE to the FID/MUX are either digital or analog signals. Control signals to the DE from the FID/MUX are converted into digital or analog commands. Analog data to and from the DE must be conditioned to ensure signal level and type compatibility between the I/O functions and the DE instrumentation and control. Digital inputs include contact closures of limit switches, flow switches, temperature switches, and pressure switches. Digital outputs include on/off commands to relays, motor starters, or solenoid valves. Analog outputs include commands such as remote reset of analog controllers. Analog inputs include measurements from temperature, humidity, pressure and flow sensors.

a. Analog input (Al) functions. Instruments monitoring physical properties such as temperature, flow, and pressure, require circuitry to convert the analog measurement to digital data. The Al function is designed to accept analog signals when measuring parameters such as temperature, flow, and pressure, and convert each to a digital quantity usable by the system.

b. Analog output (AO) functions. The AO functions is the interface between commands generated by the FID/MUX and the controlled equipment. The FID/MUX commands are converted to an analog value which is compatible with individual controllers or local loop controls.

c. Digital input (DI) functions. The DI function provides interfacing between field equipment on/off or two-state indicators and the FID/MUX. DIs monitor both momentary and maintained contracts, and serial digital pulses from electrical power meters.

d. Digital output (DO) functions. The DO function interfaces output signals between the FID/MUX and field controls that require digital commands. DOs are capable of performing momentary or maintained switching. This allows incremental control of setpoints, and momentary contact closures for devices such as motor starters, or maintained contact closures for devices such as electric heaters, solenoid valves, and lighting.

2-28. Field PLC

Electrical power for FIDs and MUXs will be obtained from a PLC with operating capabilities similar to the MCR PLC. The locations in which the FIDs and MUXs are commonly found contain elector-mechanical rotating equipment that generates voltage fluctuation and power line noise that requires the use of PLCs.

2-29. Control devices

a. It is necessary to add output devices of various types to allow the FID/MUX to override or modify the local loop control system operation. Local loop control of the building systems will be performed by the existing local control systems. Existing local control systems, when correctly interfaced to the FID, will fail to a predetermined mode of operation in the event of FID/MUX failure. Output devices include the following types:

b. Electrical relays are operated in a maintained, momentary, magnetically held, or latching configuration by an output from a Do in the FID/ MUX to operate equipment directly or through contractors. The most common types of relays for EMCS applications are time delay relays, latching relays, and solid state relays.

(1) Time delay relays operate so that there is a time lag between energizing and deenergizing a circuit. These relays are frequently used when there is a need to delay start-up, recycling, and/or shutdown of equipment.

(2) Latching relays physically “lock” themselves in the energized or deenergized position until they are manually or electrically reset.

(3) Contactors are single coil, electrically operated, magnetically held devices that are used by relays to operate equipment.

(4) Solid state relays are semiconductor-based switches with sufficient rating to replace elector-magnetic relays.

c. Electric solenoid operated pneumatic (EP) relays are operated in an on-ff manner electrically by a digital output. EP relays are placed in a pneumatic local loop control circuit to apply air pressure to a device, exhaust air pressure from a device, or transfer control from one device to another. Control air is obtained from the existing local loop control system.

d. Controllers continuously measure changes in controlled variables and automatically send appropriate signals to adjust equipment or devices to correct any deviation from the desired set point.

(1) Single input Control Point Adjustment (CPA) controllers are used when reset control is required. The setpoint of the controller can be adjusted plus or minus ten percent of the primary sensor span.

(2) Dual input controllers can be used instead of single input CPA controllers when adjustable control range needs to exceed more than plus or minus 10 percent of the primary sensor span.

e. Electric to pneumatic transducers are electrically operated by an OA in the FID/MUX. The OA signal is converted into a pneumatic output signal compatible with the local control loop. These proportional signals position valves, dampers, and reset local loop control setpoints.

2-30. Instruments

a. General. The EMCS instrumentation necessary to monitor the DE will be independent of any other instrumentation required to perform local loop control functions. EMCS control signals to the DE will interface in such a way that the local loop control function continues to operate or fails to the desired failure mode in the event of a FID/MUX failure. The following sensor descriptions include accuracy and range requirements for various applications. The accuracies are expressed as individual sensor values. Transmitters providing a DC signal proportional to the required analog measurement will be included as part of each instrument to provide a linear conditioned signal for input to the FID/MUX.

b. Temperature/relative humidity instruments.

(1) Temperature instruments include various configurations of platinum resistance temperature detectors (RTDs) and require proper housing for temperature measurement in rooms, ducts, piping, and outside air (OA). The selection of a platinum RTD for the specific application depends upon the required range and accuracy. Thermistor and thermocouples will not be used in EMCS applications. Conditioning circuitry is required, and may be integral to the sensor.

(2) Temperature switches are bimetallic or filled elements affected by input temperature that cause contacts or open (or close) at a selected temperature setting. Temperature switches must be adjustable over the operating temperature range.

c. Relative humidity instruments are used to measure percent relative humidity in spaces, ducts, and OA. Where OA measurements are required, shielding will be provided to prevent the effects of solar heating and rain.

d. Pressure instruments.

(1) Pressure transducers are pressure measurement devices which use the deformation of an elastic membrane as the primary measuring device. The various pressure transducers consist of the bellows, diaphragm, bourdon tube, and strain gauge types. Pressure transducers are subdivided into a number of categories which include those for measuring gauge pressure, absolute pressure, or differential pressure.

(2) Pressure switches are operated by an input pressure to open or close contacts at a selected pressure setting. Pressure switches may be gauge or differential type with adjustable settings, and may be manual or automatic reset.

e. Flow instruments.

(1) Flow of liquids and gases is directly or indirectly measured in the flow path. A direct metering device measures fluid flow by measuring volume or weight for a given period of time. An indirect metering device uses an intermediate parameter to measure flow.

(2) Concentric orifice plates will be used for a steady flow of clean liquid, vapor, or gas which is in the normal turbulent flow region with pipe Reynolds number of 2000 or greater.

(3) Eccentric orifice plates are used to measure fluids which carry a small amount of non-abrasive solids since the solids will flow through the bottom of the orifice rather than accumulate behind it. Eccentric plates are also useful for measuring the flow of vapors or gases which carry small amount of liquid. Eccentric plates will also be used to measure the flow of liquids carrying small amounts of gas, in which case the orifice opening is located at the top of the pipe.

(4) Flow nozzles will be used where the Reynolds number is in excess of 50,000. Flow nozzles will handle approximately 60 percent more flow with the same pressure drop as an orifice plate. At the higher Reynolds number, the amount of straight pipe required prior to the flow nozzle is reduced.

(5) Venturi tubes, like flow nozzles will handle approximately 60 percent more flow than an orifice plate, with the same pressure drop as the orifice plate. For equal flows, the pressure drop of the venturi tube will be only 10 to 20 percent of the pressure drop of an orifice plate. The venturi tube is capable of measuring any fluid flow which an orifice plate or flow nozzle can measure. Venturi tubes will be used for gas flow measurement when suspended particles are in the stream.

(6) Annular pitot tubes are a variation of the pitot tube. Pitot tubes have a single sensing point and have poor accuracy, particularly at low velocities. The annular pitot tube senses dynamic pressure at multiple sensing ports distributed along the sensing tube to provide a single output of the average flow. Static pressure is measured by a port which faces downstream at the centerline of the pipe. The sensor will have approximately 5 pipe diameters of straight pipe upstream. A major advantage of this sensor is the ability to mount an annular pitot tube into an existing line under pressure with "hot tap" methods.

(7) Turbine flow meters use the moving fluid to turn a turbine rotor. Turbine flow meters supply flow quantity information via a precisely known number of pulses for a given volume of fluid displaced. The relationship is linear for a given flow rate and viscosity. The turbine flow meter is designed on flanged ends to be mounted in-line. Recently, reduced size turbine meters have been developed for mounting into existing piping by hot-tap methods, allowing the units to be removed and reinserted without system shutdown.

(8) Vortex shedding flowmeters use a non-streamlined obstruction inserted in the pipe centerline to create eddies or vortices which grow. The detachment of the vortex from the obstruction is termed shedding. A sensor located downstream of the obstruction measures the frequency of shedding, which is proportional to the flow velocity, the output being linear with flow.

(9) Flow switches are operated by input flow to open or close contacts at a selected flow setting. Flow switches must be adjustable over the operating flow range.

f. Electrical power instruments.

(1) Electrical energy consumption measurements require the use of voltage and current transformers whose proportional outputs are connected to a dedicated watt-hour meter or transducer, or to a FID where the watthour consumption calculations are performed. Where dedicated watt-hour meters are used, a serial digital pulse output is required from the meter for input to the FID/MUX. Where watt-hour transducers are used, a 4 to 20 mA output is required for input to the FID/MUX.

(2) Electrical peak demand is calculated from the output of voltage and current transformers used for the electrical energy consumption measurements or by the use of dedicated electrical peak demand meters with a pulse output to a FID/MUX.

(3) Voltage and current measurements for ranges which do not match FID/MUX input re-

quirements will require the application of voltage and current transformers.

g. Position sensors measure the position of devices such as valves and dampers which move from one position to another. Typical position instruments include end (limit) switches and potentiometers.

(1) End (limit) switches provide a contact closure at or near the limit of the moving object's travel.

(2) Potentiometers are resistors with a continously adjustable sliding contact. Depending on the application, these devices may be either rotary or linear. They will indicate position on a percent open basis.

h. Key-operated switches including hand-off--automatic (HOT), and off-automatic, must be keyed alike.

2-31. D.C.

a. A D.C. provides the means by which the DE is interfaced to an ECCS. ECCS instrumentation and controls installed as a retrofit or as part of new building construction will be terminated on terminals in the D.C.. All wiring to be connected to a FID/MUX will be terminated at the DTC, Wiring between the D.C. and FID/MUX may be individual conductors or prefabricated wiring harnesses. No instrumentation or control devices are to be located in the D.C..

b. Identification of all terminals must include system function, operating ranges, and power requirements to ensure trouble-free connection of the FID/MUX to the DE.

c. To allow for expansion, the D.C. will contain spare terminals to accommodate 25 percent additional points over the quantity required in the initial installation. The D.C. must be divided into analog and digital groupings.

d. The D.C. provides means to perform checkout of the field equipment instrumentation and controls. When the FID/MUX needs to be removed for service or replacement, the D.C. provides a convenient interface with the field equipment.

Section IV. TRANSIENT PROTECTION

2-32. General

a. Digital logic systems are susceptible to interference from two types of transients: functional and damage upsets.

(1) Functional upsets are transients caused by inductive or capacitive coupling between data lines, control lines, and monitor lines that result in loss of data or improper control actions.

(2) Damaging upsets are transients caused by voltage surges and indirect lightning strikes that physically damage the equipment.

b. Power lines serving the system, nearby electrical and electromechanical devices, and lightning strikes are sources of transients.

c. Power line variations, due to transients from large starting loads or other disturbances, may cause temporary low voltage conditions to exist.

d. PLCs will be installed on power lines serving the MCR and each FID/MUX. Each PLC will be sized to maintain 125 percent of the required load for the connected equipment at each location.

e. Communication link from the MCR to the FIDs and between FIDs and MUXs must have surge protection circuits installed at each end and must also have triple electrode gas surge arrestors within 3 feet of the building cable entrance.

f. Power circuits serving ECCS equipment must be surge protected.

g. Control and sensor lines connected to ECCS equipment must be surge protected.

h. Communications link equipment such as MODEMs, line drivers and repeaters must have overvoltage protection for voltages up to 480 VAC rms, 60 Hz.

2-33. Transient protection devices

Surge arresters provide low impedance paths to ground for surge voltage and lightning strikes which exceed threshold voltages ranging from 6.8 volts to 100,000 volts. A variety of difference devices are available to protect against lightning and other transients in power supplies, data communications lines, digital hardware, controllers, and instruments. Fuses and circuit breakers will be used to limit current in power supplies from overcurrent and short circuits. Transient protection devices will be used to protect I/O function circuits, DTM circuits, and power inputs. Types of transient protection are enumerated below.

a. Spark gaps. Surges due to lightning or other transients are generally handled by spark gap devices, such as gas filled tubes in combination with other faster devices, which offer high impedances to ground until a threshold voltage is exceeded. Gas filled tubes are available for a range of threshold voltages to meet various applications, such as power or signal lines. Gas filled tubes are relatively slow to reach when compared to semiconductor devices, requiring that they be used in conjunction with other faster acting protection devices, such as zener diodes. These faster acting devices protect the circuit until the overvoltage is shunted to ground by the gas filled tube.

b. Varistors are devices whose resistance is voltage dependent. As the applied voltage increases, resistance of the varistor decreases, providing a shunt to ground for overvoltage.

c. Zener diodes are fast acting semiconductor regulators which maintain a constant voltage drop across themselves by varying internal resistance. Zeners are used in conjunction with spark gap devices to provide protection against overvoltage in excess of the zener diode ratings.

d. Double anode zeners are semiconductor devices, composed of back-to-back zener diodes, that provide low voltage clamping for high speed transients. Double anode zeners are also used across relay coils to eliminate coil generated electromagnetic interference (EMI).

e. Crowbars consist of any electronic circuit that rapidly senses an overvoltage and provides a low impedance path to ground. The overvoltage setpoint of crowbar circuits is adjustable to suit the application. One use of crowbars is to limit the voltage output of DC power supplies.

f. Optical isolators provide DC isolation between interconnecting wiring and input circuits by the use of LEDs and photocells. These circuits are used primarily to isolate control and sensor wiring circuits from the ECCS input circuits. Optical isolators prevent damaging transients from passing through them, but are still subject to failure when large surges occur. Optical isolators typically pro- vide up to 2500 volts RMS isolation.

g. Inductor-capacitor-resistor networks are used to attenuate high frequencies associated with fast rise times in voltage transients.

2-34. Grounding

The ideal grounding system is one which provides a zero impedance path for currents at all frequencies the system is expected to encounter. The most common type of grounding system consists of a grounding circuit that is terminated by copper rods or pipes driven into the ground. Use of underground well casings and building structural steel members in accordance with NFPA 70 are other acceptable means of grounding. To meet grounding resistance requirements, it may be necessary to combine several grounding techniques. Communications and instrumentation systems require a separate single point ground in addition to a power ground. Signal grounding conductors which run parallel to primary power or lightning conductors will be avoided. Floating signal grounding systems are not acceptable because of lack of operating stability and shock hazard. All enclosures will be tied to an equipment ground, which will be separate from communications and instrumentation grounds. Grounding will be in accordance with IEEE No.142. Additional grounding and power requirements exist for use in computer equipment areas such as the MCR. These additional requirements, defined in FIPS-94, "Guidelines for Electrical Power for ADP Installations", are to be incorporated in the MCR design in addition to other stated requirements.

2-35. Shielding

Electronic circuits sensitive to EMI will be protected by electrical shielding. Shielding is used in telephone lines, twisted pairs, coaxial cables, and other circuits to reduce the strength of interfering electric or magnetic fields. Shielding will be grounded at one end only to preclude ground loops.