

COMPUTER HARDWARE INSTALLATION MODEL

by

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CHAPTER 1 INTRODUCTION

1.1 Problem

The physical installation of a computer system is a complicated process that must be approached with caution. It is imperative that a manager have a plan formulated which completely defines the installation. This plan must start with the physical site preparation, proceed to the hardware installation, and end with the turnover of an operational system to the software technicians. Included in this plan should be an accurate timetable of all the key activities required during the installation process.

An installation manager will find that vendors provide little or no assistance either in preparing a facility for equipment installation or in the actual physical installation process. Normally adequate hardware specifications and environmental data are available to an installation manager; however, understanding this information and consolidating it into an installation plan can be a difficult and complicated task without guidance from an experienced person. Few organizations have people adequately prepared to smoothly install hardware.

1.2 Solution

The solution to this problem is presented as a model for a manager to use which can be applied to any type of hardware installation and which results in the detailed

activities necessary for an installation plan. The activities are grouped into three major areas--environmental, electrical, and physical installation, and are presented in the following format:

1. Lists of activities encompassing all phases of the installation
2. A detailed description and explanation of the activities
3. Activity dependencies expressed as a partial ordering of activities through a network

Additionally, the model addresses use of the activities to formulate events in the construction phase, the physical installation phase, and terminates in the acceptance of the system by the systems analysts.

The model does not include either security considerations or a budgeting, cost determination, and accounting system. However, general cost data for construction is provided in Appendix 2 to aid the installation manager in approximating construction costs in support of the computer.⁶ We are fully aware of the importance of these general management issues in such a project; however, it is felt they are beyond the scope of this project.

1.3 Intended Audience

This model is designed primarily for the use of a hardware installation manager directly involved with the

detail planning of the installation. Thus, it provides a level of detail required by the manager to relate accurately and intelligently the physical installation requirements to a construction contractor and to a hardware vendor.

The model is also envisioned to be useful as an educational tool for new managers who may become involved in hardware installation. It might also be helpful to higher level managers involved in the hardware selection process, and in determining operational dates, to gain an appreciation of the time and manpower requirements of the installation process.

1.4 Organization

This paper is organized into five additional chapters and two appendices. Chapter 2 describes the three parts of the model. Chapter 3 elaborates upon the activities described in Chapter 2 to provide specific functional details to the manager as these activities are considered. Chapter 4 presents the project management tools to implement the model in a given installation. These tools include checklists and critical path networks. The question of automation of these tools is also considered in this chapter. Chapter 5 provides the manager with an example of the use of the PERT system in a typical installation. The final chapter summarizes the results of this project and indicates areas for further development.

The model activities are presented incrementally within the text. These activities, if they are to be useful to a manager involved in an installation, need to be consolidated into partially ordered lists. Appendix 1 provides this function. Finally, estimated construction costs per square foot are provided in Appendix 2.

CHAPTER 2 AN INSTALLATION MODEL

2.1 Introduction

The chapter presents the activities (Section 2.2) and the dependencies of the events represented by the termination of these activities (Section 2.3) which comprise the fundamental components of this installation model. The presentation of detailed information necessary to understand exactly how to carry out the majority of the activities during an installation is delayed until Chapter 3.

2.2 Activities

There are four broad categories of identified activities which must concern an installation manager; these categories are environmental preparation, electrical construction, physical installation, and special considerations (see Figure 2-1). Environmental preparation activities includes the submodels--site selection, miscellaneous construction, flooring, air conditioning, acoustics, fire protection and safety. Electrical construction activities are divided into the five submodels--power requirements, cabling configuration, grounding system, equipment compatibilities and system configuration. Physical installation includes the submodels--movement planning, movement technique and hardware installation. Special considerations include those additional activities which would have to be accomplished if

Environmental Preparation
 Site Selection Activities
 Miscellaneous Construction Activities
 Flooring Activities
 Air Conditioning
 Acoustics
 Fire Protection
 Safety

Electrical Construction
 Power Requirements
 Cabling Configuration
 Grounding System
 Equipment Compatibilities
 System Configuration

Physical Installation
 Movement Planning
 Movement Technique
 Hardware Installation

Special Considerations

Figure 2-1
ACTIVITIES MODEL

an installation were not a stand-alone replacement which completely or almost completely replaced another system in a very short time-frame. Safety appears as an activity under environmental preparation but safety is an integral part of many other subarea activities (e.g., movement planning) and is included in all appropriate areas.

2.3 Submodel Definition

Each of the submodels are detailed at one additional level of detail. These submodels are presented in this section as partially ordered lists. A few of the items in these lists are either commonly understood or require specific knowledge of the organization for which the installation is being accomplished, and no further guidelines to accomplishment are provided. Based upon experience of people who have installed hardware, some activities need further clarification. These activities are detailed in Chapter 3.

The submodel, site selection, is given in Figure 2-2. It includes seventeen activities of which all are in Chapter 3 under the major paragraph headings as shown in the figure.

Miscellaneous construction is the next submodel and contains four activities of which all are discussed under one major paragraph heading (see Figure 2-3). The submodel, flooring, includes ten activities all of which are addressed under four major topic areas as shown in Figure 2-4. The

Environmental Preparations

- Establish contact with vendor and contractor

Construction Support

- Estimate scope of construction
- Establish site availability date
- Obtain fire code specification
- Determine flooring requirements
- Determine requirements for equipment access into area

Space

- Calculate square foot requirements for hardware
- Determine media storage space
- Calculate maintenance space
- Calculate space for air conditioning
- Compute total square footage required
- Calculate space for protective power system

Power

- Verify adequate power source is available
- Estimate kVA
- Estimate KBTU/HR

Clearance

- Establish ceiling clearance
- Obtain vendor and contractor approval of site

Floor Loading

- Calculate floor loading specifications

Ceiling

- Establish need for false ceiling

Figure 2-2
SITE SELECTION ACTIVITIES

Miscellaneous Construction

- Determine requirements for partitions and permanent walls
- Verify that all wall board edges under the raised floor are sealed
- Determine requirement for additional entrances and windows
- Review and approve contractors construction specifications

Figure 2-3
MISCELLANEOUS CONSTRUCTION ACTIVITIES

Flooring Activities

- Determine type floor required
- Evaluate options for raised floor
- Provide raised floor requirements to contractor
- Seal raised floor when used as plenum

Floor Covering Material

- Ground raised floor if static electricity problems are expected

Dust Control

- Seal under-floor with epoxy

Floor Tile Cutouts

- Obtain contractors specification for raised floor grid
- Line cutouts with protective trim
- Purchase extra floor panels from contractor
- Establish raised floor cutout requirements

Figure 2-4
FLOORING ACTIVITIES

air conditioning activities are listed in Figure 2-5 and are all discussed in Section 3.1.4 of Chapter 3. There are only three activities listed under the submodel, acoustics, and the explanation of these functions is given in Chapter 3, Section 3.1.5. The submodel is shown in Figure 2-6. The submodel, fire protection contains eight activities (see Figure 2-7). Three of these were considered self-explanatory. These are: a) assure all exits are easily reachable and clearly posted, b) verify that all equipment aisle ways are large enough to accommodate portable fire fighting equipment, and c) police area of trash during construction and installation. Safety is a submodel that cannot be discussed under a single installation section. Figure 2-8 breaks out the activities for safety under the major installation areas where they are discussed. This completes the submodels that are part of environmental preparation.

The next group of activities listed are grouped by submodel under the major category, electrical activities. The submodels include power requirements, cabling and grounding, equipment compatibilities and system configuration. The submodel, power requirements, is composed of eighteen activities and represents the largest submodel in the report. Figure 2-9 depicts the activities. Three of these activities all listed under miscellaneous are felt to be in no need of further explanation. Cable activities, the next submodel, is shown in Figure 2-10 with

Air Conditioning

- Decide if air conditioning is to be dedicated to the computer
- Establish drainage under the raised floor
- Determine optimum location for air conditioning system
- Avoid overhead air vents blowing directly into equipment

Air Flow Requirements

- Determine type of cooling system required
- Install separate humidity control
- Install temperature control device

Cooling System Requirements

- Determine temperature and humidity specification

Air Cleaning

- Determine air cleaning requirements

Computing Total Heat Load

- Compute total heat load

Static Electricity

- Evaluate methods for reducing static electricity

Testing

- Test air conditioning system
- Balance air distribution after hardware installation
- Monitor system after initial power up

Requirements

- Submit detailed cooling requirements to contractor

Figure 2-5
AIR CONDITIONING ACTIVITIES

Acoustics

- Review general guidelines for sound absorbtion
- Review general guidelines for sound isolation
- Estimate requirement for acoustical treatment

Figure 2-6
ACOUSTIC ACTIVITIES

Fire Protection

- Coordinate installation with fire inspector
- Assure all exits are easily reachable and clearly posted
- Verify that all equipment aisles are large enough to accommodate portable fire fighting equipment
- Clean area of trash during construction and installation

Electrical Systems

- Position electrical shut-down switches at all exits

General Storage

- Establish proper storage areas for supplies

Type of Fire Protection

- Install and test fire protection equipment
- Locate fire extinguishers in computer area

Figure 2-7
FIRE PROTECTION ACTIVITIES

Flooring

- Avoid exposed cabling on the floor

Fire Protection

- Post the number of fire department
- Post electrical shut down procedures
- Establish evacuation routes

Power Requirements

- Use only qualified electricians to wire power to equipment
- Install emergency lighting
- Locate emergency power off switches at all exits

Movement Techniques

- Cover all raised floor cutouts and open floor areas

Hardware Installation

- Verify that the equipment is grounded prior to power up
- Level all equipment prior to power up

Safety

- Restrict access to the construction area

Figure 2-8
SAFETY ACTIVITIES

Power Requirements

- Isolate power for computer from other power systems

AC Power Distribution

- Install separate power panels for main frame and peripheral equipment
- Locate power panels in same room with equipment
- Determine which equipment components are "hard-wired" or require receptacles

Protective Power Systems

- Evaluate requirement to install protective power systems

AC Convenience Outlets

- Locate convenience outlets in computer room

Lightning Protection

- Install lightning protection

Overhead Lighting

- Evaluate need for overhead lighting
- Coordinate location of overhead lights with equipment

Emergency Lighting

- Install emergency power off switches at all exits

Phase Balancing

- Phase balance electrical power

Figure 2-9
continued

Communications Support

- Determine electrical support required for communications equipment

Remote Terminals

- Install phone lines

Detail Power Requirements

- Determine electrical requirements for all equipment
- Provide contractor with equipment layout and electrical requirements

Miscellaneous

- Assure spare breakers are installed in all power panels
- Schedule electrician to connect power to equipment
- Verify line voltages prior to power up

Figure 2-9
POWER ACTIVITIES

Cabling

- Determine type and length of data cable
- Order data cable after final hardware layout has been approved
- Tag cable showing length and equipment destination
- Develop overlay depicting the major cable routes between equipment
- Locate and identify any under floor obstructions

Cable Installation

- Install data cable prior to equipment installation

Cable Connection

- Schedule maintenance personnel to connect data cable

Figure 2-10
CABLE ACTIVITIES

seven activities. All of the activities are discussed in Chapter 3 in Section 3.2.2. The grounding submodel contains four activities which provide a general concept for grounding a computer system. It should be noted that grounding schemes vary from vendor to vendor and specific vendor specifications must be accomplished by the manager. These are noted as vendor dependent. The submodel contains activities of a general nature (see Figure 2-11). The last submodel under the major category, electrical construction, is equipment compatibilities and system configuration. This submodel contains eight activities (see Figure 2-12). All of these are elaborated in Chapter 3, Section 3.2.4.

The next major category is physical installation with three submodels: movement planning, hardware installation and special considerations. All the movement planning activities listed are nearly self-explanatory; therefore, there is only a short discussion of this submodel in Chapter 3, Section 3.3.1. Figure 2-13 lists these activities. Movement technique is a submodel that requires considerable explanation because of the innovative ideas advocated by the author. All activities in Figure 2-14 are discussed in Chapter 3, Section 3.3.2. The submodel, hardware installation, represents the final phase of the model. The activities listed are all discussed in Chapter 3, Section 3.3.3 (see Figure 2-15).

The final category is called special considerations. The reason for its inclusion in the model is that this model

Earth Connections

- Install and test earth ground

Green Wire or Green Yellow Safety Ground

- Hook up green wire ground as per equipment specification

Signal Ground

- Install equipment ground braids for signal ground if required by equipment specification
- Determine vendor dependent grounding requirements

Figure 2-11
GROUNDING ACTIVITIES

Logical Configuration

- Develop logical configuration to support software requirements

Physical Configuration

- Determine minimum distance allowable between equipment for maintenance and operator access
- Determine the maximum cable length allowed between equipment
- Develop hardware configuration to support operational requirements
- Consider ease of operator access, control and visual observation of peripheral equipment
- Consider efficient work flow pattern supported by equipment layout
- Establish space between equipment to allow ease of tape changing, printer paper loading and removal, access for service, etc.

Site Layout

- Develop site layout to document final hardware layout

Figure 2-12
EQUIPMENT COMPATIBILITIES AND SYSTEM
CONFIGURATION ACTIVITIES

- Verify size and weight capacity before using an elevator
- Check size of all doorways leading into the site
- Arrange for temporary storage of equipment if required
- Verify that hallways and turns permit passage of the largest component of equipment
- Check unloading area for limitations on vehicle size
- Establish projected delivery date for equipment
- Arrange for carrier
- Survey of equipment by moving contractor
- Estimate time required to load and deliver hardware
- Reserve area for truck unloading
- Clear route from carrier parking area to computer room
- Arrange for equipment packaging and crating removal
- Schedule personnel to bolt main frame together and level equipment
- Determine if there will be a single or phased equipment delivery

Figure 2-13
MOVEMENT PLANNING ACTIVITIES

- Arrange for temporary protection of floor along route
- Tag all major components of equipment
- Post equipment layouts at room entry points
- Provide personnel to direct movers in the placement of equipment
- Cover all floor cutouts
- Mark hardware layout on floor with tape, verify accuracy of layout

Figure 2-14
MOVEMENT TECHNIQUE ACTIVITIES

- Level all equipment
- Connect mainframe
- Install copper straps for signal ground
- Monitor equipment as it is powered up
- Schedule maintenance personnel to connect data cable
- Turn the system over to systems analysts

Incremental Installation

- Determine the timetable for hardware installation

Figure 2-15
HARDWARE INSTALLATION ACTIVITIES

has been developed to aid a manager in the installation of hardware without consideration given as to whether:

1. this is an initial installation, or
2. the hardware is to be interfaced to an already existing system, or
3. the hardware is to be installed as an additional stand alone system.

If the first case applies, the general model will satisfy management requirements. If either of the later two cases apply to an installation, additional activities will have to be considered and more precise planning and coordination may be required. These additional activities are provided in a separate list (see Figure 2-16).

2.4 Dependencies

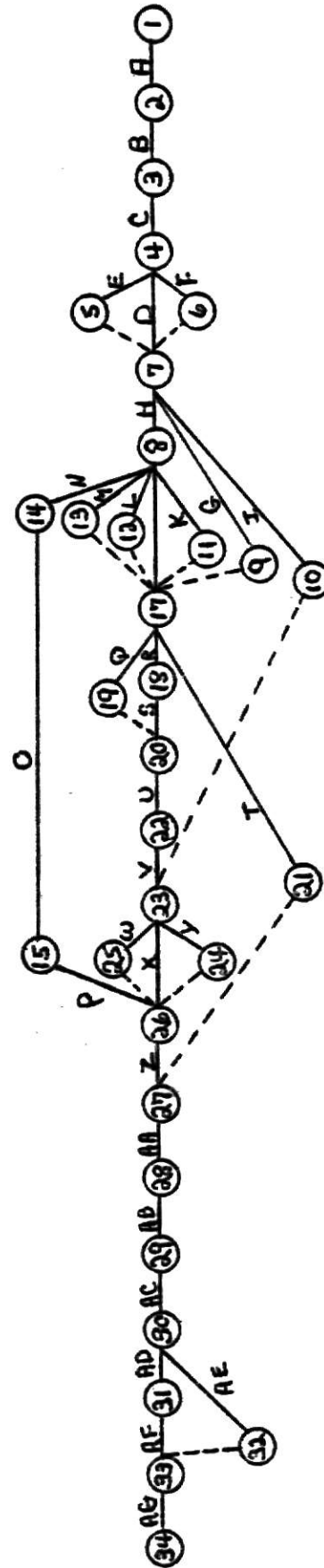
The events listed in Section 2.2 have been consolidated into thirty-four key installation activities and the dependencies between these major activities depicted in a PERT network system (see Figure 2-17, 2-18). The PERT network serves as a management and planning tool providing a graphic picture of the goals to be achieved and their interrelationships. A further discussion of PERT and its application is given in Chapters 4 and 5.

- Coordinate installation schedule with computer operations
- Schedule computer down time for electrical work
- Determine requirements to change logical configuration to support installation of additional hardware
- Isolate existing system from new construction area
- Schedule computer down time during nonpeak workload periods
- Schedule integration testing of new and existing system
- Determine requirement to revise physical configuration of existing system to accommodate new system
- Verify that existing air conditioning can accommodate additional heat load
- Plan to power new system from separate power panels to minimize interruptions to existing system
- Determine maximum drive distances before interfacing systems

Figure 2-16
SPECIAL CONSIDERATION ACTIVITIES

Task ID	Event Description
A	Points of contact with vendor and contractor
B	Determine logical configuration
C	Establish initial hardware layout and square foot requirements
D	Site selection process
E	Estimate of construction completion date
F	Estimate construction requirements
G	Miscellaneous construction requirements
H	Final hardware layout
I	Initial movement plan
J	Electrical requirements
K	Air conditioning requirements
L	Raised floor requirements
M	Acoustical requirements
N	Cable requirements
O	Order and receive cable
P	Mark cable
Q	Develop floor cutout requirements from floor specification
R	Consolidate construction requirements
S	Review contractor construction specifications
T	Tag hardware
U	Start construction
V	Complete construction
W	Test air conditioning
X	Final movement plan
Y	Mark floor layout
Z	Install data cable
AA	Install hardware
BB	Electrical connection and grounding
AC	Power-up equipment
AD	Connect data cable
AE	Balance air
AF	Test hardware
AG	Acceptance of system by systems analysts

Figure 2-17
EVENT DEPENDENCY LIST



LEGEND:

○ represents the beginning or conclusion of an activity

— = activity

LETTERS = represent the activities listed in Figure 2-17

Figure 2-18
MASTER NETWORK

CHAPTER 3 ACTIVITY DESCRIPTION AND RECOMMENDED PROCEDURE

3.0 Introduction

This chapter is designed to supplement the activities list and activity dependencies by providing sufficient information to accomplish the activity. The model is presented under the three major submodels--environmental preparation (Section 3.1), electrical construction (Section 3.2), and physical installation (Section 3.3).

3.1 Environmental Preparation

As soon as a computer has been contracted for or it is known that one is being considered for acquisition, contact the vendor representative. Determine from the vendor how much support will be provided in the installation of the hardware. Subsequently, obtain the equipment specifications. Contact will also have to be established with a construction contractor if any room or building modifications are anticipated. These initial activities will have to be completed prior to beginning environmental preparation. Subactivities of environmental preparation are discussed in the following paragraphs.

3.1.1 Site Selection Activities

The major factors that must be satisfied when selecting a site are construction support, space, power, clearance, floor loading, and ceiling clearance. These topics are

covered in the following six sections. Usually, the selection of a proposed site(s) can be accomplished with in-house personnel.

3.1.1.1 Space

An initial site layout must be developed in order to estimate the square footage needed for the equipment. The initial site layout does not necessarily have to be the final product, but serves as a guide to estimate the space required. However, in developing this layout, the procedures listed under the Equipment Compatibilities (see Section 3.2.4) should be followed. Many vendors provide standard equipment configurations which can be used as a guide in estimating room size. Also in determining space, consideration should be given for the daily storage of tapes, cards, printed forms, etc., within the computer room. All other materials such as permanent master documents, punched cards, magnetic tapes, etc., should be stored in a properly designed and protected storage area outside the computer area. Consideration should be given to locating storage areas to minimize both the amount of space required and the travel time between areas. Space must be planned for storage cabinets, card and record files, work tables, desks and communications facilities within the computer room, as well as office space outside the computer room for the computer operations support personnel. A maintenance work area may also have to be provided for maintenance

personnel and for the storage of spare parts and maintenance equipment. To assure only authorized personnel have access to the parts and test equipment and to increase maintenance response time, the area should be enclosed and adjacent to the computer room. Space should also be considered for air conditioning units or system, located in the computer room or separate area.¹ Also estimate space required for a protective power system and determine its optimum location by consulting with the vendor and contractor.

3.1.1.2 Site Selection

Selection of the best site can be approached by developing an initial list of the support requirements for the equipment and estimated construction requirements. This list should include total KBTU/HR, total KVA, both of which can easily be obtained from the equipment specifications, requirement for raised floor, number of equipment components that must be powered, any wall modifications, false ceiling, cutting in new doorways or windows, additional overhead lighting, etc. These requirements should be made known to the contractor in order for him to estimate site availability dates based on construction required. This is only an initial estimate of the construction support that will be needed. The more detailed requirements are developed after the final site selection has been made.

If higher management requires a specific installation date, make sure the contractors projected completion date

for construction falls within that schedule. The projected installation date might very well dictate the site selected and, in fact, could dictate the type of system installed if several vendors are under consideration.

3.1.1.3 Power

To obtain an estimate of the electrical load needed for the system, add up the KVA rating for all equipment that will be located in the facility. Request your local power company to make a site visit and determine if the power requirement can be supported.

3.1.1.4 Clearance

The primary concern is the height of the ceiling. If a raised floor and or a ceiling is to be installed make sure measurements are made from the surface of the raised floor to the surface of the false ceiling. The equipment specifications will dictate the minimum ceiling clearance. When selecting the site, verify that equipment access into the area is adequate. Measure all doorways and halls leading into the site. If the facility is not on the ground level determine the size and loading capacity of the elevator.¹⁶

Prior to finalizing site selection the vendor representative and construction contractor should visit the proposed site. It is only necessary to obtain vendor approval of the site selected for the hardware if you are

contracting with him for maintenance. It is important for the construction contractor to visit the site in order that he may determine if the initial construction requirements can be accomplished within the associated timetable.

3.1.1.5 Floor Loading

The equipment loading figures can be obtained from the hardware specification manual or site planning guide. See Section 3.1.3 on flooring for a discussion of floor loading requirements.

3.1.1.6 Ceiling Installation

Check the material and composition of the ceiling. If it lends itself to collecting dust or dirt that may fall into the equipment or shows evidence of flaking or peeling, it would be best to install a false ceiling.

3.1.2 Miscellaneous Construction Activities

Miscellaneous construction generally covers anything that does not fall under the other categories. This includes requirements for new walls, the removal of existing walls, and the cutting of new entrances and windows into the area. The miscellaneous construction requirements should be documented on a separate drawing and provided to the contractor.

3.1.3 Flooring Activities

The majority of the computer systems require raised flooring for cooling, and access of power and logic cables. It is recommended that raised flooring be used for all computer equipment. This eliminates the problem of covering data cable and power cables runs, allows for future layout changes with minimum cost, and provides better personnel safety.

The raised floor can be constructed of steel, aluminum, or fire resistant wood. However, no metal should be exposed to the walking surface. Such exposure is considered to be an electrical safety hazard and can also cause static discharge problems. The raised floor should be at least twelve inches above the true floor if it is to be used as an air plenum by the air conditioning system. Before a raised floor height is decided upon, verify that ceiling height will be adequate.¹⁹

The raised flooring will have to satisfy the loading requirements of the equipment. This is usually specified in pounds per square foot (sq ft), and can be obtained from the hardware specifications. The majority of equipment loading has a maximum value of 200 pounds per sq ft.¹ In addition to the loading capacity of the raised floor, the loading capacity of the true floor cannot be exceeded. The raised floor load will be approximately 10 pounds/sq ft, and the equipment load per sq ft can be computed by adding weights of all units and supporting equipment and dividing by total

squate feet. Most office buildings have a floor rating of 50 pounds per square foot with an additional allowance of 20-25 pounds per square foot for partitions, which could be used for the additional equipment weight.¹⁹

Panels should be interchangeable and easily removeable with a lift tool. The pedestal assembly of the raised floor should allow vertical adjustment in order to level the false floor. The floor system should be laterally stable in all directions with panels in place or removed without the use of additional framing or horizontal stringers. The completed floor system should be rigid, free of vibration and of rocking panels.³ Two general floor types are shown in Figure 3-1 and 3-2.

For equipment that does not require under the floor cooling, there are several companies that sell a raised floor that can be installed by the customer. The raised floor is available both in tile and in low static carpet. This type of raised floor is excellent for hiding cable runs, for ease of maintenance, and providing an acoustically improved environment. These raised floors are only three to five inches high and are not recommended for systems that require under the floor cooling (see Figure 3-3).²³

3.1.3.1 Floor Covering Material

The floor covering on the false floor can cause high static electrical charges as a result of the movement of people, chairs, carts, etc. across the floor. Abrupt

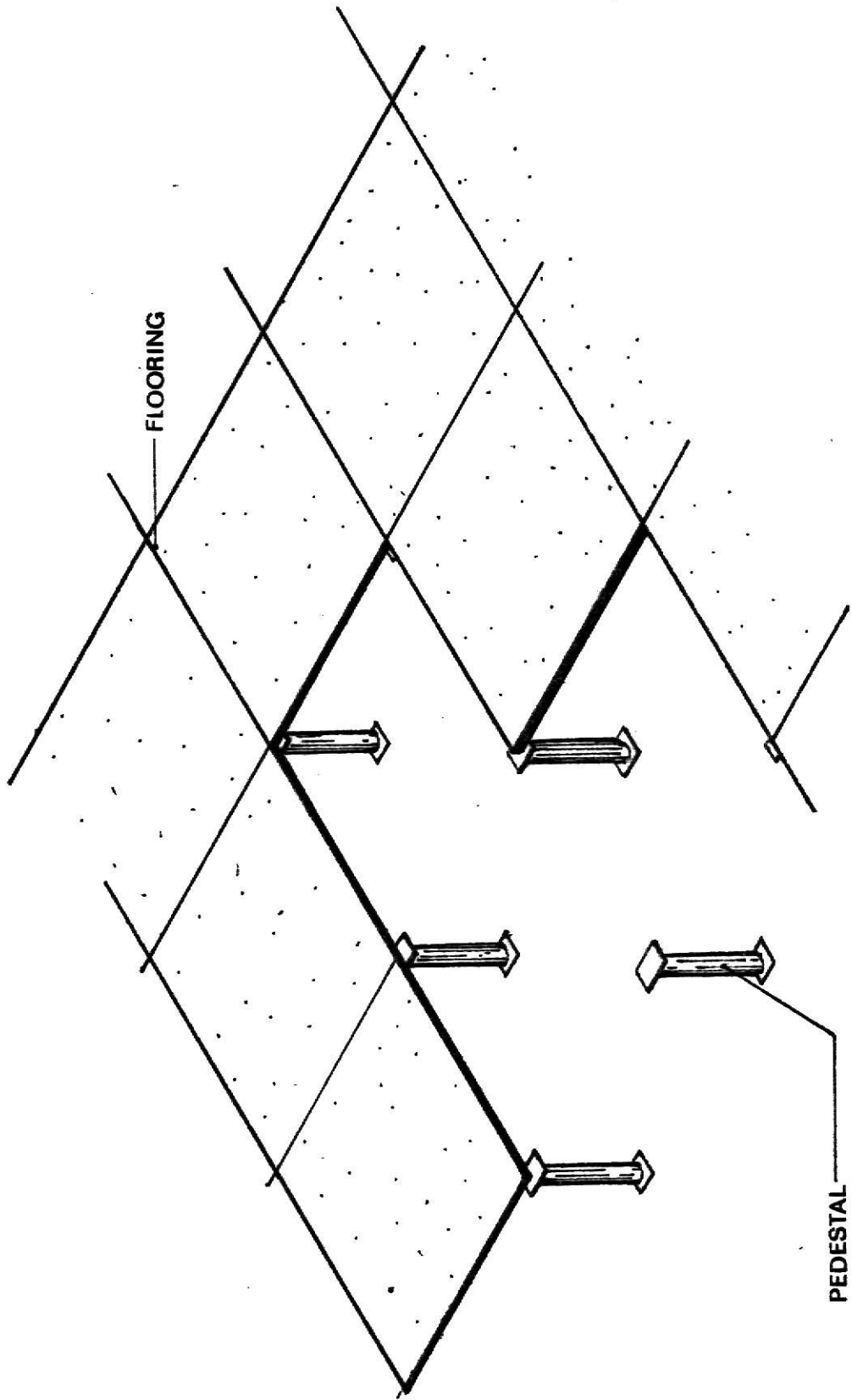


Figure 3-1
FREE STANDING FRAME

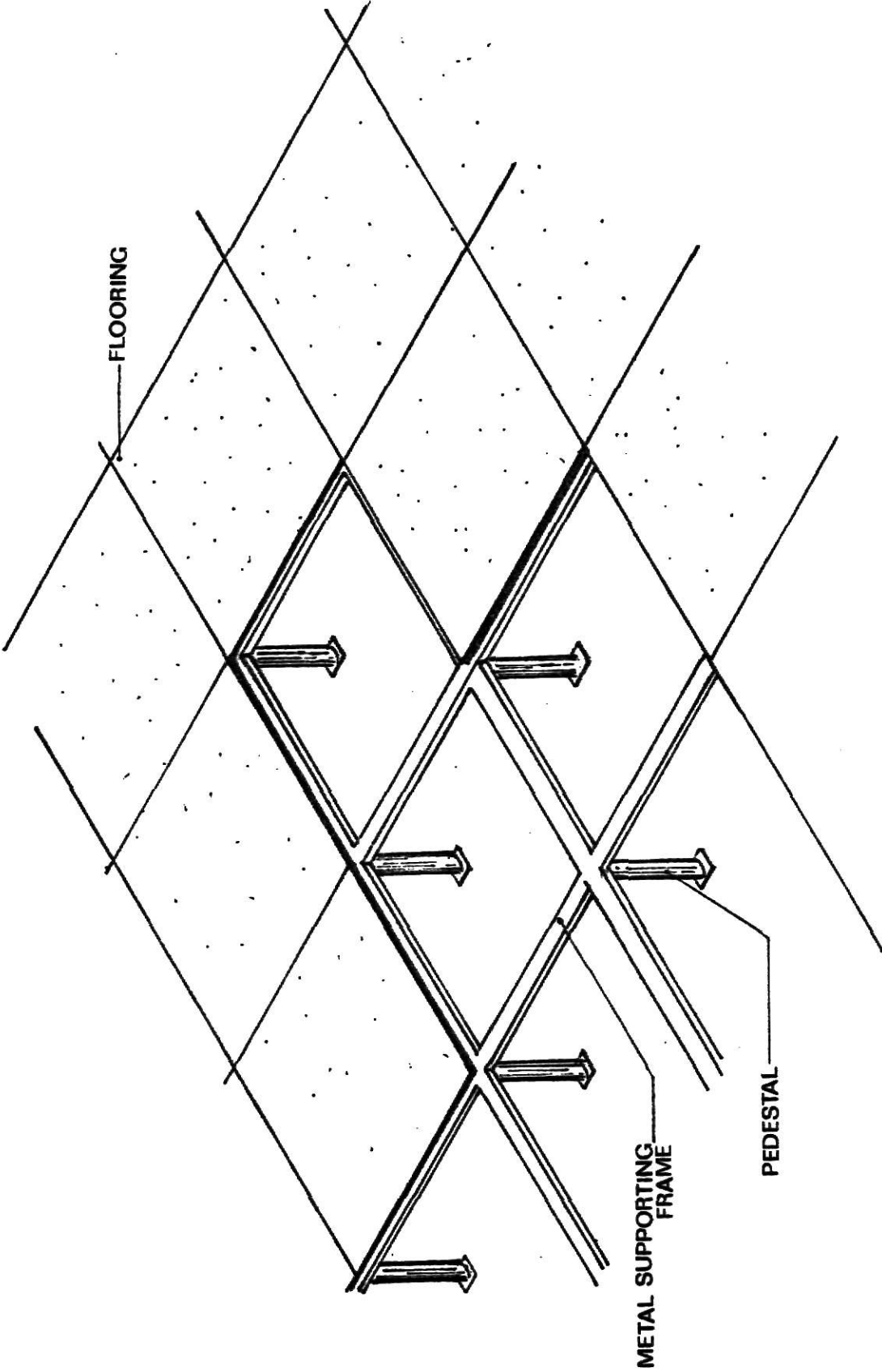


Figure 3-2
FRAMED SUPPORTED RAISED FLOOR

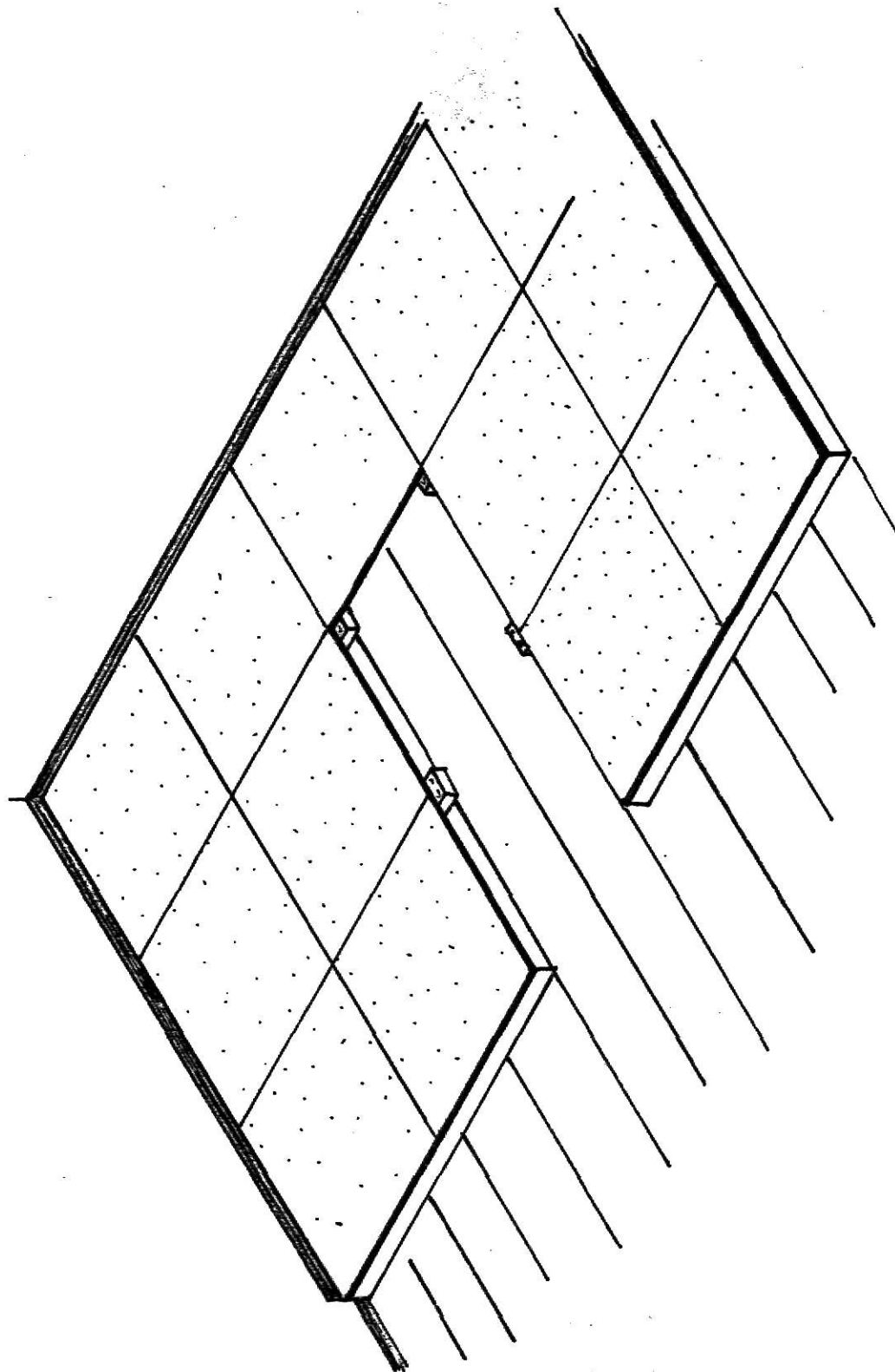


Figure 3-3
MINI-RAISED FLOOR

discharge of these static charges to metal surfaces or to other people cause discomfort to personnel and may cause malfunction to the equipment. Static build up and discharge can be reduced by grounding the raised floor structure to earth ground, by assuring the maximum resistance for floor surface material is 2×10 ohms (this would have to be done by an electrical contractor), measured between floor surface and building or by installing carpeted floor covering that is antistatic.¹⁹ (See Section 3.1.4 for further detail.)

3.1.3.2 Dust Control

To reduce the accumulation of dust and dirt under the raised floor, have the contractor seal the true floor. This is usually done with epoxy paint prior to the installation of the raised floor. Also include provisions for the contractor to vacuum the area thoroughly after all construction work is completed. This is particularly important if an under the floor air circulation system is to be used.

3.1.3.3 Floor Tile Cutouts

It is strongly recommended that all raised floor cut-outs be completed prior to the physical installation of the equipment. The floor tile should not be cut after the equipment is installed, for dust and metal particles can cause severe damage to the hardware. Floor tile cutout requirements can be determined two ways:

1. The recommended method is to obtain the raised floor grid overlay from the contractor. Superimpose the final hardware layout over the floor grid drawing and determine the floor tile cutout requirements as documented in Figure 3-4. Provide the drawing to the contractor, as soon as possible. This method allows the contractor to precut the floor panels and install them as the raised floor is constructed.
2. A less desirable method is to wait until the contractor has completed work and then using full size equipment templates mark off the cutouts directly on the floor. Have the contractor return to cut the raised floor. The biggest drawback with this method is that it is very time consuming.

The first method has some risk involved because requirements are determined from a scaled drawing; however, because of its timeliness it is the preferred method.

All cutouts must be lined with a protective trim. This keeps the electrical and data cables from being damaged by the sharp edges of the floor tile. The most common material used is plastic. Also have the contractor provide you with extra floor tile or carpet panels. This will provide the flexibility of later relocating and removing equipment without the worry of finding matching tile or patching existing tile.

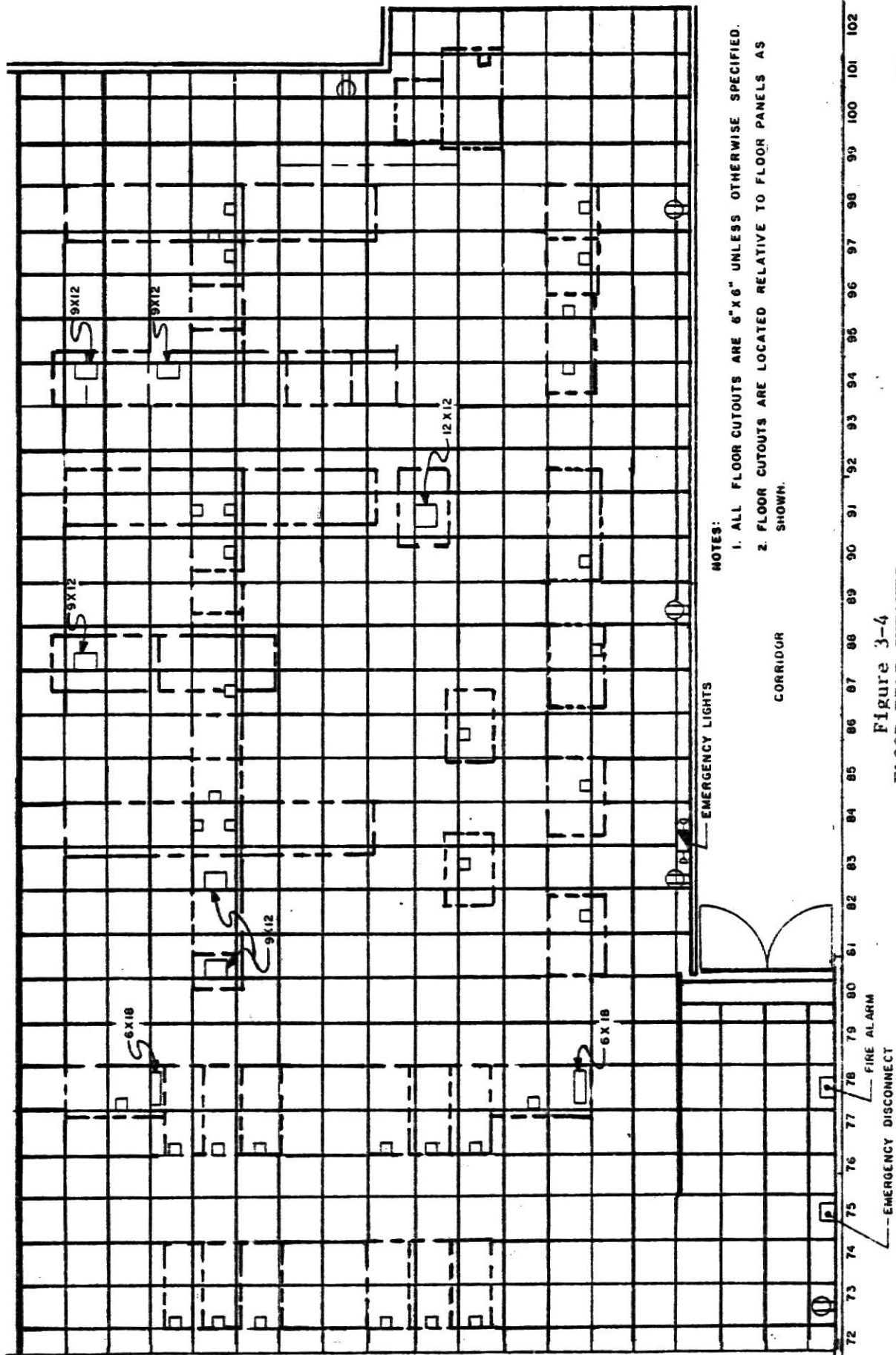


Figure 3-4
FLOOR TILE CUTOUTS

3.1.4 Air Conditioning

For large computer installations, it is essential that the air conditioning system be designed by a competent engineer to insure consideration of all factors determining air conditioning system capacity. These factors are as follows:

Machine heat dissipation

Personnel

Proper air distribution

Infiltration of heat through outer walls

Ceiling

Floors

Door openings

Partitions

Glass wall area

Possible reheat

Growth in the computer system

Lighting load

Humidity control

Adequate space available for units¹⁶

A separate air conditioning system is recommended for the computer system. The size unit required will naturally depend on the total heat load of the hardware. The heat generated by the equipment is measured in BTU/hr, and this rating can be taken from the hardware specification manual or hardware installation guides. Air conditioning systems are designed to cool the facility at a given temperature

based on the total heat load generated by equipment and surrounding environment.

Many air conditioning units are designed to be installed in the computer room with the equipment. This type of system is used when only forced air concentrated under the floor is required and the size of the heat load is relatively small (below 200 KBTU/hr). The stand alone system in the computer room requires very little construction support and is easily installed. The only difficulty may be installing the drain in the floor required by stand alone systems.¹⁷ The added noise introduced into the room by this system is significant and may cause acoustical problems. Avoid placing the air conditioning unit on the raised floor if possible. The vibration and added weight may cause damage to the raised floor structure.

For larger systems a separate mechanical equipment room may be required. This type of air conditioning system will require additional space in a separate area of the building and construction of air ducts into the computer room. The primary advantage of this system is that air distribution can be better controlled through the use of overhead vents, thus making it easier to eliminate "hot spots" in the room. Also, the noise of the system is not present in the room. There are seven topics related to air conditioning which are elaborated. These are air flow requirements, cooling system requirements, air cleaning, computing total heat load, static electricity, testing, and cooling requirements.

3.1.4.1 Air Flow Requirements

Most equipment is designed for forced air cooling by means of blowers located within each cabinet which circulate room air through the cabinet.

Air distribution in the data processing room may be through overhead duct work or plenum, or underfloor ducts or plenum. Careful consideration must be given to the placement and design of air outlet grills and the air returns to ensure proper air flow within the room. They should use recirculated air with a set minimum introduction of fresh air for personnel. These minimum fresh air introductions will enable the machine area to be pressurized so that air leakage is always outward.¹⁹ Air flow requirements are provided by one of three systems--single duct, underfloor and two duct.

3.1.4.1.1 Single Duct (Overhead System)

With a single duct system, the entire heat load of the room including heat generated by the computer system, is absorbed by the air supplied to the computer room. The air is generally supplied from either an overhead duct and diffuser system or by ceiling plenum. The return air to the conditioning system is taken either from ceiling return registers above the heat-producing units, or a fixed pattern of returns both in the ceiling or on the walls around the periphery of the room. Diffusers must be of the adjustable air pattern type and must be balanced to provide a

distribution of air which will eliminate hot spots. The ceiling height should be at least 8 1/2 feet. The temperature control system should consist of temperature and humidity controls placed in a representative location within the machine room. A temperature and humidity recorder would be mounted adjacent to the controls to monitor the room conditions.¹⁹

3.1.4.1.2 Under Floor System

With an underfloor system, the space between the raised floor and true floor is used as an air plenum. All air is discharged into the room through floor registers around the computer room. The air is returned to the air conditioning system through overhead registers located directly above the equipment. A higher return temperature can be used in this system without affecting the design conditions of the overall room. The design of this system takes into consideration a heat transfer factor through the metal floor. This allows for a certain amount of reheat to control relative humidity of air before it enters the room. The temperature recorder should be under the raised floor to prevent an uncomfortably cold floor. The floor cutouts should be sealed around the cables to allow correct distribution of air through the registers.

3.1.4.1.3 Two Duct System

One air handling unit with separate controls supplies air to the area under the raised floor. This air is discharged into the room through the floor panels or registers. Air absorbs the heat generated by the machine and is discharged from the top of the units into the room. Temperatures should be controlled to prevent condensation on or inside the equipment. The second air handling unit supplies air directly to the room through a separate overhead duct system and should be large enough to absorb the remaining heat load in the computer area.¹⁹

3.1.4.2 Cooling System Requirements

The temperature and humidity of conditioned air provided to a computer room and the air distribution within the room are very important factors in maintenance and efficient operation of the hardware. It is, therefore, important that the temperature and humidity specifications for the hardware be satisfied. Most facilities are designed for 73 degrees C and 50 percent relative humidity.

Continuous monitoring of temperature and humidity is necessary in order to keep the computer room within the air conditioning requirements. Because deviations of only a few degrees will cause a build up of a static charge, the system should be automatically controlled and provided with a high/low alarm and a continuously recording device. Direct recording instruments with seven day charts are the most

effective monitoring devices. Alarms should be provided to alert the system's operator when the environment approaches the operating limits of the computer system.^{16,19}

3.1.4.3 Air Cleaning

Minimizing the amount of dust particles in the air reduces the frequency of use of cleaning equipment and increases the reliability of the system. Mechanical air filters are adequate unless the system is subject to corrosive gases, salt air, or unusual dirt or dust conditions. The air filters should have an efficiency rating of not less than 20 percent by the Bureau of Standards.¹⁶

Electronic air cleaners are recommended where clean air is a problem. They require special application engineering to avoid electromagnetic interference with the computer. The vendor or air conditioning contractor can assist in determining what type of filtering system should be needed.²

3.1.4.4 Computing Total Heat Load

If an engineer is computing requirements, he/she will only need to know the BTU/hr for equipment and the number of operating personnel. If possible the distribution of the heat load throughout the room should be indicated on a scaled drawing of the room. This will assist the designer in selecting the correct number and location of floor and overhead vents. For those who wish to perform their own

calculations, a method is outlined below that will result in a fairly accurate estimate.²¹

Because personnel, equipment and building materials generate heat, the following list provides common heat sources that may be found in a room with estimated BTU/hr.

1. Exterior wall areas excluding windows - 5 to 11 BTU/hr per sq. ft. dependent on exposure to sun
2. Thermopane window areas, clear glass, no protection - 27 to 77 BTU/hr per sq. ft. dependent on exposure to sun
3. Thermopane window areas, glass with shades, blinds, or tint - 21 to 51 BTU/hr per sq. ft. dependent on exposure to sun
4. Roof areas with ceiling underneath - 4 to 7 BTU/hr per sq. ft. dependent on exposure to sun
5. Interior wall areas exposed to unconditioned areas - 8 to 14 BTU/hr per sq. ft. dependent on exposure to sun
6. Ceiling areas exposed to unconditioned areas - 4 BTU/hr per sq. ft.
7. Floor areas exposed to unconditioned areas - 5 to 9 BTU/hr per sq. ft. dependent on office/factory environment
8. Lighting - 3.4 BTU/hr per watt
9. Personnel - 500 BTU/hr per person
10. Fresh air ventilation @ 15 CFM per person - 340 to 825 BTU/hr per person dependent on condition

of incoming air

11. Computer and peripheral equipment - taken from hardware specifications

Total the BTU/hr for each item in the list and then add a thirty percent safety factor. This will give an estimated cooling load for the computer room which is 130 percent of the total BTU/hr calculated.

3.1.4.5 Static Electricity

Static electricity and the dirt it attracts are responsible for:

1. Printer malfunction
2. Paper jamming
3. Destruction of sensitive logic and memory circuits and
4. The attraction of contaminants to read/write heads and magnetic recording surfaces.

Static electricity is created whenever there is friction or contact/separation between two nonconductive substances. The simple movement of a person standing up can create as much as 500 volts of static electricity. A person walking across a room wearing garments of synthetic fabric can easily generate 20,000 volts. Someone approaching a data-entry terminal across a rug can generate up to 30,000 volts on an operator's skin and clothing. Computer operators are constantly moving around their equipment, and

even the act of cleaning that equipment involves static generating friction.²⁶

Since static electricity can cause data loss and computer downtime, steps should be taken to prevent its buildup or to eliminate it entirely. A highly effective means of preventing the buildup of static charges is to maintain a sufficiently high relative humidity (RH) (50 percent) in the computer room. When the RH is sufficiently high, an invisible film of moisture forms on surfaces in the room. The presence of mineral deposits makes this film a conductor that carries static electricity harmlessly to the ground before it can build up to a spark-producing or dust-gathering potential.

Data processing operations require a stable RH range of 40 percent to 60 percent to protect magnetic tape, paper and punch cards from changing dimensions or becoming brittle, which could cause system malfunction. Although a constantly high RH level is required for static control, maintaining too high a moisture level can damage computer equipment because corrosion is accelerated. Humidity stabilizing equipment is essential for maintaining proper humidity levels and preventing serious problems in the computer room.

For the detection, monitoring, and control of potentially dangerous static charges, a hygrometer (humidity indicator) is indispensable. This instrument will inform the computer room users when there is too little humidity, which may cause static charge buildup, or too much, which

may speed up corrosion. Once warned of static buildup, steps must be taken to remove these harmful charges from the environment before people suffer shocks or the system malfunctions.

A static eliminator spray is a quick and inexpensive method of effectively removing charges. It is sprayed on furniture, floors, carpets, chairs and around computers, work processing stations, terminals, magnetic tape and disk drives, computer printer forms and peripheral equipment. When the spray settles on the surface of a water-reacting material, moisture is gathered from the atmosphere and concentrated in a condensed layer on the material being treated, thus lowering its surface charge. Under most conditions, this reduction of electrical resistance or increase in conductivity is sufficient to allow electrical charges to migrate over the surface and thus dissipate to ground. The antistatic solution acts as a dust repellent by breaking up the static attraction.

The static eliminator brush is another weapon that can be used against static buildup. High concentrations of charges are generated when paper enters and leaves computer printers, causing paper jamming. By placing brushes at the paper entrance and exit, the electricity on the printer forms is dissipated. This inexpensive neutralizer is made with soft wire bristles along a bar and is grounded to the printer. It dissipates static electricity by ionization of the air. Negative or positive ions of the charged paper are

cancelled out or neutralized by equal numbers of oppositely charged ions at the tufts of the static eliminator brush.

No electric power is required in this ionization process because the static charge itself is employed as the neutralizing agent, so the brush has no operating cost. The static eliminator brush has no upper limit of ionization. It will effectively and safely neutralize even the highest static charges, resulting in clearer printouts, reduction of downtime and freedom from paper jamming, dust and lint.

Since walking across a computer room floor can generate more than 20,000 volts of electricity, an operator must "cool down" significantly before touching a machine to avoid personal shocks and destruction of junctions in sensitive integrated circuits. A simple and effective solution to this problem is to place grounded static discharge mats in high traffic areas of the computer room, such as terminals, printers and disk drives. When the mat is stepped on, static electricity bleeds from the carrier to the grounded mat.²⁶

Also the static buildup and discharge can be minimized by grounding the raised floor support frame and panels. Floor material with a lower resistance will further decrease static buildup. If carpet flooring covering is used, it should be of the type marketed by carpet manufacturers as antistatic.³

In combating static electricity, do not overlook the visual display screen of the CRT. Static accumulating on

these delicate screens is just as damaging as static accumulating on other computer equipment. The buildup of charges attracts dust and dirt to terminal windows, which can cause operator eye fatigue as well as input errors. Wiping the screen periodically with a chemically treated static-neutralizing cloth will stop the attraction of contaminants and prevent data errors, especially during periods of low humidity.²⁶

3.1.4.6 Testing

Before any equipment is installed, the air conditioning system must be tested. Air flow, humidity, and temperature should be checked against the hardware specifications. The air cleaning system should be monitored to assure excessive dirt particles are not being introduced into the computer area. You should use air conditioning specialists to adequately test the system. The only way an air conditioning system can be tested prior to equipment installation is to convert the estimated total cooling load to an equivalent air flow specification measured in cubic feet per minute (CFM). The formula to do this conversion is complicated and requires a specialists in the field. Once the conversion has been made, the air flow of the system is measured and compared against the computed specifications.^{2,15} After the hardware is installed and operating, the air supply dampers must be adjusted to balance the air temperature throughout the room to eliminate

"hot spots." To assist in eliminating the creating of "hot spots", provide the contractor with hardware layout with heat load shown for each item of equipment (see Figure 3-5).

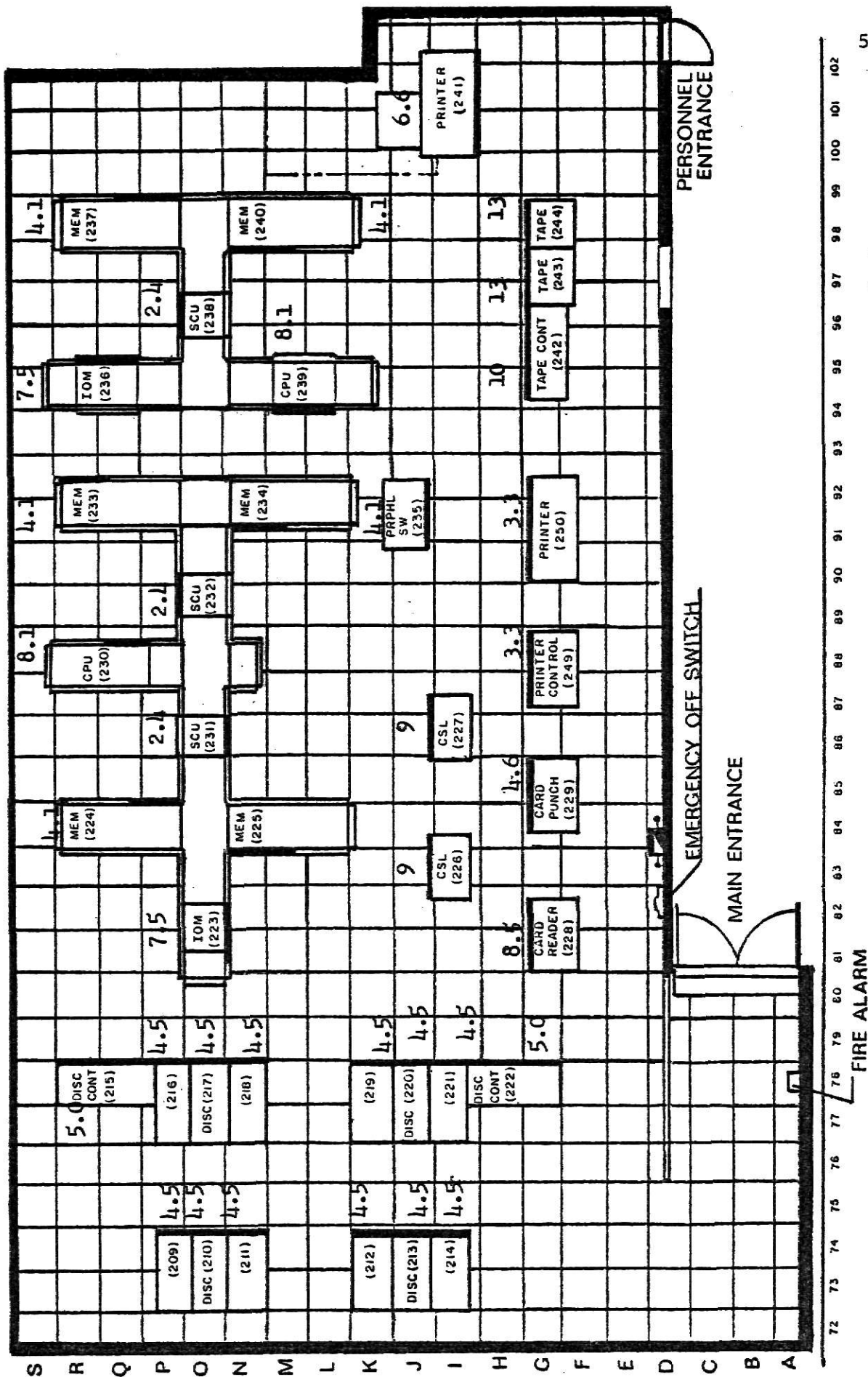
3.1.4.7 Requirements

The following format is recommended as a guide when providing cooling requirements to a contractor:

- a. Figure 3-5, Heat Distribution
- b. Total heat load
- c. Cooling system requirements
- d. Type air distribution system required
- e. The temperature and humidity controls

3.1.5 Acoustics

Acoustical treatment of the computer room is recommended to provide for more efficient and comfortable operation. For the majority of installations, two approaches are generally taken to solve acoustical problems. The first is to arbitrarily decide that all facility site preparation plans will include the requirement to install an acoustical ceiling and to acoustically treat all walls. This is a safe approach but can be a very costly in terms of time and money. The second approach is to wait until the computer is installed and running and then take steps to correct any noise problems that may arise. However, attempting to do any construction work while the computer is running is disastrous to computer operations and computer



maintenance.

Since neither of these alternatives is satisfactory, it would be best to acquire the services of an acoustical specialist who can make an accurate determination prior to the installation of the hardware of the type and amount of acoustic treatment that will be required.

Do not consider all commercial firms who install acoustical material to be "acoustical experts." Often their method of operation is to examine a computer room with the customer and agree that there is a problem. At that point they immediately begin installing sound proofing material. If possible they will start with the raised floor, since carpeted flooring has the most eye appeal, and then proceed to the walls and ceiling.

At some phase of the installation, usually after the floor is completed, the contractor will meet with the customer and they will listen and decide if more sound proofing is required. If the customer is happy, the contractor presents his bill and leaves; otherwise the process starts over again, but this time with the walls. This is not a good engineering approach. The next three sections provide the information necessary to accomplish acoustical estimates.

3.1.5.1 Estimating Acoustical Treatment

In lieu of hiring an acoustical engineer or leaving your facility in the hands of a hit and miss acoustical

firm, the following two methods are provided to assist calculation of the approximate amount of sound absorption material a room will need and where it is best applied.

These methods both provide general guidelines for the amount of construction work that will be needed to adequately sound proof the computer facility.

As shown on the chart in Figure 3-6, the normal range of speech is 50 to 70 decibels. Continuous exposure to a noise level above 85 decibels can cause damage to the ear. Most computer equipment operates at a sound frequency of 1000 HZ with a noise level of 80 plus or minus 5 decibels.⁸

Most rooms will contain some sound absorbing materials which will reduce the sound level of the equipment. The problem is to determine whether the room will reduce the sound to an acceptable level and, if not, how much acoustic treatment is required and where should it be applied. The effectiveness of any material as a sound absorber can be expressed by its absorption coefficient. This coefficient describes the fraction of incident sound energy that a material absorbs. Theoretically it can vary from 0 (no sound absorption) to 1.0 (all incident sound absorbed). Coefficients are derived from laboratory tests or calculated from measurements in finished rooms. A sample list of sound absorption coefficients can be found in Figure 3-7. The usage of these methods will be presented via an example.¹⁰

	Decibels (dB)	Examples	Subjective Evaluations
Continuous exposure above here is likely to degrade the hearing of most people	- 130	Threshold of pain	
	- 120	Threshold of feeling (hard rock band)	Deafening
	- 90	Noisy urban street	Very loud
		Noisy factory	
	- 80	School cafeteria w/untreated surfaces	
Range of speech	- 70	Stenographic room	Loud
	- 60	Near freeway auto traffic	
	- 50	Average office	Moderate
	40	Soft radio music in apartment	
	- 30	Average residence w/o stereo playing	Faint

Figure 3-6
BASIC THEORY--COMMON SOUNDS IN DECIBELS (dB)

Material	Sound Absorption Coefficient					
	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
WALLS						
Sound-reflecting:						
Brick, unglazed	0.03	0.03	0.03	0.04	0.05	0.07
Concrete block, painted	0.10	0.05	0.06	0.07	0.09	0.08
Glass, typical window	0.35	0.25	0.18	0.12	0.07	0.04
Gypsum board, 1/2 in. paneling	0.29	0.10	0.05	0.04	0.07	0.09
Plywood, 3/8 in. paneling	0.28	0.22	0.17	0.09	0.10	0.11
Sound-absorbing:						
Concrete block, coarse	0.36	0.44	0.31	0.29	0.39	0.25
Fiberglas fabric cur- tain, 8 1/2 oz/sq yd, draped to half area	0.09	0.32	0.68	0.83	0.39	0.76
Thick, porous sound- absorbing material with open facing	0.60	0.75	0.82	0.80	0.60	0.38
Carpet, heavy, on 5/8 in. perforated mineral fiberboard with air space behind	0.37	0.41	0.63	0.85	0.96	0.92

Figure 3-7
continued

FLOORS

Sound-reflecting:

Cork, rubber, lino-
leum, or asphalt tile
on concrete

0.02 0.03 0.03 0.03 0.03 0.02

Wood

0.15 0.11 0.10 0.07 0.06 0.07

Sound-absorbing:

Carpet, heavy, on
concrete

0.02 0.06 0.14 0.37 0.60 0.65

Indoor-outdoor carpet

0.01 0.05 0.10 0.20 0.45 0.65

CEILINGS

Sound-reflecting:

Gypsum board, 1/2 in.
thick

0.29 0.10 0.05 0.04 0.07 0.09

Plywood, 3/8 in. thick

0.28 0.22 0.17 0.09 0.10 0.11

Sound-absorbing:

Suspended acoustical
tile, 3/4 in. thick

0.76 0.93 0.83 0.99 0.99 0.94

Figure 3-7
SOUND ABSORPTION DATA FOR COMMON
BUILDING MATERIALS AND FURNISHINGS

METHOD 1:

Suppose a proposed site is selected. The room is 40 feet by 100 feet by 10 feet. The ceiling is gypsum board, the walls are concrete block and the floor is linoleum. The problem is to determine if acoustical treatment is required in the room. This can be done in four easy steps.

1. Compute the surface areas for each type of material in the room.

- a. The surface area of the gypsum board is

$$S = 40 \times 100 = 4000 \text{ square feet.}$$

- b. The surface area of the concrete wall is

$$S = 10 \times 100 \times 2 + 10 \times 40 \times 2 = 2800 \text{ square feet.}$$

For this problem the doors and window material have been overlooked.

- c. The surface area of the linoleum is

$$S = 40 \times 100 = 4000 \text{ square feet.}$$

2. Determine from Figure 3-7 the absorption coefficient (a) for each of the materials and multiply the coefficient by the total surface area of the corresponding material. The formula for absorption is $A = (S) \times (a)$ (measured in sabins)

- a. Gypsum

$$a = .04$$

thus

$$A = .04 \times 4000 \text{ square feet} = 160 \text{ sabins}$$

- b. Concrete $a = .29$

thus

$$A = .29 \times 2800 \text{ square feet} = 812 \text{ sabins}$$

c. Linoleum

$$a = .03$$

thus

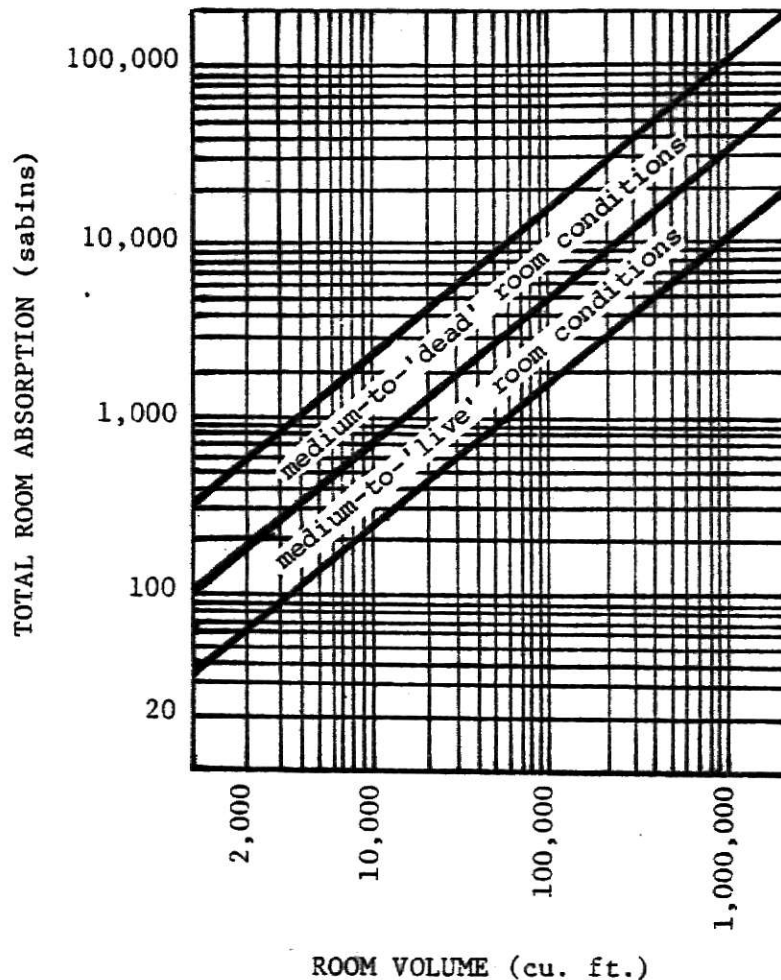
$$A = .03 \times 4000 \text{ square feet} = 120 \text{ sabins}$$

3. Add the components of absorbtion, i.e., $A_1 + A_2 + A_3$, to get total room absorbtion; in this case, $A_T = 1092$.
4. Compute the volume of the room (40,000 cu. ft.) and then enter the chart in Figure 3-8 with A_T and cu. ft. If the intersection of the two values falls within the area called "dead", no treatment is necessary. If the intersection falls below the line, treatment may be required.

In this example, the intersection of room volume and total room absorbtion falls within the "medium to live" area. From the chart the minimum absorbtion required to be in the dead area is 9,000 sabins. By reworking the formulas, it is possible to determine how much absorbtion material would be required. For example, if acoustic treatment is to be added to the ceiling, it would be necessary to know the absorbtion coefficient of the material.

1. The total absorbtion of the walls and floor is:

$$812 + 120 = 932.$$
2. The absorbtion for the ceiling must be:



'DEAD'
ROOM CONDITIONS

MECHANICAL EQUIPMENT ROOMS
OTHER SPACES WHERE SIGNIFICANT
NOISE LEVELS ARE INVOLVED

'MEDIUM'-TO-'DEAD'
ROOM CONDITIONS

ELEMENTARY CLASSROOMS, CORRIDORS,
GENERAL OFFICE
OTHER LARGE MEDIUM-OCCUPANCY SPACES

'MEDIUM'
ROOM CONDITIONS

STORES, PRIVATE OFFICE
OTHER SMALL LOW-OCCUPANCY SPACES

'MEDIUM'-TO-'LIVE'
ROOM CONDITIONS

CONFERENCE AREAS
OTHER SMALL-TO-MEDIUM SIZED SPACES
WHERE AURAL COMMUNICATION IS A
PREDOMINANT ACTIVITY

Figure 3-8¹⁰
BACKGROUND NOISE (ROOM SOUND ABSORPTION)

$$9000 - 932 = 8068.$$

3. Using the absorbtion formula:

$$A = S \times a$$

thus

$$a = \frac{8068}{40,000} = .20.$$

The chart of absorbtion coefficients for a ceiling (see Figure 3-7) indicates it is possible to add acoustic treatment only to the ceiling and fall within the dead zone. The chart and formula can be used to determine within a reasonable estimate the type, location and amount of material needed to bring the total absorbtion value within the dead space on the chart. This method is not guaranteed to be completely accurate, but it is a good tool for approximating construction requirements.

3.1.5.2 Reverberation Time

Another method to determine room acoustics is reverberation time, a very straight forward procedure. Reverberation time is the time it takes sound in a room to decrease to 1×10^{-6} of its original intensity. The expression for reverberation time is:

$$T = .05 \frac{V}{a}, \text{ where}$$

T = reverberation time, sec

V = room volume, cu. ft.

a = total room absorption

The preferred range of reverberation times, based on experience with completed spaces for a computer room, is .20

to .25 seconds. Using the previous example, the reverberation time of the room is:

$$T = \frac{.05 \times 4000}{1092} = 1.83 \text{ sec.}$$

This is greater than the .25 seconds maximum allowable time. The required total absorption to bring the reverberation time to the maximum allowable time of .25 seconds can be found by reapplying the above equation:

$$.25 = \frac{.05 \times 40,000}{a}, \text{ thus } a = 8000 \text{ sabins}$$

which says the minimum amount of room absorption required will be 8000 sabins which is close to the calculation computed earlier.¹⁰

3.1.5.3 Guidelines for Sound Absorption

In addition to the two methods for computing sound absorption, the following general guidelines are provided for effective sound absorption:

1. In smaller rooms containing closely spaced or high-level noise sources (such as business machine rooms), the maximum average absorption coefficient after treatment should be 0.50. This will prevent the room from being too "dead."
2. In order to create a definite and noticeable improvement in noise reduction, the total room absorption (average absorption coefficient before treatment) must be increased at least

three fold.

3. Never put sound-absorbing material on a surface that is needed for useful sound reflections.
4. Place sound-absorbing material on any surface that can be expected to produce annoying echoes or to focus sound.
5. In general, cover ceilings for noise reduction within rooms, unless the floor is carpeted and the room is filled with draperies and heavily upholstered furniture. Sound-absorbing materials are commercially available that have a factory-applied surface finish which is reasonably durable for ceiling applications.
6. In long, narrow, or very high rooms, consider using absorption on the walls. In very large rooms with low ceilings, wall absorption is rarely beneficial (see Figures 3-9, 3-10).
7. Generally, the construction of the building determines the mounting method. Check carefully so the mounting used is best suited for the absorption desired. The method of mounting is important since it will control absorption efficiency. For example, sound-absorbing materials applied with adhesive are poor low frequency absorbers. However, when applied to furring systems, they will give somewhat better low frequency absorption; and when used in

Noise control and reverberation control treatments can be placed on any available surface; the important goal is to provide sufficient absorption. The examples below show that high-efficiency absorptive treatment of walls can be more effective in smaller rooms, whereas treatment of ceilings is more effective in larger rooms.

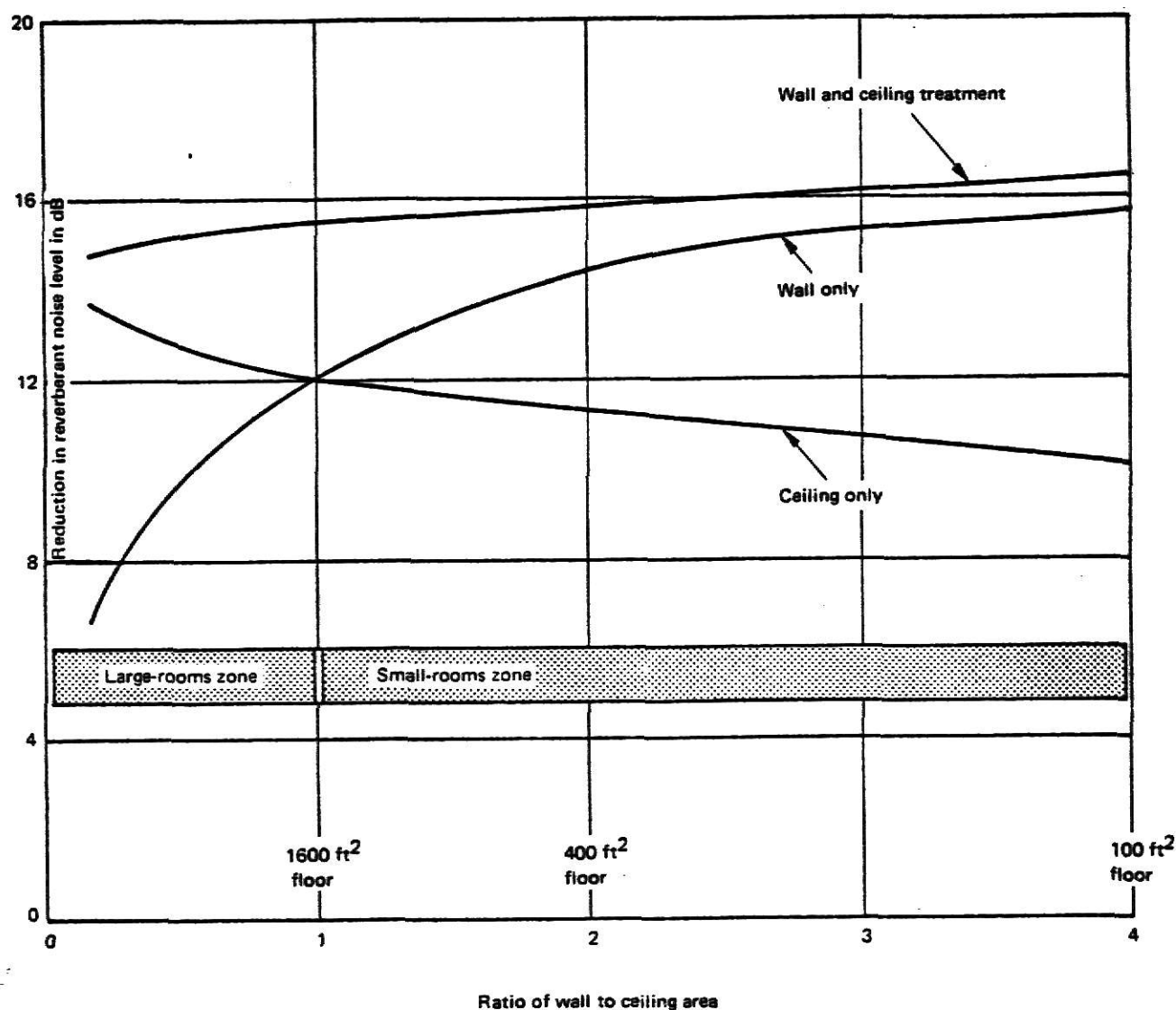


Figure 3-9¹⁰
 SOUND ABSORPTION: RELATIVE EFFECTIVENESS OF WALL AND
 CEILING ABSORPTION TREATMENT

The addition of ceiling sound absorption to a 20' by 20' by 10' high room reduces the sound level by 10 dB in the reverberant field, as shown below. However, close to the sound source the reduction is only about 3 dB. If the ceiling and all four walls are treated with sound-absorbing material, the sound level in the reverberant field drops an additional 6 dB, but the sound level near the source, in the free field, remains unchanged.

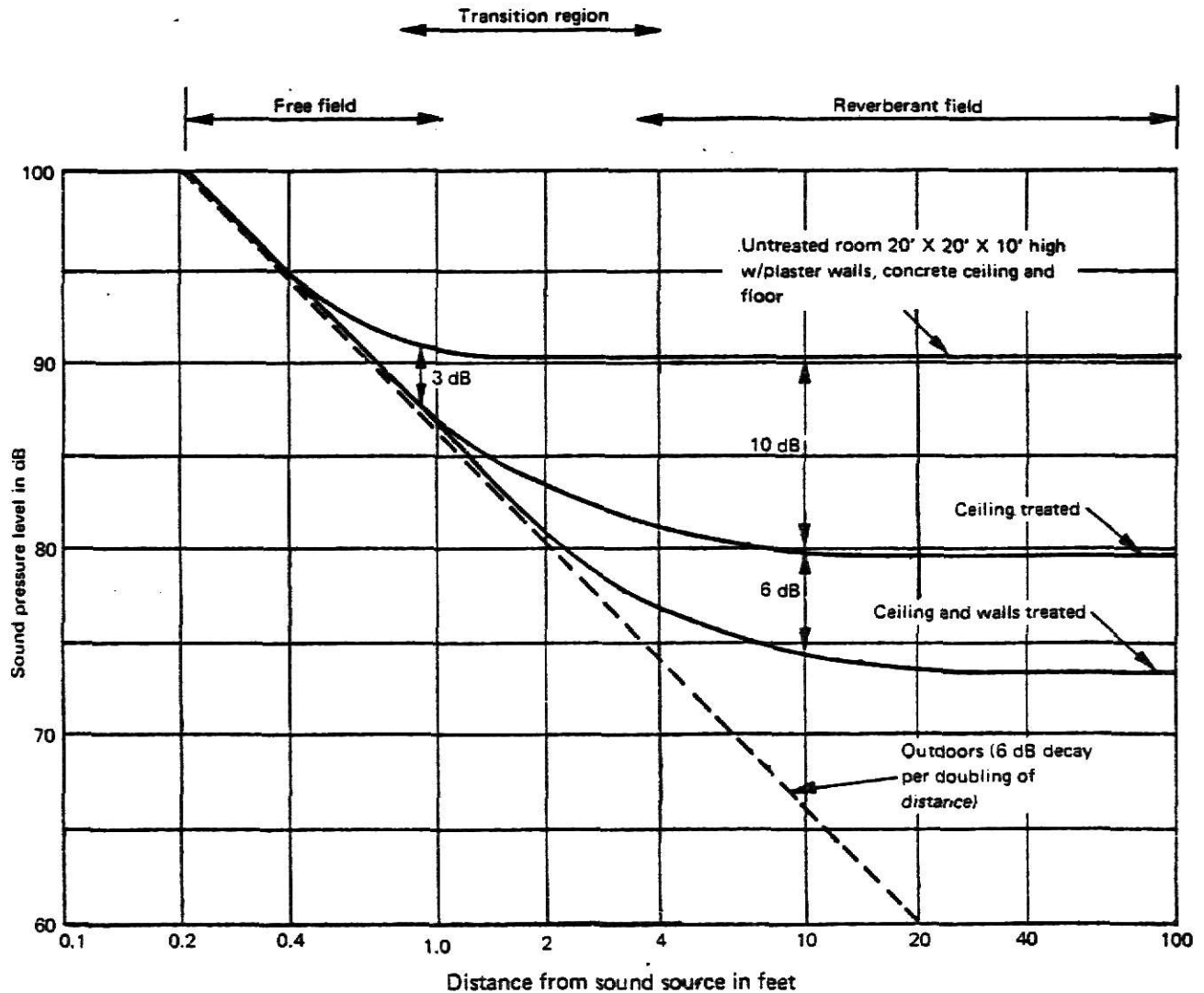


Figure 3-10¹⁰
SOUND ABSORPTION: EFFECT OF ROOM SURFACE
SOUND-ABSORPTING TREATMENT

suspended ceiling systems, they will provide balanced absorption.

8. The amount of treatment is determined by the absorbing material already in the room, plus the size of the room.
9. Whenever possible enclose noisy equipment in sound absorbing cabinets.⁹

In addition to reducing the noise level within the computer room, the noise projected outside the computer area is also an important consideration. Common sense plays an important role in this area. For instance, do not locate the computer equipment next to the executive offices or a briefing room, and enclose the computer area with complete floor to ceiling walls. Additional considerations are listed below:

1. Sound-absorbing materials by themselves normally provide little sound isolation. For example, sound can travel up and over a partition attached to a suspended porous sound-absorbing ceiling, using the open plenum to travel from one room to another.
2. Sound will travel through any opening, however small. For effective isolation, provisions should be made to seal cracks or openings in all construction.
3. Wall and ceiling material should be balanced to provide approximately the same amount of sound

transmission loss through each. Mass is always a major consideration in sound isolation. For example,

- a. Sand is more effective than lightweight aggregates in basecoat plasters.
 - b. Dense concrete blocks are more effective than those made with lightweight aggregates. Check density closely, as it may vary widely between different manufacturers products.
 - c. The integrity of the mass should never be violated by placing electrical outlets back-to-back. Avoid back-to-back electrical outlets by staggering them, and pack the outlet box with mineral wool and seal the box airtight to the partition.
4. While sound-absorbing materials by themselves are not satisfactory for sound isolation, sound absorbtion does perform a function of contributing to sound isolation.
 5. Avoid attaching vibrating or noisy equipment directly to the structural surfaces in a building.
 6. Pipe and conduit connections to vibrating equipment should be vibration isolated for a considerable distance to interrupt the transmission path. All electrical conduits and pipe connections should be flexible, i.e., flexible conduit whenever possible. Avoid metal-to-metal contact.

7. Avoid construction such as untreated mechanical ducts or rigid conduits, which can act as speaking tubes to transmit sound from one area to another. Line common ducts with glass fiber and, where they pass through walls, floors, etc, isolate them from the structure with resilient materials and caulk the perimeter.⁹

3.1.6 Fire Protection

The location and installation of fire detection and extinguishing equipment requires considerable planning. Local experts in fire protection, the local fire marshall and building authorities should be contacted prior to selecting a site. Fire protection is elaborated in six topic areas--general construction, electrical systems, air conditioning, general storage, type of fire protection and the Halon 130/system.

3.1.6.1 General Construction

1. The computer area should be located in a non-combustible or fire-resistive building or room.
2. Walls enclosing a computer area should consist of non-combustible materials, and should have at least a one hour fire resistance rating. These walls should extend from the structural floor to the structural ceiling. Openings in the walls

will be protected by fire doors, fire windows, fire dampers or glass blocks.

3. Where a false ceiling is to be installed, it should be constructed of non-combustible or fire-resistant material. All ducts and insulating material should be non-combustible and non-dusting.
4. Raised floors including structural supporting timbers should be constructed of non-combustible materials.
5. Openings in raised floors for electric and data cables and cooling will be protected to minimize the entrance of combustible material. This can be accomplished by placing equipment over the openings. If the structural floor is of combustible material, an insulating non-combustible material should be installed over the flooring or it should be protected from the ceiling below preferably by water sprinklers. The roof or floor above the computer and media storage areas should be watertight.¹⁴

3.1.6.2 Electrical Systems

Wiring throughout the computer area will be in accordance with the national electric code, NFPA 70. Wiring to electronic equipment should be flame retardent and if run

under raised floor, it must be water resistant. Communications or other wiring of similar nature under raised floors shall be separated from lighting or power circuit wiring as required by article 800-3g, NFPA70. No wire splices or connections should be made in the under floor area except within junction boxes or by means of receptacles or connectors.

In addition to any emergency shutdown switches for individual components or other units of equipment, controls for disconnecting power to all electric equipment must be located at each principal entrance to the computer room.¹

3.1.6.3 Air Conditioning .

Air conditioning systems shall conform to the requirement of NFPA No. 90A, "Air Conditioning and Ventilation Systems." The design of the air distribution system, if not dedicated to the computer area, should prohibit the spread of fire, smoke, fumes, etc., into the computer area. In such cases, fire doors should be provided to maintain the fire integrity of the equipment area enclosure. All air filters must be non-combustible. Air ducts serving other areas should not pass through the computer area.¹

3.1.6.4 General Storage

The operation of computer equipment involves storage of sizeable quantities of combustible materials. Printout

paper, stationery supplies, unused magnetic and paper tapes, packaging materials and other types of flammable supplies are customarily stored in the computer room. If not rigorously controlled, the storage of these items may become a serious fire hazard. An accumulation of supplies should be clearly recognized as fuel source for potential fires which might damage costly computer hardware and destroy valuable records.

Within the computer equipment area, the storage of all combustible material should be restricted to the minimum level required for efficient day-to-day operations; and these materials should be kept in totally enclosed metal containers or file cabinets.

Storage rooms outside the computer area should be provided for reserve stocks of supplies, including paper, unused magnetic tapes and other items required for continuing operations.¹⁴

3.1.6.5 Type of fire Protection

Local fire protection codes or fire insurance regulations may require the installation of automatic extinguishing systems. Three types, automatic sprinkler, automatic fire detection and portable fire fighting equipment, are discussed below.

Automatic sprinkler protection for electronic equipment areas shall be in accordance with NFPA 13, "Sprinkler Systems." Each automatic sprinkler system shall be provided

with both local and automatically transmitted water flow alarm. The sprinkler system should preferably be valved independently from other sprinkler systems. In a situation where a raised floor covers a large area and is greater in depth than 12 inches, includes extensive cable runs, allows for the possible accumulation of combustibles, etc., special consideration should be given to the installation of sprinklers under the floor.

When required, automatic fire detection equipment capable of detecting fire in its earliest stage will be installed. The equipment used must be the product-of-combustion (ionization) type. Installation should be in accordance with current NFPA standards for equipment of this type. Each installation must be engineered for the area to be protected, giving due consideration to air currents, under floor areas, false ceiling spaces, cable ways and tunnels and return air ducts connected directly to equipment. The fire detection equipment should be designed to detect a specified size and type fire within a fixed period of time. These parameters should be established by the fire marshall and or local fire codes. In the instance where a fire detection system is included with an installation, the detection system should sound an alarm in the area. When a fire alarm system is in use, it is used to transmit the electronic equipment area alarm to a constantly supervised location.

Detection equipment should be arranged to shut down all power and air conditioning to the involved equipment, except where air handling equipment is specifically designed for smoke removal.

Shutdown of all power and air conditioning will not always be possible as this feature requires precise zoning of the detection equipment. It may be better to use the detection equipment to shut down power to all equipment in the area. Again, with the air conditioning, it may be better to keep the air conditioning running to clear out the smoke using the detection equipment if possible to convert the air conditioning from recirculation to total fresh air supply and total exhaust. There has been a fear that the air conditioning system will supply fresh oxygen to the fire. However, there is sufficient oxygen already in the room to feed the largest fire likely to occur, thus reducing the importance of this fear. Portable fire fighting equipment should be installed. Carbon dioxide fire extinguishers or hose reel systems are recommended for electrical fires. No other class C (electrically nonconducting) extinguishing agents should be used. Plain water-type fire extinguishers are required in addition to the carbon dioxide extinguishers because of the inevitable presence of ordinary combustibles (paper, wood, cloth, plastics, etc.,) in the form of records, logs, work sheets, interior finish or decorations, etc. Every computer area should be provided with carbon dioxide fire extinguishers,

permanently located so that no electrically powered machine or other electrical equipment is more than 50 feet travel distance from a carbon dioxide fire extinguisher of at least 15 pound capacity.¹⁴ The computer equipment area should be provided with plain water fire extinguishers, permanently located so that no person working in the electronic equipment area will have to travel more than 50 feet to obtain a fire extinguisher having a capacity of at least 2 1/2 gallons. All fire extinguishers should be properly maintained, charged, and in good working order. Fire extinguishers will not be blocked or located so that a small fire may block the approach to the fire extinguisher.^{13,4}

3.1.6.6 Halon 1301 Total Flooding System

An automatic total flooding Halon 1301 system may be used to provide complete machine room protection. The system requires automatic early detection of fire and timed release of the 1301 extinguishing agent. The system must be engineered for the specific area to be protected in accordance with NFPA 12-A-1973, Halogenated Extinguishing Agent Systems--Halon 1301.¹⁶

3.1.7 Safety

Safety cannot be overemphasized, especially in a construction area and where electronic equipment is concerned. During the construction phase, all unauthorized personnel should be restricted from the area. Curiosity

seekers from top management on down who want to "see how things are going" should be discouraged from visiting. The contractor is responsible for enforcing safety practices among his own personnel; however, if unsafe practices are observed, bring them to his/her attention.

After construction is complete, the installation manager is responsible for the area and strict access control should be maintained. During the hardware installation phase, use only personnel who are qualified to move, ground, electrically connect and power up equipment. The chance of electrical shock or damaging equipment is greatly increased if "self-appointed experts" are used for the installation of equipment. The points listed in the safety submodel are important and should be evaluated carefully. Safety is included in many of the checklists and sections because it is often difficult to consider safety out of context.

3.2 Electrical Construction

3.2.1 Power Requirements

It is very difficult and costly to install the AC power wiring after the computer is delivered on site. To minimize the physical space problems and to reduce delays in the installation schedule, all electrical support should be installed and tested prior to the installation of the computer.

The primary power source for the computer should be isolated from the rest of the facilities in the building. The central system (main frame) will usually be isolated by a motor generation (MG) set or uninterruptable power system (UPS) (see paragraph on Protective Power System). Peripheral devices should be powered from an isolation transformer; again this transformer should only serve the peripheral equipment. This isolation of power will minimize the electrical interference from other electrical devices in the building.^{16,19}

The primary AC power specifications for the computer should be obtained from the vendor or from the H/W specifications manual. The exact power specifications must be known before it can be determined if the power supplied to a site is adequate. For the most part, city-supplied power is generally adequate to support a computer installation. The specifications normally needed by a contractor are voltage and tolerance, frequency, number of phases and tolerance and total harmonic content.¹⁶

Ten topics provide necessary detail to an installation manager. These are AC power distribution, protective power systems, AC convenience outlets, lighting protection, overhead lighting, emergency lighting, phase balancing, remote terminals and detailed power requirements. These paragraphs provide only a recommended approach for establishing electrical support to the computer equipment. The manager will have to determine based on his particular

situation if all or only part of the following detail will be employed.

3.2.1.1 AC Power Distribution

The following paragraph provides a list of components basic to any large computer system and references Figure 3-11, representing a typical power distribution diagram.

1. Disconnect switch or circuit breaker for the input to the motor generator or EPU (Reference A).
2. Distribution panel and circuit breakers for the central system. The rating of the main breaker will be determined by the total load (Reference B).
3. Distribution panel and circuit breakers for peripheral equipment (Reference C).
4. Emergency off switch for peripheral distribution panel (Reference D).
5. Primary power wiring and conduit or square ducting (Figure 3-12) from distribution panels to each central system unit and each peripheral unit (Reference F). The power ducting should be installed as close to the raised floor as possible and routed along equipment aisles. The use of ducting is preferred over conduit for large systems because of the ability to consolidate power runs. Conduit into the

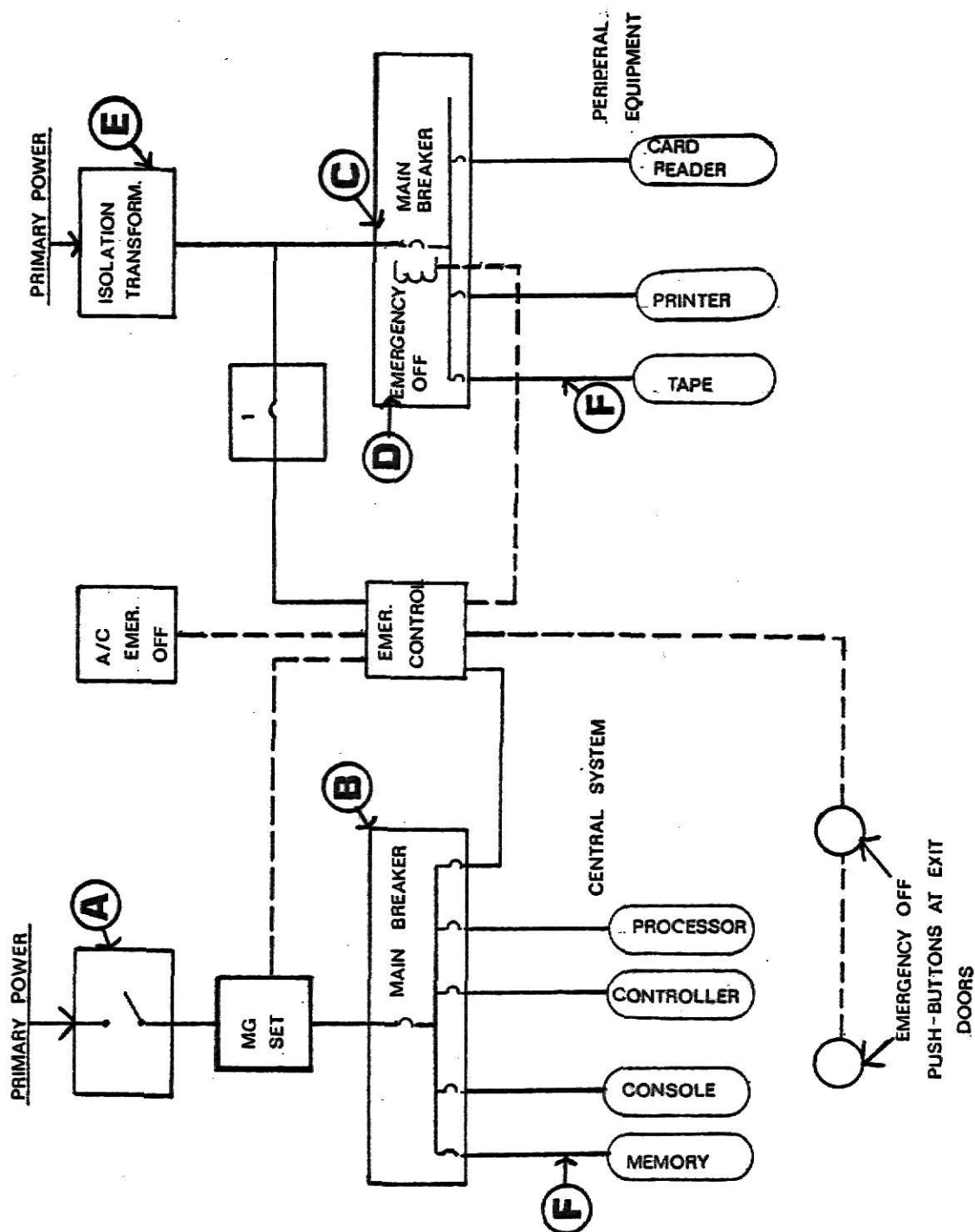
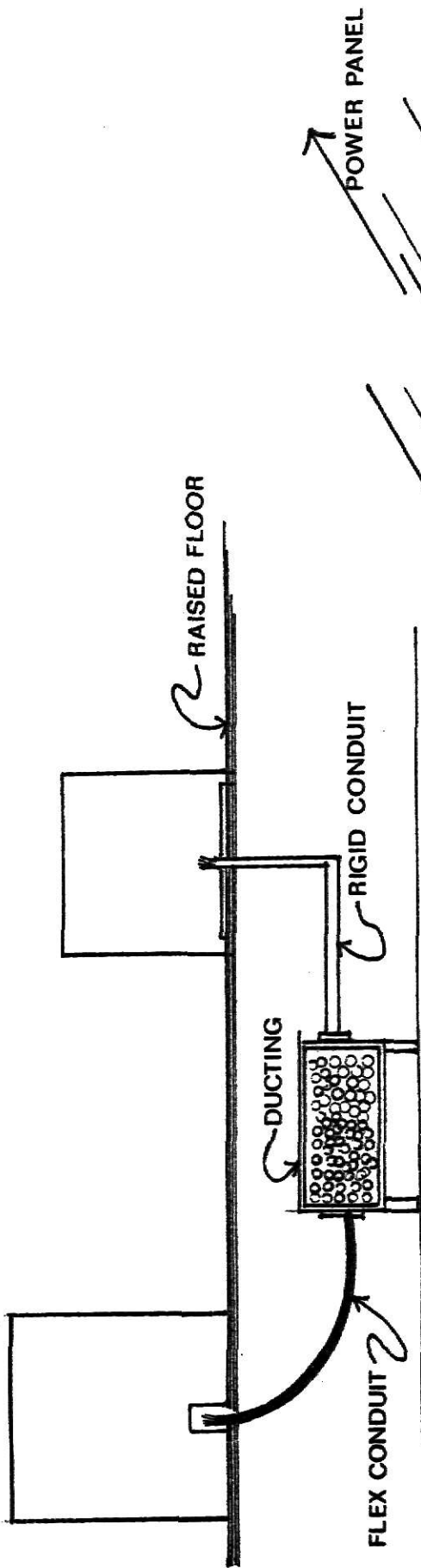
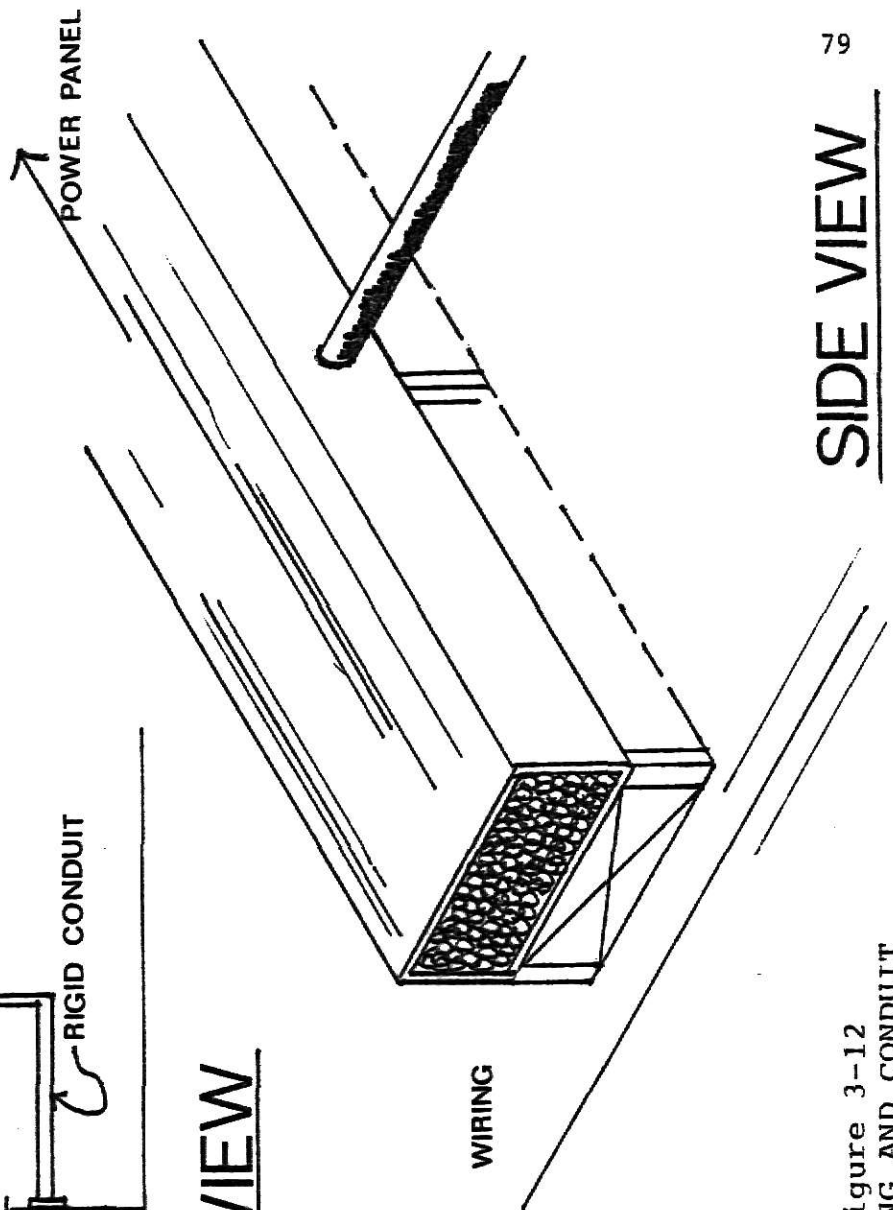


Figure 3-11
POWER DISTRIBUTION



FRONT VIEW



SIDE VIEW

Figure 3-12
DUCTING AND CONDUIT

equipment should be of the flexible type. The electrical wiring should extend four feet beyond the length of the conduit, which will allow for the electrical connection of the equipment.

6. Transformers to isolate power for the peripherals independent of the normal building power (Reference E).
7. To minimize the effects of possible high frequency interference, the power panels should be mounted on the steel structure of the building or be connected via a ground strap to the steel. If this is not possible, the installation of a ground plate is satisfactory.
8. Protective power systems should be located near the computer system but in a separate room where the operating sound level will not disturb personnel. The system should be installed, wired and tested prior to the installation of the computer.
9. Determination must be made as to what equipment will require receptacles and what equipment will be wired internally to the power (hard wired).^{16,20,3}

3.2.1.2 Protective Power Systems

Because it is so important to protect the computer equipment from power disturbances, which are a common

occurrence when city power is used, and the general lack of understanding of how to correct these problems, the following information is provided on protective power systems. The information was primarily taken from an article written by R. L. Cooper, "The Electrical Energy Crisis and You."⁸

Computer systems demand a high degree of technical sophistication in combining power, power conversion, and controls into a single integrated system. The result is a precise power system, the components of which must be designed and selected to function in complete compatibility to deliver the desired performance. How well they do so is dependent upon the integration of three different technical disciplines: electrical, electronic and mechanical.

There is no standard power system. It is nearly always a "special" engineered solution to a specific problem. System design parameters may vary widely, depending upon your system needs, various aspects of performance "packaging" and environmental protection. Typical design considerations, occurring singly or in combination, are:

1. Integrity of input power (voltage, frequency, wave shape)
2. Operational dependability
3. Environmental conditions (temperature, atmosphere, mechanical vibration or shock)
4. Heat capacities of system components
5. Output requirements

6. Dimensions, weight and configuration

7. Maintainability

A precise power system can assume an almost infinite variety of forms. It may be a complex stand-by emergency power supply. It may be a motor generator with controls for producing and precisely regulating a desired output power; or it may be an electrical motor with precisely engineered performance, combined with mechanical power transmission devices and electrical controls.

The following paragraphs discuss a step by step method that can be used to determine the type power protection you may need and some common devices used to monitor and correct power problems.

The first step towards protection is to take inventory of all the electrical equipment in the operation of your facility. Each and every piece of equipment should be considered with regard to its sensitivity to undervoltages, overvoltages, frequency variations and transients. Much of this information can be taken from the nameplate data or the equipment specification manual.

Undervoltage conditions can have all sorts of adverse effects on equipment operation; most electrical equipment will become less efficient, overheat and, at some point, fail entirely.

Create a complete inventory of all electrical equipment and note the electrical input tolerances of each as well as the adverse effects of sub-marginal power to that equipment.

Step 2 involves the monitoring, measuring, and evaluation of the quality of the electrical service currently received. Adequate monitoring of their incoming electrical power may indicate that their electrical service is marginal, even before the utility company cuts voltage by five percent to eight percent during peak load periods. Electrical power monitoring equipment provide a continuous record of the quality of service received, but many commercial models also provide an alarm to alert operating personnel to a marginal situation. Steps then can be taken to prevent the disastrous effects of brownout conditions. In the meantime, the recorded history of the line quality is available to assist engineers and management in making decisions for the acquisition of appropriate protective equipment. With such a record, a facility is unlikely to suffer a costly shutdown before the problem is recognized.

Electrical power monitoring equipment can range from relatively inexpensive recording voltmeters (single-phase/single-parameter stripchart recording devices) to sophisticated multi-phase/multi-parameter electronic monitors which detect and record power disturbances instantly. The electronic monitor can be extremely valuable with sensitive equipment such as computers and telecommunications equipment. The record that these devices provide can be invaluable in tracing the source of an equipment malfunction or failure. Some units can be interfaced with the computers and can even control the

shutdown of nonessential equipment during marginal electrical conditions, making more power and voltage available for the more sensitive and essential equipment.

In the past, too little emphasis has been given to monitoring. It is stressed here because it is imperative that a manager be aware of the quality of his electrical service prior to the installation of computer hardware.¹¹

In Step 3, corrective action may be taken. At this point, a manager should have no hesitation in engaging a competent engineer to assist in analyzing equipment requirements compared to the quality of electrical service being received. An engineer can also assist in the selection of the optimum means of correcting deficiencies and protecting equipment.⁸

Four topics, transformers, motor generators, uninterruptable power systems and secondary power sources relevant to corrective action are discussed in the following three sections. Depending on the degree of sensitivity of the equipment and the nature of the disturbances experienced, there is a wide variety of equipment available for correcting power deficiencies.

3.2.1.2.1 Transformers

Step-up transformers, voltage-regulating transformers, or AC line regulators are used to handle low voltage problems. The isolation transformer is used to eliminate power line noise problems associated with sensitive

equipment. They isolate sensitive instrumentation from noisy power lines, isolate noisy equipment from noise sensitive equipment and isolate sensitive power lines from noisy equipment.³⁰

3.2.1.2.2 Motor Generators

Motor generator (MG) sets are designed to provide reliable and uniform power to meet the demands of critical power loads. They offer the precise frequency, tightly regulated voltage, and transient-free power required by computer systems.¹⁰ By isolating the computer from the main power supply, possible malfunctions due to line fluctuations or transients are avoided. The MG set provides an "electrical flywheel" effect to over-ride line disturbances.³⁰

The majority of the computer manufacturers provide their own model MG sets and they can be purchased through the vendor. The MG set is the most commonly used protective power system. It should be emphasized that the MG set will not protect the computer from brownout or blackout conditions.

3.2.1.2.3 Uninterruptable Power System (UPS)

If the records indicate that your facility suffers from frequent voltage dips, severe brownouts, power surges or short blackouts, an uninterruptable power system (UPS) may be required. The uninterruptable power system can protect

the sensitive equipment while the less-sensitive equipment may be able to tolerate power disturbances.

Uninterruptable power systems have gained much prominence in the last two or three years. This, of course, has been brought about by the diametrically opposing forces of a degenerating electrical power condition coupled with significantly more installations of complex electronics equipment.

There are several different configurations for uninterruptable power systems; but, basically, a UPS is composed of a rectifier and/or battery charger which receives the incoming utility power and converts it to a regulated DC voltage. The DC voltage is then fed into an inverter which outputs a clean, regulated AC voltage waveform, free of transients and voltage variations and essentially guarantees clean power to the critical load. Usually, storage batteries are floated from the periods that the utility power is at nominal voltage levels. Whenever the utility power voltage falls below prescribed levels (or during severe brownout or blackout conditions), the battery supplies the DC power to the inverter, which continues to provide the regulated AC voltage to the critical load for a length of time determined by the storage capacity of the batteries involved. Typically, the batteries can provide sufficient power to last from five to thirty minutes during a blackout condition. However, the capacity of the batteries is usually selected based on the minimum time a

critical load must operate after a blackout or severe brownout occurs. Thus, for prolonged outages, additional protection would be needed in the form of a secondary power source. Type of batteries normally used in UPS systems rated above a few kilowatts are: lead-calcium, lead-acid, or nickel-cadmium. Each type varies considerably in the cost size, weight, short-term current output capabilities, etc. Due consideration should be given to the selection of batteries, dictated by the demands of the critical load.

The inverters used in UPS systems used many different conversion techniques (which have an effect on their size, cost, weight, efficiency and output electrical characteristics). Since the inverter is the most critical component of the UPS system, careful attention should be given to its characteristics so that the needs of the load are properly satisfied in the most economical fashion.¹¹

3.2.1.2.4 Secondary Power Source

If the record indicates that a facility experiences prolonged brownout or blackout conditions lasting more than a few minutes, and the equipment that must stay on line, then an auxiliary or secondary power source may be required in addition to an uninterruptable power system. These units vary in size and capacity from a few kilowatts to thousands of kilowatts. They may take the form of gasoline-driven engine generators, diesel engine generators, gas engine generators, turbine engine generators, and others. In some

instances, manufacturing units and hospitals have installed their own primary source generating plants.³⁰

3.2.1.3 AC Convenience Outlets

All convenience outlets in the computer room must be on a separate feeder to eliminate the possibility of electrical noise interference. Sufficient outlets should be provided around the computer room such that each piece of equipment can be serviced by test equipment without the use of an extension cord. This distance is usually fifteen feet.¹⁶

3.2.1.4 Lightning Protection

To ensure the safety of equipment and personnel primary power transformers must be protected by lightning arrestors. It is also recommended that similar protection be provided at the service entrance to the building.^{19,20}

3.2.1.5 Overhead Lighting

An intensity of 70-90 foot candles measured at 30 inches above the floor is adequate lighting for a computer area. Flourescent lighting is the best because of the small amount of heat generated and the even distribution of light provided. If lights are to be installed in the main frame area, the light fixtures should be installed directly over the equipment aisle ways and not over the equipment. Lights installed in the peripheral area should be positioned to take into account the requirement that switches and read

indicators must be free of glare. Lights should be sectionally controlled so that some portion of the lighting can be turned off if desired. The overhead lights should not be powered from the computer power panel. Direct sunlight should be avoided because a lower level of illumination is needed to read lights and indicators. Windows that do not face north should be covered with venetian blinds, tinted or covered with some other material to block out the direct sunlight.¹⁹

3.2.1.6 Emergency Lighting

Emergency lighting should be installed for the safety of personnel. The emergency lighting system will normally consist of a battery operated lighting unit that will automatically illuminate a designated area in case of power failure. These units are wired to and controlled by the lighting circuits.²⁰

3.2.1.7 Phase Balancing

In a three phase electrical system, phase unbalance currents flow in the neutral wire. High neutral return current can generate noises which may interfere with the computer system. To avoid this problem, attention should be given to balancing loads on the protective power system and on the power distribution transformer. Values for amperes per phase are provided with the hardware specifications and should be used as a guide in balancing each phase.¹ This

naturally must be accomplished with a qualified electrician.

3.2.1.8 Communications Support

To support the operation of remote terminal devices, modems must be installed in the main frame area. A decision on the required quantity and type of modems to be used must be made early enough to ensure delivery with the main system. Consideration must be given to the maintenance access, power, and cable requirements of each type of modem used.

3.2.1.9 Remote Terminals

If remote terminals are to be installed outside the computer area, special arrangements will have to be made to install the data cable from the computer room to the remote terminal locations. The vendor must be made aware of the distances from the computer room to the remote terminals so that the correct modems will be installed.

For remote terminals located external to the computer building or to support a dial-up capability, telephone lines or other communication media most generally will have to be used. Coordinate with the telephone company the installation of lines in support of the remote terminals.

3.2.1.10 Detailed Power Requirements

In order for the electrical contractor to provide the correct electrical support, it is imperative that he/she is

provided with requirements in an accurate and understandable format.

1. Provide the contractor with a scheme similar to the drawing in Figure 3-11. This will provide the contractor with an overall view of the electrical support required. This layout may vary depending on the type computer system installed.
2. The primary power specifications as provided by the hardware, specification manual (see Figure 3-13).
3. A final layout of the hardware with an indication of where power is applied to the equipment. Each component on the layout will have a name and a number. As an example, the card reader would appear as card reader (228). (See Figure 3-14.) If overhead lighting is to be installed, the hardware layout will enable the contractor to correctly position the lights.
4. A corresponding list showing code number of item and the electrical requirements for that piece of equipment (see Figure 3-15).
5. Figure 3-16 diagrams a scheme for laying out the electrical support to the equipment. This approach works well when there are many hardware components to be installed. It also supports the installation of the data cable (see Data

1. 60 Hz nominal with 60.5 Hz maximum and 59.4 Hz minimum frequency
2. 208, 240, 440, or 480 V $\pm$ ten percent for the motor generator (MG) set. The voltages available determine MG set used
3. 120/208 V, five-wire wye plus ground, for the peripheral equipment with limits of 208 V $\pm$ ten percent
4. A total harmonic content of less than ten percent of the fundamental frequency
5. Three phase with a maximum phase variation of five percent from the nominal 120 degree relation

Figure 3-13
EXAMPLE OF POWER SPECIFICATIONS
IN A HARDWARE SPECIFICATION MANUAL

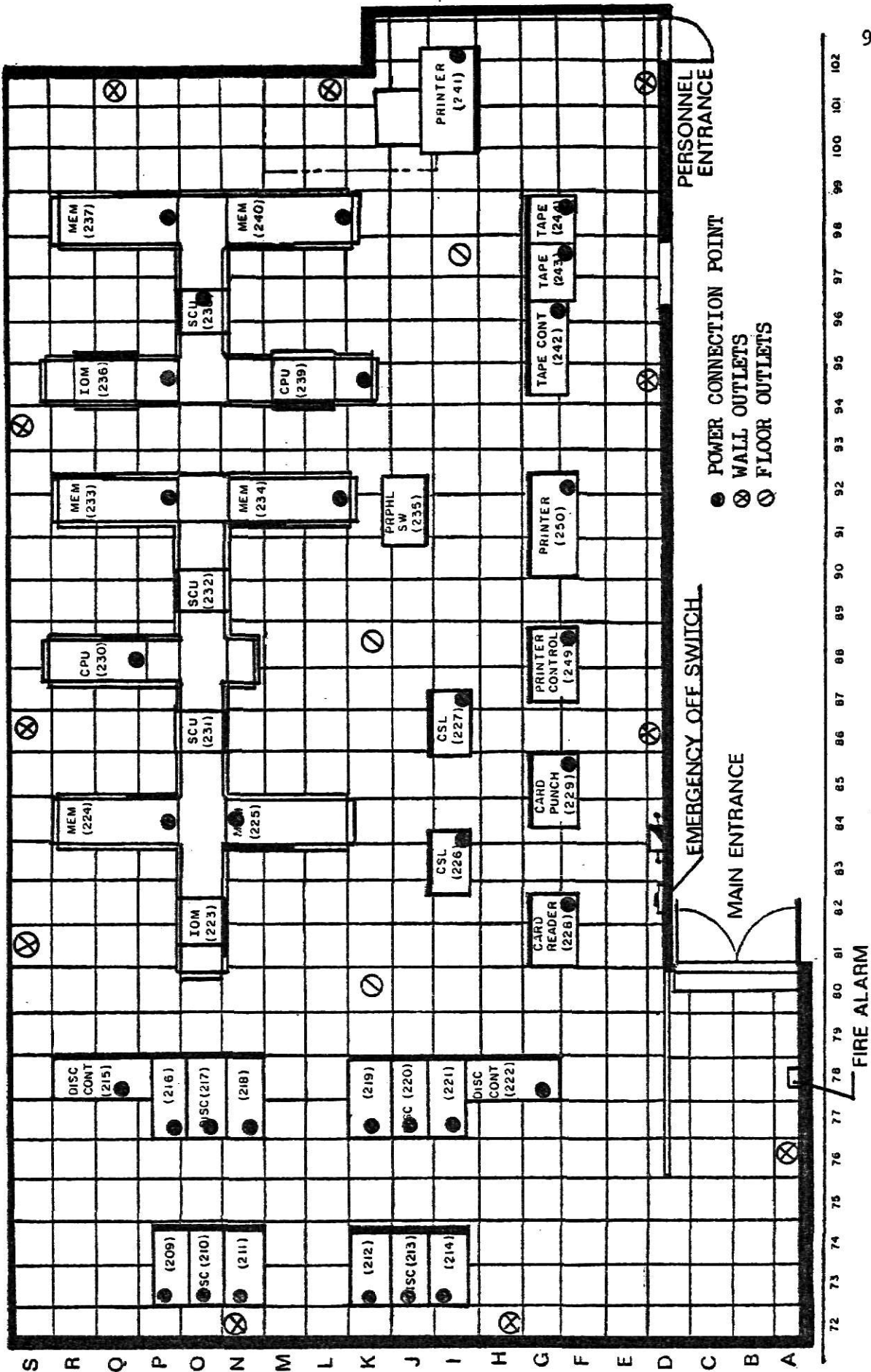


Figure 3-14
ROOM LAYOUT FOR ELECTRICAL SUPPORT

EQUIPMENT #	POLE/AMP	WIRE NO. AND SIZE	CONNECTION	COLOR CODE
Printer 250 A	3P/20A	5 #12	Plug, Hubbel 2503	
MEM 234	3P/30A	5 #12	Hard wired	A
SCU 231	3P/30A	5 #12	Hard wired	A
.				
.				
.				
.				
.				
Convenience Outlets	2P/20A	---	Standrad 3 Prong Duplex Outlet	---
Color Code	Phase A	Phase B	Phase C	
A	Black	Red	Blue	
D	Black	Red	Blue	
I	Black	Red	Blue	
neutral - white				
ground - green				

Figure 3-15
EQUIPMENT POWER

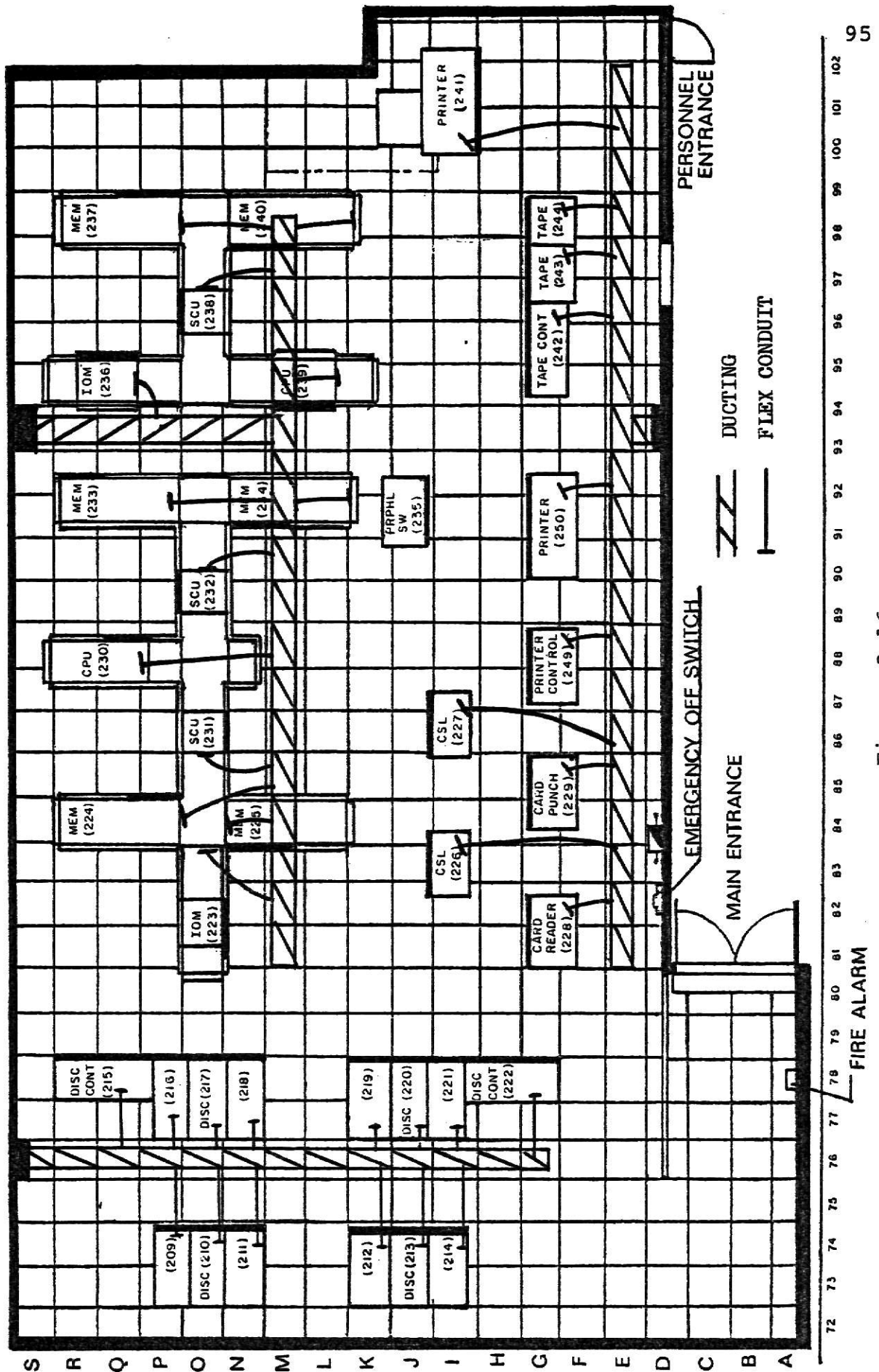


Figure 3-16
SAMPLE POWER LAYOUT

Cable).

6. Have the contractor label all circuit breakers in the power panels. This is particularly important when it is time to electrically connect the equipment. A recommended format for the contractor to use is shown in Figure 3-17. This power panel schedule should be posted inside the power panel.²⁰

3.2.2 Cabling Configuration

The data cable configuration of the computer system can be the most difficult phase of the installation if the issue is not addressed initially. As soon as it is known what type of hardware is to be purchased, the systems analyst and the vendor must get together and decide what system logical configuration will best satisfy the software requirements. Once the logical layout has been determined, it must be converted into a physical data cable layout. This should be performed by the installation personnel in conjunction with the vendor, systems analyst, and maintenance representative, if available.

Knowing the inter-component cable configuration, the next step is to note the maximum cable length for each type of cable used. These data cable limitations must be considered when developing the hardware layout (see *Equipment Compatibilities*). It is important to note that when computing the cable length between pieces of equipment,

PANEL NO. PS-34

ROOM 3302

MAIN 40 AMP COMM PWR

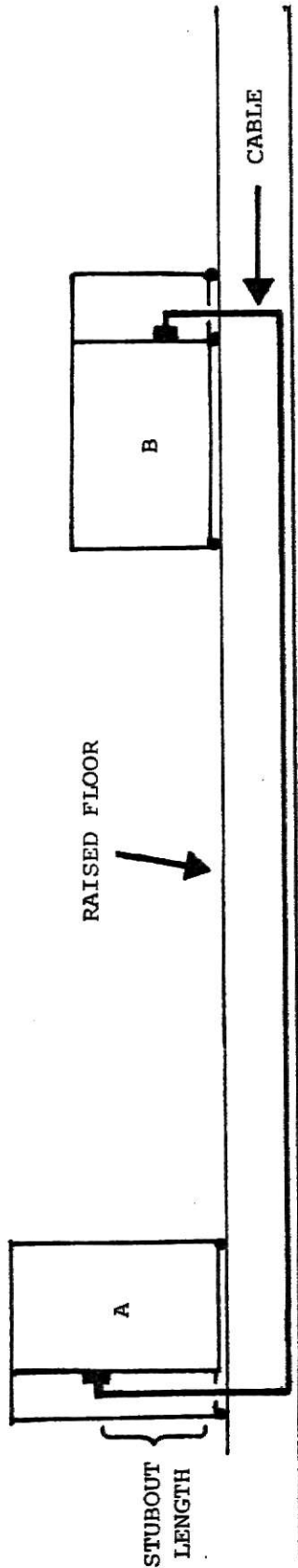
UNIT NAME	UNIT NO.	BKR AMP	CKT	CKT	BKR AMP	UNIT NO.	UNIT NAME
CONVENIENCE OUTLETS	A (4)	15	1	2	20		SPARE
TAPE HANDLER (MTH501)	244		3	4			
		15	5	6	20	250	PRINTER (PRT300)
			7	8			
PERIPHERAL SWITCH	235	15	9	10	20		SPARE
			11	12			
CARD READER (CRZ201)	228		13	14		241	PRINTER (PRT201)
		20	15	16	30		
			17	18			
CARD PUNCH (CPZ201)	229		19	20		243	TAPE HANDLER
		20	21	22	15		(MTH501)
.							.
.							.
.							.

Figure 3.17
POWER PANEL SCHEDULE

the height of the raised floor, the stub out length (the length of cable taken up by equipment entry, may vary from one to three feet), and the side of the equipment the cable enters must be considered (see Figure 3-18). Also the cable should follow a specific route and not run under the floor in a random manner. In particular data cable that runs from one part of the room to the other should be routed along equipment aisles and under the electrical power ducting and conduit where possible. Check for any under floor obstructions that might block the routing of cable. Mark these obstructions on the room layout before the final H/W layout is developed.

After the hardware configuration has been finalized, a list of cable requirements must be developed and provided to the vendor. The cable order must be in to the vendor early enough to guarantee delivery of the cable. Generally this is not less than two weeks prior to the scheduled installation date of the hardware. Allow enough time to verify the correctness of the order upon delivery.

Figure 3-19 shows a recommended method for listing the data cable required for a hardware configuration. When the data cable is delivered, it should be completely inventoried for completeness and lengths of the data cable verified. Nothing is as devastating to the installation schedule as a missing data cable or cable that is too short. As the cable is inventoried, mark both ends with a plastic or cardboard



PHYSICAL DISTANCE BETWEEN EQUIPMENT	50 ft.
RAISED FLOOR HEIGHT	1 ft. x 2
STUBOUT LENGTH FOR A	3 ft.
STUBOUT LENGTH FOR B	1 ft.
TOTAL	56 ft.
10% SAFETY FACTOR	+5
LENGTH CABLE REQUIREMENTS	61 ft.

NOTE: Cable runs that involve intraroom or intrabuilding routing or runs that are at the maximum cable length should physically be measured. This is best done by laying a string or cord along the exact route.

Figure 3-18
MEASURING DISTANCE BETWEEN EQUIPMENT

CABLE TYPE NUMBER	FROM	TO	QUANTITY	LENGTH
43B221747G	SCU232	CPU230	1	10 ft
44B221818G	SCU232	MEM233-234	2	15 ft
468C3322H	DISC217	DISCCONT215	5	20 ft
.				
.				
.				
.				
.				
.				
.				

FIGURE 3-19
CABLE TO BE ORDERED

tag listing the equipment designations, length and cable type number (see Figure 3-20).

3.2.2.1 Cable Installation

The installation of the data cable should begin about a week prior to the hardware installation date. The time it takes to install the cable will of course depend upon the size of the system. Prior to the actual installation, develop an overlay showing the hardware and the proposed routing for the cable. The layout will not show the routing for each cable but only show a general cable routing scheme (see Figure 3-21). The individual routing will be obtained from the information in Figure 2-19. Using the overlay as a guide, lift all the floor tile along the major routes and lay the cable. For personnel safety it is best to work on one section of the room at a time.

3.2.2.2 Cable Connection

Schedule the maintenance personnel to connect the data cable to the equipment immediately after the equipment is powered up. Only qualified maintenance personnel should be used to connect data cables. The pin connections on the equipment and cables can easily be damaged, and there are many port connections on the equipment each of which must be matched correctly with the data cable.

(destination)
(source)

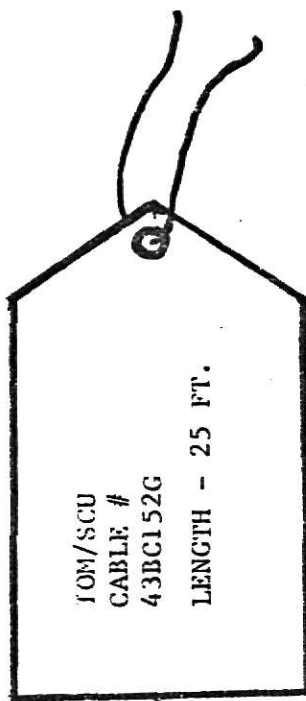
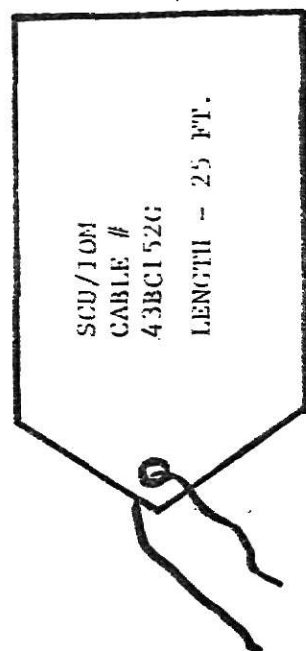


Figure 3-20
CABLE TAGGING SCHEME

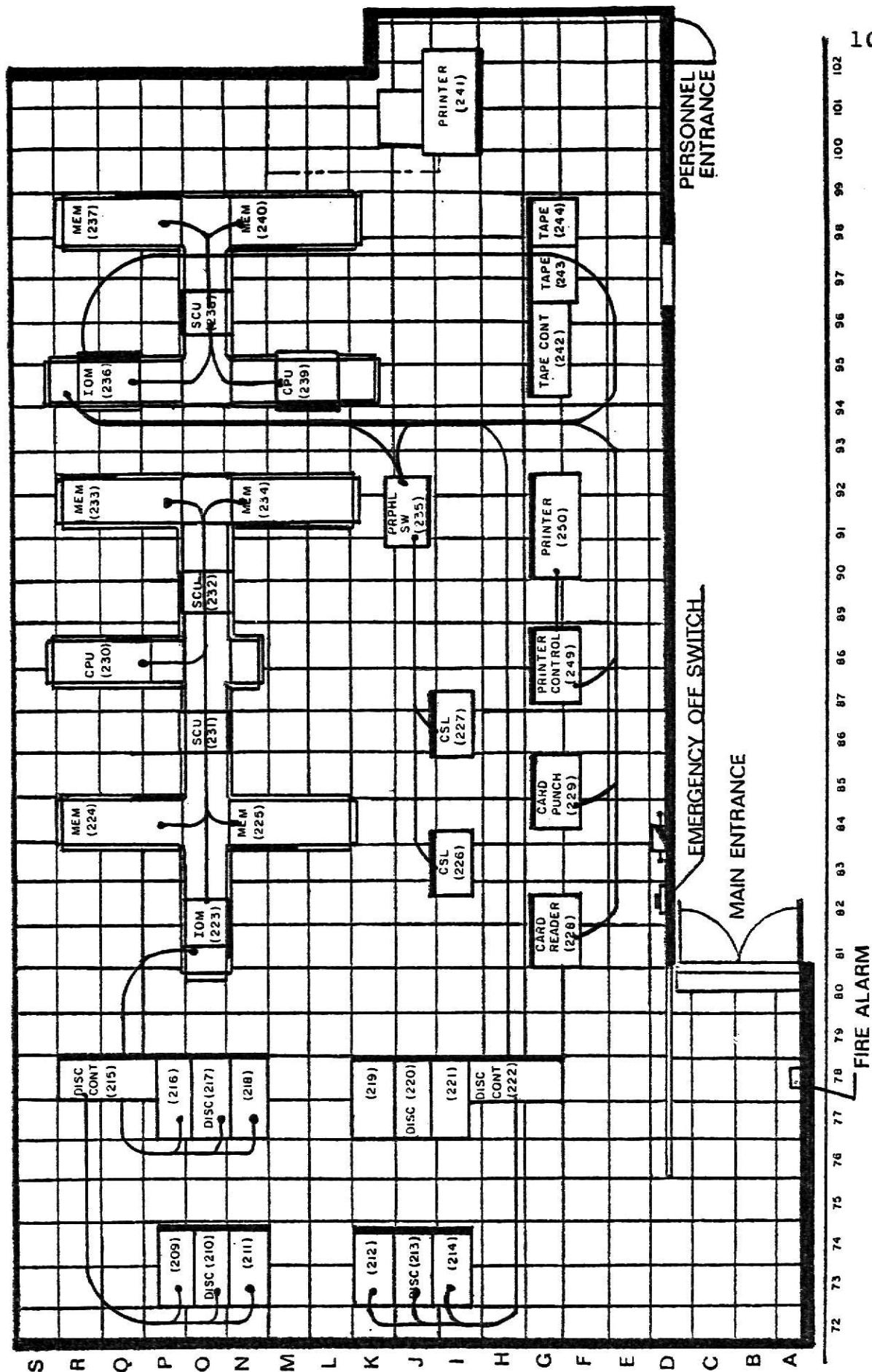


Figure 3-21
DATA CABLE ROUTING

3.2.3 Grounding System

The successful operation of the computer is dependent on correct grounding techniques. It is critical that grounding requirements for the system being installed be obtained from the vendor or the site installation manual. Provided below are some general grounding practices that are used on computer systems, should grounding details for your system be unavailable. Consult with your contractor prior to committing yourself to these specifications. Four topic areas are addressed in describing a grounding scheme, reason for ground, earth connections, green wire ground, and signal ground.¹

3.2.3.1 Background

The most important reasons for grounding equipment are:

1. To prevent a low-impedance, fault-return path to protect personnel and equipment in the event of AC power fault to the ground. The objective is to keep the potential between the computer equipment and adjacent structures low enough so as to protect personnel and cause power shutdown to equipment before it is damaged.
2. To provide a low-impedance path to earth for lightning current.
3. To provide a common equipotential plane for the overall computer system. The objective is to keep all of the equipment on the same potential

by shorting out differences through a single-point-ground system.

4. To provide protection against external high-frequency grounds.
5. To provide a low-impedance path to ground for static electricity which might otherwise cause a spark.

It is important to note that while all ground circuits are eventually connected to "earth" ground, ground conductors should not be used indiscriminately. Signal grounds must be isolated from conduit, wall breaker panel and raised floor grounds to prevent interaction between signal paths and noise.¹⁶

3.2.3.2 Earth Connections

The most important part of any ground system is the actual connection to earth. The low-resistance path to ground "earth" is dependent upon the adequacy of this connection, and the design objective should be to reduce this resistance to as near zero as possible. A maximum of 25 ohms is allowed as measured with a ground megaohm meter. Your power company will probably be willing to make this measurement.

Earth grounds are usually of two types:

1. Connections to underground metal water piping systems, metal frame structures of buildings, or other metal structures that are in good contact

with the earth. In many large structures, the building or architectural ground is most often used, since it is the most readily available point for equipotential planes.

2. Connections to ground rod plates which have been placed in the earth for the specific purpose of providing an adequate ground connection.

Experience indicates that continuous underground water piping systems can, depending on soil conditions, provide a resistance to ground of less than 15 ohms. When considering water piping as ground, precautions must be taken to ensure that the metal piping does not connect with plastic piping just outside the building.

It is significant that a resistance path to earth of less than 25 ohms can be obtained by using multiple ground rod electrodes. In some instances, it may be necessary to use this method to get an acceptable ground.

Regardless of the type of ground conductor used, many conditions affecting the ground must be considered in attempting to make an adequate ground connection. The effectiveness of the ground electrode is determined by:

1. the characteristics of the electrode,
2. the resistivity of the soil around the electrode.

Some of these factors are subject to change over a period of time and may affect the original measured resistance path to earth. This must be considered in

evaluating the effectiveness of the ground connection (for example, the soil condition will likely change with the change from a wet to a dry season).

Underground piping used for grounding must have the following characteristics:

1. At least 10 feet (3m) of metallic length underground.
2. Continuous and not excessively corroded.
3. Must not be coated or wrapped with insulating material.
4. Deep burial to reduce the effects of seasonal soil changes.

Where grounding to water piping systems is not practical or not permitted by local code, rod-type electrodes driven into the ground can be used. These are less expensive than other types of grounds such as buried plates or grids; but because they are usually shallow, they may be more susceptible to changes in soil resistivity caused by climatic changes.

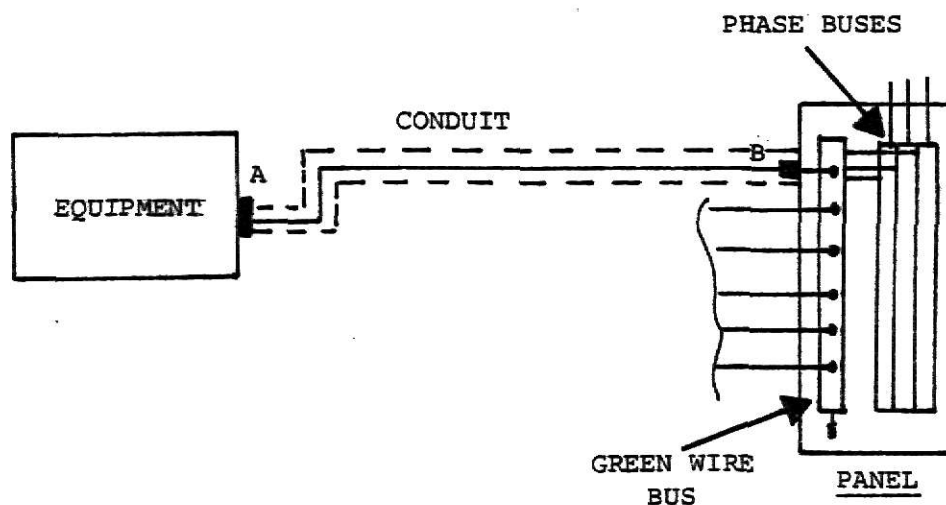
In most cases, two or more rods in parallel can be used to decrease ground resistance; however, primary consideration must be given to the spacing of the rods. Approximately ninety percent of the potential drop from the ground electrode takes place within ten feet (3m) of the electrode. Rods spaced closer than six feet (1.8m) will appear as a single rod with almost no reduction in ground resistance over that obtained with a single rod. Because of

this characteristic, the ground rods should be spaced at least twenty feet (6.1m) apart.

Ground inspections should be a normal part of your building maintenance routine. Ground connections should be checked on a periodic basis for tightness, damage, and corrosion. Inspection should be performed at least every six months.^{16,20}

3.2.3.3 Green Wire or Green Yellow Safety Ground

- A. Every equipment power run must have a separate, continuous, insulated wire for use as a frame (protective) ground (sometimes referred to as the "green wire" ground). It is run inside the conduit or power cord with the conductors and AC neutral. The frame ground wire must be securely fastened to the frame of the equipment and to the power distribution panel frame or ground bus (not the AC neutral bus) (see Figure 3-22).
- B. A single-point ground system must always be used with all "green wire" ground tied together at the circuit breaker panel. The breaker panel should have a copper ground bus to which all equipment grounds can be attached. The grounds for the central system and grounds for the peripheral equipment must not be tied together at the circuit breaker panels.
- C. In all equipment, the protective ground (green



A - This end of conduit isolated with plastic pipe fitting to avoid ground loop

B - Indicates green safety wire run in continuous conduit. This end bonded to frame of power panel

Figure 3-22
GREEN WIRE GROUND

wire) conductor is connected directly to the ground lug inside the unit's electrical junction box.

- D. Conduit alone is not acceptable as ground for the computer system. For safety reasons, all conduit runs should be bonded at the primary power end. All paint, coatings, or similar insulting materials must be removed from boxes, panels, etc., before the conduit is attached.^{19,20}

3.2.3.4 Signal Ground

In spite of the grounding practices described previously, the DC interface between the central system equipment makes ground loops (current loops) inherent in the central system. To minimize the inductance of these loops, with the high frequencies involved, low-impedance conductors (thin copper braid) are used to establish a system ground network. This ground network provides the low-impedance connection required to keep the reference ground of all equipment in the central system at a common potential.

This use of signal ground is not used by all computer manufacturers; however, it is recommended to eliminate the possibility of stray currents flowing between equipment components. One piece of

equipment is designated as the "root" of ground system and all equipment is eventually grounded back to that piece of equipment. It is then grounded back to the protective power system or earth ground (see Figure 3-23). If this method of ground is used, ground braid must be delivered at the same time the data cable is delivered. It should also be marked and installed with the data cable installation.¹⁶

3.2.4 Equipment Compatabilities and System Configuration

3.2.4.1 Logical Configuration

Prior to developing a hardware layout it will be necessary to determine the logical configuration of the system. This is simply determining the data flow paths between equipment components that will support the software requirements. Many of these data paths are standard while others must be tailored to the needs of the software specifications. The local systems analysts will need to work with the vendor or maintenance representative to determine the data path requirements within the system. The logical configuration must then be converted to a physical cable layout. To convert this information into a physical cable, layout the following type

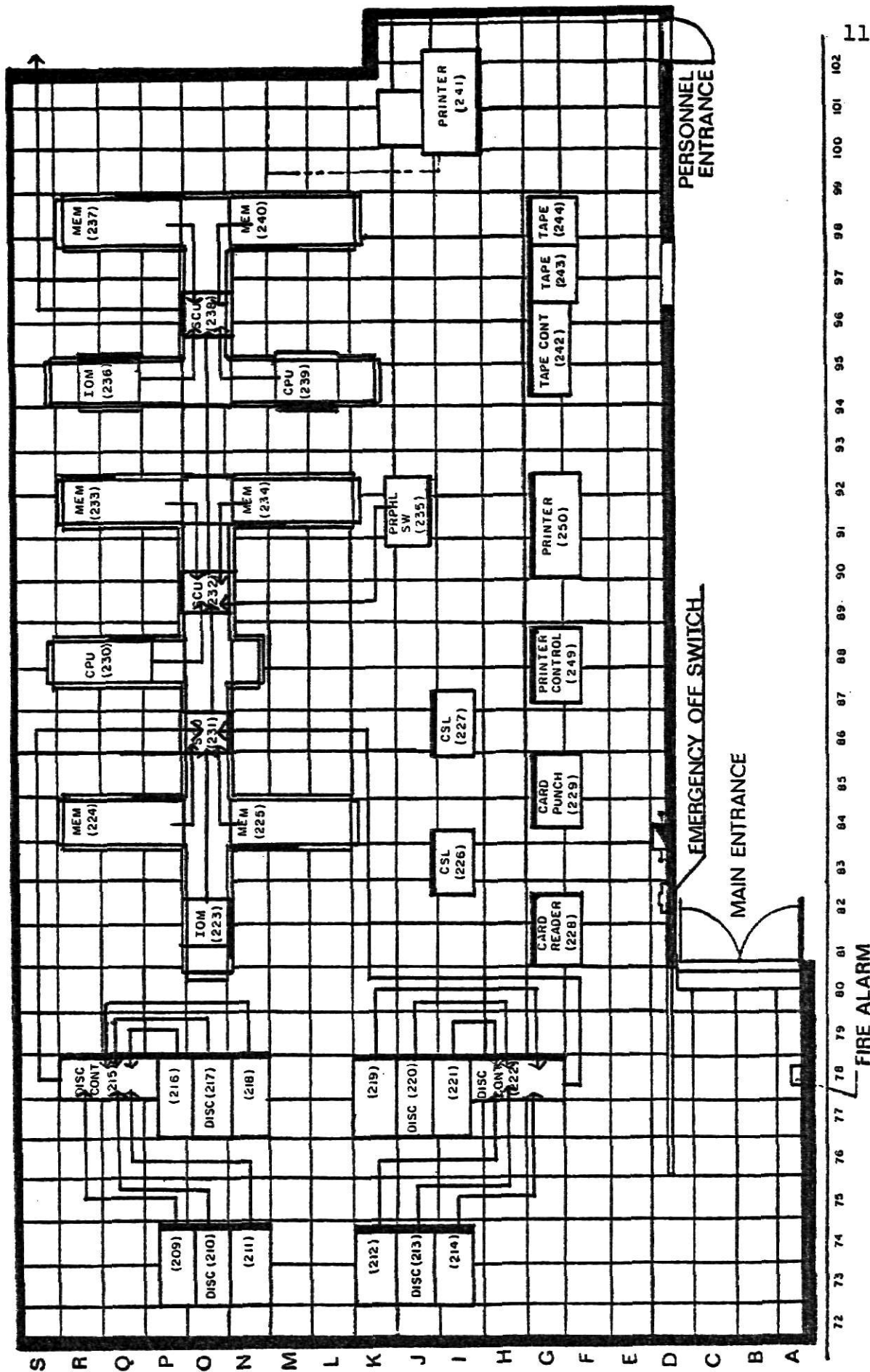


Figure 3-23
CENTRAL SYSTEM OR SIGNAL GROUND SYSTEM

information will have to be considered:

1. Control units to be assigned to each channel
2. Channel sequence or priority
3. Features on all machines
4. Physical and logical sequence of control units on each channel
5. Number of input/output devices or features attached to each control unit.
6. Disc subsystem configuration²⁴

As the inter data cabling requirements are developed, document the cable information as shown in Figure 3-24 and use it as a guide for developing the hardware layout, and finalizing the cable order.

3.2.4.2 Physical Configuration

The physical configuration of the system should satisfy operational requirements with consideration given to the following type factors:

1. Ease of operator control and visual observation of peripherals
2. Efficient work flow pattern
3. Adequate spacing to allow ease of tape changing
4. Printer paper loading and removal
5. Space for future expansion²¹

At the same time, the physical configuration must satisfy the technical requirements of the hardware. This pertains to the cable length limitation of the data cable and the

CABLE TYPE NUMBER	FROM	TO	MAXIMUM LENGTH AVAILABLE
43D221747G	SCU232	CPU230	30 ft
43D221747G	SCU238	CPU239	30 ft
43D23347C	SCU238	MEM234	10 ft
.			
.			
.			
.			

Figure 3-24
DATA CABLE REQUIRED TO SUPPORT
LOGICAL CONFIGURATION

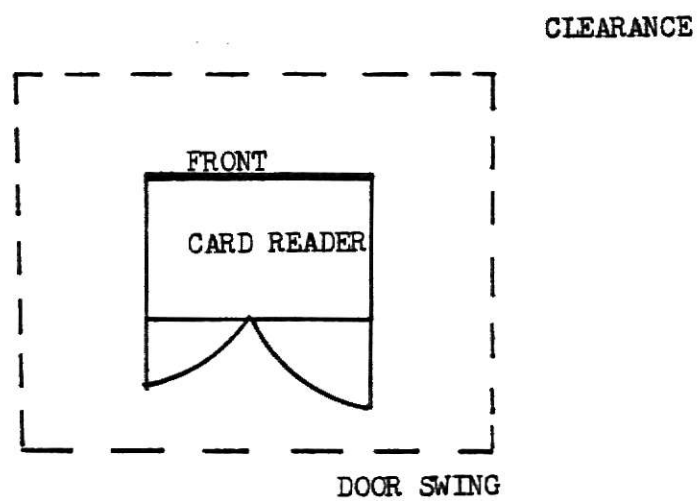
minimum spacing of equipment to allow operator and maintenance access. A recommended method for determining cable length is shown in the section on cabling. Equipment templates drawn to scale showing the required clearances can be obtained from the vendor or fabricated on site by using a hardware specifications or installation manual or site planning guide (see Figure 3-25). These templates should be used in conjunction with layout grid sheets in developing the site layout.

Standard system configurations are often provided in the vendors site planning guide. If these configurations satisfy operational needs and they conform to the shape of the computer room, it is recommended that they be used. Unfortunately many times either operational requirements or an odd shaped room will preclude the use of these layouts. When nonstandard configurations are developed, work with computer operations and the vendor to assure both the technical and operational requirements are satisfied.

The final hardware layout should be just that--final. Once the data cable has been ordered, the commitment is to a specific configuration. If there are any doubts concerning the stability of the "final layout," resolve the problem before ordering cable.

3.2.4.3 Site Layout

The hardware layout may go through several iterations before a final configuration is decided upon. When



NOT TO SCALE

Figure 3-25
SAMPLE EQUIPMENT TEMPLATE

developing the layouts, it is important that an accurate representation of the area and all necessary information is portrayed on the room layout will assure accurate preplanning of equipment locations. Also it is important that the final hardware configuration be presented in a meaningful and useful format. Recommended approaches for developing and portraying a room layout and final hardware configuration are presented below.

3.2.4.4 Room Layout

1. Block out the size and shape of the computer room on a grid layout sheet. If raised floor already exists, use the raised floor grid.
2. Show all room entrances/exits as well as any doors that cannot be used for equipment entry, adjacent corridor size, ramps, elevators, stairwells, building columns, media storage area, and maintenance space.
3. All under floor and above floor obstructions that block the routing of cable. Any areas where the ceiling height will be lower than the minimum specification.
4. Indicate external windows and view windows.

Figure 3-26 is a sample layout. If raised flooring must be installed reorient the layout on the new raised floor grid as soon as it is made available by the contractor.²⁰

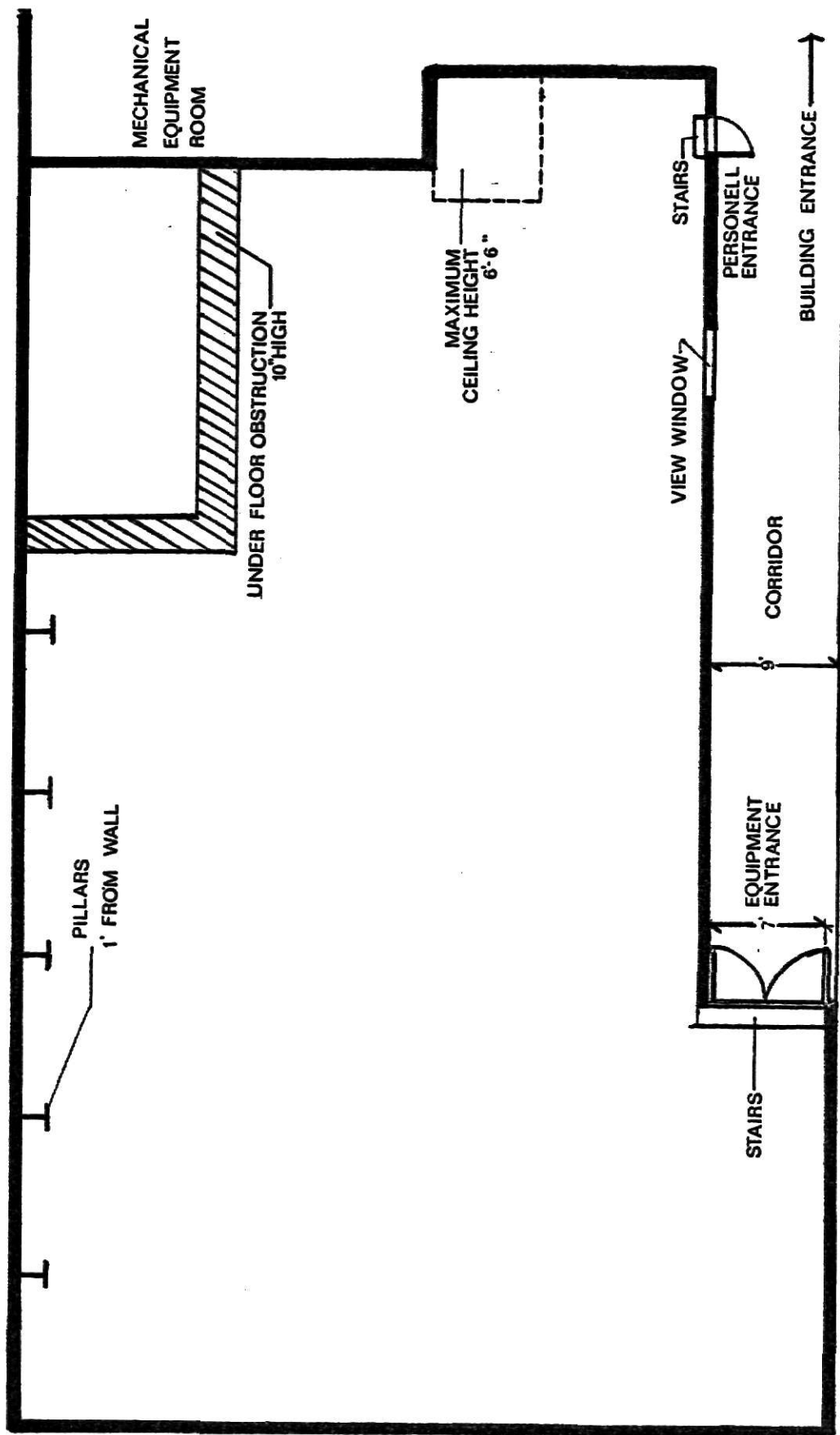


Figure 3-26
ROOM OUTLINE

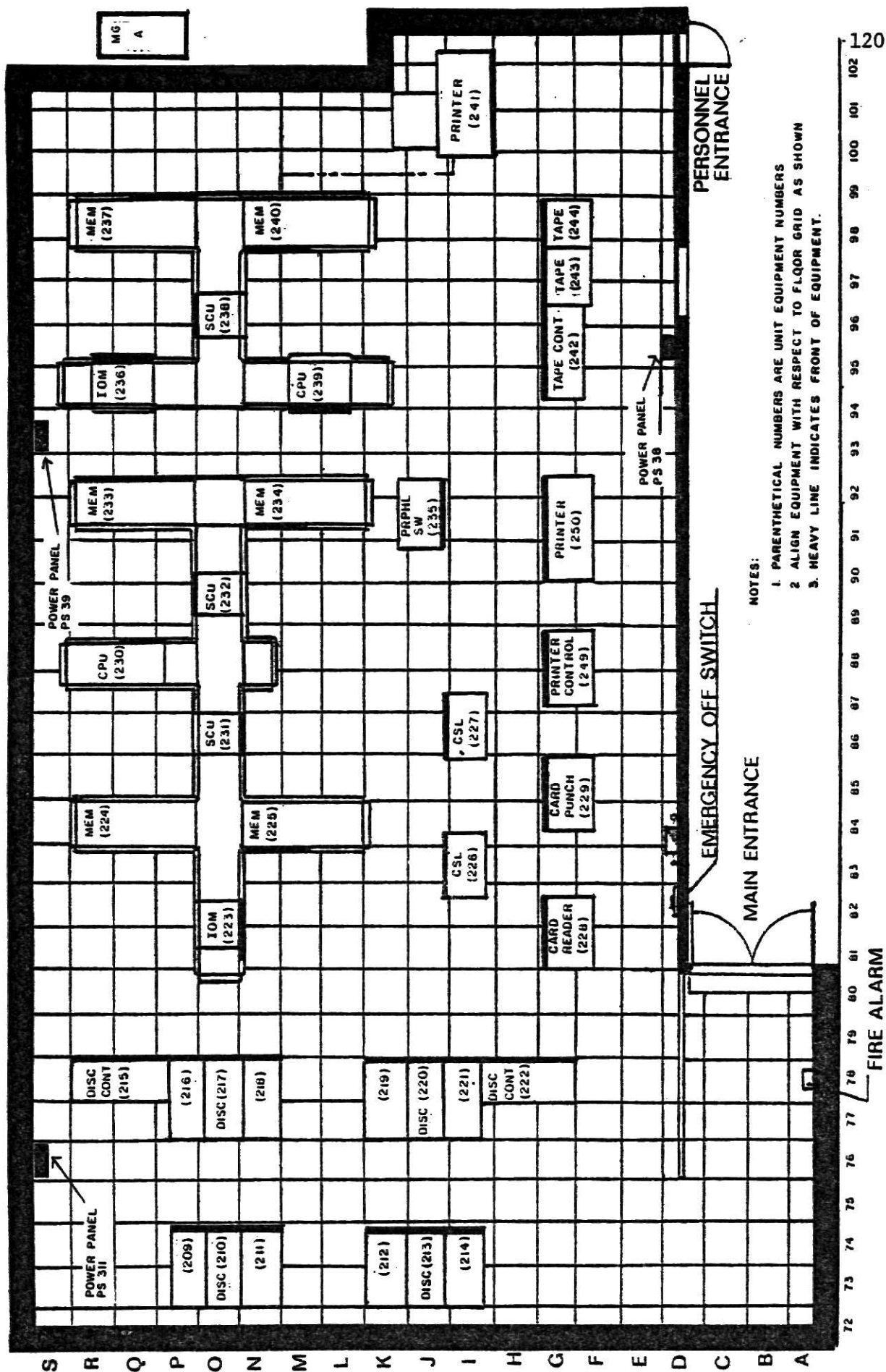
3.2.4.5 Equipment Layout

It is important to include all equipment related to the system on your layout drawing. If this is an add-on order, specifically identify the added equipment. In addition, show the location of the following:

1. Motor generator sets/Uninterruptable Power Systems (UPS)
2. AC load centers
3. Motor generator control unit
4. Emergency off switches
5. Communication terminals (if used)

Keep these points in mind:

1. Location of computer equipment must conform to cable-length limits
2. Layout must be coordinated with the air conditioning to avoid conditions that can create hot spots. Do not place units directly under diffusers which produce a strong downdraft. Protect against the heat load of large window areas exposed to direct sunlight.
3. Give consideration to the location of paper media peripherals to avoid the possibility of clogging the filters of other units with paper dust (see Figure 3-27 and 3-28 for format).¹⁶



NOTES:

1. PARENTHEetical NUMBERS ARE UNIT EQUIPMENT NUMBERS
2. ALIGN EQUIPMENT WITH RESPECT TO FLOOR GRID AS SHOWN
3. HEAVY LINE INDICATES FRONT OF EQUIPMENT.

Figure 3-27
EQUIPMENT LAYOUT

FIRE ALARM

UNIT NO.	UNIT NAME	CKT BRKR SIZE	PWR (KVA)	HEAT (KBTU)	WT (LB)	SIZE 8IN.)		
						W	D	H
235	PRPHL SW PSC200	2P15A	.4	1.5	400	41	27	72
236	I/O MULTI- PLEXER DC8035	3020A	2.8	8.5	1,250	46	30	82
237	MEMORY MM8034	3P20A	2.1	6.2	1,900	80	30	77
238	SCU MC8035	3P20A	1.2	2.7	850	34	30	77
239	CPU CP8034	3P20A	1.4	4.4	1,250	43	30	82
240	MEMORY MM8034	3P20A	2.1	6.2	1,900	80	30	77
241	PRINTER PRT201	3030A	4.2	10.2	1,460	77	35	57
242	TAPE CONTROL MTC502	3P20A	1.8	4.3	500	55	28	50
243	TAPE MTH501	3P15A	1.5	4.1	800	30	30	66
244	TAPE MTH501	3P15A	1.5	4.1	800	30	30	66

Figure 3-28
EQUIPMENT SPECIFICATIONS

3.3 Physical Installation

3.3.1 Movement Planning

The submodel provided covers for movement planning. If it is the installation manager's responsibility to arrange the movement of the equipment, make sure to select a moving company that has had experience in moving Automatic Data Processing Equipment.

Insist that a site survey be conducted by the individuals that are actually going to be moving the equipment, if at all possible.

3.3.2 Movement Technique

For the installation of a large system, the following movement scheme is highly recommended.

1. After construction has been completed, use the hardware layout to actually mark the locations of the equipment on the floor with tape. Mark on the tape or on a separate card taped to the floor the equipment numbers. As the equipment locations are determined, also verify the accuracy of the floor cutouts. (Have the tape cut at all floor tile edges so that if the raised floor is lifted the tape will not be pulled away from the floor.)
2. Post the site layout at the equipment entrances; and as the movers bring in the equipment, have personnel available to direct them to the

correct locations.

3. Cover all the floor tile cutouts with wood or metal sheeting.
4. In order to readily identify where each hardware component is to be placed, use equipment tags on the front and back of each piece of equipment, marked with room number, room coordinate location, and component number (see Figure 3-29).

If possible mark the hardware components prior to shipment. Otherwise tag the equipment as it is unloaded from the truck. Request the assistance of a vendor representative in correctly identifying each item of equipment.

3.3.3 Hardware Installation

Hardware installation is more than just locating the equipment components in the correct location in the room. There are several major activities associated with the physical installation that must be planned for:

1. After the equipment is located in the room, it must be set up on leveling pads. All the equipment components come with rollers or casters for ease of movement. When the equipment is in place, it must be stabilized by lowering the leveling pads. Additionally, the main frame equipment may have to be bolted

```
*****
*
*
*
*
*      ROOM NUMBER:
*
*
*      COORDINATE LOCATION:
*
*
*      COMPONENT NUMBER:
*
*
*
*
*****
```

MATERIAL: (1) 3 by 5 card
(2) Masking tape

Figure 3-29
EQUIPMENT TAGS

together by using interconnecting frames that come with the equipment.

2. The copper grounding straps must be installed if signal ground is to be used.
3. The electrical connection of the equipment should only be done with qualified electricians to assure the power is connected correctly and that green wire ground is securely and correctly wired. As each piece of equipment is powered up, it should be carefully monitored by the maintenance personnel and electricians.
4. After equipment is powered up, the temperature in the room should be monitored and adjustments made to the air flow to correct the occurrence of "hot spots" in the room. Again for a large system use only qualified personnel.
5. The data cable connection will be the last step in the physical installation. This task should be performed by maintenance personnel, working with the systems analysts. After the cable is connected, the maintenance personnel will test the hardware for any possible damage or missing components.

The most important thing for the manager to do during this phase of the installation is to assure that all of these activities have been scheduled and that they occur on time.

Now that the system is installed, there is one more hurdle to overcome--the acceptance of the system by the systems analysts. Their task is to verify that the logical configuration of the system is correct. Until they accept the system, the installation manager is responsible. When no faults with the cable configuration can be detected, the installation phase is complete.

3.3.3.1 Incremental Installation

It is possible that hardware may not be delivered by the vendor as one complete package. Delivery may be spread over weeks or even months. If this is the case, as each component or group of components arrive, install the hardware according to the activities listed in section 3.3.3, Hardware Installation.

With incremental hardware installation, firm delivery dates and a detailed list of equipment components to arrive with each delivery should be obtained. Incremental hardware installation should not affect the cable installation scheme. Insist that all cable be delivered at one time as reflected on the dependency network. This will minimize the time required to install and interface the individual components as they are delivered.

By studying the time estimates and activities that occur during the hardware installation phase, latest delivery dates can be approximated for equipment components by back tracking from the projected operational date. This

will of course depend on the hardware components being considered for delivery and their planned location within the room. Space and equipment access points into the room may dictate the order in which equipment must be installed.

As this phased installation occurs, a point will be reached where a minimum number of components will be installed that constitute a "system." When this occurs, that system will be turned over to the systems analysts. As the remaining hardware arrives, it will have to be installed through close coordination with Computer Operations and the Computer Operating Schedule.

CHAPTER 4 MANAGEMENT TOOLS

4.1 Introduction

The activity checklist and event dependency network can be used to measure progress and to determine project status during the installation process. The purpose of this chapter is to provide background and suggestions for the use of the checklist and dependency network as project management tools.

4.2 Activity Checklists

The activity lists provided in Chapter 2 can be reformed as shown in Appendix A and used by the manager to assign tasks, to maintain a progress status log, and estimate project workload.

Also the checklist could easily be automated and used by management in an interactive environment. Management would have the option to update the list, add additional activities, and receive reports on activities not yet completed, categorized by major activity area and responsible agency. Since the project would have to be custom programmed, each manager will have to determine the cost benefit of this automation.

4.3 Program Evaluation and Review Technique (PERT)

The PERT technique can be used to obtain and manage using the activity dependencies. This section introduces the technique and provides insight into its use in hardware installation. The need to help managers control the use of manpower material and facilities became apparent in several industries in the mid 1950's. The pioneering application of the network or arrow diagram and the "critical path" concept was jointly sponsored by E. I. duPont de Nemours and Company and the Sperry-Rand Corporation. The objective was to improve the planning, scheduling, and coordination of their engineering projects. By September 1957, an actual application was conducted on a pilot system using the Univac I computer and thus evolved into the Critical Path Method (CPM).

At the same time, a research team was established by the Navy to develop a program evaluation technique for the Ballistic Missile Development Program. Through the efforts of the team, the Program Evaluation and Review Technique (PERT) was developed and implemented as a management tool for the Navy's Polaris Program.⁵

PERT was designed to be event-oriented based on specific identifiable events that must occur on the way to the completion of a project, while CPM was activity-oriented with the cost of carrying out the activity in its normal time and the cost of carrying out an activity in the shortest possible time used to examine the relationship

between project time and cost.

The essential differences between these two systems relate to the different problems they were designed to solve; but today these distinctions have largely disappeared and the two terms are used interchangeably.²²

In a broad sense, the objectives of PERT are to:

1. Provide planning and evaluation information so that timely judgments can be made to meet all program objectives.
2. Designed to aid the manager in planning and controlling one-of-a-kind or few-of-a-kind projects such as engineering development or building construction.
3. Force development of a comprehensive and logical plan for the accomplishment of a program.
4. Allows quick response to unforeseen changes in the program, early detection of probable future trouble areas and evaluation of proposed alternative courses of action.¹⁸

PERT can be defined as a management planning and analysis tool which makes use of a graphic display called a network to show the relationships between various tasks making up a program. Before PERT was developed, it was very difficult to organize the multiple task making up large projects into one correlated plan.⁵

One of the most significant values of the PERT system is that it forces management at all levels to plan. The

PERT system shows the program plan as a series of interrelated events (nodes) and activities (arcs) which can be depicted as a network indicating the interdependencies of these events in terms of time.

PERT was designed primarily as a program-planning tool; and when used correctly, it can provide the following:

1. Delivery or completion dates for major end items
2. Orderly plans and schedules showing how the work will be accomplished and when the products will be delivered
3. Resource applications plans and schedules, showing the required manpower, facilities and funds which should be acquired and utilized.
(The reader is reminded we have eliminated funding from this model.)

After a PERT network has been developed and processed, the expected completion dates (TE) and latest allowable completion dates (TL) can be used as a basis for determining schedule dates, if no other schedule exists. If scheduled dates for the events are available, they can be compared to the expected completion dates to determine program status.¹⁸

The computer can be a very useful tool for initiating and updating a PERT network. However, the initial task of preparing the input data can be a very long and tedious job. For a small network, ≤ 300 activities, the work involved in preparing the data will probably be greater than performing the calculations by hand, thus it probably will be possible

to obtain answers faster by manual calculation.²² One factor that will greatly influence the decision to use a computer is the frequency of update. Figure 4-1, taken from Network Analysis in Project Management by McLaren and Buesnel, provides a guide to computer usage related to size of network and the frequency of update.

The complexity of the PERT network also has a bearing on the advisability of computer usage. A network that is primarily linear does not justify computer usage.

If the computer is to be used, select a PERT package that will provide meaningful output. There are three things that should be available:

1. designation of the critical path(s)
2. graphic output of the network
3. the capability to calculate probability of completing the project based on different end dates.

Not all PERT packages have these output options. For a large project (> 700 events), it is probably still advisable to use the best PERT system available.

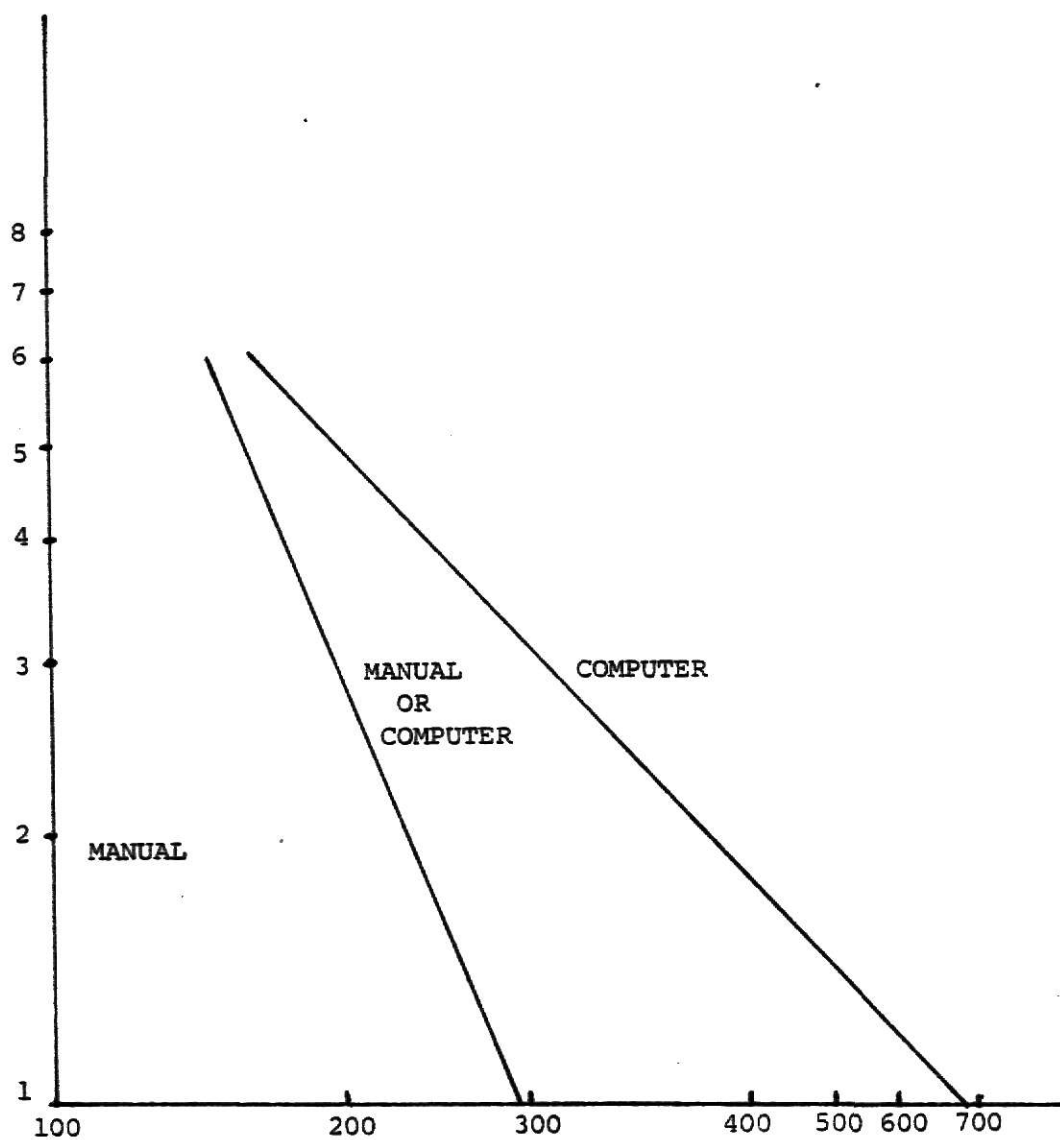


Figure
COMPUTER V.S. MANUAL APPLICATION

CHAPTER 5 TYPICAL INSTALLATION NETWORK

5.0 Introduction

The installation of a specific hardware system is a unique problem with some of the activities in this model involving into large tasks while others may not be applicable. However, there are some general guidelines of event dependencies and these are illustrated in the example presented in this chapter. The model activities are collapsed into thirty-four aggregate activities. This chapter explains a management method for creation of the event dependency network, Program Evaluation and Review Technique (PERT).

5.1 Program Evaluation and Review Technique (PERT)

A PERT network is provided to show a proper sequence of the thirty-four major activities leading up to the installation of the hardware and subsequent turnover of the system to the systems analysts.

The times for each activity are representative of an average installation and may vary greatly from your particular installation. The PERT network can be expanded by subdividing the activities into individual networks, called subnets or by simply adding more activities to the network.

In the paragraphs to follow an explanation of terms basic to PERT are provided, followed by the use of a computerized demonstration of a PERT network.

5.2 Definitions

The following definitions are basic to any PERT system.^{18,22}

Event - the initiation or termination of an activity

Activity - line or arc that connects two events

Expected elapsed time (te) - the time an activity is expected to require. This time is derived from the calculation of a statistically weighted average time estimate, using optimistic (a) most likely (m) and pessimistic (b) time estimates.

$$te = \frac{a + 4m + b}{6}$$

Te - the time it will take to complete the project. It is found by adding the te of each activity along the path with the greatest time constraint.

Event expected completion date (TE) - the calendar date on which an event can be expected to occur. Calculated by summing the expected elapsed time (te) of all activities leading up to that event along the longest path.

Event latest allowable completion date (TL) - the latest calendar date on which an event can occur without delaying the completion of a program

Slack time - slack time is a measure of how long the completion of an event may be delayed without affecting

the project completion date.

Critical path - the path with the greatest time constraint on the final event. It determines the date upon which the project will be completed. The slack time along the critical path is usually zero. The importance of critical path determination is to focus attention on the activities which are key to accomplishment of the project based on the projected completion date. In a large complex program, these activities are difficult to locate and consequently critical tasks are often overlooked. Each activity on the critical path must be analyzed and the following factors considered:

1. Whether any activity on the critical path can be sequenced in parallel with others on the critical path and what added risk and resource planning impact is incurred by taking this approach.
2. The time estimates for an activity on the critical path can be shortened (to a point) by adding resources, and will this increase risk in meeting performance or reliability.
3. If meeting the performance schedule is paramount, whether performance or reliability objectives for any activity can be waived.

This type of analysis should be applied to all paths in the network that are critical. If the project can be completed ahead of schedule, the critical path analysis

becomes a means of identifying the tasks that control the schedule. Thus the manager can ensure they are given top priority and do not slip the schedule.

Actual date - the date on which the completion of an event or activity occurred.

Master network - a graphic representation which shows in broad outline the main tasks or activities involved in the project. It is sufficiently detailed to show the interrelationships clearly, while still allowing the project to be viewed as a whole.

Subnetwork - separate networks which are developed from a group of activities or a single activity in the master network. The subnetworking principle can be extended to three or four levels; and in cases where subnetworks are not practical, the level of detail required can be obtained by producing a new expanded version of the master network.

5.3 Automated PERT for Hardware Installation

The master network (Figure 2-18) illustrates how the major activities for the hardware installation plan can be incorporated into a PERT system. Only the major activities are depicted with an average time to completion estimated for each activity. The network could easily be expanded to include more of the activities included on the activity checklist.

The times used in this network are representative of the time it would take to complete an average hardware installation project. The project manager will have to coordinate his schedule with the hardware vendor and construction contractor before determining actual event times.

5.4 Automated PERT

The PERT package selected for this model is project Management System/370 (360A-CP-04X) Version 2, Part 1 DMS/360, Network Processor.

The standard output provided is:

1. An echo print of the activity, names, times, and dependencies entered by the user (see Figure 5-1).
2. This PERT system provides a handy reference tool for analyzing events and the activities leading into these events. For any event, the following information may be ascertained (see Figure 5-2):
 - a. The number of constraints or activities leading into the event.
 - b. The expected completion date of each of the activities constraining the event. The activity with the latest expected completion date is the "pacing" activity.
 - c. The latest allowable completion date for the event.

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LINE OF ASTERISKS FLAG ILLEGAL CHARACTERS
WHEN ASSUMPTIONS ARE MADE, THE MODIFIED RECORD IS PRINTED

00	H/W	INST	PLN	NI45412240024002400509091419	2937490049004900454536	
01	NET1					SUB1
05	00780201007					
10	070CT78	COMPUTER	INSTALLATION	MODEL		NET1
15	070CT78	COMPUTER	INSTALLATION	MODEL		SUB1
20	AA	STD				SUB1
30	S	00001			15OCT78	SUB1
30	AA	000010000201/1			H/W ESTAB. PTS. OF CONTACT	SUB1
30	AA	000020000301/1			H/W LOGICAL CONFIGURATION	SUB1
30	AA	000030000401/1			H/W H/W LAYOUT & SOFT REQ	SUB1
30	AA	000040000701/6			CON SITE SELECTION PROCESS	SUB1
30	AA	000040000501/4			CON EST. TIME FOR CONSTRUCT.	SUB1
30	AA	000040000601/3			CON EST-OF CONSTRUCTION REQ	SUB1
30	AA	000050000700/0			CON DUMMY	SUB1
30	AA	000060000700/0			CON DUMMY	SUB1
30	AA	000070000801/1			H/W FINAL H/W LAYOUT	SUB1
30	AA	000070000900/4			CON MI SC COSTRUCTION REQ	SUB1
30	AA	000070001000/5			H/W INITIAL MOVEMENT PLAN	SUB1
30	AA	000080001100/5			CON A/C REQUIREMENTS	SUB1
30	AA	000080001200/5			CON FLOORING REQ.	SUB1
30	AA	000080001300/5			CON ACOUSTICAL REQ.	SUB1
30	AA	000080001400/5			H/W CABLE REQ.	SUB1
30	AA	000080001700/6			CON ELECTRICAL REQ.	SUB1
30	AA	000090001700/0			CON DUMMY	SUB1
30	AA	000110001700/0			CON DUMMY	SUB1
30	AA	000120001700/0			CON DUMMY	SUB1
30	AA	000130001700/0			CON DUMMY	SUB1
30	AA	000140001503/4			H/W ORDER & RECIEVE CABLE	SUB1

(CONTINUED)

LINES OF ASTERISKS FLAG ILLEGAL CHARACTERS
 WHEN ASSUMPTIONS ARE MADE, THE MODIFIED RECORD IS PRINTED

30	AA	000150002600/5	H/W MARK CABLE	SUB1
30	AA	000170001900/5	CON FLOOR CUTOUT REQ TO CON.SUB1	
30	AA	000170001800/5	CON CONST. REQ. TO CONTR.	SUB1
30	AA	000170002100/2	H/W TAG HARDWARE	SUB1
30	AA	000180002000/5	CON REVIEW CONTR. SPECS	SUB1
30	AA	000190002000/0	CON DUMMY	SUB1
30	AA	000200002200/3	CON START CONSTRUCTION	SUB1
30	AA	000220002309/4	CON COMPLETE CCNSTRUCTION	SUB1
30	AA	000100002300/0	H/W DUMMY	SUB1
30	AA	000230002600/5	H/W FINAL MOVEMENT PLAN	SUB1
30	AA	000230002500/2	CON TEST A/C	SUB1
30	AA	000230002400/2	H/W MARK FLOOR LAYOUT	SUB1
30	AA	000250002600/0	CON DUMMY	SUB1
30	AA	000240002600/0	H/W DUMMY	SUB1
30	AA	000210002700/0	H/W DUMMY	SUB1
30	AA	000260002700/5	H/W INSTALL DATA CABLE	SUB1
30	AA	000270002800/3	H/W INSTALL HARDWARE	SUB1
30	AA	000280002900/3	CON ELECTRICAL & GROUND CNT.	SUB1
30	AA	000290003000/5	H/W POWER UP EQUIPMENT	SUB1
30	AA	000300003100/3	H/W HOOK UP DATA CABLE	SUB1
30	AA	000300003200/3	CON BALANCE A/C	SUB1
30	AA	000310003300/3	H/W TEST H/W	SUB1
30	AA	000320003300/0	H/W DUMMY	SUB1
30	AA	000330003400/3	H/W SYSTEM TURN OVER TO S.A.SUB1	
30	E	00034		SUB1

END

Figure 5-1
 NETWORK INPUT DATA

SORTED BY PRIMARY SLACK

LEVEL DETAIL

PRE- EVENT	SUCC- EVENT	CYCLE CODE	ACTIVITY DESCRIPTION	TIME ESTIMATES A M B	SLACK PRIMR SECON	COMPLETION DATES EXPECTED LATEST	SCHED. DATE	DEPT.
1	1	S	ESTAB. PTS. OF CONTACT	01/1	-0	A150C178 150C178		
2	2	AA	LOGICAL CONFIGURATION	01/1	-0	230C178 230C178		H/W
3	3	AA	H/W LAYOUT & SOFT REQ	01/1	-0	310C178 310C178		H/W
4	4	AA	SITE SELECTION PROCESS	01/6	-0	08NOV78 08NOV78		H/W
7	7	AA	FINAL H/W LAYOUT	01/1	-0	21NOV78 21NOV78		CON
8	8	AA	ELECTRICAL REQ.	00/6	-0	29NOV78 29NOV78		H/W
17	17	AA	CONST. REQ. TO CONTR.	00/5	-0	05DEC78 05DEC78		CON
18	18	AA	REVIEW CONTR. SPECS	00/5	-0	10DEC78 10DEC78		CON
20	20	AA	START CONSTRUCTION	00/3	-0	15DEC78 15DEC78		CON
22	22	AA	COMPLETE CONSTRUCTION	09/4	-0	18DEC78 18DEC78		CON
23	23	AA	FINAL MOVEMENT PLAN	00/5	-0	23FEB79 23FEB79		CON
26	26	AA	INSTALL DATA CABLE	00/5	-0	28FEB79 28FEB79		H/W
27	27	AA	INSTALL HARDWARE	00/3	-0	05MAR79 05MAR79		H/W
28	28	AA	ELECTRICAL & GROUND CNT.	00/3	-0	08MAR79 08MAR79		H/W
29	29	AA	POWER UP EQUIPMENT	00/3	-0	11MAR79 11MAR79		CON
30	30	AA	HOOK UP DATA CABLE	00/5	-0	16MAR79 16MAR79		H/W
31	31	AA	TEST H/W	00/3	-0	19MAR79 19MAR79		H/W
33	33	E	SYSTEM TURN OVER TO S.A.	00/3	-0	22MAR79 22MAR79		H/W
34	34	AA	A/C REQUIREMENTS	00/5	-1	25MAR79 25MAR79		H/W
8	8	AA	FLOORING REQ.	00/5	-1	04DEC78 05DEC78		CON
11	11	AA	ACOUSTICAL REQ.	00/5	-1	04DEC78 05DEC78		CON
12	12	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
17	17	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
17	17	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
5	5	AA	EST. TIME FOR CONSTRUCT.	01/4	-3	04DEC78 05DEC78		CON
6	6	AA	EST. OF CONSTRUCTION REQ	01/3	-3	19NOV78 21NOV78		CON
7	7	AA	DUMMY	00/0	-4	18NOV78 21NOV78		CON
23	23	AA	MARK FLOOR LAYOUT	00/2	-4	25FEB79 28FEB79		H/W
24	24	AA	TEST A/C	00/2	-4	25FEB79 28FEB79		CON
25	25	AA	DUMMY	00/0	-4	25FEB79 28FEB79		H/W
26	26	AA	DUMMY	00/0	-4	25FEB79 28FEB79		CON
30	30	AA	BALANCE A/C	00/3	-4	19MAR79 22MAR79		CON
32	32	AA	DUMMY	00/0	-4	19MAR79 22MAR79		H/W
17	17	AA	FLOOR CUTOUT REQ TO CON.	00/5	-7	10DEC78 15DEC78		CON
19	19	AA	DUMMY	00/0	-7	10DEC78 15DEC78		CON
7	7	AA	MISC CONSTRUCTION REQ	00/4	-1	25NOV78 05DEC78		CON
9	9	AA	DUMMY	00/0	-1	25NOV78 05DEC78		CON
14	14	AA	CABLE REQ.	00/5	-8	04DEC78 29JAN79		H/W
15	15	AA	ORDER & RECEIVE CABLE	03/4	-8	29DEC78 23FEB79		H/W
26	26	AA	MARK CABLE	00/5	-8	03JAN79 28FEB79		H/W
17	17	AA	TAG HARDWARE	00/2	-12.6	07DEC78 05MAR79		H/W
21	21	AA	DUMMY	00/0	-12.6	07DEC78 05MAR79		H/W
7	7	AA	INITIAL MOVEMENT PLAN	00/5	-12.7	26NOV78 23FEB79		H/W
10	10	AA	DUMMY	00/0	-12.7	26NOV78 23FEB79		H/W

Figure 5-2

ACTIVITIES SORTED BY PREDECESSOR, SUCCESSOR EVENT

- d. The scheduled or actual completion date for the event.
 - e. The slack associated with the event.
3. A sort of events by slack is most important for analytical purposes (see Figure 5-3). It lists the paths in algebraic order of slack or criticality, i.e., a path of one-week slack will be listed before a path of a three-week slack. Activity slack may be positive or negative. If activity slack is positive, it is a measure of how much the activities along a path may be delayed without endangering the timely completion of the terminal event. If activity slack is negative, it is a measure of how much time must be made up along the particular path if the terminal event is to be completed on schedule. Slack helps direct management attention to specific problem areas, and indicates the effect of plan changes on the entire program. Thus, management actions which are overcorrective, misapplied, and wasteful of resources may be minimized. In addition, slack indicates areas from which resources (in terms of manpower, overtime, budget, equipment, etc.) might be made available for application to more critical areas.²²

PAGE 1

KSU PMS/360 ACTIVITY TIME STATUS REPORT

RUN DATE 27NOV78

NET1
SUB1

PROGRAM 070CT78 COMPUTER INSTALLATION MODEL
PROJECT 070CT78 COMPUTER INSTALLATION MODEL

SORTED BY PREDEC.. SUCC.

LEVEL DETAIL

PRED. EVENT	SUCC. EVENT	CYCLE CODE	ACTIVITY DESCRIPTION	TIME ESTIMATES A M S	SLACK PRIMR SECD	COMPLETION DATES EXPECTED LATEST	SCHED. DATE	DEPT.
1	1	S	ESTAB. PTS. OF CONTACT	01/1	-0	A150CT78 150CT78		H/W
2	2	AA	LOGICAL CONFIGURATION	01/1	-0	230CT78 230CT78		H/W
3	3	AA	H/W LAYOUT & SOFT REQ	01/1	-0	310CT78 310CT78		H/W
4	4	AA	EST. TIME FOR CONSTRUCT.	01/4	-3	19NOV78 08NOV78		CON
5	5	AA	EST. OF CONSTRUCTION REQ	01/3	-4	19NOV78 21NOV78		CON
6	6	AA	SITE SELECTION PROCESS	01/6	-0	19NOV78 21NOV78		CON
7	7	AA	DUMMY	00/0	-3	19NOV78 21NOV78		CON
8	8	AA	FINAL H/W LAYOUT	01/1	-0	29NOV78 29NOV78		H/W
9	9	AA	MISC CONSTRUCTION REQ	00/4	1.4	25NOV78 05DEC78		CON
10	10	AA	INITIAL MOVEMENT PLAN	00/5	12.7	26NOV78 23FEB79		H/W
11	11	AA	A/C REQUIREMENTS	00/5	-1	04DEC78 05DEC78		CON
12	12	AA	FLOORING REQ.	00/5	-1	04DEC78 05DEC78		CON
13	13	AA	ACOUSTICAL REQ.	00/5	-1	04DEC78 05DEC78		CON
14	14	AA	CABLE REQ.	00/5	8.0	04DEC78 29JAN79		H/W
15	15	AA	ELECTRICAL REQ.	00/6	-0	05DEC78 05DEC78		CON
16	16	AA	DUMMY	00/0	1.4	25NOV78 05DEC78		CON
17	17	AA	DUMMY	00/0	12.7	26NOV78 23FEB79		H/W
18	18	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
19	19	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
20	20	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
21	21	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
22	22	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
23	23	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
24	24	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
25	25	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
26	26	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
27	27	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
28	28	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
29	29	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
30	30	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
31	31	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
32	32	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
33	33	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
34	34	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
35	35	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
36	36	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
37	37	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
38	38	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
39	39	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
40	40	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
41	41	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
42	42	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
43	43	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
44	44	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
45	45	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
46	46	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
47	47	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
48	48	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
49	49	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
50	50	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
51	51	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
52	52	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
53	53	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
54	54	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
55	55	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
56	56	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
57	57	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
58	58	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
59	59	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
60	60	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
61	61	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
62	62	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
63	63	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
64	64	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
65	65	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
66	66	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
67	67	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
68	68	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
69	69	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
70	70	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
71	71	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
72	72	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
73	73	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
74	74	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
75	75	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
76	76	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
77	77	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
78	78	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
79	79	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
80	80	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
81	81	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
82	82	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
83	83	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
84	84	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
85	85	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
86	86	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
87	87	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
88	88	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
89	89	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
90	90	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
91	91	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
92	92	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
93	93	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
94	94	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
95	95	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
96	96	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
97	97	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
98	98	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
99	99	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON
100	100	AA	DUMMY	00/0	-1	04DEC78 05DEC78		CON

Figure 5-3

ACTIVITIES SORTED BY PRIMARY SLACK

5.5 Expected Time for Activities

PERT calculates the expected value of an activity duration as a weighted average of the three times estimates. Specifically, it makes the assumption that the optimistic activity time, (a), and pessimistic activity time, (b), are equally likely to occur. It assumes that the most probable activity time, (m), is four times more likely to occur than the other two estimates (based upon a normal distribution of times). So by applying these weights to the three time estimates, the following formula is used to compute expected activity duration:

$$t_e = \frac{a + 4m + b}{6}$$

This formula was used to compute the single time estimate (te) shown in the listing (Figure 5.1). The time estimate is in the format XX/Y or XX.Y, where XX represents the number of weeks and Y represents the number of days. See also Figure 5-4 for a listing of time estimates.

5.6 Variability of Activity Times

In addition to having a means of computing average time, it is helpful to know how reliable that estimate is. If the range of the time estimates for an activity is large, there will be less confidence in the time than if they were closer together. A wide range of estimates represents greater uncertainty and therefore less confidence in anticipating the actual time that the activity will require. What is needed is a method of measuring the reliability of

TASK ID	DESCRIPTION	a	M	b	te	V _T
P	Mark cable	1	3	7	5	1
Q	Develop floor cutout requirements from floor specifications	2	4	7	5	1
r	Consolidate construction requirements	2	3	5	5	1
S	Review contractor construction specification	2	5	7	5	1
T	Tag hardware	1	2	5	2	1
U	Start construction	2	3	5	3	1
V	Complete construction	30	60	90	60	100
W	Test air conditioning	1	2	4	2	0
X	Final movement plan	2	5	7	5	1
Y	mark floor layout	1	2	4	2	0
Z	Install data cable	2	5	10	5	1
AA	Install hardware	2	3	5	3	1
AB	Electrical connection and grounding	1	3	5	3	1
AC	Power up equipment	2	4	7	5	1
AD	Hook up data cable	1	3	5	3	1
AE	Balance air conditioning	1	2	5	3	1
AF	Test hardware	1	3	7	3	1
AG	Acceptance of system by S. A.	2	3	5	3	1
A	Points of contact estab- lished with vendor and contractor	3	7	14	8	4

Figure 5-4
continued

B	Determine logical configuration to support S/W requirements	3	7	14	8	4
C	Establish initial H/W layout and sq. ft. requirement	3	7	14	8	4
D	Site selection process	5	14	20	13	9
E	estimate of construction completion	3	12	15	11	4
F	Estimate of construction requirements	2	10	17	10	9
G	Miscellaneous construction requirements	1	3	10	4	4
H	Final H/W layout	3	7	14	8	4
I	Initial movement plan	3	5	8	5	1
J	Electrical requirements	2	5	14	6	4
K	Air conditioning requirements	2	5	10	5	1
L	Raised floor requirements	1	5	7	5	1
M	Acoustical requirements	2	5	7	5	1
N	Cable requirements	2	5	7	5	1
O	Order and receive cable	30	15	60	25	25

Te for the project = 160 days
 Total variance along critical path = 140 days
 Standard deviation = 11.8 or 12 days

Figure 5-4
 PERT ACTIVITY DESCRIPTION

the expected time, as determined by the three time estimates. This can be done by measuring the variability of an activity time duration.

One measure of variability of possible activity times is given by the standard deviation. The variance is the average squared difference of all numbers from their mean value. The standard deviation is the square root of the variance.

PERT simplifies the calculation of variance with the following formula:

$$v_t = \left(\frac{b - a}{6} \right)^2$$

A high standard deviation, (St), represents a high degree of uncertainty of the activity. This means that there is a reasonable chance that the actual time required to complete an activity will differ greatly from the expected time, t_e .¹⁸

5.7 Critical Path

Turn to Figure 5-3 which shows the activities sorted by primary slack. The activities that have no slack time, that is, activities that cannot be delayed without affecting the completion date of the project, are listed first, followed by activities with increasing slack time. By listing all activities that have zero slack time, the critical paths of the PERT network can be ascertained. In case there may be more than one critical path in the network, use the predecessor/successor listing to distinguish the different

paths. For this example, the critical path consists of events 1-2-3-4-7-8-17-18-20-22-23-26-27-38-49-30-31-33-34.

5.8 Near Critical Path

The project length, obtained by adding the individual te 's of the critical path activities, might not always be the best estimate of project length. A near critical path may exist with a higher variance of te 's than the critical path. If problems arise in activities on the critical path, it is possible for the near critical path to become the critical path. Therefore, it is important to calculate the lengths of all paths with a low slack time.

Looking at the activities sorted by slack in Figure 5-3, the paths with a low slack time are 1-2-3-4-7-8-(11, 12 or 13)-17, with the remaining events the same as the critical path.

5.9 The Expected Length of a Critical Path

The expected length of a sequence of activities is the sum of their expected lengths. The expected length of the project (Te) is determined by summing the te 's along the critical path. The variance of Te equals the sum of all the variances of these activities. The higher the standard deviation of the project length (St), the more likely it is that the actual time required to complete the project will differ from Te .

Looking at the activity list in Figure 5-4, you can see where the expected time, standard deviation and variance were calculated. The variance of the critical path is found by summing the individual variances of each event, along the critical path which is equal to 140 days, corresponding to a standard deviation of 11.8 days.¹⁸

5.10 Probability of Completing a Project by a Given Date

The average or expected project length, T_e , was calculated by adding the t_e 's along the critical path. T_e follows what is called a normal distribution, the familiar bell-shaped curve. A normal distribution is symmetric with a single peak value, and it is described completely by its mean, or average, value and its standard deviation. Since we know much about the normal curve, we can infer a good deal of managerial information about a project's length if the expected length and standard deviation is known.

For example .68 percent of the area under a normal curve is within one standard deviation of the average of the distribution as shown in Figure 5-5. In terms of project duration, there is a 68 percent chance that the actual project duration will be within one standard deviation of the estimated length of the project. There is a 95 percent chance that the project length will be within two standard deviations of the estimated length, and 99.7 percent within three standard deviations.

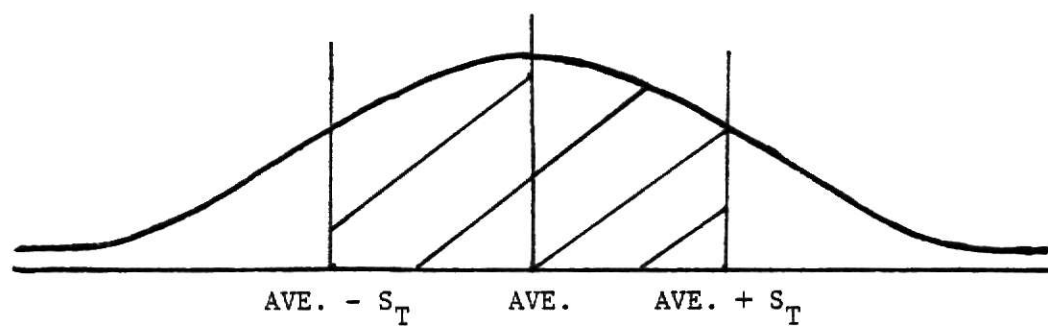


Figure 5-5
NORMAL PROBABILITY DISTRIBUTION

From the hardware installation PERT, the T_e is 160 days, with a variance of 140 which equates to a standard deviation of 11.8 or 12 days which says that there is a 68 percent chance of completing the project within 160 ± 12 days; likewise a 95 percent chance that the project will not exceed the limits of 160 ± 24 days.

The same idea can be used to answer the question, what is the probability of completing the project by a given time?

Standard normal tables are used to make this calculation (see Figure 5-6). A formula for the calculation is as follows:

$$z = \frac{D - T_e}{ST}$$

where D is the due date and ST the standard deviation. Z is the number of standard deviations by which D exceeds T_e .

Suppose the due date is set for the Hardware Installation Project on 1 March or 150 days from the starting date. What is the probability of completing the project on that date?

$$z = \frac{150 - 160}{12} = -.83$$

which from the chart says there is less than a 21 percent chance of completing the project ten days early.

The above examples have shown how effective PERT can be for installation planning. It provides the manager with the capability to plan in advance the action or actions that must be taken to produce a reliable schedule, to predict

z	Probability of Meeting Due Date
3.0	.999
2.8	.997
2.6	.995
2.4	.992
2.2	.986
2.0	.977
1.8	.964
1.6	.945
1.4	.919
1.2	.885
1.0	.841
.8	.788
.6	.726
.4	.655
.2	.579
0.0	.500
-.2	.421
-.4	.345
-.6	.274
-.8	.212
-1.0	.159
-1.2	.155
-1.4	.081
-1.6	.055
-1.8	.036
-2.0	.023
-2.2	.014
-2.4	.008
-2.6	.005
-2.8	.003
-3.0	.001

Figure 5-6
STANDARD NORMAL TABLE

probable performance time, to improve the plan when predicated performance is not adequate, and to measure performance and control programs.³⁴

CHAPTER 6 CONCLUSIONS

6.1 Results

The report has presented a model for preparing a facility to support a major computer system. The model included a list of activities representative of key issues a manager must be concerned with when constructing a site, and installing hardware. The activities were presented as partially ordered lists under four major categories--environmental, electrical, physical installation, and special considerations. In addition to the activities, a detailed narrative describing the activities was provided. The narrative was developed to assist managers in evaluating and understanding the activities. It also provides recommended methods for developing and documenting the installation requirements. Finally the activities list was reduced to 34 key installation activities, depicted in a PERT network, to illustrate the dependency analysis and problem solving a manager must accomplish.

6.2 Future Development

This hardware installation model could be expanded to include two methods of cost determination. The first is cost analysis with the concomitant application of the Critical Path Method (CPM). In many project activities involving the engineering, construction, and maintenance of facilities and installations, the critical path method is a

powerful management tool that has been used with success. It integrates all of the factors or building blocks of a project--manpower, money, time, materials, and equipment. Thus, it is a tool to assist management in the development of a balanced, optimum time-cost schedule, which assures timeliness, a minimum use of resources, and provides a vehicle for management by exception.

The second method would be to develop a detailed costing algorithm for construction in support of the computer system. The costing data could be broken out by major construction areas as presented in the model. For example:

Air Conditioning Costs

Electrical Costs

Equipment power

Lighting

Fire protection equipment

Grounding

Flooring costs

Miscellaneous Construction Costs

Ceiling

Walls and entrance ways

Windows

These costing algorithms will serve as valuable tools for the installation manager in projecting costs, and budgeting for expenses during the construction phase of the installation process.

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APPENDIX 1

N/A	YES	NO	RESPON- SIBLE AGENCY	SITE SELECTION
				Establish single point of contact with hardware vendor and construction contractor
				Raised floor required
				Square footage requirement established for hardware (initial hardware layout)
				Future expansion considered in selecting the computer site
				Square footage requirement established for media storage
				Square footage requirement established for maintenance area
				Computer area located in a noncombustible fire restrictive building or room
				Additional area required for air conditioning units
				Adequate power source enclose proximity to proposed site

				Current floor loading specifications adequate (include raised floor, office equipment and hardware)
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N/A	YES	NO	RESPON- SIBLE AGENCY	SITE SELECTION
				Ceiling height adequate
				Adequate equipment entries into the site
				Estimate approximate KVA required for total equipment
				Estimate approximate KBTV/HR (equipment and personnel)
				Walk-through with vendor and contractor prior to finalizing site selection
				Separate area established for protective power system
				Establish need for false ceiling
				Estimate scope of construction support required if more than one site is being considered
				Compute total square footage required
				Availability date of site, prime consideration in selecting a site

N/A	YES	NO	RESPON- SIBLE AGENCY	MISCELLANEOUS CONSTRUCTION
				Determine requirements for partitions and permanent walls
				Requirement for false ceiling
				Review and approve contractors construction specifications
				All wall board edges below raised floor level taped or sealed
				Requirement for additional entrances and windows

N/A	YES	NO	RESPON- SIBLE AGENCY	ACOUSTICS
				Reviewed the general guidelines for sound absorbtion
				Reviewed general guidelines for sound isolation
				Determine need for acoustical treatment of room

N/A	YES	NO	RESPON- SIBLE AGENCY	ELECTRICAL
				Isolate power of computer from other power systems
				Requirement to install protective power system evaluated
				Install separate power panels for mainframe and peripheral equipment
				Determine which equipment components are "hard-wired" and those which require recepticals
				Circuit breaker panels must be located in same room with equipment
				Identify requirement for convenience outlets
				Determine electrical requirement for all equipment
				Provide contractor with scaled drawing of equipment layout and electrical requirements
				Have contractor provide spare breakers in all circuit breaker panels
				Determine electrical support required

				for communications equipment
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N/A	YES	NO	RESPON- SIBLE AGENCY	ELECTRICAL
				Phase balance electrical power immediately after equipment is power up
				Maintenance personnel and electricians stationed with equipment as it is initially powered up
				Evaluate need for overhead lighting
				Coordinate the installation of overhead lights with equipment location
				Install lightning protection
				Install emergency power off switch by all exits
				Phone lines installed for remote terminals

N/A	YES	NO	RESPON- SIBLE AGENCY	AIR CONDITIONING
				Determine temperature and humidity specifications
				Determine type of cooling system required
				Construct H/W layout depicting heat load for each piece of equipment
				Require contractor install separate humidity control device
				Will air conditioning system be dedicated to computer hardware
				Drainage required under raised floor
				Compute total heat load (personnel + computer + support equipment)
				Temperature and humidity control devices installed in computer room
				Submit detailed cooling requirements to contractor
				Provisions made to formally test A/C system prior to hardware installation

N/A	YES	NO	RESPON- SIBLE AGENCY	AIR CONDITIONING
				Verify that overhead air registers do not blow directly into equipment
				Balance air conditioning after hardware installation
				Determine optimum location for A/C units
				Provisions made to closely monitor equipment after initial power up

N/A	YES	NO	RESPON- SIBLE AGENCY	FLOORING
				Raised floor required to support system
				Review different options for raised flooring
				Provide raised floor requirement to contractor
				Obtain contractors specifications of raised floor grid
				Document raised floor cutout requirements and submit to contractor
				Floor tile cutouts lined with protective trim
				Cable access holes sealed when raised floor used as air plenum
				Under floor sealed with epoxy paint
				Provisions for contractor to provide extra raised floor panels
				Ground raised floor if static electricity problems are expected

N/A	YES	NO	RESPON- SIBLE AGENCY	GROUNDING
				Earth ground installed and tested
				Install equipment ground braids if signal ground is used
				Green wire ground as per equipment specification
				If static electricity problems are anticipated ground raised flooring
				Determine vendor dependent grounding requirements

N/A	YES	NO	RESPON- SIBLE AGENCY	CABLING
				Determine type and length of data cable required
				Order data cable after final hardware layout has been approved
				Tag cable showing length and equipment destination
				Develop overlay depicting the major cable routes between equipment
				Locate and identify any under floor obstructions
				Install data cable prior to equipment installation
				Maintenance personnel on site to connect data cable

N/A	YES	NO	RESPON- SIBLE AGENCY	EQUIPMENT COMPATIBILITIES AND SYSTEM CONFIGURATION
				Determine minimum distance allowed between equipment for maintenance and operator access
				Determine the maximum cable length allowed between equipment
				Develop logical configuration to support software requirements (interdata cable configuration)
				Hardware configuration developed to support operational requirements
				Ease of operator access, control and visual observation of peripheral equipment considered in developing layout
				Efficient work flow pattern supported by equipment layout
				Adequate spacing of equipment to allow for ease of tape changing printer paper loading and removal, and access for service
				Develop site layout to document final H/W layout

N/A	YES	NO	RESPON- SIBLE AGENCY	SAFETY ENVIRONMENT
				Cover all raised floor cutouts and open floor areas with metal or wood sheeting
				Post the number of the fire department
				Post emergency electrical shutdown procedures
				Establish evacuation routes
				Avoid exposed cabling on the floor
				Verify the proper grounding of each piece of equipment prior to powering up equipment
				Only qualified electricians assigned to test voltages and hook power to equipment
				Install emergency lighting
				Emergency power off switches located at all exits
				Verify all equipment has been properly leveled prior to power up

				Restrict access to construction area
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N/A	YES	NO	RESPON- SIBLE AGENCY	FIRE PROTECTION
				Coordinate with fire inspector on the hardware layout and construction plans
				Install and test fire protection equipment
				All exits easily reachable and clearly posted
				Equipment aisle spaces large enough to accommodate portable fire fighting equipment
				Provisions made to locate fire extinguishers within the computer area
				Area constantly policed during the construction and installation phase
				Establish proper storage areas for supplies
				Position electrical shut down switches at all exits

N/A	YES	NO	RESPON- SIBLE AGENCY	MOVEMENT PLANNING (INITIAL)
				Check size and weight capacity before using an elevator
				Check the size of all doorways leading into the site
				Arrange for temporary storage of equipment if required
				Verify that hallways and turns permit passage of the largest component of equipment
				Will the unloading area restrict the size of the delivery trucks
				Has a no later than delivery date of equipment been specified by management

N/A	YES	NO	RESPON- SIBLE AGENCY	MOVEMENT PLANNING (FINAL)
				Arrange for carrier
				Establish delivery date for equipment
				Survey of equipment by moving contractor
				Estimate time required to load and deliver hardware
				Reserve area for truck unloading
				Clear route from carrier parking area to computer room
				Arrange for equipment packaging and crating removal
				Personnel designated to bolt main frame together and level equipment
				Will hardware be delivered at one time or phased in over a specified time period

N/A	YES	NO	RESPON- SIBLE AGENCY	HARDWARE INSTALLATION
				Level all equipment and connect main frame
				Install copper straps for signal ground
				Monitor equipment as it is powered up
				Schedule maintenance personnel to connect data cable
				Turn the system over to the systems analysts.
				Determine time table for hardware delivery

N/A	YES	NO	RESPON- SIBLE AGENCY	MOVEMENT TECHNIQUE
				Arrange for temporary protection of floor along route
				Tag all major components of equipment
				Layout of equipment posted at the entry points
				Provide personnel to direct movers in the placement of equipment
				Cover all floor cutouts
				Mark H/W layout on floor with tape, verify accuracy of cutouts

N/A	YES	NO	RESPON- SIBLE AGENCY	SPECIAL CONSIDERATIONS
				Coordinate installation schedule with computer operations
				Schedule computer down time to allow electrical work
				Will additional hardware require a revision to the logical configuration of existing system
				Provisions made to seal off existing system to allow construction to occur in support of new system
				Attempt to schedule computer down time during nonpeak workload periods
				Schedule time to test integration of new system with existing
				Requirement to revise the physical configuration of existing system
				Verify existing air conditioning system can accommodate additional heat load
				Plans to power new system from separate power panels to minimize interruptions to existing system

				If interfacing two systems is there a maximum data cable length specified
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APPENDIX 2

The cost figures provided below represent the average cost per square foot for construction in support of a computer system. These figures are based on 1978 prices with a projected increase of one percent per month.

1. Average cost per square foot for the construction of a building dedicated to a computer system \$ 60.00

2. Average cost per square foot to modify an existing facility in support of a computer system
 - a. Electrical (power, lights, fire detection system) \$ 6.00
 - b. False ceiling \$.50
 - c. Walls
 - (1) Permanent walls (cost per cubic foot) \$ 10.00
 - (2) Permanent partitions \$ 4.00
 - d. Raised flooring \$ 10.00
 - e. Air Conditioning
 - (1) Heat load less than 240 KBTU/hr \$ 15.00
 - (2) heat load greater than 240 KBTU/hr \$ 7.00

COMPUTER HARDWARE INSTALLATION MODEL

by

DANNY ROY MICHAEL

B.S., University of Texas at El Paso, 1966

AN ABSTRACT OF A MASTER'S REPORT

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requirements for the degree

MASTER OF SCIENCE

Department of Computer Science

KANSAS STATE UNIVERSITY
Manhattan, Kansas
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ABSTRACT

This report represents a model for a manager to use which can be applied to any type of hardware installation and which results the detailed activities necessary for an installation plan. The activities are grouped into three major areas--environmental, electrical, and physical installation, and are presented in the following format:

1. Lists of activities encompassing all phases of the installation
2. A detailed description and explanation of the activities
3. Activity dependencies expressed as a partial ordering of activities through a network

Additionally, the model addresses use of the activities to formulate events in the construction phase, the physical installation phase, and terminates in the acceptance of the system by the systems analysts.