EQUIPMENT ROOM AIR DISTRIBUTION
DESIGN CRITERIA

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Figures

1. GENERAL

1.01 This section discusses and provides standards for equipment room air distribution. These standards are provided for use in the design of new buildings or building additions that are intended to house telephone equipment that meets the requirements of Section 800-610-164, "New Equipment-Building System (NEBS), General Equipment Requirements."

1.02 Revision arrows are used to emphasize significant changes. The reason(s) for reissue are specified below:

(a) Explains a new method of determining total equipment heat release for Electronic Switching System (ESS) equipment

(b) Defines the terms "throw" and "terminal velocity"

(c) Adds Part 7, Summary of Equipment Room Air Distribution.

2. SCOPE

2.01 Efficient, low-cost cooling of telephone switching, transmission, and power equipment through heat exchange with air requires a carefully engineered room air-distribution system. The system must deliver the required airflow rate to the area adjacent to the heat-dissipating items in a manner to remove the heat efficiently, to confine operating equipment temperatures within limits that yield long component life, and to provide a comfortable working environment.

2.02 The conventional comfort cooling practices employed to yield a suitable environment for people in a room with a low level of heat removal are generally sufficient for telephone equipment with heat dissipation up to 20 watts per square foot of floor space. In these applications, there needs to be only enough design flexibility to allow local flow-rate changes and to provide air-direction control in one or more of the hotter equipment aisles during the final air-balancing stages.

2.03 In equipment rooms with high-heat density equipment, such as in the No. 4 ESS, the heat-exchange properties of the air at the equipment (such as flow rate and velocity) become considerably more important; therefore, increased control of the air supply to the equipment is required. Above 20 watts per square foot heat dissipation averaged over an equipment room, the engineering and designing of the air-distribution system must be carefully planned to ensure adequate displacement of air past the equipment frames in which the heat-dissipating items are located.

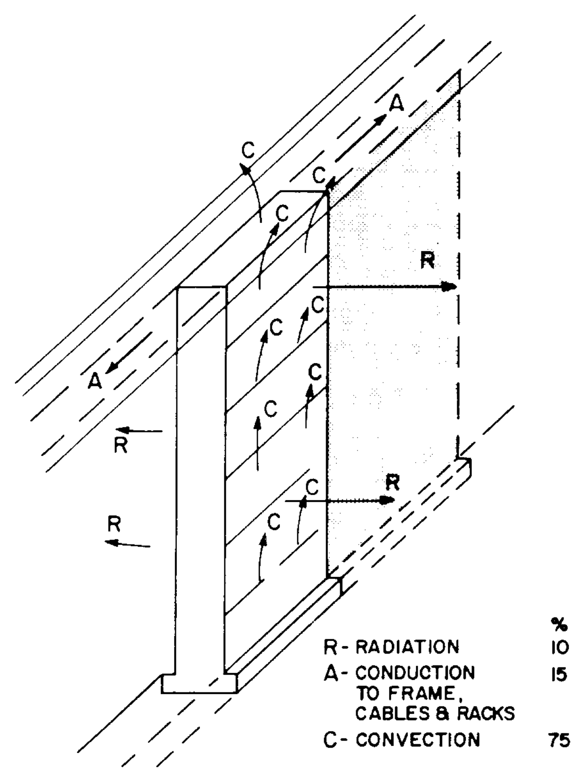


Fig. 1—Modes of Heat Transfer From Equipment

3. EQUIPMENT HEAT TRANSFER TO ROOM AIR

3.01 The primary heat transfer from the circuit packs and shelves on which the heat-dissipating items are located typically occurs through convection and turbulent mixing of air (ie, mass exchange of air at different temperatures). As shown in Fig. 1, some heat is also transferred by conduction and radiation, but these amounts are usually small and the radiant flux tends to reradiate from neighboring equipment frames. The parameters affecting equipment heat transfer, in the order of importance to the enhancement of equipment cooling, are:

(a) Local mass movement of air at the equipment frame

(b) Temperature difference between the equipment and aisle ambient

(c) Temperature difference between supply air and aisle ambient

(d) Local heat-transfer film coefficient from the equipment components.

3.02 This order of importance is given because the first three parameters are directly controlled by the design of the air-conditioning system, which is under the control of the building engineer. The last parameter has relatively fixed physical limits and results principally from the equipment design.

3.03 The heat generated within frames can also be dissipated by forcing room air through the equipment with fans located in the frames. Only a few types of equipment employ this method of cooling. Examples are the KS-2113 140V, 200A rectifier used in the 415A power plant, ♦No. 5 ESS equipment,♦ and some commercial equipment used in standard systems employing minicomputers. For this type of frame, airflow in the room should be directed to avoid any interference with the stream of exhaust air. Heat from components can also be dissipated by conduction to water which is circulated within the framework and then to the refrigeration plant. The Waveguide Transmission System (WT4) Repeaters employ this type of cooling to maintain the temperature of critical electronic components.

3.04 Forcing air or water through frames is costly in terms of the added mechanical assemblies and space required within the frame when compared to equipment designed to be cooled by convection within the frame. Therefore, these methods should only be employed in special circumstances. Also, while it would appear that forced air inside the equipment frame would be a great aid in cooling components, in reality, the heat removal from equipment can be more than doubled by increasing the room ambient air motion by using air outlets at higher than normal terminal velocities (100 feet per minute).

3.05 This action of increasing the ambient air motion at the face of the equipment frame beyond that obtained with normal air-conditioning terminal velocities provides momentum for added replacement of the air within the equipment frame. This action can considerably reduce the cumulative internal air temperature rise from the bottom to the top of the frame, resulting in a more uniform temperature distribution within the frame.

4. DETERMINATION OF ROOM HEAT LOADS

4.01 The first step in defining the room air-distribution requirements is to determine both total and average heat loads and to identify any local hot spots in the room. This should be done as follows:

(a) An accurate layout of installed equipment, as well as the anticipated future growth, must be obtained. The heat dissipation will vary for different equipment frames in a system and will not be uniform in an equipment area. ➧Heat dissipation information for ESS equipment can be obtained from Engineering Letters, Floor Plan Data Sheets (FPDS) and the Telephone Office Planning and Engineering System (TOPES) "data" section. Frame-by-frame heat release information from both these sources is given for several modes of frame operation. It is recommended that only "planning value" from "TOPES Data" or "24 Hour Average Value" from the FPDS be used for sizing, heating, ventilating, and air-conditioning (HVAC) equipment. "Planning value" is the average heat release value for a fully equipped frame. System curves or algorithms from TOPES or FPDS take into account the diversity that takes place when frames are assembled to serve a number of customer lines. Because the summation of published frame heat-release values can lead to excessive heat-release values, it is recommended that where "system curves or algorithms" are provided, the total heat release of the system be used to size refrigeration and fan systems. It will be necessary then to prorate the published frame heat-release data by the ratio of the system heat release to the summation of the frame heat-release values, as shown in the example below, to properly design the air-distribution system.➧

$$\frac{\text{System Heat Release} \times \text{Published Frame Value}}{\text{Summation of Frame Values}} = \text{Adjusted Frame Value}$$

(b) The heat dissipation for each equipment frame should be marked on the equipment layout. These heat dissipations should be added and summarized for each equipment lineup. This will indicate the location of high-heat concentrations and the orientation, type, and number of diffusers required.

(c) The heat dissipation for the lineups within the boundaries of each building bay in the equipment area should be determined. This will identify high-heat building bays. Building bay heat loads will be used to design the supply ducts.

(d) ➧The fan and the refrigeration capacity should be sized based upon the system heat release, toll and power equipment heat dissipation, lighting load, and the envelope load of the building. Adjusted frame heat values should be used to proportion the air quantities in the space.➧

5. AIR-DISTRIBUTION SYSTEMS FOR NEW EQUIPMENT BUILDING SYSTEM (NEBS) OFFICES

5.01 There are a variety of ways to distribute the cooling air effectively and at low cost. Figure 2 gives general information and schematics on the air-distribution system elements available for use by the building engineer. In addition to the type A overhead supply systems of the conventional duct diffuser and register type, individually mounted linear diffusers that are connected to the supply ducts by flexible trunks (type B) are available. Ceiling plenums with air slots are employed in types C and E, while raised floors are used to distribute air in types D and E. When space is available, round duct is cheaper and more efficient than rectangular duct. Air-distribution patterns in equipment aisles from these various supply systems depend on the number and location of the diffusers or air slots. Unit cost and labor charges will affect the choice of a selected system as much as the expected performance, since there is a large overlap in the heat load which can be satisfactorily handled by these five types of air-supply systems.

5.02 ➧It is important to understand the definition of "throw" and "terminal velocity" before going into various air-distribution systems. "Throw" is the horizontal or vertical distance that the air supplied from a register or diffuser will travel and "terminal velocity" is the maximum airstream velocity at the end of its throw. Use of higher terminal velocities when sizing air registers results in the establishment of higher ambient air velocities. For normal comfort cooling, a 50-foot-per-minute terminal velocity is considered adequate. For telephone equipment cooling, a 50-foot-per-minute terminal velocity should be utilized for equipment heat release of 20 watts per square foot and lower. For heat release above 20 watts per square foot,use a terminal velocity of 100 feet per minute. It is impossible to measure terminal velocity without sophisticated laboratory equipment.➧

5.03 ➧The success of a HVAC system depends a great deal on its air distribution. Usually there are two types of complaints that arise from a poor or faulty air-distribution system: drafts or stuffiness. Draft is a result of excessive air velocities in the occupied area and gives a feeling of being too cold. Stuffiness is the opposite and gives a feeling of stagnant air. These conditions arise not only due to air-distribution problems but can also be due to temperature, humidity, or the combination of all three. For both office space and telephone equipment areas, proper selection of air outlets is very critical for people comfort and equipment cooling. Outlets should be selected with proper "throw" and "terminal velocity". In equipment areas, drafts are not as big a problem as in people areas. In these areas, air outlets should be selected to get the cool air down in the aisles where the high heat-producing equipment is.➧

TYPE A—OVERHEAD DUCTED SUPPLY

5.04 The assembly of type A air ducts over cable racks, lights, and equipment for a typical arrangement in an electronic switching office is shown in Fig. 3. A thermal map and the airflow directions are indicated for a maintenance aisle. The air is injected into the room at the 10-foot level from diffusers or registers spaced approximately 12 feet apart.

5.05 For example, in a No. 1 ESS call store area (NEBS equipment) in an existing building, each 2-foot 2-inch equipment frame dissipates about 500 watts. Primary air enters the room at 800 to 1100 feet per minute and sweeps down between the lights and racks. Ambient air velocities range from 25 to 300 feet per minute at the 5-foot level, 2 inches from the frame face. The aisle contains relatively high-velocity airstreams and a few stagnant areas. Air temperatures in the middle of the aisle at the 5-foot level for the lineup range from 80° to 85°F. Air temperatures 2 inches in front of the equipment range from 68° to 80°F, with a relatively high temperature area opposite the still-air region.

5.06 These temperatures and air movements are representative of the level of environmental control from a low-pressure, low-velocity, air-distribution system when overhead diffusers or registers are positioned to direct a large volume of air into the aisle. Air velocities greater than that provided for comfort cooling are maintained in front of the frames at the 5-foot level, and selected high-heat frames are washed with higher velocity air. The aisle temperature variation is small but is influenced by local convection.

TYPE B—DROPPED DIFFUSERS FROM DUCTED SUPPLY

5.07 Compared to type A systems, airflow patterns would be more uniform with air injected into the room from type B dropped diffusers spaced at 5-foot intervals to coincide with the cable pathways. (See Section 800-610-164, Issue 2.) A 10-foot diffuser mounting height is standard when used with the Cableway racking system (Section 801-006-158), which maintains large openings for installation of cable and air passages. The KS-21344 diffuser may be used to accomplish the air distribution. A standard 8-inch diameter flexible duct or a rigid metallic duct supplies the air. ➧Section 760-550-218* covers the selection and application of KS-21344 diffusers.➧

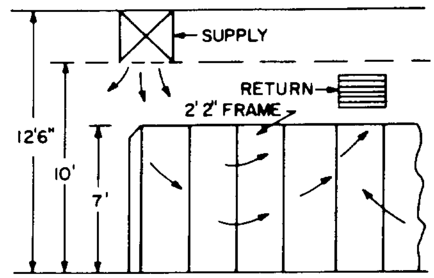
5.08 The dropped diffuser arrangement can handle heat loads between 20 and 60 watts per square

* Check Divisional Index 760 for availability.

Type A—Overhead Ducted Supply

Point Returns on Wall or Above Wiring Aisles —

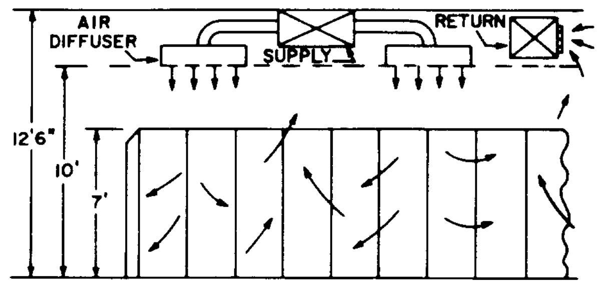
May be used up to 20 watts per square foot with minor balancing needed at high-heat frames. Air discharge registers with opposed blade dampers, 4-way adjustable. Approach velocity of the return air should not exceed 40 feet per minute in occupied areas.



Type B—Dropped Diffusers From Ducted Supply

Point Returns on Wall or Above Wiring Aisles —

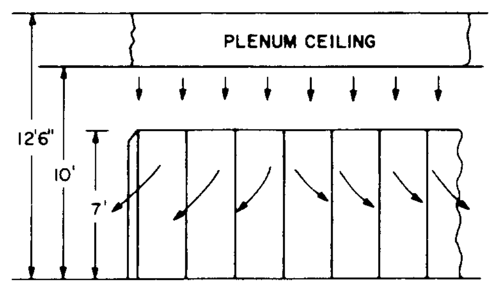
May be used between 20 watts per square foot and 60 watts per square foot. Provides considerable flexibility in adjusting for local high heat. Overhead ducts supply air to diffusers (KS-21344) Section 760-550-215. Maximum point return distance limited to 40 feet for high-heat area of 60 watts per square foot.



Type C—Plenum Ceiling Supply

Returns in Ceiling or at Wall —

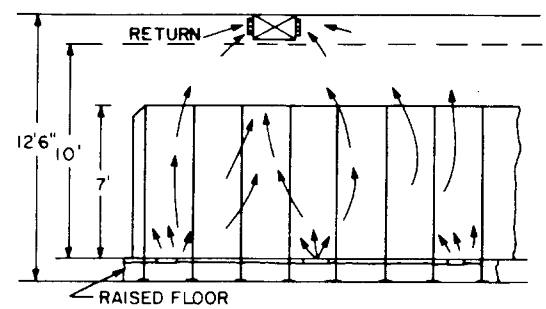
May be used up to 60 watts per square foot. Provides total flexibility in adjusting for local high heat. Central fans or process coolers (KS-21355) can supply air to the ceiling plenum, X-74404 (KS-21359). Distance to point returns located in walls, process coolers, or in the ceiling to a ducted return should be limited to 50 feet. System is simply balanced for ceiling pressures above 0.20 inch wg.



Type D—Raised Floor Supply

Returns Above Wiring Aisles or at Walls —

May be used up to 40 watts per square foot. Provides limited flexibility in adjusting for high heat. Supply air enters room through slots in raised floor, X-74403 (KS-21358), and returns through overhead ducts or to point returns at walls. Must guard against short circuiting to air-return system. Cold air in aisle prompts craft persons complaints.



Type E—Modular Cooling System

Plenum Ceiling Supply, Raised Floor Air Return —

May be used between 20 watts per square foot and 100 watts per square foot. Supply air enters ceiling plenum, X-74404 (KS-21359), from process coolers (KS-21355), passes through equipment room, and returns through slots in raised floor, X-74403 (KS-21358). Total flexibility provided to accommodate office rearrangement and changes experienced during early planning periods and the life of the building.

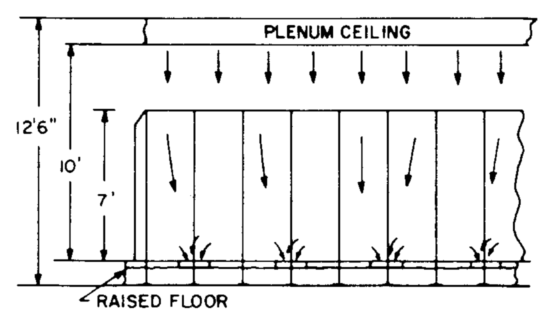


Fig. 2—NEBS Room Air-Distribution Arrangements

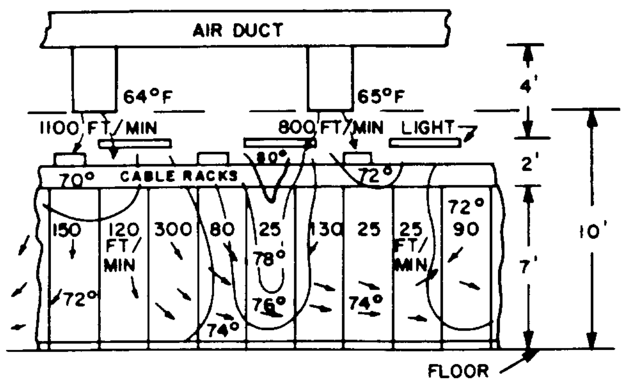


Fig. 3—Air Direction, Velocity, and Temperature in the Maintenance Aisle of a Portion of an Electronic Equipment Office

foot and is particularly useful in cases where new high-heat equipment is added under an existing type A overhead duct air-distribution system. Relatively inexpensive round ducts can be added to connect the dropped diffuser to the supply air ducts.

TYPE C—PLENUM CEILING SUPPLY

5.09 With a type C air-supply arrangement that uses the X-74404 (KS-21359) suspended ceiling, excellent air distribution will be provided from slots in the ceiling that are positioned parallel to and directly over the maintenance aisles. Uniform airflow at velocities from 50 feet per minute to 100 feet per minute measured at the 5-foot level and 4 inches in front of the frames can be obtained with this type of system, depending on the heat load and plenum pressure.

5.10 The proper airflow rate to the frames at required velocity is automatically achieved through matching of the overhead air slot closure patterns to the frame heat dissipation. Design and application data are provided for suspended ceiling air supplies in the Modular Cooling System (MCS) Planning and Engineering Sections. The ceiling system can be fed with conditioned air from process coolers located in the equipment room or from a centrally located fan room. In either case, care must be taken in the location of the air-return points, which should be no more than 50 feet away from associated supply slots to avoid regions of poor air exchange. ➧The KS ceiling provides two air streams 4 inches from the face of the frames in the maintenance aisle (Fig. 4). If a commercial ceiling is used, ensure that two streams of air are discharged, instead of one at the center line of the maintenance aisle.➧

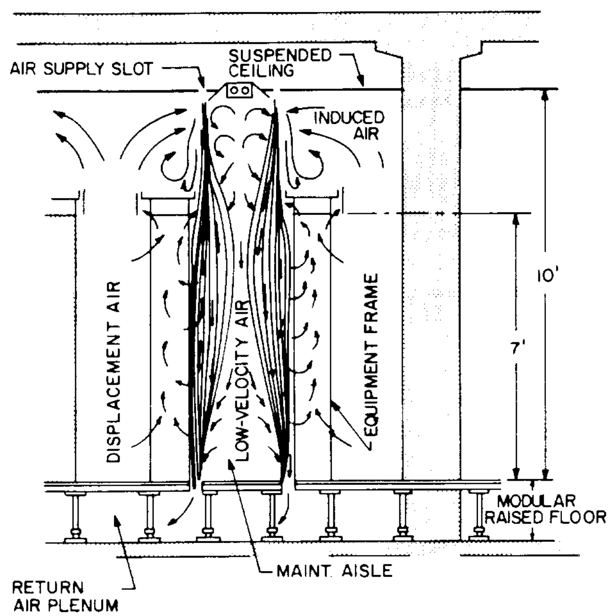


Fig. 4—MCS Air Streamlines at Equipment

TYPE D—RAISED FLOOR SUPPLY

5.11 A raised floor plenum with linear diffusers can supply conditioned air that has been ducted into the plenum from a central fan room. Point or ducted returns are employed as noted under type D in Fig. 2. This type of system can be used for heat loads up to 40 watts per square foot. It is only recommended where a raised floor will be used to mount cable (or other equipment such as commercial computers) or for an adjacent operating center. Supply air at 65°F or less injected at the floor will create unpleasant working conditions. Therefore, care should be taken to locate the floor diffuser away from spots designated as craft person positions, and the velocity of air exiting from the floor diffuser should be limited to 150 to 200 feet per minute.

5.12 To obtain equal cooling, more energy and considerably more fan capacity are required to move air from the type D floor plenum than from overhead supply systems. The lack of buoyancy accelerates the downward flowing airstream from overhead supply systems but retards the upward moving air from floor supply systems. Therefore, overhead supply systems have advantages in that a greater throw can be obtained for the same exit velocity. Additionally, a counter-flow heat exchange condition occurs with downward flow of the coolest air that reaches the upper (usually hottest) part of the frame first and improves the rate of dissipation of heat from the equipment to provide more uniform temperature distribution within the frame.

♦**5.13** Raised floor systems are very high in cost and an economic analysis should be made to justify the additional expense. It is very difficult to maintain the same floor level and this causes problems when telephone equipment is installed. Types A and B generally can do an equally good job at less cost.♦

TYPE E—MODULAR COOLING SYSTEM (MCS)

5.14 For cooling high-heat telephone equipment in large equipment rooms, the MCS can be used. In this system, as shown in Fig. 4, air is discharged (at nominally 0.20 inch water gauge) vertically down in front of the frame face into the aisle from slots in the ceiling. The total room airflow rate required is determined by the total heat dissipation and by allowing an 18°F (10°C) or less rise in temperature from air supply to air return. Depending on heat load and plenum pressure, the heat dissipation in each lineup is used to establish the overhead slot row closure patterns, thereby controlling the airflow rate, air plenum pressure, and frame face velocities. The resultant mass flow of combined supply and entrained air is considerable, and turbulent mixing occurs along the frame face to maintain near room temperatures in most of the air channels within the equipment frame.

5.15 Figure 5 shows the test results of cooling a 1000-watt frame, comparing natural convection cooling and that provided by the MCS or any system which provides the required airflow in front of the frame. As noted, the card air gap temperature rise is confined to lower limits at all shelf levels. Above the frames, cableways project into the aisle and reduce the turbulent mixing (exchange) processes at the upper frame shelf levels. Higher equipment operating temperatures result toward the top of the frame.

5.16 Modular cooling systems will provide direction of proper airflow and coordination of cabling, lighting, equipment location, and equipment

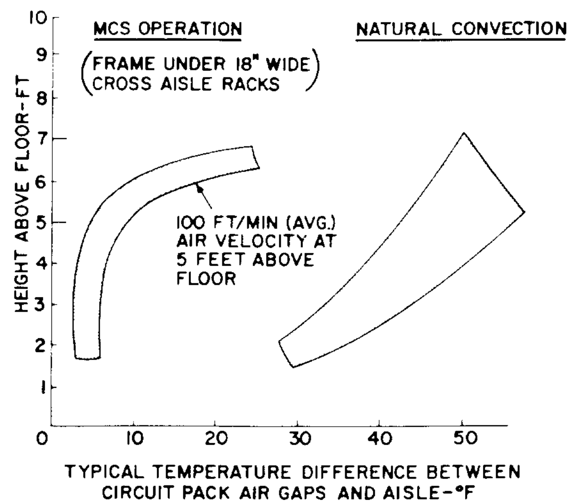


Fig. 5—Frame Cooling Effectiveness (1000 Watts Dissipated in 2-Foot 2-Inch Frame)

cooling. These are provided inherently by the integrated design of the system. Also, changes in equipment location or office growth which result in heat-load changes in different areas of the equipment room can be accommodated by adding or shifting ceiling and floor panels to coincide with the equipment relocation. Similarly, process coolers can be added or relocated to handle the heat loads. The air-supply slots in the plenum ceiling are easily adjusted to provide the local air distribution needed. Additional building engineering and construction are not required to accommodate these changes.

6. ROOM AIRFLOW REQUIREMENTS

6.01 Once the heat loads throughout the equipment room and the type of air-distribution system to be used have been determined, airflow can be allocated to each section of the room as needed. For low-heat areas (defined here as having uniformly distributed equipment room heat loads of less than 20 watts per square foot of floor space), maintaining the ambient conditions described below will satisfy requirements. In estimating heat load in watts per square foot of floor space averaged over an equipment area, all aisles and floor space not occupied by equipment should also be included.

6.02 All equipment is designed to remain operational within the ambient temperature and humidity limits specified below unless otherwise noted on the FPDS. The ambient conditions refer to the temperature and humidity at a location 5 feet above the floor and 15 inches in front of the applicable equipment. These conditions are usually a sufficient specification of the environment for cooling low-heat equipment. (See Table A.)

TABLE A

AMBIENT CONDITIONS	TEMPERATURE	RELATIVE HUMIDITY
Operating	40 to 100°F (4 to 38°C)	20 to 55%
Short-Term*	35 to 120°F (2 to 49°C)	20 to 80%
Nominal Operating Condition (Cooling)	80°F (27°C)	20 to 55%

* Short-term refers to a period of not more than 72 consecutive hours and a total of not more than 15 days in 1 year.

6.03 Special nonuniform heat-load conditions or hot-spot requirements may have to be considered on an individual basis for high-heat equipment rooms (defined as having heat loads of ▶20◀ or more watts per square foot of floor area averaged over the equipment area) or for high-heat equipment frames (defined as having 600 or more watts heat dissipation uniformly distributed in a 2-foot 2-inch by 7-foot equipment bay).

▶**6.04** Standby power should be provided for the fans in case the loss of refrigeration is caused by a commercial power failure. Fans will run to maintain 80°F in the high-heat areas such as processor, central control, etc.◀ Maintaining airflow will reduce temperature and temperature variations within the equipment and also reduce undesirable thermal shock effects when refrigeration is restored. An example of the benefits in systems which maintain air movement during refrigeration shutdown is shown in Fig. 6.

6.05 For the first 4 hours, effective cooling of the equipment through the use of air recirculation is about half of what can be obtained using refrigeration. The figure shows the aisle temperatures obtained with refrigeration, with the blower alone and

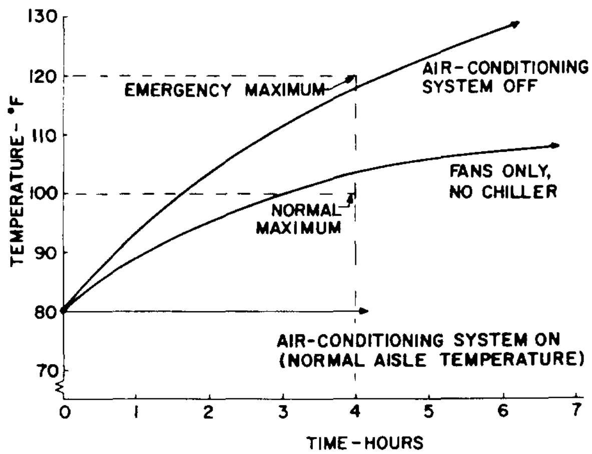


Fig. 6—Room Temperature Conditions for High-Heat Equipment Space (Heat Load = 30 Watts per Square Foot)

with complete system shutdown. In the example of 30 watts per square foot, the 120°F maximum temperature limit is reached after about 4 hours. For 40 watts per square foot, the time required will be less.

▶**6.06** For high-heat equipment frames having more than approximately 600 watts heat dissipation per 2-foot 2-inch width, the air supply should be designed with throws selected for 100 feet per minute terminal velocities with nearly vertical airflow approximately 4 inches in front of the frame and with throws selected so that the supply air reaches the area between floor level and 5 feet above the floor.◀

6.07 The airflow rate can be averaged over three equipment bays (6 feet 6 inches). A type E system conforming to design standards will automatically direct this air and provide the required average frame face velocities. Normally verification will not be required. Because effects of aisle obstruction can be alleviated by increasing the velocities at one or both sides of an obstruction, the term average has particular significance here. Higher-velocity air is much more effective in cooling equipment than colder air at normal air-conditioning design terminal velocity of ▶50◀ feet per minute. Generally, wherever a heat problem exists, the required cooling level will be obtained if the airflow rate at the frame face is directed downward and the airflow rate is increased so that the local maintenance aisle temperature does not exceed 80°F.

6.08 As installers and craft persons work in front of high-heat frames, they intercept thermal energy and experience radiation heating on their bodies and clothing. This effect could lead to complaints about working conditions or the air-conditioning system. Figure 7 shows the range in effective aisle temperature sensed by a person standing in front of an equipment frame. (It is assumed that about 10 percent of the frame dissipation is radiated.)

6.09 When working in still air before a typical 500-watt frame, the craft person experiences roughly a 5°F increase above ambient temperature. The effect is most apparent when the high-heat area is at face level. This factor should be assessed when first dealing with complaints about temperature conditions in the equipment aisles. If an office experiences problems that seem to be temperature-related, ♦while the actual space temperatures are within acceptable limits (average of 65° to 80°F occupied),♦ the operating company should first make certain that all class A changes have been made. If equipment performance problems persist, a class 4 engineering complaint should be filed prior to undertaking extensive changes to the air-distribution system.

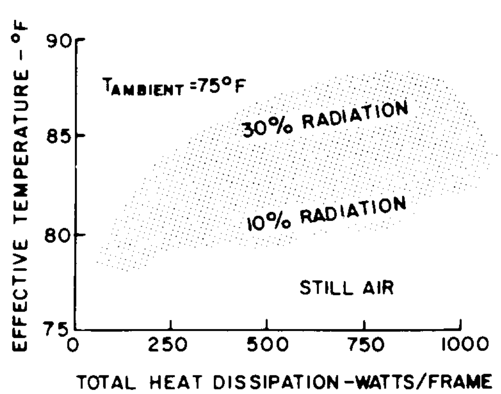


Fig. 7—Effective Aisle Temperature Due to Equipment Frame Radiant Heat

♦7. SUMMARY OF EQUIPMENT ROOM AIR DISTRIBUTION

7.01 Obtain an accurate layout of the equipment installed and the anticipated future growth.

7.02 Determine the heat dissipation for each equipment frame using FPDS and/or TOPES values. Use the "total system heat release" value from "System Curves or Algorithms" to size the refrigeration and fan systems. The air quantities should be prorated using the adjusted frame values as explained in paragraph 4.01.

7.03 Determine the average heat load in watts per square foot of floor area and use Fig. 2 to determine the type of air-distribution system to handle the heat load.

7.04 Use a 50-foot-per-minute terminal velocity for heat loads of 20 watts per square foot and below. For heat loads of 20 watts per square foot and above, use a 100 foot-per-minute terminal velocity to have a higher ambient air motion for better heat transfer.

7.05 For high-heat equipment rooms, provide standby power for the fans only to maintain 80°F in the critical areas such as processor, central control, etc.♦