Sun Microsystems Data Center Site Planning Guide

Data Centers' Best Practices

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Preface

This document provides the necessary information for constructing a suitable data center environment for a Sun Microsystems server.

Acknowledgments

Thanks to Worldwide Environmental Services (WES) for their work on the Sun Data Center Site Planning Guide.

How This Book Is Organized

Chapter 1 provides information on general site selection criteria.

Chapter 2 provides information on designing and building a computer room.

Chapter 3 provides information on cooling and air distribution.

Chapter 4 provides information on environmental contaminants.

Chapter 5 provides information on safety and security

Chapter 6 provides information on facility power requirements.

Chapter 7 provides information on receiving, transporting, and staging guidelines.

Appendix A provides conversion information.

Appendix B provides a list of references.

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General Site Selection Criteria

It is easier to address facility design issues in the planning stages than to correct problems after the fact. Often, it is impossible to implement extensive actions in an on-line computer room without impacting uptime. For this reason, it is extremely important that adequate attention is paid to issues such as the physical location of the building, the location of the data center relative to the other areas of the building, and all aspects of the support infrastructure. A little extra planning can save a tremendous amount of time, money and aggravation over the lifetime of the facility.

1.1   Locating the Building

Cost and numerous external factors influence the site selection for a building accommodating a new data center. Not least among these factors is the potential environmental impacts the building will have on the data center. Often, a site planner weighs numerous conflicting criteria when selecting the most appropriate location. Whenever possible, consider the following factors.

- **Natural Disasters**; avoid sites in areas susceptible to natural disasters. Flood plains, tornado or hurricane hot-spots or seismically active areas are not optimal choices. While precautions can be taken to accommodate building in such areas, there are additional cost considerations, and more likelihood of impact on utilities or other infrastructure support.
- **Electromagnetic Interference**; avoid choosing a site near sources of electromagnetic interference (EMI) or Radio Frequency Interference (RFI). Telecommunications signal facilities, airports, electrical railways, or other similar sites are often associated with high levels of EMI/RFI that could interfere with the proper functioning of computer hardware. Shielding computer rooms from EMI/RFI adds to the construction cost.

- **Industrial Pollution**; avoid locating the facility near major sources of industrial pollution, such as factories, manufacturing facilities, or sewage treatment facilities. Chemicals associated with these facilities can impact hardware reliability if they migrate to the controlled areas of the data center. Even the chemicals associated with field treatment in large agricultural areas have been known to cause hardware failures. While these contaminants can normally be arrested with high-efficiency filtration or chemical filters, these processes can add significant costs to the maintenance of the data center

- **Vibration**; avoid locating the site near major sources of vibration. Airports, rail lines, busy highways, traffic tunnels, mines and other similar sites can generate continued or intermittent vibration that could disrupt operations. Such vibration can affect disruption of utilities or support equipment, or it might directly disrupt the hardware.

- **Established security**; consider locating the building within an existing complex so as to take advantage of established security measures. Costs associated with the expansion of existing patrols and security systems will most likely be less than replicating these at a separate site. Both active and passive security measures should be employed to protect the data center from vandalism, industrial espionage, or terrorism.

- **Minimized Target**; avoid making the data center a crime target. Besides the vapor barrier concerns normally associated with them, exterior windows can also pinpoint the location of the data center for designed assault. In addition, due to its 24 hour operation, data center windows have been known to be targeted in vandalism shootings simply because they are the only lights on in the middle of the night.

- **Proximity to neighboring structures**; isolate the building from the risks associated with neighboring structures. Office areas or industrial buildings have a higher risk of fires or other hazards. The data center should not be susceptible to downtime caused by activities not associated with its functioning.

- **Emergency services**; ensure adequate access for support and emergency services. This is particularly important in congested urban areas. Access for large delivery trucks or emergency fire response should be free of obstacles at all times. Parking for emergency power generation or air conditioning vehicles, necessary during a prolonged outage, should be considered.

- **Availability of utilities**; ensure adequate utilities are available. While urban areas pose many logistical problems, they normally provide the availability of redundant utility feeds and good infrastructure support. Extreme rural areas may be more susceptible to single points of failure, making the data center more reliant on its on-site backup equipment.

1.2   Locating the Computer Room

Whether a dedicated facility or part of a multipurpose building, the physical location of the data center is extremely important. The raised floor space, air conditioning support, uninterruptable power supply (UPS), generators, and related support equipment must be coordinated with the other areas of the building and properly positioned within the building perimeter in order to optimize their interaction and the overall support of operations. The location of the data center within the overall facility should be based on numerous criteria, including the following general considerations.

■ **Isolation from contaminants**; isolate the computer room from contaminant-producing activities. Isolate the computer room from contaminant-producing activities. Influences from print rooms, machine shops, kitchens, loading docks, or any area with high levels of contaminant generation or operator activity should be avoided. Ensure the exhaust from generators or other sources does not directly enter the intake of air handlers serving the computer room.

■ **Access**; ensure adequate access for hardware from loading dock, freight elevator or appropriate entrances. This will include appropriate door sizes negotiable corners, ramps and smooth floor surfaces. In addition, it is important that proper access is provided in support areas to allow for service or replacement of UPS, chillers and other large items. As a facility grows or changes, access paths are often eliminated or changed.

■ **Security**; provide secure points of entry to the computer room. This helps secure sensitive data, limit the possibility of employee vandalism, minimize exposure to inappropriate psychrometric or contaminant conditions, and control the possibility of failures caused by inadvertent actions of untrained personnel.

■ **Raised flooring**; design the raised floor computer spaces in convenient proximity to the support equipment (UPS, chillers, etc.). It is often appropriate to locate the data center on floors above the support equipment in order to consolidate cooling and power trunklines.

■ **Air conditioning**; consider the type of air conditioning to be used. Chilled water units will need to be connected to chillers located in the building or an adjoining support facility, and may require cooling towers. Due to noise and structural issues, chillers are normally located in the basement of the facility or in a separate wing of the main building. Direct expansion air conditioners require condenser units located outside the building. In addition, the roof or outside pads should provide adequate structural stability to accommodate the condensers.

■ **Risk of leaks**; avoid locating the hardware areas beneath potential liquid leaks. Do not run the air conditioner piping through the ceiling void of the computer room. Do not locate the data center beneath kitchens, workshops, or other areas that have a high potential for leaks. Locating the computer room below building grade adds the potential for leaks from outside the building. In addition, locating the computer room on the lower floors of a multistory building, particularly one

with multiple tenants, runs the risk of leaks associated with a sprinkler discharge in the floors above. Expansion joints, conduit or pipe penetrations, cracks and other breaches can all allow for water infiltration.

- **Proximity to tenants**; avoid locating the computer room near areas leased by other tenants. While the current application of the neighboring room may be appropriate, this could change dramatically should the lease change hands. In addition an area with a short-term lease may change hands frequently, necessitating potentially disruptive renovation activity.
- **Room to expand**; locate the computer room in an area that offers the potential for future expansion. Even though technology changes tend to make hardware more space-efficient over time, the ability to expand, either within the current footprint of the building, or through additions, should be available to accommodate possible growth as the room evolves. If growth is anticipated, constructing surrounding offices on a preinstalled raised floor will facilitate the conversion to hardware areas. If growth is not anticipated in the near future, but is still possible, applications that can be easily moved should be considered for the surrounding areas. Avoid land-locking the computer room. While the expansion need not be directly connected to the existing areas, it is often easier to share support equipment, such as chilled water loops or security, if they are located in close proximity.

General Computer Room Criteria

This Chapter details the proper design and building of a computer room as indicated in the Sections that follow:

- "Designing the Room" on page 2-1
- "Designing the Floor" on page 2-4
- "Building the Room" on page 2-7

2.1 Designing the Room

Proper planning of the data center does not end with its conception and construction. The computer environment is constantly evolving to accommodate changes in technology and the business landscape. Tools that help adapt to these changing needs are essential in a modern data center. Just as it is important to monitor of environmental conditions, it is also important to keep updated working drawings of the computer areas.

2.1.1 Computer Aided Design (CAD) Drawings

A computerized drafting system is an investment in the future of the data center. This allows for the continued updating of the electrical, mechanical and computer systems. Updated drawings can be used in site evaluation and future planning, and various scenarios can be explored in detail. The availability of accurate, updated plans also facilitates projects involving outside contractors. The maintenance of updated, computerized prints is highly recommended.

2.1.2 Design Flexibility and Planned Redundancy

When designing the data center, it is important to include additional resources for redundancy. This may be in the form of available power, environmental support equipment or floor space. This redundancy allows for the flexibility necessary to accommodate changes and short-term growth associated with hardware upgrades. It also allows for uninterrupted operations during upgrades or replacements in hardware. New hardware can be run simultaneously with the hardware it is replacing, rather than swapping the two. Redundancy also allows security in the event of a failure. This is particularly true of the environmental support equipment.

While most data centers are designed with at least a minimal amount of redundancy, this issue is often forgotten in future planning. Excess floor space or support systems that were designed for redundancy, are often used for growth, reducing the protection they once provided. It is important to carry through this important factor in the future planning of the room. The redundancy must be maintained, even as the demands of the data center grow. The amount of redundancy planned can be increased in the design phases to address this. This will provide room for growth while still providing the back-up needed. If this is not done, the support systems should be increased along with the hardware during the expansions. Failure to provide adequate redundancy can lead to logistical problems and may degrade the overall reliability of the computer operations.

2.1.3 Expansion Considerations and Preparations

Each evolution in hardware technology dramatically increases the computing or data storage capacity per square foot of the room. This is how most data centers have been able to survive for so long without continually expanding their physical dimensions. The evolution of the computer room is normally a continuous process of minor growth and changes within a larger cyclical pattern of more dramatic changes. Hardware will normally continue to grow in the room until it nears capacity, then changes will be made to regain some of this floor space through upgrades in technology. The computer room will then begin to encroach on this newly available space as demands on the computer room continue to increase, and the cycle will repeat. In some cases the changes in technology and the increased needs for computing or storage capacity will evolve at the same speed, in other instances, one will out-pace the other.

When technology evolves more quickly than the needs of the business, the data center will normally develop open areas, devoid of hardware. These may remain for some time, and are often very attractive real estate to other areas of the business. It is important not to be too quick to down-size the data center areas, as properly designed hardware spaces are much more expensive to construct than typical office environments. All planning of expansions or reductions to the raised floor computer

room areas must be considered in macro terms. It is often much more financially prudent to allow portions of a well-designed room to remain vacant than to try to reconstruct this from converted office space when the data center demands increase.

If the needs of the business outpace the evolution of the technology, it may be necessary to increase the physical dimensions of the data center. This should also be done in conjunction with long-term planning. Moving to more space efficient technologies, when available, may prove to be more cost effective than expanding the physical dimensions of the computer room.

2.1.4   Room Layout and Planning

Whether a design-built room, or a renovated area, the computer room must be able to accommodate diverse hardware designs and requirements. The mission of a computer room rarely remains stable, and the hardware designs and configurations change as technology and the goals of the company evolve. While the future of a computer room can rarely be anticipated, it is essential that the hardware areas are planned in such a fashion as to allow for seamless adaptation to the changing needs.

The main criteria driving the type of hardware in the room will be determined by the applications of the business. The following general guidelines should be used in planning the current layout of the Sun Microsystems hardware and support equipment, and to help in preparation for future changes.

- Do not determine air conditioner placement based on convenience. Often air conditioners are placed around the perimeter of the room because of the convenience of piping, water detection and other issues. This is not normally the most effective placement for the units, except in some smaller rooms. The hardware heat-load of the room will change repeatedly over the life of the room, and it is important that the primary criteria in the determination of the air conditioner placement be its effectiveness in addressing the current planned load, and their adaptability to changes in configurations.
- Consider the air-flow patterns of the hardware being installed. Does it draw supply air directly from the subfloor? Does it draw air from the ambient room above the floor surface? Is the air exhausted out the back or top of the cabinet? If the hardware is not in a cabinet, or if it is in an open rack system, what is the design of the individual components? Does air flow side-to-side, front-to back, front-to-top or bottom-to-top? Be sure that the units are not laid out in a fashion that exhausts air from one unit into the intake of the next.
- Provide adequate aisle space to allow for unobstructed passage, and to allow for the replacement of cabinets within a string without interference to neighboring units. Strings of cabinets should be kept to manageable lengths so as to allow clear passage between aisles in the event of an emergency, or in order to respond to a problem with a unit. Long, unbroken strings necessitate a significant amount of time to move from one aisle to another, or even from the front of a unit to its back.

- Design the operator traffic patterns to minimize the possibility of accidental contact with sensitive components. Avoid placing operations in a fashion that necessitates personnel traveling through a sensitive area, such as the main machine room, to a less sensitive area. For example, operators should not have to travel through the computer areas to get from the command center to the print room.
- Position hardware in strings or rows that run perpendicular to the air handlers. This allows for an unobstructed return of heated air back to the air conditioners. Where possible, avoid air-flow patterns that necessitate the air traveling over tall hardware cabinets to return to the air conditioners.

2.1.5   Computer Room Access

Access to the computer rooms should be strictly regulated, and limited to only those personnel necessary for its operation. All personnel working within the data center should have at least a basic understanding of the sensitivities of the hardware so as to avoid activities that pose a direct risk to the hardware. Accidental contact with hardware buttons, cable connections, terminals or emergency response controls can all cause system interruptions of varying degrees.

All points of access to the computer rooms and other sensitive areas should be controlled by checkpoints or coded card readers to restrict access to authorized personnel. Security personnel should also remotely monitor points of entry via camera.

2.2   Designing the Floor

The raised access floor system provides the flexibility in wiring, hardware location and air conditioning. The raised floor should be constructed of 24 inches x 24 inches (61 cm x 61 cm) panels interchangeable with perforated tiles for air distribution or custom cut tiles for cable or utility passage. This design isolates data lines, power cables and piping to provide a safe environment for operators and to protect hardware operations. In addition, the raised floor design provides a means for flexible and efficient air distribution to the hardware. While it is possible to accommodate a small number of hardware units in alternately designed rooms, it is highly recommended that large numbers of hardware cabinets are installed in a raised floor system.

2.2.1   Floor Height

There should ideally be 24 inches (61 cm) between the raised floor system and the structural deck. A minimum of 18 inches (46 cm) should be provided. Variations from this figure should be based on air conditioner design and anticipated subfloor congestion. Inadequate subfloor depth will lead to difficulties in systems reconfiguration over time, may make the removal of unused or obsolete cables difficult, and will likely obstruct airflow. Additional space may be advisable if subfloor obstructions are abundant.

2.2.2   General Support Grid Recommendations

A raised floor system utilizing bolted stringers is recommended to provide the maximum rigidity for dynamic loads as well as to enhance the signal reference grid. Snap-on stringers often come loose affecting the integrity of the floor structure. While some stringerless systems claim the same benefits as bolted stringer systems, a great deal of research should be done prior to choosing an alternative to the recommendation. In addition, stringerless systems may require additional supports where custom cable cutouts are made for air or cable transfer. In addition, bolted stringer systems allow for the removal of adjacent tiles without threat to the integrity of the floor.

2.2.3   General Tile Construction Recommendations

The floor tiles in the raised floor should be 24 inch x 24 inch (61 cm x 61 cm). The tile core may be constructed of compressed wood or concrete, or may be an open structural metal design. The entire tile should be constructed of, or encased in, galvanized or painted steel. Alternately, cast aluminum tiles may be used.

The tiles should have a high-pressure laminate top surface. The floor surface must allow for proper dissipation of electrostatic charges. The floor tiles and grid systems should provide a safe path to ground through the tile surface, to the floor substructure and through the signal reference grid. The top surface of the floor covering to understructure resistance should be between a minimum of 1.5 x 105 ohms and a maximum of 2 x 1010 ohms (as per NFPA 56A Test Method). The panel structure (not surface laminate) to understructure resistance should be less than 10 ohms.

Carpeted tiles should not be used in hardware areas. Carpeted tiles can harbor contaminants that are agitated every time the tile is walked on. In addition, these tiles are more easily damaged by the movement of hardware, or even when removed using specially designed tile lifters that incorporate spikes designed to catch the loops of the tiles. Carpeted tiles designed with static dissipative properties can

become less effective in this regard as they wear over time. Carpeted tiles that are laid over an existing raised floor surface, are normally offset from the grid, and make it more difficult to access the subfloor. Carpeted tiles should only be used in command centers, or other that do not house sensitive hardware, and do not require frequent access to the subfloor void.

2.2.4 Floor Maintenance

The tile surface should be maintained to the manufacturer's specifications. The guidelines listed in Section 4.2.6, "Cleaning Activity" on page 4-5" should be used. No waxes or insulative coatings should be used, as these can form a barrier that interferes with the static dissipative properties of the floor. It is also extremely important that the stringers and pedestal tops be kept clean, as a buildup of contaminants on these surfaces can potentially impact the functioning of the floor as well. Replace tiles as the surface becomes damaged, or as they become warped by heavy loads. A damaged surface or a tile that does not sit tightly in the grid can affect the ability of the tile to properly dissipate static charges, and could pose a safety hazard.

2.2.5 Cutouts and Other Tile Customizations

Tiles will need to be customized to accommodate the shape of the room, the air conditioners and the hardware. All tile modifications should be performed according to manufacturer recommendations. Additional structural support may be necessary where partial tiles are installed along walls, around columns or by air conditioners. The exposed cut edges of all cut-outs for cable or air passage should be capped with protective trim. Exposed metal edges can damage cabling, and the exposed cores of some tiles can shed particulate matter into the airstream.

2.2.6 General Load Rating Recommendations

The load capacity of the structural floor must be taken into account when designing the data center. Some areas designed for light duty, such as office, may be inadequate. A qualified structural engineer should be consulted in the evaluation of potential areas for the location of a new data center within an existing building. Enhanced support may be advisable in high traffic areas, or areas with heavier than normal loads. Enhanced support should also be considered for ramps and the raised floor areas immediately above them.

The raised floor load rating will vary depending on the design and use of the room. In most cases, a floor designed for a concentrated load imposed by stationary furniture and equipment of 1000 Lbs (454 kg) with a maximum deflection 0.080 inch (0.2 cm) from any point on panel top should be sufficient. Rooms or areas with high levels of motorized traffic or heavy rolling loads should consider a higher rated tile.

2.2.7   Fire Rating

The raised floor system should be in compliance with the specifications laid out in the National Fire Protection Associations Document, NFPA 75: Protection of Electronic/Data Processing Equipment within the USA, or relevant National standards outside of the USA.

2.2.8   Supplemental Bracing

While the practice should be avoided when possible, it is sometimes necessary to locate data centers in seismically active zones. Seismic bracing for the raised floor system can normally be obtained from the floor manufacturer. As a general practice, heavier components should be installed lower on the racks to avoid top-heavy equipment.

2.3   Building the Room

No activity in the data center should be allowed to significantly degrade the environment. Because of the dynamic nature of a data center, it is often necessary to implement projects to address its changing needs or mission. This may encompass moving walls to expand or reduce the size of the computer space, replacing older floors or ceilings, or upgrading environmental support equipment, among other things. It is essential that these actions, meant to improve the stability and operation of the data center, are not allowed to degrade conditions and threaten uptime.

Precautions must be taken to control psychrometrics and air distribution, and to limit or contain contaminant production. Even though the actual activities are common, the environmental requirements of the computer room pose unique problems. Normal cutting, drilling or demolition is unacceptable without proper precautions.

2.3.1 Building Preparation

Whether the data center is located in a new or existing structure, the building must be properly prepared to receive the hardware prior to its installation. Construction projects are expensive, and the construction of controlled data center areas is more expensive than most. There is always a great deal of pressure to meet deadlines and keep within costs, but it is extremely important that this is not achieved by cutting corners and settling for inferior workmanship.

A data center requires more precise control over temperature, relative humidity, airflow, and contaminants than does a typical office environment. If the specific needs of this environment are to be met, they must be addressed throughout the design and construction of the room. Prior to installation of the hardware, the room should be inspected to identify any remaining exposures, and all surfaces in the room must be appropriately decontaminated. The final punch-list items should include specific tasks designed to bring the computer room environment within specific parameters. The following actions should be performed in the general order listed.

- Perform a general construction decontamination of the room. A rough cleaning of the room should first be conducted to remove all major construction-related debris. Low-grade industrial vacuums can be used at this stage to remove heavy deposits. This stage of the cleaning would include those steps typical to any construction project, and is aimed primarily at appearance.
- The vapor barrier of the room should be checked. Any breaches that could allow significant moisture migration should be noted and fixed. In the subfloor void, these can include perimeter penetrations around pipe or conduit passages, cracks in the deck or perimeter walls, expansion joints or open ducts or walls that connect the subfloor void to the ceiling void or to other floors. In the above floor space, these can include holes or cracks in the perimeter walls, gaps around pipe or duct penetrations, interior or exterior windows, access windows or perimeter mail slots, gaps around doors or light fixtures with designed air vents. Above the drop ceiling, breaches can include gaps around pipes, ducts or conduit. Gaps around structural beams or between perimeter walls and corrugated roofing materials, open ceiling voids to other areas, gaps around access doors to the roof or other floors or roof vents.
- Load test the generators, UPS and other power infrastructure components. Perform functionality tests to ensure the data center is ready to accommodate on-line computer operations.
- Perform a final inspection on the environmental support equipment. Check for proper installation and functioning of all equipment. Put the air conditioners and humidifiers through their cycles by adjusting their set points to force them into stages of cooling, heating, humidifying, dehumidifying, etc. By this stage, chillers, UPS, generators and all other similar support units should have been tested. Make any necessary adjustments.

- Prior to the installation of the hardware, but during and after the construction cleaning, the air conditioners should be run continuously to filter the room air. These units need not be cooling, as the primary purpose of this action is particulate arrestance. Ideally 60% efficiency filters will be used at this point. These filters will be replaced prior to hardware installation, as they will likely become inundated with particles that can be re-dispersed by the subfloor pressure forcing air through a unit in a reverse pattern should one of the air conditioners be turned off.
- After the construction cleaning, it is essential that a thorough decontamination of the room surfaces be conducted to remove any residual particulate in final preparation for the installation of the hardware. Low-grade vacuum equipment, such as that used during the construction phases of the project, lacks the filtration necessary to arrest most particulate. Vacuums equipped with High Efficiency Particulate Arrestance (HEPA) filtration must be used at this stage. In addition, special equipment and procedures should be employed, as outlined in the later sections of this report.
- Prior to the hardware installation, the room should be stabilized within the goal specifications established within this document. It may be difficult to achieve precise balancing and appropriate environmental support equipment cycling in the controlled space until the designed heatload is installed, but conditions should be made as balanced and appropriate as possible prior to installation. Temperatures, relative humidity levels, subfloor pressurization, room pressurization and airborne particulate levels should all be checked.

2.3.2   Building Materials Selection

All building materials should be chosen with an aim towards cleanliness and moisture retention. Materials should be chosen or treated to avoid shedding or deterioration that might be tolerable in more loosely controlled environments. Particular attention should be paid to areas in the direct airflow patterns of the room, and materials that require repeated movement or disturbance in the normal occupation of the room. Ceiling tiles should have a vinyl or foil face that will provide a moisture barrier, and will help protect the tiles from shedding as they are moved. All supply plenum surfaces should be constructed of appropriately treated materials, such as encapsulated concrete or galvanized or painted metals.

Ideally, materials in keeping with the design of a class 100,000 cleanroom should be considered appropriate.

Panels and other necessary items should be pre-cut and drilled outside the room to minimize the activity necessary within the room. This may add time and effort, but will help limit contaminant production within the room.

Not all activity can be performed outside the room, so it is also important that efforts are made to contain or arrest contaminants produced by activities performed within the controlled space. Plastic sheeting can be used to isolate work areas from other

areas of the room. Portable filter systems can be rented or purchased to help arrest particulate in the air (it should be noted that these are normally only effective in localized areas). Vacuum units equipped with High Efficiency Particulate Air (HEPA) filtration should be used to address any contamination produced by drilling or sawing as soon as it is produced.

In addition, it is extremely important that the temperature, relative humidity and air distribution conditions are taken into account, and that these conditions are not significantly degraded. Doors to the data center must not be left open, it may be necessary to design a temporary personnel trap to limit exposure caused by increased traffic through the controlled spaces. Similar isolation may be necessary if changes to the room perimeter produce exposures. The job progression should be planned in such a manner so as to limit exposures. Care should be taken when removing floor tiles to ensure that the subfloor pressure levels remain adequate for proper air distribution. It is also important that any activity that involves the environmental support equipment be carried out without affecting the ability of the units to address the conditioning and humidification needs of the subject areas.

Proper implementation of construction and renovation projects in an on-line data center require additional time, planning and expense, but these precautions are essential if the uninterrupted operation of the data center is a priority. Ignoring these issues can lead to catastrophic failures, or long-term performance problems.

Cooling and Air Distribution

Maintenance of appropriate temperature and relative humidity (RH) levels in a data center environment is extremely important. Computer hardware requires a balanced and appropriate environment for optimal systems operations. Temperatures or RH levels outside the specified operating ranges, or extreme swings in conditions, can detrimentally affect component reliability. To complicate this, the heat load of most computer rooms is extremely complex and experiences normal fluctuations during its evolution. A great deal of importance must be placed on maintaining appropriate temperature and RH levels throughout the data center at all times. The information in this Chapter includes the following Sections:

3.1 Temperature Recommendations

An ambient temperature range of 70⁰ to 74⁰ F (21⁰ C to 23⁰ C) is optimal for system reliability and operator comfort levels. Most computer equipment can operate within a wide psychrometric range, but a temperature level near 72⁰ F (22⁰ C) is desirable because it is easier to maintain safe associated relative humidity levels at this temperature, and there is an acceptably wide operational buffer in case of environmental support systems down-time. Though individual standards vary slightly, 70⁰ to 74⁰ F (21⁰ C to 23⁰ C) should be used as an optimal recommendation.

3.2 Relative Humidity Recommendations

Relative humidity is the amount of moisture in a given sample of air at a given temperature in relation to the maximum amount of moisture that a sample could contain at the same temperature. A volume of air at a given temperature can hold a certain amount of moisture. Because air is a gas, it expands as it is heated. As air gets warmer, its volume increases and the amount of moisture it can hold increases, thus causing its relative humidity to decrease. Therefore, in a system utilizing subfloor air distribution, the ambient relative humidity will always be lower than in the subfloor.

Ambient relative humidity levels between 45% and 50% RH are the most suitable for safe data processing operations. Under certain circumstances, most data processing equipment can operate within a fairly wide environmental range (20% to 80% RH), but the optimal goal should be specified at 45% to 50% RH for several reasons. The optimal range helps protect computer systems from corrosivity problems associated with high humidity levels. It also provides the greatest operating time buffer in the event of environmental control system failure. In addition, this range helps avoid failures or temporary malfunctions caused by intermittent interference from static discharges that occur when relative humidity is too low. Electrostatic discharge (ESD) is easily generated and less easily dissipated in areas where the relative humidity is below 35% RH, and becomes critical when levels drop below 30% RH. The 5% RH range may seem unreasonably tight when compared to the guidelines used in typical office environments or other loosely controlled areas, but it is not so difficult to maintain in a data center because of the high efficiency vapor barrier and low rate of air changes normally present

TABLE 3-1   Environmental Requirements

Environmental Factor	Optimal	Operating	Non-operating
Temperature	70º to 74º F (21º to 23º C)	50º to 90º F (10º to 32º C)[*]	-4º to 140º F (-20º to 60º C)
Relative Humidity	45% to 50% RH	20% to 80% RH1 (noncondensing)	up to 93% RH
Altitude[†]	up to 10,000 ft (3,048 m)	up to 10,000 ft (3,048 m)	up to 40,000 ft (12,192 m)

*   Severe temperature or relative humidity swings should be avoided. Conditions should not be allowed to change by more than 10º F (5.5º C) or 10% RH in any 60 minute period of operation.

†   For altitudes outside these ranges please consult your Sun Microsystems representative.

Though the design limits for this hardware are wide, conditions should always be maintained near the optimal levels. It should also be noted that certain extremes within this range can lead to unacceptable conditions. If very high temperatures are maintained in conjunction with very high relative humidity conditions, condensation can occur. Also, if very low temperatures are maintained with very low relative humidity levels, even a slight rise in temperature can lead to unacceptably low relative humidity levels. The reliability and life expectancy of the hardware will be enhanced by maintaining conditions within the optimal ranges.

3.3   Temperature and Relative Humidity Problems

Temperature and relative humidity conditions should be maintained at levels that allow for the greatest operational buffer in case of environmental support equipment down-time. The goal levels for the computer room should be determined in a manner that will achieve the greatest operational buffer and the least possibility of negative influence. The specific hardware design, room configuration, environmental support equipment design and other influencing factors should be taken into consideration when determining the specific relative humidity control appropriate for a particular room. Psychrometrics can affect hardware through thermal influences, Electrostatic Discharge (ESD), and increases in environmental corrosivity.

3.3.1 Thermal Concerns

Temperature conditions should be maintained as close to the optimal recommendation as possible. Near the limits of the temperature range, there is less of a buffer to absorb influences from actions in the room. The temperature profile can be dramatically affected by problems with the environmental support equipment, such as component failure or even scheduled preventive maintenance.

There is also less tolerance when the heat load of the room changes due to the installations, de-installation or reconfiguration of hardware. Significant changes in cooling temperature can also be caused by the removal of excessive numbers of floor tiles for subfloor work, such as cabling. Appropriate temperatures also make it easier to maintain appropriate moisture levels. Even if appropriate relative humidity levels can be maintained at high or low temperatures, it is likely that the actual moisture content, in grains of moisture, of the air would be inappropriate.

3.3.2 Electrostatic Discharge (ESD)

Another consideration is the generation and neutralization of static charges, as well as the effects such charges can have on sensitive electronics equipment, as well as some means of preventing such damage. Appropriate relative humidity levels help maintain an environment in which static charges are more easily dissipated. Please refer to Section 6.8 for additional information.

3.3.3 Corrosion

High humidity environments increase the corrosivity potential of gaseous contaminants in the atmosphere. Gases suspended in the air can be transferred to the room's hardware via the moisture in the air. It should also be noted that drastic changes in temperature can cause latent heat changes, leading to the formation of condensation. This is particularly common in areas where hot and cold air meet. Excessive moisture in the air and condensation can cause a number of hardware problems. Water can react directly with metals, attacking them and forming corrosion. Another way that a moist atmosphere can degrade hardware is by forming conductive solutions (electrochemically). If there are electrical potential differences between two dissimilar metals in a component, electrolytic or galvanic corrosion processes can set in. The water can also form a more reactive combination with gases present in the atmosphere. The resultant compounds can then attack the hardware surfaces. Excessively high RH levels should be avoided.

3.4 Temperature and Relative Humidity Monitoring

Accurate and comprehensive monitoring of environmental support equipment and in-room conditions is extremely important in an environment as complex and sensitive as a data center. The monitoring system used must effectively assess the room conditions, or it will provide an inaccurate representation that can lead to inappropriate actions or ill-founded assumptions. The following considerations should be addressed

- The system in place must provide a detailed and representative profile of room conditions. If a single point of reference is used, it will not give an accurate picture of the room's profile. If a single sensor is placed in an area with appropriate conditions, such as on a column directly above a perforated tile, the monitoring system would be indicating that room conditions are appropriate even though this may not be the case. Assumptions concerning the environment that are based on such data can lead to decisions that could actually degrade conditions. The same can be said about a multi-point system that has inappropriately placed sensors.
- The system should have historical trend capabilities. The data gleaned from analysis of historical psychrometric information can be instrumental in determining seasonal changes or other outside influences. The data should be easily available, and the operating system should be powerful and adaptable.
- The system should have critical alarm capabilities. At the very least, the system should be set to notify appropriate personnel when conditions move outside certain parameters. Depending on the design of the data center, it may also be useful to have a system that performs certain functions automatically, such as switching to a back-up chiller if the primary chiller fails.
- The system configuration and data should be periodically examined and evaluated by trained personnel to ensure that they are appropriate for the current room demands, and to identify any problems missed in the day-to-day operations of the room.
- Ideally, an integrated building monitoring system should be used to track conditions in all of the building systems. This would include not only the in-room air conditioners and humidifiers, but also the cooling support systems, power back-up, fire detection and suppression, water detection, security and other building infrastructure and life-safety systems.

While an added expense to the design and maintenance of a facility, comprehensive monitoring systems provide an invaluable tool to building maintenance personnel. They are essential in correcting current problems in an expedient manner and identifying potential susceptibilities before they impact hardware operations.

3.5 Air Conditioner and Humidifier Design, Maintenance, and Placement

While the specific details of the environmental support systems will vary from site-to-site, an air conditioning system with a downward flow should be utilized in all designed computer rooms. Appropriate conditions can be maintained for a small amount of hardware space utilizing other designs, but the air-flow patterns associated with the downward flow design allow for the most efficient cooling of the hardware. The data center should not be designed based on the same school of thought used in general comfort cooling applications. The efficiency of a precision air conditioning system is not only measured by the degree of temperature control, but also on the ability of the system to get the conditioned air to the units of hardware in need of cooling. Computer rooms require precision cooling for a number of reasons:

- The heat load in a computer room is very dense. Computer rooms generally have six to eight times the heat density of normal offices.
- The heat load in a computer room varies across the room's area. The air conditioning system must be able to address the specific needs of particular units of heat-producing hardware in order to achieve a balanced psychrometric profile.
- A computer room requires precision temperature control. The air conditioners need to be set accurately with a sensitivity of +/- 2° F (+/-1° C) and +/- 3% RH or closer.
- Electronic equipment radiates a "drier" heat than the human body. Therefore, computer room precision cooling systems require a higher sensible heat ratio (SHR) than office areas. Ideally, a computer room cooling system should have a sensible heat ratio of 1:1; that is, it should provide 100% sensible cooling. Most precision systems have between 85% and 100% sensible cooling, while comfort cooling systems normally rate much lower.
- The computer room heat load changes with additions or reconfiguration of hardware. The air conditioning system must adapt to these changes.
- The precision cooling environment must provide an adequate change of air in the conditioned space. While a normal office cooling environment requires only two air changes per hour, the high-density heat load in a computer room requires as many as 30 changes per hour. Precision air conditioners pass more than 500 CFM/ton, comfort cooling air conditioners may pass as little as 350 CFM/ton. If the volume of air is inadequate, the supply air will heat up before it reaches the areas in need of cooling, and will subsequently be less effective in addressing the heat loads in the room.

The downward-flow air conditioning system typically utilized in data centers and other similar environments incorporates a raised floor system. The raised floor should be 24 inches (60cm) with a minimum of 18 inches (47 cm) above the structural deck to allow for both the running of cables and pipes as well as for the

distribution of conditioned air to the hardware. The modular tile design allows for ease of movement for both hardware and air distribution reconfigurations. As hardware is added, solid tiles are replaced by tiles with cut-outs to allow cable access, and perforated tiles are positioned to deliver conditioned air to the hardware intakes.

In the general airflow patterns associated with most computer room process coolers, room air enters the top of the air conditioner (Return Air) where it is cleaned by air filter banks. As the return air passes over the cooling coil, the air temperature is lowered significantly, and large fans at the bottom of the unit push the conditioned air (Supply Air) into the room's subfloor void where it is introduced into the computer space via cable cutouts, floor grilles or perforated floor tiles. Once in the ambient room space, the conditioned air mixes with the hardware heat load and flows back to the air conditioners for reconditioning. This produces an efficient airflow pattern.
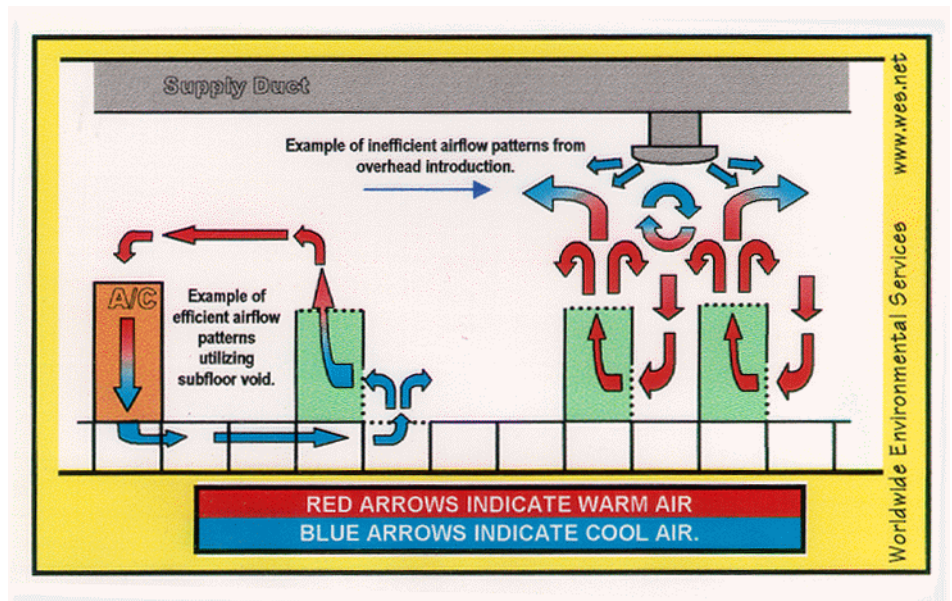
FIGURE 3-1 Typical Upward Verses Downward Computer Room Air Flow Patterns

Centralized systems, using a single large air handling unit, should be avoided. Whether the system introduces the conditioned air into the subfloor, or directly into the hardware space, centralized systems generally lack the redundancy present with individual packaged units. Centralized systems also lack the degree of control present with multiple units. In most centralized systems, the temperature and relative humidity are regulated by a single sensor set in the ambient space of the

room, or in the return air duct. This can give an inaccurate representation of room conditions, as it is unlikely that conditions in all areas are the same as they are at this single sensor point.

Overhead air introduction or upflow air conditioning should be avoided due to their associated turbulent airflow patterns. The majority of the hardware in most rooms takes in air for cooling at the front or bottom of the unit ad exhausts it out the back or top. Introducing conditioned air from the ceiling level causes turbulence as the conditioned air meets the hot exhaust.

It is extremely important that the hardware in the room be taken into consideration in order to ensure that the air conditioners have adequate control over cooling and heating cycles. Hardware units that rely on direct subfloor cooling are particularly susceptible to large swings in temperature associated with direct expansion air conditioners that have only two or four stages of cooling. Because the regulation of the air conditioners is controlled by sensors in the return airflow, there is a delay in response that can cause significant fluctuations in conditions. Chilled water systems with modulated controls are more appropriate where temperature fluctuations are a significant concern.

Humidification can take place within the in-room packaged air conditioners, or it can be provided by stand-alone units mounted within the room. While ordering the humidifiers as a feature of the air conditioner may be more convenient, a moisture introduction directly into the warmer ambient air is preferable to an introduction into the cold supply air within the enclosed air conditioner. The following considerations should be taken into account when determining the design of the system.

■ Ideally, the actual process of humidification should not take place within the room's air conditioners since cold air flows cannot accept high levels of moisture. Condensation formations and water spills are a common occurrence within process coolers, and can cause accelerated levels of internal corrosion. Exposing the air conditioner's internal surfaces to excessive moisture levels will greatly reduce the operational life cycle of the units and contribute to the decay of the computer operating environment.
■ The subfloor void should not be used as a means to distribute moisture since this area normally contains cold air that may already be near saturation. Local condensation and corrosion on untreated metal surfaces can result. The best method of introducing moisture into a computer room is to inject it directly into the ambient air space where it will mix easily with the ambient temperatures.
■ The actual process of generating moisture should not produce unwanted contaminants such as mineral salts or other crystalline particles.
■ The humidification system should be responsive to room conditions and equipment demands. Hardware reliability is enhanced if psychrometric rates of change are kept to a narrow margin. Humidification systems that can monitor and adapt to the ever-changing data processing environment are most desirable.

One recommended humidification system design utilizes a closed water bottle that contains electrodes to quickly heat the contained water and produce steam. These units can be installed within the actual room space as well as inside the air conditioners. The closed bottle design removes any suspended particles from the supply water, resulting in a clean moisture supply. If properly designed and maintained, alternate designs, such as ultrasonic humidifiers, can be utilized effectively. Building steam systems distributed by a central air conditioner should not be used. These do not have the flexibility available from multiple in-room units. As with the air conditioning, the use of multiple humidifiers provides localized control or redundancy.

3.5.1 Air Conditioner and Humidifier Set-points

The set points of the environmental support equipment may vary between sites, and even between individual units at the same site. One of the advantages of multiple packaged units is the ability to modify set-points in localized areas. The hardware heatload in a room may vary from dense placement of hardware with high heat generation to open areas with little or no hardware. While the main means of addressing such variances is with adjustments to the air distribution tile placement, minor adjustments to the air conditioner or humidifier set-points may also be necessary.

Under most circumstances, air conditioners should be set at 72º F (22º C) with a sensitivity range of +/- 2º F (+/-1º C). Humidifiers, in most cases, should be set at 48% RH with a sensitivity range of +/- 3% RH. The set-points of the air conditioners should always be chosen in an effort to maintain the optimal recommended temperature and relative humidity levels for the room environment. These set points should maintain appropriate conditions, while allowing wide enough sensitivity ranges to help avoid frequent cycling of the units. While these tight ranges would be difficult to maintain in a loosely controlled office environment, they should be easily attained in a controlled data center.

Numerous factors, such as heat-load and vapor barrier integrity, will influence the actual set-points. If the room lacks adequate vapor barrier protection, for instance, it may be necessary to adjust humidifier set points to accommodate seasonal influences. Ideally, all inappropriate influences on the data center environment will be eliminated, but in the event that they are not, minor adjustments, made by trained personnel, can help alleviate their effects on the environment.

3.6 Mechanical Support Systems

The specific design of the mechanical support systems will be dependent upon the type of cooling system chosen. Numerous factors will go into the decision as to whether to use direct expansion compressorized air conditioners or a chilled water system. The specific requirements of the hardware to be cooled should be taken into consideration when determining the type of air conditioning system.

The availability of space to house large chillers, cooling towers, and piping systems associated with chilled water designs must be considered. Direct expansion units require ground-level or roof space to house large condensers. The climate of the environment in which the building is located is also a governing factor, as certain designs may be easier or less expensive in certain climates. Issues of flexibility and redundancy should also be evaluated. The system installed should provide adequate flexibility for growth, and 100% redundancy. The loss of any one component of the system should not have a significant impact on the system as a whole. The system should be designed in such a fashion so as to accommodate repairs or changes while the system is on-line, or with minimal downtime.

The system should be designed in such a manner so as minimize the opportunity for leaks of cooling water or refrigerants within the computer room controlled zone. Piping should not be run in the ceiling void of the room. It is also extremely important that air conditioner piping is not run directly in front of the air conditioner discharges. Multiple taps should be designed into chilled water piping to facilitate changes in configurations.

The mechanical support systems should be connected to the building monitoring system. Status and critical alarms should be recorded. This system should also monitor the in-room air conditioners and conditions throughout the subject areas.

3.7 Air Distribution Tile Placement

Perforated floor tiles are the supply diffusers of a downward flow air conditioning system. The modular design of the tiles allows for the flexibility necessary in a complex data center environment. The number and type of tiles for each particular site will depend on the specific characteristics of the site. The following guidelines should, however, be considered in the determination.

- Consult your air conditioner manufacturer or maintenance company. Most manufacturers recommend a specific amount of opening in the floor surface, in the form of air distribution tiles, for each model they produce. This is based on the desired air velocity and the air volume of the air conditioners. The hardware in the room will determine the precise number of tiles needed.
- Maintain appropriate subfloor pressure levels. The subfloor pressure differential enables efficient conditioned air distribution. It may be necessary to adjust the number of perforated tiles to achieve appropriate pressure levels. Some hardware designs, such as some air cooled mainframes or closed cabinet surefire or communications racks, draw conditioned air directly from the subfloor void. The tile cut-outs for these units of hardware must be taken into account when determining the number of perforated tiles for air distribution. If there is a large amount of hardware relying on direct subfloor cooling, it may be necessary to reduce the number of air distribution tiles to achieve adequate subfloor pressurization.
- Avoid unnecessary holes in the access floor surface. Oversized cable cut-outs or unnecessary holes in the access floor surface will detract from the subfloor pressurization and overall conditioning efficiency. These should be filled will appropriately rated air dampening bags or other appropriate fillers.
- Avoid cooling short cycles. Cooling short cycles occur when perforated tiles are placed between air conditioners and the nearest units of heat-producing hardware. When this happens, cold subfloor air returns to the air conditioners without addressing conditions at the hardware. Because the regulating sensors for the air conditioner are located in the return airflow, the air conditioner will register that conditions in the room are cooler than is actually the case, and the unit may cycle out of its cooling mode while conditions in the hardware areas still call for conditioning. This affects both temperature and relative humidity.
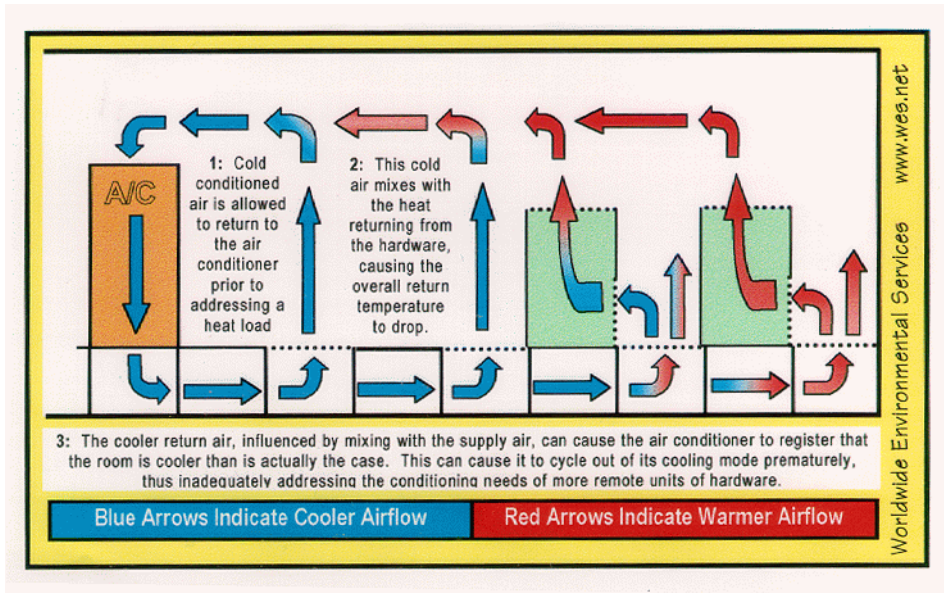
FIGURE 3-2 Cooling Short Cycle Air Patterns

- Form hardware rows perpendicular to air conditioners. After the conditioned air mixes with the heat load of the room, it should have an unobstructed path back to the air conditioner return. If the hardware rows are generally perpendicular to the air conditioners, the air can travel down the aisles to the returns. If the rows are parallel to the air conditioners, the return air must travel over the hardware units in a less efficient manner. Returns through the open ceiling void of the room should be avoided. These can affect the efficient response of the air conditioners to the in-room conditions, and expose the controlled areas to the ceiling void conditions. In addition the large volume of the ceiling void may have to be taken into account in certain types of fire suppression systems that rely on precise concentrations of gasses to function properly.
- Avoid subfloor obstructions that could hinder conditioned air distribution The subfloor void should not be used for storage of any kind. Cabling should be effectively managed to avoid jumbled cables or congested areas. Cables piled from the subfloor deck surface to the bottom of the raised floor can partition portions of the subfloor, isolating them from the air conditioners.
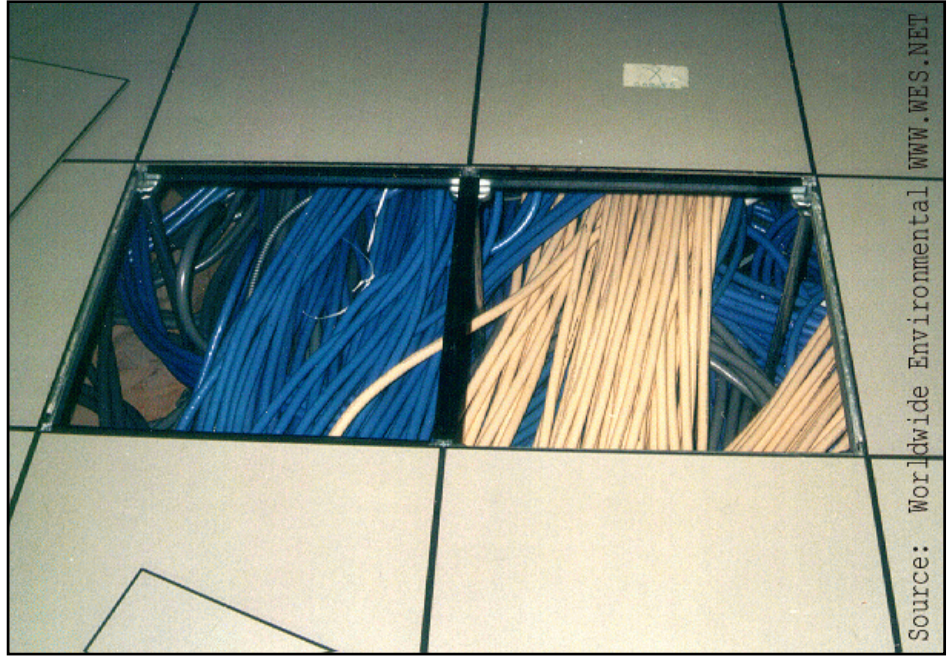
FIGURE 3-3   Congested Cabling

3.8   Hardware Placement

The following recommendations are based on the basic front-to-back air-flow cabinets used by most Sun Microsystems equipment. The installation documentation for the hardware being installed should be consulted prior to installation. The specific hardware in place in the various subject areas of the facility must be taken into consideration when assessing the environment. The density and complexity of the heat load can offer many challenging problems. The necessity of maintaining appropriate conditions in a mainframe environment are universally understood, but environmental conditions in server areas are often overlooked. The heat load of small, individual servers or storage arrays is generally low, but when these units are stacked in cabinets, the density of the heat load increases dramatically. In addition, the newer technologies utilize denser geometries in their internal components than many older ones. In many instances, large server rooms can have a much higher heat load than traditional mainframe rooms.

The philosophy used when addressing the needs of a single server or storage array cabinet may no longer apply when large numbers of these cabinets are grouped together. Simply multiplying the needs of the one to determine the needs of the

group will often overlook important factors. The interactions must also be taken into account. How the units are placed in relation to one another can have a significant impact on heatload concentration, conditioned air distribution and service accessibility. While a single unit may be very tolerant, as its needs are more easily met, a large group requires a great deal of thought and planning to properly accommodate, and continued vigilance to properly maintain.

Many studies have been conducted regarding the changing trends in technology. There is no question that the same computing power can now be achieved with equipment taking up a fraction of the floor space previously needed. Thus, a comparison of computing or storage capacity versus heat load will indicate a significant decrease in heat load in recent years since far less equipment is needed for the same data capacity. What this comparison does not indicate, however, is that while you now need less equipment to do the same things, the heat load per square foot is much denser. Thus, if you fill the same amount of floor space with new equipment, you will have much more computing power, but you will also often have a much higher or more concentrated heat load.

The majority of Sun racks are designed to take in conditioned supply air in the front, pass it over the heat-loads of the internal components, and exhaust it from the rear. These racks house a wide variety of components with differing designs. Some components utilize airflow patterns that go from bottom to top, some go from front to back, and some go from one side to the other. In each of these instances, the cabinet converts the airflow pattern to a front-to-back or front-to-top design. This allows for ease of planning in that it is not necessary to accommodate multiple airflow designs. The cabinet provides a generally uniform design.

Because of the front-to-back air-flow patterns, the ideal placement would have the units installed face-to-face (and back-to-back) as illustrated in FIGURE 3-4. By configuring the units in this fashion, direct transfer of the hot exhaust of one unit into the intake of another is eliminated. If the aisle width is maintained at the appropriate width of 4 feet (1.22 meters), in this scenario, the side-to-side spacing between racks can be reduced virtually to zero. Enough clearance should be maintained to allow any rack within that lineup to be removed for service or replacement. This is possible because the side panels of the Sun cabinets are solid, and not used for air flow. If all air conditioning considerations are appropriately addressed, the aisles between the exhausts can be made as narrow as 3 ft. (0.9 m). If the units are placed closely together, it is recommended that no more than five (5) cabinets be grouped before a minimum of 1 1/2 feet (.46 m) is left for access to their rear, or between aisles.
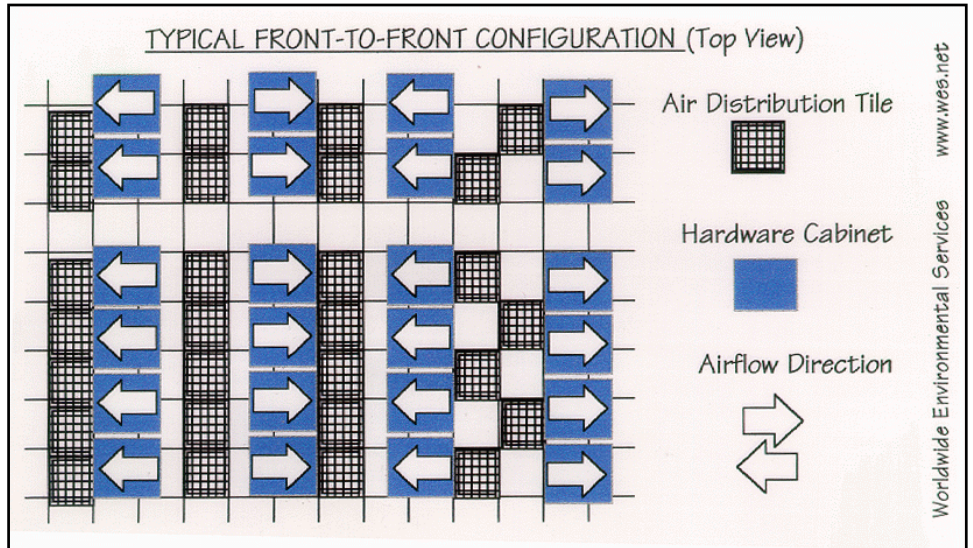
FIGURE 3-4 Preferred Hardware Placement

If, for some reason, the units must be installed all facing in the same direction (not recommended), it is important that adequate space be left between the aisles to avoid the direct transfer of the heated air from the exhaust of one unit into the intake of another as illustrated in FIGURE 3-5. This can be accomplished by allowing adequate space between the units and the aisles. The amount of space necessary will be dependent on numerous factors in the room. Assuming that there is adequate air conditioning, and that it is being efficiently distributed, 4 feet (1.22 meters) should be enough space for the aisles. In some instances, where conditioned air distribution is less than optimal, wider aisles may be necessary. If the width of the aisles is less than this recommendation, it is advised that there be a minimum of 1 ft. (0.3 m) between the units to help spread out the heat load.
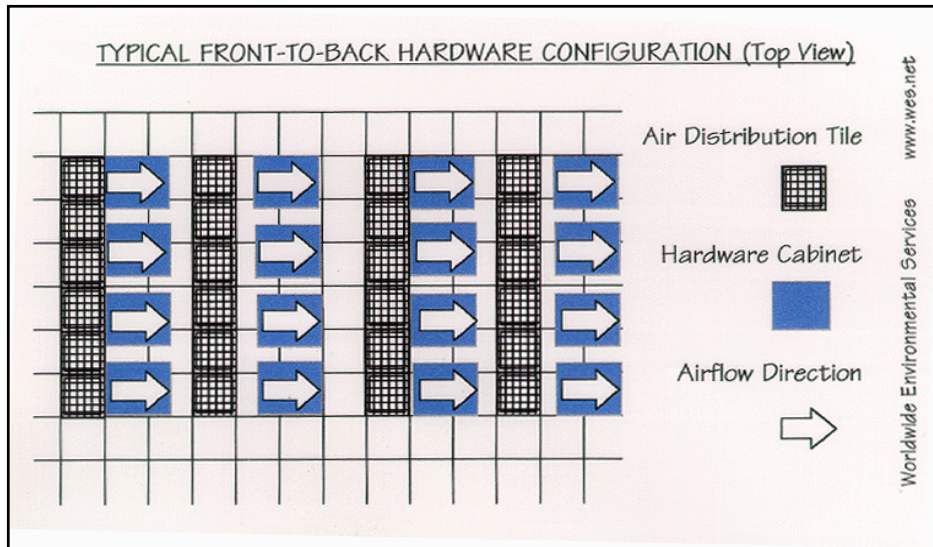
FIGURE 3-5 Alternate Hardware Placement

It is important to remember that the many aspects of the computer room environment are interconnected. Changes to one aspect will, in turn, affect others. Along the same lines, implementing one change in isolation may produce undesirable results. The overall effects on the environment of the room must be taken into consideration. In either scenario, the following considerations must be taken into account:

- It is important that at least one floor tile is removable in each aisle. Though there may be some flexibility, depending on the configuration, aisles should measure approximately 1.2 m (4 ft). This width may be slightly higher or lower depending on tile and cut-out placement.
- Adequate spacing must be left either between the units or between groups of units to allow movement behind the cabinets and between aisles.
- Air distribution tiles should be placed in such a fashion so as to deliver conditioned air to the intake of each cabinet.
- The subfloor pressure differential must be adequate to deliver the air to the areas in need of conditioning. The subfloor pressure differential should be maintained at an optimal level of 0.05 in wg, though 0.02 in wg is normally acceptable as a minimum level.
- The air conditioning return should be placed in such a fashion that the air has a clear path to return down the aisle. The air must not be forced to travel over the cabinets to get to the return.

- Optimal temperatures in the above floor hardware space should be kept between 70° to 74° F (21° C to 23° C), and relative humidity levels should be maintained between 45% and 50% RH. While the hardware can operate within a much wider range, these recommendations provided the greatest buffer against inappropriate influences.

It should be noted that the preceding recommendations are for hardware installed in Sun Microsystems cabinets. Components installed outside of these cabinets may have very different requirements. Components with a side-to-side air-flow pattern are converted to front-to-back air flow by the Sun Cabinets. If these components are installed outside of these cabinets, it is important that they not be placed closely next to each other, as the exhaust of one unit will enter the intake of the next, leading to very high temperatures down the line. For these same reason, it is extremely important that the units are not installed in after market or custom cabinets without first consulting and gaining approval from your Sun Microsystems representative.

3.9 Subfloor Pressure Differential Recommendations

It is not enough for appropriate return air temperature to be maintained by the air conditioning system, the conditioned air must also be efficiently transferred to the areas of the room in need of conditioning. If the conditioned air provided by the environmental control equipment is not delivered to the hardware properly, the air conditioning system is not performing efficiently. Because the subfloor void acts as a duct, with the air distribution tiles and cable cut-outs acting to distribute the conditioned air, an adequate subfloor pressure is necessary in order to deliver the cooled air. If the subfloor pressure is too low, the conditioned air will not be forced to the areas of the room in need of cooling. Air conditioner manufacturers normally recommend the appropriate free area in the form of air distribution grilles and perforated floor panels.

Ideally, the positive pressurization of the subfloor void in relation to the above-floor hardware space should be maintained at or near the optimal recommendation of 0.05 in wg. Subfloor pressurization should not be allowed to fall below the minimum recommendation of 0.02 in wg. Designed airflow velocity (FPM), breaches in the supply plenum, perforated tile and cable cut-out size and number and hardware design will all influence pressurization. It is important that the pressurization across the room is periodically checked to ensure that conditions remain appropriate. While pressurization will generally equalize across the supply plenum, conditions can vary significantly across a large room, as influences such as air conditioner or perforated tile placement cause pressure to build-up or dissipate. In addition, it is extremely important that subfloor pressure conditions are monitored any time subfloor work is taking place. Each solid tile represents 4 ft² of floor area. This is equivalent to four

typical perforated tiles (with a 25% perforation). Lifting four solid tiles is roughly equivalent to the recommended free area (in the form of perforated tiles) for a typical 24 ton direct expansion air conditioner. Removing excessive numbers of tiles can have a dramatic effect on air distribution in a room.

3.10 Supply Air Plenum Integrity Concerns

The subfloor void in a downward-flow air conditioning system is a supply plenum in the air distribution system. The conditioned air traveling to the hardware passes through the air conditioners, into this plenum, and then through perforated tiles and into the room space. By introducing more air into the plenum than is allowed to escape, a positive pressurization of the subfloor void is achieved. This pressurization is essential to the efficient cooling of the hardware. If the subfloor pressure is inadequate, the conditioned air will not be effectively pushed to the areas of hardware in need of cooling.

- Excessive breaches in the subfloor: Excessive breaches in the subfloor plenum perimeter, whether intentional or unintentional, deplete the subfloor pressure, and the overall conditioning efficiency.
- Excessive numbers of air distribution tiles or grilles: A typical 25% perforation tile represents 1 ft² of free area (higher perforation percentages are not recommended as they can limit air distribution adjustment). The number of air distribution tiles should be chosen carefully in order to achieve proper pressurization.
- Over-sized or unnecessary custom cable cut-outs: Cable cut-outs designed to allow for the passage of data and power cables between hardware and the subfloor void are often oversized, and can allow for the unintentional escape of significant amounts of conditioned air. Cut-outs should be minimized, or excess openings should be filled with appropriately rated filler bags or closed-cell foam.
- Gaps between tiles: Airflow can pass through the space between loosely fitting tiles, or between tiles and walls. All gaps should be minimized or filled, as appropriate.
- Subfloor perimeter penetrations: Often holes created for the passage of pipes or cables between rooms or floors are left open. This allows for the unintentional escape of subfloor conditioned air.

FIGURE 3-6 Subfloor Penetration

- Out-of-service air conditioners: If an air conditioner is turned off for an extended period of time, the unit should be capped with an appropriate, non-shedding material. If the unit is left uncapped, subfloor pressure will escape through the unit. This is a significant undesigned drain on pressure, and can be a contaminant concern, as the reverse airflow can dislodge particulate from the filters and force it airborne.
- Cable chases: Designed cable chases between computer room floors can allow for significant airflow if not properly sealed. Holes in columns that connect the subfloor void to the ceiling void are also a concern, as they can act as chimneys, depleting the subfloor pressure and pressurizing the ceiling void. The pressurized ceiling void is also a concern from a contamination standpoint, as this area is not normally controlled, and can introduce contaminants into the data center areas.

3.11 Vapor Barrier Design and Conditions

A superior vapor barrier is essential in maintaining adequate controllability over in-room conditions. Any significant breaches in the vapor seal of the room will expose the computer room controlled area to potentially disruptive influences.

The first line of defense is the exterior shell of the building. Most modern buildings are normally constructed with at least a minimal designed protection against moisture migration. This is normally intended to protect the building structure itself as well as to make the environmental support more energy efficient. Because of the more stringent environmental requirements in the data center, it is normally necessary to incorporate additional vapor barrier protection into the perimeter of the controlled areas. Failure to protect against outside influences could over-tax the environmental support equipment, and could lead to inappropriate conditions within the controlled environment. The following points will help provide an effective barrier against moisture migration.

- Avoid designed perimeter penetrations such as open access windows or mail slots. These allow exposure to the more loosely controlled surrounding areas.
- Seal any undesigned perimeter breaches, such as cable, pipe or duct passages. These holes should be addressed in the subfloor void, in the hardware areas and in the ceiling void. Avoid common ceiling voids between the data center and other areas of the building. Be sure to use appropriately rated materials. Be sure to address any gap between the perimeter walls and the structural deck or roof.
- Place high efficiency gaskets and sweeps on all perimeter doors. Similar precautions should be taken to help isolate more sensitive rooms of the facility from more loosely controlled areas, such as doors between the main machine room and a command center or print room.
- Seal any cracks or joints in the perimeter walls and subfloor deck. Do not use any materials that will hinder the functioning of expansion joints.
- Paint all perimeter walls, from structural deck to structural ceiling, to help limit moisture migration through the building material surfaces.
- Thoroughly encapsulate the subfloor concrete deck and all subfloor perimeter walls. Typical concrete surface hardeners, such as those used at the point of building construction, are not normally efficient protection against moisture migration or surface degradation.

Proper implementation of these precautions will help protect against inappropriate or potentially damaging influences.

Environmental Contaminants

Control over contaminant levels in a computer room is an extremely important consideration when evaluating an environment. The impact of contamination on sensitive electronic hardware is well recognized, but the most harmful contaminants are often overlooked because they are so small. Most particles smaller than 10 microns are not visible to the naked eye under most conditions; yet, it is these particles that are most likely to migrate to areas where they can do damage. The following Sections describes these issues and presents recommendations and guidelines.

4.1 Recommended Air Quality Levels

Particles, gasses and other contaminants may impact the sustained operations of computer hardware. Effects can range from intermittent interference to actual component failures. The computer room should be designed to achieve a high level of cleanliness. Airborne dusts, gasses and vapors should be maintained within defined limits to help minimize their potential impact on the hardware.

Airborne particulate levels should be maintained within the limits of *Federal Standard 209E, Airborne Particulate Cleanliness Classes in Cleanrooms and Clean Zones, Class 100,000.* This standard defines air quality classes for clean zones based on airborne particulate concentrations. While this standard defines the limits of various classes, and the methods for testing and analysis, it does not define the nature of the particulate. The least stringent of these, Class 100,000, is generally accepted as an appropriate measure of data center environments. The lower class limits designate conditions for clean room classification generally associated with research and development, manufacturing and other specialized applications.

Although FED-STD-209E is a widely accepted computer room standard, it does not include some of the most harmful dust sizes: 0.3 microns and smaller. These particles are harmful to most data processing hardware because they have the

tendency to exist in large numbers and can easily circumvent many sensitive components' internal air filtration systems. Like other particles, they have the ability to agglomerate into large masses or absorb corrosive agents under certain psychrometric conditions. When computer hardware is exposed to these submicronic particles in great numbers they endanger system reliability by posing a threat to moving parts, sensitive contacts and component corrosion. Concentrations of ultrafine particles must be considered when evaluating a controlled environment.

Excessive concentrations of certain gasses can accelerate corrosion and cause failure in electronic components. Gaseous contaminants are a particular concern in a computer room both because of the sensitivity of the hardware, and because a proper computer room environment is almost entirely recirculating. Any contaminant threat in the room is compounded by the cyclical nature of the airflow patterns. Levels of exposure that might not be concerning in a well ventilated site repeatedly attack the hardware in a room with recirculating air. The isolation that prevents exposure of the computer room environment to outside influences can also multiply any detrimental influences left unaddressed in the room.

Gasses that are particularly dangerous to electronic components include chlorine compounds, ammonia and its derivatives, oxides of sulfur and petrol hydrocarbons. The sources and effects of these and other gasses are included in the "Contaminant Properties and Sources" section of this manual. In the absence of appropriate hardware exposure limits, health exposure limits should be used. The following chart outlines limits for various gasses that could pose a threat to hardware. These limits should not be used as absolute limits, as numerous other factors, such as the moisture content of the air, can influence environmental corrosivity and gaseous contaminant transfer at lower levels. Concentrations exceeding these levels should, however, be considered concerning.

TABLE 4-1   Gas Limit Recommendations

Chemical Name	Formula	ASHRAE	OSHA (PEL)	ACGIH	NIOSH
Acetic Acid	CH_3COOH	Not defined	10 ppm	Not defined	Not defined
Ammonia	NH	3500 $\mu g/m^3$	350 ppm	25 ppm	Not defined
Chlorine	Cl	2100 $\mu g/m^3$	31 ppm (c)	Not defined	0.5 ppm (c)
Hydrogen Chloride	HCl	Not defined	5 ppm (c)	Not defined	Not defined
Hydrogen Sulfide	H_2S	50 $\mu g/m^3$	320 ppm (c)	10 ppm	10 ppm
Ozone	O_3	235 $\mu g/m^3$	30.1 ppm	Not defined	Not defined
Petrol-hydrocarbons	C_nH_n	Not defined	500 ppm	75 ppm	300 ppm
Sulfur Dioxide	SO_2	80 $\mu g/m^3$	35 ppm	2 ppm	0.5 ppm (c)
Sulfuric Acid	H_2SO_4	Not defined	1 ppm	Not defined	1 ppm (c)

PEL: Permissible Exposure Limit
ppm: Parts Per Million
$\mu g/m^3$: Micrograms Per Cubic Meter
(c): ceiling

4.2   Contaminant Properties and Sources

Contaminants in the room can take many forms, and can come from numerous sources. The processes by which particles with the properties that make them dangerous to sensitive hardware are produced and the means by which they make their way to areas where they can do damage vary. Any mechanical process in the room can produce dangerous contaminants or agitate settled contaminants. The sources of contamination are as diverse as the contaminants themselves.

A particle must meet two basic criteria to be considered a contaminant. First, it must have the physical properties that could potentially cause damage to the hardware. Second, it must be able to migrate to areas where it can cause the physical damage. The difference between a potential contaminant and an actual contaminant is time and location. It is only necessary for one potential contaminant to be instigated to active status for a failure to occur. If all hardware units with a specified design life are designed to endure a given number of potential contaminants before one becomes active and interferes with the functioning of the components, then it stands to reason that a decrease in the potential contaminants in the operating environment

will lower the possibility of a potential contaminant moving to an area where it can do damage. Thus, a reduction of potential contaminants will decrease the possibility of contaminant-related failure and increase product life.

Particulate matter is most likely to migrate to areas where it can do damage if it is airborne. For this reason, airborne particulate concentration is a useful measurement in determining the quality of the computer room environment. Depending on local conditions, particles as big as 1,000 microns can become airborne, but their active life is very short, and they are arrested by most filtration devices. Submicronic particulate is much more dangerous to sensitive computer hardware, because it remains airborne for a much longer period of time, and they are more apt to bypass filters.

4.2.1 Operator Activity

Human movement within the computer space is probably the single greatest source of contamination in an otherwise clean computer room. Normal movement can dislodge tissue fragments, such as dander or hair, or fabric fibers from clothing. The opening and closing of drawers or hardware panels or any metal-on-metal activity can produce metal filings. Simply walking across the floor can agitate settled contamination making it airborne and potentially dangerous.

4.2.2 Hardware Movement

Hardware installation or reconfiguration involves a great deal of subfloor activity, and settled contaminants can very easily be disturbed, forcing them to become airborne in the supply air stream to the room's hardware. This is particularly dangerous if the subfloor deck is unsealed. Unsealed concrete sheds fine dust particles into the airstream, and is susceptible to efflorescence -- mineral salts brought to the surface of the deck through evaporation or hydrostatic pressure.

4.2.3 Outside Air

Air introduced into the hardware space can be a source of contamination. Inadequately filtered air from outside the controlled environment can introduce innumerable contaminants. Post-filtration contamination in duct work can be dislodged by air flow, and introduced into the hardware environment. This is particularly important in a downward-flow air conditioning system in which the subfloor void is used as a supply air duct. If the structural deck is contaminated, or if the concrete slab is not sealed, fine particulate matter (such as concrete dust or efflorescence) can be carried directly to the room's hardware.

4.2.4   Stored Items

Storage and handling of unused hardware or supplies can also be a source of contamination. Corrugated cardboard boxes or wooden skids shed fibers when moved or handled. Evidence of this is indicated by the prevalence of the materials in samples obtained from subfloor deposits. Stored items are not only contamination sources; their handling in the computer room controlled areas can agitate settled contamination already in the room.

4.2.5   Outside Influences

A negatively pressurized environment can allow contaminants from adjoining office areas or the exterior of the building to infiltrate the computer room environment through gaps in the doors or penetrations in the walls. Ammonia and phosphates are often associated with agricultural processes, and numerous chemical agents can be produced in manufacturing areas. If such industries are present in the vicinity of the data center facility, chemical filtration may be necessary. Potential impact from automobile emissions, dusts from local quarries or masonry fabrication facilities or sea mists should also be assessed if relevant.

4.2.6   Cleaning Activity

Inappropriate cleaning practices can also degrade the environment. Many chemicals used in normal or "office" cleaning applications can damage sensitive computer equipment. Potentially hazardous chemicals outlined in the Section 4.8, "Cleaning Procedures and Equipment" on page 4-14" should be avoided. Out-gassing from these products or direct contact with hardware components can cause failure. Certain biocide treatments used in building air handlers are also inappropriate for use in computer rooms either because they contain chemicals, that can degrade components, or because they are not designed to be used in the airstream of a recirculating air system. The use of push mops or inadequately filtered vacuums can also stimulate contamination.

It is essential that steps be taken to prevent air contaminants, such as metal particles, atmospheric dust, solvent vapors, corrosive gasses, soot, airborne fibers or salts from entering or being generated within the computer room environment. In the absence of hardware exposure limits, applicable human exposure limits from OSHA, NIOSH or the ACGIH should be used. ASHRAE Standard 62 is also an adequate guideline for both operator safety and hardware exposure. Information regarding these agencies and organizations is included in the "References" section of this manual.

4.3　Contaminant Effects

Destructive interactions between airborne particulate and electronic instrumentation can occur in numerous ways. The means of interference depends on the time and location of the critical incident, the physical properties of the contaminant and the environment in which the component is placed.

4.3.1　Physical Interference

Hard particles with a tensile strength at least 10% greater than that of the component material can remove material from the surface of the component by grinding action or embedding. Soft particles will not damage the surface of the component, but can collect in patches, that can interfere with proper functioning. If these particles are tacky they can collect other particulate matter. Even very small particles can have an impact if they collect on a tacky surface, or agglomerate as the result of electrostatic charge build-up.

4.3.2　Corrosive Failure

Corrosive failure or contact intermittence due to the intrinsic composition of the particles, or due to absorption of water vapor and gaseous contaminants by the particles can also cause failures. The chemical composition of the contaminant can be very important. Salts, for instance, can grow in size by absorbing water vapor from the air (nucleating). If a mineral salts deposit exists in a sensitive location, and the environment is sufficiently moist, it can grow to a size where it can physically interfere with a mechanism, or can cause damage by forming salt solutions.

4.3.3　Shorts

Conductive pathways can arise through the accumulation of particles on circuit boards or other components. Many types of particulate are not inherently conductive, but can absorb significant quantities of water in high-moisture environments. Problems caused by electrically conductive particles can range from intermittent malfunctioning to actual damage to components and operational failures.

4.3.4 Thermal Failure

Premature clogging of filtered devices will cause a restriction in air flow that could induce internal overheating and head crashes. Heavy layers of accumulated dust on hardware components can also form an insulative layer that can lead to heat-related failures.

4.4 Room Conditions

All surfaces within the controlled zone of the data center should be maintained at a high level of cleanliness. All surfaces should be periodically cleaned by trained professionals on a regular basis, as outlined in the Section 4.8, "Cleaning Procedures and Equipment" on page 4-14." Particular attention should be paid to the areas beneath the hardware, and the access floor grid. Contaminants near the air intakes of the hardware can more easily be transferred to areas where they can do damage. Particulate accumulations on the access floor grid can be forced airborne when floor tiles are lifted to gain access to the subfloor. It is important that these deposits be removed in an appropriate manner, and that all surfaces are maintained in good condition, so as to not contribute contamination to the environment.
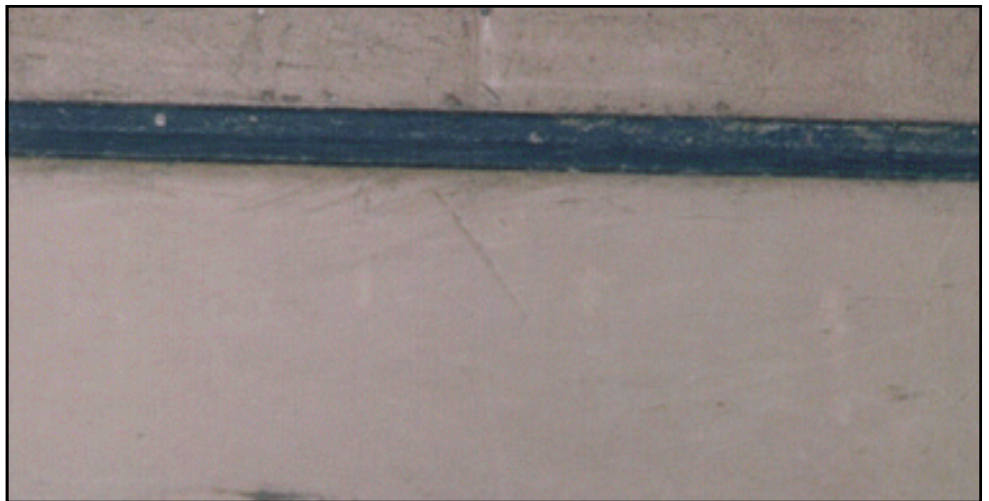
FIGURE 4-1   Floor Surface Contaminants Air Plenum Conditions.

The subfloor void in a downward-flow air conditioning system acts as the supply air plenum. This area is pressurized by the air conditioners, and the conditioned air is then introduced into the hardware spaces through perforated floor panels. Thus, all

air traveling from the air conditioners to the hardware must first pass through the subfloor void. Inappropriate conditions in the supply air plenum can have a dramatic effect on conditions in the hardware areas.

FIGURE 4-2 Subfloor Penetration
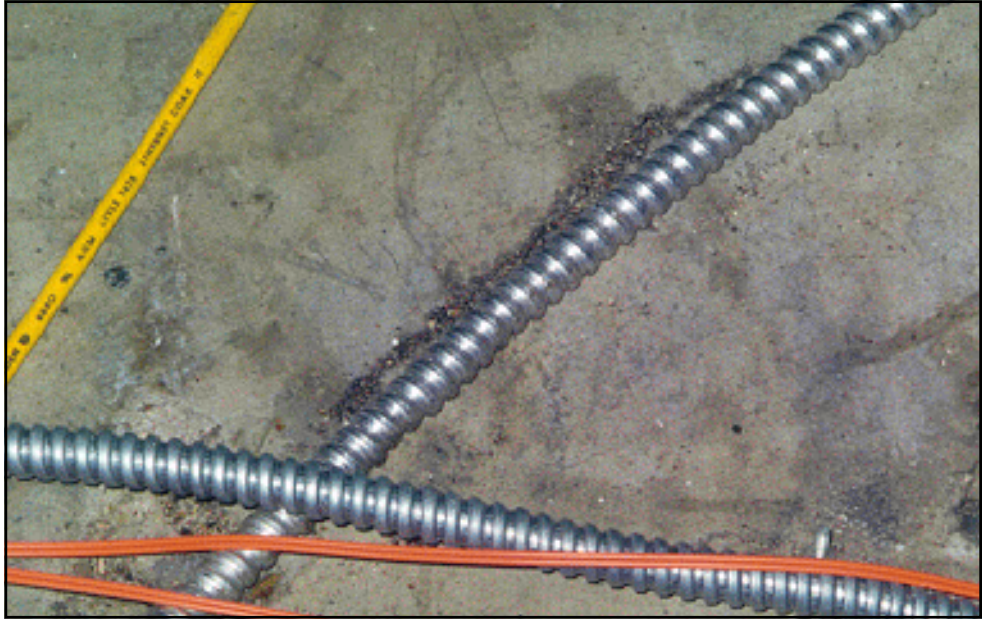
FIGURE 4-3   Dirty Unsealed Subfloor

The subfloor void in a data center is often viewed solely as a convenient place to run cables and pipes. It is important to remember that this is also a duct, and that conditions below the false floor must be maintained at a high level of cleanliness. Contaminant sources can include degrading building materials, operator activity or infiltration from outside the controlled zone. Often particulate deposits are formed where cables or other subfloor items form air dams that allow particulate to settle and accumulate. When these items are moved, the particulate is re-introduced into the supply airstream, where it can be carried directly to hardware.

Damaged or inappropriately protected building materials are often sources of subfloor contamination. Unprotected concrete, masonry block, plaster or gypsum wall-board will deteriorate over time, shedding fine particulate into the airstream. Corrosion on post-filtration air conditioner surfaces, or subfloor items can also be a concern. The subfloor void must be thoroughly and appropriately decontaminated on a regular basis to address these contaminants. Only vacuums equipped with High Efficiency Particulate Air (HEPA) filtration should be used in any decontamination procedure. Inadequately filtered vacuums are incapable of arresting fine particles, passing them through the unit at high speeds, and forcing them airborne.

Unsealed concrete, masonry or other similar materials are subject to continued degradation. The sealants and hardeners normally used during construction are often designed to protect the deck against heavy traffic, or to prepare the deck for

the application of flooring materials, and are not meant for the interior surfaces of a supply air plenum. While regular decontaminations will help address loose particulate, the surfaces will still be subject to deterioration over time, or as subfloor activity causes wear. Ideally all of the subfloor surfaces will be appropriately sealed at the time of construction. If this is not the case, special precautions will be necessary to address the surfaces in an on-line room.
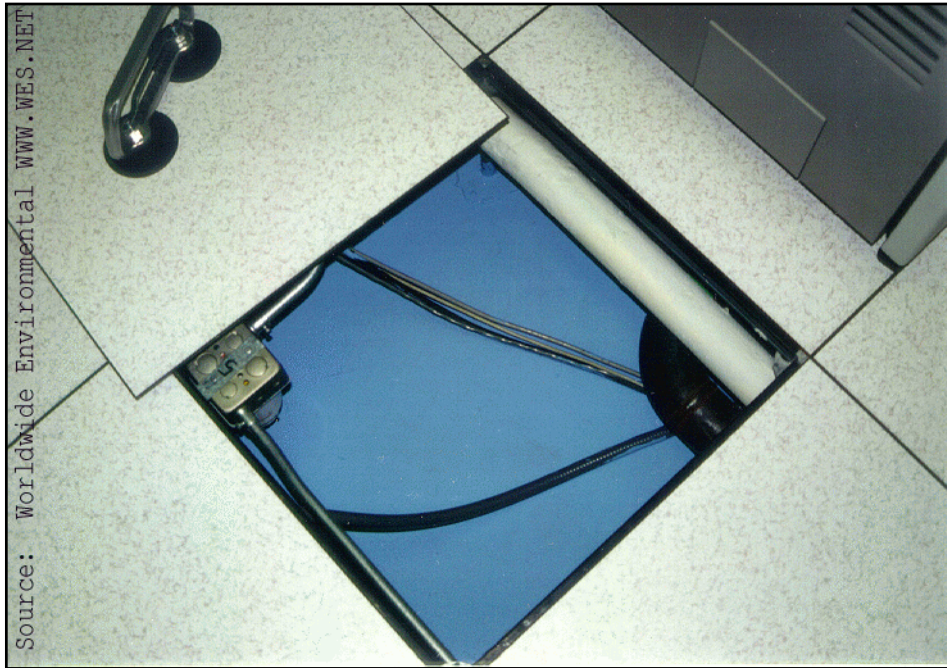
FIGURE 4-4   Well-sealed Subfloor

It is extremely important that only appropriate materials and methodology are used in the encapsulation process. Inappropriate sealants or procedures can actually degrade the conditions they are meant to improve, impacting hardware operations and reliability. The following precautions should be taken when encapsulating the supply air plenum in an on-line room.

- Manually apply the encapsulant. Spray applications are totally inappropriate in an on-line data center. The spraying process forces the sealant airborne in the supply airstream, and is more likely to adhere cables to the deck.
- Use a pigmented encapsulant. The pigmentation makes the encapsulant visible in application, ensuring thorough coverage, and helps in identifying areas that are damaged or exposed over time.
- It must have a high flexibility and low porosity in order to effectively cover the irregular textures of the subject area, and to minimize moisture migration and water damage.

■ The encapsulant must not out-gas any harmful contaminants. Many encapsulants commonly used in industry are highly ammoniated or contain other chemicals that can be harmful to hardware. It is very unlikely that this out-gassing could cause immediate, catastrophic failure, but these chemicals will often contribute to corrosion of contacts, heads or other components.

Effectively encapsulating a subfloor deck in an on-line computer room is a very sensitive and difficult task, but it can be conducted safely if appropriate procedures and materials are used.

Avoid using the ceiling void as an open supply or return for the building air system. This area is typically very dirty and difficult to clean. Often the structural surfaces are coated with fibrous fire-proofing, and the ceiling tiles and insulation are also subject to shedding. Even prior to filtration, this is an unnecessary exposure that can adversely affect environmental conditions in the room. It is also important that the ceiling void does not become pressurized, as this will force air from this typically dirty area into the computer room. Columns or cable chases with penetrations in both the subfloor and ceiling void can lead to ceiling void pressurization.

4.5 Exposure Points

All potential exposure points in the data center should be addressed so as to minimize potential influences from outside the controlled zone. Positive pressurization of the computer rooms will help limit contaminant infiltration, but it is also important to minimize any breaches in the room perimeter.

All doors should fit snugly in their frames. Gaskets and sweeps can be used to address any gaps. Automatic doors should be avoided in areas where they can be accidentally triggered, as this is an unnecessary exposure. An alternate means of control would be to remotely locate a door trigger so that personnel pushing carts can open the doors easily. In highly sensitive areas, or where the data center is exposed to undesirable conditions, it may be advisable to design and install personnel traps. Double sets of doors with a buffer between can help limit direct exposure to outside conditions.

The data center should be an isolated environment if controllability is to be achieved. Seal all penetrations between the data center and adjacent areas. Avoid sharing a computer room ceiling or subfloor plenum with loosely controlled adjacent areas.

4.6 Filtration

Filtration is an effective means of addressing airborne particulate in a controlled environment. It is important that all air handlers serving the data center are adequately filtered to ensure appropriate conditions are maintained within the room. The necessary efficiency is dependent on the design and application of the air handlers.

In room process cooling is the recommended method of controlling the room environment. The in-room process coolers recirculate room air. Air from the hardware areas is passed through the units where it is filtered and cooled, and then introduced into the subfloor plenum. The plenum is pressurized, and the conditioned air is forced into the room, through perforated tiles, and then travels back to the air conditioner for reconditioning. The airflow patterns and design associated with a typical computer room air handler have a much higher rate of air change than do typical comfort cooling air conditioners. This means that the air is filtered much more often than would be the case in an office environment. Proper filtration can thus accomplish a great deal of particulate arrestance. The filters installed in the in-room, recirculating air conditioners should have a minimum efficiency of 40% (Atmospheric Dust-Spot Efficiency, ASHRAE Standard 52.1). Low-grade prefilters should be installed to help prolong the life of the more expensive primary filters.

Any air being introduced into the computer room controlled zone, for ventilation or positive pressurization, should first pass through high efficiency filtration. Ideally, air from sources outside the building should be filtered using High Efficiency Particulate Air (HEPA) filtration rated at 99.97% efficiency (DOP Efficiency MIL-STD-282) or greater. The expensive high efficiency filters should be protected by multiple layers of prefilters that are changed on a more frequent basis. Low-grade prefilters, 20% ASHRAE atmospheric dust-spot efficiency, should be the primary line

of defense. The next filter bank should consist of pleated or bag type filters with efficiencies between 60% and 80% ASHRAE atmospheric dust-spot efficiency. Please refer to TABLE 4-2 for a comparison of filter efficiencies.

TABLE 4-2 Filter Efficiency Comparison

Typical Efficiencies of Various Filters			
ASHRAE 52-76	Fractional Efficiencies,%		
Dust spot efficiency,%	3.0 micron	1.0 micron	0.3 micron
25-30	80	20	<5
60-65	93	50	20
80-85	99	90	50
95	>99	92	60
DOP 95	--	>99	95

Note – Source: *ASHRAE Journal,* February 1995

As the previous chart demonstrates, low efficiency filters are almost totally ineffective at removing submicronic particulate from the air.

It is also important that the filters used are properly sized for the air handlers. Gaps around the filter panels can allow air to bypass the filter as it passes through the air conditioner. Any gaps or openings should be filled using appropriate materials, such as stainless steel panels or custom filter assemblies.

4.7 Positive Pressurization and Ventilation

A designed introduction of air from outside the computer room system will be necessary in order to accommodate positive pressurization and ventilation requirements. The data center should be designed to achieve positive pressurization in relation to more loosely controlled surrounding areas. Positive pressurization of the more sensitive areas is an effective means of controlling contaminant infiltration through any minor breaches in the room perimeter. Positive pressure systems are designed to apply outward air forces to doorways and other access points within the data processing center in order to minimize contaminant infiltration of the computer room. Only a minimal amount of air should be introduced into the controlled environment. In data centers with multiple rooms, the most sensitive areas should be the most highly pressurized. It is, however, extremely important that the air being

used to positively pressurize the room does not adversely affect the environmental conditions in the room. It is essential that any air introduction from outside the computer room is adequately filtered and conditioned to ensure that it is within acceptable parameters. These parameters can be looser than the goal conditions for the room since the air introduction should be minimal. A precise determination of acceptable limits should be based on the amount of air being introduced and the potential impact on the environment of the data center.

Because a closed-loop, recirculating air conditioning system is used in most data centers, it will be necessary to introduce a minimal amount of air to meet the ventilation requirements of the room occupants. Data center areas normally have a very low human population density, thus the air required for ventilation will be minimal. In most cases, the air needed to achieve positive pressurization will likely exceed that needed to accommodate the room occupants. Normally, outside air quantities of less than 5% make-up air should be sufficient (ASHRAE Handbook: Applications, Chapter 17). A volume of 15 CFM outside air per occupant or workstation should sufficiently accommodate the ventilation needs of the room (Uniform Building Code, Chapter 12). The amount of air introduced should be kept to the absolute minimum necessary to achieve the positive pressurization and ventilation requirements of the room.

4.8 Cleaning Procedures and Equipment

Even a perfectly designed data center will require continued maintenance. Data centers containing design flaws or compromises may require extensive efforts to maintain conditions within desired limits. Hardware performance is an important factor contributing to the need for a high level of cleanliness in the data center. All electronic and mechanical devices are sensitive to contamination in a variety of ways and means. Increased component failure caused by excessive contaminant exposure will result in an interruption of service to the data processing users.

Operator awareness is another consideration. Maintaining a fairly high level of cleanliness will raise the level of occupant awareness with respect to special requirements and restrictions while in the data center. Occupants or visitors to the data center will hold the controlled environment in high regard and are more likely to act appropriately. Any environment that is maintained to a fairly high level of cleanliness and is kept in a neat and well organized fashion will also command respect from the room's inhabitants and visitors. When potential clients visit the room they will interpret the overall appearance of the room as a reflection of an overall commitment to excellence and quality.

An effective cleaning schedule must consist of specially designed short-term and long-term actions. These can be summarized as follows:

TABLE 4-3 Cleaning Schedule

Frequency	Task
Daily Actions	Rubbish removal
Weekly Actions	Access floor maintenance (vacuum and damp mop)
Quarterly Actions	Hardware decontamination
	Room surface decontamination
Bi-Annual Actions	Subfloor void decontamination
	Air conditioner decontamination (as necessary)

4.8.1 Daily Tasks

This statement of work focuses on the removal of each day's discarded trash and rubbish from the room. In addition, daily floor vacuuming may be required in Print Rooms or rooms with a considerable amount of operator activity.

4.8.2 Weekly Tasks

This statement of work focuses on the maintenance of the access floor system. During the week, the access floor becomes soiled with dust accumulations and blemishes. The entire access floor should be vacuumed and damp mopped. All vacuums used in the data center, for any purpose, should be equipped with High Efficiency Particulate Air (HEPA) filtration. Inadequately filtered equipment can not arrest smaller particles, and simply agitates them, degrading the environment they were meant to improve. It is also important that mop-heads and dust wipes are of appropriate non-shedding designs.

Cleaning solutions used within the data center must not pose a threat to the hardware. Solutions that could potentially damage hardware include ammoniated products, chlorine based products, phosphate based products, bleach enriched products, petrol-chemical based products, floor strippers or re-conditioners. It is also important that the recommended concentrations are used, as even an appropriate agent in an inappropriate concentration can be potentially damaging. The solution should be maintained in good condition throughout the project, and excessive applications should be avoided.

4.8.3   Quarterly Tasks

The quarterly statement of work involves a much more detailed and comprehensive decontamination schedule and should only be conducted by experienced computer room contamination-control professionals. These actions should be performed three to four times per year, based on the levels of activity and contamination present.

All room surfaces should be thoroughly decontaminated including cupboards, ledges, racks, shelves and support equipment. High ledges and light fixtures and generally accessible areas should be treated or vacuumed as appropriate. Vertical surfaces including windows, glass partitions, doors, etc. should be thoroughly treated. Special dust cloths that are impregnated with a particle absorbent material are to be used in the surface decontamination process. Do not use generic dust rags or fabric cloths to perform these activities. Do not use any chemicals, waxes or solvents during these activities.

Settled contamination should be removed from all exterior hardware surfaces including horizontal and vertical surfaces. The unit's air inlet and outlet grilles should be treated as well. Do not wipe the unit's control surfaces, these areas can be decontaminated by the use of lightly compressed air. Special care should also be taken when cleaning keyboards and life-safety controls. Specially treated dust wipes should be used to treat all hardware surfaces. Monitors should be treated with optical cleansers and static-free cloths. No ElectroStatic Discharge (ESD) dissipative chemicals should be used on the computer hardware, since these agents are caustic and harmful to most sensitive hardware. The computer hardware is sufficiently designed to permit Electrostatic dissipation thus no further treatments are required.

After all of the hardware and room surfaces have been thoroughly decontaminated, the access floor should be HEPA vacuumed and damp mopped as detailed in the Weekly Actions.

4.8.4   Bi-Annual Tasks

The subfloor void should be decontaminated every 18 months to 24 months based on the conditions of the plenum surfaces and the degree of contaminant accumulation. Over the course of the year, the subfloor void undergoes a considerable amount of activity, that creates new contamination accumulations. Although the weekly above floor cleaning activities will greatly reduce the subfloor dust accumulations, a certain amount of surface dirt will migrate into the subfloor void. It is important to maintain the subfloor to a high degree of cleanliness since this area acts as the hardware's supply air plenum. It is best to perform the subfloor decontamination treatment in a short time frame to reduce cross contamination. The personnel performing this operation should be fully trained to assess cable connectivity and priority. Each exposed area of the subfloor void should be individually inspected and assessed for possible cable handling and movement. All

twist-in and plug-in connections should be checked and fully engaged before cable movement. All subfloor activities must be conducted with proper consideration for air distribution and floor loading. In an effort to maintain access floor integrity and proper psychrometric conditions, the number of floor tiles removed from the floor system should be carefully managed. In most cases, each work crew should have no more than 24 square feet (six tiles) of open access flooring at any one time.

The access floor's supporting grid system should also be thoroughly decontaminated, first by vacuuming the loose debris and then by damp-sponging the accumulated residue. Rubber gaskets, if present, as the metal framework that makes up the grid system should be removed from the grid work and cleaned with a damp sponge as well. Any unusual conditions, such as damaged floor suspension, floor tiles, cables and surfaces, within the floor void should be noted and reported.

4.9 Activity and Processes

Isolation of the data center is an integral factor in maintaining appropriate conditions. All unnecessary activity should be avoided in the data center, and access should be limited to necessary personnel only. Periodic activity, such as tours, should be limited, and traffic should be restricted to away from the hardware so as to avoid accidental contact. All personnel working in the room, including temporary employees and janitorial personnel, should be trained in the most basic sensitivities of the hardware so as to avoid unnecessary exposure.

The controlled areas of the data center should be thoroughly isolated from contaminant producing activities. Ideally, print rooms, check sorting rooms, command centers or other areas with high levels of mechanical or human activity should have no direct exposure to the data center. Paths to and from these areas should not necessitate traffic through the main data center areas.

Safety and Security

Safety and security issues relate to both the hardware and the operators working in the room. Design considerations should take the safety of those exposed to the environment into account in the design. In most cases, the goals for the electronic equipment are in keeping with the human safety goals. A balance must be achieved.

5.1 Fire Prevention in a Computer Room

A fire within the data center can have catastrophic effects on the operations of the room. The destructive force of a large-scale fire can damage electronic equipment, and the building structure, beyond repair. The contamination from a smoldering fire can also have very damaging effects on the hardware, and can carry heavy costs in cosmetic repairs. Even if the actual fire is avoided, discharge of the fire suppression medium can have a damaging impact on hardware. Whether measured in their threat to human safety, damage to computer equipment or loss of business due to systems disruption, the costs of a fire can be staggering.

Numerous steps can be taken to avoid the risk of fire in the computer room environment. Compliance with NFPA 75 will greatly increase the fire safety in the data center. The following precautions should be taken into consideration in the design and maintenance of the computer room and support areas.

■ Avoid unnecessary storage. Combustible materials should be avoided in the data center. Only the minimum supplies absolutely necessary to the functioning of the room should be kept within its perimeter. Packing materials and other unnecessary items should be removed as soon as possible.

■ Check reheat coils on the air conditioners periodically. If left unused for long periods of time, these can collect layers of dust that smolder or ignite when the unit is called for.

- Periodically inspect the room perimeter for penetrations. Penetrations can expose the data center to influences from more loosely controlled areas. An alarm or suppression system discharge caused by conditions outside the data center is unacceptable.
- To help minimize the damage caused by a fire, detailed disaster response plans should be created, and room personnel should be properly trained.

5.2 Physical Structure

The first line of fire defense and containment is dependent upon the actual building structure. The various rooms of the data center must be isolated by fire-walls that extend from the concrete subfloor deck to the structural ceiling. Appropriately controlled firebreaks must also be present. NFPA 75 states:

2-1.3: The computer room shall be separated from other occupancies within the building by fire-resistant rated walls, floor, and ceiling constructed of noncombustible or limited combustible materials. The fire resistant rating shall be commensurate with the exposure, but not less than one hour.

2-1.4: The fire-rated enclosures of the computer room and/or storage rooms shall extend from the structural floor to the structural floor above, or the roof.

The HVAC system should be dedicated exclusively to the data center controlled areas. If this is not, however, the case, appropriately rated fire dampers must be placed in all common ducts or plenums.

5.3 Fire Detection and Suppression

The most common sources of fires in data centers are the electrical system or the hardware. Breakdowns in insulation and the resultant short circuiting can lead to intense heat that can melt materials or cause a fire. Computer room fires are often small or smoldering, with little effect on the temperatures in the room. Because the smoke itself can impact the computer hardware, it is necessary to employ a detection system that is sensitive to smoke and other products of combustion rather than temperature. The specific detection and extinguishing system is dependent on the specific design and exposures of the individual data center area. NFPA 75 states:

5-2: Automatic detection equipment shall be installed to provide early warning of fire. The equipment used shall a be listed smoke detection type. Each installation shall be engineered for the specific area to be protected, giving due consideration to air currents and patterns within the space and shall be installed and maintained in accordance with NFPA 72E, Standard on Automatic Fire Detectors.

2-4.3a: An automatic detection and extinguishing system shall be installed in the space below the raised floor.

A passive suppression system reacts to detected hazards with no manual intervention. The most common forms of passive suppression are sprinkler systems or chemical suppression systems. Sprinkler systems can be flooded (wet pipe) or pre-action (dry pipe). A flooded system incorporates pipes that are full at all times, allowing the system to discharge immediately upon threat detection. A pre-action system will flood the sprinkler pipes upon an initial detection, but will have a delay before actual discharge. Chemical total flooding systems work by suffocating the fire within the controlled zone. The suppression chemical most often found in data centers is Halon 1301. Halon is being eliminated in favor of the more environmentally friendly FM200 or various forms of water suppression. Carbon dioxide suppression systems are also used, but can be a concern due to operator safety issues in the instance of a discharge. These can be used independently, or in combination depending on the exposures in the room, local ordinances and insurance requirements.

The ideal system would incorporate both a gas system and a pre-action water sprinkler system in the ambient space. The gas suppression systems are friendlier to the hardware in the event of a discharge. Water sprinklers often cause catastrophic and irreparable damage to the hardware, whereas the hardware in a room subjected to a gas discharge can often be brought back on-line soon after the room is purged. Gas systems are, however, "one-shot" designs. If the fire is not put out in the initial discharge, there is no second chance. The gas system cannot be reused until it is recharged or connected to a back-up source. Water systems can continue to address the fire until it has been brought under control. While this is more likely to damage the hardware, it is also a more secure means of protecting the building structure. Water suppression systems are often preferred or mandated by building owners or insurance companies. Water systems are also highly recommended in areas containing a high level of combustible materials use or storage. The decision of what means of fire suppression to utilize must incorporate numerous factors including the mission and criticality of the data center operations.

Halon 1301 fire suppression gas is no longer in production, as of January 1994, and may be subject to punative tariffs under certain circumstances. Alternate gasses, such as FM-200, are available. FM-200 requires a slightly higher gas concentration than Halon 1301 (7% versus 5%), but is similar in effectiveness and has none of the environmental side-effects that led to the banning of Halon 1301.

Manual means of fire suppression system discharge should also be installed. These should take the form of manual pull stations at strategic points in the room. In areas where gas suppression systems are used, there is normally also a means of manual abort for the suppression system. In designs where it is necessary to hold the abort button to maintain the delay in discharge, it is essential that a means of communication is available within reach.

Portable fire extinguishers should also be placed strategically throughout the room. These should be unobstructed, and should be clearly marked. Labels should be visible above the tall computer equipment from across the room. Appropriate tile lifters should be located at each extinguisher station to allow access to the subfloor void for inspection, or to address a fire.

5.4 Water Detection and Leak Precautions

Water detection is important for a number of reasons. Leaks in the subfloor can cause serious threats to both personnel and hardware. Leaks are indicative of inappropriate functioning or conditions of the building infrastructure. They are normally caused by problems with the air conditioners or support piping, and early detection of leaks can help identify problems with the air conditioners. Less frequently, leaks are caused by infiltration of water from outside the room perimeter. Standing water in the subfloor can be extremely dangerous. Shorts where the water enters electrical connections can interfere with systems up-time, and can pose a shock hazard to personnel working in the subfloor. Standing water in the subfloor has also been known to breed biological material that can be recirculated through the room by the air conditioning. This can cause a health hazard to operators, and can even impact hardware in extreme instances. Problems such as efflorescence, the release of trapped mineral salts from masonry, can also be caused or aggravated by water leaks.

Monitoring, barriers and drains can all be used to address the detection and containment of liquids in the data center. At the very least, spot liquid detectors should be placed in the vicinity of air conditioners or water sources within the room. A more comprehensive system would employ a network of sensing cables. Drains, troughs and dams can all help contain leaks in the subfloor void. These should be used to isolate potential problem areas, such as the air conditioners or piping from the electrical and data lines in the subfloor.

5.5   Personnel Safety

Manual controls for the various support systems in the data center should be located conveniently in the room. Ideally, fire, leak detection, HVAC, power and abort or silence controls and an independent phone line should all be grouped by the appropriate doors. All controls should be clearly labeled, and concise operating instructions should be available at each station.

5.6   Operator Health Considerations

The most important safety precautions that can be taken in a data center are to limit the number of personnel in the sensitive areas to the absolute minimum, and ensure that all personnel are fully trained to respond to emergency situations.

In order to maintain the appropriate control over in-room psychrometric conditions necessitated by the hardware, the air in a computer room is primarily recirculating. Only a minimum amount of make-up air from outside the computer room must be introduced for ventilation and positive pressurization purposes. It may actually be necessary to introduce air in excess of the minimum ventilation requirement per workstation in order to maintain a positive pressure differential in the controlled areas. Ventilation for the human occupants of the data center should be assessed and adjusted as changes in room design or procedure dictate. In addition, gaseous contaminants can pose a threat to both hardware and human occupants. Contaminant problems can be accentuated by the recirculating air-flow patterns of the room.

Facility Power Requirements

To prevent catastrophic failures, the design of the power system must ensure that adequate power, within appropriate limits, is provided to the computer hardware. Sun Microsystems suggests that all power to Sun equipment be derived from dedicated electrical distribution panels. Electrical work and installations must comply with applicable local, state and national electrical codes.

Sun Microsystems makes every effort to minimize the effects of power failures and interruptions to the hardware. However, if the computer equipment is subjected to repeated significant power interruptions and fluctuations, it is susceptible to a higher component failure rate than it would be with a stable power source. Provide a stable power source to reduce the possibility of component failures.

6.1   Power System Design

Power quality issues are often difficult to identify, and can be even more difficult to correct. Often, the symptoms are very similar to those caused by other environmental problems or software issues. The most effective means of mitigating power problems is through the appropriate design of the system. The goal of the power system design should be to provide power, at appropriate levels and quality, without interruption. Integral to this task is the incorporation of sufficient redundancy, and the elimination of single points of failure. While Sun Microsystems equipment is designed to be robust and tolerant of most electrical problems, a thoughtfully designed power infrastructure is an important part of any facility. The following areas should be addressed in the design of the power systems for a computer room.

6.1.1 Multiple Utility Feeds

Ideally, multiple utility feeds should be provided from separate sub-stations or power grids. While not essential, this provides back-up and redundancy. The criticality and extent of this issue should be determined through an examination of the size and role of the data center.

6.1.2 Uninterruptible Power Supply (UPS)

An Uninterruptible Power Supply (UPS) should be installed to carry:

- 100% of the computer hardware load for a period at least long enough to transfer the equipment to an alternate utility feed or back-up generators.
- 150% of the load to accommodate fault overload conditions.

On-line UPS that runs continuously should be used as opposed to an off-line unit. The on-line UPS filters, conditions, and regulates the power. Battery back-up should be capable of maintaining the critical load of the room for a minimum of 15 minutes during a power failure to allow for the transfer of power to an alternate feed or generator.

If a UPS is not used as a bare minimum, then surge suppression should be designed into the panels and a stand-alone isolation/regulation transformer should be designed into the power system to control the incoming power and protect the equipment.
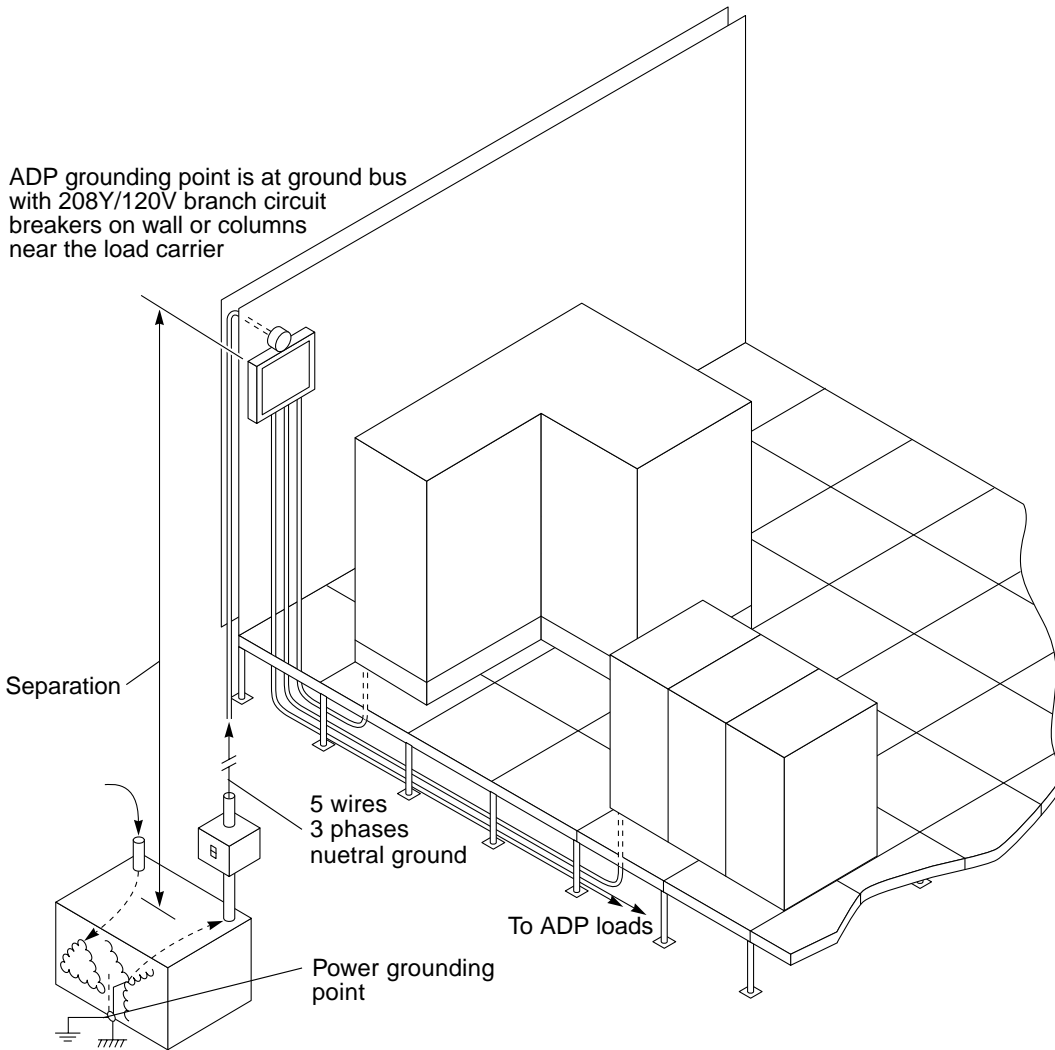
6.1.3 Backup Power Generators

Backup power generators should be installed to carry the load of both the computer equipment, as well as all necessary support equipment (such as air conditioners). Depending upon the criticality of the site, it may be acceptable to use the UPS and multiple utility feeds without generators.

6.1.4 Maintenance Bypass

The power system design should provide the means for bypassing and isolating any point of the system to allow for maintenance, repair or modification without interruption to systems operations. The system should be designed to avoid all single points of failure.
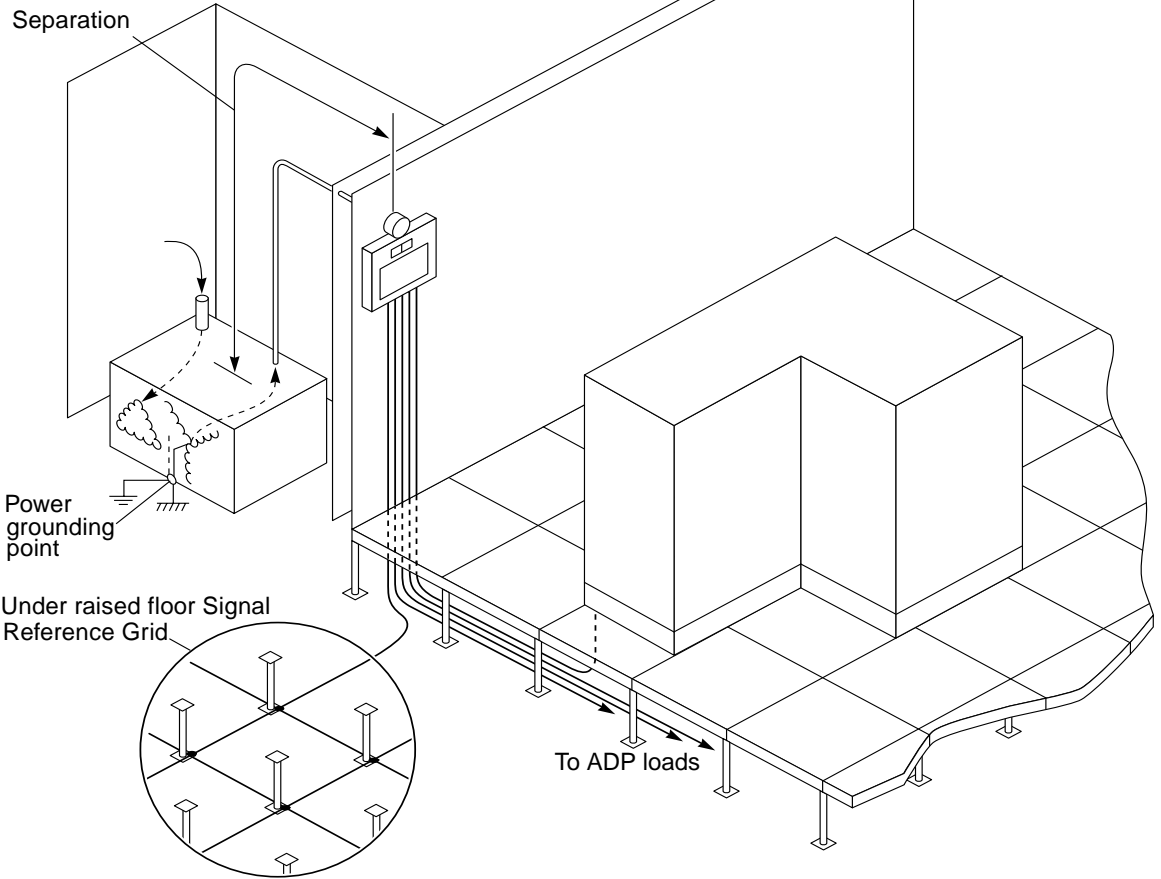
6.1.5   Installation and Placement

The power distribution equipment for computer applications should be installed as close as reasonable to the load, as depicted in FIGURE 6-3. All loads being supported need to be identified and evaluated for compatibility with the computer equipment. Heavy loads that are cyclic, such as elevators, air conditioners, and copy machines should not be connected directly to the same source as the computer room equipment.

ADP grounding point is at ground bus
with 208Y/120V branch circuit
breakers on wall or columns
near the load carrier

Separation

5 wires
3 phases
nuetral ground

To ADP loads

Power grounding
point

Note: Subject to noise and voltage differences due to separation of voltage source and ADP ground points.

FIGURE 6-1   Example of Poor Equipment Installation and Placement

ADP grounding point is at ground bus
with 208Y/120V branch circuit
breakers on wall or columns
near the load center

Separation

Power
grounding
point

Under raised floor Signal
Reference Grid

To ADP loads

Note: Separation of voltage source and ADP grounding points has been decreased.

FIGURE 6-2   Example of Better Equipment Installation and Placement

408 V 3-wire circuit
breaker on wall or
column

To ADP loads

Under raised floor Signal
Reference Grid
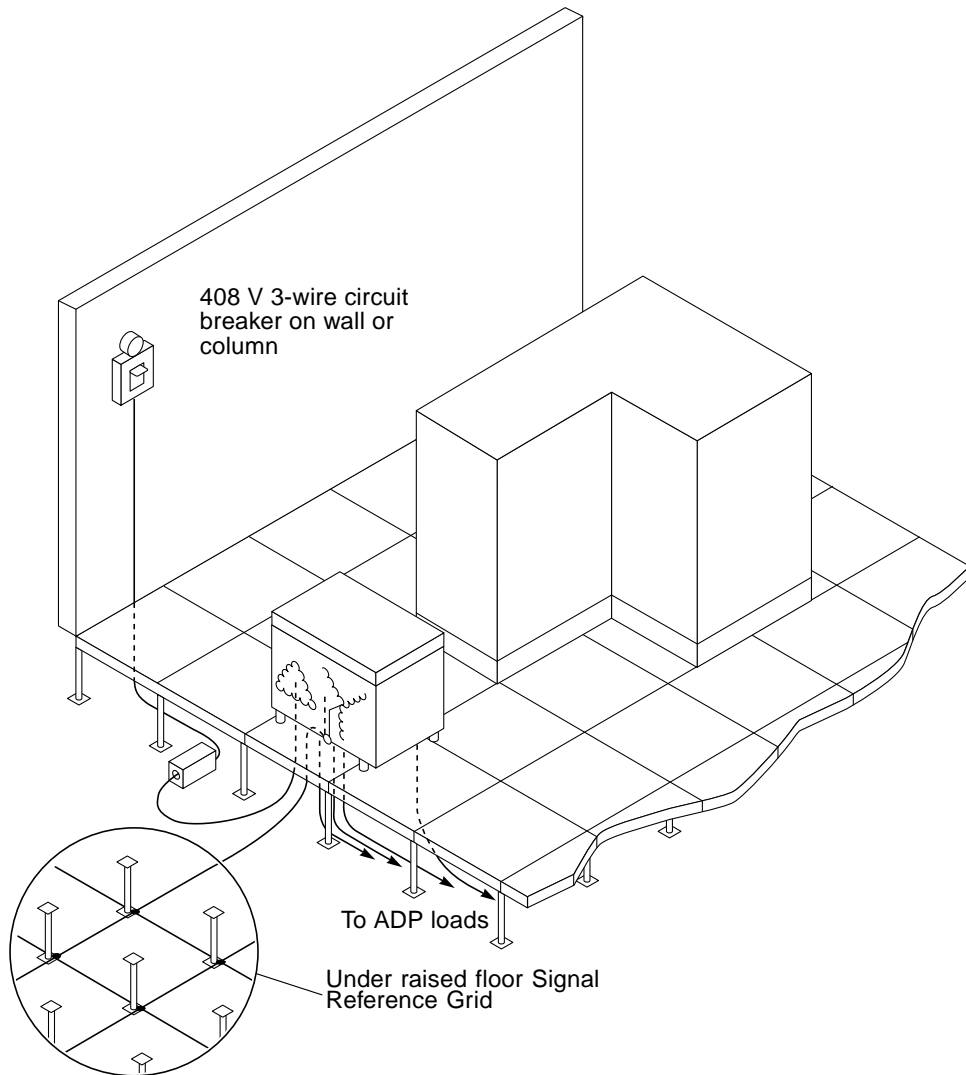
Note: Voltage source and ADP grounding points are the same. Computer room power center
is near the computer and load circuit breakers are in power center. Branch circuit at 480 V require
fewer and smaller wires, less voltage drop and may be less expensive.

FIGURE 6-3   Example of Best Equipment Installation and Placement

Note – Source FIPS PUB 94, Guideline On Electrical Power for ADP Installations

6.1.6 Single-and Three-Phase Power

Most large commercial buildings will be supplied with three-phase power. Most data centers are comprised of both three-phase and single-phase equipment. Single phase equipment requires that steps be taken to ensure that the system is balanced (the phase currents are nearly equal). This will require forethought in wiring design, and a balancing of equipment on the phases. The phase currents will need to be monitored, often accomplished by the UPS, and taken into consideration in the planning of the electrical load distribution.

In addition to load balancing, the design must take into account the nonlinear loads of computing equipment. Most Sun AC-powered equipment has power factor correction that meets EN6100-3-2 as part of the power supply. Installations need to consider other equipment that is non power factor corrected and appropriate deratings need to be applied to the wiring, distribution equipment, and transformers.

6.1.7 Separately Derived Systems

Separately derived systems have no direct electrical connection between the output conductors and the input conductors. Separately derived systems are required by the NEC to have a load-side, neutral-ground bond that is connected to the grounding electrode system. All equipment grounding conductors, any isolated grounding conductors, neutral conductors, and the metal enclosure of the separately derived system, are required to be bonded together and bonded to the grounding electrode conductor. Visual inspection and measurements with a ground impedance tester can be used to determine the quality of these connections.

6.2 Grounding and Bonding

Grounding is an extremely important electrical consideration for the proper operation of electronic equipment. The ground conductor provides a designed path to ground (earth). Grounding design in a data center environment must address both the electrical service as well as the equipment. Grounding design should comply with Article 250 of the National electrical Code (NEC 250 -- Grounding) unless superseded by local codes. The National Electric Code (NEC) section #250-51, Effective Grounding Path states:

The path to ground from circuits, equipment and conductor enclosures shall: (1) be permanent and continuous; (2) have capacity to conduct safely any current likely to be imposed upon it; and (3) have sufficient low impedance to limit the voltage to ground and to facilitate the operation of the circuit protection devices in the circuit. The earth shall not be used as the sole equipment grounding conductor.

A properly designed grounding system should have as low an impedance as is practically achievable for proper operation of electronic devices as well as for safety. It is also important that the ground should be continuous from the central grounding point at the origin of the building system. Electronic equipment can be sensitive to stray currents and electronic noise. It is important to utilize a continuous, dedicated ground for the entire power system so as to avoid a ground differential between various grounds being used.

All metallic objects on the premises that enclose electrical conductors or that are likely to be energized by electrical currents (e.g., circuit faults, electrostatic discharge, and lightning) should be effectively grounded for reasons of personnel safety, fire hazard reduction, protection of the equipment itself, and performance. Solidly grounding these metallic objects will facilitate overcurrent device operation and permit return currents from EMI filters and surge suppressors, connected line-to-ground or line-to-chassis, to flow in the proper fashion.

The common point of grounding can be connected to any number of sources (water piping, driven earth rod, buried grid, building steel, etc.) at the service entrance. It is important that whatever the source, the ground is carried through the entire system from this source. Ideally, the central point of grounding at the service entrance will be connected to multiple ground sources, such as the building steel, buried grid and cold water piping. If they are connected at the same point, there is no potential for ground loops, yet a redundancy is achieved. A water pipe used for a ground could rupture, building steel could have accumulated resistance over several floors. By tying into all of these, the possibility of a disruption is greatly minimized.

6.2.1 Ground

Contrary to popular notion, the National Electrical Code (NEC) does not favor the use of a ground rod. Section 250-81 states that if the following items are available, they are to be used first and bonded together to form the grounding electrode system:

- Metal underground water pipe
- Metal frame of the building, where effectively grounded
- Concrete-encased electrode
- ground ring

Section 250-83 states that if none of the above is available, then and only then can you ensure any of the following:

- Other local metal underground systems or structures
- Rod and pipe electrodes
- Plate electrodes

6.2.2 Recommended Acceptable Values

The most elaborate grounding system may not perform satisfactorily unless the connection of the system to earth is adequate for the particular installation. It follows, therefore, that the earth connection is one of the most important parts of the whole grounding system. It is also the most difficult to design.

The connection to earth or the electrode system, needs to have sufficiently low resistance to help permit prompt operation of the circuit protective devices in the event of a ground fault, to provide the required safety from shock to personnel, and protect the equipment from voltage gradients that may damage the equipment. Resistances in the range of 1 to 5 ohm range are generally found to be suitable for computer center installations. The 25 ohm value noted in the NEC applies to the maximum resistance for a single made electrode for safety requirements. This should not be interpreted to mean that 25 ohms is a satisfactory level for computer grounding systems.

6.2.3 Equipment Grounding Conductor Impedance

Electronic equipment is required by the NEC and local codes to be grounded through the equipment grounding conductor and bonded to the grounding electrode system at the power source. The impedance of the equipment grounding conductor from the electronic equipment back to the source neutral-ground bonding point is a measure of the quality of the fault return path. A high impedance measurement indicates that there are poor quality connections in the equipment grounding system. Properly installed and maintained equipment grounding conductors will exhibit very low impedance levels. Recommended levels for equipment grounding conductors is to have levels that meet the code requirements and has a value of less than 0.25 ohm.

6.2.4 Grounding of Building Structural Steel

Where it is accessible, all structural steel should be electrically grounded and bonded into a single electrically conductive mass. Such grounding and bonding may be by structural means, such as welding, bolting, riveting, or by grounding and bonding jumpers. Earthing of the structural building steel system is also recommended. The structural building steel system is required to be bonded to the

grounded conductor of the incoming ac supply system at the service entrance as well as to the equipment grounding conductor system and the main (metallic) cold water piping system.

6.2.5 Special Forms of Earth Grounding Electrodes

The use of any separate, isolated, insulated, dedicated, clean, quiet, signal, computer, electronic, or other such improper form of earth grounding electrodes for use as a point of connection of the Isolated Ground (IG) Equipment Grounding Conductor is not recommended. These IG grounding schemes may not meet code requirements for effective grounding. The general perceived need for an isolated earth grounding electrode scheme in relation to the IG method is not based on good engineering practice. Isolated earth grounding electrode designs have no means for limiting the potential developed across the intervening impedance in the commonly shared ground medium when a current is caused to flow through it. As a result, lightning may create conditions of several thousands of volts between two or more grounding electrodes causing a safety hazard and damage to associated equipment.

6.2.6 Bonding of Metal Sleeves

The behavior of an independent grounding conductor is very different from that of a power circuit grounding conductor. These installations need to be treated specially and have each end of the metal sleeve bonded to the associated ground conductor. This requirement is due to the one way current flowing in the ground conductor acting on the metal sleeve as if it is a magnetic core of an inductor. Failure to properly bond these structures will allow for substantial voltage differences to occur on the associated equipment creating a safety hazard and potential equipment failure. These installations are commonly found on metal conduits entering the computer rooms or where physical protection is being applied to ground wires.

6.3 Signal Reference Grid

A signal reference grid should be designed for the computer room. This provides an equal potential plane of reference over a broad band of frequencies through the use of a network of low-impedance conductors installed throughout the facility.

Certain access floor designs can be used to provide the signal reference grid. The integrity of the grid must be maintained in order to achieve a reliable reference plane. Typically, this will involve a floor system with bolted stringers. Snap-on stringers or "stringerless" designs are also available, though these cannot provide the

same integrity. A supplemental grid constructed of #4 AWG copper bonded at its intersections should be installed (FIPS PUB 94). For bolted stringer systems, 24 inch or 36 inch grids should be sufficient. In snap-on or stringerless systems where the floor grid does not provide the signal reference grid, the signal reference grid should be constructed with 24 inch intersections. The entire grid should be tied into the common point of ground.

6.3.1 Recommended Practices for Signal Reference Grid (SRG)

The following is a list of recommended pratices for an SRG see FIGURE 6-4:

1. **Follow applicable codes and standards for safe grounding. There is no conflict between safe grounding for people and effective high frequency grounding for sensitive electronic equipment.**

2. **Select a suitable SRG approach and assure that it is installed and maintained properly.**

3. **Permanently bond the SRG to all accessible building steel and to each metallic path crossing the plane of, or within 6 ft. of, the SRG.**

4. **If a single point of entry for power and grounding cables into the space exists, then single-point grounding of the area to local building steel is acceptable if this grounding system is verified periodically by skilled test personnel. The equipment protected by the SRG should be multipoint grounded to the SRG.**

5. **Bond the SRG to each piece of sensitive equipment.**

   Sun equipment is typically not classified as sensitive electrical equipment and proper application of power cord grounding meets product grounding requirements. Supplemental bonding of the equipment is at the customers discretion.

6. **Bonding connections to the SRG should be as short as practical with no sharp folds or bends.**

7. **Connections of sensitive electronic equipment should not be made to the outermost grid conductor of the SRG. Heating, ventilation, air-conditioning equipment and panelboards should be connected to the outer most grid conductor. Critical equipment should be located and bonded to the SRG at more than 6 feet away from the building steel or other potential lightning paths.**

8. **All separately derived systems, serving the equipment on the SRG, should have their power grounding point bonded to the SRG.**

9. **All cooling, heating, ventilation, and air conditioning equipment, associated piping, metal wall studs, panelboards, switchboards, transformers, and similar equipment within the protected area, shall be bonded to the SRG.**

10. **No connections should be made to remote or dedicated earth grounding points or any similar attempt at separate earth ground paths.**

11. **All data and power cables should lay on or be very close to the SRG.**

12. **Documentation should be complete in all details, including the proper grounding and bonding of heating, ventilation, and air conditioning equipment, piping, raceways, and similar items. The responsible engineer should not expect the installers to complete the design.**

Note – Source IEEE STD 1100-1992 Powering and Grounding Sensitive Electronic Equipment

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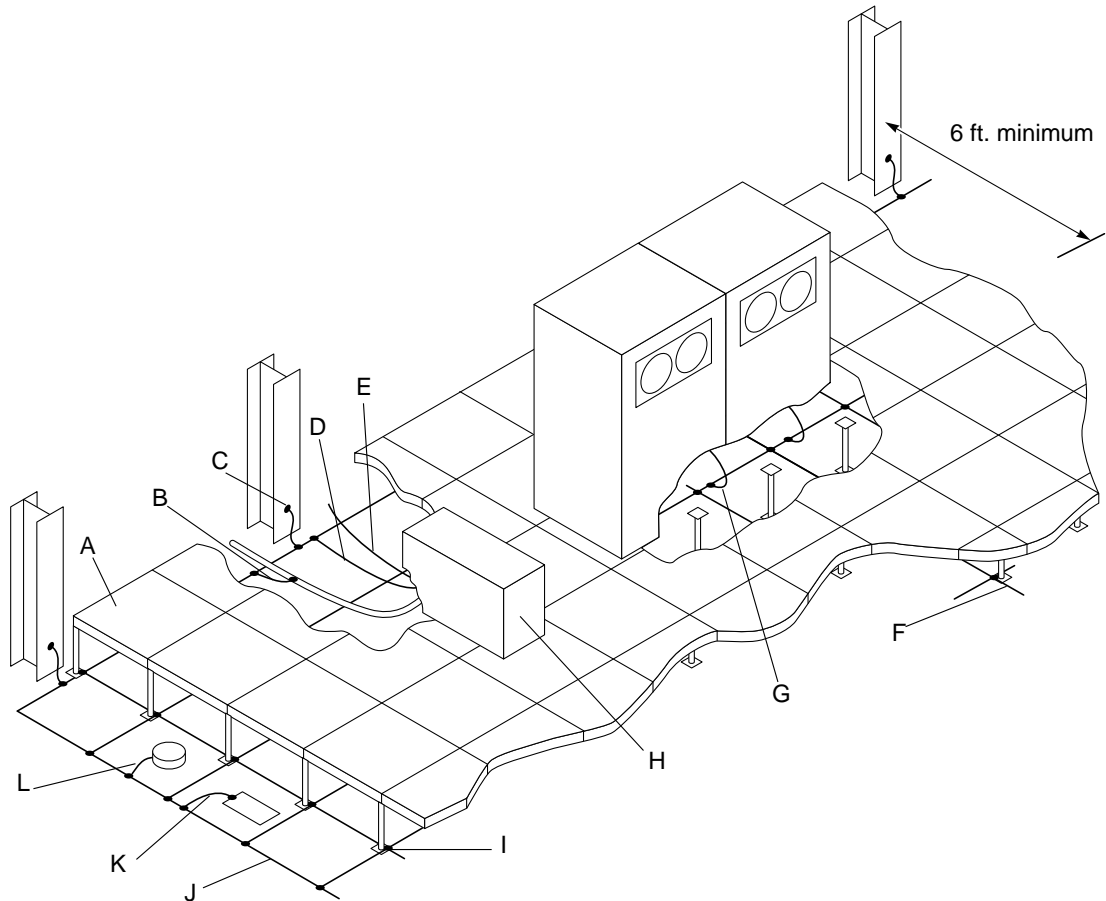
Legend:
A-Typical 2 ft. x 2 ft. floor panel
B-Conduit entering room bonded to SRG
C-Welded connection to steel column
D-PDU ground connector to SRG
E-Metallic bond to ground electrode
F-SRG
G-Equipment bonding strap to SRG (optional)
H-PDU (Power Distribution Unit)
I-Pedestal connection to SRG
J-Perimeter bond strand (#4 Awg minimum)
K-Metallic objects typically bonded to perimeter conductor (HVAC, plumbing or electrical)
L-Data conduit bond to outer strand of SRG.

FIGURE 6-4   Typical Installations With Power Distribution Unit and Signal Reference Grid

6.4   Input Power Quality

The quality of the incoming power can be a governing factor in the determination of the system components and design. A well-designed power and grounding system can be instrumental in maintaining appropriate conditions and avoiding unplanned outages. Numerous factors can disrupt, degrade or destroy electronic systems. High frequency, high amplitude noise, high ground currents, a low power factor, surges or sags in voltage, harmonic distortion or numerous other factors can all affect proper functioning of electronic components. Each individual hardware design will have specific tolerances, but the following chart from FIPS PUB 94 is a useful guide when other more specific information is not available. Additional information regarding the tolerances of specific models of Sun Microsystems hardware can be found in this Chapter.

TABLE 6-1   FIPS PUB 94 Tolerances Chart

Environmental attribute	Typical Environment	Typical acceptable limits for computers and power sources		Units affected and comments
		Normal	Critical	
Line frequency	0.1%- 3%	1%	0.3%	Disk packs, tape, regulators
Rate of frequency change	0.5-20 Hz/s	1.5 Hz/s	0.3 Hz/s	Disk packs
Over- and under-voltage	5-6%,-13.3%	+5%, -10%	3%	Unregulated power supplies
Phase imbalance	2% - 10%	5% max	3% max	Polyphase rectifiers, motors
Power source: tolerance to low power factor	0.85-0.6 lagging	0.8 lagging	<0.6 lagging or 0.9 leading	Indirectly limits power source or requires greater capacity unit with reduced overall efficiency
Tolerance to high steady state peak current	1.3-1.6 peak/rms	1.0-2.5 peak/rms	>2.5 peak/rms	1.414 normal; departures cause wave shape distortion

TABLE 6-1   FIPS PUB 94 Tolerances Chart *(Continued)*

Environmental attribute	Typical Environment	Typical acceptable limits for computers and power sources		Units affected and comments
		Normal	Critical	
Harmonics (voltage)	0-20% total rms	10-20% total; 5-10% largest	5% max total 3% largest	Voltage regulators, signal circuits
DC load current capability of power source	Negligible to 5% or more	<0.1% w/ exceptions	As low as 0.5%	Half wave rectifier load can saturate some power source, trip circuits
Voltage deviation from sine wave	5-50%	5-10%	3-5%	Affects regulators, signal circuits
Voltage modulation	Negligible to 10%	3% max	1% max	Voltage regulators, servo motors
Transient surges/sags	+10%, -15%	+20%, -30%	+5%, -5%	Regulated power, motor torques
Transient impulses	2-3 times nominal peak value (0-130% V-s)	Varies:1,000-1,500V typical	Varies:200-500V typical	Memory, disks, tapes having data transfer rates, low level data signals
RFI/EMI and "tone bursts" normal and common modes	10V up to 20 Khz; less at high freq.	Varies widely-3V typical	Varies widely-0.3 typical	Same as above
Ground currents	0-10 A rms + impulse noise current	0.001-0.5 A or more	0.0035 A or less	May trip GFI devices, violate code, introduce noise in signal circuits

Note – Source FIPS PUB 94, Guideline On Electrical Power for ADP Installations

6.4.1   Power Conditioning Technology

When the power source does not meet the equipment requirements additional hardware is required to allow the system to operate in its environment. TABLE 6-2 gives a typical cross reference of power issues and possible solutions that can be evaluated for specific problems.

TABLE 6-2   Power Conditioning Technology

Power Quality Condition	Mode	Transient Voltage Surge Suppressor	EMI / RFI filter	Isolation Transformer	Voltage Regulator (electronic)	Voltage Regulator (ferroresonant)	Motor Generator	Standby Power System	Uninterruptible Power Supply	Standby Engine Generator
Transient Voltage Surge	CM	2		1	2	1	1	2	2	
	NM	2			2	1	1	2	1	
Noise	CM		2	1	2	1	1	2	2	
	NM		2	2	2	1	1	2	1	
Notches				2		1	1		1	
Voltage Distortion						2	1		2	
Sag									1	
Swell					2	1	1	2	1	
Undervoltage					1	1	1	2	2	
Overvoltage					1	1	1	2	2	
Momentary Interruption							2	1	1	
Long-term Interruption										1
Frequency Variation								2	1	2

1. It is reasonable to expect that the indicated condition will be corrected by this power conditioning technology

2. There is significant variation in the power conditioning product performance. The indicated condition may not be fully corrected by this technology.

Note – Source IEEE STD 1100-1992 Powering and Grounding Sensitive Electronic Equipment

6.4.2 Voltage Tolerance

All of the Sun Microsystems equipment models covered in this guide are of a single phase design. Nominal voltage ranges can be 100/120 or 200/240 depending on individual unit specifications.

6.4.3 Frequency Tolerance

Most Sun equipment is designed to operate within a current frequency range of 47-63 Hz. This range should provide adequate flexibility to accommodate differences in power sources both in the united states (60 Hz) and abroad (50 and 60 Hz).

6.4.4 Harmonic Content

Potential harmonics problems can be caused in a data center by the interaction of the electronic equipment with the power loads or by switching power supplies. Numerous factors, such as harmonic distortion, load imbalance, high neutral current and a low power factor can all affect the power distribution system. The results can lead to decreases in efficiency and reliability that can adversely affect overall computer operations. Harmonics mitigation, however, is extremely difficult as it is contributed to by the computer hardware, and any changes in the room load or configuration can change create new problems and negate any previous corrections.

Sun Microsystems equipment has been designed to address the concerns of Harmonic Distortion, and should be generally compatible with other modern equipment of similar designs. Other equipment designs that do not have the advantages of currently accepted design corrections should ideally be isolated on separate circuits.

6.4.5 Branch Circuits

Each branch circuit should contain a dedicated grounding conductor that is grounded to earth at the central grounding point. While the conduit can be used as the safety ground, a separate wire is recommended. All wires must be of the same gauge, and the neutral wire must be connected to ground at the source. All national and local wiring codes must be followed. The hardware will achieve its path to ground through the power cord. It may not be necessary, but is highly recommended, to strap each unit of hardware to the signal reference grid.

6.4.6   Voltage Spikes

Voltage spikes are rises in the voltage that are caused most often within the power distribution circuits by items turning on and off, such as the cycling of compressor motors. A UPS, and filtering on the primary side of the system, will normally stop most spikes originating upstream from the UPS. If, due to design decisions at a particular site, a UPS is not being used then some other form of regulation or surge suppression should be designed into the system. Circuits serving sensitive electronic equipment should be isolated from such influences. Large spikes can interfere with energy transfer or the associated electrical noise can cause signal corruption.

6.4.7   Lightning Protection

Lightning protection systems should be designed, installed and maintained in accordance with NFPA 78, Lightning Protection Code or any superseding local or National Codes. The impact of lightning on computer installations can either be direct or indirect. The effects may be on the utility power feed, directly on the equipment, or through high frequency electromagnetic interference or surge currents.

Lightning surges cannot be stopped, but they can be diverted. The plans for the data center should be thoroughly reviewed to identify any paths for surge entry into the data center. Surge arrestors can be designed into the system to help mitigate the potential for lightning damage within the data center. These should divert the power of the surge by providing a path to ground for the surge energy. Protection should be placed on both the primary and secondary side of the service transformer. It is also necessary to protect against surges through the communications lines. The specific design of the lightning protection system for the data center will be dependent on the design of the building and utilities and existing protection measures.

Sun equipment is designed to meet the surge requirements of IEC 1000-4-5.

6.4.8   Emergency Power Control

Within the data center, a single point of disconnect for all electronic systems is required by NFPA 70 and NFPA 75 at each point of entry. Multiple disconnect means for these power systems are also acceptable, but in either case, the switches must be unobstructed and clearly marked. Protective covers may be placed over the buttons to avoid accidental contact, but access cannot be locked out. This switch should disconnect power to all computer systems, HVAC, UPS and batteries. If the UPS is located within the data center, the disconnecting means must stop power to this unit.

If the unit is located remotely, the disconnecting means must stop the supply from this unit to the room. Exceptions to this rule include small UPS (750 volt-amperes or less) within the room.

Even though it is not required by code, it is still recommended that all power sources in the room, including the exceptions listed, be controlled by the disconnecting means so as to provide the greatest degree of safety to the hardware and personnel. It could be these systems, or the gear they supply, that are the cause of the fire.

6.5 Wiring and Cabling

All wiring and cabling should be designed and installed in accordance with the requirements outlined in this document and the National Electrical Code (NFPA 70) or superseding national or local codes or standards. In some cases, the recommendations provided in this document may exceed the minimum recommendations outlined in NFPA 70.

All wiring and cabling should be run in an orderly and efficient manner. This is particularly important beneath the raised floor. The nature of the data center requires frequent modifications, and it is extremely important that obsolete cabling be removed so as to avoid air-flow obstructions and to allow for future installations. Orderly cabling will minimize the potential for disruption due to disconnection of cables when work is taking place.
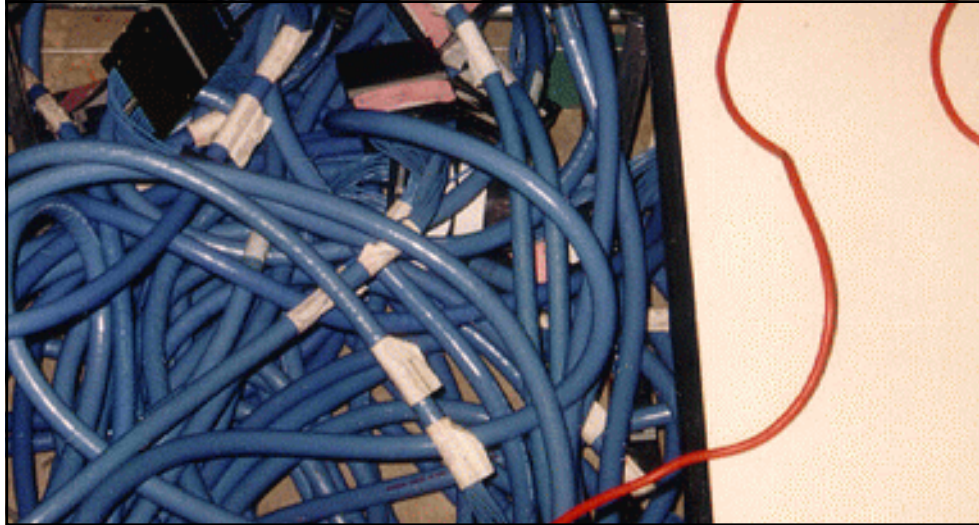
FIGURE 6-5   Disorganized Cabling

Whenever possible, data and power cables should intersect perpendicularly so as to minimize the potential for generation of disruptive electronic noise on the lines. For the same reason, try to run data and power cables at least 6 inches apart when they are parallel. Unused or partially connected cables can also act as antennas. Cables should not be cut in place and left in the subfloor void.

Temporary extension cords should not be used in the subfloor void. If these are used above the raised floor, proper safety precautions should be taken to ensure that they are not a tripping hazard, and that they will not be damaged.

Do not use power strips with switches, surge protectors and fuses within the data center. These can counter some of the designed protections of the hardware, and are not necessary. In addition, the switches on these strips can easily be tripped, causing unwanted outages. This is a particular susceptibility when they are placed on the raised floor beneath desks, or on the edges of aisles.

6.6   Electromagnetic Compatibility (EMC)

Electromagnetic interference (EMI) is radiated and conducted energy from electrical devices that produce electromagnetic fields, and can come from a variety of sources. The electrical noise currents associated with EMI can interfere with the signals carried by the electronic components and cabling of some equipment. Sources of EMI or Radio frequency interference (RFI) can be found within or outside the

computer room environment. Airports, telecommunications or satellite centers and similar facilities are common external sources of EMI/RFI. Internal sources include the hardware itself. Sun equipment will be tolerant of most common EMI/RFI levels. If high levels are suspected, it may be necessary to conduct a study to determine whether shielding or other remedial actions are necessary.

6.7 Electrostatic Discharge (ESD)

Electrostatic Discharge (ESD) can be extremely damaging to electronic components. By definition, static electricity is an electrical charge at rest. The discharge of this built-up energy can cause numerous problems.

6.7.1 ESD Damage

Today's electronic equipment has a much denser geometry, and is composed of thinner, more easily damaged, materials. Changes in the design, manufacturing process and materials used has improved ESD sensitivity considerably. While Sun equipment has been designed to be tolerant of significant ESD events, it is important to take precautions in the design of the computer room to minimize exposure to discharges. This is particularly important when unprotected components are being handled during installations or upgrades.

Damage caused by ESD can take the form of catastrophic failures, but is more often low-grade damage that may not show up during initial setup, but can make the unit more susceptible to a later failure. Cumulative degradation of the components can also occur as the result of repeated, low voltage exposures. These types of problems are very subtle, and extremely difficult to detect.

6.7.2 ESD Control

There are numerous means of controlling static generation and ESD. The following is a brief listing. A detailed site-specific evaluation should be conducted to determine the most appropriate program for each controlled area.

- The use of appropriate personal grounding equipment (wrist straps, heel grounders, etc.) by operators in contact with sensitive components can lessen the likelihood of human instigation of ESD.
- Cabinet covers should be closed at all times. Covers should only be opened by trained personnel using proper grounding when inspections, repairs or reconfigurations are needed.

- A properly grounded access floor system with static dissipative tile surfaces will provide a proper path to ground. Excessive build-up of contaminants on the floor grid, or the use of inappropriate cleaning agents can allow an insulative barrier to accumulate, affecting the static dissipative capabilities of the floor.
- The use of appropriate carts and furniture in the room will significantly decrease the risk of ESD since the movement of inappropriate chairs or carts can easily generate static charges.
- Room ionizers may be appropriate to help neutralize static charges in manufacturing areas or print rooms. An ionizer emits negative and positive ions that are attracted to charged objects, and can neutralize them.
- Isolation of activities or hardware that are likely to generate static charges can decrease the risks to more sensitive hardware. This is one reason why print equipment should be kept out of the computer room.
- The maintenance of appropriate relative humidity levels is probably the most universal and easiest means of addressing ESD concerns. Appropriate moisture levels will help ease the dissipation of charges, lessening the likelihood of catastrophic failures. The following chart illustrates the effect moisture levels can have on electrostatic charge generation.

TABLE 6-3   Electrostatic Voltage At Workstations

	Static Voltage	
Means Of Static Generation	**Relative Humidity 10-20%**	**Relative Humidity 65-90%**
Walking Across Carpet	35,000	1,500
Walking over vinyl floor	12,000	250
Worker at bench	6,000	100
Vinyl envelopes for work instructions	7,000	600
Common polly bag picked up from bench	20,000	1,200
Work chair padded with urethane foam	18,000	1,500

Note – Source Simco, A Basic Guide to an ESD Control Program for Electronics Manufacturers

6.8 Site Surveys and Site Power Analyses

High speed electronic systems and equipment may be more sensitive to disturbances in the ac power system than conventional loads. The effects of power disturbances on sensitive electronic equipment can take a wide variety of forms including data errors, system halts, memory or program loss, and equipment damage. In many cases it is difficult to determine whether the system hardware and software malfunctions are actually caused by disturbances in the power system supplying the equipment. Usually some level of survey and analysis of the power system is required to determine if the power disturbances are effecting the system performance. The basic objectives of surveys and site power analyses are:

- Determine the soundness of the power distribution (wiring) and grounding systems supplying the equipment
- Determine the quality of the ac voltage supplying the equipment
- Determine the source and impact of power system disturbances on equipment performance
- Analyze the survey data to identify cost effective improvements or corrections, both immediate and future.

It is important to keep these approaches in mind when a site is experiencing problems that appear to be power related. All too often, corrective action is installed in a "shotgun" attempt to solve the problem. Although this method will sometimes minimize the problem, in a majority of cases, it may do little or nothing to solve the problem and can even aggravate conditions.

An effective site power survey should also include the participation of the local electric utility. Utility personnel can provide site-specific information on disturbances that can occur on the system and assist in the evaluation of equipment to meet the site requirements.

Sun recommends that large new installations and sites having problems contract with a trained professional to conduct a site survey for verification of installation and mitigation of problems that may affect the installed equipment.

Receiving, Transporting, and Staging Guidelines

Prior to the installation of hardware in a newly constructed to renovated area, a final inspection should be performed. All electrical and mechanical systems should be tested to ensure proper operation. All areas both above and below the raised floor should be examined, and problem areas should be corrected. Environmental conditions in the room should be brought to optimal levels prior to the installation of the hardware. It should be noted that the installation of the hardware will change the environmental condition, through the addition of the heat-load, and additional set-point and air distribution modifications will likely be necessary. A final decontamination should also be performed in accordance with the guidelines presented in Section 4.9, "Activity and Processes" on page 4-17.

7.1 Unloading, Moving, Unpacking, and Storing Guidelines

All hardware should be thoroughly inspected prior to acceptance. All packaging should be examined for signs of physical damage to the packing materials. Any damage to the packing materials or evidence of water or fire exposure should be noted on the shipping receipt. The equipment should then be unpacked (at its final location) and visually examined to identify any damage to the unit itself. Any such damage should also be duly noted prior to acceptance.

The hardware should not be exposed to dramatic fluctuations in temperature. The equipment should be allowed to acclimate to conditions for at least 24 hours prior to installation. This is particularly important if the unit is significantly colder than the environment in which it will be installed. Please consult your Sun Microsystems representative or you hardware installation manuals for the specific limits for the hardware to be installed.

Plan the access route from the delivery point to the staging area and then to the final destination of the hardware. Ensure that all corridors, doorways and aisles provide adequate clearance. If the existing loading dock meets height or ramp requirements for a standard freight carrier truck, a pallet jack can be used to unload the system. If not, a standard forklift [with a maximum outside tine dimension of 27 inches (685.5 mm) and a minimum inside tine dimension of 15 inches (381.0 mm)] or other means must be provided. The unit can also be shipped via a truck with a lift gate.

Please consult your Sun Microsystems representative or refer to the installation guide for the specific hardware being installed for the dimensions of the hardware and shipping crates.

7.2 Equipment Staging Area Guidelines

Ideally, a dedicated staging area will be designed into the plans for the data center. This area would be maintained within the same parameters as the computer areas, but would be isolated from the operational hardware areas. The packing, unpacking and handling of hardware as it's being installed or deinstalled can generate or stimulate considerable amounts of contamination. In addition, the actions associated with these activities often require elevated levels of traffic in and out of the data center; thus increasing the possibility of exposure to more loosely controlled surrounding areas. The very nature of a typical data center dictates the necessity for frequent changes to accommodate revised needs and technology changes. This volatile, changing characteristic of the environment should be accommodated in the planning of the room, so as to minimize the possible detrimental effects of the necessary actions.

Conversion Information

TABLE A-1 Conversion Factors

Multiply	By	To Obtain
˚C	(˚C*1.8)+32	˚F
˚F	(˚F-32)/1.8	˚C
Btu/hr	0.252	kcal/hr
kcal/hr	3.968	Btu/hr
tons	12,000	Btu/hr
Btu/hr	0.0000833	tons
kW	3412.97	Btu/hr
Btu/hr	0.000293	kW
CFM	0.0283	m^3/min
m^3/min	35.315	CFM
m^2	10.764	ft^2
ft^2	0.0929	m^2
m	3.281	ft
ft	0.3048	m
cm	0.3937	in.
in.	2.540	cm

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