CHAPTER 8

INSTALLATION

8-1. Objectives of an automated data processing (ADP) system

The objective of an ADP system is to provide accurate, reliable, and continuous data. This objective can only be achieved through the careful and intelligent design of all aspects of the complete ADP system. The purpose of this chapter is to ensure that the installation of the system is performed in such a manner that a continuous trouble-free service is achieved. Initial site preparation and proper installation procedures can prevent many of these related problems. Other power related problems can only be remedied through the proper use of the proper power line conditioning devices.

a. Environmental conditions play a major part in insuring that computer systems operate at maximum efficiency. Proper temperature control becomes very important. Variations in temperature lead to component thermal shock, resulting in excessive downtime. High particulate counts in the atmosphere contaminate and cause problems. Corrosives have short- and long-term adverse effects. Vibration in heavy industrial areas and 40-story plus buildings must be observed and considered. Radio frequency interference (RFI) must be detected and prevented, as is the case with electrostatic discharge (ESD).

b. The personnel responsible for the design, installation, startup, maintenance, and operation of an ADP system must possess a high degree of knowledge in many seemingly unrelated fields. They not only must have a wide ranging technical ability but must also have a background in bid documents and interpreting specifications.

8-2. Contract bidding

The general philosophy of the contract bidding process is one of competition. Originally the idea was to give everyone a fair chance to compete for contracts but with competitive bidding to keep the vendors honest and provide the lowest price possible. The procurement methodologies grew around this conception and were designed to produce open and honest competition for all purchases.

a. It soon became apparent that finding the lowest bidder was neither appropriate nor practical for all procurements. There are many cases where it was absolutely necessary for an executive decision to determine which bidder was truly capable of providing the required product or services that would fulfill the client specifications in an acceptable manner. Experience demonstrates that in many cases the product or services of the low bidder may be simply unacceptable.

b. The specifications that are furnished to the bidders are the technical requirements of the end product and also as important, these specifications become the legal framework of a contract between vendor and client. The bidders are provided a detailed description of what must be supplied and are cautioned to bid realistically because their product must pass the scrutiny of inspectors that are knowledgeable and expert in their fields. The bidder must be aware that failure to fulfill the terms of the specifications may result in rejection of the product. Under these circumstances the contractor offering the lowest bid to produce that which has been clearly specified is awarded the contract.

c. Throughout the installation of an ADP system it is absolutely mandatory that the inspectors and engineers assigned to the project become familiar, proficient, and expert in understanding the bid specifications and the construction specifications.

d. The ADP manufacturer must submit in its proposal an item-by-item detailed compliance statement to all requirements of these specifications as well as complete floor plans, one-line diagrams, bill of materials, and all the data requested in the various parts of these specifications. The requested data should be presented on the specification compliance forms in the proposal. One-line diagrams must specify type, frame, and trip ratings of all circuit breakers. Floor plans shall identify all proposed equipment with weights, dimensions, access, and cooling requirements. Presentation of equipment not in full compliance to this specification must not relieve the successful bidder from meeting all requirements of this specification at no extra cost to the owner after the award of contract.

e. In the event of discrepancies between the drawings/attachments and the technical specifications, the technical specifications shall take precedence.

f. Off loading, setting in place, installation, interconnection cables, hardware, lugs, and testing of all equipment specified are to be the responsibility of the contractor including any and all associated labor, parts, tools, and equipment.

g. The final acceptance is to be made after the equipment has been adjusted and has demonstrated (site acceptance test) that it fulfills the requirements of the specifications and the supplier has furnished all required test documents in accordance with the specified testing procedures.

8-3. Inspection requirements

Installation inspection may be listed under the very broad heading of construction management. The inspector has the responsibility of being the eyes and ears on site throughout installation and should possess skills in many disciplines of engineering and construction. It is strictly the responsibility of the installation inspection individual or team to make certain that he receives the opportunity to evaluate all factors throughout an installation. The inspector must carefully determine the requirements and present appropriate and valid information to the other members of the construction management team.

a. The ultimate and final responsibility for a completed, one-line installation will rest upon a single agency or with an individual within that agency. The responsibility of the personnel performing startup inspections and verifying the compliance of the completed system with the specifications cannot be overemphasized.

b. Although there is considerable similarity in the design of all electrical apparatus associated with an ADP installation, there can be extreme variations in design tolerances, mechanical and electrical settings, and other physical characteristics.

c. Many quality features are now built into equipment, some of which add to the apparatus cost, principally because the manufacturer must protect his product from abuse and failure in normal use. Even though a system has been properly engineered and quality apparatus of the specified rating has been purchased, the equipment will ultimately experience premature failure if the proper installation and startup procedures are not adhered to. Reliability can be built into a system but proper installation is the key factor in initiating a proper equipment life cycle.

d. Many unknown and sometimes hazardous conditions are discovered through installation inspections. At times a simple and apparently minor adjustment can be made during installation which if found in time may benefit both client and vendor.

e. From the viewpoint of economics, the inspection process cannot and must not be allowed to degenerate into complacency. Assumptions cannot and must not be tolerated, and one must not assume the vendor or contractor possesses all of the necessary experience to complete a successful installation. It is the responsibility and duty of the purchaser and user to ensure that all equipment is installed so as to fulfill the concept of the design and to produce a reliable finished product.

f. The inspector or inspection team must make certain to continue to develop his expertise to enable him to carry out the responsibilities assigned to him. Inspection personnel must be able to work closely with both vendor and with those in authority within his own organization. The need for attention to detail cannot be over emphasized. In summary, it is the inspection staff that will carry the responsibility for maintaining a high standard of construction and start up of any project.

8-4. Ground system installation inspections

The earth ground system is a direct conducting connection to the earth or a body of water serving as a low impedance path to earth for the purpose of establishing an earth reference for the X0 terminal on the secondary of a transformer and for the purpose of providing a low impedance path for the discharge of lightning. The National Electrical Code (NEC) requires that the resistance to ground (earthing impedance) be less than 25 ohms (NEC Article 250-56). The grounding electrode conductor must be minimum No. 8 AWG copper or as shown in Table 250-66 of the NEC. The earthing impedance for a computer quality installation should be less than 5 ohms, and the earthing conductors should be the same AWG size as the supply conductors connected to the transformer secondary. The earthing electrode should penetrate the earth to a depth of 8 feet below the frost line and the earthing conductor must be connected to the earthing electrode with either cad-weld, silver solder, or a terminal block clamp located below ground level. Use of a saddle clamp is unacceptable as it will loosen with age, freezing, thawing, etc.

a. Doubling the diameter of an earthing electrode will decrease earth impedance by 10 percent, while doubling the length of a ground rod will decrease earth impedance by up to 40 percent. The most cost-effective and common method, however, is generally multiple electrodes. A technique of multiple electrodes spaced a minimum of 6 feet apart is the most effective. When the existing service entrance electrode cannot be measured (not able to shut building down), a second electrode should be driven 6 feet from the service entrance electrode. If earth impedance of the new electrode is less than standard, the service entrance electrode and the new electrode should be tied together with the same size conductor as used to connect the original electrode to the service entrance. If the second electrode impedance is above standard, drive a third electrode. Tie these two electrodes together with the same AWG wire used to the service entrance (No. 8 AWG minimum). Measure the impedance to earth. Continue this process, encircling the original electrode, until the standard is achieved. Then tie earthing electrodes to the original electrode as above. New electrical grounding test equipment is now available that can measure the ground resistance without disconnection of the earthing electrode and shutting the building down.

b. There is a difference between a neutral (grounded conductor) and ground (grounding conductor). The neutral carries current back to the source (transformer). A separate non-current carrying grounding conductor is also required to meet the NEC requirements for safety. This equipment grounding conductor is required to bond equipment frames to ground and to carry any fault currents to insure circuit breaker trips under fault conditions. On delta connected systems always insure that a separate ground wire is run to bond equipment frames to ground. Additionally, a separate, full-sized, non-current carrying, insulated conductor (back to the transformer earthing electrode) may be required to provide a zero volt system reference point for ADP equipment (see paragraph 4-6). This single point grounding conductor is used to connect the ADP equipment signal ground to the electrical service entrance point and is required by the NEC.

8-5. Neutral junction installation inspections

Neutral is the junction point on a wye circuit or the center tap on a split-phase circuit. The neutral conductor provides the return path for current from the load to the supplying transformer. The neutral conductor is connected to the grounding electrode system by a grounding electrode conductor. This connection may be made at any location between the source terminals (typically a transformer or generator) and the first disconnecting means or overcurrent device. The neutral is then bonded to the equipment grounding conductors at this same point.

a. The neutral wire cannot be used for safety grounding. In the NEC, the neutral is referred to as the grounded conductor, while the safety ground is referred to as the grounding conductor. The grounding conductor (green wire) is the non-current carrying conductor (Section 250-26 of the NEC) and should carry zero current, except for any ground fault currents and for the discharge of static electricity. Underwriters' Laboratories (UL) approved or listed equipment does not cause current to flow in the ground conductor. The neutral conductor may never be connected to the grounding conductor in any circuit breaker panel except the main entrance panel (Section 250-24). The neutral conductor should never contact conduit or circuit panel cases. Connecting the neutral to ground in breaker panels causes the ground to operate as another neutral. This violates the code and is a safety hazard and can be a primary contributor to ground potential differences in a building.

b. The only place ground and neutral can deliberately be tied together is at the building entrance distribution panel and on the secondary of any distribution transformer, including isolation transformers.

8-6. Safety ground installation inspections

Grounding accomplishes several purposes and safety considerations must take precedent whenever there is a conflict of interest. The task to be accomplished is to make the installation as safe as possible and at the same time satisfy all practical requirements for noise emission and susceptibility. The three basic purposes of grounding are safety, logic reference, and shielding. Safety falls into the categories of limiting "touch" voltage and providing a return path for fault current to ground. Logic reference provides a zero volt system reference for power supplies and shielding protects the electronics from high frequency noise.

a. Safety ground is an alternate path for the return of fault current for the purpose of interrupting (tripping) the branch circuit breaker and for establishing a point of reference to X0 terminal of the transformer. This conductor should be sized with the ability to handle the appropriate current to permit tripping the branch circuit breaker in the event of a fault. The impedance from any outlet to the transformer X0 terminal shall not exceed 2 ohms at 120 volts ac, 1 ohm for 240 volts ac, 0.5 ohm for 480 volts ac, etc. A clamp-on ammeter on the ground conductor should read near zero. Any reading in excess of 0.2 A should be cause for concern and the reason for this excess current should be found and eliminated. Earth ground and safety ground should touch only at the X0 terminal.

b. Any fault or leakage between an ungrounded conductor and a grounded enclosure will produce fault current. Leakage current may be harmlessly drained away, but a short circuit current must be promptly terminated by protective fuses or circuit breakers. The same devices which protect against line-to-line or line-to-neutral faults also protect against line-to-ground faults. Therefore, the ground return path must have a low enough impedance so as not to limit the fault current to a value that will prevent prompt tripping of the protective device. The electrically continuous conduit and equipment ground conductor must be connected directly to the neutral of the power source at the building entrance neutral-ground bond. This is at a secondary of a transformer, output of a motor-generator (M-G), or at the building entrance service equipment if no isolating transformer is interposed.

c. The connection between the conduit or enclosure safety ground and neutral must not permit fault current to flow through a separate connection between the enclosure and a driven earth or other qualified ground connection. If fault currents have to pass through two driven earth stakes or rods, the resistance of these earth grounds would prevent many circuit breakers from tripping. A very low ground resistance for a driven earth ground might be 5 ohms (25 ohms is often acceptable). Two such earth grounds in series would be 10 ohms and when in series with a 120 volt ground fault would allow only 12 A of current to flow. This is not enough current to trip the lowest circuit breaker rating in common use, a 15 A breaker.

d. To ensure prompt operation, a circuit breaker must see from five to ten times its rated current. Ground path impedance between the fault point and the connection to neutral, plus all other circuit impedances, should not exceed 0.8 ohm for a 15 A circuit breaker (to meet a times ten criteria). For a 150 A circuit, this would be 0.08 ohms maximum. It is clear that driven earthing rods cannot meet this requirement, but direct wiring connections can.

e. Connecting some equipment to one ground rod and other equipment to a separate ground rod is a violation of the NEC and will create noise currents and voltages between the two rods. These ground loop currents result in noise on computers and other electronic systems and their interconnecting data cables.

f. The predominant type of grounding in Europe and the United Kingdom is the “TN” system. Like the method used predominantly in the United States and Canada, this scheme uses a grounded power source with the frame of the load grounded directly through a separate safety ground conductor to the neutral at the power source.

g. The ground conductors connect equipment frames to safety ground and to each other to limit the voltage that can be present on the frame of a product to a safe level to protect personnel. The voltage difference between the ends of a safety ground conductor should never exceed a fraction of a volt at power frequencies (50 or 60 hertz) except during a fault to ground condition and then only until a protective circuit element (circuit breaker or fuse) can interrupt the power from the source. Such a ground fault might be the result of either an insulation or component failure in the equipment or a failure in the conductors supplying power. The conduit and grounding conductors are not intended to carry any portion of the load current. They are to carry only fault currents, leakage currents, and noise currents.

h. At power frequencies, 30 volts root mean square (RMS) is commonly specified as an upper limit for “safe” voltages. A momentary excursion above this during the time it takes for a fuse or circuit breaker to clear a fault is not considered a significant hazard.

i. At higher frequencies and with short duration impulses, the human body can tolerate much higher voltages and currents than at power frequencies. This is fortunate because as frequency content increases, the voltage drop for a given leakage or noise current also increases. High frequency and impulse voltage signals of 150 to 200 volts appear regularly on ground conductors associated with 120 volt circuits. Their duration, however, is usually measured in microseconds and they cannot normally be detected by touch.

j. The most important consideration for computer reliability and operation, as well as other electronic systems is a simple point ground reference within its environment. The computer system’s reliability will be enhanced by using this technique. The building service entrance should be the initial reference for the single point ground system or even more desirable is the reference for the computer system's treatment device.

8-7. Inspecting for unbalanced loads

High or "noisy" neutral-to-ground readings can indicate a poor power balance between loads. Improperly balanced loads will cause excessive neutral current to flow, resulting in a voltage drop across the neutral conductor. Balancing the loads should reduce this current/voltage and if it does not, the neutral-to-ground bond should be checked, and the grounding conductor size and insulation verified. Where the major portion of the load consists of electric discharge lighting, data processing, or similar equipment, there will be harmonic currents present in the neutral.

8-8. Utility power systems installation inspections

American utility companies attempt to maintain electrical power within certain tolerances. See Section 2-2.b. for a discussion of typical values.

a. In addition to the voltage and frequency tolerances allowed by the utility supplying the ADP system, there are six basic power line problems to be considered when inspecting an ADP installation.

(1) No voltage (loss of power) is very easy to detect. No instrumentation is required, only attempting to turn on the lights or some piece of equipment. Causes can range from downed power lines to failed transformers, to tripped circuit breakers, etc. These power outages may last for a short one-half cycle of the 60 hertz sinewave (8.3 milliseconds) or for several hours. Most are no longer than a few seconds.

(2) High or low voltages/amplitude changes in the sinewave can be detected with a voltmeter or a voltage recorder. Causes may be power lines, distribution panels, and/or the wiring being too heavily loaded. In addition, being too close to the source of the power or too far from the source of power can cause large voltage fluctuations, as well as starting or stopping heavy motor loads, non-uniform loading of poly-phase transformers, or poor regulation. If these conditions continue for more than 8.3 milliseconds, but less than 2 seconds they are high or low voltage line conditions, often referred to as high-average or low-average line voltage.

(3) Harmonic distortion refers to sinewave misshaping caused by harmonics (multiples) of the primary frequency. When 60 hertz power is generated, inherently all the odd harmonic frequencies (180 hertz, 300 hertz, 420 hertz, etc.) are generated but only the 3^{rd}, 5^{th}, and 7^{th} normally have sufficient amplitude to be of concern. Generally, these are so small as to go undetected except with very sophisticated equipment. Flat-topping of the sinewave, as seen on an oscilloscope, is the first indication of harmonic distortion. Causes may range from overloading or improper loading of transformers, faulty regulation transformers, fluorescent or other electric-discharge lighting, to data processing equipment.

(4) Noise is normally detected as bad or faulty data and is investigated with an oscilloscope. Oscilloscopes are used to detect and analyze high frequency events or even to analyze the 60 hertz power sinewave. Noise is a low voltage, low current, high frequency signal riding on the 60 hertz sinewave and is characterized by having a repeatable frequency pattern, one that can be determined and analyzed. Generally it is electromagnetic interference (EMI) and is caused by having the power or data lines or the equipment too close to a source of EMI; a large motor or transformer for instance. Improper grounds or grounding can also be a cause. Noise can also be RFI if a radio tower or transmitter is located nearby.

(5) Transients or impulses are high voltage, high-current, fast bursts of energy riding on the 60 hertz sinewave. They also exhibit a non-repeatable frequency pattern even when resulting from the same repeated event. They exhibit extremely fast rise times (1 microsecond to peak) and last for less than 8.3 milliseconds, usually decaying to 50 percent of peak value in 1 millisecond or less. Because they have no repeatable frequency pattern and are random in occurrence, they are extremely difficult to detect. Power line analyzers must be used to detect the presence of transients although the first indication of their existence is usually data errors, computer crashes, and damaged circuitry. Microprocessor based equipment is very susceptible to damage from these anomalies. Transients occur whenever the current through any inductive load (motors, transformers, coils of any kind) is changed at a rapid rate. The result is a voltage impulse that follows the equation, $-E = L\,di/dt$. This rapid change in current is the result of switching actions, sudden power outages, and applications of power. Transients are also induced on power and data lines by nearby lightning strikes or have data lines too close to power lines that are being switched.

(6) Finally, the sixth of these anomalies and the most common one is any combination of the above. While any of these problems can and do occur by themselves, the more general rule is for them to occur in combinations. Transients always accompany voltage outages. High or low voltages may result in noise when power supplies are put under the strain of having to work at input voltage levels outside their design limits.

8-9. RFI inspections

RFI is any emission of electromagnetic (EM) energy having an undesirable effect on other electronic equipment. As electronic data processing equipment has become more sophisticated and dependence on the continued on-line operation of this equipment has grown, the effects of RFI have become more prevalent.

a. Although RFI of sufficient levels can adversely affect most electronic circuitry, among the most susceptible are disc drive positioning circuits and plotter mechanisms. As little as 1.0 volt/meter can be harmful to this equipment. The necessary sensitivity of these circuits make them susceptible to extremely low level interference unless they are adequately shielded. Due to the necessity for special instrumentation to detect EM radiation and its possible presence in practically any location or environment, it is imperative that RFI susceptibility specifications for all ADP equipment be published by the manufacturer and that an RFI survey be included in all site preparation surveys for proposed systems locations.

b. Regardless of location, urban or rural, industrial or residential, sources of RFI abound. Some of the more prevalent sources of RFI are:

(1) Radio transmitters

(2) Radar transmitters

(3) Aircraft navigational equipment

(4) Microwave ovens

(5) Automobile ignition systems

(6) Induction ovens

(7) Diathermy equipment

(8) Relay operated equipment

(9) Electric motors

(10) Radio receivers

(11) Television receivers

(12) Furnaces

(13) Home appliances

(14) Switching contacts

(15) Other electronic equipment

c. These devices can appear at any time before or after the installation of ADP systems, without any noticeable change to the environment, adding to the subtlety of failures induced by the effects of undersized EM radiation. A survey for RFI presence may save considerable time and duress when troubleshooting recurring intermittents and failures without apparent cause.

d. A survey of the vicinity will reveal a transmitting tower, or a check with occupants in nearby facilities will indicate other interference problems. In any case, a survey utilizing appropriate instrumentation is recommended when interference is suspected.

e. Many commercially available instruments can be utilized in performing the survey. Field strength meters, electronic field sensors, spectrum analyzers, and the electronic oscilloscope are most common. The spectrum analyzer is the most sensitive and accurate device to locate the presence and identify the source of RFI. Tuning the spectrum analyzer over the band will indicate the relative levels of radiation as well as its frequency. A portable electronic field sensor should be used to check for areas of increased or decreased field strengths once the source has been identified.

f. To begin a survey, first make a plan drawing of the location indicating all windows, doors, furniture, and equipment. Near the affected equipment, set up a spectrum analyzer and record all frequencies indicated with their respective power levels. Using the portable electronic field sensor, observe the field strength present at the affected equipment and record the reading in volts per meter on the respective location of your plan drawing. Now record several readings within the location using the portable sensor.

(1) Record the field strength outside the building on each side and try to identify the source of any interference by noting the direction of strongest readings.

(2) Compare all recorded field strengths to the published equipment specifications and note any readings that are excessive.

(3) Should you not have the necessary instrumentation, and the interference is from a radio or television broadcast station, the following method may be used to determine field strength.

(a) Obtain the station's radiated power from the station engineer.

(b) To determine the approximate field strength use the formula:

$$E = \frac{(30P_t)^{1/2}}{d} \text{ volts/meter}$$

Where: E = field strength in RMS volts/meter
P_t = transmitted power in watts
d = distance from isotropic antenna in meters

This calculation does not account for any insertion loss resulting from walls, buildings, etc.

(4) If it is suspected that interference is occurring sporadically or only at various times, a strip recorder can be connected to the E field sensor and left to record field strength over several days.

g. The methods chosen to eliminate RFI problems will depend on the physical characteristics of the site as well as the field strength present. Some interference problems may be corrected by simply providing a separate grounding connection to the frame or case of the affected equipment or moving equipment to another room. More serious cases may require the purchase or construction of a completely shielded enclosure incorporating filtered power and shielded ventilation.

h. In some cases, it is recommended that all walls, ceiling, floor, doors, and windows be shielded. The shielding material should be bonded at all seams to ensure maximum effectiveness of the shielding. The shielding material should then be connected to a good earth ground. This treatment can provide as much as 80 decibels (dB) attenuation at 100 megahertz (MHz), when door sealing and ventilation duct shielding have been provided. Attenuation by 80 dB will reduce field strengths to one ten-thousandth of their former levels.

i. RFI problems are primarily solved with Faraday Shielding and special window glass like that used in microwave ovens. When shielding of the entire room is required, run a No. 12 AWG bare copper wire around the bottom of the shield, solder it to the shield, solder the shield together and reference the shield to the transformer ground (X0). An RFI detector reading of one-half (1/2) volt per square meter to 1 volt per square meter is the maximum allowable.

j. Never place electronic equipment closer than 3 feet to fluorescent lighting due to the RFI radiation from the lamps.

8-10. ESD inspection

ESD is a transfer of charge between bodies of differing electrostatic potentials. The term ESD event also includes both EM fields and corona effects before and during a discharge. The ESD event may include significant electric (E) and magnetic (H) field phenomena due to current flow. ESD phenomena thus includes EM field generation over a broad range of frequencies, from dc to the low gigahertz region.

a. One of the subjects may be fabricated electronic equipment or subassemblies. This subject is generally at local electrostatic ground potential. The second body, usually in the role of an intruder, is often a human; but it may be any mobile object such as a wheeled chair, an equipment cart, a vacuum cleaner, etc. The victim may also be affected by the EM fields generated by a discharge between an intruder and a third mass which is not itself the subject.

b. Static electrification refers to all processes which produce segregation of positive and negative electrical charges by mechanical action. These processes operate by contact between two surfaces with subsequent separation.

c. The most common charging mechanism is frictional or tribo-electrification. This mechanism involves electron or even ion transfer upon contact due to the frictional localized heating of microscopic contact between solid surfaces. The localized microscopic zones are fluidized, leading to increased charge mobility. Accumulation of charges can occur if the relaxation time or charge decay is long due to low conductivity values.

d. The distinction between a conducting and a non-conducting object is based on its surface resistance in ohms-per-square centimeter. A non-conductive object cannot be discharged by grounding points on its surface. The electrostatic charge that can be developed between two materials is a function of their relative position in the tribo-electric series. The term tribo-electric derives from the Greek “tribos” meaning to rub. Hence, tribo-electric is the generation of static charge by rubbing.

e. Everyday actions can develop large electrostatic potentials due to static charging. As a typical example, walking across a synthetic fiber carpet on a relatively dry day (30 percent relative humidity) can easily develop an electrostatic potential of 20 kV or more. The floor need not be carpeted. Walking across many present day floor coverings can also produce an electrostatic charge. Waxing the floor may worsen the situation, adding to the electrostatic charge that may be developed. Simple movement of the body within clothing can also develop large static potentials. At 15 percent relative humidity, walking 20 feet on a vinyl floor, the human is charged to 12 kV, whereas at 80 percent relative humidity, the human is only charged to 1.5 kV. Walking on a carpet at 15 percent relative humidity, the human can charge to 35 kV.

f. The minimum voltage necessary for a person to detect an electrostatic discharge is approximately 300 volts. However, sufficient energy may be contained in electrostatic discharges that are below the threshold of human perception to cause damage to electronic equipment. The maximum potentials that may be routinely developed via electrostatic charging ranges from 1 to 10 kV. Given the proper conditions, potentials may reach 20 to 25 kV. Corona effects, which bleed off charge, limit maximum electrostatic potentials to 35 to 40 kV. The electrostatic potential difference that exists between two charged objects, or between a charged and uncharged object, may be viewed or modeled as existing between two plates of a charged capacitor. In the extreme case, human body electrostatic discharges may contain energy levels as great at 400 millijoules for voltages of 40 kV and a capacitance of 300 picofarads (pF).

g. Damage to equipment caused by electrostatic discharge can be minimized by placing grounded static discharge mats in areas where movable furniture (chairs, file racks, etc.) or pedestrian traffic can discharge into a sensitive component. Personnel working on sensitive equipment may need to be continuously grounded through a wrist strap. Equipment used in the maintenance of sensitive components should be grounded and special manufacturer maintenance procedures must be followed.

8-11. ADP system environment inspections

Computers and other ADP devices along with their peripheral equipment have very precise environmental tolerance limits. Therefore, the precise control of temperature, humidity, and particulate contamination is critical to their proper operation.

a. The ideal computer room environment is critical.

(1) Temperature should be adjustable from 65°F to 80°F but shall optimally be set at 72°F and not vary more than ±1°F from that setting. The temperature should not vary by more than 10°F anywhere in the room. Variations of the component temperatures, with time, causes flexing of the components, component leads, printed circuit boards, connectors, etc. Every time a junction or connection is flexed it is stressed and every time it is stressed it deteriorates.

(2) Humidity is also critical and shall be controlled within ±2.5 percent R.H. over an operating range adjustable from 45 to 55 percent R. H. The ideal setting is 55 percent (±5 percent) as there are minimum static problems at 55 percent relative humidity. Humidification is the only way to control static.

(3) The only acceptable form of humidification is with pure steam humidifie rs designed for computer room environmental control. These offer the highest efficiency and lowest maintenance and the steam is distilled. Never use cold mist humidifiers that release water-born contaminates into the computer room atmosphere. Wet bulb humidifiers with heating elements require continual cleaning of sludge tanks to keep them efficient. Evaporative and infrared methods can release corrosive salts, excessive humidity, and mineral contaminates directly into the computer room environment, eventually leading to computer system failures.

b. To help execute these parameters, the computer room should be constructed with wall insulation rated R-19 or better; floors and ceilings should also be insulated. All windows should be thermopane. All outside windows should have sunscreens and all glass above the 12th floor should be Faraday shielded. Airflow from the air conditioner should be designed to provide the maximum amount of mixing possible from the discharge to the return. Discharge should not be directly into the equipment to prevent thermal shock to components when air conditioner operates on and off. Equipment should be laid out to avoid creating any air dams; i.e., equipment in a line should have a minimum open spacing between individual products of 8 inches, and particulate producing equipment such as printers should be placed closest to the cold air return in the product lineup.

c. The computer room air conditioner should run almost all of the time to eliminate temperature cycling. Ethylene glycol coolant is best suited for meeting this requirement because it uses a smooth running turbine compressor, it can be easily regulated, and has a heat transfer 1 to 1.6 times that of water, depending upon the ratio of water to ethylene glycol. However, to use ethylene glycol, a 243-hour chilled water loop is required. If ethylene glycol cannot be used, then use freon. However, freon cannot be throttled and will result in more frequent temperature cycling.

(1) The advanced A-frame air-conditioner arrangement with cross-circuited cooling coils connected to two separate refrigeration systems under electronic sequencing control provides greater sensitivity in cooling and dehumidification. Greater surface area and lower velocity air offers quiet, efficient cooling with less turbulence. This system enables 60 percent cooling to continue during servicing of one of the refrigeration systems.

(2) The air-conditioning unit should have an electric resistance heater sized to offset the sensible cooling capacity in the dehumidification mode. The reheat element should be of low-watt density, tubular construction with a no-corrosive metal sheath. The electric reheat should be three-phase system identical, to prevent the possibility of uneven phase balance. The reheat element should be electrically and thermally protected in accordance with UL requirements. Both heating and cooling functions should have automatic step starting with time delay to minimize power line requirements. Temperature and humidity sensors should be solid-state devices to ensure accurate system control and high reliability.

(3) When evaluating the air-conditioning system it is desirable to have a high coolant pressure differential across the compressor, but, a high delta P across the evaporator causes freezing and is an indication that either the dryer is dirty or the airflow over the evaporator is insufficient. A check of feeder line amperage gives a good indication of the continuing health of the air conditioner. A drop in current from previous readings indicates a loss of freon.

d. Computer room air must be filtered to 15 microns or less. The newer disc drives require 10 micron filtration. Electronic filters must be equipped with Faraday shielding, have internal water jets for wash-down cleaning and address smoke, hydrocarbons, and particulates. Air supply shafts must have Faraday shielding because spark gap precipitators generate frequencies in the gigahertz range. Particulate count must be less than 150 parts per liter, chlorine count less than 10 parts per billion, and sulfur count below 10 parts per billion.

8-12. Pre-site inspection

Computers and other electronic systems are often adversely affected by the environment in which they are located and expected to function. Variations in temperature will stress solder joints and contact points due to the variations in the expansion and contraction characteristics of the different materials involved; i.e., fiberglass, plastic, metals, etc. If the humidity is too low, static becomes a problem; too high, and things begin to grow. Chemicals in the air can corrode and airborne particulates can be conductive or abrasive and affect circuit boards and the operation of electronics, as do externally generated voltage impulse transients and noise.

a. To optimize operation, all of the above areas must be considered and dealt with and the problems eliminated. Ideally, this should be done prior to the installation of the computer or electronic system. Practically, however, these areas are very often not properly addressed until after installation and the equipment operation begins to suffer, thus causing attention. Whether addressed prior to or after installation, the physical steps taken to insure the best possible site preparation should be nearly the same.

b. Begin a pre-site inspection several miles from the site and always involve as many of the following personnel as possible – the salesman who sold the equipment, the data processing manager, maintenance manager, building contractor, air-conditioning contractor, and electrical contractor. Within a five-mile radius of the site, note the general terrain, other industries in the area and their types, antennas, transmission lines, etc. Determine whether the power is brought into the facility underground or overhead. Note everything, even the prevailing winds. When arriving at the site, view the building from all sides and especially from the roof.

8-13. Pre-inspection for electrical systems

Perform the electrical inspections with the electrical contractor or the electrician. Start at the building's main service entrance.

a. Find and verify the earthing electrode installation.

b. At the transformer, check for any contamination, corrosion, or leakage; check the transformer temperature and insulation and the cooling fans, if any.

c. Follow the power to the ADP or electronics room. Check all transformers as above. Observe all aluminum terminals for correct connections and connection integrity (listen and smell).

d. Measure and record currents and voltages at each transformer and in the distribution panels.

e. Check and record voltage across each circuit breaker and the current on each breaker.

f. Check all neutral and ground wires for current.

g. Verify the neutral and ground busses to be insulated and isolated. Verify that the voltage between the neutral and ground is no more than 0.2 volt RMS (1-2 volts peak to peak as measured on an oscilloscope).

h. Check primary and secondary bus voltages and check for any ground to neutral voltages. Verify voltages and current and that the system is balanced. Check that wire sizes and breaker sizes are compatible.

i. Verify that there is a neutral wire for each circuit breaker in the distribution panel; i.e., the same number of neutrals as there are circuit breakers.

j. If the ADP equipment is not yet in place, verify that it can be unloaded at the dock and moved to the final destination with a minimal risk of damage. Verify that equipment can be properly stored to protect it from the elements prior to installation. Verify proper clearances, stairways, elevators, door widths, heights, etc., so the equipment can be transported to its final location without fear of damage.

8-14. ADP room inspection

Inspect the computer or electronics room where the equipment is, or will be, located. The ac power for this equipment should be supplied from a transformer dedicated for this purpose and located as close as possible to this room. This transformer, and any isolation transformer, must have the secondary neutral solidly grounded. If the ac specifications for the equipment cannot be met, a line treatment device will also be required. All receptacles in this room should be the isolated ground type.

a. The computer (electronics) room should not be a passage area; i.e., no convenient pathway from one area to another area. It should have a raised floor, minimum height 6 inches, with ramps rather than stairs into the room and be vinyl covered. Wash the computer room floors with Ivory soap and wet mop only. Use no ammonia (chlorine) and the floor should be one piece vinyl. Seal all masonry and have no glass or carpets on the walls.

b. Raised floor posts must be painted, galvanized, or cad-plated to prevent rust. Permit no roller chairs in the room to prevent electrostatic discharge problems. All floor supports should also be grounded. This ground should be a “dirty ground” back to the isolation transformer X0. It is not to be connected to neutral or computer ground except at the transformer X0. This ground can be used for grounding of non-electrical items such as static mats, etc.

8-15. Air-conditioning system inspection

The room should have its own air-conditioning system. The air conditioner should be dust free. Electronic filtering is the optimum. The air conditioner should provide positive air pressure in the room to help keep out outside contaminants. There should be no corrosives in the room. Possible corrosives include ammonia, hydrocarbons, hydrogen sulfide, nitrates, oxides or nitrogen, oxidants, and sulfur dioxide. Room temperature should not vary more than 10°F from hottest to coldest spot anywhere in the room and the overall temperature should not vary more than 10°F per hour. This can best be attained by using a chilled water coolant system rather than freon, as chilled water systems are easier to throttle, meaning less “on and off” operations. Humidity should be between 50 and 60 percent at all times.

Equipment should not be positioned in a manner to create air dams. Provide a minimum of 8 inches clearance between any side-by-side devices. Note the intake and exhaust vents; they should be located to allow maximum air mixing in the room. If there are outside windows exposed to sunlight, some type of correction will be required to shade the windows.

8-16. Lighting system inspection

Lighting should be from 55 to 72 candlepower throughout the room, with the backs of all equipment receiving equal or greater lighting from the fronts. Place no equipment closer than 3 feet to any fluorescent lighting to prevent RFI radiation problems. It is more than likely that the fluorescent fixtures in a large business complex will be powered from a three-phase, four-wire system. Fluorescent lighting systems are non-linear loads and, therefore, are generators of 3^{rd} harmonic currents. The recently developed electronic ballast consumes less power but has the decided disadvantage of injecting even higher levels of 3^{rd} harmonic current into a power distribution system. It is essential that the special characteristics of these non-linear loads be understood to prevent the failure or disturbance to critical systems. Every part of the room must have telephone access through additional telephone jacks or long telephone cords.

8-17. Fire safety inspection

If fire safety is provided through a sprinkler system, a means should be provided to automatically disconnect the computer or electronics power when the sprinkler is activated. Due to restrictions on the emission of chloro-fluorinated hydrocarbons (CFC) to the atmosphere, Halon systems are being phased out. The next generation of clean agent fire suppression systems uses environmentally friendly products such as FM-200, a compound of carbon, fluorine, and hydrogen, that is odorless, colorless, electrically non-conductive, non-corrosive and leaves no residue when discharged. Since FM-200 is discharged as a gaseous vapor, it is able to penetrate enclosures and reach areas that water or dry chemical agents cannot. A fast response, automatic fire detection system is commonly installed to activate the suppression system and limit both fire and smoke damage. In most cases, photoelectric smoke detectors will be used due to the high airflow conditions found in ADP facilities. Careful attention must be paid to airflow rate and how it impacts detector spacing. Aspirating (air sampling) smoke detection systems may also be installed in some facilities to allow detection during the fire's incipient stages.

8-18. Total evaluation

During the first site preparation walk-through, all the above information should be recorded, as taken, and stored. Every six months to a year, all information should be recorded again and compared to the previous and original data. In this way, the affects of added equipment can be evaluated and any addition of equipment that is not readily apparent or should not be on the dedicated system can be found.

a. Proper environmental instrumentation will help in collecting much of the required data. Instruments are available for monitoring: light levels (light meter), humidity (sling psychrometer or hydrometer), temperature (chart recorder), RFI (field strength meter), static (Anderson Effect Meter), vibration, and microbial contamination. If, however, these instruments are not readily available, a fairly thorough evaluation of environmental conditions can be made with an amprobe, a sling psychrometer, and the human eye. Green door hinges indicate the presence of chlorine; black or greasy door hinges result from hydrocarbons. Check air-conditioning vents for signs of corrosion and hydrocarbons. A white powder on the printer is caused by chlorine and blackening of the leads of the dual-in-line packs (DIPS) and chips are caused by the presence of sulfur. A glass ashtray can be used to detect vibration. Place it on a smooth surface and clearly mark its location. Return in a few days and if it has moved, vibration is indicated.

b. Hydrocarbons and sulfur can be removed with an electronic air cleaner. Chlorine or a high concentration of sulfur will require a scrubber. Vibration difficulties can be handled by placing the equipment on four-inch thick cork mats. High noise levels may require special noise abatement procedures such as special acoustic wall covering, ceiling tiles, etc.