CHAPTER 4

SYSTEM ENGINEERING REQUIREMENTS

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4-2. Standards and specifications. Definitive standards and specifications for hardening facilities against HEMP/TEMPEST do not exist. However, efforts are underway to develop them and to integrate them with other HEMP/TEMPEST requirements and with electromagnetic compatibility (EM) standards. Results of some recent studies have been reported (refs 4-1 through 4-3). Campi et al. (ref 4-1) compiled a listing of Government and industrial standards, specifications, and handbooks related to HEMP/TEMPEST mitigation. Most of these standards pertain to EMC and TEMPEST (table 4-1). However, many of these specifications and standards may be useful in integrating EMP hardening requirements. A comprehensive listing of EMP-related standards is available in reference 4-4.

4-3. Electromagnetic integration. Facilities often are required to be protected against several EM environments, including HEMP (or other EMP), electromagnetic interference (EMI), electromagnetic compatibility, and lightning. The facility may also have TEMPEST requirements that impose the need for communications security through control of compromising EM emanations.

a. Incompatible design approaches. Vance et al. (ref 4-2) have examined 70 related standards and specifications and tabulated areas in which the design approaches are not compatible for all EM protection requirements. Many of these incompatibilities are related to methods for grounding cable shields and allowances for penetrating conductors.

b. Correcting incompatibilities. Graf et al. (ref 4-3) have recommended ways to correct these incompatibilities. In view of these studies and other programs, unified EM specifications and standards probably will eventually become available. Meanwhile, designers will find it necessary to integrate the EM design on a site-, facility-, and system-specific basis.

c. Electromagnetic shielding. Generally, the main method used in EM protection is EM shielding. The shielding required for HEMP/TEMPEST is usually more than enough for all other EM protection. A comprehensive discussion of grounding and bonding technology for all EM protection is in MIL-HDBK-419A (ref 4-5). MIL-STD-188-124A gives specific grounding and bonding requirements (ref 4-6).

d. Surge protection. An area in which care must be taken to ensure compatibility in EM integration is surge protection. Some surge arresters used for lightning do not clamp fast enough to protect against EMP. Some ESAs used for EMP may not have great enough current carrying capacity for lightning protection in all situations. Thus, for compatible lightning and EMP protection, a carefully selected combination of protection elements will be required.

4-4. HEMP and lightning protection integration. The EM environment generated by lightning differs from that of HEMP in energy spectral distribution rise time, current levels, pulse repetition and coverage area.

a. Lightning rise time. Many early studies indicated that the typical rise time of lightning was almost three orders of magnitude slower than that of HEMP. More recent work, however, has shown that radiation fields produced by lightning can have much faster rise times. Step leaders in the initial stroke have had measured rise times reportedly approaching 30 nanoseconds. Return strokes have been determined to have initial portions with rise time in the 40- to 200-nanosecond range. A complete lightning flash contains a first stroke with a downward-moving step leader and usually numerous return strokes as shown in figure 4-1. The total flash time can be greater than 1 second.

b. Frequency and current levels. A comparison of lightning and HEMP in the frequency domain shows that radiated lightning energy is higher at low frequencies and lower at high frequencies as indicated in figure 4-2. The current levels of lightning return strokes average nearly 35 kiloamps, but may be less than 10 kiloamps and as high as several hundred kiloamps for so-called "superbolts."

c. Induced transients and injected current. Hazards common with both HEMP and lightning are induced transients coupled onto sensitive elements and injected current from exterior electrical conductors. Lightning also can strike directly with extreme damage potential. In rare cases, the direct strike has been known to cause structural damage as well as electrical damage, even to underground facilities. Thus, facilities need a system of lightning rods with suitable grounding to divert the extremely high currents (up to hundreds of kiloamperes peak) away.

d. Voltage surges. Lightning can produce high voltage surges on power lines without a direct strike. Figure 4-3 shows some typical surge values versus distance from the stroke.

e. Radiated and static fields. One study has identified radiated fields associated with lightning (ref 4-7). Figure 4-4 summarizes approximated typical near-field radiated E-field values. Another study has identified radiated and static fields associated with lightning (ref 4-8). Figure 4-5 shows averages for these fields.

f. Magnetic fields. Table 4-2 lists typical values of the H-field close to a stroke. The close in H-field from lightning thus has higher magnitude than the HEMP H-field (see table 4-2 for magnitudes); since it has greater energy content at low frequencies, shield thickness must be greater than for HEMP.

g. Summary. In summary, integrating HEMP and lightning protection requires--

(1) Greater shield thickness for lightning if protection from close-in strokes is required since the H-field magnitude can be greater, although this is not common practice.

(2) More robust surge arresters for lightning.

(3) Use of lightning rods.

(4) High-frequency protection for HEMP using more sophisticated transient protection and filtering.

4-5. HEMP/TEMPEST and electromagnetic integration. EMC is defined in ref 4-9 as the ability of communications-electronics equipments, subsystems, and systems to operate in their intended environments without suffering or causing unacceptable degradation because of unintentional EM radiation or response. Electromagnetic interference (EMI) results when EM energy causes unacceptable or undesirable responses, malfunctions, degrades or interrupts the intended operation of electronic equipment, subsystems, or systems. RFI is a special case of EMI for which the radio frequency transmission (usually narrow-band) causes unintentional problems in equipment operation. For commercial electronic and electrical equipment, systems, or subsystems, the Federal Communications Commission (FCC) has regulations defining allowable emission and susceptibility levels. Military equipment is regulated by MIL STD 461 and MIL STD 462 (refs 4-10 and 4-11). MIL STD 461 defines allowable emission levels, both conducted and radiated, and allowable susceptibilities, also both conducted and radiated. Other specifications exist, but they apply to specific equipment.

a. Electromagnetic compatibility (EMC). EMC requirements usually apply to individual equipment as well as to the overall system. Because of equipment level requirements, the equipment cabinets or racks often must have a degree of protection, which comprises part of the topological protection.

b. Electromagnetic interference (EMI). The EMI environment has contributors from three main classes:

(1) Natural radio noise. Natural radio noise originating mainly from atmospheric disturbances (including lightning) and partly from extraterrestrial sources.

(2) Purposely generated signals. Signals that are generated purposely to convey information but that may interfere with the operation of other equipment.

(3) Man-made noise. Man-made noise such as spectral components generated incidentally by various electrical and electronic devices, motors, generators, and other machinery.

c. Achieving electromagnetic compatibility. Achieving EMC involves the same principles as protection against HEMP/TEMPEST. Generally, a HEMP/TEMPEST-protected facility will provide EMC protection as well over most of the desired frequency range. Some exceptions are--

(1) Frequency ranges. EMC encompasses the low frequencies, including the power frequency spectrum (5 to 400 hertz), and therefore, may have shielding and filtering requirements different than those for HEMP or TEMPEST protection.

(2) Spectra encompassed. EMC includes the VHF and microwave spectra as well as system-specific radiators or susceptibilities requiring special

treatment. Examples are susceptibilities to high power radars beyond the HEMP/TEMPEST frequency range and switching transients below the HEMP/TEMPEST frequency range.

(3) Interference within enclosures. EMC also can include interference between equipment within the same shielded enclosures.

d. Exceptions. Clearly, EMC integration requires that special engineering attention be given to these stated exceptions. For further guidance, see references 4-9 and 4-12.

4-6. Environmental requirements. HEMP/TEMPEST protection must withstand adverse environmental conditions that may occur at the facility. The major concern is corrosion of buried grounding or shielding system elements, including exterior steel sheets and buried water pipe or conduit. Other environments of concern include those with high temperatures, excessive vibration, and potential ground shock.

a. Corrosion. Design details and the materials used for external grounding systems and underground shielding elements will affect the corrosion of all exterior exposed metal installed underground throughout the facility complex. Galvanic cells are the main cause of corrosion associated with grounding system and adjacent underground metal objects. A galvanic cell is produced when two dissimilar metals are immersed in an electrolyte and the potential difference between electrodes causes a current to flow in a low-resistance path between them. For HEMP/TEMPEST-protected facilities, the many grounding connections between steel objects, including shielding and reinforcing bars in contact with the shield, and the external grounding system provide a low-resistance conductive path between interconnected metals in the soil. Current will flow from cathodic material, such as copper or concrete-encased steel, through these connections to bare steel, such as pipes and conduits (anodic material). The current flow carries ferrous ions into the earth electrolyte, resulting in galvanic corrosion of the pipes and conduits. Conventional design practice for corrosion protection is to electrically isolate the ferrous metal to be protected from buried copper and concrete embedded steel. The protected metal often is coated with a dielectric material. Conventional procedures must be modified to meet the restrictions and limitations imposed by HEMP/TEMPEST requirements for electrically continuous and grounded pipes, conduit, and electrical equipment. Close coordination is required between grounding system design and that for corrosion protection. Through such coordination, it is often possible to design grounding systems that avoid corrosion problems, reduce corrosion protective requirements, and simultaneously improve the grounding system.

b. Groundwater. In areas with high water tables, groundwater presents a threat to underground shielding elements. Careful design is required to obtain water-tight penetrations of the floor, roof, and exterior walls. This includes piping, conduit, and utility or access tunnel connections.

c. Thermal effects. If the metallic shield is subjected to temperatures somewhat higher than adjacent concrete, the sheets will tend to buckle outward. This condition could occur during construction or during building operation. Shield buckling is undesirable because welds can be damaged, compromising the shield and possibly the steel envelope's structural integrity. To eliminate buckling, provisions for expansion, temperature control, and/or securing the plates must be included in shielding design.

d. Vibration and acoustics. Shielded rooms in which the audible noise level is high should be studied for possible acoustical treatment because of steel's low sound absorption. Likewise, shielded rooms that have vibrating equipment should be given special consideration to avoid resonant vibration of shield panels or shielding elements. Excessive panel vibration could eventually damage welded seams, thus compromising the shielding.

e. Ground shock. If the hardened facility will be in an area of high seismic activity, or if it must withstand nuclear strikes with high overpressures, requirements will be defined for ground shock resistance. Expansion joints may be required between linear plate shielded structures to protect against differential motion from ground shock. Design for ground shock protection should be delegated to structural engineers who have appropriate experience and expertise.

4-7. Cited references.

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4-11. MIL-STD-462, (U) Measurement of Electromagnetic Interference Characteristics (DOD, 9 February 1971). (C)

4-12. USAF Design Handbook DH-1.

4-13. NACSEM 5204, (U) Shielded Enclosures (National Security Agency, May 1978). (C)

4-14. NACSEM 5203, (U) Guidelines for Facility Design and Red/Black Installation, (National Security Agency, June 1982). (C)

4-15. MIL-HDBK-232A, (U) Red/Black Engineering Installation Guidelines (Draft). (C)