

American (U.S.) vs. European (German) Building Code/Standards Comparison
Electrical Power and Medical Gas Systems for U.S. Healthcare Facilities in Germany

EXECUTIVE SUMMARY

1. **BACKGROUND.** During initiation of the designs for two U.S. Department of Defense (DoD) military hospitals in Germany, fundamental differences were discovered between the respective National building codes and industry practices, pertaining to electrical power and medical gas systems design and construction. Certain of these differences were resolved during initial efforts, without compromise to the letter or intent of either Nation's code, and the designed systems were constructible using standard Host-Nation local construction materials and trade practices. In several other cases, it became clear that solutions designed to meet the *letter* of material and hardware requirements of both codes, as opposed to the fundamental *intent* of the code provisions, raised issues with overall system safety, as well as practical constructability and maintainability. The U.S. Army Corps of Engineers (USACE) therefore engaged an independent engineering team of U.S. and German experts (the "Study Team") in the fields of U.S. and German healthcare facility design, tasking them to examine the respective National codes, perform field investigations and interviews, query code officials as necessary, and develop recommendations for construction materials and practices to achieve the safest, most reliable, and maintainable systems for DoD military healthcare facilities in Germany.

2. **ELECTRICAL POWER SYSTEM.**

a. **Basic Normal/Emergency Power System Configuration.** Fundamental differences between U.S. and German/European code requirements for overall power system configuration, hardware (such as Automatic Transfer Switching and overload protection equipment), and overall performance level were resolved early in 2001-2002, when the German building officials agreed that their standard could be modified to meet the U.S. codes without violating any German criteria or regulation. As a result, our German hospital designs fully meet or exceed NFPA Standards 70 and 99, and MIL-HDBK-1191 (*Military Handbook, Department of Defense Medical Military Facilities Design and Construction Criteria*), requirements for a separate and independent normal and emergency power system configuration with single-point system grounding, ten second power outage limitation, no-break power for surgical suites, recovery, other critical areas, and redundant grounding for all patient care areas.

b. **Primary Code Comparison Issues.** U.S. and German/European codes largely agree in recognizing the need for proper circuitry grounding in patient care areas, physical protection of circuits, separation of emergency branch feeder classes, and protection against Electromagnetic/Radio-Frequency Interference (EMI/RFI). However, the codes differ in several respects as to the permissible materials and practices to achieve the required protection or performance level. U.S. codes rely on fully enclosed metallic raceways (normally conduit) to achieve circuit protection, separation, and a second (redundant) ground return path, by what might be termed a prescriptive method.

German/European codes provide for separation of emergency and normal circuitry in a similar fashion to the U.S., though the approach to grounding and circuit physical protection

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does not require, nor in some cases even recognize, enclosed metallic raceways for these applications. In fact, while metallic conduit, Mineral Insulated (MI) metal clad cable, and other raceway systems are available, they are seldom, if ever, used in the German commercial building industry. To meet the letter of the U.S. codes would involve specifying a raceway system which German hospital construction and maintenance personnel were unfamiliar with, raising serious concerns with the probable quality, integrity, and maintainability, of such a system. The resolution of these issues was the primary focus of the code comparison effort. The Study Team focused on the following five (5) areas.

(1) Circuit Grounding. Both NFPA 70 and DIN VDE require a continuous ground path from load to source. The U.S. codes require branch circuits for patient care areas to be provided with a separate, insulated copper grounding conductor, and installed in a metallic raceway, armored cable, or sheathed cable, to serve as a second (redundant) ground return path. For branch circuits, German/European codes require only a single ground return path and, in standard hospital practice, utilize the metallic shield of shielded-conductor, non metallic sheathed cable as the ground conductor, requiring the engineer to calculate the required conductor area. The German codes do however allow a second grounding conductor to be installed with the circuit cable, thereby providing primary and redundant ground return paths. Standard German practice is to support circuit cables with metallic cable trays. Unlike the U.S. codes, German/European codes do not recognize the metallic cable tray as a ground return path, but require that it be properly bonded to the grounding system.

The Study Team recommended against a grounding system based on metallic conduit or MI cable, due to the unfamiliarity of these materials and their installation to German construction and maintenance technicians. They advised that such a non-standard approach would result in a high probability of construction deficiencies, including cable and conductor damage during cable-pull due to such factors as cut-conduit burrs, or overstressing at inadequate bend radii. Of further concern, is that Local National/German technicians responsible for maintaining U.S. facilities could properly maintain such a system.

The Study Team recommended that grounding be based on the German system, utilizing the shielding conductor of shielded-conductor, non-metallic sheathed cable, with a separate grounding conductor installed within the cable as a second ground path to meet the NFPA 70 redundant ground requirement for patient care areas.

(2) Emergency Power Separation/Fault Isolation. NFPA 70 and DIN VDE are very similar in that both require emergency system circuits to be entirely separate from other circuits. Fault isolation is not specifically addressed by either code, but is recognized as a desired benefit of having emergency circuits protected from potentially damaging effects of close-proximity ground fault or bolt-fault conditions in other circuitry. The U.S. system for fault protection requires conductors to be installed in raceways or armored cables, and routing the services via separate raceways, boxes, and cabinets. The DIN VDE provides this protection by requiring that emergency cables be insulated and fire resistance rated for either 30, 60 or 90 minutes, and by

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requiring separation by barriers in single cable trays, or by separate cable trays. This fire rating is an absolute requirement for German installers, as they risk loss of licensure for any deviations.

The Study Team recommended against the use of conduit or MI cable as the basic fault protection feature, for reasons of worker unfamiliarity and maintainability already discussed above. The team recommended a DIN VDE system modified to meet more stringent NFPA 70 separation requirements. This recommendation utilizes German fire rated NHXCH shielded-conductor non-metallic sheathed power cables for emergency power, installed in an appropriately designed, closed, protected cable tray system. The electrical power equipment branch circuitry is to be entirely separate from the critical and life safety branch circuitry, including distribution panel boards. Critical branch and life safety branch circuitry may be supported together by the same cable tray, but must be physically separated by a full height, continuous metallic barrier.

(3) Mechanical Protection. The U.S. standards provide for protection of circuitry from physical or fire damage by enclosure in metallic raceways, cable armor, or MI cable. The German/European standard provides this protection by requiring cables to be fire rated (30, 60 or 90 minutes as discussed above), supported within cable trays, and by restricting installation to very restricted standard-dimensioned "zones" within building walls or partitions. The Study Team recommended against the use of metallic conduit or MI cable as the basis for physical protection of emergency circuitry, for the reasons of worker unfamiliarity and non-maintainability already discussed. Instead, they recommended a DIN VDE system modified to provide additional protection features. This system provides for NHXCH emergency cables to be installed in appropriately separated (as discussed above), covered metallic cable trays, with cable drops protected by electrical rooms on the source end, and by interior walls on the load end.

(4) RFI/EMI Protection. U.S. codes inherently provide for interference shielding by the requirement for conductors to be installed within enclosed metallic raceways, chiefly metallic conduit. Studies have shown that metallic conduit is a very effective EMI and RFI shield. The German/European standards require a very prescriptive approach, utilizing a metallic cable shield and carefully defining the minimum separation distances from cable installations to equipment. Again due to the concerns associated with the installation and maintenance of conduit or MI cable systems by unfamiliar workers in Germany, the Study Team recommended RFI/EMI protection using the German/European code methods.

(5) Grounding Circuit Integrity in Patient Care Areas. U.S. codes require that grounding circuits and conductors be installed such that the electrical continuity of the ground path is maintained and not dependent upon device connections. This includes the requirement that removal of a receptacle will not interrupt the ground path. The DIN VDE codes provide the same requirement. However, as DIN VDE systems do not normally include the redundant grounding conductor, the Study Team developed a receptacle connection detail that would maintain the continuity of both grounds with receptacle removal/replacement. The Team's

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recommendation was to utilize the modified DIN VDE system utilizing the connection detail they developed.

3. MEDICAL GAS SYSTEM. In most respects there is agreement between the U.S. codes and standards (NFPA 99 and Military Handbook 1191) and the German/European Standard (EN 737), regarding system configuration, performance, monitoring requirements, material specifications and handling, installation procedures, and testing/certification. As should be expected, there are differences resulting from the relative detail with which each code body treats the individual system aspects, differences in materials and construction practices, and differences mandated by unique clinical practices and requirements of the medical user. The relative stringency of both codes varies depending upon the system aspect under consideration. Compliance with NFPA 99 has always been a fundamental goal of the U.S. members of the design team to assure system safety. However, issues of construction contractor licensure also dictated compliance with EN 737 if the system were to be practically constructible in Germany. The Study Team examined both code bodies in detail, and provided background information and recommendations of how best to provide the safest, most reliable, and maintainable systems, focusing on the following twelve (12) principle areas.

a. Labeling of Medical Gas Piping. Both U.S. and German/European codes require gas-specific labeling at locations and intervals defined by code language. As the color-coding and gas nomenclature are not the same, there is concern that German maintenance workers or U.S. clinicians might confuse the identification of the gas. In view of the fact that almost all medical gas piping is located in spaces normally accessible only to (Local National/German) maintenance staff, the Study Team recommended utilizing the German/European color-coding system with German language gas names, but with the addition of the English language name, and the gas's chemical symbol, at the label location.

b. Color Coding/Adaptor Geometry of Gas Outlets/Vacuum Inlets. Both codes require that adaptors be geometrically specific for a single gas, connectable only to the corresponding adaptor for that gas. The color codes for the respective gases differ between the U.S. and German/European Codes, and the outlet adaptors must be suitable for the connected equipment, whether German/European or American. As the outlets are directly accessible to U.S. clinicians, as well as to Local National/German maintenance personnel, the preferential selection of one color code over another inevitably risks confusion and possible error. As a result, the Study Team recommended the adoption of a "neutral" color-coding scheme, consisting either of black or white background plates with white or black lettering respectively, of the appropriate gas chemical symbol. Both of these neutral color schemes are acceptable under the German/European standard. Additionally, we will provide colors on the medical gas symbols in accordance with Table 4-3.1.2.4 of NFPA 99 to assist our clinical staff in quickly identifying the appropriate outlet in emergency situations.

c. System Flow and Pressure Requirements. Due to differences in clinical practice, the respective national standards differ in the definition of required minimum flow rates and distribution pressures. As the end-users of these systems will be U.S. clinical practitioners, and

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as the U.S. criteria generally require higher rates of flow, the Study Team recommended the system design be based on U.S. criteria.

d. Preparation (Cleaning) of Piping and Fittings. Both U.S. and German/European codes require that piping and fittings be factory cleaned for oxygen service and delivered to the jobsite with ends capped or plugged. EN 737 has a more rigid hydrocarbon residue level. The U.S. standards address field cleaning of pipe or fittings that become contaminated on the site, whereas EN 737 does not address field cleaning. The Study Team recommended that pipe and fittings be cleaned in accordance with EN 737, with the provision added that any piping which becomes contaminated shall be rejected and replaced.

e. Nitrogen Purge. U.S. codes provide for oil-free (dry) nitrogen purge of piping during brazing to prevent the formation of copper oxide. The German/European standard provides that a non-specific "inert gas" be used for this purpose, which may include nitrogen. The U.S. also requires a nitrogen purge or "initial blow down" to remove particulate from the piping. EN 737 does not include this requirement. The Study Team recommended to restrict the brazing shield gas to oil-free (dry) nitrogen, and to add the requirement for the nitrogen blow down to all project specifications.

f. Brazing Materials. U.S. and German/European standards differ slightly in the specification of brazing metals, although both require high temperature filler metal alloys for this purpose. The U.S. codes specifically do not allow the use of flux in brazing, whereas EN 737 is silent on the matter. While it is common practice in Germany to use no flux in medical gas brazing, the Study Team recommended to utilize brazing filler metal in accordance with EN 737, but also to add to all project specifications a prohibition against the use of flux.

g. System Testing and Certification. In many respects the testing requirements are similar in both U.S. and German/European codes. The German/European code "Test for Particulate Contamination of the Pipeline" is not as rigorous as the "Piping Particulate Test" required by NFPA 99. In addition, the "Piping Purity Test" requirement of the U.S. code is not a requirement of EN 737. The German standard permits all testing, including final certification, to be accomplished by the construction contractor in the presence of an authorized person, whereas the U.S. standard requires final testing and certification to be made by an independent organization. The Study Team recommended requiring testing and certification in accordance with EN 737, modified to require the more rigorous testing parameters of the NFPA 99 Piping Particulate Test, and to include the NFPA 99 Piping Purity Test. In addition, the Study Team recommended that following contractor testing of the systems in accordance with EN 737, the U.S. Government provide for a final certification by an independent expert in NFPA 99 medical gas systems certification.

h. Material Standards for Medical Gas Valves. NFPA 99 requires isolation valves to be full-port, quarter turn, ball type, with brass or bronze three-piece construction and tubing extensions for brazing. German/European standards do not specify materials prescriptively, but provide that materials in contact with gas be compatible with oxygen and other gases in the temperature range

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of -20 to + 60 C. The German/European standard permits mechanical jointed valves, and the Study Team advised that there is a successful track record with these valves in medical gas systems in Germany. The Study Team recommended permitting this option in Germany as the valves are routinely used, familiar to installers, and are more readily serviceable or replaceable than brazed valves. The Study Team also recommended that the project specifications require these valves be of the ball type.

i. Source Equipment Supply Requirements. In general, EN 737 is more stringent than the U.S. standards in requiring three (3) sources of supply - basically a double back up system - for each medical gas/medical air/medical vacuum system, excepting only the vacuum producer for the Waste Anesthesia Vacuum System (WAGE). The U.S. criteria are more stringent in requiring that the WAGE system be served by a minimum of two vacuum producers. The Study Team recommended specifying three sources of supply for the medical gas, air, and vacuum systems in accordance with EN 737, and to require a backup vacuum producer for the WAGE system.

j. Medical Air Dewpoint Requirement. The German/European standard requires a more stringent dryness level (a lower dewpoint) of the medical air supply than the U.S. standard. The Study Team recommended that the medical air system be required to comply with EN 737.

k. Zone Valve Boxes. Both German/European and U.S. standards have detailed requirements on zone valve boxes. Overall, the German/European standard has more stringent requirements and requires several features that provide additional safety, including a box vent, physical separation of service capability, and required emergency or maintenance ports. The U.S. standard has two features providing greater safety, i.e., the requirement for a pressure gauge on the pipeline at each box and the requirement for a valve on the vacuum line. The typical German valve box is provided with such gauges, although not required by EN 737. The Study Team recommended specifying valve boxes in accordance with EN 737 with the addition of a pressure gauge on each pipeline, and a valve on the vacuum line at the box location.

l. Alarm and Monitoring Requirements. Alarm panel requirements are similar between the German/European and U.S. standards, with source equipment and service to individual areas requiring monitoring. NFPA 99 requires two master alarm panels, whereas EN 737 requires only one. In addition, NFPA 99 requires several master alarm and source alarm signals or features not covered by the German/European standard. The Study Team recommended that alarm panel and monitoring design be in accordance with EN 737 with the following modifications to meet NFPA 99 requirements:

- (1) Two master alarm panels.
- (2) Master alarm panels to include the following additional signals or features:
 - Audible alarm signal
 - Medical air dew point level high
 - Local alarm signal
 - WAGE low alarm

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- Instrument air dewpoint high

(3) Local alarms for source equipment to include the following additional signals or features:

- Lag compressor in operation
- High carbon monoxide level
- High medical air dew point
- Lag vacuum pump in operation
- WAGE lag unit in operation
- High instrument air dew point.
- High water level (for liquid ring turbines only)
- High water in separators (liquid ring units only)
- High discharge air temperature

(4) Provide alarm sensors on the source side of the zone valve box for anesthetizing locations.

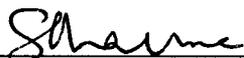
4. CONCLUSIONS.

a. The Study Team's expert recommendations, concerning the design and construction of electrical and medical gas systems in Germany, ensure that the intent of both the U.S. and German/European codes are being met for life-safety and the safeguarding of persons and property from hazards. Where the U.S. and German/European standards were not found to be equivalent in terms of specific details, materials and methods, the Study Team recommended modified design and construction criteria based on the following factors in the order of importance:

- (1) Life Safety and Protection for Hazards
- (2) Maintainability
- (3) Availability of Construction Materials
- (4) Availability of Construction Means

b. Recommendations of the Study Team have been presented to and accepted by the DoD Healthcare Facilities Steering Committee (HFSC). This is the Tri-Service, DoD Authority Having Jurisdiction (AHJ) for the environment of care physical plant standards for all DoD medical military healthcare facilities, worldwide. Therefore, the AHJ has directed that the recommendations be developed into specific criteria language for inclusion in MIL-HDBK-1191, as design guidance for all DoD medical military facilities in Germany.

5. ENDORSEMENT.



Surinder K. Sharma, P.E.
Director, Defense Medical Facilities Office
Tricare Management Activity



Dean Samet, CHSP, CJCS
Associate Director, Standards Interpretation Group
Joint Commission on Accreditation of Healthcare
Organizations

**Proposed Revisions to MIL-HDBK-1191
Implementing U.S./American vs. German/European Code Study Results**

1. Revision to SECTION 01: GENERAL DESIGN GUIDANCE.

Current Version:

1.2 Applicability. This document sets forth DoD policy, procedures, and technical criteria for the design and construction of facilities in the Department of Defense Medical (DoDM) Military Construction (MILCON) program, and other medical design and construction projects over \$750,000 regardless of the funding source (JFIP, CDIP, BRAC, etc.). When feasible, the technical criteria in this document shall be the basis of design for Operations and Maintenance (O&M) and/or Repair and Maintenance (R&M) work, though the specific submittal and approval requirements may vary for these types of projects. In overseas locations, where Status of Forces Agreements (SOFA) or local host country codes and standards conflict with the criteria in this handbook, conflicts will be resolved on a case-by-case basis and whenever feasible settled at the Design Agent level with concurrence of TMA/DMFO.

Proposed New Version:

1.2 Applicability. This document sets forth DoD policy, procedures, and technical criteria for the design and construction of facilities in the Department of Defense Medical (DoDM) Military Construction (MILCON) program, and other medical design and construction projects over \$500,000. When feasible, the technical criteria in this document shall be the basis of design for Operations and Maintenance (O&M) or Repair and Maintenance (R&M) work, though the specific submittal and approval requirements may vary for those types of projects. In overseas locations where either Status of Forces Agreements (SOFA), local host country codes and standards, or other local circumstances may conflict with the criteria in this handbook, alternate design approaches shall be developed to achieve the intent of the criteria without compromising life safety or the safeguarding of persons and property. Conflicts shall be resolved at the Design Agent level, when the Design Agent's medical facilities design office or center of expertise determines that resolution does not represent a significant change to criteria affecting building occupant safety or health. All other proposed changes shall be coordinated through the Design Agent's medical office or center for submission to the Healthcare Facilities Steering Committee.

2. Proposed addition to SECTION 09: PLUMBING AND MEDICAL GASES.

9.1.3 Criteria For Medical Gas Design in the Federal Republic of Germany (FRG).

Considerations of safety and practical constructability require that medical gas systems design for facilities in the FRG be in accordance with European Norm (EN) 737 Standards 1-4, and other EN and Deutsche Industrie Normen (DIN) standards cited therein, supplemented with the following requirements of this Military Handbook and NFPA 99:

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- Pipe marking labels shall be color coded per EN standard, with German language name of the gas or vacuum. In addition, a label carrying the English language name of the gas shall be affixed at the same location.

- Gas outlet and vacuum inlets shall have connections geometrically specific to a single gas or vacuum, non-interchangeable among other gases. Outlet and inlet labels shall be of a neutral color meeting EN requirements, consisting of a black or white background with white or black lettering, respectively, identifying the gas's chemical symbol. Additionally, colors on the medical gas symbols will be in accordance with Table 4-3.1.2.4 of NFPA 99 to assist in quickly identifying the appropriate outlet.

- Piping and source producer shall be sized to meet the maximum demand identified by this Military Handbook or by NFPA 99, at distribution pressures identified herein.

- Flux shall not be used in the brazing process.

- Continuous piping purge with oil-free nitrogen gas shall be required during brazing.

- A nitrogen purge blow down of piping shall be required before connection of the gas or vacuum outlet/inlet in accordance with NFPA 99.

- The EN 737 "Test for Particulate Testing of the Pipeline" shall be modified to meet the more rigid testing requirements of the "Piping Particulate Test" of NFPA 99.

- Two master alarm panels shall be provided for each facility. Additional alarm features required by NFPA 99, but not by EN 737, shall be provided for master, local area, and source equipment alarms panels.

- Medical gas zone valves shall be in accordance with EN 737, of the ball type. Pressure gauges shall be provided on the pipelines at the valve box locations. The medical vacuum line shall include a shutoff valve similarly as the other gas services.

- Two vacuum producers, each sized for 100% of demand, shall be provided for the Waste Anesthesia Gas Evacuation (WAGE) system.

3. Proposed additions to SECTION 09: PLUMBING AND MEDICAL GASES, REFERENCES.

9aa. European Norm (EN) 737-1, *Terminal Units for Compressed Medical Gases and Vacuum*

9bb. EN 737-2; *Anesthetic Gas Scavenging Disposal System*

9cc. EN 737-3, *Pipelines for Compressed Medical Gases and Vacuum*

9dd. EN 737-4; *Terminal units for anesthetic gas scavenging systems*

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4. Proposed Revision/Addition to SECTION 10: ELECTRICAL.

a. Add following to paragraph 10.1.

In countries other than the United States, when host nation treaties, codes, standards, or special local conditions conflict with the criteria in this chapter, resolution shall be achieved in accordance with paragraph 1.2 of this Military Handbook.

b. Add following new paragraph 10.1.1.3.

10.1.1.3 Criteria For Designs in the Federal Republic of Germany (FRG). The electrical design shall be in accordance with DIN VDE Standards 0100, 0298, and 4102, modified to meet the additional safety requirements described herein.

a. The normal and alternate (emergency) power system configuration and protocol shall comply with paragraphs 10.2 and 10.3 covered herein, and those requirements mandated by the National Fire Protection Association (NFPA) standards 70, 99 and 110 for the appropriate medical facility type. The normal and alternate (emergency) power system shall be separate and independent (separate derived source) with single-point grounding that incorporates an uninterruptible power supply (UPS) to bridge the 10 second delay between loss of normal power and restoration of essential functions by the alternate power source for operating rooms, recovery rooms, and other critical areas.

b. Automatic transfer switches (ATS)s with bypass/isolation switches (BP/IS) shall be of the double throw, four pole, draw-out construction complying with paragraph 10.3 and with the requirements of NFPA 70 and 99.

c. Mechanical protection of the normal and emergency system power cables shall be achieved with metallic cable tray, fully enclosed for emergency cables. Essential power branches of the emergency power system, Critical -1, Critical -2, and Life Safety, may be installed in the same cable tray if separated by full height, continuous metallic barriers; the Emergency Equipment branch may be installed in the same cable tray as normal power cables if similarly separated by a full height, continuous metal barrier. When sufficient distribution space is available, complete separation of each branch of the emergency power system in separate cable trays is preferred to minimize the chance of intermingling of cables. All cable trays shall be bonded to ground and each section continuously bonded to the next.

d. Essential branch cable shall be 30, 60 or 90 minute fire rated type NHXCH, including an insulated, properly color-coded grounding conductor, and a concentric, copper conducting shield to be utilized as a second (redundant) grounding conductor.

e. Normal power cables shall be type NYCY cable, including an insulated, properly color-coded grounding conductor and a concentric, copper conducting shield to be utilized as a second (redundant) grounding conductor.

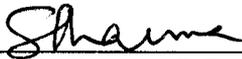
Updated per JCAHO comments, 25 June 2003
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f. Circuit grounding conductors shall be so installed that removal of a receptacle or other device will not interrupt the return ground path, in accordance with NFPA 70 and 99.

g. Circuit protection against electromagnetic interference (EMI) and radio frequency interference (RFI) shall be achieved by the use of cable shielding, and compliance with DIN VDE minimum separation distances to medical equipment.

5. Endorsements.



Surinder K. Sharma, P.E.
Director, Defense Medical Facilities Office
Tricare Management Activity



Dean Samet, CHSP, CJCS
Associate Director, Standards Interpretation Group
Joint Commission on Accreditation of Healthcare
Organizations