Trends, Issues and Requirements for Operating Room Electrical Safety & Design

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Objectives:

- Understanding Potential Shock Hazards for Patients & Staff
- Review Definitions & Requirements - Isolated Power System and Line Isolation Monitor per (NEC 517 and NFPA 99)
- Discuss Wet Procedure Designation & Risk Assessment per (NFPA 99)
- NEC 517 Key Sections Related to Isolated Power System
- Examine IPS Advantages & Comparison of Isolated Power System & GFCI
- IPS & LIM Start Up & Maintenance Requirements
- IPS Locations, Patient Care Areas and OR Examples
Electric Shock Hazards

- Threshold of perception for an average adult is 1 mA. This amount of current will produce slight tingling feeling through the finger tips.
- Between 10 and 20 mA, the person experiences muscle contractions and finds it more difficult to release his or hand from an electrode.
- An externally applied current of 50 mA causes pain, possible fainting, and exhaustion.
- An increase to 100 mA will cause ventricular fibrillation.

The NIOSH states "Under dry conditions, the resistance offered by the human body may be as high as 100,000 Ohms. Wet or broken skin may drop the body's resistance to 1,000 Ohms," adding that "high-voltage electrical energy quickly breaks down human skin, reducing the human body's resistance to 500 Ohms."[15]
Electric Shock Hazards

According to the scenario outlined in Appendix B of the 2005 edition of NFPA 99, factors that might cause electrical shock include these:

- A piece of line-powered equipment is within reach.
- A damaged line cord, attachment plugs, or exposed metal presents a risk of direct exposure to a conductor.
- Equipment is damaged and the metal is “live.”
- Exposed metal becomes ungrounded.
- A person makes contact with the live metal surface.
- A second exposed conductive surface is within reach, a person makes contacts with it, and the resultant current flow is sufficient to cause injury.
Isolated Power System Key Standards

- **NFPA 70 – Article 517 Health Care Facilities**
  - Covers the Installation of the system
  - Sections to be considered
    - 517.19 Critical Care Areas
    - 517.20 Wet Procedure Locations
    - 517.30 Essential Electrical Systems for Hospitals
    - 517.60 Anesthetizing Location Classification
    - VII. Isolated Power Systems 517.160

- **NFPA 99 – Health Care Facilities Code**
  - Covers the Performance of system
  - Sections to be considered
    - Chapter 1 – Administration
      - 1.3.4 Patient Care Rooms
    - Chapter 3 – Definitions
      - 3.3.89 Isolated Power System
      - 3.3.90 Isolated Transformers
      - 3.3.97 Line Isolation Monitor
      - 3.3.138 Patient Care Rooms
      - 3.3.184 Wet Procedure Locations
    - Chapter 6 – Electrical Systems
517.2 Definition - Isolated Power System:
“A system comprising an isolating transformer or its equivalent, a line isolation monitor, and its ungrounded circuit conductors.

517.2 Definitions - Line Isolation Monitor:
“A test instrument designed to continually check the balanced and unbalanced impedance from each line of an isolated circuit to ground and equipped with a built in test circuit to exercise the alarm without adding to the leakage current hazard.”
Isolated Power System – NFPA 99 2012

- **Section 3.3.89 Definition - Isolated Power System:**
  “A system comprising an isolating transformer or its equivalent, a line isolation monitor, and its ungrounded circuit conductors.”

- **Section 3.3.9 Definitions - Line Isolation Monitor:**
  “A test instrument designed to continually check the balanced and unbalanced impedance from each line of an isolated circuit to ground and equipped with a built in test circuit to exercise the alarm without adding to the leakage current hazard.”
Section 3.3.184 Definition – Wet Procedure

Location:
"The area in a patient care room where a procedure is performed that is normally subject to wet conditions while patients are present, including standing fluids on the floor or drenching of the work area, either of which condition is intimate to the patient or staff."
Section 6.3.2.2.8.1 states "Wet procedure locations shall be provided with special protection against electric shock."

Section 6.3.2.2.8.4 states "Operating rooms shall be considered to be a wet procedure location, unless a risk assessment conducted by the health care governing body determines otherwise."

**This is the most controversial section. There are parties on both sides but as of today this issue - a majority of attendees at the 2011 NFPA annual meeting voted in favor of the proposal and it became code.**
A Risk Assessment is based on the specific procedures and not on the room itself!

The Risk Assessment Option - A Risk Assessment by the health care governing body can in fact deem an operating room not to be a wet procedure location. The NFPA directs the health care governing body to consult with all relevant parties, including clinicians, biomedical engineering staff, and facility safety engineering staff.
Step 1. Form a risk assessment group to develop a process for evaluating ORs.

Step 2. The risk assessment group gathers information to determine which surgical procedures qualify as wet procedures. Rooms in which wet procedures are never performed do not need a more in-depth study.

Step 3. When a more in-depth risk assessment is needed to determine whether an OR should be classified as a wet procedure location, evaluate the condition of the room during surgical procedures. Maintaining a log for each OR can be done in several ways — including having OR personnel maintain a log for each procedure with a checkbox for when wet conditions occur or by having the environmental services department track the number of times they are called to clean up fluid or spills from ORs.
Step 4. If the risk assessment group determines the facility has wet procedure locations, protect those ORs with isolated power or ground-fault interrupters.

Step 5. If the facility has wet procedure locations, assess whether staff would be in danger of electrical shock from standing in a pool of liquid and touching a faulty medical device.

Step 6. Review the risk assessment annually to confirm the validity of the process and that conditions (e.g., different surgical procedures or new surgeons) have not changed for any operating room.

Once Designated Not Wet Procedure Facility, Procedures in the Suite Are Limited
NFPA 70 NEC (2005-2014)
Key Sections of Article 517

Sections Related to Isolated Power Systems and Line Isolation Monitors

● 517.19 Critical Care Areas
● 517.20 Wet Procedure Locations
● 517.30 Essential Electrical Systems for Hospitals
● 517.60 Anesthetizing Location Classification
● 517.160 Isolated Power Systems
517.19(C)(1) Operating Room Receptacles

(1) Minimum Number and Supply. Each operating room shall be provided with a minimum of 36 receptacles, at least 12 of which shall be connected to either of the following:

(1) The normal system branch circuit required in 517.19(A)

(2) A critical branch circuit supplied by a different transfer switch than the other receptacles at the same location
# 517.20 Wet Procedure Locations


Option 1 or 2? – What will you choose?

- **517.20 Wet Procedure Locations**

  "(A) Receptacles and Fixed Equipment. Wet procedure location patient care areas shall be provided with special protection against electric shock by one of the following means:

- **(1) Power distribution system that inherently limits the possible ground-fault current due to a first fault to a low value, without interrupting the power supply**

- **(2) Power distribution system in which the power supply is interrupted if the ground-fault current does, in fact, exceed a value of 6mA"
517.30  Essential Electrical Systems for Hospitals & 517.33 Critical Branch.

517.30  (C) (2) Isolated Power Systems. Where isolated power systems are installed in any of the areas in 517.33(A)(1) and (A)(2), each system shall be supplied by an individual circuit serving no other load.

- 517.33(A)(1) Critical care areas that utilize anesthetizing gases — task illumination, selected receptacles, and fixed equipment.
- 517.33(A)(1) The isolated power systems in special environments
517.160 Isolated Power Systems

(A) Installation

- NEC – Section 517 – 2011/2014 (Based on 2005) Covers installation of the System

B) Line Isolation Monitor.

(1) Characteristics. In addition to the usual control and overcurrent protective devices, each isolated power system shall be provided with a continually operating line isolation monitor that indicates total hazard current. The monitor shall be designed such that a green signal lamp, conspicuously visible to persons in each area served by the isolated power system, remains lighted when the system is adequately isolated from ground. An adjacent red signal lamp and an audible warning signal (remote if desired) shall be energized when the total hazard current (consisting of possible resistive and capacitive leakage currents) from either isolated conductor to ground reaches a threshold value of 5 mA under nominal line voltage conditions. The line monitor shall not alarm for a fault hazard of less than 3.7 mA or for a total hazard current of less than 5 mA.

- Exception: A system shall be permitted to be designed to operate at a lower threshold value of total hazard current. A line isolation monitor for such a system shall be permitted to be approved, with the provision that the fault hazard current shall be permitted to be reduced but not to less than 35 percent of the corresponding threshold value of the total hazard current, and the monitor hazard current is to be correspondingly reduced to not more than 50 percent of the alarm threshold value of the total hazard current.
517.160 Isolated Power Systems
Installation (B) Line Isolation Monitor

- NEC – Section 517 – 2011/2014 (Based on 2005)
  Covers installation of the System

(B) Line Isolation Monitor.

(2) Impedance. The line isolation monitor shall be designed to have sufficient internal impedance such that, when properly connected to the isolated system, the maximum internal current that can flow through the line isolation monitor, when any point of the isolated system is grounded, shall be 1 mA.

- Exception: The line isolation monitor shall be permitted to be of the low-impedance type such that the current through the line isolation monitor, when any point of the isolated system is grounded, will not exceed twice the alarm threshold value for a period not exceeding 5 milliseconds.

- Informational Note: Reduction of the monitor hazard current, provided this reduction results in an increased “not alarm” threshold value for the fault hazard current, will increase circuit capacity.

(3) Ammeter. An ammeter calibrated in the total hazard current of the system (contribution of the fault hazard current plus monitor hazard current) shall be mounted in a plainly visible place on the line isolation monitor with the “alarm on” zone at approximately the center of the scale.

- Exception: The line isolation monitor shall be permitted to be a composite unit, with a sensing section cabled to a separate display panel section on which the alarm or test functions are located.

- Informational Note: It is desirable to locate the ammeter so that it is conspicuously visible to persons in the anesthetizing location.
IPS Advantages

- Reduced shock hazard
- Continuity of power
- Advance warning of equipment failure
IPS Advantages - Reduced Shock Hazard

Body resistance of 1000 ohms

- The Grounded System
  - XFMR Neutral Bonded to Ground
  - Expect 0v to ground to neutral
  - 120v line conductor to g/n

- The Isolated Power System
  - Neutral -Ground is omitted
  - Correctly Installed results in very low leakage current
  - Balanced system except 60v  L1,L2 to ground
IPS Advantages – Advanced Warning

Benefits:

● Continuously monitors for current leakage
● Monitors equipment connected to system
● Faulty equipment detection that alarms the operator of potential issue
  • Either replace or continue usage of equipment
  • Determines safe condition during initial setup
IPS Advantages – Continuity of Power

- No interruption Reliable Power in Operating Rooms is critical
- Equipment in *Wet Procedure Locations* that cannot withstand an interruption of power require an Isolated Power System.

  Option 1 or 2? – What will you choose?
- 517.20 Wet Procedure Locations
  "(A) Receptacles and Fixed Equipment. Wet procedure location patient care areas shall be provided with special protection against electric shock by one of the following means: (1) **Power distribution system that inherently limits the possible ground-fault current due to a first fault to a low value, without interrupting the power supply**
  (2) **Power distribution system in which the power supply is interrupted if the ground-fault current does, in fact, exceed a value of 6mA"
Isolated Power System (IPS) vs GFCI

- An Isolated Power System (IPS) is a way of providing protection, and has the inherent advantage of not requiring an interruption of the power supply should a phase-to-ground fault condition occur.

- Whereas with an Ground Fault Circuit Interrupters (GFCI), the interruption of electrical power to critical piece of medical equipment from the tripping of GFCI device, from either an actual phase-to-ground fault or a nuisance tripping condition.

History: Isolated Power Systems were first introduced into the hospital environment as a means of reducing the risk of explosions in operating rooms and any other area where flammable anesthetizing agents are used.
Commissioning & Maintenance  (NFPA 99)

- 6.3.2.6.2 Impedance of Isolated Wiring

- 6.3.3.3.2 Line Isolation Monitor Tests. The line isolation monitor (LIM) circuit shall be tested after installation, and prior to being placed in service, by successively grounding each line of the energized distribution system through a resistor whose value is $200 \times V$ (ohms), where $V$ equals measured line voltage. The visual and audible alarms (see 6.3.2.6.3.2) shall be activated

- 6.3.4.1.4 The LIM circuit shall be tested at intervals of not more than 1 month by actuating the LIM test switch (see 6.3.2.6.3.6). For a LIM circuit with automated self-test and self-calibration capabilities, this test shall be performed at intervals of not more than 12 months. Actuation of the test switch shall activate both visual and audible alarm indicators.

- 6.3.4.1.5 After any repair or renovation to an electrical distribution system, the LIM circuit shall be tested in accordance with 6.3.3.3.2.

- Record Keeping. A written record of inspection, performance, exercising period, and repairs shall be regularly maintained and available for inspection by the authority having jurisdiction.
IPS Locations

- Intensive care units (ICU’s)
- Coronary care units (CCU’s)
- Emergency departments
- Special procedure rooms
- Cardiovascular laboratories
- Dialysis units
- Various Wet Locations
Patient Care Areas Defined

**General Care Areas**: patient bedrooms, examining rooms, treatment rooms, clinics, and similar areas. In these areas, the patient may come in contact with ordinary appliances, such as nurse call systems, electrical beds, examining lamps, telephones, and entertainment devices. Patients may also be connected to electro-medical devices, such as heating pads, EKGs, drainage pumps, monitors, otoscopes, ophthalmoscopes, and IV lines.

**Critical Care Areas**: special care units, intensive care units, coronary care units, angiography laboratories, cardiac catheterization laboratories, delivery rooms, operating rooms, and similar areas. In these areas, patients are subjected to invasive procedures and connected to line operated, electro-medical devices.
Isolation Panel System Function

A test instrument designed to continually check the balanced and unbalanced impedance from each line of an isolated circuit to ground and equipped with a built-in test circuit to exercise the alarm without adding to the leakage current hazard.

- Small Local network with low leakage capacitance
- Predictive system instead of reactive system via a Line Isolation Monitor
What is an Isolation Panel System?

Small Local network with low leakage capacitance
Grounds

NEC-517.13 – All branch circuits serving patient care areas shall be provided with an effective ground-fault current path by installation in a metal raceway system, or a cable having a metallic armor or sheath assembly. Since the armor or sheath is not used in these areas this means an equipment ground conductor as described in 250.118..
Conductors

● 517.160 (5)

Conductor Identification

1. Orange (stripe)
2. Brown (stripe)
Conductors

- The impedance (capacitive and resistive) to ground of either conductor of an isolated system shall exceed 200,000 ohms when installed. The installation at this point shall include receptacles but is not required to include lighting fixtures or components of fixtures.
Conductors
Minimizing the length of branch-circuits conductors

Conductor insulations with a dielectric constant less than 3.5 & insulation resistance constant greater than 6100 megohm-meters

XHHW or XHHW-2
Conductors

Wire-Pulling Compounds compounds that increase the dielectric constant SHALL NOT be used on the secondary conductors.
Receptacles

Lights

Other loads
Receptacles

- Operating rooms shall be provided with a minimum of 36 receptacles.
Isolation Panel  
(NEC 517-160)

(A)(4) Transformer
- UL-1047
- Low Leakage

(A) (1) Isolated Power Circuits
- Simultaneously disconnected

(A) (2) Circuit Characteristics

(B) Line Isolation Monitor

It is desirable to limit the size of the transformer to 10kVA or less
Isolated Power Systems - LIM

NFPA 99 and NEC

- Lighted when system isolated from ground
- Red Signal Light: Lighted when THC reaches limit
- Green signal lamp: Lighted when system isolated from ground
- Audible warning as well
- Ammeter: "Alarm Zone" – center of the scale
Isolated Power Systems- Composite Unit

- Green Signal Lamp
  Lighted when system isolated from ground

- Red Signal Light
  Lighted when THC reaches limit

  Audible warnings as well

- Test Function

- Mute for local silence
Isolation Panel Application Examples

517.160 (4) – Isolation Transformers

- Shall not serve more than one room
- Allowed to serve single receptacles in several patient areas
  - 150 Volts or higher
  - Not interchangeable with the receptacles on the local isolated power system
STEP ONE – DETERMINE POWER NEEDS
Which Panels to use?

● **Power Requirements**
  ● Once it been determine that Isolation Power System is required, it is required for all Power Systems in the room
  ● 120 Volts – need for all operating rooms
  ● 208 V (240 V) depending on the procedures being performed and the equipment available at the facility

● **New Facilities are going to plan for both power requirements**
Which Panels to use?

● Amount of 120 Volts
  ● 36 Receptacles in Operating Rooms
    ● 4 per 20 amp circuit – 9 circuits
  ● Boom – power (Brakes, lights)
  ● Surgical Lights
  ● Clocks

● Amount of 208 Volts (240 Volts)
  ● Portable Laser Equipment – 30 Amp
  ● Portable X-ray Equipment – 50 Amp
STEP TWO – ROOM LAYOUT
Options

Dual Voltage (ISO – 1A)  Standard Panel (ISO-1B)
Options

Dual Voltage (ISO – 1A)  Standard Panel (ISO-1B)

Side View
Options

Dual Voltage (ISO – 1A)  Standard Panel (ISO-1B)
Options

Dual Voltage (ISO – 8A & 8B)

208 Volts

- Not shown on the drawing for the individual room

- But once the room is set for Isolation Power System for 120 Volts need it also for the 208 Volt System.
Summary – Operating Rooms

● If only 120 Volt required
  ● Duplex Panel
  ● Two Standard Panels

● If both 120 Volt and 208 Volt required
  ● Dual Voltage
  ● One Standard Panel

● If Depth of wall issue when 120 and 208 Volts Required
  ● Duplex Panel or two Standard Panels
  ● Centrally located Control Panel with Power Modules
Summary – General

• IPS Required for Hazardous Locations

• IPS or GFCI Required for Wet Procedure Location

• Is continuous power required?

• Limit Circuit Count and Spares!
Questions/Discussion

Thank you!