

Electrostatic Discharge Interference In The Clinical Environment

*Brief cold snaps or humidification disruptions
can cause BSD problems.*

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The ever-increasing concentration of microprocessor-controlled clinical instrumentation elevates the need to control environmental electromagnetic (EM) noise. Disrupting signals transmitted over power lines can be effectively controlled by the installation of surge suppressors or uninterruptible power supplies. The suppression of interfering signals transmitted through space can be much more difficult to accomplish, however, as anyone who is wrestling with communication signal- or electrostatic unit (ESU)-generated interference can attest to. Electrostatic discharge (ESD)-generated signal produces another form of interfering noise that can be EM-field-transmitted and similarly difficult to avoid.

ESD is the transfer of static charge between bodies of different electrostatic potential, in proximity or through direct contact.¹ The more common form of ESD in the clinical environment results from a discharge through an air gap; an example would be a user accumulating thousands of volts of potential by walking across certain floor surfaces and then reaching for a device. EM field generation resulting from such ESD is difficult to model because the field radiates from conductors acting as antennas on both sides of the spark. Even reproducibility of test results is difficult to achieve because control of the many sparks influencing parameters (e.g., contact approach speed) is complicated.²

The consequences of interference created by ESD are often similar to problems created by power-line noise. A major difference, however, is that devices that are not even connected to wall power are susceptible. The broad-spectrum radiofrequency signal created by an arc can result in electromagnetic field transmission of adequate power to be received on (j.p circuit boards, leading to disruption of control signals. Apparatus that is not designed with adequate fail-safe protection can create unpredicted situations when ESD-influenced [iP operation degrades or disrupts control signals.

DIAGNOSING ESD INTERFERENCE

Proving that ESD resulted in the malfunction of a device can be very difficult. One those occasions when apparatus obviously begins to operate erratically, coincidental with perception of an arc (Figure 1), diagnosis may be easy. When no arc is seen, evidence of the cause can be impossible to produce. Rebooting an ESD-influenced computer found to be operating in an error mode often brings a return to normal operation. After rebooting, it may be that no evidence of the malfunction will remain. Where evidence does remain it is likely to be microscopic and undetectable with common troubleshooting tools.

So how is ESD identified as the culprit responsible for producing these phantom nightmares? This is the challenge faced by technicians and incident investigators as well as clinicians. The solution to this puzzle relies on connections with circumstantial evidence.

Inexplicable problems occurring during very cold weather, for instance, are sufficient to make investigators suspect ESD interference. Once suspicion exists, the device manufacturer can be the best source of information. It has been the experience of the authors, however, that ignorance on the part of manufacturers' representatives regarding such problems should not be interpreted as conclusive evidence against ESD interference. Where the consequence of the interference is not dire, verification of the cause is often possible by monitoring natural repeat occurrences. If consequences are too potentially dangerous, artificial means of testing an ESD interference hypothesis must be contrived.



Figure 1. Simulated electrostatic discharge between a finger and a door knob.

ESD CONSEQUENCES

Consequences of ESD can range from clinician discomfort or inconvenience to life-support disruption. Fortunately, ESD-generated malfunctions frequently occur in the presence of clinical staff during periods of access to system controls. Generation of the electrical charge is most commonly produced triboelectrically by an individual's having walked across certain floor surfaces with rubber-soled shoes. Contact with clinical apparatus after accumulating such charge may involve clinical staff, support service staff, family members of the patient, or even ambulating patients.

The literature³ commonly categorizes the consequences of ESD in three ways: transient errors, soft errors, and hard errors. Transient errors may produce temporary disruption of data or control signals but normal operation returns with no human interaction. Soft errors require a manual reset or microprocessor reboot to produce a return to normal operation. Hard errors produce destruction of electronic components.

Removing a device that is suspected of being susceptible to ESD interference from the environment in which problems have occurred makes incident simulation difficult. Even though clinical environmental conditions vary with daily changes in outdoor temperature and humidity, approximation of conditions under which incidents have occurred will usually have greatest success at the site where problems have been observed. This is the case since contributing factors include electrical (ground and interconnected apparatus) as well as temperature and humidity influences. Portable static charge generators are a convenient diagnostic tool. The use of static charge generators eliminates the need to closely

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The consequences of interference created are often similar to problems created by power-line noise.

control temperature and humidity conditions during testing. Testing conditions designed for both the laboratory and post-installation environments defined by IEC 1000-4-2⁴ help in standardizing methods for evaluating a device's general susceptibility to ESD. Adherence to such protocols may not be optimal during attempts to determine whether or not ESD is responsible for unexplained phenomena, however. Much can be determined regarding specific response to ESD within a unique electrical environment by using the portable generator to reproduce observed or hypothesized circumstances-Care must be taken while performing discharge tests. A test protocol that involves increasing discharge voltage magnitude in small increments does not ensure absence of permanent damage. Even having a reputable third-party incident investigator or private laboratory carry out tests can not ensure nondestructive results.

INCIDENTS OF ESD INTERFERENCE

Following are descriptions of three situations investigated by the authors where ESD was concluded to have produced malfunction of clinical devices. In each case the device influenced was a model that is widely used at present.

Case 1

A neonate was receiving an infusion of 3.7 mL/hour of total parenteral nutrition. During regularly scheduled patient charting, fluid status was checked and the nurse found the general-purpose microinfusion pump to be delivering at a rate of 88.8 mL/hour with no alarms indicated. Compensatory therapy was necessary to restore the patient's blood chemistry to normal. Continued infusion at the erroneous rate would have been lethal. Clinical staff interviewed indicated the belief that no one had manually altered the pump control settings. Consultation with the manufacturer's representatives revealed that when the microprocessor is reset, the rate

register defaults to 88.8 mL/hour as a means of providing seven-segment display verification. Such a reset is accompanied by an audible alarm and a halt in fluid delivery.

Laboratory examination of the pump revealed no evidence of any malfunction. Controlled electrostatic discharge of greater than 5 KV to circuit ground or to the IV pole was demonstrated to reset the microprocessor, albeit with coincidental alarm. While it was not possible in the laboratory to recreate the precise consequences observed during the clinical incident, ESD interference is believed to have been a contributing factor.

The temperature outside the hospital was less than 20°F when the incident occurred. While a hygrometer was not in place at the time, humidity levels in the high 20% range were subsequently measured within the neonatal intensive care unit, prior to adjusting the humidification system.

Case 2

While making rounds, a nurse in a postsurgical orthopedic unit measured and documented patient temperature with a battery-powered IR tympanic thermometer. As the nurse inserted the device into the patient's ear, a spark occurred that "shocked" both the patient's ear and one of the nurse's fingers of the hand that was holding the thermometer. Coincidental with the spark, the thermometer sounded an audible alarm that could be terminated only by removal of the batteries-Upon replacement of the batteries, normal function was restored, with no deviation from manufacturer's specifications discernible.

Both the nurse and the patient were certain that they had been shocked by the tympanic thermometer. Examination of the device, however, revealed no defect in its plastic insulative housing, nor any operating voltage greater than 15 volts. When interviewed, the nurse agreed that ESD could have occurred between her finger and the patient's earlobe, both of which were in close proximity to the device. The fact that no permanent damage was obvious makes the temporary malfunction

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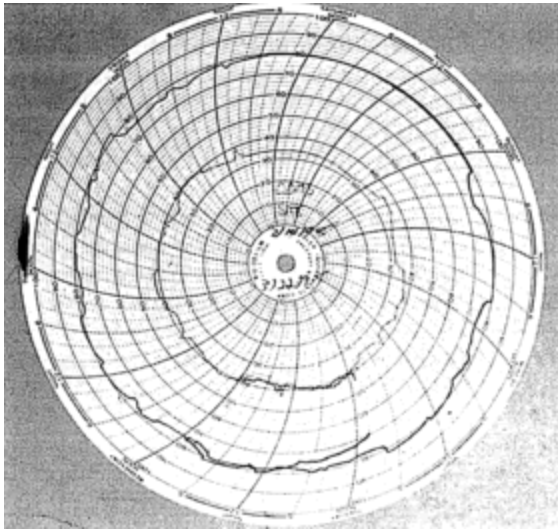


Figure 2. Graphic record of relative humidity, inner pen, and temperature, outer pen, produced by a hygrometer.

appear to have been related to radiofrequency interference of the microprocessor, secondary to the ESD.

Case 3

Portable electrocardiographs function predictably throughout a hospital for nine months out of the year. During the coldest months, they are subject to intermittent unpredictable failure modes. Technicians' attempts to "repair" the devices are frustrated by the lack of any evidence of the malfunction during subsequent laboratory tests.

Most cardiograph malfunctions suspected of being attributable to ESD occur while the devices are being used to acquire ECGs on patient floors, as opposed to within the cardiology department. Manufacturer modifications of circuit grounds are found to significantly reduce failure incidence.

The authors are aware of other ESD-related malfunctions having occurred as well, with apparatus including cardiopulmonary-bypass pumps, hemodialysis equipment, physiologic monitoring systems, and an assortment of hospital information system devices.

ESD AVOIDANCE

In a facility known to have ESD problems, steps can be taken, prior to acquisition of new apparatus, to reduce their likelihood. Mere reference to high ESD immunity within bid specs is one such step. Some manufacturers will provide results of ESD testing. Improvement of device internal circuits grounding may be an option as

exemplified in case 3 above. Similarly, adding shielding around, or RF filtering to, a known susceptible circuit may be possible. Often these strategies are not fiscally feasible, however.

For apparatus users, the primary ESD avoidance tactic is maintenance of the clinical working environment at a relative humidity that is high enough to enable adequate static-decay rates through the atmosphere. The American Institute of Architects Committee on Architecture for Health makes recommendations regarding temperature and humidity control.⁵ These recommendations indicate an appropriate range of 30-60% for critical care areas, and a range of 45-60% for surgical suites and temperatures in the low 70-degree range (Fahrenheit). Their values were formulated based on comfort, asepsis, and odor control. No limits are placed on many other instrumentation intensive clinical areas.

The authors have observed disruptive, unintentional ESD to occur in a room where the relative humidity was being monitored. The hygrometer indicated a relative humidity level of 36% when the discharge was observed (Figure 2). Since control of humidity between possibly 40% and 60% is more costly and difficult to achieve, this single precautionary measure is likely to be inadequate.

A second common tactic employed in the antistatic charge-generation armamentarium is the use of antistatic flooring. Various synthetic tiles and carpets are effective in eliminating the floor-shoe generator. When both humidity levels and floor composition vary throughout an institution, however, the possibility exists that a charge generated in one room or hall will be carried into an area employing susceptible apparatus. It would also be a mistake to assume that movements of shoes on floors are the only static generators in hospitals. Contact between plastics and synthetic clothing, for instance, has also been found to create destructive levels of charge.⁶

Localized use of antistatic sprays or liquids is more complicated still. Different products have varying degrees of effectiveness, and some produce side effects on humans (e.g., eye and nose irritation). Also, reliance on such tools requires frequent use that may be forgotten when no one has been "shocked" recently.

Restriction of access to, or electrical isolation of, a site to which ESD is known to produce undesirable consequences can be an effective

means of eliminating a recurring problem. When an IV pole was shown to act as an antenna for an EMI signal generated by ESD to the pole. For example, an insulative pole covering was employed.



Figure 3. IV pole modified with an electrically insulative covering to reduce the probability of ESD to this device.

(Figure 3).

Where not superseded by a product-specific standard, IEC 10004-2 indicates that equipment may display "temporary degradation or loss of function or performance which is self-recoverable," given air discharge ESD of a potential 4 kV. Between 4 and 8 kV the standard allows "temporary degradation or loss of function

Institutions believed not to have a problem can also benefit from preventive measures.

or performance which requires operator intervention.* While environmental conditions are obviously critical, the authors have found naturally occurring potentials of between 10 kV and 15 kV to be fairly common within health care institutions. Walking across certain carpeted flooring with relative humidity levels below 20% has been found to generate potentials in the range of 35 kV.

Institutions believed not to have an ESD problem can also benefit from preventive ESD measures. Where potential exists for even uncommon brief cold snaps or humidification disruptions, previously unforeseen consequences can result.

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