# UNDERSTANDING AND ADDRESSING EQUIPMENT LIMITATIONS THROUGH TESTING

**Peter J. Chiaro Jr.**
**Oak Ridge National Laboratory**
**Oak Ridge, Tennessee, 37831-6004, USA 865/576-4598**

## ABSTRACT

Safeguards demands have brought about the use of new, advanced equipment. These new systems are typically more complex than previous systems sometimes making use of dense circuitry and complex controls that can bring out previously unseen susceptibilities to various environmental conditions. In addition to possibly being susceptible to ambient conditions such as temperature and humidity, there may be a misunderstanding regarding the operational limitations of the equipment. Will a radiation detector respond to a moving source? Will other types of radiation overwhelm the response of the detector to the radiation of interest? Will the electronics survive or become incapacitated after exposure to radiation?

These questions and others need to be addressed through the use of a systematic testing program. The program should not be used as a tool for criticism, but as a method of improving the reliability of equipment in the field and as a technique for improving the operation of the equipment.

This document presents some of the information that was obtained at Oak Ridge National Laboratory where a series of tests were performed on various types of equipment with differing functions. Equipment tested included data transmission devices and radiation sensors.

Tests performed included ionizing radiation to test for effects from interfering radiation and as a characterization tool for such things as response to moving sources. Other tests involved the use of non-ionizing radiation to determine whether interference could occur when equipment is exposed to radio frequency or magnetic field environments. The remaining tests were performed to establish whether susceptibilities exist when equipment is exposed to various temperature and humidity environments.

Although more testing may be needed, the test methodologies used could provide a direction to future qualification plans.

## IONIZING RADIATION

### Interfering Radiation

This series of tests is used to determine if, and to what level, a safeguards system or component is susceptible to ionizing radiation. Ionizing radiation consists of alpha, beta, gamma, neutron,

and x-ray. The primary concern is with x-ray, gamma, and neutron since they will most likely be present where safeguards equipment is used and the relative inability or difficulty to completely shield the system or a component. The other radiation types are primarily a contamination concern, although secondary radiation caused by high levels of contamination could interact with equipment.

Ionizing radiation can cause equipment to fail through electronic failures or cause radiation response data to be misinterpreted or not read at all. In order to address these concerns, a series of tests were performed involving the exposure of data transmission devices to different radiation types. Another series of tests involved exposing a radiation sensor to radiation types that were not the designed purpose of the radiation sensor. The radiation types included neutron ($^{252}$Cf, PuBe), x-ray, and gamma ($^{137}$Cs, $^{60}$Co).

In addition, sensors were exposed to overload levels of ionizing radiation. An overload level is a level of radiation that is much greater than the designed response range of the sensor. This may be ten-, or one hundred-times the maximum response range of the sensor.

One of the tests involved the exposure of a radiation sensor to a $^{137}$Cs source, which was the radiation of interest. Readings were taken and then the sensor was exposed to other types of radiation to determine whether the signal was degraded. Results indicated that at generally higher radiation fields, the signal of interest was not observable. Other components of the system were also evaluated including data transmission devices with acceptable results.

**Radiation Characterization**

In addition to radiation susceptibilities, various tests should be developed to determine the radiation or response characteristics of a system. At Oak Ridge National Laboratory (ORNL), we wanted to know how a radiation sensor would respond to such things as a moving radiation source. Could the sensor system respond to a moving source of radiation such as those associated with sensing movement of material between storage or operations locations? What are the systems limitations as to movement speed, orientation?

A test system was developed that allows the operator to select a movement speed for an attached sled. The sled could either hold a radiation source or other material for non-radiation based systems, or the sensor moving it linearly past a radiation source or sensor system. In tests performed, two different sensors were attached to the sled and moved through a collimated radiation field emitted from a $^{137}$Cs-beam irradiator. Each sensor was evaluated at speeds of 10 and 20 cm/sec through radiation fields of 50 and 500 mR/hr (500 and 5000 ? Sv/hr). Appendix 1 contains three charts that contain the results from the 10 cm/second at 50 mR/hr (500 ? Sv/hr) test.

Modeling or technical expertise can be used, but it is far more advantageous to perform actual measurements. These measurements can verify or validate claims made by the designer or

manufacturer, or be used during the development stage as a means for the designer to validate and/or change the equipment. Systems where this technique could be used include portal monitors, vehicle monitors, or other similar systems that monitor for movement or changes in ambient radiation levels. Non-radiation based systems such as barcode scanners could also be evaluated.

## ENVIRONMENTAL SUSCEPTIBILITIES

Various safeguards systems have been designed based on operational requirements established by the purchasing authority. These requirements include what the equipment is supposed to do (functional requirements) and under what conditions the equipment is expected to function in (environmental requirements). To ensure that the equipment meets these operational requirements tests are performed.

Functional requirements are typically straightforward whereas environmental requirements may not be. The ambient conditions within the facility where the equipment is to be installed may be quite different from the conditions expected when the equipment was designed. In addition, the system may have to be shipped through undeveloped areas or using transportation that either the equipment or packaging was not designed for.

The existing qualification protocol may not provide the level of intensity or number of tests needed to ensure that potential vulnerabilities are found and addressed prior to acceptance and installation. Without knowing and addressing these susceptibilities, extra burdens regarding costs and manpower could be faced.

### Non-Ionizing Radiation

Non-ionizing radiation primarily involves the effects from electromagnetic fields both radiated and conducted. Due to the differing conditions expected for a system that could be used throughout the world, quantifying expected conditions is very difficult. One technique to consider is to measure the actual conditions at the specific site. Another is to make each system/component hardened. Neither one of these options is realistic due to the associated costs and time. Therefore, a set of requirements should be established that is based on existing international standards and on levels that are appropriate for the field conditions that normally exist.

The International Electrotechnical Commission (IEC) is the standards organization that has established testing requirements for electronic equipment. A series of standards are available that address electromagnetic testing. Using these standards as a basis, ORNL has developed a testing protocol regarding EM fields. Using this protocol, many different types of equipment have been evaluated primarily related to radiation protection instrumentation.

It is critical for the developer and user to understand the limitations of these tests. Normally, RF tests should be performed over a wide frequency range to establish where or if a component or system is susceptible to EM fields. If a frequency or frequency range is found to cause some upset in the functionality of a system, additional evaluations should be performed to determine if the frequency range is of interest and whether these conditions exist in the facility where the equipment is to be installed. Sometimes a simple shield or filter could be installed to reduce or eliminate the problem.

**Temperature and Humidity**

As stated previously, a specific temperature test range is difficult to establish on a world wide scale although most electronics equipment manufacturers will use a specified range of –25 to 60 as outside boundaries for usage (not shipping) temperature requirements. Some may consider this range extreme for operational requirements, but these limits may indeed be possible at numerous locations especially when equipment is used in an uncontrolled or enclosed environment.

Humidity levels must also be considered in addition to temperature. Such things as dew points can cause seals to swell then shrink becoming less effective and allowing equipment to become more vulnerable to moisture problems. A testing regime that includes temperature cycling with high levels of humidity, although not typically found in nature, can be used to aggravate possible weaknesses in the design of the unit.

Various systems have been evaluated to determine if response changes or other operational deficiencies exist. Some radiation sensors will over respond when placed in colder environments with the opposite reaction in warmer environments. This is highly dependent on the type of sensor used. Control and data transmission components typically remain acceptable when exposed to varying temperature environments. Longer term tests are required to ensure that seals or other protective devices work as required. Temperature cycling can drastically shorten the time required for testing as stated previously.

**Transportation**

Conditions related to the transportation of components or systems can be difficult to quantify. Nevertheless, it is critical for the eventual user to take those conditions into consideration when placing requirements on a manufacturer or developer. Will the equipment be shipped by air? Truck? Rail? Could varying atmospheric pressures cause seals to become degraded to the point of failure? These conditions will need to be addressed. There are existing consensus standards that can be used to establish testing parameters that should be used.

Testing for various transportation techniques is necessary but shouldn't be required routinely. Type testing or a thorough review of the transport container should be all that is needed to address conditions such as shock and vibration. The temperature evaluation typically will include a series of exposures to high and low temperatures without power.

## CONCLUSION

In order to ensure that safeguards equipment meets the needs of the user, testing needs to be performed. Test protocols should be based on consensus standards with the realization that special conditions may exist at different facilities. Equipment vulnerabilities to environmental conditions should be understood as well as operational limitations. The goal of any testing and evaluation program should be the improvement and increased reliability of the equipment. This may be best accomplished during the development stage rather than during acceptance testing. The various tests performed at ORNL may be used as a basis for a safeguards-specific testing protocol. Information gained during testing could then be used to develop equipment specifications that are appropriate for field use conditions expected at installation locations.

## APPENDIX 1

## SENSOR RESPONSE TO CHANGING RADIATION FIELDS

Chart 1 shows the results obtained from Sensor A as it moves through a 50-mR/hr field at 10 cm/second. Each measurement obtained from the stationary position is indicated on the chart. The measured response from the center position (mean response from +5 to –5 cm range) was 96% of the response obtained when the sensor was stationary. Chart 2 contains the results from Sensor B. The measured response from the center position (mean response from +5 to –5 cm range) was 100% of the response obtained when the sensor was stationary. Chart 3 displays the response comparison between the two sensors. The chart clearly indicates that Sensor A is much more sensitive to the radiation field when compared to Sensor B although this does not necessarily mean that Sensor B is a better sensor.

**Chart 1**

**Sensor A**

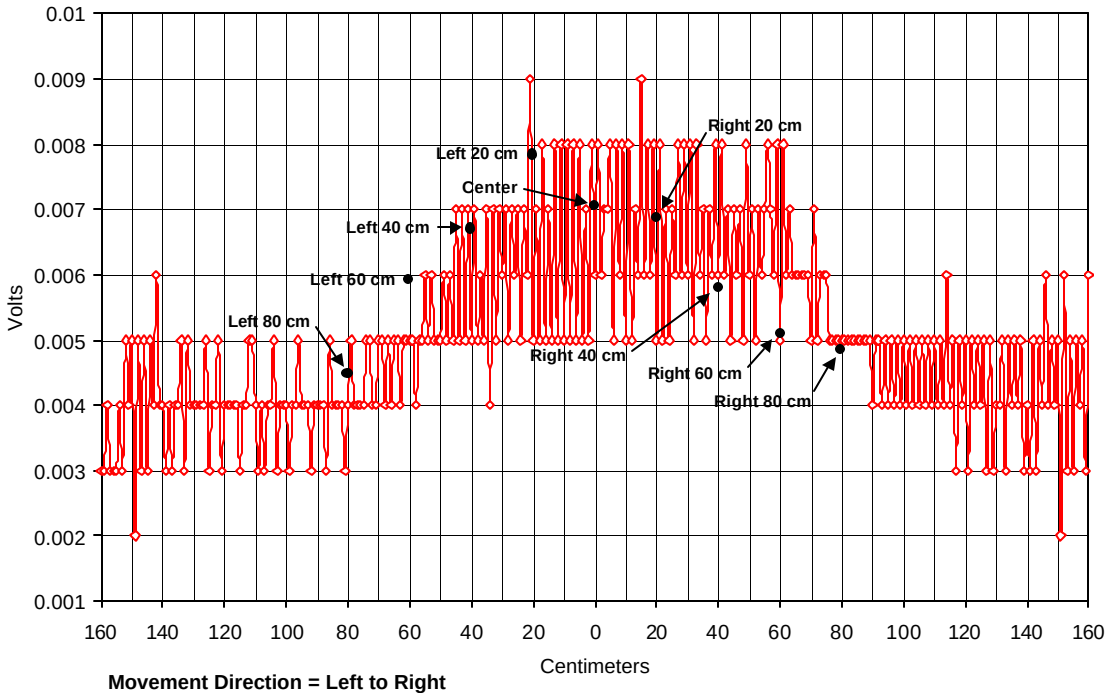


**Chart 2**

**Sensor B**

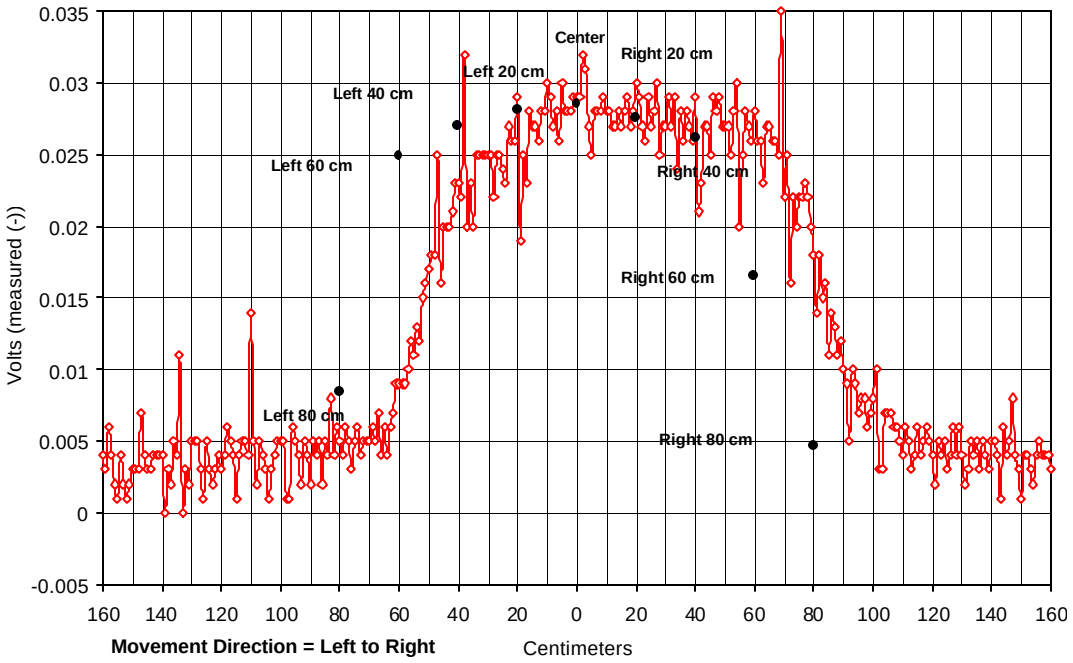
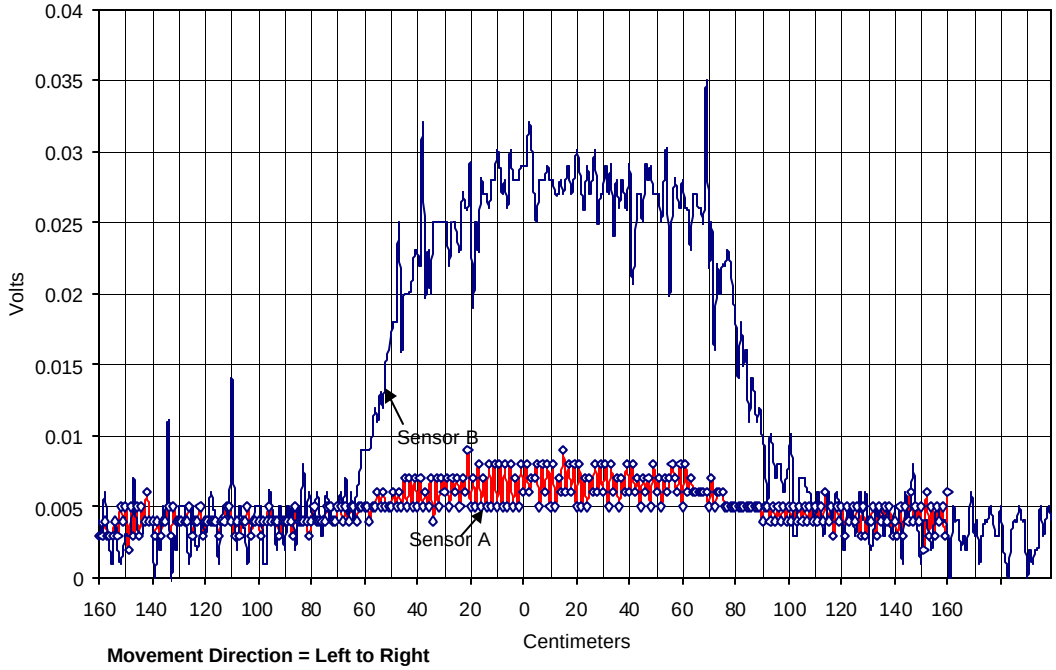



**Chart 3**

**Comparison Chart**

**10 cm/sec. Speed @ 50 mr/hr**