Degraded Instrument Performance due to Radio Interference: Criteria and Standards

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Performance standards for air sampling instruments have a serious deficiency in not adequately addressing instrument operation with respect to the electromagnetic environment. Degraded performance caused by electromagnetic fields can range from subtle deviations in readings to gross errors or even complete shutdown of the instrument. This degraded performance is called electromagnetic susceptibility. It is now time for industrial hygiene instrument standards to give serious attention to electromagnetic susceptibility. This article proposes using the American National Standards Institute C95.1-1982 human exposure standard as a basis for such an instrument requirement and demonstrates that this criterion is both realistic and attainable. For the sake of example, this article makes reference to certain models of industrial hygiene instruments. This is not an endorsement, recommendation, preference, approval, or condemnation of any of these products. Feldman, R.F.: Degraded Instrument Performance due to Radio Interference: Criteria and Standards. Appl. Occup. Environ. Hyg. 8(4):351–355; 1993.

Introduction

Throughout the electronics industry, there is a concern that electromagnetic (EM) fields in the environment can interfere with the operation of sensitive, low-power instruments. The same concern exists for industrial hygiene air sampling instruments. Many of these instruments are too susceptible to be used in common occupational environments where EM fields are often much stronger than typically encountered by most consumer products. This adverse response to EM fields is called electromagnetic susceptibility (EMS).

Susceptibility problems can appear as errors or malfunctions, usually without any signal to alert the operator that something is happening. Some observed malfunctions include false alarms, intermittent operation, illogical displays, and even complete shutdown. In a demonstration at the International Symposium on Air Sampling Instrument Performance, it was shown that the flow rate of an air sampling pump could more than double as a result of the operation of a walkie-talkie several feet away. This is not a desirable feature and carries a high price later through incorrect data, false alarms, poor operation, lost citations, and possible degradation of worker protection.

In 1983 the Occupational Safety and Health Administration (OSHA) and the Mine Safety and Health Administration (MSHA) each recalled about 400 DuPont Mark 1 audiodosimeters to retrofit them with EM shielding to correct an EMS problem. Such recalls consume valuable resources, in both manpower and dollars.

Of greater concern is the effect on safety. In 1982, at the damaged Three Mile Island No. 2 nuclear reactor, a workman's two-way portable radio triggered a combustible gas meter into a false-alarm condition. This, in turn, led to an 8.5-hour, low-level alert being erroneously called at the plant.[1]

Veteran compliance officers will agree that EMS was not a problem experienced with older, bulkier instruments. These instruments were enclosed in heavy metal cases and had circuitry that used high power levels; in fact, some needed to be plugged into electrical outlets. These high-level signals were affected very little by the much smaller radiofrequency fields. Some instruments, such as air sampling pumps, contained no electronic components at all.

Demands grew, however, for smaller and lighter instruments with the capability of incorporating more and more processes. Newer instruments have circuitry and sensors that are designed to operate at lower power levels; amplifiers and microprocessors are part of every instrument, even pumps; heavy metal cases have been discarded for lighter weight plastic ones. One disadvantage has often been overlooked—everything that helped make the instruments smaller and lighter has also made them more susceptible to the EM environment.

Prompted by the EMS-triggered alert at Three Mile Island, AT&T Bell Laboratories performed EMS tests on several air sampling instruments. In November 1984 Cook and Huggins[1] reported on the test results: "Hence it is recommended that two-way radios not be used during operation of combustible gas meters. . . . Anyone using these instru-

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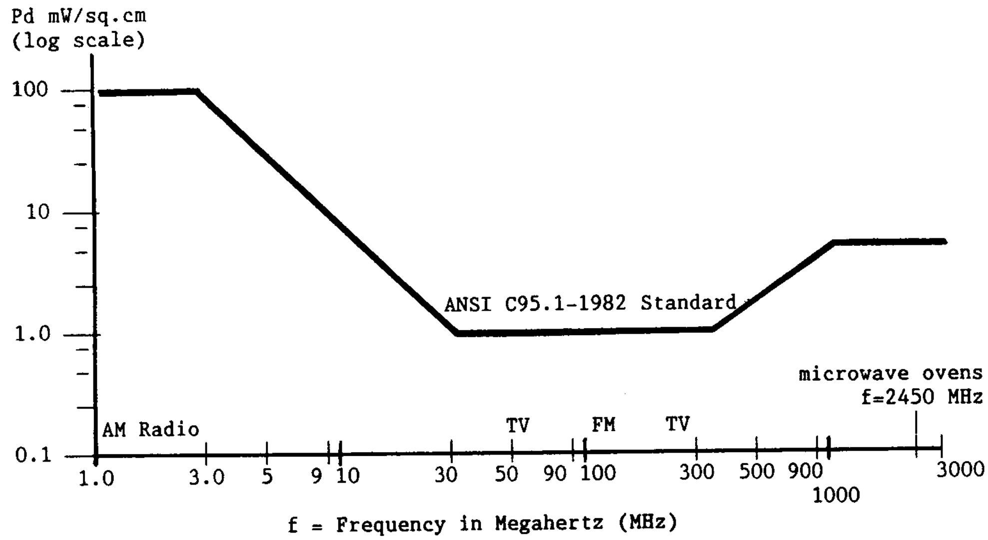

FIGURE 1. Graph of ANSI C95.1-1982 Radio Frequency Protection Guides (RFPG).

ments and other instruments containing amplifiers should be warned that they should not be used near radio frequency sources."

A recent article in *EMC Technology Magazine*[2] stated, "Analog circuits, especially those built around operational amplifiers, are maximally susceptible to radiated EMI at frequencies between 30 MHz and 500 MHz." Today, most air sampling instruments contain at least one operational amplifier.

To compound the problem national standards for air sampling instruments either did not address EMS at all or gave only token attention to it. At most, they specified keying a walkie-talkie at one or two randomly chosen frequencies, 1 meter from the instrument. An example of this is American National Standards Institute (ANSI)/ISA-S12.13, Part 1-1986, "Performance Requirements, Combustible Gas Detectors."[3]

In 1985, during a test of a new combustible gas and oxygen meter, it was discovered that operating a 418-MHz walkie-talkie near the instrument caused erroneous readings and activated its alarm. Displayed readings 6 feet from the meter could be influenced, even though this meter had obviously met existing standards (it had both UL and FM approvals).

Because available standards provided little help in finding practical and reasonable EMS criteria for industrial environments, one directly involved with such environments, the ANSI C95.1-1982 human exposure standard, was chosen. Figure 1 shows a plot of EM field levels that ANSI C95.1-1982 calls the "Radio Frequency Protection Guides" (RFPG).[4] The human exposure standard was chosen as the basis for the EMS criteria because industrial hygiene instrumentation should be able to function in the same electromagnetic environment as the worker.

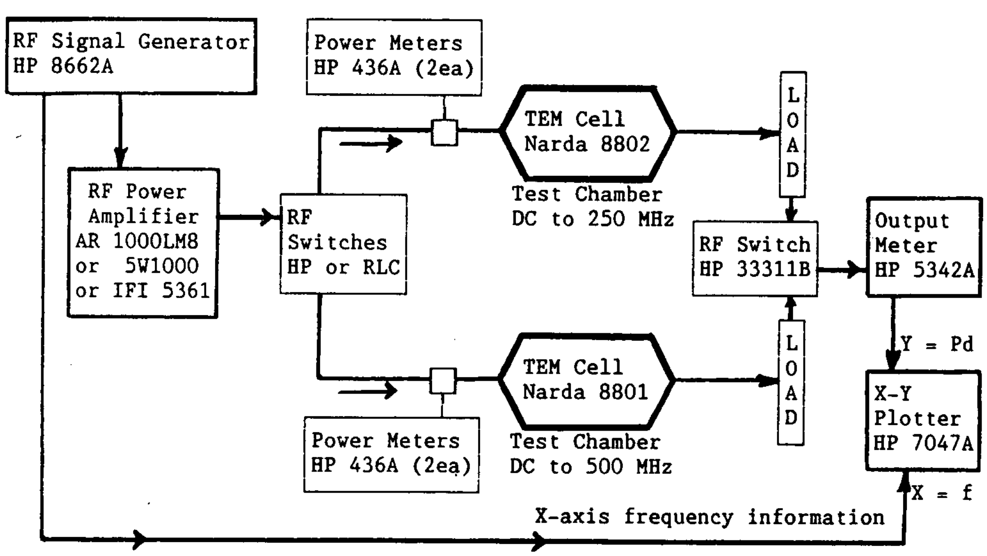

FIGURE 2. Block diagram of the EMS test system developed by OSHA's Cincinnati Laboratory.

Methods

Because the EMS-related problems had potential safety and compliance effects, a system was constructed to test the response of instruments owned by OSHA to well-defined and controlled EM fields. Testing at just a few frequencies would not ensure identification of performance problems at other frequencies across the broad EM spectrum; thus, 1000 test frequencies ranging from 10 MHz to 500 MHz were used. The goal of the program was to eliminate all reasonable possibilities of EMS-related deficiencies in OSHA's compliance and safety instruments.

The OSHA EMS test system consists of a signal generator, amplifiers, power meters, test chambers, and an x–y plotter.[5] Figure 2 is a block diagram of the test system. During the tests, the instrument is placed inside a test chamber called a transverse electromagnetic (TEM) cell,[6] where it is exposed to well-defined EM fields. While the frequency and power density of the EM field are varied, the performance of the instrument is observed either through a port in the side or top wall of the TEM cell or by externally connected equipment.

Figure 3 shows a sample plot made during the EMS tests. The x-axis represents the frequency of the EM field in megaHertz, and the y-axis is the power density of the EM field in mW/cm². The sample plot in Figure 3 was generated by increasing the power density of the EM field until a specified instrument error was observed; the data point was then marked with the x–y plotter. In this case investigators looked for a 5 percent change in flow rate of an air sampling pump. The frequency was then increased slightly, the power density was adjusted to maintain the instrument's error, that data point was also marked, and so forth. The finished plot (EMS profile) shows the power density versus frequency required to cause the given error. Poor instrument performance is identified by data points representing the specified instrument error that occurs at low power density levels. The criteria curve is the flatter curve labeled "ANSI C95.1-1982." Data plotted below the criteria curve do not meet the criteria, and data plotted above the criteria curve meet or exceed the criteria.

Half of the profile in Figure 3 extends below the criteria curve, thus failing to meet the criteria for that frequency range. If the power density is increased above that indicated by the profile, the instrument errors increase rapidly. If the power density is increased further at some frequencies, the instrument can be expected to shut down, even before reaching the criteria curve.

Results

Of the first ten instruments tested, nine failed to meet the EMS criteria. The instrument that passed did so because EMS was addressed during the design stage of the instrument.

An EM field is composed of an electric (E) field and mag-

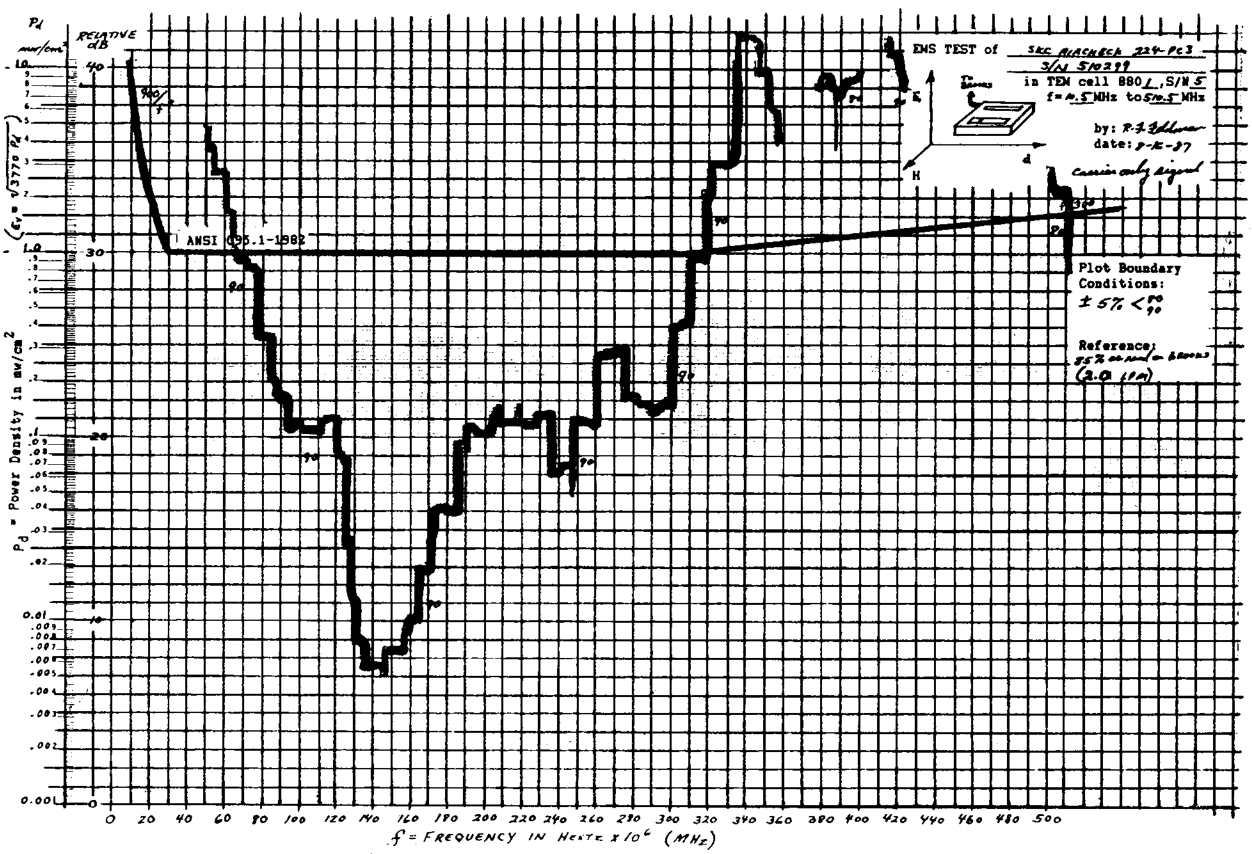

FIGURE 3. Sample EMS plot (EMS profile).

netic (H) field, both space vectors, whose directions are orthogonal to each other and to the direction of travel. During EMS testing, the instrument is oriented in several positions in an attempt to find the orientation in which the EM field most disrupts the instrument's performance (this position can vary with frequency). Figures 4 through 7 represent the worst case of three or more orientations of each instrument in the EM field.

Figure 4 shows the EMS profile of an unshielded combustible gas and oxygen meter (Scott S-105, Scott Aviation, Lancaster, New York), which failed the EMS criteria (lighter plot) and a profile of the same instrument after painting the outside of its plastic case with conductive nickel paint (darker plot). The improvement ranges from 5 dB at 120 MHz to more than 23 dB at higher frequencies. Both of these plots track a 0.5 change in a 21.0 percent oxygen reading (20.5 or 21.5) due to the EM fields indicated.

Figure 5 shows the EMS profile of another model combustible gas and oxygen meter (MX-241, Industrial Scientific Corp., Oakdale, Pennsylvania), which conformed to the criteria by adding a conductive gasket, a thin metal screen in the display window, and an amplifier change. These plots track a 0.02 change in the 0.09 LFL reading of a methane-in-air mixture due to the EM fields indicated.

A third combustible gas and oxygen meter (Microgard, MSA, Inc., Pittsburgh, Pennsylvania) was also modified to conform to the performance criteria (plot not shown). Other instruments were found deficient and were made to conform to the same type of performance criteria. These include the air sampling pump (GilAir, Gilian Instruments, West Caldwell, New Jersey) shown in Figure 6 and the air velocity meter (Model 9850, Alnor, Skokie, Illinois) shown in Figure 7. All the improvements were made through the use of shielding and inexpensive circuit modifications, such as addition of small capacitors and/or ferrite beads.

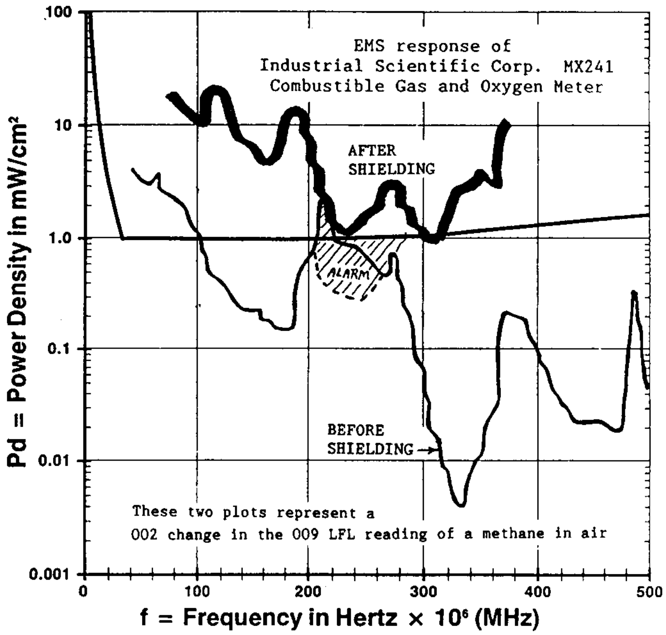

FIGURE 5. EMS profile of the ISC MX-241 before and after shielding.

In Figure 6 the profile for the unshielded GilAir extends well below the range of the graph; however, with a shielded case, the profile improved by more than 40 dB at some frequencies and met the criteria. These plots track a 5 percent change in a reference 2 L/min flow rate due to the EM fields indicated.

In Figure 7, the Alnor 9850 air velocity meter was made to conform to the criteria through the use of a vacuum-deposited aluminum coating on the inside of the case and adding ferrite beads to circuit leads. These plots track a 20 ft/min change in a 200 ft/min air velocity reading due to the EM fields indicated.

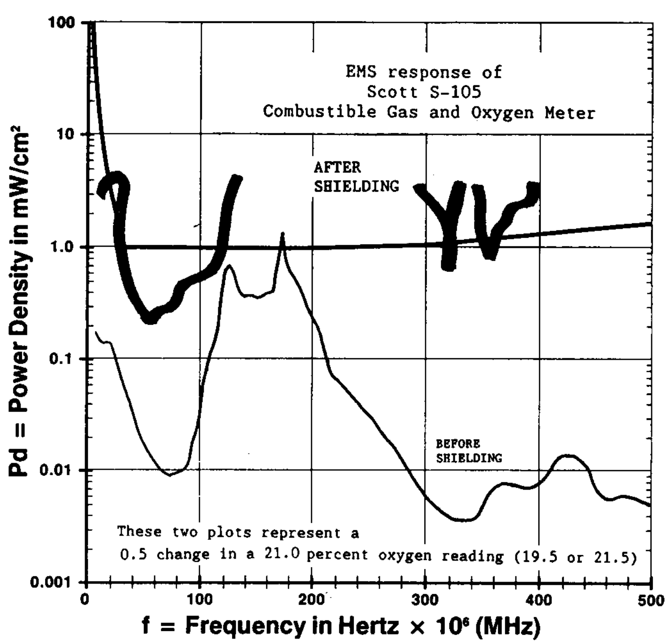

FIGURE 4. EMS profile of the Scott S-105 before and after shielding.

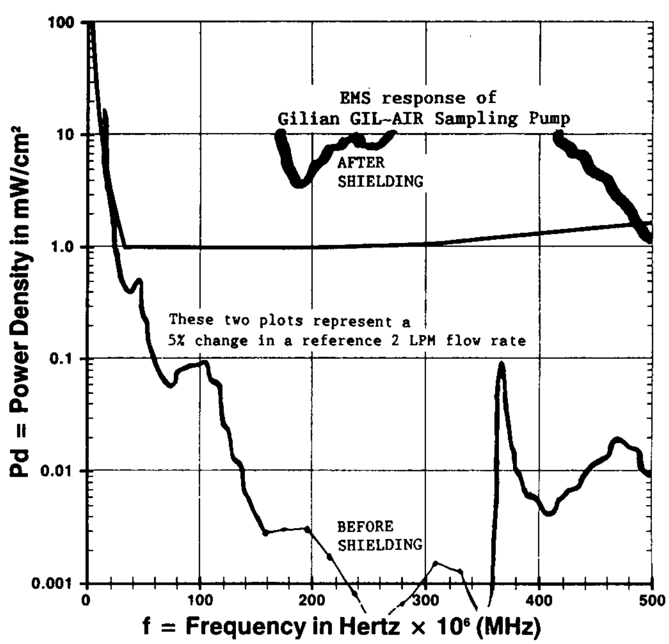

FIGURE 6. EMS profile of the GIL-AIR before and after shielding.

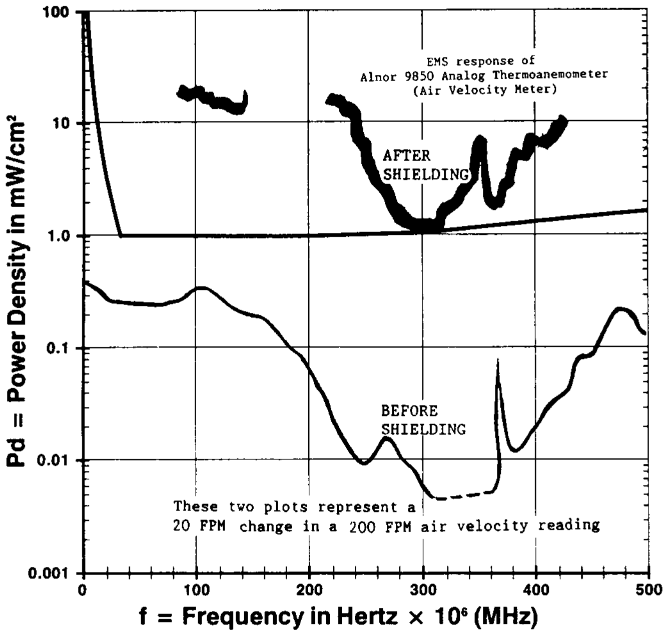

FIGURE 7. EMS profile of the Alnor 9850 before and after shielding.

One instrument, a carbon monoxide detector (Model 190, National Draeger, Pittsburgh, Pennsylvania) passed the initial tests in 1988 because EMS was addressed in the design stage of the instrument.

Discussion

EMS is a problem for air sampling instruments. In the absence of adequate instrument performance standards, the OSHA Cincinnati Laboratory has proposed criteria to address the problem. The criteria have been demonstrated to be both reasonable and attainable, at least for the tested frequency range of 10 to 500 MHz. When EMS is adequately addressed in national instrument performance standards, manufacturers will more readily address it during the design stage and eliminate the need for retrofitting with modifications.

The industrial hygiene instrument community can learn from the OSHA experience and initiate steps to ensure that national instrument standards are adopted that will adequately address EMS.

The OSHA Cincinnati Laboratory has generic EMS specifications available. Write or telephone Ray Feldman or John Englert at OSHA Cincinnati Laboratory, USPO Bldg., Room 108, 5th & Walnut Streets, Cincinnati, OH 45202; (513) 684-3721.

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