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EMI ANALYSIS
NUMAC LEAK DETECTION MONITOR

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1. Introduction

1.1 Scope

This document reviews the types of electromagnetic interference (EMI) (including radio frequency interference or RFI) and electrical surges found in power plant control rooms, the major standards available for EMI and surge susceptibility testing, EMI and surge withstand testing performed on NUMAC equipment, and the applicability of the test methods and test results on the NUMAC Leak Detection Monitor (LDM).

Data are arranged by types of interference. They are:

a. Interference from Radiated Electric Fields - Noise reaches equipment as a result of energy stored in and propagated by electric fields. Radio transmissions are an example.

b. Interference from Radiated Magnetic Fields - Noise reaches equipment as a result of energy stored in and propagated by magnetic fields. Stray fields from rotating devices are an example.

c. Interference from Radiated Electromagnetic Fields - Noise reaches equipment as a result of energy stored in and propagated by fields having both significant electric and magnetic components. Fields generated by certain military weapons are an example.

d. Interference from Electrostatic Discharges - Noise (and perhaps damage) caused by discharging static electric fields into equipment. The touching of equipment by personnel who have accumulated static charge on their bodies is an example.

e. Interference from Conducted Noise - Electrical noise injected by conduction onto power and signal connectors and onto attached leads. The noise injected onto power busses by switching devices is an example.

1.2 Military Tests

All military testing referenced in this document is with respect to Mil-Std-461, Electromagnetic Emission and Susceptibility Requirements for the Control of Electromagnetic Interference, and to Mil-Std-462, Measurement of Electromagnetic Interference Characteristics. The current revision of Mil-Std-461 is "C" (Notices 1 and 2 apply). Mil-Std-462 has never been revised but Notices 1 through 6 apply.

The above documents are currently undergoing extensive revisions, including the addition, deletion and changing of test requirements and procedures, and the inclusion of rationales for the various tests specified. As a result, the (proposed) revision of Mil-Std-461 makes it easier to see which of the Mil-Std-461/2 EMI tests might apply to power plant instrumentation. The revision also makes it easier to assess test stress levels.

Unless indicated otherwise, reference to Mil-Std-461 in this report will imply the February 14, 1992 draft of the proposed revision to the Standard.

1.3 Results of Testing

Whenever this document indicates that a piece of NUMAC equipment underwent a specific EMI test, it is to be assumed that the equipment passed the test, unless otherwise noted.

2. Radiated Electric Fields

2.1 Sources

Radiated electric fields induce noise in equipment as a result of energy stored in and propagated by electric fields.

2.1.1 Sources Found in Power Plants

Sources of radiated electric fields found in power plants are primarily the following:

a. Transmissions from antennas of "walkie talkies" and other portable transceivers.

b. Transmissions from fixed radio antennas (transmitters, repeaters, etc) inside the plant.

c. Stray transmissions from radio and TV receivers, high speed electronics, fluorescent lights, etc.

2.1.2 External Sources

Sources of electric fields external to power plants include the following.

a. Broadcast antennas (AM/FM/TV, communications)

b. Radars and tracking equipment.

c. Military communications (mobile, aircraft, spacecraft).

2.2 Current Standards

The following are the major current standards on radiated electric fields:

a. ANSI/IEEE Std C37.90.2 Trial Use (1987), IEEE Trial-Use Standard Withstand Capability of Relay Systems to Radiated Electromagnetic Interference from Transceivers

A test method in which the equipment being tested is placed in a shielded, enclosed room together with an antenna that radiates an electric field with a strength of 10 to 20 V/m (at the equipment) over a frequency range of 25 and 1000 MHz. Sweep rates, RF modulation and keying, orientation of equipment to antenna, etc, are described in the standard. Other types of antennae may be used, if they provide equivalent fields.

b. SAMA PMC 33.1-1978, Electromagnetic Susceptibility of Process Control Instrumentation.

This is an earlier version of ANSI/IEEE Std C37.90.2, above, and is no longer supported by SAMA.

c. Mil-Std-461/2

(1) Method RS103 (Radiated susceptibility, electric field, 10 kz to 40 GHz). Testing above 18 GHz is performed when there is a need (ie, the equipment being tested may see such frequencies in its operating environment). Maximum field strength for outdoor equipment is 200 volts/meter, for indoor equipment 50 volts/meter.

This test method corresponds to RS03 of the current published versions of Mil-Std-461/2 (see 1.2).

d. International Standards

(1) IEC Standard 801-3 (Electromagnetic compatibility for industrial-process measurement and control equipment - Part 3: Radiated electromagnetic field requirements) - The equipment under test is subjected to radio fields of 10 V/m or greater using fixed antennas or hand-held RF probes. The frequency range covered is 27 to 500 MHz.

This test is similar to those given in ANSI/IEEE Std C37.90.2 and SAMA PMC 33.1, except for field strengths and frequency range.

2.3 <u>Testing Performed on NUMAC Equipment</u>

The following tests were conducted on NUMAC instruments:

a. SAMA PMC 33.1 - A NUMAC Reactor Building Vent Radiation Monitor (RBVRM) system, including a Digital (G-M tube) Sensor & Converter, a Solid-State Sensor & Converter, a Splitter and an Interface Panel were subjected to radio fields of 65 V/m or greater using hand-held RF probes. The frequency range was 20 to 990 MHz. The probe was held against all sides of the equipment, inside the RBVRM chassis, etc. The system had to function within specified limits.

b. IEC Standard 801-3 - A NUMAC Wide Range Neutron Monitoring (WRNM) system, including a Pr~ mplifier and Remote Display, were subjected to radio field. of 10 V/m or greater using hand-held RF probes. The frequency range was 27 to 500 MHz. The probe was held against all sides of the equipment, against seams in equipment cases, connectors, openings, etc. The system had to function within specified limits.

2.4 Analysis of Test Methods

The ANSI/IEEE method challenges the equipment more because of RF modulation and keying. RS103 challenges the equipment more because of its wider frequency range. GE's test of the RBVRM was probably the most challenging, even if RF modulation and keying were not employed. However, the frequency range, though approximately the same as for the ANSI/IEEE test, was not as wide as for the RS103 test. Plant measurement or analysis would have to determine what RF frequency range and what field strengths are to be encountered.

2.5 Applicability to Leak Detection Monitor

The following indicates the susceptibility of each component part of the Leak Detection Monitor to electric fields.

a. Chassis

Electric fields may induce currents in the chassis case. These currents are removed via case ground. Case is standard for NUMAC. Testing was performed on the WRNM to 500 MHz and on the RBVRM to 1000 MHz.

b. Front Panel

Electric fields may induce currents in the front panel. These currents are removed via front panel ground. Panel is standard for NUMAC. Testing was performed on the WRNM to 500 MHz and on the RBVRM to 1000 MHz.

c. Rear Connector Bracket

Electric fields may induce currents in the rear connector bracket. These currents are removed via connector ground. Bracket varies from instrument to instrument with respect to exact size, uncovered holes drilled in bracket, number, size and type of connectors used, and components mounted on bracket.

Fields may induce currents in connectors attached to the bracket and in conductors attached to the connectors.

There is no covering at the rear of the chassis between top cover and the rear connector bracket. This is true for all NUMAC instruments because some instruments (but not the LDM) require that connectors be attached directly to back edge of circuit modules.

2.5 Applicability to Leak Detection Monitor (cont'd)

The rear connector brackets of the WRNM and RBVRM tested, and the connectors mounted on them are typical of those used in the LDM. When the RF probe was placed at the rear of the chassis (where there is no covering) no upsets were noted. Again, this would be typical of the LDM, even though the LDM has some different modules (for which, see below).

d. Motherboard

Internal to instrument and not directly affected. Motherboard is standard for NUMAC and was used in WRNM and RBVRM tests.

e. Low Voltage Power Supplies
f. Computer Module
g. Analog Module
h. Display Control Module

These modules are used in all NUMAC instruments and in the same relative locations within these instruments (the cardfile location of the Analog Module may vary slightly). They were tested in the WRNM to 500 MHz and in the RBVRM to 1000 MHz.

i. Open Drain I/O Module
j. 16-Ch Analog Output Module

These modules are used in the RBVRM (in approximately the same cardfile locations) where they were tested to 1000 MHz. No malfunctions due to RF pickup on the external wiring going to these modules were noted. External wiring was connected to the modules.

k. GEDAC Communications Module

The GEDAC Communications Module has not been subjected to RF susceptibility testing. However, it is similar in function and circuitry to the previously tested RS422/RS485 Communications module used in the RBVRM and to the previously tested RS232 Communications Module used in the WRNM. External wiring to these modules was included in this testing and no malfunctions due to RF pickup on these wires were noted. The GEDAC module contains a daughter board to handle a fiber optic data interface. This board (interface) was not part of the two communications modules tested. However, fiber optic circuits are generally immune to radio frequency interference. The logic circuits also included with the daughter board have likewise been found immune to RF susceptibility.

2.5 <u>Applicability to Leak Detection Monitor (cont'd)</u>

1. 6-Thermocouple Input Module

The 6-Thermocouple Input Module has not been subjected to RF susceptibility testing. There is nothing in the module to make it sensitive to 25 - 1000 MHz carrier waves. Major points of non-linearity (ie, rectification) are in the front end amplifiers of the six input channels. However, 0.5 Hz low pass filters are built into these front ends so that only very low frequency carrier modulations could find their way into the input module. Of course, the LDM's chassis cover shields the module against RF. The external signal wires going to the module have not been tested for RF pickup. However, any noise picked up in this manner would also be subject to the 0.5 HZ input filters. Thus, the 6-Thermocouple Input Module should be relatively immune to RF pickup on its input wiring.

2.6 <u>Conclusions</u>

As a result of testing performed on the RBVRM and WRNM, as well as analysis of the 6-Thermocouple Input Module, the LDM can be reasonably expected to be immune to RF in the range of 25 to 1000 MHz. If, at the LDM's location, significant electric fields outside this range are present, or if ambient fields having significant low frequency modulation (see 2.51) are present, then further RF testing may be advisable.

3. Radiated Magnetic Fields

3.1 Sources

Radiated magnetic fields induce noise in equipment as a result of energy stored in and propagated by magnetic fields

3.1.1 Sources Found in Power Plants

Sources of radiated magnetic fields found in power plants are primarily the following:

a. Earth's magnetic field, magnetized structures, permanent magnets

b. Strays fields from rotating devices

c. Stray fields from magnetic circuitry

d. Magnetically coupled noise on wires and cables

3.1.2 External Sources

Sources of magnetic fields external to power plants include the following.

a. Communications/detection equipment based on the propagation of magnetic fields

3.2 Current Standards

The following are the major current standards on radiated magnetic fields:

a. Mil-Std-461/2

(1) Method RS101 (Radiated susceptibility, magnetic fields, 30 Hz to 50 kHz) (5E-5 Tesla/ampere) (testing limited to equipment sensitive to low frequency magnetic fields such as used in antisubmarine warfare, mine detection)

This test method corresponds to RS01 of the current published versions of Mil-Std-461/2 (see 1.2).

Note that the proposed revisions to Mil-Std-461/2 do not include a test similar to RS02 found in the current published versions.

3.2 Current Standards (cont'd)

b. General Electric Specification 249A1238, Revision 5, "EMI Susceptibility Test Guide"

Fifty-foot cables or lead wires are attached to the inputs/outputs of the equipment being tested. Wires/cables are laid out flat (ie, not coiled). Fifty-foot wires from a test generator are placed in contact with the input/output wires. Two types of signals are placed on the test wires:

(1) 300 Vp-p oscillations at 1/2 to 1 Hz repetition rate with a damped oscillation of 6 to 7 Hz at 100, 200, 300, 400 and 500 kHz.

(2) 5 Vp-p oscillations from 0.5 to 100 MHz at a rate of 1 to 5 MHz/Sec.

In both cases, equipment must operate within test acceptance limits. The tests were designed to be representative of actual conditions in nuclear power plants.

3.3 Testing Performed on NUMAC Equipment

The following tests were conducted on NUMAC instruments:

a. 249A1238, Revision 5, "EMI Susceptibility Test Guide"

These tests were conducted on the NUMAC Log Rad Monitor (LRM), Source Range Monitor (SRM), Wide Range Neutron Monitor (WRNM), DC Wide Range Monitor (DCWRM), and Reactor Building Vent Radiation Monitor (RBVRM).

3.4 Analysis of Test Methods

Method RS101 is intended primarily to insure that performance of equipment potentially sensitive to low frequency magnetic fields is not degraded. NUMAC equipment is not generally sensitive to such fields. The Navy's test limits are based on maximum magnetic field emissions from equipments and subsystems. The Army's limits are based on maximum allowable induced current.

3.4 Analysis of Test Methods (cont'd)

Method RS02 (in the current version of Mil-Std-461/2) and 249A1238 both test susceptibility to magnetically induced noise on signal leads, although different methods are used. RS02 places wires under test in a known magnetic field. This makes the test quite reproducible (an objective of the military tests). However, this is not the way noise is induced in power plant applications. 249A1238, more realistically, places noise on parallel running wires which generate the interfering magnetic fields, though the precise field strengths are not known.

Testing in accordance with 249A1238 should be sufficient to demonstrate immunity to magnetically induced noise on signal leads.

3.5 Applicability to Leak Detection Monitor

The following indicates the susceptibility of each component part of the Leak Detection Monitor to magnetic fields.

a. Chassis
b. Front Panel
c. Rear Connector Bracket

Because the chassis is made from both ferromagnetic and non-ferromagnetic materials, it must be presumed that the LDM's outer case does not defend against magnetic fields. However, the performance of the chassis' components are not effected by ordinary magnetic field, including the electroluminescent display mounted on the front panel. For a discussion of the magnetic coupling of signals into the conductors attached to the rear connector bracket, see below).

d. Motherboard

The motherboard does not contain any circuits that can be affected by magnetic fields. Unless there were strong external magnetic fields in the vicinity, it is highly unlikely that signals can be magnetically coupled into the traces on the wires attached to the motherboard. Moreover, the lengths of these conductors would be too short to permit significant coupling of signal.

3.5 Applicability to Leak Detection Monitor (cont'd)

e. LVPS

The Low Voltage Power Supplies contain transformers and chokes that use ferromagnetic cores. Thus, the paths of the (relatively high) magnetic fields used in the power conversion process are confined to these cores. It is highly unlikely that conventional external magnetic fields can disturb the fields in the ferromagnetic cores.

It should also be noted that the operation of the LDM is not affected by any stray magnetic fields that might be emitted from the LVPSs.

Susceptibility to magnetically coupled noise at the power supply inputs was tested in various NUMAC instruments in accordance with GE specification 249A1238, Revision 5, "EMI Susceptibility Test Guide".

3.5 Applicability to Leak Detection Monitor (cont'd)

f. Computer Module
g. Analog Module
h. Display Control Module
i. Open Drain I/O Module
j. 16-Ch Analog Output Module
k. GEDAC Communications Module
l. 6-Thermocouple Input Module

The components and circuits contained in the LDM's electronic modules are not susceptible to ordinary magnetic fields. Circuit board traces and internal chassis wiring are too short to allow significant magnetic coupling of external signals.

Of the above modules, only the Open Drain I/O module, the 16-Ch Analog Output module, the GEDAC module, and the Thermocouple module connect to the external world (via wire cables, fiber optic cables, or wire conductors). The external signal wires going to the Open Drain I/O module and 16-Ch Analog Output module were tested in the RBVRM in accordance with GE specification 249A1238, Revision 5, "EMI Susceptibility Test Guide". The electrical signal I/O circuits of the GEDAC module are similar to those found in the RS232 and RS422/485 Communications modules. The external signal wires going to these two communications modules were tested in the WRNM and RBVRM, respectively, in accordance with GE specification 249A1238, Revision 5, "EMI Susceptibility Test Guide". The fiber optic cables go to the GEDAC Communications module are not susceptible to magnetic fields.

3.5 Applicability to Leak Detection Monitor (cont'd)

No testing of magnetic pickup on the external signal wires going to the Thermocouple module have been performed. However, whatever magnetically induced noise there might be would be subject to the 0.5 Hz filters on the module and, thus, the LDM should be relatively immune to such external signals.

3.6 Conclusions

The LDM instrument, including power and I/O leads to it, can reasonably be expected to be immune to noises induced by external magnetic fields. However, if strong magnetic fields are present at the LDM's mounting location, or if wires carrying high currents run alongside the LDM's I/O wiring, especially the wiring to the Thermocouple module, then further testing may be advisable.

4. Radiated Electromagnetic Fields

4.1 Sources

Radiated electromagnetic field noise is induced in equipment as a result of energy stored in and propagated by fields having both significant electric and magnetic components.

4.1.1 Sources Found in Power Plants

Sources of radiated electromagnetic fields found in power plants are primarily the following:

a. None.

4.1.2 External Sources

Sources of electromagnetic fields external to power plants include the following.

a. Military weapons.

4.2 Current Standards

The following are the major current standards on radiated electromagnetic fields:

a. Mil-Std-461/2

(1) Method RS105 (Radiated susceptibility, transient, electromagnetic field). This is a limited application test designed for equipment exposed to the electromagnetic pulse (EMP) threat.

This test method corresponds to RS01 of the current published versions of Mil-Std-461/2 (see 1.2).

Note that the proposed revisions to Mil-Std-461/2 do not include a test similar to RS02 found in the current published versions.

4.3 Testing Performed on NUMAC Equipment

No testing strictly electromagnetic in nature (see 4.2) has been performed on NUMAC equipment.

4.4 Analysis of Test Methods

The military test procedure simulates electromagnetic pulses generated from the explosion of nuclear weapons. This scenario does not apply to power plant environments. Hence, no further analysis is required.

4.5 Applicability to Leak Detection Monitor

The use of Test Method RS105 is not applicable to the Leak Detection Monitor.

4.6 Conclusions

There are currently no radiated electromagnetic susceptibility tests applicable to NUMAC equipment. Since radiated EMI seen by NUMAC equipment is either predominantly electric or predominantly magnetic, no separate testing for electromagnetic susceptibility is required.

5. Electrostatic Discharges

5.1 Sources

Electrostatic discharges noise (and perhaps damage) is caused by discharging static electric fields into equipment.

5.1.1 Sources Found in Power Plants

The prime source of electrostatic discharge is the touching of equipment by operating personnel who have accumulated static charges on their bodies (eg, by walking on certain floor surfaces).

5.1.2 External Sources

None.

5.2 Current Standards

The following are the major current standards on radiated electromagnetic fields:

a. International

(1) IEC Standard 801-2 (Electromagnetic compatibility for industrial-process measurement and control equipment - Part 2: Electrostatic discharge requirements) - The output of an electrostatic discharge simulator, with test level settings of 2, 4, 8 and/or 16 KV, is applied to various accessible portions of the equipment being tested.

5.3 Testing Performed on NUMAC Equipment

The following test was performed on NUMAC instruments:

a. IEC Standard 801-2 - The WRNM equipment was tested. The output of an electrostatic discharge simulator, with test levels set to 2, 4 and 8 KV was applied to various accessible portions of the WRNM equipment. The equipment must met specification with the interfering signal applied. Some flicker of the electroluminescent screen was noted during the discharges, but instrument operation was otherwise not affected and no damage occurred.

5.4 Analysis of Tests Performed

The IEC procedure provides a means for thoroughly and severely testing the electrostatic immunity of electronic/electrical equipment.

5.5 Applicability to Leak Detection Monitor

The main locations where a user/operator might touch an installed LDM are the front panel and the rear connector bracket. An appropriate electrostatic discharge test at these locations was performed for the WRNM. Compared to the WRNM, the LDM's front panel and its methods of grounding are identical. The LDM's rear connector bracket is similar to that of the WRNM, and its method of shielding/grounding identical.

5.6 Conclusions

Based on its similarity to the NUMAC Wide Range Neutron Monitor that was tested and found not to be susceptible to electrostatic discharge, it is reasonable to assume that the LDM is likewise not susceptible to electrostatic discharge.

6. Conducted Noise

6.1 Sources

Conducted noises are electrical signals resulting from EMI which are injected into equipment at I/O terminations or via cables and conductors attached to these terminations.

6.1.1 Sources Found in Power Plants

Prime sources of conducted noise in power plants include:

a. Lightning entering power distribution system

b. Switching transients caused by failures in power generation and distribution systems

c. Switching of power sources

d. Switching of loads on power lines

e. Failures in connected equipment

6.1.2 External Sources

None.

6.2 Current Standards

The following are the major current standards relating to conducted noise:

a. ANSI/IEEE

(1) C37.90.1-1989, IEEE Standard Surge Withstand Capability (SWC) Tests for Protective Relays and Relay Systems

This is the successor document to the old IEEE Std 472 on surge withstand capability. The current document indicates what input/output circuits are to be tested, and how. It provides for common mode tests (one lead from a test generator is connected, via capacitors, to several I/O points of the equipment, the other lead is connected to equipment ground, and transverse mode tests (the signal from a test generator is applied between two I/O points of the equipment being tested).

(2) C62.41-1991, IEEE Recommended Practice on Surge Voltages in Low-Voltage AC Power Circuits

This document is tutorial on what phenomena cause surges and provides data to assist in establishing the surge protection requirements for equipments.

6.2 Current Standards (cont'd)

(3) C62-45-1987, IEEE Guide on Surge Testing for Equipment Connected to Low-Voltage AC Power Circuits

This document provides guidelines on how to best perform surge testing on a given piece of equipment. Various types of tests, and their objectives, are discussed but specific tests and requirements are not given.

b. Mil-Std-461/2

(1) Method CS101 (Conducted susceptibility, power leads, 30 Hz to 50 kHz). The purpose of this test is to assure that equipment operation will not be degraded due to (allowable) distortions of power supply waveforms. In CS01, sine waves, 30 Hz to 50 KHz, one frequency per decade, are transformer coupled into one of power leads of the equipment being tested. The test voltage is 10% of the supply voltage or 5.0 V(RMS), whichever is less.

This test method corresponds to CS01 of the current published versions of Mil-Std-461/2 (see 1.2).

(2) Method CS109 (Conducted susceptibility, structure current, 60 Hz to 100 kHz) (special test relating to the susceptibility of highly sensitive submarine equipment to magnetic fields generated by currents flowing in housing structures)

This test method corresponds to CS09 of the current published versions of Mil-Std-461/2 (see 1.2).

Note: The phenomenon being guarded against is a magnetic field. The test, however, uses conducted noise.

6.2 Current Standards (cont'd)

(3) Method CS114 (Conducted susceptibility, bulk cable injection, 10 kHz to 400 MHz) (the test simulates currents induced into cables by electromagnetic fields generated via antenna transmissions) (signals are coupled into cable because use of antenna during test is difficult) (Testing up to 30 Mhz applies to all military equipment. For aircraft and space systems the upper range is extended to 200 Mhz. Anything above a specified range is optional (ie, per contract document). Test limits within the specified ranges depend further upon application.

This is a new test method and does not correspond to any method in the current published versions of Mil-Std-461/2 (see 1.2).

Note: The phenomenon being guarded against is an electric field. The test, however, uses conducted noise.

(4) Method CS115 (Conducted susceptibility, bulk cable injection, impulse excitation) (5-ampere current pulses (500 volts across a 100 ohm loop impedance), 30 nS wide with rise and fall times less than 2 nS, are injected a 30 Hz rate for 1 minute) (used primarily to test aircraft and spacecraft, requirements have been correlated with observations made in aircraft)

This is a new test method and does not correspond to any method in the current published versions of Mil-Std-461/2 (see 1.2).

(5) Method CS116 (Conducted susceptibility, damped sinusoidal transients, cable and power leads, 10 kHz to 100 MHz) The test is designed to simulate current and voltage transients arising from natural phenomena such as lightning. Transients are magnetically coupled onto leads at a rate of 0.5 to 1.0 transients per seconds. Transients are damped sinuisoids at frequencies of .01, .1, 1. 10 and 100 Mhz. Maximum currents are 10 A (Army and Navy), 5 A (Air Force).

This is a new test method and does not correspond to any method in the current published versions of Mil-Std-461/2 (see 1.2).

Note that the proposed revisions to Mil-Std-461/2 do not include tests similar to CS02, CS06, CS10 and CS11 found in the current published versions.

6.2 <u>Current Standards (cont'd)</u>

c. General Electric Specification 249A1238, Revision 5, "EMI Susceptibility Test Guide"

Two types of signal are applied to each ungrounded power input lead of the equipment being tested (directly if AC powered, via capacitors if DC powered):

(1) 300 Vp-p oscillations at 1/2 to 1 Hz repetition rate with a damped oscillation of 6 to 7 Hz at 100, 200, 300, 400 and 500 kHz.

(2) 5 Vp-p oscillations from 0.5 to 100 MHz at a rate of 1 to 5 MHz/Sec.

In both cases, equipment must operate within test acceptance limits.

c. Svensk Standard SS 436 15 03 (Swedish)

(1) With no signal or power leads attached, sequences of +/- 3 KV pulses are applied via capacitors to power input and other selected I/O points. After each application, signal leads are attached, power is applied and equipment tested to specification. Pulses are applied between power leads, between power leads and chassis ground, and between power leads and signal leads.

(2) With power on and with external circuits simulated by impedances, a 250 volt sinusoid is applied at selected I/O points. The equipment must meet specification with the interfering signal applied. Sinusoids are applied between output leads, between output leads and chassis ground, and between chassis grounds of connected equipments.

(3) With power on, bursts of short (up to 50 nS) sawtooth transients, +/-2 to 4 KV, are simultaneously applied (via 2 meter long wires) to selected signal and power I/O points, to selected chassis ground points, and to selected cable and chassis ground points. The equipment must meet specification with the interfering signal applied.

(4) With power on, a damped 1 MHz sinusoid (1 KV or 0.5 KV max) at a repetition rate of 300 to 500 per second are simultaneously applied (via 2 meter long wires) at selected signal and power I/O points, and at selected chassis ground points. The equipment must meet specification with the interfering signal applied.

6.3 Testing Performed on NUMAC Equipment

The following tests were conducted on NUMAC instruments

a. IEEE Std C37.90.1-1989 (old IEEE Std 472)

A susceptibility test, specifically requested by one of GE's customers and reflecting the requirements of the IEEE standard, was performed on the RBVRM and its accessory equipment. For this test, the equipment had to operate within acceptance limits when six (6) one-shot transients (from a model 510 Surge Transient Generator set to 2500 Volts) were applied to AC input line and to output relay contacts.

b. 249A1238, Revision 5, "EMI Susceptibility Test Guide"

These tests were conducted on the NUMAC Log Rad Monitor (LRM), Source Range Monitor (SRM), Wide Range Neutron Monitor (WRNM), DC Wide Range Monitor (DCWRM), and Reactor Building Vent Radiation Monitor (RBVRM).

c. Svensk Standard SS 436 15 03 (Swedish)

All four tests were performed on the WRNM and its accessory equipment. All pieces were connected as they would be in actual system usage.

6.4 Analysis of Testing Performed

The conducted noise tests outlined above cover a variety of noise environments (aircraft, shipboard, industrial, etc). The specific tests that a given equipment must pass will depend both on where it is used and on the types and amplitudes of noise to be encountered. In general, equipment must be able to withstand repetitive bursts of high voltage, high frequency transients, and continuous application of lower voltage, lower frequency sine waves.

The Swedish Standard (SS 436 15 03) tests conducted on the WRNM equipment represents a fairly comprehensive tests for conducted noise. The standard was meant to cover, among other applications, control room installations.

6.5 Applicability to Leak Detection Monitor

The following indicates the susceptibility of each component part of the Leak Detection Monitor to electrically conducted noise.

a. Chassis
b. Front Panel
c. Rear Connector Bracket

These items do not carry or process electrical signals. During testing of the WRNM, no damage of chassis items, sparkovers, etc, were noted. By similarity, this applies to the LDM. The front panel's display, keypad, and keylock switch are not connected to LDM signal/power I/O points. The effects of conducted noise on the signals entering the instrument via connectors on the rear connector bracket are discussed below.

d. Motherboard

The motherboard passes some I/O signals from/to electronic modules in the chassis. During testing of the WRNM, no damage of the motherboard, sparkovers, etc, were noted. By similarity, this applies to the LDM. The motherboard itself does not perform signal processing. The effects of conducted noise on these signals are discussed below. The motherboard itself does not perform signal processing.

e. LVPS

The conducted noise tests of Svensk Standard SS 436 15 03 were performed on the power supplies in the WRNM. Although these supplies operate on 230 Vac input, the results should apply equally to supplies operating on 120 Vac (minor input transformer differences). The conducted noise tests of GE specification 249A1238, Revision 5, "EMI Susceptibility Test Guide", were performed on the power supplies in the RBVRM. These supplies were 120 Vac units. In both sets of tests, no damage or malfunctions of the LVPSs were noted.

f. Computer Module
g. Analog Module
g. Display Control Module

I/O signals do not enter/leave these modules.

6.5 Applicability to Leak Detection Monitor (cont'd)

h. Open Drain I/O Module
i. 16-Ch Analog Output Module

These modules, found in the RBVRM but not in the WRNM, were subjected to the conducted noise tests of GE specification 249A1238, Revision 5, "EMI Susceptibility Test Guide". They were not tested to the more severe standards of Svensk Standard SS 436 15 03. The external wiring to these modules should be examined to see if high voltage spikes such as those generated during IEEE Standard or Swedish Standard surge withstand testing might be encountered. If so, testing of the modules would be advisable.

j. GEDAC Communications Module

The electrical I/O circuits of the GEDAC Communications Module are similar to both those of the RS232 Communications Module (successfully tested in the WRNM to the Swedish standard) and those of the RS422/485 Communications Module (successfully tested in the RBVRM to the GE specification). It is therefore reasonable to assume that the electrical I/O circuits of the GEDAC module are likewise immune. The fiber optic I/O of the GEDAC module is not susceptible to electrically conducted noise.

k. 6-Thermocouple Input Module

The electrical surge protection circuits on the Thermocouple module are similar to those found on signal I/O modules meeting the Swedish standard (RS232 Communications), or the GE specification (Open Drain I/O, 16-Ch Analog Output, RS422/485 Communications). However, the external wiring to the 6-Thermocouple Input Module should be examined to see if high voltage spikes such as those generated during IEEE Standard or Swedish Standard surge withstand testing might be encountered. If so, testing of the 6-Thermocouple Input Module would be advisable.

6.6 Conclusions

The LDM is reasonably immune to conducted electrical noise. However, the possibility of noise, especially high voltage spikes, at the LDM's I/O terminals leading to the Open Drain I/O Module, the 16-Ch Analog Output Module, and the 6-Thermocouple Input Module should be examined. If such noise is present, then further testing may be advisable.

7. OVERALL RESULTS AND CONCLUSIONS

Leak Detection Monitors are reasonably immune to EMI provided the service conditions they encounter (plus test margins) are not more severe than the conditions for which NUMAC products have been tested. Further EMI/Susceptibility testing may be advisable if data and/or analysis indicate one or more of the following:

a. EMI conditions are more severe than those for which NUMAC products have been tested.

b. Significant electrical radiation outside the range of 25 to 1000 MHz or ambient radiation having significant low frequency modulation is/are present near the LDM mounting locations (see 2.6).

c. Significant magnetic fields are present near the LDM mounting locations, or wires carrying high currents run alongside LDM I/O wiring, especially wiring to the 6-Thermocouple Input Module (see 3.6).

d. Conducted noise, especially high voltage spikes of the type generated during susceptibility testing, may be present on external wiring that leads to an LDM's Open Drain I/O Module, 16-Ch Analog Output Module, or 6-Thermocouple Input Module (see 6.6).

NLS-93-045
ATTACHMENT 2
(2 PP)

Summary

(This Summary is not a part of IEEE C62.41-1991, IEEE Recommended Practice on Surge Voltages in Low-Voltage AC Power Circuits.)

This document describes the occurrence of surges in low-voltage ac power circuits and provides guidance on the simplification of a complex data base into a limited set of representative surges. This simplification will assist designers of equipment in providing the appropriate degree of withstand capability in their designs, allow users of equipment to specify appropriate levels of withstand requirements, and provide test equipment suppliers and test laboratories with a recommended practice for a limited number of well-defined test waveforms.

Protection from surge voltages in ac power circuits can best be achieved through the application of protective devices matched to the environment and to the operational requirements of the equipment. Environmental conditions can be represented by two selected voltage-current waveforms, described as standard waveforms, with amplitude and available energy dependent upon the pertinent location within the power system or distance from the surge source. Circumstances may be encountered where other waveforms, described as additional waveforms, may be appropriate to represent surges caused by less frequent mechanisms or by the presence of equipment recognized as the cause of longer or shorter disturbances.

Standard Waveforms

For practical purposes, locations are divided into three categories. Surge characteristics, that is, rates of occurrence, waveforms, source impedances, and amplitudes, are discussed for each category of location and exposure.

(1) Locations
Category A: Long branch circuits, receptacles (indoor)
Category B: Major feeders, short branch circuits, service panel (indoor)
Category C: Outdoor overhead lines, service entrance

(2) Exposure
Low Exposure: Systems in geographical areas known for low lightning activity, with little load-switching activity.
Medium Exposure: Systems in geographical areas known for medium to high lightning activity, or with significant switching transients, or both.
High Exposure: Those rare installations that have greater surge exposure than those defined by Low Exposure and Medium Exposure.

(3) Recommended Values
Recommended values are given for the waveforms, voltage amplitude, and current amplitude of representative surges in line-to-neutral, line-to-line, and neutral-to-ground configurations.

Additional Waveforms

Special situations have been identified in which additional waveforms may be appropriate; these have been added to the standard waveforms initially defined in the 1980 version of this document. These special situations include the presence of large banks of switched capacitors or the operation of fuses at the end of long cables. These cases warrant consideration of additional waveforms that have the capability of depositing substantial energy in a surge-diverting protective device and causing failure of devices not sized for that occurrence. However, the characteristics of these phenomena are closely related to the specifics of the situation, so that it is difficult to provide

generally applicable recommendations. For that reason, this document presents information on these surges as a range of values rather than specific numbers.

The presence of nearby equipment involving load switching can couple bursts of fast transients that have the capability of interfering with logic circuits and causing upsets. This situation has been recognized, and test procedures have been defined by other organizations to demonstrate immunity of equipment that may be subjected to these bursts. This document endorses the recommendations made by these organizations and includes the fast-transient burst where applicable.

Guidance Versus Specification

The recommendations given in this document are provided as the basis for selecting specifications appropriate to the needs of equipment designers and users, depending on the particulars of the situation. While recognizing the desirability of sweeping general specifications, this document cautions the reader against such practice. The specification of equipment withstand capability, and of test levels to prove this capability, remains the responsibility of equipment suppliers and equipment users, based on an understanding of the situation that this document is attempting to provide. While short-term monitoring of an individual site often gives some useful information, the environment is so dynamic that the analysis of a brief period may not give a good prediction of the future environment.

Readers are also warned on the economic fallacy of specifying unrealistic complexities of test procedures or excessive withstand capability in an attempt to obtain greater reliability. The complexity of the surge environment is such that no set of test waveforms will ever completely simulate the environment, and a slightly higher level of surges can always be proposed to boost equipment withstand. This document was prepared with the intent to avoid such unrealistic requirements.

NLS-93-045 ATTACHMENT 3 (4pp)

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

NLU-82-360

DATE RECEIVED
JUL 6 1982
BY LICENSING

JUL 2 - 1982

Docket Nos. 50-325
50-324

Mr. J. A. Jones
Senior Executive Vice President
Carolina Power & Light Company
336 Fayetteville Street
Raleigh, North Carolina 27602

Dear Mr. Jones:

Subject: Electromagnetic Interference Measurement Program

Re: Brunswick Steam Electric Plant, Units 1 and 2

The NRC has initiated a program to experimentally determine the Electromagnetic Interference (EMI) at various locations within a typical BWR and PWR due to plant and transmission system operations, area meteorological conditions, and other normally existing EMI sources. This data base will be used to assess the EMI vulnerability of proposed or existing designs in the event an operating incident indicates possible EMI involvement. The program is expected to be completed by the end of September 1982 at selected nuclear power plants.

Lawrence Livermore National Laboratory (LLNL) is providing the technical assistance for this program and is developing a detailed plan that will be used to investigate typical BWR control and electrical systems for which EMI vulnerability may be a concern. This investigation will include the identification of reactor plant systems or functions which may be EMI vulnerable, identification of electrical components needed to operate the systems or perform the functions, and the determination of test sensor placements. LLNL has previously completed a verification test to identify and resolve any technical or logistical problems that may have existed with the test equipment or scheme.

The meteorological conditions at the Brunswick site are representative of those leading to the maximum possible EMI involvement due to meteorological conditions. We, therefore, request your assistance in conducting our EMI program. We would like to perform data measurements to define the EMI levels at Brunswick. These measurements consist of monitoring for spurious low-level high-frequency signals that may penetrate instrument sensor outputs, cables, and data processing inputs, and result in random equipment malfunctions or failures. The Enclosure presents the pertinent information regarding the impact of the proposed EMI data measurements.

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4pp

The program will not impact plant safety nor have an adverse affect on plant operations.

As noted in the er.insure, we have scheduled the measurements to be made during Aug[illegible] 1982. For planning purposes, LLNL would like to visit the site duri[illegible] the week of July 19. 1982. Therefore we would appreciate your response [illegible] this [illegible]equest within two weeks. This program and the program schedul[illegible] ha[illegible]e been previously discussed with members of your corporate and [illegible] staffs. If you wish to discuss further details on the proposed me[illegible]urements please contact the Brunswick Project Manager.

Sincerely,

Domenic B. Va[illegible]llo, Chief
Operating Reactors Branch #2
Division of Licensing

Enclosure:
Impact of EM[illegible]
Measurements

cc w/enclosure:
See next page

IMPACT OF EMI DATA MEASUREMENTS

Test Equipment: The electronic test equipment (excepting the sensors), spectrum analyzer, and oscilloscope will be housed in three four-foot high, 19-inch wide, relay racks with an approximate total weight of 400 pounds. The relay racks will be wheel mounted and, therefore, somewhat portable. The power required to operate the test equipment can be supplied by a 20 ampere (110 volt) circuit. Power for air-conditioning will also require a separate 20 ampere (110 volt) supply.

Sensors: Two to four electric field and magnetic field sensors are to be suspended in free space or temporarily attached to the outside surface of panels (using temporary means) in previously approved locations. These locations are expected to be in approximately four different areas such as the control room, relay room, cable-spreading room, and the motor control center. These sensors will have no electrical attachments to any plant systems and, therefore, are completely isolated.

In addition to the above, eight to ten current clamp-on probes are to be clamped to existing plant cables. These probes are clamped to the outside of the cable insulation and will remain electrically isolated from all plant systems. The location of these probes will be determined by LLNL after a review of the drawings and discussions with the utility. It is expected that the same four areas used for the (E/H) sensors will be utilized. All of the above sensors will be linked to

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the above equipment racks with instrument cabling that will be approximately 50 feet in length.

Personnel: LLNL is planning to have a maximum of three of their engineers on-site during the requested time frame. LLNL will need the services of a utility representative (Electrical Engineer - Electrical Technician) for equipment and cabling location information and for plant equipment information.

Time Required: Lawrence Livermore National Laboratory (LLNL) has requested that a total of two weeks be scheduled during the month of August 1982, for the EMI test. For planning purposes, August 9 through August 20, 1982, are the preferred dates. LLNL also requests that an initial visit to the plant site be scheduled during the week of July 12, 1982.

Equipment Removal: The instrumentation package (including sensors) can be disconnected and dismantled at any time during the testing period and removed from the plant upon request by the utility. The planned removal time will be at the completion of the testing period and can be accomplished in a period of several hours.

NLS-93-045
ATTACHMENT 4
(2 PP)

1 of 2

Dietz

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CP&L
Carolina Power & Light Company

JUL 29 1982

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CP 1351A

Office of Nuclear Reactor Regulation
ATTN: Mr. D. B. Vassallo, Chief
Operating Reactors Branch No. 2
United States Nuclear Regulatory Commission
Washington, D.C. 20555

82 07 30

BRUNSWICK STEAM ELECTRIC PLANT, UNIT NOS. 1 AND 2
DOCKET NOS. 50-325 AND 50-324
LICENSE NOS. DPR-71 AND DPR-62
ELECTROMAGNETIC INTERFERENCE MEASUREMENT PROGRAM

Dear Mr. Vassallo:

Carolina Power & Light Company (CP&L) has received your letter dated July 2, 1982 requesting assistance for the NRC-sponsored Electromagnetic Interference (EMI) Measurement Program. By this letter, CP&L hereby agrees to host representatives from Lawrence Livermore National Laboratory (LLNL) to conduct EMI measurements at the Brunswick Steam Electric Plant (BSEP).

Carolina Power & Light Company understands data measurements will be performed to define the EMI levels at BSEP Unit Nos. 1 and 2 as the meteorological conditions found there are representative of those leading to the maximum possible EMI involvement. We agree to provide assistance to LLNL as set forth in your July 2, 1982, letter.

Mr. ry Thompson will serve as the CP&L contact for the LLNL EMI measurement program. Please coordinate appropriate details with Mr. Thompson directly at (919) 457-9521, Extension 449.

Yours very truly,

Original Signed By
S. R. Zimmerman

S. R. Zimmerman
Manager
Licensing & Permits

MSG/cr (550C3T5)

cc: Messrs. D. O. My... (NRC-BSEP)
J. P. O'Reilly (NRC-RII)
J. A. Van Vliet (NRC)

RECEIVED
JUL 30 1982
BSEP

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bcc: Mr. D. L. Bensinger
Mr. J. R. Bohannon
Mr. N. J. Chiangi
Mr. R. M. Coats
Mr. F. R. Coburn
Mr. A. B. Cutter
Mr. C. A. Dietz
Dr. T. S. Elleman
M[illegible] s. J. Furr
[illegible]r. J. D. E. Jeffries
Mr. I. A. Johnson
Mr. R. L. Mayton, Jr.
Mr. S. McManus
Mr. J. A. McQueen, Jr.
Mr. C. H. Moseley, Jr.
Mr. J. C. Plunkett (LIS)
Mr. J. J. Sheppard
Mr. G. A. Thompson (BSEP)
File: BC/A-4
File: B-X-0040