UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

TENNESSEE VALLEY AUTHORITY

BROWNS FERRY NUCLEAR POWER PLANT, UNITS 1, 2 AND 3

DOCKET NOS. 50-259, 50-260, and 50-296

1.0 INTRODUCTION/BACKGROUND

On April 13, 1993, the NRC staff issued amendments to the operating licenses for the Browns Ferry Nuclear Plant (BFN) Units 1, 2, and 3 which reflected replacement of analog components in the reactor building ventilation radiation monitoring (RBVRM) system with digital equipment from the General Electric (GE) Nuclear Measurement Analysis and Control (NUMAC) product line. These amendments were requested on July 23, 1992 by the Tennessee Valley Authority (the licensee or TVA). As part of its safety evaluation, the staff required the licensee to perform a survey of electromagnetic interference and radio frequency interference (EMI/RFI) at the site and to submit a report on the survey results to the staff. Interim operation of the digital equipment was accepted pending staff acceptance of the test results.

On December 23, 1993, the licensee submitted a description of administrative controls to assure that spurious signals from walkie-talkies and temporary equipment in the area of the NUMAC RBVRM equipment would not affect the RBVRM performance, the results of on-site EMI/RFI surveys, and the results of the radiated and conducted transient EMI/RFI susceptibility tests. The NRC staff requested additional information on December 8, 1994, which the licensee provided on April 14, 1995. The licensee also provided additional information on July 25, 1996 in response to verbal requests from the staff.

2.0 EVALUATION

2.1 Administrative Controls

In the letter dated December 23, 1993, TVA stated that in order to preclude use of temporary equipment that could potentially impact the operation of the RBVRM sensors, they marked the floor area surrounding the RBVRM digital sensors on the refuel floor with black and yellow caution striping and conspicuously posted signs that prohibit the use of temporary equipment and walkie-talkies in areas around the sensors.

The staff finds TVA's administrative controls for prohibiting use of temporary equipment and walkie-talkies in areas around the sensors acceptable.

2.2 Site-survey and Susceptibility Tests

In its March 16, 1993 letter, the licensee committed to perform 2 days of on-site EMI/RFI surveys, with 1 day during transient conditions and 1 day

during stable conditions for both the refuel floor and the control room, and to perform EMI/RFI susceptibility tests. GE performed the susceptibility tests, and National Technical System (NTS) performed the EMI/RFI site-surveys and analyzed the results of the susceptibility tests and the site-survey data.

2.2.1 Site Survey

The licensee performed site-surveys in the immediate vicinity of the RBVRM sensors located on the refuel floor and the RBVRM chassis located in the control rooms of each BFN unit. The refuel floor survey was performed during stable plant conditions and during refueling conditions, which included fuel movement. The control room survey was performed during the startup of Unit 2 and during stable plant conditions. These site-surveys were performed in accordance with survey methods described in MIL-STD-462 and were found acceptable by the staff.

2.2.2 Susceptibility Tests

In the March 16, 1993 letter, the licensee committed to perform electrostatic discharge and EMI/RFI susceptibility tests as follows:

1. Radiated magnetic and electric field emissions in accordance with MIL-STD-462D RS 101 and RS 103 test methods,

2. Conducted transient emissions in accordance with the ANSI/IEEE C37.90.1 test method, and

3. Conducted continuous signal emissions in accordance with MIL STD-462D CS114 test method.

For Item 1, the staff finds the test methods to be consistent with appropriate industry standards and practice, and are therefore acceptable. Test results acceptably bound the measured emissions at BFN.

For Item 2, the licensee used international standard IEC 801-5, instead of the ANSI/IEEE C37.90.1 test method because the test signals required for the IEC 801-5 test method sufficiently bound the measured emissions at BFN. The staff finds this test method acceptable. Test results acceptably bound the measured emissions at BFN.

For Item 3, the licensee used the IEC 801-4 test method instead of the MIL STD-462D CS114, because the licensee's analysis determined that the fast transient/burst test signals required for the IEC 801-4 test method, sufficiently bound test signals required for the MIL STD-462D CS114 test. As discussed below, the staff finds this test unacceptable because the licensee equated the worst conducted continuous signal emissions on input power lines to test signals of fast transient/bursts tests.

In a July 1993 telephone conference, the staff indicated to the licensee that the fast transient/burst tests may not adequately bound the conducted continuous signal emissions and requested clarifications from the licensee. The staff documented its request for additional information on the above issue

in a letter to the licensee dated December 8, 1994. In a letter dated April 14, 1995, the licensee stated that fast transient/burst test signals in the time domain when converted to the frequency domain by means of a Fourier Transformation (FT), demonstrate that low frequencies covered by the conducted continuous signal test are present in the fast transient/burst tests beginning at 10 Hz and extending beyond 100 MHz.

The staff agrees that an FT can convert time domain signals into frequency domain and vice versa. However, performing a FT on complicated signals, such as fast transient/bursts, is difficult and the staff requested additional detailed information on the licensee's analysis. In a letter dated July 25, 1996, the licensee responded to the staff's request by enclosing Appendix A of Test Report No. 33036-97N, prepared for the licensee NTS.

The technical justification in the NTS report is that the fast transient/burst test signals contain a signal spectrum of all frequencies, and the input impedance of the equipment under the test is constant. Therefore, NTS concludes an FT of the transient/burst test signals can be performed. NTS used an FT to convert the test signals for the IEC 801-4 test method from time domain to frequency domain. To perform an FT, the NTS report assumed that:

1. the fast transient/burst test signals are periodic (see Figure 1, attached),

2. the fast transient/burst signals generated for the test are the same and are without any variations and distortions, and

3. all spectra of fast transient/burst test signals were coupled onto the RBVRM power line without any attenuation throughout all frequency ranges.

Additionally, since the fast transient/burst test signals used in the IEC 801-4 test method are voltage signals in the time domain and the conducted continuous signal emissions measured at the site were current signals, in order to convert the voltage transient pulse into the current transient pulse NTS assumed that the load impedance seen by the fast transient/burst test signals is 50 ohms. Based on these assumptions, NTS converted the fast transient/burst voltage signals from the time domain to frequency domain current signals and equated them with survey data and test signals of the MIL-STD-462D CS 114 test method.

Tables 1 and 2 (attached) are from the IEC 801-4 standard, and show the characteristics of the fast transient/burst test signal generator and characteristics of the coupling and decoupling network used for the test. These tables do not support NTS's assumptions used for allowing the conversion. The significant characteristics of the test signals are the short rise time, the repetition rate, and the low energy of the transients. Table 1 shows that the fast transient/burst duration is 15 mSec. ± 20% and burst period is 300 mSec. ± 20%. This is significantly different from the NTS assumption that transient/burst duration is as shown in Figure 1. This difference in the burst period will change the mathematical expression for the time domain transient signal, and may change the results of the FT

significantly. Therefore, this difference might significantly change the NTS conversion analysis results from their stated results.

Table 1 also shows allowed variations between transient pulses for the test. However, for its conversion analysis, NTS assumed no variation between transient pulses and also assumed that the effects of the distortion on these pulses is negligible. Since the variation changes the mathematical representation of the time domain transient pulse and the distortion may represent the missing frequency spectrum in the time domain transient pulse, the results of the NTS conversion analysis might be significantly changed from their stated results.

Table 2 shows allowed attenuation of the transient pulse signals before being coupled into power lines for a frequency range 1 Mhz to 100 Mhz. The IEC 801-4, test method however, does not show how much of the signal can be attenuated below 1 Mhz, which is the frequency range for conducted emission current measured on the power leads. Further, for its conversion analysis, NTS assumes that all frequency spectra of transient pulses are coupled on to the power line without any attenuation. Since building such a broad band generator and coupling network is difficult, and the purpose of performing the fast transient/burst test in accordance with the IEC 801-4 test method is to inject a fast rising transient pulse, it is more likely that a low frequency spectrum is sacrificed for a high frequency spectrum. Therefore, the results of NTS's conversion analysis might be significantly changed from NTS's stated results.

Additionally, Ohm's law defines the voltage and current relationship in an impedance as:

Current = Voltage / Impedance

Therefore, the amount of current injected into the equipment by the fast rising voltage transient pulse applied across on a load (e.g., instrumentation) is equal to the transient pulse voltage divided by the input impedance of the load. Section 6.1.2 of IEC 801-4 requires the transient voltage generator to be terminated by a 50 ohm load resistor in order to verify that the transient voltage pulses meet the requirements identified in Table 1. However, the actual load, which is the RBVRM, is not 50 ohms. See Figure 2 (attached). The input impedance seen at Nodes A and B of Figure 2 may vary with frequency. One way to determine this input impedance is by measuring the frequency response of the RBVRM. For the conversion analysis, NTS assumed the input impedance of the RBVRM to be 50 ohms and calculated the current amplitude. Therefore, since current and voltage have the above algebraic relationship and the input impedance is not 50 ohms, the results of the NTS's conversion analysis might be significantly changed from NTS's stated results.

Based on the above analysis, the staff disagrees with the NTS assumptions for converting the time domain voltage signal into the frequency domain current signal, and finds NTS's Fourier Analysis not acceptable. The staff's findings are consistent with current industry electromagnetic capability

practices and the recommendations provided in EPRI TR-102323, IEC 801 series and standards, and MIL-STD-462 and 462D.

3.0 CONCLUSION

The staff finds the administrative controls and the results of the licensee's EMI/RFI site-survey consistent with industry standards and practice, and therefore, acceptable. However, although the susceptibility tests performed by the licensee demonstrate that the GE RBVRM is qualified for the radiated and transient EMI/RFI measured during a site-survey, the staff finds that the licensee's susceptibility tests and the provided technical justifications do not demonstrate that the GE digital RBVRM is qualified for BFN's conducted continuous signal emissions current measured on power leads during the site-survey. Therefore, the staff finds that until the licensee shows that the GE digital RBVRM is qualified for conducted continuous signal emissions, the GE digital RBVRM has not been demonstrated to be acceptable for the BFN specific application environment. Therefore, the licensee is requested to provide a schedule and description of a susceptibility test which will fulfill the commitment of the March 16, 1993 letter.

The staff finds that the conclusions expressed in the safety evaluation of April 13, 1993 regarding the acceptability of operations are still valid, pending closure of issues associated with the susceptibility testing.

Attachment: Figures & Tables

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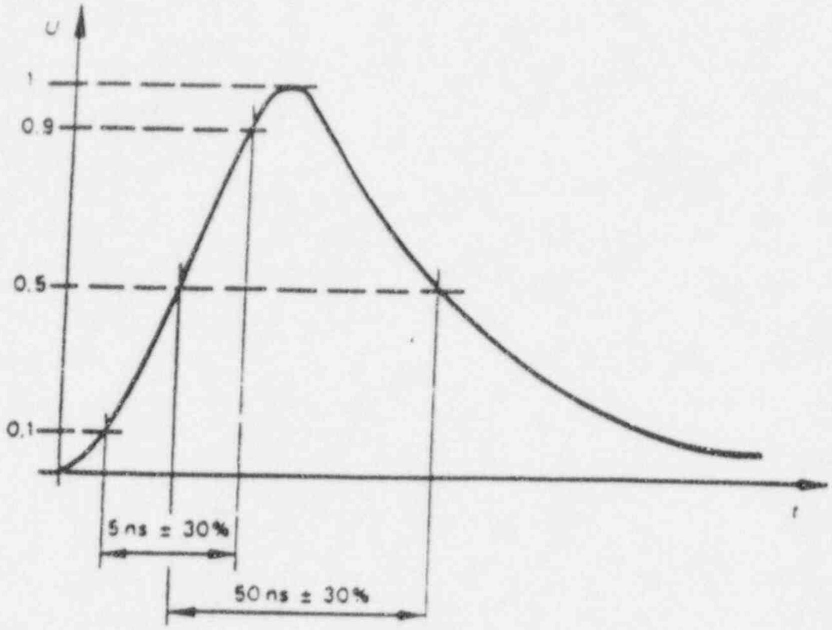
Dated: December 11, 1996



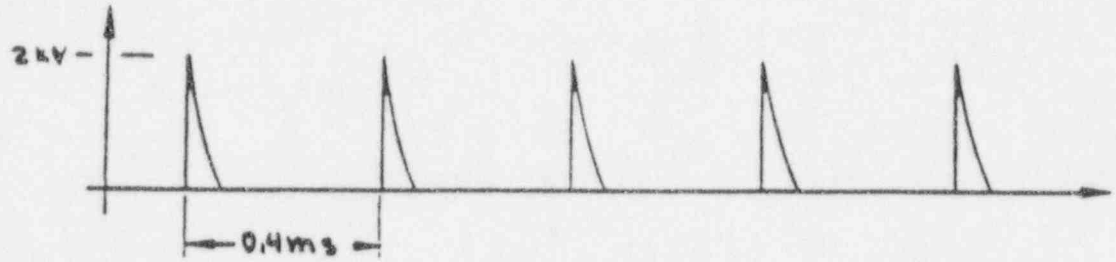


Figure 1. General graph of a fast transient/burst.

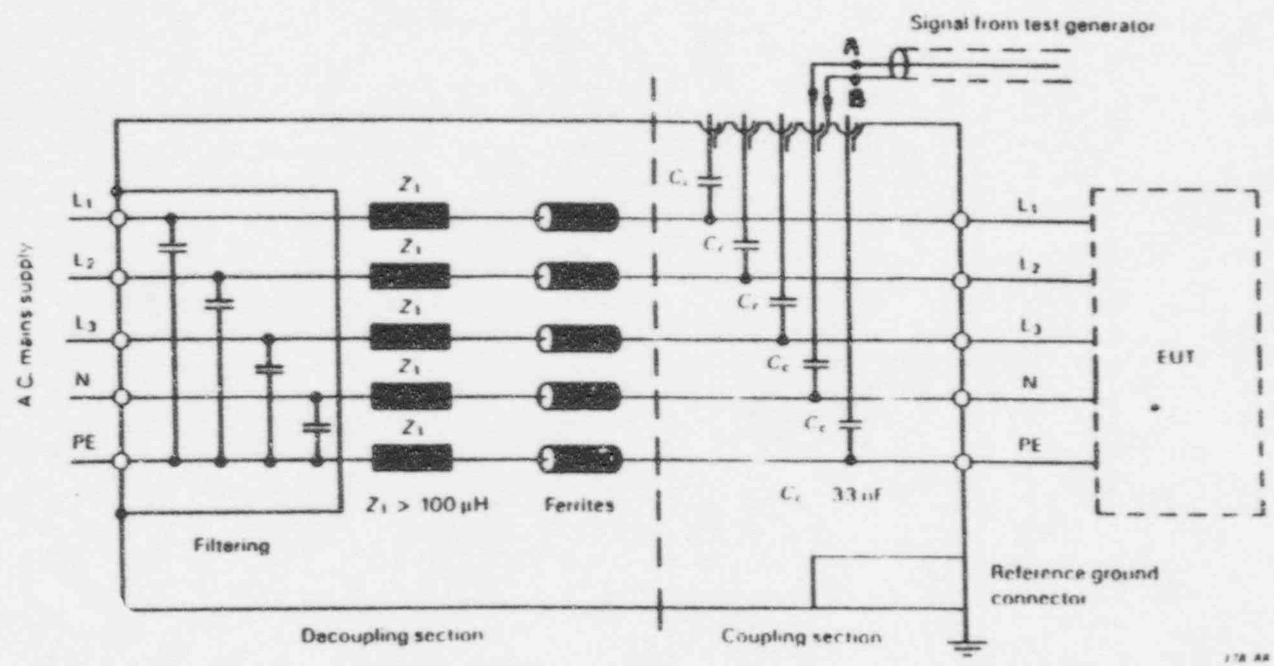
Attachment

Characteristics for operation into 50 Ω load conditions	
- Maximum energy	4 mJ/pulse at 2 kV into 50 Ω load
- Polarity	Positive/negative
- Output type	Coaxial
- Dynamic source impedance (see Note)	50 Ω ± 20% between 1 MHz and 100 MHz
- D.C.-blocking capacitor inside the generator	10 nF
- Repetition frequency of the impulses	Function of the selected severity level (see Sub-clause 6.1.2)
- Risetime of one pulse	5 ns ± 30% (see Sub-clause 6.1.2 and Figure 3)
- Impulse duration (50% value)	50 ns ± 30% (see Sub-clause 6.1.2 and Figure 3)
- Waveshape of the pulse matched output into 50 Ω load	See Sub-clause 6.1.2 and Figure 3
- Relation to power supply	Asynchronous
- Burst duration	15 ms ± 20% (see Sub-clause 6.1.2 and Figure 2)
- Burst period	300 ms ± 20% (see Sub-clause 6.1.2 and Figure 2)

Table 1. - Characteristics of performance of the fast/burst generator

Frequency range	1 MHz to 100 MHz
Coupling capacitors	33 nF
Coupling attenuation	< 2 dB
Decoupling attenuation in non-symmetrical condition	> 20 dB
Crosstalk attenuation in the network between each line to the other	> 30 dB
Insulation withstand capability of the coupling capacitors	5 kV (Test-pulse 1.2/50 μs)

Table 2. - Characteristics of coupling/decoupling network for a.c./d.c mains supply circuit



(Example. - Construction for 3-phase lines. D.C. lines/terminals shall be treated in a similar way)
Note: EUT = Equipment Under Test

Figure 2. - Coupling/decoupling network for a.c./d.c. power mains supply lines/terminals.