Preliminary EMI/RFI Evaluation
AEPSC Reactor Protection and Control System Replacement Project
Report Number 2985-HEI-03, Rev. 0

1. INTRODUCTION

1.1 Background

American Electric Power Service Corporation (AEPSC) is performing a design change which replaces the analog processing hardware for the Reactor Protection and Control system. This is considered to be a major equipment replacement project, and as a result, many of the details of the original design are being revisited in order to determine acceptability of the replacement equipment. The replacement equipment must be able to function in the environment in which it will reside; namely, the main control room. Electromagnetic and radio frequency signals, which are or could be present in the control room, are a part of this environment.

The equipment which has been chosen for these cabinets is of the Foxboro Spec 200 product line. Experience to date shows no significant problems with respect to EMI/RFI on the existing equipment (Foxboro H-Line); however, the design is proceeding cautiously in this area.

The potential for undesirable effects from EMI/RFI has been recognized for some time. The Donald C. Cook Nuclear Plant (DCCNP) has various administrative controls in place to limit the exposure of critical electronic equipment to EMI/RFI. The administrative controls adhere to industry practices know to provide defense in depth against the detrimental effects of electromagnetic interference. As a part of the replacement, AEPSC is performing tests to demonstrate that the replacement equipment tolerance to EMI is adequate to ensure performance of its intended function.

1.2 Purpose

The purposes of this report are:

A) to document the reasons that the Foxboro Spec 200 equipment is expected to perform acceptably in the control room EMI/RFI environment, and

B) to describe the specific steps being undertaken to ensure that the replacement equipment is capable of performing the required functions in the control room environments.

1.3 Overview

This report evaluates the generic EMI/RFI testing for Foxboro Spec 200 equipment in order to provide confidence that the Spec 200 equipment is resistant to EMI/RFI effects, and can acceptably perform in the EMI/RFI environment which will be present at the control room at DCCNP.

This document also provides a preliminary assessment of the control room EMI/RFI environment. This assessment will briefly summarize the findings of the following activities to obtain an estimated control room environment.

A. EMI/RFI site surveys, which were conducted in the control rooms of each unit at DCCNP,
B. Research into the EMI/RFI sources in the DCCNP area and at the plant site,
C. Investigations into conducted and radiated emissions performed at an AEPSC laboratory facility which provided preliminary results on Taylor Mod 30 EMI/RFI emissions, and
D. The Foxboro Spec 200 Micro EMI/RFI emissions report.

Certain credit is taken for the inherent shielding of the control room due to the rebar in the concrete walls, floor and ceiling in order to limit the research into item B above.

This report provides confidence that the requirements within the supplemental EMI/RFI test procedure for the Foxboro Spec 200 equipment will adequately envelop the expected environment in the DCCNP control rooms.

A final detailed determination of the control room environment will be prepared in the near future to validate the field strength levels used in the Reactor Protection and Control System (RPCS) supplemental EMI/RFI testing.

2.0 REFERENCES

2.1 ANSI/IEEE C37.90.2-1987; "Withstand Capability of Relay Systems to Radiated Electromagnetic Interference from Transceivers".

2.2 Foxboro/National Testing Services Test Procedure No. 60095-93N and Addendum; "Electromagnetic Interference Test Procedure for AEPSC Process Control System"; August 14, 1992.

2.3 Mil-Std-461C; "Electromagnetic Emission and Susceptibility Requirements for the Control of Electromagnetic Interference"; April 1, 1980.

2.4 IEEE Standard 1050-1989; "Guide for Instrumentation and Control Equipment Grounding in Generating Stations".

2.5 Interference Control Technologies, Inc. Paper; "Site Specific Requirements Development and Measurements" Presented at EPRI EMI/RFI Conference in Baltimore, MD on September 10-11, 1992. Author: W. D. Nason.

2.6 Foxboro Test Report No. 88-1033a; "Interference Testing of (1) 2CCA Spec 200 Micro Control Card, (1) 2CDA-S1 Spec 200 Micro Display, (1) 2AI-I2V Spec 200 Converter, (1) 2AO-VAI Spec 200 Converter, and (1) 2ARPS05 Spec 200 Power Supply"; November 30, 1988.

2.7 Foxboro Test Report No. 85-1182A; "Evaluation of (21) 2CCA Style A Spec 200 Micro Control Cards"; November 13, 1985.

2.8 National Testing Services Test Report 60132-93N, "Test Report for EMI Mapping of Main Control Room, D.C. Cook Station, Unit 1 and 2"; 11/3/92.

2.9 AEPSC Specification No. DCC-IC-500-QCN, Reactor Protection and Control Instrumentation, April 3, 1989. (and Modifications to this Specification)

2.10 Bacon's Radio/TV Directory; December, 1991.

2.11 IEEE Standard 518-1982;"Installation of Electrical Equipment to Minimize Electrical Noise Inputs to Controllers from External Sources".

2.12 Plant Building Floor Layout, Section, Slab Detail Drawings:

12-3316-16	12-3317-11	12-3321-22
12-3322-23	12-3327-18	12-3328-12
12-3335-21	12-3336-17	12-3339-17
12-3340-20	12-3342-24	12-3343-18
12-3344-18	12-3367-6	12-3371-3
12-3372-1.		

2.13 DCCNP Plot Plan Drawing 12-5160-10.

2.14 DCCNP Grounding Evaluation, Report 2985-HEI-02.

2.15 Report No. 2985-HEI-04, Review of Supplemental EMI/RFI Test Procedure for Spec 200 Equipment.

2.16 Foxboro Report 85-1182A,"Evaluation of (21) 2CCA Style A Spec 200 Micro Control Cards"; November 13, 1985.

2.17 "EMC Considerations Concerning Equipment Upgrades at a Nuclear Utility Power Generating Station; A Case History", Martin J. Metcalf, Paper Presented at EMC Conference in Baltimore, MD on September 10, 1992.

2.18 Mil-Std-462; "Measurement of Electromagnetic Interference Characteristics", July 31, 1967 and all Subsequent Notices.

2.19 Test Report 98689-ICE-3711, "EMI Site Survey of the D. C. Cook Unit 2 Control Room for American Electric Power Service Corporation", July 20, 1992.

2.20 Report 2985-HEI-11, "Review of EMI Mapping Report".

2.21 AEPSC Memo From D. A. Klinect-Groveport To R.C. Carruth-Columbus, "Donald C. Cook Plant Controls EMI Testing", dated November 4, 1992.

2.22 NUREG CR-3270. "Investigation of Electromagnetic Interference (EMI) Levels in Commercial Nuclear Power Plants", August 1983.

3.0 ANALYSIS

3.1 Preliminary Evaluation of Equipment

The equipment to be used as replacements for the Foxboro H-Line Reactor Protection System process instrumentation is Foxboro Spec 200. All of the equipment is analog in nature except for the internal workings of the Spec 200 Micro control cards. Generally, the Spec 200 equipment operates based on 0-10 Volt DC signals. Inputs are converted from mA to 0 to 10 Volts by I/V cards for processing within the cabinets. Outputs are converted from 0 to 10 Volts to mA using V/I cards.

3.1.1 Generic Testing

Results of generic tests for EMI/RFI, Electrostatic Discharge (ESD), Surge Withstand, and Lightning effects for the Spec 200 Micro control card are summarized in Reference 2.6. The test setups were configured such that all inputs to the cabinet go through I/V cards and all outputs go through V/I cards. This will be the installed condition of the cabinets at AEPSC, and is therefore a valid test configuration.

Electrostatic discharge voltages of 2 to 10 kV were applied and removed from the display unit. These tests were performed in accordance with IEC 801-2 (Level 3), CES 278 Section 3.2.3, CES 288:59. Reference 2.4 gives typical ESD voltage levels of approximately 5 kV. Therefore, the levels applied for testing are reasonable. During this testing, errors in the system were observed at a maximum of 2% of span (including the display unit, which is not being used for this project) with no catastrophic failures. Errors dropped to 0.1% of span after the voltages were removed. Since this is within the reference accuracy of the control cards, these results are considered to be acceptable. Based on these results, no additional ESD testing is considered necessary for the new equipment.

The generic radiated EMI/RFI susceptibility tests were performed in accordance with IEC Publication 801-3, CES 278 Section 3.1.3 (Levels 2, 3). Although the frequency range for this testing was not as broad as that required by Reference 2.3, the frequencies ranged from 20 to 500 MHz at intensities of 10 V/m and 3 V/m. The worst case output shift magnitude of the Spec 200 Micro control card was 2.57% of span, which is within Foxboro specifications. Seventy percent of the points taken were within 1.5% of span at intensities of 10 V/m and greater than 80% of the points taken were within 0.2% of span at 3 V/m. The results of the site survey for DCCNP show that all surveyed field intensities are less than 2 V/m.

The generic high frequency transient tests were performed in accordance with IEC Publication 801-4 (Level 3), CES 278 Section 3.3. Transients of 0.5 and 1 kV were applied in the normal mode to the AC mains for a duration of one minute. Magnitudes of 1 and 2 kV were applied in the common mode. The maximum output shift was 0.01% of span. Transients of 0.5 and 1 kV were applied to the signal leads via a capacitive clamp for a duration of one minute. The maximum output shift was again 0.01% of span. This is a negligible output shift, and is considered acceptable.

The generic lightning effects were tested in accordance with IEC Publication 801-5, CES 278 Section 3.5.2 (Levels 3, 4). Level 4 was applied to the AC mains, and level 3 was applied to the input and output cards. No output shift magnitudes were observed in excess of 0.03% of span for level 3 testing, or 0.12% of span for level 4 testing. These shifts are considered acceptable, since the normal uncertainties associated with the Micro control cards is +/- 0.1% of span. The testing performed above is considered adequate to prove system performance. Therefore, the results of the testing is acceptable, and no additional lightning strike testing is considered necessary for the new systems.

No anomalies were identified by the test report (Reference 2.6). Therefore, the performance of the Spec 200 Micro control card to the generic tests described above is acceptable. The Foxboro Spec 200 equipment has a long history of successful nuclear plant performance in analog applications. This history, combined with the successful completion of the testing described above, provides a high level of assurance that the Foxboro Spec 200 will perform reliably under normal, ESD, lightning, and EMI/RFI environments.

3.1.2 Plant Design Parameters

A site survey was performed at the DCCNP control rooms, which demonstrates that unusually high conducted and radiated emissions do not exist in the control room environments.

Various aspects of the design of DCCNP help to reduce the effects of EMI/RFI on equipment located in the control room. The inherent shielding in the structure of

the control room and the application of good grounding and shielding practices to the installed equipment provide a reduction in the coupling of conducted and radiated emissions into control room equipment.

The control rooms at DCCNP are surrounded on all sides (including top and bottom) by concrete, which is supported with a lattice of rebar. The center to center distance between the rebar is 1 foot or less (Reference 2.12). Per presentations made by Interference Control Technologies, Inc. at an EPRI conference on EMI/RFI on September 10-11, 1992, the rebar lattice acts as an effective shield to radiated electromagnetic signals with wavelengths greater than or equal to twice the center to center distance of the rebar. As shown in the equation below, the effective shielding occurs for signals with frequencies at or below 491 MHz.

$$F = c/\lambda = (2.998E8 \text{ m/s})\text{x}(39.37 \text{ in/m})/24 \text{ in} = 491.8 \text{ MHz.}$$

where: λ = wavelength
c = Speed of light in a vacuum

This is validated by site survey data taken on pages 9-73 through 9-87 of Reference 2.8. Radio signals at approximately 456 and 451 MHz generated outside the control rooms were measured both inside and outside the control rooms. Readings at various locations were taken inside the control rooms with doors open and closed. Then a reading was taken outside the control rooms to determine the general shielding effectiveness. The minimum signal attenuation measured from outside the control rooms to any location inside the control rooms for these two signals appears to be approximately 29 dB.

New design changes at DCCNP include the addition of the air terminals to increase the protection of plant structures and equipment from lightning strikes at DCCNP. These changes were made to the containment building, diesel generator buildings, and the auxiliary buildings, as described in Reference 2.14. Also, the grounding practices used at DCCNP limit the effects of lightning strikes on plant instrumentation and control equipment.

Plant design practices at the DCCNP site call for instrument signal cables to be twisted shielded conductors with the shield drain wire terminated at one end only, preferably in the control room cabinet (at a single point). These are practices recommended by References 2.4 and 2.11 to prevent coupling of EMI into electronic equipment. By twisting the wires, a series of adjacent loops is formed in the instrument circuit rather than one loop, which would be formed by using two parallel conductors. Any magnetic field that goes through the instrument cable will tend to be canceled out by the adjacent loops, as the currents induced by the magnetic fields into adjacent loops in each wire are in opposite directions. Additionally, the area of the loop is kept to a minimum.

Grounding the shields at only one end considerably reduces capacitive interference from other conductors. This arrangement is particularly effective against lower frequency noise signals (< approximately 300 kHz per Reference 2.4). This arrangement, along with single point shield grounding within a cabinet, prevents unwanted ground loops, which can induce noise onto the signal wires. It also prevents stray ground fault currents from flowing through the shield, which can produce undesirable electrical noise and even cause cable damage under extreme conditions.

At DCCNP, instrument cables are routed in separate raceways from power and control cables. Therefore, spatial separation of the cables will reduce cable crosstalk. In addition, a large percentage of the signal cable runs for RPCS are routed through grounded rigid steel conduit. These practices tend to reduce EMI/RFI signal coupling into the circuits of the replacement cabinets.

Grounding of the Foxboro equipment will be accomplished in accordance with manufacturer recommendations. This will include separate cabinet ground busses for power and signal grounds. The grounding system at DCCNP was evaluated by Reference 2.14. This report shows that the DCCNP grounding scheme uses a ground mat which is tied up to the control room. This mat is connected to the Foxboro cabinets with redundant 4/0 ground conductors, which are recommended by Reference 2.4. All protection and control cabinets are connected to the ground mat in this fashion in the DCCNP control rooms.

All of the qualities listed above are acceptable grounding and shielding practices as recommended by References 2.4 and 2.11.

In addition to grounding and shielding practices, other features of DCCNP tend to reduce or eliminate EMI/RFI signals at the source. The inverter outputs which provide power to the RPCS cabinets include filter capacitors to reduce the EMI/RFI produced by the inverter circuitry. The RPCS DC power supplies also have output filter capacitors to reduce EMI introduced from these supplies. Administrative procedures prohibit the use of hand held radios within the control room, which reduces the field strength of the resulting EMI/RFI at the cabinet locations. As shown by industry attention to this issue, the use of hand held radios in control rooms is one of the largest contributors to EMI/RFI problems experienced by control systems. Limiting the use of the radios to areas outside the control room significantly decreases the field strength of the signals at the control cabinets, as demonstrated by the site survey results.

Since the power to the components within the RPCS cabinets is DC, supplied from 24V or 80V power supplies within the cabinet, high frequency conducted noise on the incoming AC lines should not significantly propagate through the power supplies to the devices within the cabinets.

From the descriptions given above, the design attributes of DCCNP tend to reduce electromagnetic signal intensities. Abnormally high levels of radiated or conducted noise should not be experienced by the Foxboro Spec 200 cabinets in the DCCNP control room environment. The Foxboro Spec 200 equipment performed well during the generic EMI/RFI testing. Therefore, the equipment installed as a part of the Reactor Protection and Control System Replacement Project is predicted to perform acceptably in the EMI/RFI environments anticipated at the DCCNP control rooms.

3.2 Description of Site Specific EMI/RFI Susceptibility Testing

The DCCNP specific RPCS design will be subjected to EMI/RFI supplemental testing to provide final documented proof of EMI/RFI tolerance of the replacement equipment. In order to develop valid test parameters, a set of site specific requirements for EMI/RFI testing will be determined. The tests chosen and frequencies covered are based on industry experience from previous EMI/RFI testing of digital equipment for the nuclear power industry. Tests chosen and general guidance on test methodology are derived from Mil-Std-461C and 462. The field strengths given within the susceptibility test will be validated for this application by performing a detailed determination of the EMI/RFI environment in the control room at a later date. However, a preliminary general assessment of the control room environment will be done in this report to give confidence in the field strengths used in these tests.

3.2.1 General Control Room Environment Assessment

It should be realized that the EMI/RFI signals are not as easily controlled as other environmental aspects. It is possible for other radar/microwave/radio transmitters to move into the geographic area of the plant site and potentially increase the RFI signal levels within the control room. However, it is most likely that the added signals will be attenuated by distance and shielding such that no significant impact will be made on the control room EMI/RFI environment. An effort has been made to assess the present environment, and the design features of the plant appear to provide ample margin to limit the exposure of the equipment to the effects of any external sources. The following three activities were performed to assess the present EMI/RFI environment for the DCCNP control rooms.

A. A series of site surveys has been taken for both units to define the continuous and intermittent electromagnetic signals which are present in the control room. These surveys recorded the frequencies and magnitudes of the signals to use for evaluation purposes. (Reference 2.8, 2.19)

B. The replacement equipment for the Reactor Protection and Control System and the Process Control Groups could generate low levels of EMI/RFI. Emissions testing on Taylor Mod 30 equipment and previous emissions

testing for Foxboro Spec 200 equipment are preliminarily assessed for environmental impact.

C. Finally, research has been conducted in the surrounding area to the DCCNP plant site to determine the any potential intermittent signals which could be present, but not detected by the site survey. Approximate field strengths of the signals are estimated in the general vicinity of the plant.

3.2.1.1 EMI/RFI Site Surveys

Testing has been conducted for the assessment of the control room EMI/RFI environment in three intervals covering a range of power plant operating modes. Data has been taken from both units, which covers a sampling of conducted and radiated environments.

Operating modes reflected in the study range from full load through half load, and mode 3 startup to mode 5. Data taken was chosen to be representative of the environments at different operating modes, but was not intended to represent a comprehensive survey of both units, in every operating mode, for all conducted and radiated geometries. Consistency in data gathered supports the validity of this approach to establishing the EMI/RFI environment.

In addition to the bulk of the survey data, which represents an assessment of the steady state or background EMI/RFI environment present, special tests were run to demonstrate the effects of systems which, because of cable routing or presence in the control room, were considered likely to contribute to the environment. Data was also taken for the purpose of assessing the shielding effects of the control room walls.

General conclusions were as follows.

Conducted and radiated environments are comparable between units and at different locations within each unit control room, with some tendency for levels to be slightly higher in amplitude in Unit 2.

The environment in the control room is relatively unaffected by activity outside the control room. Much of the conducted and radiated EMI/RFI environment in the control rooms is created by equipment located within the control room, such as equipment power supplies and lighting.

Significant shielding effects were noted from the control room walls for radiated signals in the range of plant communications. This is based on staged tests with data taken inside and outside the control room walls, and observations taken of the control room radiated environment, with the doors open and closed.

Conducted data taken on equipment grounds indicated low levels compared to conducted tests run on power and instrument cables, indicating both the absence of significant conducted emissions entering the cabinets via this path and the effectiveness of ground paths present for higher frequencies to be dissipated in parallel with the low resistance grounding system.

Emissions from the operation of systems like Rod Drive Control, plant portable communications (repeaters) and Reactor Coolant Pumps were included in the site survey testing. The field strengths given in Tables 5 and 6 include the effects from these emissions.

The following field strength conclusions can be obtained from Reference 2.8.

Conducted emissions:

Per page 9-2 of Reference 2.8, observed conducted emissions from tests CE01 and CE03 were principally self induced by the existing RPCS cabinet power supplies. The conducted emissions are expected to be low, and the levels specified by Mil-Std-461C should be conservative with respect to the control room environment.

Radiated emissions:

Magnetic field strengths of up to 2 to 4 Gauss were sensed during the magnetic field testing in the control room. However, if the sources within the RPCS cabinets are removed, (since they are being replaced), the DC magnetic fields measured by test REXX at the replacement cabinet locations were representative of those associated with the earth's magnetic fields. (300-500 milliGauss). Therefore, the supplemental testing to be done for susceptibility will be adequate to cover the full range of the magnetic field environment. (Reference 2.20)

In order to obtain representative radiated EMI/RFI field strengths in the control rooms, Table 5 was created to summarize the worst case field strength levels per frequency, measured by test RE02 of Reference 2.8. The levels are converted to units of V/m in order to compare these to the test parameters in the supplemental EMI/RFI test procedure.

Table 6 was created for the worst case hand held radios field strength levels measured in the control rooms by RE02 tests. The testing adequately covered the frequencies which could be used from hand held radios, and was performed in many locations within the control room, with the control room doors open and closed. It should be noted that signal strengths are not solely from the hand held communications devices, but also reflect the effect of the plant wide repeater transmissions.

One conclusion which can be drawn from the site surveys is that the D.C. Cook Nuclear Plant control rooms do not have an unusually high presence of EMI/RFI signals. Generally, the EMI/RFI environment was generally found to be mild in comparison to the supplementary test environment.

3.2.1.2 Control System Upgrade Impact Assessment

Additional signals which would be present during operation in the control room could be created by the addition of the Taylor Mod 30 equipment and the Foxboro Spec 200 equipment. Since these cabinets were not installed at the time of the site survey, the signals could not have been observed during the site surveys. Consideration will be given to the impact of these emissions when conducting the planned supplemental EMI/RFI testing on the Spec 200 and Taylor Mod 30 equipment.

3.2.1.2.1 Taylor Mod 30 Emissions Testing (Process Control Groups)

The impact of the addition of the Taylor Mod 30 equipment to the control rooms and its effect on the test program for supplemental EMI/RFI testing for the Foxboro Spec 200 will be formally assessed as part of the EMI/RFI testing planned later for the replacement Control Group equipment.

In an effort to gain insight into the environment change, a survey of conducted and radiated emissions was conducted at an AEPSC test facility in Groveport, Ohio (Reference 2.21). This survey was conducted in conformance to Mil-Std-461C and 462. The data is used to provide an assessment of the adequacy of the EMI/RFI testing planned for the Protection upgrade equipment.

In addition to the Mil-Standard tests, additional investigations were conducted to assess 1) the additive effects of the multiple sources present in the control racks (controllers and math units), and 2) the effect of distance in attenuation of radiated emissions.

The test setup included external cabling similar to the actual field installation, a comparable grounding system, and the actual prototype racks. These racks are used to proof the design and are also destined to be used in the Seismic and EMI/RFI testing. Testing was conducted with the cabinet doors both open and closed.

Test results for radiated emissions in the lower frequency range showed tuned signals in the range of 90 kHz to 200 kHz, as well as broadband noise in the lower end of the test range. Levels were of an amplitude less than or equal to 115 dBμV/m/MHz, originating primarily from the power supplies: roughly what already exists in the control room environment at comparable levels.

Test results in the 20 MHz to 50 MHz range showed emissions generated by the Plasma displays at levels comparable to what already exists in the control rooms. Data obtained with cabinet doors open was slightly higher than with the doors closed.

Tests run to establish the additive effect of modules demonstrated that emissions from the controllers were far in excess of emissions from the Math units. This is explained by the presence of significantly more display area on the controller units. Measurements taken as modules were sequentially added demonstrated that emissions generally increased for the first several units, after which additional units had negligible impact on emissions levels. This effect was anticipated, based on the nature of the emissions generated. Emissions measurements taken, at three meters from the cabinets, indicated a 6 dB drop off. Again this is approximately what would be expected, given the distributed nature of the emitters.

No significant emissions could be traced to the microprocessor activity, although there were several minor emissions at frequencies that could have been the result of the 9 MHz oscillator on the modules.

Conducted emissions tests yielded roughly the same conclusions as reached in the control room surveys, i.e. that the power supplies were the primary contributors. Levels were entirely dependent on the impedance level of the cable terminations. High impedance terminations tended to yield uniformly higher conducted values, while low impedance terminations yielded lower values with more defined peaks.

The general conclusion reached in this initial assessment was that introduction of the Taylor Mod 30 equipment into the control racks would have negligible impact on the control room EMI/RFI environment experienced by the Foxboro Spec 200 protection equipment.

3.2.1.2.2 Foxboro Spec 200 Emissions Testing (RPCS Cabinets)

Reference 2.16 performed emissions testing on the Foxboro Spec 200 equipment. Page 7 and Graphs 1 and 2 describe the results of the emissions testing done for one of the dual Spec 200 Micro control cards. The emissions observed at one meter from the control card are as shown in Graphs 1 and 2 for vertical and horizontal orientations. These graphs show that the Micro control cards emit frequencies of between 50 and 200 MHz at intensity levels less than 70 dBμV. Per Reference 2.17, the equation for converting this to an equivalent V/m measurement is given below.

$$dB\mu V = 20 \log ((\text{peak volts/meter})/(1\ \mu V))$$

Using this conversion, the intensity corresponding to 70 dB is .00316 V/m. Per the same lines of reasoning in the preliminary Taylor Mod 30 evaluations above, the emissions level of multiple cards will be low. Given the low field strength

emitted by the dual cards, that each control panel will provide a measure of shielding, and that a maximum of 4 Micro control cards is currently designed to be installed in any one cabinet, it is judged that the emissions from the Foxboro Spec 200 equipment will not significantly increase the EMI/RFI environment for the replacement equipment. Based on this, no added or existing equipment is expected to be affected by the emissions of the Spec 200 or Taylor Mod 30 equipment.

3.2.1.3 Research on Microwaves/Radars/EMI Sources in the Area

In order to predict the EMI/RFI signals and intensities for the replacement equipment, research was conducted in the following sources: Bacon's Radio/TV Directory (Reference 2.10), the Federal Communications Commission microfiche, and the AEPSC Communications Department.

A search was made for towns in a 50 mile radius around the plant site. Note that this search performs only 2 purposes. The first is to identify any signals with frequencies above 491 MHz (the effective shielding frequency of the control room rebar) that would not have been detectable by the DCCNP site surveys. The second is to get an idea of the signals present in the area, for postulating future emissions.

Tables 1 and 2 show the list of TV and radio stations in the 50 mile radius of the plant. However, note that these are continuous EMI/RFI sources. Therefore, the signals produced by these sources would have been picked up by the site survey, and do not need to be considered in addition to the environment defined by the site surveys.

Research was also performed with the microfiche at the Federal Communications Commission pertaining to the frequencies and power levels of the licensees in the DCCNP geographic area. There are many industries, companies and individuals licensed by the FCC within a 50 mile radius of the plant site. Therefore, the search was limited to those signals above 491 MHz, since the control room rebar effectively shields signals with lower frequencies. The cities researched are listed in Table 3. The large majority of the licensed transmitters observed in the search were continuous sources, such as cable companies, AT&T, MCI, etc. Even the lesser known sources were expected to be operated on a very frequent basis (Pagers, cellular telephone systems, etc.). The site surveys should have detected the environment created by these signals. Therefore, no additional sources were added to the environment due to the research into the Federal Communications Commission microfiche.

Finally, information was obtained from the AEPSC Telecommunications Department about the local frequencies used. Table 4 is a listing of the sources given by the Telecommunications Department and the frequencies and power levels involved with them. The distance from the repeaters to the control room is estimated at 50

meters. Distances for mobile/portable transceivers and portable phones are also estimated as 50 meters. The sheriff's department/state police distances are estimated as the distance to the microwave tower. Note that the hand held radios, repeaters, sheriff's department transmitters, and state police transmitters were included in the site survey information, and the highest field strengths associated with these are noted in Table 6. Overhead crane distances are estimated as 50 meters. The estimates of distances should be conservative, with respect to actual locations. Noted in the tables are the signals which have frequencies below 491 MHz. The frequencies below 491 MHz are effectively blocked by the control room rebar. For the frequencies above 491 MHz, the signal intensities are low enough to be considered negligible. The microwave tower is directional and not directed towards the control room. Therefore, field strengths associated with the microwave are negligible. Finally, the pager signals are considered to be adequately covered by the site surveys.

In summary, the research done on area transmitters yielded no signals which need to be considered in addition to that revealed by the site surveys.

3.2.1.4 Summary of EMI/RFI Environment

The detailed definition of the required control room EMI/RFI environment will be performed at a later date. The general assessment of the control room environment shows that the levels of EMI/RFI are likely to be very mild with respect to the limits defined in the supplementary EMI/RFI testing. An initial assessment of the field strength environment required for radiated susceptibility testing are summarized in Tables 5 and 6.

3.2.2 Spec 200 Susceptibility Testing

Reference 2.2 is the EMI/RFI Supplemental Test procedure for the DCCNP specific Foxboro Spec 200 equipment. Reference 2.15 is the evaluation of Reference 2.2. This documents the acceptability of the test procedure to test per References 2.3 and 2.9. An accepted method of testing per Reference 2.3 is Reference 2.18. All testing done in Reference 2.2 is performed per Reference 2.18. A short summary of the testing to be performed follows.

The purchase specification for the Foxboro hardware requires that the EMI/RFI susceptibility testing be done per the following sections of Mil-Std-461C: CS01, CS02, CS06, RS02, and RS03. Per Table 4-1 of the Mil-Standard, these tests were appropriately selected for the digital equipment applications. CS01, 02, and 06 are performed on equipment and subsystem AC and DC power leads, including grounds and neutrals, which are not grounded internally to the equipment or subsystem. Reference 2.2 appropriately performs this test on the input power leads to the cabinets. RS02 and RS03 are performed to test the equipment for susceptibility to radiated emissions.

CS01 tests the equipment for susceptibility to conducted emissions in the frequency range of 30 Hz to 50 kHz. A 5 Vrms test signal is used up to 1.5 kHz, and then linearly falls off to 1 Vrms at 50 kHz, per the Mil-Standard. Per the discussion given above for the DCCNP control room environment, these test parameters should envelop the required environment.

CS02 tests the equipment for susceptibility to conducted emissions, but no specific frequency range is given. The August 4, 1986 notice to Reference 2.18 recommends power lead testing per CS02 for the frequency range of 50 kHz to 400 MHz. Reference 2.2 complies with these frequency limits at the voltage requirements of Reference 2.3 (1 Vrms). As discussed above, these test parameters should envelop the required environment.

CS06 tests the equipment for susceptibility to conducted spikes. The limits specified in Reference 2.2 meet the requirements for the "ARMY" limits given in Reference 2.3.

RS02 tests the equipment for susceptibility to radiated spikes and power frequencies. The requirements for the "ARMY" limits given in Reference 2.3 are met by the testing in Reference 2.2.

RS03 tests the equipment for susceptibility to radiated emissions and noise from 14 kHz to 10 GHz. The signal intensities given in References 2.2 envelop that given in Reference 2.3 for "ARMY" equipment. The field strengths for the supplemental tests are given below.

14 kHz to 2 MHz:	5 V/m
2 MHz to 30 MHz:	10 V/m
30 MHz to 2 GHz:	10 V/m
2 GHz to 10 GHz:	5 V/m.

It is evident that these intensities envelop the preliminary assessed EMI/RFI environments shown in Tables 5 and 6. It should be noted that for the 14 kHz to 2 MHz test, the level has been increased above the Mil-Std-461C level of 1 V/m in order to envelop the DCCNP environment.

For each of these tests, if susceptible frequencies are found in the Foxboro Spec 200 equipment, the threshold level will be determined at the frequency in question. The threshold level should be greater than that defined for the environment to demonstrate that the equipment will function in the control rooms.

4.0 SUMMARY

As described above, successful previous testing of the Foxboro Spec 200 Micro equipment with respect to EMI/RFI issues, along with good grounding and shielding practices and design features of DCCNP, give confidence that the Foxboro Spec 200 Micro components will perform acceptably in the EMI/RFI environment at the D.C. Cook control rooms. This will be further validated at a later date by additional supplemental EMI/RFI susceptibility testing.

A conservative assessment of the required EMI/RFI environment is made herein. This assessment is based on site survey information, research into the transmitters in the surrounding area, and emissions testing of new equipment to be added to the control room. This assessment shows very mild EMI/RFI levels predicted within the control rooms at DCCNP. A detailed final assessment of the DCCNP control room EMI/RFI environment will be made at a later date. The results of this assessment will be used to validate the test parameters used in the supplemental testing.

Reference 2.2 outlines the supplemental EMI/RFI test procedure, which meets the requirements of the purchase specification and the applicable requirements of Reference 2.3 and 2.18. These test parameters should envelop the EMI/RFI environment for the DCCNP control rooms. These supplemental tests should be adequate to establish that the Reactor Protection and Control system replacement cabinets can perform their required functions in the EMI/RFI environments of the control rooms at DCCNP.

5.0 APPROVALS

Prepared By: Kirk R Melson Date: 11/17/92

Reviewed By: [signature] Date: 11/18/92

Approved By: [signature] Date: 11/20/92

Table 1: Television Stations Within 50 Mile Radius of DCCNP

Location	Distance (Miles)	Distance (KM)	Frequency Range (MHZ)	Frequency Audio (MHZ)	Visual (MHZ)	Eff. Rad. Pow(ERP) (KW)	Plant Vicinity Field Strength (V/M) *
Elkhart, IN	34	54.72	490-496	495.74	491.24	60	0.0245
Elkhart, IN	34	54.72	554-560	559.76	555.26	120	0.0347
South Bend, IN	22	35.40	662-668	667.75	663.25	60	0.0379
South Bend, IN	22	35.40	482-488	487.75	483.25	110	0.0513
South Bend, IN	22	35.40	518-524	523.75	519.25	120	0.0536
Kalamazoo, MI	50	80.47	60-66	65.76	61.26	10	0.0068
Kalamazoo, MI	50	80.47	770-776	775.75	771.25	0	0.0000

* Calculated by the equation: Field Strength(V/m) = ((30*ERP(W))^0.5)/Dist(m).

Table 2: Radio Stations Within 50 Mile Radius of DCCNP

Location	Distance (Miles)	Distance (KM)	Frequency (MHZ)	Eff. Rad. Pow(ERP) (KW)	Plant Vicinity Fld Strength (V/M) *
Allegan, MI	50	80.47	92.30	3.00	0.0037
Benton Harbor, MI	8	12.87	99.90	50.00	0.0951
Benton Harbor, MI	8	12.87	1.06	5.00	0.0301
Berrien Springs, M	10	16.09	90.70	48.00	0.0746
Cassopolis, MI	28	45.06	0.91	1.00	0.0038
Dowagiac, MI	23	37.01	1.44	1.00	0.0047
Dowagiac, MI	23	37.01	92.10	3.00	0.0081
Kalamazoo, MI	50	80.47	0.59	5.00	0.0048
Kalamazoo, MI	50	80.47	1.36	5.00	0.0048
Kalamazoo, MI	50	80.47	1.42	1.00	0.0022
Kalamazoo, MI	50	80.47	1.47	0.80	0.0019
Kalamazoo, MI	50	80.47	1.56	5.00	0.0048
Kalamazoo, MI	50	80.47	89.10	0.10	0.0007
Kalamazoo, MI	50	80.47	102.10	50.00	0.0152
Kalamazoo, MI	50	80.47	103.30	50.00	0.0152
Kalamazoo, MI	50	80.47	106.50	33.00	0.0124
Niles, MI	19	30.58	95.30	0.30	0.0031
Niles, MI	19	30.58	1.29	0.50	0.0040
South Haven, MI	32	51.50	98.30	3.00	0.0058
South Haven, MI	32	51.50	0.94	3.00	0.0058
St. Josephs, MI	7	11.27	107.10	3.00	0.0266
St. Josephs, MI	7	11.27	1.40	1.00	0.0154
Three Rivers, MI	47	75.64	95.90	3.00	0.0040
Three Rivers, MI	47	75.64	1.51	0.50	0.0016

* Calculated by the equation: Field Strength (V/m) = ((30*ERP(W)) ^ 0.5)/Dist(m)

Table 2: Radio Stations Within 50 Mile Radius of DCCNP
(Continued)

Location	Distance (Miles)	Distance (KM)	Frequency (MHZ)	Eff. Rad. Pow(ERP) (KW)	Plant Vicinity Fld Strength (V/M) *
Goshen, IN	47	75.64	91.10	7.40	0.0062
Goshen, IN	47	75.64	97.70	3.00	0.0040
Goshen, IN	47	75.64	1.46	1.00	0.0023
Elkhart, IN	34	54.72	88.10	10.50	0.0103
Elkhart, IN	34	54.72	104.70	50.00	0.0224
Elkhart, IN	34	54.72	1.27	5.00	0.0071
Elkhart, IN	34	54.72	1.34	1.00	0.0032
Mishawaka, IN	31	49.89	100.70	50.00	0.0245
Mishawaka, IN	31	49.89	103.90	3.00	0.0060
South Bend, IN	22	35.40	91.70	3.00	0.0085
South Bend, IN	22	35.40	92.90	12.50	0.0173
South Bend, IN	22	35.40	101.50	18.00	0.0208
South Bend, IN	22	35.40	102.30	3.00	0.0085
South Bend, IN	22	35.40	103.10	3.00	0.0085
South Bend, IN	22	35.40	0.96	5.00	0.0109
South Bend, IN	22	35.40	1.49	1.00	0.0049
South Bend, IN	22	35.40	1.58	1.00	0.0049
La'Porte, IN	27	43.45	96.70	3.00	0.0069
La'Porte, IN	27	43.45	1.54	0.25	0.0020
Michigan City, IN	22	35.40	95.90	3.00	0.0085
Michigan City, IN	22	35.40	1.42	5.00	0.0109

* Calculated by the equation: Field Strength (V/m) = ((30*ERP(W)) ^ 0.5)/Dist(m)

Table 3: Cities Researched in FCC Microfiche for Licensees

State	Michigan	Michigan	Michigan	Michigan	Michigan	Indiana
Cities	Alamo	Decatur	Hagar Shores	North Lake	Three Oaks	Beverly Shores
	Allegan	Douglas	Harbert	Oshtemo	Three Rivers	Bremen
	Baroda	Dowagiac	Hartford	Paw Paw	Vandalia	Bristol
	Barron Lake	Eagle Lake	Indian Lake	Paw Paw Lake	Volinia	Chesterton
	Benton Harbor	Eau Claire	Kalamazoo	Pearl	Wakelee	Elkhart
	Berrien Center	Edwardsburg	Keeler	Pertrand	Watervliet	Goshen
	Berrien Springs	Fair Plain	Kendall	Pullman		Hudson Lake
	Bloomingdale	Fennville	Lacota	Riverside		Kingsbury
	Bravo	Galien	Lake Shore	Saugatuck		La'Porte
	Bridgman	Gangor	Lawrence	Sawyer		Michigan City
	Buchanon	Garges	Lawton	Schoolcraft		Mishawaka
	Calvin Center	Glendora	Marcellus	Shoreham		Monroe Manor
	Cassopolis	Glenn	Mattawan	Sodus		New Carlisle
	Castle Park	Glenndale	Michiana	South Haven		Osceola
	Coloma	Gobles	Milburg	St. Josephs		South Bend
	Covert	Grand Beach	New Troy	Stevensville		Trail Creek
	Dayton	Grand Junction	Niles	Summerville		Waterford

Table 4: Communication Dept. Information on Local Transmitters

	Distance (Miles)	Distance (KM)	Frequency (MHz)	Eff Rad Pow(ERP) (W)	Cont Rm Vicinity Field Strength (V/m) (Note 2)	Notes
DCCNP Repeaters	0.03	0.05	451.23	2.00	0.1549	1
	0.03	0.05	451.38	2.00	0.1549	1
	0.03	0.05	451.25	2.00	0.1549	1
	0.03	0.05	451.03	2.00	0.1549	1
	0.03	0.05	451.08	2.00	0.1549	1
	0.03	0.05	451.05	2.00	0.1549	1
	0.03	0.05	451.20	2.00	0.1549	1
	0.03	0.05	462.75	2.00	0.1549	1
	0.03	0.05	37.70	2.00	0.1549	1
	0.03	0.05	37.80	2.00	0.1549	1
Mobile & Portables	0.03	0.05	456.23	20.00	0.4899	1
	0.03	0.05	456.38	20.00	0.4899	1
	0.03	0.05	456.03	20.00	0.4899	1
	0.03	0.05	456.08	20.00	0.4899	1
	0.03	0.05	456.25	20.00	0.4899	1
	0.03	0.05	456.20	20.00	0.4899	1
	0.03	0.05	451.14	20.00	0.4899	1
	0.03	0.05	31.20	20.00	0.4899	1
Overhead Cranes	0.03	0.05	467.75	1.00	0.1095	1
	0.03	0.05	467.93	1.00	0.1095	1
	0.03	0.05	451.69	1.00	0.1095	1
Microwave	0.25	0.40	6605.00	60.00	0.1055	
Sheriff's Dept.	0.25	0.40	465.10	100.00	0.1369	1
State Police	0.25	0.40	42.50	100.00	0.1369	1
Cellular Phones	0.09	0.15	800.00	3.00	0.0632	
	0.09	0.15	900.00	3.00	0.0632	
Pagers			150.00	None Available		1
			450.00	None Available		1
			900.00	None Available		

Notes:
1. Frequency is below 491 MHz, therefore not of concern.
2. Calculated by the equation: Field Stength(V/m) = ((30*ERP(W)) ^ 0.5)/Dist(m)

Table 5: Survey Maximums from Graphs - RE02

Frequency Range (MHz)	Narrowband Graph (dBuV/m)	RPC Cab. Fld Strength (V/m) (Note 2)	Broadband Graph (dBuV/m)	RPC Cab. Fld Strength (V/m) (Note 2)	Notes
.014-.02	72.00	0.0040	124.00	1.5849	1
.02-.05	74.00	0.0050	124.00	1.5849	1
.05-.1	59.00	0.0009	117.00	0.7079	1
.1-.2	62.00	0.0013	105.00	0.1778	1
.2-.5	56.00	0.0006	98.00	0.0794	1
.5-1	57.00	0.0007	98.00	0.0794	1
1-2	58.00	0.0008	92.00	0.0398	1
2-5	64.00	0.0016	94.00	0.0501	1
5-10	59.00	0.0009	93.00	0.0447	1
10-20	54.00	0.0005	88.00	0.0251	1
20-50	65.00	0.0018	90.00	0.0316	1
50-100	61.00	0.0011	85.00	0.0178	1
100-200	61.00	0.0011	90.00	0.0316	1
200-500	52.00	0.0004	100.00	0.1000	1
500-1000	49.00	0.0003	63.00	0.0014	1

Notes:
1. Some data points lie outside of acceptance band in Mil-Std-461C.
2. Derived by the following equation:

Field Strength(V/m) = ((10 ^ (graph(dBuV/m)/20))/1000000.

Table 6: Survey Maximums from Graphs - RE02 Hand Held Radio

Frequency (MHz)	Narrowband Graph (dBuV/m)	RPC Cab. Fld Strength (V/m) (Note 2)	Notes
0	25.00	0.0000	
42	43.00	0.0001	
449	35.00	0.0001	
451	52.00	0.0004	
452	33.00	0.0000	
456	65.00	0.0018	1
456.5	31.00	0.0000	

Notes:

1. Some data points lie outside of acceptance band in Mil-Std-461C.
2. Derived by the following equation:

Field Strength(V/m) = ((10 ^ (graph(dBuV/m)/20))/1000000.