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

DEC 09 1981

MEMORANDUM FOR: Commissioner Ahearne

FROM: Robert B. Minogue, Director
Office of Nuclear Regulatory Research

THRU: W. J. Dircks, Executive Director for Operations /s/ William J. Dircks

SUBJECT: MEMORANDUM, AHEARNE TO DIRCKS, "RIL 123 ELECTRICAL TERMINAL BLOCKS", SEPTEMBER 28, 1981

Your memorandum dated September 28, 1981 requested RES comments on the user offices' disposition of the recommendations made in the Research Information Letter (RIL) 123 and also asked whether the data in NUREG/CR-1682 supports the contractor's recommendations.

With regard to the first question, the following is a summary of each recommendation in RIL 123, the user offices' proposed disposition of each and the RES reaction to that disposition:

RIL Recommendation 1:

"All nuclear power plants using terminal blocks in circuits important to safety within the reactor containment should be inspected to verify that all terminal blocks are enclosed in a protective enclosure."

The user offices do not intend to conduct special inspections of terminal blocks in response to the RIL; however, they indicate that terminal blocks, as well as other electric equipment are inspected by IE during the normal course of the inspection program.

RES agrees that routine inspections can be an adequate way of implementing this recommendation if proper attention is given to the terminal block issues highlighted by the research and the RIL. The IE Information Notice planned on this subject could help to focus attention to these problems. The Information Notice planned by IE is apparently only an addition to one of the periodic composite information notices, rather than a specific information notice on terminal blocks, which we think would be preferable. To insure that licensees and other readers can draw the proper conclusions, it is essential that the recommendations made in the report and their bases be included in the IE Notice. To help assure that the Information Notice places the proper emphasis on these problems, RES will participate in its preparation.

RIL Recommendations 2 and 3:

"All terminal blocks utilized in systems important to safety should be cleaned at least once after construction and possibly periodically thereafter... (and)...procedures should be established to keep the terminal blocks clean. ...appropriate guidelines should be issued to maintenance personnel regarding the removal of enclosure covers and the cleanliness of terminal blocks."

The user offices believe that the issue of cleaning terminal blocks is already being addressed. They stated that, "In accordance with Appendix B to 10 CFR Part 50, it is the licensees' responsibility to establish appropriate procedures based upon manufacturer's recommendations, operating experience and specific components' characteristics to assure that equipment is maintained in an acceptable state. There are several IEEE, ANS, and ANSI Standards and NRC Regulatory Guides which address the installation, cleanliness, and ongoing maintenance of Class IE electric systems, including terminal blocks. These are presently being used by designers, installers, and maintenance personnel associated with the nuclear power industry...IE will include the results of the SANDIA testing of the terminal blocks in one of the periodic composite information notices to all licensees."

RES agrees that inspection of terminal blocks to establish their general degree of cleanliness would be a good start. However, since there is currently no established method of cleaning terminal blocks in a nuclear power plant, it will be difficult for an inspector to make a judgment with regard to the required degree of cleanliness. The planned IE Information Notice can, if properly worded, help to assure that the issue of terminal block cleaning is adequately addressed by licensees and NRC inspectors. For the longer term, RES intends to foster the development of industry standards on the cleaning of terminal blocks.

With regard to keeping the terminal blocks covered when not being worked on, the research conducted clearly shows the problem is caused by dirt and moisture. Licensees should be made aware of these problems and encouraged to ensure that the terminal blocks are covered at all times when not actually being worked on. The IE Information Notice should help encourage this practice.

RIL Recommendation 4:

"For new plants it is recommended that terminal blocks be eliminated, placed in a hermetically sealed enclosure when used in electric equipment important to safety, or moved outside of containment." The recommendation allowed for the "possibility that a different type of terminal block, utilizing different geometry and/or insulating material can be shown to have a low enough failure probability that a nonhermetically sealed enclosure can be used."

It is the user offices' position that, "It is the applicants' responsibility to select an appropriate design, e.g., a covered terminal block or a hermetically sealed box, as long as it can be shown to have acceptable performance during postulated accidents."

As acknowledged in the RIL, there may be terminal block designs that have a satisfactorily low probability of failure, especially if they are utilized with proper maintenance procedures, and that the applicants should be allowed to use these terminal blocks if adequate qualification can be demonstrated. The user offices' and RES's views are consistent in this regard.

However, a major point of the research, documented in the subject NUREG and the RIL, is that a single successful test of a terminal block under LOCA conditions should not be accepted as adequate qualification. If nonhermetically sealed terminal blocks are to be accepted for future plants, additional testing to establish a statistical basis for qualification should be required. It is RES's opinion that the alternative of placing terminal blocks in a hermetically sealed enclosure is preferable and should be identified as an acceptable practice.

With regard to your second question, the following is a discussion of the bases for each of the contractor's (SANDIA) recommendations in NUREG/CR-1682.

Contractor's Recommendation No. 1:

"For existing reactors, steam cleaning of terminal blocks is recommended."

The Sandia research provides a basis for concern about the ability of terminal blocks to perform their function during a loss of coolant accident and indicates that a significant contributing factor influencing the failure rate during LOCA conditions is terminal block surface contamination and containment spray. The primary failure mechanism for terminal blocks in a LOCA environment involves the formation of condensate and a conducting electrolyte on the surface of the terminal block. In general, the electrolytic film will be more conductive if the surface of the terminal block is contaminated before being exposed to the LOCA environment or if there is a conductive fluid associated with the LOCA environment. Cleaning terminal blocks will not completely eliminate the possibility of their failure during a LOCA, especially if a conductive containment spray is used, but it should reduce the probability of failure.

The Sandia research establishes a statistical relationship between terminal block leakage current and failure probability. Specifically, the model developed shows that an increase in leakage current results in a proportional increase in failure probability. The effect of surface contamination can be seen at all conditions for which test data was obtained. Analysis of a group of about 300 measurements made on uncovered terminal blocks at TMI-2 steam conditions using both clean and contaminated terminal blocks, where the contaminents were applied both individually and in groups, indicates that there is a factor of 2 to 3 increase in the leakage current (and therefore the failure probability) between clean and contaminated blocks. A comparison of clean and contaminated terminal blocks, excluding measurements with containment spray, indicates a factor of 1.5 to 2 increase in leakage current. An additional indication of the effect of surface contamination can be obtained from the 22 terminal block measurements, within the group discussed above, which exhibited a high enough leakage current during testing to be judged a complete breakdown or failure. Examination of the test conditions for these failures indicates that surface

contamination accounted for almost half of the failures and containment spray accounted for the other half of the failures. Comparison of the number of failures to the number of tests conducted for each of the various test conditions indicates that surface contamination resulted in about half the failure ratio that occurred with chemical containment spraying during testing and a much smaller failure ratio occurred for clean terminal blocks. Although the data supports the conclusion that cleaning tends to reduce terminal block leakage current and failure probability, it is not conclusive. Therefore, the recommendation to clean terminal blocks made by Sandia and by RES in the RIL is based primarily on engineering judgement of the issue and on support from the test results that cleaning probably will help. To conclusively prove or refute this recommendation with experimental data would require additional research.

The method of steam cleaning was found to be effective on a number of terminal blocks that failed in the test program in that their performance was returned to normal with regard to leakage current, after steam cleaning followed by wiping with alcohol. The contractor's report and the RIL did not intend to imply that this method of cleaning is the only method or necessarily even the best cleaning method; however, it was one method that was found to work. As part of the RES effort to foster the development of an industry standard on this subject, other methods will be examined.

Contractor's Recommendation No. 2:

"The protective boxes in the containment should be inspected for loose, open, or missing lids. The boxes should be tightened, and the weepholes should be eliminated, decreased in diameter (e.g., by insertion of flow retarders); or equipped with some kind of bimetallic closing device which automatically activates at high temperatures."

The research test results support this conclusion in that they showed that the greater the degree of isolation of the terminal blocks from the environment the less chance of failure. Moisture and contamination were shown to be major contributors to degraded performance and failure. In general, these recommendations were supported by the RIL.

Contractor's Recommendation No. 3:

"For new reactors or for thorough retrofit situations, elimination of terminal boxes in safety-related circuits should be considered."

Based on the results from testing the TMI-2 type terminal blocks, SANDIA concluded that this approach would be a conservative solution to the problem. RES tempered the recommendation in the RIL by allowing for hermetically sealed and even non-hermetically sealed terminal blocks if they can be adequately qualified and shown to have a low enough probability of failure. RES recognized that it may be impractical to eliminate terminal blocks from containment and, in fact, may generate other problems affecting safety because of maintenance problems.

Contractor's Recommendation No. 4:

"Special attention should be given to penetration boxes and instrument boxes on the containment wall; they are connected to a heat sink and the blocks inside will suffer higher water absorption."

No specific tests were conducted to verify this conclusion; however, it is evident that the statement is correct because the failure mechanism is dependent on the presence of moisture which will condense on any relatively lower temperature surface.

This point was not covered in the RIL since the corrective measures recommended would adequately ensure the integrity of all terminal blocks, including those that may be installed on a surface that would act as a heat sink during a loss of coolant accident.

Contractor's Recommendation No. 5:

"Circuit overloads leading to insulation burns have to be avoided; smoke from burning wire insulation enhances breakdown."

This recommendation reflects the fact that electrical overloads and fires are a source of contamination that could result in terminal block failure. The research test results show that any contamination that could result in a conductive film in the presence of moisture should be avoided, if possible. This specific recommendation was not included in the RIL because it is encompassed by other recommendations made with regard to cleanliness.

Contractor's Recommendation No. 6:

"Terminal blocks should not be mounted in such a way that condensate can collect in screwholes close to a potential breakdown path."

No specific tests were conducted to substantiate this recommendation. However, this is a reasonable deduction from the test results, which show that the failure mechanism is dependent on the collection of moisture that can create a conductive path between terminal and ground or between terminals. This specific recommendation was not included in the RIL since it reflects a level of design detail not normally considered by NRC and is largely superseded by other recommendations in the RIL.

Contractor's Recommendation No. 7:

"For accident analysis, it should be kept in mind that broken-down blocks may heal. Low voltage post-accident tests do not permit conclusions concerning the behavior of a circuit during the accident."

The test results show that some failures were reversed after the blocks were allowed to dry at normal ambient conditions. Specifically, some terminal blocks were observed to be in a failed condition because of excessive leakage current

at elevated temperature and humidity conditions, but when retested at normal plant ambient conditions, performed normally.

The RIL does not include a recommendation on this point but it is discussed in the conclusions section of the RIL. The observation relates primarily to the manner in which qualification tests are conducted, suggesting making measurements during the test and testing more than one terminal block. RES intends to investigate these issues further.

Contractor's Recommendation No. 8:

"Large amounts of effective contaminants seem to exist in containments, without clear reason. Consideration should be given to eliminating most of them."

The basis for the statement is primarily the data on containment contaminants reported in the TMI-2 FSAR. This data was identified during a literature survey conducted in developing the research test program to determine what contaminants should be used in the test program.

No such recommendation is made in the RIL. The solutions recommended in the RIL to assure that terminal blocks are clean and protected are a more practical resolution of the problem.

Contractor's Recommendation No. 9:

"The screening tests performed at the behest of the U.S. NRC are quite meaningful in general; however, due to the highly statistical nature of breakdowns they should not be used for detailed decisions."

The tests performed by the contractor on terminal blocks resultedin some breakdowns and tests performed by others have shown some breakdowns. Failure does not always occur. Therefore, the contractor concluded that the "screening tests," which were a one-shot environment qualification test, should not be used for "detailed decisions" or definite conclusions. The contractor's conclusion was based on the observation that failures do not occur each time a test is conducted, hence a single test should not be considered conclusive.

This specific contractor recommendation is not made in the RIL because it goes beyond the scope of the research and the RIL. The point is discussed in the discussion section of the RIL and RES intends to investigate this further.

Contractor's Recommendation No. 10:

"For a complete assessment of terminal block malfunctioning, a detailed circuit analysis has to be performed."

The failure criteria utilized in the research tests was leakage current. An exact extrapolation from leakage current to a circuit failure requires an analysis for each circuit because some circuits are more tolerant of leakage current than others. The contractor's failure model utilized a critical value of measured leakage current that would result in a failure for many circuits.

Although the contractor did not perform an analysis or conduct any tests to verify this conclusion/recommendation, it can be deduced from an understanding of the diversity of circuits utilized in safety systems. It is not included in the RIL because it was considered to be outside of the scope of the research conducted and the RIL. However, RES does intend to examine this issue further.

If you have any further questions with regard to this terminal block issue, or wish to meet with the staff or the contractor, please let me know.

Robert B Minogue

Robert B. Minogue, Director
Office of Nuclear Regulatory Research

cc: Chairman Palladino
Commissioner Gilinsky
Commissioner Bradford
Commissioner Roberts

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