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

March 14, 1991

MEMORANDUM FOR: James E. Richardson, Director
Division of Engineering Technology
Office of Nuclear Reactor Regulation

FROM: Joseph Muscara, Sr. Metallurgical Engineer
Division of Engineering
Office of Nuclear Regulatory Research

SUBJECT: INDEPENDENT REVIEW OF IMPLEMENTATION OF TOPICAL REPORT HAFA 135 (P-A)

Per your request, I have conducted an independent review of the implementation of Topical Report HAFA 135 (P-A), "Instrumented Inspection Technique (IIT) as an Alternative to the Hydrostatic Testing Requirements for ASME Class 1, 2 and 3 Systems and Components." I have had total and free access to the staff's files on this subject. My activity involved a thorough review, study and comparison of the documents listed in Attachment 1. Particular emphasis was placed on the review and evaluation of the Topical Report HAFA 135 (P-A), two letters from NRC to H.A.F.A. International, Inc., dtd December 21, 1989 and June 6, 1990, which outlined problems with the implementation of the IIT in the first letter and which rescinded NRC approval to conduct testing under Topical Report HAFA 135 (P-A) in the second letter, the two letters from H.A.F.A. International, Inc. to NRC dated March 22, 1990 and September 26, 1990, which respond to the two aforementioned NRC letters, and the Official Transcript for the meeting held at NRC headquarters on February 1, 1990, between NRC staff and H.A.F.A. representatives. I have also reviewed a number of NRC inspection reports, NRC letters to utilities and the utilities' responses regarding potentially invalid leak detection tests at their power plants, and allegations regarding the implementation of IIT at nuclear power plant sites.

Based on my review and evaluation of the above mentioned documents, I am in complete agreement with the staff's concerns, comments, evaluations, findings and conclusions contained in the two NRC letters to H.A.F.A. International, Inc. identified above regarding the field implementation of the IIT as represented in Topical Report HAFA 135 (P-A). Furthermore, I found no evidence in any of the documents including the two H.A.F.A. International, Inc. letters to NRC or in any of the H.A.F.A. statements in the Official Transcript of the February 1, 1990 meeting, to convince me to conclude otherwise. In fact, the statements and discussions in the meeting of February 1, 1990, lend more credence and support for the staff's findings. I can substantiate and support every statement in the two NRC letters to H.A.F.A. International, Inc. In particular, I conclude that the IIT, as practiced at operating plant sites, fell far short with regard to the number and types of instruments and sensors used in comparison to what was represented in the Topical Report HAFA 135 (P-A) and that the tests should be considered invalid. Further, I believe that if through-wall cracks producing small leaks had been present in some of the pressure boundary piping and components tested, they would not have been detected or located.

9103210435
XA

In my review and evaluation of the documents listed in the attachment, I have made many notes and comments directly on the pages of these documents. A detailed reporting of my review and findings would produce a report very similar to the enclosure, "Safety Evaluation-Implementation of HAFA Topical Report 135 (P-A)" to the NRC letter, dated June 6, 1990, to H.A.F.A. International, Inc. As already stated, I agree completely with that safety evaluation. Instead, what follows is an overview discussion of some key points arrived at by considering the documents reviewed taken together. The HAFA Topical Report gives background and describes the development of a methodology defined by H.A.F.A. as Instrumented Inspection Technique (IIT) that uses added instrumentation such as local flow and pressure measuring devices coupled with acoustic emission monitoring for the detection and location of internal and/or pressure boundary leaks during an inservice pressure test. It was clear that the methodology developed was evolutionary. Various aspects of the methodology were evaluated or validated through testing and data collection of several systems at several operating plant sites. The topical report discusses 9 such tests conducted at 8 power plants; details of the tests and results are discussed in the body of the HAFA Topical Report and its Appendix I. Most of the individual tests were not meant to demonstrate the full concept of the IIT, but H.A.F.A. used results from these tests to integrate the use of the various instruments and analyses into its proprietary IIT. The HAFA Topical Report states that IIT utilizes a two-fold approach to quantify and locate system leakage. The replacement volume of flow measurement is utilized to determine total system leakage, exit flow measurement is utilized to determine individual component leaks through selected boundary valves. Acoustic leak detection techniques are utilized to identify the component or the position in the piping system which is the source of the leakage. The report further states that IIT is a term employed by H.A.F.A. International, Inc. to distinguish its test method from conventional testing. It utilizes the following equipment: 1) Multi-Media Leak Testing Device; 2) Leak Measuring Device Models, 10, 20 and 30; 3) Modified Model 5120 Acoustic Valve Leak Detector; 4) Acoustic Sensors for High and Low Temperature Application; and 5) HAFA Acoustic Leak Sensing Equipment (ALSE) and MMD Software Package. Clearly, the HAFA proprietary IIT as described in their topical report requires the use of inlet and outlet flow measuring devices to quantify leakage and the use of acoustic emission on valves and along the piping to detect and locate internal and external (pressure boundary) leakage. The HAFA Topical Report asserts that IIT provides results equivalent or superior to the conventional method of hydrostatic pressure testing in the areas of sensitivity and reliability and that it can detect, locate and quantify small external and intersystem leaks quickly.

Based on the description and capabilities of IIT as described in the Topical Report HAFA 135 (P-A) and summarized above, the NRC staff accepted the report for referencing in license applications in its letter to H.A.F.A. International, Inc. dated November 7, 1985. The letter indicated that the report is acceptable to the extent specified in the NRC proprietary and non-proprietary evaluations enclosed with the letter and that the evaluations define the basis for acceptance of the report. The acceptance letter and its

enclosure, the NRC staff's Topical Report Evaluation, were published by H.A.F.A. International, Inc. as part of its approved Topical Report HAFA 135 (P-A) in December 1985. The NRC review and evaluation concluded that the IIT is a suitable alternative for the ASME Section XI Code requirements for pressure tests. The Evaluation reiterated that, 1) the IIT employs leak measuring and leak detection instrumentation to quantify and locate system or component leakage, 2) the replacement volume of flow measurement is used to determine system leakage rate, and 3) acoustic leak detection techniques are used to locate the component or the position in a piping system where leakage occurs. Further, the Evaluation described the equipment used in IIT to quantify and locate leakage: Various flow measuring devices, acoustic emission equipment and acoustic emission sensors. The Evaluation pointed out that the major difference between IIT and conventional pressure testing is that the additional equipment enables testing personnel to locate leaks faster, detect smaller leaks, and detect intersystem leaks. The Evaluation stated that application of the alternative method (IIT) provides added assurance of system and component structural integrity and leak tightness when compared to the conventional pressure testing methods. The Evaluation stated that implementation of IIT is not intended to circumvent Section XI Code requirements for pressure tests. The Code requirement for Visual Testing, VT-2, is to be maintained, however, the requirement for the four hour hold time prior to VT-2 of insulated systems and components may be reduced to two hours for IIT. Further, where the Code required test pressures (above normal operating pressures) are impractical to attain and hold, IIT could be performed at normal operating pressures. The Code requirement for pressure test hold time of four hours prior to visual examination of insulated system is based on allowing sufficient time to elapse for a leaking fluid to penetrate the insulation and be detected by the visual inspection. The HAFA Topical Report had pointed out that leakage is sometimes difficult or impossible to find with visual examination even during test periods that last as long as nine hours. The NRC acceptance in its Evaluation of the reduced pressure (normal operating pressure) and hold time (2 hours) before visual testing was based on the capabilities of IIT for rapid detection and location of small leaks. The testing reported in the HAFA Topical Report demonstrated that small leaks were detected by IIT and that changes in leak rates between normal oeprating pressures and the Code required pressures were relatively small. Further, Appendix I (pg. A1-43), in discussing acoustic emission data from test No. 3 at Davis-Besse Nuclear Power Station, states that "it can be seen that no greater sensitivity is achieved by testing at maximum operating pressure when using acoustic emission as a leak testing tool."

The IIT as described in Topical Report HAFA 135 (P-A) and accepted by NRC in 1985 was represented as an alternative pressure testing methodology that used a complement of instruments, sensors and analyses that had the capability for rapid detection, location and quantification of small intersystem and external leaks. To accomplish this, IIT utilized inlet and outlet flow measurements for quantifying leak rates and acoustic emission equipment and sensors for detecting and locating through-wall leaks along a piping system or leaks through valves. Thus, the structural integrity of a system being tested could

be evaluated. In the two 1990 letters from H.A.F.A. International, Inc. to NRC (in response to NRC concerns about implementation of the HAFA Topical Report and rescinding approval of the report) and the meeting minutes from the February 1, 1990 meeting between H.A.F.A. International, Inc. and NRC staff, H.A.F.A. essentially claims that, 1) it was not their intent or commitment in the topical report to use acoustic sensors at intervals (every 12 ft.) along the piping on IIT leak tests, 2) a leak measuring device at the inlet only was necessary and not at the outlet or test boundaries, 3) no flow or mass balance is mentioned or illustrated in the topical report, 4) the "staff position" may reflect their thinking in 1990, but not the thinking of the staff in 1985 when the HAFA Topical Report was accepted, and 5) no cases have been disclosed that through-wall leakage has been missed through implementation of IIT leak testing under the topical report. I find that the staff position in 1990 exactly reflects what the staff found in 1985 in its Topical Report Evaluation with respect to the instrumentation and sensors to be used and the claims made for the capability of IIT. Again, that IIT can quantify small pressure boundary leakage through the use of inlet and outlet leak measurement devices and analyses and that it can rapidly detect and locate small pressure boundary leakage along piping locations by using acoustic emission monitoring equipment and sensors to provide added assurance of the structural integrity and leak tightness of systems and components.

If, as H.A.F.A. International, Inc. implies now, the staff misinterpreted the IIT methodology, its use and capabilities, why did H.A.F.A. accept the NRC's Topical Report Evaluation and publish it as part of its approved Topical Report HAFA 135 (P-A)? I believe it was because NRC did not misinterpret the report and H.A.F.A. believed the Topical Report Evaluation to be correct. The Topical Report (or the NRC Evaluation) did not say sometimes IIT would use acoustic emission equipment and sensors and sometimes not, it did not say IIT would sometimes use inlet and outlet flow measurements and sometimes not; it did say that IIT utilizes a two-fold approach to quantify and locate system leakage: the replacement volume of flow measurement (inlet) is utilized to determine total system leakage, exit flow measurement is utilized to determine individual component leaks through selected boundary valves, and acoustic leak detection techniques are utilized to identify the component or the position in the piping system which is the source of the leakage. Documents developed by H.A.F.A. after their topical report was approved (November 7, 1985) also indicate that the NRC's Topical Report Evaluation and NRC's interpretation of IIT was (and is) correct and that H.A.F.A. represented the same things. That is, that IIT uses acoustic emission monitoring and inlet and outlet leak rate measuring devices. One document is an open literature article in the December 1989 issue of Materials Evaluation where it is stated that the IIT described in the article is that approved by NRC through the HAFA Topical Report. In this article, the use of acoustic emission monitoring is described for leak location along with the use of data from inlet and outlet leak rate measurements for quantifying leak rate through the pressure boundary by the use of a flow balance. The other document is an undated H.A.F.A. hand-out (available in NRC files) for a presentation made by several H.A.F.A. technical and management staff. Although the hand-out is undated, the information contained in it places the presentation after approval of the topical report on November 7, 1985 and before December 1, 1985. Enclosure 2 is the second page of the hand-out and gives HAFA's overview of IIT.

In reviewing the implementation of Topical Report HAFA 135 (P-A), it is important to remember that IIT was an acceptable alternative testing methodology for ASME Code required pressure tests which are conducted to ensure structural integrity of the tested components. That is why the ASME Code requires a visual test for leaks following an appropriate hold time beyond the pressurization, i.e., one is looking for leaks through the pressure boundary. Although the Topical Report may lack specificity with respect to field implementation of given test procedures and equipment of the IIT methodology, the report is clear on the equipment and sensors to be used and on the claims made for the capabilities of the IIT methodology. When IIT is used in lieu of ASME required pressure tests and IIT is claimed to be able to quantify leakage, naturally, one is most interested in quantifying through-wall leakage in the pressure boundary components, piping for example. When IIT is claimed to be able to locate small leaks on positions along the piping, clearly this means locating small through-wall leaks along the piping. Some very basic things are central in accomplishing this quantification and location of through-wall leaks with IIT. To quantify the leakage, the replacement volume of flow measurement (inlet flow) and the exit flow measurement are needed as stated in the Topical Report. The leakage rate through the pressure boundary, then, is the difference between the inlet flow and the outlet flow through the test boundary valves. HAFA claims that they did not state flow or mass balance in their Topical Report; this is true, however, in order to quantify through wall leaks, the process implied in the Topical Report and more fully described in the Materials Evaluation article is effectively a flow balance. With respect to locating small through-wall leaks along the piping, it is necessary to use acoustic emission sensors at intervals along the piping and appropriate acoustic emission monitoring equipment and analsyses. Certainly, it is important to conduct appropriate calibration of equipment before and after the test. The background noise level needs to be established and the acoustic emission level expected from small leaks needs to be known. To be able to detect and locate the leak, the acoustic emission from the leak must be higher than the background noise level. Because the acoustic emission signals are damped as they travel from the leaking source to the sensors, the attenuation characteristics of the piping (or component) need to be measured. The attenuation is affected by the piping material itself, the types and numbers of welds, the geometry of component and obstructions, the fluid within the pipe, etc., between the source and the sensor. So, in order to determine the spacing between transducers for effective leak detection and location, one needs to know the background noise level, the level of acoustic emission expected from the small leaks of interest and the attenuation characteristics of the piping (or component) between the leak source and the sensors. The results presented in the HAFA Topical Report (and its Appendix 1) and results from other research programs (for example, at Argonne National Laboratory) indicate that for effective through-wall leak detection from piping systems in typical nuclear power plant environments that acoustic emission sensor spacing on the order of a few tens of feet is required, not hundreds of feet (this would be too distant for leak signals to reach the sensor or be detectable above background).

My review of the documents listed in the attachment indicated that field application of IIT at nuclear power plants of four utilities often did not use outlet flow measurements at the test boundary valves to allow for quantification of through-wall leakage and rarely used acoustic emission monitoring and sensors at reasonable intervals along the piping being tested to allow effective detection and location of small pressure boundary leaks. Where acoustic emission sensors were used on valves they were too far apart to be effective in locating leaks along the piping. Therefore, HAFA's implementation of the IIT at nuclear power plants was not in accordance with the Topical Report HAFA 135 (P-A) nor with the NRC Topical Report Evaluation and these tests should be considered invalid. Further, the IIT as implemented at the plant sites, with only the inlet flow monitoring and no effective acoustic emission monitoring along the pipe lengths, is considered ineffective and certainly less effective than the ASME Code requirements since the IIT was conducted at lower pressures and the visual inspection conducted after a shorter hold period for insulated components. As conducted, the IIT did not have the capability for detecting, locating or quantifying small through-wall leakage of the pressure boundary. HAFA's contention that there have been no reports of missed leaks through implementation of IIT testing does not mean that if small through-wall leaks had been present, IIT would have detected them. Through-wall leaks in the nuclear reactor pressure boundary are rare events, and most likely no through-wall leaks were present in the components tested. Finally, three utilities that had used H.A.F.A. International, Inc. to conduct pressure tests at their plants have declared the testing to be invalid because of poor control of the testing and personnel qualifications or accepted the NRC Notice of Violation. Finally, I found the statement 2.D from Enclosure 2 to be of interest.

If you have any questions regarding this memorandum or need further clarification, please let me know.

Joseph Muscara

Joseph Muscara, PhD
Senior Metallurgical Engineer
Materials Engineering Branch
Division of Engineering
Office of Nuclear Regulatory Research

Enclosures:
As Stated

Enclosure 1

List of Documents Reviewed for the
Independent Review of
Implementation of Topical Report HAFA 135 (P-A)

Topical Report HAFA 135 (P-A), Dec. 1985, controlled copy No. 80.

Letter from J.E. Richardson (NRC) to H.A.F.A International, Inc., dated December 21, 1989, Subject: Instrumented Inspection Techniques (IIT). Discusses NRC concerns with implementation and considering withdrawal of NRC approval.

Letter from F.H. Hess (HAFA) to J.E. Richardson (NRC), dated March 22, 1990. Responds to Richardson's letter of 12/21/89.

Letter from J.E. Richardson (NRC) to F. Hess (HAFA), dated June 6, 1990. Included a Safety Evaluation on Implementation of HAFA Topical Report 135 (P-A) and rescinded approval of the report.

Letter from A.E. Wehrmeister (HAFA) to J.E. Richardson (NRC), dated September 26, 1990. Responds to Richardson's letter of June 6, 1990.

Letter from T. Lewis, U.S. Congressman to K. Carr, Chairman, NRC, dated October 9, 1990.

H. Askwith, et al, "Leak Testing With Volume Replacement and Acoustic Techniques," Materials Evaluation, V. 47, No. 12, December 1989, p. 1378-1381.

Memorandum from R.A. Hermann (NRC) to C.Y. Cheng (NRC), dated 3/1/90. Regarding February 1, 1990 meeting with HAFA.

Official Transcript of Proceedings, Meeting with H.A.F.A. International, Inc., regarding Instrumented Inspection Technology, February 1, 1990. Closed and Open meeting portions.

Memorandum from DeMiranda (NRC/RII) to R. Brady (NRC), dated March 4, 1989, Questionable Acoustic Emission Testing of the Main Steam, Davis-Besse. Transmitts record of phone conversation with alleger.

Memorandum from C.H. Weil (NRC/RIII) to R. Brady (NRC), dated July 18, 1989, Acoustic Emission Testing Allegations Involving Davis-Besse, Palisades, and Beaver Valley. Includes several enclosures including alleger's letter to RIII stating his allegations, letter from NRC/RIII to TE transmitting details of allegations; TE response to allegation.

Memorandum from H.J. Miller (NRC/RIII) to M. Virgilio (NRC/NRR), dated September 25, 1989, Request for Technical Assistance - Inconclusive Pressure Testing of Piping and Components at Palisades and Davis-Besse.

Letter from J.P. Durr (NRC/RI) to J.D. Sieber (Duquesne Light Co.), dated September 25, 1989, Beaver Valley Inspection Report No. 50-334/89-15.

Letter from C.A. Julian (NRC/RII) to J.H. Goldberg (Florida Power and Light Co.), dated November 16, 1989, NRC Inspection Report Nos. 50-335/89-25 and 50-389/89-25.

Letter from H.J. Miller (NRC/RIII) to D.P. Hoffman (Consumers Power Co.), dated December 8, 1989. Includes Notice of Violation, Inspection Report No. 50-255/89026 (DRS) and NRC consultant's report and evaluation of AE leak monitoring.

Letter from H.J. Miller (NRC/RIII) to D. Shelton (Toledo Edison Co.), dated December 8, 1989. Includes Notice of Violation, Inspection Report No. 50-346/89021 (DRS) and NRC consultant's report and evaluation of AE leak monitoring.

Memorandum from C.Y. Cheng (NRC/NRR) to R.W. Cooper (NRC/RIII), dated January 9, 1990. Closure NRR Allegation 89-A-0031. Includes a number of HAFA letters and contact reports.

Contact Report from HAFA to G. Johnson (NRC/NRR), dated April 13, 1988, regarding personnel certification.

Letter from H. Askwith (HAFA) to G. Johnson (NRC), dated May 17, 1988, transmitts HAFA report on Beaver Valley 1 test summary report for the acoustic emission leak detection on main steam piping systems, main feedwater piping systems and steam generator flowdown piping systems.

NRC/RIII Inspection Report 50-346/89027 (DRS), dated February 13, 1990. Inspection at Davis-Besse on January 8-12, 1990.

Letter from D.C. Shelton (Toledo Edison) to NRC, Docket 50-346, dated February 6, 1990, Validity of IIT Tests Performed as an Alternative to ASME, Section XI Hydrostatic Tests.

Letter from D.C. Shelton (Toledo Edison) to NRC, Docket 50-346, dated February 6, 1990, Response to Inspection Report No. 50-346/89021.

Letter from D.A. Sager (FPL) to NRC, dated February 8, 1990. St. Lucie Units 1 and 2, Potentially Invalid Leak Detection Tests.

Letter from J.D. Sieber (Duquesne Light Co.) to NRC, dated May 3, 1990, Beaver Valley 1 and 2, Potentially Invalid Leak Detection Tests. Responds to NRC letter and finds IIT tests invalid.

Letter from K.W. Berry (Consumers Power) to NRC, dated June 1, 1990, Docket 50-255, response to NRC letter of November 1, 1989 regarding validity of HAFA testing and revised response to notice of violation. Includes CP consultant's report.

HAFA "hand-out." HAFA presentation titled, "Brief Introduction to the Instrumented Inspection Technique by H.A.F.A. International, Inc., 10 pages - no date, but based on the information on the 10 pages, the presentation can be placed somewhere between November 7, 1985 and December 1, 1985.

Letter from Toledo Edison to NRC, dated August 9, 1990, Supplemental Response to Inspection Report No. 50-346/89021.

Enclosure 2

INSTRUMENTED INSPECTION TECHNIQUE (IIT)

Concept Overview

1. The IIT is based on system concept of testing as opposed to a component concept of testing. IIT is used to detect and quantify leaks in sections of pipe which are pressurized to normal operating pressures. At the present time, IIT is not recognized as an inspection technique by ASME Section XI. IIT is accepted by the NRC as an alternative ISI inspection method under 10 CFR 50.55a(a)(3).

2. In-depth engineering procedures, written safety evaluations, approved plant inspection procedures, certified personnel and two types of devices are used in the IIT process.

   A. Leak Monitoring Device (LMD)(HAFA PAT. 4364261) which measures the leak in either fluid or gas with calibrated flow meters. A low pressure LMD uses series connected ball float meters. A high pressure LMD uses an orifice flowmeter.

   B. Acoustic Emission (AE) sensors along with a computerized analysis for detecting the location of leaks. Although the basic design of the hardware used is approximately ten years old, the software (copyright applied for) used has developed rapidly over the last ten years to eliminate extraneous background "noise" and accurately pinpoint the location of leaks.

   C. Prior to implementation of the IIT, all personnel utilizing the equipment are required to pass written examinations, demonstrate proficiency in equipment operations, and to be certified to the HAFA Quality Assurance Procedure 9.2, a testing qualification program that meets the intent of ANSI 45.2.6.

   D. IIT is not being freely released to the nuclear industry. Instead, TED and HAFA are in the process of working out an agreement, though not signed yet, to maintain the process as a marketable item in which TED and HAFA may share the profit. This consideration was developed because of HAFA's long relationship with TED and the fact that the highest pressure tests conducted in support of the Topical Report 135 were conducted on Davis-Besse's HPI system.

   E. The NRC has granted an SER to HAFA on the IIT Topical Report. FPL's St. Lucie No. 1 and Davis-Besse Unit No. 1 have submitted request letters and received approval to use IIT on Class 1, 2 and 3 systems.