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ATTACHMENT B

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

VERMONT YANKEE NUCLEAR POWER CORPORATION

VERMONT YANKEE NUCLEAR POWER STATION

DOCKET NO. 50-271

REINSPECTION AND REPAIRS OF VERMONT YANKEE REACTOR COOLANT SYSTEM PIPING

INTRODUCTION

Vermont Yankee Nuclear Power Station was shutdown on June 16, 1984 in order to accomplish refueling and to perform inspection and repair of ASME Class I austenitic stainless steel piping susceptible to intergranular stress corrosion cracking (IGSCC).

During the Vermont Yankee 1984 refueling outage, a total of 69 stainless steel piping welds were ultrasonically inspected in accordance with Generic Letter 84-11 (GL 84-11). Of these, 57 welds were in the recirculation system and 12 welds were in the residual heat removal (RHR) system. All 12 welds found defective and not repaired during last outage and 17 overlay repaired welds with flaw length over 10% of the circumference were inspected. The licensee, Vermont Yankee Nuclear Power Corporation (VYNPC) originally planned to inspect only 55 welds in accordance with the initial sampling requirements of GL 84-11. The selection of weld samples for inspection was mainly based on field experience and welds most prone to IGSCC were inspected first. The scope of the inspection was expanded after cracks were found in welds of 22" and 28" recirculation pipes and of 20" RHR pipes. Except for eight 28" recirculation pipe welds, all intergranular stress corrosion cracking (IGSCC) susceptible welds in the 22" and 28" recirculation piping and 20" RHR piping, not inspected in the previous outage, were inspected ultrasonically during this outage. The licensee indicated that six local leakage detectors (moisture sensitive tapes) will be installed to monitor the potential leakage from the eight uninspected 28" recirculation piping welds.

Prior to the 1984 refueling outage, the licensee had replaced all IGSCC susceptible piping in the reactor water cleanup (RWCU) system and the core spray system (up to the first isolation valve and 200°F) with 316 L stainless steel materials. Also prior to the 1984 refueling outage, the licensee had replaced the 4" bypass lines with cast stainless steel materials and removed the control rod drive lines and capped them with low-carbon stainless steel materials. In addition, all the furnace sensitized safe-ends were replaced and the nozzles rebuttered with low-carbon stainless steel materials. The licensee also indicated that no IGSCC susceptible welds exist in the jet pump instrumentation nozzle penetration assemblies.

Personnel from Independent Testing Laboratory (ITL), Magnaflux, and Yankee Atomic Electric Company (YAEC) performed ultrasonic testing (UT) for the licensee. The UT results submitted by the licensee consisted of those crack indications which were evaluated by YAEC nondestructive examination personnel. Region I of the NRC has determined that their UT procedures, calibration standards, equipment and IGSCC detection capabilities were satisfactorily demonstrated in accordance with I&E Bulletin 83-02, and the same procedures and techniques were used in the UT examination. Region I also indicated that all their UT personnel conducting these inspections have received appropriate training in IGSCC inspection using cracked thick-wall pipe specimens. ITL performed the majority of the UT for detection using the Projection Image Scanning (P-Scan) system in conjunction with the MWS-2 semi-automatic scanner. This system provided graphical displays of the top, side and end views of the weld and corresponding ultrasonic amplitude information. Standard 2.25 megahertz (MH_z) contact type shear wave transducers were coupled to the P-Scan used to perform inspections at Vermont Yankee. The primary detection angle used was 45° nominal with 52° nominal used for additional investigations and to compensate for coverage limitations of the 45° probe on certain welds.

The examination with a P-Scan was limited to some extent by the inspection fixture. The areas not examined with P-Scan were manually examined by Magnaflux where possible. The sizing of IGSCC was performed manually using a number of different techniques by three individuals who passed the EPRI NDE Center course, "UT Operator Training for Planar Flaw Sizing." To provide additional information about the characteristics of the flaw indications a research team from Battelle Pacific Northwest Laboratories (PNL), funded by the NRC, performed an independent examination of selected regions of nine welds. The detailed evaluation of the examination results is presented in the section entitled, "Ultrasonic Examination."

The results of the UT inspections indicated that a total of 17 welds showed reportable linear indications. Of these, 11 are 28" recirculation welds, five are 22" header welds and one is a 20" RHR weld. During 1983 refueling outage, 12 defective welds were not repaired because cracks in these welds are shallow and significant crack growth is not expected in one fuel cycle. These 12 welds were reinspected during this outage by qualified personnel using advanced techniques for sizing. Five of the 12 defective welds were determined to be not cracked. The 1984 flaw depth measurements of the other seven welds are slightly deeper (2-10%) than the 1983 measurements. Assuming both depth measurements to be reasonably accurate, this indicates that the crack growth in these seven welds is very slow. Because of ALARA consideration, the flaw length measurements during the 1983 refueling outage were not extensive in many cases; therefore, a valid comparison of flaw lengths between the 1983 and 1984 measurements cannot be made. Ten welds not inspected during the 1983 outage were found to be defective during the current outage. Except for one 20" RHR weld (weld 32-4) containing a short axial crack (1/4" in length), all other defective welds contained only circumferential flaws. All flaws were reported to be located at the heat-affected-zone. The reported depth of the circumferential flaws are relatively shallow, varying from 12% to 27% of the wall thickness. The flaw lengths varied from 1.1% to 34.7% of the circumference. Eleven welds have flaw lengths less than 10% of the circumference and one 22" weld (weld 30B) has a flaw length exceeding 1/3 of the circumference. Of the 17 defective welds, one 20" RHR weld (weld 32-4) containing one axial crack was weld overlay repaired and the others, based on fracture mechanics analysis, were not repaired.

Structural Integrity Associates (SIA) performed flaw evaluations for the licensee. The results of the evaluation indicated that none of the 16 defective welds required weld overlay repair. The crack growth calculations were performed in accordance with the guidelines in Generic Letter 84-11. Thermal stresses and overlay repair shrinkages stresses were included in the computation of the corresponding stress ratio. The calculations showed that the circumferential flaws in the 16 defective welds will not grow beyond 30% of the wall thickness at the end of a 14-month operating period. The calculated final flaw size is well within the 2/3 of the ASME Code, Section XI, IWB-3640 limits.

SIA also designed the weld overlay for the licensee. During the current refueling outages, overlay was applied to two welds (RHR weld 32-4 and riser weld 32). RHR weld 32-4 (20") was repaired with a thin weld overlay (3/16 inches thickness) to provide a leakage barrier for the potential growth of an axial flaw. A mini-overlay was designed for weld 32 (12" riser) during the previous refueling outage. The mini-overlay design relied on the structural strength of the uncracked ligament of the piping to meet the ASME Code, Section XI, IWB-3640 limits. Such overlay design may not be conservative because the safety margin of the design depends upon the accuracy in the UT determination of the flaw depth. To ensure that there is adequate design margin in the overlay repaired weld 32, additional layers were applied during this outage. The thickness of the overlay on weld 32 was increased from 0.15 inch to 0.30 inch and is considered to be a full structural strength weld overlay.

The licensee stated that before reactor restart six modified local leakage detectors (moisture sensitive tapes) will be installed to monitor the eight uninspected 28" recirculation piping welds for potential leakage from these welds. The moisture sensitive tapes are very sensitive and can detect leakage as low as 0.1 gpm. The field experience of the similar detectors during the last fuel cycle was poor, because of frequent malfunctioning of the electronic components. The electronics malfunctioned after prolonged exposure to high temperature and radiation. The electronics in the modified detectors were removed from the sensor, which is installed at the weld under surveillance to a location that is away from high temperature and radiation. The licensee agreed to inform the NRC before the close of the next working day of any significant changes in the status of the moisture-sensitive tape system and any corrective action to be taken, during the next fuel cycle. To assure a timely investigation of unidentified leakage, the licensee also indicated that each item in attachment 1 to Generic Letter 84-11 for leak detection and leakage limits will be followed.

The licensee has stated that all IGSCC susceptible stainless steel piping in the recirculation and RHR systems will be replaced with nuclear grade 316 stainless steel during the 1985 refueling outage.

Replacement of the remaining sections of the core spray system operating at 200°F and the vessel bottom head drain line is also under consideration by the licensee.

ULTRASONIC EXAMINATION

The staff's review of the UT methods used by the licensee during the 1984 outage for the detection and sizing of IGSCC is based on the evaluation of the examination results from two commercial inspection agencies and YAEC personnel employed by the licensee and one (1) independent research team funded by the NRC. Each of the commercial organizations used different instrumentation and a number of ultrasonic techniques to perform an integrated examination. All unrepaired welds with IGSCC indications detected during the 1983 outage were inspected again. The UT methods applied during both 1984 and 1983 outages will be described since different ultrasonic techniques were used and contributed to the different examination results when 1983 and 1984 results are compared for the same weld as summarized by the licensee in Table 1.

(1) Inspection Techniques Used During 1984 for Detection and Sizing

For the detection of IGSCC, the licensee used equipment and personnel demonstrated to be qualified in accordance with the EPRI NDE Center course, "U.T. Operator Training for the Detection of IGSCC." The sizing of IGSCC was performed manually by three examiners that passed the EPRI NDE Center course, "UT Operator Training for Planar Flaw Sizing." All personnel performing detection, discrimination and sizing, who are NDE Level II or III, were qualified on an individual basis.

ITL was contracted by the licensee to perform the majority of ultrasonic examinations for detection using the computer-based P-Scan system and a semi-automatic scanner with manual manipulation of the transducer. The system provided graphical displays of the top, side, and end views of the weld and corresponding ultrasonic amplitude information. The data was automatically recorded on magnetic tape that allowed off-line evaluation of information at various ultrasonic sensitivities from printed projection images of the weld. The semi-automated system permitted the licensee to increase the examination work scope within the radiation exposure limits of available qualified personnel.

Standard 2.25 megahertz contact type shear wave transducers were coupled to the P-Scan to perform inspections at Vermont Yankee. The primary detection angle used was 45° nominal with 52° nominal used for additional investigation and to compensate for coverage limitations of the 45° probe on certain welds. The transducers was manipulated manually in a rectangular scan pattern, with the ultrasonic beam directed perpendicular to the centerline of the weld. The resulting ultrasonic data and corresponding position of the transducer was recorded automatically for additional analysis.

The rectangular scan pattern generally is used to detect reflectors oriented parallel to the centerline of the weld, i.e., circumferential indications. With the P-Scan, the transducer was not skewed nor was the weld scanned with the ultrasonic beam directed parallel to the weld centerline, looking solely for axial indications. During the qualification tests from I&E Bulletin 83-02, the P-Scan demonstrated an ability to detect "pure axial" flaws without the benefit of additional compensatory scans with the ultrasonic beam directed parallel to the weld centerline and the system has no restrictions on detection based on flaw orientation. The P-Scan records the presence of all ultrasonic reflectors to approximately -64 Db of the 10% notch reflector used for calibration which is essentially down to the inherent electronic noise level of the instrument. The licensee considers this ability for "off-line" evaluation of flaw indications far below normal recording levels as the technical basis for the detection of small or off-axis flaws without skewing or swiveling the search unit.

Examinations with the P-Scan system were limited to some extent by the inspection fixture. Although the P-Scan system is capable of inspection of pipe-to-pipe and pipe-to-elbow configurations on both sides of the weld, on pipe-to-tee, pipe-to-valve, and pipe-to-pump, only one-side examinations were performed. Scan limitations are noted on the P-Scan data sheets. The areas not scanned with P-Scan were examined by qualified examiners from Magnaflux manually where possible. All pipe-to-pipe and pipe-to-elbow configurations were scanned on both sides, with minor areas not scanned due to interference of integral supports or branch connections. All pipe-to-pump, pipe-to-valve, and pipe-to-tee configurations were completed on the pipe side only. The heavy sections of the fitting and necessary weld taper precluded any examinations in these areas. No relevant ultrasonic information is available on the component side of the weld because ultrasonic examination of the component side of the weld joint is not possible. However, the component side of the weld joint is usually fabricated from IGSCC resistant material such as cast stainless steel. In the submittal dated July 30, 1984, the licensee has summarized the examination restrictions for all welds examined during the 1984 outage.

The Magnaflux or the YAEC examiners performed manual ultrasonic examinations for detection in the areas that were considered to be flawed from the P-Scan data. The ALN-4060 system, which was programmed by EPRI to discriminate IGSCC from geometric reflectors, was also used to evaluate the regions with flaw indications. Manual examinations for evaluation used scan patterns intended to detect both circumferential and axial flaws. The licensee also used the WSY-70 transducer, commonly known as the ID "creeping wave" transducer, to confirm flaws in a number of welds.

The licensee used a number of techniques to size detected IGSCC to determine the through-wall flaw dimensions. These techniques fall into four main categories. High Angle Longitudinal Beam Techniques (HALT) were utilized to investigate the outer 4/10 of the pipe wall for crack faces or crack tips which may have propagated into that region. Flaws found to be located in that region can be confirmed with a full-vee examination. Pulse Arrival Time Technique (PATT) was utilized to interrogate the remaining volume to determine crack tips below the O.D. region. As a complement to PATT, a similar Satellite Pulse Observation Technique (SPOT) was used to both observe the crack tip and relate its position to the root of the flaw through observations of both pulses simultaneously. The Multi-Pulse Observation Sizing Technique (MOST), which insonifies the entire pipe wall with several angles and modes of sound beam, was used to augment the aforementioned techniques. Through observation of several constant and changing pulse relationships, the licensee determined the through-wall depth. All flawed welds were evaluated on a weld-by-weld basis as to the need to grind for flaw sizing. Grinding, when necessary, was performed to facilitate flaw sizing.

The licensee also examined welds that were repaired during the 1983 outage by weld clad overlay. The examinations consisted of manual UT for clad bond and clad integrity. The clad bond examination consisted of a straight beam examination with the principal area of concern the clad-to-base metal interface. A 3/8" diameter flat-bottomed hole at the clad-to-base metal interface of a clad calibration standard was used as the reference reflector. Scanning sensitivity were at least +6 dB gain. The acceptance criteria was 50% of the 3/8" diameter hole reference signal or any indication with an area less than the reference reflector at reference sensitivity. This examination did not identify any relevant indications.

The clad integrity examination consisted of an angle beam inspection of the clad and clad-to-base metal interface. The inspections were performed with a dual element, 3/8 x 3/4" 45° refracted longitudinal beam search unit at a frequency of 1.5 MHz. The reference reflectors were 1/16" diameter side-drilled holes which were positioned such that an examination zone contained weld metal, weld-to-base metal interface, and base metal. The calibration was performed on welded clad pipe of essentially the same material as the piping components in the plant. These calibration standards were manufactured in such a way as to duplicate the weld process and surface conditions of the actual repairs. Overlay calibration standards were fabricated at the minimum and maximum overlay thickness anticipated, thus bracketing the overlays examined. Any indication less than 50% of the reference reflector was acceptable. No cracks, lack of penetration, or lack of fusion were allowed. No elongated indications greater than 1/4" were permitted. The results did not identify any relevant indications in the overlay or overlay-to-base metal interface.

(2) Inspection Techniques Used During 1983 for Detection and Sizing

For the detection of IGSCC the licensee performed manual scanning and evaluation of welds with equipment and personnel demonstrated to be qualified in accordance with I&E Bulletin 83-02. The primary method of sizing IGSCC indications was the "Amplitude Drop Method" using dual element 1.5 MH_z transducers having a nominal shear wave beam angle of 45°. All personnel performing detection and discrimination were qualified as a team. Therefore, occupational radiation exposure requirements on key members of the qualified team limited the scope of the examination program.

Magnaflux, with YAEC personnel as part of the qualified team, was contracted by the licensee to perform the majority of ultrasonic examinations for detection using manual scanning and data recording. Detection of IGSCC was based on signal characteristics and location of the reflector with respect to the weld root geometry. The UT methods generally consisted of 1/2 vee path 45° shear wave examinations performed at 1.5 MHz. Supplemental examinations were performed using 60° shear wave examination techniques. The length of a flaw indication was considered at an end point when the amplitude of the signal dropped to 50% of the average maximum signal for a given indication when scanning with a procedure intended to determine linear extent. In instances where indications continued for any distance at less than one-half maximum amplitude, the indication was continued over the full extent until the indication definitely dropped. In 1983, welds were scanned for both axial and circumferential indications in full scope examinations.

Due to radiation exposure constraints, some large bore piping was scanned by a procedure known as the cardinal point examination at locations 90° apart. During these examinations the licensee only scanned for circumferential reflectors in four areas of the weld joint, 12 inches in length, centered at 0°, 90°, 180° and 270° around the joint. If an indication was determined to extend beyond the original scan length, the examination was continued to determine the full extent of that indication. Other scan limitations were also noted on the data sheets. Pipe-to-pipe and pipe-to-elbow configurations were scanned from both sides with minor areas not scanned due to interference with integral supports. Pipe-to-component configurations such as pipe-to-valve, pipe-to-tee, and pipe-to-pump were scanned on the pipe side only. No relevant ultrasonic information is available on the component side of the weld because ultrasonic examination of the component side of the weld joint is not possible. However, the component side of the weld joint is usually fabricated from IGSCC resistant material such as cast stainless steel. In the submittal dated July 30, 1984, the licensee has summarized the examination restrictions on the twelve welds with crack indication that were not repaired in 1983.

Sizing was performed on indications in 12", 22", and 28" pipe although all 12" welds with flaw indications, regardless of size, were overlayed. The primary method utilized for sizing ultrasonic indications of IGSCC at Vermont Yankee was the "Amplitude Drop Method" using dual element 1.5 MHz transducers having a nominal shear wave beam angle of 45°. The through-wall dimension of the indication was determined by comparing the ultrasonic response to that of a 10% notch in a basic calibration block. During the inspection the instrument sweep changes were recorded that correspond to the maximum amplitude from the 10% notch and then leading and trailing beam half maximum amplitudes (6 dB drop) were recorded. During evaluation scanning, the sweep changes are recorded for the noted indications and then plotted on full size sketches of the weld joint section as determined by actual field measurement. A linear relationship was maintained in comparison to the 10% notch. Through-wall dimensions were calculated to the next higher full percent and reported for engineering evaluation. No beam spread correction was applied to the depth sizing.

(3) Basis for Improved Inspection Results

Table 1 provides a comparison of 1983 and 1984 inspection results for the twelve large diameter pipe with unrepaired flaw indications detected during the 1983 outage. The licensee considers the 1984 inspection program to be significantly better than the 1983 inspection and attributes the improvement (1) to better training of personnel, which was validated by performance examination, (2) to a multifaceted examination procedure that provided a greater amount of detailed technical information and (3) to an increased work scope for the extent of examination within the limits of total radiation exposure.

The staff evaluation of the inspection results will be discussed in the section entitled "Evaluation."

(4) Inspections by Pacific Northwest Laboratory (PNL) During 1984

To provide additional information about the characteristics of the circumferentially-oriented IGSCC, arrangements were made for a seven-man research team from PNL, funded by the NRC, to examine selected regions of nine welds. PNL performed investigations using the SAFT-UT system, a high resolution computer-based ultrasonic imaging system. The data taken from the current SAFT-UT was returned to PNL for computer processing and evaluation.

PNL performed manual inspections to selected areas for investigation and to evaluate manual crack sizing techniques. An automatic scanner was used to examine selected regions of eight large diameter pipe welds examined by the licensee during 1984. PNL also investigated a 12 inch diameter pipe weld that was overlaid in 1983 but was unable to make a call.

Regions of weld numbers 1A, 17B, 26A, 36, 36B, 58, 59, 61, and 64 were examined with SAFT-UT. The independent PNL examination results provided a supplementary characterization of indications in each weld and the PNL classification of the welds as either cracked or not cracked agreed with the results obtained by the licensee in 1984 on seven of eight welds. The licensee characterizes weld number 64 as not cracked based on the 1984 inspection. PNL examined a region of approximately 11 inches of weld number 64 and identified a region of under two inches with "crack-like" properties. A PNL review of the construction radiographs showed that evidence of extensive weld root repairs were performed in this region of weld number 64 and PNL considers that the detected signals may originate from this geometric condition. However, based on the available information, PNL conservatively characterized the region as cracked.

PNL obtained information on the depth of flaws with SAFT-UT which tended to be deeper than reported by the licensee in 1984. PNL has not established acceptance criteria for determining flaw depths with SAFT-UT. As an interim measure the PNL field data for depth measurement was correlated with laboratory information on sawcuts and leads to conservative oversizing by as much as 100%.

EVALUATION

The staff has reviewed the licensee's submittals including the ultrasonic examination results, weld overlay design and the flaw evaluation to support the continuing service of a 12-month fuel cycle of 23 overlay repaired welds (22 12" riser welds and one 20" RHR weld) and 16 unrepaired defective welds (11 28" and five 22" recirculation welds).

The staff has reviewed the information provided by the licensee regarding the examination results from the 1984 inspection, and has taken into consideration the difference in examination results from the 1983 inspections as illustrated by Table 1. During both refueling outages augmented inservice inspections for the detection of IGSCC were performed by inspection agencies qualified under I&E Bulletin 83-02 using different UT methods and instrumentation. In 1984 the licensee employed personnel that used a combination of techniques to demonstrate and qualify their flaw sizing capability. The staff has determined that the results from the ultrasonic inspections performed by the licensee for detection and sizing of circumferentially-oriented IGSCC during 1984 represents the actual condition of the welds inspected within the limitations of the current state-of-the-art and the design restrictions to examination. This determination was based on the following considerations:

1. The qualified Magnaflux and YAEC inspection personnel used examination procedures and instrumentation for detection during the 1983 and 1984 inspections that are technically similar to most inspection agencies performing manual UT for the detection of IGSCC in BWR piping. The widely recognized technical problem is the ability to differentiate between ultrasonic responses from IGSCC and innocuous reflectors adjacent to the weld root and along the weld fusion line especially for the large diameter piping. The amount of supplemental inspection or reinspection is limited by ALARA constraints. Therefore, "over-calling" of suspected IGSCC may occur with high ultrasonic sensitivity 45° shear wave techniques when unanticipated geometrical anomalies or metallurgical microstructures, such as inside diameter weld metal repairs or buildup, produce ultrasonic reflectors in regions where IGSCC typically occurs.

2. The examination with the P-Scan system resulted in an inspection at a higher ultrasonic sensitivity with data that is automatically recorded in a manner that would permit a more accurate location of the relative position of the weld fusion line and the reflector than manual data recording. Sixteen of the seventeen flaws detected were circumferentially oriented. The examination with conventional 45° shear wave transducers with the P-Scan assumes that scanning at high ultrasonic sensitivity and accurate position data will permit the detection of isolated axial flaws. The staff is not convinced that all axial flaws will be detected without skewing the transducer or transversing the weld at a beam angle other than perpendicular to the weld centerline. However, the staff has determined that IGSCC oriented transverse to the weld centerline does not represent a safety problem because axial flaws tend to be short in length and arrest adjacent to the HAZ of the weld, and eventually will lead to leakage rather than rupture.

3. An evaluation of the 1984 examination results indicates that sixteen of the flaws were detected with the P-Scan and one was detected manually. IGSCC was detected in several welds on the pipe side of pipe-to-component configurations where examinations were performed only from the pipe side. Although the licensee could not perform examinations on the component side of these unrepaired flawed welds, the staff considers that IGSCC is less likely to occur in these locations than other susceptible welds because the components are generally fabricated from cast stainless steel.

4. The staff considers the demonstrated and qualified ability to size IGSCC a benefit in the correct characterization of the condition of the weld.

5. The results from the NRC-supported research contractor with SAFT-UT tended to support the licensee's characterizations of the origin of the reflectors for pipe welds without weld overlay repairs.

6. All existing weld overlays of repaired welds with indications over ten percent of the circumference were inspected by the licensee with manual UT procedures to verify the integrity of both the clad weld metal and its bond to the pipe base material in a manner consistent with ASME Code, Section V, Paragraph T-550, "Ultrasonic Examination for Thickness Determination." The licensee fabricated representative mockups with artificial reflectors to establish the test calibration. Although the licensee used ultrasonic amplitude-based acceptance criteria, no cracks, lack of penetration or lack of fusion were allowed in the clad weld metal. The examination results obtained by the licensee did not identify any relevant indications in the overlay or overlay-to-base metal interface.

The staff concludes that the licensee has used experienced personnel to perform the examination of the clad weld metal and the examinations performed by the licensee could detect lack of clad bond and could identify flaws in the clad weld metal that would affect the structural integrity of the clad overlay.

The reported crack depths in the 16 unrepaired defective welds were shallow (12 - 27% of wall thickness) and the crack lengths in 11 of the 16 unrepaired welds were less than 10% of the circumference. The staff does not consider the 11 defective welds that have short total flaw lengths a major safety concern. However, to determine that there is adequate safety margin considering crack growth in the five defective welds (four 28" welds 26A, 61, 59, and 65A and one 22" weld 30B) that have long flaws (including weld 30B which has the longest total flaw length, about 35% of the circumference) the staff performed independent crack growth calculations. These bounded the five defective welds with flaw lengths over 10% of the circumference. The largest sustained load including the shrinkage stress was 8057 psi and the initial crack depth (23% of wall thickness) was doubled in the calculation. The crack growth rate was based on a conservative crack growth curve representing the upper bound of the weld sensitized materials. The stress intensity factor (K) was calculated by using an influence function and by conservatively assuming a full 360 degree crack with a depth of 46% of wall thickness. The results of the staff's calculations indicated that the crack growth at the end of a 12-month period will not exceed 54% of the wall thickness. The staff also performed a calculation for the growth of crack length assuming the growth in crack length to be proportional to the growth in crack depth. The crack length at the end of a 12-month period is calculated to be about 40% of the circumference. In addition, the staff performed an independent limit load analysis to evaluate the design safety margin that will be present in the five unrepaired welds based on the above calculated flaw size at the end of a 12-month period. A flow stress of

41.1 ksi and an axial stress of 6.44 ksi were used in the analysis. The flow stress corresponds to half of the ASME Code allowed yield stress plus tensile stress for 304 stainless steel at a temperature of 550°F and the axial stress corresponds to a design pressure of 1150 psi. The limit load calculation has shown that there is a safety margin over a factor of 10 on the bending stress (2.8 ksi), which includes the primary (dead weight and seismic stress) as well as the secondary (thermal stress and shrinkage stress) bending stresses. Therefore, the staff agrees with the licensee's conclusion that the continued operation for a 12-month period with the 16 defective welds in its as-is configuration is justified because the Code design safety margin would be maintained.

The staff has reviewed the overlay designs for the 23 repaired defective welds. Weld 32-4 (20" RHR) contained only one short axial flaw. A thin layer about 3/16 inch thick is considered adequate to provide a leakage barrier. For the other 22 overlay repaired welds, the overlay designs and fabrication were made prior to the issuance of the repair guidelines in Generic Letter 84-11. Additional overlay thickness was applied to riser weld 32 during this outage to meet the full structural overlay requirement. Based on the "as-built" overlay thickness, the 22 repaired welds are considered to have full structural strength weld overlays. However, the overlay thickness took credit for the thickness of the first layer and a penetrant test (PT) was not performed after the completion of the first layer. This practice is not in conformance with the guidelincs provided in Generic Letter 84-11. The purpose of requiring PT of the first layer and not allowing credit for the thickness of the first layer is to provide additional conservatism in overlay design. These additional design margins were considered desirable because at the time the subject requirements were introduced, substantial uncertainties existed in the UT crack depth sizing, and experimental measurements had not been performed to support the presence of beneficial residual stresses resulting from weld overlay repair. Since then, the quality of UT crack depth sizing has been greatly improved and the extent of the beneficial compressive residual stresses from weld overlay repair have been substantiated by both analytical and experimental measurements. Therefore, the staff considers that this additional design conservatism is not needed if the IGSCC resistance and the integrity of the first layer were demonstrated. In this regard, the licensee indicated that ferrite examinations were made on the first layer weld metal of several repaired welds. All the readings were in excess of the required 8 FN indicating that the subject welding process incurred very little ferrite dilation from the base metal. UT was performed after completion of the overlay repair to confirm the structural and bonding integrity of the overlay. During the last outage, 17 welds with circumferential cracks longer than 10% of the circumference were overlay repaired. These were reexamined by UT during this outage. The results of this reexaminations showed that the structural and bond integrity of these overlays were maintained. The flaws underneath the repaired overlay were not monitored because a reliable UT method has not yet been developed. As the 22 defective welds were repaired with full structural strength weld overlays, monitoring of the flaws in the defective piping materials is desirable but not essential for the acceptance of the subject overlay repaired welds for service beyond one fuel cycle. The staff concludes that the reported "as-built" weld overlay thickness for the 23 overlay repaired welds is acceptable and all overlay repaired welds can be returned to service for another 12-month fuel cycle. The staff's conclusions are based on the following considerations:

(1) The defective welds were repaired with full structural strength weld overlays. The strength of the defective piping is not relied upon to maintain the integrity of the piping system.

(2) The UT examination results showed that after one fuel cycle of service, the structural and bonding integrity of the overlays has been maintained.

(3) The depths of the flaws in the repaired defective welds are shallow so further growth in the presence of the compressive residual stresses resulting from the weld overlay process is not expected.

(4) The licensee indicated that the recirculation and RHR system piping including all the overlay repaired piping will be replaced with IGSCC resistant materials during the 1985 refueling outage and a 12-month period is required to properly plan and organize such activities, so that the outage time and the man-rem exposure can be minimized. The staff considers it prudent to approve plant operation for another fuel cycle to allow the licensee to properly plan and carry out the piping replacement program.

The staff has reviewed the adequacy of the licensee's reinspection program of piping welds susceptible to IGSCC in Vermont Yankee during the current 1984 refueling outage. The original sample size for reinspection, in accordance with Generic Letter 84-11, was 55 welds in the recirculation and RHR piping systems. After finding cracks in the 22" and 28" recirculation piping welds and one 20" RHR piping weld, the sample size was expanded to a total of 69 welds, which included 100% of the IGSCC susceptible welds in the 22" recirculation and 20" RHR piping. Eight 28" recirculation piping welds were not examined as required by the sample expansion guidelines in 84-11. The licensee indicated that ALARA considerations were the main reason for not inspecting the remaining eight (8) 28" recirculation welds because the available man-rem exposure of the qualified UT personnel would not allow them to complete the additional inspection. To recruit and train additional UT personnel, the licensee anticipated an outage extension of about two weeks if the additional eight welds were to be inspected. The staff concludes that the licensee's reinspection program is acceptable, and that not inspecting the remaining eight 28" recirculation welds will not cause any major safety concern during the operation in the next fuel cycle. The staff's conclusions are based on the following considerations:

(1) The reported flaw depth in all the defective welds in Vermont Yankee is shallow (27% of wall thickness). Therefore, even if IGSCC was present in the uninspected 28" welds, the staff does not expect the extent of cracking to be drastically different from what has already been reported in the other inspected welds.

(2) Except for two cross to reducer welds, the identical weld (mirror image) of each uninspected 28" weld in the other loop was inspected. No cracks were found in these similar welds. This indicates that no abnormal environmental or stress conditions exist in these locations.

(3) The licensee indicated that, based on field experience, welds most prone to IGSCC were inspected first and the remaining eight 28" welds are considered to be less prone to IGSCC. Therefore, even if IGSCC occurred in these welds, the extent of cracking is not expected to be any more severe than that which has already been reported in other inspected welds.

(4) During this outage, all the unrepaired defective welds were ultrasonically examined. The results of the examinations showed that there was only minor growth (2-10% of wall thickness) in the unrepaired defective welds after a period of one fuel cycle. This experience indicates that even if IGSCC occurred in these uninspected 28" welds, extensive crack growth is not expected during the next fuel cycle.

(5) The licensee indicated that local leakage detectors of moisture sensitive tapes will be installed to monitor the potential leakage from these uninspected 28" welds. Therefore, in the unlikely event of cracks growing through the pipe wall of these welds, the leakage will be identified by the moisture sensitive tape system and the augmented leakage monitoring system, prior to the cracks growing to the extent that would compromise the integrity of the piping system.

(6) In view of the licensee's plan to replace all the recirculation and RHR system piping during the 1985 refueling outage, and the unlikelihood that severe cracking will take place in these uninspected 28" welds as discussed above, the staff has determined that any payoff from the expenditure of additional man-rem exposure to inspect the remaining 28" welds would be small. Therefore, the staff considers that the licensee's request for relief from inspecting the eight 28" welds is acceptable.

CONCLUSION

The staff has reviewed the licensee's submittals, and performed its own independent evaluations. Based on the above considerations, and the fact that all recirculation and RHR system piping will be replaced during the 1985 refueling outage, the staff concludes that the Vermont Yankee plant can be safely returned to power and operated in its present configuration for one 12-month fuel cycle.

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TABLE 1

(TABLE V REVISION 1, FROM LICENSEE SUBMITTAL

FVY 8495, JULY 31, 1984)

Large Diameter Piping

Comparison of 1983 to 1984 Inspection Results

		1983		1984	
Pipe Size	Weld ISI No.	L(1)	A/T(2) (% TWD)	L(1)	A/T(2) (% TWD)
28"	64	20"	10-15	No Flaw	N/A
	1A	48"	15	5"	22
	2	360° (intermittent)	10	2"	15
	9A	360° (intermittent)	10	5"	20
	65A	9.5"	15	15"	23
	15A	23"	15	No Flaw	N/A
	58	31.5"	15	No Flaw	N/A
	59	36"	15	13"	20
22"	16B	4.5"	10	0.8"	12
	36B	14.5"	10	No Flaw	N/A
	30B	17"	15	24.0"	20
24"	RHR31 Weld 1	4.0"	7	No Flaw	N/A

(1) L Total length of all circumferential indications
(2) A/T Flaw depth as a percentage of wall thickness (based on weighted average depths of all flaws).