VERMONT YANKEE
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BVY 92-055
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U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Attn: Document Control Desk

Reference: a) License No. DPR-28 (Docket No. 50-271)

Dear Sir:

Subject: **Proposed Alternative for Compliance with 10CFR50.55a Regarding RPV Cladding Indications**

During the current 1992 refueling outage, Vermont Yankee performed a reactor vessel head inspection to address concerns raised in General Electric SIL No. 539. This SIL discussed the situation at Quad Cities Unit 2, where cracking was detected in both the stainless steel cladding and the low alloy steel under the cladding of the reactor pressure vessel head. Vermont Yankee discovered indications in areas of cladding inside the reactor vessel head. Additionally, during the 1992 refueling outage, Vermont Yankee utilized a new technique (remote color video inspection camera) to perform visual inspection of reactor pressure vessel (RPV) internals. This visual inspection revealed similar cladding indications, primarily in the shell flange region of the vessel.

The purpose of the stainless steel reactor vessel cladding at Vermont Yankee is to reduce the presence of iron oxide products in reactor coolant, thus reducing the demand on reactor coolant demineralizer equipment to maintain water purity. Vessel cladding does not form a part of the reactor pressure vessel structure and no credit is taken for it in the structural analysis of the vessel or vessel head.

Vermont Yankee has performed extensive ultrasonic examination techniques of over 140 indications and employed manual exploration of a typical "worst case" visual indication to investigate the nature of the indications. As a result of these investigations, we have concluded that the indications are the result of stress corrosion cracking of the cladding, and there is no evidence that the indications compromise the structural integrity of the reactor pressure vessel or vessel head. This conclusion has been confirmed by the volumetric and other examinations described in the enclosed "Engineering Evaluation".

The inspection of the RPV head had been performed in response to GE SIL 539. If the inspection was being performed as part of the inservice inspection program of Section XI of the ASME Code, the acceptance criteria would be obtained from IWB-3520. Since the 1980 Edition of the Code, which is the applicable Code Edition for the Vermont Yankee ISI program, does not provide any standards for the evaluation, the 1989 Edition of the Code was consulted for guidance. Paragraph IWB-3520.2 provides acceptance standards in the 1989 Code.

IWB-3520.2 requires that relevant conditions be corrected in accordance with the requirements of IWB-3142. Paragraph IWB-3142.2 allows acceptance of relevant conditions by supplemental examination, and directs the user to IWB-3200. Paragraph IWB-3200(b) states, "Visual examinations that reveal relevant conditions described in the standards of this Article may be supplemented by surface or volumetric examinations to determine the extent of the unacceptable conditions and the need for corrective measures, repairs, analytical evaluation, or replacement."

As long as it can be determined that the extent of the supplemental examination is adequate to provide assurance that there is no need for "corrective measures, repairs, analytical evaluation, or replacement," it does not appear that the Code requires an evaluation of 100% of the indications.

Ultrasonic inspections (UT) have been performed in all representative areas of the reactor head and in the reactor vessel near the head flange area. In excess of 140 indications were interrogated by UT, with no indication of basemetal penetration. Thirty-two of these indications were in the lower vessel flange and upper shell course area. The inspections performed by Vermont Yankee provide a high level of confidence that the regions inspected reflect all areas where similar indications exist in the reactor pressure vessel cladding.

This condition was discussed with NRC NRR and Region I officials on April 1, 1992 at which time the question of an alternatives application under 10CFR50.55a(a)(3) was considered. This application is submitted in response to a NRC suggestion due to the uncertainty regarding the application of the ASME Section XI Code to this situation. Therefore, this letter formally requests NRC approval of a proposed alternative to Section XI of the ASME Code.

The specific alternative being proposed is to allow sampling of conditions believed to be benign rather than requiring examination of all indications. The sampling performed by Vermont Yankee provides a high level of confidence that the cladding indications do not penetrate into the basemetal.

The attached report provides a detailed discussion documenting the technical acceptability of the proposed alternative.

We request your prompt approval of this request. Should you have any questions regarding the attached information or require further information, please do not hesitate to contact me directly. In addition, should you find it necessary, we are prepared to meet with the NRC staff to present our findings on short notice.

Very truly yours,

Vermont Yankee Nuclear Power Corporation

W. P. Murphy
Senior Vice President, Operations

cc: USNRC Region I Administrator
USNRC Resident Inspector VYNPS
USNRC Project Manager, VYNPS

ENGINEERING EVALUATION

OF VERMONT YANKEE REACTOR PRESSURE

VESSEL CLAD INDICATIONS

1992 REFUELING OUTAGE

BACKGROUND

In November 1991 GE issued SIL 539, which recommended that plants with stainless steel clad reactor pressure vessel heads inspect the area corresponding to the Quad Cities cracking. This SIL discussed the Quad Cities plant, where cracking was detected in both the stainless steel cladding and in the low alloy steel under the cladding of the reactor pressure vessel head.

A visual inspection of the internal surfaces of the Vermont Yankee reactor pressure vessel head was performed on March 17, 1992 in accordance with the recommendations of the GE SIL No. 539. Numerous areas of rust on the stainless steel cladding were noted. This would be indicative of clad penetration down to the alloy steel basemetal. The rust areas were seen at the area of the flange to head butt weld and on the manual cladding on the flange forging [see Figure 1]. Additional rusting was observed on the manual cladding of the dollar plate section of the head. These areas were mostly limited to locations of manually applied cladding; however, some rusting was also visible in the area of automatically applied cladding. Some of the areas of rust were associated with visual linear indications. The majority of the rust marks are on the flange area with a long indication at the manual-to-automatic clad weld interface. Approximately 2/3 of the circumference at that interface shows some rust. There are also some indications on the manually clad area of the dollar plate. This area is about five feet in diameter at the top of the head. Most of the rust marks follow the circumferential clad weld beads.

In addition, during visual examination of the RPV internals, similar rust areas were observed on the vessel cladding. This type of indication was visible due to the use of a new remote color video inspection camera. The vessel cladding indications were visually similar to the head cladding indication and were primarily in the vessel flange region of the vessel.

Vermont Yankee immediately reviewed the conditions seen at the Quad Cities 2 power plant for any similarity to Vermont Yankee. Discussions were held with Commonwealth Edison, General Electric Company and Structural Integrity Associates (SIA). SIA had performed evaluations of the Quad Cities RPV head for Commonwealth Edison and EPRI. These discussions revealed that the Quad Cities RPV head was experiencing two different conditions. The cladding developed intergranular stress corrosion cracking (IGSCC) attributed to low ferrite content, welding residual stresses, cold work stresses from grinding and an aggressive environment. The Quad Cities RPV head basemetal developed cracks from a mechanism known as reheat cracking. This is caused by reduced material ductility resulting from alloy impurities along with residual stresses from coldwork and differential thermal expansion. The high heat input strip clad process used by Babcock and Wilcox (the fabricator of the Quad Cities RPV) in the early 1970's is now known for producing reheat cracking in certain low alloy steels.

The metallurgical samples taken from Quad Cities showed evidence of stress corrosion cracking in the clad and reheat cracking in the basemetal. In some cases the cracks meet at the clad/basemetal fusion line. It is important to stress that there is no evidence at Quad Cities that the IGSCC cracks progressed into the basemetal.

VERMONT YANKEE CONDITION

The following was observed and concluded regarding the conditions on the Vermont Yankee reactor pressure vessel head:

Fabrication Process

None of the cladding on the Vermont Yankee vessel was applied by the high heat input strip cladding process used on the Quad Cities vessel. The automatic clad welding process used at Vermont Yankee required only one layer of clad. The manual clad welding process required two layers; more could be applied if required to meet the nominal clad thickness requirement of 3/16 inches. During the welding process the basemetal layer

melts and mixes with the weld metal that is being deposited. As the welding heat input is increased, a greater amount of basemetal is melted. This results in an altered chemistry of the weld deposit, as compared with the original welding electrode. Depending on the heat input, this re alloying process can occur in multiple layers of weld deposit. Studies performed in 1986 during the development of the core spray nozzle weld overlay at Vermont Yankee showed that a minimum of three weld layers were needed to obtain an unaffected weld material chemistry sample, and this was from a very tightly controlled heat input welding process. Similar experiences are reported in the technical literature. An engineering investigation performed as part of the Vermont Yankee recirculation system pipe replacement project in 1985 showed that as carbon content increased above about 0.05 w/o the amount of ferrite required for IGSCC resistance increased rapidly [see Figure 2]. Therefore, it is likely that the cladding has low IGSCC resistance.

The post weld heat treatment [PWHT] process for the Vermont Yankee vessel was evaluated to determine if the fabrication process could have reduced the ferrite conte · of the RPV head cladding. No significant effect on the ferrite content would be expected.

The RPV head flange is a SA508 CL2 forging. The head plate material is SA533 GrB. Structural Integrity Associates reviewed the material certifications for the head flange and plate material and concluded the forging could be susceptible to reheat cracking. However, reheat cracking would only occur if significant welding residual stresses, cold work or differential thermal expansion stresses were present. The fabrication records do not indicate this to be true, therefore reheat cracking is unlikely. Extensive ultrasonic examination of the head and shell flange regions, as described below, demonstrate that there is no cracking in the basemetal.

INSPECTION RESULTS

The investigation techniques used at Vermont Yankee, visual, penetrant, and ultrasonic, followed the recommendations of the SIL. It is understood from discussions with Commonwealth Edison that the ultrasonic techniques were reviewed by the NRC for Quad Cities and were qualified at the EPRI NDE Center by performance demonstration on controlled flaw samples.

- **Penetrant Testing and Manual Exploration**

  Two one foot square areas on the head flange were penetrant tested. The indications appeared to closely resemble the size, frequency and pattern of the rust indications. An investigation to determine the depth of an indication was then undertaken. A typical "worst case" (from visual appearance) indication was selected. A length of about 3 inches of the indication was excavated. At steps of 1/16 inch or less in depth, a penetrant test was performed to determine if the indication was still present. As the cladding was removed, and the depth increased, the indication appeared to break up into more numerous finer indications and grew tighter and more diffuse, which would be indicative of IGSCC. At a depth of almost 3/16 inch, the indication had almost disappeared, except for some very faint areas, which upon closer inspection appeared to be tight craze cracking. These faint indications remained within the cladding.

- **Ultrasonic Examination**

  UT evaluation of a number of indications, including the one that was manually explored, confirmed that the flaw depths were contained with in the clad thickness.

  The clad is nominally .19 inch thick, and is specified to be .125 inch minimum with no maximum specified. An original piece of vendor supplied vessel material with cladding (the RPV vessel ultrasonic calibration block) is available. The clad penetration on this block measures between 0.125 inch and 0.375 inch thick. This was measured directly off of the block cross section and also with a high resolution ultrasonic straight beam search unit.

Ultrasonic inspections were performed in accordance with the GE SIL recommended techniques. These techniques successfully detected and sized the 2% notch on the RPV vessel calibration block. Various locations on the inside surface of the head flange, the dollar plate, the vessel flange, and the upper shell course were examined. UT was also performed from the OD of the head. In excess of 147 reflectors were measured by UT, with no indication of basemetal penetration. The depths ranged from 0.08" to 0.30". Several of the deeper reflectors were re-evaluated with the straight beam search unit to determine the clad depth at those locations, and confirmed the cladding was thicker at these points.

During the visual examination of the RPV internals, a rust area was observed adjacent to the fillet weld where the steam dryer support bracket weld meets the vessel cladding. This indication was quite visible since the in-vessel examinations were being conducted with a color camera. The 1983 black and white video tape of the same area was reviewed. In the same area as the rust, one could discern a slightly lighter region. This was not recorded as a region of concern in 1983 and if not for the increased contrast of the color view in the 1992 inspection, it would be hardly noticeable. The area was thoroughly UT examined from outside the vessel. No evidence of any flaw propagation into the basemetal was detected [see Figure 3].

- **Ferrite Testing**

  Ferrite readings were taken at 24 locations on the head flange inside surface and 12 locations on the vessel flange inside surface. The lowest reading was 5% to 7.5%, with the majority of readings at 7.5% to 10%. This provides evidence that the cracking in both the RPV head clad and the vessel flange clad is due to IGSCC and not micro-fissuring which can occur in low ferrite, in the 0-3% range, stainless steel weld metal.

- **Chemical Analysis**

  Metal chips were removed from the head and vessel flange area cladding for chemical analysis. The carbon content of the material removed was 0.079 w/o for the head flange and 0.11 w/o for the shell flange. The carbon content of the shell flange cladding is well above the specification upper limit for carbon of 0.08 w/o max. The head flange value is within specification range. However, a review of all the welding electrode material certifications showed no heats to be this high. Thus it can be concluded that the cladding has picked up carbon from the basemetal during welding of the cladding. These carbon levels place the cladding in the highly susceptible region for IGSCC [see Figure 2].

FRACTURE MECHANICS EVALUATION

Even though we have found no evidence of penetration into the basemetal, in order to provide additional assurance of safe plant operation, Vermont Yankee had a fracture mechanics evaluation performed by SIA.

Fracture mechanics evaluations were performed to determine allowable flaw depths as well as time to reach these allowable depths for flaws which might continue to propagate from possible through-clad cracks. The evaluations conservatively considered flaws in both the reactor vessel head and the vessel wall adjacent to a steam dryer bracket.

- **Vessel Head**

  Allowable flaw sizes and the potential for flaw growth in the low alloy steel of the pressure vessel head at Vermont Yankee have been estimated using SIA's fracture mechanics software pc-CRACK. Recent data was used to derive a conservative crack growth rate for SCC-assisted cracking in the low alloy steel. Stresses were obtained from the Chicago Bridge & Iron (CB&I) stress report for the Vermont Yankee reactor vessel.

A 360° circumferential crack model in the cladding was assumed. Crack growth in the low alloy steel was assumed to begin immediately upon exposure to the water environment due to a through-clad crack. Both of these assumptions are obviously conservative. A number of cases were run.

In the most limiting case, the applied K reaches a value of 63.25 ($K_{Ia}/\sqrt{10}$, where K_{Ia} = 200 ksi-$\sqrt{in}$ from Figure A-4200-1 of ASME Section XI) at a depth of about 1.25 inches. The crack growth analyses show that a crack could grow to a depth of 1.25 inch in approximately 56,000 hours (about 6.5 years) for the base case. For the worst case, the time for a crack to reach that depth would be about 39,000 hours (≈ 4.5 years). For locations where the residual stress is zero, the time for a flaw to reach one inch would be at least 77,000 hours (≈ 8.8 years). Crack growth time to the allowable flaw size in the flange area was on the order of 40 years.

As noted above, the assumptions used to construct these cases make the results extremely conservative. In this analysis, cracks or other flaws that penetrated the stainless steel cladding are assumed to continue to propagate into the low alloy steel head immediately. This would not be expected. Stress corrosion cracking can occur in low alloy steels in BWR environments, however, the crack growth rate expressions are derived from specimens loaded under conditions that are ideal for crack growth. Initiation times are typically not reported.

Of greater significance to this case is that a very small area of alloy steel will be exposed to the environment, unlike the crack growth tests where fairly substantial specimens are exposed. This area effect may be extremely significant relative to SCC susceptibility (particularly crack initiation) since cracking propensity has been shown to be dependent upon sulfur content. In high purity environments, dissolution of manganese sulfide inclusions produces an acidic sulfate environment at the metal surface which is conducive to crack growth. The dependence of SCC on both the number of inclusions and their shape demonstrates that cracking in high purity water is a function of the probability of the environment intersecting a manganese sulfide inclusion. Even a 360° flaw through the entire thickness of the cladding would expose only a very small area of low alloy steel. The probability of intersecting an inclusion is highly unlikely.

- <u>Region Near Steam Dryer Bracket</u>

  To determine the critical flaw size in the reactor vessel wall, an analysis similar to that for the vessel head was conducted. A flaw in excess of 1.5 inches was determined to be acceptable.

  To determine IGSCC crack growth, the same conservative evaluation was conducted as noted above. The crack growth analysis showed that the time for a crack to grow from the clad-to-base metal interface to 1.5 inches would exceed 40 years of operation. If the maximum computed clad stresses (for cold conditions) were used in the crack growth analysis, then the time to grow to 1.5 inches would approach 81,760 hours (approximately 9 years).

ASME CODE REQUIREMENTS

The dryer support bracket was examined per Section XI. The acceptance standards are provided in IWB-3520. The 1980 Edition of Section XI, with Winter 1980 Addenda, governs the Vermont Yankee ISI program. That version of the Code states that the criteria for IWB-3520 are "in the course of preparation." The 1989 Edition of Section XI was consulted for guidance. The 1989 Code would reject "crack-like surface flaws on the welds joining the attachment to the vessel that exceed the allowable flaw standards of IWB-3510" (IWB-3520.1(a)). This visible indication exceeds the acceptance standards of Table IWB-3510.3. However, the location of the indication is adjacent to the blend radius of the attachment weld meets the vessel cladding. The blend radius does not add any strength to the attachment weld; its purpose is to act as a stress concentration mitigator. Thus, it could be judged that the Code does not apply to this location. A conservative approach is

taken by assuming the Code does apply. A supplemental examination (UT) was performed as allowed by IWB-3142.2. Since no relevant conditions were detected, the condition is deemed acceptable for continued service.

The inspection of the RPV head was being performed in response to the GE SIL 539. If the inspection was being performed as part of the inservice inspection program, the acceptance criteria would be obtained from IWB-3520. Since the 1980 Edition of the Code does not provide any standards for evaluation the 1989 Edition of the Code was again consulted for guidance. Paragraph IWB-3520.2 provide acceptance standards.

IWB-3520.2 requires that relevant conditions be corrected in accordance with the requirements of IWB-3142. Paragraph IWB-3142.2 allows acceptance of relevant conditions by supplemental examination and directs the user to IWB-3200. Paragraph IWB-3200(b) states, "Visual examinations that reveal relevant conditions described in the standards of this Article may be supplemented by surface or volumetric examinations to determine the extent of the unacceptable conditions and the need for corrective measures, repairs, analytical evaluation, or replacement."

For a given large population, a sample of acceptable measurements of the size taken by Vermont Yankee will accept that population with a high level of confidence. The number of flaws evaluated provides a high level of confidence that there is no basemetal penetration, and thus no corrective measures, repairs, analytical evaluations or replacements are required.

OTHER CONSIDERATIONS

Consideration has been given to possible "spalling" of the cladding from the pressure vessel basemetal. From an engineering perspective, there is negligible stress perpendicular to the basemetal/clad interface to cause the IGSCC to "turn" and grow along the interface. It is now known that the dryer support bracket indication is at least nine years old. That area was thoroughly examined ultrasonically to determine if any delamination was occurring. No evidence of any lack of bond was detected.

Consideration has also been given to the possibility of clad indications existing in other places of the reactor pressure vessel. The fracture mechanics evaluations were performed using end-of-life vessel fracture toughness properties for the vessel beltline region, thereby accounting for vessel embrittlement. As a point of interest, the end of life vessel fluence for Vermont Yankee is less than 2.3×10^{17} n/cm^2 at the location of the peak fluence. This is a very low fluence compared to most reactor pressure vessels. Therefore, if similar flaws existed in the beltline region of the reactor pressure vessel the fracture mechanics evaluation bounds this condition.

Vermont Yankee also ultrasonically inspects the four feedwater inlet nozzles every refueling outage. These nozzles are clad with stainless steel and are subject to thermal fatigue cycling. No indication of any basemetal cracking has been detected.

CONCLUSIONS

Based on the above observations and analysis, it is concluded that the following condition exists:

The RPV head and vessel clad indications and the indication at the dryer support bracket attachment weld result from IGSCC susceptible clad material, sufficient stress and an aggressive environment. The clad material is susceptible due to cladding dilution during the weld metal application. This mechanism is the same for both the RPV head and vessel clad indications. The sampling of indications that were evaluated using UT provide a high level of confidence that these cladding indications do not extend into the basemetal.

There is no evidence of cladding flaws extending into the basemetal. Growth of cladding flaws into the low alloy steel basemetal is very unlikely. This is evidenced by the work performed by Commonwealth Edison in their investigation of the Quad Cities event and supported by EPRI research on stress corrosion of low alloy steel.

Fracture mechanics evaluations demonstrate that in the worst case three operating cycles would be required before any cladding flaws would exceed the Code acceptable flaw size. These fracture mechanics evaluations have been performed using conservative assumptions. These evaluations show that full circumferential flaws in the reactor pressure vessel in excess of one inch deep would be acceptable under Code flaw evaluation rules. Conservative flaw growth calculations were performed.

FUTURE INSPECTION PLANS

Vermont Yankee is still evaluating the extent of future actions and will have these plans developed no later than 30 days prior to the 1993 refueling outage. As a minimum, Vermont Yankee will:

- re-inspect the dryer support bracket indication during the 1993 refueling outage and the following two examination periods.

- perform visual and UT inspection on the RPV head flange cladding during the 1993 refueling outage. The inspection areas will be within the same areas as inspected in 1992.

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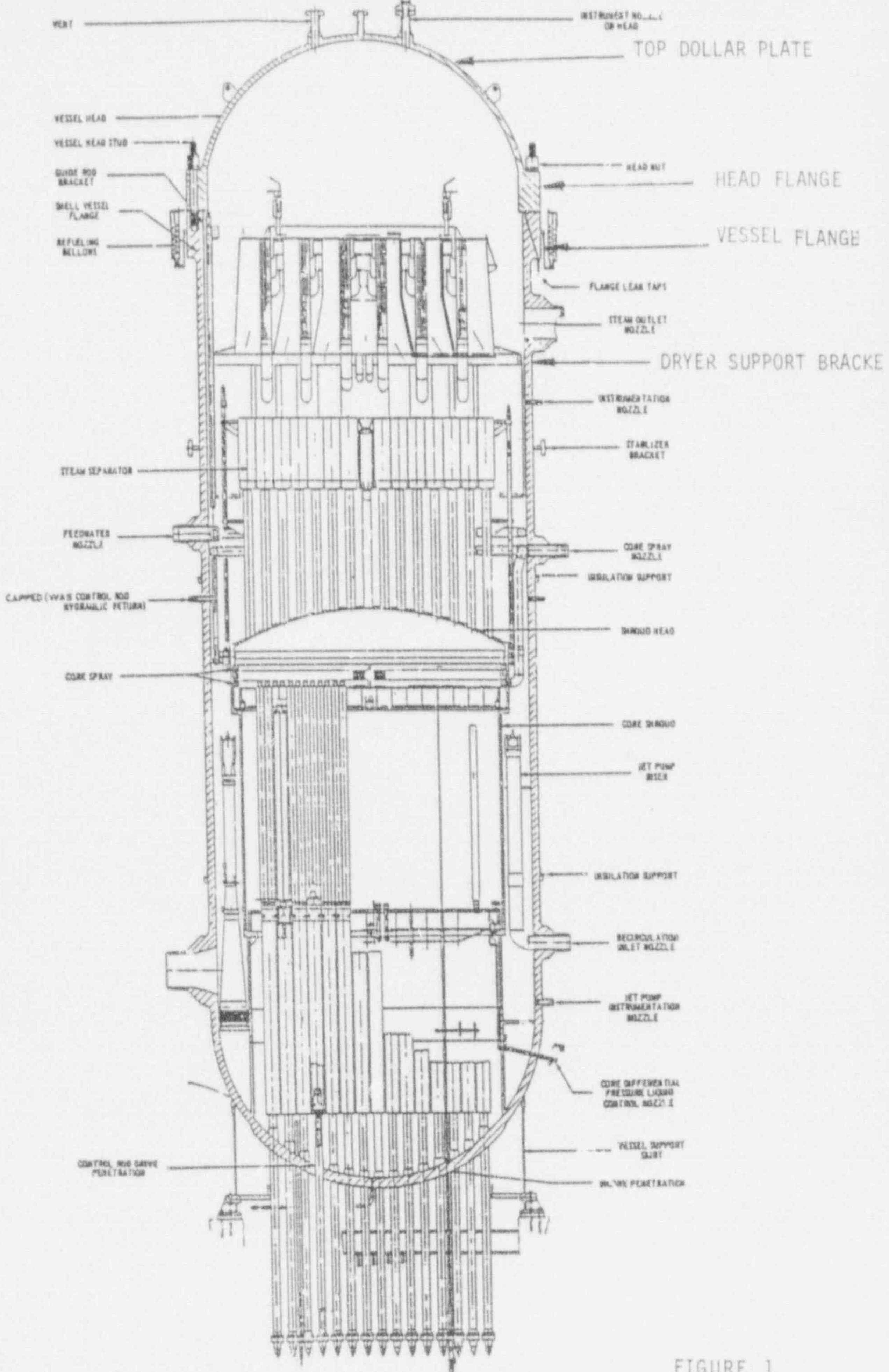
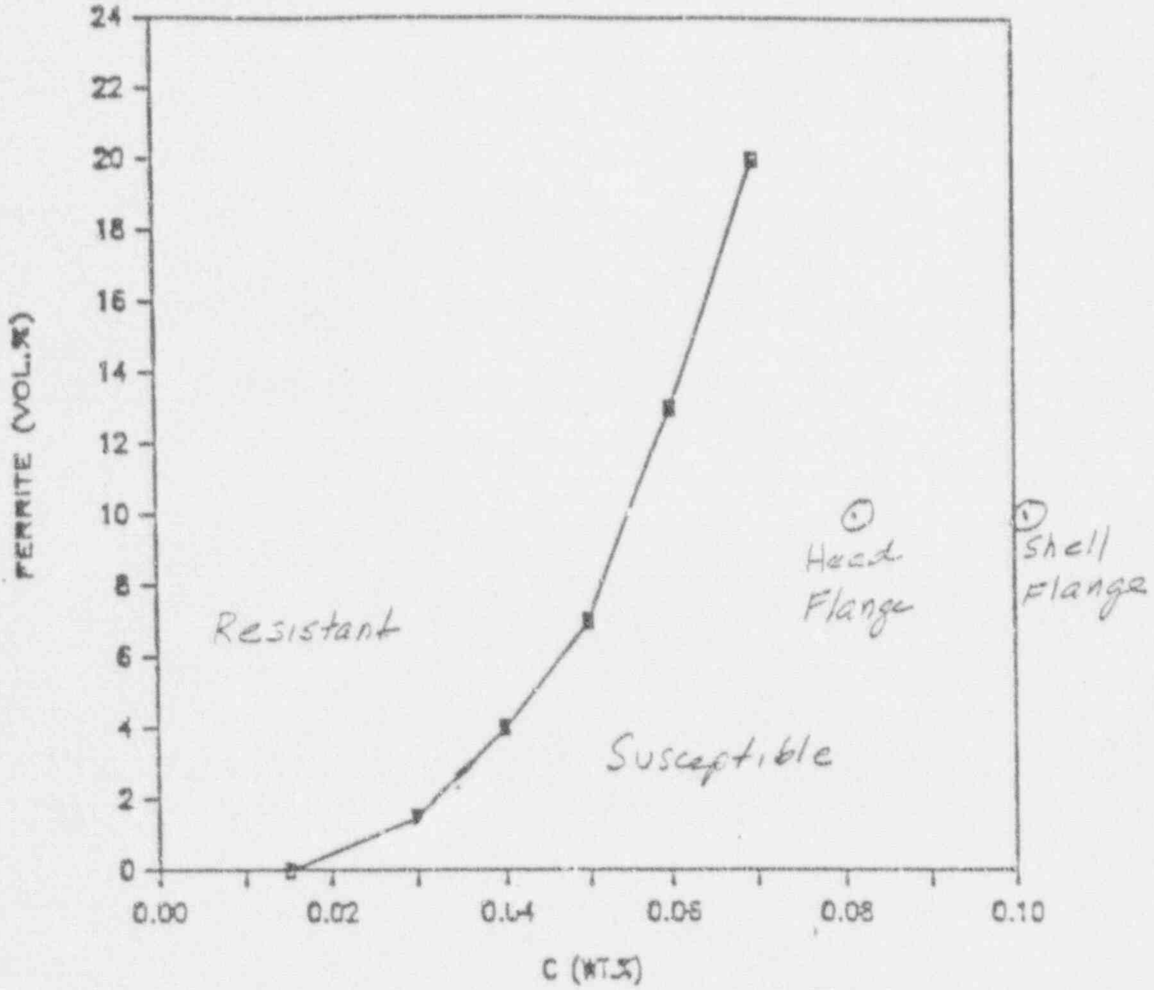

VENT
TOP DOLLAR PLATE
VESSEL HEAD
VESSEL HEAD STUD
HEAD NUT
GUIDE ROD BRACKET
HEAD FLANGE
SHELL VESSEL FLANGE
REFUELING BELLOWS
VESSEL FLANGE
FLANGE LEAK TAPS
STEAM OUTLET NOZZLE
DRYER SUPPORT BRACKE
INSTRUMENTATION NOZZLE
STABILIZER BRACKET
STEAM SEPARATOR
FEEDWATER NOZZLE
CORE SPRAY NOZZLE
INSULATION SUPPORT
CAPPED (WAS CONTROL ROD HYDRAULIC RETURN)
SHROUD HEAD
CORE SPRAY
CORE SHROUD
JET PUMP RISER
INSULATION SUPPORT
RECIRCULATION INLET NOZZLE
JET PUMP INSTRUMENTATION NOZZLE
CORE DIFFERENTIAL PRESSURE LIQUID CONTROL NOZZLE
VESSEL SUPPORT SKIRT
CONTROL ROD DRIVE PENETRATION

FIGURE 1



Predicted Ferrite Requirements Versus Carbon Content to Give Immunity Against SCC for Grade CF8 Castings

FIGURE 2

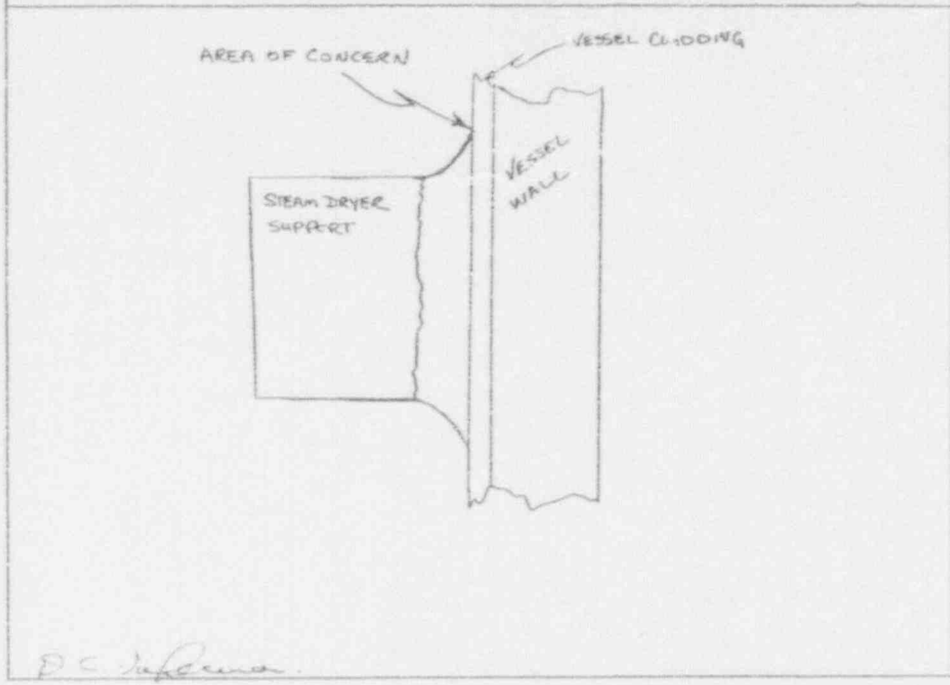
EXAMINATION DATA SHEET - SKETCH SHEET

VERMONT YANKEE NUCLEAR POWER PLANT

Visual Examination of Reactor Internals and Components
By the Use of Underwater TV Camera
In-Vessel ISI Report ____ of ____

Video Tape Reel Number: 92-20 Date 3-21-92 Page 2 of 2

Indication No. 1 Description STEAM DRYER SUPPORT BRACKET 215½°



Reviewed By ______________________ Date ____________
R/CE Supervisor

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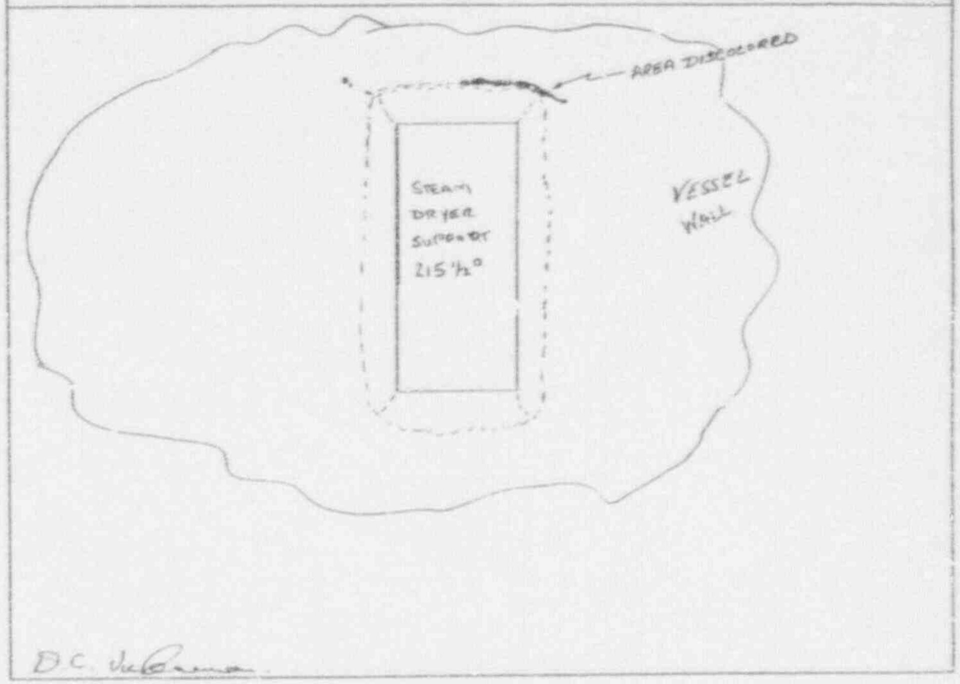

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FIGURE 3