UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

In the matter of COMMONWEALTH EDISON COMPANY (Zion Nuclear Power Station, Unit Nos. 1 and 2)	))))))	Docket Nos. 50-295 and 50-304

EXEMPTION

I.

The Commonwealth Edison Company (the licensee), is the holder of Facility Operating License Nos. DPR-39 and DPR-48 which authorize operation of Zion Nuclear Power Station, Units 1 and 2, at a steady-state power level not in excess of 3250 megawatts thermal. The facility consists of two pressurized water reactors located at the licensee's site in Lake County, Illinois. The licenses provide, among other things, that they are subject to all rules, regulations and orders of the Nuclear Regulatory Commission (the Commission) now and hereafter in effect.

II.

In a letter dated December 3, 1993, the licensee provided an assessment of the reference temperature for pressurized thermal shock (RT_{PTS}) for the design life (32 effective full power years) for the Zion Nuclear Power Station Units 1 and 2 (Zion 1 and 2) reactor vessels and requested an exemption from determining the unirradiated reference temperature (initial RT_{NDT}) in accordance with NB-2331 of Section III of the ASME Boiler and Pressure Vessel Code (ASME Code), as specified in 10 CFR 50.61(b)(2)(i). Prior correspondence commenced with the licensee's letter dated December 13, 1991, that replied to the amendment to 10 CFR 50.61 which was published in the Federal Register on May 15, 1991, (56 FR 22300). In a letter dated March 13, 1992, the licensee provided its flux reduction program to ensure the intermediate-to-lower shell circumferential weld for Zion Unit 1 would remain less than the screening criterion through 32 EFPY. In a letter dated May 22, 1992, the licensee used data provided by the Babcock and Wilcox Owners' Group (B&WOG) to address the initial RT_{NDT} and RT_{PTS} for the Zion Unit 1 and 2 reactor pressure vessels (RPVs). With this data, the licensee was able to show that the RPVs will satisfy the pressurized thermal shock (PTS) screening criteria through 32 EFPY. After reviewing the licensee's submittals, the staff requested additional information in a letter dated December 2, 1992. The licensee responded in a letter dated January 28, 1993. On June 9, 1993, the staff met with the licensee to discuss the performance of a modified analysis utilizing improved analytical techniques. In a letter dated September 1, 1993, the licensee provided a summary report demonstrating that the Zion RPVs will not exceed the end of life PTS screening criteria. In another letter dated October 5, 1993, the licensee detailed the development of the methodology utilized in performing the PTS evaluation for the Zion RPVs.

III.

The Pressurized Thermal Shock (PTS) rule, 10 CFR 50.61, "Fracture toughness requirements for protection against pressurized thermal shock events," adopted on July 23, 1985, establishes screening criteria that define a limiting level of embrittlement beyond which operation cannot continue without further plant-specific evaluation. The screening criteria are given in terms of reference temperature, RT_{PTS}. The screening criteria are 270°F for plates and axial welds and 300°F for circumferential welds. The RT_{PTS} is defined as the sum of (a) the unirradiated reference temperature, (b) the margin to be added to cover uncertainties in the initial properties, copper and nickel contents, fluence, and calculation procedures, and (c) the increase in RT_{PTS} caused by irradiation. The amount of increase in RT_{PTS} is based on the amount of neutron irradiation and the amount of copper and nickel in the material. The greater the amounts of copper, nickel and neutron fluence, the greater the increase in RT_{PTS} for the material and the lower its fracture resistance. The PTS rule requires that the unirradiated reference temperature be determined from measurements as defined in the ASME Code, Section III, Paragraph NB-2331. The amount of margin is dependent on whether: (a) the material is a weld or a base metal, (b) the unirradiated reference temperature is a generic value or a measured value, and (c) the increase in RT_{PTS} is from credible surveillance material or is from the chemistry factor tables in the PTS rule.

The PTS rule was amended on May 15, 1991. The amended rule changed the method of calculating embrittlement to the method recommended in Regulatory Guide (RG) 1.99, Revision 2, "Radiation Embrittlement of Reactor Vessel Materials", and requires licensees to consider the effect of reactor vessel operating temperature and surveillance results on the calculated RT_{PTS} value. The licensee provided this assessment in a letter dated July 2, 1992, which contained the licensee's response to Generic Letter (GL) 92-01, Revision 1, "Reactor Vessel Structural Integrity, 10 CFR 50.54(f)". The purpose of GL 92-01 was to obtain information needed to assess compliance with requirements set forth in 10 CFR Part 50, Appendices G and H and commitments made in response to GL 88-11 regarding reactor vessel structural integrity. The licensee's responses to GL 92-01 are being evaluated and will be resolved as an issue separate from this exemption request.

Pressurized Thermal Shock (PTS) Evaluation

Licensee's Evaluation

The licensee reports that the beltline of each reactor vessel consists of a forging, four plates, four longitudinal welds and three circumferential welds. There are sufficient records to identify the heat number and chemical composition (percentage copper and nickel) of all beltline materials.

Unirradiated Reference Temperature

The unirradiated reference temperature for the beltline forgings and plates was determined from test results from the materials. The licensee used a generic value (-5°F) for the unirradiated reference temperature of all beltline weld metals, with the exception of the weld metal identified as WF-70. The unirradiated reference temperature for WF-70 weld metal was determined from drop weight tests and fracture toughness tests from welds fabricated with WF-70 and WF-209-1 weld metal. Since WF-70 and WF-209-1 welds were fabricated using the same heat number of weld wire and the same type of flux, their material properties are considered equivalent. The licensee's data will be discussed in the Staff Evaluation of Unirradiated Reference Temperature for WF-70.

The unirradiated reference temperature that is defined in Section III of the ASME Code, Paragraph NB-2331 is determined from Charpy V-notch (CVN) impact and drop weight tests. These tests have been performed on WF-70 weld metal by the licensees for Zion and Oconee, the B&WOG and Oak Ridge National Laboratory (ORNL). The test results indicate that the unirradiated reference temperature varies from -3°F to +123°F with a standard deviation of 43.1°F and a mean value of 49°F. This wide variability was a surprise to the staff because welds similar to WF-70 were reported to have a mean value of -4.8°F and a standard deviation of 19.7°F. The staff believes that the large uncertainty in unirradiated reference temperature for WF-70 weld metal is due to the low upper-shelf behavior of the material and that the definition of unirradiated reference temperature in the ASME Code is not applicable for material with low upper-shelf behavior like WF-70 weld metal. The licensee has proposed to determine the unirradiated reference temperature from drop weight and fracture toughness tests instead of the method defined in Section III of the ASME Code. The licensee proposes to define the unirradiated reference temperature as equal to the sum of: (a) the mean value for the nil-ductility transition temperature, T_{NDT}, from the drop weight test data from WF-70 and WF-209-1 welds and (b) the two standard deviation value determined from the drop weight test data. This method results in a mean value for the T_{NDT} of -56°F and a standard deviation of 14.8°F for WF-70 weld metal. Using these values of T_{NDT} and standard deviation, the unirradiated reference temperature is -26°F for WF-70 weld metal. Since the licensee has not followed the method in Section III of the ASME Code, the licensee's method for determining the unirradiated reference temperature of WF-70 does not meet the requirements of 10 CFR 50.61. The licensee has, therefore, requested an exemption from the requirement to determine the unirradiated reference temperature (initial RT_{NDT}) in accordance with NB-2331 of Section III of the

ASME Boiler and Pressure Vessel Code (ASME Code), as specified in 10 CFR 50.61(b)(2)(i).

Increase in RT_{PTS} and Margin

The increase in RT_{PTS} for each beltline material, except WF-70 weld metal, was determined using the chemistry factor tables in the PTS rule. The increase in RT_{PTS} for WF-70 weld metal was determined from Charpy impact tests on WF-70 weld metal irradiated in the Zion Units 1 and 2 surveillance capsules. The increase in RT_{PTS} for WF-70 weld metal was determined using the methodology documented in Section 2.1 of RG 1.99, Revision 2.

The amount of margin for each beltline plate and forging was the amount identified in the PTS rule for base metal with measured unirradiated reference temperature. The amount of margin for each beltline weld, with the exception of WF-70, was the amount identified in the PTS rule for weld metal with generic values of unirradiated reference temperature. The amount of margin for WF-70 weld metal was determined using the standard deviation for the increase in RT_{PTS} from irradiation in RG 1.99, Revision 2, when credible surveillance data is available. This results in a margin value of 28°F for WF-70 weld metal.

Paragraph 10 CFR 50.61(b)(3) requires that RT_{PTS} values which are modified by surveillance data be approved by the Director, Office of Nuclear Reactor Regulation. The staff believes that using the methodology in RG 1.99, Revision 2 for determining the increase in RT_{PTS} from surveillance material is an acceptable alternative to the value determined from the chemistry factor tables in the PTS rule. The staff believes that the amount of margin for WF-70 should be the amount determined using the standard deviation for the increase in RT_{PTS} from irradiation in RG 1.99, Revision 2. This results in a margin value of 28°F and an unirradiated reference temperature of -26°F for WF-70. The reasons for not including the uncertainty of the unirradiated reference temperature in the margin, but adding it to the T_{NDT} will be discussed in the Staff Evaluation of Unirradiated Reference Temperature for WF-70.

RT_{PTS} at Expiration of the Zion 1 and 2 Licenses

The licensee has projected that at the expiration of their licenses, WF-70 weld metal in Units 1 and 2 will have RT_{PTS} values of 230°F and 172°F, respectively. Both these values are significantly below the PTS screening criteria in the PTS rule. As a result of the licensee's evaluation of WF-70 weld metal, the limiting material in Unit 1 is a circumferential weld fabricated using WF-154 weld metal and the limiting material in Unit 2 is a circumferential weld fabricated using SA-1769 weld metal. The RT_{PTS} values for these welds at the expiration of the Units 1 and 2 licenses are 268°F and 269°F, respectively. Both of these values are significantly below the PTS screening criterion, 300°F, in the PTS rule.

Staff Evaluation of Unirradiated Reference Temperature for WF-70

As discussed previously, the licensee and the B&WOG have concluded that determination of unirradiated reference temperature via the CVN procedure of NB-2331 of Section III of the ASME Code is not appropriate for the Zion beltline welds fabricated with WF-70 weld metal. The staff recognizes that the ASME Code procedure, when applied to low upper shelf materials such as WF-70, may not produce a reasonable determination of unirradiated reference temperature. The staff has, therefore, encouraged the licensee to pursue alternate approaches to determine the unirradiated reference temperature for WF-70. The approach selected by the licensee and the B&WOG involves analysis of WF-70 fracture toughness data in accordance with the Draft ASTM Standard on Fracture Toughness in the Transition Range (Draft 5, Rev. 3-3-93). The purpose of the licensee's analysis is to demonstrate that the above methodology "bounds" the fracture toughness data and can be indexed to the ASME fracture toughness reference curves. The indexing to either the K_{IC} or K_{IR} curves is used to show that the reference temperature determined from drop weight tests provides an appropriate unirradiated reference temperature for WF-70.

At a meeting with the licensee on June 9, 1993, the staff acknowledged the meri' of the ASTM approach and encouraged the licensee to pursue it to complet . At that time, the staff also indicated that the licensee should consider onstraint adjustments and strain rate effects on the data. In particular, the staff questioned the basis for directly indexing the Babcock and Wilcox (B&W) dynamic fracture toughness data to the ASME K_{IR} curve with respect to the differing strain rates involved in generation of the data. The licensee subsequently submitted a B&W report (BAW-2202, September, 1993) which addresses its revised analysis for the determination of the unirradiated reference temperature.

The staff has independently evaluated the data provided in BAW-2202 and the previous report (BAW-2100, January, 1993) in accordance with the Draft ASTM Standard on Fracture Toughness in the Transition Range. The staff analysis, presented in the attached Figure 1, considered both constraint and rate effects on the data. Figure 1 presents the B&W dynamic fracture toughness data as the open symbols. The solid symbols represent the same data constraint corrected using the procedure suggested by Anderson and Dodds, 1993. The ASTM curves (K_{jc} median, 95% CL and lower bound) were derived from the constraint-corrected data at 0°F where it can be seen that the magnitude of the correction was small. It is seen that the ASTM K_{jc} lower bound curve effectively bounds all of the data with the possible exception of the constraint-corrected point at +132°F. However, the specimen at +132°F exhibited a significant amount of ductile tearing prior to failure by cleavage. It is known that the Anderson-Dodds procedure will "over-correct" for constraint in such instances.

With respect to strain rate effects, the B&W dynamic data were generated at a rate of approximately 7×10^4 ksi√in/sec. This rate is on the threshold of the rates achieved in the crack arrest tests which constitute the ASME K_{IR} curve. Figure 1 also shows a direct comparison between the B&W dynamic fracture toughness data and some recently available crack arrest data on WF-70 from the ORNL. While the crack arrest data are generally conservative in comparison to the B&W data, it is seen that the ASTM K_{jc} lower bound curve also bounds the ORNL data. On the basis of this analysis, the staff finds the methodology of indexing the B&W dynamic data to the K_{IR} curve acceptable.

In conclusion, the staff analysis which addresses constraint and rate effects has shown the fracture toughness based procedure for determination of unirradiated reference temperature to be acceptable for WF-70. As shown in Figure 1, the ASME K_{IR} curve, with a reference temperature of -26°F bounds all of the constraint-adjusted data and the ASTM curves up to approximately 140°F.

This analysis therefore supports an unirradiated reference temperature of -26°F for the WF-70 material.

Other procedures for determination of RT_{NDT} may serve as acceptable alternatives to NB-2331 contingent on staff review and approval. However, it should be noted that the staff acceptance of the alternative procedure in this evaluation was contingent on the analysis of a significant amount of fracture toughness data for the WF-70 weld metal. Acceptance of such a procedure in a case where little or no fracture toughness data were available would be difficult in the absence of an officially sanctioned consensus standard.

As part of the resolution of low upper-shelf reference temperature issues on a generic basis, the ASME Code has tasked the Failure Modes of Components Committee of the Pressure Vessel Research Council (PVRC) to consider alternate procedures for the determination of unirradiated reference temperature. To this end, the PVRC recently held a 1/2 day workshop on "K_{IR} Curves and RT_{NDT}" on October 11, 1993, where the ASTM fracture toughness based approach was highlighted. As a result of the workshop, it is expected that the Committee will be able to make recommendations to the ASME Code by December 31, 1994.

Irradiation Temperature and Surveillance Material Test Results

The methods of calculating the increase in RT_{PTS} in the PTS rule and in RG 1.99, Revision 2 were empirically derived from surveillance data from U.S. commercially operated nuclear reactor vessels. The methods are valid for a nominal irradiation temperature of 550°F. Irradiation below 525°F is considered to produce embrittlement greater than the values predicted in the PTS rule and RG 1.99, Revision 2.

In its response to GL 92-01, the licensee reported that the cold leg temperature during nuclear systems power operation varied linearly between 547.0°F at 0 percent power and 529.4°F at 100 percent power. Hence, irradiation occurred at temperatures exceeding 525°F and the methodologies in the PTS rule and RG 1.99, Revision 2 are applicable to Zion Units 1 and 2.

Regulatory Guide 1.99, Revision 2 indicates that about a best-fit line to the surveillance data, scatter should be less than 28°F for welds and for fluence of two or more orders of magnitude, the scatter should be less than 56°F. Zion 1 has four irradiated surveillance data points and Zion 2 has three irradiated surveillance data points from WF-70 weld metal. The maximum difference between the measured increase in reference temperature and the best fit line is 20°F. Since this is less than 28°F, the increase in RT_{PTS} and the associated standard deviation may be based on the methodology in Section 2.1 of RG 1.99, Revision 2.

Conclusions

Based on the Zion 1 and 2 irradiation temperature and surveillance data, the methodologies in the PTS rule and RG 1.99, Revision 2 are applicable to Zion 1 and 2. As a result of its review, the staff concludes that the licensee's method of determining the unirradiated reference temperature is an acceptable alternative to the method described in NB-2331 of Section III of the ASME Code because staff and licensee analyses indicate that the fracture toughness data are bounded by the ASME K_{IR} curve with an unirradiated reference temperature of -26°F. However, since the unirradiated reference temperature was not determined in accordance with the method in Section III of the ASME Code, an exemption to the PTS rule is required. The RT_{PTS} values for all beltline materials will be below the PTS screening criteria when the Zion 1 and 2 licenses expire. 10 CFR 50.12(a)(1) allows the Commission to grant exemptions which are authorized by law, will not present an undue risk to the public health and safety, and are consistent with the common defense and security. Since the licensee's method of determining the unirradiated reference temperature is an acceptable alternative to the method in NB-2331 of Section III of the ASME Code, RT_{PTS} values for WF-70 weld metal that are calculated using the licensee's method are authorized by law and will not present an undue risk to the public health and safety and are consistent with the common defense and security. For the same reason, the staff finds that application of the regulation would not serve the underlying purpose of the rule, which is to ensure that reactor pressure vessels in service are not susceptible to fracture as a result of pressurized thermal shock. On this basis, the staff finds that the licensee has demonstrated that there are special circumstances present as required by 10 CFR 50.12(a)(2).

References

(1) "Properties of Weld Wire Heat Number 72105 (Weld Metals WF-70 and WF-209-1), BAW-2100, January, 1993.

(2) "Test Practice (Method) for Fracture Toughness in the Transition Range," Draft 5, Rev. 3-3-93, presented at the ASTM E08 Committee Meetings, Atlanta, GA, May, 1993.

(3) "Fracture Toughness Characterization of WF-70 Weld Metal," BAW-2202, September, 1993.

(4) "Simple Constraint Corrections for Subsize Fracture Toughness Specimens," T.L. Anderson and R.H. Dodds, Jr., ASTM STP 1024, 1993, pp. 93-105.

IV.

Accordingly, the Commission has determined that, pursuant to 10 CFR 50.12, an exemption is authorized by law and will not endanger life or property or the common defense and security and is otherwise in the public interest and hereby grants the following exemption with respect to a requirement of 10 CFR 50.61:

For Zion Nuclear Power Station, Units 1 and 2, the licensee's method of determining the unirradiated reference temperature (initial RT_{NDT}) from drop weight and fracture toughness tests is an acceptable alternative to the method in NB-2331 of Section III of the ASME Code as specified in 10 CFR 50.61(b)(2)(i).

Pursuant to 10 CFR 51.32, the Commission has determined that the granting of the subject exemption will not have a significant effect on the quality of the human environment (59 FR 4727).

This exemption is effective upon issuance.

FOR THE NUCLEAR REGULATORY COMMISSION

Original signed by:
Jack W. Roe, Director
Director of Reactor Projects III/IV/V
Office of Nuclear Reactor Regulation

Dated at Rockville, Maryland
this 22nd day of February 1994

*See previous concurrence

OFC	LA:PDIII-2	PM:PDIII-2	D:PDIII-2	OGC*	AD:R3:DRPW	D:DRPW
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COPY	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO	YES/NO

(4) "Simple Constraint Corrections for Subsize Fracture Toughness Specimens," T.L. Anderson and R.H. Dodds, Jr., ASTM STP 1024, 1993, pp. 93-105.

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FOR THE NUCLEAR REGULATORY COMMISSION

Jack W Roe

Jack W. Roe, Director
Director of Reactor Projects III/IV/V
Office of Nuclear Reactor Regulation

Dated at Rockville, Maryland
this 22nd day of February 1994

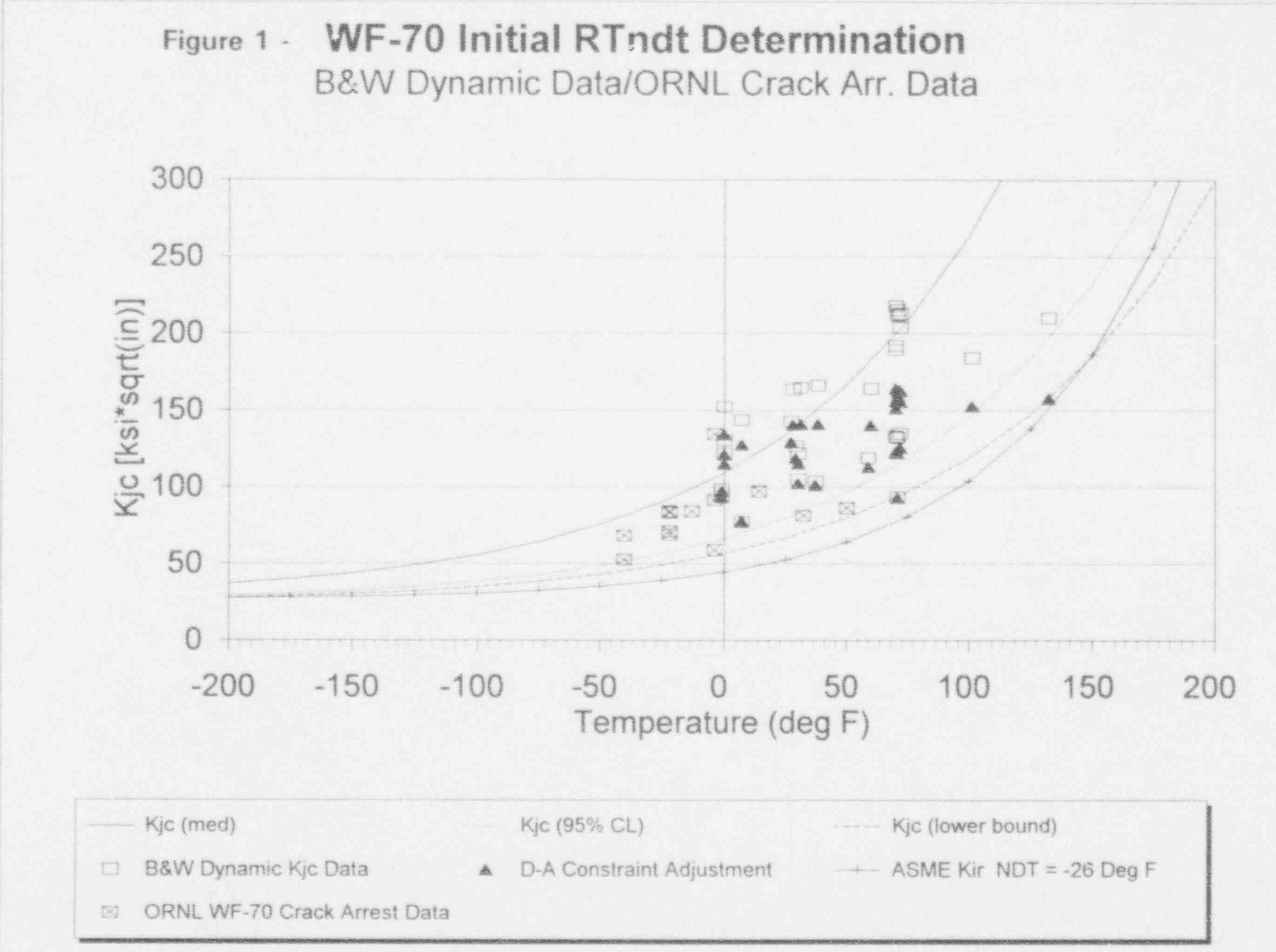
Figure 1 - WF-70 Initial RTndt Determination
B&W Dynamic Data/ORNL Crack Arr. Data
300
250
200
150
100
50
0
Kjc [ksi*sqrt(in)]
-200
-150
-100
-50
0
50
100
150
200
Temperature (deg F)
Kjc (med)
Kjc (95% CL)
Kjc (lower bound)
B&W Dynamic Kjc Data
D-A Constraint Adjustment
ASME Kir NDT = -26 Deg F
ORNL WF-70 Crack Arrest Data

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

February 22, 1994

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DOCKET NO. 50-295 and 50-304

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SUBJECT: COMMONWEALTH EDISON COMPANY - Zion Nuclear Power Station, Units 1 & 2

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James E. Dyer, Director, PDIII-2

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