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

August 27, 1990

Docket No. 50-029

MEMORANDUM FOR: Victor Nerses, Acting Director
Project Directorate I-3
Division of Reactor Projects - I/II

FROM: Patrick M. Sears, Project Manager
Project Directorate I-3
Division of Reactor Projects - I/II

SUBJECT: SUMMARY OF MEETING WITH YANKEE ROWE

Representatives of Yankee Rowe met with members of the staff on August 21, 1990 and discussed Yankee Rowe's reactor vessel. Three areas of data gathering/inspection were discussed as follows:

1. Over the next month -
Upper welds will be sampled for chemistry with possibility of showing material similarity with belt line welds.

2. Over next 12 to 18 months -
Develop better understanding of stitch welded cladding and demonstrate the ability to examine base metal for flaws. (Yankee's reactor vessel and pressurizer have stitch welded cladding).

Develop inspection methods which will be compatible with the existing tight dimensional spaces involved so that the reactor vessel can be eddy current volumetrically tested with the thermal shield left in place.

Develop data for plate weld material for operating temperature in the 500°F range.

Develop a test matrix for various temperatures, irradiations, metallurgical contents, heat treats, etc.

3. Summer 1993 Outage -
Do inspection and sampling of belt line welds and lower plates.

Continue test matrix.

Items for near future -
Fluences calculated by Westinghouse will be available October 1, 1990.

DF01
1/1

Results of peer evaluation of Yankee's July 5, 1990 submittal will be available in 2 to 3 months.

The details of the staff's review of the July 5, 1990, Yankee submittal were not discussed.

Enclosure 1 is a list of persons that attended the meeting.

Enclosure 2 is slides used by Yankee in their presentation.

Original signed by
Patrick M. Sears, Project Manager
Project Directorate I-3
Division of Reactor Projects - I/II

Enclosures:
As stated

cc w/enclosures:
See next page

OFC	:PDI-3/LA(A)	:PDI-3/PM	:PDI-3/DIR(A)	:NRR/DET	:NRR/DST	:ADP:NRR
NAME	:BClayton	:PSears:mw	:VNerses	:CRichardson	:AThadani	:JPartlow
DATE	: 8/24/90	:8/24/90	: / /90	:8/24/90	:8/24/90	:8/24/90
OFC	:ADT:NRR	:	:	:	:	:
NAME	:WRussell	:	:	:	:	:
DATE	:8/27/90	:	:	:	:	:

OFFICIAL RECORD COPY
Document Name: SUMMARY MEETING YANKEE ROWE

cc:
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Bolton, Massachusetts 01740-1398

ENCLOSURE 1

AUG. 21, 1990

YANKEE ROWE MEETING

NAME	COMPANY/AGENCY	PHONE
PATRICK SEARS	USNRC / PD1-3	492-1436
Lynn Connor	SAIC	827-4957
Andrew C Kadak	Yankee Atomic	508-779-6711
John D. Haseltine	Yankee Atomic	508-779-6711
David R. Noonan	SEARCH Licensing/Bechtel	301-417-3097
Jim PARTLOW	NRC/ADP	492-1284
Frank G. Hrspe	NRC/DMHS	492-1275
ASHOK THADANI	NRC/DST	
Jim Richardson	NRC/DET	492-0722
W.T. RUSSELL	NRC/ADT	492-1274
Tom MURLEY	NRR	492-1270
EL IGNE	LCES	492-0842

ENCLOSURE 2

Yankee Position on Reference Temperature of Reactor Vessel Materials

August 21, 1990

Reference Temperature

	Yankee	NRC	Variance
Upper Plate	190F	280F	~~110F~~ 90
Lower Plate	183	325	142
Circ Weld	229	360	131
Axial Weld	141	230	89

Upper Plate

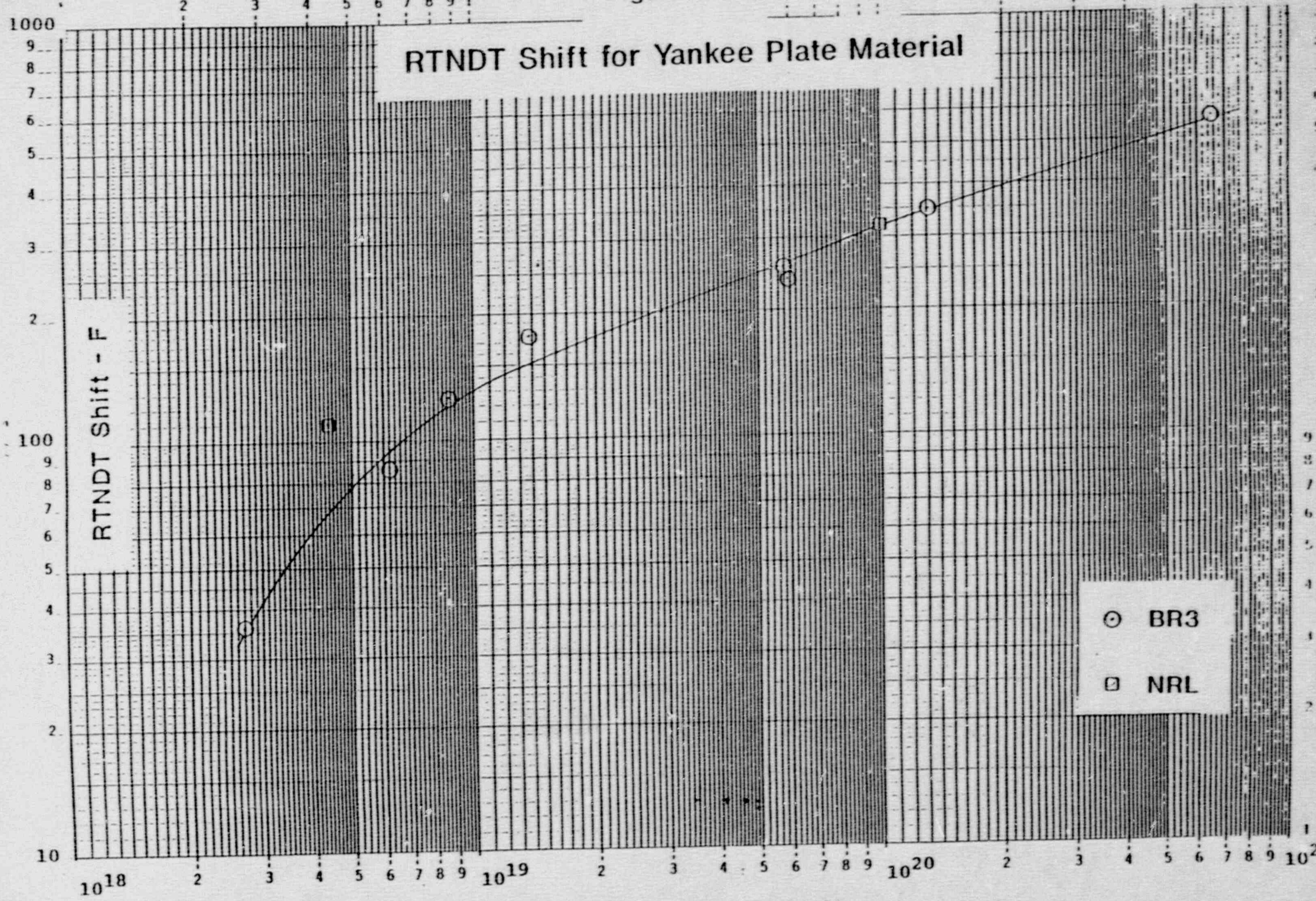
- Type of Material - A 302-B
- Composition - Cu=.18 wt% , Ni=.21wt%
- Heat Treatment - austenitized at 1750F to 1800F; quenched and tempered
- Austenite Grain Size - ASTM No. 7 (35.9 microns) from Yankee specimens at BR3
- Peak 1990 Beltline Fluence 2.16E+19 n/cm2
- Average 1990 Beltline Fluence 0.82E+19 n/cm2
- Average Cold Leg Temperature - 503F
- Initial RTNDT - 10F
- RTNDT Shift to 1990 - 180F
- 1990 RTNDT - 190F

Upper Plate

- The upper plate reference temperature was determined using the surveillance data from Yankee plate material irradiated at Yankee and at BR3.
- No temperature correction was made because of the insensitivity of the plate to irradiation temperature.

K&E LOGARITHMIC 2 X 3 CYCLES KEUFFEL & ESSER CO. MADE IN U.S.A. 46 7320

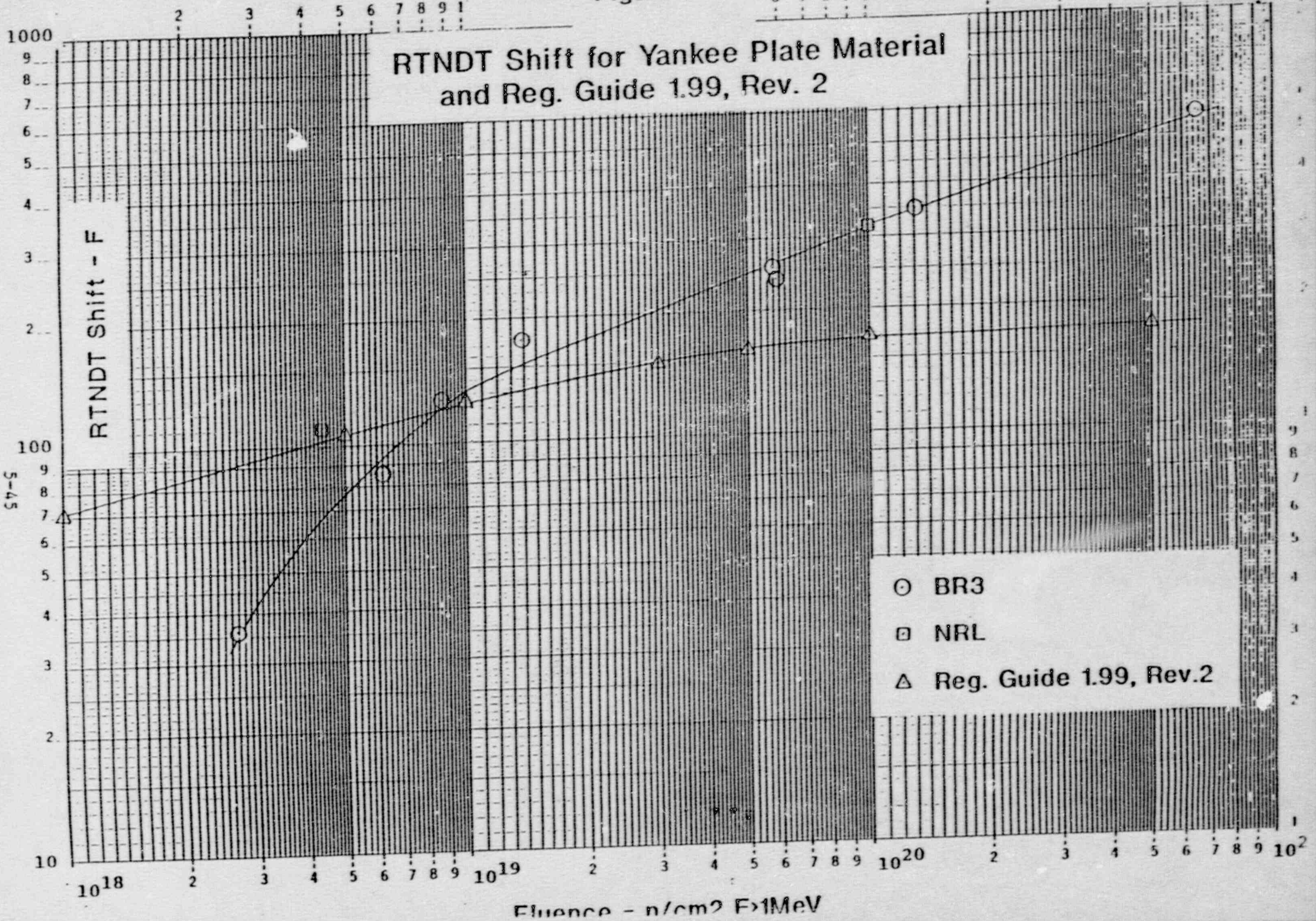
Figure 5-6



Comparison to Reg. Guide 1.99, Rev. 2

- Indicates that Reg.Guide data is not applicable to Yankee plate.
- Indicates higher fluence threshold shift in reference temperature.
- Indicates higher shifts once threshold is reached.
- Yankee plate data was not included in the Reg. Guide data base.
- Conclusion is that Yankee plate material is different than Reg. Guide and cannot be applied to determine Yankee plate shifts.

Figure 5-7



RTNDT Shift for Yankee Plate Material
and Reg. Guide 1.99, Rev. 2
RTNDT Shift - F
Fluence - n/cm2 E>1MeV
BR3
NRL
Reg. Guide 1.99, Rev.2

NRL Fluence

- The original surveillance program at Yankee was carefully designed to place four high flux capsules in identical locations between the core baffle and barrel to obtain similar results. The locations were chosen next to equivalent enrichments of fuel to assure equal exposure. Both Yankee plate specimens and reference steel specimens were put into the capsules.

- The capsule tested had five flux monitors in it which showed a range of fluence from 8 to 10.6E+19 n/cm2. The flux was also determined from a reference steel charpy specimen to be 4.88E+19 n/cm2. A decision was made by NRL to assume a fluence of 5E+19 n/cm2 for this capsule.

NRL Fluence Continued

- The assumed fluence is obviously inconsistent with flux monitors in the same capsule and is inconsistent with seven other fluence readings which ranged from 7.38 to 10.2E+19 n/cm2 from the three other capsules in similar locations.
- As a check on the fluence seen by the capsule, Westinghouse performed a fluence evaluation of Core 2 and specifically calculated the fluence at the nominal location of the capsule. The result showed a 9.1E+19 n/cm2 fluence.
- If the reference shift from the Yankee capsule is compared with reference shifts from the identical Yankee plate performed at BR3, its shows that the fluence would have to be at least doubled to be consistent with the BR3 data.

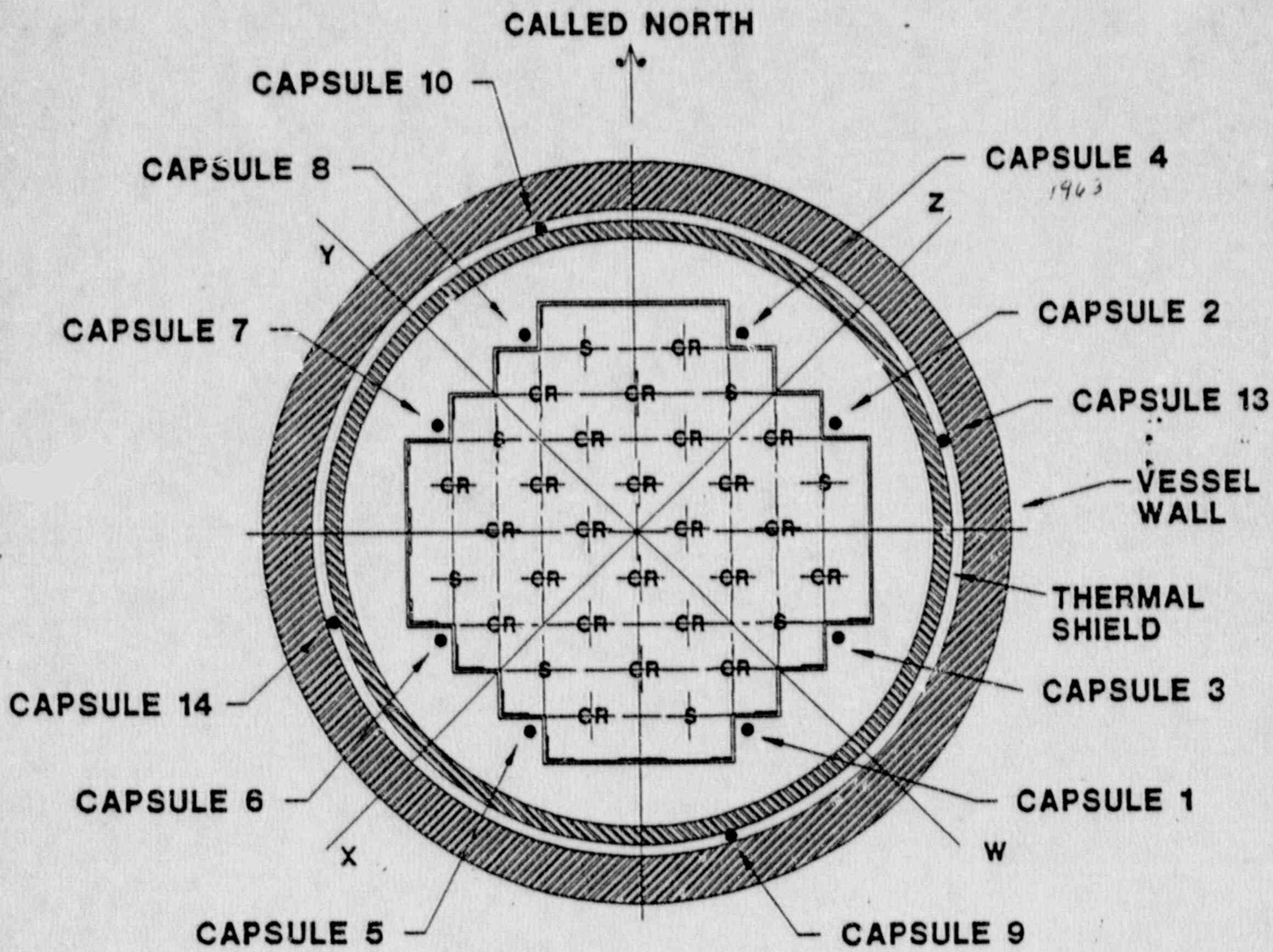


Figure 4-1

Surveillance Capsule Locations

NRL Fluence Continued

- Based on the flux monitoring in the Yankee capsules, the calculated Westinghouse fluence and the results of BR3, the NRL fluence should be adjusted by a factor of 2 to determine the actual fluence seen by the capsules.

High Flux Capsules
Core 2

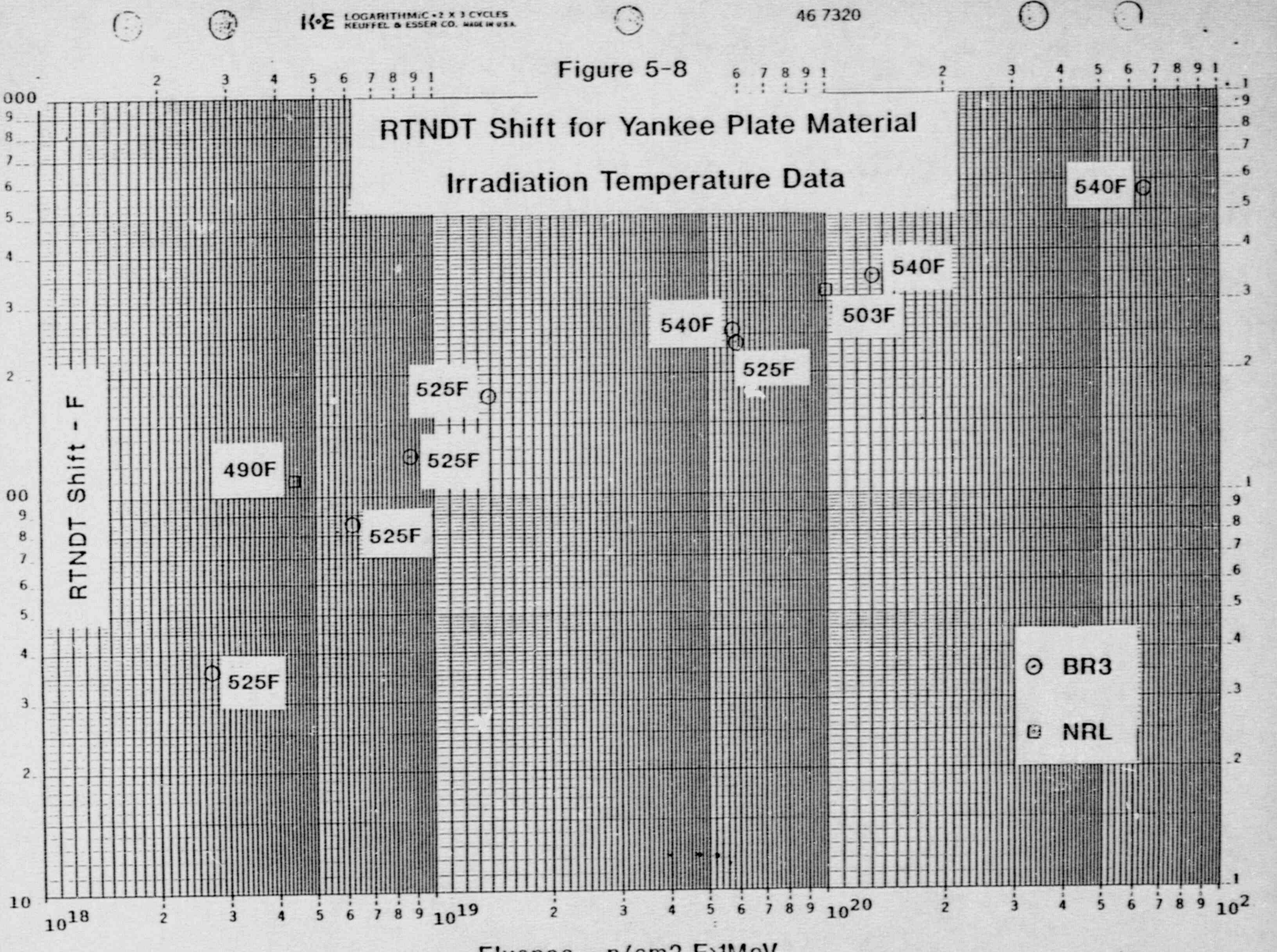
Capsule No.	Charpy Specimen Fluence-n/cm2	Flux Monitor n/cm2
1	9.38E+19	9.92E+19
		9.87E+19
		9.81E+19
		10.2E+19
2	8.83E+19	N/A
5	7.38E+19	N/A
8	4.88E+19	10.6E+19
		10.6E+19
		10.2E+19
		7.96E+19
		8.94E+19

- The recent Westinghouse calculation for the Core 2 cycle at the capsule 8 location showed the nominal fluence to be 9.1E+ 19n/cm2 which agrees well with all flux monitors.

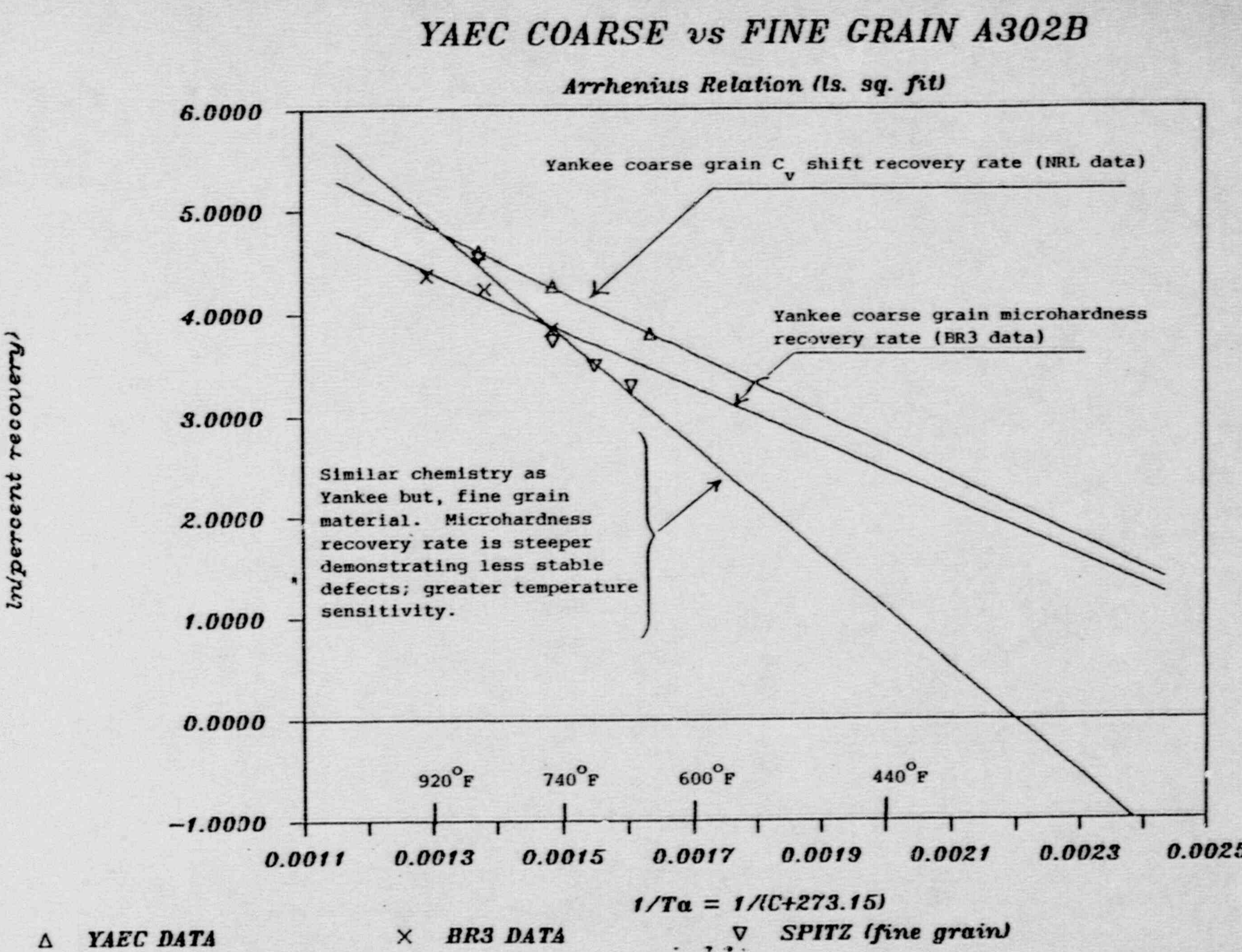
Temperature Effect

- Irradiation temperature has little effect on Yankee plate RTNDT shift based on actual data from the Yankee plate material.
- The Yankee plate material irradiated at BR3 at two different temperatures (525F and 540F) and very similar fluences (5.9 and 5.78E+19 n/cm2) show no effect of temperature. Actually the data point at 525F shows a lower shift than the 540F point.
- Using diffusion theory and data from annealing studies of Yankee plate by NRL, plots were made of material property changes for Yankee plate material and fine grain plate material of similar chemistry from Westinghouse which showed that the Yankee coarse grained material is far less sensitive to irradiation temperature.

Figure 5-8



K&E LOGARITHMIC 2 X 3 CYCLES KEUFFEL & ESSER CO. MADE IN U.S.A.
46 7320
RTNDT Shift for Yankee Plate Material
Irradiation Temperature Data
RTNDT Shift - F
540F
540F
503F
540F
525F
525F
490F
525F
525F
525F
BR3
NRL
10
100
1000
10^{18}
10^{19}
10^{20}



YAEC COARSE vs FINE GRAIN A302B
Arrhenius Relation (ls. sq. fit)
6.0000
5.0000
4.0000
3.0000
2.0000
1.0000
0.0000
-1.0000
ln(percent recovery)
Yankee coarse grain C v shift recovery rate (NRL data)
Yankee coarse grain microhardness recovery rate (BR3 data)
Similar chemistry as Yankee but, fine grain material. Microhardness recovery rate is steeper demonstrating less stable defects; greater temperature sensitivity.
920°F
740°F
600°F
440°F
0.0011
0.0013
0.0015
0.0017
0.0019
0.0021
0.0023
0.0025
1/Ta = 1/(C+273.15)
Δ YAEC DATA
× BR3 DATA
∇ SPITZ (fine grain)

Conclusion

- For the upper plate we know what the reference temperature shift is.

Lower Plate

- Type of Material - A 302-B Modified
- Composition - Cu=.20 wt% , Ni=.63 wt%
- Heat Treatment - austenitized at 1750F to 1800F; quenched and tempered
- Peak 1990 Beltline Fluence 1.93E+19 n/cm2
- Average 1990 Beltline Fluence 0.67E+19 n/cm2
- Average Cold Leg Temperature - 503F
- Initial RTNDT - 10F
- RTNDT Shift to 1990 - 173F
- 1990 RTNDT - 183F

Lower Plate

- The lower plate is similar to the upper plate except that it contains 0.63 wt% vs. 0.21 wt% nickel. The fluence at the lower plate is 89% of the peak beltline fluence.
- The lower plate reference temperature was determined using the surveillance data from the upper plate and maximum fluence for the lower plate. No temperature or nickel effects were considered.

Nickel Effect

- The nickel effect on reference temperature shifts has been reported by various authors to have a minimal effect below a threshold value.
- The Yankee lower plate with 0.2 wt% copper and 0.63 wt% nickel are below the threshold and is expected to have a similar shift to the upper plate which has 0.18 wt% copper and 0.18 wt% nickel.
- Nickel defect mechanisms have been isolated through instrumented Charpy impact testing.
- The nickel defect has shown that it is dependent on irradiation temperature. Since the Yankee plate material is not sensitive to irradiation temperature then it will also not be sensitive to a nickel effect.

Quotes From Authors For Ni/Cu Threshold

"Note that the model (nickel) does not predict a large difference in the effect of nickel in the range of 0.2 to 0.4% Cu, consistent with observation."

Source: Odette, Lucas, "Irradiation Embrittlement of LWR Pressure Vessel Steels," EPRI-NP-6114, January 1989, pp 4-8.

"Nickel was found to reduce the damage introduced by neutron irradiation up to a content of about 1.0% over which it develops an independent high negative effect. The beneficial effect of nickel below 1.0% decreases by percent as the fluence increases."

Source: Maricchiolo, Milella, Pini, "Prediction of Reference Transition Temperature Increase Due to Neutron Irradiation Exposure;" Radiation Embrittlement of Nuclear Reactor Pressure Vessel Steels: An International Review (Second Volume, ASTM STP-909, L.E. Steele, Ed., American Society for Testing and Materials, Philadelphia, 1989, pp 96-105.

"This figure (#25), when combined with the previous one (#24), suggests that in low copper content steels (<0.1 wt.%) nickel levels between 0.64 - 0.85 wt.% are not deleterious, whereas, at intermediate and high levels of copper (0.2 -0.35 wt.%), concentrations of nickel in excess of 0.85 wt.% generally are."

Source: Fisher, Buswell, "A Model for PWR Pressure Vessel Embrittlement," Central Electricity Generating Board, Berkley Nuclear Laboratories, Berkley Gloucestershire, Report No. TPRD/B/0745/R86 February 1986.

"Nickel was found to be associated with the Cu-rich clusters: however, this association is not expected to modify radiation embrittlement sensitivity significantly. No other sysnergism between copper and nickel was found."

Source: Ebrahimi, et al., "Development of a Mechanistic Understanding of Radiation Embrittlement in Reactor Pressure Vessel Steel," NUREG/CR-5063, MEA-2268, January 1988.

Beltline Welds

- The beltline weld reference temperatures were determined by using Reg. Guide 1.99 Rev. 2 shift predictions and the 1990 fluences at the weld locations.
- The copper and nickel content of the welds was assumed to be equal to BR3's (0.18 wt% Cu and 0.70 wt% Ni).
- A temperature correction factor of 8% of the shift was added to compensate for operation with a cold leg temperature of 500F to 525F. Regulatory guidance does not require temperature correction above 525F.

Weld Copper/Nickel Content

- The copper and nickel contents of the Yankee beltline welds were estimated based upon Yankee and BR3 samples.
- Both the BR3 and Yankee welding was accomplished in the same shop, with the Oxweld 40 wire and Linde 80 flux called for in the shop sheets.
- The weld specifications required the weld filler metal to match the base metal and if the base materials were dissimilar then the filler metal should match the lower mechanical properties (P-order) of the material.
- The Yankee circumferential weld in the reactor vessel head was sampled and showed 0.12 wt% copper and 0.08 wt% nickel. The shop sheet requirements for the head weld was identical to the beltline welds except no nickel was added to the flux. The beltline welds have nickel added to the flux.

Weld Copper/Nickel Content

- The head circumferential weld joined two dissimilar base materials and the filler metal matched the low P-order flange material quite closely.

- The BR3 longitudinal weld was sampled and showed 0.183 wt% copper and 0.70 wt% nickel. The BR3 weld called for nickel addition to the flux identical to Yankee's.

- The longitudinal weld joined a single base material and the weld filler metal matched the chemistry of the base material very closely. (Just like they matched the material on Yankee's head.)

- For determination of reference temperature shifts, the BR3 copper and nickel content was used. The copper content is higher than Yankee's (0.18 vs. 0.12) and the nickel content (0.70) is representative of Yankee's beltline welds.

Yankee Head Chemistries

P-Order	Location	C	Mn	P	S	Cu	Si	Ni	Cr	Mo	Al
P1	Head Flange	0.27	0.73	0.018	0.008		0.21				
P3	Dome	0.20	1.25	0.019	0.024	0.19	0.23	.18	0.11	0.47	
	Head Circ Weld *	0.26	0.69	<.01	0.02	0.12	0.22	0.08	0.05	0.03	

* The head circumferential weld shop sheet called for no nickel addition and the weld specification called for the weld filler metal to match the low P-Order or the head flange base material.

BR3 Chemistries

P-Order	Location	C	Mn	P	S	Cu	Si	Ni	Cr	Mo	Al
P3	Shell	0.28	1.25	0.02	0.02	0.19	0.26	0.56	0.06	0.47	<0.04
	Long. Weld*	0.12	1.20	0.018	0.019	0.183	0.32	0.70	0.06	0.49	<0.01

* The longitudinal weld shop sheet called for nickel addition and the weld filler material to match the base material.

Weld Conclusions

- Yankee samples of weld on head and BR3 samples on beltline show the B&W shop fabrication practices resulted in weld composition which match requirements.
- This evidence supports Yankee's contention that the beltline welds are 0.2% Cu and 0.7% Ni.
- The fact that BR3 was built at the same time and in the same shop also supports the conclusions.

Mean vs. Bounding Data

- PTS evaluations use mean values with standard deviations for input parameters.
- R.G. 1.154 assumes a 210F mean with a margin of 60F to set the 270F screening criteria.
- H.B. Robinson also used a mean of 211F with a margin 59F to perform a hypothetical evaluation of their vessel with a weld at the screening criteria.
- Fluence, copper content, nickel content, reference temperature, initial reference temperature, Kic and Kia are input parameters that use the mean plus standard deviations.
- Yankee used a mean line through surveillance data to determine mean reference temperature an added a three sigma distribution of 84F to it for the PTS evaluation.

Mean vs. Bounding Data

- Upper bounding surveillance data and adding a three sigma distribution is inconsistent with using R.G. 1.99 which determines a mean and then adding a three sigma distribution to it for the PTS evaluation.

- Odette's use of a compilation of weld and plate data irradiated at 500F, upper bounding it and calling it a mean temperature for weld, and then adding a three sigma distribution is also inconsistent with the intent of the PTS evaluation.

Len Steele Peer Review

- Tests conducted at NRL during L. Steele's residence, at irradiation temperatures similar to Yankee's, confirm microstructure effect.
- The microstructure effect is the reason Yankee does not conform to Reg. Guide 1.99 shift predictions for plate.
- The trend curve using BR3 and Yankee data is an acceptable surveillance trend curve.
- The dosimetry analysis presented by Yankee for correcting the NRL fluence on Yankee surveillance data is justified.
- Temperature and composition factors such as copper and nickel content are secondary to microstructural effects on reference temperature shifts.

G. R. Odette Shift Estimates

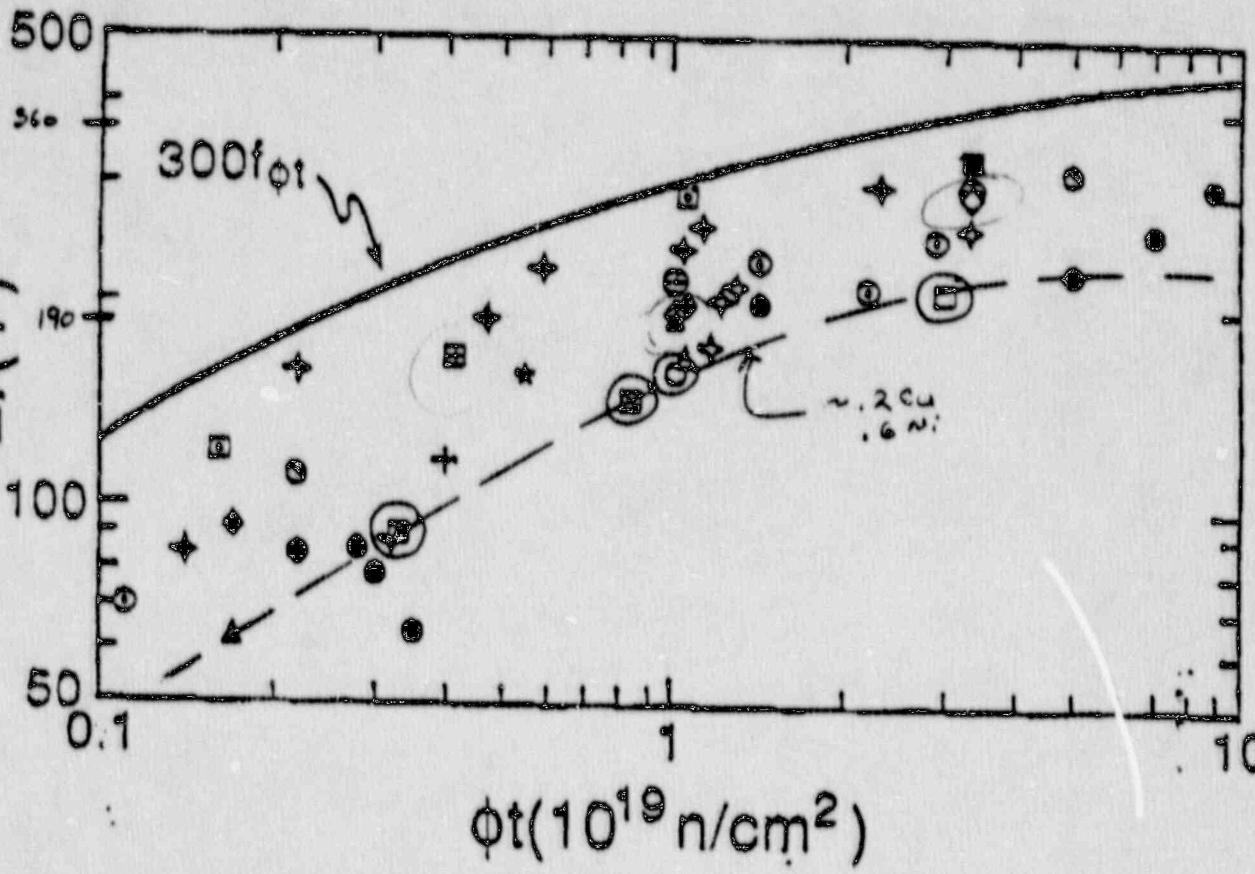
- Assumptions have been made to assess the temperature and nickel effects on Yankee beltline materials. which ignore product forms (weld vs. plate) and chemistry variances.

- The bounding curve used to determine the shift for Yankee weld metal was set by data characterized as "a plate containing only 0.21% Cu and 0.17% Ni, presumably due to some undefined source of extra "sensitivity"." Our review of the reference used for the data shows that the data points were for weld not a plate and that the weld had been quenched and tempered. This weld is completely unrepresentative of Yankee's weld metal.

G. R. Odette Shift Estimates

- If the quenched and tempered weld data is removed, the bounding curve would decrease by about 50F. The remaining data also shows clearly that high copper and moderate nickel have larger shifts than low copper and moderate nickel which is the case for Yankee.

- Claims are made that the Yankee evaluation was reviewed but very little was written about any of Yankee's positions. Mention was made that Yankee had misinterpreted data from EPRI-NP-6114. Yankee presented data for temperature effects and provided positions by recognized authors on nickel effects but no assessment of the data or information was made.



Cu/Ni/P	Prod. Form	Ref.	Cu/Ni/P	Prod. Form	Ref.
0.19/0.55/0.011	B	9	0.17/0.12/0.016	W	7*
0.23/0.56/0.013	W	9	0.20/0.18/0.011	B	10
0.30/0.56/0.021	W	9	0.26/0.28/0.012	B	10
0.26/0.56/0.020	W	9	0.21/0.54/0.016	W	8
0.32/0.67/0.017	W	9	0.35/0.66/0.014	W	8
0.19/0.55/0.011	W	9	0.22/0.60/0.015	W	8
0.15/0.09/0.025	B	7*	0.42/0.60/0.018	W	8
0.19/0.07/0.017	B	7*	0.40/0.59/0.011	W	8
0.24/0.25/0.024	B	7*	0.18/0.18/0.011 (YR-Plate)	B	1
0.21/0.17/0.033	B	7*			

Figure 4 Shift data for 300 ± 10°F irradiations versus fluence and preliminary recommended trend curve.

GRO A 4-787

* Quenched and Tempered (Not like Yankee)

12

8

Peer Review Group
Irradiation Effects Experts

- Lendell E. Steele

  Technical Consultant. Retired; Head of Reactor Materials Branch at U.S. Naval Research Laboratory.

- Albert Fabry

  Physicist at SCK/CEN in Mol, Belgium Project Manager for BR3 Safety and Annealing Studies.

- Dr. Dieter Pachur

  Research physicist at the Nuclear Research Center in Julich, West Germany

STATEMENT OF PROFESSIONAL QUALIFICATIONS OF LENDELL E. STEELE

Education

B.S. Chemistry - George Washington University (1950)
M.A. Economics - American University (1959)

Honors

Award for Achievement in Engineering Sciences
Washington Academy (1962)
ASTM, Charles B. Dudley Medal (1972)
American Nuclear Society Special Award and Prize (1972)
ASM, elected Fellow (1974)
ASTM, Society Award of Merit, Fellow (1978)
Appointed Chairman, International Atomic Energy Agency (IAEA) Coordinated Research Program (1978)
President, Federation of Materials Societies (1984)
Appointed Chief Coordinator, IAEA Research Program on Reactor Vessels (1984)
Chairman of Board of Directors, ASTM (1985)

Registered Professional Engineer

California (1976)

Employment

Technical Consultant (1986-Present)

As a technical consultant, Mr. Steele has been retained by a number of companies and associations primarily for the purpose of evaluating issues related to the environmental degradation of materials in components for power systems and measures for assuring the structural integrity of these systems.

U.S. Naval Research Laboratory (1979-1986)

Executive Management (U.S. Federal Senior Executive Service, ES-4) - Associate Superintendent of the Materials Science and Technology Division and Head, Thermostructural Materials Branch. In this capacity, Mr. Steele was responsible for managing basic and applied research on advanced structural materials for the Navy Power and Propulsion Systems with special emphasis on combined environmental effects, especially high temperatures, severe stresses, and nuclear radiation at various exposure levels.

U.S. Naval Research Laboratory (1964-1979)

Head, Reactor Materials Branch; Head, Thermostructural Materials Branch. In this capacity, Mr. Steele developed a research team which developed solutions to the phenomenon of neutron irradiation embrittlement of steels and demonstrated industrial technology for producing materials resistant to radiation damage. Related criteria for assuring structural integrity of major nuclear power plant components were developed as well. His responsibility also encompassed similar research on a variety of high temperature materials for power and propulsion applications.

Research Scientist (1950-1964)

Committee Participation

American Society of Testing and Materials
- Chairman Committee E10 on Nuclear Technology (1970-1976)
- Board of Directors, (1980-1982)
- Vice Chairman of Board (1983-1984)
- Chairman of Board (1985)

Federation of Materials Societies
- Member, Board of Trustees (1983-1985)
- President (1984)

International Atomic Energy Agency
- U.S. Representative to Working Group on Reliability of Reactor Pressure Components (1970-1986)
- Coordinator-Research Program on Neutron Irradiation and Embrittlement (1975-Present)

Major Publications-Books (Author and Editor-Author)

"Analysis of Reactor Vessel Radiation Effects Surveillance Programs," ASTM, 1970.

"Neutron Irradiation Embrittlement of Reactor Pressure Vessel Steels," IAEA, 1975.

"Assuring Structural Integrity of Steel Reactor Pressure Vessels," Applied Science, 1980.

"Structural Integrity of Light Water Reactor Components," Applied Science Publishers, 1982.

"Status of USA Nuclear Reactor Pressure Vessel Surveillance for Radiation Effects," ASTM, 1983.

"Light Water Reactor Structural Integrity," Elsevier Applied Science Publishers, 1984.

"Assuring Structural Integrity of Steel Reactor Pressure Boundary Components," Elsevier Applied Science Publishers, 1988.

"Radiation Embrittlement of Nuclear Reactor Pressure Vessels: An International Review," Vol. 3, ASTM, 1989. (Two prior volumes as well.)

Mr. Albert Fabry

Project Manager for BR3 Safety and Annealing Studies.

Analyst: Irradiation Effects on Reactor Vessel Steels

Background is Physics

SCK/CEN
Centre D'Etude De L'Energie Nucleaire
Mol, Belgium

Publications

Mr. Fabry authored numerous technical studies regarding the BR3 annealing program. These studies were published by SCK/CEN as program progress reports. The culmination of the [redacted] work is:

"Influence Of Neutron Irradiation On The Notch Ductility OF LWR Welds," NUREG/CR/4940. This NUREG is still under review as it a joint venture with:

D. Pachur - KFA Julich
F. Stallman - ORNL
F. Kam - ORNL

Dr. Dieter Pachur (phonetic: Pa-Koor)

Reaseearch physicist

Nuclear Research Center
(Kernforschungsanlage Julich)
Julich, West Germany

Sample of Publications

"Apparent Embrittlement Saturation and Radiation Mechanisms of Reactor Pressure Vessel Steels," ASTM STP 725, 1981, pp 5-19.

"Radiation And Annealing Mechanisms Of Low Alloyed Reactor Pressure Vessel Steel," 2nd International Symposium on Degradation of Materials in Nuclear Power Systems, ANS, 1985, pp.502-513, funded by DOE Contract No. DE-AC07-76ID01570.

"Radiation Annealing Mechanisms Of Low-Alloy Reactor Pressure Vessel Steels Dependent On Irradiation Temperature And Neutron Fluence," Nuclear Technology, Vol. 59, Dec. 1982, ANS.

"Neutron-Irradiated Reactor Pressure Vessel Steels Investigated By Positron Annihilation" (with others), Journal of Nuclear Materials, Vol. 161, 1989.

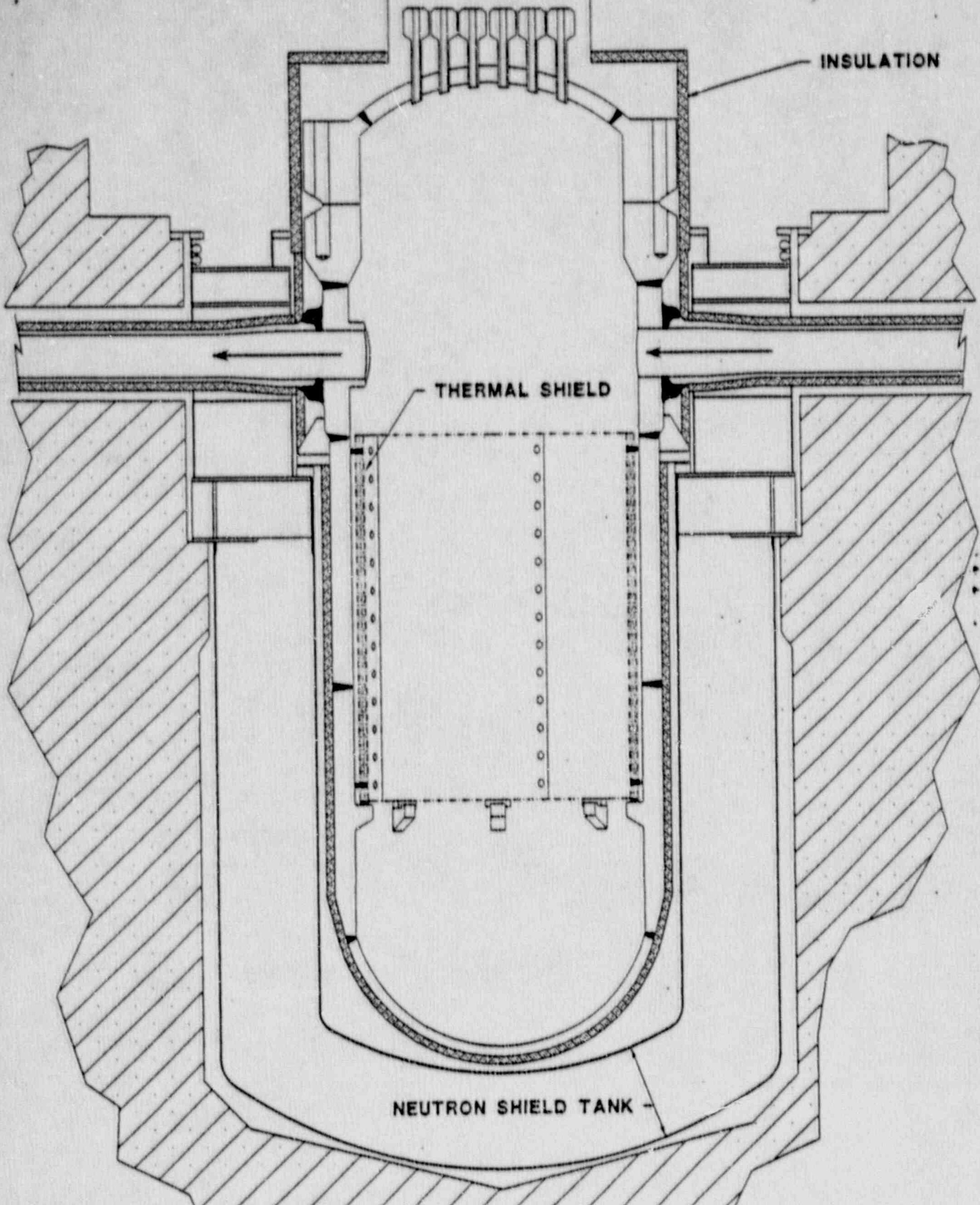
"Influence Of Radiation Damage Mechanisms On The Load Signal And On The Transition Curve Of Instrumented Impact Testing," Journal of Nuclear Materials, Vol. 160, 1988.

Future Programs

- Weld Composition
- Weld and Plate Characterizations
- Schedule
- Inspection

Weld Composition

- The weld composition has been estimated based upon sampling Yankee's head and BR3's longitudinal weld.
- To provide conclusive evidence of the beltline weld composition, Yankee proposes to sample two longitudinal welds in the nozzle region of the reactor vessel. Access to the welds is available by cutting through the upper portion of the neutron shield tank.
- Mockups of the reactor configuration in the nozzle region are now being made.
- The nozzle region has three plates welded together with three longitudinal welds. All plates are A 302-B or A 302-B Modified.



YANKEE VESSEL SUPPORT

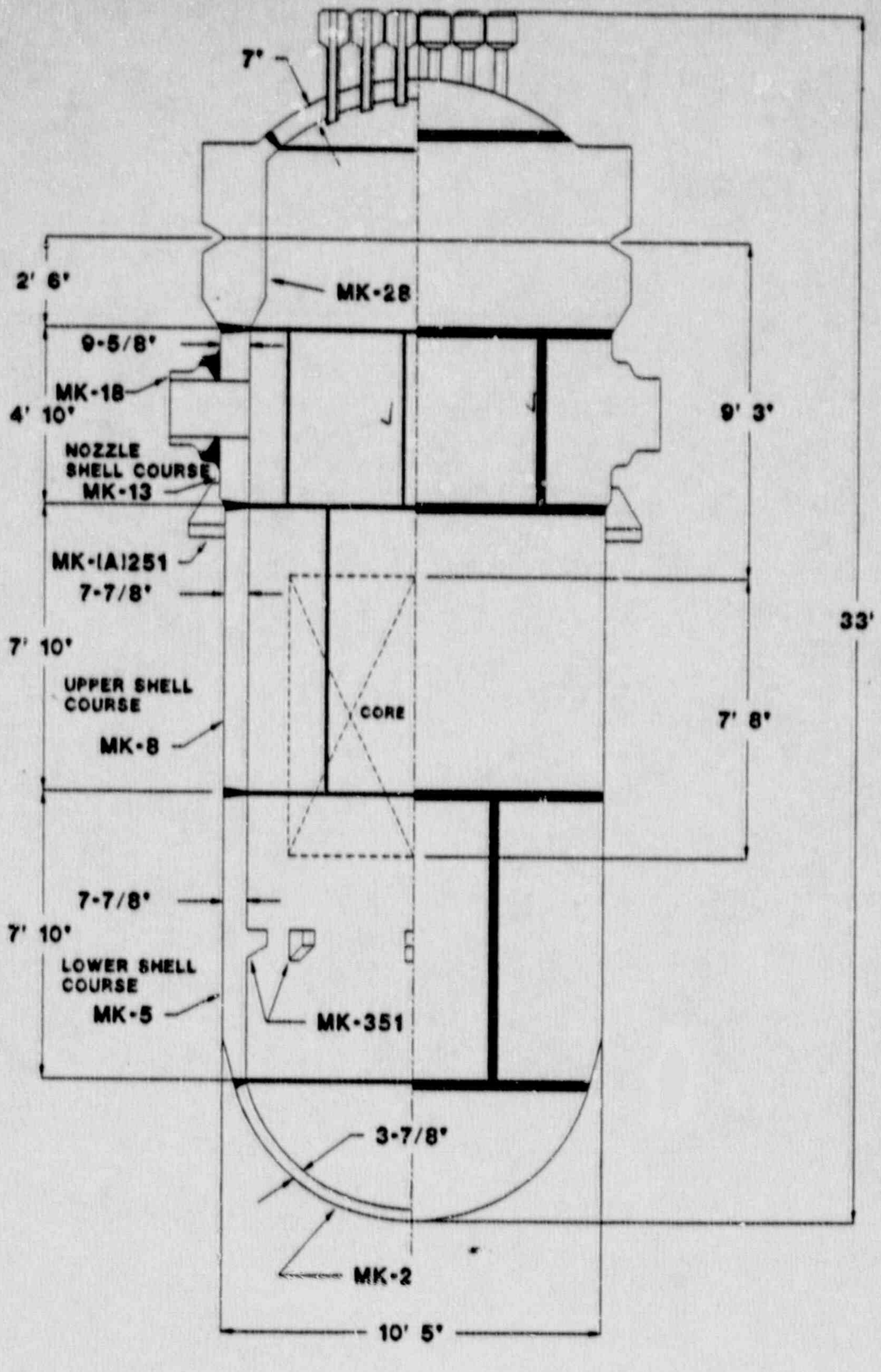
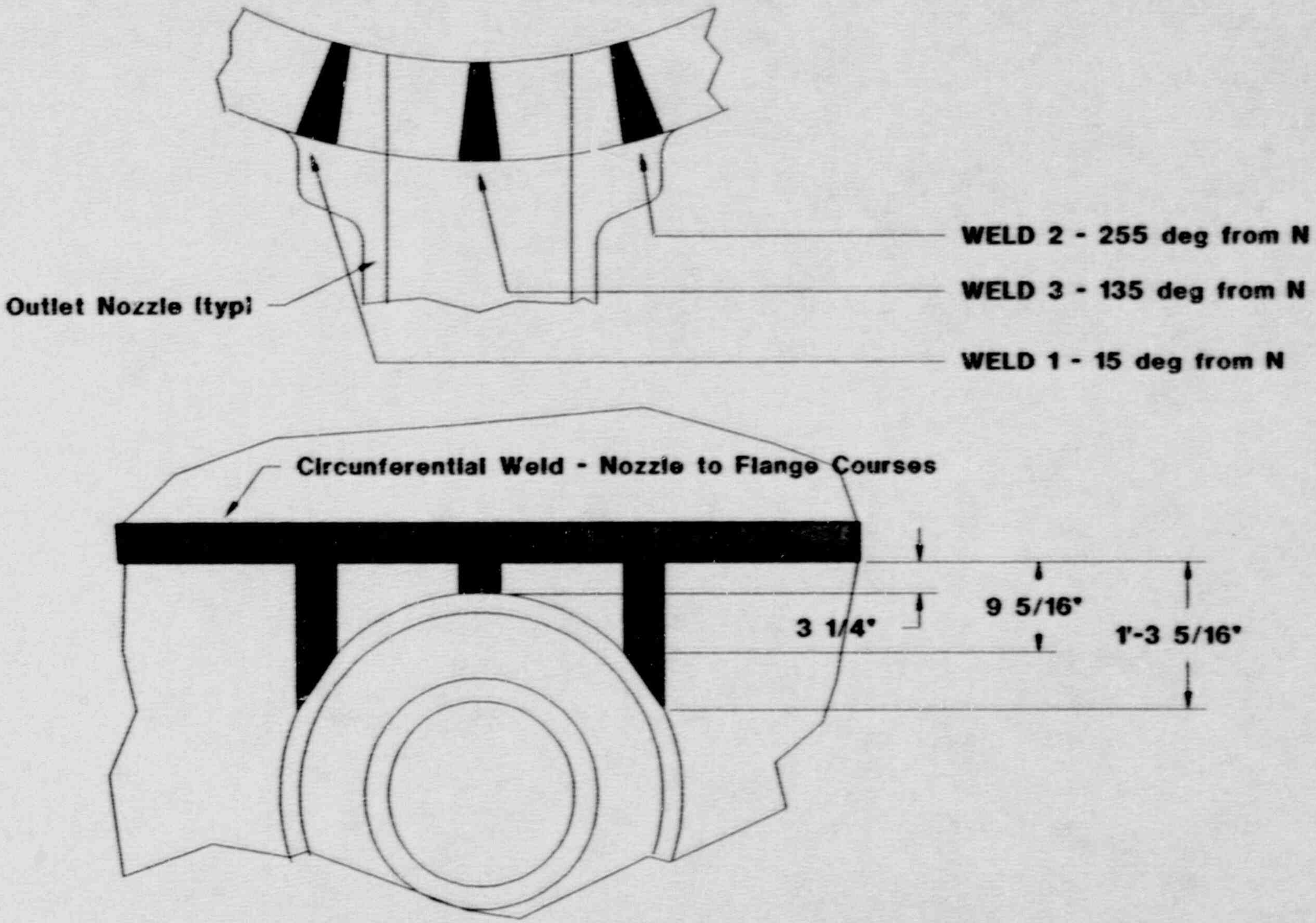


FIGURE 1-2

Weld & Plate Locations



DEVELOPED WELD LENGTHS

Weld Composition Continued

- Two of the plates have copper and nickel contents similar to the beltline lower plate and one of the plates has a copper and nickel content similar to the beltline upper plate.
- The weld specification and shop sheets are identical for the nozzle longitudinal welds and beltline welds including the addition of nickel to the flux.
- Both welds require that the filler metal match the plate material.
- Therefore, the longitudinal welds of the nozzle course should be identical to the beltline materials.

Nozzle Region Plate Chemistries

P-Order	Location	C	Mn	P	S	Cu	Si	Ni	Cr	Mo	Al
P3	Nozzle Course	0.20	1.25	0.019	0.024	0.19	0.23	0.18		0.47	
P3	Nozzle Course	0.21	1.25	0.017	0.025	0.20	0.24	0.60	0.10	0.47	

The nozzle region longitudinal welds called for the addition of nickel to the flux and the weld filler metal to match the base metal.

Beltline Region Plate Chemistries

P-Order	Location	C	Mn	P	S	Cu	Si	Ni	Cr	Mo	Al
P3	Upper Shell	0.20	1.27	0.02	0.028	0.18	0.21	0.21	0.06	0.48	
P3	Lower Shell	0.19	1.18	0.016	0.026	0.20	0.20	0.63	0.13	0.48	

The circumferential and longitudinal welds of the beltline plates called for the addition of nickel to the flux and the weld filler material to match the base material.

Weld Characterization

- A verification will be made to assure that the Yankee welds are within the family of the B&WOG Linde 80 welds. Samples of Yankee, BR3, or other applicable welds will be compared with the B&WOG Linde 80 welds.

- The temperature correlation for the weld at 500F will then be determined from the BR3 research and B&WOG data, or if not conclusive then weld metal may have to be irradiated in a test reactor.

Plate Characterization

- We are working with NRC, B&W, CE, Bettis Labs, and Naval Reactors to locate plate materials. Three heats of A 302-B and A 302-B modified will be obtained and will be heat treated to obtain similar characterization as Yankee beltline plates.

- Specimens from the plate will be irradiated at representative temperatures to present and future fluences. Irradiated compact tension, Charpy, and tensile specimens will be tested.

- A long term program for license renewal will be developed using the weld and plate material from the previous programs and placing them into a power reactor.

Schedule

- The longitudinal weld samples will be taken in early September if the NRC agrees that they would be representative of the beltline welds.
- A complete program for short and long term activities will be developed and submitted for NRC review and approval. NRC approval would be expected by the end of the year. The collection of weld and plate material would proceed in parallel.
- If the Yankee weld fits the Linde 80 data set and there is available data for a temperature correlation, this phase of the work would be completed in 1991.

Inspection

Three issues need to addressed for inspection.

1. Access to the vessel interior with the major pieces of inspection equipment. A new crane or new lower internals support stand must be designed and available for use at the 1993 refueling. The crane or stand will be designed and available for use during the 1993 outage.

2. Access to the annular space between the thermal shield and reactor vessel. Robotics equipment for the annular space will be adapted and a vendor or vendors will be selected to develop the equipment. The vendor will develop and qualify the equipment by the 1993 outage.

Inspection Continued

3. Inspection of weld and base material in the beltline region. The weld is a conventional weld deposited configuration which can be inspected with known equipment. Inspection underneath the spot welded cladding will use eddy current and advanced UT techniques. The techniques are expected to meet ASME criteria for flaw identification.

- Progress to Date

  1. We have inspected the Pressurizer with our newly developed eddy current method and are able to distinquish between cracks in the cladding and base metal. The Pressurizer showed no cracks in the base metal.

  2. SWRI is developing calibration blocks in order to qualify the technique to ASME requirements.

Summary

- Sufficient data and supporting research exists that supports our analysis.
- An extensive peer review process is underway.
- More data is being gathered to support our conclusions.

SUMMARY MEETING YANKEE ROWE

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