This letter forwards proprietary information in accordance with 10 CFR 2.390. The balance of this letter may be considered non-proprietary upon removal of Enclosure 6.

P.O. Box 63
Lycoming, New York 13093
315.349.5206
315.349.1321 Fax

CENG[SM]
a joint venture of Constellation Energy · eDF

NINE MILE POINT
NUCLEAR STATION

December 30, 2011

U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

ATTENTION: Document Control Desk

SUBJECT: Nine Mile Point Nuclear Station
Unit No. 2, Docket No. 50-410

License Amendment Request Pursuant to 10 CFR 50.90: Use of Modified Alloy 718 Material in Jet Pump Holddown Beams

Pursuant to 10 CFR 50.90, Nine Mile Point Nuclear Station, LLC (NMPNS) hereby requests an amendment to the Nine Mile Point Unit 2 (NMP2) Renewed Facility Operating License NPF-69. NMPNS is requesting NRC approval to use Modified Alloy 718 material for fabrication of the NMP2 reactor recirculation system jet pump holddown beams. The existing holddown beam material is Alloy X-750. The Modified Alloy 718 material has been included in American Society of Mechanical Engineers (ASME) Code Case N-60-6, "Material for Core Support Structures, Section III, Division 1;" however, this Code Case revision has not yet been approved for use by the NRC in Regulatory Guide 1.84, "Design, Fabrication, and Material Code Case Acceptability, ASME Section III."

NRC approval of this proposed change to the NMP2 current licensing basis would be reflected in a revision to Section 4.5 of the NMP2 Updated Safety Analysis Report (USAR), which provides a description of the materials used in the reactor internals, including the jet pump assemblies. The Technical Specifications are not affected by this amendment request.

Enclosure 1 provides a description and technical bases for the proposed amendment, and existing USAR pages marked up to show the proposed changes. NMPNS has concluded that the activities associated with the proposed amendment represent no significant hazards consideration under the standards set forth

This letter forwards proprietary information in accordance with 10 CFR 2.390. The balance of this letter may be considered non-proprietary upon removal of Enclosure 6.

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NRR

in 10 CFR 50.92. A related regulatory commitment regarding Modified Alloy 718 jet pump holddown beam inspection intervals is described in Enclosure 2.

Enclosure 3 provides Toshiba Corporation Record 10-1516, "Code Case Revision," which contains information supporting the requested addition of Modified Alloy 718 material to Code Case N-60-5.

Enclosure 6 (proprietary) provides Toshiba Corporation document SMV-2011-000034-P, Revision 0, "Toshiba Engineering Report, Jet Pump Beam Fabrication – Comparison of Modified Alloy 718 and Alloy X-750 Materials." This document is used to support the evaluation of the proposed change included in Enclosure 1. Enclosure 6 is considered by Toshiba to contain proprietary information exempt from disclosure pursuant to 10 CFR 2.390. Therefore, on behalf of Toshiba, NMPNS hereby makes application to withhold this attachment from public disclosure in accordance with 10 CFR 2.390(b)(1). The affidavit from Toshiba detailing the reasons for the request to withhold the proprietary information is provided in Enclosure 5. Enclosure 4 provides a non-proprietary version of the same document.

Approval of the proposed license amendment is requested by April 1, 2012, with implementation within 30 days of receipt of the approved amendment. Approval by the requested date is desired to support jet pump modifications scheduled for implementation during the upcoming NMP2 refueling outage, which is currently scheduled to begin in April 2012.

Pursuant to 10 CFR 50.91(b)(1), NMPNS has provided a copy of this license amendment request, with non-proprietary Enclosures, to the appropriate state representative.

Should you have any questions regarding the information in this submittal, please contact John J. Dosa, Director Licensing, at (315) 349-5219.

Very truly yours,

Frank R. Payne
Manager Operations

STATE OF NEW YORK :
: **TO WIT:**
COUNTY OF OSWEGO :

I, Frank R. Payne, being duly sworn, state that I am Manager Operations, and that I am duly authorized to execute and file this license amendment request on behalf of Nine Mile Point Nuclear Station, LLC. To the best of my knowledge and belief, the statements contained in this document are true and correct. To the extent that these statements are not based on my personal knowledge, they are based upon information provided by other Nine Mile Point employees and/or consultants. Such information has been reviewed in accordance with company practice and I believe it to be reliable.

Subscribed and sworn before me, a Notary Public in and for the State of New York and County of Oswego, this 30 day of December, 2011.

WITNESS my Hand and Notarial Seal:

Notary Public

My Commission Expires:

9/12/2013
Date

Lisa M. Doran
Notary Public in the State of New York
Oswego County Reg. No. 01DO6029220
My Commission Expires 9/12/2013

FRP/DEV

Enclosures:

1. Evaluation of the Proposed Change

2. List of Regulatory Commitments

3. Toshiba Corporation Record 10-1516, Code Case Revision

4. SMV-2011-000034-NP, Revision 0, Toshiba Engineering Report, Jet Pump Beam Fabrication – Comparison of Modified Alloy 718 and Alloy X-750 Materials (Non-Proprietary)

5. Affidavit from Toshiba Corporation Justifying Withholding Proprietary Information

6. SMV-2011-000034-P, Revision 0, Toshiba Engineering Report, Jet Pump Beam Fabrication – Comparison of Modified Alloy 718 and Alloy X-750 Materials (Proprietary)

cc: Regional Administrator, Region I, NRC
Project Manager, NRC
Resident Inspector, NRC
A. L. Peterson, NYSERDA (w/o Enclosure 6)

ENCLOSURE 1

EVALUATION OF THE PROPOSED CHANGE

TABLE OF CONTENTS

1.0 SUMMARY DESCRIPTION

2.0 DETAILED DESCRIPTION

2.1 Description of the Proposed Change
2.2 Background

3.0 TECHNICAL EVALUATION

4.0 REGULATORY EVALUATION

4.1 Applicable Regulatory Requirements/Criteria
4.2 Significant Hazards Consideration
4.3 Conclusions

5.0 ENVIRONMENTAL CONSIDERATION

6.0 REFERENCES

ATTACHMENT

1. Proposed Changes to the Nine Mile Point Unit 2 Updated Safety Analysis Report (USAR) (Mark-up)

1.0 SUMMARY DESCRIPTION

This evaluation supports a request to amend Renewed Facility Operating License NPF-69 for Nine Mile Point Unit 2 (NMP2).

Nine Mile Point Nuclear Station, LLC (NMPNS) is requesting NRC approval to use Modified Alloy 718 material for fabrication of the NMP2 reactor recirculation system jet pump holddown beams. The existing holddown beam material is Alloy X-750. The Modified Alloy 718 material is the same material described by Specification SB-637 and identified as Grade 718 Type 2 in American Society of Mechanical Engineers (ASME) Code Case N-60-6. It has the same chemical composition as conventional Grade 718 (Type 1) material, but the heat treatment condition differs (the reason for using the term "Modified"). For simplicity, the term "Modified Alloy 718" will be used hereafter to identify this material.

The jet pump assemblies are reactor vessel internals but are not core support structures. As noted in Section 4.5.2 of the NMP2 Updated Safety Analysis Report (USAR), such reactor internals are not ASME code components but are fabricated from American Society for Testing and Materials (ASTM) or ASME specification materials. This is consistent with the acceptance criteria in NUREG-0800, Standard Review Plan (SRP), Section 4.5.2, which states that for core support structures and reactor internals, the permitted material specifications are those given in the ASME Code Section III, Division 1, with properties of these materials specified in the ASME Code Section II. In addition, the SRP states that additional permitted materials are identified in ASME Code Cases approved for use by an NRC regulatory guide. The Modified Alloy 718 material has been included in ASME Code Case N-60-6, "Material for Core Support Structures, Section III, Division 1" (see Attachment 2 to Enclosures 4 and 6). This Code Case revision was approved by ASME on December 6, 2011; however, it has not yet been approved for use by the NRC in a regulatory guide (i.e., Regulatory Guide 1.84). Thus, this license amendment request seeks NRC approval to consider Modified Alloy 718 a permitted reactor internals material for the NMP2 jet pump holddown beams.

2.0 DETAILED DESCRIPTION

2.1 Description of the Proposed Change

The proposed change to the NMP2 licensing basis would revise USAR Section 4.5 as shown in Attachment 1. The USAR revision would identify Modified Alloy 718 as the material used to fabricate the jet pump holddown beams. The jet pump inlet mixer pin and insert are made of Alloy X-750 and are not being changed to the Modified Alloy 718 material. Following NRC approval of the license amendment request, the NMP2 USAR will be updated to incorporate the changes identified in Attachment 1 in accordance with 10 CFR 50.71(e).

2.2 Background

The NMP2 reactor recirculation system includes 20 jet pump assemblies that are located within the reactor pressure vessel (RPV), in the downcomer annulus between the core shroud and the RPV wall. During normal operation, the jet pumps direct reactor coolant flow to the core. Following a loss of coolant accident, the jet pumps function to maintain the ability to reflood the reactor to two-thirds core height. The jet pump nozzle entry section is connected to the inlet riser by a metal-to-metal, spherical-to-conical seal joint. Firm contact is maintained by a holddown beam (clamp). The holddown beams are currently fabricated from Alloy X-750 material.

NMP2 is planning to replace all 20 of the jet pump inlet mixers in the upcoming Spring 2012 refueling outage. As part of that modification, replacement holddown beams are being provided that are fabricated from Modified Alloy 718 material. NMPNS evaluation of the Modified Alloy 718 material concluded that it has similar or improved material properties and improved resistance to stress corrosion cracking (SCC) initiation and propagation as compared to the existing Alloy X-750 material. Further discussion is provided in the following Technical Evaluation section.

3.0 TECHNICAL EVALUATION

The jet pump holddown beams apply a downward clamping force on each inlet subassembly to resist the elbow and nozzle hydraulic reaction forces. To accommodate the clamping loads generated by holding the inlet-throat subassembly in place, the current holddown beams are fabricated from high strength Alloy X-750 material. As an alternative to the Alloy X-750 material, NMPNS is proposing to use Modified Alloy 718 material, which has been developed based on conventional Alloy 718 material. The Modified Alloy 718 material has similar or improved material properties and improved resistance to SCC initiation and propagation as compared to Alloy X-750 material.

Information that supported the addition of Modified Alloy 718 material to Code Case N-60-5 is provided in Enclosure 3. This information includes data on yield strength, tensile strength, stress intensity, fatigue, and other material properties. The data and evaluations documented in Enclosure 3 demonstrate that Modified Alloy 718 material is comparable to Alloy X-750 material (or SB-637 Grade 688 Type 3; now referred to as UNS N07750).

Enclosure 6 provides additional details of the Modified Alloy 718 material, including descriptions of the modified heat treatment process and SCC resistance. Attachment 1 of Enclosure 6 also includes an evaluation of conformance with BWRVIP-84, Revision 1 (Reference 1).

The information provided in Enclosures 3, 4, and 6 indicates that the Modified Alloy 718 material has the following attributes as compared to Alloy X-750:

- Higher resistance to SCC initiation
- Higher resistance to low temperature SCC (BWRVIP-84)
- Higher resistance to SCC crack growth (BWRVIP-138, Revision 1 (Reference 2))
- Similar strength and hardness
- Higher ductility
- Superior fatigue and spring properties
- Similar irradiation relaxation rate

Based on the above comparison, the proposed change of jet pump holddown beam material from Alloy X-750 to Modified Alloy 718 will not affect the design function of the holddown beams and will improve the beams' resistance to SCC.

Inspection intervals for the Modified Alloy 718 holddown beam are not currently addressed in BWRVIP-138. NMPNS will be performing evaluations to establish inspection intervals for the Modified Alloy 718 holddown beam and expects that inspection intervals similar to those for Group 3 beams in BWRVIP-138 can be demonstrated. In accordance with BWRVIP guidelines, NMPNS will submit to the NRC an evaluation to support establishment of inspection intervals for the new holddown beams in accordance with criteria contained in the latest revision of BWRVIP-41, "BWR Vessel and Internals Project, BWR Jet Pump Assembly Inspection and Flaw Evaluation Guidelines." Basing the inspection intervals on the latest BWRVIP-41 criteria is consistent with USAR Section 3.9B.5.1.2 and USAR Appendix C, Section C.1.12. This NMPNS evaluation will be submitted approximately one year prior to the next scheduled NMP2 refueling outage following installation of the Modified Alloy 718 jet pump holddown beams.

4.0 REGULATORY EVALUATION

4.1 Applicable Regulatory Requirements/Criteria

General Design Criterion (GDC) 1, "Quality standards and records," requires that structures, systems and components (SSC) important to safety be designed, fabricated, and tested to quality standards commensurate with the importance of the safety functions to be performed, and that, where generally recognized codes and standards are used, they be identified and evaluated to determine their applicability, adequacy, and sufficiency, and are supplemented or modified as necessary to assure a quality product in keeping with the required safety function.

10 CFR 50.55a, "Codes and standards," requires that SSCs be designed, fabricated, erected, constructed, tested, and inspected to quality standards commensurate with the importance of the safety function to be performed. This regulation identifies editions and addenda of the ASME Boiler and Pressure Vessel Code that have been approved for incorporation by reference, and also identifies regulatory guides that identify ASME Code Cases approved for use by the NRC.

The jet pump assemblies, including the holddown beams, are reactor vessel internals, but are not core support structures. They are not ASME code components, but are fabricated from ASTM or ASME specification materials. This is consistent with the acceptance criteria in SRP Section 4.5.2, which states that for core support structures and reactor internals, the permitted material specifications are those given in the ASME Code Section III, Division 1, with properties of these materials specified in the ASME Code Section II. In addition, the SRP states that additional permitted materials are identified in ASME Code Cases approved for use by an NRC regulatory guide. The Modified Alloy 718 material has been included in ASME Code Case N-60-6, "Material for Core Support Structures, Section III, Division 1." This Code Case revision was approved by ASME on December 6, 2011; however, it has not yet been approved for use by the NRC in a regulatory guide (i.e., Regulatory Guide 1.84). The evaluations provided in Section 3.0 above demonstrate that the Modified Alloy 718 material has similar or improved properties as compared to the existing Alloy X-750 material, thereby assuring a quality component in keeping with the required function of the jet pump assemblies.

4.2 Significant Hazards Consideration

Nine Mile Point Nuclear Station LLC (NMPNS) is requesting an amendment to Renewed Facility Operating License NPF-69 for Nine Mile Point Unit 2 (NMP2). The proposed amendment would revise the NMP2 licensing basis to allow for the use of a new material, Modified Alloy 718, for the reactor recirculation system jet pump holddown beam that is not currently described in the NMP2 Updated Safety Analysis Report (USAR).

NMPNS has evaluated whether or not a significant hazards consideration is involved with the proposed amendment by focusing on the three standards set forth in 10 CFR 50.92, "Issuance of Amendment," as discussed below:

1. Does the proposed amendment involve a significant increase in the probability or consequences of an accident previously evaluated?

   Response: No.

   The proposed change is limited to replacement of the existing jet pump holddown beam material with Modified Alloy 718 material. The jet pump assemblies are not considered an initiator of any previously evaluated accident. The jet pumps are passive devices that direct reactor coolant flow to the core during normal plant operation and function to maintain the ability to reflood the reactor to two-thirds core height following a loss of coolant accident (LOCA). The Modified Alloy 718 material has similar or improved material properties compared to the existing jet pump beam material (Alloy X-750). Thus, the jet pump holddown beams fabricated from the Modified Alloy 718 material are no more likely to fail than the existing jet pump beams, thereby assuring that the jet pump assemblies will continue to function to maintain the ability to reflood the reactor to two-thirds core height following a LOCA. In addition, the material change does not affect the design or operation of any accident mitigation system. Therefore, neither the types or amounts of radiation released nor the predicted radiological consequences of previously evaluated accidents will be affected.

   Based on the above discussion, it is concluded that the proposed amendment does not involve a significant increase in the probability or consequences of an accident previously evaluated.

2. Does the proposed amendment create the possibility of a new or different kind of accident from any accident previously evaluated?

   Response: No.

   The proposed change is limited to the replacement of the existing jet pump holddown beam material with Modified Alloy 718 material. The proposed change does not affect any material-related failure mechanisms or malfunctions that could be associated with the jet pump holddown beam and does not affect the design function of the beam to apply a downward clamping force on each inlet subassembly to resist the elbow and nozzle hydraulic reaction forces during normal operation.

   The material change does not affect the ability of the jet pump assemblies to function to maintain the ability to reflood the reactor to two-thirds core height following a LOCA, and does not affect the design function or operation of any plant system or component. The proposed material change also does not introduce any new or different plant operating modes, and does not change any setpoints that would alter the dynamic response of plant equipment. Therefore, the jet pump holddown beam material change does not introduce any new or different accident initiation mechanisms.

   Based on the above discussion, it is concluded that the proposed amendment does not create the possibility of a new or different kind of accident from any accident previously evaluated.

3. Does the proposed amendment involve a significant reduction in a margin of safety?

   Response: No.

   The proposed change is limited to replacement of the existing jet pump holddown beam material with Modified Alloy 718 material. The Modified Alloy 718 material has similar or improved material properties compared to the existing material such that the jet pump assembly design functions are not adversely affected. The proposed change does not alter any setpoints at which protective actions are initiated, and there are no changes to the design or operational requirements for systems or equipment assumed to operate for accident mitigation.

   Based on the above discussion, it is concluded that the proposed amendment does not involve a significant reduction in a margin of safety.

Based on the above, NMPNS concludes that the proposed amendment does not involve a significant hazards consideration under the standards set forth in 10 CFR 50.92(c), and, accordingly, a finding of "no significant hazards consideration" is justified.

4.3 Conclusions

In conclusion, based on the considerations discussed above, (1) there is reasonable assurance that the health and safety of the public will not be endangered by operation in the proposed manner, (2) such activities will be conducted in compliance with the Commission's regulations, and (3) the issuance of the amendment will not be inimical to the common defense and security or to the health and safety of the public.

5.0 ENVIRONMENTAL CONSIDERATION

A review has determined that the proposed amendment would change a requirement with respect to installation or use of a facility component located within the restricted area, as defined in 10 CFR 20. However, the proposed amendment does not involve: (i) a significant hazards consideration, (ii) a significant change in the types or significant increase in the amounts of any effluent that may be released offsite, or (iii) a significant increase in individual or cumulative occupational radiation exposure. Accordingly, the proposed amendment meets the eligibility criterion for categorical exclusion set forth in 10 CFR 51.22(c)(9). Therefore, pursuant to 10 CFR 51.22(b), no environmental impact statement or environmental assessment need be prepared in connection with the proposed amendment.

6.0 REFERENCES

1. BWRVIP-84, Revision 1, "BWR Vessel and Internals Project, Guidelines for Selection and Use of Materials for Repairs to BWR Internal Components," August 2011

2. BWRVIP-138, Revision 1, "BWR Vessel and Internals Project, Updated Jet Pump Beam Inspection and Flaw Evaluation Guidelines," December 2008

ATTACHMENT 1

PROPOSED CHANGES TO THE NINE MILE POINT UNIT 2

UPDATED SAFETY ANALYSIS REPORT (USAR)

(MARK-UP)

The current versions of Nine Mile Point Unit 2 USAR pages 4.5-6, 4.5-8, and 4.5-9 have been marked-up by hand to reflect the proposed changes. Page 4.5-5 is provided for information only and does not include a markup. Following NRC approval of the license amendment request, the USAR will be updated to incorporate these proposed changes in accordance with 10 CFR 50.71(e).

For Information - No changes to this page.

Control rod drive housing	ASME SA-312, Type 304 and ASME SA-182, Type 304
Control rod guide tube	ASTM A351 or ASME SA-351, Type CF8, ASME SA-358, SA-312, SA-249, and ASTM A312, A240, A276, A269, A358 (Type 304)
Orificed fuel support	ASME SA-351, Type CF8

Materials employed in other reactor internal structures include:

1. Steam Separator and Steam Dryer All materials are 300 series stainless steel:

Plate, sheet, and strip	ASTM A240, Type 304 or 316L
Forgings	ASTM A182, Grade F304
Bars	ASTM A276, Type 304 or 316L
Pipe	ASTM A312, Grade TP 304
Tube	ASTM A269, Grade TP 304
Bolting material	ASTM A193, Grade B8
Nuts	ASTM A194, Grade 8
Castings	ASTM A351, Grade CF8 (Type 304)

2. Jet Pump Assemblies The components in the jet pump assemblies are a riser, inlet mixer, diffuser, and riser brace. Materials used for these components are to the following specifications:

Castings	ASTM A351, Grade CF8 and ASME SA-351, Grade CF3 ASTM A194, Grade 8 or 8M
Bars	ASTM A276, Type 304 ASME SA-479, 316L ASTM A479, 304L
Bolts	ASTM A193, Grade B8 or B8M
Sheet and plate	ASTM A240, Type 304, and ASTM A240, Type 304L
Tubing	ASTM A269, Grade TP 304

Pipe	ASTM A358, Type 304, ASTM A312, Type 304, and ASME SA312, Grade TP 304
Welded fittings	ASTM A403, Grade WP304
Forging	ASME SA-182, Grade F304, ASTM B166, and ASTM A637, Grade 688

Materials in the jet pump assemblies that are not Type 304 stainless steel are listed below:

a. The inlet mixer adaptor casting, wedge casting, bracket casting, adjusting screw casting, and diffuser collar casting are Type 304 hard surfaced with Stellite 6 for slip fit joints.

b. The diffuser is a bimetallic component made by welding a Type 304 forged ring to a forged Inconel 600 ring, made to Specification ASTM B166.

Insert 1

c. The inlet-mixer contains a pin, and insert, ~~and beam~~ made of Inconel X-750 to Specification ASTM A637, Grade 688, or ASTM B637, Grade UNS N07750, Type 3.

3. Core Spray Spargers and Core Spray Lines Materials used for these components are:

ASME SA-312 Type 304L for core spray spargers.

ASME SA-376 Type 316L for core spray lines.

All core support structures are fabricated from ASME- and ASTM-specified materials and designed using ASME Section III as a guide. The other reactor internals are noncoded and are fabricated from ASTM or ASME specification materials. Material requirements in the ASTM specifications are identical to requirements in corresponding ASME material specifications.

4.5.2.2 Controls on Welding

Requirements of ASME Boiler and Pressure Vessel Code, Section IX, are followed in fabrication of core support structures and other internals.

4.5.2.3 Nondestructive Examination of Wrought Seamless Tubular Products

Wrought seamless tubular products for CRD guide tubes, CRD housings, and peripheral fuel supports were supplied in

The degree of cleanliness obtained by these procedures is assessed to meet the requirements of RG 1.37.

Regulatory Guide 1.44 All wrought austenitic stainless steel was purchased in the solution heat-treated condition. Heating above 800°F was prohibited (except for welding) unless the stainless steel was subsequently solution annealed. For Type 304 steel with carbon content in excess of 0.035 percent carbon, purchase specifications restricted the maximum weld heat input to 110,000 joules/in, and the weld interpass temperature to 350°F maximum. Welding was performed in accordance with Section IX of the ASME Boiler and Pressure Vessel Code. These controls were employed to avoid severe sensitization and are assessed to meet the intent of RG 1.44.

Regulatory Guide 1.71 There are few restrictive welds involved in the fabrication of items described in this section. Mockup welding was performed on the welds with most difficult access. Mockups were examined with radiography or by sectioning.

4.5.2.5 Other Materials

Hardenable martensitic stainless steels and precipitation-hardening stainless steels are not used in the reactor internals.

Materials, other than Type 300 stainless steel, employed in vessel internals are:

SB-166, SB-167, and SB-168 nickel-chrome-iron (Inconel 600).

SA-637, Grade 688 (Inconel X-750). SB-637, Modified Alloy 718

Inconel 600 tubing plate and sheet are used in the annealed condition. Bar may be in the annealed or cold-drawn condition. Inconel X-750 components are fabricated in the annealed or equalized condition and aged 20 hr at 1,300°F. Insert 2

Stellite 6 hard surfacing is applied to austenitic stainless steel castings using the gas tungsten arc welding or plasma arc surfacing processes.

~~All materials have been successfully used for the past 10 to 15 yr in BWR applications.~~

4.5.3 Control Rod Drive Housing Supports

All CRD housing support subassemblies are fabricated of ASTM A-36 structural steel, except for the following items:

INSERT 1 (for NMP2 USAR Section 4.5.2.1; page 4.5-6)

d. The jet pump beam is fabricated from Modified Alloy 718 material, specified as Grade 718 Type 2 in ASME Code Case N-60-6. Use of this material for the jet pump beams was approved in License Amendment No. XXX (Reference 1).

INSERT 2 (for NMP2 USAR Section 4.5.2.5; page 4.5-8)

Modified Alloy 718 components are solution annealed and precipitation hardened for 6 hr at 1,300°F.

Item	Material
Grid	ASTM A-441
Disc springs	Schnorr, Type BS-125-71-8
Hex bolts and nuts	ASTM A-307
6 x 4 x 3/8 tubes	ASTM A-500, Grade B

For further CRD housing support information, refer to Section 4.6.1.2.

4.5.4 References

1. [Add reference to the NRC letter approving use of the Modified Alloy 718 material.]

Add

ENCLOSURE 2

LIST OF REGULATORY COMMITMENTS

The following table identifies the regulatory commitments in this document. Any other statements in this submittal represent intended or planned actions. They are provided for information purposes and are not considered to be regulatory commitments.

REGULATORY COMMITMENT	DUE DATE
In accordance with BWRVIP guidelines, NMPNS will submit to the NRC an evaluation to support establishment of inspection intervals for the new holddown beams in accordance with criteria contained in the latest revision of BWRVIP-41, "BWR Vessel and Internals Project, BWR Jet Pump Assembly Inspection and Flaw Evaluation Guidelines." This NMPNS evaluation will be submitted approximately one year prior to the next scheduled NMP2 refueling outage following installation of the Modified Alloy 718 jet pump holddown beams.	March 1, 2013

ENCLOSURE 3

TOSHIBA CORPORATION RECORD 10-1516

CODE CASE REVISION

PSN-2011-0561
PM-2010-0348 Rev.2
May, 2011 (Rev. 070911)
Toshiba Corporation

Subject: Code Case Revision

Scope: Code Case N-60-5, Material for Core Support Structures, Section III, Division 1

Request: Add Modified Alloy 718 material to Code Case N-60-5, Material for Core Support Structures, Section III, Division 1. The values shown in the markups, of Tables A, B and C from the Code Case, below shall be included in Code Case N-60-5. The nomenclatures for these tables correspond to the Tables in Code Case N-60-5.

Background 1: The materials utilized for light water reactors core support structures constructed to the requirements of Subsection NG of Section III, Division 1 are those listed in Tables 2A and 2B, Section II, Part D, Subpart 1. Code Case N-60-5 lists additional materials that can be utilized for core support structures constructed to the requirements of Subsection NG of Section III, Division 1.

Currently material SB-637 modified alloy 718 is not listed in Section II, Part D, Subpart 1 or Code Case N-60-5. However, a material with similar yield and tensile strength properties, SB-637 Grade 688 (now referred to as UNS N07750) Type 3 is listed in Code Case N-60-5. Modified alloy 718 has high strength satisfied with the requirements of the strength value comparable to SB-637 Grade 688 Type 3.

The following material properties for modified alloy 718 are required for inclusion into Code Case N-60-5.

- Yield Strength values (Sy) at temperature
- Tensile Strength values (Su) at temperature
- Stress Intensity values (Sm) at temperature

The first step was to calculate the Yield Strength values (Sy) and Tensile Strength values (Su) at temperature. Then the Stress Intensity values (Sm) at temperature were calculated in accordance with ASME Section II, Part D, Mandatory Appendix 2.

The calculations of material properties are documented in Attachment 1 of this request. The results of these calculations were compared to those of the SB-637 Grade 688 Type 3 material, with similar yield and tensile strength properties, and found to be very comparable, as shown in Figures 4, 5 and 6 in Attachment 1. In addition, three heats of tensile test data as a function of temperature were provided and analyzed with the BPV II TG Data Analysis software tool to calculate yield and tensile strength trend curves, in addition to the required Design Stress Intensity values for the Modified 718 Alloy (Pages 29 thru 35 of this document). Therefore, it is concluded that the Modified Alloy 718 material properties proposed herein are suitable for incorporation into Code Case N-60-5 for the construction of core support structures in accordance with Section III, Div. 1, Subsection NG, Class CS rules.

Background 2: In addition to above tensile data, the following material properties for modified alloy 718 are required in ASME Section II, Part D, Mandatory Appendix 5, Guideline on the Approval of New Materials under the ASME Boiler and Pressure Vessel Code.

- Fatigue data over the range of design temperatures
- Coefficient of thermal expansion over the range of temperatures for which the material is to be used
- Thermal conductivity and diffusivity over the range of temperatures for which the material is to be used
- Young's modulus over the range of temperatures for which the material is to be used
- Poisson's ratio over the range of temperatures for which the material is to be used
- Shear modulus over the range of temperatures for which the material is to be used

Fatigue data are document in Attachment 2 of this request. Fatigue data were compared to existed design fatigue curves for austenitic steels, nickel-chromium-iron alloy, nickel-iron-chromium alloy, and nickel-copper alloy in ASME Sec. III, Division 1, Mandatory Appendix I. Fatigue data of modified alloy 718 located above the ASME design fatigue curves, which were conservative for modified alloy 718, as shown in Figure A2-1 in Attachment 2. Therefore, it is concluded that modified alloy 718 can be applied the existed ASME design fatigue curves and is suitable for use in construction of core support structures.

Other properties of coefficient of thermal expansion, thermal conductivity and diffusivity, Young's modulus, Poisson's ratio, shear modulus and density are document in Attachment 3 of this request. The data of modified alloy 718 were compared to those of the conventional material SB-637 Grade 718 (now referred to as UNS N07718) and the equivalent material SB-637 Grade 688 (now referred to as UNS N07750) in ASME Sec. II, Part D, and found to be very comparable, as shown in Figures A3-1, A3-2, A3-3, A3-4 and Table A3-2 in Attachment 3. Therefore, it is concluded that the other properties proposed herein are suitable for use with modified alloy 718 used in construction of core support structures.

Table A																	
								Stress Intensity, Kips/sq in. (MPa) for Metal Temperature, °F (℃), Not to Exceed									
Nominal Composition	P No.	Prod. Form	Spec. No.	Type or Grade	Notes	Min. Yield Str.	Min. Unit. Tens. Str.	100 (38)	200 (93)	300 (149)	400 (204)	500 (260)	600 (316)	650 (343)	700 (371)	750 (399)	800 (427)
Ni-Cr-Fe	....	FFBS	SB-637	718 Type 2	16	100 (689)	160 (1103)	53.3 (368)	53.3 (368)	53.3 (368)	53.3 (368)	52.3 (361)	51.2 (353)	50.7 (349)	50.1 (345)	49.5 (341)	48.8 (336)

NOTES:(16) Chemical composition of Grade 718 Type 2 is same as that of conventional Grade 718 (Type 1). Heat treatment condition of Type 2 is modified for that of Type 1.

Table B															
Yield Strength Values Sy						Yield Strength, Kips/sq in. (MPa) for Metal Temperature, °F (℃), Not to Exceed									
Nominal Composition	Prod. Form	Spec. No.	Type or Grade	Notes	Spec. Min. Yield	100 (38)	200 (93)	300 (149)	400 (204)	500 (260)	600 (316)	650 (343)	700 (371)	750 (399)	800 (427)
Ni-Cr-Fe	FFBS	SB-637	718 Type 2	10	100.0 (689)	98.6 (680)	95.4 (658)	93.3 (643)	91.9 (633)	90.9 (627)	90.1 (621)	89.6 (618)	89.1 (614)	88.4 (609)	87.5 (603)

NOTES:(10) Chemical composition of Grade 718 Type 2 is same as that of conventional Grade 718 (Type 1). Heat treatment condition of Type 2 is modified for that of Type 1.

Table C														
MATERIALS PROPERTIES, SUBSECTION NG TENSILE STRENGTHS, Su														
Tensile Strength Values, Su, Kips/sq in. (MPa) for Austenitic Steel and High Nickel Alloys for Class 1 Components														
					Temperature, °F (℃)									
Nominal Composition	Prod. Form	Spec. No.	Type or Grade	Spec. Min. T.S.	100 (38)	200 (93)	300 (149)	400 (204)	500 (260)	600 (316)	650 (343)	700 (371)	750 (399)	800 (427)
Ni-Cr-Fe	FFBS	SB-637	718 Type 2	160.0 (1103)	160.0 (1103)	160.0 (1103)	160.0 (1103)	160.0 (1103)	157.0 (1082)	153.7 (1060)	152.0 (1048)	150.2 (1036)	148.4 (1023)	146.4 (1009)

NOTE: Chemical composition of Grade 718 Type 2 is same as that of conventional Grade 718 (Type 1). Heat treatment condition of Type 2 is modified for that of Type 1.

FFBS-Fittings, Forgings, Bars, Shapes

ATTACHMENT – 1

Calculations of Sy, Su, Sm values: The first step was to calculate the Yield Strength values (Sy) and Tensile Strength values (Su) at temperature based on the tensile test data provided from three heats of material. Chemical compositions of three heats of material (Heat ID A, B and C) used in tensile tests are shown in Table A1-1. The tensile test method employed was JIS (Japanese Industrial Standards) test method. Test temperatures were room temperature (20℃), 75℃, 100℃, 150℃, 200℃, 250℃, 275℃, 300℃, 325℃, 350℃, 400℃ and 425℃, and converted to Fahrenheit temperatures. Tensile tests were conducted three times for each heat and temperature. Tensile data of modified alloy 718 are listed in Table A1-2. Tensile test data of yield strength (σ y) and tensile strength (σ u) at temperature are shown in Figure A1-1. Average temperature dependent trend curves of yield strength (σ y) and tensile strength (σ u) were obtained based on the average value for three heats of material in each temperature as shown in Figure A1-2 . They were normalized by the yield strength (σ y) and tensile strength (σ u) in room temperature (20℃) respectively, and R_Y, R_T values at temperature were obtained as shown in Figure A1-3.

where

R_Y =ratio of the average temperature dependent trend curve value of yield strength to the room temperature yield strength

R_T =ratio of the average temperature dependent trend curve value of tensile strength to the room temperature tensile strength

Yield Strength values (Sy) shown at temperature in Table B are the least of the following:

(1) S_Y: Minimum yield strength at room temperature specified in ASME/ASTM SB-637/B637 for equivalent material Grade 688 Type 3 (100ksi)

(2) $R_Y \times S_Y$

Tensile Strength values (Su) shown at temperature in Table C are the least of the following:

(1) S_T: Minimum tensile strength at room temperature specified in ASME/ASTM SB-637/B637 for equivalent material Grade 688 Type 3 (160ksi)

(2) $R_T \times S_T \times 1.1$

Then the Stress Intensity values (Sm) shown at temperature in Table A were calculated in accordance with ASME Section II, Part D, Mandatory Appendix 2.

The results of these calculations were compared to those of the equivalent material SB-637 Grade 688 Type 3 as shown in Figures A1-4, A1-5 and A1-6. Yield strength (σ y, Sy) and tensile strength (σ u, Su) at temperature were summarized in Figure A1-7.

Table A1-1 Chemical compositions of three heats of material

Specification* / Heat ID	Chemical Composition (%)														
	C	Si	Mn	P	S	Ni	Cr	Co	Mo	Nb+Ta	Cu	Al	Ti	B	Fe
	max 0.08	*max* 0.35	*max* 0.35	*max* 0.015	*max* 0.015	50.0 −55.0	17.0 −21.0	*max* 1.0	2.80 −3.30	4.75 −5.50	*max* 0.30	0.20 −0.80	0.65 −1.15	*max* 0.006	Bal.
A	0.03	0.10	0.04	0.004	0.0003	52.41	18.59	0.03	3.07	5.12	0.01	0.52	0.95	0.0048	Bal
B	0.03	0.08	0.04	0.004	0.0002	52.49	18.65	0.02	3.08	5.07	0.01	0.55	0.94	0.0038	Bal
C	0.03	0.06	0.04	0.003	0.0001	52.34	18.69	0.03	3.09	5.11	0.02	0.54	0.96	0.0042	Bal

∗ ASME/ASTM SB-637/B637 alloy UNS N07718 (Grade 718)

・Solution Heat Treatment: 1030℃×1h O.C

・Precipitation Hardening Heat Treatment: 704℃×6h A.C

Table A1-2 Tensile data of modified alloy 718

Test Temperature		Test Run	Heat ID																							
			A								B								C							
			Yield Strength (0.2% offset)		Tensile Strength		Elongation	Reduction of Area	Yield Strength (0.2% offset)		Tensile Strength		Elongation	Reduction of Area	Yield Strength (0.2% offset)		Tensile Strength		Elongation	Reduction of Area						
(°F)	(°C)		(ksi)	(MPa)	(ksi)	(MPa)	(%)	(%)	(ksi)	(MPa)	(ksi)	(MPa)	(%)	(%)	(ksi)	(MPa)	(ksi)	(MPa)	(%)	(%)						
68	20	1	126.4	871.3	167.6	1155	38.3	56.4	132.3	912.0	170.1	1173	33.7	54.9	118.8	818.8	163.6	1128	41.9	56.0						
68	20	2	122.8	846.5	163.3	1126	35.8	56.4	134.1	924.7	171.2	1180	32.2	55.5	115.8	798.3	160.8	1108	40.0	54.4						
68	20	3	127.3	877.6	168.4	1161	38.3	55.1	135.3	932.7	172.8	1191	35.5	56.0	116.6	804.1	162.1	1117	39.8	50.4						
167	75	1	117.0	806.8	158.9	1096	38.1	56.2	130.4	899.2	166.2	1146	32.6	55.9	113.8	784.8	156.7	1080	35.0	53.5						
167	75	2	122.8	846.7	162.3	1119	36.5	54.8	129.0	889.5	165.8	1143	35.1	55.0	112.9	778.2	156.8	1081	40.7	55.3						
167	75	3	117.5	810.1	159.1	1097	38.8	55.5	129.7	894.1	166.0	1145	32.6	53.1	111.6	769.3	155.8	1074	41.0	51.6						
212	100	1	123.6	852.1	160.8	1109	32.9	53.7	129.7	894.3	165.7	1142	33.2	56.4	114.3	788.3	155.4	1072	35.5	52.6						
212	100	2	121.8	839.5	158.1	1090	30.2	53.8	125.4	864.9	163.4	1126	37.1	55.3	112.1	772.7	154.6	1066	42.7	56.4						
212	100	3	116.1	800.2	156.9	1082	39.4	55.4	126.0	868.4	163.3	1126	37.8	55.7	114.3	788.4	156.2	1077	40.7	53.5						
302	150	1	115.5	796.2	153.9	1061	36.3	54.3	126.7	873.8	161.8	1116	34.2	55.8	111.6	769.3	151.4	1044	36.3	55.8						
302	150	2	115.8	798.7	155.4	1071	37.2	53.9	127.4	878.3	161.8	1116	31.7	55.7	110.4	761.0	150.9	1041	36.1	53.8						
302	150	3	112.3	774.1	151.1	1042	35.0	56.2	123.2	849.6	158.9	1095	31.8	53.5	108.3	746.8	150.0	1035	37.2	53.8						
392	200	1	110.3	760.4	147.8	1019	33.6	54.4	124.2	856.5	158.8	1095	33.9	55.1	108.7	749.5	148.7	1025	35.4	52.2						
392	200	2	110.7	763.4	150.8	1040	37.8	54.2	124.4	857.5	157.7	1087	34.9	55.5	109.0	751.6	148.7	1025	37.1	52.6						
392	200	3	115.0	792.7	151.4	1044	32.8	54.4	120.7	832.4	155.9	1075	33.7	55.5	111.9	771.8	150.0	1034	35.8	47.4						
482	250	1	113.6	783.1	148.6	1025	37.5	54.9	125.3	863.9	156.1	1077	31.7	53.5	108.9	751.1	145.7	1004	32.8	53.6						
482	250	2	111.2	766.9	145.5	1003	32.5	54.5	123.1	848.9	155.1	1069	32.6	53.8	106.9	737.1	145.4	1003	39.7	52.2						
482	250	3	114.9	792.3	149.5	1031	35.0	51.7	119.5	823.8	153.0	1055	35.2	55.1	105.4	726.4	144.8	998.6	39.1	57.3						
527	275	1	118.7	818.5	150.8	1040	30.7	53.5	120.7	832.4	152.6	1052	33.3	56.0	102.2	704.7	140.4	968.1	40.2	55.8						
527	275	2	112.9	778.5	147.1	1014	34.0	53.7	121.4	837.1	152.6	1052	33.5	56.4	105.7	728.7	142.1	979.9	33.6	52.4						
527	275	3	110.6	762.9	146.1	1007	32.7	48.4	119.4	822.9	151.3	1043	34.7	56.0	110.2	760.0	144.7	998.0	34.0	54.7						
572	300	1	110.0	758.6	143.5	989.2	33.7	55.5	118.5	817.1	150.3	1036	37.4	56.4	106.0	730.9	143.2	987.5	39.0	52.2						
572	300	2	113.3	781.3	144.6	996.7	29.6	53.7	124.0	855.0	152.9	1055	32.5	56.2	106.4	733.7	142.8	984.8	38.0	52.2						
572	300	3	118.3	815.5	148.8	1026	33.5	54.5	123.5	851.4	153.3	1057	33.0	56.4	109.6	755.6	142.4	981.6	34.1	52.4						
617	325	1	113.3	781.4	144.8	998.5	35.0	55.1	120.6	831.7	150.3	1036	32.2	55.2	104.3	719.3	140.6	969.1	39.6	56.0						
617	325	2	111.2	766.9	142.9	985.5	32.0	52.8	120.8	832.6	149.8	1033	32.9	55.3	108.0	744.3	141.8	977.4	34.2	56.0						
617	325	3	117.0	807.0	148.7	1026	34.4	53.5	118.9	819.6	148.3	1022	33.3	54.8	106.0	731.1	140.5	968.8	36.0	56.0						
662	350	1	108.9	750.9	141.2	973.7	36.6	50.3	118.1	814.1	146.3	1009	32.9	55.3	103.9	716.3	137.7	949.1	37.6	53.9						
662	350	2	107.7	742.3	139.6	962.2	35.0	53.4	121.2	835.6	148.7	1025	32.1	56.2	108.9	750.6	141.3	973.9	36.8	54.0						
662	350	3	113.8	784.9	144.1	993.8	33.0	53.5	119.7	825.5	148.8	1026	35.3	54.7	104.8	722.7	139.0	958.1	36.3	56.7						
752	400	1	111.1	765.9	141.6	976.3	34.1	52.4	119.6	824.3	145.3	1002	33.7	55.1	102.7	708.4	136.2	939.2	38.8	53.8						
752	400	2	109.2	752.6	139.0	958.2	33.9	54.9	116.7	804.3	143.7	990.7	34.3	55.5	103.8	715.5	135.8	936.5	35.0	53.3						
752	400	3	110.1	758.9	138.7	956.4	30.0	54.7	116.9	806.2	143.8	991.6	32.8	55.5	104.3	719.4	136.9	944.1	32.7	53.1						
797	425	1	109.2	753.1	138.7	956.0	32.1	53.3	117.4	809.2	143.5	989.6	33.4	55.6	101.7	701.5	134.0	923.8	37.0	53.8						
797	425	2	105.0	723.9	134.8	929.1	35.1	53.4	119.0	820.8	144.8	998.6	30.5	54.7	102.1	703.7	133.7	921.6	36.6	52.8						
797	425	3	112.2	773.4	141.4	975.0	35.6	52.6	116.6	804.1	143.1	986.3	34.9	56.0	109.0	751.3	137.7	949.6	33.7	54.4						

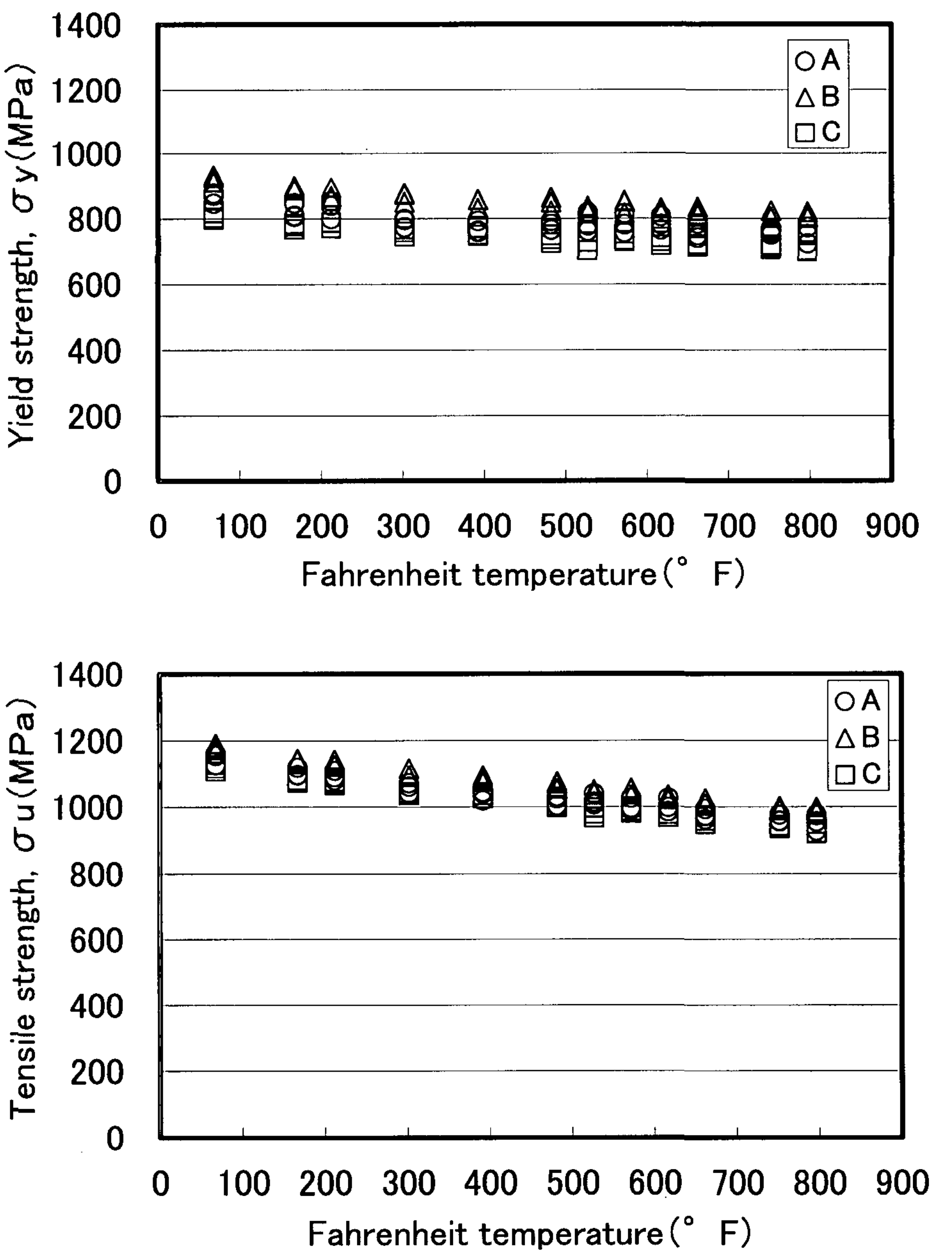
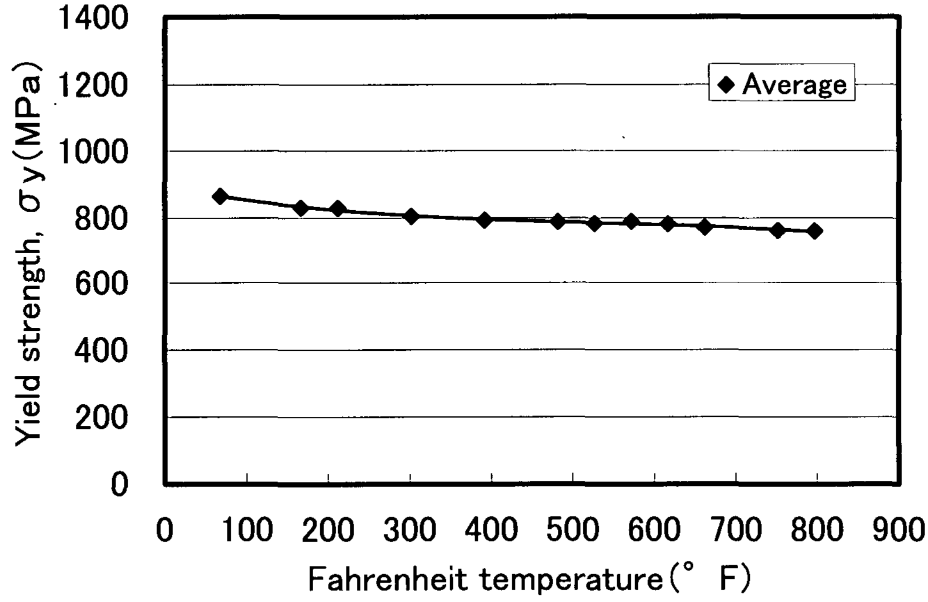


Figure A1-1 Tensile test data of yield strength and tensile strength at temperature



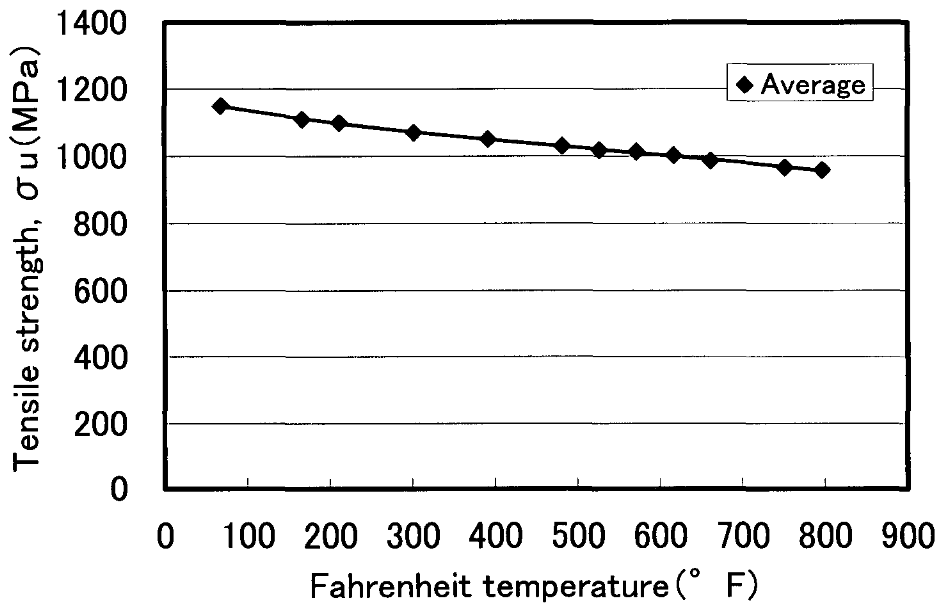
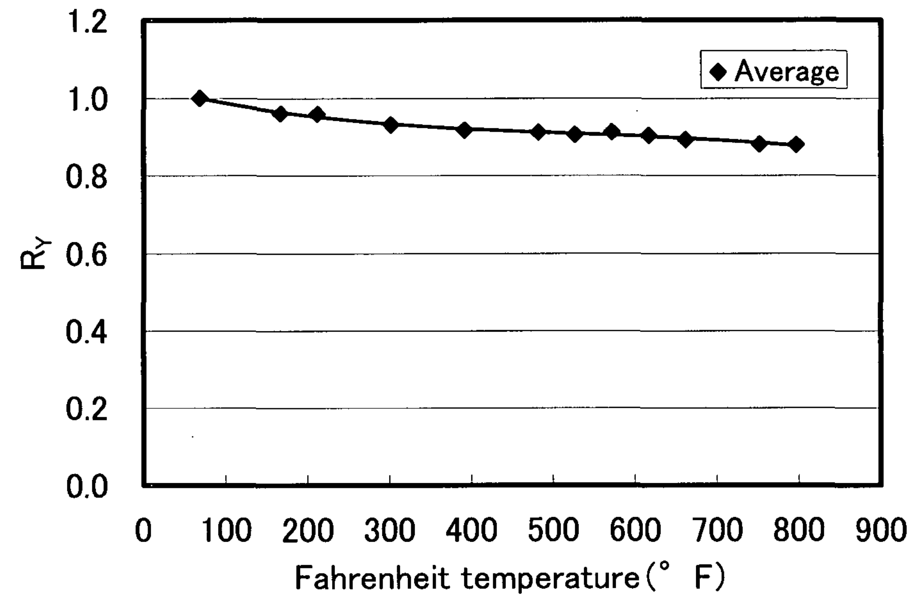


Figure A1-2 Average temperature dependent trend curves of yield strength and tensile strength



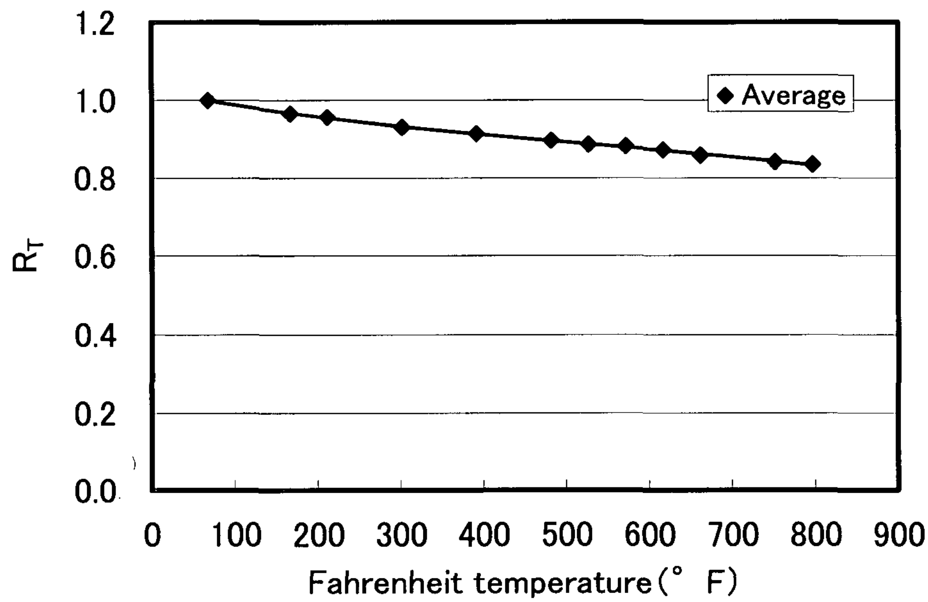


Figure A1-3 R_Y, R_T values at temperature

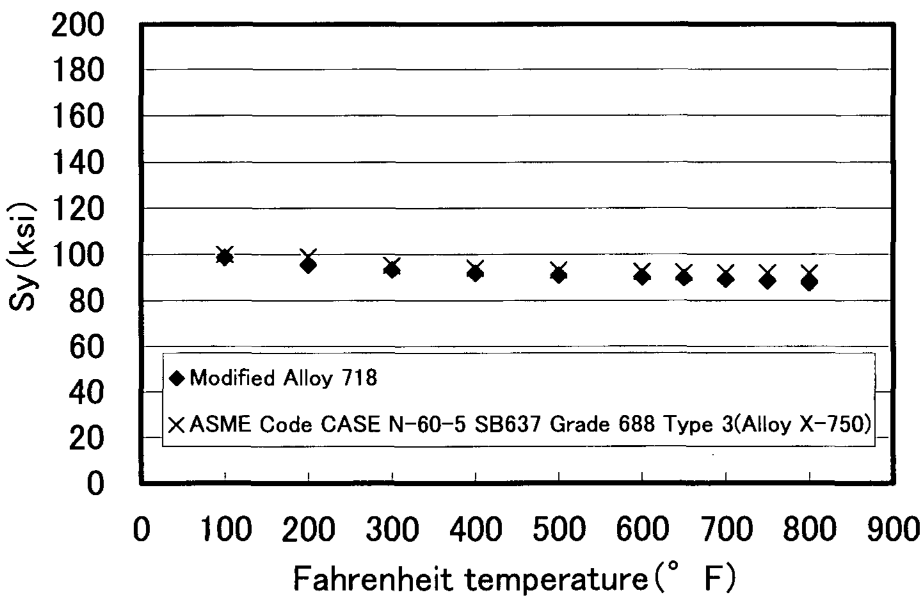


Figure A1-4 Yield Strength values at temperature

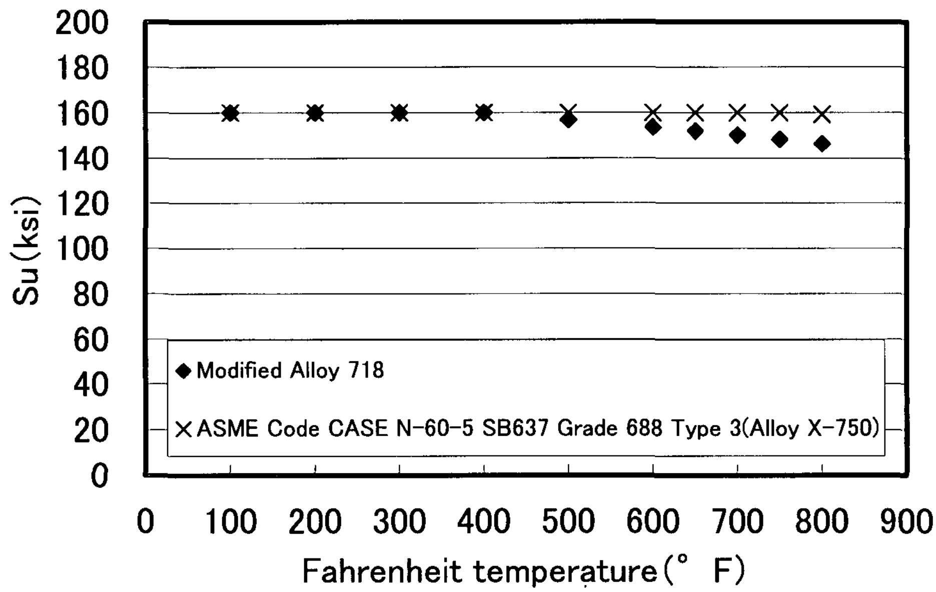


Figure A1-5 Tensile Strength values at temperature

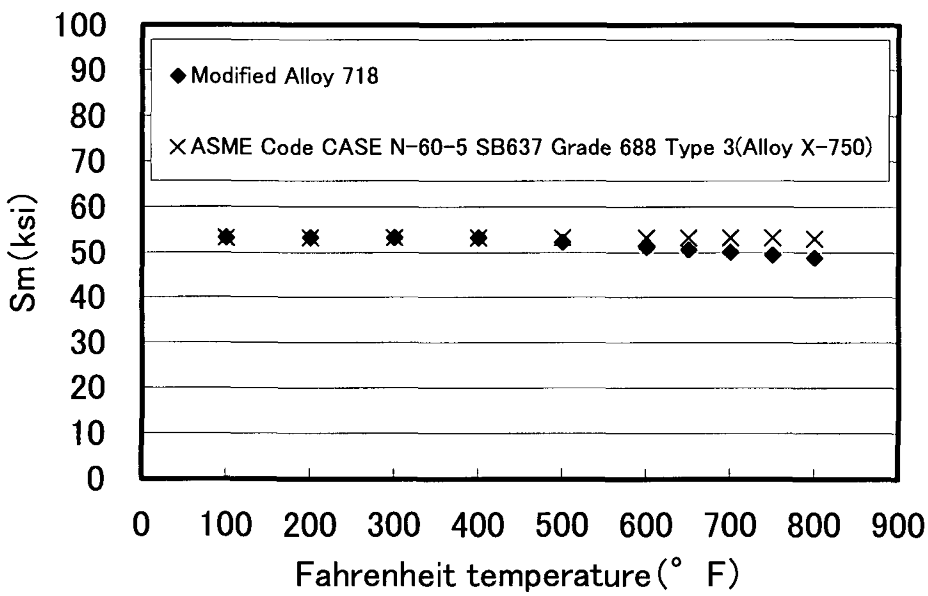
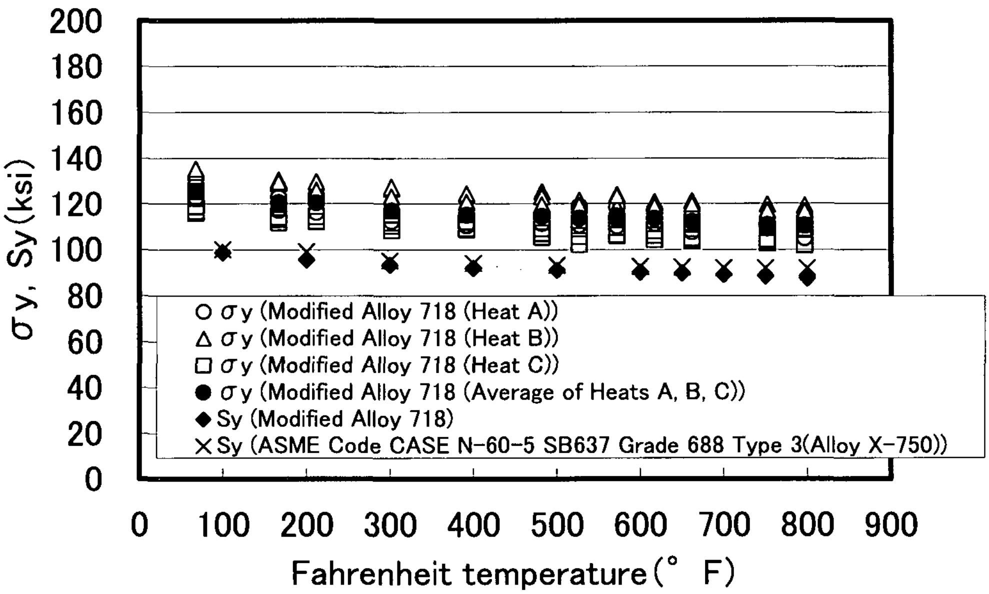


Figure A1-6 Stress Intensity values at temperature



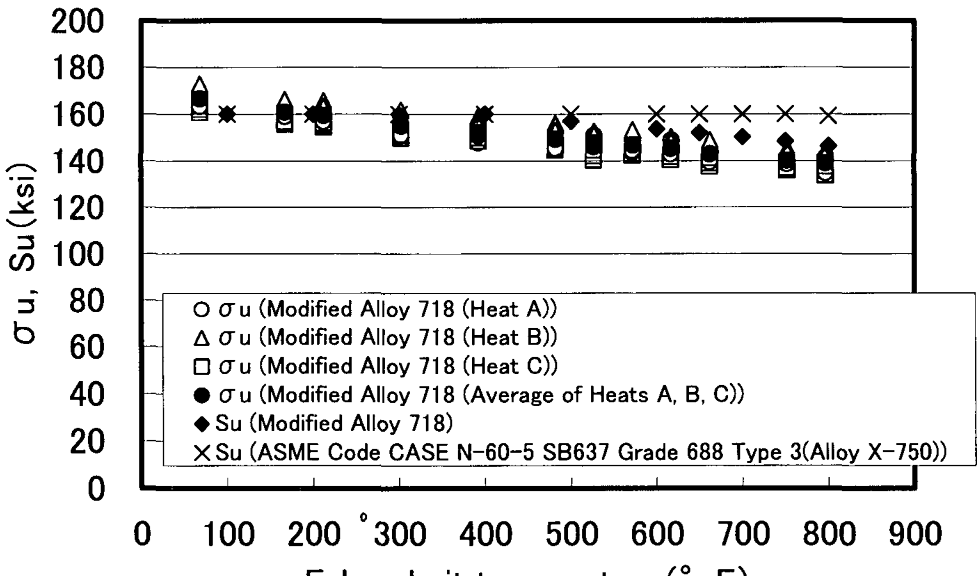


Figure A1-7 Yield strength (σ y, Sy) and tensile strength (σ u, Su) at temperature

ATTACHMENT – 2

Fatigue data: Fatigue tests from three heats of modified alloy 718 were conducted in order to compare to existed design fatigue curves for austenitic steels, nickel-chromium-iron alloy, nickel-iron-chromium alloy, and nickel-copper alloy in ASME Sec. III, Division 1, Mandatory Appendix I. Same three heats of material used in tensile tests (see Attachment 1) were used in the fatigue tests. Chemical compositions of three heats of material (Heat ID A, B and C) used in fatigue tests are shown in Table A2-1. Test temperatures were room temperature (21-26℃(70-79°F)) and BWR design temperature (302℃(576°F)). Load-controlled fatigue tests (stress ration: -1) were conducted in accordance with ASTM E 466 under the condition of the stress amplitude below the yield strength. Test specimens based on ASTM E 466 Fig.1 were used in load-controlled fatigue tests. Strain-controlled fatigue tests (strain ratio: -1) were conducted in accordance with ASTM E 606 under the condition of the stress amplitude beyond the yield strength. Test specimens based on ASTM E 606 Fig.1 were used in strain-controlled fatigue tests. In the strain-controlled fatigue tests, stress value (σ) was calculated from strain value (ε) and Young's modulus (E) based on Figure A3-3 in Attachment 3. ($\sigma = \varepsilon E$, E (RT)= 203GPa (29.4×10^6 psi), E (302℃(576°F))= 191GPa (27.7×10^6 psi))

Fatigue data of modified alloy 718 are listed in Table A2-2. In Figure A2-1, fatigue data were compared to the existed design fatigue curves for austenitic steels, nickel-chromium-iron alloy, nickel-iron-chromium alloy, and nickel-copper alloy in ASME Sec. III, Division 1, Mandatory Appendix I. Fatigue data of modified alloy 718 located above the ASME design fatigue curves, which were conservative for modified alloy 718.

Table A2-1 Chemical compositions of three heats of material

Specification* / Heat ID	Chemical Composition (%)														
	C	Si	Mn	P	S	Ni	Cr	Co	Mo	Nb+Ta	Cu	Al	Ti	B	Fe
	max 0.08	max 0.35	max 0.35	max 0.015	max 0.015	50.0 -55.0	17.0 -21.0	max 1.0	2.80 -3.30	4.75 -5.50	max 0.30	0.20 -0.80	0.65 -1.15	max 0.006	Bal.
A	0.03	0.10	0.04	0.004	0.0003	52.41	18.59	0.03	3.07	5.12	0.01	0.52	0.95	0.0048	Bal
B	0.03	0.08	0.04	0.004	0.0002	52.49	18.65	0.02	3.08	5.07	0.01	0.55	0.94	0.0038	Bal
C	0.03	0.06	0.04	0.003	0.0001	52.34	18.69	0.03	3.09	5.11	0.02	0.54	0.96	0.0042	Bal

* ASME/ASTM SB-637/B637 alloy UNS N07718 (Grade 718)

- Solution Heat Treatment: 1030℃×1h O.C
- Precipitation Hardening Heat Treatment: 704℃×6h A.C

Table A2-2 Fatigue data of modified alloy 718

Heat ID	Test Temperature			Stress Amplitude		Strain Amplitude	Fatigue Life (Fracture)	Remarks*
	(°F)		(°C)	(ksi)	(MPa)	(%)	(Number of cycles)	
A	RT	78	26	131	900	0.44	2.03×10^4	(1)
		76	24	87	600	-	1.89×10^5	(2)
		77	25	73	500	-	6.88×10^5	(2)
B	RT	75	24	435	3000	1.48	8.89×10^2	(1)
		71	22	218	1500	0.74	3.29×10^3	(1)
		74	23	131	900	0.44	1.25×10^4	(1)
		76	24	87	600	-	1.63×10^5	(2)
		76	25	73	500	-	7.21×10^5	(2)
		72	22	65	450	-	4.60×10^6	(2)
	BWR Design Temp.	576	302	131	900	0.47	1.17×10^4	(1)
		576	302	87	600	-	5.57×10^4	(2)
		576	302	73	500	-	1.98×10^5	(2)
C	RT	70	21	131	900	0.44	1.07×10^4	(1)
		76	24	87	600	-	8.00×10^4	(2)
		72	22	73	500	-	3.18×10^5	(2)

* (1) Strain-Controlled fatigue testing (Strain ration: -1)
Stress value (σ) was calculated from strain value (ε) and Young's modulus (E).
($\sigma = \varepsilon E$, E(RT)=203 GPa(29.4×10^6 psi), E(302°C(576°F))=191 GPa(27.7×10^6 psi))
(2) Load-Controlled fatigue testing (Stress ration: -1)

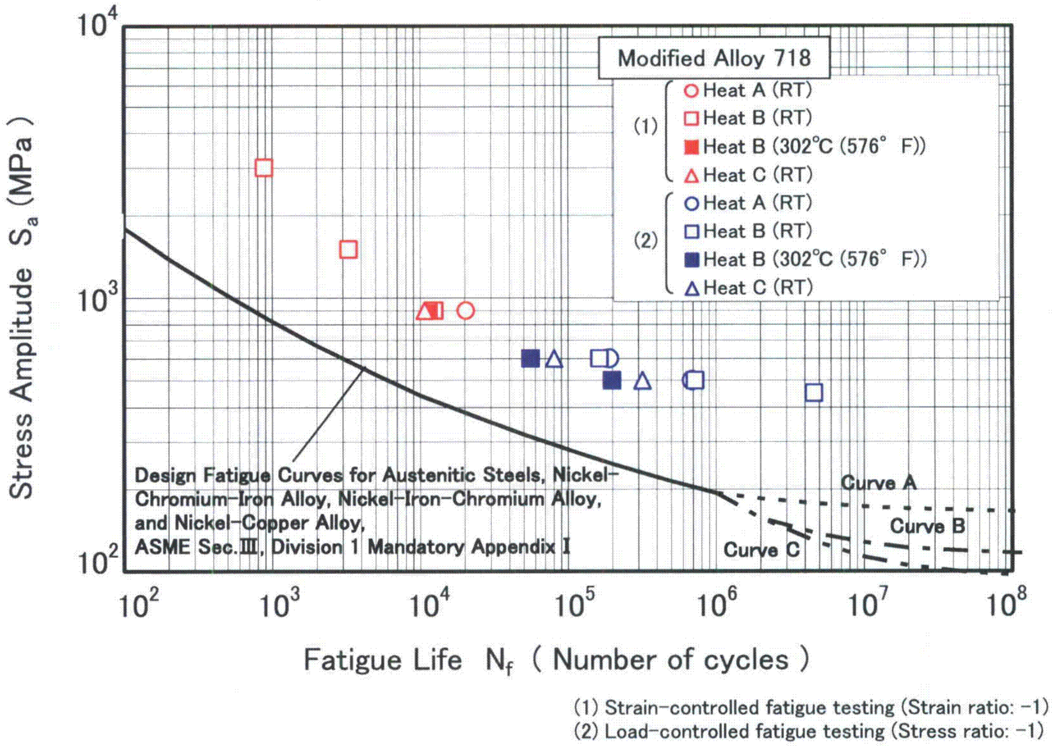


Figure A2-1 Fatigue data of modified alloy 718

ATTACHMENT – 3

Other properties: Other properties of coefficient of thermal expansion, thermal conductivity and diffusivity, Young's modulus, Poisson's ratio, shear modulus and density were obtained from three heats of modified alloy 718. Same three heats of material used in tensile tests and fatigue tests (see Attachment 1 and 2) were used in the property tests. Chemical compositions of three heats of material (Heat ID A, B and C) used in the property tests are shown in Table A3-1. The property test methods employed were JIS (Japanese Industrial Standards) test methods. Test temperatures were room temperature (20℃), 100℃, 200℃, 300℃, 400℃ and 425℃, except for the testing of thermal conductivity and diffusivity, and density. Thermal conductivity and diffusivity were obtained at room temperature (20℃), 200℃ and 425℃. Density was obtained at room temperature (20℃). Test temperatures were converted to Fahrenheit temperatures.

Instantaneous coefficient of thermal expansion (coefficient A), mean coefficient of thermal expansion (coefficient B) and linear thermal expansion (coefficient C) at temperature are shown in Figure A3-1. Thermal conductivity (TC) and diffusivity (TD) at temperature are shown in Figure A3-2. Young's modulus and Poisson's ratio at temperature are shown in Figure A3-3. Shear modulus (G) data at temperature are calculated from Young's modulus (E) and Poisson's ratio (ν) by the equation of $G=E/2(1+\nu)$, and shown in Figure A3-4. Density data are shown in Table A3-2. The data of modified alloy 718 were compared to those of the conventional material SB-637 Grade 718 (now referred to as UNS N07718) and the equivalent material SB-637 Grade 688 (now referred to as UNS N07750) in ASME Sec. II, Part D, and found to be very comparable.

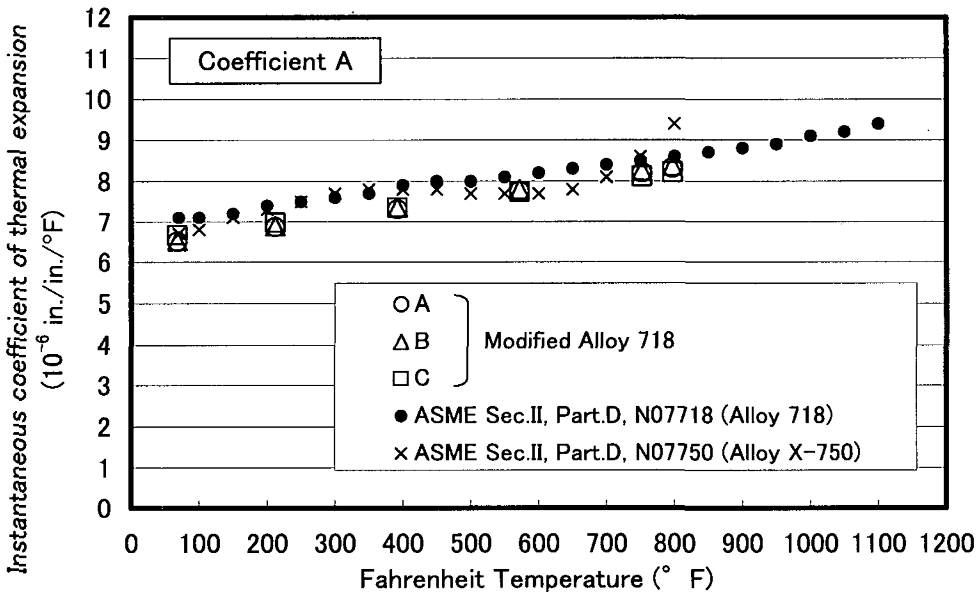
Table A3-1 Chemical compositions of three heats of material

Specification* / Heat ID	Chemical Composition (%)														
	C	Si	Mn	P	S	Ni	Cr	Co	Mo	Nb+Ta	Cu	Al	Ti	B	Fe
	max 0.08	max 0.35	max 0.35	max 0.015	max 0.015	50.0 -55.0	17.0 -21.0	max 1.0	2.80 -3.30	4.75 -5.50	max 0.30	0.20 -0.80	0.65 -1.15	max 0.006	Bal.
A	0.03	0.10	0.04	0.004	0.0003	52.41	18.59	0.03	3.07	5.12	0.01	0.52	0.95	0.0048	Bal
B	0.03	0.08	0.04	0.004	0.0002	52.49	18.65	0.02	3.08	5.07	0.01	0.55	0.94	0.0038	Bal
C	0.03	0.06	0.04	0.003	0.0001	52.34	18.69	0.03	3.09	5.11	0.02	0.54	0.96	0.0042	Bal

＊ ASME/ASTM SB-637/B637 alloy UNS N07718 (Grade 718)

・Solution Heat Treatment: 1030℃×1h O.C

・Precipitation Hardening Heat Treatment: 704℃×6h A.C



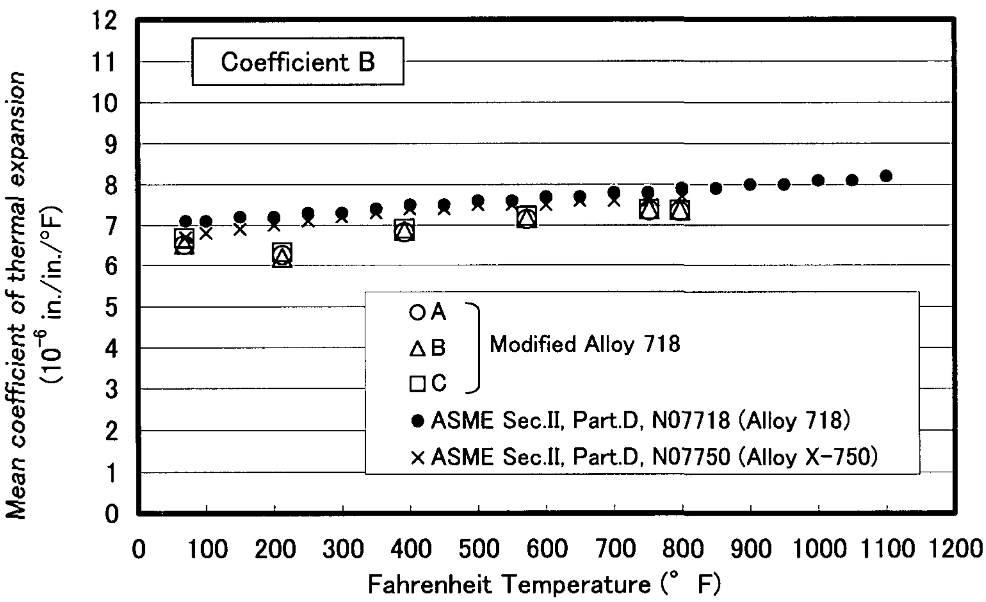


Figure A3-1 Thermal expansion at temperature (1/2)

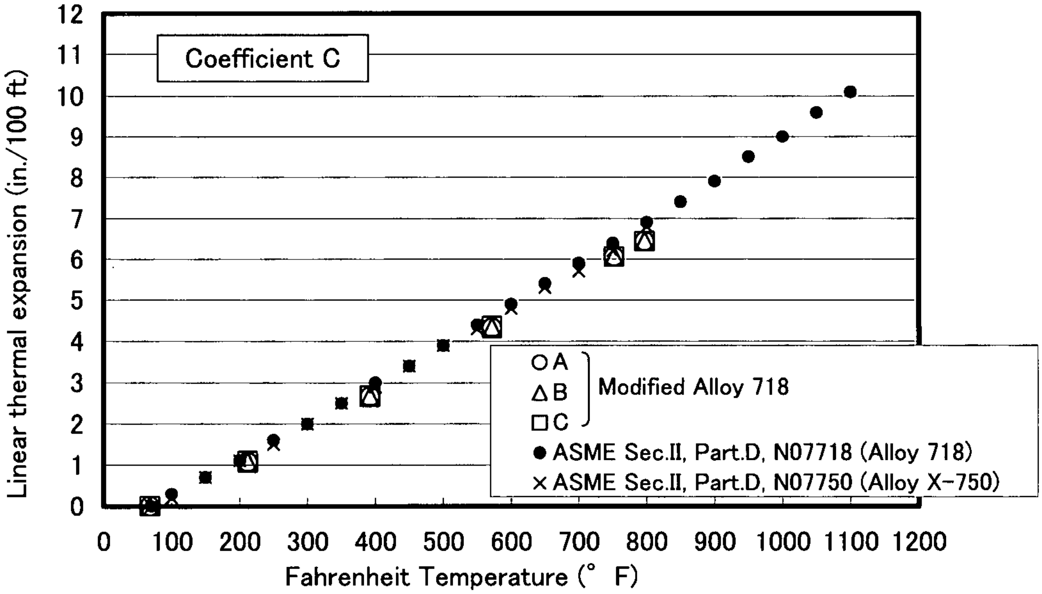


Figure A3-1 Thermal expansion at temperature (2/2)

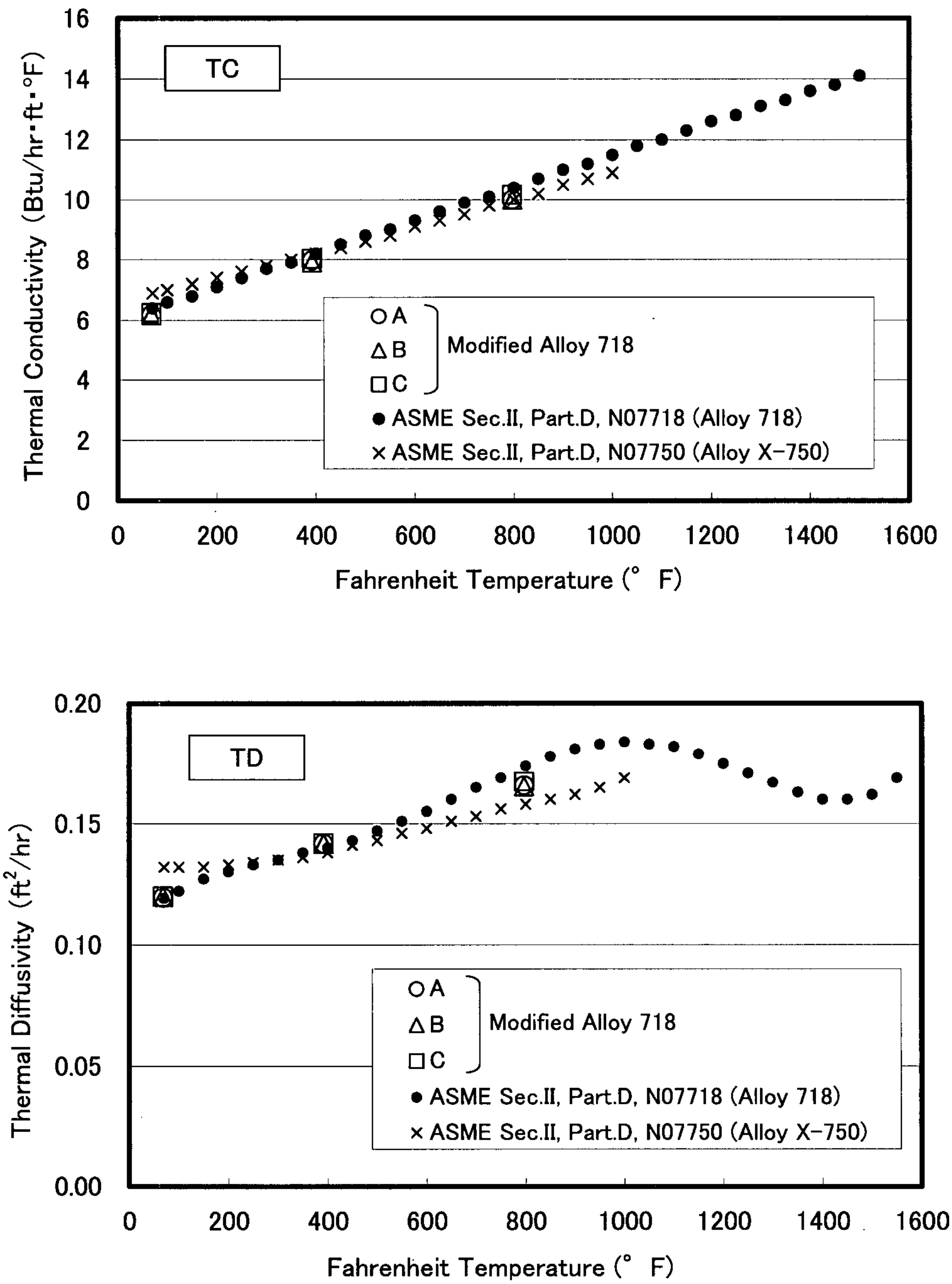
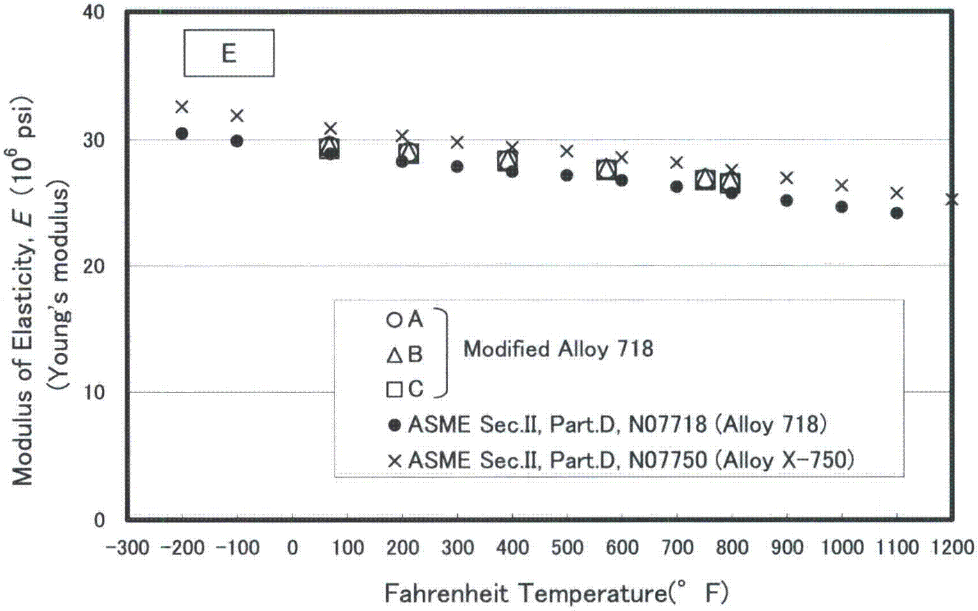


Figure A3-2 Thermal conductivity and diffusivity at temperature



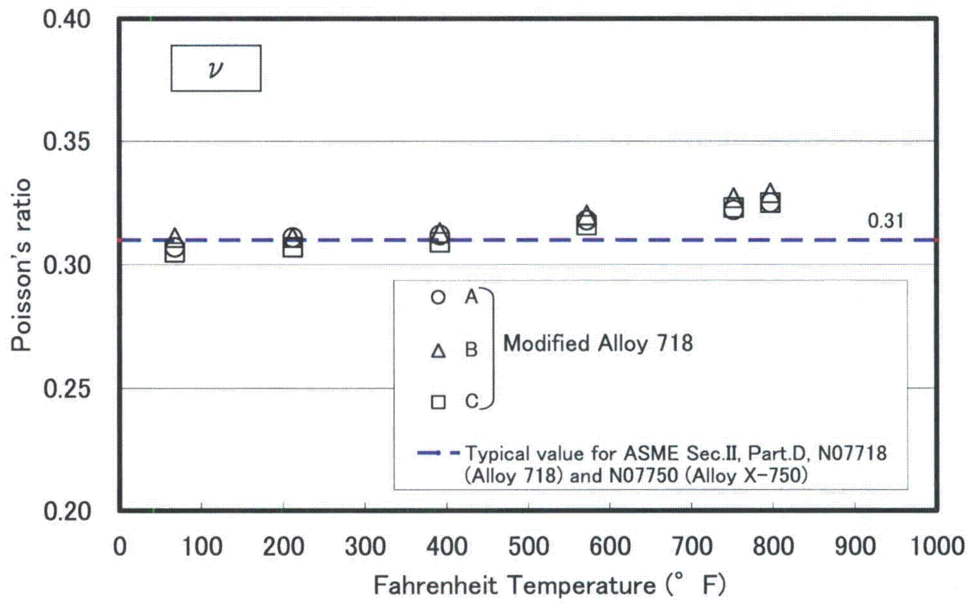


Figure A3-3 Young's modulus and Poisson's ratio at temperature

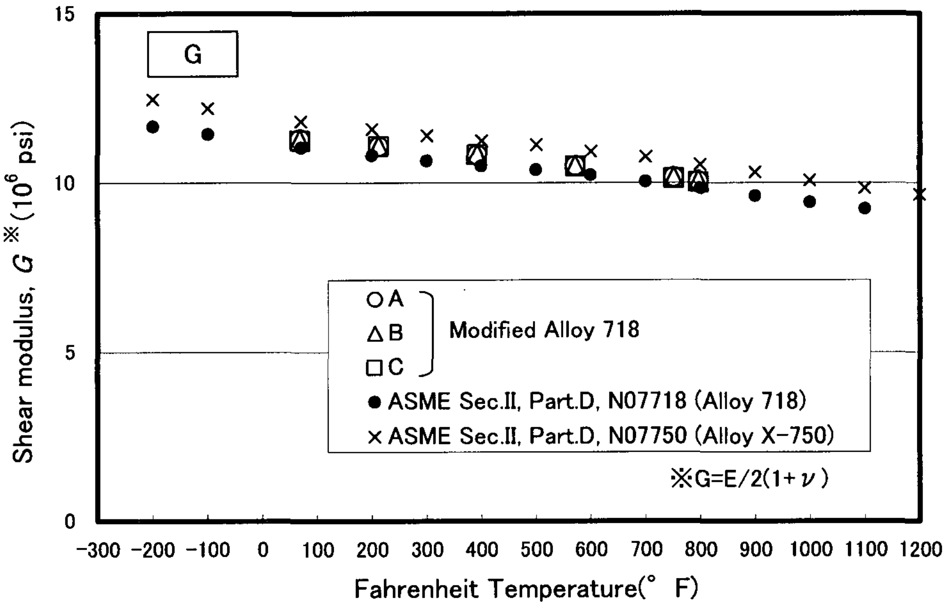


Figure A3-4 Shear modulus at temperature

Table A3-2 Density

Density ($lb/in.^3$)				
Modified Alloy 718			ASME Sec. II, Part D	
Heat ID			N07718 (Alloy 718)	N07750 (Alloy X-750)
A	B	C		
0.287	0.288	0.288	0.297	0.298

Toshiba - Modified 718 Tensile Test Data					
Heat	Temp (°F)	YS (ksi)	UTS (ksi)	Elong. (%)	Red. Area (%)
A	RT	126.4	167.6	38.3	56.4
A	RT	122.8	163.3	35.8	56.4
A	RT	127.3	168.4	38.3	55.1
A	167	117.0	158.9	38.1	56.2
A	167	122.8	162.3	36.5	54.8
A	167	117.5	159.1	38.8	55.5
A	212	123.6	160.8	32.9	53.7
A	212	121.8	158.1	30.2	53.8
A	212	116.1	156.9	39.4	55.4
A	302	115.5	153.9	36.3	54.3
A	302	115.8	155.4	37.2	53.9
A	302	112.3	151.1	35.0	56.2
A	392	110.3	147.8	33.6	54.4
A	392	110.7	150.8	37.8	54.2
A	392	115.0	151.4	32.8	54.4
A	482	113.6	148.6	37.5	54.9
A	482	111.2	145.5	32.5	54.5
A	482	114.9	149.5	35.0	51.7
A	527	118.7	150.8	30.7	53.5
A	527	112.9	147.1	34.0	53.7
A	527	110.6	146.1	32.7	48.4
A	572	110.0	143.5	33.7	55.5
A	572	113.3	144.6	29.6	53.7
A	572	118.3	148.8	33.5	54.5
A	617	113.3	144.8	35.0	55.1
A	617	111.2	142.9	32.0	52.8
A	617	117.0	148.7	34.4	53.5
A	662	108.9	141.2	36.6	50.3
A	662	107.7	139.6	35.0	53.4
A	662	113.8	144.1	33.0	53.5
A	752	111.1	141.6	34.1	52.4
A	752	109.2	139.0	33.9	54.9
A	752	110.1	138.7	30.0	54.7
A	797	109.2	138.7	32.1	53.3
A	797	105.0	134.8	35.1	53.4
A	797	112.2	141.4	35.6	52.6

Toshiba - Modified 718 Tensile Test Data					
Heat	Temp (°F)	YS (ksi)	UTS (ksi)	Elong. (%)	Red. Area (%)
B	RT	132.3	170.1	33.7	54.9
B	RT	134.1	171.2	32.2	55.5
B	RT	135.3	172.8	35.5	56.0
B	167	130.4	166.2	32.6	55.9
B	167	129.0	165.8	35.1	55.0
B	167	129.7	166.0	32.6	53.1
B	212	129.7	165.7	33.2	56.4
B	212	125.4	163.4	37.1	55.3
B	212	126.0	163.3	37.8	55.7
B	302	126.7	161.8	34.2	55.8
B	302	127.4	161.8	31.7	55.7
B	302	123.2	158.9	31.8	53.5
B	392	124.2	158.8	33.9	55.1
B	392	124.4	157.7	34.9	55.5
B	392	120.7	155.9	33.7	55.5
B	482	125.3	156.1	31.7	53.5
B	482	123.1	155.1	32.6	53.8
B	482	119.5	153.0	35.2	55.1
B	527	120.7	152.6	33.3	56.0
B	527	121.4	152.6	33.5	56.4
B	527	119.4	151.3	34.7	56.0
B	572	118.5	150.3	37.4	56.4
B	572	124.0	152.9	32.5	56.2
B	572	123.5	153.3	33.0	56.4
B	617	120.6	150.3	32.2	55.2
B	617	120.8	149.8	32.9	55.3
B	617	118.9	148.3	33.3	54.8
B	662	118.1	146.3	32.9	55.3
B	662	121.2	148.7	32.1	56.2
B	662	119.7	148.8	35.3	54.7
B	752	119.6	145.3	33.7	55.1
B	752	116.7	143.7	34.3	55.5
B	752	116.9	143.8	32.8	55.5
B	797	117.4	143.5	33.4	55.6
B	797	119.0	144.8	30.5	54.7
B	797	116.6	143.1	34.9	56.0

Toshiba - Modified 718 Tensile Test Data					
Heat	Temp (°F)	YS (ksi)	UTS (ksi)	Elong. (%)	Red. Area (%)
C	RT	118.8	163.6	41.9	56.0
C	RT	115.8	160.8	40.0	54.4
C	RT	116.6	162.1	39.8	50.4
C	167	113.8	156.7	35.0	53.5
C	167	112.9	156.8	40.7	55.3
C	167	111.6	155.8	41.0	51.6
C	212	114.3	155.4	35.5	52.6
C	212	112.1	154.6	42.7	56.4
C	212	114.3 .	156.2	40.7	53.5
C	302	111.6	151.4	36.3	55.8
C	302	110.4	150.9	36.1	53.8
C	302	108.3	150.0	37.2	53.8
C	392	108.7	148.7	35.4	52.2
C	392	109.0	148.7	37.1	52.6
C	392	111.9	150.0	35.8	47.4
C	482	108.9	145.7	32.8	53.6
C	482	106.9	145.4	39.7	52.2
C	482	105.4	144.8	39.1	57.3
C	527	102.2	140.4	40.2	55.8
C	527	105.7	142.1	33.6	52.4
C	527	110.2	144.7	34.0	54.7
C	572	106.0	143.2	39.0	52.2
C	572	106.4	142.8	38.0	52.2
C	572	109.6	142.4	34.1	52.4
C	617	104.3	140.6	39.6	56.0
C	617	108.0	141.8	34.2	56.0
C	617	106.0	140.5	36.0	56.0
C	662	103.9	137.7	37.6	53.9
C	662	108.9	141.3	36.8	54.0
C	662	104.8	139.0	36.3	56.7
C	752	102.7	136.2	38.8	53.8
C	752	103.8	135.8	35.0	53.3
C	752	104.3	136.9	32.7	53.1
C	797	101.7	134.0	37.0	53.8
C	797	102.1	133.7	36.6	52.8
C	797	109.0	137.7	33.7	54.4

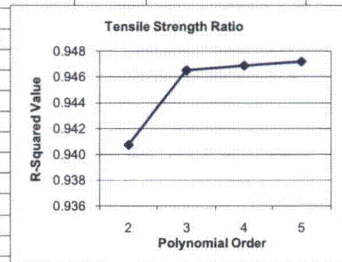
		Normalized Input Data				Curve Fit	
Heat	Temp	YS	UTS	EL	RA	YS	UTS
A	167	0.932	0.955	1.017	1.017	0.966	0.967
A	167	0.978	0.975	0.974	0.974	0.966	0.967
A	167	0.936	0.956	1.036	1.036	0.966	0.967
B	167	0.973861	0.96985	0.964497	0.964497	0.966143	0.967278
B	167	0.963405	0.967516	1.038462	1.038462	0.966143	0.967278
B	167	0.968633	0.968683	0.964497	0.964497	0.966143	0.967278
C	167	0.972096	0.96629	0.862777	0.862777	0.966143	0.967278
C	167	0.964408	0.966906	1.003287	1.003287	0.966143	0.967278
C	167	0.953303	0.96074	1.010682	1.010682	0.966143	0.967278
A	212	0.985	0.966	0.878	0.878	0.952	0.954
A	212	0.971	0.950	0.806	0.806	0.952	0.954
A	212	0.925	0.943	1.052	1.052	0.952	0.954
B	212	0.969	0.967	0.982	0.982	0.952	0.954
B	212	0.937	0.954	1.098	1.098	0.952	0.954
B	212	0.941	0.953	1.118	1.118	0.952	0.954
C	212	0.976367	0.958273	0.875103	0.875103	0.951665	0.953741
C	212	0.957574	0.95334	1.052588	1.052588	0.951665	0.953741
C	212	0.957574	0.963207	1.003287	1.003287	0.951665	0.953741
A	302	0.920319	0.924695	0.968861	0.968861	0.930017	0.930878
A	302	0.922709	0.933707	0.992883	0.992883	0.930017	0.930878
A	302	0.894821	0.907871	0.934164	0.934164	0.930017	0.930878
B	302	0.946	0.944	1.012	1.012	0.930	0.931
B	302	0.951	0.944	0.938	0.938	0.930	0.931
B	302	0.920	0.927	0.941	0.941	0.930	0.931
C	302	0.953	0.934	0.895	0.895	0.930	0.931
C	302	0.943	0.931	0.890	0.890	0.930	0.931
C	302	0.925	0.925	0.917	0.917	0.930	0.931
A	392	0.879	0.888	0.897	0.897	0.918	0.913
A	392	0.882	0.906	1.009	1.009	0.918	0.913
A	392	0.916	0.910	0.875	0.875	0.918	0.913
B	392	0.927558	0.926668	1.002959	1.002959	0.918256	0.912611
B	392	0.929051	0.920249	1.032544	1.032544	0.918256	0.912611
B	392	0.901419	0.909745	0.997041	0.997041	0.918256	0.912611
C	392	0.928531	0.916958	0.872638	0.872638	0.918256	0.912611
C	392	0.931093	0.916958	0.914544	0.914544	0.918256	0.912611
C	392	0.955866	0.924974	0.882498	0.882498	0.918256	0.912611
A	482	0.905	0.893	1.001	1.001	0.912	0.896
A	482	0.886	0.874	0.867	0.867	0.912	0.896
A	482	0.916	0.898	0.934	0.934	0.912	0.896
B	482	0.936	0.911	0.938	0.938	0.912	0.896
B	482	0.919	0.905	0.964	0.964	0.912	0.896
B	482	0.892	0.893	1.041	1.041	0.912	0.896
C	482	0.930239	0.898458	0.808546	0.808546	0.912104	0.89623
C	482	0.913155	0.896608	0.978636	0.978636	0.912104	0.89623
C	482	0.900342	0.892909	0.963845	0.963845	0.912104	0.89623
A	527	0.945817	0.906069	0.819395	0.819395	0.909232	0.88783
A	527	0.899602	0.883837	0.907473	0.907473	0.909232	0.88783
A	527	0.881275	0.877829	0.872776	0.872776	0.909232	0.88783
B	527	0.901419	0.890488	0.985207	0.985207	0.909232	0.88783
B	527	0.906647	0.890488	0.991124	0.991124	0.909232	0.88783
B	527	0.89171	0.882902	1.026627	1.026627	0.909232	0.88783
C	527	0.873	0.866	0.991	0.991	0.909	0.888
C	527	0.903	0.876	0.828	0.828	0.909	0.888
C	527	0.941	0.892	0.838	0.838	0.909	0.888
A	572	0.876	0.862	0.899	0.899	0.906	0.879

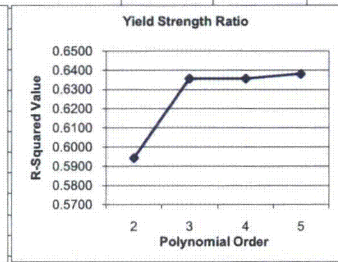
	R^2 Value	
Order	YS	UTS
2	0.594	0.941
3	0.636	0.947
4	0.636	0.947
5	0.638	0.947

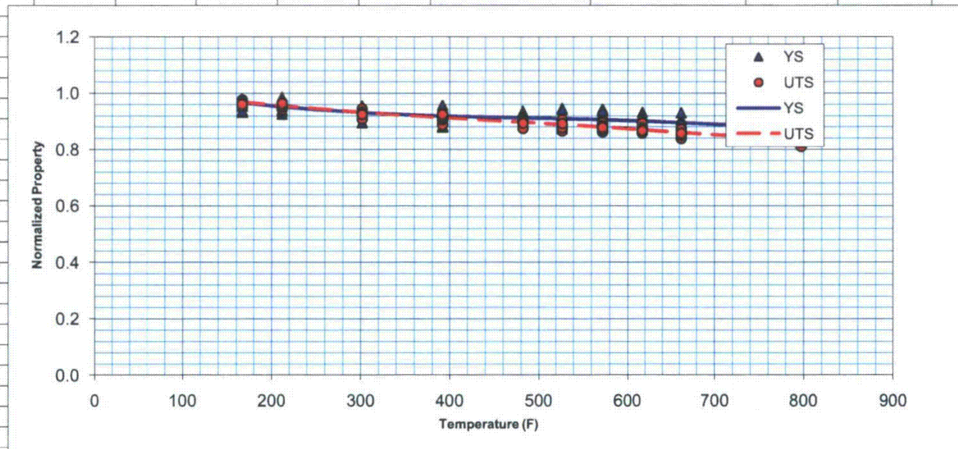
Data Analysis

- ☑ Show Table 1
- ☑ Show Table 2
- ☑ Show Table 3
- ☑ Show Table 4
- ☑ Show Table 5

	Coefficients		Contribution	
Term	YS	UTS	YS	UTS
0	1	1	1	1
1	-3.1889177312E-04	-3.4597744454E-04	-0.15275	-0.165723
2	-7.5327636256E-07	-5.9511561236E-08	-0.17283	-0.013654
3	5.5225715615E-09	1.9810050690E-09	0.60694	0.217717
4	-9.6518566859E-12	-4.1638518858E-12	-0.50810	-0.219198
5	5.3276602294E-15	2.5561466577E-15	0.13434	0.064456
@ Temp	500	VALUES	0.907600	0.883597







A	572	0.903	0.869	0.790	0.790	0.906	0.879
A	572	0.943	0.894	0.894	0.894	0.906	0.879
B	572	0.884989	0.877067	1.106509	1.106509	0.905603	0.878951
B	572	0.926064	0.892239	0.961538	0.961538	0.905603	0.878951
B	572	0.92233	0.894573	0.976331	0.976331	0.905603	0.878951
C	572	0.905467	0.883042	0.96138	0.96138	0.905603	0.878951
C	572	0.908884	0.880576	0.93673	0.93673	0.905603	0.878951
C	572	0.936219	0.878109	0.840592	0.840592	0.905603	0.878951
A	617	0.903	0.870	0.934	0.934	0.901	0.870
A	617	0.886	0.859	0.854	0.854	0.901	0.870
A	617	0.932	0.893	0.918	0.918	0.901	0.870
B	617	0.901	0.877	0.953	0.953	0.901	0.870
B	617	0.902	0.874	0.973	0.973	0.901	0.870
B	617	0.888	0.865	0.985	0.985	0.901	0.870
C	617	0.890945	0.867009	0.976171	0.976171	0.900827	0.86953
C	617	0.922551	0.874409	0.843057	0.843057	0.900827	0.86953
C	617	0.905467	0.866393	0.887428	0.887428	0.900827	0.86953
A	662	0.867729	0.848388	0.976868	0.976868	0.894883	0.859728
A	662	0.858167	0.838774	0.934164	0.934164	0.894883	0.859728
A	662	0.906773	0.865812	0.880783	0.880783	0.894883	0.859728
B	662	0.882001	0.853725	0.973373	0.973373	0.894883	0.859728
B	662	0.905153	0.86773	0.949704	0.949704	0.894883	0.859728
B	662	0.893951	0.868314	1.044379	1.044379	0.894883	0.859728
C	662	0.888	0.849	0.927	0.927	0.895	0.860
C	662	0.930	0.871	0.907	0.907	0.895	0.860
C	662	0.895	0.857	0.895	0.895	0.895	0.860
A	752	0.885	0.851	0.910	0.910	0.882	0.841
A	752	0.870	0.835	0.905	0.905	0.882	0.841
A	752	0.877	0.833	0.801	0.801	0.882	0.841
B	752	0.893204	0.84789	0.997041	0.997041	0.881943	0.841066
B	752	0.871546	0.838553	1.014793	1.014793	0.881943	0.841066
B	752	0.87304	0.839136	0.970414	0.970414	0.881943	0.841066
C	752	0.877278	0.839877	0.95645	0.95645	0.881943	0.841066
C	752	0.886674	0.83741	0.862777	0.862777	0.881943	0.841066
C	752	0.890945	0.844193	0.806081	0.806081	0.881943	0.841066
A	797	0.870	0.833	0.857	0.857	0.878	0.834
A	797	0.837	0.810	0.937	0.937	0.878	0.834
A	797	0.894	0.850	0.950	0.950	0.878	0.834
B	797	0.877	0.837	0.988	0.988	0.878	0.834
B	797	0.889	0.845	0.902	0.902	0.878	0.834
B	797	0.871	0.835	1.033	1.033	0.878	0.834
C	797	0.868736	0.82631	0.912079	0.912079	0.877799	0.834145
C	797	0.872153	0.82446	0.902219	0.902219	0.877799	0.834145
C	797	0.931093	0.849126	0.830731	0.830731	0.877799	0.834145

Section IID **Table 2A,2B** **US Customary Units**

	A	B	C	D	E	F	G	H
4	Specifications	(Enter size range here)(Enter size range here)(Enter size range here)						
5	Type/Grade							
6	Min TS in B6 (ksi)	160		(If SI spec use hard coversions for columns D and E)				
7	Min YS in B7 (ksi)	100		(If SI spec use hard coversions for columns D and E)				
9		Ratio/Stress=A+B(T-T0)+C(T-T0)^2+D(T-T0)^3+E(T-T0)^4+F(T-T0)^5						
10		A	B	C	D	E	F	T0 (F)
11	Enter Ry Constants	1	-3.18892E-04	-7.53276E-07	5.52257E-09	-9.65186E-12	5.32766E-15	69.8
12	Enter Rt Constants	1	-3.45977E-04	-5.95116E-08	1.98101E-09	-4.16385E-12	2.55615E-15	69.8

Term	Coefficients
Term	**YS**
0	1
1	-3.18891776259989E-04
2	-7.53276367504441E-07
3	5.52257173325188E-09
4	-9.65185657092471E-12
5	5.32766020834357E-15
Term	**UTS**
0	1
1	-3.45977430697531E-04
2	-5.95115601242924E-08
3	1.98100513770783E-09
4	-4.16385198889757E-12
5	2.55614659382911E-15

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
19	Temperature deg F			75	100	150	200	250	300	350	400	500	550	600	650	700	750	800
21	**Min YS Ratio, Ry**			**1.000**	**1.000**	**0.972**	**0.955**	**0.941**	**0.930**	**0.923**	**0.918**	**0.911**	**0.908**	**0.903**	**0.897**	**0.889**	**0.882**	**0.878**
22	**MinYS, SyRy (Y-1)**		**(B7)*(C$21)**	**100.0**	**100.0**	**97.2**	**95.5**	**94.1**	**93.0**	**92.3**	**91.8**	**91.1**	**90.8**	**90.3**	**89.7**	**88.9**	**88.2**	**87.8**
23	**Min TS Ratio, Rt**			**1.000**	**1.000**	**0.973**	**0.957**	**0.943**	**0.931**	**0.921**	**0.911**	**0.893**	**0.883**	**0.873**	**0.862**	**0.851**	**0.841**	**0.834**
24	Min TS, StRt		(B6)*(C$23)	160.0	160.0	155.6	153.2	150.9	149.0	147.3	145.8	142.9	141.3	139.7	138.0	136.2	134.6	133.4
25	**1.1*Min TS., 1.1StRt (U)**		**1.1*(C24)**	**176.0**	**176.0**	**171.2**	**168.5**	**166.0**	**163.9**	**162.0**	**160.4**	**157.2**	**155.5**	**153.7**	**151.8**	**149.9**	**148.1**	**146.7**
29	0.9 SyRy		0.9*(C22)	90.0	90.0	87.5	86.0	84.7	83.7	83.0	82.6	82.0	81.7	81.2	80.7	80.0	79.4	79.0
30	2/3 SyRy		(2/3)*(C22)	66.7	66.7	64.8	63.7	62.7	62.0	61.5	61.2	60.7	60.5	60.2	59.8	59.3	58.8	58.5
31	St/3		(B6)/3	53.3	53.3	53.3	53.3	53.3	53.3	53.3	53.3	53.3	53.3	53.3	53.3	53.3	53.3	53.3
32	1.1StRt/3		1.1*(C24)/3	58.7	58.7	57.1	56.2	55.3	54.6	54.0	53.5	52.4	51.8	51.2	50.6	50.0	49.4	48.9
33	2/3Sy		(2/3)*B7	66.7	66.7	66.7	66.7	66.7	66.7	66.7	66.7	66.7	66.7	66.7	66.7	66.7	66.7	66.7
39	Design Stress - Hi	(ksi)	MIN(C$29,C$3	53.3	53.3	53.3	53.3	53.3	53.3	53.3	53.3	52.4	51.8	51.2	50.6	50.0	49.4	48.9
40	**Design Stress - Lo**	**(ksi)**	**MIN(C$30,C$3**	**53.3**	**53.3**	**53.3**	**53.3**	**53.3**	**53.3**	**53.3**	**53.3**	**52.4**	**51.8**	**51.2**	**50.6**	**50.0**	**49.4**	**48.9**
44	Design Stress * 0.85 - Hi	(ksi)	=0.85*C39	45.3	45.3	45.3	45.3	45.3	45.3	45.3	45.3	44.5	44.1	43.5	43.0	42.5	42.0	41.6
45	Design Stress * 0.85 - Lo	(ksi)	=0.85*C40	45.3	45.3	45.3	45.3	45.3	45.3	45.3	45.3	44.5	44.1	43.5	43.0	42.5	42.0	41.6

Section IID **Table 2A,2B** **SI Metric Units**

Specifications	(Enter size range here)(Enter size range here)(Enter size range here)
Type/Grade	
Min TS in B6 (ksi)	1103.161499 — **Metric is 585 If CU spec the soft conversion will appear in B6**
Min YS in B7 (ksi)	689.4758911 — **Metric is 415 If CU spec the soft conversion will appear in B7**

Ratio/Stress=A+B(T-T0)+C(T-T0)^2+D(T-T0)^3+E(T-T0)^4+F(T-T0)^5

	A	B	C	D	E	F	T0 (C)
Enter Ry Constants	1	-5.74005E-04	-2.44062E-06	3.22076E-08	-1.01321E-10	1.00670E-13	21
Enter Rt Constants	1	-6.22759E-04	-1.92817E-07	1.15532E-08	-4.37104E-11	4.83001E-14	21

	Coefficients
Term	**YS**
0	1
1	-5.74005169897280E-04
2	-2.44061519795918E-06
3	3.22076337409858E-08
4	-1.01321310213432E-10
5	1.00669738444055E-13
Term	**UTS**
0	1
1	-6.22759345560075E-04
2	-1.92817436414203E-07
3	1.15532203104105E-08
4	-4.37104443015449E-11
5	4.83001165544386E-14

Temperature deg C		21	40	65	100	125	150	175	200	225	250	275	300	325	350	375	400	425	450
Min YS Ratio, Ry		**1.000**	**1.000**	**0.972**	**0.952**	**0.940**	**0.930**	**0.923**	**0.918**	**0.915**	**0.912**	**0.909**	**0.906**	**0.901**	**0.895**	**0.888**	**0.882**	**0.878**	**0.878**
MinYS, SyRy (Y-1)	**=(B7)*(C$21**	**689**	**689**	**670.4**	**656.1**	**647.8**	**641.2**	**636.4**	**633.1**	**630.8**	**628.9**	**626.9**	**624.4**	**621.1**	**617.0**	**612.4**	**608.1**	**605.2**	**605.2**
Min TS Ratio, Rt		**1.000**	**1.000**	**0.973**	**0.954**	**0.942**	**0.931**	**0.921**	**0.913**	**0.904**	**0.896**	**0.888**	**0.879**	**0.870**	**0.860**	**0.850**	**0.841**	**0.834**	**0.831**
Min TS, StRt	=(B6)*(C$23	1103.2	1103.2	1073.4	1052.1	1038.8	1026.9	1016.4	1006.8	997.7	988.7	979.4	969.6	959.2	948.4	937.7	927.8	920.2	916.5
1.1*Min TS., 1.1StRt (U)	**=1.1*(C24)**	**1213**	**1213**	**1180.8**	**1157.3**	**1142.6**	**1129.6**	**1118.0**	**1107.4**	**1097.4**	**1087.6**	**1077.4**	**1066.6**	**1055.2**	**1043.3**	**1031.4**	**1020.6**	**1012.2**	**1008.2**
0.9 SyRy	=0.9*(C22)	620.5	620.5	603.4	590.5	583.0	577.1	572.8	569.8	567.7	566.0	564.2	562.0	559.0	555.3	551.2	547.3	544.7	544.7
2/3 SyRy	=(2/3)*(C22)	459.7	459.7	447.0	437.4	431.8	427.5	424.3	422.1	420.5	419.2	417.9	416.3	414.1	411.3	408.3	405.4	403.5	403.5
St/3	=(B6)/3	367.7	367.7	367.7	367.7	367.7	367.7	367.7	367.7	367.7	367.7	367.7	367.7	367.7	367.7	367.7	367.7	367.7	367.7
1.1StRt/3	=1.1*(C24)/3	404.5	404.5	393.6	385.8	380.9	376.5	372.7	369.1	365.8	362.5	359.1	355.5	351.7	347.8	343.8	340.2	337.4	336.1
2/3Sy	=(2/3)*B7	459.7	459.7	459.7	459.7	459.7	459.7	459.7	459.7	459.7	459.7	459.7	459.7	459.7	459.7	459.7	459.7	459.7	459.7
Design Stress - Hi	MIN(C$29,C$3	368	368	368	368	368	368	368	368	366	363	359	356	352	348	344	340	337	336
Design Stress - Lo	**MIN(C$30,C$3**	**368**	**368**	**368**	**368**	**368**	**368**	**368**	**368**	**366**	**363**	**359**	**356**	**352**	**348**	**344**	**340**	**337**	**336**
Design Stress * 0.85 - Hi	=0.85*C39	313	313	313	313	313	313	313	313	311	308	305	302	299	296	292	289	287	286
Design Stress * 0.85 - Lo	=0.85*C40	313	313	313	313	313	313	313	313	311	308	305	302	299	296	292	289	287	286

Approval Date: February 15, 1994

See Numeric Index for expiration and any reaffirmation dates.

Case N-60-5 **Material for Core Support Structures** **Section III, Division 1**	
Inquiry: What materials, in addition to those listed in Tables 2A, 2B, and 4, Section II, Part D, Subpart 1, may be used for core support structures constructed to the requirements of Subsection NG of Section III, Division 1?	
Reply: It is the opinion of the Committee that the materials and stress intensity values listed in Table A may be used in the construction of core support structures in addition to those listed in Tables 2A, 2B and 4, Section II, Part D, Subpart 1. The following additional requirements shall be met.	
(a) All other requirements of Subsection NG of Section III, Division 1, shall be met.	
(b) Strain hardened SA-479 shall be identified with this Case number.	
(c) Where welds are applied to strain hardened material, the stress intensity in the sections of the material where the temperatures during welding exceed 800°F shall not exceed values for annealed materials.	
(d) Yield strength values are listed in Table B.	
(e) Tensile strength values are listed in Table C.	
(f) Chemical composition for Ni-Cr-Fe ASTM B 637 Types 1 and 2 is listed in Table D.	
(g) Heat treatments for Ni-Cr-Fe ASTM B 637 Types 1 and 2 are listed in Table E.	Insert and Grade 718 Type 2
(h) Room temperature mechanical properties for Ni-Cr-Fe ASTM B 637 Types 1 and 2 are listed in Table F.	Insert and Grade 718 Type 2

TABLE A

Nominal Composition	P No.	Prod. Form	Spec. No.	Type or Grade	Notes	Min. Yield Str.	Min. Ult. Tens. Str.	Stress Intensity, Kips/sq in. for Metal Temperature, °F, Not to Exceed									
								100	200	300	400	500	600	650	700	750	800
13Cr	6	Plate	SA-240	TP-410		30.0	60.0	20.0	18.4	17.7	17.4	17.2	16.8	16.5	16.2	15.7	15.1
22Cr-13Ni-5Mn	...	Plate	SA-240	XM-19	7,8	55.0	100.0	33.3	33.2	31.4	30.2	29.7	29.2	29.0	28.8	28.5	28.2
22Cr-13Ni-5Mn	...	Bar	A 479-74	XM-19	7,8	55.0	100.0	33.3	33.2	31.4	30.2	29.7	29.2	29.0	28.8	28.5	28.2
18Cr-8Ni	8	FFBS	SA-193	B8	7	30.0	75.0	20.0	20.0	20.0	18.7	17.4	16.4	16.1	15.9	15.5	15.1
16Cr-12Ni-2Mo	8	FFBS	SA-193	B8M	7	30.0	75.0	20.0	20.0	20.0	19.2	17.9	17.0	16.6	16.3	16.0	15.8
18Cr-10Ni-Ti	8	FFBS	SA-193	B8T	7	30.0	75.0	20.0	20.0	20.0	19.2	17.9	17.0	16.6	16.3	16.0	15.8
18Cr-10Ni-Cb	8	FFBS	SA-193	B8C	7	30.0	75.0	20.0	20.0	20.0	20.0	19.9	19.3	18.9	18.6	18.4	18.3
26Ni-15Cr-2Ti	...	FFBS	SA-453	660	5,7	85.0	130.0	43.3	43.3	43.3	43.3	43.3	43.3	43.3	43.3	43.3	42.6
18Cr-8Ni	8	Smls Tube	A 511-71	MT304	6,7	30	75	20.0	20.0	20.0	18.7	17.4	16.4	16.1	15.9	15.5	15.1
18Cr-8Ni	8	Smls Tube	A 511-71	MT304L	6,7	25	70	16.6	16.6	16.6	15.7	14.7	13.9	13.7	13.4	13.2	13.0
16Cr-12Ni-2Mo	8	Smls Tube	A 511-71	MT316	6,7	30	75	20.0	20.0	20.0	19.2	17.9	17.0	16.6	16.3	16.0	15.8
16Cr-12Ni-2Mo	8	Smls Tube	A 511-71	MT316L	6,7	25	70	16.6	16.6	16.6	15.5	14.4	13.5	13.2	12.8	12.6	12.3
18Cr-8Ni	8	Weld Tube	A 554-72	MT304	6,7	30	75	20.0	20.0	20.0	18.7	17.4	16.4	16.1	15.9	15.5	15.1
18Cr-8Ni	8	Weld Tube	A 554-72	MT304L	6,7	25.0	70.0	16.6	16.6	16.6	15.7	14.7	13.9	13.7	13.4	13.2	13.0
16Cr-12Ni-2Mo	8	Weld Tube	A 554-72	MT316	6,7	30	75	20.0	20.0	20.0	19.2	17.9	17.0	16.6	16.3	16.0	15.8
16Cr-12Ni-2Mo	8	Weld Tube	A 554-72	MT316L	6,7	25.0	70.0	16.6	16.6	16.6	15.5	14.4	13.5	13.2	12.8	12.6	12.3
Ni-Cr-Fe	...	FFBS	SB-637	688	9	40	100	26.7	26.1	25.5	25.1	24.6	24.3	24.1	24.0	23.9	23.8
Ni-Cr-Fe	...	FFBS	SB-637	688	5,10	90	140	46.7	46.7	46.7	46.7	46.7	46.7	46.7	46.7	46.7	46.5
Ni-Cr-Fe	...	FFBS	SB-637	688	5,11	115	170	56.7	56.7	56.7	56.7	56.7	56.7	56.7	56.7	56.7	56.5
Ni-Cr-Fe	...	FFBS	SB-637	688	5,12	100	160	53.3	53.3	53.3	53.3	53.3	53.3	53.3	53.3	53.3	53.1
Ni-Cr-Fe	43	Plate	SB-168	...	15	35	80	23.3	23.2	23.3	23.3	23.3	23.3	23.3	23.3	23.3	23.3
Ni-Cr-Fe	...	FFBS	B 637	TP-1	5	100	160	53.3	53.3	53.3	53.3	53.3	53.2	52.7	52.1	51.5	...
Ni-Cr-Fe	...	FFBS	B 637	TP-2	5	85	150	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	...
16Cr-12Ni-2Mo	8	FFBS	SA-479	316	1,2,7,13	60	85	28.3	28.3	26.8	25.9	25.7	25.7	25.7	25.7	25.7	25.4
16Cr-12Ni-2Mo	8	FFBS	SA-479	316	1,2,7,14	65	85	28.3	28.3	26.8	25.9	25.7	25.7	25.7	25.7	25.7	25.4
16Cr-12Ni-2Mo	8	FFBS	SA-193	B8M	1,2,7	50	90	30.0	30.0	28.3	27.4	26.8	26.4	26.1	25.7	25.2	24.6
16Cr-12Ni-2Mo	8	FFBS	SA-193	B8M	1,2,7	65	90	31.6	31.6	29.9	29.0	28.7	28.7	28.7	28.7	28.7	28.4
16Cr-12Ni-2Mo	8	FFBS	SA-193	B8M	1,2,3,5,7	80	100	33.3	33.3	31.5	30.5	30.2	30.2	30.2	30.2	30.2	29.9
16Cr-12Ni-2Mo	8	FFBS	SA-193	B8M	1,2,4,5,7	95	110	36.6	36.6	34.6	33.5	33.3	33.3	33.3	33.3	33.3	32.8

Insert A: See attached page

TABLE A (CONT'D)

NOTES:

(1) Strain hardened. (The tensile properties for these items shall meet the minimum specified. These materials shall conform to all other requirements of the referenced specification. Surface hardness as shown in SA-479 is not required.)

(2) Yield strength values are listed in Table B.

(3) Maximum tensile strength—140,000 psi.

(4) Maximum tensile strength—150,000 psi.

(5) The designer shall consider the effects of temperature and environment on the material properties of precipitation hardening alloys and cold worked austenitic stainless steels.

(6) Supplementary requirement S-2 for tensile testing of the specification is mandatory.

(7) At temperatures above 100°F, the design stress intensity values may exceed 66⅔% and may also reach 90% of the yield strength (0.2% offset) at temperature. This may result in a permanent strain of as much as 0.1%. When this amount of deformation is not acceptable, the designer should reduce the design stress intensity to obtain an acceptable deformation. Section III, Division 1, Table 1-2.4 lists multiplying factors which, when applied to the yield strength values shown on Table I-2.2, will give a design stress intensity that will result in lower levels of permanent strain.

(8) The S_y values for Type XM-19 stainless steels vary with the annealing temperature (see Table B).

(9) Solution heat treated.

(10) Type 1.

(11) Type 2.

(12) Type 3.

(13) Over 2 in.

(14) Up to and including 2 in.

(15) Hot finished.

Insert A': See attached page

TABLE B

Nominal Composition	Prod. Form	Spec. No.	Type or Grade	Notes	Spec. Min. Yield	100	200	300	400	500	600	650	700	750	800
Yield Strength Values S_y						Yield Strength, Kips/sq in. for Metal Temperature °F, Not to Exceed									
18Cr-8Ni	Smls Tube	A 511-71	MT304	...	30.0	30.0	25.0	22.5	20.7	19.4	18.2	17.9	17.7	17.3	16.8
18Cr-8Ni	Smls Tube	A 511-71	MT304L	...	25.0	25.0	21.3	19.1	17.5	16.3	15.5	15.2	14.9	14.7	14.4
16Cr-12Ni-2Mo	Smls Tube	A 511-71	MT316	...	30.0	30.0	25.8	23.3	21.4	19.9	18.8	18.5	18.1	17.8	17.6
16Cr-12Ni-2Mo	Smls Tube	A 511-71	MT316L	...	25.0	25.0	21.1	18.9	17.2	15.4	15.0	14.6	14.3	14.0	13.7
18Cr-8Ni	Wld Tube	A 554-72	MT304	...	30.0	30.0	25.0	22.5	20.7	19.4	18.2	17.9	17.7	17.3	16.8
18Cr-8Ni	Wld Tube	A 554-72	MT304L	...	25.0	25.0	21.3	19.1	17.5	16.3	15.5	15.2	14.9	14.7	14.4
16Cr-12Ni-2Mo	Wld Tube	A 554-72	MT316	...	30.0	30.0	25.8	23.3	21.4	19.9	18.8	18.5	18.1	17.8	17.6
16Cr-12Ni-2Mo	Wld Tube	A 554-72	MT316L	...	25.0	25.0	21.2	18.9	17.2	15.9	15.0	14.6	14.3	14.0	13.7
Ni-Cr-Fe	FFBS	SB-637	688	3	40.0	40.0	39.1	38.3	37.6	36.9	36.4	36.2	36.0	35.9	35.7
Ni-Cr-Fe	FFBS	SB-637	688	4	90.0	90.0	87.7	86.4	85.3	84.5	84.1	83.9	83.8	83.7	83.6
Ni-Cr-Fe	FFBS	SB-637	688	5	115.0	115.0	112.0	110.2	109.0	108.0	107.5	107.2	107.0	106.9	106.8
Ni-Cr-Fe	FFBS	SB-637	688	6	100.0	100.0	99.0	95.2	94.0	93.1	92.5	92.2	92.0	91.9	91.8
Ni-Cr-Fe	FFBS	B 637	TP-1	...	100.0	100.0	97.1	95.2	93.4	92.0	90.0	90.4	90.1	89.9	...
Ni-Cr-Fe	FFBS	B 637	TP-2	...	85.0	85.0	82.4	81.2	80.4	79.9	79.8	79.8	79.8	79.8	...
16Cr-12Ni-2Mo	FFBS	SA-479	316	7	60.0	60.0	55.1	52.1	49.8	48.3	47.5	47.0	46.3	45.4	44.5
16Cr-12Ni-2Mo	FFBS	SA-479	316	8	65.0	65.0	59.8	56.5	54.0	52.3	51.4	50.9	50.1	49.1	48.1
Ni-Cr-Fe	Plate	SB-168		9	35.0	35.0	32.7	31.0	29.8	28.8	27.9	27.4	27.0	26.5	26.1
16Cr-12Ni-2Mo	FFBS	SA-193	B8M	...	50.0	50.0	46.0	43.5	41.5	40.3	39.6	39.2	38.6	37.8	37.0
16Cr-12Ni-2Mo	FFBS	SA-193	B8M	...	65.0	65.0	59.8	56.5	54.0	52.3	51.4	50.9	50.1	49.1	48.1
16Cr-12Ni-2Mo	FFBS	SA-193	B8M	...	80.0	80.0	73.5	69.6	56.5	64.5	53.3	62.6	61.8	60.5	59.0
16Cr-12Ni-2Mo	FFBS	SA-193	B8M	...	95.0	95.0	87.5	82.6	78.9	76.5	75.1	74.4	73.3	71.9	70.5
22Cr-13Ni-5Mn	Plate	SA-240	XM-19	1	55.0	55.0	47.0	43.4	40.8	38.8	37.3	36.8	36.3	35.8	35.3
22Cr-13Ni-5Mn	Bar	A 479-74	XM-19	1	55.0	55.0	47.0	43.4	40.8	38.8	37.3	36.8	36.3	35.8	35.3
22Cr-13Ni-5Mn	Plate	SA-240	XM-19	2	55.0	55.0	44.6	39.3	35.7	33.3	32.0	31.5	31.4	31.2	31.1
22Cr-13Ni-5Mn	Bar	A 479-74	XM-19	2	55.0	55.0	44.6	39.3	35.7	33.3	32.0	31.5	31.4	31.2	31.1

Insert B: See attached Page

NOTES:
(1) For material annealed at 1925-1975°F.
(2) For material annealed at 2025-2075°F.
(3) Solution heat treated.
(4) Type 1.
(5) Type 2.
(6) Type 3.
(7) Over 2 in.
(8) Up to and including 2 in.
(9) Hot finished.

Insert B': See attached Page

Insert C : See attached page

TABLE C
MATERIALS PROPERTIES, SUBSECTION NG TENSILE STRENGTHS, S_u

Tensile Strength Values, S_u for Austenitic Steel and High Nickel Alloys for Class 1 Components

Nominal Composition	Prod. Form	Spec. No.	Type or Grade	Spec. Min. T.S.	100	200	300	400	500	600	650	700	750	800
					Temperature, °F									
18Cr-8Ni	FFBS	SA-193	B8	75.0	75.0	70.9	66.0	64.3	63.5	63.5	63.5	63.5	63.2	62.6
16Cr-12Ni-2Mo	FFBS	SA-193	B8M	75.0	75.0	75.0	73.4	71.8	71.8	71.8	71.8	71.8	71.5	71.0
18Cr-10Ni-Ti	FFBS	SA-193	B8T	75.0	75.0	73.4	67.3	68.5	68.5	68.5	68.5	68.5	68.5	68.5
18Cr-10Ni-Cb	FFBS	SA-193	B8C	75.0	75.0	71.8	66.0	61.9	60.2	59.4	58.9	58.5	58.5	58.5
26Ni-15Cr-2Ti	FFBS	SA-453	660	130.0	130.0	130.0	130.0	130.0	130.0	130.0	130.0	130.0	130.0	130.0
18Cr-8Ni	Smls. Tube	A 511	MT304	75.0	75.0	70.9	66.0	64.3	63.5	63.5	63.5	63.5	63.2	62.6
18Cr-8Ni	Smls. Tube	A 511	MT304L	70.0	70.0	66.2	60.8	58.5	57.7	57.0	56.6	56.2	55.8	55.4
16Cr-12Ni-2Mo	Smls. Tube	A 511	MT316	75.0	75.0	75.0	73.4	71.8	71.8	71.8	71.8	71.8	71.5	71.0
16Cr-12Ni-2Mo	Smls. Tube	A 511	MT316L	70.0	70.0	67.7	63.9	62.4	61.6	61.6	61.6	61.6	61.2	60.8
18Cr-8Ni	Wld. Tube	A 554	MT304	75.0	75.0	70.9	66.0	64.3	63.5	63.5	63.5	63.5	63.2	62.6
16Cr-12Ni-2Mo	Wld. Tube	A 554	MT316	75.0	75.0	75.0	73.4	71.8	71.8	71.8	71.8	71.8	71.5	71.0
Ni-Cr-Fe	FFBS	SB-637	Solu. Treated 688	100.0	100.0	100.0	100.0	100.0	100.0	99.4	98.8	98.5	98.2	98.0
Ni-Cr-Fe	FFBS	SB-637	Type 1 688	140.0	140.0	140.0	140.0	140.0	140.0	140.0	140.0	140.0	140.0	139.8
Ni-Cr-Fe	FFBS	SB-637	Type 2 688	170.0	170.0	170.0	170.0	170.0	170.0	170.0	170.0	170.0	170.0	169.8
Ni-Cr-Fe	FFBS	SB-637	Type 3 688	160.0	160.0	160.0	160.0	160.0	160.0	160.0	160.0	160.0	160.0	159.2
~~Ni-Cr-Fe~~	~~FFBS~~	~~B 637~~	~~Type 1~~	~~160.0~~	~~160.0~~	~~156.4~~	~~152.7~~	~~150.2~~	~~147.8~~	~~145.2~~	~~143.8~~	~~142.2~~	~~140.4~~	...
Ni-Cr-Fe	FFBS	B 637	Type 2	150.0	150.0	147.2	145.5	144.0	142.5	140.9	140.0	139.1	138.7	...
16Cr-12Ni-2Mo	FFBS	SA-479	316	85.0	85.0	85.0	80.3	77.6	77.1	77.1	77.1	77.1	77.1	76.3
16Cr-12Ni-2Mo	FFBS	SA-193	B8M	90.0	90.0	90.0	85.1	82.4	81.6	81.6	81.6	81.6	81.6	80.9
16Cr-12Ni-2Mo	FFBS	SA-193	B8M	100.0	100.0	100.0	94.6	91.5	90.8	90.8	90.8	90.8	90.8	89.6
16Cr-12Ni-2Mo	FFBS	SA-193	B8M	110.0	110.0	110.0	104.0	100.7	99.9	99.9	99.9	99.9	99.9	98.6
13Cr	Plate	SA-240	410	60.0	60.0	60.0	58.9	57.7	56.9	55.4	54.5	53.0	51.3	49.1
16Cr-12Ni-2Mo	Wld. Tube	A 554	MT316L	70.0	70.0	67.7	63.9	62.4	61.6	61.6	61.6	61.6	61.2	60.3
18Cr-8Ni	Wld. Tube	A 554	MT304L	70.0	70.0	66.2	60.8	58.5	57.7	57.0	56.6	56.2	55.8	55.0
15Cr-26Ni-2Ti	FFBS	SA-638	660	130.0	130.0	130.0	130.0	130.0	130.0	130.0	130.0	130.0	130.0	130.0
18Cr-10Ni-Cb	FFBS	SA-182	F347	75.0	75.0	71.8	66.0	61.7	60.2	59.4	58.9	58.5	58.5	58.5
18Cr-8Ni	FFBS	SA-479	304	75.0	75.0	71.0	66.0	64.3	63.5	63.5	63.5	63.5	63.1	62.6
16Cr-12Ni-2Mo	FFBS	SA-479	316	75.0	75.0	75.0	73.4	71.8	71.8	71.8	71.8	71.8	71.4	70.9
18Cr-10Ni-Cb	FFBS	SA-479	347	75.0	75.0	71.8	66.0	61.9	60.2	59.4	58.9	58.5	58.5	58.5
18Cr-8Ni	FFBS	SA-479	304L	70.0	70.0	66.2	60.8	58.5	57.7	57.0	56.6	56.2	55.8	55.4
16Cr-12Ni-2Mo	FFBS	SA-479	316L	70.0	70.0	67.9	63.9	62.4	61.6	61.6	61.6	61.6	61.2	60.8
18Cr-8Ni	Nuts	SA-194	8	75.0	75.0	71.0	66.0	64.3	63.5	63.5	63.5	63.5	63.1	62.6
18Cr-10Ni-Cb	Nuts	SA-194	8C	75.0	75.0	71.8	66.0	61.9	60.2	59.4	58.9	58.5	58.5	58.5
16Cr-12Ni-2Mo	Nuts	SA-194	8M	75.0	75.0	75.0	73.4	71.8	71.8	71.8	71.8	71.8	71.4	70.9
22Cr-13Ni-5Mn	Plate	SA-240	XM-19	100.0	100.0	99.5	94.3	90.7	89.1	87.8	87.1	86.5	85.7	84.8
22Cr-13Ni-5Mn	Bar	A 479-74	XM-19	100.0	100.0	99.5	94.3	90.7	89.1	87.8	87.1	86.5	85.7	84.8

GENERAL NOTE: The tabulated values of tensile strength and yield strength are those which the Committee believes are suitable for use in design calculations required by this Case. At temperatures above room temperature the values of tensile strength tend toward an average or expected value which may be as much as 10% above the tensile strength trend curve adjusted to the minimum specified room temperature tensile strength. At temperatures above room temperature the yield strength values correspond to the yield strength trend curve adjusted to the minimum specified room temperature yield strength. Neither the tensile strength nor the yield strength values correspond exactly to either *average* or *minimum* as these terms are applied to a statistical treatment of a homogeneous set of data. Neither the ASME Material Specifications nor the rules of this Section require elevated temperature testing for tensile or yield strengths of production material for use in Code components. It is not intended that results of such tests, if performed, be compared with these tabulated tensile and yield strength values for ASME Code acceptance/rejection purposes for materials. If some elevated temperature tests results on production material are lower than these tabulated values by a large amount (more than the typical variability of material and suggesting the possibility of some error) further investigation by retest or other means should be considered.

Insert C′ : See attached page

TABLE D
ASTM B 637 TYPES 1 AND 2
CHEMICAL REQUIREMENTS

Element	Percent
Carbon	0.020 – 0.060
Manganese	1.00 max
Silicon	0.50 max
Phosphorus	0.008 max
Sulfur	0.003 max
Chromium	14.50 – 17.00
Cobalt	0.050 max
Columbium + Tantalum	0.70 – 1.20
Titanium	2.25 – 2.75
Alumunium	0.40 – 1.00
Boron	0.007 max
Iron	5.00 – 9.00
Copper	0.50 max
Zirconium	0.050 max
Vanadium	0.10 max
Nickel	70.00 min

No change to Table D Chemical Requirements for Grade 718 Type 2 are the same as B637 Grade 718

TABLE E
ASTM B 637 HEAT TREATMENT

Solution Annealing	Precipitation Hardening
Type 1	
1975°F ± 25°F, hold 1 to 2 h, cool by water or oil quenching	1320°F ± 25°F, hold 20 h, +2 −0 h, air cool
Type 2	
1975°F ± 25°F, hold 1 to 2 h, cool by water or oil quenching	1400°F ± 25°F, hold 100 h, +4 −0 h, air cool
Grade 718 Type 2	
1850° to 1922°F, hold 1 to 2 h, cool by water or oil quenching	1300°F ±15°F, hold 6 h +1h -0 min., air cool

Add Heat treatment for Grade 718 Type 2 to Table E

TABLE F
ASTM B 637 MECHANICAL PROPERTIES
(Minimum Room Temperature)

Add Mechanical Properties for Grade 718 Type 2 to Table F

Property	Type 1	Type 2	Grade 718 Type 2
Yield strength psi	100,000	85,000	100,000
Tensile strength psi	160,000	150,000	160,000
Elongation in 2 in. %	20	20	20
Reduction of area %	20	20	20
Hardness	267–363 HB 27–40 RC		267-363 HBW 27-40 HRC

Table A

								Stress Intensity, Kips/sq in. ~~(MPa)~~ for Metal Temperature, °F ~~(°C)~~, Not to Exceed									
Nominal Composition	P No.	Prod. Form	Spec. No.	Type or Grade	Notes	Min. Yield Str.	Min. Unit. Tens. Str.	100 ~~(38)~~	200 ~~(93)~~	300 ~~(149)~~	400 ~~(204)~~	500 ~~(260)~~	600 ~~(316)~~	650 ~~(343)~~	700 ~~(371)~~	750 ~~(399)~~	800 ~~(427)~~
Ni-Cr-Fe	....	FFBS	SB-637	718 Type 2	16	100 ~~(689)~~	160 ~~(1103)~~	53.3 ~~(368)~~	53.3 ~~(368)~~	53.3 ~~(368)~~	53.3 ~~(368)~~	52.3 ~~(361)~~	51.2 ~~(353)~~	50.7 ~~(349)~~	50.1 ~~(345)~~	49.5 ~~(341)~~	48.8 ~~(336)~~

Insert A

NOTES: (16) Chemical composition of Grade 718 Type 2 is same as that of conventional Grade 718 (Type 1). Heat treatment condition of Type 2 is modified for that of Type 1.

Insert A'

Table B

Yield Strength Values Sy						Yield Strength, Kips/sq in. ~~(MPa)~~ for Metal Temperature, °F ~~(°C)~~, Not to Exceed									
Nominal Composition	Prod. Form	Spec. No.	Type or Grade	Notes	Spec. Min. Yield	100 ~~(38)~~	200 ~~(93)~~	300 ~~(149)~~	400 ~~(204)~~	500 ~~(260)~~	600 ~~(316)~~	650 ~~(343)~~	700 ~~(371)~~	750 ~~(399)~~	800 ~~(427)~~
Ni-Cr-Fe	FFBS	SB-637	718 Type 2	10	100.0 ~~(689)~~	98.6 ~~(680)~~	95.4 ~~(658)~~	93.3 ~~(643)~~	91.9 ~~(633)~~	90.9 ~~(627)~~	90.1 ~~(621)~~	89.6 ~~(618)~~	89.1 ~~(614)~~	88.4 ~~(609)~~	87.5 ~~(603)~~

Insert B

NOTES: (10) Chemical composition of Grade 718 Type 2 is same as that of conventional Grade 718 (Type 1). Heat treatment condition of Type 2 is modified for that of Type 1.

Insert B'

Table C

MATERIALS PROPERTIES, SUBSECTION NG TENSILE STRENGTHS, Su

Tensile Strength Values, Su, Kips/sq in. ~~(MPa)~~ for Austenitic Steel and High Nickel Alloys for Class 1 Components

					Temperature, °F ~~(°C)~~									
Nominal Composition	Prod. Form	Spec. No.	Type or Grade	Spec. Min. T.S.	100 ~~(38)~~	200 ~~(93)~~	300 ~~(149)~~	400 ~~(204)~~	500 ~~(260)~~	600 ~~(316)~~	650 ~~(343)~~	700 ~~(371)~~	750 ~~(399)~~	800 ~~(427)~~
Ni-Cr-Fe	FFBS	SB-637	718 Type 2	160.0 ~~(1103)~~	160.0 ~~(1103)~~	160.0 ~~(1103)~~	160.0 ~~(1103)~~	160.0 ~~(1103)~~	157.0 ~~(1082)~~	153.7 ~~(1060)~~	152.0 ~~(1048)~~	150.2 ~~(1036)~~	148.4 ~~(1023)~~	146.4 ~~(1009)~~

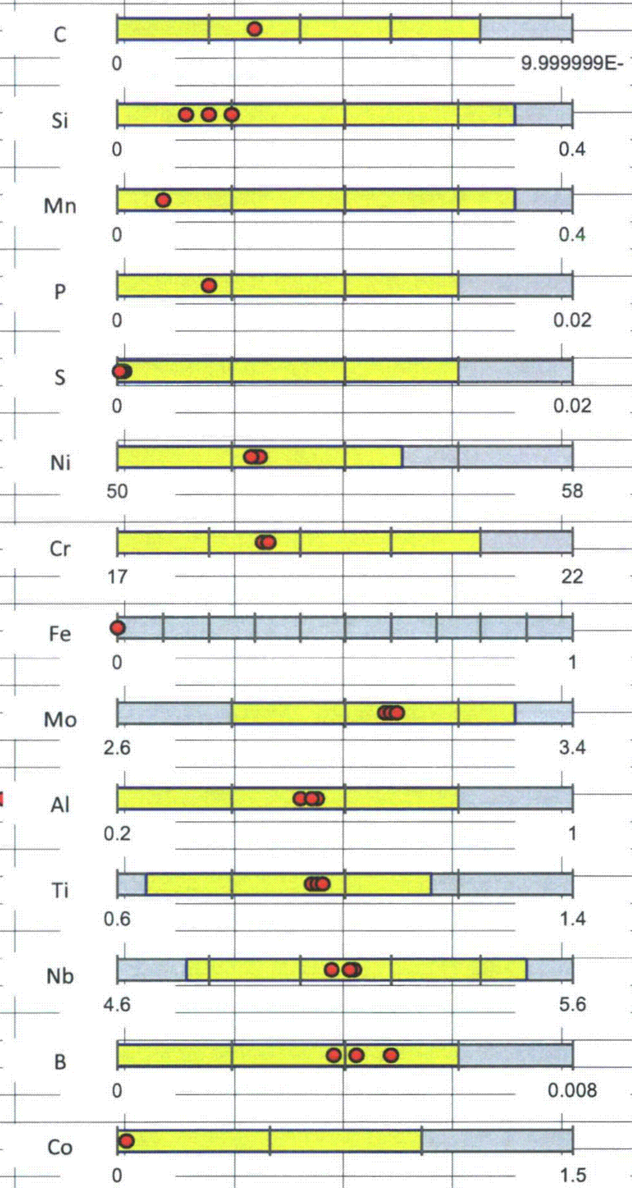
Insert C

NOTE: Chemical composition of Grade 718 Type 2 is same as that of conventional Grade 718 (Type 1). Heat treatment condition of Type 2 is modified for that of Type 1.

Insert C'

FFBS-Fittings, Forgings, Bars, Shapes

# Components	14			
Component	Balance	Nom	Min	Max
C	No		0	0.08
Si	No		0	0.35
Mn	No		0	0.35
P	No		0	0.015
S	No		0	0.015
Ni	No		50	55
Cr	No		17	21
Fe	Yes			
Mo	No		2.8	3.3
Al	No		0.2	0.8
Ti	No		0.65	1.15
Nb	No		4.75	5.5
B	No		0	0.006
Co	No		0	1



Number of Heats 3

CHEMISTRY

HEAT ID	LOT	C	Si	Mn	P	S	Ni	Cr	Fe	Mo	Al	Ti	Nb	B	Co
A		0.03	0.1	0.04	0.004	0.0003	52.41	18.59	0	3.07	0.52	0.94	5.12	0.0048	0.03
B		0.03	0.08	0.04	0.004	0.0002	52.49	18.65	0	3.08	0.55	0.95	5.07	0.0038	0.03
C		0.03	0.06	0.04	0.004	0.0001	52.34	18.65	0	3.09	0.54	0.96	5.11	0.0042	0.03

ENCLOSURE 4

SMV-2011-000034-NP, REVISION 0

TOSHIBA ENGINEERING REPORT

JET PUMP BEAM FABRICATION – COMPARISON OF MODIFIED ALLOY 718 AND ALLOY X-750 MATERIALS

(Non-Proprietary)

Nine Mile Point Nuclear Station, LLC
December 30, 2011

PSNE Control Number: WEC-2011-000199

Westinghouse Document Number	TR-MODS-11-4-NP

Toshiba Engineering Report
Jet Pump Beam Fabrication –

Comparison of Modified Alloy 718 and Alloy X-750 Materials

Rev.	Initial Issue Date	Issued by	Approved by	Reviewed by	Prepared by	Summary

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0	Dec. 26, 2011	Material Engineering Group	T. Tomiyama Dec. 26, 2011	T. Tomiyama Dec. 26, 2011	N. Tanaka Dec. 26, 2011	SMV-2011-000034-NP

TOSHIBA CORPORATION

Nuclear Energy Systems & Services Division

TABLE OF CONTENTS

1	INTRODUCTION	1
2	JET PUMP BEAM ASSEMBLY	1
2.1	BACKGROUND	1
2.2	MATERIAL OPTIMIZATION OF MODIFIED ALLOY 718	2
2.3	MANUFACTURING PROCESS OF MODIFIED ALLOY 718 JET-PUMP BEAM	3
2.4	MATERIAL PROPERTIES	4
2.5	CHEMICAL COMPOSITION	8
2.6	MODIFIED HEAT TREATMENT	8
2.7	MECHANICAL PROPERTY	10
2.8	SCC SUSCEPTIBILITY IN HIGH AND LOW TEMPERATURE WATER	15
2.9	GRAIN BOUNDARY ANALYSIS	17
2.10	LONG-TERM CONSTANT LOAD TEST	18
2.11	REQUIRED TESTS IN BWRVIP-84 AND BWRVIP-138	19
2.12	FATIGUE PROPERTY	23
2.13	RADIATION RELAXATION RATE	24
2.14	SPRING PROPERTY OF JET-PUMP BEAM	26
2.15	SUMMARY OF MATERIAL PROPERTY TESTS AS RELATED TO JP BEAMS	27
3	REFERENCES	28
	ATTACHMENT 1 – CROSS REFERENCE TABLE - VIP84 R1 REQUIREMENTS FOR X-750 VS. FABRICATION METHODS UTILIZED FOR ALLOY 718 JP BEAM	
	ATTACHMENT 2 – CODE CASE 60-N-6	

1 INTRODUCTION

Westinghouse / Toshiba are supplying Constellation Energy Nuclear Group (CENG) with 20 new jet pump (JP) beams to replace the ones currently installed at Nine Mile Point Unit 2 (NMP2). The installed jet pump beams are a General Electric design, and are fabricated from alloy X-750 material. This choice of material, along with stresses inherent to the design of the beam, makes the beam susceptible to premature failure. The new beams to be installed by Westinghouse are a Toshiba design, and they are fabricated from modified heat treatment alloy 718 material. Note that the adjective "Modified" refers to the modified heat treatment for this particular alloy. For simplicity, the term Modified Alloy 718 will be used hereafter in this document to identify this material. This report compares the structural properties of both materials, and demonstrates the superiority of alloy 718 over alloy X-750. The requirements of BWR VIP-84 are also factored in to this comparison (Attachment 1).

2 JET PUMP BEAM ASSEMBLY

Jet pump beams are located at the top of the inlet mixer assembly and are used to seat and mechanically lock the inlet mixer to the riser pipe transition piece. The jet pump beam is deflected during installation to provide an axial preload of approximately 25,000 pounds on the corresponding jet pump. It is hydraulically deflected while in place above the jet pump assembly, and is fixed in the preloaded condition via a bolt that is integral to the jet pump beam assembly. The bolt is threaded through the jet pump beam and contacts the top of the jet pump. After contact, the bolt is loaded to a predetermined torque value through a given angular rotation. An iterative process is used and both the torque and the rotation are monitored to verify that the jet pump beam and inlet mixer are properly seated. After the beam is tensioned, an integral locking device engages around the bolt and prevents it from loosening. This in turn prevents the beam from losing preload during reactor operation.

2.1 BACKGROUND

The OEM jet pump beam material was fabricated from alloy X-750. Although stress corrosion cracking (SCC) susceptibility of alloy X-750 was improved by modified heat treatment, SCC failures of alloy X-750 jet pump beams have occurred in BWR plants. The material chosen, along with the geometry of the beam, makes the OEM beam susceptible to premature failure.

The Toshiba-designed jet pump beams being installed at NMP2 (Figure 2-1) are an improvement over the existing beam design. Toshiba has developed a modified alloy 718 which has greater material reliability than alloy X-750. Compared to X-750, the modified alloy 718 beam has greater SCC resistance, higher ductility, and superior fatigue and spring properties. Its high strength and hardness is similar to that of X-750, allowing it to meet the requirements of bolting materials. In addition, Toshiba adjusted the beam geometry to minimize stresses under the preloaded condition. The combination of material choice and geometry improvements reduce the Toshiba beam's susceptibility to IGSCC.

Alloy 718 was selected as an alternative material to X-750 and alloy 725 for the following reasons;

1. Superior material properties such as corrosion resistance as compared to X-750.

2. Higher manufacturability for various product forms such as plate, strip, bar, wire, and forging, than alloy 725 (normally alloy 725 is applicable for bar, strip and pipe).

3. Alloy 718 has been widely used in jet engines, gas turbines, aerospace and nuclear fuel with established manufacturing process. On the other hand, alloy 725 has not been widely used for industry application. In addition to the standard 718 specification, modified heat treatment conditions have been developed to improve SCC resistance and to provide similar mechanical strength to X-750. Toshiba believes that modified alloy 718 has excellent material properties based upon the results of testing.

Alloy 725 would be considered as a possible alternative to alloy X-750, but alloy 725 has not been widely used for industrial applications. Because alloy 718 has a proven in-service record, it was deemed a more prudent choice.

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Figure 2-1 Modified Alloy 718 Jet Pump Beam

2.2 MATERIAL OPTIMIZATION OF MODIFIED ALLOY 718

The Toshiba modified alloy 718 has the following material optimization:

- Higher resistance to SCC initiation compared to alloy X-750
- Higher resistance to low temperature SCC compared to alloy X-750 (Requirement of EPRI BWRVIP-84)

- Higher resistance to SCC crack growth compared to alloy X-750 (Requirement of EPRI BWRVIP-138)
- Similar strength and hardness compared to alloy X-750
- Higher ductility compared to alloy X-750
- Superior fatigue and spring properties compared to alloy X-750
- Similar irradiation relaxation rate compared to alloy X-750

2.3 MANUFACTURING PROCESS OF MODIFIED ALLOY 718 JET-PUMP BEAM

The Toshiba manufacturing process for the modified alloy 718 jet pump beam is shown in Figure 2-2. Remelt processes such as vacuum induction melt (VIM) and vacuum arc remelt (VAR) are applied to the modified alloy 718 jet pump beam. δ-phase formed during hot forming can be solutionized by solution heat treatment at 1030°C (1886°F). There is no difference in the manufacturing process between modified alloy 718 and alloy X-750 Jet-Pump Beams except for heat treatment conditions. Grain size can be controlled within a range of No.3 to No. 5 (ASTM grain size number).

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Figure 2-2 Manufacturing Process of Modified Alloy 718 Jet-Pump Beam

2.4 MATERIAL PROPERTIES

Table 2-1 shows the evaluation program for material properties of modified alloy 718 compared to alloy X-750. Several tests from many heats of material were conducted to evaluate material properties of modified alloy 718. Table 2-2 shows the chemical composition of the test materials, and Table 2-3 shows the heat treatment condition of the test materials.

Table 2-1 Beam Evaluation Program

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Table 2-2 Chemical Compositions of Test Materials

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Table 2-3 Heat Treatment Condition of Test Materials

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Toshiba Proprietary Information

2.5 CHEMICAL COMPOSITION

The chemical composition of modified alloy 718 shall be in accordance with Table 2-4. The chemical composition of modified alloy 718 is the same as that of conventional alloy 718 specified with ASME SB-637 alloy UNS N07718.

Table 2-4 Chemical Composition for Alloy 718 (%)

ASME SB-637	C	Si	Mn	P	S	Ni	Cr	Fe*	Mo	Cu	Al	Ti	Nb+Ta	B	Co
Alloy 718 (UNS N07718)	≤0.08	≤0.35	≤0.35	≤0.015	≤0.015	50.0~55.0	17.0~21.0	Remainder	2.80~3.30	≤0.30	0.20~0.80	0.65~1.15	4.75~5.50	≤0.006	≤0.25

* The element shall be determined arithmetically by difference.

2.6 MODIFIED HEAT TREATMENT

Solution heat treatment (SHT) for modified alloy 718 shall be 1850°F–1922°F (1010°C–1050°C), target temperature of 1886°F (1030°C), for 1 to 2 hours, followed by rapid quenching in oil or water. SHT for modified alloy 718 shall be followed by precipitation hardening heat treatment at 1300°F±15°F (704°C±8°C) for 6 hours, +1 -0 hours, followed by air cooling. Solution and precipitation hardening heat treatment conditions were determined from the T-T-P (time-temperature-precipitation) curve (Reference 3 and Figure 2-3) and isothermal aging curves for yield strength and elongation of alloy 718 (Figure 2-4). In order to improve SCC resistance and ductility, SHT temperature 1010–1050°C was selected for complete solution and the precipitation hardening heat treatment condition 704°C/6 hours was selected to avoid the precipitation of δ-phase from Figure 2-3, which are more than 101,526 psi (700 MPa) in yield strength and 30% in elongation, for alternative material to alloy X-750, are given by the precipitation hardening heat treatment condition of 704°C/6 hours from Figure 2-4.

For application of modified alloy 718 for the jet pump beam, the yield strength of modified alloy 718 is similar to that of alloy X-750 by the selection of 704°C (1300°F)/6 h as the aging condition. As a result, elongation of modified alloy 718 is much higher than that of alloy X-750.

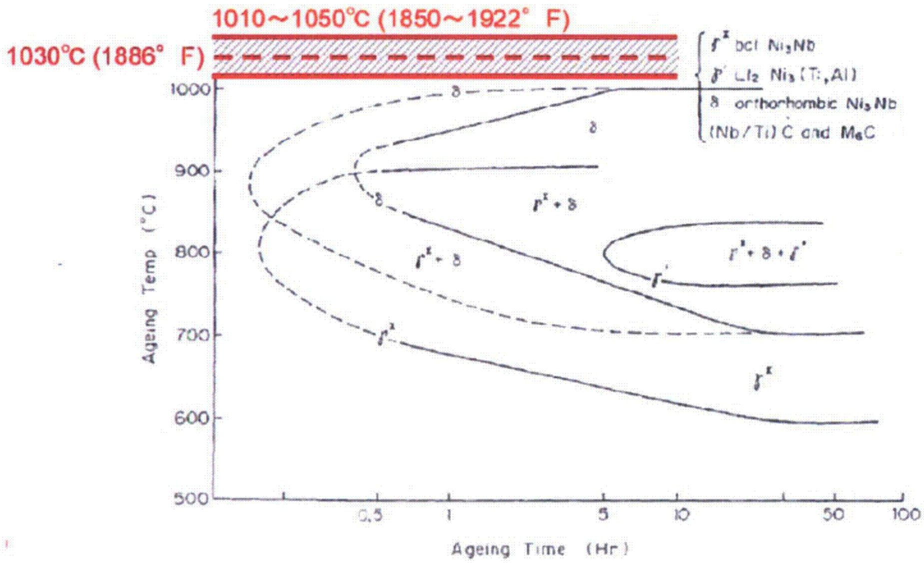

Figure 2-3 T-T-P Diagram for Alloy 718 (Reference 3)

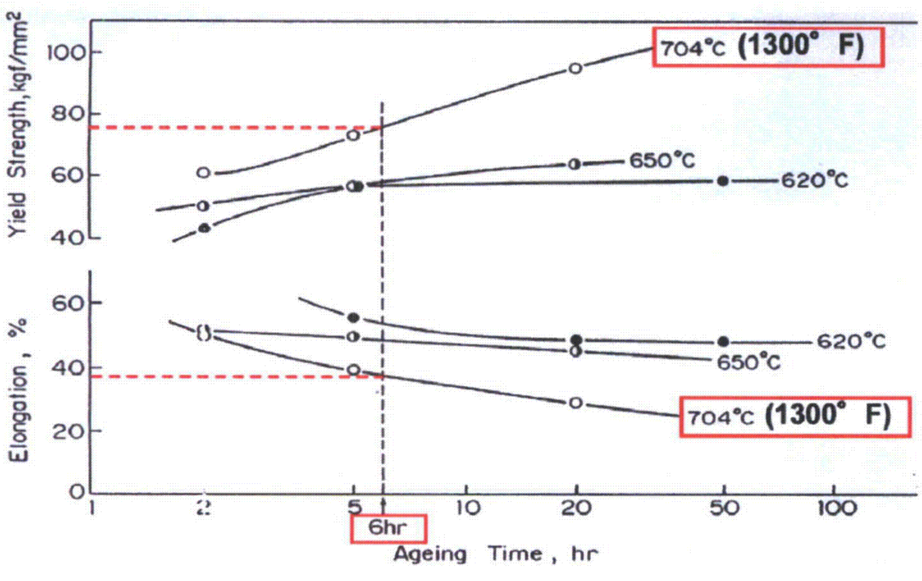

Figure 2-4 Aging Condition Dependency for Yield Strength and Elongation of Alloy 718 (Reference 3)

2.7 MECHANICAL PROPERTY

Figure 2-5 shows yield strength and Figure 2-6 shows tensile strength of modified alloy 718 compared to alloy X-750. Figure 2-7 shows elongation and Figure 2-8 shows reduction of area of modified alloy 718 compared to alloy X-750. Yield strength, tensile strength, elongation and reduction of area of modified alloy 718 are satisfied with minimum requirement of alloy X-750 (UNS N07750 (Grade 688)) Type 3 specified in ASME/ASTM SB-637/B637. Modified alloy 718 has similar strength and higher ductility compared to alloy X-750. Figure 2-9, Figure 2-10, and Figure 2-11, respectively, show yield strength, tensile strength and elongation of cold rolled and aged modified alloy 718, conventional alloy 718 and alloy X-750 (Reference 3). Yield strength and tensile strength of modified alloy 718 are similar to those of alloy X-750 in the all of the range of cold roll reduction ratio. Elongation of modified alloy 718 is very excellent and higher than that of alloy X-750 in the range of 0 to 30% cold roll reduction ratio. Figure 2-12 shows hardness of modified alloy 718 compared to alloy X-750. Hardness of modified alloy 718 is satisfied with requirement of alloy X-750 (UNS N07750 (Grade 688)) Type 3 specified in ASME/ASTM SB-637/B637. Modified alloy 718 has similar hardness compared to alloy X-750.

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Figure 2-5 Yield Strength of Modified Alloy 718 Compared to Alloy X-750

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Figure 2-6 Tensile Strength of Modified Alloy 718 Compared to Alloy X-750

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Figure 2-7 Elongation of Modified Alloy 718 Compared to Alloy X-750

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Figure 2-8 Reduction of Area of Modified Alloy 718 Compared to Alloy X-750

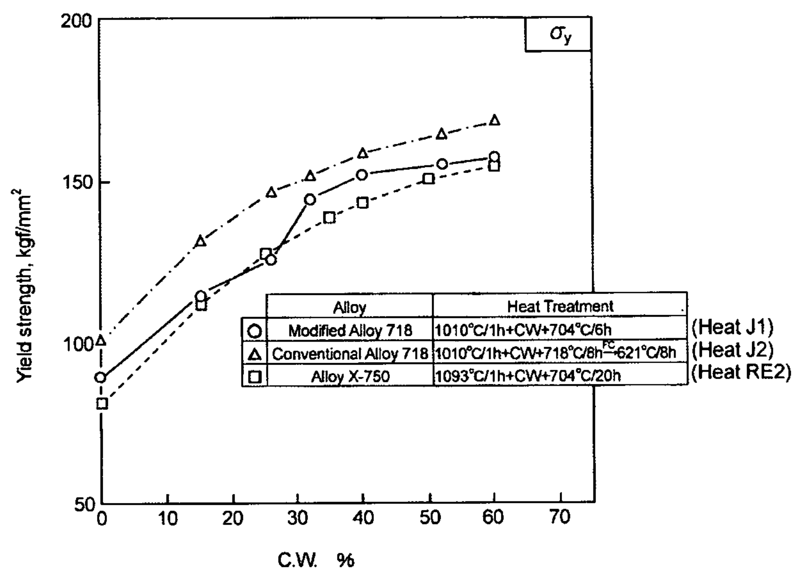

Figure 2-9 Yield Strength of Cold Rolled and Aged Modified Alloy 718, Conventional Alloy 718 and Alloy X-750 (Reference 3)

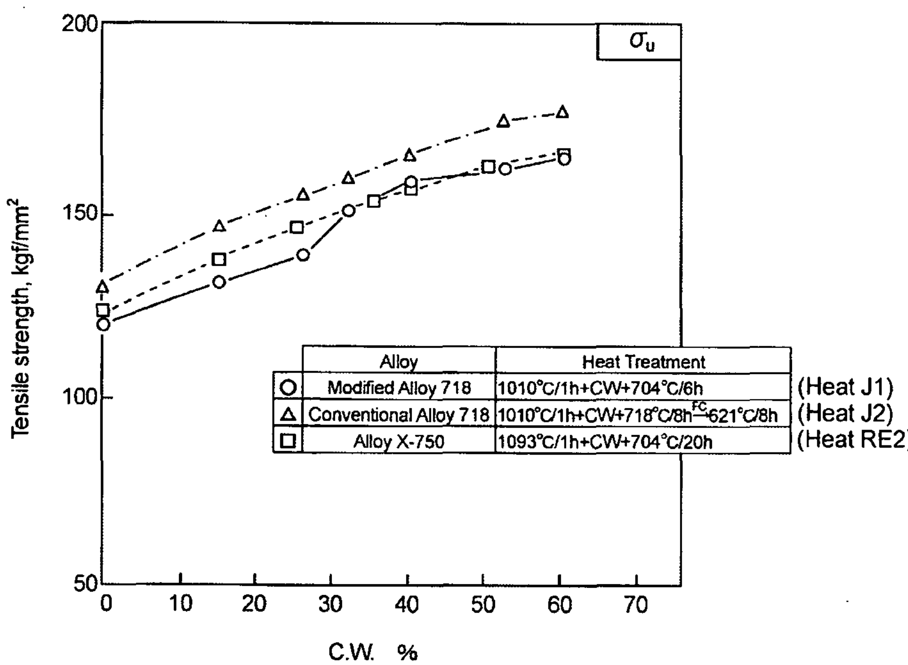

Figure 2-10 Tensile Strength of Cold Rolled and Aged Modified Alloy 718, Conventional Alloy 718 and Alloy X-750 (Reference 3)

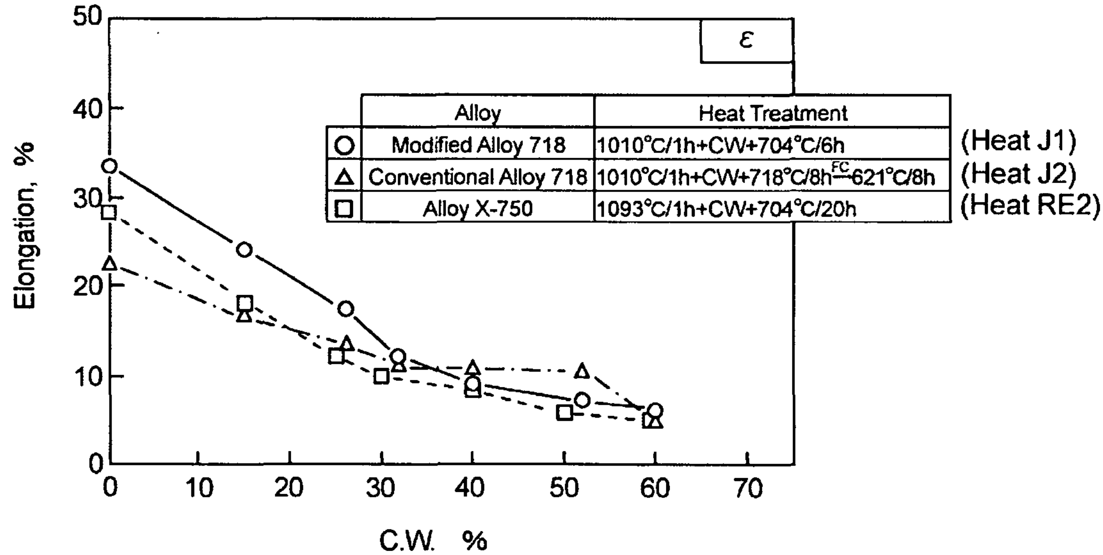

Figure 2-11 Elongation of Cold Rolled and Aged Modified Alloy 718, Conventional Alloy 718 and Alloy X-750 (Reference 3)

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Figure 2-12 Hardness of Modified Alloy 718 Compared to Alloy X-750

2.8 SCC SUSCEPTIBILITY IN HIGH AND LOW TEMPERATURE WATER

Resistance to SCC initiation in high temperature water was evaluated by CBB (Creviced Bent Beam) test (refer to Figure 2-15). Specimens (50 mm x 10 mm x 2 mm) were bent along the device with the curvature of 100 mm in radius, and a constant strain of 1% was applied in the outer surface of the specimens. Graphite wool, the material chosen to form the crevice, was attached to the outer surface of specimens. Test specimens were exposed to the high temperature water (550°F (288°C)) for 500 hours in an autoclave installed in a recirculating loop. Table 2-5 shows CBB test results of modified alloy 718 in 288°C pure water (20 ppm O_2). Figure 2-13 shows micro-observation results for a cross-section of modified alloy 718 test specimen after the CBB test. Modified alloy 718 shows no cracking in all specimens. SCC susceptibility of modified alloy 718 is extremely low compared to that of alloy X-750 (see Figure 2-14). The figure shows SCC crack depth of modified alloy 718, alloy X-750, and sensitized type 304 stainless steel after CBB test in high temperature water with various chloride content (288°C, 8 ppm O_2) (Reference 3). Alloy X-750 is most susceptible to SCC in almost all of the range of chloride content. Next is sensitized type 304 stainless steel. Modified alloy 718 is nearly immune to SCC in the range of less than 50 ppb of chloride content. Figure 2-16 shows chromium profiles perpendicular to the grain boundaries of modified alloy 718 and alloy X-750 (Reference 3). Figure 2-16 also shows the Transmission Electron Microscope (TEM) photos near the grain boundaries of modified alloy 718, and alloy X-750 (Reference 3). No precipitate is visible on the grain boundaries of modified alloy 718. However, large chromium carbides form on the grain boundary of alloy X-750. Modified alloy 718 has no chromium depletion like that observed in alloy X-750. A long-term uni-axis constant load (UCL) test was also conducted for modified alloy 718 and alloy X-750 to evaluate resistance to SCC initiation in high temperature water. The test specimen was loaded by the piston upon which the force is generated by the initial pressure of high temperature water. Applied stress was varied by changing the diameter of the specimens. Graphite wool was used to create a crevice around the gage section of the specimen. Test machines were equipped in high temperature water loop (288°C, 8 ppm O_2). Figure 2-17 shows the applied stress of modified alloy 718 and alloy X-750 (Reference 7). Tests of modified alloy 718 for 10,000 hours were conducted. Modified alloy 718 showed no failure for 10,000 hours at applied stress beyond the yield strength (700-800 MPa in 288°C). The margin of SCC initiation for applied stress of modified alloy 718 is higher than that of alloy X-750. Modified alloy 718 has excellent resistance to high temperature SCC.

Section 2.11.2 describes the rising load test and how it evaluated resistance to SCC initiation in low temperature water.

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Figure 2-13 Micro-Observation for Cross-Section of Test Specimen after CBB Test

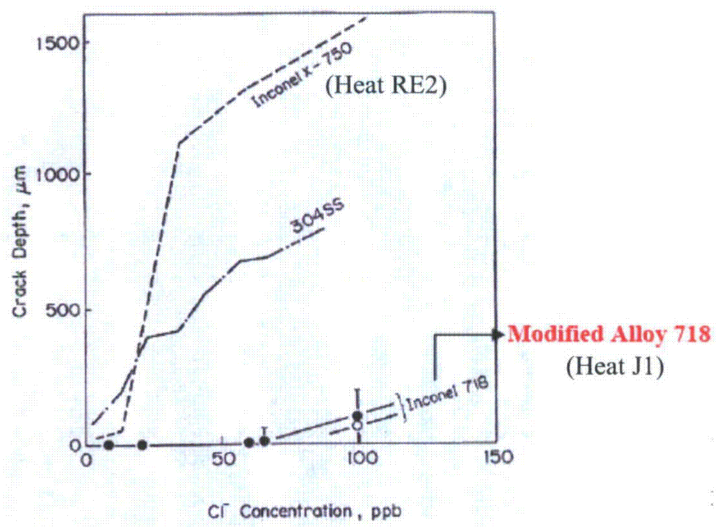

Figure 2-14 CBB Test Results for Modified Alloy 718, Alloy X-750, and 304SS (288°C Water - 8 ppm O_2) (Reference 3)

Table 2-5 CBB Test Result

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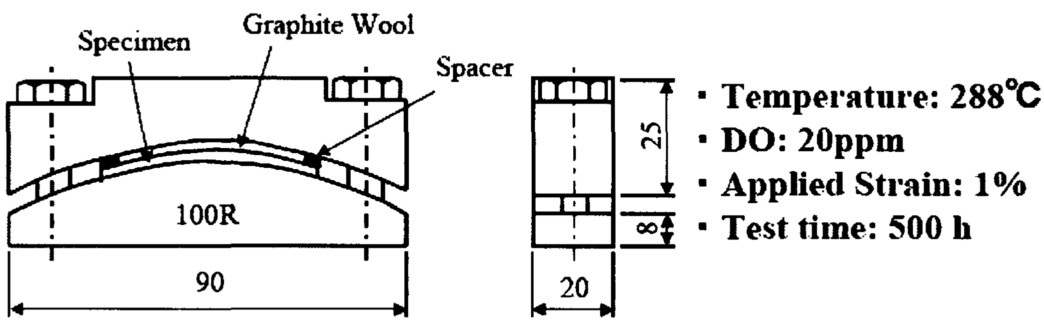

Figure 2-15 CBB (Creviced Bent Beam) Test Device

2.9 GRAIN BOUNDARY ANALYSIS

As mentioned in Section 2.8, Figure 2-16 shows chromium profiles perpendicular to the grain boundaries of modified alloy 718 and alloy X-750 (Reference 3). Figure 2-16 also shows the Transmission Electron Microscope (TEM) photos near the grain boundaries of modified alloy 718, and alloy X-750 (Reference 3). No precipitate is visible on the grain boundaries of the modified alloy 718. However, large chromium carbides form on the grain boundary of alloy X-750. Modified alloy 718 has no chromium depletion like that observed in alloy X-750.

To summarize, no chromium depletion near the grain boundaries of modified alloy 718 were observed by TEM analysis.

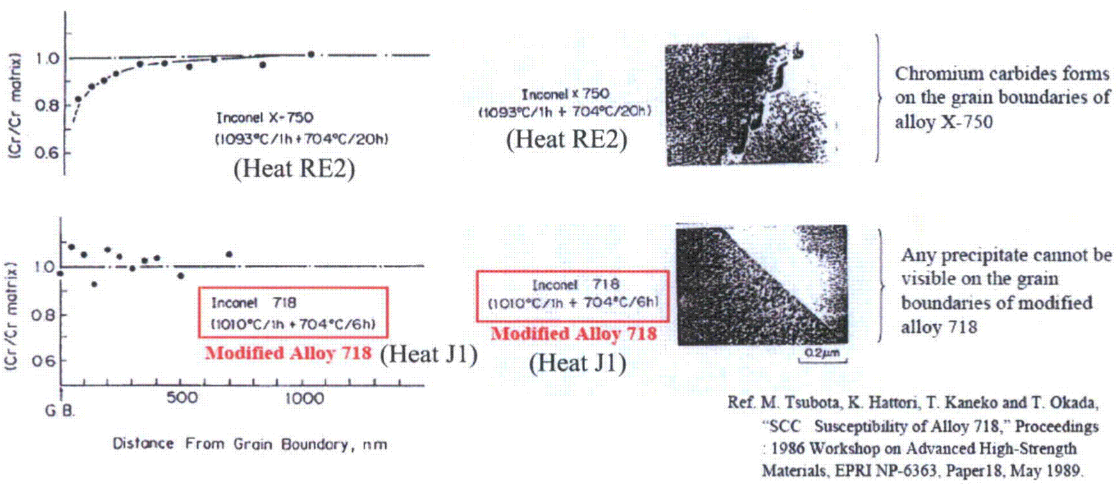

Figure 2-16 Chromium Profiles at Grain Boundaries for Modified Alloy 718 and Alloy X-750 (Reference 3)

2.10 LONG-TERM CONSTANT LOAD TEST

As discussed in Section 2.8, Figure 2-17 shows the applied stress of modified alloy 718 and alloy X-750 (Reference 7). Long-term UCL (Uni-axis Constant Load) tests of modified alloy 718 for 10,000 hours were conducted. Modified alloy 718 showed no failure for 10,000 hours at applied stress beyond the yield strength (700-800 MPa in 288°C). The margin of SCC initiation for applied stress of modified alloy 718 is higher than that of alloy X-750. Modified alloy 718 has excellent resistance to high temperature SCC.

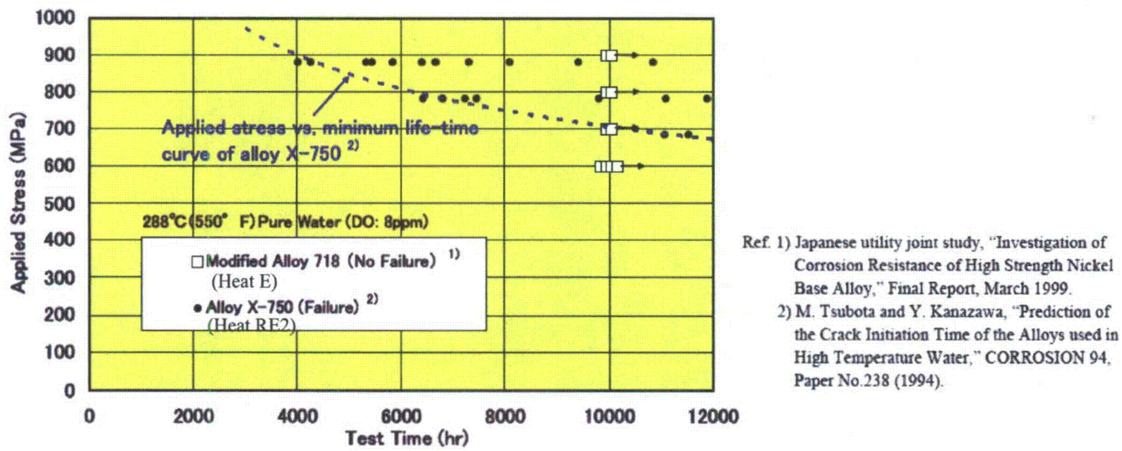

Figure 2-17 UCL Test Result of Modified Alloy 718 and Alloy X-750 (Reference 7)

2.11 REQUIRED TESTS IN BWRVIP-84 AND BWRVIP-138

The following tests for modified alloy 718 were conducted in order to obtain the material property data required in EPRI BWRVIP.

- Rising Load Test (BWRVIP-84)
- SCC Crack Growth Rate Test (BWRVIP-138)

The rising load test is required to evaluate SCC resistance of the material in low temperature water environment.

The SCC crack growth rate test is required to evaluate SCC growth behavior and set up the periodical inspection intervals for Jet-Pump Beam.

2.11.1 RISING LOAD TEST PROCEDURE

A rising load test was conducted in accordance with Appendix A of MIL-DTL-24114F(SH), Nickel-Chromium-Iron Age-Hardenable Alloy, Rods, and Forgings (ANSI Approved). The rising load test conducted is shown in Figure 2-18.

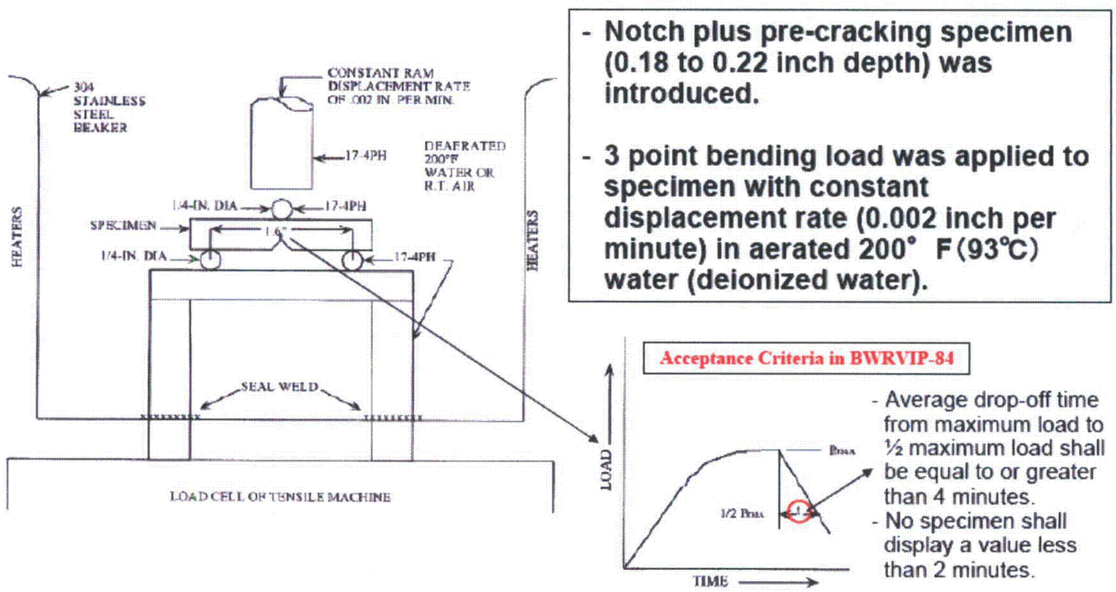

Figure 2-18 Rising Load Test Procedure

2.11.2 RISING LOAD TEST RESULT

Resistance to SCC initiation in low temperature water was evaluated by a rising load test in accordance with MIL-DTL-24114F(SH) Appendix A (Reference 2). A notch plus pre-cracking (0.18 inch to 0.22 inch depth) was introduced to the specimen. A 3-point bending load was applied to the specimen with a constant displacement rate (0.002 inch per minute) in aerated 200°F (93°C) water (deionized water). The rising load test acceptance criteria for alloy X-750 are defined in BWRVIP-84, which states that average drop-off time from maximum load to 1/2 maximum load shall be equal to or greater than 4 minutes, and no specimen shall display a value less than 2 minutes (Reference 10). Figure 2-19 and Figure 2-20 show drop-off time from maximum load to 1/2 maximum load of modified alloy 718 and alloy-X-750 after the rising load test. Both modified alloy 718 and alloy X-750 satisfy the criteria for alloy X-750 in BWRVIP-84. However, the time of modified alloy 718 is about 15 times longer than that of alloy X-750. It was confirmed that modified alloy 718 has excellent resistance to low temperature SCC.

All specimens of modified alloy 718 displayed large lateral deformation. All specimens of alloy X-750 showed little lateral deformation. The results of the macro-observation of fracture surface after the rising load test for modified alloy 718 and alloy X-750 are shown in Figure 2-21 and Figure 2-22.

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Figure 2-19 Drop-Off Time for Alloy X-750 and Modified Alloy 718 for All Data

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Figure 2-20 Drop-Off Time for Alloy X-750 and Modified Alloy 718 for Average

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Figure 2-21 Macro-Observation of Fracture Surface after Rising Load Test for Modified Alloy 718

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Figure 2-22 Macro-Observation of Fracture Surface after Rising Load Test for Alloy X-750

2.11.3 SCC CRACK GROWTH RATE TEST PROCEDURE

SCC crack growth rate test using 0.5TCT specimens was conducted under constant load condition. The crack length was monitored with potential drop method (PDM).

Test Conditions:

- Temperature: 288°C
- Water Chemistry: NWC (ECP ≥ 150m VSHE)
- Conductivity: Inlet < 0.1 μS/cm, Outlet < 0.2 μS/cm
- Stress Intensity Factor (K): 30–50 MPa·√m

Proposed SCC Crack Growth Rate Curves for X-750 in BWRVIP-138 are shown in Figure 2-23.

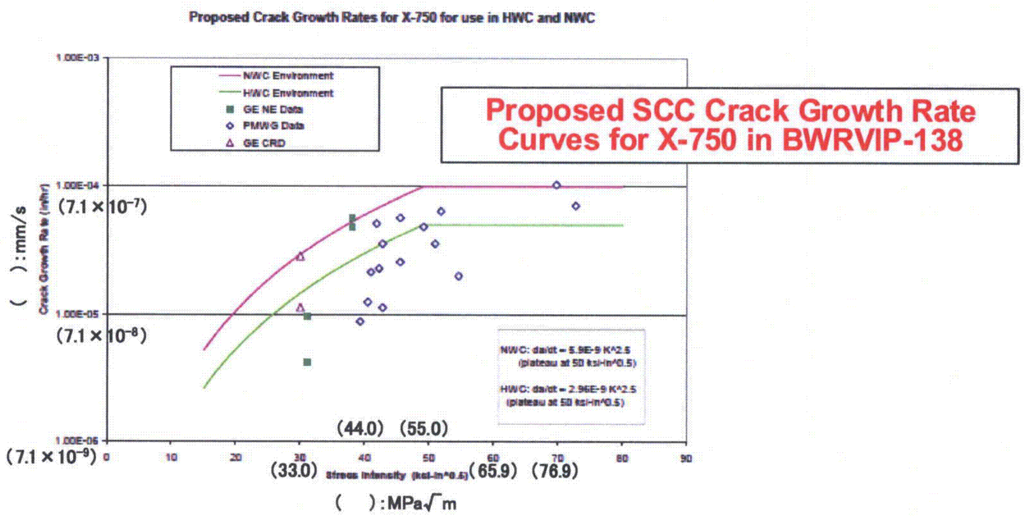

Figure 2-23 Proposed SCC Crack Growth Rate Curves for X-750 in BWRVIP-138

2.11.4 SCC CRACK GROWTH RATE TEST RESULT

Resistance to SCC propagation in high temperature water was evaluated by crack growth rate test under a constant load condition. 0.5TCT specimen (B=12.7 mm, W=25.4 mm) was used for the test at 30 to 60 MPa √m of stress intensity factor (K). The crack growth test was conducted in an autoclave installed in a recirculating loop. The crack lengths were monitored by means of the reversing DC potential drop method (PDM). The dissolved oxygen (DO) concentration was controlled to be more than 15ppm to adjust corrosion potential to be more than 150 mV-SHE simulating NWC condition. Table 2-6 and Figure 2-24 show the relation between SCC growth rate and K for modified alloy 718 and alloy X-750. SCC growth rate data for alloy X-750 is below the proposed curves in BWRVIP-138 (Reference 1). SCC growth rate for modified alloy 718 is much lower (more than 1 order of magnitude lower) than that for alloy X-750.

Table 2-6 Crack Growth Rate for Materials

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Figure 2-24 SCC Growth Rate Data for Modified Alloy 718 and Alloy X-750

2.12 FATIGUE PROPERTY

Fatigue property in air was evaluated by fatigue testing under a cyclic load condition. Load-controlled fatigue tests (stress ratio: -1) were conducted in accordance with ASTM E 466 (Reference 5) under the condition of the stress amplitude below the yield strength. Test specimens based on ASTM E 466 Fig.1 were used in load-controlled fatigue tests. Strain-controlled fatigue tests (strain ratio: -1) were conducted in accordance with ASTM E 606 (Reference 4) under the condition of the stress amplitude beyond the yield strength. Test specimens based on ASTM E 606 Fig.1 were used in strain-controlled fatigue tests. In the strain-controlled fatigue tests, stress value (σ) was calculated from strain value (ε) and Young's modulus (E) ($\sigma=\varepsilon E$, E (RT)= 203 GPa (29.4×10^6 psi), E (302°C (576°F))= 191GPa (27.7×10^6 psi)). Figure 2-25 shows fatigue test results for modified alloy 718 and alloy X-750 (Reference 7). Modified alloy 718 has high fatigue strength. Fatigue life of modified alloy 718 is longer than that of alloy X-750 and hence is superior to alloy X-750.

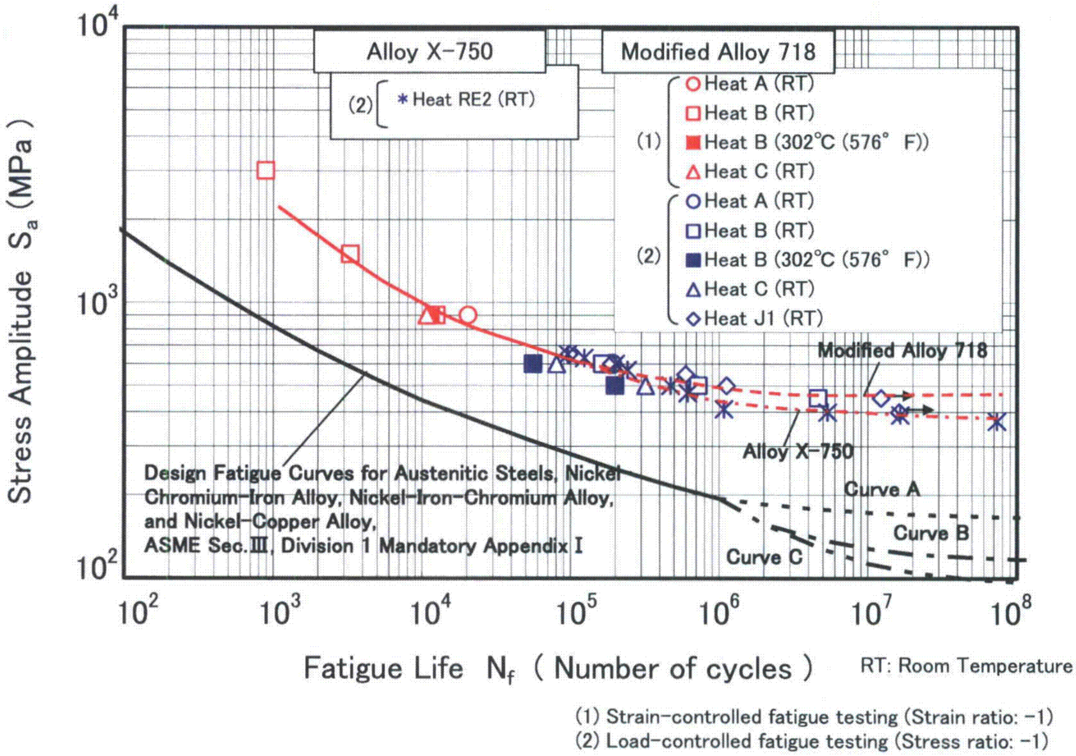

Figure 2-25 Fatigue Test Results for Modified Alloy 718 and Alloy X-750 (Reference 7)

2.13 RADIATION RELAXATION RATE

Alloy 718 has similar radiation relaxation rates in comparison to alloy X-750. See Figure 2-26 and Figure 2-27 (References 8 and 9).

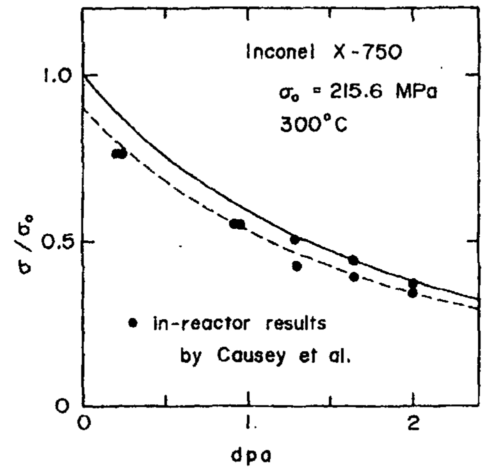

Fig. 3. Calculated stress relaxation of Inconel X-750 at 300°C, 3×10^{-8} dpa/s with experimental data of the similar condition.

Figure 2-26 Stress Relaxation of X-750 in an Irradiated Environment (Reference 9)

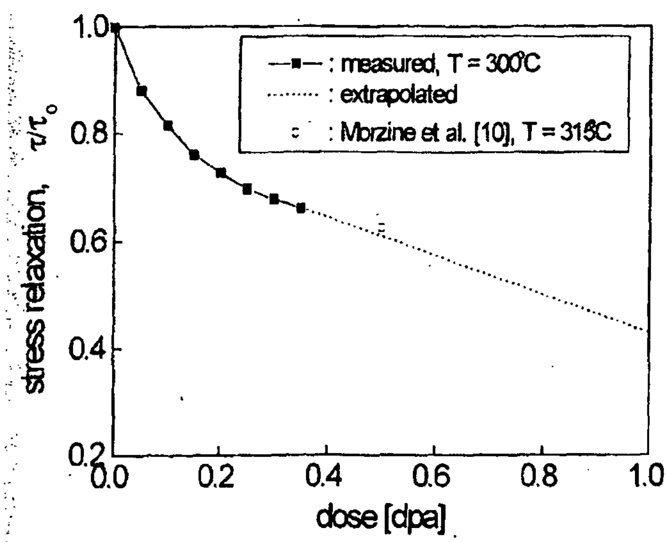

Fig. 4. Stress relaxation for Inconel 718. The hollow circle represents bend stress relaxation measured after in-pile irradiation at 315°C [10].

Figure 2-27 Stress Relaxation of 718 in an Irradiated Environment (Reference 8)

2.14 SPRING PROPERTY OF JET-PUMP BEAM

The spring property of a jet pump beam was tested as shown in Figure 2-28 (Reference 7). The results of the test, which is a comparison of the modified alloy 718 to alloy X-750 jet pump beams, are shown in Figure 2-29 (Reference 7). The test results are summarized below.

- Bending tests for Jet Pump Beams were conducted at applied load of 50 ton×1 cycle.
- Apparent permanent strain remained in alloy X-750 beam after the bending test.
- No permanent strain remained in modified alloy 718 beam after the bending test.

This testing demonstrates that modified alloy 718 has superior spring property compared to alloy X-750.

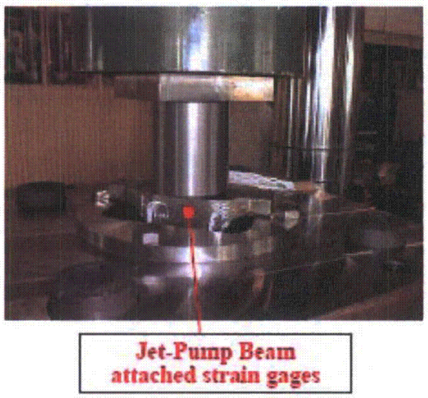

Figure 2-28 Spring Property of a Jet-Pump Beam (Reference 7)

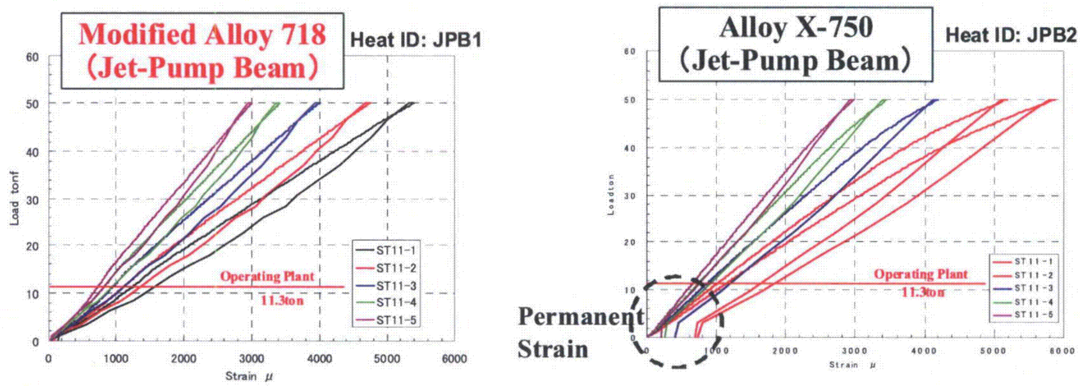

Figure 2-29 Load vs Strain Curves for Modified Alloy 718 and Alloy X-750 (Reference 7)

2.15 SUMMARY OF MATERIAL PROPERTY TESTS AS RELATED TO JP BEAMS

The testing has demonstrated that modified alloy 718 has superior ductility, fatigue and spring properties, as well as greater resistance to SCC initiation and crack growth than alloy X-750 (See Table 2-7). As such, modified alloy 718 can be applied as an alternative material to alloy X-750 for jet pump beams. Note that Toshiba has proposed to include modified alloy 718 in the BWRVIP-84 Appendix.

Table 2-7 Summary of Material Properties of Modified Alloy 718

	Mechanical Property	Resistance to SCC Initiation (Low and High Temp.)	Resistance to SCC Propogation	Fatigue Property
Modified Alloy 718	○ : Strength ◉ : Ductility	◉	◉	◉

◉ : Superior to alloy X-750 ○ : Similar to alloy X-750

Modified Alloy 718 is defined in ASME Code Case N-60-6 as grade 718 type 2. The code case is approved as of December Balloting. The Issued Code Case from ASME will be published in Supplement 8 of the 2010 Edition and cannot be expected to be available for several months, minimum, possibly up to six months. Included as Attachment 2 is a clean version of the code case revisions just to include the Modified 718 material. When published, ASME Code Case N-60-6 will look different because other changes will have also been incorporated. The modified alloy 718 is in full compliance with the ASME approved code case requirements specified as grade 718 type 2.

3 REFERENCES

1. Toshiba report PM-2009-0162, Rev. 1, June 2011, Material Properties of Modified Alloy 718 For Use in BWR Internals.

2. Navy Military Specification, MIL-DTL-24114F(SH) Appendix A.

3. M. Tsubota, K. Hattori, T. Kaneko and T. Okada, "SCC Susceptibility of Alloy 718," Proceedings : 1986 Workshop on Advanced High-Strength Materials, EPRI NP-6363, Paper 18, May 1989.

4. ASTM E 606 – 04, Standard Practice for Strain Controlled Fatigue Testing, 2005.

5. ASTM E 466 – 07, Standard Practice for Conducting Force Controlled Constant Amplitude Axial Fatigue Tests of Metallic Materials.

6. BWRVIP-138, Revision 1: "BWR Vessel and Internals Project, Updated Jet Pump Beam Inspection and Flaw Evaluation Guidelines," EPRI Technical Report 1016574, December 2008.

7. Y. Katayama, M. Tsubota, Y. Saito, N. Tanaka and S. Tanaka, "SCC Properties of Modified Alloy 718 in BWR Plant," 15th International Conference on Environmental Degradation of Materials in Nuclear Power Systems – Water Reactors, August 7-11, 2011.

8. Journal of Nuclear Materials, "Proton irradiation creep of Inconel 718 at 300°C," R. Scholz and R. Matera, 2000.

9. Journal of Nuclear Materials, "Calculation of radiation-induced stress relaxation," J. Nagakawa, 1995.

10. BWRVIP-84-Revision 1: BWR Vessel Internals Project, "Guidelines for Selection and Use of Materials for Repairs to BWR Internal Components," Final Report, EPRI, August 2011.

Attachment 1

Cross Reference Table – VIP84 R1 Requirements for X-750 vs.

Fabrication Methods Utilized for Alloy 718 JP Beam

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Attachment 2

Code Case 60-N-6

CASES OF ASME BOILER AND PRESSURE VESSEL CODE

Approval Date: December 6, 2011

See Numeric Index for expiration and any reaffirmation dates.

Case N-60-6

Material for Core Support Structures Section III, Division 1

Inquiry: What materials, in addition to those listed in Tables 2A, 2B, and 4, Section II, Part D, Subpart 1, may be used for core support structures constructed to the requirements of Subsection NG of Section III, Division 1?

Reply: It is the opinion of the Committee that the materials and stress intensity values listed in Table A may be used in the construction of core support structures in addition to those listed in Tables 2A, 2B and 4, Section II, Part D, Subpart 1. The following additional requirements shall be met.

(a) All other requirements of Subsection NG of Section III, Division 1, shall be met.
(b) Strain hardened SA-479 shall be identified with this Case number.
(c) Where welds are applied to strain hardened material, the stress intensity in the sections of the material where the temperatures during welding exceed 800°F shall not exceed values for annealed materials.
(d) Yield strength values are listed in Table B.
(e) Tensile strength values are listed in Table C.
(f) Chemical composition for Ni-Cr-Fe ASTM B 637 Types 1 and 2 is listed in Table D.
(g) Heat treatments for Ni-Cr-Fe ASTM B 637 Types 1 and 2 and Grade 718 Type 2 are listed in Table E.
(h) Room temperature mechanical properties for Ni-Cr-Fe ASTM B 637 Types 1 and 2 and Grade 718 Type 2 are listed in Table F.

TABLE A

Nominal Composition	S No.	Prod. Form	Spec. No.	Type or Grade	Notes	Min. Yield Str.	Min. Ult. Tens. Str.	Stress Intensity, ksi, For Metal Temperature, °F, Not to Exceed 100	200	300	400	500	600	650	700	750	800
13Cr	6	Plate	SA-240	TP-410		30.0	60.0	20.0	18.4	17.7	17.4	17.2	16.8	16.5	16.2	15.7	15.1
22Cr-13Ni-5Mn	. . .	Plate	SA-240	XM-19	7,8	55.0	100.0	33.3	33.2	31.4	30.2	29.7	29.2	29.0	28.8	28.5	28.2
22Cr-13Ni-5Mn	. . .	Bar	A 479-74	XM-19	7,8	55.0	100.0	33.3	33.2	31.4	30.2	29.7	29.2	29.0	28.8	28.5	28.2
18Cr-8Ni	8	FFBS	SA-193	B8	7	30.0	75.0	20.0	20.0	20.0	18.7	17.4	16.4	16.1	15.9	15.5	15.1
16Cr-12Ni-2Mo	8	FFBS	SA-193	B8M	7	30.0	75.0	20.0	20.0	20.0	19.2	17.9	17.0	16.6	16.3	16.0	15.8
18Cr-10Ni-Ti	8	FFBS	SA-193	B8T	7	30.0	75.0	20.0	20.0	20.0	19.2	17.9	17.0	16.6	16.3	16.0	15.8
18Cr-10Ni-Cb	8	FFBS	SA-193	B8C	7	30.0	75.0	20.0	20.0	20.0	20.0	19.9	19.3	18.9	18.6	18.4	18.3
26Ni-15Cr-2Ti	. . .	FFBS	SA-453	660	5,7	85.0	130.0	43.3	43.3	43.3	43.3	43.3	43.3	43.3	43.3	43.3	42.6
18Cr-8Ni	8	Smls Tube	A 511-71	MT304	6,7	30	75	20.0	20.0	20.0	18.7	17.4	16.4	16.1	15.9	15.5	15.1
18Cr-8Ni	8	Smls Tube	A 511-71	MT304L	6,7	25	70	16.6	16.6	16.6	15.7	14.7	13.9	13.7	13.4	13.2	13.0
16Cr-12Ni-2Mo	8	Smls Tube	A 511-71	MT316	6,7	30	75	20.0	20.0	20.0	19.2	17.9	17.0	16.6	16.3	16.0	15.8
16Cr-12Ni-2Mo	8	Smls Tube	A 511-71	MT316L	6,7	25	70	16.6	16.6	16.6	15.5	14.4	13.5	13.2	12.8	12.6	12.3
18Cr-8Ni	8	Weld Tube	A 554-72	MT304	6,7	30	75	20.0	20.0	20.0	18.7	17.4	16.4	16.1	15.9	15.5	15.1
18Cr-8Ni	8	Weld Tube	A 554-72	MT304L	6,7	25.0	70.0	16.6	16.6	16.6	15.7	14.7	13.9	13.7	13.4	13.2	13.0
16Cr-12Ni-2Mo	8	Weld Tube	A 554-72	MT316	6,7	30	75	20.0	20.0	20.0	19.2	17.9	17.0	16.6	16.3	16.0	15.8
16Cr-12Ni-2Mo	8	Weld Tube	A 554-72	MT316L	6,7	25.0	70.0	16.6	16.6	16.6	15.5	14.4	13.5	13.2	12.8	12.6	12.3
Ni-Cr-Fe	. . .	FFBS	SB-637	688	9	40	100	26.7	26.1	25.5	25.1	24.6	24.3	24.1	24.0	23.9	23.8
Ni-Cr-Fe	. . .	FFBS	SB-637	688	5,10	90	140	46.7	46.7	46.7	46.7	46.7	46.7	46.7	46.7	46.7	46.5
Ni-Cr-Fe	. . .	FFBS	SB-637	688	5,11	115	170	56.7	56.7	56.7	56.7	56.7	56.7	56.7	56.7	56.7	56.5
Ni-Cr-Fe	. . .	FFBS	SB-637	688	5,12	100	160	53.3	53.3	53.3	53.3	53.3	53.3	53.3	53.3	53.3	53.1
Ni-Cr-Fe	43	Plate	SB-168	. . .	15	35	80	23.3	23.2	23.3	23.3	23.3	23.3	23.3	23.3	23.3	23.3
Ni-Cr-Fe	. . .	FFBS	B 637	TP-1	5	100	160	53.3	53.3	53.3	53.3	53.3	53.2	52.7	52.1	51.5	. . .
Ni-Cr-Fe	. . .	FFBS	B 637	TP-2	5	85	150	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	. . .
Ni-Cr-Fe			SB-637	718 Type 2		100	160	53.3	53.3	53.3	53.3	52.4	51.2	50.6	50	49.4	
16Cr-12Ni-2Mo	8	FFBS	SA-479	316	1,2,7,13	60	85	28.3	28.3	26.8	25.9	25.7	25.7	25.7	25.7	25.7	25.4
16Cr-12Ni-2Mo	8	FFBS	SA-479	316	1,2,7,14	65	85	28.3	28.3	26.8	25.9	25.7	25.7	25.7	25.7	25.7	25.4
16Cr-12Ni-2Mo	8	FFBS	SA-193	B8M	1,2,7	50	90	30.0	30.0	28.3	27.4	26.8	26.4	26.1	25.7	25.2	24.6
16Cr-12Ni-2Mo	8	FFBS	SA-193	B8M	1,2,7	65	90	31.6	31.6	29.9	29.0	28.7	28.7	28.7	28.7	28.7	28.4
16Cr-12Ni-2Mo	8	FFBS	SA-193	B8M	1,2,3,5,7	80	100	33.3	33.3	31.5	30.5	30.2	30.2	30.2	30.2	30.2	29.9
16Cr-12Ni-2Mo	8	FFBS	SA-193	B8M	1,2,4,5,7	95	110	36.6	36.6	34.6	33.5	33.3	33.3	33.3	33.3	33.3	32.8

See following page for notes.

[Notes to Table A]

NOTES:

(1) Strain hardened. (The tensile properties for these items shall meet the minimum specified. These materials shall conform to all other requirements of the referenced specification. Surface hardness as shown in SA-479 is not required.)
(2) Yield strength values are listed in Table B.
(3) Maximum tensile strength—140,000 psi.
(4) Maximum tensile strength—150,000 psi.
(5) The designer shall consider the effects of temperature and environment on the material properties of precipitation hardening alloys and cold worked austenitic stainless steels.
(6) Supplementary requirement S-2 for tensile testing of the specification is mandatory.
(7) At temperatures above 100°F, the design stress intensity values may exceed 66⅔% and may also reach 90% of the yield strength (0.2% offset) at temperature. This may result in a permanent strain of as much as 0.1%. When this amount of deformation is not acceptable, the designer should reduce the design stress intensity to obtain an acceptabledeformation. Section III, Division 1, Table 1-2.4 lists multiplying factors which, when applied to the yield strength values shown on Table I-2.2, will give a design stress intensity that will result in lower levels of permanent strain.
(8) The Sy values for Type XM-19 stainless steels vary with the annealing temperature (see Table B).
(9) Solution heat treated.
(10) Type 1.
(11) Type 2.
(12) Type 3.
(13) Over 2 in.
(14) Up to and including 2 in.
(15) Hot finished.

TABLE B Yield Strength Values S_Y

Nominal Composition	Prod. Form	Spec. No.	Type or Grade	Notes	Spec. Min. Yield	Yield Strength (Ksi) for Metal Temperature °F, Not to Exceed 100	200	300	400	500	600	650	700	750	800
18Cr-8Ni	Smls Tube	A 511-71	MT304	. . .	30.0	30.0	25.0	22.5	20.7	19.4	18.2	17.9	17.7	17.3	16.8
18Cr-8Ni	Smls Tube	A 511-71	MT304L	. . .	25.0	25.0	21.3	19.1	17.5	16.3	15.5	15.2	14.9	14.7	14.4
16Cr-12Ni-2Mo	Smls Tube	A 511-71	MT316	. . .	30.0	30.0	25.8	23.3	21.4	19.9	18.8	18.5	18.1	17.8	17.6
16Cr-12Ni-2Mo	Smls Tube	A 511-71	MT316L	. . .	25.0	25.0	21.1	18.9	17.2	15.4	15.0	14.6	14.3	14.0	13.7
18Cr-8Ni	Wld Tube	A 554-72	MT304	. . .	30.0	30.0	25.0	22.5	20.7	19.4	18.2	17.9	17.7	17.3	16.8
18Cr-8Ni	Wld Tube	A 554-72	MT304L	. . .	25.0	25.0	21.3	19.1	17.5	16.3	15.5	15.2	14.9	14.7	14.4
16Cr-12Ni-2Mo	Wld Tube	A 554-72	MT316	. . .	30.0	30.0	25.8	23.3	21.4	19.9	18.8	18.5	18.1	17.8	17.6
16Cr-12Ni-2Mo	Wld Tube	A 554-72	MT316L	. . .	25.0	25.0	21.2	18.9	17.2	15.9	15.0	14.6	14.3	14.0	13.7
Ni-Cr-Fe	FFBS	SB-637	688	3	40.0	40.0	39.1	38.3	37.6	36.9	36.4	36.2	36.0	35.9	35.7
Ni-Cr-Fe	FFBS	SB-637	688	4	90.0	90.0	87.7	86.4	85.3	84.5	84.1	83.9	83.8	83.7	83.6
Ni-Cr-Fe	FFBS	SB-637	688	5	115.0	115.0	112.0	110.2	109.0	108.0	107.5	107.2	107.0	106.9	106.8
Ni-Cr-Fe	FFBS	SB-637	688	6	100.0	100.0	99.0	95.2	94.0	93.1	92.5	92.2	92.0	91.9	91.8
Ni-Cr-Fe	FFBS	B 637	TP-1	. . .	100.0	100.0	97.1	95.2	93.4	92.0	90.0	90.4	90.1	89.9	. . .
Ni-Cr-Fe	FFBS	B 637	TP-2	. . .	85.0	85.0	82.4	81.2	80.4	79.9	79.8	79.8	79.8	79.8	. . .
Ni-Cr-Fe		SB-637	718 Type 2		100.0	100.0	95.5	93.0	91.8	91.1	90.3	89.7	88.9	88.2	. . .
16Cr-12Ni-2Mo	FFBS	SA-479	316	7	60.0	60.0	55.1	52.1	49.8	48.3	47.5	47.0	46.3	45.4	44.5
16Cr-12Ni-2Mo	FFBS	SA-479	316	8	65.0	65.0	59.8	56.5	54.0	52.3	51.4	50.9	50.1	49.1	48.1
Ni-Cr-Fe	Plate	SB-168		9	35.0	35.0	32.7	31.0	29.8	28.8	27.9	27.4	27.0	26.5	26.1
16Cr-12Ni-2Mo	FFBS	SA-193	B8M	. . .	50.0	50.0	46.0	43.5	41.5	40.3	39.6	39.2	38.6	37.8	37.0
16Cr-12Ni-2Mo	FFBS	SA-193	B8M	. . .	65.0	65.0	59.8	56.5	54.0	52.3	51.4	50.9	50.1	49.1	48.1
16Cr-12Ni-2Mo	FFBS	SA-193	B8M	. . .	80.0	80.0	73.5	69.6	56.5	64.5	53.3	62.6	61.8	60.5	59.0
16Cr-12Ni-2Mo	FFBS	SA-193	B8M	. . .	95.0	95.0	87.5	82.6	78.9	76.5	75.1	74.4	73.3	71.9	70.5
22Cr-13Ni-5Mn	Plate	SA-240	XM-19	1	55.0	55.0	47.0	43.4	40.8	38.8	37.3	36.8	36.3	35.8	35.3
22Cr-13Ni-5Mn	Bar	A 479-74	XM-19	1	55.0	55.0	47.0	43.4	40.8	38.8	37.3	36.8	36.3	35.8	35.3
22Cr-13Ni-5Mn	Plate	SA-240	XM-19	2	55.0	55.0	44.6	39.3	35.7	33.3	32.0	31.5	31.4	31.2	31.1
22Cr-13Ni-5Mn	Bar	A 479-74	XM-19	2	55.0	55.0	44.6	39.3	35.7	33.3	32.0	31.5	31.4	31.2	31.1

NOTES:
(1) For material annealed at 1925-1975°F.
(2) For material annealed at 2025-2075°F.
(3) Solution heat treated.
(4) Type 1.
(5) Type 2.
(6) Type 3.
(7) Over 2 in.
(8) Up to and including 2 in.
(9) Hot finished.

TABLE C
MATERIALS PROPERTIES, SUBSECTION NG TENSILE STRENGTHS, S_U
Tensile Strength Values, S_U (ksi), for Austenitic Steel and High Nickel Alloys for Class 1 Components Spec. Temperature, °F

Nominal Composition	Prod. Form	Spec. No.	Type or Grade	Spec. Min. T.S.	100	200	300	400	500	600	650	700	750	800
18Cr-8Ni	FFBS	SA-193	B8	75.0	75.0	70.9	66.0	64.3	63.5	63.5	63.5	63.5	63.2	62.6
16Cr-12Ni-2Mo	FFBS	SA-193	B8M	75.0	75.0	75.0	73.4	71.8	71.8	71.8	71.8	71.8	71.5	71.0
18Cr-10Ni-Ti	FFBS	SA-193	B8T	75.0	75.0	73.4	67.3	68.5	68.5	68.5	68.5	68.5	68.5	68.5
18Cr-10Ni-Cb	FFBS	SA-193	B8C	75.0	75.0	71.8	66.0	61.9	60.2	59.4	58.9	58.5	58.5	58.5
26Ni-15Cr-2Ti	FFBS	SA-453	660	130.0	130.0	130.0	130.0	130.0	130.0	130.0	130.0	130.0	130.0	130.0
18Cr-8Ni	Smls. Tube	A 511	MT304	75.0	75.0	70.9	66.0	64.3	63.5	63.5	63.5	63.5	63.2	62.6
18Cr-8Ni	Smls. Tube	A 511	MT304L	70.0	70.0	66.2	60.8	58.5	57.7	57.0	56.6	56.2	55.8	55.4
16Cr-12Ni-2Mo	Smls. Tube	A 511	MT316	75.0	75.0	75.0	73.4	71.8	71.8	71.8	71.8	71.8	71.5	71.0
16Cr-12Ni-2Mo	Smls. Tube	A 511	MT316L	70.0	70.0	67.7	63.9	62.4	61.6	61.6	61.6	61.6	61.2	60.8
18Cr-8Ni	Wld. Tube	A 554	MT304	75.0	75.0	70.9	66.0	64.3	63.5	63.5	63.5	63.5	63.2	62.6
16Cr-12Ni-2Mo	Wld. Tube	A 554	MT316	75.0	75.0	75.0	73.4	71.8	71.8	71.8	71.8	71.8	71.5	71.0
Ni-Cr-Fe	FFBS	SB-637	Soln. Treated 688	100.0	100.0	100.0	100.0	100.0	100.0	99.4	98.8	98.5	98.2	98.0
Ni-Cr-Fe	FFBS	SB-637	Type 1 688	140.0	140.0	140.0	140.0	140.0	140.0	140.0	140.0	140.0	140.0	139.8
Ni-Cr-Fe	FFBS	SB-637	Type 2 688	170.0	170.0	170.0	170.0	170.0	170.0	170.0	170.0	170.0	170.0	169.8
Ni-Cr-Fe	FFBS	SB-637	Type 3 688	160.0	160.0	160.0	160.0	160.0	160.0	160.0	160.0	160.0	160.0	159.2
Ni-Cr-Fe	FFBS	B 637	Type 1	160.0	160.0	156.4	152.7	150.2	147.8	145.2	143.8	142.2	140.4	...
Ni-Cr-Fe	FFBS	B 637	Type 2	150.0	150.0	147.2	145.5	144.0	142.5	140.9	140.0	139.1	138.7	...
Ni-Cr-Fe		SB-637	718 Type 2	160.0	160.0	160.0	160.0	160	157.2	153.7	151.8	149.9	148.1	...
16Cr-12Ni-2Mo	FFBS	SA-479	316	85.0	85.0	85.0	80.3	77.6	77.1	77.1	77.1	77.1	77.1	76.3
16Cr-12Ni-2Mo	FFBS	SA-193	B8M	90.0	90.0	90.0	85.1	82.4	81.6	81.6	81.6	81.6	81.6	80.9
16Cr-12Ni-2Mo	FFBS	SA-193	B8M	100.0	100.0	100.0	94.6	91.5	90.8	90.8	90.8	90.8	90.8	89.6
16Cr-12Ni-2Mo	FFBS	SA-193	B8M	110.0	110.0	110.0	104.0	100.7	99.9	99.9	99.9	99.9	99.9	98.6
13Cr	Plate	SA-240	410	60.0	60.0	60.0	58.9	57.7	56.9	55.4	54.5	53.0	51.3	49.1
16Cr-12Ni-2Mo	Wld. Tube	A 554	MT316L	70.0	70.0	67.7	63.9	62.4	61.6	61.6	61.6	61.6	61.2	60.3
18Cr-8Ni	Wld. Tube	A 554	MT304L	70.0	70.0	66.2	60.8	58.5	57.7	57.0	56.6	56.2	55.8	55.0
15Cr-26Ni-2Ti	FFBS	SA-638	660	130.0	130.0	130.0	130.0	130.0	130.0	130.0	130.0	130.0	130.0	130.0
18Cr-10Ni-Cb	FFBS	SA-182	F347	75.0	75.0	71.8	66.0	61.7	60.2	59.4	58.9	58.5	58.5	58.5
18Cr-8Ni	FFBS	SA-479	304	75.0	75.0	71.0	66.0	64.3	63.5	63.5	63.5	63.5	63.1	62.6
16Cr-12Ni-2Mo	FFBS	SA-479	316	75.0	75.0	75.0	73.4	71.8	71.8	71.8	71.8	71.8	71.4	70.9
18Cr-10Ni-Cb	FFBS	SA-479	347	75.0	75.0	71.8	66.0	61.9	60.2	59.4	58.9	58.5	58.5	58.5
18Cr-8Ni	FFBS	SA-479	304L	70.0	70.0	66.2	60.8	58.5	57.7	57.0	56.6	56.2	55.8	55.4
16Cr-12Ni-2Mo	FFBS	SA-479	316L	70.0	70.0	67.9	63.9	62.4	61.6	61.6	61.6	61.6	61.2	60.8
18Cr-8Ni	Nuts	SA-194	8	75.0	75.0	71.0	66.0	64.3	63.5	63.5	63.5	63.5	63.1	62.6
18Cr-10Ni-Cb	Nuts	SA-194	8C	75.0	75.0	71.8	66.0	61.9	60.2	59.4	58.9	58.5	58.5	58.5
16Cr-12Ni-2Mo	Nuts	SA-194	8M	75.0	75.0	75.0	73.4	71.8	71.8	71.8	71.8	71.8	71.4	70.9
22Cr-13Ni-5Mn	Plate	SA-240	XM-19	100.0	100.0	99.5	94.3	90.7	89.1	87.8	87.1	86.5	85.7	84.8
22Cr-13Ni-5Mn	Bar	A 479-74	XM-19	100.0	100.0	99.5	94.3	90.7	89.1	87.8	87.1	86.5	85.7	84.8

TABLE D
ASTM B 637 TYPES 1 AND 2
CHEMICAL REQUIREMENTS

Element	Percent
Carbon	0.020 – 0.060
Manganese	1.00 max
Silicon	0.50 max
Phosphorus	0.008 max
Sulfur	0.003 max
Chromium	14.50 – 17.00
Cobalt 0.050 max	0.050 max
Columbium + Tantalum	0.70 – 1.20
Titanium	2.25 – 2.75
Alumunium	0.40 – 1.00
Boron	0.007 max
Iron	5.00 – 9.00
Copper	0.50 max
Zirconium	0.050 max
Vanadium	0.10 max
Nickel	70.00 min

TABLE E
ASTM B 637 HEAT TREATMENT

Solution Annealing	Precipitation Hardening
Type 1	
1975°F ± 25°F, hold 1 to 2 h, cool by water or oil quenching	1320°F ± 25°F, hold 20 h, +2–0 h, air cool
Type 2	
1975°F ± 25°F, hold 1 to 2 h, cool by water or oil quenching	1400°F ± 25°F, hold 100 h, +4–0 h, air cool
Grade 718 Type 2	
1850° to 1922°F, hold 1 to 2 h, cool by water or oil quenching	1300°F ±15°F, hold 6 h +1h -0 min., air cool

TABLE F
ASTM B 637 MECHANICAL PROPERTIES
(Minimum Room Temperature)

Property	Type 1	Type 2	Grade 718 Type 2
Yield strength, psi	100,000	85,000	100,000
Tensile strength, psi	160,000	150,000	160,000
Elongation in 2 in. %	20	20	20
Reduction of area, %	20	20	20
Hardness	267–363 HB 27–40 RC		267–363 HB 27–40 RC

ENCLOSURE 5

AFFIDAVIT FROM TOSHIBA CORPORATION JUSTIFYING WITHHOLDING PROPRIETARY INFORMATION

Affidavit for Withholding Confidential and Proprietary Information from Public Disclosure under 10 CFR § 2.390

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

In the Matter of

Constellation Energy LLC
Nine Mile Point
Unit 2

AFFIDAVIT

I, Tadahiko Torimaru, being duly sworn, hereby depose and state that I am Group Manager, Material Engineering Group, System Design & Engineering Department, Nuclear Energy Systems & Services Division, Power Systems Company, Toshiba Corporation; that I am duly authorized by Toshiba Corporation to sign and file with the Nuclear Regulatory Commission the following application for withholding Toshiba Corporation's confidential and proprietary information from public disclosure; that I am familiar with the content thereof; and that the matters set forth therein are true and correct to the best of my knowledge and belief.

In accordance with 10 CFR § 2.390(b)(ii), I hereby state, depose, and apply as follows on behalf of Toshiba Corporation:

(A) Toshiba Corporation seeks to withhold from public disclosure the documents listed in Attachment 1 of this affidavit, and all information identified as "Proprietary Class 2" therein (collectively, "Confidential Information").

(B) The Confidential Information is owned by Toshiba Corporation. In my position as Group Manager, Material Engineering Group, System Design & Engineering Department, Nuclear Energy Systems & Services Division, Power System Company, Toshiba Corporation, I have been specifically delegated the function of reviewing the Confidential Information and have been authorized to apply for its withholding on behalf of Toshiba Corporation.

(C) This document contains information regarding Modified alloy 718 material which is used for the fabrication of jet pump beams for the inlet mixer replacement project being performed at Nine Mile Point Unit 2. This document constituting and containing Confidential Information is entirely confidential and proprietary to Toshiba Corporation, as indicated by the phrase "Proprietary Class 2" at the top of their cover pages.

(D) Consistent with the provisions of 10 CFR § 2.390(a)(4), the basis for proposing that the Confidential Information be withheld is that it constitutes Toshiba Corporation's trade secrets and confidential and proprietary commercial information.

(E) Public disclosure of the Confidential Information is likely to cause substantial harm to Toshiba Corporation's competitive position by (1) disclosing confidential and proprietary commercial information about the design, manufacture and operation systems for nuclear power reactors to other parties whose commercial interests may be adverse to those of Toshiba Corporation, and (2) giving such parties access to and use of such information at little or no cost, in contrast to the significant costs incurred by Toshiba Corporation to develop such information.

Toshiba Corporation has a rational basis for determining the types of information customarily held in confidence by it, and utilizes a system to determine when and whether to hold certain types of information in confidence.
The basis for claiming the information so designated as proprietary is as follows:

(a) The information reveals the distinguishing aspects of a process (or component, structure, tool, method, etc.) where prevention of its use by any of Toshiba Corporation's competitors without license from Toshiba Corporation constitutes a competitive economic advantage over other companies.

(b) It consists of supporting data, including test data, relative to a process (or component, structure, tool, method, etc.), the application of which data secures a competitive economic advantage, e.g., by optimization or improved marketability.

(c) Its use by a competitor would reduce his expenditure of resources or improve his competitive position in the design, manufacture, shipment, installation, assurance of quality, or licensing a similar product.

(d) It reveals cost or price information, production capacities, budget levels, or commercial strategies of Toshiba Corporation, its customers or suppliers.

(e) It reveals aspects of past, present, or future Toshiba Corporation or customer funded development plans and programs of potential commercial value to Toshiba Corporation.

(f) It contains patentable ideas, for which patent protection may be desirable.

There are sound policy reasons behind the Toshiba Corporation system which include the following:

(a) The use of such information by Toshiba Corporation gives Toshiba Corporation a competitive advantage over its competitors. It is, therefore, withheld from disclosure to protect the Toshiba Corporation competitive position.

(b) It is information that is marketable in many ways. The extent to which such information is available to competitors diminishes the Toshiba Corporation ability to sell products and services involving the use of the information.

(c) Use by our competitor would put Toshiba Corporation at a competitive disadvantage by reducing his expenditure of resources at our expense.

(d) Each component of proprietary information pertinent to a particular competitive advantage is potentially as valuable as the total competitive advantage. If competitors acquire components of proprietary information, anyone component may be the key to the entire puzzle, thereby depriving Toshiba Corporation of a competitive advantage.

(e) Unrestricted disclosure would jeopardize the position of prominence of Toshiba Corporation in the world market, and thereby give a market advantage to the competition of those countries.

(f) The Toshiba Corporation capacity to invest corporate assets in research and development depends upon the success in obtaining and maintaining a competitive advantage.

Further, on behalf of Toshiba Corporation, I affirm that:

(a) The Confidential Information is confidential and proprietary information of Toshiba Corporation.

(b) The Confidential Information is information of a type customarily held in confidence by Toshiba Corporation, and there is a rational basis for doing so given the sensitive and valuable nature of the Confidential Information as discussed above in paragraphs (D) and (E).

(c) The Confidential Information is being transmitted to the NRC in confidence.

(d) The Confidential Information is not available in public sources.

(e) Public disclosure of the Confidential Document is likely to cause substantial harm to the competitive position of Toshiba Corporation, taking into account the value of the Confidential Information to Toshiba Corporation, the amount of money and effort expended by Toshiba Corporation in developing the Confidential Information, and the ease or difficulty with which the Confidential Information could be properly acquired or duplicated by others.

T. Torimaru
Dec. 26, 2011

Tadahiko Torimaru
Group Manager
Material Engineering Group
Systems Design & Engineering Department
Nuclear Energy Systems & Services Division
POWER SYSTEMS COMPANY
TOSHIBA CORPORATION

Attachment 1 to the Toshiba Affidavit to the NRC
(Proprietary Information)

DOCUMENTS ENCLOSED (TO BE WITHELD FROM PUBLIC DISCLOSURE PER 2.390)

Item	Document Description	Document Number	Revision
1.	Toshiba Engineering Report Jet Pump Beam Fabrication – Comparison of Modified Alloy 718 and Alloy X-750 Materials	SMV-2011-000034-P	0