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ENGINEERING DATA TRANSMITTAL

Page 1 of 1

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RELEASE AUTHORIZATION

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Document Title: Design Support Document for the K Basins Vertical Fuel Handling Tools

Release Date: March 6, 1995

Limited-Use Category: Patentable Subject Matter

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March 6, 1995

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7. Abstract The K Basins Vertical Fuel Handling Tools design basis, principles of operation, and fabrication are documented. This document and the released drawings are the primary documents required for insertion and use of the tools in the K Basins.		
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DESIGN SUPPORT DOCUMENT FOR THE
K BASINS VERTICAL FUEL HANDLING TOOLS

AE Bridges
TA Delucchi
TA Meling
SL Hecht

February 1995

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MASTER

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1.0 INTRODUCTION

The purpose of this document is to provide the design support information for the Vertical Fuel Handling Tools, developed for the removal of N Reactor fuel elements from their storage canisters in the K Basins storage pool and insertion into the Single Fuel Element Can for subsequent shipment to a Hot Cell for examination. Examination of these N Reactor fuel elements is part of the overall characterization effort. These new hand tools are required since previous fuel movement has involved grasping the fuel in a horizontal position. These tools are required to lift an element vertically from the storage canister.

Additionally, a Mark II storage canister Lip Seal Protector was designed and fabricated for use during fuel retrieval. This device was required to prevent damage to the canister lip should a fuel element accidentally be dropped during its retrieval, using the handling tools. Supporting documentation for this device is included in this document.

1.1 Objective

The primary objective of this design support document is to provide sufficient information to allow the insertion and usage of these tools by K Basins' operators during the forthcoming fuel shipment for characterization. The purpose of shipping the fuel elements to the Hot Cell is to permit their examination (destructive and nondestructive). These data are needed to characterize the current status of the fuel, supporting their interim and final disposition. The fuel handling tools were designed to Safety Class 3 with safety and quality assurance approvals, in accordance with WHC-CM-3-5, *Document Control and Records Management Manual*, Section 12.7, Approval of Environmental, Safety, and Quality Affecting Documents. The Mark II storage canister Lip Seal Protector was determined to be Safety Class 4.

1.2 Authority

A work plan describing the purpose, design requirements, and engineering tasks was issued (Bridges 1994). This work plan provided the primary authorization for the development of the Vertical Fuel Handling Tools.

2.0 DESCRIPTION

2.1 Vertical Fuel Handling Tool for Inner Elements

Figure 2.1-1 is a sketch of the Vertical Fuel Handling Tool developed to lift N Reactor Mark IV inner fuel elements. The tool consists of the following parts: 1) an expanding mandrel; 2) a collet (expanding collar); 3) a collet holder; 4) an adapter sleeve; 5) an approximately 22-feet long pole; 6) an

approximately 21-feet long rod; 7) an index rod; 8) a screw rod; 9) a wheel; 10) a handle; 11) a stop; and 12) a float.

The mandrel was fabricated from Inconel 718 and has a 1°30" taper. Similarly, the collet has a matching 1°30" taper and was fabricated from Inconel 718. The collet has machined slots that allow it to expand as the mandrel is drawn through it. Its range of expansion is 0.45 inch to 0.51 inch. The collet has a groove on the outside of one end that allows it to be snapped into the collet holder. This collet holder was fabricated from 316 Stainless Steel (SS) and was designed to allow the collet to be easily detached from the pole.

The collet holder was joined to the adapter sleeve by a 3/8-inch threaded connection. The adapter sleeve (316 SS) is used to attach the collet holder to the pole through a welded joint. The pole was fabricated from various lengths of 316 SS tubing (7/8-inch outer diameter x 1/16-inch wall thickness), joined by welding.

The mandrel was attached via a threaded joint to a 316 SS rod fabricated by welding various lengths of 316 SS rods (3/8-inch diameter) together. The mandrel is threaded (1/4-20) and the rod is tapped. This approximately 21-foot long rod is attached via a threaded connection to an index rod. The index rod (316 SS) has a rollpin placed in its middle during final assembly and was designed to limit the movement of the mandrel.

A threaded screw rod (316 SS) is attached to the index rod and provides the connection for the wheel and handle. The screw rod passes through a Brass bushing at the top of the pole. This bushing is used as an aid in centering the screw rod and acts as a rest for the wheel. The bushing is held in place by two machine screws which are tapped through the pole and into the bushing.

The wheel and handle were tapped with a 3/8-inch thread to join with the screw rod. The wheel (Aluminum or 316 SS) is used to raise the mandrel upward into the collet via the inner rod assembly. The handle (Brass or Aluminum) was designed to provide a grip for the operator to use when turning the wheel. Additionally, this handle has a hex screw at the top which permits a good striking face for a mallet. A light strike by a soft-faced mallet is necessary when disengaging the mandrel from the collet, allowing the fuel element to be released. Two hex nuts were used to lock the handle in place on the screw rod.

The stop was designed to allow the operator to place the tool at a certain elevation and "lock" it in place. It consists of two clamps and a 3/8-inch thick, 6.7-inch diameter acrylic disk. The clamps allow the operator to adjust the position of the disk and it is of sufficient diameter to keep the tool from slipping through the grating slot.

The float was fabricated from Styrofoam and encased in acrylic tubing. It was designed to offset the weight of the tool. A log of pipe insulation (Styrofoam) was cut to a length of approximately 29 inches and a 1-inch diameter hole was made through its centerline. The outer diameter of the

Styrofoam log is approximately 5.9 inches in diameter. An acrylic tube with a 6-inch outer diameter, a 1/4-inch wall thickness, and a length of approximately 30 inches was placed around the Styrofoam float to provide protection of the float from damage by contact with objects. Two endcaps (acrylic) were fabricated to fit onto the ends of the acrylic tube. Clamps were used to hold the float in place (one placed on the pole at either end of the float). While the exact position of the float will be set in the field, it initially was placed approximately 10 feet from the bottom of the tool to the top of the float.

2.2 Vertical Fuel Handling Tool for Outer Elements

Figure 2.2-1 is a sketch of the Vertical Fuel Handling Tool developed to lift N Reactor Mark IV outer fuel elements. This tool is basically the same as the tool for lifting inner fuel elements. The only exceptions are 1) the mandrel, 2) collet, and 3) collet holder. The major difference between the different parts of this tool and the other one is one of diameter. Since the outer fuel element has a larger inner diameter, the mandrel has to have a corresponding larger diameter. The collet was grooved on the inside of one end to allow it to be snapped onto the collet holder. The mandrel has was tapped to permit a threaded connection to the rod. All parts above the collet holder, mandrel and collet are the same as for the tool for lifting inner elements.

2.3 Canister Lip Seal Protector

Figure 2.3-1 shows the Mark II canister Lip Seal Protector. The canister Lip Seal Protector consists basically of a 1/2-inch thick, 304 Stainless Steel plate with a 2-inch thick, nitrile rubber pad bonded to its lower side. This device is designed to center upon a Mark II canister's locking lugs. A 7.8-inch hole was placed in the device to allow access to the open canister barrel. Only one barrel is accessible at a time. The nitrile rubber was fabricated to allow room for the valves of the canister's other barrel which still has the lid on.

3.0 APPLICABLE DOCUMENTS

3.1 American Society for Testing and Materials Publications

- ASTM A 193 - 94b Specification for Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service
- ASTM A 194 - 94a Specification for Carbon and Alloy Steel Nuts for Bolts for High-Pressure and High-Temperature Service
- ASTM A 213 - 94b Specification for Seamless Ferritic and Austenitic Alloy-Steel Boiler, Superheater, and Heat-Exchanger Tubes
- ASTM A 276 - 94b Specification for Stainless and Heat-Resisting Steel Bars and Shapes

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ASTM A 479 - 94a Specification for Stainless and Heat-Resisting Steel Bars and Shapes for Use Boilers and Other Pressure Vessels

ASTM B 637 - 93a Specification for Precipitation-Hardening Nickel Alloy Bars, Forgings, and Forging Stock for High-Temperature Service

3.2 American National Standards

ANSI B18.2.2 - 87 Square and Hex Nuts (Inch Series)

ANSI B18.3 - 82 Socket Cap, Shoulder, and Set Screws - Inch Series

ANSI B18.8.2 - 78 Taper Pins, Dowel Pins, Straight Pins, Grooved Pins, and Spring Pins (Inch Series)

ANSI B46.1 - 85 Surface Texture (Surface Roughness, Waviness, and Lay)

ANSI Y14.5M - 82 Dimensioning and Tolerancing

3.3 Other Documents

WHC-CM-4-2 Quality Assurance Manual

WHC-CM-6-1 Standard Engineering Practices

WHC-IP-1026 Engineering Practices Guidelines

HS-V-S-0013 Welding of Stainless Steel and Nickel Alloy Structural and Other Components

3.4 Engineering Drawings

H-1-80543 Vertical Fuel Handling Tool - Inner Element

H-1-80544 Vertical Fuel Handling Tool - Outer Element Tools

H-1-80546 Mark II Canister Lip Seal Protector

4.0 PRINCIPLES OF OPERATION

The Vertical Fuel handling Tools operate in the following manner:

- 1) The stop is placed at a predetermined position on the pole to prevent the tool from going too far into the fuel element.
- 2) The roll pin in the index rod must be secured (clamped or taped) at the position that has the collet at it minimum diameter (the mandrel is fully extended). This is necessary to keep the mandrel from moving upward while the operator tries to hit the fuel element hole.

- 3) The tool is lowered into the basin until the mandrel and collet are inserted into the inner hole of the desired fuel element. Caution must be taken with the tool for lifting inner fuel elements not to drive the collet against the fuel element top as this may cause the thin segments to bend.
- 4) The index rod rollpin, secured in step 2, is released and the wheel is turned clockwise until it is tight. This raises the mandrel upward, causing the collet to expand and interact with the inner diameter of the fuel element.
- 5) The pole is lifted and the fuel element is moved to its desired location (the Single Fuel Element Canister if the fuel element will be shipped to a Hot Cell for examination).
- 6) The fuel element is released by turning the wheel counterclockwise until approximately two (2) inches of thread is visible between the wheel and the top of the bushing then lightly striking the top of the handle with a soft-headed mallet. This will drive the mandrel downward, allowing the collet to compress and free the fuel element.
- 7) Should the tool become stuck, the lower end (collet, collet holder, and mandrel) is removable. The mandrel is loosened first by removing the rollpin and turning the rod counterclockwise. The collet and collet holder are removed by turning the pole or tubing counterclockwise.

The Mark II canister Lip Seal Protector is lowered into place on the uncovered canister's locking bar lugs in the Decapping Station by an Aluminum pole. The protector is centered such that opening permits access to the uncovered fuel elements. This device must be in place prior to fuel movement.

5.0 DESIGN ANALYSES

Detailed design analyses were performed to establish the design adequacy of the Vertical Fuel Handling Tools and the Lip Seal Protector. These analyses, performed by WHC-Nuclear Fuel Evaluations, indicate the devices are acceptable as designed. Appendix A contains the analyses.

5.1 Vertical Fuel Handling Tools

The Vertical Fuel Handling Tools were designed to operate with the maximum weight of the Mark IV fuel elements. An analysis of the stress on the collet was performed by WHC-Nuclear Fuels Evaluations. Maximum principal stresses of 18,900 and 15,600 psi were calculated for the tool for lifting outer elements and for the tool for lifting inner elements, respectively. A large margin

exists between these stresses and the minimum yield strength of Inconel 718 (approximately 144,700 psi).

The collet was the only item analyzed since the overall operation of the tools were simulated in testing conducted in the 305 Building Cold Test Facility (Meling 1995). This testing consisted of functional tests, load tests, and operations acceptance tests. All tests were completed successfully. The tools were load tested with a weight of approximately 62 lbs which is more than the maximum fuel assembly (inner and outer elements combined) weight of approximately 52 lbs. Each new tool fabricated should be load tested prior to its use.

5.2 Mark II Canister Lip Seal Protector

The Lip Seal Protector was designed to protect the canister lip from damage during an accidental drop of a fuel element. The device was determined to be necessary by analysis of the consequences due to the impact of a fuel element on the canister lip. It was determined that sufficient damage to the lip would occur that the Grafoil seal would fail to function. A further analysis indicate that a 1/2-inch plate with a 2-inch rubber layer beneath it would provide adequate protection for the canister lip when placed on the canister locking bar lugs.

The worst case analyzed postulated a drop of the heaviest Mark IV outer fuel element (approximately 38 lbs) from a height of 25 inches onto the plate directly above a locking lug. The height of 25 inches is the expected maximum height a fuel element can attain during transfer operations and still meet shielding requirements. This worst case drop is was predicted to exert a maximum force of 3000 lbs on the lug, corresponding to a maximum stress marginally less than the material yield strength of 30 to 35 ksi. The detailed analyses for the Lip Seal Protector are contained in Appendix A.

6.0 TECHNICAL REQUIREMENTS

6.1 Materials

The tools meet the dimensional requirements, material specifications, and standards described on the drawings, H-1-80543 and H-1-80544. Each tool was identified with the drawing number and revision number. Certification of materials used in fabrication of these tools is contained in Appendix B.

6.2 Fabrication

Welding shall be in accordance with HS-V-S-0013, "Welding of Stainless Steel and Nickel Alloy Structural and Other Components". Visual inspection of the welds by the welding engineer was the only requirement for these Safety Class 3 tools. Certification of the welding is contained in Appendix C.

6.3 Finished Products Requirements

All finished products requirements are listed on the drawings. They were met during fabrication.

6.4 Installation Requirements

Since the tools are intended for use as portable tools in the K West and K East Basins, they should follow the procedures and requirements for installation of such equipment for those facilities. No special requirements other than the typical care needed to not damage the tools during movement and insertion into the pools is necessary. The tool for lifting inner elements is potentially more susceptible to damage due to the small thickness of the collet. Care must be taken not to bend the collet segments.

7.0 QUALITY ASSURANCE

The Quality Assurance requirements, identified in the Work Plan document (Bridges 1994) and on the drawings, were met.

8.0 REFERENCES

Bridges, A. E., November 1994, *Work Plan for Development of K-Basin Fuel Handling*, WHC-SD-SNF-WP-011, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Bridges, A. E., T. A. Meling, and S. L. Hecht, February 1995, *Test Plan for K-Basin Fuel Handling Tools*, WHC-SD-SNF-TP-010, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Meling, T. A., February 1995, *Test Report for the K Basins Vertical Fuel Handling Tools*, WHC-SD-SNF-TRP-003, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Figure 2.1-1. Sketch of the Vertical Fuel Handling Tool for Inner Elements.

Figure 2.2-1. Sketch of the Vertical Fuel Handling Tool for Outer Elements.

Figure 2.3-1. Sketch of Mark II Canister Lip Seal Protector.

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APPENDIX A
DESIGN CALCULATIONS

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**Westinghouse
Hanford Company****Internal
Memo**

From: Nuclear Fuel Evaluations
Phone: 376-4193
Date: February 16, 1995
Subject: STRUCTURAL INTEGRITY ASSESSMENT OF FUEL HANDLING TOOLS AND EQUIPMENT

To: A. E. Bridges L5-01

cc:	T. A. Delucchi	L6-38
	J. J. Jernberg	X3-61
	T. A. Meling	L5-01
	B. J. Makenas	L5-01
	R. P. Omberg	HO-40
	SLH File/LB	

References: (1) Memo, S. L. Hecht to R. P. Omberg, "Canister Damage Assessment from Postulated Dropped Fuel Element", January 19, 1995.

An analytical evaluation was made to assess the structural integrity of tools and related equipment which will initially be used in the handling and removal of N Reactor fuel elements from MK II Canisters. The elements are to be transferred to a shipping cask for subsequent shipping to and evaluation in 300 Area Laboratories. Considered here, are the tools which grasp and lift the fuel elements out of the canister and the plate which protect the canister from a postulated drop fuel accident. The supporting analysis (i.e., hand calculations) are provided in the attachment.

Reference 1, showed the need for providing a protection plate, or other protective measures, so that the canister lip is not damaged to the extent that a seal cannot be assured. The reference 1 analysis, showed that almost any fuel element drop could damage the canister and affect the sealing characteristics. The protective plate (H-1-80546) is made of 1/2 stainless steel bound to a 2 inch thick rubber layer. This composite plate rests on the canister locking bar lugs. The attached analysis, predicted that for the worst case drop, i.e., a heaviest outer fuel element (38 lbs) dropping the maximum distance allowed under shielding requirements (25 inches) and at a location directly above one lug (maximum force/lug), the canister will remain un-damaged. The maximum force on the lug was predicted at 3,000 lbs. The corresponding maximum stress in the lug-to-strength ring weld, was calculated to be marginally below the minimum yield strength of the weld material ($S_y = 30-35$ ksi).

Prototypes of the fuel element pick-up tools (H-1-80543, 544), have been successfully tested in both the 306 building pit (dry) and 305 Cold Test Facility (under water). A major load on this assembly is the torque applied at the top hand wheel, which actuates the grasping mechanism. This torque loading is unknown (operator and fuel element geometry dependent), and

A. E. Bridges
February 16, 1995
Page 2

hence, analysis of components in the associated load path would be difficult. Since prototype testing was representative of the proposed K basin operation, it is felt that this successful testing represent acceptance of said components. A critical component of the handling tools is the expanding collar. This component has physical stops which limit the deformations, and associated stresses. The attached analysis calculated maximum peak principal stresses of 18,900 and 15,600 psi, for the large and small unit, respectively. As the minimum yield stress of the Inconel 718, of which the collars are constructed, is 144,700 psi, there is a large design margin on the expanding collar.

In conclusion, the components evaluated herein, are predicted to maintain their structural integrity under design and expected operating conditions.

S. L. Hecht
Nuclear Fuel Evaluations

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page 1 of 3
 (4) Building KW (5) Rev. _____ (6) Job No. _____
 (7) Subject STRUCTURAL ANALYSIS / KW TOOLS AND RELATED
 (8) Originator S.L. HOGHT Date 2-9-95
 (9) Checker AE Bridges Alvin E. Bridges Date 2-16-95

(10)

(1) PROTECTION PLATE

ASSUME THAT DROP FUEL IS A OUTER ELEMENT (38 lbs)
 FALLING A MAXIMUM DISTANCES (ALLOWABLE FOR SHIELDS
 (~25 IN)). ASSUME DROP IS DIRECTLY ABOVE
 ONE CANISTER LUG (THIS WILL GIVE MAXIMUM
 LOAD ON LUG).

FOOT PRINT OF LUG $A_{LUG} = (.375)(2.64) = 0.99 \text{ in}^2$
 ASSUME LOAD/STRESS FANS OUT 20° ANGLE (CONSERVATIVE) AS
 IT IS TRANSMITTED THROUGH 2 INCH OF RUBBER.

$$L' - (2) \tan 20^\circ = .73$$

$$L'_{ff} = 2.64 + (2)(.73) = 4.1$$

$$W' = (.375)(2)(.73) = 1.8$$

$$A_{TRAP} = (4.1)(1.8) = 7.4$$

$$A_{AUS} = (7.4 + .99)/2 = 4.2$$

SOLN IS ITERIVE PROCESS (NON-LINEAR CHARACTERISTIC
 OF RUBBER IN COMPRESSION).

1ST ITERATION: ASSUME RUBBER COMPRESSED .65% of h.

(See fig. pg. 2)

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page 2 of 2
 (4) Building _____ (5) Rev. _____ (6) Job No. _____
 (7) Subject _____
 (8) Originator MM Date 2-7
 (9) Checker Olivia E. Bridges Date 2-16-95

(10)

Figure 2. Uniaxial extension and compression (derived from equibiaxial extension) (21). Broken curve, experimental; full curve, theoretical. To convert MPa to psi, multiply by 145. Courtesy of Rubber Chemistry and Technology and The Faraday Society.

(From: Encyclopedia of
CHEMICAL TECH. 3rd ed.
 Vol 8, January 1977)

FROM FIG $E_{MAX} = 3.1 \text{ MPa} = 450 \text{ psi}$
 $E_{AVG} \approx E_{MAX} / 2 = 225 \text{ psi}$

$$K_{eff} = \frac{A_0 E_0}{L} = \frac{(4.2)(225)}{2} = 470 \text{ lb/in}$$

The POTENTIAL ENERGY (PE) PRIOR TO DROP = WH ,
 This IS TRANSFORMED TO KINETIC ENERGY AT IMPACT,
 AND THEN INTO ELASTIC STRAIN ENERGY (WORK) IN
 THE RUBBER (CONSERVATION NEGLECT VISCO-ELASTIC
 EFFECTS). THIS WORK IS

$$W_e = \int F \cdot ds = k \int_0^x x \cdot dx = \frac{kx^2}{2}$$

FROM CONSERVATION OF ENERGY

$$PE = W_e$$

$$WH = \frac{kx^2}{2}$$

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page 3 of 8
 (4) Building _____ (5) Rev. _____ (6) Job No. _____
 (7) Subject _____
 (8) Originator AM Date 2-9
 (9) Checker Alvin E. Bridges Date 2-16-95

(10)

$$X = \sqrt{\frac{2wh}{K}} = \sqrt{\frac{1900}{K}}$$

$$= \sqrt{\frac{1900}{470}} = 2.00 \text{ in} > .65 (2) \text{ } \phi \text{ - iterative.}$$

Try 72% compression

EXTRAPOLATION FROM FIGURE

$$E_{MAX} = 7 \text{ MPa} = 1015 \text{ psi}$$

$$E_{AVG} = 1015 / 2 = 507 \text{ } j' = K_{AVG} = \frac{(4.2)(507)}{2} = 1070 \text{ lb/in}$$

$$X = \sqrt{\frac{1900}{1070}} = 1.34 \text{ in}$$

$$X_{ASSUMED} = (2)(.72) = 1.44 \text{ in OK. good approx}$$

$$K_{MAX} = 2K_{AVG} = (2)(1070) = 2140 \text{ lb/in}$$

$$F_{MAX} = K_X = (2140)(1.44) = \underline{\underline{3081.6 \text{ lbs.}}}$$

CHECK STRENGTH OF LUG WELD TO STRAIGHT RIVET

SHEAR AND MOMENT REACTED AT WELD

$$L = 1.25 - 0.5 = .75$$

$$M = (.75)(3,000) = 2,250 \text{ in-lb}$$

$$T_{AVG} = \frac{(1.44)P}{nL_w} = \frac{(1.44)(3,000)}{(18)(3.76)} = 9,030 \text{ psi}$$

1/8 inch weld

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page 4 of 9
 (4) Building _____ (5) Rev. _____ (6) Job No. _____
 (7) Subject _____
 (8) Originator ALT Date 2-9
 (9) Checker Alvin E. Bridges Date 2-16-95

(10)

$$\sigma_b < \frac{(4.24)M}{I L^2} = \frac{(4.25)(2,250)}{(1.387,125)^2} = 33,700 \text{ psi}$$

These two STRESSES compared are not compared as they MAX occur at locations where they do not co-exist. Therefore consider separately.

Well MATERIAL IS ASSUMED TO HAVE ^{MIN.} PROPERTIES
 of SA 304 at RT. or 308/30EL

$$304 \quad S_{y \text{ min}} = 29,700 \quad S_{U \text{ min}} = 69,900$$

$$308 \quad S_{y \text{ min}} = 35,000 \quad S_{U \text{ min}} = 73,000$$

WITH $\tau_{avg} < S_y/2$ There is no problem with the shear stress.

However σ_b of 33,700 psi (conservative calculation)

is only slightly GREATER THAN MIN S_y of 29,700

There is a possibility of some small amount of plastic deformation (with strain hardening) but not failure. However, considering the conservatism used in the analysis, THE DESIGN IS CONSIDERED ACCEPTABLE.

(11) H.A. ROXBART, MECHANICAL DESIGN AND SYSTEM HANDBOOK
 MCGRAW HILL, 1964.

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page 5 of 8
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 (8) Originator APM Date 2-9
 (9) Checker Alvira E. Andjoo Date 2-16-95

- (10) OTHER COMPONENTS IN THE LOAD PATH ARE ACCEPTABLE BY COMPARISON.

2. FUEL PICK-UP TOOL'S

EXPANDING COLLAR'S

THESE COMPONENTS CAN STRUCTURALLY BE CONSIDERED AS A SERIES OF BEAMS ARRANGED IN A CIRCUMFERENTIAL MANNER. A RADIAL LOAD, WHICH IS EVENTUALLY REJECTED BY THE I.D. OF THE FUEL ELEMENT, PROVIDE A INCREASE IN RADIAL MOTION. THIS RADIAL MOTION, IS REJECTED IN THE HOPF DIRECTION BY BENDING OF EACH OF BEAMS, WHICH PROVIDES THE INCREASE IN CIRCUMFERENCE.

LARGE COLLAR

THIS COMPONENT HAS A AS-BUILT EXPANSION RANGE FROM A O.D. OF 1.67 in. to 1.76 inches Fully Expanded (STOP LIMITS)

ON THE THICK SIDE:

$$D_{TH} = (1.67 + 1.20) / 2 = 1.435 \text{ AND } t = (1.67 - 1.20) / 2 = 0.235 \text{ in}$$

ON THE THINNING SIDE:

$$\delta_t = L \sin \theta = 3 \sin (1.5^\circ) = .078 \rightarrow \Delta D \text{ of } .156$$

$$\therefore ID = 1.20 + .156 = 1.356 ; D_{AVG} = (1.67 + 1.356) / 2 = 1.513$$

$$t = .157$$

OVERALL AVG:

$$D_m = (1.435 + 1.513) / 2 = 1.474$$

$$t = (.235 + .157) / 2 = .196 = b$$

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page 6 of 8
 (4) Building _____ (5) Rev. _____ (6) Job No. _____
 (7) Subject FLK-UP TOOL
 (8) Originator S.L. HATCH Date 2-10-95
 (9) Checker Alvin E. Bridges Date 2-16-95

(10)

EACH BEAM SECTION

INNOV. 712 : 0.25" R.H. NS.M.H.

$$E = 29 \times 10^6 \text{ psi}$$

$$S_{y \text{ min}} = 143,700$$

$$S_{x \text{ min}} = 185,500$$

$$L = 3 - .25 - .2 = 2.55 \text{ in}$$

$$C_m = \pi D_m = 4.631 \text{ in}$$

$$h = ? \quad h = \left[C_m - \frac{(20)(.080)}{\text{slots}} \right] / 20 = .151$$

$$I_m = \frac{bh^3}{12} = \frac{(.196)(.153)^3}{12} = 5.62 \times 10^{-5} \text{ in}^4$$

$$k = \frac{3EI}{L^3} = \frac{(3)(29 \times 10^6)(5.62 \times 10^{-5})}{(2.55)^3} = 295 \text{ lb/in}$$

each beam section must deflect by δ_m to the max
 VARIAC MOTION

$$\text{FRAC. CHANGE in DIA} = \frac{1.76 - 1.67}{1.67} = .0539$$

∴ Circumference, C_m , must increase by the same
 percentage

$$\Delta C = (.0539)(C_m) = (.0539)(4.631) = .2501$$

for 20 slots (28)

$$\text{or } \delta = (.2501) / (20)(28) = .00624 \text{ each beam} = \delta$$

$$F = k\delta = (295)(.00624) = 1.84 \text{ lbs.}$$

$$M_{\text{max}} = Fl = (1.84)(2.55) = 4.69 \text{ in-lbs}$$

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page 7 of 8
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 (9) Checker Alvora E. Bridges Date 2-16-95

(10)

$$\sigma = \frac{Mc}{I} = \frac{(4.67)(1.51/2)}{5.62 \times 10^{-5}} = \underline{6,300 \text{ psi}}$$

For fatigue, consider worst case stresses concentration
 $K_f = 3.0$ { E.S. Roark, Formulas for Stress & Strain 4ed,
 Table XVIII, Case 9 }

$$\sigma_{peak} = (3)(6,300) = 18,900 \text{ psi} < S_y$$

LARGE MARGIN of safety = O.K.

SMALL COLLAR

ON THE THICK SIDE $D_{AVE} = (4.5 + 2.52)/2 = 3.51$, $t = .099$

ON THE THIN SIDE $(2.37)(\sin(15^\circ)) = .062$

$$D_{min} = (.252) + (2 \times .062) = .376 \Rightarrow D_{AVE} = .413, t = .037$$

OVERALL AVG:

$$D_{AV} = .382$$

$$t_{AV} = .068$$

$$\therefore C_{AV} = \pi D_{AV} = 1.20$$

$$h = (C_{AVE} - C_{SLOT})/12 = [1.20 - 12(.04)]/12 = .060 \text{ in}$$

$$b = t_{AV}$$

$$\therefore I = \frac{bh^3}{12} = \frac{(.068)(.060)^3}{12} = 1.22 \times 10^{-6} \text{ in}^4$$

$$K = \frac{3EI}{l^3} = \frac{(3)(29 \times 10^6)(1.22 \times 10^{-6})}{(1.38)^3} = 16.1 \text{ lb/in}$$

$$l = 2.37 - .24 - .25 = 1.88$$

DESIGN CALCULATION

(1) Drawing _____ (2) Doc. No. _____ (3) Page 8 of 8
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 (7) Subject _____
 (8) Originator S.L. HIGHT Date 2-13-95
 (9) Checker Olivia E. Bridges Date 2-16-95

(10)

THE MAXIMUM EXPANSION (DIAMETER) IS TO 0.510 IN, or

$$\Delta D = .510 - .450 = .060 \text{ INCHES}$$

$$\frac{\Delta D}{D_0} = \frac{.060}{.45} = .133$$

$$\Delta C = (\Delta D / D_0) C_m = (.133)(1.20) = .160$$

for 12 slots (28)

$$\text{or } \delta = (.160) / (12)(2) = .00665 \text{ IN}$$

$$F = k\delta = (15.37)(.00665) = 0.101 \text{ LB}$$

$$M_{\text{MAX}} = FL = (0.101)(1.89) = 0.201 \text{ IN-LB}$$

$$\sigma_b = \frac{Mc}{I} = \frac{(.201)(.063/2)}{1.22 \times 10^{-6}} = 5,200 \text{ PSI}$$

Considering stress concentration, $K_f \approx 3.0$

$$\sigma_b^{\text{REL}} = (5,200)(3) = 15,600 \text{ PSI}$$

As the material is Inconel 718, $S_{y(\text{min})} = 147,700 \text{ PSI}$

The design is ACCEPTABLE

**Westinghouse
Hanford Company**
**Internal
Memo**

From: Nuclear Fuel Evaluations
 Phone: 376-4193 L5-01
 Date: January 19, 1995
 Subject: CANISTER DAMAGE ASSESSMENT FROM POSTULATED DROPPED FUEL ELEMENT

To: R. P. Omberg R3-85

cc: C. L. Bennett X3-77 T. A. Meling L5-01
 D. W. Bergmann R3-86 B. J. Makenas L5-01
 A. E. Bridges L5-01 D. W. Siddoway R3-85
 B. S. Carlisle X3-71 C. A. Thompson X3-72
 K. E. Dobbins N1-21 J. E. Truax X3-71
 J. C. Fulton R3-85 SLH File/LB L5-01
 J. J. Jernberg X3-61

- References: (1) S. L. Hecht, ALGOR Computer Code QA, WHC-SD-GN-CSWD-321, August 1, 1991.
- (2) NUCLEAR SYSTEM MATERIAL HANDBOOK, TID-26666, Rev. 37, ORNL, September 1988.
- (3) F. H. Huang, Brittle-Fracture Potential of Irradiated Zircaloy-2 Pressure Tubes, J. Nuclear Material 207 (1993) 103-115.
- (4) FUELS ENGINEERING TECHNICAL HANDBOOK, UNI-M-61, April 1979.
- (5) C. O. Smith, NUCLEAR REACTOR MATERIALS, Addison-Wesley, 1967.
- (6) W. E. Baker, et al., EXPLOSION HAZARDS AND EVALUATION, Elsevier Sci. 1983.
- (7) Structural Analysis and Design of Nuclear Plant Facilities, ASCE - Man. and Reports Engineering Practices No. 58, 1980.

An evaluation was made to assess the potential for damaging a MK II Canister, such that it could not maintain its sealing capabilities, after being struck by a postulated dropped fuel element, or single element canister. Irradiated N Reactor fuel elements are planned to be removed from MK II Canisters in the K West transfer pit, for subsequent examination. Because the potential condition of the fuel and the type of handling equipment, it is credible that a fuel element, or parts thereof, could potentially be dropped during handling. Should the element be a location vertically above the canister it was removed from, the fuel element could then drop and impact the open canister. One concern, and that evaluated

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herein, is that the canister is damaged to a point where it becomes non-functional with respect to sealing fuel element and associated contaminants. Two potential damage scenarios are considered. These are: (1) fuel/canister drops on the MK II canisters thin lip (0.060 in. thick), which is a sealing surface, and the lip is deformed (dinged, dented, etc.) to the extent that a seal is not maintained, (2) fuel drops into the canister (empty location) and punctures the bottom plate or fails the bottom plate seal weld.

These potential damaging mechanisms are analytically evaluated herein, and as a result of this analysis, recommendations as to operational procedures and design change are made.

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

An conservative analytical evaluation was made which assessed the extent of a damage to a MK II canister, during a postulated dropped fuel element handling accident. The results of the evaluation showed that virtually any drop of a fuel element (<0.4 in.) could deform the canister lip to the extent that a absolute seal may not be maintained, with the current sealing design. Fuel element drops, of possibly up to 8 in., might be acceptable if very small leaks are permitted, or a new lid-seal design utilized. Analysis also showed that a dropped fuel element would not penetrate the canister bottom plate.

Several methods could be deployed to eliminate or mitigate the potential for loss of seal integrity. These include: (1) use of a protective barrier (strike plate--or energy absorbing device); (2) change the seal design on the MK canister lid to a more compliant design, e.g., rubber o-ring, which can accommodate small distortions and have a acceptable life. Additionally, investigation into the possible acceptance of "small leaks" and the risk acceptance related to the accident scenario.

ANALYSIS

The analysis is divided into two parts. The first part is the fluid dynamics evaluation, in which impact velocities (and associated kinetic energies) are calculated. This work was done by G. L. Fox (recently retired), and is presented in it's entirety in Attachment 1. The second part is the structural evaluation which uses the calculated velocities as input, and assesses the adequacy/limitations of the canister after impact.

Fluid Mechanics Analysis

It is assumed that a drop will not occur from a elevation higher than that allowed for shielding purposes, i.e., approximately 6 ft above the transfer pit floor. For the shortest fuel element (MK IAF), which is 15 in. long, maximum drops can be 30 or 57 in. to the top of the canister lip or the bottom plate, respectively. The fuel is assumed to drop in a vertical

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orientation, so as to consider the maximum possible velocity and impact conditions. The determination of velocity, as a function of drop height was based on the equation of motion, i.e., the incremental summations of time integration of the drop element acceleration. The instantaneous acceleration is the sum of the downward forces (weight, buoyancy, drag) at the given time divided by the mass. As the drag is a function of the velocity squared, the acceleration changes with time (until terminal velocity). The numerical method and solution is given in Attachment 1.

Figure 1 gives the results of the calculation for a drop fuel element. As shown, for the drop distance considered, the velocities in water are not much different when fluid effect are not considered $[(2gh)^{1/2}]$. Velocities for the total element (shown) are the same as that for either a inner or outer element, as the drag coefficient and the component densities are uniform. Kinetic energy at impact, can then be consider equal to the potential energy before the drop (Wh), as fluid drag effects are negligible. This is a slightly conservative assumption.

Structural Analysis

Structural analysis , given herein, consist of two parts. The first part is the evaluation of the deformation of the canister lip. The second part deal with penetration of the canister bottom plate.

Calculation of the deformation of the canister lip, involve a non-linear elastic-plastic finite element analysis. The procedure is to calculate permanent inelastic deformations and associated plastic work (strain energy). When the deformation becomes unacceptable with respect to sealing capabilities, the corresponding plastic strain energy is determined. This energy is than equated to a kinetic energy at impact (conservation of energy) which relates to a allowable drop height (e.g., from Figure 1).

Prior to the inelastic analysis, elastic analyses were preformed, to aid in the determination of the load history for the inelastic analysis. These elastic analyses also determine which is the most damaging component (loading) to evaluate in the subsequent inelastic analysis. Elastic, finite element model, using the ALGOR¹ finite element analysis program, is shown pictorially in Figure 2, and represents a 30 degree segment of a canister barrel. Symmetry is provided about the center, and hence only 1/2 the load from the fuel element is applied. Loading is applied as a uniform nodal forces (except at center) to simulate a uniform pressure, and represents a 2 g static load from either a inner or outer fuel element. The 3-D, 8 node, elastic brick elements, with three translational degrees of freedom per node, are used here. Elastic material properties were those for SA 304 SS at room temperature, taken from Reference 2.

The results of the elastic analysis, showed that the loading from the outer fuel elements is more severe than that from a inner element, and hence only

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the outer element drop was considered for the subsequent inelastic analysis. For the inner and outer fuel elements, the maximum effective stress for a 1 g load (weight of 18 or 38 pounds) is 347 psi and 878 psi, respectively. These results are shown in Figure 2.

For the elastic-plastic analysis, a 2-D analysis was used, as opposed to the 3-D analysis for the elastic analysis. The 3-D elastic analysis, showed very little effect of the curvature of the plate (this was latter confirmed from the 2-D model--i.e., a 2 to 3% effect). It was also desirable to simplify the inelastic analysis as it is much more computationally intensive, than a corresponding elastic analysis. The model (see Figure 3) represent a ("rolled out to flat plate") section of symmetry about the center of 1/2 the outer fuel element loading. Model, mesh size, and boundary conditions were specified to adequately model the zone where the plastic deformations would likely occur, without undue computational complexity of a larger model. Four node, plane stress isoparametric quadrilaterals (2 degrees of freedom per node and 2 x 2 internal integration) were employed. The plasticity model was based on Von Mises yield criterion, and a bi-linear stress strain curve. For conservatism, the softest (minimum) material properties² were used, i.e., $S_y = 24,000$ psi and $E_t = 138,700$ psi.

The elastic-plastic analysis load history involved 60 load steps (+convergence sub iterations). The first step is the same loading condition that was used in the 3-D elastic analysis (i.e., 2 g's). The next step was at 26 G load, which is at a point just below at which plasticity would be expected. The load was that incremented by approximately 5% each load step, up to a 100 G load. Figure 3, shows the resulting effective stress contour and deformed shape (maximum deflection is 0.102 in.) at the last load step (100 G). ALGOR does not calculate in-elastic strain energy (plastic work). As the plastic work, W_p , for a unit volume is:

$$W_p = \int \sigma_e d\epsilon_p$$

or on a incremental basis, with respect to the results given in Figure 3.

$$W_p = \sum V \bar{\sigma}_e \epsilon_p$$

Therefore, the plastic works was calculated by summing up the plastic work over the model on a element by element basis. As the model only included

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1/4 of the loaded regions, the plastic work calculated for the model is multiplied by four to get the total work on the structure. Tabulated below are results of the elastic-plastic analysis:

<u>LOAD STEP</u>	<u>LOAD (G's)</u>	<u>δ max (in.)</u>	<u>$W_p \times 4$ (in.-lb)</u>
10	37	0.001	1
20	50	0.013	15
40	75	0.050	116
60	100	0.102	284

It was assumed that all of the energy absorbed via plastic work will occur in the 304 SS canister wall. This implies that no energy is absorbed by in-elastic deformation in the fuel element, which is generally a conservative assumption, when calculation of MK II canister wall deformation is considered. This assumption is expected to be fairly realistic, because of the relative strength of the material of the interacting components. At the region of contact (intersection cylindrical shells), the dominated structural behavior is of symmetrical hertz type contact. For the 100 G load, the maximum effective stress is approximately 75,000 psi (near the minimum ultimate stress of the SA 304 SS). The N Reactor fuel element, is made of a Uranium alloy (601) clad in a zircaloy 2 tube (co-extruded). Irradiated N Reactor zircaloy 2, has a yield strength of approximately 120 Ksi³ at room temperature. The yield strength at room temperature of unirradiated uranium 601 has been reported at 63 Ksi.⁴ While I could not find any irradiated tensile properties for uranium 601, pure Uranium has been shown to significantly fluence harden. Reference 5, reports more than a 100% increase in yield strength for Uranium after irradiation. Based on the above, it is assumed that the fuel element will not plastically deform, and absorb energy via plastic work, at loadings up to 100 g's.

As the primary concern is loss of seal integrity, the questions of "what constitutes acceptable deformation on the canister lip?," arises. This can be somewhat arbitrary, and subjective. The canister is sealed with a Grafoil gasket type seal, mounted in a groove on the canister lid. This 0.015 in. thick gasket is compressed against the canister lip, for sealing. Upon review of the tolerance on the canister lip and the "Grafoil vendor data," suggest that for "perfect sealing" no more than a 0.005 to 0.010 in. dent could be tolerated. Consider the 0.102 deformation, at the 100 G (3800 lb) load. Here, total gap (two dents) of 0.102×0.359 (thickness of outer fuel element) would produce a flow path of slightly less than two 0.036 in² gaps.

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To determine the maximum drop height, we need only equate the drop potential energy (Wh) with the plastic work as given in the proceeding table. Here, the drop height (h) is the plastic work divided by the weight, or:

$$h = W_p/W$$

Consider the heaviest outer element, $W = 38$ lb. Here for the case of assuring a absolute seal, $h = 15/38 = 0.4$ in. For the case of a reasonably small leak (e.g., 100 G load), then $h = 384/38 = 7.5$ in. Therefore, it appears that if a very small leak is acceptable, a operating procedure and or equipment could be developed and implemented which could preclude unacceptable drop scenarios. Otherwise, a device need be installed to protect the lip of the canister.

The other concern is that a fuel element will drop into the canister and penetrate the bottom 1/4 in. thick 304 SS plate. For conservatism it is assumed that the heavier outer fuel element is dropped. In reality, it is likely that only the smaller inner element could directly impact the bottom plate, as space restriction would generally prevent the large element from by-passing the remaining fuel elements. Failure of the bottom plate weld is considered unlikely, because the plate sits on a concrete floor, and hence, shear and moment reactions would not occur under loading.

To determine if the dropped fuel will penetrate the canister bottom plate, empirical and design relationships were used. These relationships came primarily from armor-plate and ballistics test data. Reference 6 gives a relationship for penetration velocity of projectiles hitting unbacked metal plates. As the canister sits on the pit concrete floor, the evaluation given herein is ultra-conservative. This relationship is shown in the figure below, and involves the use of nondimensional parameter groups.

Nondimensional Limit Velocity Versus Nondimensional Thickness
 for "Chunky," Non-Deforming Fragments (2)

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The relationship was based on data from spherical projectiles (radius = a). As the projectile evaluated here is concentric cylindrical tubes, a equivalent spherical radius is calculated with the formula recommended in Reference 6, and given below:

$$a = [m/(\rho_p 4\pi/3)]^{1/3}$$

where

m = Mass of the projectile

ρ_p = Mass density of the projectile

$$a = [(38/386.4)/\{(.67/386.4)(1.333)\pi\}]^{1/3} = 2.34 \text{ in.}$$

Then

$$h/a = 0.25/2.34 = 0.11, \text{ where } h = \text{thickness of plate} = 0.25 \text{ in.}$$

from the figure above,

$$(\rho_p V_{50})/(\sigma_t \rho_t)^{1/2} = 0.42$$

where

σ_t = the yield strength of the plate = 24,000 psi

ρ_t = mass density of the plate = $0.283/386.4 = 7.32 \times 10^{-4}$

V_{50} = 50% probability penetration velocity

Therefore,

$$V_{50} = (0.42)[(24,000)(7.32 \times 10^{-4})]^{1/2}/1.73 \times 10^{-3} = 1,020 \text{ in./s} \\ = 85 \text{ ft/s}$$

Two other empirical/design relationships were also evaluated. These^{6,7} predicted penetration velocities between 88 and 193 ft/s, depending on assumptions. It is apparent, that penetration of the bottom plate is not expected, as the maximum impact velocity is 17 ft/s (Figure 1).

S. L. Hecht
Nuclear Fuel Evaluations

jmn

N Reactor Fuel Drop Results

(Inner + Outer Elements)

FIGURE 1

FIGURE 2

lastin& sview candr2

FUELFALL.BAS
by George Fox

ATTACHMENT 1

This program calculates the terminal velocity of N-reactor fuel cylinders being transported within a pool of water and dropped while at some height.

'Define the initial conditions

H = 5 'Height of drop, ft
A = .0238 'Fuel frontal area, ft^2
L = 2.175 'Length of element, ft
M = 1.71739 'Mass of element, slugs
RhoW = 1.9379 'Density of water, slugs/ft^3
XD1 = 0 'Initial velocity of fuel, ft/sec
Coef = .82 'Drag coefficient
Delt = .001 'Time step, sec

form\$ = " ###.## ###.### ###.### ##.### ####.##"
form1\$ = " ###.## #.#### ##.### #.#### #.#### "
form2\$ = " ##.### ##.## #.#### #.#### ##.###^#### ##.####^####"

OPEN "scrn:" FOR OUTPUT AS #1
OPEN "e:fuelfall" FOR OUTPUT AS #2

'Acceleration of gravity, ft/sec^2
g = 32.2

X1 = H
Energy = .5 * M * XD1 ^ 2

'Evaluate force coefficients needed later

C1 = -M * g + A * L * RhoW * g
C2 = Coef * RhoW * A * .5

'Calculate initial acceleration

XDD1 = (C1 + C2 * XD1 ^ 2) / M

'Print input and headings

```
CLS
FOR k = 1 TO 2
PRINT #k, "          FUEL DROP PROBLEM"
PRINT #k,
PRINT #k, "          H          A          L          M          RhoW"
PRINT #k, USING form1$; H; A; L; M; RhoW
PRINT #k,
PRINT #k, "          X1          XD1          Coef          Delt          C1          C2"
PRINT #k, USING form2$; X1; XD1; Coef; Delt; C1; C2
PRINT #k,
PRINT #k,
PRINT #k, "          Time          XDD          XD          X          Energy"
PRINT #k, "          sec          ft/sec^2          ft/sec          ft          ft-lb"
PRINT #k,
PRINT #k, USING form$; Time; XDD1; XD1; X1; Energy
NEXT k
```

' Dynamic motion calculations begin here
DO WHILE X1 > 0

'Use predictor-corrector method of calculation

FOR I = 1 TO 50 'Set iterations between printouts
XDD2 = XDD1
XD2 = XD1 + (XDD2 + XDD1) * .5 * Delt

' Calculate new XDD2

XDD2 = (C1 + C2 * XD2 ^ 2) / M
XD2 = XD1 + (XDD2 + XDD1) * .5 * Delt
X2 = X1 + (XD2 + XD1) * .5 * Delt

```
Update parameters
  Time = Time + Delt
  X1 = X2
  XD1 = XD2
  XDD1 = XDD2
  Energy = .5 * M * XD1 ^ 2

  IF X1 <= 0 THEN EXIT FOR
NEXT I

Print output
  FOR k = 1 TO 2
  PRINT #k, USING form$; Time; XDD1; XD1; X1; Energy
  NEXT k

LOOP

CLOSE #1
CLOSE #2

END
```

FUEL DROP PROBLEM

H	A	L	M	RhoW	
5.00	0.0238	2.175	1.7174	1.9379	
X1	XD1	Coef	Delt	C1	C2
5.000	0.00	0.8200	0.0010	-5.207E+01	1.8910E-02

Time sec	XDD ft/sec ²	XD ft/sec	X ft	Energy ft-lb
0.00	-30.319	0.000	5.000	0.00
0.05	-30.294	-1.516	4.962	1.97
0.10	-30.218	-3.029	4.848	7.88
0.15	-30.093	-4.537	4.659	17.67
0.20	-29.918	-6.037	4.395	31.30
0.25	-29.695	-7.528	4.056	48.66
0.30	-29.426	-9.006	3.642	69.64
0.35	-29.112	-10.469	3.155	94.12
0.40	-28.756	-11.916	2.596	121.93
0.45	-28.358	-13.344	1.964	152.91
0.50	-27.923	-14.751	1.262	186.86
0.55	-27.452	-16.136	0.489	223.58
0.58	-27.154	-16.955	-0.007	246.85

Revised
12/14/02

Fuel drop summary table

**** (Inner + outer elements) ****					Single element canister	
Drop Height	Without		With		With	
	*** Water ***	***	*** Water ***	***	*** Water ***	***
ft	Velocity ft/sec	Energy ft-lb	Velocity ft/sec	Energy ft-lb	Velocity ft/sec	Energy ft-lb
0.0	0.0	0.0	0.0	0.0	0.00	0.00
0.5	5.7	27.9	5.5	26.0	5.19	34.15
1.0	8.1	55.7	7.8	51.8	7.24	66.46
1.5	9.9	83.4	9.5	77.1	8.79	97.89
2.0	11.4	110.9	10.9	102.1	10.04	127.65
2.5	12.7	138.9	12.1	126.7	11.10	156.05
3.0	13.9	166.2	13.3	151.6	12.03	183.31
3.5	15.0	194.2	14.3	175.7	12.88	210.13
4.0	16.1	221.7	15.3	199.8	13.61	234.81
4.5	17.0	249.2	16.1	223.6	14.30	259.08
5.0	18.0	277.2	17.0	246.9	14.92	282.08
5.5	18.8	304.7	17.7	270.2	15.50	304.35
6.0	19.7	332.4	18.5	293.4	16.03	325.82
6.5	20.5	360.1	19.2	315.7	16.53	346.40
7.0	21.3	387.8	19.9	338.4	16.99	366.05
7.5	22.0	415.3	20.5	360.8	17.42	384.74
8.0	22.7	442.5	21.1	382.7	17.82	402.46
8.5	23.4	470.6	21.7	404.1	18.20	419.82
9.0	24.1	498.1	22.3	425.8	18.55	436.20
9.5	24.8	526.5	22.8	446.8	18.89	452.20
10.0	25.4	554.2	23.3	468.2	19.20	467.21

N Reactor Fuel Drop Results

Single Fuel Element Canister

WHC-SD-SNF-DR-001, Rev.0

Revised
12/28/94

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WHC-SD-SNF-DR-001, Rev. 0

APPENDIX B
MATERIALS CERTIFICATION

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CARPENTER
TECHNOLOGY CORPORATION
P.O. BOX 662 • READING, PA. 19603

MC-105

CERTIFICATE OF TESTS

DATE: 6/28/74
WESTINGHOUSE HANFORD CO.
ACCTS. PAY.
P.O. BOX 1970
RICHLAND, WA 99352

PAGE #1 OF #2

ATTN: R. CUTERI
PROCUREMENT & MATL. CONTROL DEPT.
BLDG. 337 AREA 300

MC 105
L-492

CUSTOMER ORDER NO.	CARP. ORDER NO.	DATE SHIPPED	
Y4J-444-14007	W64470 NUCLR	6/28/74	SF
PRODUCT DESCRIPTION		SPECIFICATION	
TYPE 316 ANLD CG		* SEE BELOW	

WEIGHT	SIZE	HEAT NO.	C	MN	SI	P	S	CR	NI	MO	CU
587#	.375" RD.	66498-3									
		LADLE:	.065	1.75	.66	.010	.007	17.28	12.24	2.28	
		CHECK:	.063	1.77	.60	.012	.002	17.26	12.25	2.31	

ITEM #1

*SPECS:

ASME SA 479
RDT M7-3T AUGUST 1972 AMEND. 1
ATTACHMENT 1 MAY 10, 1973
REQUIREMENTS A, C, I, M, P, S, T, U, W
ATTACHMENT 2 MAY 10, 1973

YIELD STRENGTH, KSI @ .2% 63.2 ✓
TENSILE STRENGTH, KSI 88.7 ✓
ELONGATION IN 2 ".% 66.7 ✓
REDUCTION OF AREA, % 80.5 ✓
HARDNESS

HEAT TREATMENT:
TEMPERATURE
TIME
COOL

ANNEAL
1040°C = 1904°F
1 HOUR
WATER QUENCH

(CONTINUED)

I CERTIFY THIS INFORMATION TO BE TRUE AND
CORRECT AS CONTAINED IN THE RECORDS OF
CARPENTER TECHNOLOGY CORPORATION

NUCLEAR MATERIALS
RELEASE COORDINATOR

NOTE: ALL OTHER TECHNICAL DATA SHOWN REPRESENT THE RESULTS OF ANALYSES AND TESTS MADE ON SAMPLES COLLECTED FROM THE TOTAL LOT.

STATE OF PENNSYLVANIA
COUNTY OF BERKS

Subscribed and sworn to before me

this _____ day of _____ 19____

NOTARY PUBLIC

MY COMMISSION EXPIRES _____

OK to
ASME SA 479
and
RDT M7-3T
gfp
1-12-79

2-69-GM

CARPENTER
TECHNOLOGY CORPORATION

PAGE #2 OF #2

P. O. BOX 662 • READING, PA. 19603

CERTIFICATE OF TESTS

CARP. ORDER NO. W64470 NUCLR

HEAT NO. 66498-3

ULTRASONIC - SATISFACTORY PER CARTECH S-UT-I-186, 2/19/74 ✓

PACKING BOX MARKED WITH 316, ANLD, RDT M7-3T, .375" RD., HEAT #66498,
INGOT #3, CARTECH

SOURCE SURVEILLANCE BY JOSEPH FERRARA 6/24/74

LIQUID PENETRANT INSPECTION WAS NOT PERFORMED ✓

I HEREBY CERTIFY THAT ALL INSPECTIONS AND TESTS REQUESTED BY THE CONTRACT,
HAVE BEEN COMPLETED WITH RESULTS CONSISTENT WITH THE CONTRACTUAL REQUIREMENTS.

ATTACHMENTS:

ULTRASONIC INSPECTION REPORT AND COUPLANT MATERIALS CERTIFICATION

QUALITY VERIFICATION PLAN AND ALL CHANGES

PERSONNEL QUALIFICATIONS FOR ULTRASONIC INSPECTION

FORM #BD-7310-054 (8/72)

AKK/IN 6

WS 3

LABORATORY TEST REPORT

Plymouth Tube

Division of Van Pelt Corp.
Ellwood Iving Plant
Marshall, Pa. 19044

Shipped to **Vestinghouse Hanford Co., Richland, Wash.** Date Shipped _____
170-444-392-99 DO-E-1
 Customer's Order No. **5305833** Mill Order No. **SE 1730** Specification **ASTM A-213**

Special Markings					Grade					
.875" OD X .065" Average W-11					316 S					
Shipper's No.	O. D.	I. D. or Wall	Shape	Area	Yield Point Lbs. PSI	Ultimate Lbs. PSI	Elong. % 2 Ins.	Rockwell Hardness	Footage	Heat No.
6191	.873	.068	R	.1718	62,800	95,600	40%	B-81	✓	180916

FLARE SATISFACTORY
 FLAT SATISFACTORY
 FLANGE SATISFACTORY
 REVERSE FLAT SATIS.
 EMBRITTLEMENT SATIS.

HYDRO. TEST SATIS.
 EDDY CURRENT SATIS.
 PASSIVATION TEST SATIS.

OK TO ASTM A-213

JAN 24 1990

Inspector

M. Williams
 M. Williams,
 QUALITY CONTROL

100

ALLVAC 4 ASHCRAFT AVE.
MONROE, N. C. 28110 PHONE 704/288-4511
TWX 810/645-1359

FOR HANDLING: SOCKET PINS MSA, FTR SURVEILLANCE

TO: RICHMOND, WA.
CUSTOMER ORDER NO. Y3C-444-16102
QUANTITY 472147
DATE 2-20-75

ALLOY Allvac 718		SPECIFICATION RDT M2-18T		ASTM A637 SAMPLES														
HEAT NO. H-578		SIZE .500" Dia.		R1B OR														
CHEMICAL COMPOSITION * (Ladle Analysis) **	C	S	Mn	Si	Cr	Mo	Co	Ti	Al	B	Zr	Fe	Cu	Ni	P	Cb-Ta	Ta	
	.030	.003	.10	.07	17.60	2.90	.01	.94	.52	.002		Del.	<.01	53.30	.003	5.13	.02	
	.026	.002	.10	.02	17.25	3.00	<.01	.94	.50	.003		Del.	<.01	53.08	.003	5.27	.01	
MECHANICAL TEST	TENSILE									STRESS RUPTURE								
	Heat Treatment	Temp. °F	UTS Ksi	.2% Yield Ksi	.02% Yield Ksi	El %	Ra %	Hard Rc	Heat Treatment	Temp. °F	Load Ksi	Life Hrs.	El %	Ra %	Hard Rc	Type Bar		
	No. 2	Room	217.7	188.1		21.2	43.6	45.0	No. 2	1200	100	147.5	28.9	56.8	46.0	SM.		
	CHEMICAL OK TO ASTM B-23 1/15/90									JAN 25 1990								
	Bar Diameter									Notch Radius								
METALLOGRAPHY TEST	HEAT TREATMENT No. 1		GRAIN SIZE Predominately ASTM 10's															
HEAT TREATMENT	NO. 1		NO. 2		NO. 3													
	1800°F., 1/2 hr., AC		No. 1 plus 1325°F., 8 hrs., FC to 1150°F., * , AC		*Total age 18 hours													
CONDITION SHIPPED	HEAT TREATMENT No. 1		HARDNESS		TELEDYNE ALLVAC NO. 68445-A													
	SURFACE: Primed As Rolled Descaled Shot/Blast Centerless Ground X Etched X Other																	

REMARKS: Material conforms to Grade 718 Nickel Alloy bar, RDT M2-18T dated July 1973 and Amendment No. 1. Material has been ultrasonic tested and accepted according to the examination and acceptance criteria of DT F3-37, Section 5.1.2(a). Ultrasonic test report attached. Material has been liquid penetrant tested and accepted according to the examination and acceptance criteria of RDT F3-37, Section 5.1.2(c). Liquid Penetrant report attached.

Material and/or parts components, or services furnished under this contract have been manufactured and inspected in accordance with all applicable contract requirements and specifications and such inspection records as required by this contract are on file and available for review/inspection.

Reference Quality Verification Plan No. WH-9.

Chemical check analysis (Adjacent to mechanical test specimen)

Chemical ladle analysis

We certify that this date is correct and true to our knowledge and belief.

TELEDYNE ALLVAC

QUALITY CONTROL DEPT.

2-20-75
SWORN AND SUBSCRIBED TO BEFORE ME

5-14-75
NOTARY PUBLIC

amp'd to AB37

Linda J. Fairley
NOTARY PUBLIC

TELEDYNE
ALLVAC

P. O. BOX 798
AIRCRAFT AVE.
MONROE, N. C. 28110 TWX 810/645-1359

PHONE 704/289-4511

L-501

MC 98

Richland, Washington
CUSTOMER ORDER NO. Y3C-444-16102 1
QUANTITY 5-10-155 DATE 12-9.

ALLOY Allvac 718
HEAT NO. H-674

SPECIFICATION RDT M2-15T Amend. 1, 2 & 3 SAMPLES
SIZE 1.750" Dia. ASTM A-637

CHEMICAL COMPOSITION *	C	S	Mn	Si	Cr	Mo	Co	Ti	Al	B	Zr	Fe	Cu	Ni	P	Cb	Ta
(Ladle Analysis) **	.038	.002	.11	.05	17.20	2.90	.01	.96	.50	.003		18.30	.01	54.20	.003	5.06	.02
	.041	.002	.15	.07	17.15	2.96	.01	1.00	.48	.003		18.08	.01	54.30	.003	5.30	.02

MECHANICAL TEST	TENSILE								STRESS RUPTURE							
	Heat Treatment	Temp. °F	UTS Ksi	2% Yield Ksi	.02% Yield Ksi	El. %	Ra %	Hard Rc	Heat Treatment	Temp. °F	Load Ksi	Life Hrs.	El %	Ra %	Hard Rc	Type Bar
No. 2	Room	216.7	172.1			19.5	34.6	42.5	No. 2	1200	110	29.8	43.4	55.6	44.5	SM.
									No. 2	1200	110	23.6	23.4	58.0	44.5	SM.

METALLOGRAPHY TEST	HEAT TREATMENT	GRAIN SIZE
	No. 1	Predominately ASTM 7-10

HEAT TREATMENT	NO. 1	NO. 2	NO. 3
	1750°F., 1 hr., AC	NO. 1 plus 1325°F., 8 hrs., FC to 1150°F., * AC *Total age hours	

CONDITION SHIPPED	HEAT TREATMENT	HARDNESS	TELEDYNE ALLVAC NO.
	No. 1		67676-T
	SURFACE: Primed As Rolled Discolored Shot-Blast Centerless Ground Etched Other		

REMARKS: Material conforms to Grade 718 Nickel Alloy Bar, RDT M2-15 dated October 1971 and Amendments 1 & 2 dated January and April 1972 and Amendment 3 dated January 1973. Material has been ultrasonic tested and accepted according to the examination and acceptance criteria of RDT F3-37, Section 5.1.2(a) Ultrasonic test report attached. Material has been liquid penetrant tested and accepted according to the examination and acceptance criteria of RDT F3-37, Section 5.1.2(c). Liquid Penetrant report attached. Materials and/or parts, components, or services furnished under this contract have been manufactured and inspected in accordance with all applicable contract requirements and specifications and such inspection records as required by this contract are on file and available for review/inspection. Reference Quality Verification Plan No. WH-7a. Chemical Check Analysis taken adjacent to Mechanical Test Specimen

We certify that this data is correct and true to our knowledge and belief.
TELEDYNE ALLVAC
QUALITY CONTROL DEPT.
12-9-74
SWORN AND SUBSCRIBED TO BEFORE ME
5-4-74
NOTARY PUBLIC

WHC-SD-SNF-DR-001, Rev:0

DIVISION OF JOSELYN
MFG. AND SUPPLY CO.

2400 TAYLOR ST. WYOMING

FORT WAYNE, IND. 46801

F.O.B. FORT WAYNE, INDIANA

13285	12-19-74	C 72191	CONSOLIDATED	12 0657 530 2265
	12-20-74	1	COMPL	12-20-74

ESCO CORPORATION
P O BOX 2583 TR
SPokane WASHINGTON

99220

ATLANTIC RICHFIELD
P O BOX
RICHMOND WASH.

99352

REPRESENTATIVE MECHANICAL AND CHEMICAL REPORT

66619	✓	✓	✓	1.750	✓	HRAP	✓	500	652	BHN187	00580	60000	46.5	60.0
304LC	024	164	032	015	050	1867	0969	037	033	020				

ASTM 276 67

MARK G SR X49 44712

OK mars

1 3/4" 56' total

THIS MATERIAL PASSED THE INTERGRANULAR CORROSION TEST, THE EMBRITTLEMENT TEST
AND HAS BEEN MACRO ETCHED.

to "L" book

nixon L-273

OK to A 276
mars 12-20-74

415-561-514

F.O.B. FORT WAYNE, INDIANA

58968	ORDER DATE 03/06/75	STD. CON. P	WIR. OR. SIZE 75234	TYPE CONSOLIDATED	INVOICE NO. 05 0039	4293
JOSLYN F.W. NO.	SHIPPED DATE 05/02/75	SHIP NO. 1	PARTIAL/WHY COMPL	INVOICE ESTIMATED WITH	INVOICE DATE 05/02/75	CUSTOMER'S ORDER NO.

SOLD
TO

ALASKAN COPPER AND BRASS CO
P O BOX 3546
SEATTLE WASHINGTON

98124

SHIP
TO

ALASKAN COPPER AND BRASS CO
3223 SIXTH SOUTH
SEATTLE WASHINGTON

98134

CUSTOMER NO. 01281	PRIORITY
SALESMAN 201	A S I STATE TAX 166 47 04

REPRESENTATIVE MECHANICAL AND CHEMICAL REPORT

HEAT	SIZE					SHAPE FINISH		ENL. CUP		ENL. SHIP		HARDNESS	TEMPER. STR	YIELD STR	ELONG	R. A.
W365	1	1	✓	1	1.250	-RC--CG-		1000		1097		BIIN179	89000	51500	59.7	74.5
TEMP	C	AN	P	S	CS	TA	EN	EN	OTHER	OTHER	OTHER	HARDENABLE				
304LC	027	156	034	008	056	1826	0967	069	027	021						

ASTMA 276

HEAT 006 11-3-81

MC67

ALASKAN COPPER & BRASS CO.

TO: ATLANTIC RICHFIELD HANFORD
COMPANY

ATTN:

P.O. NO. G5R-X49-51422

REGISTER NO. 81489

MATERIAL T304L Stainless

Steel Bar

QUANTITY Item No. 2 - 96 LFT.

ARHCO
QC 14

TEST REPORT OKI
BUYER 23
DATE 5-9-75

I HEREBY CERTIFY THAT THE REPORTED FIGURES ARE CORRECT,
AS CONTAINED IN THE RECORDS OF THE CORPORATION

CERTIFICATION

[Signature]

NOTARY PUBLIC

49-1275-20

DIVISION OF JOSLYN
MFG. AND SUPPLY CO.

JOSLYN STEEL

2400 TAYLOR ST. WEST

FORT WAYNE, IND. 46804

F.O.B. FORT WAYNE INDIANA

56367	DATE 03/14/75	QUANTITY 2	W/B OR S/L	SHIP VIA	INVOICE NO. 03/14/75	53 01284
JOSLYN F.W. NO.	05/12/75	CUMPL	RT WAYN	INVOICE DATE 05/12/75	CUSTOMER'S ORDER NO.	

ESCO CORPORATION
P O BOX 155 TA
SPokane WASHINGTON

99270

CUSTOMER NO. 05608	PRIOR TO
CR. MAN.	DATE
201	156

Rockwell International

SHI
TC 68w - x49 - 77045

C08-77045-1-A REPRESENTATIVE MECHANICAL AND CHEMICAL REPORT

ITEM	SIZE	SHAPE - FINISH	10S O'D	10S SHIP	HARDNESS	TENSILE	YIELD	ELONG	RED
71365	1.000	-RI--CG-	1000		241	101300	90100	37.5	72.8
304LC	0.27	150	134	0.08	10.26	0947	049	0.27	0.2

ASTMA 276

THIS MATERIAL PASSED THE INTERGRANULAR CORROSION TEST, THE EMBRITTLEMENT TEST, AND HAS BEEN MACRO ETCHED

OK to
ASTM A-276
12-27-76
L-462
MC790

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WHC-SD-SNF-DR-001, Rev. 0

APPENDIX C
WELDING CERTIFICATION

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Westinghouse
Hanford Company

WHC-SD-SNF-DR-001, Rev. 0

Internal
Memo

From: Equipment Development
Phone: 376-3116 L6-38
Date: February 28, 1995
Subject: STATEMENT OF WELDING CONFORMANCE K-BASIN FUEL HANDLING TOOLS

To: A. E. Bridges L5-01
cc: J. R. Thielges L6-38
TAD File/LB

All welds were performed in accordance with WHC-CM-6-10, Welding Manual, WHC-SD-MA-SPP-001, Welding Procedure Supporting Document and HS-V-S-0013, Welding of Structural Stainless Steel and Nickel Alloy Components.

Welding Procedure WHC-W-GT-SS-1, is the reference procedure for all of the welds.

Copies of Record of Welds qualification are retained within the 306E facility.

T. A. Delucchi 2/28/95
T. A. Delucchi
Welding Engineer

sb