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DEVELOPMENT AND FABRICATION OF INSTRUMENTED-PLATE
ADVANCED TEST REACTOR FUEL ELEMENTS

J. H. Erwin, W. J. Werner, and M. M. Martin

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ABSTRACT

A procedure was developed for manufacturing instrumented advanced test reactor fuel elements. The full-size assemblies are unique in that they contain one or two double-core fuel plates, which eliminate the intervening water channel to provide thermocouple wells for in-reactor temperature measurements. The two cores are replicas of the replaced standard cores fabricated into a single 0.178-in.-thick plate to provide internal temperature measurement at 5 to 16 separate locations.

Deviations from normal ATR fuel-element processing comprise solid-state reaction to prepare stoichiometric UAl_3 , roll bonding of dual-cored plates, and marforming in compression. During fabrication development, we observed noteworthy differences in the fabricability of U_3O_8 - and UAl_3 -bearing plates of equivalent uranium loading and geometry. When compared to U_3O_8 , the UAl_3 -aluminum dispersion showed excessive growth during vacuum anneals, severe thickening or dog-boning near the core ends, and separation of tandem cores in rolling.

INTRODUCTION

The fuel core for the Advanced Test Reactor, shown schematically in Fig. 1, is made up of 40 interchangeable 45° wedge-shaped elements, each of which contains 19 fuel plates $49\frac{1}{2}$ in. long and varying in width from 2.136 to 3.973 in. Heat transfer measurements were required in the reactor core. To obtain them, a single plate replaced two normal fuel plates and the intervening water channel; this plate was instrumented with thermocouples placed at critical locations along the fuel element.

This report is concerned with the techniques used to manufacture five fuel elements with the thermocouple wells incorporated. A schematic representation of a cross section of the replacement plate, showing fuel core location, channel blockage, and thermocouple holes for in-reactor

Fig. 1. Sections of ATR Fuel Elements Arranged to Show the Reactor Core Configuration.

instrumentation, appears in Fig. 2. Two instrumented plates of slightly differing widths were required as replacements for four standard fuel plates and two intervening water channels in the assembled elements. One plate replaced fuel plates 15 and 16 and plugged the usual passage between the two standard plates. The second plate similarly replaced fuel plates 17 and 18. These plates will be referred to as types 15/16 and 17/18 hereafter. The cross section of one instrumented ATR element is shown schematically by Fig. 3. During this program three elements were assembled incorporating both types 15/16 and 17/18 plates. Two additional elements were produced that contained only the type 17/18 plates.

Fig. 2. Schematic Representation of ATR Instrumented Fuel Plate.

Fig. 3. Typical Cross Section of ATR Fuel Element Showing Location of Instrumented Fuel Plates.

Since we have already reported¹⁻⁴ developmental work on the ATR fuel element, this report will be limited to the manufacture of the instrumented plates and their assembly with standard plates and hardware furnished by Idaho Nuclear Corporation to produce the test elements.

FUEL PLATE MANUFACTURE

Production of the instrumented plates required attention to the following topics: (1) specifications, (2) preparation of UAl_3 -aluminum fuel compacts, (3) roll bonding of fuel plates, (4) drilling of thermocouple holes, and (5) fuel plate forming.

Specifications

Drawings describing the ATR fuel element and the modifications required in this program, as designed by Idaho Nuclear Corporation, are given in Appendix A. Table 1 lists specifications applicable to the instrumented plates.

Preparation of UAl_3 -Aluminum Fuel Compacts

We synthesized stoichiometric UAl_3 according to procedures developed during the production of four special ORR fuel elements.^{5,6} This consisted

¹R. J. Beaver, G. M. Adamson, Jr., and P. Patriarca, Procedures for Fabricating Aluminum-Base ATR Fuel Elements, ORNL-3632 (June 1964).

²J. H. Erwin, S. Peterson, and C. F. Leitten, Jr., Development of a Forming Method for Curved ATR Fuel Plates, ORNL-3983 (August 1966).

³D. O. Hobson, R. L. Heestand, and C. F. Leitten, Jr., Fabrication Development of U_3O_8 -Aluminum Composite Fuel Plates for the Advanced Test Reactor, ORNL-3644 (July 1964).

⁴R. W. Knight and C. F. Leitten, Jr., Development of the Assembly Method for Fuel Elements for the Advanced Test Reactor, ORNL-3643 (August 1964).

⁵W. J. Werner, M. M. Martin, J. H. Erwin, and C. F. Leitten, Jr., Metals and Ceramics Div. Ann. Progr. Rept. June 30, 1965, ORNL-3870, pp. 96-98.

⁶W. J. Werner, M. M. Martin, and J. H. Erwin, Metals and Ceramics Div. Ann. Progr. Rept. June 30, 1966, ORNL-3970, pp. 107-109.

Table 1. Specifications Unique to Instrumented ATR Plates

Item	Value
Overall plate dimensions, in.	
Thickness	0.178 ± 0.000 $- 0.002$
Length	$49.5 \pm 1/32$
Width	
Plate 15/16	3.616 ± 0.001
Plate 17/18	3.820 ± 0.001
Core-related dimensions, in.	
Core thickness	0.020 ± 0.000 $- 0.002$
Cladding thickness	0.015 min
Core separation	0.108 nominal
Core length, collective	48 ± 0.75
Core length, individual	47.75 ± 0.75
Core width, plate 15/16	3.087 ± 0.050
Core width, plate 17/18	3.288 ± 0.050
Thermocouple holes	
Number per plate	16
Diameter, in.	0.0595
Terminal point	0.350 in. inside fuel core edge; center line 0.089 ± 0.002 in. from either surface of plate
Loading requirements, gm	
^{235}U	
Plate 15/16	61.41, 63.30
Plate 17/18	65.19, 67.20
B_4C	
Plate 15/16	0.337, 0.347
Plate 17/18	0.357, 0.367

of (1) hydriding high-purity uranium metal to produce fine particles, (2) intimately mixing these particles with high-purity aluminum powder in an oblique dry blender, and (3) heating the mixture. The initial charge contained 10% excess aluminum as compensation for evaporation loss. To facilitate the reaction, the blend was placed in a graphite die, hydrogen was removed, and then the blend was pressed at 1000°C in an argon atmosphere. After cooling, the reacted material was reduced by disk crushing to the $-170 +325$ mesh screen fraction and analyzed for uranium content. The calculated proportions of UAl_3 , vacuum-annealed aluminum, and B_4C powders required for each fuel compact were then

weighed, dry blended, and pressed at 22.5 tsi. Three of these compacts were used for each fuel core.

Serious swelling was encountered during the vacuum degassing treatment performed on the fuel compacts previous to billet assembly.⁶ Figure 4 compares structures of an as-cold-pressed compact and one that had swelled during vacuum degassing at 590°C for 2 hr. With these degassing conditions the UAl_3 compacts swelled about 14%, whereas compacts containing U_3O_8 as the fissile material swelled only 0.8%. Gregg, Crouse, and Werner⁷ have shown that swelling of the UAl_3 -aluminum compacts results primarily from void formation accompanying the reaction $UAl_3 + Al \rightarrow UAl_4$ and that the reaction rate is temperature dependent. They also conclude that the swelling is apparently independent of the method of producing UAl_3 and of the type of aluminum powder used.

The swelling problem was minimized for these experimental plates by reducing the outgassing temperature to 525°C; at this temperature, the growth averages approximately 4%.

Roll Bonding of Fuel Plates

The initial fabrication parameters for the special ATR fuel plates were based on previous experience with the production of similarly shaped miniature plates for irradiation experiments.^{8,9} These miniatures, however, had not been scaled up to full-size fuel plates. The first prototype instrumented plate was made with a volume of U_3O_8 equivalent to the required amount of UAl_3 . The data obtained from the fabrication of this plate were used to establish rolling parameters for the plates containing the UAl_3 fuel.

An exploded view of the rolling billets is shown in Fig. 5. The cavities on either side of the frame are machined as mirror images.

⁷J. L. Gregg, R. S. Crouse, and W. J. Werner, Swelling of UAl_3 -Al Compacts, ORNL-4056 (January 1967).

⁸M. M. Martin, W. J. Werner, and C. F. Leitten, Jr. Fabrication of Aluminum-Base Irradiation Test Plates, ORNL-TM-1377 (February 1966).

⁹V. A. Walker, M. J. Gruber, and G. W. Gibson, ATR Fuel Materials Development Irradiation Results - Part II, IDO-17157 (June 1966).

Fig. 4. Microstructures of UAl_3 -X8001 Compacts. (a) As cold compacted, and (b) after degassing for 2 hr at 590°C in vacuum. As polished.

Fig. 5. Exploded View of Fuel Plate Rolling Billet.

Each fuel section consists of three tandem powder metal compacts that are shrink fitted into the cavities. Because the growth of the compacts was not controlled during degassing, the cavity dimensions in the frame could not be predicted. For each core, three matched compacts with the correct loading were selected, and the cavity was machined to fit them. Frame cavities for the tandem compacts were machined approximately 3.5% undersize. This allowed for the unequal expansion of the cores and frames and provided metal-to-metal contact of the components at the hot-rolling temperature. To partially compensate for the void space associated with compact swelling, the thickness of the compacts was 0.005 to 0.012 in. greater than the standard cavity depth.

The initial step in loading the rolling billets was to preheat the clean empty frame with the cover plates in place at 500°C for 1 hr. Then the top cover plate was removed, and three compacts meeting the fuel requirement of the even-numbered core were loaded into the frame cavity. The cover plate was then replaced and seal-welded to the frame. The half-loaded billet was returned to the preheat furnace and the process repeated for the odd-numbered fuel core.

To mark the even-numbered cores, an 1100 aluminum plug 1/4 in. in diameter and 1/8 in. high was set into the cover plate flush with the surface and near the end weld. A 0.5-in.-OD $\times$ 0.065-in.-wall aluminum evacuation tube was then welded to the frame, completing the billet assembly. To aid in the production of blister-free plates, the billets were evacuated overnight at 400°C, and then the evacuation tube was sealed by forging under vacuum. (The completed plates did not blister.)

The sealed billets were rolled to the required 0.178-in. thickness in a four-phase reduction schedule: (1) densification of compacts, (2) cross roll for core width, (3) parallel roll to 1.2 times final thickness, and (4) cold roll to final gage. Typical rolling schedules for the two plates appear in Appendix B.

The billets were set on edge in the furnace, preheated 2 hr at 500°C, passed through the mill, rotated 180° for the next rolling pass, and returned to the furnace for reheating. With each subsequent hot reduction pass the reheat period was graduated compatible with the reduced plate thickness. To minimize fuel core end flash and consolidate the swollen fuel compacts, we took two initial light mill passes (each about 3% reduction) parallel to the fuel core length. Further reductions required to produce the desired core dimensions had been calculated from previous experience. The amount of reduction by cross rolling required to give the desired core width was divided into an equal number of passes; the reductions per pass did not exceed 3.9%. After the cross rolling we longitudinally rolled the billets to 0.222-in. thickness with 14 mill passes at a reduction rate of approximately 14% per pass with the exception of two light final passes at about 7%. After a 1.5-hr stress relief anneal at 500°C, we cold reduced the billets in four passes, two at about 8% each and then two more at 3%.

The cold-rolled plate was flattened by passage through a 2 x 12-in. nine-roll leveler and then annealed by heating 2 hr at 500°C between two 1-in.-thick platens and furnace cooling to below 110°C.

Inspection of radiographs provided the dimensional data to determine machining requirements to centrally locate the cores within the final plate dimensions. The machined widths were 3.616 and 3.820 in., respectively, for the 15/16 and 17/18 plates. A 6° angle, determined experimentally, was machined into the 49.5-in.-long sides of the flat fuel plate (see Fig. 2, p. 3) to provide the differential width needed to compensate for the lack of equal plastic flow across the plate thickness during forming the 45° circular segment. The even-numbered cores were on the wider side.

Drilling of Thermocouple Holes

To accommodate thermocouples to monitor the temperature of the special fuel plates during reactor operation, a series of 0.0595-in.-diam flat-bottom holes were drilled into the fuel plate edges at 45° to the plate longitudinal axis and terminated 0.350 in. inside the fuel core edges. The bottoms of the holes were required to be located equidistant (within 0.002 in.) between the two fuel plate surfaces. The holes were drilled 0.055 in. in diameter and reamed to 0.0595 in. in diameter with a flat-end drill. The jig shown in Fig. 6 positioned the drill and aligned it for drilling through the plate edge. Access holes in the side plates to match the thermocouple holes were drilled with the aid of an off-take template made from the drilling jig.

Three major problems were encountered in meeting the specifications for the thermocouple holes. These were (1) determination of hole depth to place the bottom center at a distance of 0.350 in. from the fuel core edges as measured in the curved and assembled fuel plate, (2) development of a drilling technique that would produce holes at the desired location in the flat plate, and (3) investigation of inspection techniques to reliably ascertain the location of the hole bottom with respect to the fuel core edges and the fuel plate surfaces. To surmount these difficulties, we assumed the following.

Fig. 6. Jigging for Thermocouple Hole Drilling. (1) Template with drill bushings (2) mounted in the edge. (3) Support plate to hold fuel plate firmly against template. (4) Finger-sensitive-feed drill chuck.

(1) The locations of the bottoms of the holes are not changed in their relation to the fuel core edge or the fuel plate surface during curving of the plate. Dimensions obtained from the flat plate are then applicable to the curved plate.

(2) Allowances are not necessary to correct for thickness change in the convex and concave sides of the plate as a result of forming.

(3) Radiographs reflect true dimensions when they are obtained from an x-ray beam emitted at right angles to the measurement and film from a point located 80 in. away.

Since the instrumented fuel plates are formed under lateral compression (see below), the stationary forming axis is near the convex surface rather than midway through the plate. Thus, the average thickness increases at a rate equivalent to the shortening of the inner

concave surface, as shown below. If the thickness of the final plate $t_x = R_2 - R_1$, and if the cross sectional area is constant,

$$A = (\ell_1 + \ell_2)t_1/2 = (\pi R_2^2 - \pi R_1^2)/8 - 2(0.178)(0.157) . \quad (1)$$

Solving,

$$R_1 = \sqrt{R_2^2 - [4t_1(\ell_1 + \ell_2) + 0.4472]/\pi} , \quad (2)$$

where

R_2 = convex radius of plate, in.,

R_1 = concave radius of plate, in.,

A = cross-sectional area, in.²,

ℓ_1, ℓ_2 = lengths of sides on the trapezoidal cross section of the plate, in.,

t_1 = thickness of flat plate, in.

The result from Eq. (2) is a 0.002-in. thickness increase during forming. However, as determined by direct observation, this change is not uniform across the plate width but does represent the average thickening. The hole locations and dimensions are also affected by the plastic metal flow, but no attempt was made to determine these, since the total shift was shown above to average only 0.002 in.

To determine the hole drilling depth, we measured the distance from the fuel plate edge to the fuel core edges at the drilling location and calculated the distance to insert the drill. These measurements were made from high-contrast radiographs showing the machined plate edge and the fuel core edges. The x-ray source was located 80 in. from and in line with the fuel core edge. An angular stop, adjusted with the aid of gage blocks, limited drill penetration to the desired depth.

Hardened drill bushings within the drill jig shown in Fig. 6 provided drill alignment. However, normal drilling methods gave as much as 0.008 in. runout at the bottom of the holes. We minimized this effect by use of the finger-sensitive feed control built into the drill chuck, the "stinger" lead tip ground on the drill (see Fig. 7), and Cindol 3102 anti-seize cut aid lubricant for drill chip removal. Inspection of sections

Fig. 7. "Stinger" Tip Lead Drill (0.055 in. diam) Used to Drill Thermocouple Holes in Instrumented Fuel Plates. 20X.

through holes that were drilled from the edge of a 0.178-in.-thick 6061-0 aluminum plate with these techniques showed that the maximum hole centerline misplacement was reduced to 0.003 in.

Fuel Plate Forming

The 0.178-in.-thick instrumented plates are approximately 45° sectors of concentric annuli. The inside radii are 4.857 and 5.113 in., respectively, for plates 15/16 and 17/18. Standard plates can be formed by the low-pressure marforming process.¹⁰ Unfortunately, when this technique was applied to the thick instrumented plates, tensile strain caused cracking in the outer core. Figure 8 shows examples.

To prevent core cracking, the instrumented plates were formed under lateral compression. On the side to become convex, a 0.187-in.-thick 1/2-hard 1100 aluminum backup plate was bonded to the fuel plate with a thin layer of Armstrong A-12 adhesive. The support overlapped the fuel plate by 1/4 in. to ensure a uniform radius. Each composite plate was then formed by the low-pressure marforming process to approximately the required radius with 3700 psi applied to a 4.250-in.-radius punch. The backup plate was separated from the fuel plate by heating to 200°C. Small amounts of adhesive remaining attached to the plate were removed with Armstrong stripper. Both fuel plates were sized by adjusting the curvature with a 6.687-in.-radius punch, a 4.125-in. punch, or both.

¹⁰J. H. Erwin, S. Peterson, and C. F. Leitten, Jr., Development of a Forming Method for Curved ATR Fuel Plates, ORNL-3983 (August 1966).

Fig. 8. Cross Section of Instrumented ATR UAl_3 Plate Low-Pressure Marformed Without Supporting Backup Plate - Cracks Shown at Arrows. 16X. As polished.

The thermocouple wells, drilled in the fuel plate edge, were reduced in diameter as a result of the compressive forming. To reestablish the hole diameter in the curved plate, we swaged the metal outward using a 0.060-in.-diam $\times$ 0.062-in.-long swaging tool lubricated by Cindol¹¹ 3102. To obtain the functional tool, which could be driven to the hole bottom, we machined a 0.060-in.-diam $\times$ 1.75-in.-long stainless steel wire to 0.050 in. in diameter leaving the original 0.060-in. diameter at the end.

¹¹Product of E. F. Houghton & Company, Philadelphia.

ASSEMBLY OF FUEL PLATES

General Procedure

The assembly of standard ATR fuel elements has been described by Knight and Leitten,¹² and their procedures were, in general, used for assembling the instrumented elements. Minor revisions in the equipment and procedures, which are discussed below, contributed to an improvement in the overall quality of these elements. A fuel element in assembly is shown in Fig. 9.

¹²R. W. Knight and C. F. Leitten, Jr., Development of the Assembly Method for Fuel Elements for the Advanced Test Reactor, ORNL-3643 (August 1964).

Fig. 9. ATR Fuel Element in Assembly. (1) Teflon strips to ensure minimum channel thickness. (2) Dial indicator to check location and straightness of plate being installed. (3) Hold-down roller. (4) Roll swaging head. (5) Supporting rig.

To use the finish-machined side plates furnished by Idaho Nuclear, we needed to build an assembly jig. The jig minimized expansion during roll swaging, had relief to accommodate the external side plate bosses, and incorporated reference points for dimensional inspection.

The roll swager was modified by increasing the diameter of the swaging wheels to $7/8$ in. to provide better control of metal deformation. The valving on the air supply to the swaging wheel load cylinders was changed from a "Christmas tree" of single-port valves to four-way valves that operated the individual two-way cylinders without back pressure. Concave compression rolls resting on the fuel plate to hold it firmly in position were added before and after the swaging rolls.

Each standard fuel plate was formed to a radius approximately $1/2$ in. smaller than the final dimensions to provide extra assembly clearance in the side plate grooves. After being inserted, each plate was supported from below, beginning with a wooden shim under the plate 1 and followed by $1/2$ -in.-wide Teflon shims about 0.074 in. thick placed in each cooling channel (see Fig. 9) under each successive plate. After placement of the shims but before roll swaging, the fuel plate was forced into the required position with the concave rollers on the swaging head. To join the standard fuel plates to the side plates, the roll swaging wheels were preloaded with a force of 320 lb (about 60,000 psi), moved along the fuel element, and returned for a second pass. A fuel plate improperly seated after roll swaging was corrected to the desired position with the concave pressure rollers.

The instrumented plates were too strong to be positioned by the concave rollers. These plates were machined to a width dimension that provided only 0.005 in. total (0.0025 in. each side) clearance between the properly curved plate and the grooved bottoms and then formed to the required final curvature as described above. When these plates were located in the proper positions, the Teflon support strips could not be inserted into the channels beneath them. However, the plates were roll swaged to the side plates as described for the standard plates.

Welding of Instrumented Plates

The instrumented plate joints were strengthened by welding. The weld design is shown in Fig. 10. Tensile tests of mock-up welds made according to this design indicated a minimum yield strength of about 20,000 psi, which corresponds to about 3500 lb per linear inch of a 0.178-in.-thick plate. We calculated that six evenly spaced 1-in.-long plug weld attachments of the side plate to the instrumented plate would be more than adequate to meet the ATR joint strength specification of 250 lb per linear inch. Of course, we had to deviate from equal spacing

Fig. 10. ATR Instrumented Plate Weld Joint Design.

to shift the weld locations away from thermocouple holes and coolant pressure relief cutouts. The shifts did not compromise the overall joint strength. Weld locations in a typical joint are shown in Fig. 11.

Distortion during welding was minimized by selection of the weld sequence, and use of the jig shown in Fig. 12. The jig consists of three form-fitting clamps that hold the element down to a stiff structural member; a shim placed under the central clamp flexed the fuel element 0.090 in. toward plate 19 to compensate for bowing. Welding was initiated in the central grooves and progressed to the end grooves by "hop" fashion where the weld on one plate edge was followed by a similar weld on the

Fig. 11. Typical Grooves Through Side Plates for Fuel-Plate Attachment Welds. (1) Machined weld grooves. (2) Water cooling channel vents.

Fig. 12. Welding Jig Used to Prestress the ATR Fuel Element. A 0.090-in.-thick shim was placed under the central support before start of welding sequence.

other edge. This welding sequence accumulated as nearly as possible weld shrinkage at each end of the fuel element. The welded element remained in the jig until cool enough to be handled without gloves.

After the excess weld metal had been removed, dimensional inspection indicated varying amounts of nonuniform distortion in the form of camber, twist, or both in the fuel elements. To correct these defects,

compensating welds (see Fig. 13) were made on the surface of the side plates. The number of compensating welds and their placement on the side plate were dependent upon the distortion shown by a thorough dimensional inspection.

Fig. 13. Welded Fuel Element. (1) Instrumented-fuel-plate attachment welds. (2) Compensating welds to straighten fuel element.

End Adapter Attachment

The end adapters were also supplied in the finish-machined condition except for a top rib to be dressed by Idaho Nuclear Corporation. To meet the exacting locational dimensions for all of the adapter surfaces, we allowed for weld distortion when the adapters were rigidly clamped to the fuel element in the welding jig. The welding sequence was initiated with the weld at the bottom and adjacent to the fuel plate ends. The attachment then progressed outward in criss-cross fashion from side to side and from bottom to top to bottom until the adapters were firmly fixed to the fuel element. Since the shrinkage allowance usually proved to be difficult to predict, we aligned the adapter with the fuel element by counterwelding and/or cold forging of the side plate ends.

INSPECTIONS

All instrumented fuel plates were inspected to ensure that bonding and the specified dimensions had been achieved in rolling, machining, and drilling the thermocouple wells. The Inspection Engineering Department at ORNL tested the plates for continuity of ultrasound

transmission and supplied radiographs for detailed measurements. An extensive metallographic examination described the rolling effects and cladding-to-core relationship in extra plates. After assembly, numerous mechanical and radiographic measurements verified the thermocouple-well locations, channel spacing, and exterior dimensions of the completed elements. Homogeneity of the fuel and total fuel loading were not verified.

Dimensions

To assure that the fuel elements approached the desired specifications, unusual methods and procedures of inspection were required in addition to normal shop techniques. The dimensional results that are descriptive of each fuel element are tabulated in Appendices C, D, E, F, and G. Since several of the values from the measurements are dependent upon the method used, the inspections will be described below.

Instrumented Fuel Plates

External Dimensions. - The width, length, and thickness of the fabricated plate were measured with ordinary machine shop inspection tools.

Geometrical Relationship of the Fuel Cores. - Within each plate the plan dimensions of the two fuel cores were distinguished by the combination of three radiographs. Initially, to identify each of the two fuel cores, the angular projection of the fuel core ends, as viewed in a radiograph obtained from a source located directly over the lengthwise center of the plate, was compared with similar projections from a source located directly over the two fuel plate ends. With the identity established, plan dimensions, relative locations, etc. describing each fuel core were obtained. No correction was made for angular distortion, since the x-ray beam originated from a source located at a distance of 80 in. and directly above the film. Typical fuel core-cladding dimensional relationships were obtained by metallographic techniques described later (Metallographic Examination).

Thermocouple Wells. - To locate the bottom of the thermocouple holes, we used both indirect mechanical measurements and radiography on the fuel plate before forming. The mechanical method located the hole center line with respect to the fuel plate surfaces by use of height-gage measurements from both plate surface planes to a tight-fitting pinhole gage extended as a mirror replica of each well. (A 10-lb weight placed on the plate surface, directly over the hole being inspected, held the plate firmly in contact with the reference plane.) Through radiography, we located the bottom of the hole with reference to the fuel core edges, plate edges, and plate ends. To provide contrast and reference points on the radiograph film, we inserted steel pins into each thermocouple hole and placed a 0.015-in.-thick $\times$ 0.500-in.-wide steel shim at a prescribed location on the fuel-plate surface nearest the x-ray source. Again, to limit distortion in the radiograph we located the x-ray source 80 in. away and in a plane that intersected the measurement at 90°. The exposed film was measured with a 10X optical shadowgraph. The radiography was repeated to examine the holes in each flat and curved plate.

Fuel Element

Channel Thickness. - The distance between adjacent fuel plates was measured near each side plate and at the center of the arc. These measurements were repeated at 2-in. intervals along the 49.5-in. length for a total of 72 observations per channel. To perform this inspection, we inserted a 25-in.-long demitron probe from either end of the fuel element to the furthest desired measuring position and then withdrew it in 2-in. increments, measuring the thickness at each location. A thin petroleum lubricant applied to the probe minimized friction and metal pickup from contact of the steel with the soft aluminum plates. The instrument calibration was checked periodically by inserting the probe into three apertures of known dimensions between 1/4-in.-thick flat aluminum plates.

Concurrently with the inspection, channels showing out-of-tolerance measurement were altered and remeasured until acceptable dimensions were

achieved. The dimensional values obtained in fuel element HP-1 are related graphically in Fig. 14. To alter channel dimensions, we pulled Teflon disks, lubricated with lightweight household oil, through the smaller channels. The disks were 1 1/2 to 2 3/4 in. in diameter by 0.074 to 0.084 in. thick and grooved on the periphery to accept a 1/16-in.-diam nylon cord.

As verification of in-tolerance measurements at the vents, drills with diameters equivalent to the maximum dimensions allowable were used as go no-go gages. Actual dimensions were not determined at these locations.

Fig. 14. Water Cooling Channel Measurement Magnitude Distribution for ATR Fuel Element HP-1.

External Dimensions. - Dimensions of importance to the fit of the fuel element into the reactor grid are relative to a reference center line established in the assembled plate section. Most of these dimensions also depend upon an angle of resolution. In the absence of an inspection fixture that contains the needed compensating factors, we proceeded in the following manner.

The reference center line was established from 14 sets of 26 measurements to best satisfy all of the dimensional requirements, and the average angle between the outer surfaces of the side plates was calculated from nine respective measurements of the fuel element width obtained

with the aid of steel balls placed against the side plate spanning the element at plates 1, 10, and 19. With the reference center line and the angle between side plates established, we supported the element at both ends of the center line and used a machinist's sine table to relate all the dimensions to axial planes through the reference center line. The measurements were obtained with a machinist's height gage.

The envelope fit requirement was satisfied by measurements indicating the position of the element lying free of pressure in the assembly jig of known dimensions. The position of the reference centers, adapter pads, fuel plates 1 and 19, and the outer edge of the side plates were dimensionally related to the assembly jig used here as the envelope.

Thermocouple Wells. - We inspected the thermocouple wells in the assembled fuel elements by a procedure similar to that described for the fuel plate. Radiographic film was placed in the water channel beneath the instrumented plate to record the hole location with respect to the side plates. Again, the steel pins were inserted in the holes for delineation and steel strips were placed on top of the plate for base reference measuring points.

In addition to the measurements by radiography, the distance from the outer surface of the side plate to the bottom of the hole was verified by mechanical measurement after fuel-element assembly. This distance was calculated from depth micrometer measurement (see Fig. 15) of the extension above the side plate of a pinhole gage of known length placed in the hole.

Metallographic Examination

Fuel plates were sectioned for both metallographic observation and measurement of dimensions in the thickness direction. Six longitudinal samples were cut from each of the two types of plates (15/16 and 17/18). They were taken one fourth way and halfway across the plates at a fuel core end, at the approximate center of an original compact, and at an interface between compacts. We also examined transverse sections of the fuel core at the edge and near the center of the plate.

Severe "dog-boning" (thickening of the core) is evident in sections from the core end shown in Figs. 16 and 17. A somewhat lesser degree

Photo 84509

Fig. 15. The Arrangement of Depth Micrometers for Measurement of the Thermocouple Well. Extension of the pinhole gage is measured as it conforms to the 45° angle block.

Y-74774

Fig. 16. Typical Fuel Core Ends in ATR Instrumented Plates Containing UAl_3 . As polished. 16x.

Fig. 17. Typical Fuel Core Ends in ATR Instrumented Plates Containing UAl_3 . Etchant: 10% HNO_3 -1% HF . 50X. (a) Top core. (b) Bottom core.

of dog-boning occurred at the ends of the individual compacts, shown in Fig. 18. The same figure shows that the compacts separated longitudinally during rolling. Figure 19 shows this bulge at higher magnification. Figure 20 shows the core edges in a transverse section, and Fig. 21 shows typical sections through nonbulging regions of the core. Since cracks are visible in the UAl_3 at 500X, we believe that the holes that appear in the photomicrographs result from loss of fuel particles during preparation of the metallographic specimens.

Fig. 18. Longitudinal Section of Instrumented ATR Fuel Plate Containing UAl_3 , Showing Rolled Interface Between Original Powder Metal Compacts. As polished. 10X.

The fuel core and cladding thickness measurements made on the specimens described above are summarized in Table 2. Except at the core ends and the interfaces between compacts, the core and cladding thicknesses (21 and 15 mils) agreed reasonably well with the intended values (20 and 15 mils). In contrast, at the fuel core end we had a 0.032-in. core with 0.009-in. cladding, and at the compact interface we had a 0.025-in. core and 0.013-in. cladding. Similarly, the aluminum separating the two fuel cores was reduced at the ends of the original compacts.

The large "dog bone" and longitudinal separation of the fuel compacts observed in these measurements and in Figs. 16 through 19 appear to result from a material characteristic that was influenced by the high UAl_3 loading, about 51 wt %. The same effect did not occur in some experimental plates for the ORR in which the core contained 30 wt % UAl_3 ; measurements on these plates are shown in Table 2 for comparison. Also listed are our measurements on instrumented ATR plates made with oxide fuel. Negligible dog-boning of the Al-55 wt % U_3O_8 core is evident in the listed measurements as well as in Fig. 22 and 23, which show the core ends, and Fig. 24, which shows the interfaces between compacts.

Fig. 19. Longitudinal Sections Through Instrumented ATR Fuel Plate Containing UAl_3 at Compact Interface, Showing Fuel Core Bulge at Compact End. Etchant: 10% HNO_3 -1% HF . 50X. (a) Top core. (b) Bottom core.

Fig. 20. Transverse Section of Instrumented ATR Fuel Plate Containing UAl_3 , Showing Fuel Core Edge. As polished. 10x.

Figure 24 also shows the absence of compact separation in the oxide cores. We did not attempt to evaluate physical phenomena of the fuel materials that may account for the differences in behavior.

Figure 25 shows that interfacial grain growth occurred across approximately 30% of the cladding-to-frame bond line.

Ultrasonic Inspection

We used ultrasound transmission (with a 5-Mc lithium sulfate transducer) to examine the instrumented plates for faults in the metallurgical bond between the sandwiched parts. Sound transmission through the plates was compared with known fault standards built into a 0.178-in.-thick 6061-O aluminum plate to give loss of sound indications from greater than 1/16- and 1/8-in.-diam imperfections at each interface position within the comparable instrumented plate.

Representative inspection results are given by the report sheets reproduced in Appendix H. No loss of sound transmission was observed within the instrumented plates other than a loss observed at the core edges and a loss at the interfaces between UAl_3 compacts. Similarly, the core outline of the U_3O_8 -bearing plates showed loss of sound;

Fig. 21. Typical Sections of UAl_3 -Bearing Core of Instrumented ATR Fuel Plate. Etchant: 20% HNO_3 -1% HF . 100X. (a) Transverse.
(b) Longitudinal.

Table 2. Cross-Sectional Measurements of Roll-Bonded Powder Metallurgy Fuel Plates^a

Measurement	Value, in.		
	ORR UAl ₃	ATR UAl ₃	ATR U ₃ O ₈
<u>Intended Dimensions</u>			
Cladding	0.015	0.015	0.015
Core	0.020	0.020	0.020
Core separation	None	0.108	0.108
<u>Average plate dimensions excluding core and compact ends</u>			
Top cladding	0.015	0.0145	0.0152
Top core	0.020	0.0213	0.0209
Core separation		0.1061	0.1052
Bottom core		0.0213	0.0212
Bottom cladding	0.015	0.0148	0.0155
<u>Average plate dimensions at core ends</u>			
Top cladding	0.016	0.0085	0.0155
Top core	0.018	0.0320 ^b	0.0232
Core separation (extrapolated)		0.0910	0.1025
Bottom core		0.0365 ^b	0.0216
Bottom cladding	0.016	0.0100	0.0152
<u>Average plate dimensions at compact ends</u>			
Top cladding		0.0121	0.0155
Top core		0.0245 ^b	0.0210
Core separation (extrapolated)		0.1029	0.1045
Bottom core		0.0252 ^b	0.0220
Bottom cladding		0.0133	0.0150

^aFuel elements manufactured for the ORR from Al-30% UAl₃ powder metallurgy cores.

^bNote increase over intended values.

Fig. 22. Typical Fuel Core Ends in Instrumented ATR Plate Containing U_3O_8 . As polished. 16x.

however, the compact interfaces could not be located in this manner, although the joint was seen in contrast on radiographs.

CLEANING AND PACKAGING

At the request of Idaho Nuclear Corporation, the assembled fuel elements were cleaned by pumping acetone through the cooling channels. The fuel element was suspended vertically in a tall tank while a stream of acetone from a 5-gpm pump circulated through the element for 5 min. The cleaning was repeated before both welding and final packaging. Additional local cleaning with Magnaflux Spot Check cleaner removed oil residue from the weld slots.

The acetone residue was allowed to evaporate completely before the elements were placed in individual plastic bags. Moisture-absorbent dryer bags were included at each end of the fuel element.

SUMMARY

A fabrication procedure was developed for manufacturing instrumented ATR fuel elements that contain one and two plugged coolant channels. A single 0.178-in.-thick fuel plate, which includes two cores with provision

Fig. 23. Typical Fuel Core Ends in Instrumented ATR Plate Containing U_3O_8 . Etchant: 10% HNO_3 -1% HF . 50X. (a) Top core. (b) Bottom core.

Fig. 24. Longitudinal Section Through Compact Interface in Instrumented ATR Fuel Plate Containing U_3O_8 . As polished. (a) 16X. (b) 50X.

Fig. 25. Recrystallized Structure at Cladding-Frame Interface in Instrumented ATR Fuel Plate. Electropolished with HBF_3 . (a) Outer interface. (b) Inner interface.

for inserting thermocouples into the aluminum between them, blocks the water passage to permit in-reactor temperature measurements. We supplied the Idaho Nuclear Corporation with five such assemblies for testing at NRTS. Appendices C through H record the physical inspection data in detail.

The instrumented fuel plates were fabricated by roll bonding and marforming techniques. We successfully scaled up the plate fabrication from our irradiation test miniatures. However, the size of the required fuel cores necessitated tandem arrangement of powder-metallurgy compacts, and hot evacuation of the larger billet excluded entrapped gases. In the marforming operation, the plates were first formed undersize and then re-formed to the required radius. To prevent tension cracking of the outer core, we attached a backup sheet of aluminum that forced the fuel plate to remain in compression during the initial forming step.

In assembly of the elements, the standard fuel plates were roll swaged to the side plates and the end adapters were fillet welded to the side plates. The thick instrumented plates also required six welds per side to ensure the desired joint strength of 150 lb per linear inch.

Drilling and inspection of the thermocouple wells in the sides of the instrumented plates were formidable tasks, especially the final examination (after assembly). Special drills, jigs, and fixtures were required to place the center of the hole bottom within 0.002 in. of the thickness-wise center of the plate. The minimum access depth of 0.720 in. was achieved but not the 0.010-in. tolerance. Extensive training of an inspector and calibration of radiographic and mechanical techniques, however, provided measurement of this dimension to an accuracy of 0.005 in.

The fabrication of one instrumented plate that contained 44.7% U_3O_8 and 0.2% B_4C dispersed in X8001 aluminum instead of the normal 51.1% UAl_3 permitted the direct comparison of the fabricability of the two fuel materials. Noteworthy differences were observed. When compared to U_3O_8 , the UAl_3 compacts showed excessive growth when heat treated in vacuum, and the fuel core in the rolled plate showed severe thickening

(dog-boning) near the compact and core ends accompanied by a separation of the tandem compacts of up to 0.125 in. Although these deficiencies of the UAl_3 -bearing instrumented plates were deemed acceptable for the in-reactor tests, additional knowledge of the fabricability of UAl_3 is needed to fabricate functional fuel elements.

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APPENDIX A
ENGINEERING DRAWINGS

DETAIL 'F' SPECIAL FUEL PLATE DETAILS

ALL DIMENSIONS IN INCHES

NO.54 (0.0550) DRILL, NO.53 (0.0595) REDRILL
TO NOTED DEPTH 'L' (TYP) PLATE HOLE LOCATIONS

Fig. A-1. Design of Special Fuel Plates for Instrumented ATR Fuel Elements. Adapted from Idaho Nuclear Corporation drawing ATR-D-1485.

- ① T-BAR SUPPORT KEY
- ② UPPER END FITTING
- ③ LOWER END FITTING

- ④ SIDE PLATE VENTS
- ⑤ SIDE PLATES (ALUMINUM)
- ⑥ FUEL PLATES (ALUMINUM CLAD)

DIMENSIONS IN INCHES

TOP VIEW

SECTION Z-Z

BOTTOM VIEW

Fig. A-2. ATR Fuel Element. Adapted from Idaho Nuclear Corporation drawings.

APPENDIX B
SAMPLE ROLLING LOGS

ROLLING SCHEDULE

MILL SETTINGS			SHEET NUMBER	DATE
TOTAL	DIAL	Reheat Time	CORE ORDER NUMBER	PLATE NUMBER
1.742				March 1, 1966
1.090 Long		12	790-1,2,3 - 15	ATR-15 + 16 - J
1.639 double		20	791-1,2,3 - 16	
1.600 6 1/2" dir.		12	Annealed at 525°C	
1.572 double		44	Cavity 2.914 X 5.312	
1.358		12	FRAME SIZE 6 1/2 x 9 3/8 x 1.448	
1.168		12	COVER PLATE THICKNESS 0.147 X 6 1/4 X 9 1/8	
1.000		15	ROLLING TEMPERATURE 500 °C	
0.855		15	PREHEAT TIME 2 hr MINUTES	
0.735		15	REHEAT TIME See schedule MINUTES	
0.630		15	ROLL TO 0.225 hot 0.178 cold INCHES	
0.542		15	REVERSE ☒ Yes ☐ No	
0.466		12	ROLLING DIRECTION ☒ Yes ☐ No	
0.401		10	FLIP PLATE OVER ☒ Yes ☐ No	
0.346		10	DOUBLE END ANNEAL ☐ Yes ☐ No	
0.297		10	Anneal 1 1/2 hr at 500°C after hot rolling.	
COMMENTS			BILLET ROLLING DIRECTION	
0.255		10		
0.240		10	Machine plate width to 3.61 in. on 16-in. side	
0.225		90	49.50 in. long.	
Cold				
0.207				
0.190				
0.184				
0.178 double				

ROLLING SCHEDULE

MILL SETTINGS			SHEET NUMBER	DATE
TOTAL	DIAL	Reheat Time		March 24, 1966
1.867			CORE ORDER NUMBER	PLATE NUMBER
1.811	Double	12	787-1,2,3	ATR-17, + 18 - 14
1.757		20	786-4,5,6	
1.708	Cross	12		
1.660		12	Cavity 2.893 X 5.272	
1.613	Double	12	FRAME SIZE 6 1/2 x 9 3/8 x 1.552	
1.568		20	COVER PLATE THICKNESS 0.157 X 6 1/4 X 9 1/8	
1.358		12	ROLLING TEMPERATURE	500 °C
1.168		12	PREHEAT TIME	2 hr MINUTES
1.000		15	REHEAT TIME	See schedule MINUTES
0.855		15	ROLL TO	0.225 hot 0.178 cold INCHES
0.735		15	REVERSE ROLLING DIRECTION	☒ Yes ☐ No
0.630		15	FLIP PLATE OVER	☒ Yes ☐ No
0.542		15	DOUBLE END ANNEAL	☐ Yes ☐ No
0.466		12	Anneal 1 1/2 hr at 500°C after hot rolling.	
0.401		10		
COMMENTS			BILLET ROLLING DIRECTION	
0.346		10		
0.297		10	Machine to 3.820 X 49 1/2 in.	
0.255		10		
0.240		10		
0.225		90		
0.207	cold			
0.190				
0.184				
0.178	double			

APPENDIX C
SAMPLE THERMOCOUPLE WELL INSPECTION DATA

Element No. 2

FUEL PLATE NO. _____ ATR 18-K
Flat

Side 18

Side 17

[illegible]

Note -Dim. G is from outside of sideplate to bottom of hole, after assembly.

APPENDIX D
SUMMARY OF THERMOCOUPLE WELL LOCATIONS

Table D-1. ATR Fuel Element No. HP-1 Thermocouple Hole Location^a

Hole No.	Tip Deviation From Center off C-L	Flat Plate		Curved Plate					Assembly Measurement						Location of Hole Bottom From Top of Plate (in.)
		Drill Depth	Distance From Plate Edge to Hole Outer Corner	Distance From Core Edges to Hole Corner		Uncorrected Distance Plate Edge To Hole Corner	Distance - Core Edges to Hole Corner		Radiographic Plate to Hole Corner		Core Edges To Hole		Mechanical		
				Outer	Inner		Outer	Inner	Outer (Shim)	Inner (Shim)	Outer Corner	Inner	Hole Depth (Center)	Side Plate to Hole Corner (45°):030	
L-16-2	0.002	0.886	0.632	0.375(16) ^b	0.364(15) ^b	0.630	0.370	No	0.741	0.755	0.364	No	1.106	0.746	9 7/8
3	0.001		0.6285	0.3735	0.361	0.634	0.375	overlap	0.737	0.751	0.366	overlap	1.106	0.746	10 5/8
4	0.002		0.6345	0.377	0.3635	0.638	0.3755		0.740	0.750	0.367		1.107	0.747	11 29/32
5	0.004		0.641	0.3785	0.367	0.638	0.374		0.739	0.750	0.365		1.111	0.750	12 29/32
6	0.003	0.886	0.638	0.376	0.364	0.637	0.371		0.739	0.735	0.367		1.100	0.742	14 7/8
E-17-3	0.0015	0.881	0.608	0.350	0.320	0.597	0.336	0.321	0.748	0.750	0.339	0.303	1.113	0.751	10 27/32
4	0.0015	0.881	0.604	0.341	0.315	0.600	0.336	0.321	0.751	0.750	0.336	0.300	1.112	0.750	11 27/32
E-18-1	0.0015	0.836	0.618	0.500	0.393	0.630	0.413	0.392	0.740	0.740	0.401	No	1.100	0.742	7 27/32
2	0.002		0.602	0.391	0.381	0.600	0.397	0.376	0.742	0.745	0.417	overlap	1.084	0.731	9 7/8
3	0.002		0.620	0.408	0.399	0.612	0.407	0.388	0.726	0.730	0.404		1.097	0.740	10 27/32
4	0.0015		0.607	0.403	0.390	0.609	0.411	0.392	0.727	0.728	0.410		1.079	0.727	11 27/32
5	0.002		0.610	0.410	0.399	0.608	0.414	0.391	0.717	0.718	0.406		1.083	0.730	12 7/8
6	0.000		0.619	0.419	0.413	0.613	0.424	0.404	0.739	0.742	0.420		0.096	0.739	14 27/32
7	0.0005		0.586	0.383	0.370	0.564	0.375	0.348	0.692	0.687	0.378		1.049	0.706	16 13/16
8	0.002		0.587	0.384	0.378	0.577	0.380	0.350	0.692	0.695	0.377		1.050	0.707	19 13/16
9	0.0015	0.836	0.575	0.376	0.365	0.568	0.370	0.349	0.679	0.675	0.366		1.019	0.685	24 27/32

^aRadiographs were taken with film fit to plate surface. Curved plates were elevated to make subject holes about 90° to beam. Assembled plates were elevated, raising the side plate to parallel with the beam.

^b(15) Reference core edge, typical.

Table D-2. ATR Fuel Element No. HP-2 Thermocouple Hole Location^a

Hole No.	Tip Deviation From Center	Drill Depth Hole Center	Flat Plate		Uncorrected Curved Plate				Assembly Measurement						Location of Hole Bottom From Top of Plate (in.)
			Distance From Plate Edge to Outer Hole Corner	Distance From Core Edges To Hole Corner Outer Inner	Uncorrected Distance Plate Edge To Hole Corner	Distance - Core Edges To Hole Corner Outer Inner	Radiographic				Mechanical				
							Outer Surface Side Plate to Hole Corner		Core Edges to Hole .		Hole Depth (Center)	Side Plate to Hole Corner			
							(Outer Shim)	(Inner Shim)	Outer Corner	Inner					
H-16-13	0.001	0.850	0.587	0.352	No overlap				0.703	0.700(15) ^b	0.350	0.339(16) ^b	1.056	0.711	30 7/8
15	0.002		0.584	0.349					0.704	0.700	0.349	0.341	1.056	0.711	31 7/8
16	0.002		0.582	0.348	---	Not	Checked	---	0.704	0.690	0.346	0.336	1.052	0.715	32 7/8
17	0.002		0.579	0.347					0.696	0.700	0.337	0.328	1.052	0.708	33 7/8
18	0.002	0.850	0.587	0.345					0.705	0.690	0.347	0.336	1.054	0.710	34 7/8
K-17-16	0.002	0.898	0.624	0.368(17) ^b	0.335(18) ^b	0.631	0.379(17)	0.331(18)	0.741	0.745	0.378(17)	0.3365(18)	1.099	0.741	32 15/16
17	0.002	0.898	0.624	0.370	0.340	0.6295	0.3775	0.332	0.730		0.368	0.326	1.087	0.733	33 29/32
K-18-9	0.001	0.922	0.625	0.351(18)	0.336(17)	0.634	0.351(18)	0.345(17)	0.743	0.745	0.344	No overlap	1.104	0.745	24 29/32
10	0.001		0.631	0.353	0.338	0.637	0.351	0.344	0.740	0.750	0.348		1.113	0.751	27 7/8
12	0.003		0.643	0.366	0.352	0.646	0.363	0.351	0.749	0.745	0.345		1.103	0.794	29 27/32
13	0.005		0.637	0.359	0.346	0.645	0.360	0.350	0.746	0.750	0.353		1.108	0.748	30 29/32
15	0.001		0.627	0.348	0.335	0.640	0.360	0.350	0.746	0.743	0.347		1.108	0.748	31 29/32
16	0.002		0.633	0.350	0.340	0.638	0.352	0.343	0.752	0.750	0.354		1.113	0.751	32 29/32
17	0.003		0.633	0.351	0.340	0.638	0.353	0.344	0.752	0.750	0.348		1.108	0.748	33 7/8
18	0.005		0.640	0.354	0.342	0.646	0.361	0.354	0.760	0.740	0.356		1.108	0.748	33 7/8
19	0.006	0.922	0.630	0.352	0.339	0.632	0.348	0.343	0.760	0.750	0.343		1.107	0.747	37 7/8

^a Radiographs were taken with film fit to plate surface. Curved plates were elevated to make subject holes about 90° to beam. Assembled plates were elevated raising the side plate to parallel with the beam.

^b(15) Reference core edge, typical.

Table D-3. ATR Fuel Element No. HP-3 Thermocouple Hole Location^a

Hole No.	Tip Deviation From Center	Flat Plate		Uncorrected Curved Plate					Assembly Measurements						Location of Hole Bottom from top of Plate (in.)
		Drill Depth Hole Center	Distance From Plate Edge to Outer Hole Corner	Distance From Core Edges To Hole Corner	Distance From Plate Edge To Hole Corner	Distance - Core Edges to Hole Corner	Radiographic				Mechanical				
							Outer Surface Plate to Hole Corner	Side to Hole Corner	Core Edges to Hole		Hole Depth (Center)	Side Plate to Hole Corner			
									Outer	Inner			Outer	Inner	
J-16-13	0.002	0.886	0.593	0.335(16) ^b	0.320(15)	0.581	0.337(16)	0.134(15)	0.709	(16)0.329	0.324(15)	1.049	0.706	30 7/8	
15	0.000	0.886	0.592	0.339	0.323	0.585	0.340	0.317	0.712	0.331	0.325	1.056	0.711	31 7/8	
16	0.001	0.886	0.601	0.341	0.328	0.588	0.341	0.324	0.712	0.328	0.322	1.049	0.706	32 7/8	
17	0.002	0.886	0.601	0.344	0.336	0.588	0.343	0.327	0.715	0.332	0.327	1.053	0.709	33 7/8	
18	0.001	0.886	0.605	0.344	0.337	0.587	0.339	0.321	0.718	0.334	0.334	1.051	0.708	34 7/8	
I-17-16	0.002	0.900	0.613	0.364(17)	0.318(18)	0.608	0.359(17)	0.312(18)	0.721	(17)0.371	0.314(18)	1.069	0.720	32 7/8	
17	0.004	0.900	0.619	0.368	0.317	0.607	0.360	0.314	0.719	0.371	0.312	1.073	0.723	33 7/8	
I-18-9	0.005	0.914	0.627	0.359(18)	0.322(17)	0.615	0.354(18)	0.322(17)	0.739	(18)0.353	0.328(17)	1.090	0.735	24 7/8	
10	0.001	0.914	0.622	0.355	0.315	0.612	0.355	0.320	0.732	0.354	0.324	1.074	0.724	27 7/8	
12	0.003	0.914	0.640	0.368	0.326	0.630	0.374	0.337	0.748	0.370	0.341	1.083	0.730	29 7/8	
13	0.004	0.914	0.622	0.363	0.317	0.614	0.361	0.322	0.726	0.351	0.325	1.094	0.738	30 7/8	
15	0.003	0.914	0.632	0.370	0.325	0.621	0.366	0.330	0.739	0.365	0.336	1.084	0.731	31 7/8	
16	0.001	0.914	0.624	0.364	0.318	0.609	0.352	0.318	0.727	0.353	0.324	1.086	0.732	32 29/32	
17	0.005	0.914	0.622	0.364	0.318	0.606	0.354	0.316	0.718	0.346	0.319	1.089	0.734	33 7/8	
18	0.003	0.914	0.622	0.365	0.316	0.608	0.356	0.321	0.728	0.357	0.328	1.075	0.724	34 7/8	
19	0.001	0.914	0.629	0.368	0.321	0.620	0.362	0.325	0.737	0.363	0.334	1.094	0.738	37 7/8	

^a Radiographs were taken with film fit to plate surface. Curved plates were elevated to make subject holes about 90° to beam. Assembled plates were elevated, raising the side plate to parallel with the beam.

^b (15) Reference core edge, typical.

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Table D-4. ATR Fuel Element No. HP-4 Thermocouple Hole Location

Hole No.	Tip Deviation From Center off C-L	Drill Depth Hole Center	Flat Plate		Curved Plate		Uncorrected		Radiographic		Assembly Measurement				Location of Hole Bottom From Top of Plate (in.)
			Distance From Plate Edge to Outer Corner	Distance From Core Edges to Hole Corner	Distance From Plate Edge To Hole Corner	Distance From Core Edges To Hole Corner	Outer Surface Side Plate to Hole Corner (Outer Shim)	Core Edges to Hole Corner (Inner Shim)	Core Edges to Hole		Mechanical				
									Outer Corner	Inner Corner	Hole Depth (Center)	Side Plate to Hole Corner			
P-17-13	0.003	0.871	0.595	0.355 ⁽¹⁷⁾	0.325 ⁽¹⁸⁾	0.584	0.361 ⁽¹⁷⁾	0.318 ⁽¹⁸⁾	0.705	0.713	0.349 ⁽¹⁷⁾	0.340 ⁽¹⁸⁾	1.052	0.708	30 7/8
-16	0.003	0.871	0.596	0.350	0.345	0.576	0.337	0.303	0.700	0.710	0.351	0.348	1.053	0.709	32 7/8
Desired hole			0.595						0.715	0.715			1.061	0.715	
P-18-2	0.002	0.886	0.609	0.372 ⁽¹⁸⁾	0.349 ⁽¹⁷⁾	0.596	0.367 ⁽¹⁸⁾	0.340 ⁽¹⁷⁾	0.727	0.721	0.366 ⁽¹⁸⁾	0.349 ⁽¹⁷⁾	1.062	0.715	9 13/16
-3	0.000	0.886	0.609	0.372	0.349	0.593	0.360	0.333	0.717	0.715	0.360	0.348	1.063	0.716	10 13/16
-4	0.000	0.886	0.609	0.370	0.346	0.587	0.355	0.330	0.721	0.720	0.362	0.352	1.061	0.715	11 13/16
-5	0.000	0.886	0.610	0.365	0.344	0.590	0.356	0.331	0.722	0.720	0.360	0.350	1.059	0.713	12 13/16
-6	0.003	0.886	0.611	0.360	0.336	0.599	0.350	0.324	0.728	0.722	0.350	0.342	1.052	0.708	14 25/32
-8	0.003	0.886	0.607	0.353	0.332	0.591	0.342	0.318	0.726	0.720	0.350	0.334	1.054	0.710	19 25/32
-9	0.002	0.886	0.607	0.354	0.333	0.581	0.338	0.316	0.703	0.704	0.348	0.332	1.056	0.711	24 13/16
-11	0.003	0.886	0.617	0.368	0.338	0.596	0.352	0.322	0.720	0.721	0.357	0.349	1.054	0.710	29 5/16
-13	0.001	0.886	0.615	0.367	0.341	0.597	0.358	0.331	0.729	0.728	0.365	0.359	1.057	0.712	30 13/16
-14	0.001	0.886	0.615	0.368	0.345	0.602	0.364	0.335	0.728	0.722	0.360	0.355	1.055	0.710	31 5/16
-15	0.000	0.886	0.606	0.369	0.338	0.584	0.348	0.323	0.718	0.720	0.358	0.350	1.059	0.713	31 13/16
-16	0.003	0.886	0.609	0.371	0.348	0.600	0.361	0.338	0.731	0.737	0.365	0.356	1.060	0.714	32 13/16
-17	0.002	0.886	0.608	0.372	0.352	0.599	0.361	0.332	0.722	0.722	0.360	0.353	1.059	0.713	33 13/16
-18	0.003	0.886	0.608	0.373	0.352	0.597	0.357	0.332	0.726	0.735	0.363	0.358	1.059	0.713	34 13/16
Desired hole			0.605	0.360					0.725	0.725			1.076	0.725	

Table D-5. ATR Fuel Element No. HP-5 Thermocouple Hole Location

Hole No.	Tip Deviation From Center off C-L	Drill Depth Hole Center	Flat Plate		Curved Plate		Assembly Measurement						Location of Hole Bottom From Top of Plate (in.)		
			From Plate Edge to Outer Corner	Distance From Core Edges to Hole Corner Outer Inner	Uncorrected Distance Plate Edge to Hole Corner	Distance Core Edges to Hole Corner Outer Inner	Radiographic		Core Edges to Hole		Mechanical				
							Outer Surface Side Plate to Hole Corner (Outer Shim)	Inner Shim)	Outer Corner	Inner	Hole Depth (Center)	Side Plate to Hole Corner			
D-17-2	0.003	0.931	0.644	0.369		0.640	0.368		0.750	0.365		1.098	0.741	9 13/16	
-3	0.003	0.931	0.644	0.364		0.637	0.361		0.748	0.353		1.097	0.740	10 12/16	
-4	0.004	0.931	0.633	0.352		0.641	0.363		0.752	0.355		1.099	0.741	11 13/16	
-5	0.002	0.931	0.644	0.360		0.642	0.359	Shim did not appear on radiograph	0.748	0.355		1.098	0.741	12 13/16	
-6	0.001	0.931	0.653	0.366		0.652	0.379		0.745	0.352		1.098	0.741	14 13/16	
-8	0.003	0.931	0.642	0.353		0.639	0.350		0.739	0.340		1.097	0.740	19 13/16	
-9	0.003	0.931	0.623	0.332	No overlap of cores	0.643	0.340		0.743	0.336		1.098	0.741	24 7/8	
-11	0.001	0.931	0.620	0.332		0.638	0.339		0.743	0.332		1.096	0.739	29 3/8	
-13	0.003	0.931	a	a		0.636	0.337		0.746	0.340		1.096	0.739	30 7/8	
-14	0.005	0.931	0.654	0.353		0.641	0.342		0.753	0.338		1.097	0.740	31 3/8	
-15	0.004	0.931	0.648	0.345		0.632	0.332		0.748	0.339		1.099	0.741	31 7/8	
-16	0.008	0.931	0.649	0.349		0.635	0.335		0.745	0.335		1.098	0.741	32 7/8	
-17	0.002	0.931	0.645	0.354		a	a		a	a		1.098	0.741	33 7/8	
-18	0.001	0.931	0.653	0.360		0.630	0.335		0.748	0.345		1.099	0.741	34 7/8	
Desired hole			0.637	0.350					0.757			1.122	0.757		
D-18-13	0.002	0.907	0.627	0.381			0.614	0.378	0.358	0.739	0.364		1.099	0.741	30 7/8
-16	0.002	0.907	0.623	0.377			0.618	0.374	0.359	0.740	0.363		1.099	0.741	32 7/8
Desired hole			0.620	0.350					0.740			1.097	0.740		

^aPin for radiographic contrast not at bottom of hole.

APPENDIX E
ELEMENTS ENVELOPE DATA

Table E-1. ATR FUEL ELEMENT INSPECTION ENVELOPE DATA

Fuel Element No. HP-1.

Position (in.)	Deviation from Theoretical Template (mils) at Indicated Position					
	A	B	C	D	E	F
End (Bottom)	15	10	7	6	8	12
4	12	10	13	13	12	7
8	16	14	8	8	11	12
12	16	11	10	9	11	10
16	16	16	11	8	8	10
20	16	15	13	12	10	6
24	13	9	9	10	11	11
28	16	16	11	10	9	6
32	16	16	13	10	10	10
36	16	15	14	10	7	5
40	--	16	13	8	10	11
44	16	12	13	11	11	7
48	16	15	10	7	8	9
End (Top)	16	14	8	8	7	10
Max.	16	17	14	13	14	13
Min.	9	6	6	5	6	2

Top (H) Relative theo. center 3.507
 (I) Left side 1.296
 (J) Right side 1.307

Bottom (H) Relative theo. center 3.510
 (I) Left side 1.298
 (J) Right side 1.302
 Under Pad 0.219

Table E-2. ATR FUEL ELEMENT INSPECTION ENVELOPE DATA

Fuel Element No. HP-2

Position (in.)	Deviation from Theoretical Template (mils) at Indicated Position						
	A	B	C	D	E	F	G
End (Bottom)	16	14	6	0	5	10	14
4	16	13	13	10	7	6	9
8	16	15	12	8	10	11	14
12	16	16	14	10	15	15	16
16	16	17	13	8	11	13	16
20	16	14	13	9	13	12	14
24	14	7	8	5	7	11	14
28	16	12	11	8	9	11	14
32	16	10	9	7	10	13	16
36	16	10	10	8	12	18	--
40	--	10	11	10	13	11	13
44	16	15	10	5	8	10	10
48	16	10	7	4	7	8	9
End (Top)	16	12	11	3	8	9	10
Max.	16	17	15	13	15	18	16
Min.	16	5	6	0	4	5	5

Top (H) Relative theo. center 3.506
 (I) Left side 1.299
 (J) Right side 1.305

Bottom (H) Relative theo. center 3.505
 (I) Left side 1.299
 (J) Right side 1.296
 Under pad 0.220

Table E-3. ATR FUEL ELEMENT INSPECTION ENVELOPE DATA

Fuel Element No. HP-3

Position (in.)	Deviation from Theoretical Template (mils) at Indicated Position						
	A	B	C	D	E	F	G
End (Bottom)	14	8	2	7	12	17	16
4	11	7	8	8	11	11	12
8	12	15	9	2	9	11	12
12	11	15	10	7	14	17	11
16	10	15	9	5	11	16	10
20	10	13	10	10	13	13	10
24	9	8	5	5	10	15	9
28	10	17	12	7	11	13	9
32	10	18	12	6	12	15	9
36	10	12	7	0	8	15	--
40	--	5	3	0	6	7	8
44	10	12	6	-1	3	5	4
48	10	5	4	-1	4	7	5
End (Top)	11	9	6	1	4	11	11
Max.	14	17	14	11	15	18	16
Min.	-1	-4	2	-5	0	3	-10

Top (H) Relative theo. center 3.503
 (I) Left side 1.111
 (J) Right side 1.108

Bottom (H) Relative theo. center 3.509
 (I) Left side 1.109
 (J) Right side 1.112
 Under pad 0.225

Table E-4. ATR INSPECTION ENVELOPE DATA

Fuel Element No. HP-4

Position (in.)	Deviation from Theoretical Template at Inspection Position (mils)						
	A	B	C	D	E	F	G
End (Bottom)	10	2	1	0	6	17	18
4	3	-1	3	4	10	14	12
8	14	5	3	2	7	16	16
12	10	2	3	1	5	16	19
16	14	5	3	-2	4	17	19
20	12	3	2	-3	2	16	18
24	7	1	1	-3	-1	12	14
28	12	13	2	-3	-2	11	11
32	17	11	5	0	4	15	15
36	9	6	6	4	7	16	--
40	--	5	3	-1	6	17	17
44	9	3	3	1	6	11	10
48	12	4	3	-1	5	14	15
End (Top)	18	5	2	0	3	15	15
Max	18	14	6	4	10	19	20
Min	0	-2	1	-3	-3	10	7

Top adaptor

(H) Relative theoretical center 3.495

(I) Left side 1.300

(J) Right side 1.287

Bottom adaptor

(H) Relative theoretical center 3.505

(I) Left side 1.303

(J) Right side 1.293

Under pad 0.220

Table E-5. ATR INSPECTION ENVELOPE DATA

Fuel Element No. HP-5

Position (in.)	Deviation from Theoretical Template at Inspection Position (mils)						
	A	B	C	D	E	F	G
End (Bottom)	10	11	12	12	15	18	12
4	3	9	10	9	10	13	11
8	13	9	10	8	11	12	14
12	11	7	6	5	8	13	16
16	15	8	6	6	8	14	16
20	15	9	9	7	11	14	15
24	15	9	12	12	12	12	14
28	15	12	12	10	12	14	16
32	18	13	11	9	12	15	17
36	13	13	11	8	13	17	--
40	--	10	8	6	13	17	19
44	16	9	12	11	14	13	14
48	18	12	13	11	14	17	17
End (Top)	19	13	15	11	14	16	18
Max	19	13	15	13	15	18	19
Min	3	5	5	5	7	8	8

Top adaptor

(H) Relative theoretical center 3.499

(I) Left side 1.298

(J) Right side 1.302

Bottom adaptor

(H) Relative theoretical center 3.505

(I) Left side 1.304

(J) Right side 1.292

Under pad 0.220

APPENDIX F
SAMPLE CHANNEL SPACING DATA

ATR FUEL PLATE SPACE INSPECTION

ATR No. HP-1Space No. 1

	A	B	C		TOTAL		AVERAGE	
1	0.0 78	0.0 81	0.0 80		.239		0.0796	
2	78	79	81		.238		.0793	
3	78	78	81		.237		.0790	
4	80	81	82		.243		.0810	
5	81	82	82		.245		.0816	
6	82	82	82		.246		.0820	
7	83	82	81		.246		.0820	
8	80	82	81		.243		.0810	
9	80	83	80		.243		.0810	
10	81	83	80		.244		.0813	
11	81	83	81		.245		.0816	
12	82	81	81		.244		.0813	
13	76	78	80		.234		.0780	
14	75	76	79		.230		.0766	
15	77	78	78		.233		.0776	
16	79	82	78		.239		.0796	
17	76	82	78		.236		.0786	
18	76	78	77		.231		.0770	
19	75	78	76		.229		.0763	
20	75	78	77		.230		.0766	
21	77	80	78		.235		.0783	
22	78	82	79		.239		.0796	
23	77	82	79		.238		.0793	
24	78	79	79		.236		.0786	

TOT	1.883	1.930	1.910
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AV	.0784	.0804	.0795
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ATR FUEL PLATE SPACE INSPECTION

ATR No. HP-1Space No. 2

	A	B	C		TOTAL		AVERAGE	
1	0.0 80	0.0 82	0.0 80		.242		0.0806	
2	80	80	78		.238		.0793	
3	80	81	80		.241		.0803	
4	80	82	81		.243		.0810	
5	80	81	81		.242		.0806	
6	79	82	80		.241		.0803	
7	80	81	81		.242		.0806	
8	79	80	81		.240		.0800	
9	78	78	81		.237		.0790	
10	78	78	81		.237		.0790	
11	79	81	82		.242		.0806	
12	79	80	83		.242		.0806	
13	77	78	78		.233		.0776	
14	77	77	79		.233		.0776	
15	75	75	79		.229		.0763	
16	76	75	79		.230		.0766	
17	77	75	80		.232		.0773	
18	77	76	78		.231		.0770	
19	77	80	80		.237		.0790	
20	76	81	80		.237		.0790	
21	76	79	79		.234		.0780	
22	78	78	78		.234		.0780	
23	79	77	78		.234		.0780	
24	80	79	78		.237		.0790	
TOT	1.877	1.896	1.915					
AV	.0782	.0790	.0797					

ATR FUEL PLATE SPACE INSPECTION

ATR No. HP-1Space No. 3

	A	B	C		TOTAL	AVERAGE	
1	0.0 80	0.0 77	0.0 79		.236	0.0 786	
2	80	77	82		.239	.0796	
3	80	78	80		.238	.0793	
4	80	78	79		.237	.0790	
5	79	78	80		.237	.0790	
6	80	78	80		.238	.0793	
7	80	79	80		.239	.0796	
8	81	81	80		.242	.0806	
9	80	80	80		.240	.0800	
10	79	80	81		.240	.0800	
11	79	80	80		.239	.0796	
12	80	80	81		.241	.0803	
13	82	79	80		.241	.0803	
14	82	78	80		.240	.0800	
15	80	79	79		.238	.0793	
16	77	77	79		.233	.0776	
17	77	76	79		.232	.0773	
18	78	78	78		.234	.0780	
19	78	78	80		.236	.0786	
20	77	77	80		.234	.0780	
21	77	76	79		.232	.0773	
22	77	76	77		.230	.0766	
23	78	77	77		.232	.0773	
24	78	77	77		.232	.0773	

TOT	1.899	1.874	1.907
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AV	.0791	.0780	.0794
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ATR FUEL PLATE SPACE INSPECTION

ATR No. HP-1Space No. 4

	A	B	C		TOTAL		AVERAGE	
1	0.078	0.077	0.078		.233		0.0776	
2	78	77	79		.234		.0780	
3	78	78	80		.236		.0786	
4	79	78	80		.237		.0790	
5	79	78	80		.237		.0790	
6	79	78	80		.237		.0790	
7	77	80	81		.238		.0793	
8	78	80	80		.238		.0793	
9	79	80	80		.239		.0796	
10	79	80	80		.239		.0796	
11	80	82	81		.243		.0810	
12	80	82	82		.244		.0813	
13	78	78	76		.232		.0773	
14	78	80	75		.233		.0776	
15	79	80	75		.234		.0780	
16	79	78	76		.233		.0776	
17	79	76	76		.231		.0770	
18	78	77	75		.230		.0766	
19	78	77	73		.228		.0760	
20	78	77	75		.230		.0766	
21	79	77	75		.231		.0770	
22	79	77	76		.232		.0773	
23	78	76	76		.230		.0766	
24	79	75	76		.230		.0756	

TOT	1.886	1.878	1.865
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AV	.0785	.0782	.0777
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ATR FUEL PLATE SPACE INSPECTION

ATR No. HP-1Space No. 5

	A	B	C		TOTAL		AVERAGE	
1	0.0 81	0.0 79	0.0 80		.240		0.0800	
2	84	78	80		.242		.0806	
3	82	79	80		.241		.0803	
4	83	80	81		.244		.0813	
5	83	80	81		.244		.0813	
6	82	80	80		.242		.0806	
7	81	79	80		.240		.0800	
8	82	79	81		.243		.0810	
9	82	78	79		.239		.0796	
10	84	79	80		.243		.0810	
11	81	81	79		.241		.0803	
12	80	79	78		.237		.0790	
13	81	80	78		.239		.0796	
14	80	78	78		.236		.0786	
15	80	78	77		.235		.0783	
16	81	79	77		.237		.0790	
17	80	82	78		.240		.0800	
18	79	78	78		.235		.0783	
19	79	78	79		.236		.0786	
20	78	78	77		.233		.0776	
21	78	79	77		.234		.0780	
22	79	79	79		.237		.0790	
23	80	77	78		.235		.0783	
24	80	77	79		.236		.0786	
TOT	1.936	1.894	1.894					
AV	.0806	.0789	.0789					

ATR FUEL PLATE SPACE INSPECTION

ATR No. HP-1Space No. 6

	A	B	C		TOTAL		AVERAGE	
1	0.0 79	0.0 76	0.0 78		.233		0.0776	
2	79	76	78		.235		.0783	
3	78	77	79		.234		.0780	
4	79	77	78		.234		.0780	
5	79	77	78		.234		.0780	
6	80	77	79		.236		.0786	
7	78	77	79		.234		.0780	
8	79	78	79		.236		.0786	
9	79	78	78		.235		.0783	
10	79	78	80		.237		.0790	
11	79	77	80		.236		.0786	
12	78	78	79		.235		.0783	
13	76	77	75		.228		.0760	
14	76	77	75		.228		.0760	
15	76	78	75		.229		.0763	
16	75	78	77		.230		.0766	
17	75	77	76		.228		.0760	
18	76	77	77		.230		.0766	
19	77	77	78		.232		.0773	
20	78	76	77		.231		.0770	
21	77	76	76		.229		.0763	
22	76	77	75		.228		.0760	
23	75	77	76		.228		.0760	
24	77	77	76		.230		.0766	

TOT	1.860	1.850	1.858
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AV	.0775	.0770	.0774
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ATR FUEL PLATE SPACE INSPECTION

ATR No. HP-1Space No. 7

	A	B	C		TOTAL		AVERAGE	
1	0.0 79	0.0 77	0.0 77		.233		0.0776	
2	75	77	77		.229		.0763	
3	79	77	77		.233		.0776	
4	79	76	77		.232		.0773	
5	80	75	77		.232		.0773	
6	80	74	77		.231		.0770	
7	80	73	77		.230		.0766	
8	80	74	77		.233		.0776	
9	80	76	79		.235		.0783	
10	80	78	78		.236		.0786	
11	80	75	76		.231		.0770	
12	80	73	76		.229		.0763	
13	78	75	76		.229		.0763	
14	78	75	76		.229		.0763	
15	78	75	76		.229		.0763	
16	78	75	75		.228		.0760	
17	79	75	75		.229		.0763	
18	79	76	76		.231		.0770	
19	78	76	76		.230		.0766	
20	78	75	75		.228		.0760	
21	79	75	76		.230		.0766	
22	78	74	76		.228		.0760	
23	78	75	76		.229		.0763	
24	78	75	75		.228		.0760	
TOT	1.891	1.806	1.833					
AV	.0767	.0752	.0763					

ATR FUEL PLATE SPACE INSPECTION

ATR No. HP-1Space No. 8

	A	B	C		TOTAL		AVERAGE	
1	0.0 80	0.0 77	0.0 78		.235		0.0783	
2	81	78	78		.237		.0790	
3	80	79	78		.237		.0790	
4	79	79	79		.237		.0790	
5	78	79	79		.236		.0786	
6	78	79	79		.236		.0786	
7	78	78	79		.235		.0783	
8	79	77	80		.236		.0786	
9	80	76	80		.236		.0786	
10	79	77	78		.234		.0780	
11	79	77	80		.236		.0786	
12	78	78	79		.235		.0783	
13	78	75	77		.230		.0766	
14	77	75	75		.227		.0756	
15	77	76	75		.228		.0760	
16	76	77	75		.228		.0760	
17	75	77	76		.228		.0760	
18	77	77	76		.230		.0766	
19	77	77	76		.230		.0766	
20	77	78	76		.231		.0770	
21	77	76	75		.228		.0760	
22	76	76	76		.228		.0760	
23	76	77	76		.229		.0763	
24	76	77	76		.229		.0763	

TOT	1.868	1.852	1.856
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AV	.0778	.0771	.0773
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ATR FUEL PLATE SPACE INSPECTION

ATR No. HP-1Space No. 9

	A	B	C		TOTAL		AVERAGE	
1	0.0 74	0.0 79	0.0 77		.230		0.0766	
2	74	78	76		.230		.0766	
3	76	81	78		.235		.0783	
4	77	82	78		.237		.0790	
5	77	84	78		.239		.0796	
6	77	84	78		.239		.0796	
7	76	84	78		.238		.0793	
8	76	84	78		.238		.0793	
9	75	82	77		.234		.0780	
10	75	80	75		.230		.0766	
11	73	78	78		.229		.0763	
12	74	79	76		.229		.0763	
13	79	80	74		.233		.0776	
14	79	79	73		.231		.0770	
15	77	78	74		.229		.0763	
16	77	78	74		.229		.0763	
17	78	78	74		.230		.0766	
18	76	78	74		.228		.0760	
19	75	77	75		.227		.0756	
20	74	76	74		.226		.0753	
21	75	78	74		.227		.0756	
22	77	80	74		.231		.0770	
23	78	79	74		.231		.0770	
24	78	79	74		.231		.0770	
TOT	1.827	1.915	1.815					
AV	.0761	.0797	.0756					

ATR FUEL PLATE SPACE INSPECTION

ATR No. HP-1Space No. 10

	A	B	C		TOTAL		AVERAGE	
1	0.0 83	0.0 80	0.0 80		.243		0.0810	
2	82	79	78		.239		.0796	
3	80	76	76		.232		.0773	
4	81	76	79		.235		.0783	
5	83	77	80		.237		.0790	
6	82	77	80		.239		.0796	
7	82	77	80		.239		.0796	
8	82	77	80		.239		.0796	
9	82	77	81		.240		.0800	
10	82	78	80		.240		.0800	
11	83	79	83		.245		.0816	
12	83	79	81		.243		.0810	
13	77	80	77		.234		.0780	
14	78	80	77		.235		.0783	
15	77	79	76		.232		.0773	
16	77	79	76		.232		.0773	
17	76	80	76		.232		.0773	
18	76	80	77		.233		.0776	
19	76	80	76		.232		.0773	
20	76	79	75		.230		.0766	
21	75	79	75		.229		.0763	
22	75	79	74		.228		.0760	
23	76	80	75		.231		.0770	
24	76	81	75		.232		.0773	
TOT	1.900	1.888	1.867					
AV	.0791	.0786	.0777					

ATR FUEL PLATE SPACE INSPECTION

ATR No. HP-1Space No. 11

	A	B	C		TOTAL	AVERAGE	
1	0.0 77	0.0 81	0.0 83		.241	0.0803	
2	79	80	80		.239	.0796	
3	79	82	80		.241	.0803	
4	78	80	80		.238	.0793	
5	79	79	80		.238	.0793	
6	80	78	80		.238	.0793	
7	80	78	80		.238	.0793	
8	80	80	80		.240	.0800	
9	80	81	80		.241	.0803	
10	81	83	81		.245	.0816	
11	80	81	79		.240	.0800	
12	80	82	80		.242	.0806	
13	75	78	77		.230	.0766	
14	79	78	77		.234	.0780	
15	81	77	77		.235	.0783	
16	80	78	77		.235	.0783	
17	79	77	78		.234	.0780	
18	80	78	78		.236	.0786	
19	79	78	77		.234	.0780	
20	77	78	78		.233	.0776	
21	77	80	77		.234	.0780	
22	79	78	77		.234	.0780	
23	79	78	77		.234	.0780	
24	77	77	77		.231	.0770	

TOT	1.895	1.900	1.890
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AV	.0789	.0791	.0787
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ATR FUEL PLATE SPACE INSPECTION

ATR No. HP-1Space No. 12

	A	B	C		TOTAL		AVERAGE	
1	0.0 84	0.0 80	0.0 82		.246		0.0820	
2	83	80	80		.243		.0810	
3	84	80	81		.245		.0816	
4	84	78	81		.243		.0810	
5	81	77	82		.240		.0800	
6	82	77	82		.241		.0803	
7	81	77	81		.239		.0796	
8	81	78	81		.240		.0800	
9	81	79	81		.241		.0803	
10	82	79	81		.242		.0806	
11	81	78	80		.239		.0796	
12	81	77	83		.241		.0803	
13	80	79	80		.239		.0796	
14	78	81	81		.240		.0800	
15	79	77	80		.236		.0786	
16	78	77	79		.234		.0780	
17	79	77	80		.236		.0786	
18	79	78	80		.237		.0790	
19	80	77	80		.237		.0790	
20	79	76	79		.234		.0780	
21	77	75	81		.233		.0776	
22	77	75	80		.232		.0773	
23	76	75	79		.230		.0766	
24	78	75	78		.231		.0770	

TOT	1.925	1.862	1.932
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AV	.0802	.0775	.0805
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ATR FUEL PLATE SPACE INSPECTION

ATR No. HP-1Space No. 13

	A	B	C		TOTAL		AVERAGE	
1	0.0 74	0.0 76	0.0 73		.223		0.0743	
2	73	78	75		.226		.0753	
3	73	78	77		.228		.0760	
4	73	80	76		.229		.0763	
5	73	81	74		.228		.0760	
6	74	81	76		.231		.0770	
7	73	81	77		.231		.0770	
8	73	81	77		.231		.0770	
9	74	81	75		.230		.0766	
10	73	81	76		.230		.0766	
11	74	81	78		.233		.0776	
12	74	80	77		.231		.0770	
13	75	76	74		.225		.0750	
14	75	76	75		.226		.0753	
15	75	77	74		.226		.0753	
16	74	77	74		.225		.0750	
17	74	76	74		.224		.0746	
18	74	75	76		.225		.0750	
19	76	75	76		.227		.0756	
20	74	74	74		.222		.0740	
21	74	73	74		.221		.0736	
22	75	74	73		.222		.0740	
23	75	75	74		.224		.0746	
24	76	76	75		.227		.0756	

TOT	1.778	1.863	1.804
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AV	.0741	.0776	.0751
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ATR FUEL PLATE SPACE INSPECTION

ATR No. HP-1Space No. 14

	A	B	C		TOTAL		AVERAGE	
1	0.0 74	0.0 73	0.0 78		.225		0.0 750	
2	75	74	78		.227		.0756	
3	75	78	77		.230		.0766	
4	75	81	79		.235		.0783	
5	76	78	79		.233		.0776	
6	76	76	78		.230		.0766	
7	75	78	79		.232		.0773	
8	75	77	79		.231		.0770	
9	74	76	77		.227		.0756	
10	74	74	77		.225		.0750	
11	73	78	77		.228		.0760	
12	74	79	79		.232		.0773	
13	74	77	75		.226		.0753	
14	73	73	75		.221		.0736	
15	74	74	75		.223		.0743	
16	74	75	75		.224		.0746	
17	73	74	75		.222		.0740	
18	74	77	73		.224		.0746	
19	73	82	74		.229		.0763	
20	73	82	76		.231		.0770	
21	74	82	76		.232		.0773	
22	74	80	76		.230		.0766	
23	73	78	75		.226		.0753	
24	74	75	73		.222		.0740	

TOT	1.779	1.851	1.835
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AV	.0741	.0771	.0764
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ATR FUEL PLATE SPACE INSPECTION

ATR No. HP-1Space No. 16

	A	B	C		TOTAL		AVERAGE	
1	0.073	0.079	0.077		.229		0.0763	
2	77	80	74		.231		.0770	
3	75	78	75		.228		.0760	
4	77	77	74		.228		.0760	
5	76	76	72		.224		.0746	
6	75	75	74		.224		.0746	
7	74	75	73		.222		.0740	
8	75	76	72		.223		.2743	
9	74	78	73		.225		.0750	
10	75	79	73		.227		.0756	
11	79	81	74		.234		.0780	
12	76	81	75		.232		.0773	
13	79	81	73		.233		.0776	
14	77	81	72		.230		.0766	
15	76	78	72		.226		.0753	
16	74	77	74		.225		.0750	
17	74	77	74		.225		.0750	
18	75	76	74		.225		.0750	
19	76	77	76		.229		.0763	
20	74	79	77		.230		.0766	
21	78	82	78		.238		.0793	
22	75	81	75		.231		.0770	
23	72	79	75		.226		.0753	
24	73	80	75		.228		.0760	

TOT	1.809	1.883	1.781
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AV	.0753	.0784	.0742
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ATR FUEL PLATE SPACE INSPECTION

ATR No. HP-1Space No. 18

	A	B	C		TOTAL		AVERAGE	
1	0.082	0.075	0.077		.234		0.0780	
2	80	80	78		.238		.0793	
3	81	79	78		.238		.0793	
4	79	77	80		.236		.0786	
5	80	78	80		.238		.0793	
6	78	76	79		.233		.0776	
7	78	75	80		.233		.0776	
8	80	77	79		.236		.0786	
9	78	78	78		.234		.0780	
10	77	77	78		.232		.0773	
11	74	75	74		.223		.0743	
12	78	78	74		.230		.0766	
13	75	74	74		.223		.0743	
14	76	76	75		.227		.0756	
15	76	76	75		.227		.0756	
16	79	76	74		.229		.0763	
17	77	75	74		.226		.0753	
18	72	76	74		.222		.0740	
19	74	76	73		.223		.0743	
20	82	74	73		.229		.0763	
21	75	74	73		.222		.0740	
22	77	76	74		.227		.0756	
23	77	75	75		.227		.0756	
24	78	74	76		.228		.0760	

TOT	1.863	1.827	1.825
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AV	.0776	.0761	.0760
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APPENDIX G
ELEMENTS DATA SHEETS - FINAL INSPECTION

Table G-1. ELEMENT DATA SHEET - FINAL INSPECTION

ATR

ELEMENT HP-1

	PLATE NO.	U CONTENT	U-235 CONTENT	B ₄ C	LOCATION	DIMENSIONS				
						PART DIM.	L MAX.	L MIN.	R MAX.	R MIN.
1	LVB-29	32.50	30.27	.163 "	LOWER T	.284 $\pm$.005 -.000	+.010*	+.005	+.010*	+.005
2	LVC-22	38.92	36.26	.204	LOWER T	.484 $\pm$.005	.000 to -.005			
3	LVE-30	40.99	38.19	.214	LOWER T	.373 $\pm$.005 -.000	-.002	-.001	-.002	-.001
4	LVG-06	43.01	40.07	.224	LOWER T	.745 $\pm$.005 -.010	-.001			
5	LTE-23	45.04	41.96	.235	UPPER T	.373 $\pm$.005 -.000	-.001	-.001	-.001	-.001
6	LTF-21	47.20	43.97	.245	UPPER T	.745 $\pm$.005 -.010	-.001			
7	LVP-28	49.34	45.97	.255	UPPER T	.638 $\pm$.005 -.000	+.001	+.001	+.003	+.003
8	LVT-28	51.29	47.78	.265	UPPER T	.820 $\pm$.005	.001 to -.001			
9	LSJ-16	53.43	49.78	.275	UPPER END BOX	.296 $\pm$.005 -.000	-.006*	-.001	-.001	.000
10	LXA-15	55.45	51.66	.286	UPPER END BOX	.562 $\pm$.002	+.001			
11	LXC-15	57.50	53.57	.296						
12	LTN-24	59.65	55.57	.306	OUTER SIDE PLATE EDGE	2.550 $\pm$.005 (2.276) -.000	+.009*	-.003	+.010*	-.008*
13	LXF-08	61.67	57.46	.316	INNER SIDE PLATE EDGE	.274 $\pm$.005 (.3137)*	-.014*	-.008*	-.019*	-.011*
14	LXJ-25	63.73	59.37	.326	PLATE 19	5.449 (2.069)	+.016	+.005	+.017	+.010
15	ATR-L	65.91	61.41	.337	PLATE 19 (q)	5.449 (1.949)	+.004 to -.003			
16	ATR-L	67.95	63.30	.347	PLATE 1 (q)	3.015 (.484)	+.001 to -.008			
17	ATR-E	69.99	65.19	.357						
18	ATR-E	72.15	67.20	.367						
19	LXZ-17	70.40	65.58	.367	SIDE PLATE FACE	1.303 $\pm$.000 -.010	-.011	-.004	-.010	-.005
	TOTAL	1046.12	974.56	5.385	PLATE 1 TO SIDE PLATE	.056 $\pm$.010	ok			
					PLATE 19 TO SIDE PLA.	.063 $\pm$.010	ok			
					SIDE PLATE PAD	.035 $\pm$.005 -.000	ok			
					FUEL PLATE	49 1/2 $\pm$ 1/32	-1/32			
					SIDE PLATE TO FUEL	4 7/8	0			
					LOWER END BOX	2 5/8 $\pm$ 1/64	0			
					ASSEMBLY	66 1/4 $\pm$ 1/16	-1/32			

ENRICHMENT 93.15%

DATE 6/17/66

*Infraction of tolerance.

Table G-2. ELEMENT DATA SHEET - FINAL INSPECTION

ATR					ELEMENT HP-2				
	PLATE NO.	U CONTENT	U-235 CONTENT	B ₄ C	LOCATION	DIMENSIONS			
						PART DIM.	L MAX.	L MIN.	R MAX. R MIN.
1	LVB-08	32.49	30.27	.163 "	LOWER T	.284 $\pm$.005 -.000	+.001	.000	-.001* .000
2	LVC-19	38.94	36.28	.204	LOWER T	.484 $\pm$.005	-.002 to -.003		
3	LVF-15	40.98	38.18	.214	LOWER T	.373 $\pm$.005 -.000	-.005	-.002	+.003* .000
4	LVH-18	43.02	40.08	.224	LOWER T	.745 $\pm$.005 -.010	.000		
5	LTE-03	45.06	41.98	.235	UPPER T	.373 $\pm$.005 -.000	-.002	-.002	.000 .000
6	LTF-19	47.19	43.97	.245	UPPER T	.745 $\pm$.005 -.010	.000		
7	LVP-25	49.31	45.94	.255	UPPER T	.638 $\pm$.005 -.000	.000	.000	+.002 +.002
8	LVT-04	51.28	47.78	.265	UPPER T	.820 $\pm$.005	-.001 to -.002		
9	LVY-07	53.42	49.77	.275	UPPER END BOX	.296 $\pm$.005 -.000	.000	.000	.000 .000
10	LXA-16	55.43	51.63	.286	UPPER END BOX	.562 $\pm$.002	+.001		
11	LXC-03	57.50	53.57	.296					
12	LPL-10	59.63	55.56	.306	OUTER SIDE PLATE EDGE	2.550 $\pm$.005 (2.276) -.000	+.005	-.003*	+.010* +.002
13	LXF-03	61.68	57.46	.316	INNER SIDE PLATE EDGE	.274 $\pm$.005 (.3137)*	-.010	-.002*	-.010 -.002
14	LXJ-19	63.72	59.37	.326					
15	ATR-H	65.91	61.41	.337	PLATE 19	5.449 (2.069)	-.015	-.005	-.012 -.005
16	ATR-H	67.95	63.30	.347	PLATE 19 (q)	5.449 (1.949)	-.002 to -.013		
17	ATR-K	69.99	65.20	.357					
18	ATR-K	72.15	67.20	.367	PLATE 1 (q)	3.015 (.484)	+.007 to -.010		
19	LXZ-20	70.90	65.58	.367	SIDE PLATE FACE	1.303 $\pm$.000 -.010	+.002*	-.005	-.012* -.002
	TOTAL	1046.05	974.53	5.385	PLATE 1 TO SIDE PLATE	.056 $\pm$.010	ok		
					PLATE 19 TO SIDE PLA.	.063 $\pm$.010	ok		
					SIDE PLATE PAD	.035 $\pm$.005 -.000	ok		
					FUEL PLATE	49 1/2 $\pm$ 1/32	-1/32		
					SIDE PLATE TO FUEL	4 7/8	-1/32		
					LOWER END BOX	2 5/8 $\pm$ 1/64	0		
					ASSEMBLY	66 1/4 $\pm$ 1/16	0		

ENRICHMENT 93.16%

DATE 6/17/66

* Infraction of tolerance.

Table G-3. ELEMENT DATA SHEET - FINAL INSPECTION

ATR				ELEMENT HP-3					
PLATE NO.	U CONTENT	U-235 CONTENT	B ₄ C	LOCATION	D I M E N S I O N S				
					PART DIM.	L MAX.	L MIN.	R MAX.	R MIN.
1 LVB-30	32.49	30.27	.163 "	LOWER T	.284 $\pm .005$	+ .004	-.003*	+ .005	-.001
2 LVC-17	38.93	36.27	.204	LOWER T	.484 $\pm .005$	.001 to -.010*			
3 LVF-13	40.97	38.17	.214	LOWER T	.373 $\pm .005$	.000	.000	-.002	-.002
4 LVH-22	43.02	40.08	.224	LOWER T	.745 $\pm .005$	.000			
5 LTE-08	45.06	41.98	.235	UPPER T	.373 $\pm .005$	+ .001*	-.001	+ .001	-.001
6 LTF-16	47.18	43.95	.245	UPPER T	.745 $\pm .005$	-.002 to -.005			
7 LVP-24	49.35	45.98	.255	UPPER T	.638 $\pm .005$	+ .006*	+ .004	-.001	.000
8 LVT-27	51.28	47.78	.265	UPPER T	.820 $\pm .005$	-.005 to -.006*			
9 LVM-04	53.44	49.78	.275	UPPER END BOX	.296 $\pm .005$	+ .001*	.000	.000	-.001
10 LXA-17	55.43	51.64	.286	UPPER END BOX	.562 $\pm .002$	-.002 to -.003			
11 LXC-02	57.49	53.56	.296						
12 LPL-07	59.62	55.55	.306	OUTER SIDE PLATE EDGE	2.550 $\pm .005$ (2.276) $\pm .000$	+ .009*	-.002	+ .012*	+ .006
13 LXF-12	61.66	57.44	.316	INNER SIDE PLATE EDGE	.274 $\pm .005$ (.3137)*	-.027*	-.007*	-.018*	-.005
14 LXJ-21	63.13	59.37	.326	PLATE 19	5.449 (2.069)	-.010	-.005	-.020	-.014
15 ATR-J	65.91	61.41	.337	PLATE 19 (g)	5.449 (1.949)	+.004 to -.010			
16 ATR-J	67.95	63.30	.347	PLATE 1 (g)	3.015 (.484)	+.002 to -.019			
17 ATR-I	69.99	65.19	.357						
18 ATR-I	72.15	67.20	.367	SIDE PLATE FACE	1.303 $\pm .000$	-.010	-.005	-.008	-.001
19 LXV-19	70.40	65.59	.367	PLATE 1 TO SIDE PLATE	.056 $\pm .010$	ok			
				PLATE 19 TO SIDE PLA.	.063 $\pm .010$	ok			
				SIDE PLATE PAD	.035 $\pm .005$	ok			
				FUEL PLATE	49 1/2 $\pm 1/32$	-1/32			
				SIDE PLATE TO FUEL	4 7/8	-1/32			
				LOWER END BOX	2 5/8 $\pm 1/64$	-1/32			
				ASSEMBLY	66 1/4 $\pm 1/16$	-1/16			
TOTAL									

ENRICHMENT 93.16%

DATE 6/17/66

*Infraction of tolerance.

Table G-4. ELEMENT DATA SHEET - FINAL INSPECTION

ATR				ELEMENT HP-4						
		U	U	B ₄ C	LOCATION	PART DIM.	DIMENSIONS			
		CONTENT	CONTENT				L MAX.	L MIN.	L MAX.	L MIN.
1	LVB-10	32.50	30.28	0.163	LOWER T	0.284 $\begin{smallmatrix} +0.005 \\ -0.000 \end{smallmatrix}$	0.001	0.000	0.000	-0.001*
2	LVC-29	38.93	36.27	0.204	LOWER T	0.484 ± 0.005	-0.002 to -0.004			
3	LVF-14	40.98	38.18	0.214	LOWER T	0.373 $\begin{smallmatrix} +0.000 \\ -0.005 \end{smallmatrix}$	0.002*	0.001*	-0.001	-0.002
4	L VH-23	43.02	40.08	0.224	LOWER T	0.745 $\begin{smallmatrix} +0.000 \\ -0.010 \end{smallmatrix}$	0.000			
5	LTE-19	45.05	41.97	0.235	UPPER T	0.373 $\begin{smallmatrix} +0.000 \\ -0.005 \end{smallmatrix}$	0.000	0.000	0.000	0.000
6	LTE-08	47.20	43.97	0.245	UPPER T	0.745 $\begin{smallmatrix} +0.000 \\ -0.010 \end{smallmatrix}$	0.000			
7	LVP-23	49.35	45.98	0.255	UPPER T	0.638 $\begin{smallmatrix} +0.005 \\ -0.000 \end{smallmatrix}$	+0.002	+0.001	+0.004	+0.004
8	LVT-19	51.29	47.78	0.265	UPPER T	0.820 ± 0.005	-0.001 to -0.002			
9	L VY-05	53.43	49.78	0.275	UPPER END BOX	0.296 $\begin{smallmatrix} +0.000 \\ -0.005 \end{smallmatrix}$	-0.005	-0.008*	-0.001	0.000
10	LXA-18	55.47	51.68	0.286	UPPER END BOX	0.562 ± 0.002	0.000 to -0.001			
11	LXC-30	57.51	53.58	0.296						
12	L TN-05	59.66	55.57	0.306	OUTER SIDE PLATE EDGE	2.550 $\begin{smallmatrix} +0.005 \\ (2.276) -0.000 \end{smallmatrix}$	0.010*	0.002	0.010*	-0.002
13	LXF-10	61.68	57.46	0.316	INNER SIDE PLATE EDGE	0.274 $\begin{smallmatrix} +0.005 \\ (0.3137)* \end{smallmatrix}$	-0.020*	-0.003	-0.039*	-0.012*
14	LXJ-22	63.74	59.38	0.326	PLATE 19	5.449 (2.069)	-0.014	-0.008	-0.015	-0.009
15	LXK-03	65.88	61.37	0.337	PLATE 19 (C)	5.449 (1.949)	0.000 to -0.008			
16	LTV-06	67.91	63.26	0.347	PLATE 1 (C)	3.015 (0.484)	-0.008 to 0.004			
17	ATR-P	69.99	65.19	0.357	SIDE PLATE FACE	1.303 $\begin{smallmatrix} +0.000 \\ -0.010 \end{smallmatrix}$	-0.006	-0.002	-0.007	0.000
18	ATR-P	72.15	67.20	0.367	PLATE 1 TO SIDE PLATE	0.056 ± 0.010	ok			
19	LXZ-29	70.40	65.59	0.367	PLATE 19 TO SIDE PLATE	0.063 ± 0.010	ok			
TOTAL		1046.14	974.57	5.385	SIDE PLATE PAD	0.035 $\begin{smallmatrix} +0.005 \\ -0.000 \end{smallmatrix}$	ok			
ENRICHMENT <u>93.16</u> % DATE _____					FUEL PLATE	49 1/2 $\pm$ 1/32	Yes			
					SIDE PLATE TO FUEL	4 7/8	4 7/8			
					LOWER END BOX	2 5/8 $\pm$ 1/64	2 5/8			
					ASSEMBLY	66 1/4 $\pm$ 1/16	66 1/4			

*Dimension outside the tolerance.

Table G-5. ELEMENT DATA SHEET - FINAL INSPECTION

ATR					ELEMENT HP-5					
		U	U	B ₄ C	DIMENSIONS					
		CONTENT	CONTENT		LOCATION	PART DIM.	L MAX.	L MIN.	L MAX.	L MIN.
1	LVB-21	32.50	30.28	0.163	LOWER T	0.284 $\begin{smallmatrix} +0.005 \\ -0.000 \end{smallmatrix}$	+0.004	+0.003	+0.002	0.000
2	LVC-24	38.92	36.26	0.204	LOWER T	0.484 ± 0.005	0.000 to -0.005			
3	LVF-30	40.98	38.18	0.214	LOWER T	0.373 $\begin{smallmatrix} +0.000 \\ -0.005 \end{smallmatrix}$	-0.001	-0.002	+0.002*	+0.001*
4	LVH-30	43.00	40.06	0.224	LOWER T	0.745 $\begin{smallmatrix} +0.000 \\ -0.010 \end{smallmatrix}$	0.000			
5	LVE-11	45.06	41.98	0.235	UPPER T	0.373 $\begin{smallmatrix} +0.000 \\ -0.005 \end{smallmatrix}$	0.000	0.000	0.000	0.000
6	LTF-06	47.20	43.97	0.245	UPPER T	0.745 $\begin{smallmatrix} +0.000 \\ -0.010 \end{smallmatrix}$	0.000			
7	LVP-22	49.35	45.97	0.255	UPPER T	0.638 $\begin{smallmatrix} +0.005 \\ -0.000 \end{smallmatrix}$	+0.004	+0.004	+0.003	+0.004
8	LSH-08	51.26	47.76	0.265	UPPER T	0.820 ± 0.005	0.000 to -0.002			
9	LVY-22	53.28	49.63	0.275	UPPER END BOX	0.296 $\begin{smallmatrix} +0.000 \\ -0.005 \end{smallmatrix}$	-0.010*	-0.010*	-0.010*	-0.010*
10	LXA-23	55.46	51.67	0.286	UPPER END BOX	0.562 ± 0.002	-0.002 to -0.004*			
11	LXC-24	57.50	53.57	0.296						
12	LTN-17	59.65	55.57	0.306	OUTER SIDE PLATE EDGE	2.550 $\begin{smallmatrix} +0.005 \\ (2.276) -0.000 \end{smallmatrix}$	+0.004	-0.002*	-0.003	-0.002*
13	LXF-18	61.68	57.46	0.316	INNER SIDE PLATE EDGE	0.274 ± 0.005 (0.3137)*	-0.001	-0.001	0.000	-0.015*
14	101	63.66	59.29	0.326	PLATE 19	5.449 (2.069)	-0.005	-0.012	-0.002	-0.010
15	LXL-29	65.88	61.38	0.337	PLATE 19 (E)	5.449 (1.949)	0.000 to -0.007+0.008 -0.006			
16	LPT-06	67.88	63.24	0.347	PLATE 1 (E)	3.015 (0.484)	0.000 to +0.016+0.005 -0.028			
17	ATR-D	69.99	65.19	0.357	SIDE PLATE FACE	1.303 $\begin{smallmatrix} +0.000 \\ -0.010 \end{smallmatrix}$	0.000	-0.002	0.000	-0.010
18	ATR-D	72.15	67.20	0.367	PLATE 1 TO SIDE PLATE	0.056 ± 0.010	ok			
19	LXZ-04	70.36	65.55	0.367	PLATE 19 TO SIDE PLATE	0.063 ± 0.010	ok			
TOTAL		1045.76	974.21	5.385	SIDE PLATE PAD	0.035 $\begin{smallmatrix} +0.005 \\ -0.000 \end{smallmatrix}$	+0.001			
ENRICHMENT 93.16%					FUEL PLATE	49 1/2 $\pm$ 1/32	Yes			
					SIDE PLATE TO FUEL	4 7/8	4 7/8			
					LOWER END BOX	2 5/8 $\pm$ 1/64	2 5/8			
					ASSEMBLY	66 1/4 $\pm$ 1/16	66 5/32*			

*Dimension outside the tolerance.

APPENDIX H
ULTRASONIC INSPECTION REPORTS

Fig. 1 ATR FUEL PLATES

IR No. 10269

ULTRASONIC NONBOND TEST

Results

Indications shown are not less in diameter than $1/16$ in. or more than $1/8$ in., according to the standard.

Fig. 2 ATR FUEL PLATES
ULTRASONIC NONBOND TEST

IR No. 10269

Results

The two nonbond indications shown are 5/64 in. wide according to the reference standard.

Fig. 3 ATR FUEL PLATES
ULTRASONIC NONBOND TEST

IR No. 10269

Results

Indications shown are greater than $1/16$ -in. diam and less than $1/8$ in.

Fig. 4 ATR FUEL PLATES
ULTRASONIC NONBOND TEST

IR No. 10269

Results

Indications shown are greater than 1/16-in. diam and less than 1/8 in.

Fig. 5 ATR FUEL PLATES

IR No. 10269

ULTRASONIC NONBOND TEST

Results

No indication of nonbond as great as 1/16-in.-diam reference standard.

Fig. 6 ATR FUEL PLATES
ULTRASONIC NONBOND TEST

IR No. 10269

Results

Fig. 7 ATR FUEL PLATESIR NO. 10269ULTRASONIC NONBOND TEST Results

No indications except at edge of filler material.

Fig. 8 ATR FUEL PLATESIR NO. 10269ULTRASONIC NONBOND TEST Results

Indications shown are greater than $1/16$ -in. diam and less than $1/8$ in.

ATR FUEL PLATES

IR NO. 10269

ULTRASONIC NONBOND TEST

Results

Indications of nonbond shown are:

1. > indications from $\frac{1}{16}$ " dia. FBH reference standard.
2. < indications from $\frac{1}{8}$ " dia. FBH reference standard.
3. Intermittent.

By J. C. Didrick (CPL)

Date 3-16-66

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