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Westinghouse Reload Fuel Mechanical Design Evaluation For the Fort Calhoun Station Unit 1

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S. L. Davidson
J. B. Mayers
C. R. Savage
D. D. Seel
R. A. Weiner

Approved:

D. Rowland, Manager
Product Programs

R. Knott, Manager
Product Development and Test

WESTINGHOUSE ELECTRIC CORPORATION
Commercial Nuclear Fuel Division
P.O. Box 355
Pittsburgh, Pennsylvania 15230

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1.0 Introduction and Summary

The Fort Calhoun Station Unit 1 (FCS) is currently operating with a core consisting of Combustion Engineering (CE) and Advanced Nuclear Fuel (ANF) 14x14 fueled assemblies. For Cycle 14, 52 Westinghouse 14x14 fuel assemblies containing advanced features will be loaded into the FCS. The Westinghouse fuel assembly is designed to be compatible with the current CE 14x14 design and contains several of the Westinghouse advanced design features adapted from the VANTAGE 5 fuel assembly design, Reference 1. The Westinghouse fuel is designed to be compatible with the CE-Fort Calhoun fuel from the stand point of mechanical, hydraulic and nuclear characteristics.

A brief summary of the Westinghouse design features contained in the Westinghouse-Fort Calhoun Batch R reload are given below. These features and figures illustrating the Westinghouse-Fort Calhoun reload design are presented in more detail in Section 2.0.

Reconstitutable Top Nozzle (RTN) - A mechanical disconnect feature facilitates the top nozzle removal and reinstallation.

Extended Burnup Capability - The Westinghouse reload fuel design will be capable of achieving burnups of ([ ]$^{+}$ MWD/MTU lead rod average) (a,c)
consistent with typical Westinghouse design and licensing practice.

Integral Fuel Burnable Absorber (IFBA) - The IFBA features a thin boride coating on the fuel pellet surface in the central portion of the enriched UO_2 pellet stack to provide power peaking and moderator temperature coefficient control.

Debris Filter Bottom Nozzle (DFBN) - The bottom nozzle is designed to reduce the likelihood of debris entering the active fuel region of the core (should any exist) and thereby, improves fuel performance by minimizing debris related fuel failures.

Zircaloy Mid-Grids - Westinghouse has adapted its Zircaloy grid technology and experience, Reference 2, to the CE geometry, including the outer grid strap anti-snag features.

This report utilizes the NRC Standard Review Plan, Section 4.2 Fuel System Design basis/evaluation described in Reference 3, and can be used as a reference document in support of the mechanical design of the Fort Calhoun reload with Westinghouse fuel. The Mechanical Design Evaluation in this report provides a description, the design bases and an evaluation of the Westinghouse fuel assembly and fuel rod, a neutronic evaluation and a summary of the mechanical and hydraulic testing used to support the design of the Westinghouse fuel.

The Westinghouse - Fort Calhoun fuel design has basic geometric similarities to that provided by Westinghouse for use in the CE reactor, Millstone 2, and in many respects is similar to that provided by CE for the FCS. Table 1-1 compares the dimensions and features of these designs to demonstrate the similarity.

The results of the mechanical evaluation described in this report lead to the following conclusions:

1. The Westinghouse 14x14 reload fuel assemblies for Fort Calhoun Cycle 14 and future cycles are mechanically compatible with the current CE fuel assemblies, CEA's, reactor internals interfaces, fuel handling equipment and fuel storage racks.

2. The Westinghouse 14x14 fuel assembly component stresses and the effects of the grid impact forces due to postulated faulted condition accidents were verified to be acceptable by Westinghouse.

3. Changes in the nuclear characteristics, i.e., temperature coefficients, doppler coefficients, rod worths, etc. due to the mechanical changes in 14x14 Westinghouse fuel are within the range normally seen from cycle to cycle.

4. This evaluation provides a reference upon which to base the Westinghouse reload mechanical design evaluation for future Fort Calhoun reloads with Westinghouse 14x14 fuel.

2.0 Fuel Assembly Mechanical Design Evaluation

2.1 Fuel Assembly Description

An illustration of the Westinghouse fuel assembly is shown on Figure 2-1 and specific design features are identified in Table 1-1. To assure mechanical compatibility, the Westinghouse fuel assembly is designed to include the same or similar mechanical interfacing features as those provided in the CE-Fort Calhoun fuel assembly. The Westinghouse product includes standard Westinghouse advanced design features which are discussed below with the components on which they occur.

The fuel assembly is composed of the following components:

a. Reconstitutable Top Nozzle (RTN)
b. Debris Filter Bottom Nozzle (DFBN)
c. Top and Bottom Inconel Grids
d. Intermediate Zircaloy Grids
e. CEA Guide Tubes and Instrument Tube
f. Fuel Rods with Integral Fuel Burnable Absorber (IFBA)

The assembled guide tubes, instrument tube, grids and nozzles are fastened together primarily by mechanical expansion joints and threaded fasteners providing a skeletal structure to support the fuel rods. The same type of structure was used on the Westinghouse Millstone 2 fuel design and is used in all current Westinghouse fuel assemblies.

The design bases and evaluations for the Westinghouse-Fort Calhoun fuel assembly are described in the following sections.

2.1.1 Fuel Assembly and Fuel Rod Growth Allowance

Design Bases - The fuel rod and fuel assembly design must preclude axial interference between the fuel rod and the top and bottom nozzles due to thermal expansion and irradiation growth. Furthermore, there must be no axial interference between the fuel assembly and the upper and lower core support structures due to thermal and irradiation growth.

Evaluation - The fuel rod and fuel assembly length have been sized to allow sufficient growth space by using Westinghouse fuel rod/fuel assembly growth design methodology, Reference 4. Growth predictions are based upon accumulated Westinghouse in-core experience including results of cooperative Westinghouse utility high burnup demonstration programs. The overall length of the fuel assembly has been established to accommodate assembly growth. The distance between the top and bottom nozzle plate has been set to accommodate the expected increased fuel rod growth for lead rod average burnups of up to [ ]+ MWD/MTU. (a,c)

Typical values for the EOL assembly growth and fuel rod growth are [ ]+% and [ ]+%, respectively. (a,c)

2.1.2 Fuel Assembly Compatibility with In-Core and Plant Equipment Interface

Design Bases - The fuel assembly design must be mechanically compatible with the current CE fuel assemblies, incore instrumentation, core components, CEAs, reactor internals interfaces and fuel loading, handling, storage and shipping equipment.

Evaluation - An evaluation of interfaces and geometry of the Westinghouse-Fort Calhoun fuel assembly has been made and found to be compatible with the mechanical interfacing features of the Fort Calhoun plant and current fuel.

2.1.3 Fuel Assembly Shipping and Handling Loads

Design Bases - The design acceleration for fuel assembly handling and shipping loads has been set at 6g lateral and 4g axial. Fuel handling acceleration at both the manufacturing facility and reactor sites has been determined to be well below the 4g value.

Evaluation - Analyses and tests of the fuel assembly have been conducted to verify that the effect of 6g lateral loads and 4g axial loads on the fuel assembly components are acceptable.

2.1.4 Fuel Assembly Structural Integrity

Design Bases - The fuel assembly design shall ensure that structural failure will not occur for the severity of loading expected throughout the life of the fuel. The main structural concerns are the assurance that gross distortions of the guide tubes and grids and other structural components do not interfere with CEA insertion for core shutdown and that a coolable geometry will be maintained.

Evaluation - The strength of the guide tubes is sufficient to preclude gross distortion of the guide tubes. The axial and lateral load tests provide assurance that the structural strength meets the design requirements. Considering the distribution of grid impact loads, during a LOCA, the top two grids were assumed to be deformed. The flow blockage associated with the deformed grids was taken into account in the LOCA analysis.

2.1.5 Fuel Assembly Fluid Dynamics

Design Bases - The spring and dimple support of the fuel rods must be sufficient to prevent large amplitude vibration motion of the fuel rods, and therefore, the potential for accelerated wear of the fuel rod induced by fluid forces.

Evaluation - Flow testing has been performed to define the hydraulic characteristics of the fuel assembly and its respective components. This flow testing coupled with in-core experience of similar grids in fuel assemblies with greater span lengths and more flexible rods has demonstrated that the fuel rod support system is sufficient to assure that clad fretting wear will be within the allowable design limits. The clad wear depth shall be limited to less than the nominal Westinghouse guideline of [ ]+% of the cladding wall thickness. (a,c)

2.2 Top Nozzle

Description - The top nozzle functions as the upper structural and alignment member of the fuel assembly. It is composed of a slotted flow plate, a lifting plate, five guide posts and a lifting plate support spring. The flow plate distributes the flow exiting the fuel assembly and provides ligaments above each row of fuel rods that prevents upward motion of the fuel rods above this elevation. The lifting plate which is held in place by the support spring and guide posts, permits lifting and handling of the fuel assembly. The guide posts, which are threaded and lockwelded to the flow plate, provide alignment and positioning of the nozzle and fuel assembly with the upper core alignment plate. An illustration of the top nozzle is shown in Figure 2-2. An adaptation of the Westinghouse (RTN) joint technology concept is provided to permit removal of the top nozzle for fuel assembly reconstitution.

Description and operation of the joints are as follows:

The top nozzle insert is fastened to the guide tube using an expansion joint. A circumferential bulge is formed near the top of the insert which is slotted to form flexible fingers. The top nozzle posts also have circumferential grooves at an elevation corresponding to that of the insert finger. After the post is slid into position over the insert fingers, the fingers deflect into engagement with the post groove. The flexible fingers are then locked in place by inserting a cylindrical lock tube inside the top nozzle insert. The lock tube is secured in place by a diametral interference provided at its upper end. The joints remain secured until the lock tube is removed using a special tool.

The RTN posts engage with holes in the upper core alignment plate providing accurate positioning of the upper end of the fuel assembly. The dimensions and tolerances used in the top nozzle design have been selected to assure satisfactory alignment and fit with the upper core alignment plate.

Design Bases -The nozzles must maintain structural and dimensional integrity during shipping, handling, and reactor events of Condition I (Normal Operation), Condition II (Incidents of Moderate Frequency), Condition III (Infrequent Incidents), and Condition IV (Limiting Faults). For shipping and handling, the nozzles must maintain dimensional stability after experiencing 4g axial and 6g lateral loads. For Conditions I, II, III, and IV, the nozzles are designed using the ASME Code III as a guideline for acceptable stress values and structural integrity.

Evaluation - Functional gaging and analysis have been performed to demonstrate the RTN's precise fit with the fuel alignment plate and handling tools. Nozzles have been tested to verify that the functional and structural capabilities of the RTN have been met. Analyses and test results have been found to be within the design limits.

2.3 Bottom Nozzle

Description - An illustration of the Debris Filter Bottom Nozzle (DFBN) is shown on Figure 2-3. The nozzle is fabricated from Type 304 stainless steel.

The DFBN is composed of a flow plate upon which five cylindrical legs are fastened by welding. A combined fastening screw and positioning pin clamps the guide tube ends to the flow plate. A similar screw without an integral pin is utilized at the center guide tube location. The fastening and the resulting pin fit-up is shown in Figure 2-6. Because of the screw type fastening and removal capability, reconstitution is also possible via the bottom nozzle.

The flow holes on the flow plate are of small diameter to limit the size of debris particles flowing into the fuel array. This reduces the potential for debris related fuel clad failures.

Alignment pads are provided between the corner legs and the flow plate allowing greater misalignment to be tolerated without hangup during refueling operations.

As in the top nozzle, the dimensions and tolerances used in the bottom nozzle design have been selected to assure satisfactory alignment and fit with the positioning holes of the lower core support plate.

Design Bases - The nozzles must maintain structural and dimensional integrity during shipping, handling, and reactor events of Conditions I, II, III, and IV. For shipping and handling, the nozzles must maintain dimensional stability after experiencing 4g axial and 6g lateral loads. For Conditions I, II, III, and IV, the nozzles are designed using the ASME Code III as a guideline for acceptable stress values and structural integrity.

Evaluation - Functional gaging and analysis has been performed to demonstrate the precise fit of the bottom nozzle with the lower core support plate. Prototype nozzles have been tested to verify that the functional structural capabilities of the bottom nozzle have been met. Analyses and test results have been found to be within the design limits.

2.4 Fuel Assembly Grids

Description - Two types of grids are used in the Westinghouse-Fort Calhoun fuel assembly to provide fuel rod and guide tube positioning and retention. Inconel grids are used at the top and bottom of the assembly. Zircaloy grids are spaced between the Inconel grids to maintain the lateral position of the fuel rods. The grids are positioned to be compatible with the current Fort Calhoun fuel.

Both types of grids are egg-crate type structures assembled from metal straps. Geometric features are die stamped and formed on the straps to produce the desired geometries such as springs and dimples. An illustration of the grid strap details is shown on Figure 2-4. The Inconel straps are fastened together using a furnace brazing process while the Zircaloy straps are electron-beam welded. The outer straps of the grids incorporate anti-snag features to aid in fuel assembly handling.

Design Bases - Position Control
The grid assemblies shall accurately position the fuel rods, guide tubes and instrumentation tube in the fuel assembly.

Evaluation - Grid assemblies of the type used in the Westinghouse-Fort Calhoun fuel assembly are designed and fabricated according to well established methods and processes. They have shown by test and years of in-core experience to meet the design requirements.

Design Bases - Grid Impact Strength
The Westinghouse-Fort Calhoun grid assemblies must be able to withstand seismic and handling, static and dynamic loads.

Evaluation - Both the Inconel and Zircaloy-4 Westinghouse-Fort Calhoun grid designs have been tested to obtain the 95 percent confidence level on the true mean impact strength. The grid impact strengths were determined in the unirradiated condition at operating temperature. Load capability for static conditions were also determined at room temperature for shipping and handling conditions.

2.5 Guide Tubes and Instrument Tube

Description - The guide tubes and instrument tube are structural members which also provide channels for the control rods and neutron sources. The guide tubes in conjunction with the grids and nozzles constitute the basic fuel assembly structure. They are mechanically fastened to the grids by locally expanding the guide tube into the grid sleeves. The top end is locally expanded to the top nozzle inserts that are retained in the top nozzle by lock tubes. The bottom end is welded to an internally threaded end plug that accepts a screw that secures the bottom nozzle. For interface considerations with control rods and neutron sources the guide tube inner diameter is the same as the CE guide tube, as shown in Table 1-1.

Design Bases - The guide tubes must maintain structural and dimensional integrity during shipping and handling and Conditions I, II, III and IV events. For all loading conditions the guide tubes are designed using the ASME Code Section III as a guideline for acceptable stress values and structural integrity.

Evaluation - Analyses and tests have been performed which simulated the guide tube loads under the defined conditions. The results confirm that the Code stress criteria have been met.

3.0 Fuel Rod Mechanical Design Evaluation

3.1 Fuel Rod Description

An illustration of the Westinghouse-Fort Calhoun fuel rod design is shown in Figure 2-5 and a comparison of the Westinghouse and CE-Fort Calhoun fuel rods and components and their design features are given in Table 1-1. The dimensions and features of the Westinghouse Millstone 2 fuel rod are also shown in Table 1-1 to compare the similarity of the designs.

The fuel rod consists of a 128.0 in. pellet stack of enriched UO_2 fuel pellets which are hermitically sealed into Zircaloy-4 tubing. A portion of the fuel stack, in some rods, will contain pellets coated with ZrB_2 (IFBA rods). A plenum and spring are provided at the top of the fuel stack to accommodate rod internal pressure increases due to fission gas release and differential growth of the fuel and clad. The spring also assures that the pellet stack location is maintained during shipping and handling. Before sealing the rod, it is filled with helium gas to aid in heat transfer and clad support. The cold void volume in the plenum, the fuel stack region and the total rod are [ ]$^+$ cubic inches, (a,c)
respectively.

A comprehensive description and discussion of the benefits and use of fuel pellets that have been coated with ZrB_2 are presented in Reference 1. IFBA rods will use a very thin, [ ]$^+$, (a,c)
zirc diboride coating on the enriched fuel pellets. Neutron absorption by the coating material provides a burnable absorber which is an integral part of the fuel rod. The absorber coating uses boron that is isotopically enriched in the B^{10} isotope.

All design bases identified in Section 3.0 for the fuel rod must also be satisfied for fuel rods containing IFBA coated uranium dioxide pellets which have additional helium gas release as the boron coating is depleted.

3.2 Rod Internal Pressure

Design Bases - The internal pressure of the lead rod in the reactor will be limited to a value below that which could cause (1) the diametral gap to increase due to outward cladding creep during steady-state operation, and (2) extensive DNB propogation to occur during accident conditions.

Evaluation - The rod internal pressure has been evaluated using the Westinghouse fuel rod design codes, References 5, 6, and design methodology, Reference 4, and meets the above requirements. Typical values for the end-of-life rod internal pressure are [ ]+ psi (a,c)
for the IFBA rods, and [ ]+ psi for the non-IFBA rods for lead (a,c)
rod average burnups up to [ ]+ MWD/MTU. Figure 3-1 provides (a,c)
the rod internal pressure histories for rod burnups up to
[ ]+ MWD/MTU. (a,c)

3.3 Clad Strain

Design Bases - For steady-state operation, the total tensile creep strain shall be less than 1 percent from the unirradiated condition. For each transient event the circumferential, elastic plus plastic (inelastic) total strain shall not exceed a tensile strain range of 1 percent from the existing steady-state condition.

Evaluation - The design has been evaluated using Westinghouse fuel rod design codes, References 5, 6, and design methodology, Reference 4, and meets the above requirements. Typical design values for the end-of-life steady state strains are [ ]%+ for (a,c)
the IFBA rods and [ ]%+ for the non-IFBA rods. Maximum values (a,c)
for the transient strain increment are less than [ ]%+ for both (a,c)
IFBA and non-IFBA rods.

3.4 Clad Stress

Design Bases - The volume average effective stress calculated with the Von Mises equation considering interference due to uniform

cylindrical pellet-clad contact, caused by pellet thermal expansion, pellet swelling and uniform clad creep, and pressure differences, is less than the 0.2 percent offset yield stress with due consideration to temperature and irradiation effects under Condition I and II events. While the clad has some capability for accommodating plastic strain, the yield stress has been accepted as a conservative design limit.

Evaluation - The design has been evaluated using Westinghouse fuel rod design codes, References 5, 6, and design methodology, Reference 4, and meets the above requirements. Typical clad steady state and transient stresses are less than [ ]+ psi and (a,c)
[ ]+ psi respectively for both IFBA and non IFBA fuel rods (a,c)
with more than [ ]+ psi margin to the design limit. (a,c)

3.5 Clad Corrosion

Design Bases - The clad surface temperature (oxide-to-metal interface) shall not exceed:

a. [ ]+°F for steady-state operation (a,c)
b. [ ]+°F for short-term transient operation (a,c)

The hydrogen pickup in the Zircaloy-4 cladding and structural components must not exceed [ ]+ ppm at end of life. (a,c)

Evaluation - The design has been evaluated using Westinghouse design codes, References 5, 6, and design methodology, Reference 4, and found to meet the design limits. For lead rod average burnups up to
[ ]+ MWD/MTU typical values for the Westinghouse-Fort Calhoun (a,c)
fuel design are: steady-state clad temperature less than [ ]+°F; (a,c)
transient clad temperature less than [ ]+°F; clad hydrogen pickup (a,c)
less than [ ]+ ppm; guide tube/grid hydrogen pickup less than (a,c)
[ ]+ ppm and guide tube/grid metal wastage less than [ ]+%. (a,c)

3.6 Fuel Temperature

Design Bases - The maximum fuel temperature shall be less than the melting temperatures of the fuel. The melting temperature of uranium dioxide fuel is 2805°C (5081°F) in the unirradiated condition and reduces 32°C (58°F) per 10,000 MWD/MTU burnup.

Evaluation - The design has been evaluated using Westinghouse fuel rod design codes, References 5, 6, and design methodology, Reference 4, and found to meet the design limits. The design evaluation has established that a design limit local heat flux of [ ]+ KW/FT (a,c) will insure that the fuel temperature criterion will be satisfied.

3.7 Clad Fatigue

Design Bases - The calculated fatigue life shall not exceed the design failure life.

Evaluation - The design has been evaluated using Westinghouse design codes, References 5, 6, and design methodology, Reference 4, and found to meet the design limits. Based on a daily load follow between 100% and 15% of full power operation plus 10 cold shutdowns per plant operating cycle, fatigue life fraction usage factors are less than [ ]+% for non-IFBA fuel rods and [ ]+% for the (a,c) IFBA fuel rods.

3.8 Clad Flattening

Design Bases - The fuel rod design shall preclude clad flattening during the projected long-term exposure.

Evaluation - Westinghouse design codes, References 5, 6, 7, and design methodology, Reference 4, confirm that current fuel rod designs employing 95% T.D. fuel with improved in-pile stability and high helium backfill pressures will not undergo clad flattening.

3.9 Rod Growth

Design Bases - Considering the effects of fuel rod irradiation growth, guide tube growth, creep and thermal expansion, the net fuel rod growth must not result in rod contact with both nozzle plates at the design rod burnup.

Evaluation - The design has been evaluated using Westinghouse fuel rod design codes, References 5, 6, and design methodology, Reference 4, and found to meet this design requirement. The best estimate EOL rod-to-nozzle gap value is [ ]+ inches, for a lead rod burnup (a,c)
of [ ]+ MWD/MTU. (a,c)

3.10 Fuel Rod Wear

Design Bases - Fuel rod wear shall be limited to less than the nominal Westinghouse guideline of [ ]+% of the tubing wall (a,c)
thickness.

Evaluation - Flow testing and in-core experience of fuel assemblies with greater span lengths and more flexible rods have shown that the fuel rod support system is sufficient to assure that the clad fretting wear is within the allowable design limit.

3.11 Fuel Rod Bow

The behavior of the Westinghouse Fort Calhoun fuel with respect to rod bow can be projected from Westinghouse 15x15 fuel using the formula:

$$\frac{L^2_{W(Fort\ Calhoun)} \;/\; I_{W(Fort\ Calhoun)}}{L^2_{W(15x15)} \;/\; I_{W(15x15)}} = 0.3210$$

where:

L = span length

I = cross sectional moment of inertia

The current design predicted gap closure (95th percentile worst span) at 33,000 MWD/MTU for Westinghouse 15x15 fuel is [ ]$^{+}$ of the gap between the rods. Burnups greater than 33,000 MWD/MTU need not be considered, since the fuel is not capable of achieving limiting peaking factors due to the decrease in fissionable isotopes and the buildup of fission product inventory. The reduction in peaking factors beyond 33,000 MWD/MTU is greater than the increase in the rod bow DNB penalty beyond 33,000 MWD/MTU. Therefore, the rod bow DNB penalty at 33,000 MWD/MTU is the maximum value used in design. (a,c)

Thus, the predicted design value for the fraction of gap closure for the Westinghouse-Fort Calhoun fuel is 0.3210 x [ ]$^{+}$. (a,c)

4.0 Mechanical Testing

The Westinghouse-Fort Calhoun Test Program was divided into fuel assembly mechanical testing and grid mechanical testing. The fuel assembly and the related core component mechanical testing was performed consistent with those used to evaluate the structural fuel assembly features being changed for Westinghouse to adapt to the Fort Calhoun design. The testing confirmed that the mechanical design changes associated with the Westinghouse designed Fort Calhoun fuel assemblies do not significantly alter the fuel assemblies structural behavior. Grid mechanical testing was also performed and resulted in grid crush strengths within the allowable limits.

5.0 Hydraulic Testing

As part of the verification testing of the Westinghouse-Fort Calhoun fuel assembly design, full-scale hydraulic flow tests were performed at the Fuel Assembly Compatability Test System (FACTS) facility in Columbia, S.C. Testing was conducted on both a Westinghouse-Fort Calhoun assembly and a CE-Fort Calhoun fuel assembly. The test results indicated that the overall fuel assembly pressure drop was within one-half of a percent of the current CE fuel design.

6.0 Nuclear Design Evaluation

The mechanical design of the Westinghouse-Fort Calhoun fuel assembly has been evaluated to assess the effect on core neutronic performance. The mechanical design supports a level of fuel assembly nuclear performance which will satisfy all appropriate design parameters and nuclear design criteria.

The nuclear characteristics of the fuel usage within a core design has been provided as key inputs to the overall mechanical fuel rod design. Expected fuel rod power histories, bounding fast flux and fluence factors, plant/cycle specific axial power profiles, peaking factor burndown behavior and rod power transient limits have all been developed for the Fort Calhoun-Westinghouse fuel assembly. These nuclear design inputs to the mechanical fuel rod design are listed in the Core Design Addendum to the Mixed Vendor Core Data List (MVCDL) in Section III. The detailed nuclear data used in the mechanical fuel rod design analysis was provided to OPPD in W-CNFD letter 91CF*-G-0004 dated January 14, 1991. The nuclear data was based on a typical equilibrium cycle for Fort Calhoun with Westinghouse fuel features which bounds all transition cycles. This "typical" cycle had an approximate cycle length of 13000 MWD/MTU and loaded 40 fuel assemblies with a 3.60/4.00 w/o U-235 enrichment split (26 and 14 assemblies respectively). Also, the fuel used enrichment zoning and 1760 IFBA rods with a 3 mg/in linear B-10 loading. The typical equilibrium cycle contained a full core of Westinghouse fuel and satisfied a design radial peaking factor limit of 1.70.

7.0 References

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TABLE 1-1

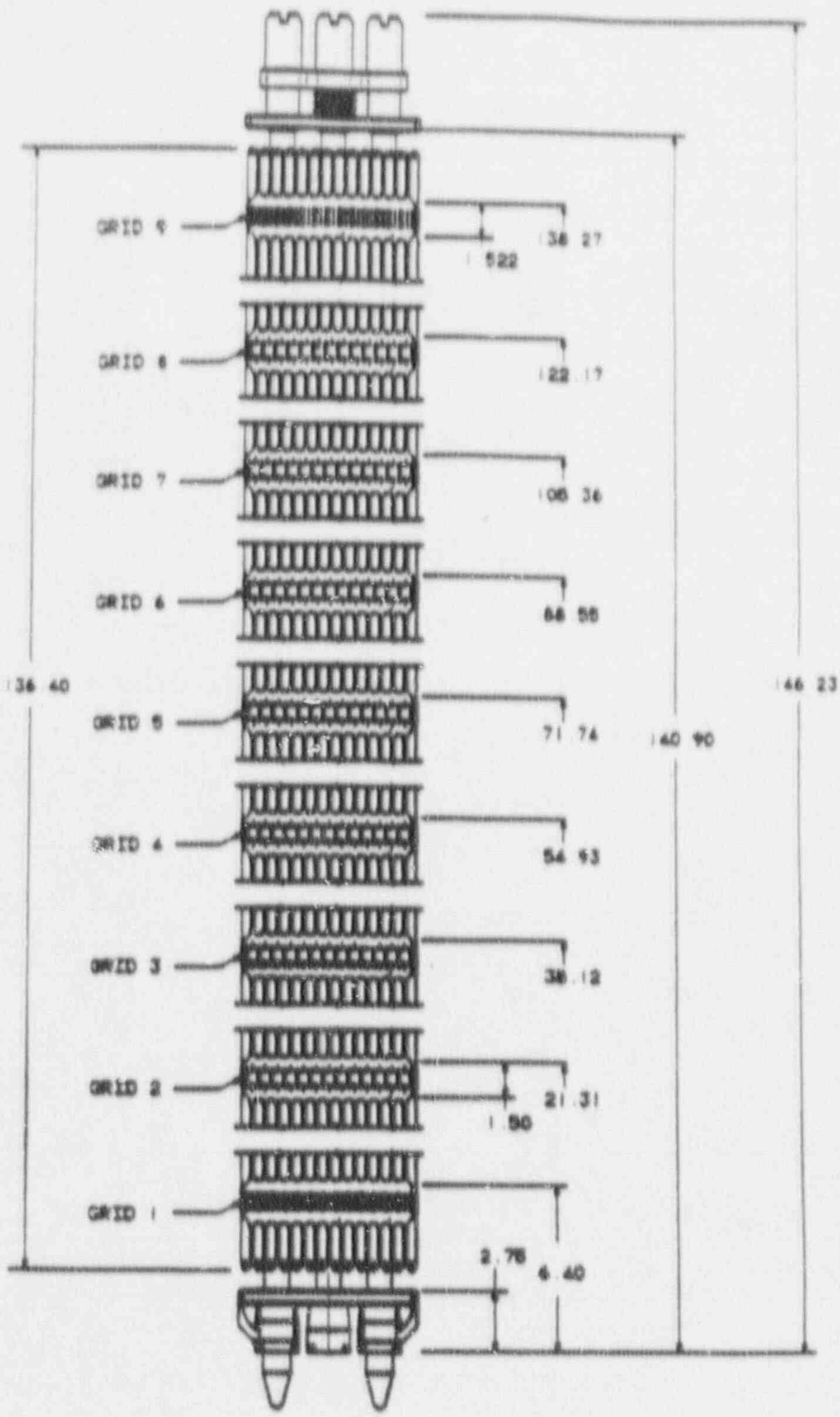
<u>COMPARISON OF WESTINGHOUSE-FORT CALHOUN FUEL DESIGN PARAMETERS</u>

	ROD ARRAY		
	14x14 (W-Fort Calhoun)	CE	14x14 Millstone (W)
Assembly Insp. envelope (in)	8.250	8.250	8.250
Assembly length (in)	146.23	146.33	157.24
No. Of fuel rods/assy	176	176	176
Fuel rod pitch (in)	0.580	0.580	0.580
No. of guide tubes/assy	4	4	4
Guide tube OD (in)	1.111	1.115	1.111
Guide tube ID (in)	1.035	1.035	1.035
Guide tube material	Annealed Zr4	Annealed Zr4	Annealed Zr4
No. of instrumentation tubes/assembly	1	1	1
Instru. tube OD (in)	1.111	1.115	1.111
Instru. tube ID (in)	1.035	1.035	1.035
Grid attachment to skeleton	Bulge at thimble/instru. tubes	Spot welded	Bulge at thimble/instru. tubes
GRID MATERIAL			
Mid grids structural (7) material	Zr-4	Zr-4	Inconel
End grids structural (2) material	Inconel	Inconel-Bottom Zr-4-Top	Inconel
GRID INNER STRAP THICKNESS (in)			
Mid-grid(s)	[ ]+	.025	[ ]+(a,c)
End grid(s)	[ ]+	.025	[ ]+(a,c)
GRID OUTER STRAP THICKNESS (in)			
Mid grids	[ ]+	.033	[ ]+ (a,c)
End grids	[ ]+	.033	[ ]+ (a,c)
GRID HEIGHT INNER STRAPS (in)			
Mid grids	[ ]+	1.375	[ ]+ (a,c)
End grids	[ ]+	1.375	[ ]+ (a,c)

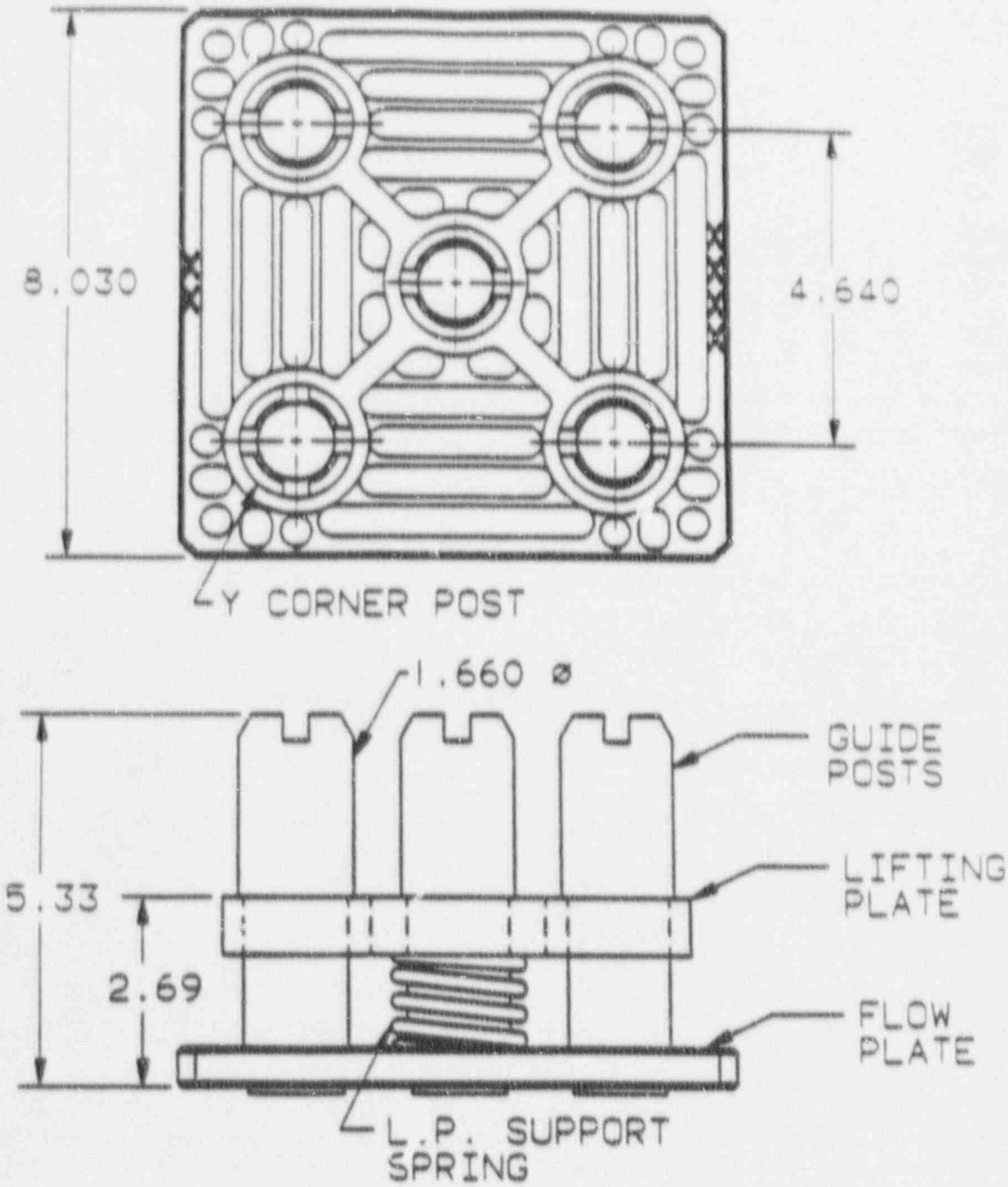
TABLE 1-1 (Cont'd.)

COMPARISON OF WESTINGHOUSE-FORT CALHOUN FUEL DESIGN PARAMETERS (Cont.)

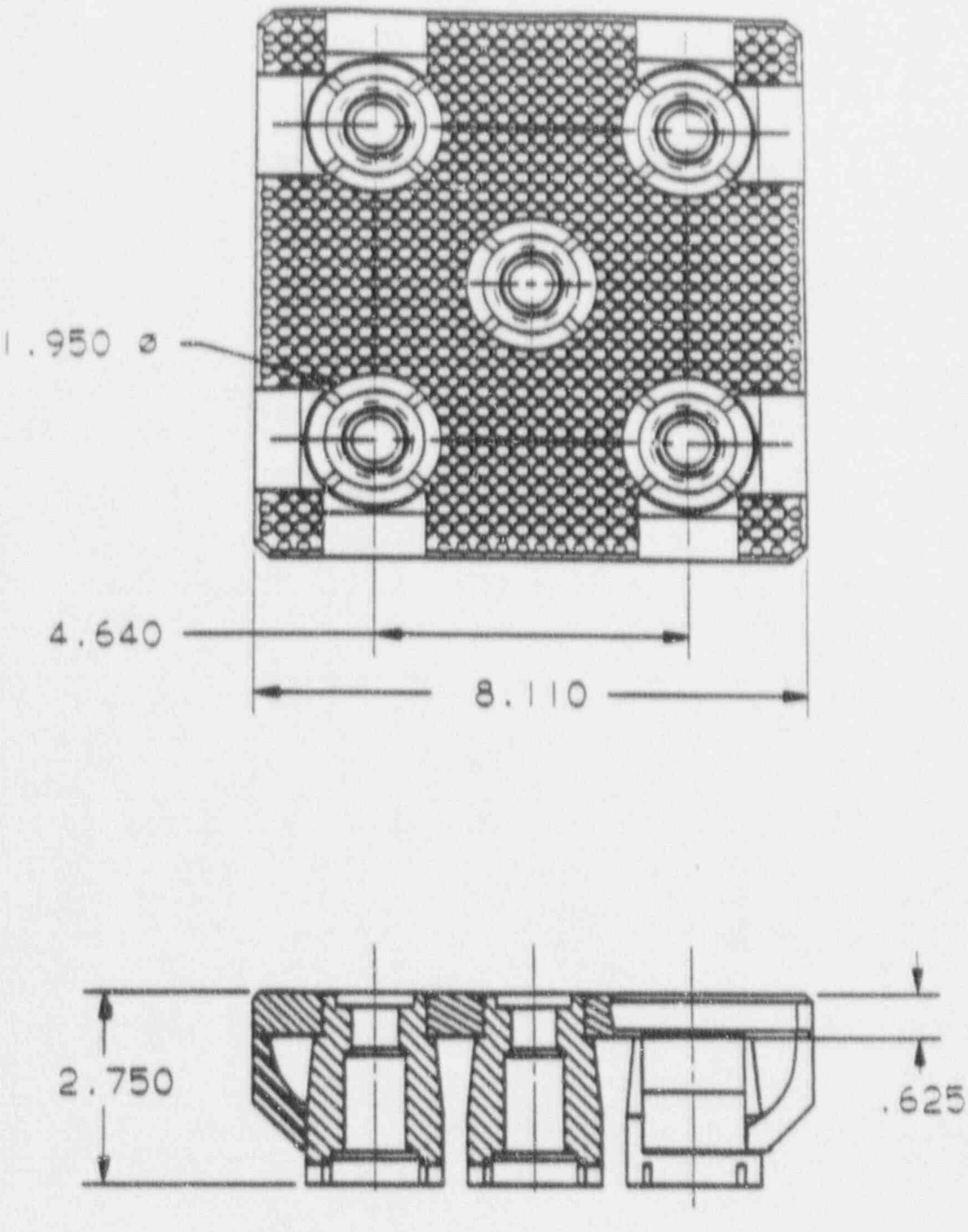
	ROD ARRAY		
	14x14 (W-Fort Calhoun)	CE	14x14 Millstone (W)
BOTTOM NOZZLE	Welded & Machined 304 SS DFBN Removable	CF8-SS Casting Non-removable	Welded & Machined 304 SS Std. BN Nonremovable
TOP NOZZLE	304 SS Removable no holddown springs (center spring)	Removable with center spring	304 SS Nonremovable type 4 coil holddown springs
FUEL ROD			
Overall length (in)	136.4	136.7	146.5
Active length (in)	128.0	128.0	136.7
Plenum length (in)	7.6	7.0	8.4
Fill gas	Helium	Helium	Helium
End plug material	Zr-4	Zr-4	Zr-4
Assembling loading (kg U)	373	364	407
FUEL CLADDING			
Outside diameter (in)	0.440	0.440	0.440
Thickness (in)	0.028	0.028	0.026
Inside diameter (in)	0.384	0.384	0.388
Material	Zr-4	Zr-4	Zr-4
FUEL PELLET			
Diameter (in)	0.3765	0.3765	0.3805
Length (in)	0.452	0.450	0.457
INTEGRAL FUEL BURNABLE ABSORBER:			
Material	ZrB_2 coating on UO_2 pellets	Fuel Displacer Al_2O_3/B_4C Rods	
Coating thickness (in)	Less than [0.001]+ in.		



Westinghouse - Fort Calhoun Fuel Assembly	Omaha Public Power District Fort Calhoun Station Unit No. 1	Figure 2-1



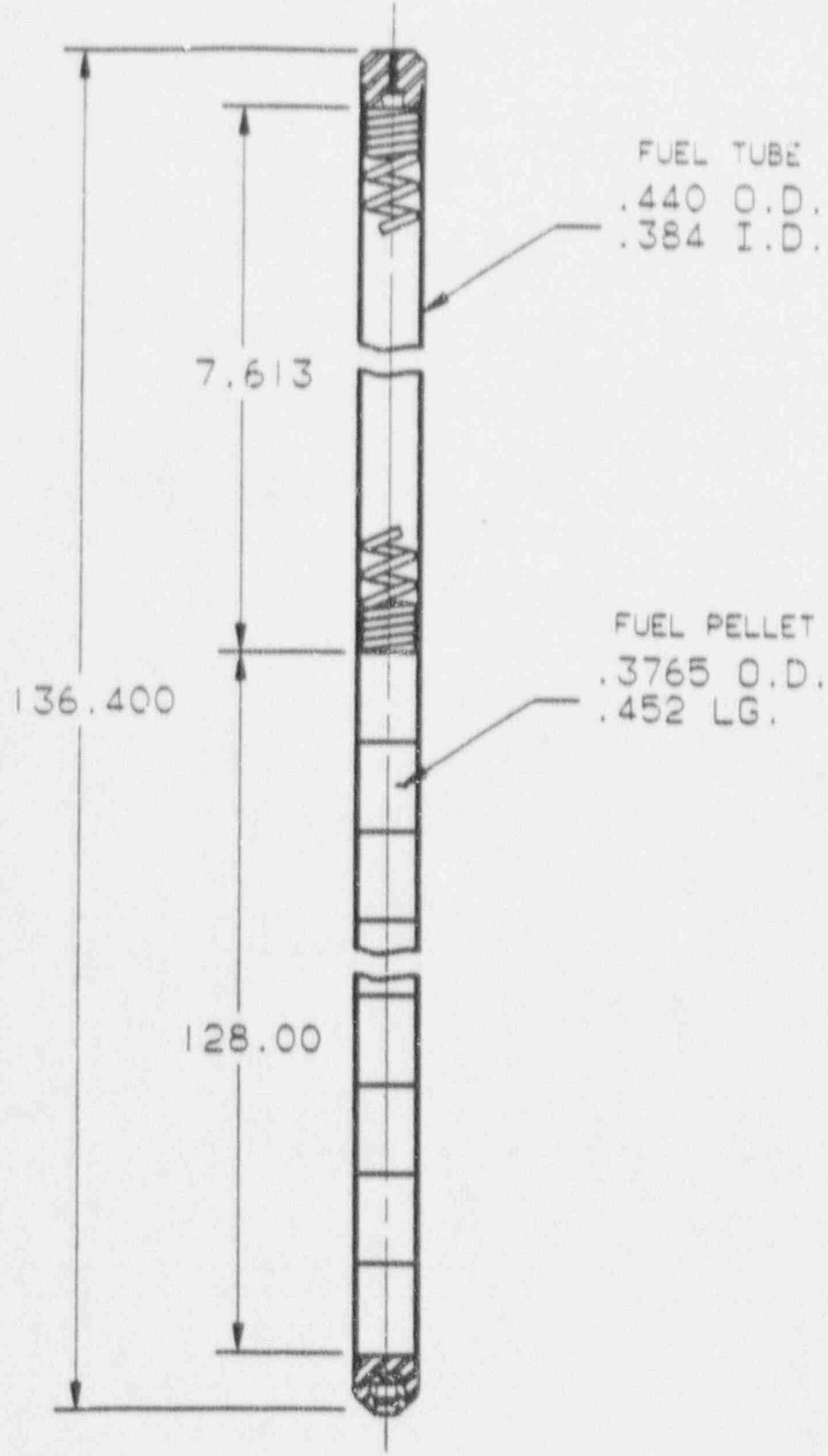
Westinghouse - Fort Calhoun Top Nozzle	Omaha Public Power District Fort Calhoun Station Unit No. 1	Figure 2-2



Westinghouse - Fort Calhoun Debris Filter Bottom Nozzle	Omaha Public Power District Fort Calhoun Station Unit No. 1	Figure 2-3

(a,c)

Westinghouse - Fort Calhoun Grid Strap Details	Omaha Public Power District Fort Calhoun Station Unit No. 1	Figure 2-4



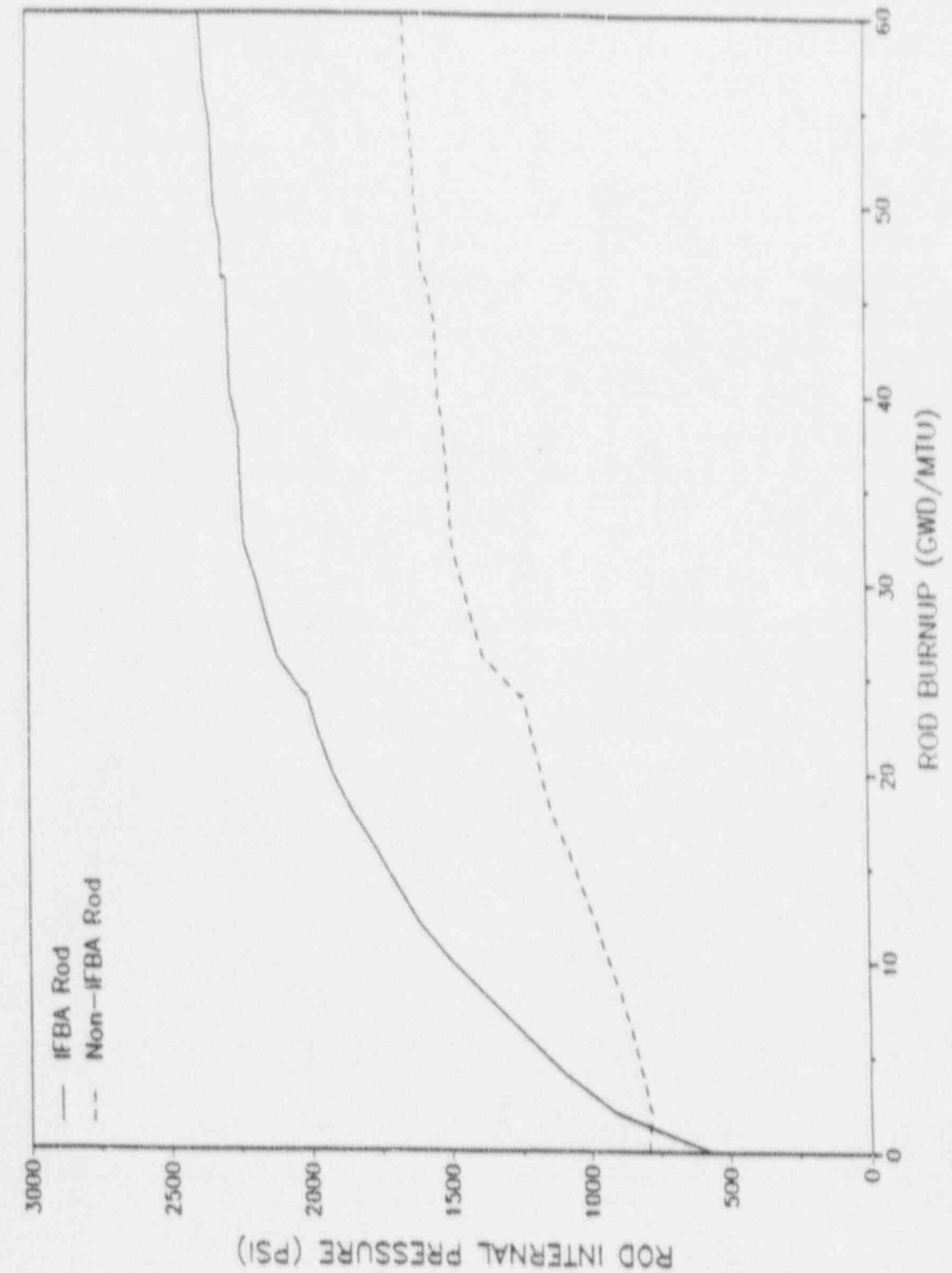
Westinghouse - Fort Calhoun Fuel Rod	Omaha Public Power District Fort Calhoun Station Unit No. 1	Figure 2-5

(a,c)

Westinghouse - Fort Calhoun Pin/Screw Fit-Up	Omaha Public Power District Fort Calhoun Station Unit No. 1	Figure 2-6

(a,c)

Westinghouse - Fort Calhoun Fuel Rod Pressure Histories Guide Post Joint	Omaha Public Power District Fort Calhoun Station Unit No. 1	Figure 2-7



Westinghouse - Fort Calhoun Fuel Rod Pressure Histories	Omaha Public Power District Fort Calhoun Station Unit No. 1	Figure 3-1

Westinghouse
Commercial Nuclear Fuel Division
P.O. Box 355
Pittsburgh, PA 15230-0355