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Carolina Power & Light Company Raleigh, N. C. 27602 E. E. Utley	1-5-73	1-9-73		X			
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FILE

DESCRIPTION:
Ltr requesting change to Tech Specs for Test Fuel Assemblies & trans the following:

PLANT NAMES: H. B. Robinson Unit No. 2

ENCLOSURES:
REPORT: Description & Evaluation of Test Assemblies Containing Gadolinia Bearing Fuel Rods.

(40 cys of encl rec'd)

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ACKNOWLEDGED

FOR ACTION/INFORMATION 1-10-73 AB

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50 - 261

Carolina Power & Light Company

January 5, 1973

Mr. John F. O'Leary, Director
Directorate of Licensing
United States Atomic Energy Commission
Washington, D. C. 20545

H. B. ROBINSON UNIT NO. 2
LICENSE DPR-23
TECHNICAL SPECIFICATION CHANGE FOR TEST FUEL ASSEMBLIES

Dear Mr. O'Leary:

Carolina Power & Light Company intends to refuel H. B. Robinson Unit No. 2 commencing March 16, 1973. The reactor is scheduled to return to power after a six-weeks' outage on April 30, 1973.

In accordance with 10CFR 50.59, it is reported that the Company intends to irradiate four fuel assemblies in Cycle 2 that will contain gadolinia dispersed with uranium oxide pellets. The enclosure attached to this letter contains a description and evaluation of these test assemblies.

To accommodate this test assembly evaluation, it is requested that the following Technical Specification change be approved:

Delete the current paragraph 5.3.1.3 and substitute:

"Reload fuel will be similar in design to the initial core except that test assemblies may be inserted for specific core performance improvement programs provided that these assemblies do not affect safety considerations or previous analyses. The enrichment of reload fuel and any test assemblies will be no more than 3.5 weight percent of U-235."

Evaluation of the Cycle 2 core configuration will be completed about February 15, 1973. If additional Technical Specification changes are required, such as rod insertion limit, they will be submitted at that time.

Very truly yours,

E. E. Utley
Vice President
Bulk Power Supply

NBB/za
Enclosure
cc: Mr. C. D. Barham, Jr.
Mr. N. B. Bessac
Mr. B. J. Furr

218

336 Fayetteville Street • P. O. Box 1551 • Raleigh, N. C. 27602

DESCRIPTION AND EVALUATION OF TEST ASSEMBLIES CONTAINING GADOLINIA BEARING FUEL RODS

INTRODUCTION

As part of its continuing core performance improvement program, Westinghouse proposes to irradiate four fuel assemblies as part of Region IV of the H. B. Robinson Unit No. 2 reactor for the purpose of evaluating the in-reactor performance of uranium dioxide pellets containing dispersed gadolinia (Gd_2O_3). The fuel assemblies containing the UO_2-Gd_2O_3 will be designed to facilitate interim and end of life fuel evaluations. The fuel rods can be removed, non-destructively examined, and reinserted at the end of intermediate fuel cycles. At the end of life (end of reactor cycle 4) or any intermediate refueling shutdown the rods can be removed for off-site destructive examinations in a hot cell laboratory.

The purpose of the test is to confirm analytical nuclear design methods relative to Gd_2O_3 bearing fuel rods. Removal rate of gadolinium poison (high cross section) isotopes is the primary design parameter to be verified.

DESIGN DESCRIPTION

General

The design of each of the four proposed assemblies will allow for the removal of fifty-two (52) fuel rods. Twelve of these removable rods in each assembly contain UO_2-Gd_2O_3 and the remaining forty rods contain pure UO_2. All non-removable fuel rods contain only UO_2.

The location of the removable rods and the gadolinia bearing rods is shown in Figure 1. All four assemblies have the gadolinia bearing fuel rods in the same location. Assemblies containing 3.0 w/o gadolinium will be installed in the H-1 and H-15 core positions during cycle 2.

Assemblies containing 1.85 w/o gadolinium will be installed in core positions A-8 and R-8 during cycle 2. Fuel rods containing gadolinium will have an enrichment of 2.27 w/o U-235 versus an enrichment of 3.1 w/o for fuel rods without gadolinium.

Mechanical

The design of the removable rod assembly is, to the extent possible, the same as a regular region 4 assembly. The overall dimensions, rod pitch, and number of rods are identical to all other region 4 assemblies. Similarly, the bottom nozzle, grids, and thimble tubes are identical to standard assemblies.

Differences between a removable rod assembly and a regular region 4 assembly, other than the fuel material, are:

a. The end plugs on the removable rods are designed to facilitate rod removal and reinsertion at the reactor site. This design makes the removable rods slightly longer. Figure 2 illustrates the removable and standard fuel rod designs.

b. The top nozzle adaptor plate is modified to allow access to the removable rods. Figure 3 shows a conventional assembly. To compare to this conventional assembly, Figure 4 shows the removable rod fuel assembly with modified adaptor plate. The remainder of the top nozzle is unchanged from the standard assemblies.

c. The thimble plugging device is modified to provide the required axial clearance for the removable fuel rods. The thimble plugging device in the removable rod assembly also supplements the top adaptor plate in preventing excessive lift-off of the removable fuel rods. The thimble plugging device is also illustrated in Figure 4.

A design criterion used in the design of the removable rod assemblies is to minimize any thermal-hydraulic effect. This criterion was used in addition to the regular region 4 design criteria (FSAR Section 3.2.3) and making the assemblies as close as possible to regular region 4 assemblies. Thermal and hydraulic perturbations to the reactor core due to the slight differences in mechanical design are negligible.

The mechanical design of the assembly is identical to the design of the removable rod assembly licensed for Virginia Electric Power (Surry Unit 1) except for rod positioning. Robinson fuel rods are centered between the top and bottom nozzles while Surry fuel rods rest on the bottom nozzle. It is comparable to the design of removable rod assemblies licensed for Commonwealth Edison (Zion Unit 1), Southern California Edison (San Onofre Unit 1), and Wisconsin Michigan Power Company/Wisconsin Electric Power Company (Point Beach Unit 1).

<u>Nuclear</u>

Standard design procedures[1] are used in the nuclear analysis of the test assemblies. The gadolinia bearing fuel rods require special treatment due to the large thermal absorption cross section of the gadolinium isotopes. Cross sections for these rods were obtained using HAMMER-AIM.[2] Critical experiment results[3] have been used to verify the adequacy of the design method.

A nuclear design criterion being used for the gadolinia bearing fuel rods is that F_R^N will not exceed 1.26 (80% of the 1.58 allowed for non-gadolinia bearing fuel rods). At the start of irradiation, the maximum F_R^N in any Gd_2O_3 fuel rod is about 0.3 and at the end of cycle 2 (reactor cycle) the maximum F_R^N is about 0.8. Burnout of the high cross section gadolinium isotopes causes the large increase in F_R^N. The prime objective of the test is to verify the capability to accurately predict this burnout. The total reactivity worth of the contained gadolinium is about 0.1%.

Material Properties

The gadolinia is uniformly distributed in the UO_2 and forms a solid solution.[4] Addition of small amounts of gadolinia to uranium dioxide affects both the thermal conductivity and the melting temperature of the fuel. The thermal conductivity of the solid solution is reduced relative to pure UO_2 below 3730°F while above that temperature the thermal conductivity is essentially the same as pure UO_2.[4] The melting temperature of the solid solution decreases with increasing gadolinia content. The melting temperature of UO_2-3 w/o Gd_2O_3 is 4530°F.[5] The melting temperature is assumed to decrease at the rate of 58°F each 10,000 MWD/MTU,[6] the same as pure UO_2, since the small amounts of Gd_2O_3 will not appreciably affect the fission fragment buildup. The net effect of the lower thermal conductivity and melting temperature is that initiation of melting occurs for a lower kw/ft for the gadolinia bearing fuel rods than for the fuel rods with pure UO_2. The difference in the $\int kdT$ to initiation of melting is 20%.[7] This is the basis for the allowed F_R^N for gadolinia bearing fuel rods being only 80% of that allowed for non-gadolinia bearing rods.

Manufacturing Quality Control

The same rigid quality control requirements for standard UO_2 fuel are employed in the manufacture of UO_2-Gd_2O_3 fuel rods. Additional procedures for the gadolinia bearing test rods are discussed here.

Gadolinia fuel is made from the blending of Gd_2O_3 with enriched UO_2 through insertion of the pellets in the fuel rod tubing in a sealed area. End plug welding and fuel rod pressurization use the same equipment as standard UO_2 fuel. The manufacturing process through insertion

of fuel pellets in the fuel rod tubing is completed for one gadolinium enrichment before the process is begun for the second enrichment. The gadolinia content of each gadolinia-uranium blend is measured.

Each removable fuel rod has an identification number stamped on the end plug. Quality Assurance checking procedures verify that each rod is in its correct location within an assembly as well as being in the correct assembly.

PREVIOUS OPERATIONAL EXPERIENCE

Removable Rod Assemblies

Previous experience with removable rod assemblies and removable rods has been attained at the Saxton, Yankee, Zorita, and San Onofre plants. Over 300 fuel rods were removed from Saxton Core II assemblies and reinserted into new assemblies during the Saxton Core II/Core III reconstitution without evidence of failure. About 200 Saxton rods have been successfully removed, examined, and reinserted into over twelve 3 x 3 subassemblies at Saxton. At Yankee, twenty-eight fuel rods were removed, examined, and reinserted into the Yankee Core V special assemblies. Similar handling of twenty-two removable rods was successfully completed during the May 1971 Zorita refueling. Eight removable rods were successfully removed and inspected during the December 1971 San Onofre Unit 1 refueling. Four of these rods were reinserted into the assemblies for further irradiation while the other four, which were selected for post-irradiation examination, were replaced. All such fuel handling has been done routinely and without difficulty.

Gadolinia Bearing Fuel[4]

Gadolinia bearing fuel rods have operated in General Electric BWR's since 1964. Gadolinia bearing fuel rods are standard design for General Electric BWR's beginning with the Quad-Cities Station Units. Evaluation

of the gadolinia bearing fuel rods by General Electric has indicated that the fuel rods have performed according to expectation. Use of the UO_2-Gd_2O_3 fuel was not relatable to any unsatisfactory mechanical performance. UO_2-Gd_2O_3 fuel rods irradiated to burnups of $\sim$ 6200 MWD/T and $\sim$ 4100 MWD/T have been examined by General Electric with the following results: (1) "no evidence of deleterious effects on the inner portions of the clad from the Gd_2O_3; (2) density variation of gadolinia as a function of radial position "in the pellet" was not apparent; and (3) no free Gd_2O_3 inclusions or UO_2 agglomerations were found in either of the two gadolinia-urania "pellet" specimens."

Safety Evaluation

Material property differences between UO_2-Gd_2O_3 and pure UO_2 could result in the gadolinia bearing fuel rods being more limiting during transients (accidents) than the normal UO_2 fuel rods should an improper design be used. This evaluation shows that the gadolinia bearing fuel rods are no more limiting than the normal UO_2 fuel rods.

Safety margins are not reduced. This is insured by reduction of the allowed power peaking in gadolinia fuel rods to 80% of that for normal UO_2 fuel rods. The enrichment of 2.27 w/o U-235 was selected to insure the reduced power peaking limit could be met in later cycles. Transients which result in gross core power or flow changes without extensive local effects are no more severe by virtue of the gadolinia bearing fuel rods being present since the safety margins are not reduced.

An ejected control rod result in extensive local effects in addition to the gross core effects. Control rods cannot be inserted in the removable rod fuel assemblies and during cycle 2, the removable rod assemblies will not be adjacent to a fuel assembly containing a full length control rod. None of the nearest neighbor full length control rods in cycle 2

is the highest worth ejected rod. The removable rod assemblies are, for cycle 2, on the periphery (in a very high neutron leakage position) and the power in the assemblies is lower than normal due to the presence of gadolinium (with its associated lower U-235 enrichment). The above facts combine to mitigate any local effects on the removable rod assemblies. The most severe core effects due to an ejected control rod will still involve the highest worth stuck or ejected control rod and, thus, will not involve the removable rod assemblies in the local effects. This transient must be re-evaluated for cycle 3 when the specific core loading pattern and power distribution are known.

Rupture of a steam line, as analyzed, results in a large local power in the neighborhood of the control rod stuck in the withdrawn position. DNBR is maintained above 1.3 for this accident. Gadolinia bearing fuel rods operate at a lower power and, thus, have a higher DNBR than the UO_2 fuel rods in the vicinity of the gadolinia bearing fuel rods. The gadolinia bearing fuel rods will not be limiting for this accident.

Erroneous prediction of the burnout rate of high cross section gadolinium isotopes will have no effect on the safety of operation. The total worth of the gadolinium is about 0.1%. Should all gadolinium disappear at the beginning of irradiation the boron concentration would increase about 10 ppm and the power in the gadolinia bearing fuel rods would increase. The power would be less than 0.8 relative power. Cycle 2 lifetime would be decreased by about 100 MWD/MTU should the concentration of high cross section gadolinium isotopes be the same at the end of cycle 2 as at the beginning of cycle 2. Neither of the above two limiting conditions has any effect on the safety of operation.

Loading one gadolinia bearing fuel rod into the wrong location in an assembly will have no effect on the safety of operation, if it occurs in spite of the quality control measures taken to prevent such an occurrence. The gadolinium poison will burn out more rapidly if the fuel rod is farther from other gadolinia rods than planned. The gadolinium poison will burn out less rapidly than predicted due to shielding effects if the gadolinia is closer to other gadolinia fuel rods than planned. As discussed above, neither of these possibilities affects the safety of operation.

Absence of any of the four assemblies from its desired cycle 2 location can be detected during startup flux mapping. The removable rod assembly itself need not be in an instrumented location as the flux depression caused by the assembly is detectable in all adjacent assemblies.

Interchange of a 1.85 w/o gadolinium assembly and a 3.0 w/o gadolinium assembly will not be detected during startup flux mapping. A slight flux tilt would occur in the latter portion of cycle 2 as the effect of the 1.85 w/o gadolinium disappears before the effect of 3.0 w/o gadolinium. F_R^N decreases with burnup during a cycle. The decrease in F_R^N more than compensates for any flux tilt due to uneven burnup of the 1.85 and 3.0 w/o gadolinium. Any flux tilt due to this core loading error would not be a safety problem.

Densification is expected to occur in the gadolinia bearing fuel material. There is no reason to expect the small amounts of Gd_2O_3 to change the amount of densification. The effect of densification on the performance of these assemblies will be covered in the evaluation of regular UO_2 fuel.

CONCLUSION

It is concluded that inclusion of these four assemblies containing twelve (12) UO_2-Gd_2O_3 fuel rods each in H. B. Robinson Unit 2 will not affect safety considerations, nor make it necessary to change the safety analyses and related engineering information submitted previously.

References

(1) Section 4.3.3.1, RESAR-3, Westinghouse Safety Analysis Report (June 1972).

(2) W. B. Henderson and W. J. Stash, "A Revised HAMMER-AIM Code," WCAP-7993, November, 1972.

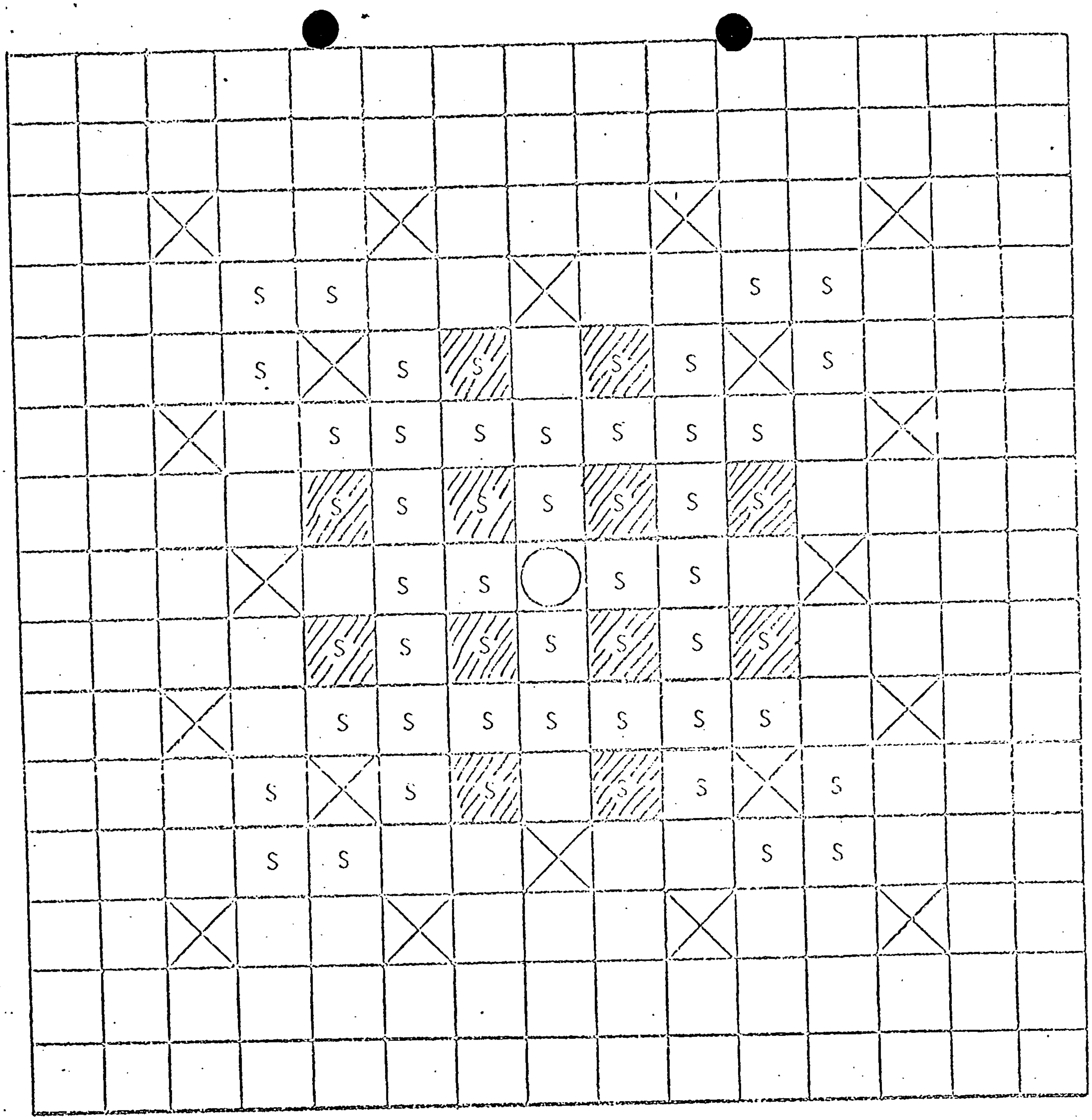
(3) W. B. Henderson, "Analysis of Critical Experiments Containing Gadolinium-Poisoned Fuel," WCAP-7992, November, 1972.

(4) Docket 50-254, Quad-Cities Station Units 1 and 2, Amendment 9, Contained Burnable Neutron Absorber as Supplementary Control.

(5) R. J. Beals, J. H. Handwerk, B. J. Wrona, "Behavior of Urania--Rare Earth Oxides at Elevated Temperatures," Journal of American Ceramics Society 52, 11 (1969).

(6) Section 4.4.2.1, RESAR-3, "Westinghouse Safety Analysis Report," (June 1972).

(7) Docket 50-237, Dresden Nuclear Power Station Unit 2, Topical Report DPR-19, Modification 71-1, Refueling (January 15, 1971 and January 25, 1971).



- Thimble Locations
- Special (Removable) Fuel Rods
- Regular Fuel Rods
- Instrumentation Tube
- Gadolinia Bearing Fuel Rods

Figure 1
Location of Removable and Gadolinia Bearing Rods Within an Assembly

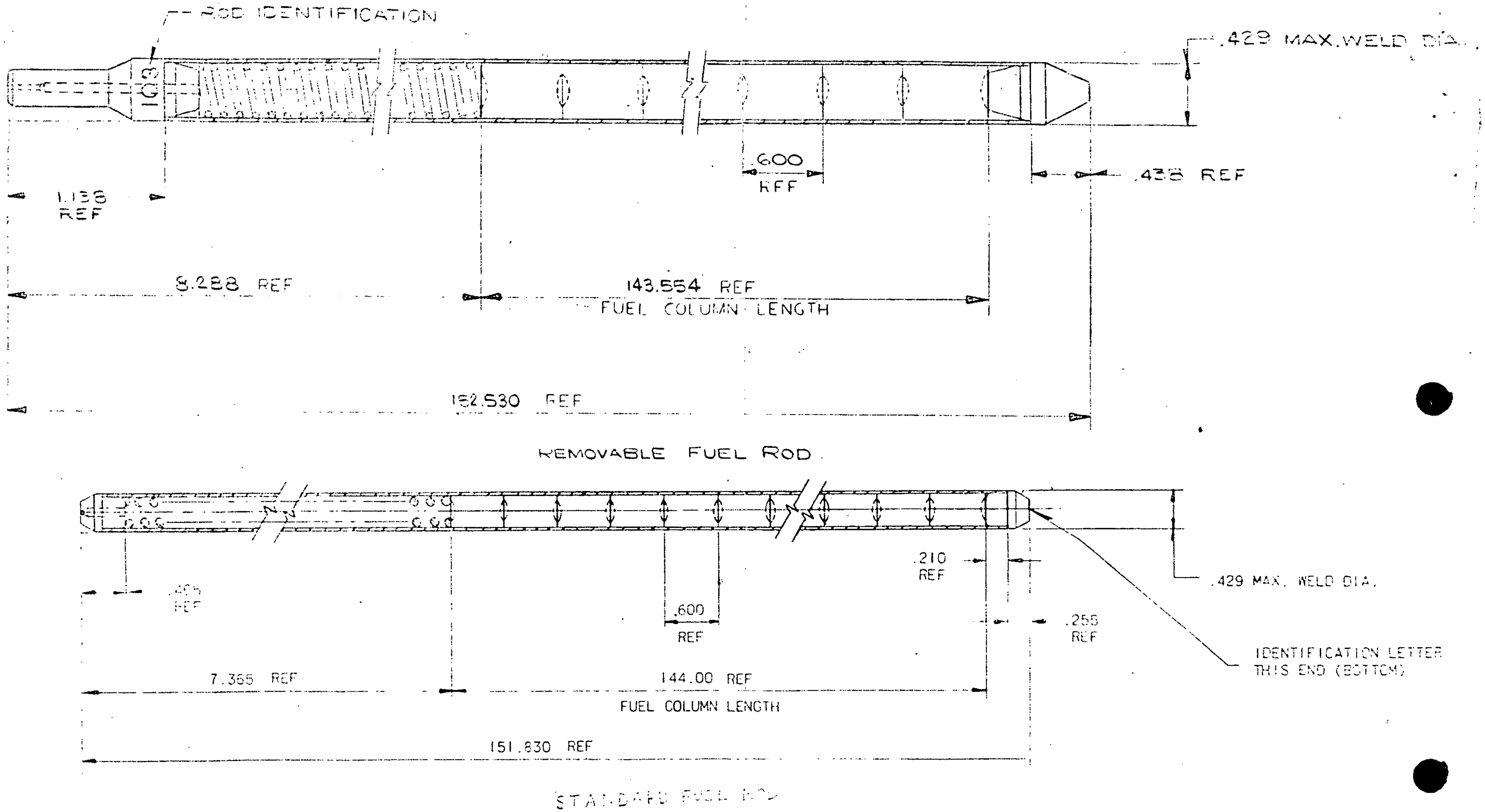


Figure 2
Removable Rod Compared
to Standard Rod

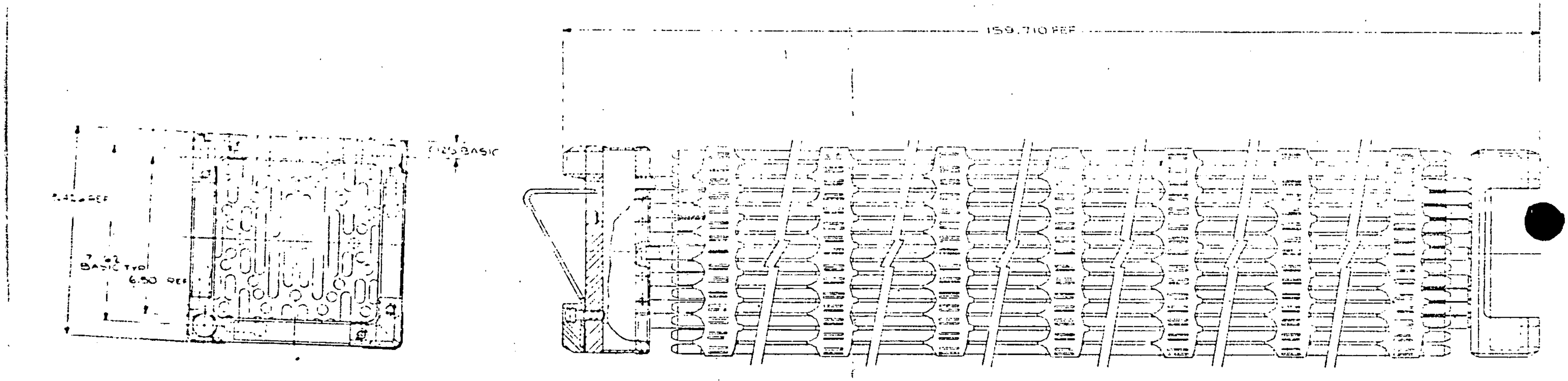


Figure 3
Standard Fuel Assembly Outline

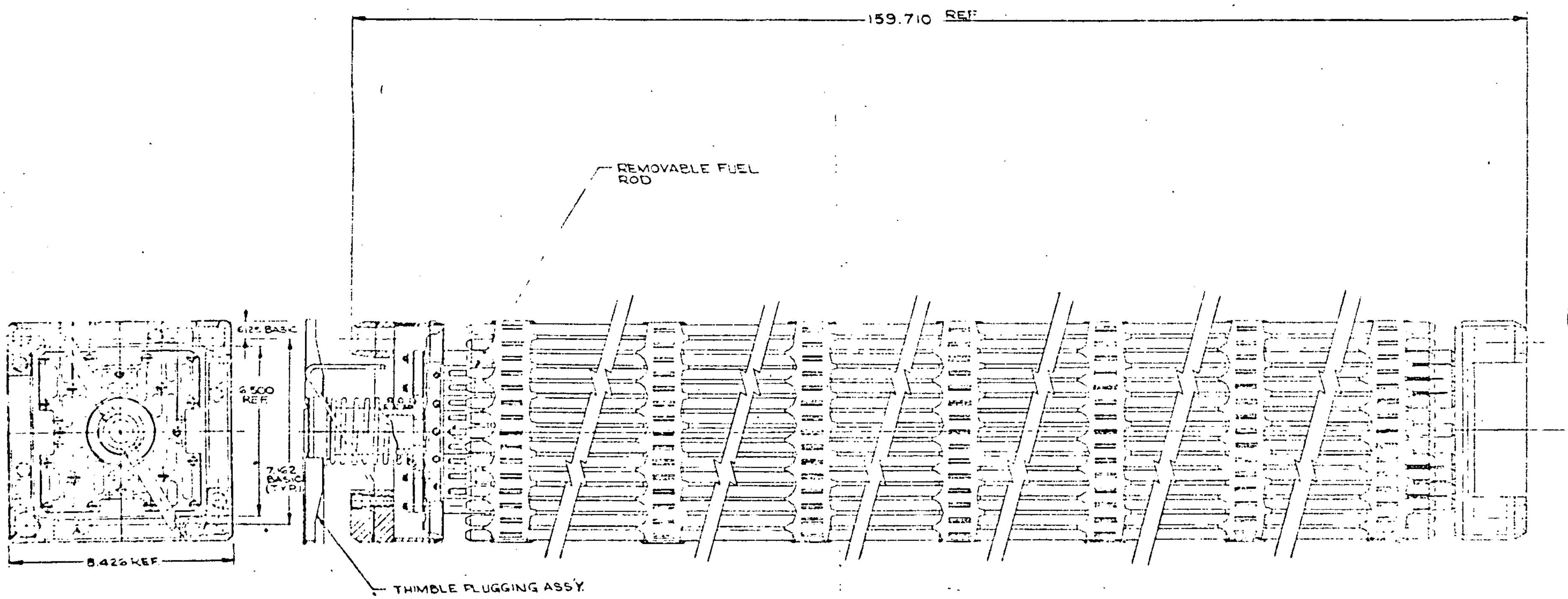


Figure 4
Removable Fuel Rod
Assembly Outline