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**DESIGN CONFIGURATION OF
GCFR CORE ASSEMBLIES**

by
M. P. LABAR, G. E. LEE, and R. J. MEYER

MASTER

MAY 1980

GENERAL ATOMIC COMPANY

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DESIGN CONFIGURATION OF GCFR CORE ASSEMBLIES*

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ABSTRACT

The current design configurations of the core assemblies for the gas-cooled fast reactor (GCFR) demonstration plant reactor core conceptual design are described. Primary emphasis is placed upon the design innovations that have been incorporated in the design of the core assemblies since the establishment of the initial design of an upflow GCFR core. A major feature of the design configurations is that they are prototypical of core assemblies for use in commercial plants; a larger number of the same assemblies would be used in a commercial plant.

INTRODUCTION

The current general arrangement and performance characteristics of the GCFR demonstration plant reactor core are contained in Ref. 1 (a paper presented in the opening session of this technical review meeting). The reactor core conceptual design is based upon an arrangement similar to that used in most liquid metal fast breeder reactors (LMFBRs) with coolant flow up through the core, a bottom grid support, a lateral core restraint system, and control rods actuated by mechanisms from above the core. An important feature that has been incorporated in the current design of the GCFR core assemblies is that they have been designed to be prototypical in as many respects as possible of those required in commercial plants. For a commercial plant, a greater number of essentially the same core assemblies would be used. The purpose of this paper is to present the design configurations of these commercially prototypical core assemblies. The information

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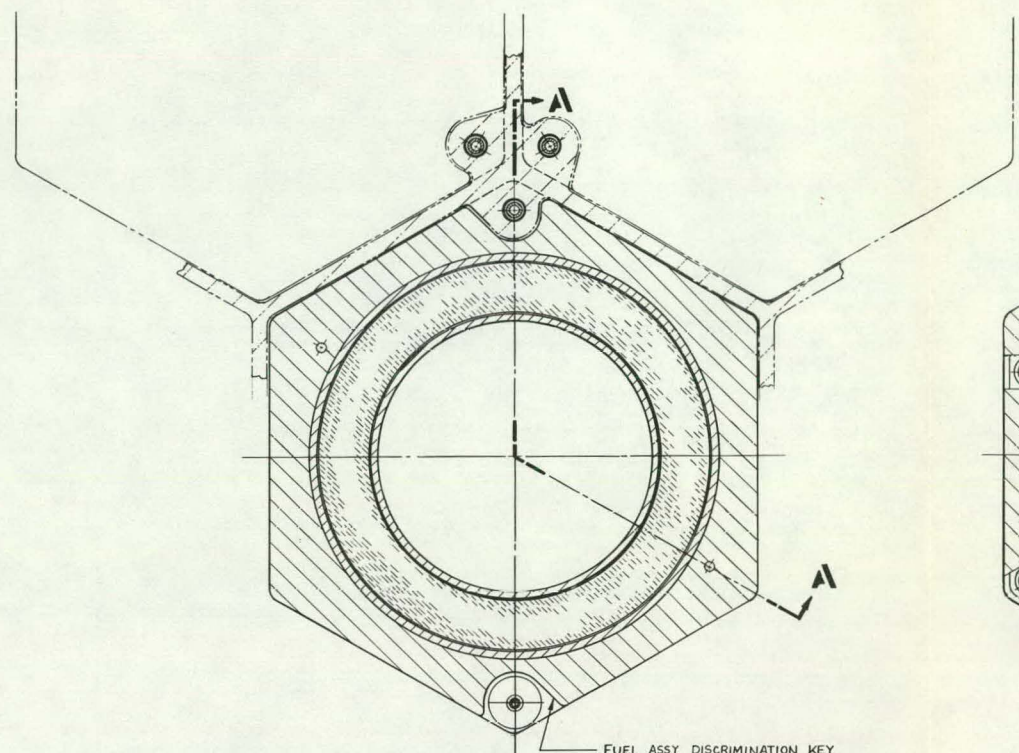
provided represents the current status of the conceptual design of the core assemblies for the GCFR demonstration plant.

The initial design configurations of the core assemblies for the upflow GCFR demonstration plant were developed as part of the study performed to assess the relative benefits of upflow versus downflow core cooling. These designs are contained in Ref. 2 (paper presented at the GCFR Program Technical Review Meeting held June 1979). The overall design configurations of the current core assemblies are very similar to those presented in Ref. 2 but have several important feature changes. In this paper attention will be focused primarily on the changes that are occurring in the evolution of the initial designs into conceptual design arrangements.

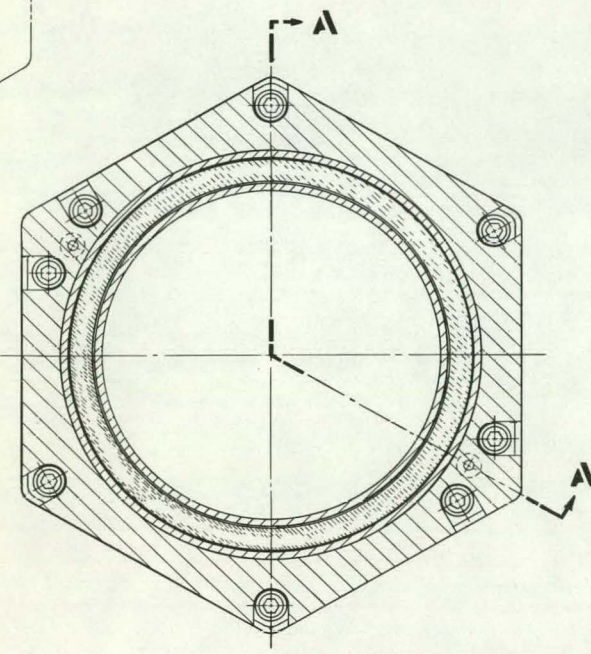
FUEL ASSEMBLY

The design of the fuel assembly is shown in Fig. 1 and the major design parameters are contained in Table 1. The fuel assembly contains a bundle of 265 fuel rods and 6 spacer grid support rods within a hexagonal flow duct. Axial shielding is provided above and below the fuel rod bundle to protect the structures above the core and the core support grid plate below the core from excessive radiation. A flow orifice is located at the outlet end of each assembly to maintain a uniform core outlet temperature.

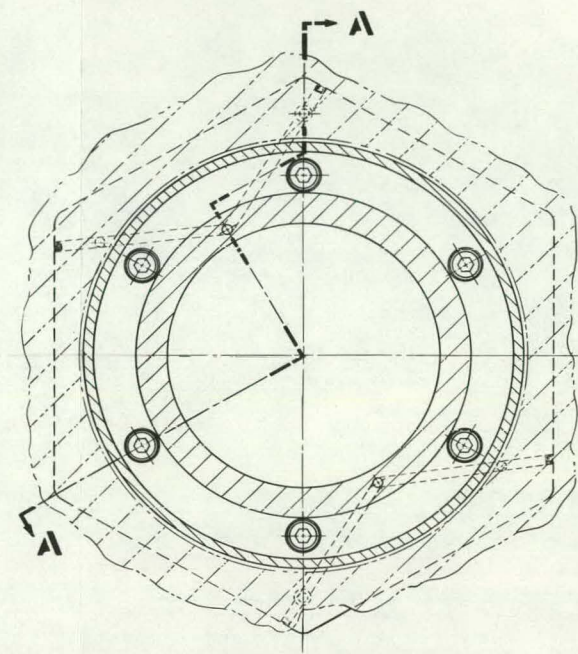
The fuel rod bundle lateral array is maintained by 12 spacer grids located along the bundle length. The fuel rods contain a 1200-mm-long stack of mixed oxide fuel pellets; a 600-mm-long stack of depleted UO₂ axial blanket pellets is located at each end of the fuel pellet stack. The outer surface of the fuel rods is roughened over the fueled portion to enhance heat transfer to the helium coolant. One of the changes that has been incorporated in the current configuration is that the roughening is provided over the entire length of the active fuel zone. In previous designs, the roughening was provided over only the high-temperature, high-heat-flux zone (the upper three-quarters of the active fuel zone). Partial length roughening results in a local dip in the axial temperature profile and the dip was



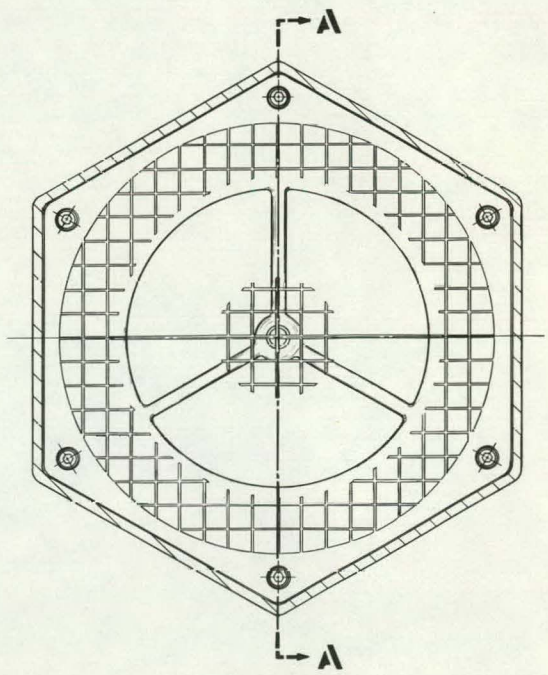
SECTION **B-B**
 FUEL ASSY DISCRIMINATION KEY
 CONFIGURATION (BLANKET ASSY
 KEY OPPOSITE HAND)



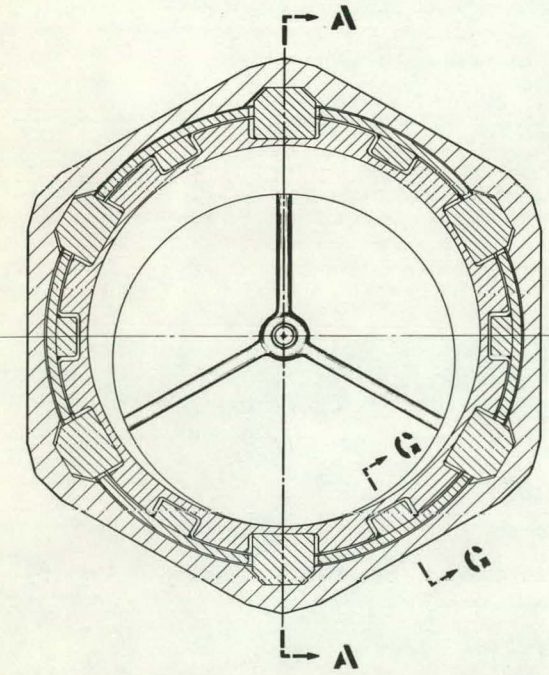
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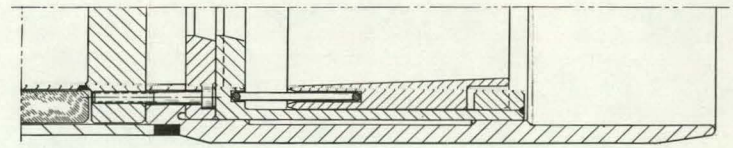
SECTION **D-D**



SECTION **E-E**



SECTION **F-F**



SECTION **G-G**
 (ROTATED 30° CW FOR CLARITY)

Fig. 1. Fuel assembly (sheet 1 of 2)

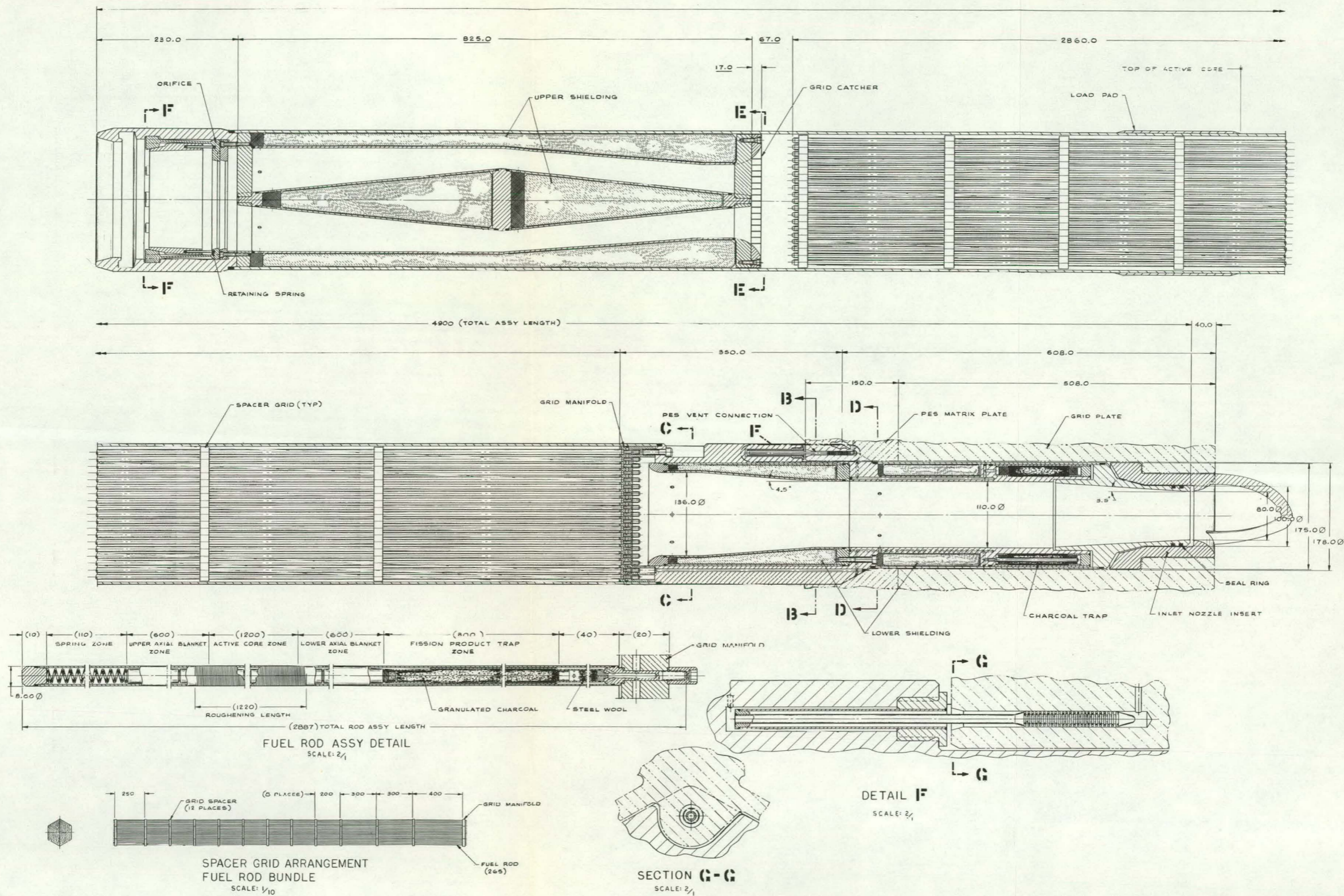


Fig. 1. Fuel assembly (sheet 2 of 2)

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TABLE 1
 FUEL ASSEMBLY DESIGN CONFIGURATION PARAMETERS FOR
 THREE-LOOP, 350-MW(e) DEMONSTRATION PLANT

Fuel Assembly	
Number of fuel assemblies/core	150
Assembly length, mm	4900
Active core height, mm	1200
Number of fuel rods/assembly	265
Number of hanger rods	6
Fuel rod spacer type	Spacer grid
Number of spacer grids	12
Duct material	D9
Duct across-flats i.d., mm	193.0
Duct across-flats o.d., mm	201.0
Duct wall thickness, mm	4.0
Fuel rod pitch, mm	11.5
Rod-to-rod gap, mm	3.5
Rod-to-duct gap, mm	2.87
Rod-to-duct gap, % of rod-to-gap	82
Total estimated assembly weight, kg	590
Fuel Rod	
Length, mm	2887
Clad material	D9
Outside diameter, mm	8.00
Outside root diameter, mm	7.74
Average volumetric diameter in rough section, mm	7.815
Inside diameter, mm	6.98
Clad root thickness, mm	0.38
Fuel and axial blanket pellet o.d., mm	6.84
Fuel and axial blanket pellet-to-clad diametral gap, mm	0.14
Fuel column length, mm	1200
Fuel material	(U,Pu)O ₂
Fuel material planar smear density, % of theoretical	85.5
Axial blanket column length (each), mm	600
Axial blanket material	Depleted UO ₂
Axial blanket material planar smear density, % of theoretical	90.0
Roughness Geometry	
Rib shape	Trapezoidal
Rib height, mm	0.13
Rib width, mm	0.45
Rib pitch, mm	1.56
Length of roughening, mm	1220

considered as a potential site for accumulation of fission product compounds. Full-length roughening was consequently provided in the present design to eliminate the temperature dip.

The pressure within the fuel rods is equalized to the reactor coolant exit pressure by means of a pressure equalization system (PES). In the PES, the fuel rods are collectively vented to a vent connection port at the assembly boundary, where a small quantity of coolant at core exit conditions sweeps the fission gases diffusing out of the fuel assembly through a vent line system to a fission gas separator in the helium purification system. A fission product trap is provided in each fuel rod and another trap is provided in the inlet nozzle region to provide for delay and decay of the fission products prior to exiting from the assemblies. The PES essentially eliminates cladding mechanical stresses due to differential pressure effects and provides a means for monitoring fuel performance. In addition, since the rods are maintained at core exit pressure, any cladding leaks will result in coolant flow into the rod, which will limit the release of radioactivity to the coolant.

The evolution of the fuel assembly design from the initial design described in Ref. 2 to the present configuration has involved the introduction of a number of design changes; descriptions of the primary changes are contained in the following sections.

Commercially Prototypical Core Assemblies

The use of core assemblies that are prototypical of commercial assemblies, coupled with the changes in the primary system parameters as discussed in Ref. 1, has resulted in a number of size changes in the fuel assembly design. The fuel assembly in the current configuration is 250 mm longer and 17 mm wider across flats than the initial design described in Ref. 2. The length increase is primarily attributable to the use of longer axial blankets (600-mm-long blankets at each end of the fuel in the current design versus 450-mm-long blankets in the initial design). Since there have been a

number of other minor length changes, the overall length is not longer by the exact amount that the axial blankets have been increased.

The across-flats width increase is the result of using slightly larger diameter fuel rods (8 mm versus 7.46 mm in the prior design) and a larger fuel rod pitch (11.5 mm versus 10.6 mm in the prior design). The use of the larger diameter fuel rod is the result of studies that indicated somewhat more optimum nuclear performance with larger rod diameters with a reasonably flat optimum in the 8 to 10 mm range. Since most of the fuel rod performance data are on rods with diameters less than 8 mm, the 8-mm size at the lower end of the optimum range was chosen for the commercially prototypical GCFR rod diameter (the Super Phenix design also uses a 8-mm-diameter rod).

The larger fuel rod pitch is a combined result of the use of a larger rod diameter and revised primary system conditions. The pitch-to-diameter ratio in the current design is 1.44 as compared to 1.42 in the initial design. The rod pitch was selected to keep the core pressure drop low enough to avoid exceeding a preselected circulator horsepower level. A much lower core pressure drop [~ 179 kPa (~ 26 psi)] was made possible in the current design, as compared to the 290-kPa (42-psi) pressure drop in the initial design, by use of a higher primary system pressure (105 bar in the current design as compared to 85 bar in the initial design).

Structural Material Change

Another of the more important changes that has been introduced, but which is the least physically apparent, is the change of the fuel assembly structural material from 20% cold-worked type 316 austenitic stainless steel (SS) to D9, a developmental austenitic SS alloy. The composition of alloy D9 is similar to type 316 SS, as shown in Table 2. In-pile tests have shown that alloy D9 undergoes considerably less swelling than type 316 SS. It had been concluded that a material having less neutron-fluence-induced metal swelling than that exhibited by 20% 316 SS would be required to achieve reasonable burnup goals. Analysis indicates that burnups of 100

MWd/kg are achievable with the D9 material in the current GCFR core configuration; corresponding lifetimes with type 316 SS are on the order of 60 MWd/kg. D9 is also the structural material that has been selected for use in the current LMFBR Conceptual Design Study.

TABLE 2
CHEMICAL COMPOSITION OF CORE STRUCTURAL MATERIALS

Element	Type 316	D9
Chromium	16.9	13.5
Nickel	13.5	15.5
Iron	65.1	66.6
Minor elements	Balance	Balance

Assembly Holddown

In the initial design of the core assemblies, a mechanical latch was employed to hold the core assemblies to the grid plate. In the current design configurations, the core assemblies are larger and heavier than in the previous designs. The core pressure drop is also reduced. Both of these changes make the use of the pneumatic balance holddown system, as suggested in Ref. 2 as an alternative to mechanical holddown, more desirable. The pneumatic holddown system consists essentially of a reduced-diameter inlet nozzle, designed to reduce the uplifting force on the assembly to a fraction of the assembly weight. The pneumatic holddown system offers considerable advantages over direct mechanical latching of the assemblies to the grid plate, namely:

1. No moving parts, which makes it a more reliable design.
2. No lock actuation required, which allows room for one additional fuel rod per assembly.

3. System cannot fail in the inserted position; thus, stuck assemblies from holddown failures would be less likely.
4. Actuation by the fuel handling equipment is not required.
5. Allows considerable simplification of the core assembly designs, especially for the control and shutdown assemblies.

In the design of the inlet nozzle as shown in Fig. 1, the sizes of the seal area and the diffuser section after the inlet entrance have been designed to provide the desired pressure balance without significant pressure drop penalty. In the pneumatic balance nozzle of Fig. 1, the pressure loss is only 1.7 kPa (0.25 psi) greater than in the mechanical latch design.

The major disadvantage of the pneumatic balance system is that it is not a "positive" lock; the holddown force is derived from the difference between the assembly weight and the hydraulic lifting force. For the current plant parameters, assuming a 200 kPa (29 psi) assembly pressure drop and a 6 kg/s mass flow rate, the fluid lifting force is about 2230 N (500 lbf). The fuel assembly weight, from Table 1, is about 5785 N (1300 lbf). Thus, the total holddown force available is about 3555 N (800 lbf). This appears to be sufficient to keep the assembly seated during normal operation. A situation in which liftoff of the assembly might be expected would be an earthquake that results in a grid plate acceleration greater than about 0.6 g. Of course, the duration of liftoff in this case would be limited to a few seconds or less, and the amount of liftoff would be limited by the backup stop (provided by the instrument trees located above the core assemblies) to an amount that prevents the nozzle seal rings from disengaging from their seal surface. At no time would cooling flow to the assembly be lost. In addition, since at first detection of an earthquake by the plant protection system (PPS) the reactor is automatically tripped, the fluid lifting forces are significantly reduced soon after the earthquake begins and nearly all the assembly weight is devoted to holddown.

A remote but conceivable mechanism for long-term liftoff of an assembly from the grid plate involves "ratcheting" of adjacent assemblies against one another in such a way that one is lifted off the grid plate. With proper choice of load pad materials and proper core restraint system design, it should be possible to eliminate ratcheting liftoff. The possibility of long-term liftoff from the grid plate has, nevertheless, been considered in the current design of the PES vent connection. Previous designs have relied on the intimate contact of mating surfaces to form the PES vent connection. With a mechanical latch this is not an unreasonable choice; however, with the change to a pneumatic balance holddown scheme, an alternative that could accommodate some motion (on the order of several centimeters) was sought. Several alternatives were developed; the most attractive appeared to be the labyrinth seal illustrated in Fig. 1. As in the case of the pneumatic balance holddown, the labyrinth PES seal is completely passive, has no moving parts, and can easily be designed to accommodate reasonable amounts of motion. While it might appear to be vulnerable to damage, the design is such that the more delicate components are "buried" in heavy structural members for protection. These parts also perform the function of alignment and guidance of mating parts, so that no strains are placed on the labyrinth seal parts.

Bottom-Mounted Grid Manifold

For collective venting of the fuel rods into the PES, all of the rods in each bundle are mechanically attached to a grid manifold at one end. A vent passage is provided in each fuel rod end plug to permit fission gases to pass out of the rod into the grid manifold. The grid manifold functions as the axial structural support for the rods as well as a manifold for collection of the fission gases. The fission gases pass from the grid manifold through redundant passages to the fission product trap in the assembly nozzle for delay and decay prior to being routed to the assembly vent connection ports where the gases exit from the assembly.

In the initial design, the grid manifold was located at the top end of the fuel assembly. The top end of the fuel rod was chosen for venting as being the least susceptible to blockage of rod internal passages by the accumulation and flow of fission product compounds. However, venting at the top end results in the grid manifold being located at the hot outlet end of the core. In addition, vent lines are required for routing the fission gases down through the active core to the fission product trap and vent connection at the bottom end of the assembly.

In the current configuration, the grid manifold has been relocated to the bottom end. Locating the grid manifold at the bottom end requires that sufficient development work be performed to avoid blockage of rod passages by the fission products. If the grid manifold were to be located at the top end, development work would be required to establish satisfactory behavior of the resultant structural arrangement. On balance, the level of development effort required for either approach was concluded to be approximately the same. Since there is already a program to study fission gas venting characteristics (the HELM experiments in the BR-2 reactor), it was concluded that attention should be focused on demonstrating or developing avoidance of rod blockages and that the bottom grid manifold location should be selected.

Flow Orifice

A flow orifice is located at the outlet end of each fuel assembly to provide for a uniform core outlet temperature. The orificing concept has been based upon using fixed-area replaceable orifices where the orifices are exchanged at each refueling outage on those assemblies that are not replaced. Refueling studies using the currently selected refueling concept have indicated that an excessive amount of time would be required for replacement of the orifices. However, adjustment of each orifice by a simple mechanical motion could be provided. Consequently, design efforts have been focused on developing an orifice concept for in-place adjustment. The selected concept is shown in Fig. 2. The design is based upon using two

circular orifice plates, one on top of the other, with eccentrically located centers. The plates are rotated relative to each other to provide a variation of the flow area. The components are held in place by means of spring members, which are lightly stressed during reactor operation to avoid significant creep. To adjust the orifice at refueling, the refueling machine needs only to engage the assembly, push down, rotate 60°, and release.

BLANKET ASSEMBLY

The design configuration of the blanket assembly is shown in Fig. 3 and major design parameters are provided in Table 3. The blanket rod bundle consists of 61 rods 22.2 mm in diameter; the spacing of the blanket rods is maintained by means of spiral wire wraps. Aside from the rod bundle, the blanket assembly is designed to use the same major components as the fuel assembly. These major components include the inlet nozzle, grid plate shielding, flow duct, exit nozzle, and orifice. The blanket rods are pressure equalized and vented the same as the fuel rods except that, due to the low fission product yield, a fission product trap is not included in each blanket rod.

CONTROL ASSEMBLY

The current design configuration of the control assembly is shown in Fig. 4 and major design parameters are given in Table 4. Components common to the fuel and blanket assemblies are used where possible. This includes the use of the same flow duct as in the other assemblies and the use of the same casing for the inlet and exit nozzles as in the other assemblies. The design of the grid plate shielding is also similar to that of the other assemblies.

The current configuration of the control assembly differs from earlier designs in two major respects. First, the fuel rods in previous control assembly designs have been eliminated and second, the control rod guide duct

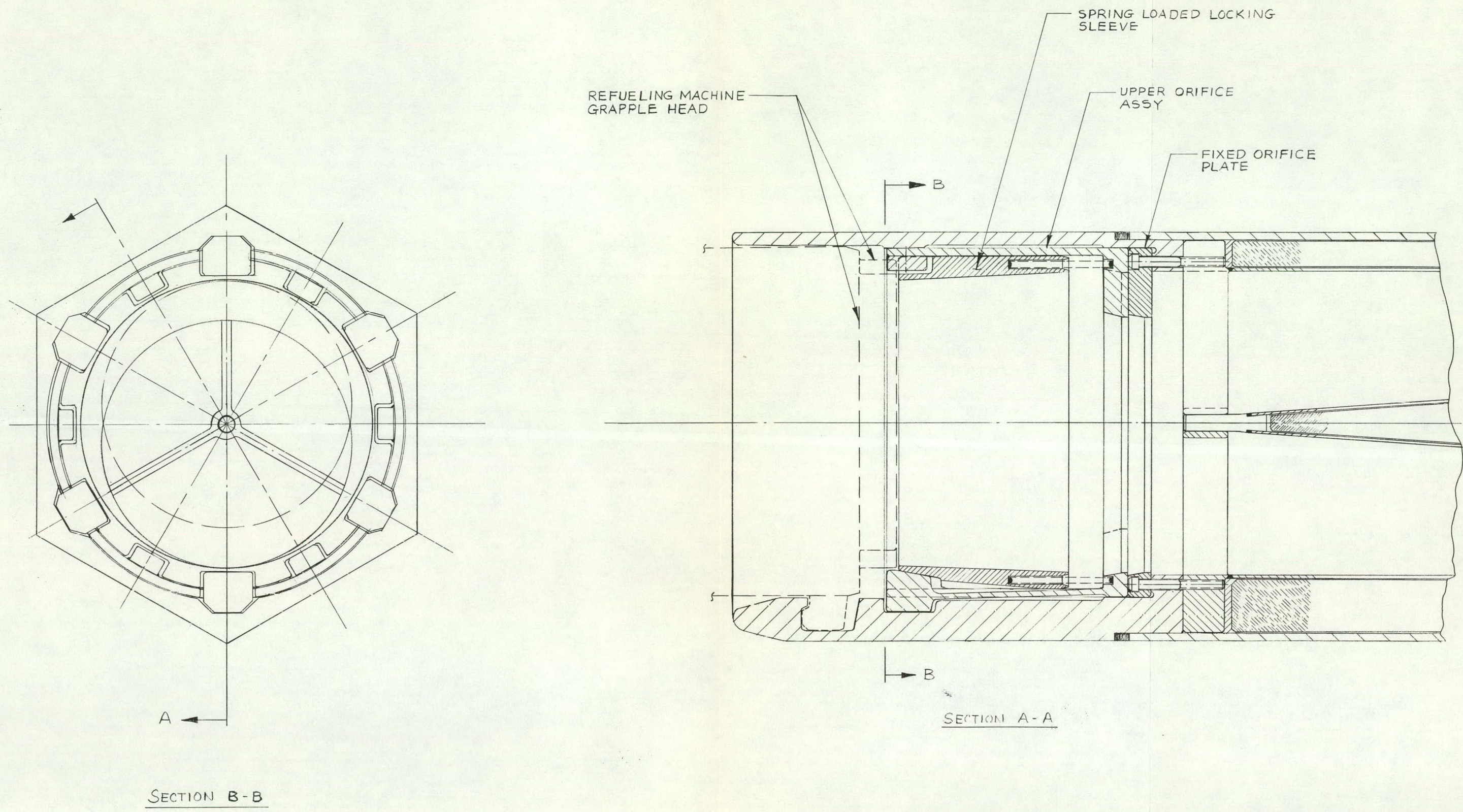


Fig. 2. In-place adjustable orifice

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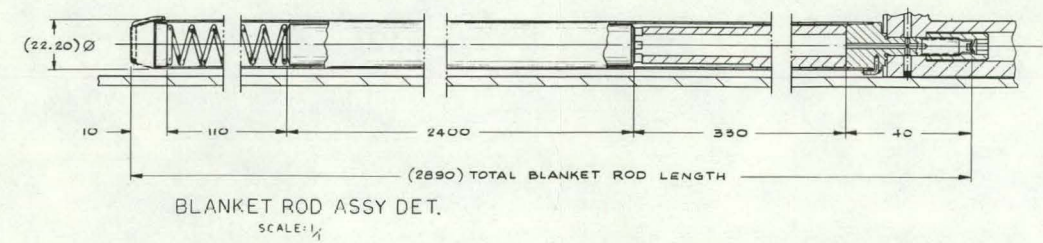
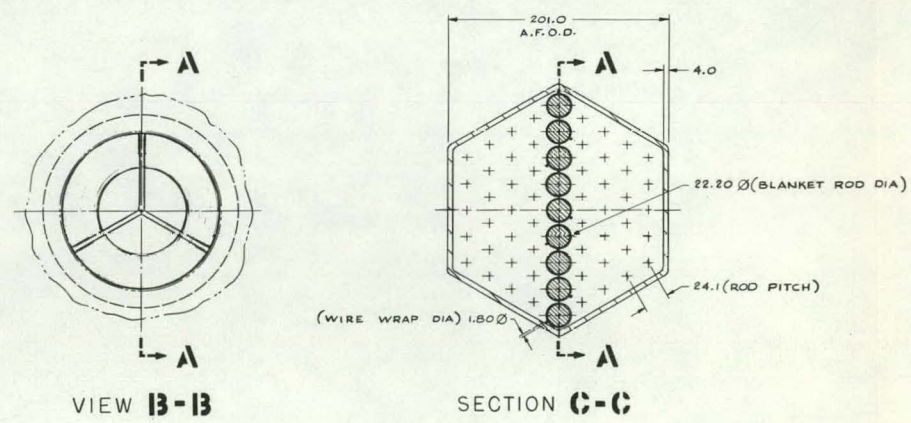
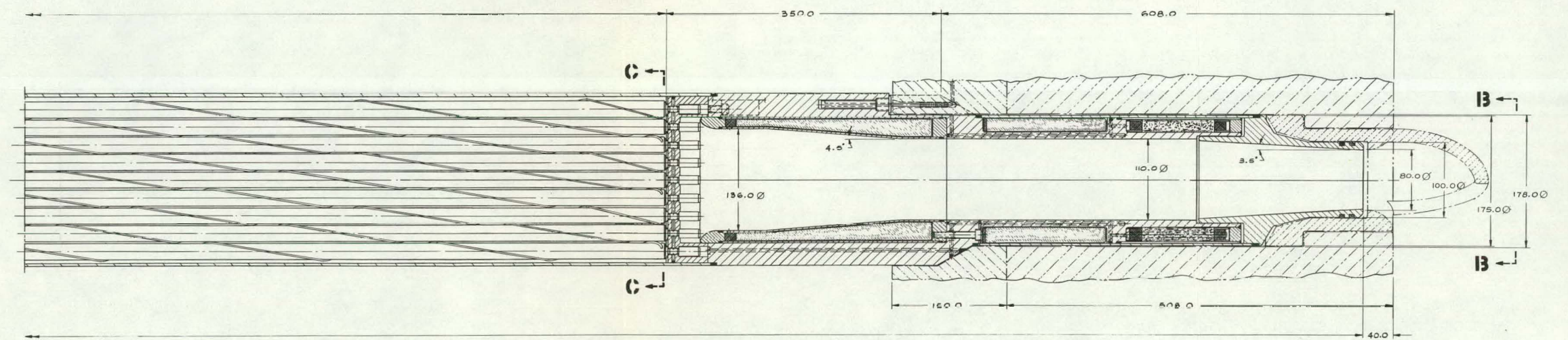
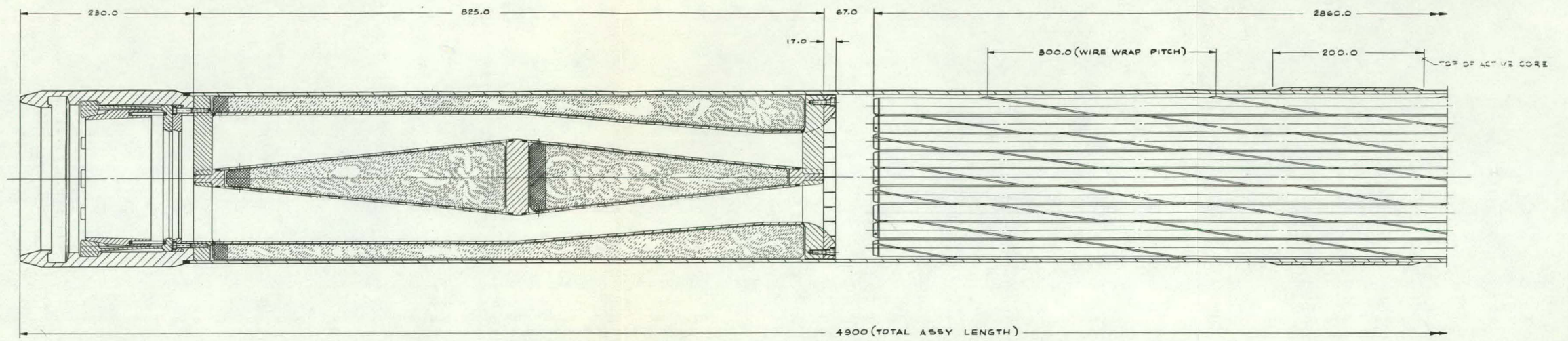


Fig. 3. Radial blanket assembly

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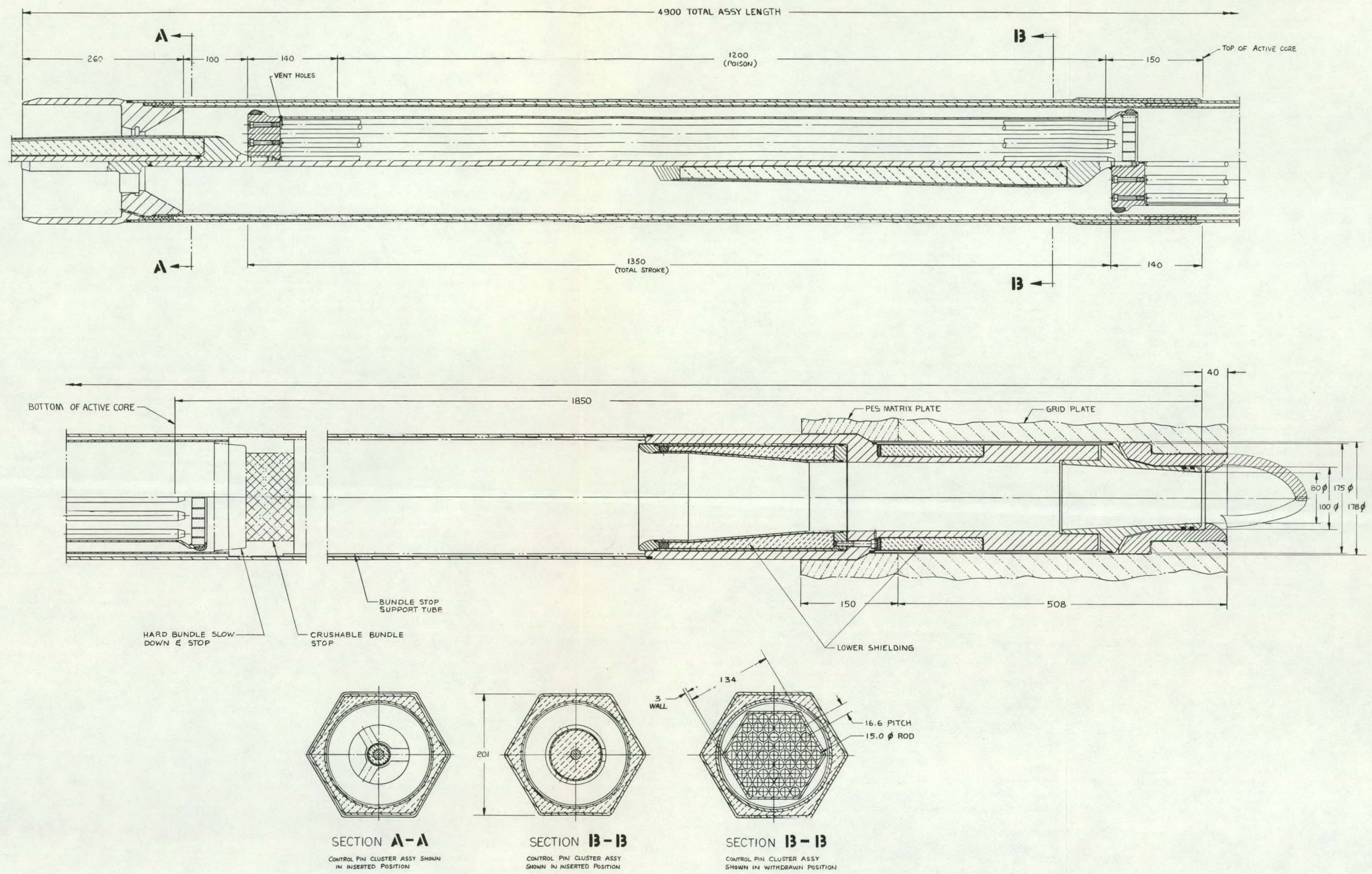


Fig. 4. Control assembly

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TABLE 3
 BLANKET ASSEMBLY DESIGN CONFIGURATION PARAMETERS FOR
 THREE-LOOP, 350 MW(e) DEMONSTRATION PLANT

Radial blanket assembly	
Number of radial blanket assemblies/core	162
Assembly length, mm	4900
Number of blanket rods/assembly	61
Blanket rod spacer system	Wire wrap
Across-flats i.d., mm	193.0
Across-flats o.d., mm	201.0
Duct wall thickness, mm	4.0
Blanket rod pitch, mm	24.1
Total estimated assembly weight, kg	875
Blanket rod	
Length, mm	2887
Clad material	D9
Outside diameter, mm	22.20
Inside diameter, mm	21.20
Wire-wrap diameter, mm	1.80
Wire-wrap pitch, mm	300.0
Blanket material	Depleted UO ₂
Blanket material smear density, % of theoretical	90.0
Blanket pellet o.d., mm	21.05
Blanket material axial length, mm	2400

TABLE 4
CONTROL ASSEMBLY DESIGN CONFIGURATION PARAMETERS FOR
THREE-LOOP, 350-MW(e) DEMONSTRATION PLANT

Control assembly

Number of control assemblies/core	15
Assembly length, mm	4,900
Control rod stroke, mm	1,350
Number of control pins/assembly	61
Control bundle configuration	Hexagonal
Control pin spacer system	Wire wrap
Duct across-flats i.d., mm	193.0
Duct across-flats o.d., mm	201.0
Duct wall thickness, mm	4.0
Control rod guide duct shape	Circular
Control rod guide duct i.d., mm	173.0
Control rod guide duct o.d., mm	181.0
Control rod guide duct wall thickness, mm	4.0
Control pin shroud across-flats i.d., mm	134.0
Control pin shroud across-flats o.d., mm	140.0
Control pin shroud wall thickness, mm	3.0
Control pin pitch, mm	16.6
Pin-to-pin gap, mm	1.6
Pin-to-shroud gap, mm	1.6

Control pins

Length, mm	1,300
Outside diameter, mm	15.0
Inside diameter, mm	14.0
Clad thickness, mm	0.5
Wire-wrap diameter, mm	1.50
Pellet o.d., mm	13.5
Poison material axial length, mm	1,200
Total absorber volume, cm ³	10,500

has been changed from a hexagonal to a circular shape. There are several reasons for changing from a "hybrid" fuel/control assembly to a "dedicated" control assembly. First, the change provides for a separation of design function between the fuel assemblies and the control assemblies. Not only is this desirable as a general design philosophy, but it is advantageous from a safety standpoint as well. Dedicated control assemblies provide the maximum separation of the control rod bundle from fuel-related events. The likelihood of a fuel-related failure propagating into the control rod bundle is therefore reduced, increasing safety. A second reason for using dedicated assemblies is that the design is mechanically far simpler than a hybrid assembly. Reduced complexity can be expected to lead to greater reliability and enhanced safety. A third reason for the elimination of fuel rods from the control assembly was that the size requirements of the control rod bundle were limiting the number of fuel rods that could be accommodated in the assembly to two or three rows of rods. The problems posed in the thermal-hydraulic design of such a configuration were very difficult, if not insurmountable. By eliminating these rods, the thermal-hydraulic design was eased considerably.

The number of fuel rods eliminated from the control assemblies is a relatively small number compared to the total number of rods in the core. The rods eliminated represented less than 5% of the nearly 40,000 fuel rods in the core, the equivalent of less than eight full fuel assemblies.

The other major change in the control assembly design is that the control rod guide duct was changed from a hexagonal duct to a circular duct. (The pads on the control rod bundle were also changed to a circular shape.) The motivation behind this was again primarily to enhance the reliability and safety of the control assembly. Use of a circular guide duct eliminates twist effects, which could cause binding when hexagonal wear pads travel in a hexagonal guide duct.

A variable flow control device has been incorporated in the control assembly. This device is currently under patent review so it will not be

discussed further. Yet to be determined is the conceptual configuration for a control rod shock absorber for accommodating an inadvertently decoupled or failed rod.

Although it might appear that additional absorber material could be incorporated into the control assembly by a better utilization of space, this is neither necessary nor desired. With the present absorber volume of about 10,000 cm³, natural or near natural enriched B₄C can be utilized. With more absorber volume, the absorber material would have to be diluted to keep the maximum rod worth below the desired limit of \$3.00.

SHUTDOWN ASSEMBLY

Conceptual design work on the shutdown assembly has not been initiated but an initial design configuration has been established. This design, shown in Fig. 5 with major design parameters given in Table 5, is based on the following tentative diversity requirements:

1. The reactivity control system should be divided into a primary control system and a shutdown system. These systems should have different designs and employ different actuating and driving mechanisms. The primary triggering signals for both systems can be initiated by the PPS.
2. The primary drive for the insertion of the shutdown rods under normal (PPS-initiated) scram may be gravity. In addition, a secondary mode should be provided to "power in" the rods with the shutdown rod drives. This action should be automatic with a normal scram and initiated by the PPS.
3. The shutdown system should also be provided with a secondary triggering mechanism that is automatic, self-actuating, and independent of the PPS. Devices that fall into this category are fusible links (either electrical or mechanical) and curie point

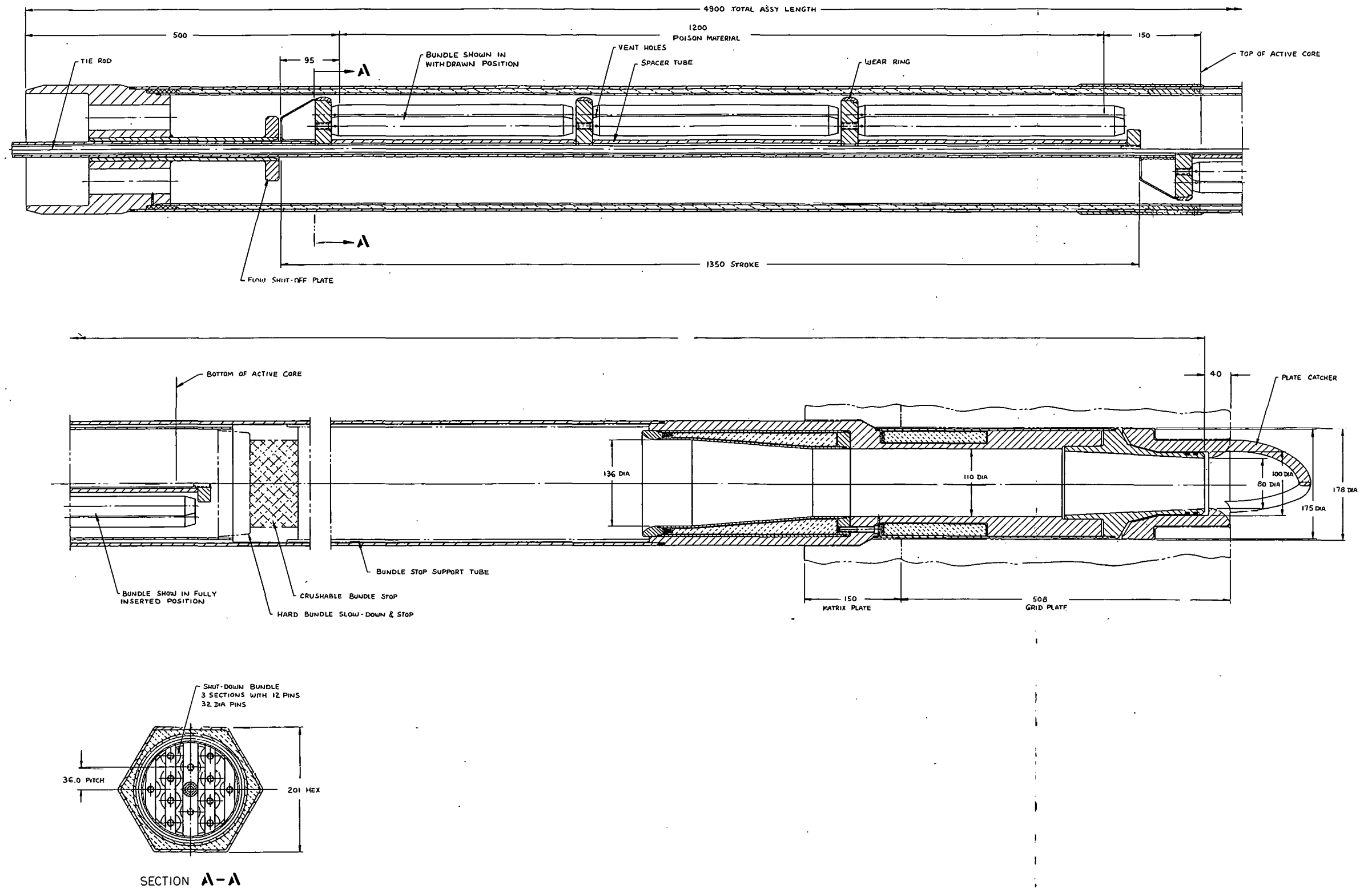


Fig. 5. Shutdown assembly

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TABLE 5
SHUTDOWN ASSEMBLY DESIGN CONFIGURATION PARAMETERS FOR
THREE-LOOP, 350-MW(e) DEMONSTRATION PLANT

Shutdown Assembly

Number of shutdown assemblies/core	4
Assembly length, mm	4,900
Shutdown rod stroke, mm	1,350
Number of shutdown pin clusters per shutdown rod	3
Number of shutdown pins per cluster	12
Shutdown bundle configuration	Circular
Duct across-flats i.d., mm	193.0
Duct across-flats o.d., mm	201.0
Duct wall thickness, mm	4.0
Shutdown rod guide duct shape	Circular
Guide duct o.d., mm	179.0
Guide duct i.d., mm	173.0
Guide duct wall thickness, mm	3.0
Shutdown pin pitch, mm	36.0

Shutdown pins

Outside diameter, mm	32.0
Inside diameter, mm	30.5
Clad wall thickness, mm	0.75
Pellet o.d., mm	30.0
Total absorber volume, cm ³	10,000

magnets. The release point for this mode needs to be located between the shutdown drive driveline and the shutdown absorber. These triggering devices would initiate a scram on high outlet plenum temperature without PPS action.

4. The control assemblies must be designed to allow insertion of the control absorber rod in the presence of the anticipated core distortions for any plant condition from PC-1 to PC-5.
5. The shutdown assemblies require absorber rods different from those in the primary control assemblies. They should permit insertion into a core distorted beyond the anticipated core distortions of a PC-5 event. (The design distortion will be determined later.)

A possible shutdown assembly that seems to meet the above criteria is shown in Fig. 5 and features a guide duct similar to that used in the control assembly, but with some simplifications. However, the shutdown absorber is entirely different in design than the control rod absorber. The shutdown absorber is divided into three segments, each consisting of a cluster of twelve pins containing absorber material. The three pin clusters are attached to a central spline, which can flex to allow the absorber to negotiate a distorted guide channel. Large clearances are provided between the wear pads on the shutdown rod and the guide duct to provide further assurance that the rod can be inserted even during extreme conditions.

A desirable feature for the conceptual design of the shutdown assembly to further enhance its reliability and diversity is a reversal of the flow direction within the absorber. The flow would enter at the bottom of the assembly, flow up in guides around the outside of the absorber to the top of the assembly, turn and flow down through the absorber, turn and flow in a second set of guides up to the top of the assembly, and exit. While

complex, such a design would provide a "pneumatic assist" to the scram action and is considered a desirable feature.

REFLECTOR/SHIELD ASSEMBLY

A fifth type of assembly used in the GCFR reactor core is a reflector/shield assembly. Two rows of these assemblies surround the radial blanket assemblies. No new work has been done on the reflector/shield configuration and the design remains unchanged from that given in Ref. 2. Design configuration parameters for the reflector/shield assembly are given in Table 6.

CLOSURE

The current design configurations of the core assemblies for the GCFR demonstration plant reactor core conceptual design have been described. The designs described represent the status of the conceptual design and are, therefore, subject to additional evolution prior to conceptual design completion.

Relative to the initial designs of core assemblies for an upflow GCFR core, many simplifications have been incorporated in the current design configurations. Paramount among the simplifications are the use of a passive (pneumatic balance) holddown system and the use of dedicated control and shutdown assemblies (fuel rods are no longer included in these assemblies). A number of other design improvements have also been included. Principal among these are the use of an alternate structural material to increase fuel lifetime, in-place adjustable orifices in the fuel and blanket assemblies, and bottom-mounted grid manifolds in the fuel and blanket assemblies.

A primary feature of the current design configurations is that they are prototypical of commercial-size core assemblies. Commercially prototypical performance of the core assemblies will be demonstrated in the GCFR demonstration plant through the use of the upgrade strategy described in Ref. 1.

TABLE 6
REFLECTOR/SHIELD ASSEMBLY DESIGN CONFIGURATION PARAMETERS FOR
THREE-LOOP, 350-MW(e) DEMONSTRATION PLANT

Reflector/shield assembly

Number of reflector/shield assemblies	138
Assembly length, mm	4900
Number of shielding rods/assembly	19
Shielding rod spacer system	Wire wrap
Across-flats i.d., mm	193.0
Across-flats o.d., mm	201.0
Duct wall thickness, mm	4.0
Shielding rod pitch, mm	42.9
Total estimated assembly weight, kg	400

Shielding rod

Clad material	D9
Outside diameter, mm	41.10
Inside diameter, mm	40.10
Wire-wrap diameter, mm	1.60
Shielding material	Boronated graphite
Shielding pellet o.d., mm	40.0

REFERENCES

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2. Lee, G. E., "GCFR Upflow Core Design," in Proceedings of the First Annual GCFR Program Technical Review Meeting, May 30, 31, and June 1, 1979, Rancho Bernardo, California, Helium Breeder Associates, 1979.



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