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COMPACT CONTROL ROD DRIVE STUDY FOR A BOILING WATER REACTOR IN A T7 TANKER

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GENERAL ELECTRIC

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SECTION 1

INTRODUCTION

1.1 Space Requirements

Significant factors in determining the size of the T7 tanker containment vessel are the size, location, and removal space requirements of the control rod drives. The reason for initiating the compact drive study for the T7 tanker was to investigate these control rod drive size, location, and removal space requirement factors and select the control rod drive mechanism which would allow optimization of the over-all size of the containment vessel. Approximately twelve mechanical/hydraulic control rod drive arrangements were considered during this study.

The phrases "installed space requirement" and "removal space requirement" are used frequently throughout this report. "Installed space requirement" is defined as the vertical distance from the bottom of the core active fuel zone to the bottom of the installed control rod drive mechanism. "Removal space requirement" is defined as the vertical distance from the bottom of the active fuel zone to the elevation to which the drive mechanism or its components must be lowered in order to remove it from the pressure vessel. The terms "removal space requirement" and "total space requirement" are synonomous.

1.2 Reactor Control

Excluding the mechanism which physically provides reactor control, there are three basic methods of providing reactor control for power changes. These are:

1. Change the neutron absorption characteristics of the moderator by dissolving a poison material homogeneously in the moderator.

2. Control neutron leakage by controlling the position of reflectors.

3. Change the neutron absorption characteristics of the core by inserting or removing fuel or solid-state poison materials.

Because the first and second methods require major reactor design changes, this study was limited to the third method - that of inserting or removing solid-state poison materials. Although liquid poison control rods would ordinarily fall into this category, they are not considered further in this study because work on this form of control was carried out in another phase of the T7 tanker program.[1] Therefore, this study was conducted to investigate and select a compact mechanical, hydraulic, or electric mechanism, or any combination of the three mechanisms, which would meet the design criteria specified for the T7 tanker control rod drive mechanism.

1.3 Design Criteria

The compact control rod drive mechanism shall meet the following design criteria:

1. The mechanism shall have a bottom entry[2] control rod which scrams upward.
2. It shall operate in conjunction with a rectangular flux trap control rod.
3. It shall be shorter than the reference bottom-mounted plant but still maintain all existing design features.
4. It shall be side- or bottom-mounted. (A previous study was made of a top-mounted locking piston drive.[3])
5. It shall be capable of being removed from the reactor pressure vessel without removing the pressure vessel head closure.
6. It shall present minimum interference to the refueling cycle.
7. It shall be suitable for application to either a 24-drive or 21-drive core arrangement.
8. It shall operate through a pressure vessel penetration less than four inches.
9. It shall be capable of being removed independently of other mechanisms.

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1. Cochran, J. T., Liquid Poison Control, T7 Tanker Memo #73, General Electric Company, Atomic Power Equipment Department, San Jose, Calif. February 17, 1960.
2. The term "bottom entry" refers to a control rod which enters the core at the bottom and scrams upward against gravity. "Top entry" refers to a control rod which enters the core from the top and scrams downward with gravity.
3. Biglieri, N. J , Top Mounted Locking Piston Drive for the T7 Tanker, GEAP 3185, General Electric Co., Atomic Power Equipment Dept., San Jose, California, May 27, 1959.

SECTION 2

SUMMARY OF CONCLUSIONS

Several of the compact control rod drive designs which were studied provided significant reduction in the overall height of the reactor and containment system. However, none of the designs which met the design criteria for this study provided significant weight and cost reduction for the overall reactor plant. These general conclusions are based on the control rod drives considered during this study. Time limitations prevented an exhaustive study of this subject to be carried out and, therefore, limited the number of control rod drives considered. However, it is believed that a sufficient variety and number of designs were considered to present a fair representation of the achievable goals utilizing compact type control rod drives and the conditions under which they should operate. It does not preclude the possibility that additional creative effort and study would produce a compact drive arrangement which provides reactor containment compactness in conjunction with significant cost and weight savings.

In addition, the following specific conclusions were drawn:

1. Of the control rod drive systems studied the system which met the design criteria and provided the most compact containment vessel arrangement was a side-mounted, bottom entry gear and rack control rod drive.

2. In order to achieve this containment vessel compactness with a side-mounted, bottom entry, gear and rack control rod drive it was determined that the control rod drive rack assembly must be an integral part of the control rod poison section. For a control rod drive having a 53.5 inch stroke, such an arrangement would reduce the total space required by 6.5 feet, i.e., from 17 feet for the reference bottom-mounted locking piston control rod drive to 10.5 feet for the side-mounted gear and rack.

3. Use of a bottom entry gear and rack control rod drive requires a positive means of rod insertion in the event of a pinion drive shaft failure. To provide this back-up feature on the selected mechanism the scram spring was located inside the pressure vessel beneath the control rods.

4. To apply side-mounted gear and rack control rod drives with internal scram springs, the reactor pressure vessel length must be increased approximately 3 feet 2 inches to accommodate a 30-inch compressed height scram spring and to meet the necessity of bringing the side-mounted mechanisms through the pressure vessel at two different

elevations. For the reference design this increases the water potentially available to a "maximum credible accident" by 157 cubic feet and correspondingly increases the design pressure of the containment vessel. Because of this higher pressure requirement, although the containment vessel for the side-mounted arrangement is reduced in overall height by approximately five feet, the containment vessel weight is 12.5 tons greater than the reference design containment vessel.

5. Penetrations for side-mounted type control rod drives complicate the reactor pressure vessel primary shielding design.

6. The potential space saving capabilities of the top mounted, bottom entry, locking piston control rod drive are equally as attractive as those of any side-mounted mechanical drive considered.

7. Although it did not meet the design criteria for bottom entry, the use of a side-mounted, top entry gear and rack control rod drive results in maximum reactor containment vessel compactness. However, the design changes in the core to accommodate top entry control rods were not studied and no further effort was expended on this type of arrangement other than to recognize its space saving potentialities.

SECTION 3

COMPARISON OF POTENTIALLY APPLICABLE MECHANISMS

3.1 Gear and Rack Drive

The first mechanism investigated in the study was a gear and rack control rod drive. This drive is similar to the control rod drives used on the Army Packaged Power Reactor (APPR) except for one significant change: the scram system was modified to supply a powered upward scram rather than the normal gravity scram. The first attempt to utilize the gear and rack drive was based upon the assumption that the scram energy source, in the form of a group of clock springs, would be mounted to the pinion drive shaft external to the reactor pressure vessel. Drawing No. 141F675, Page A-2 of the appendix, shows a comparison of the potential applications of the gear and rack control rod drives. The drawing illustrates five gear and rack external scram spring control rod drive schemes and the reference bottom-mounted locking piston drive. The dimensions on the drawing are based on a 53½-inch stroke and a cruciform control rod. The total installed lengths and removal space requirements in each of the schemes are illustrated in the drawing.

The following conclusions can be observed from the drawing:

1. Scheme 2 shows the control rod drive rack as an extension from the bottom of the control rod. Note that the drive's installed length is two feet shorter than the bottom-mounted locking piston drive. Assuming that the control rod and rack assembly is removed from the top of the vessel, it can be concluded that the drive mechanism can be side removed without requiring any significant removal space other than the normal containment sphere clearance. However, because side removal of the mechanism would require pressure vessel head removal, this arrangement would not meet the specified design criteria, since, if the pressure vessel head were not removed, the rack housing would have to be lowered vertically to clear the rack extension before the mechanism could be side-removed from among the other installed drives. Under these conditions, Scheme 2 indicates that the bottom-mounted, bottom removal gear and rack drive offers no significant vertical space savings compared to the reference bottom-mounted locking piston drive shown in Scheme 1.

2. If the rack were an extension from the bottom of the control rod, the maximum vertical space savings could be achieved only by designing the mechanism for side mounting and complete side removal. Because in this case the drives are side-mounted around the circumference of the pressure vessel, side removal is not significantly influenced by the other installed drives as is the case for side removal of bottom-mounted drives. This arrangement is shown in Scheme 3.

3. In Schemes 2 and 3 the drive rack is shown as an extension from the bottom of the control rod. This requires that at least two stroke lengths be available in the pressure vessel or pressure vessel thimbles below the core; one stroke for the withdrawn control rod and one for the rack assembly. Combining the rack and the control rod function by manufacturing the rack as an integral part of the control rod in the same stroke length of the control rod would reduce this requirement to one stroke length.

4. Scheme 4, which shows a side-mounted, side-removed mechanism, indicates that the total space required for an integrated rack and control rod is eight feet, compared to 17 feet for the reference bottom-mounted locking piston control rod drive. This represents a significant space savings.

5. For bottom entry, upward scram, Scheme 5 shows that maximum compactness of the gear and rack drive can be achieved by mounting the rack extension above the control rod. This arrangement, however, imposes severe refueling restrictions, as the drawing illustrates.

6. Maximum compactness for any gear and rack drive arrangement considered is achieved with a top entry, gravity scram, side-mounted mechanism, as shown in Scheme 6. Top entry eliminates the need for the stroke length required for control rod withdrawal in the pressure vessel below the core; this results in approximately a two-foot reduction in pressure vessel length and a consequent savings in primary shielding. The over-all space required is five feet, compared to 17 feet needed for the reference bottom-mounted locking piston drive.

The illustrated schemes clearly indicate that significant space savings can be achieved with a gear and rack configuration, provided the mechanism can be side-mounted and side removed and based on the assumption that the scram energy source can be reliably located in a position external to the pressure vessel.

Because it is felt that the potential consequences of rod dropout with bottom entry caused by shearing of the pinion drive to which the external scram spring is affixed does not justify the possible space savings of this arrangement, the gear and rack designs were modified at this stage to locate internal scram springs beneath the control rods. This arrangement provides a positive means of rod insertion in the event of a pinion drive shaft failure. These modified designs, along with other mechanisms, are shown on Drawing No. 141F683, Page A-3. Significant conclusions which can be made from this drawing are as follows:

1. Except for the use of an internal scram spring, Scheme 3 of Drawing No. 141F683 is identical to Scheme 3 of Drawing No. 141F675. Whereas the use of an external scram spring and a side removal mechanism indicates a significant space savings, conversion to an internal scram spring causes this form of gear and rack mechanism shown in the drawing to lose its space-saving advantages (16½ feet for the internal scram spring and 17 feet for the bottom-mounted locking piston drive).

2. Side removal with an internal scram spring requires removal space and extra vessel penetrations at the bottom of the pressure vessel. These requirements, in addition to a back seating arrangement for bottom scram spring removal, make the Scheme 3 arrangement undesirable unless the scram spring is designed for removal from the top of the pressure vessel.

3. The most compact internal scram spring, bottom entry, gear and rack design, with a rack extending from the control rod, is achieved by mounting the scram spring above the core. This arrangement, however, would again severely limit the refueling operations, as is illustrated in Scheme 4.

4. To utilize the maximum space savings potentialities of the gear and rack mechanism with a reliable, back-up scram mechanism, and to keep the installed length to a minimum, the control rod drive rack must be an integral part of the control rod (similar to Scheme 4, Drawing No. 141F675), and a system must be devised for removal of the scram spring from the top of the pressure vessel. With this system the total space required below the bottom of the core would be ten feet six inches, as compared to the 17 feet required for the reference bottom-mounted locking piston drive.

3.2 Cable Drive

During the initial phases of the compact drive study, all design work was centered around a core which incorporated a cruciform control rod. Investigation of the application of the gear and rack mechanism indicated that to utilize all the potential space savings capabilities of the mechanism, the rack must be a part of the cruciform control rod.

However, the configuration of the cruciform rod imposes severe design limitations on the rack's mechanical design from the standpoint of material selection, tooth loadings, suitable guidance system, and control rod drive accessibility.

Another means of eliminating the stroke length required for the drive mechanism without integrating the drive function with the control rod function is to utilize a cable drive which essentially has a flexible operating stroke. Schemes 5 and 6 of Drawing 141F683 illustrate the potential space savings capabilities of a spring-loaded cable drive mechanism with internal scram springs either above or below the core. The total space required for a bottom-mounted cable drive is approximately 11 feet, compared to the 10 feet 6 inches required for the side-mounted, integral gear and rack control rod drive. Side-mounting of a cable drive was not considered because of the possibility that the reliability of the mechanism would be severely affected when an internal cable pulley system was added to the basic drum assembly. A straight pull against a spring is the simplest application of this mechanism (Schemes 5 and 6).

Although the space savings potential of the cable drive was as favorable as the side-mounted, integral gear and rack control rod drive, two major reasons eliminated it from further consideration: one because of a necessary change in design criteria; the other because of an inherent disadvantage of the mechanism. These reasons are detailed below:

1. While this study was progressing the reactor core design changed from cruciform control rods to flux trap control rods. The flux trap rod selected was a hollow rod whose cross section was approximately 9-1/2 inches wide by 1-1/2 inches thick. This type of rod made possible the integration of the control rod and rack assembly thus restoring the significant space savings of the gear and rack mechanism.

2. The cable drive as designed can mechanically pull in only one direction. If the compression spring were to become bound in its guide tube, the cable drive could not "push" the control rod into the core. Other reactors which utilize cable drives normally have top entry control rod conditions, whereby they utilize the mechanism to "pull" the control rod out of the core and gravity to "push" the rod into the core. The T7 bottom entry conditions do not provide this gravity assistance.

3.3 Space Requirements

The following table lists the space requirements of the mechanisms on Drawings 141F675 and 141F683 which were given serious consideration:

Type of Mechanism	Total Space Required*
1. Bottom-mounted locking piston drive (Dwg. 141F675, 141F683, Scheme 1) a. Bottom entry	17.0 feet
2. Cable drive (Dwg. 141F683, Scheme 5) a. Bottom entry b. Scram spring below core	11.0 feet
3. Gear and rack drive (Dwg. 141F675, Scheme 4) a. Side-mounted, bottom entry b. Internal scram spring c. Rack integral with control rod	10.5 feet
4. Top-mounted locking piston drive (Dwg. 141F683, Scheme 2) a. Bottom entry	6.5 feet
5. Gear and rack drive (Dwg. 141F675, Scheme 6) a. Side-mounted b. Top entry, gravity scram	5.0 feet

*Total space required is defined as that distance from the bottom of the active fuel length to the lowermost position of the pressure vessel for side and top-mounted drives and the lowermost position of the control rod drive for bottom-mounted drives. Removal space if required is included in this dimension.

The table points out that the most compact bottom entry arrangement is the top-mounted locking piston drive.[1] GEAP 3185 discusses this

1. Biglieri, N. J., Top Mounted Locking Piston Drive for the T7 Tanker, GEAP 3185, General Electric Company, Atomic Power Equipment Dept., San Jose, California, May 27, 1959.

top-mounted mechanism. It concludes that the top-mounted locking piston drive is feasible but points out several areas which require additional design effort such as the refueling process, reliably supporting the control rods in the core when the pressure vessel head is removed, refueling through ports, and steam separator design. Since the design aim of the compact drive study was to select a mechanism which did not have these limitations, the side-mounted, bottom entry, integral control rod, gear and rack mechanism was recommended as an alternate drive design for the T7 tanker.

Although it did not meet the design criteria for bottom entry, the table also illustrates that the use of a side-mounted, top entry, gear and rack control rod drive results in maximum reactor containment vessel compactness. However, the design changes in the core to accommodate top entry control rods were not studied and no further effort was expended on this type of arrangement other than to recognize its space saving potentialities.

SECTION 4

DESIGN DESCRIPTION OF THE SELECTED DRIVE

4.1 Reactor Arrangement

The reactor arrangement shown in Drawing No. 141F694, Page A-4, illustrates the adaptation of a side-mounted gear and rack control rod drive mechanism. The integral rack and control rod poison element is shown in Section BB of the drawing. The lower grid is extended downward approximately two inches to allow adequate space for securing the fuel element channels in the lower grid, and for positioning and guiding the upper portion of the drive pinion support housing. Guide tubes are supplied to insure proper guidance of the scram springs. The upper portion of these guide tubes is connected to the pinion support housing and provides the vertical and lateral support for the control rod drive pinion and pinion drive shaft. The backup roller for the rack and the striker plate for the mechanical damper are also integral parts of the pinion support housing. A guide tube positioning plate is provided at the bottom of the pressure vessel for location and support of the scram spring guide tube assemblies with respect to the core.

As shown in the drawing, the 21-drive core arrangement requires that the pinion drive shafts be located at two elevations. To allow removal of a control rod, a coupling is provided to disconnect the control rod from the scram spring support plate. Although, as indicated in the table on Page 3-6, the over-all reactor vessel and drive height were reduced approximately 6.5 inches by using the integral rack and control rod core arrangement, the reactor pressure vessel length must be increased approximately three feet two inches to accommodate a 30-inch compressed height scram spring and to meet the necessity for bringing the drives in at different elevations. For the reference plant this increases the hot water potentially available to a "maximum credible accident" and correspondingly increases the design pressure of the containment vessel. Because of this higher pressure requirement, although the containment vessel for the side mounted arrangement is reduced in over-all height by approximately five feet, the containment vessel weight is 12.5 tons greater than the reference design containment vessel.

4.2 Drive Mechanism

The energy for normal shim motion is produced outside the reactor vessel by a gear motor operating a pinion drive shaft through a buffer seal. Scram energy is produced within the reactor vessel by compression springs.

Operating within the reactor pressure vessel are the pinion and pinion drive shaft, the rack, and the spring scram system. To consume vertical height, the rack is an integral part of the flux trap control rod. A buffer seal separates the internal drive components from the external components. The seal consists of a multi-ring arrangement of metal seal rings and diaphragms which act as clearance seals, progressively reducing fluid pressure from ring to ring. Reactor feedwater slightly above reactor pressure, at less than 140°F, is injected into a lantern ring located just after the first seal ring. Some of this water leaks past the first ring into the reactor. The balance of the coolant flows outward through the seals and through a second lantern ring out to the seal drain system.

The equipment outside the seal housing is shown on Drawing No. 612D559, Page A-5. In sequence after the seal are the position indicator and limit switch takeoff gears, the position indicator and limit switches, and the electromagnetic scram clutch, universal shaft, gear motor, and brake. For normal shim motion the friction brake is de-energized and the gear motor energized; the scram clutch remains engaged, and the drive shaft and pinion rotate imparting linear motion to the rack. As the control rod is withdrawn from the core the scram spring is cocked.

To accomplish a scram, the d-c power to the electromagnetic clutch is de-energized. This releases the pinion drive shaft from the gear motor drive shaft. The scram spring is no longer retained and rapidly inserts the control rod into the core. The control rod is brought to a stop by a mechanical damping mechanism which is a part of the control rod. The scram spring is sized to support the control rod with the rods fully inserted, with an additional preload, to provide the necessary acceleration during any portion of the drive stroke. The pinion drive shaft's being locked by the brake prevents rod motion against the spring because of the ship's motions.

Since the rack and pinion system can be continuously positioned, and since the shim energy source is an electric motor drive, an on-off automatic control system can be applied to any number of the drive mechanisms. Space is provided for a separate control feedback position indicator, as is shown in Section AA of Drawing No. 612D559, which shows the control rod drive's external components.

Arrangement of the control rod drives with respect to the pressure vessel is shown on Drawing No. 141F694. The mechanisms extend radially from the pressure vessel in three groups of five and one group of six.

4.3 Drive Removal

Seal removal can be accomplished without removing the reactor pressure vessel head by use of a backseating valve arrangement. The entire drive internal system, including the pinion and pinion bearings, may also be removed without head removal by withdrawing the entire drive mechanism into a drive removal cask, as illustrated on Drawing No. 141F708, Page A-6. To remove a drive the cask is mounted to a flange provided on the pressure vessel nozzle. A screw mechanism retracts the drive and seal assembly into the cask through an open gate valve. When the mechanism is completely withdrawn into the cask, the gate valve is closed, sealing off the reactor pressure vessel connection. The cask can then be drained and disconnected from the gate valve.

SECTION 5

OTHER MECHANISMS CONSIDERED

5.1 Rack and Pinion Drive - Cruciform Control Rod

Drawing No. 141F707, Page A-7, illustrates the drive work performed with a cruciform control rod. Scram springs are shown either above or below the core. Note that for these arrangements bottom removal of the scram spring is required, and in order to accomplish this, two vessel penetrations are required for each drive mechanism. This arrangement was considered undesirable and emphasized the necessity for a top removal scram spring.

One unique feature in Section BB of this drawing shows the methods provided for rotating the rack in the uncoupling process. The lower portion of the rack has circular threads of the same size and pitch as the rack teeth. With this arrangement and with the control rod fully inserted, the control rod and rack assembly can be rotated with the pinion gear still engaged to the rack.

5.2 Rack and Pinion Drive - Rack Integral with Cruciform Blade

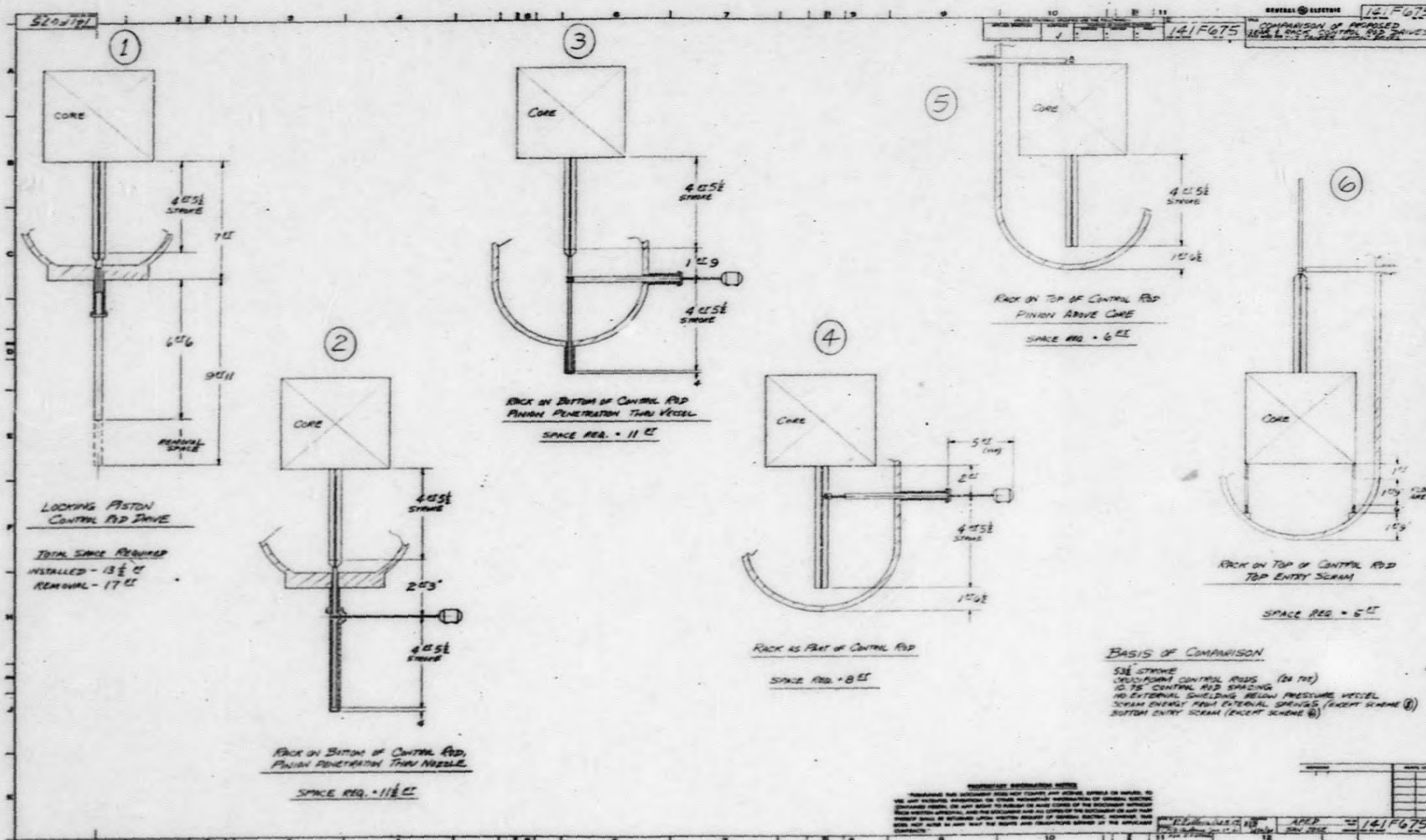
Drawing No. 612D584, Page A-8, illustrates the guidance and rack design problems encountered with an integral rack and cruciform rod. This system is not considered practical.

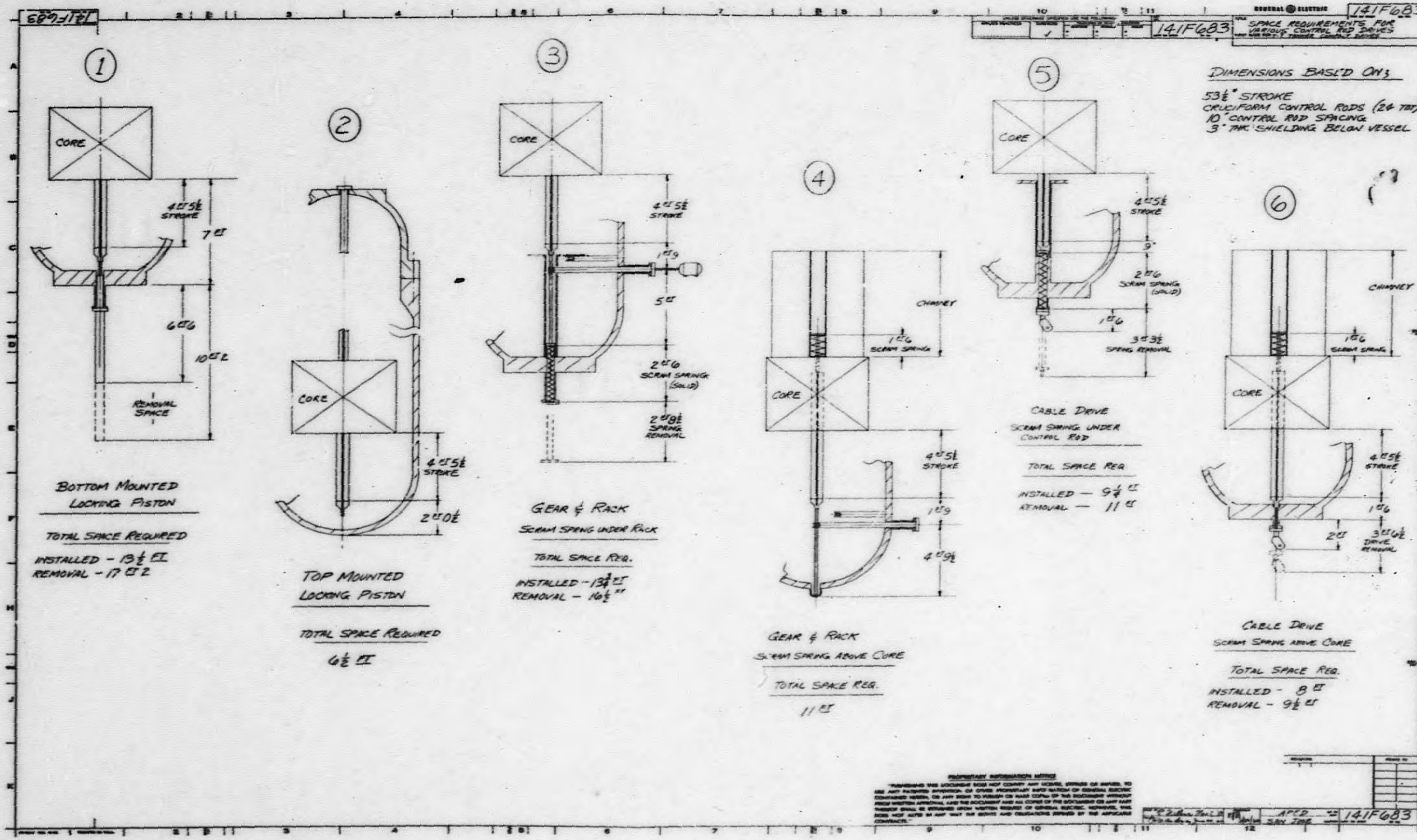
5.3 Cable Control Rod Drive

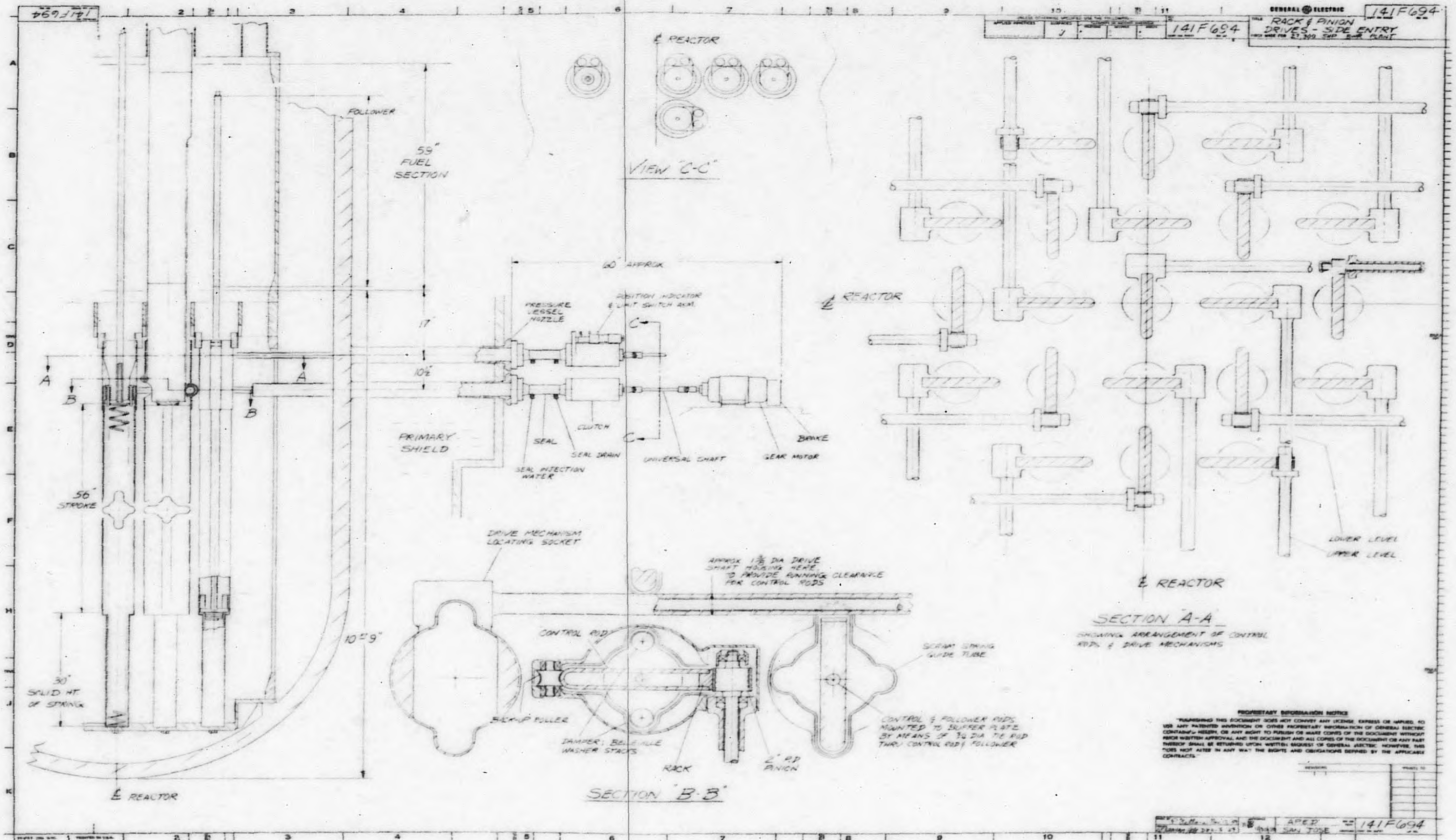
Drawing No. 612D585, Page A-9, illustrates the use of bottom-mounted cable drives in a 24-drive arrangement. A brake-motor arrangement similar to that used on gear and rack mechanisms is utilized to maintain control rod position. The drum is rotated by the drive shaft through a rotary face seal. A means of backseating for mechanism removal, and removal of the scram spring from the bottom in a cocked condition are also illustrated.

APPENDIX

Drawing No.		Page No.
141 F 675	Comparison of Proposed Gear and Rack Control Rod Drives	A-2
141 F 683	Space Requirements for Various Control Rod Drives	A-3
141 F 694	Rack and Pinion Drives - Side Entry	A-4
612 D 559	Rack and Pinion Drives - External Components	A-5
141 F 708	Removal Method - Rack and Pinion Drives	A-6
141 F 707	Rack and Pinion - Cruciform Control Rod	A-7
612 D 584	Rack and Pinion - Rack Integral with Cruciform Blade	A-8
612 D 585	Cable Control Rod Drive	A-9


141F675
COMPARISON OF PROPOSED RACK & PINION CONTROL ROD DRIVES
CORE
LOCKING PISTON CONTROL ROD DRIVE
TOTAL SPACE REQUIRED
INSTALLED - 13½ FT
REMOVAL - 17 FT
RACK ON BOTTOM OF CONTROL ROD, PINION PENETRATION THRU NOZZLE
SPACE REQ. - 11½ FT
RACK ON BOTTOM OF CONTROL ROD PINION PENETRATION THRU VESSEL
SPACE REQ. - 11 FT
RACK AS PART OF CONTROL ROD
SPACE REQ. - 8 FT
RACK ON TOP OF CONTROL ROD PINION ABOVE CORE
SPACE REQ. - 6 FT
RACK ON TOP OF CONTROL ROD TOP ENTRY SCRAM
SPACE REQ. - 5 FT
BASIS OF COMPARISON
53½ STROKE
CRUCIFORM CONTROL RODS
10.75 CONTROL ROD SPACING
NO EXTERNAL SHIELDING BELOW PRESSURE VESSEL
SCRAM ENERGY FROM EXTERNAL SPRINGS (EXCEPT SCHEME 6)
BOTTOM ENTRY SCRAM (EXCEPT SCHEME 6)


GENERAL ELECTRIC
141F683
SPACE REQUIREMENTS FOR VARIOUS CONTROL ROD DRIVES
DIMENSIONS BASED ON:
53½" STROKE
CRUCIFORM CONTROL RODS (24 TOT)
10" CONTROL ROD SPACING
3" THK. SHIELDING BELOW VESSEL
① CORE
4 FT 5½ STROKE
7 FT
6 FT 6
10 FT 2
REMOVAL SPACE
BOTTOM MOUNTED LOCKING PISTON
TOTAL SPACE REQUIRED
INSTALLED - 13½ FT
REMOVAL - 17 FT 2
② CORE
4 FT 5½ STROKE
2 FT 0½
TOP MOUNTED LOCKING PISTON
TOTAL SPACE REQUIRED
6½ FT
③ CORE
4 FT 5½ STROKE
1 FT 9
5 FT
2 FT 6 SCRAM SPRING (SOLID)
2 FT 8½ SPRING REMOVAL
GEAR & RACK
SCRAM SPRING UNDER RACK
TOTAL SPACE REQ.
INSTALLED - 13¾ FT
REMOVAL - 16½ FT
④ CHIMNEY
1 FT 6 SCRAM SPRING
CORE
4 FT 5½ STROKE
1 FT 9
4 FT 9½
GEAR & RACK
SCRAM SPRING ABOVE CORE
TOTAL SPACE REQ.
11 FT
⑤ CORE
4 FT 5½ STROKE
9"
2 FT 6 SCRAM SPRING (SOLID)
1 FT 6
3 FT 3½ SPRING REMOVAL
CABLE DRIVE
SCRAM SPRING UNDER CONTROL ROD
TOTAL SPACE REQ
INSTALLED — 9¼ FT
REMOVAL — 11 FT
⑥ CHIMNEY
1 FT 6 SCRAM SPRING
CORE
4 FT 5½ STROKE
1 FT 6
2 FT
3 FT 6½ DRIVE REMOVAL
CABLE DRIVE
SCRAM SPRING ABOVE CORE
TOTAL SPACE REQ.
INSTALLED - 8 FT
REMOVAL - 9½ FT
PROPRIETARY INFORMATION NOTICE
APED
SAN JOSE
141F683



GENERAL ELECTRIC
141F694
RACK & PINION DRIVES - SIDE ENTRY
27,300 SHP BWR PLANT
℄ REACTOR
VIEW "C-C"
FOLLOWER
59" FUEL SECTION
17"
10½"
60" APPROX
PRESSURE VESSEL NOZZLE
POSITION INDICATOR & LIMIT SWITCH ASM.
PRIMARY SHIELD
SEAL
CLUTCH
SEAL DRAIN
SEAL INJECTION WATER
UNIVERSAL SHAFT
GEAR MOTOR
BRAKE
56" STROKE
30" SOLID HT. OF SPRING
10'-9"
DRIVE MECHANISM LOCATING SOCKET
APPROX 1⅜ DIA DRIVE SHAFT HOUSING HERE TO PROVIDE RUNNING CLEARANCE FOR CONTROL RODS
CONTROL ROD
BACK-UP ROLLER
DAMPER: BELLEVILLE WASHER STACKS
RACK
2" PD PINION
SCRAM SPRING GUIDE TUBE
CONTROL & FOLLOWER RODS MOUNTED TO BUFFER PLATE BY MEANS OF ¾ DIA TIE ROD THRU CONTROL ROD & FOLLOWER
SECTION "B-B"
SECTION "A-A"
SHOWING ARRANGEMENT OF CONTROL RODS & DRIVE MECHANISMS
LOWER LEVEL
UPPER LEVEL
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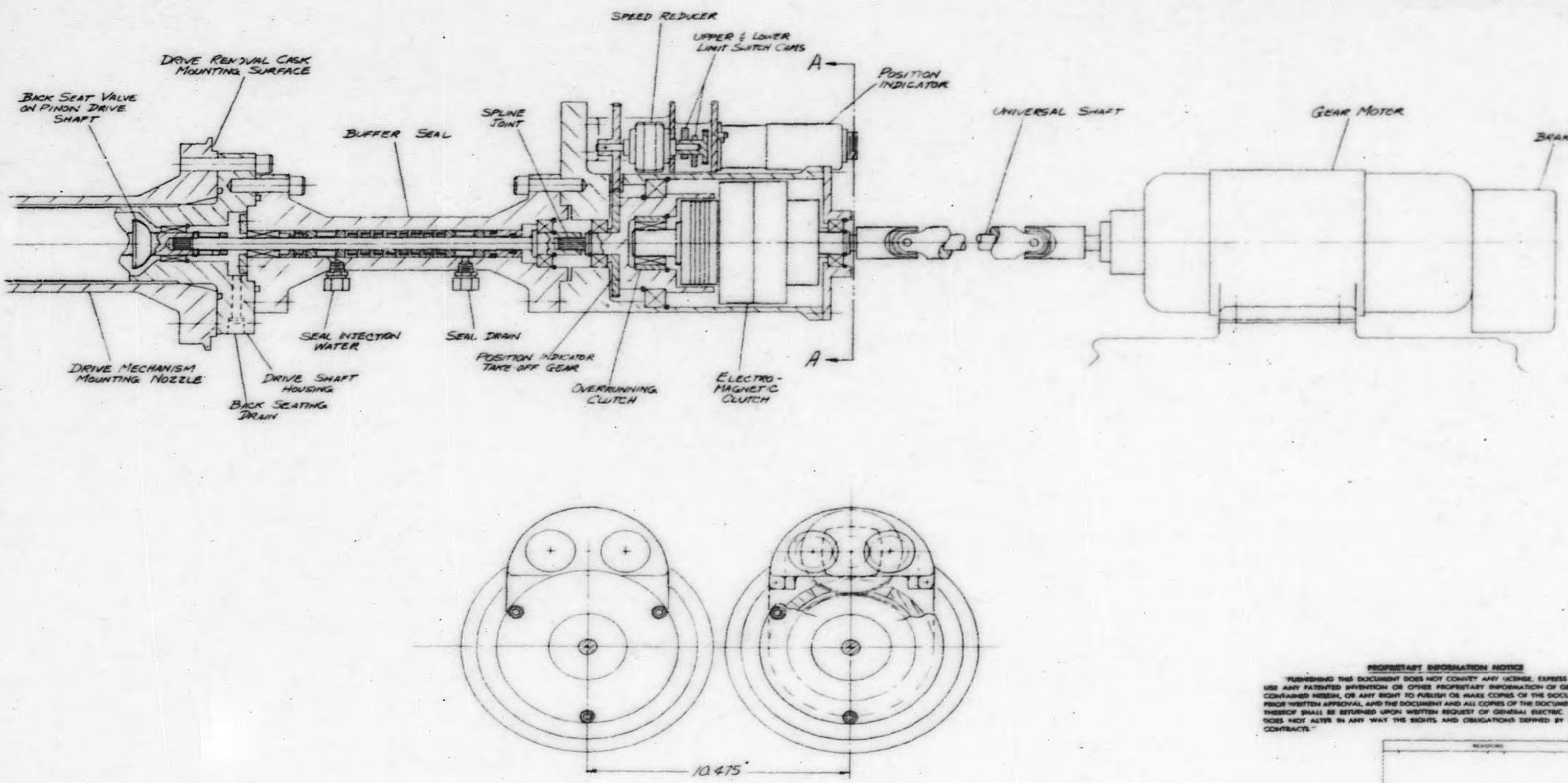
141F694

GENERAL ELECTRIC

612D559

RACK & PINION DRIVES - EXTERNAL COMPONENTS

FOR 27,300 SHP BWR PLANT

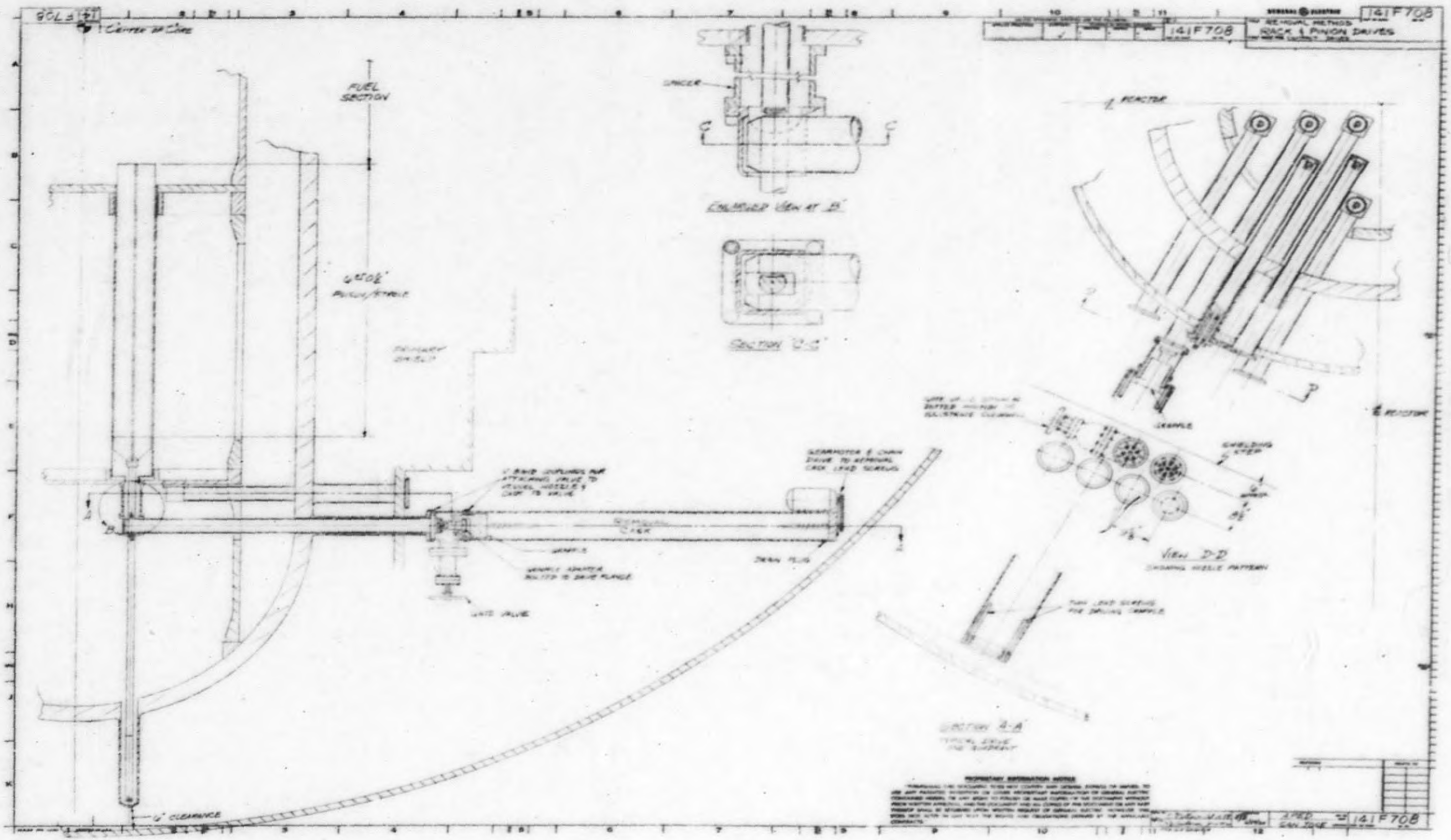


SECTION "A-A"

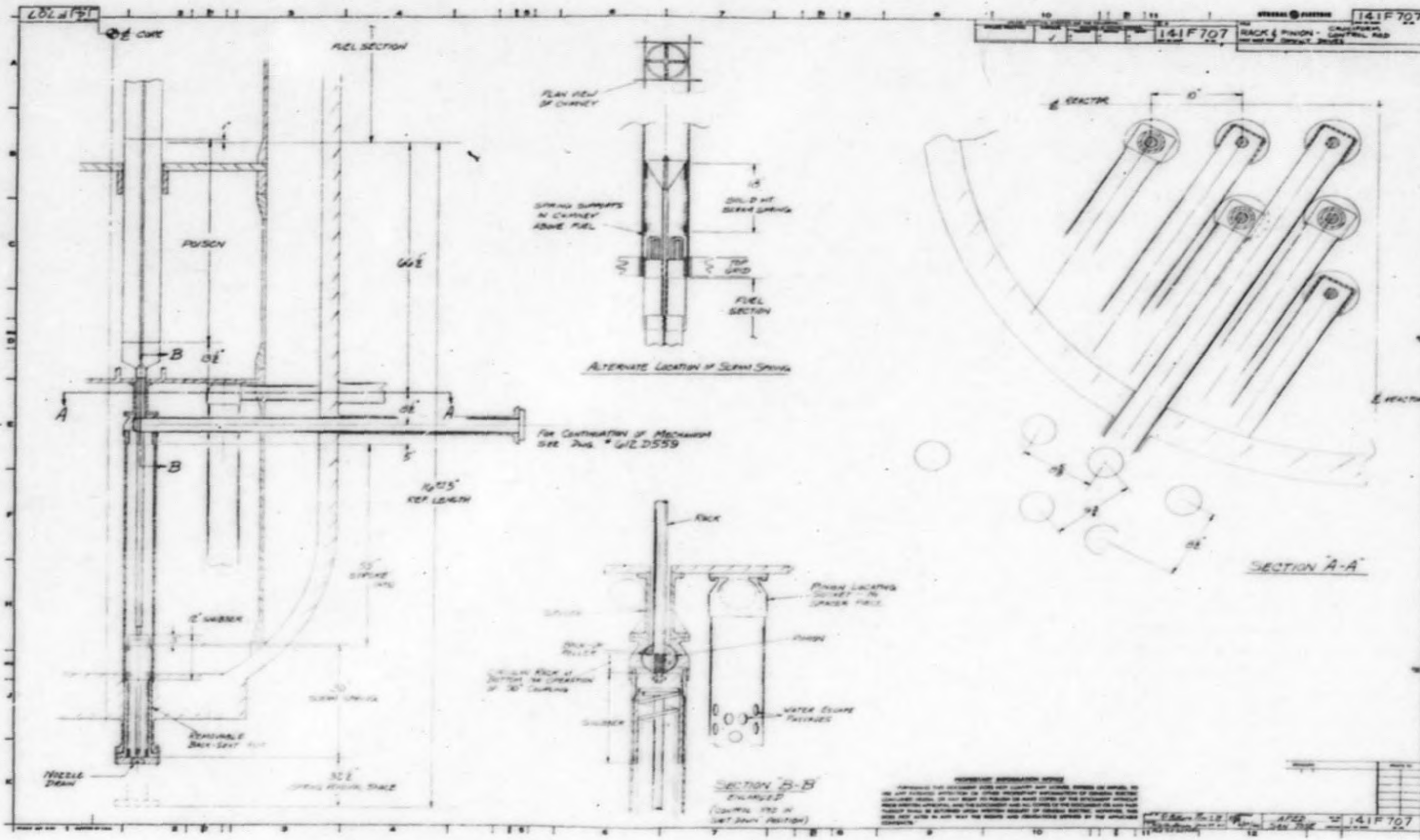
REVISIONS

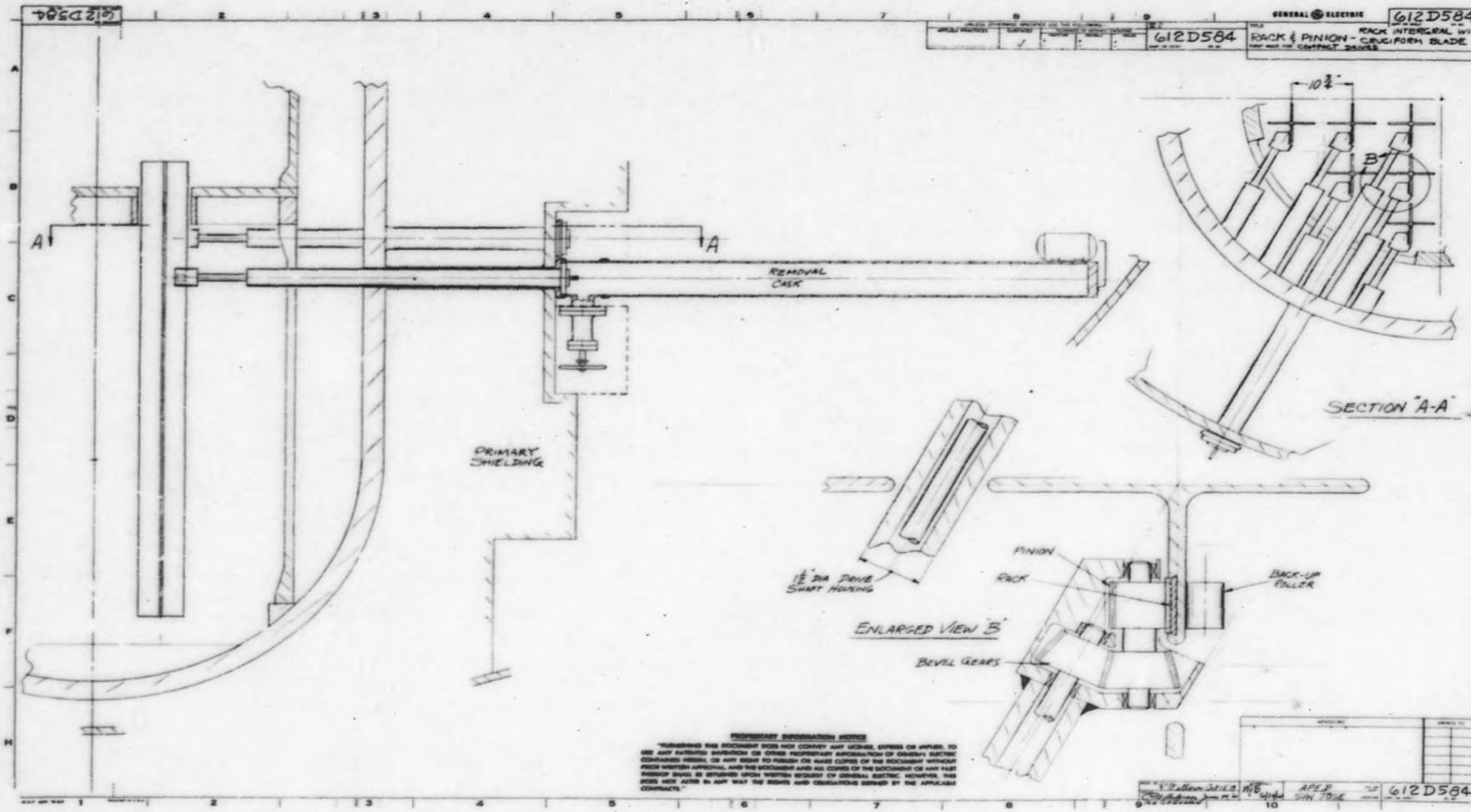
APED SAN JOSE

612D559



141F708
GENERAL ELECTRIC
REMOVAL METHOD
RACK & PINION DRIVES
CENTER OF CORE
FUEL
SECTION
PRIMARY
SHIELD
SPACER
ENLARGED VIEW AT 'B'
SECTION 'C-C'
GRAPPLE
VIEW D-D
GRAPPLE ADAPTER
BOLTED TO DRIVE FLANGE
GATE VALVE
DRAIN PLUG
SECTION 'A-A'
TYPICAL DRIVE
CLEARANCE
APED
SAN JOSE


141F707
RACK & PINION
FUEL SECTION
POISON
PLAN VIEW OF CHIMNEY
SPRING SUPPORTS IN CHIMNEY ABOVE FUEL
TOP GRID
FUEL SECTION
ALTERNATE LOCATION OF SCRAM SPRING
FOR CONTINUATION OF MECHANISM SEE DWG # 612D559
REF LENGTH
RACK
PINION
SNUBBER
WATER ESCAPE PASSAGES
NOZZLE DRAIN
SECTION "B-B" ENLARGED
SECTION "A-A"
141F707



GENERAL ELECTRIC
612D584
RACK & PINION - RACK INTERGRAL WITH CRUCIFORM BLADE
COMPACT DRIVES
10 3/4"
A
A
B
REMOVAL CASK
PRIMARY SHIELDING
SECTION "A-A"
1 1/2" DIA DRIVE SHAFT HOUSING
ENLARGED VIEW "B"
PINION
RACK
BACK-UP ROLLER
BEVEL GEARS
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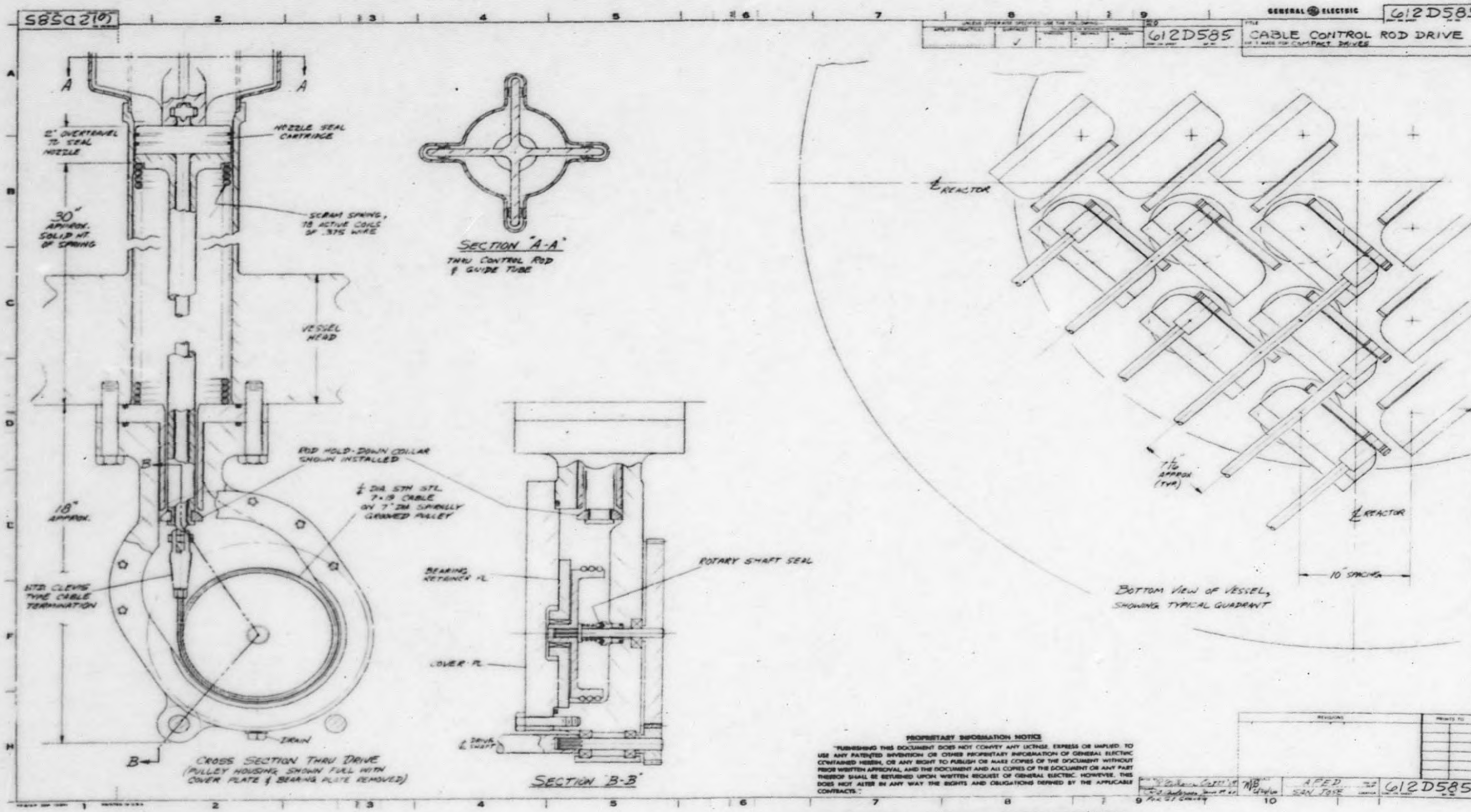

GENERAL ELECTRIC
612D585
CABLE CONTROL ROD DRIVE
COMPACT DRIVES
2" OVERTRAVEL TO SEAL NOZZLE
NOZZLE SEAL CARTRIDGE
30" APPROX. SOLID HT. OF SPRING
SCRAM SPRING, 18 ACTIVE COILS OF .375 WIRE
SECTION "A-A"
THRU CONTROL ROD & GUIDE TUBE
VESSEL HEAD
ROD HOLD-DOWN COLLAR SHOWN INSTALLED
1/4 DIA. STN STL 7×19 CABLE ON 7" DIA SPIRALLY GROOVED PULLEY
18" APPROX.
STD. CLEVIS TYPE CABLE TERMINATION
DRAIN
CROSS SECTION THRU DRIVE
(PULLEY HOUSING SHOWN FULL WITH COVER PLATE & BEARING PLATE REMOVED)
BEARING RETAINER PL.
ROTARY SHAFT SEAL
COVER PL.
SECTION "B-B"
℄ REACTOR
7 1/2" APPROX (TYP)
10" SPACING
BOTTOM VIEW OF VESSEL, SHOWING TYPICAL QUADRANT
AFED
SAN JOSE
612D585

END