NPD G.S.

SYSTEM TRAINING MANUAL

053

REACTOR BOILER AND AUXILIARIES

FUEL HANDLING SYSTEM

This manual is issued as an indoctrination course on the N.P.D. Fuel Handling System. The successful completion of the course and examinations will, however, be required as partial NO 4, NC 4 or NM 4 qualifications.

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NPD Systems - Reactor Boiler and Auxiliaries

Fuel Handling System

NEW FUEL PORT

The New Fuel Ports, one East and one West, connect between the respective East and West New Fuel Rooms and the Fuelling Machine Room. The primary purpose of the ports is to permit the loading of the Fuelling Machines without the necessity for the entry of personnel into the Fuelling Machine Room. Each port has built-in shielding providing radiation attenuation equivalent to that of the wall in which it is located.

The control of each port is fully integrated with the associated Fuelling Machine control system. Independent local control from the portable control panel is also possible.

CONSTRUCTION (See Fig. 1)

Each port comprises the following major sub-assemblies, (1) main housing, (2) shielding block, (3) magazine and magazine housing, (4) end fitting and plug, (5) loading port, (6) magazine drive and (7) hydraulic charging cylinder.

Main Housing

Support for the entire New Fuel Port is provided by the main housing which also encloses the shielding block and magazine housing. Magazine angle brackets and feet are welded to the outside of the housing which, in conjunction with bolts and jam-nuts, provide for the initial levelling and alignment of the Port before its final grouting into the concrete wall.

Shielding Block

Located at the Fuelling Machine Room end of the main housing is a shielding block assembly of masonite and steel laminations. Three steel and four masonite discs are bolted together to make up a stepped shielding plug 12 inches deep. Held in position in the main housing by means of retaining blocks, the shielding block is designed to provide shielding equivalent to that of the wall.

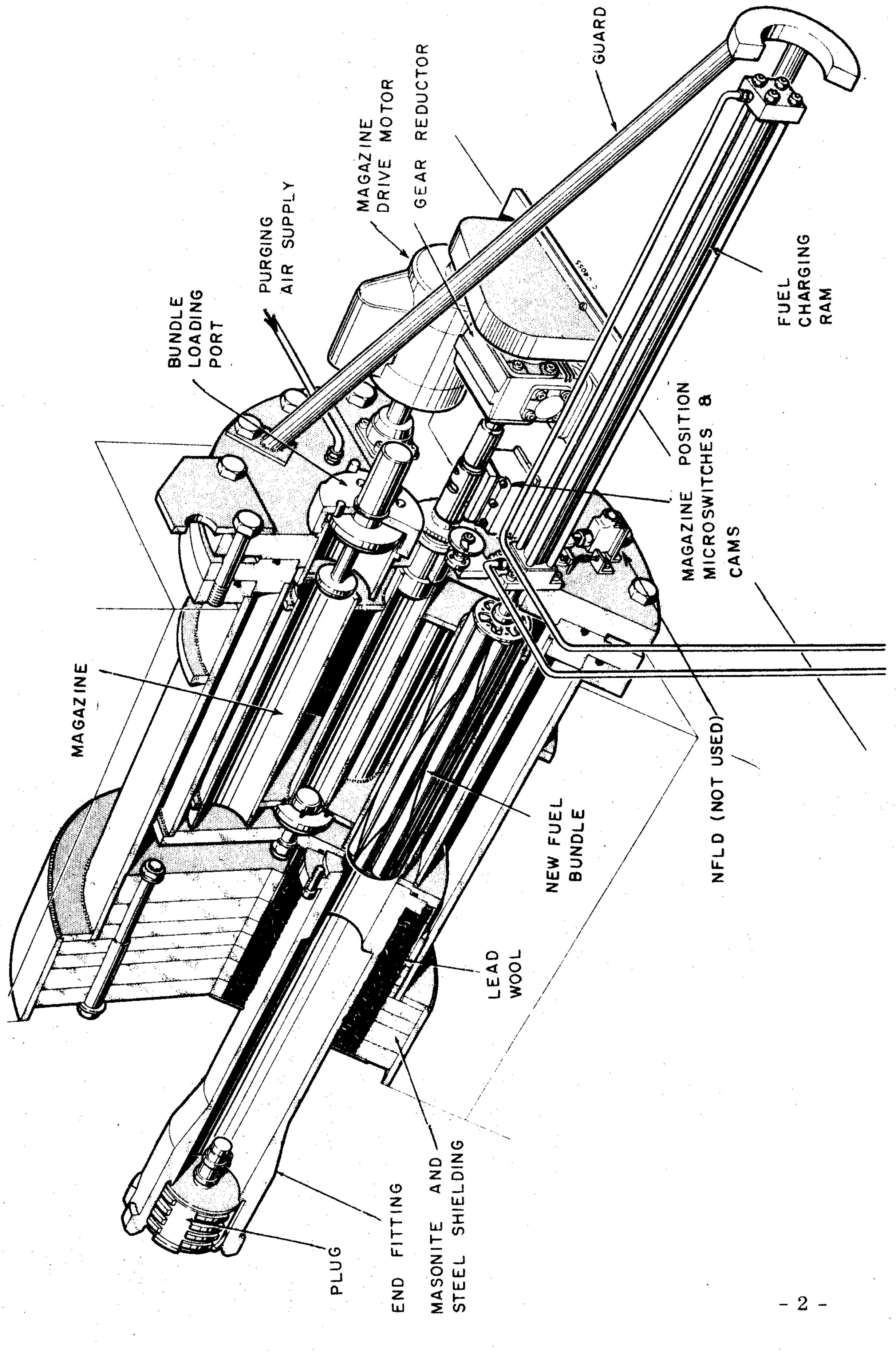


Figure 1 New Fuel Port

Threaded holes in the outermost steel shielding plate accommodate eye-bolts for removing or replacing the block.

The end-fitting passes through an 8-3/4 inch diameter hole in the shielding block. After the end-fitting has been bolted into position, the resulting annular space between the fitting and the hole in the shielding block is filled with tightly packed lead wool. Removal of the shielding block is possible from the Fuelling Machine Room provided that the lead wool is first removed.

Magazine and Magazine Housing

The magazine housing contains and partially supports the magazine. The housing itself is cantilevered from its own ring-flange which is sandwiched between a flange on the main housing and the end cover. The end plate on the magazine housing provides the attachment point for the cantilever-mounted end-fitting. The end plate also supports the inboard magazine bearing. All flanges of the magazine housing are equipped with O- ring seals and the housing itself is designed to contain an air pressure of 80 psi. A radial hole drilled into the bottom of the ring flange and closed by a Swagelok plug provides a drain point for D_2O condensate in the port.

The magazine is supported concentrically within the housing end-plate and the end cover. Two steel end-plates support five steel magazine channels lined with 2S aluminum tubing which prevents damage to the fuel bundles traversing the channels. The magazine is driven from the outboard stub-shaft which is flanged to the end-plate and extends through the end cover to engage the drive coupling. Magazine rotation is at the rate of 1-1/2 rpm.

The magazine housing, magazine, end-fitting and end cover are designed to be removed as a unit from the New Fuel Room side.

End-Fitting and Plug

The end-fitting is cantilevered from the magazine housing end-plate and extends through the shielding block into the Fuelling Machine Room. Closure of the end-fitting as well as Fuelling Machine homing, sealing and locking arrangements are identical to those at the Reactor. Internally, the fitting is machined to simulate the Reactor end-fitting and spacer sleeve, i.e. the internal shoulder represents the spacer sleeve and is the point to which the Fuelling Machine's Fuel carrier is advanced for the transfer of fuel bundles from the port.

End-Cover and Sealing Cover

The steel end cover is machined to mate with the flanges of the main housing and the magazine housing. It accomodates the loading port, the entry of the charging ram, micro-switch actuator shafts, pressure line and drive shafts and carries the magazine front bearing housing. The base plate for the magazine drive unit, the electric brake, microswitches, charging cylinder, and guard frame are all secured to the end-cover. All passages through the cover are sealed to provide pressure-tightness.

The loading port sleeve, with an inside diameter 3-7/8 inches, is welded into the end-cover. Four lugs on its external surface engage with the sealing cover to provide a pressure-tight closure. A push-rod, integral with the sealing cover, gives each fuel bundle a precise axial position with respect to the magazine at the time of loading the bundle into the port. This is necessary for the correct operation of certain micro-switches associated with position control of the magazine.

A flow of purging air is connected into the new fuel port through a solenoid operated valve. The valve is normally open but is closed when the fuelling machine has homed on and removed the end fitting plug. The purging air is discharged into the ventilation system.

Magazine Drive

The drive unit, mounted on its base-plate, consists of a 1/4 - h.p., 1100 rpm, double-ended electric motor, an electric brake, a chain drive, and a 300:1 reducer unit. One shaft extension of the motor is connected directly to a Warner 1/4 hp electric brake and the other drives the input of the reducer unit through a roller-chain and sprockets. The output shaft of the reducer drives the magazine at 1-1/2 rpm. The magazine rotates in a clockwise direction in the East new fuel port and anti-clockwise in the West new fuel port. Two cam-wheels, driven by the shaft; operate micro-switches which have control and indicating functions in the magazine drive. For a more detailed treatment of the functions of the various detectors, refer to "Operation and Control" in this lesson.

Hydraulic Charging Cylinder

The double-acting charging cylinder and ram operate to push the fuel bundle out of the magazine and into the fuel carrier of the Fuelling Machine. The working fluid is hydraulic oil supplied from the hydraulic power unit in the New Fuel Room. This unit also supplies the Shielding Gate and fine X systems. See Figure 3.

Glaswitch position detectors, mounted on the cylinder at the extremities of piston travel, are operated by ceramic magnets on the piston to indicate and control ram position. Refer to Operation and Control in this lesson.

OPERATION AND CONTROL

Normal operation of the New Fuel Port is fully integrated with the Fuelling Machine Control System. Local control from the portable control panel is also possible under the supervision of the operator at the fuelling machine control console.

Detectors

The detectors associated with the control of the New Fuel Port are as follows:

NMPD - New Fuel Port Magazine Position Detector. A cam wheel, driven at a 5-to-1 ratio from the magazine drive shaft, operates a micro-switch when any one of the magazine fuel positions is aligned for charging, i.e. is co-axial with the end fitting. The operation of this detector is ANDed with NR01D to NR05D.

NRO1D to NRO5D - Five detectors which are normally held open but are closed in conjunction with NMPD to indicate when a particular fuel port magazine channel is aligned with the loading port. Indication is given on the control console by the five indicator lights, NR01 to NR05. These lights are also used to indicate which magazine channel is opposite the eject fuel port during transfer of the fuel bundles to the fuelling machine.

NLPD - Contacts of NLPD are closed when the sealing cover on the fuel loading port is in place. An indicator on the control console is on when the port is closed.

NRRD - When the ram of the charging cylinder is fully retracted, the NRRD Glaswitch detector is actuated and the NRR indicator on the control console is on.

NRFD - When the ram is fully forward, the NRFD Glaswitch detector is actuated and the NRF indicator on the control console is on.

Drives

NFMM - New fuel magazine motor. Rotates in one direction only. Indicators NMMC and NMMH on control console both on when operating under computer control. Only indicator NMMH on when operating under manual control of control console switch.

NBK - New fuel magazine brake. Operated with the magazine drive motor, the brake is energized to release. An indicator NBKH on the console is on when the brake is energized.

NRFV and NRRV - The two solenoids of the four-way, three position control valve which controls the new fuel port ram. With NRFV energized, the ram moves the fuel into the fuelling machine carrier until NRFD is actuated. The ram is retracted when NRRV is energized.

NPBV - New fuel room oil pump selector valve. Must be energized to allow a pressure build up in the new fuel room oil pump circuit.

Loading the Port with New Fuel

A sequence is provided as part of the control system software for loading the new fuel port. It must be used in conjunction with voice communication between the fuel loading operator and the console operator.

The correct mode and sequence are selected at the control console and the first channel to be loaded is selected by pushing one of the five selector buttons marked NMO1K to NMO5K and LP. When the magazine has reached its selected position, the applicable indicator NRO1 to NRO5 comes on.

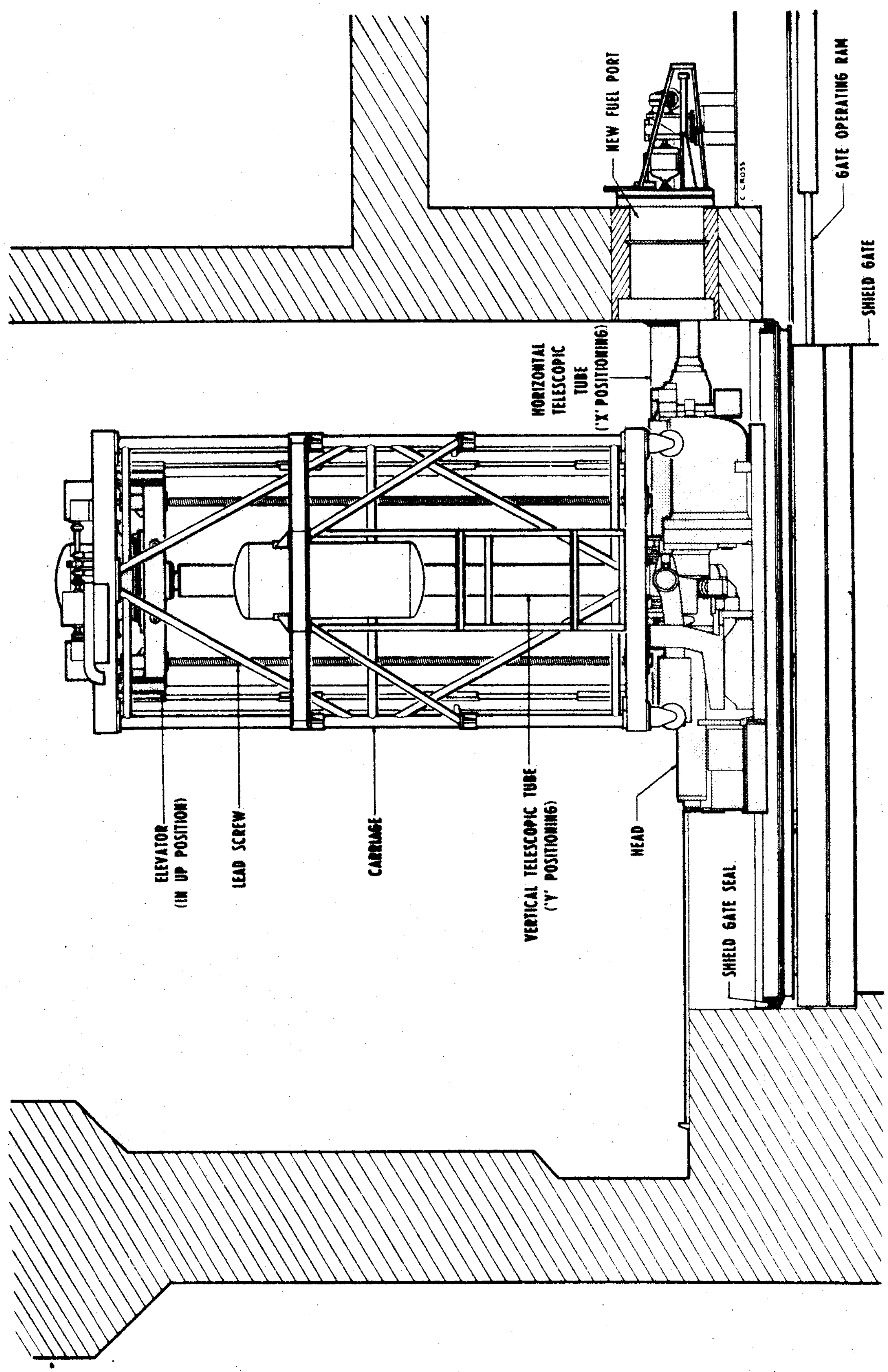
The fuel loading operator then opens the sealing cover and slides a bundle into the magazine. The sealing cover is then replaced and the next magazine position indexed and loaded and so on until the required number of channels are loaded. Indicators NPO1F to NPO5F on the console indicate the new fuel magazine channels which are full.

Fuelling Machine Accepting Fuel from the New Fuel Port

The fuelling machine to be loaded with fuel is first traversed to its new fuel port by selection of the required sequence.

With the machine at the new fuel port, the sequence "Accept Fuel from New Fuel Port" is selected. The fuelling machine magazine position to be loaded, the new fuel port magazine position, and new fuel port eject fuel are selected at the control console.

When OPERATE is selected, the fuelling machine picks up a fuel carrier and advances it into the new fuel port. The new fuel magazine is then indexed to the selected channel, with NMPD and NRO?D ANDed to give a DONE. The new fuel ram is then moved forward, NRFV energized, to move the fuel bundle into the fuel carrier, NRFD giving a DONE at the end of the stroke. The new fuel port ram is then retracted and the fuelling machine completes the sequence by placing the fuel carrier and bundle into the magazine which is then rotated to position M1. If further bundles are to be transferred from the new fuel port to the fuelling machine, the sequence must be repeated, selecting the required fuelling machine magazine channel which is to be loaded and the new fuel port magazine channel which contains the required bundle.



Fuelling Machine
Receiving New Fuel

Figure 2 Fuelling Machine At Home Position

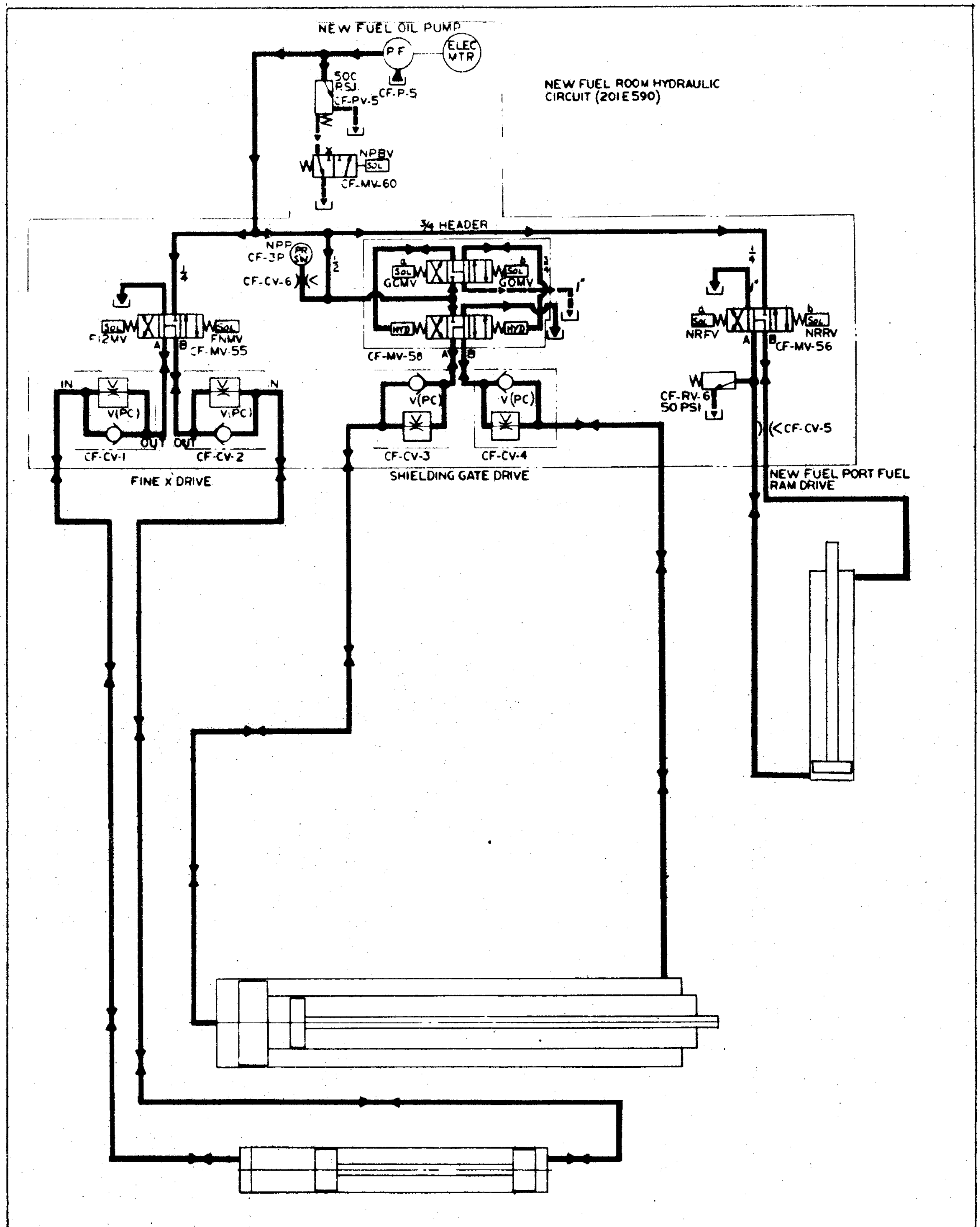


Figure 3 New Fuel Room Hydraulic Circuit

NPD Systems - Reactor Boiler and Auxiliaries

Fuel Handling System

GENERAL DESCRIPTION OF FUELLING OPERATION

The primary release of energy in the NPD reactor takes place in the 132 horizontal fuel channels, each of which contains nine fuel bundles. The nine bundles in each channel are contained in and supported by a Zircaloy 2 pressure tube approximately 13 feet long through which the heavy water coolant (heat transfer liquid) is pumped. Heat resulting from fission in the fuel is transferred to the heavy water as it flows along the channel. The coolant in the inlet header is at 982 psia and 479^{o}F and in the outlet header is at 823 psia and 520^{o}F. The coolant flow in adjacent channels is in opposite directions.

In any given channel, the power produced depends on the location of the channel in the reactor core. Channels near the centre of the reactor, where the neutron flux is highest, produce more power than channels located in the outer regions of the core where the flux is lower. At full-power operation, a fuel bundle in mid channel in a central location, produces approximately 170 Kwh, whereas the output of a fuel bundle in the corresponding position in an outer channel, is approximately 50 Kwh. For this reason, fuel in the central channels is of the 19-element type while 7-element fuel bundles are used in the outer channels. Both types are 19-1/2 inches long and contain approximately 32 pounds of uranium oxide (UO_2) for a total bundle weight of 35 pounds.

The rate of coolant flow in each channel is fixed by an orifice plate at the inlet end. These orifices are sized to produce a temperature rise across each channel, which is, as nearly as practicable, the same for all channels.

New fuel bundles enter the channel at the coolant outlet end and pass through a fuel latch. See Figure 3. This latch acts as a "non-return valve" for the fuel to permit fuel movement in the channel in one direction only. The bundle traverses the channel against the direction of coolant flow and leaves the coolant inlet end in a fully irradiated condition. Fuelling is accomplished by two fuelling machines, one located at each end of the channel where fuelling is to be carried out. One machine inserts one new fuel bundle at a time, pushing the entire string of fuel bundles along the channel, one bundle length. One bundle is therefore ejected at the opposite end of the channel to be received by the second machine.

Under normal conditions, the time taken for a bundle to pass completely through a channel must be long enough to result in a total energy yield by the bundle of approximately 6300 Mw.d/T or 150 Mw.h/kg.U. Since central

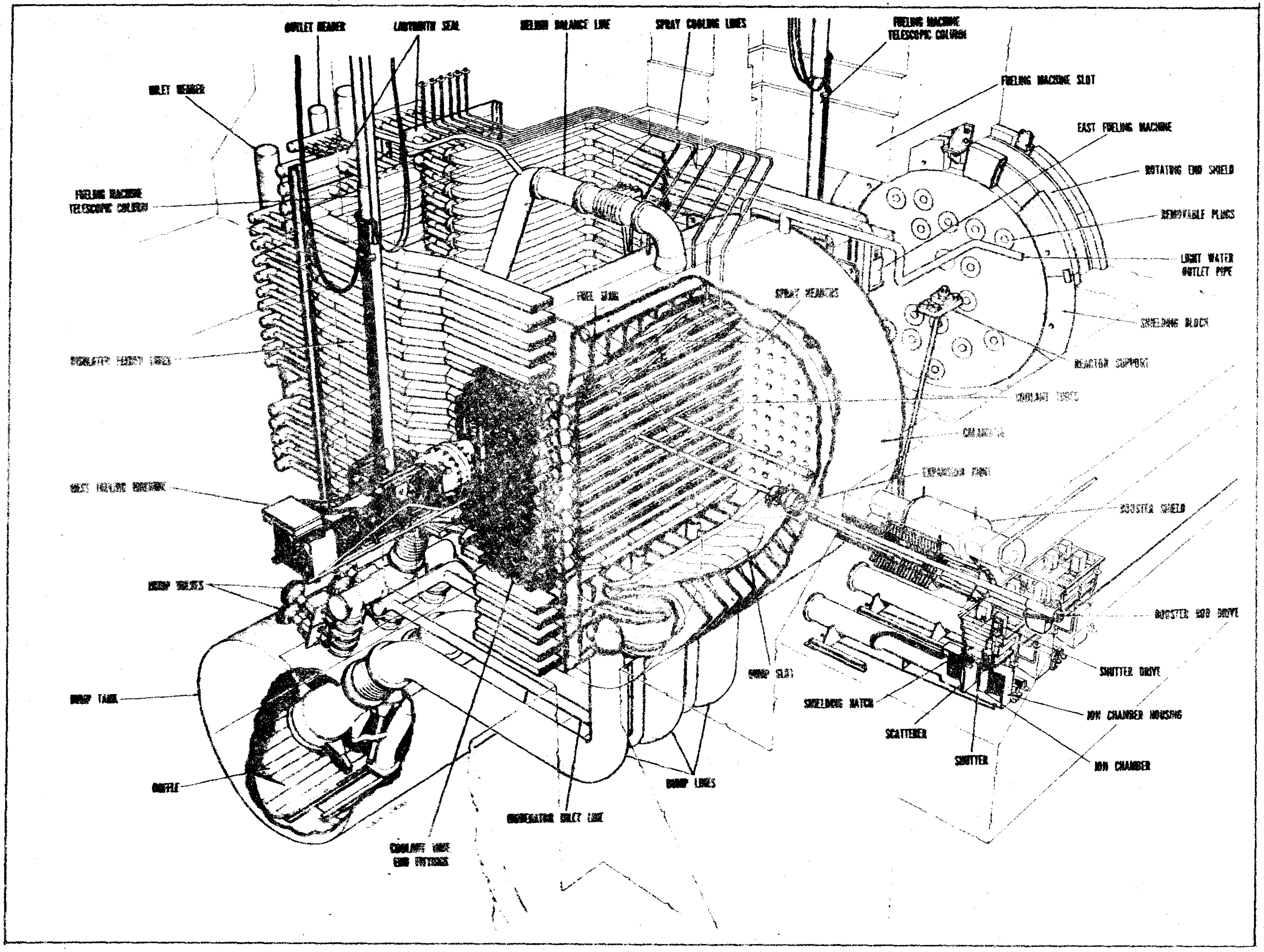


Figure 1 NPD-2 Reactor Cut-away

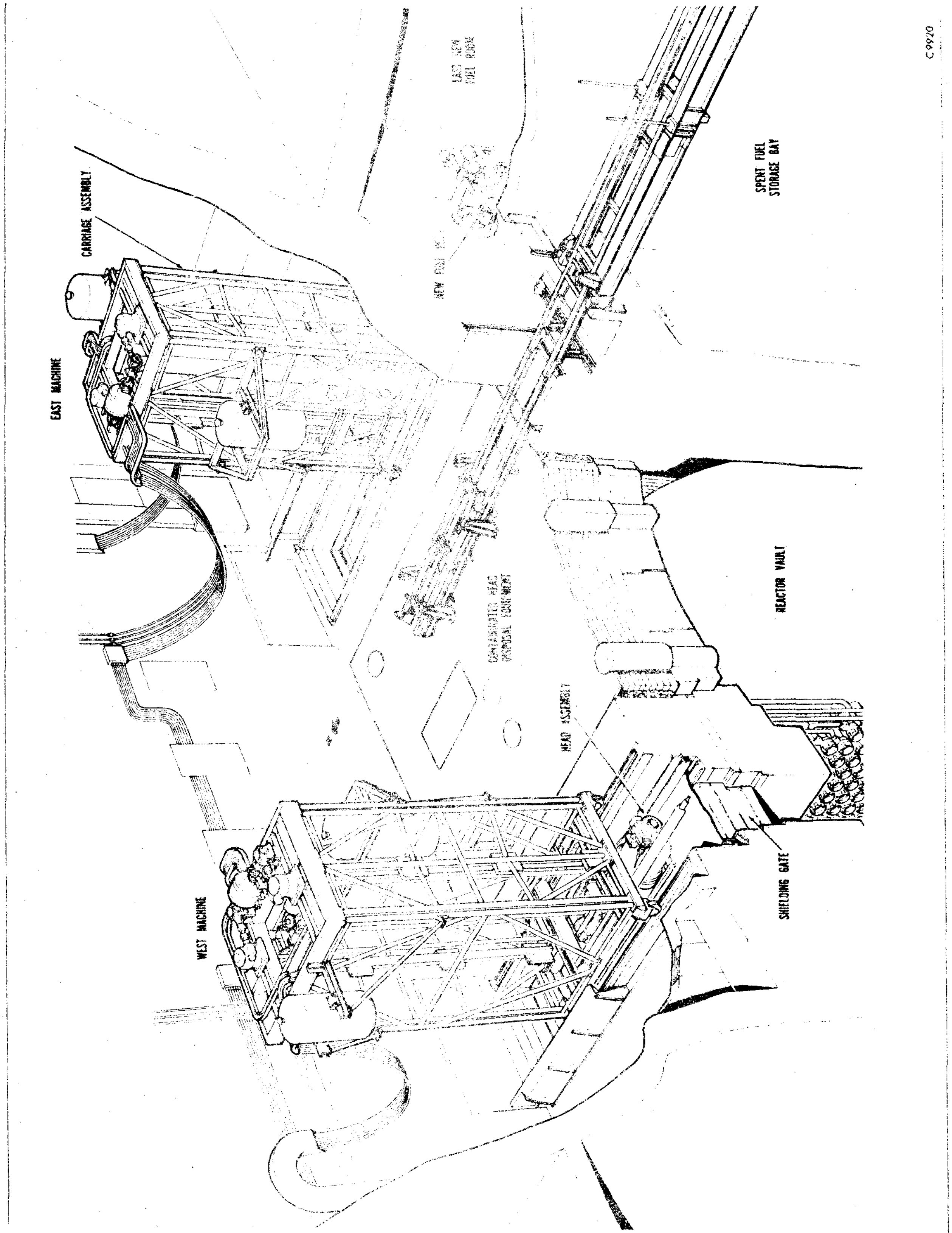


Figure 2 General View of Fuelling Machine Room

channels in the reactor produce more energy than the outer ones, fuel moves through the central channels faster, e.g. a bundle takes approximately 2.8 years to move through a central channel having a power output of 1 Mw while the traverse time for a 0.3 Mw outer channel is approximately 9 years.

EQUIPMENT AND CONTROL

The items of equipment involved in routine fuel changing are the Fuelling Machines (2), New Fuel Ports (2), Shielding Gates (2) and normal Spent Fuel Ports (2). In each case there is an East and a West Unit. The general arrangement of the fuelling equipment is shown in Figures 1 and 2.

Control is by two identical and separate control systems, one for the East Fuelling Machine and one for the West. There is interconnection between the two systems only during one phase of the fuelling operation. At all other times the systems are entirely independent. The systems operation is normally automatic under the control of the computer program. However, manual control is possible from the main control console and from a portable control panel in the fuelling machine area. Key-switches on the control console ensure that manual control can only be performed under supervision.

Fuelling Machines

A Fuelling Machine is shown in Figure 4. The two machines are identical, differing in function only, i.e. during a fuelling operation, one machine functions as the new fuel carrier and the other as the spent fuel receiver. Each machine can perform either role, as required by the reactor lattice site where fuelling is to be carried out.

During the entire fuelling operation, the machines can neither be approached nor observed and are remotely controlled. Over a large part of their operating cycle for on-power refuelling, their heads function in intense fields of radio activity of the order of 10^6 R/hour and are subjected to an internal temperature and pressure of between 400 and 500°F and 1100 psig.

When not in use the machines are locked onto the New Fuel Port in the Fuelling Machine Room. Access to this room is possible only with the Shielding Gates closed.

New Fuel Ports

The New Fuel Ports transfer the new fuel bundles from the New Fuel Rooms into the fuelling machine heads. Each port allows loading of its fuelling without personnel having to enter the Fuelling Machine Room. Each port has a capacity of five bundles which are inserted into the the port from the New Fuel Room. From the port, the fuel bundles are transferred to the fuelling machine which is locked on to the end fitting of the port.

Shielding Gates

Two slots in the shielded floor of the Fuelling Machine Room permit the passage of the fuelling machine heads into the Reactor Vault below. When the machines are not in operation these slots are kept closed by the Shielding Gates. Driven by an oil-hydraulic telescopic cylinder located in the New Fuel Room, each gate is spring-mounted on rollers to permit horizontal movement to open or close its slot. When fully retracted, the gates are located under the floor of the New Fuel Room. Each gate weighs approximately 30 tons and has a total horizontal travel of 13 feet.

When the gates are closed, a positive seal between the Reactor Vault and the Fuelling Machine Room is provided by air-inflated rubber seals around the tops of the gates.

Spent Fuel Discharge Chutes (Fig. 8 and 9)

Two spent fuel chutes serve each face of the reactor. The upper ends of the chutes terminate in end-fittings with removable-plug closures identical to those at the reactor. (Figure 3). A bundle ejected from a fuelling machine slides by gravity down the chute into the spent fuel storage bay where it enters spent fuel handling equipment positioned to receive it.

THE FUELLING SEQUENCE

Machines in the Home Position (Fig. 5)

When not in use the machines reside in the Fuelling Machines Room locked onto the N.F.P. The states of each machine's main mechanical components which define the "Home" condition are as follows:

1. Head in "AZIMUTH SERVICE" position, i.e. the horizontal longititudinal axis of the head is parallel to the carriage rails.

2. Elevator in "UP" position.

3. Vertical telescopic column (Coarse "Y") at "YT" (upper travel limit).

4. Shielding Gate closed and gate seal air pressurized.

5. Horizontal telescopic column (Coarse "X") at "XN". At this "Coarse X" position, the snout of the machine is co-axial with the end-fitting of the New Fuel Port.

6. Machine locked on to N.F.P.

7. All drive and pump motors off.

At the start of the fuelling operation the operator establishes from the lattice position which machine will be the new fuel carrier (No. 1) and which the spent fuel receiver (No. 2). No. 1 is then sent to its New Fuel Port to be charged with new fuel while No. 2 is sent to the lattice site to await the arrival of No. 1 at the opposite end of the channel.

No. 1 Machine to Accept Fuel

The "Remove Plug" sequence is called up at the automatic panel and the machine removes the plug from the New Fuel Port end-fitting and stores it in its M2 or M6 magazine position.

"Accept Fuel" is now selected during which sequence of operations the internal mechanisms of machine and port are automatically co-ordinated by the control system. The hydraulically-operated ram on the New Fuel Room side of the port pushes a bundle from the N.F.P. magazine into the end of the fuelling machine's fuel carrier which has been pushed forward to receive it. The transferred bundle is then carried back in the fuel carrier by the charging tube and stored in one of the four fuel positions in the machine's magazine. If more than one fuel bundle is to be loaded into the machine, the "Accept Fuel" sequence is repeated the required number of times with the N.F.P. magazine automatically indexing to the next loaded position after each slug is transferred.

The plug is replaced in the end-fitting and the machine is then ready to begin the "Traverse to Reactor Lattice" section of the fuelling sequence.

No. 1 Machine to Reactor Lattice Position

At the Control Panel for No. 1 machine the operator initiates the "Traverse to Lattice" sequence and selects the specific lattice site by pressing the corresponding X and Y lattice position buttons. Automatic operation proceeds in the following sequence:

1. The machine unlocks and retracts from the N.F.P. end-fitting.

2. The machine carriage moves in the "X" direction to the "X-Keyhole" position, i.e. with the head positioned to pass through the slot in the shielding.

3. The shielding gate is opened.

4. The elevator is lowered to "Down" position.

5. The head is rotated in azimuth to "Normal" position.

The preceding operations locate the head in the Reactor Vault with its horizontal axis at right angles to the plane of the ends of the end-fittings and in the Y-axis approximately 12 inches above the "A" sites (Fig. 6).

6. Coarse positioning to the "X" lattice reference previously selected follows. Cam-operated micro-switches on the carriage tracks locate the machine snout to within ± 1/2 inch of the nominal "X" position.

7. Coarse "Y" positioning is accomplished in a similar manner. The machine is now located with the snout approximately 1/2 inch away from the end-fitting.

8. The head is fine-homed to the end-fitting. Moving forward at the rate of 1/4 inch per minute ("Z" motion), the head position is simultaneously corrected in X and Y to the condition of concentricity with the end-fitting. (Fig. 7)

9. The machine locks itself to the end-fitting. This operation seals the machine to the reactor channel.

<u>No. 1 Machine Remove Plug</u>

With the machine locked onto the end fitting and with the snout gap acceptable, the plug is removed:

1. The machine head is filled with heavy water from the reservoir on the carriage.

2. The head pressure is raised by an intensifier pump to reactor pressure plus 40 psi. A further seal test is performed automatically by isolating the pressurized head and monitoring the pressure over a fixed interval.

3. The plug is removed from the end-fitting and stored in the magazine.

<u>No. 2 Machine to Reactor Lattice Position and Remove Plug</u>

"Traverse to Lattice Position" is selected at the Control Panel for No. 2 machine which goes through a sequence of operations identical to those of No. 1 machine, followed by "Remove Plug".

The two machines are now located as shown by Fig. 7.

No. 1 Machine Eject Fuel: No. 2 Machine Accept Fuel

On initiation of the "Move Fuel" sequence at the control panel of each machine, No. 1 machine carrying the new fuel automatically starts an "Eject Fuel" sequence while No. 2 goes on to its "Accept Fuel" sequence. This is the only operation during which there is communication between the two control systems.

The magazine of the No. 2 machine is rotated to align an empty fuel carrier with the charging tube and ram. The charging tube and ram locks on to the fuel carrier, unlocks it from the magazine and moves it forward ready to accept the ejected fuel bundle. The magazine of the No. 1 machine is rotated to align a new fuel bundle and carrier with the charging tube ram. The charging tube locks on to the fuel carrier, unlocks it from the magazine and moves it forward into the channel. Ram movement then pushes the fuel bundle from the carrier causing the entire column of fuel bundles to move one bundle length along the channel. This ejects the spent fuel bundle into the carrier of the No. 2 machine. Both charging tubes then retract to withdraw the fuel carriers into the magazine. The charging tubes lock the fuel carriers into the magazines and are in turn unlocked from the fuel carriers. If this is the end of the fuelling operation, the magazines are then rotated to align the plugs and adapters with the charging tubes and the plugs are both replaced.

Replace Plugs

The "Replace Plug" sequence, when a machine is on a reactor end-fitting, includes a timed reactor-to-machine plug leak-test after the plug has been replaced. When the heavy water temperature in the head has been reduced to 150^{o} F by the machine's heat exchanger, the head is depressurized and the heavy water pumped out to the reservoir until the level in the head is below the snout pressure-sleeve, as indicated by a level probe HDHD. This ensures that up to three bundles in the magazine will just be covered during traverse.

No. 2 Machine to Spent Fuel Port (01), Remove Plug, Eject Fuel, Replace Plug

The "Traverse to Spent Fuel Port","Remove Plug", Eject Fuel", and "Replace Plug" sequences are performed in that order. The machine's heavy water circulation system cools the irradiated bundle during the transfer from the lattice site to the spent fuel port. The head fill and pressurize operations are automatically omitted at the Spent Fuel Port. Figs. 8 and 9 show No. 2 machine discharging spent fuel bundles at the upper (01) Spent Fuel Discharge Port. The machine head is in the "Azimuth Service" attitude.

No. 1 & No. 2 Machines Traverse to "Home" Position

The machines are then withdrawn from the Reactor Vault and the Shielding Gates are closed. The operations in this sequence include rotation of the head in azimuth to the service position before passing through the Shielding Gates and locking on to the New Fuel Port.

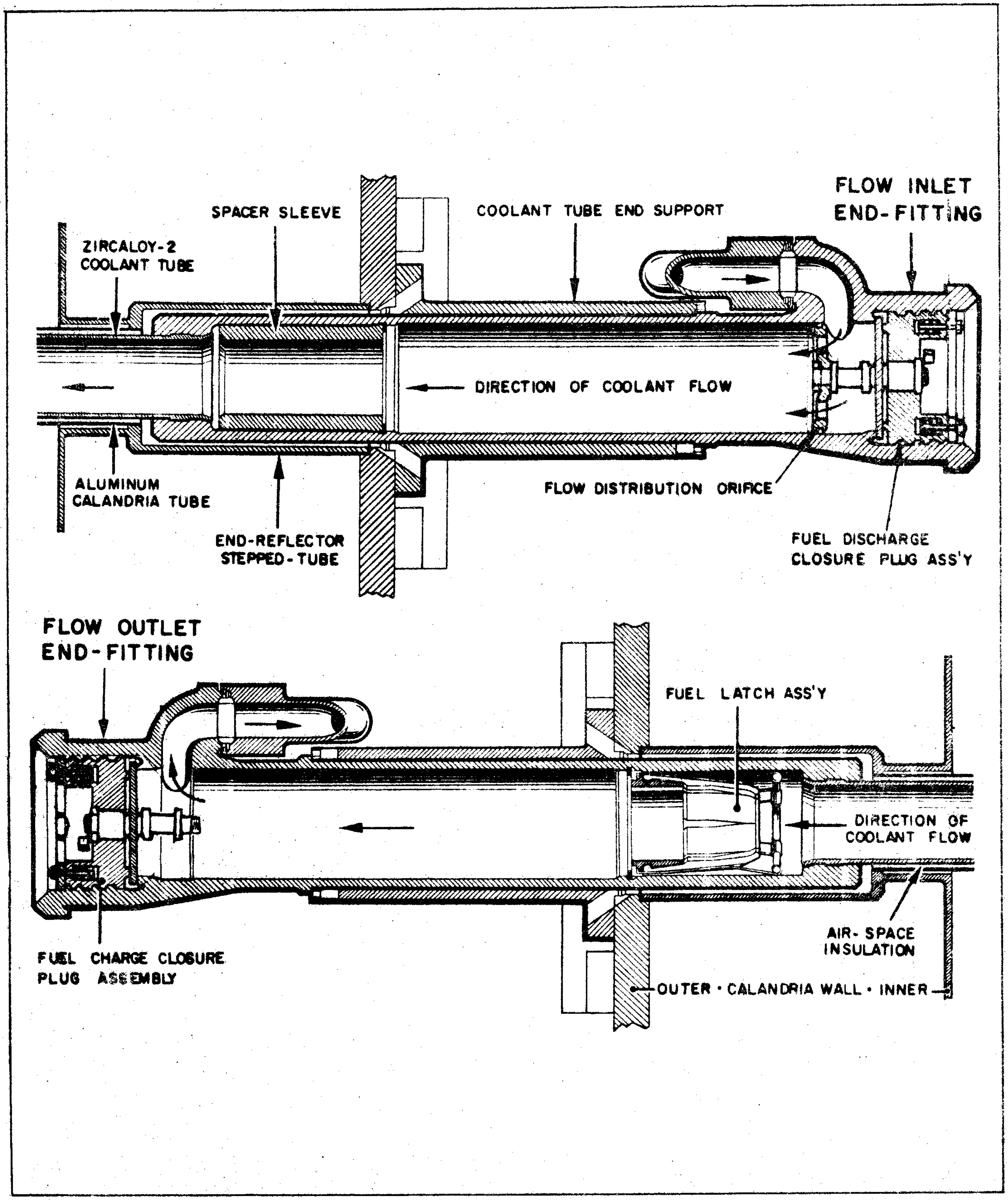


Figure 3 Reactor End Fitting, Plug and Fuel Latch

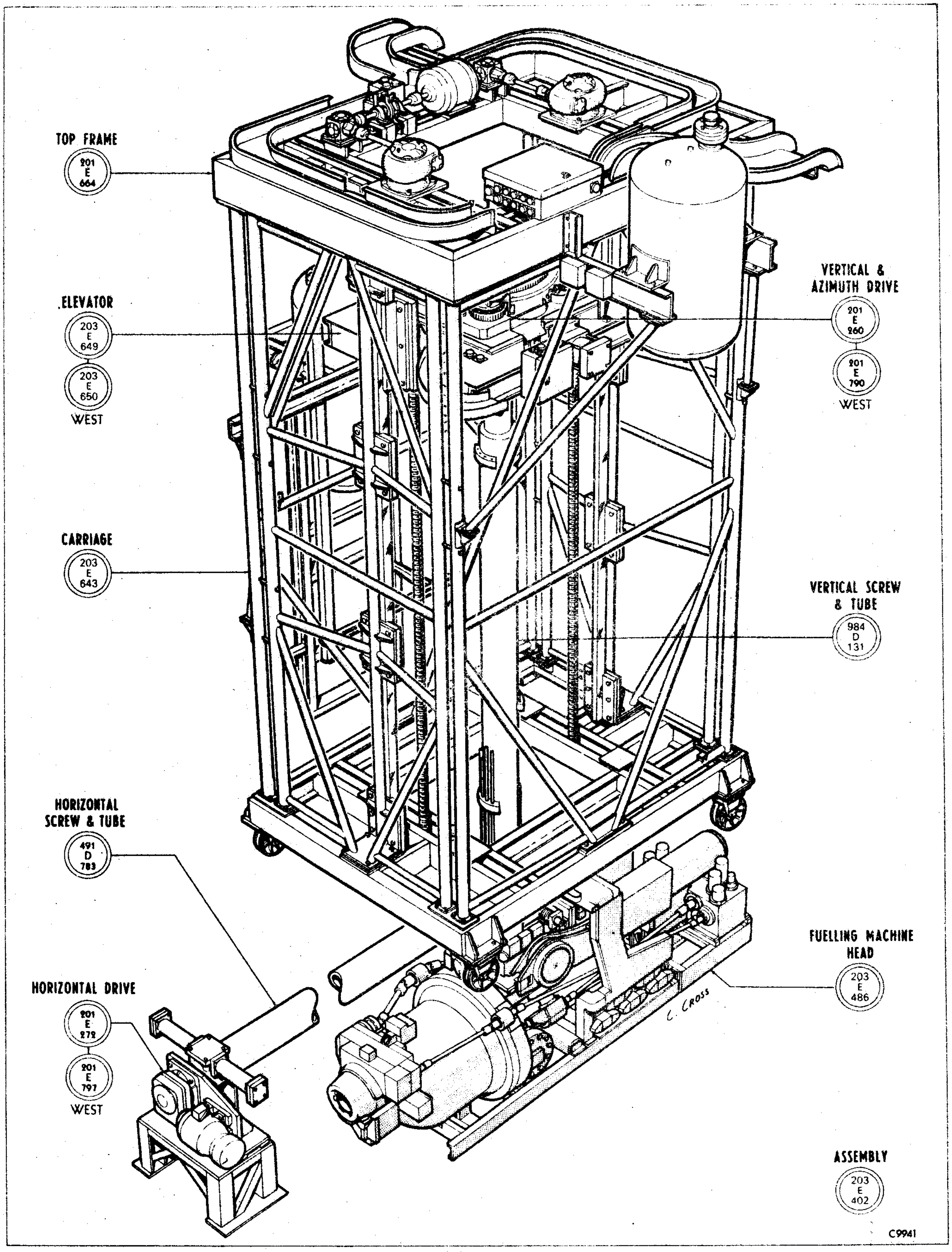


Figure 4 Fuelling Machine Assembly (East)

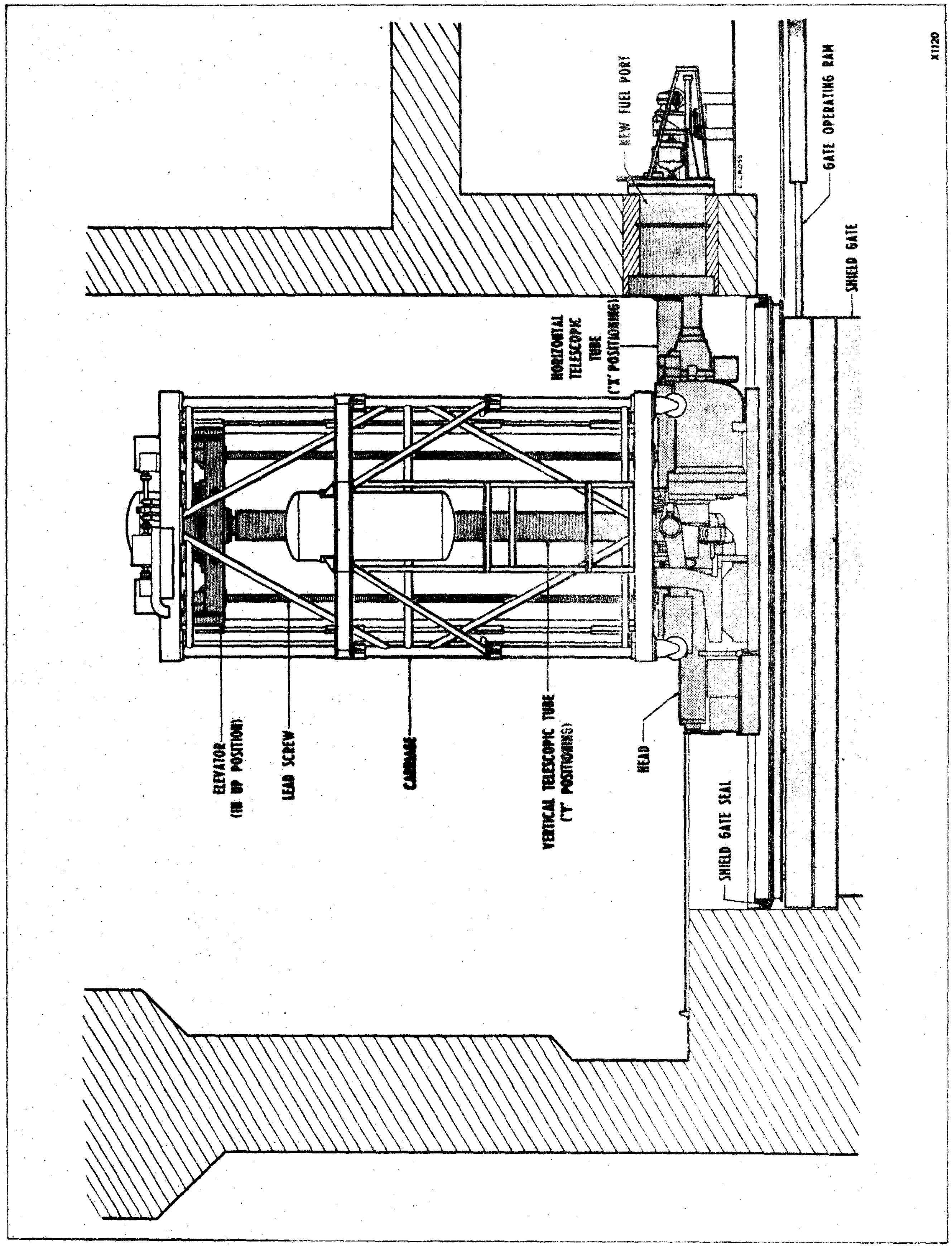


Figure 5 Fuelling Machine at "Home" Position

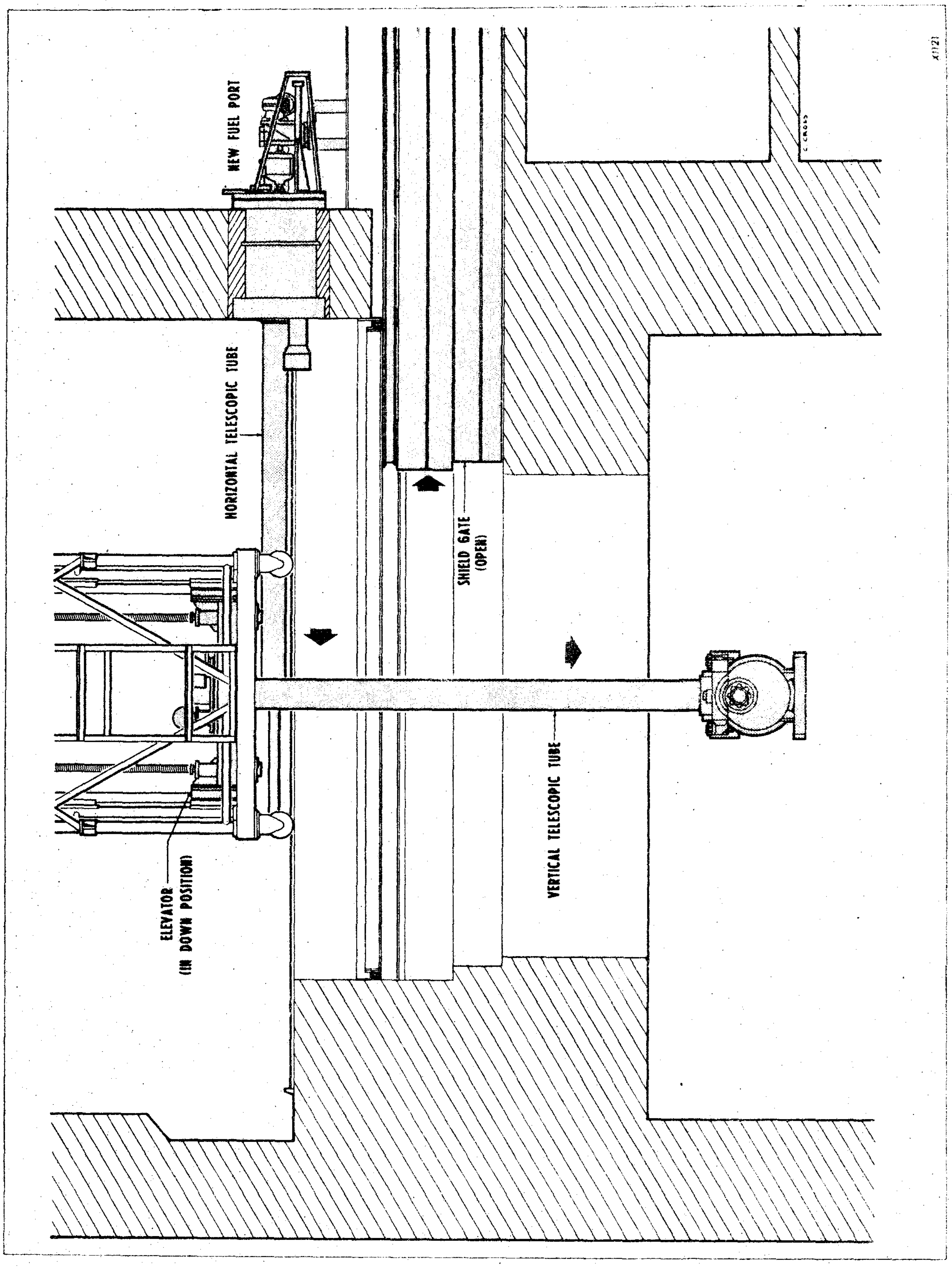


Figure 6 Fuelling Machine at Elevator Down and Azimuth Normal Positions

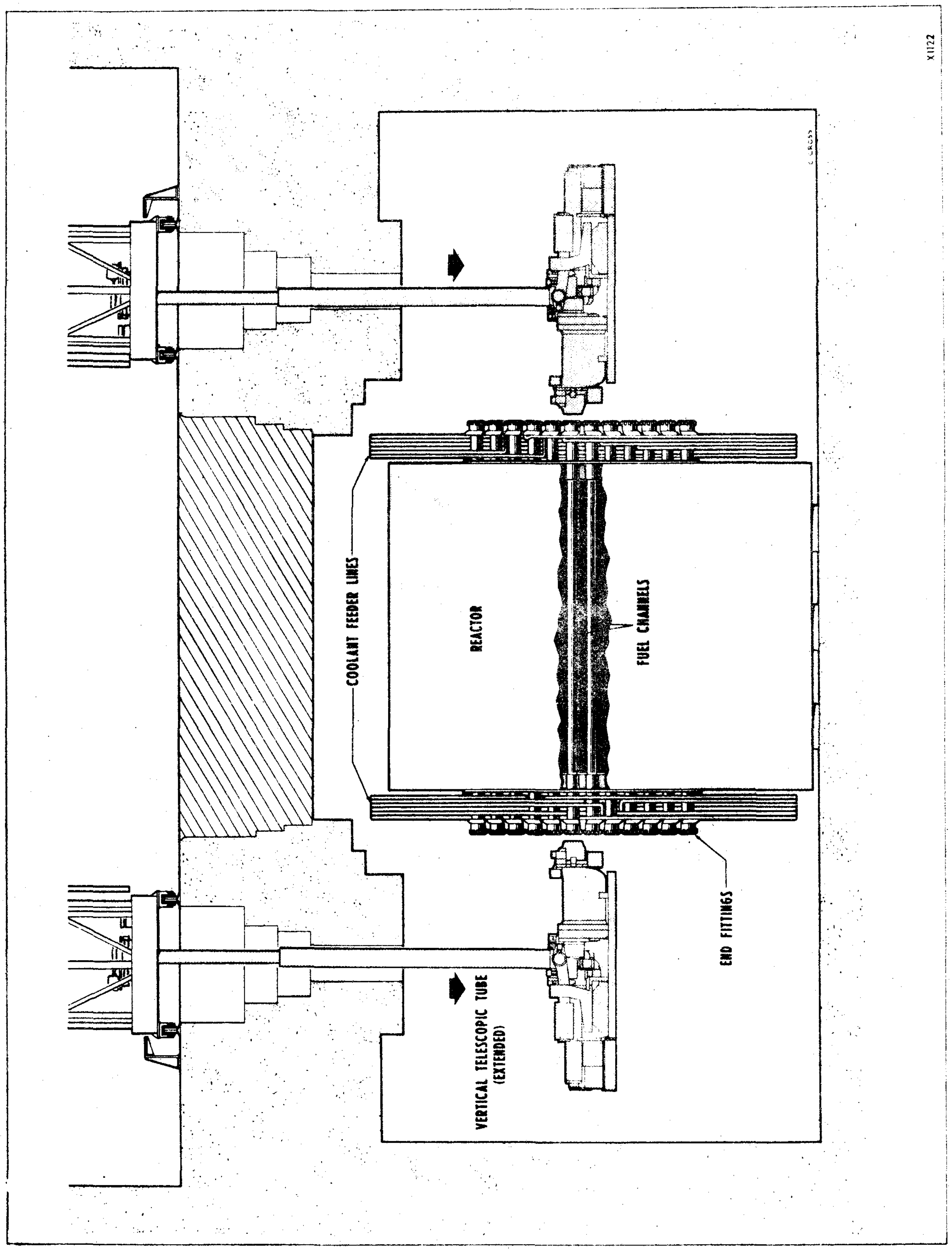


Figure 7 Both Fuelling Machines at Selected Fuel Channel

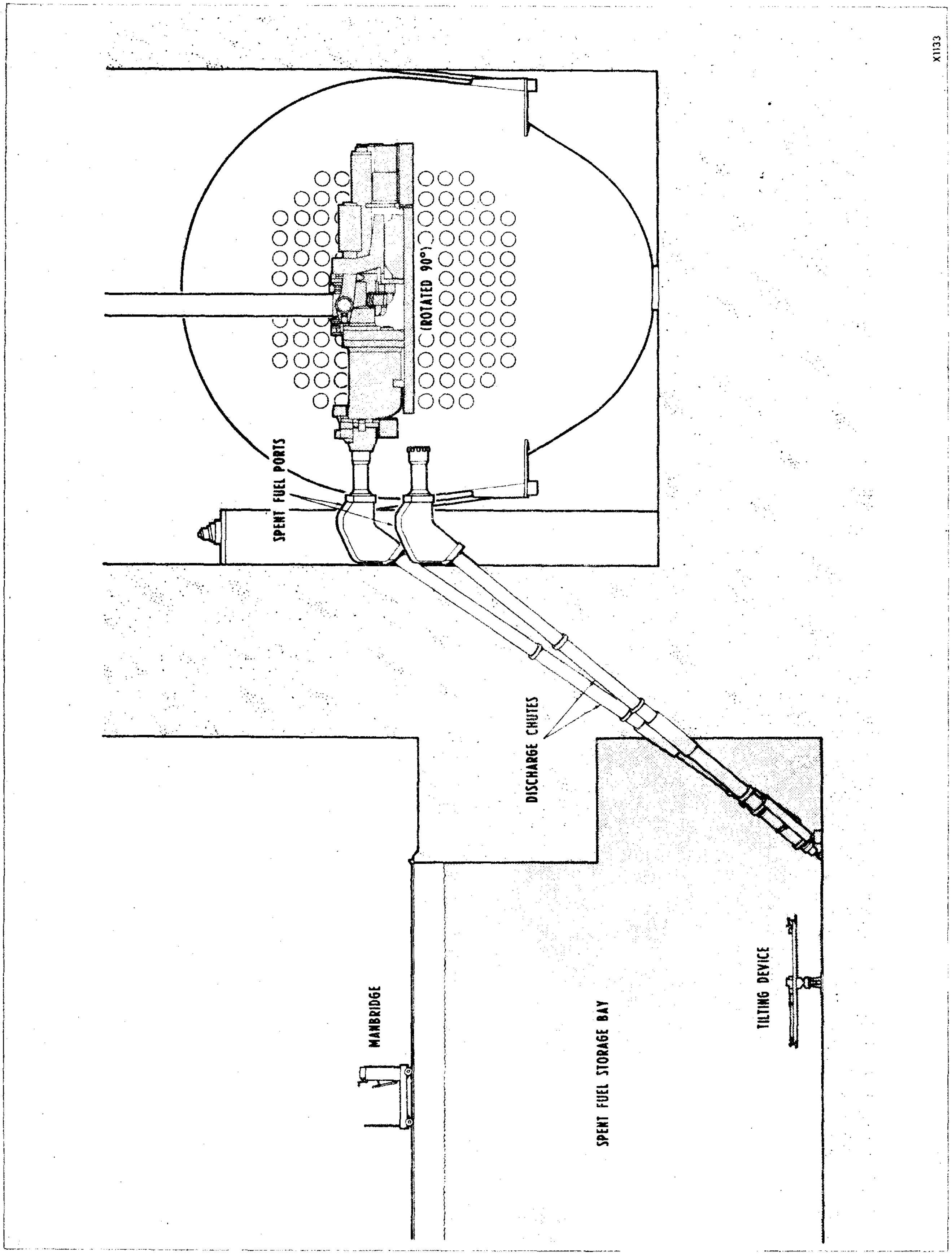


Figure 8 Fuelling Machine at Spent Fuel Port

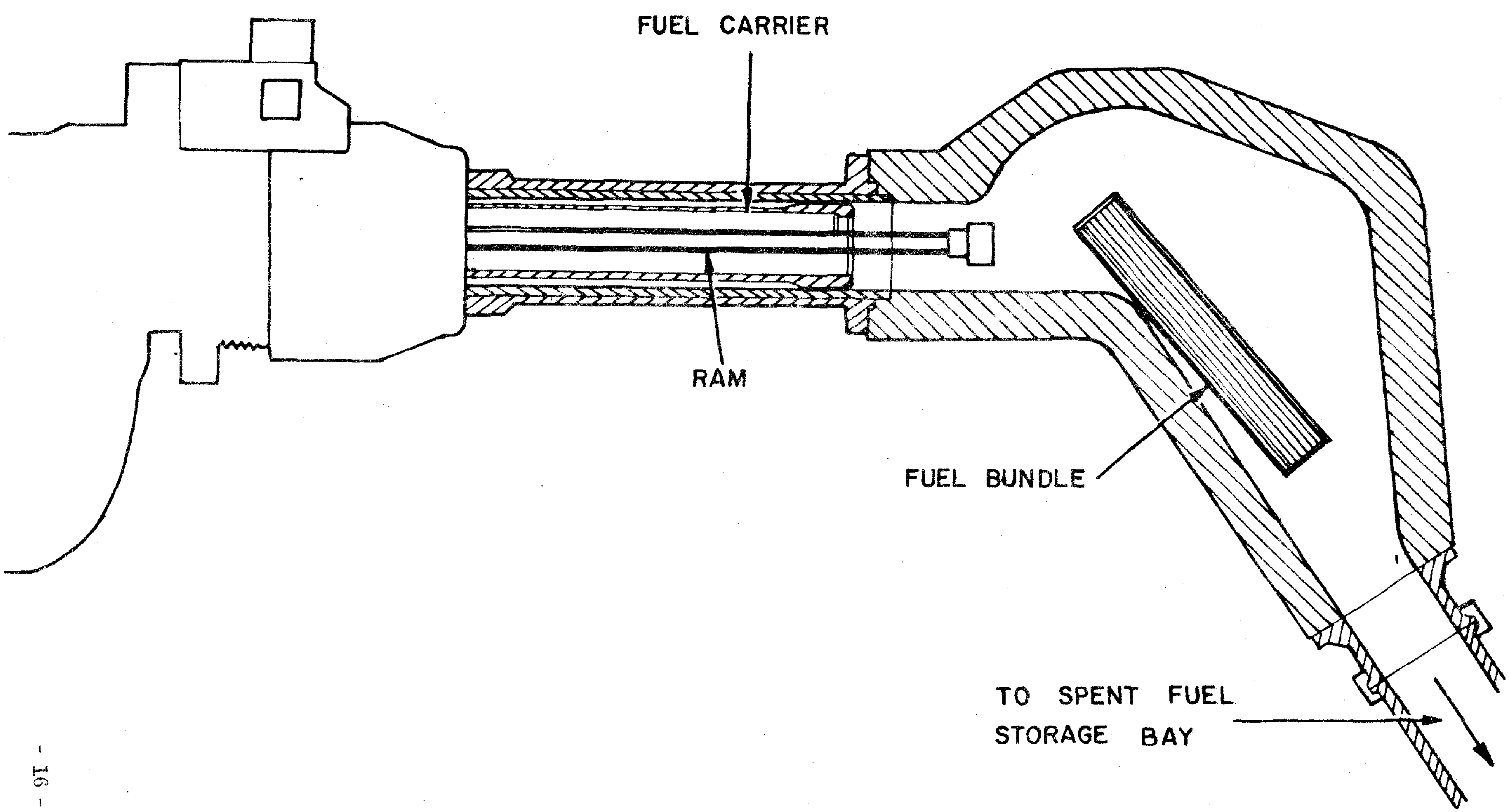


Figure 9 Fuelling Machine Discharging Spent Fuel

NPD Systems - Reactor Boiler and Auxiliaries

Fuel Handling System

FUELLING MACHINE CARRIAGE ASSEMBLY

Associated with each fuelling machine system are the following major items of equipment.

(a) Carriage Assembly
(b) Horizontal and Vertical Drive Assemblies
(c) Head Assembly
(d) Oil Hydraulic System
(e) D_2O Pressurizing and Recirculation Systems
(f) Pneumatic System
(g) Control System

In 053-352.2, the overall sequence of events of a typical fuelling cycle were described. The following lessons describe the fuelling machine mechanical assemblies while the last lesson, 053-352.12 describes the Control System. This lesson describes the Carriage Assembly.

CARRIAGE ASSEMBLY

Figure 1 shows the general arrangement of the fuelling machine head and carriage assembly. The fuelling machine head is suspended from the carriage in the fuelling machine room. The main features of the carriage are:

1. Provides support for the fuelling machine head and associated drives.

2. Provides horizontal positioning of the fuelling machine head.

3. Provides vertical positioning of the fuelling machine head.

4. Provides transverse motion of the fuelling machine.

5. Transfers the fuelling machine head between the reactor face area and an accessible area (Fuelling Machine Room).

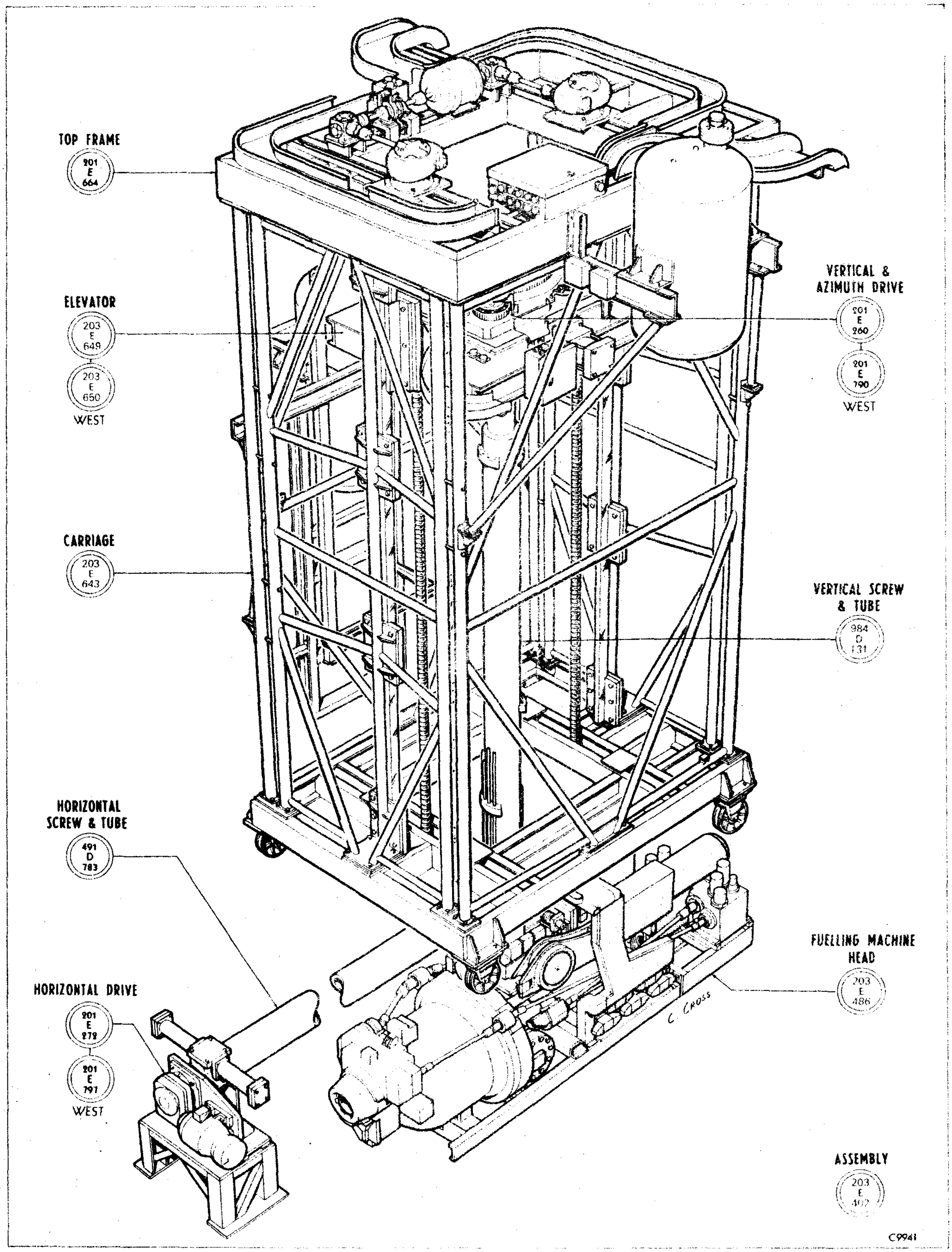


Figure 1 Fuelling Machine Head and Carriage

In addition, the carriage includes auxiliary systems such as heavy water circulation system, pressurizing system and storage tanks, electrical junction boxes, hose connections, manifolds, cable connections, etc.

CARRIAGE CONSTRUCTION (Fig. 2)

Each carriage is rectangular and constructed of welded steel pipe vertical supports with a steel channel top and bottom framework. The carriage is mounted on four wheels which run on two rails located in a North-South direction.

The horizontal telescopic drive is attached to the bottom frame and moves the carriage back and forth along the rails to position the head in the X-axis. The two wheels nearest the reactor face are provided with side play, while the other pair of wheels are free to roll only. This ensures accurate positioning while at the same time allowing for side thrusts resulting from temperature variations or rail misalignment.

Two vertical rails, mounted on each end of the carriage, form the bearing guides for the vertical travel of the elevator.

The top of the carriage is completed by a frame of channel section steel. See Figure 3. On this frame is mounted the elevator drive mechanism.

ELEVATOR

Within each carriage is mounted an elevator platform. See Figure 4. Guide blocks are attached to two sides of the elevator and these ride on fixed vertical guide rails as the platform is raised or lowered. When the fuelling machine is in the "home" position, the elevator is in the "up" (EU) position holding the head above the shielding gate. During a fuelling operation the elevator travels to the "down" (ED) position lowering the head to a point 12 inches above the top row of end fittings. Normally the elevator is held either in the "up" or the "down" position.

The oil hydraulic system which provides power for the vertical "Y" and azimuth, head motion and for the "Y" - drive lock, and also the electric drive Y - drive mechanism,are installed on the elevator.

The elevator drive mechanism is located on the top frame of the carriage. See Figure 3. It consists of a 3 horsepower motor equipped with spring-actuated solenoid-release brake. The motor output shafts are connected to two lead screws through mitre gear boxes and worm gear speed reducers for drive shaft direction change and speed reduction.

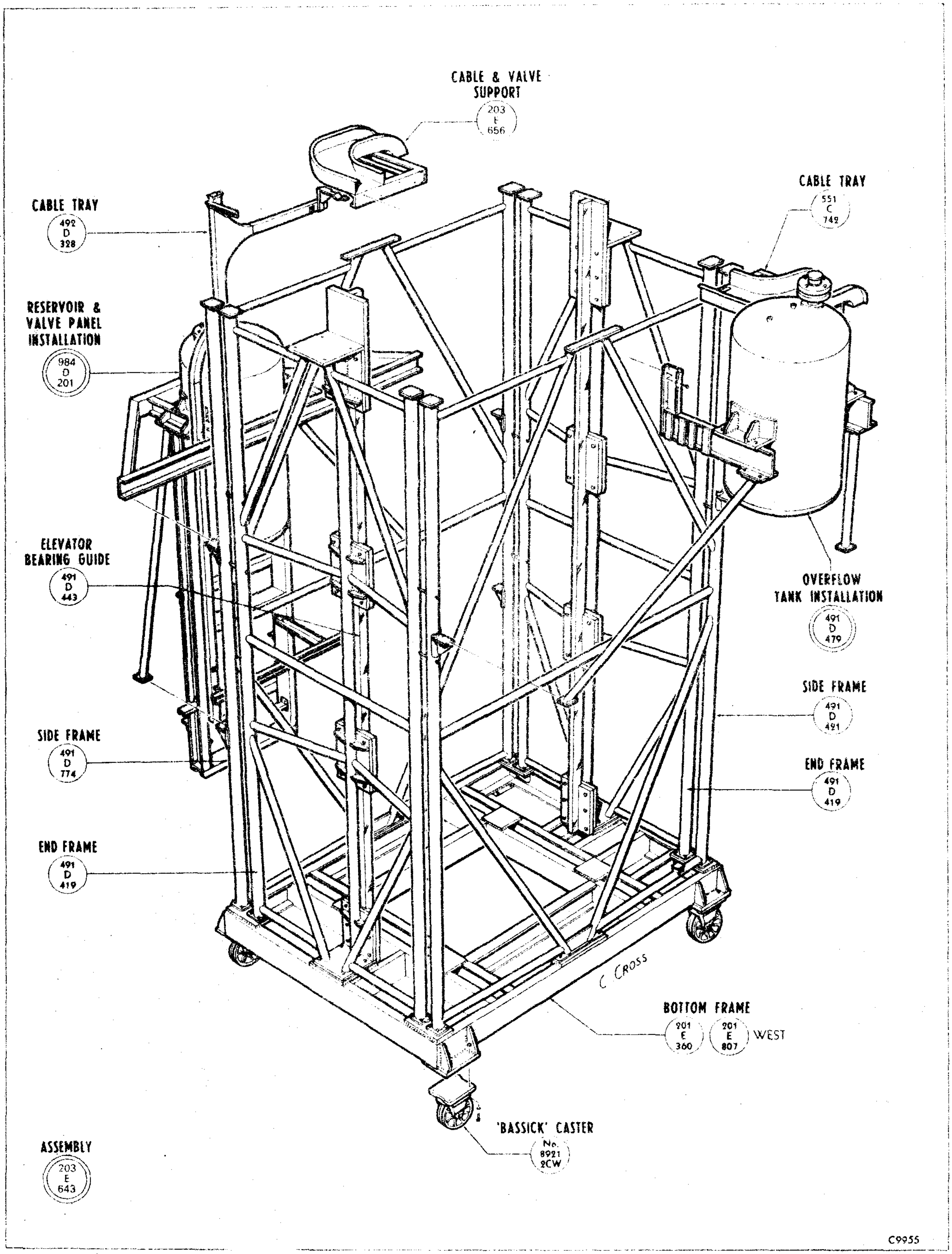


Figure 2 Carriage

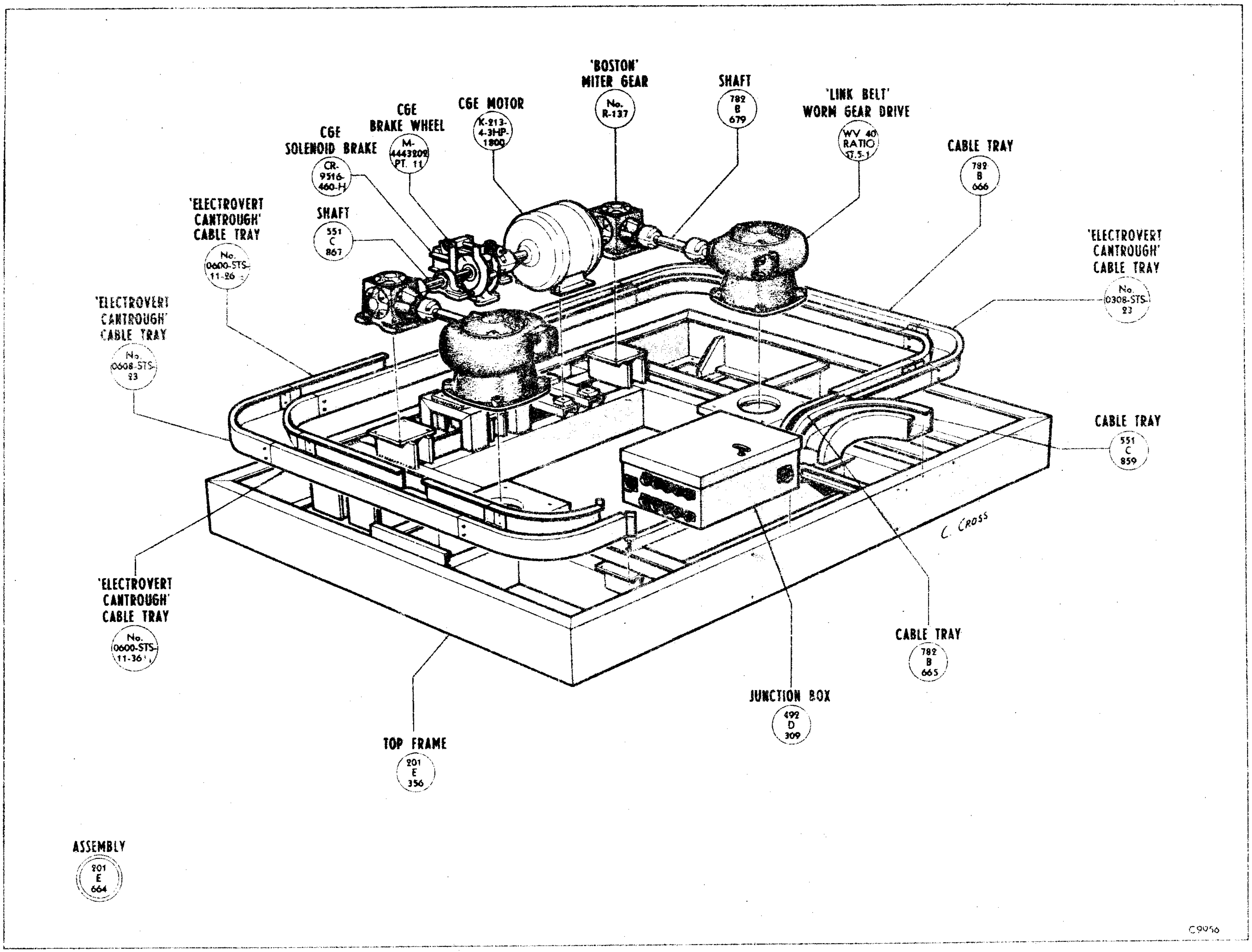


Figure 3 Carriage Top Frame Assembly

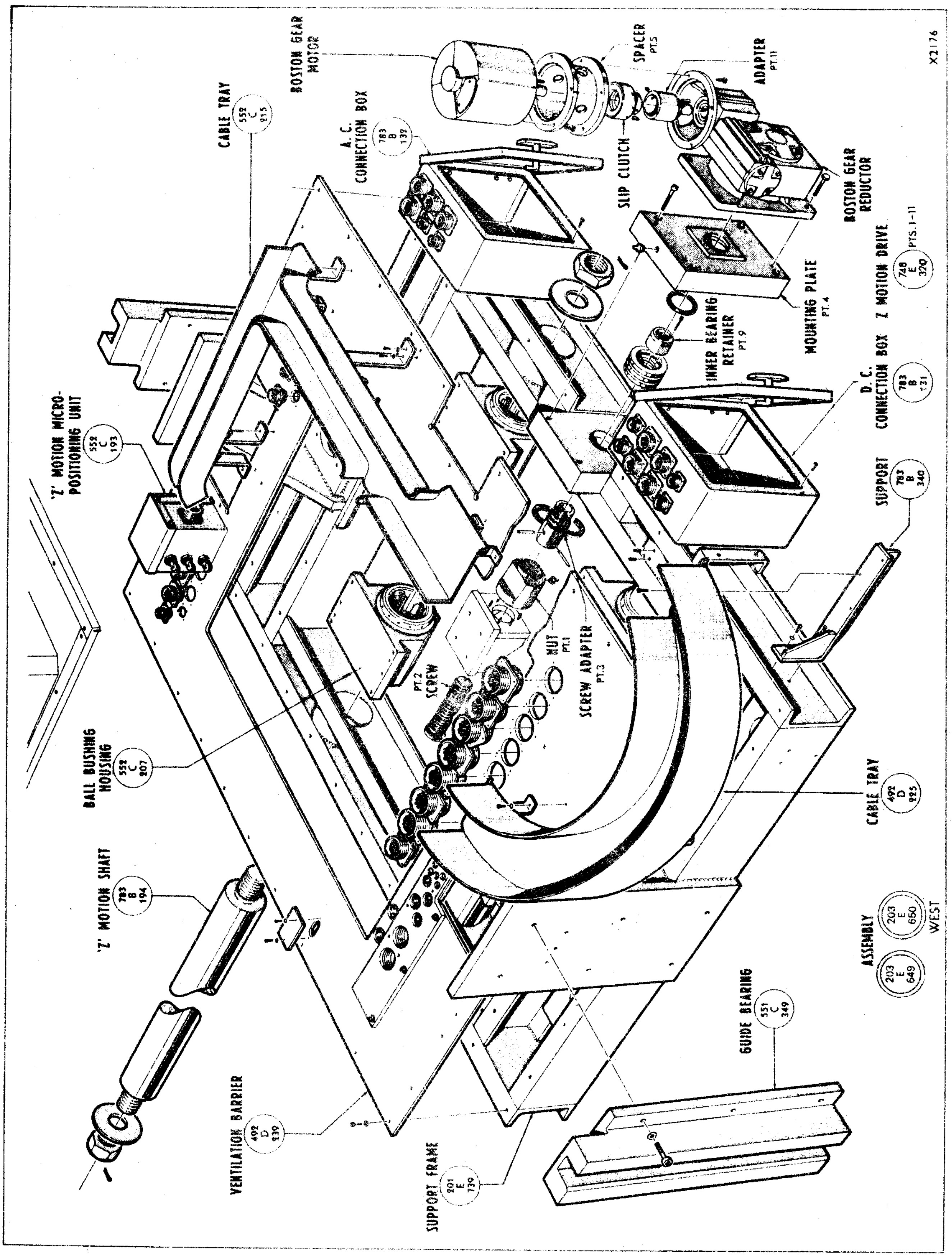


Figure 4 Elevator Assembly

Each lead screw is suspended at its upper end by a ball bearing assembly and passes through a ball nut mounted on the elevator platform. The lower end of each screw is fixed to the bottom carriage frame by a sleeve-mounted ball bearing. The lead screws are designed to operate in the open without continuous lubrication.

As the lead screws rotate, the elevator platform rides up or down on the ball screw nuts. Elevator travel at the upper and lower positions is limited by limit switches which cut off the power to stop the motor and allow the brake to engage. Refer to lesson 530-352.5.

In the down position, the elevator platform sits on four pads placed on the bottom frame of the carriage to provide accurate alignment of the fuelling machine head with the reactor and fuel port end fittings.

LATERAL MOVEMENT TABLE (Z Motion) (Fig. 5)

Mounted on the elevator platform is the lateral movement table which provides Z motion as it moves across the platform in a direction normal to the reactor face.

Two solid shafts are mounted to the inside of the elevator platform. On the bottom of the lateral movement table are four bearings with internal ball races. Two of these bearings encircle each of the shafts and the table moves in and out on these bearings for the Z motion.

Movement of the lateral movement table (Z Motion) is provided by a lead screw driven by an electric motor through a double-reduction worm-gear speed reducer, the motor and speed reducer and mounted as a unit on the elevator frame. A slip clutch limits the output torque. Refer to lesson 053-352.5.

ROTARY TABLE (Azimuth Motion) (Fig. 6)

A rotary table is mounted on the lateral movement table by tapered roller bearings. This table provides Azimuth motion and supports all the components of the vertical telescopic assembly whose column penetrates through the centre of the elevator platform, the lateral movement table and the rotary table.

A hydraulic motor, supplied with hydraulic pressure by the elevator hydraulic system, is mounted on the lateral movement table. This motor drives a gear whose teeth engage with the teeth of a gear segment fastened to the rotary table.

The rotary table is rotated through 90°, between the Azimuth Normal and Service positions, by the hydraulic motor. The position of the table is detected and limited by limit switches which control the supply of oil to the hydraulic motor and stop rotary table motion either at the Azimuth Service or Azimuth Normal positions. Stops ensure positive alignment at each position. with hydraulic pressure holding the table against the stops. Refer to lesson 053-352.5 for a descritpion of the stops.

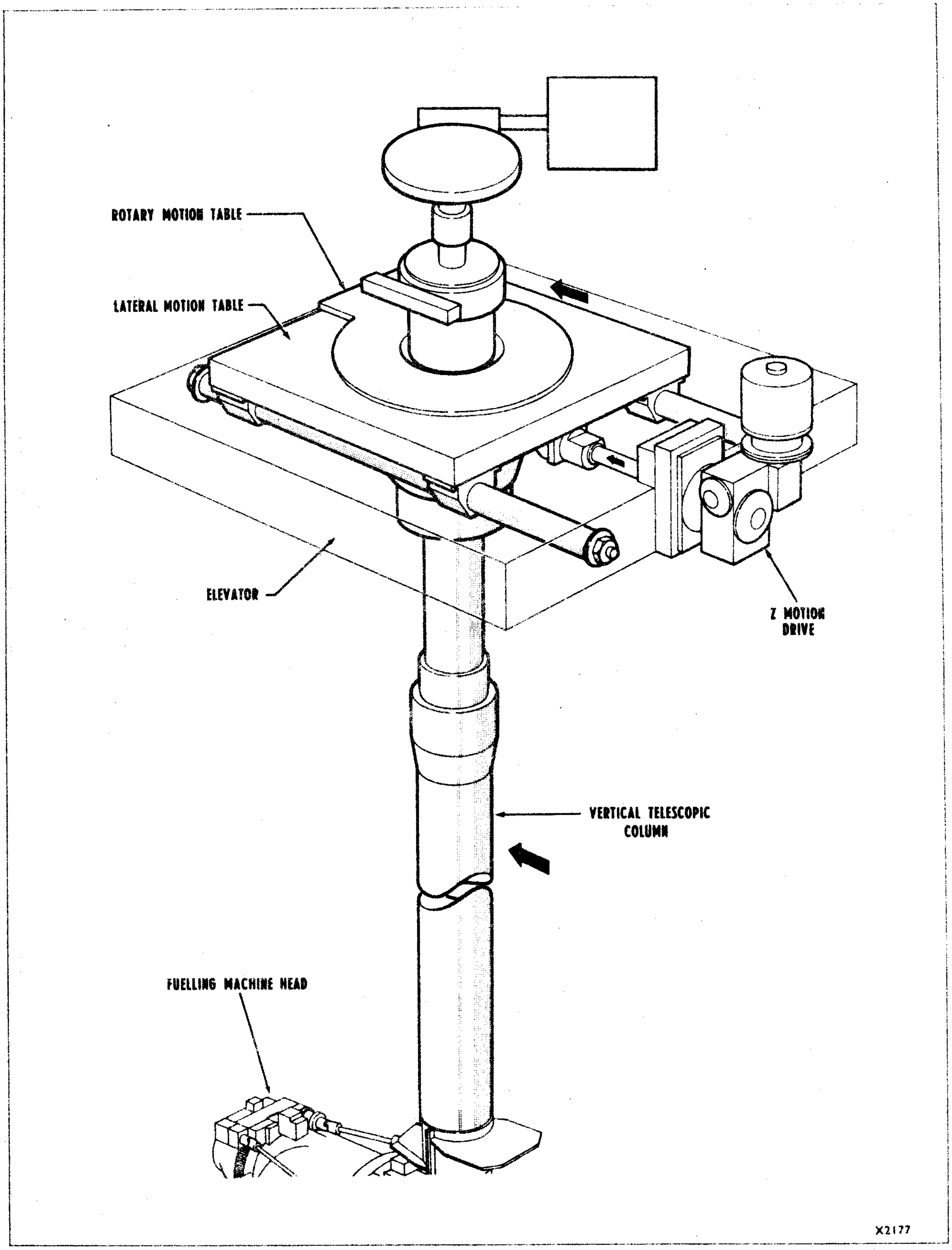


Figure 5 Lateral Motion Table

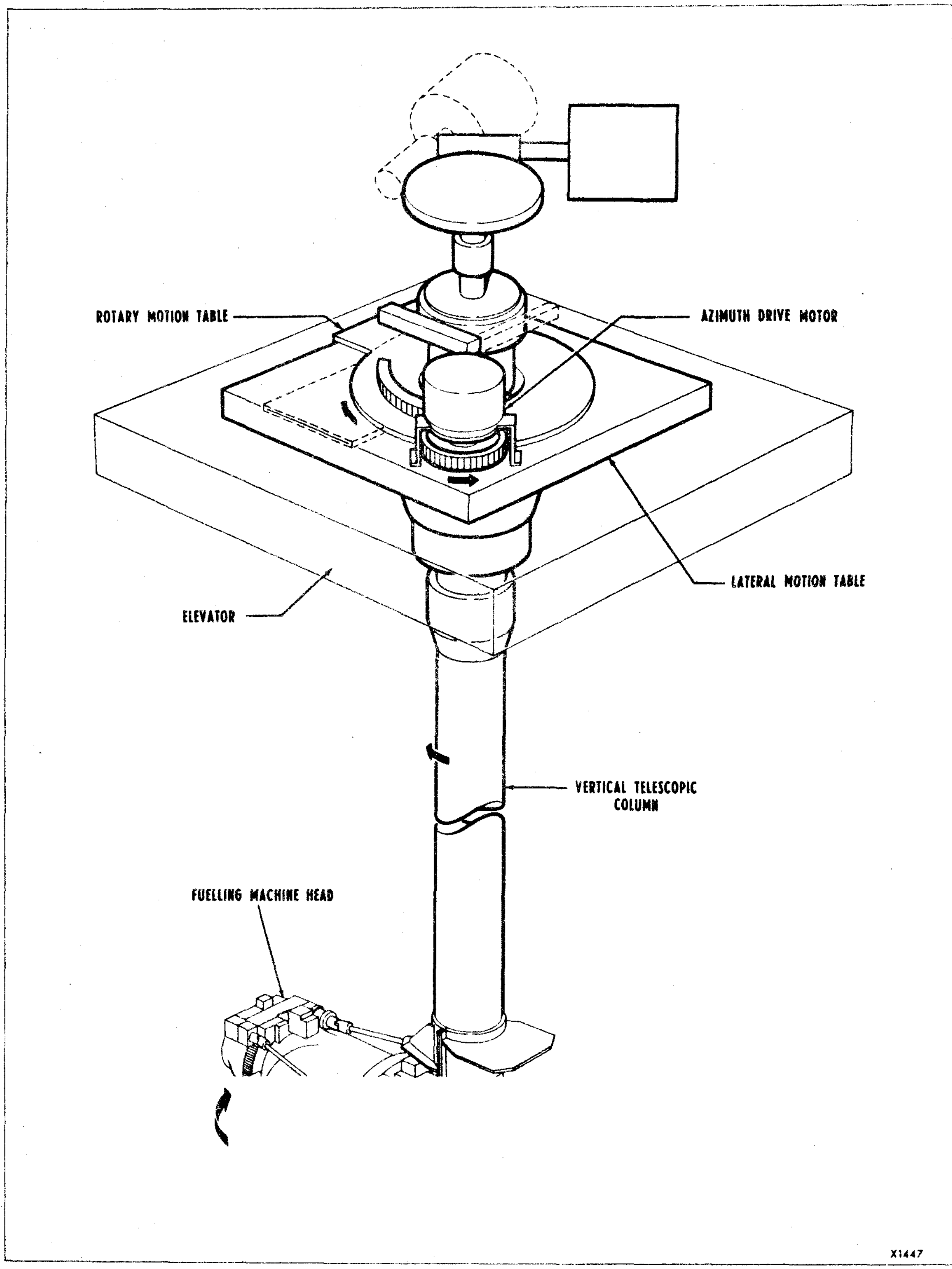


Figure 6 Rotary Motion Table

NPD Systems - Reactor Boiler and Auxiliaries

Fuel Handling System

FUELLING MACHINE HORIZONTAL AND VERTICAL TELESCOPIC DRIVES

The operation of each fuelling machine requires that the head be moved in various directions to allow positioning at the new and spent fuel ports and at each calandria end fitting. These movements may be placed in five categories and provision is made for each category as follows:

1. Horizontal (X) movement in a north-south direction provided by the horizontal telescopic tube and drive assembly.
2. Vertical movement from the Fuelling Machine Room to the Reactor Vault provided by the elevator assembly mounted on the carriage.
3. Rotation of the head through 90^{o} in a horizontal plane in the Reactor Vault provided by the Azimuth Drive Assembly.
4. Vertical (Y) positioning across the face of the calandria provided by the vertical telescopic tube and drive assembly.
5. Horizontal movement (Z) in an east-west direction towards the reactor end fittings provided by the lateral movement table.

Items 1 and 4, the horizontal and vertical telescopic tube and drive assemblies will be discussed in this lesson and the remaining items in the following lesson.

HORIZONTAL TELESCOPIC TUBE ASSEMBLY

A coarse and fine drive assembly is located in each New Fuel Room adjacent to the New Fuel Port (see Fig. 1). This drive assembly connects to the horizontal telescopic column which penetrates the Fuelling Machine Room wall and is secured to the track-mounted fuelling machine carriage, (Fig. 2). Horizontal motion is transmitted to the carriage through the telescopic column causing the carriage to move in a north-south direction on the rails thus permitting the fuelling machine head to be horizontally positioned at a desired location. This is termed the X motion of the fuelling machine head.

Coarse and Fine X Motion

Provision is made to position the fuelling machine head horizontally within 1/2 inch of any desired location without any contact being made between the fuelling machine snout and the selected end fitting. This is termed the coarse X motion.

The fine X motion involves more exact horizontal positioning of the fuelling machine head at the selected end fitting as determined by contact between finger probes projecting from the snout, and the end fitting.

Coarse X Motion (Fig. 3 and 4)

The horizontal drive assembly consists of a 1 HP motor connected through a gear reduction mechanism (Boston Gear reductor) to a coupling shaft. This coupling connects to a lead screw in the telescopic column. As the lead screw is rotated an inner shaft contained inside the telescopic column moves forward pushing the fuelling machine carriage along the track.

The motor is equipped with a spring-operated, solenoid-released brake which positively stops motion of the lead screw any time motor current is interrupted. Microswitches (detectors) are spaced along the carriage track at positions corresponding to each of the twelve vertical rows of fuel channels. Contact with the selected microswitch by the carriage assembly shuts off the motor current and applies the brake, thus stopping the carriage at the desired location.

Fine X Motion

After the fuelling machine head has been approximately positioned by the coarse X motion, the coarse X drive remains locked and further horizontal positioning is achieved by operation of the fine X drive mechanism. This operates in accordance with signals received from the snout finger probes contacting the selected end fitting.

The motor brake locks the coupling shaft preventing rotation of the lead screw during fine X motion. However, the lead screw is connected to the coupling shaft by a spline fitting which permits restricted sliding in or out of coupling shaft.

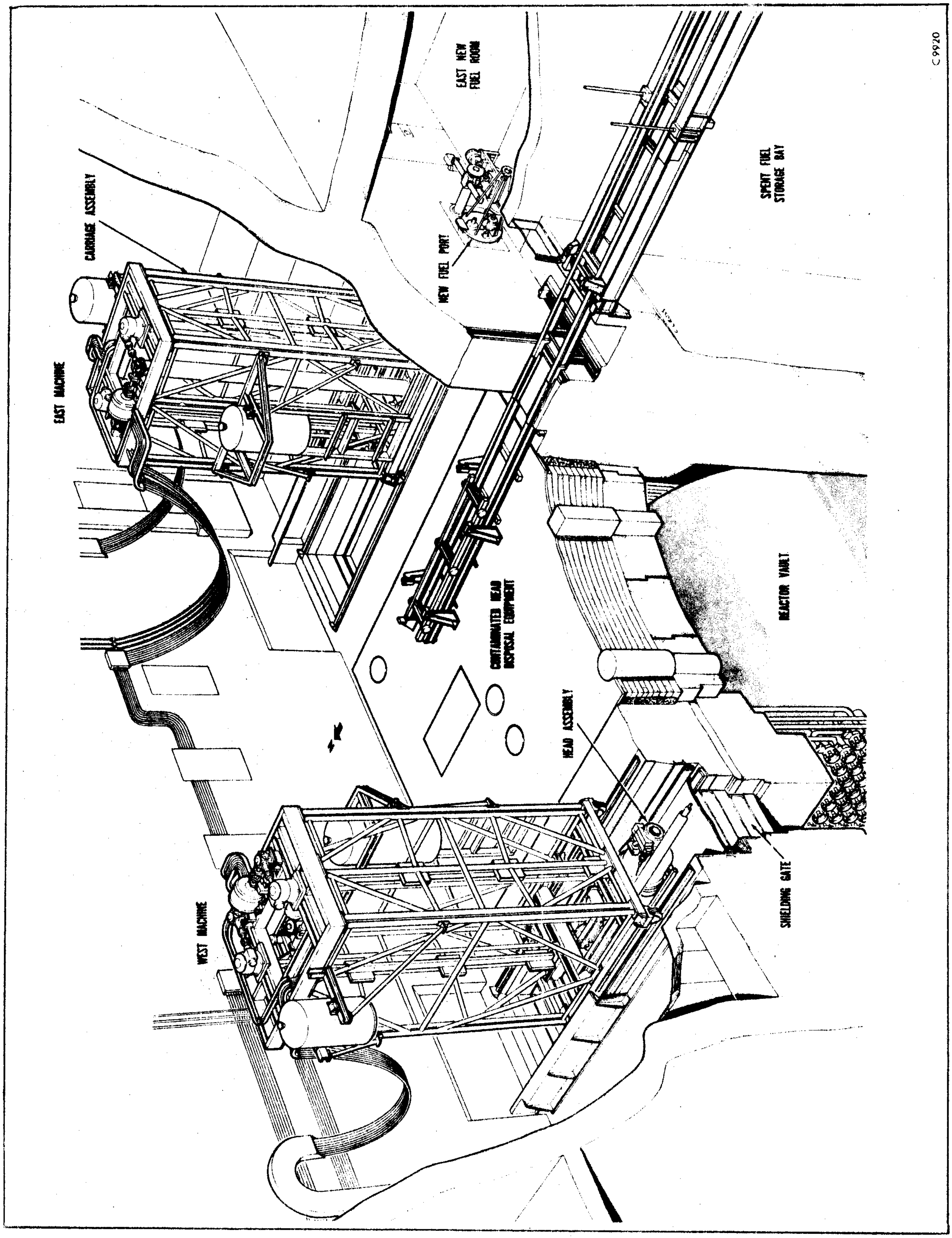


Figure 1 General View of Fuelling Machine Room

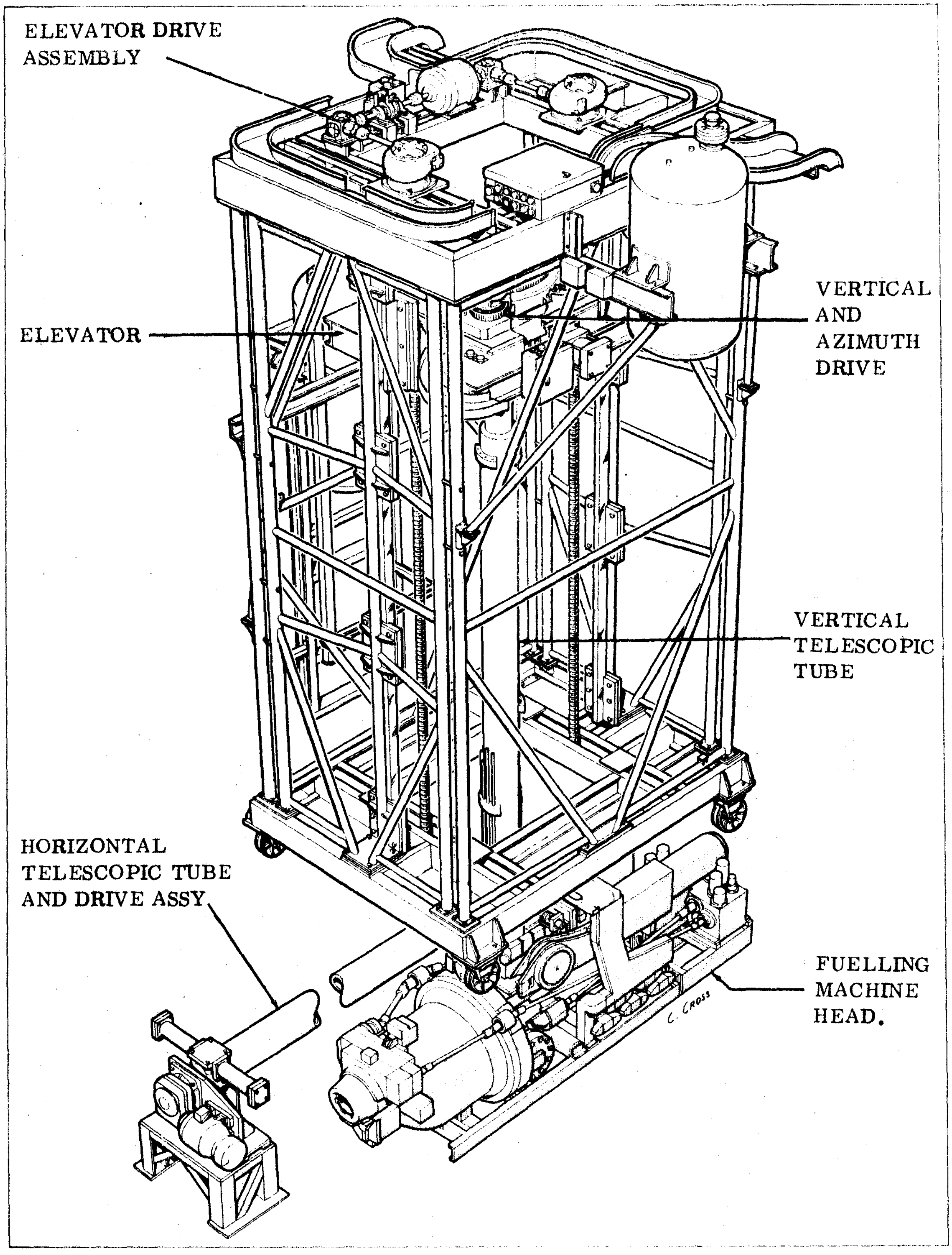


Figure 2 Fuelling Machine And Carriage

This sliding motion is controlled by the fine X drive mechanism which drives the lead screw connection up to 1/2 inch on each side of its normal position within the coupling.

Horizontal (X) Drive Assembly (Fig. 3 and 4)

The drive assembly for both coarse and fine X motion is shown on the attached Fig. 4. As indicated, the coupling from the Boston Gear reductor connects to a splined adapter the splined adapter is connected to the lead screw and is free to rotate on ball bearings within the fine drive screw Thus as the lead screw rotation is transmitted from the motor, the fine drive screw remains stationary.

Surrounding the lead screw within the telescopic column is a ball nut with an attached guide tube equal in length to the lead screw. As the lead screw rotates, the ball nut which is prevented from rotating by the attachment to the carriage at the end of the guide tube, moves along the lead screw on ball bearings carrying the guide tube with it and rolling the carriage along its tracks.

As mentioned previously, during fine X motion the splined adapter and lead screw are prevented from rotating by the motor brake. The fine drive assembly rotates the fine drive screw moving it in or out of the fine drive sleeve and carrying with it the splined adapter and guide tube assembly.

Rotation of the fine drive screw is by moving a toothed rack which engages with teeth cut in the fine drive screw. This rack is located in the fine drive cylinder assembly and forms the connecting link or piston rod between the pistons of two opposing hydraulic cylinders. As oil is introduced in one end and withdrawn from the other end of the cylinder the rack moves across the fine drive screw resulting in the fine X motion. The valves controlling the flow of oil are operated in accordance with signals received from the probes on the fuelling machine snout.

Since fine X travel is limited to 1/2 inch on either side of a central position, 3 microswitches,which ride on grooves in the back of the rack,are mounted on the fine drive cylinder. These microswitches indicate position of the rack and thus the relative location of the splined shaft within the coupling. To ensure maximum available travel in each direction at any time, the fine X drive must be centred before the coarse X drive can be operated.

VERTICAL TELESCOPIC TUBE ASSEMBLY (Fig. 5, 6 and 7)

The fuelling machine head is attached to the vertical telescopic column which is suspended from an elevator platform inside the carriage. Initial movement of the head from the Fuelling Machine Room to the Reactor Vault is obtained by lowering the elevator platform from the top to the bottom of the carriage. Structurally the elevator consists of a steel framework on which a sliding lateral table is mounted on two horizontal shafts. This lateral table permits fine motion (Z-motion) towards or away from the reactor face for locking on.

Riding on bearings on top of this lateral movement table is the rotating table, which is moved through 90^{o} to swing the fuelling machine head to face the calandria after it has been lowered into the reactor vault. This is the fuelling machine azimuth motion. The vertical drive or Y mechanism is mounted on the rotating table and the vertical telescopic column is suspended through a hole in the centre of the table.

Coarse and Fine Y Motion (Fig. 5 and 6)

As in the X motion drive, provision is made to position the fuelling machine head vertically within 1/2 inch of any desired location by the coarse Y motion without contact being required between the fuelling machine snout probes and the end fitting.

Exact vertical positioning is obtained by operation of the fine Y drive mechanism on signal from the probes.

Coarse Y Motion (Fig. 5)

A 1-1/2 HP motor mounted on the rotating table is connected to a coupling shaft through a gear reduction mechanism. This coupling shaft is connected to a lead screw in the telescopic column and rotation of the lead screw extends an inner shaft contained in the telescopic column lowering the fuelling machine head.

As in the coarse X drive, the motor is equipped with a spring-operated, solenoid-released brake which stops rotation of the lead screw at any time motor current is interrupted.

Fine Y Motion (Fig. 6)

The fine Y motion operates on the same principle as the fine X motion. After the fuelling machine head has been positioned

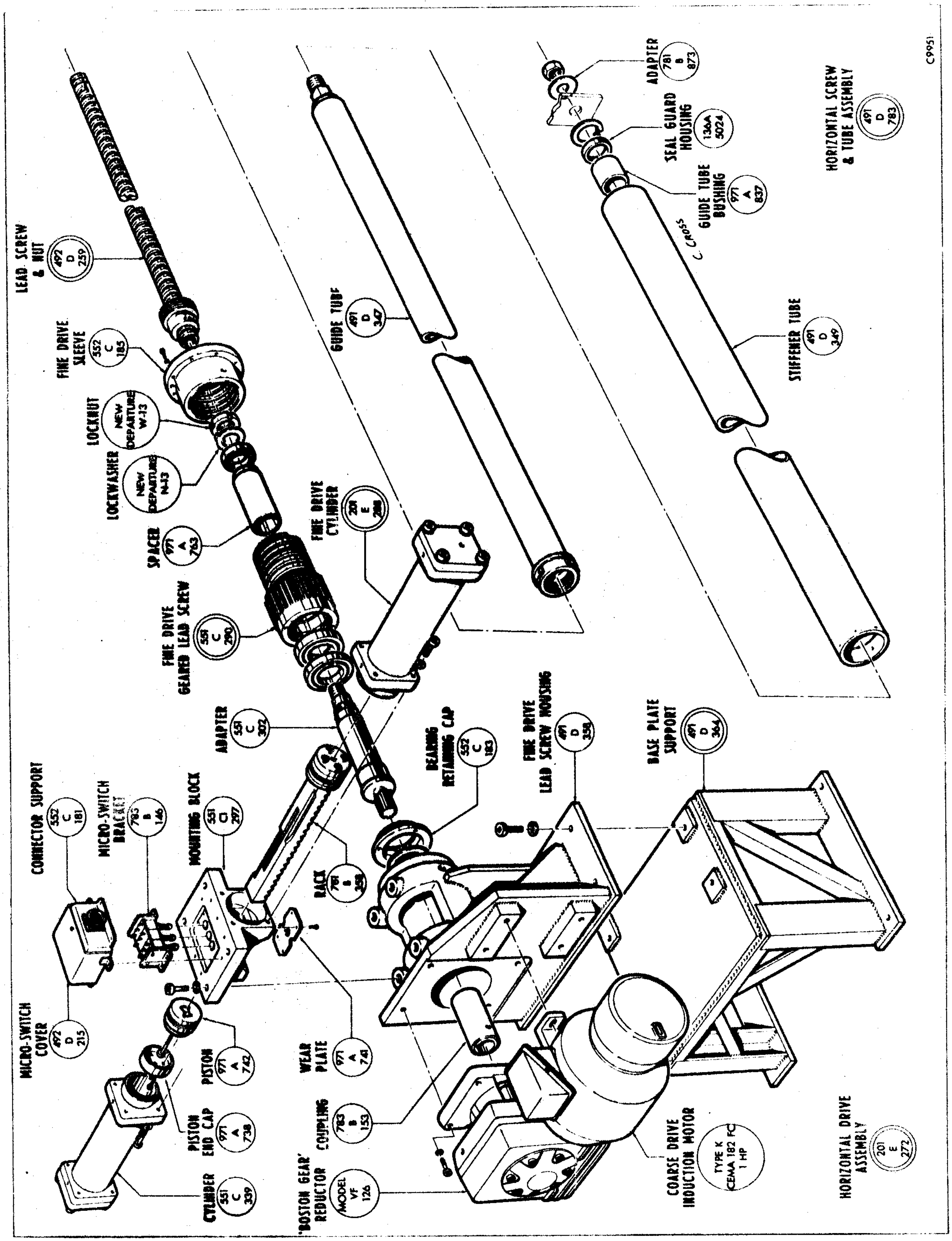


Figure 3 Horizontal Drive and Telescopic Tube

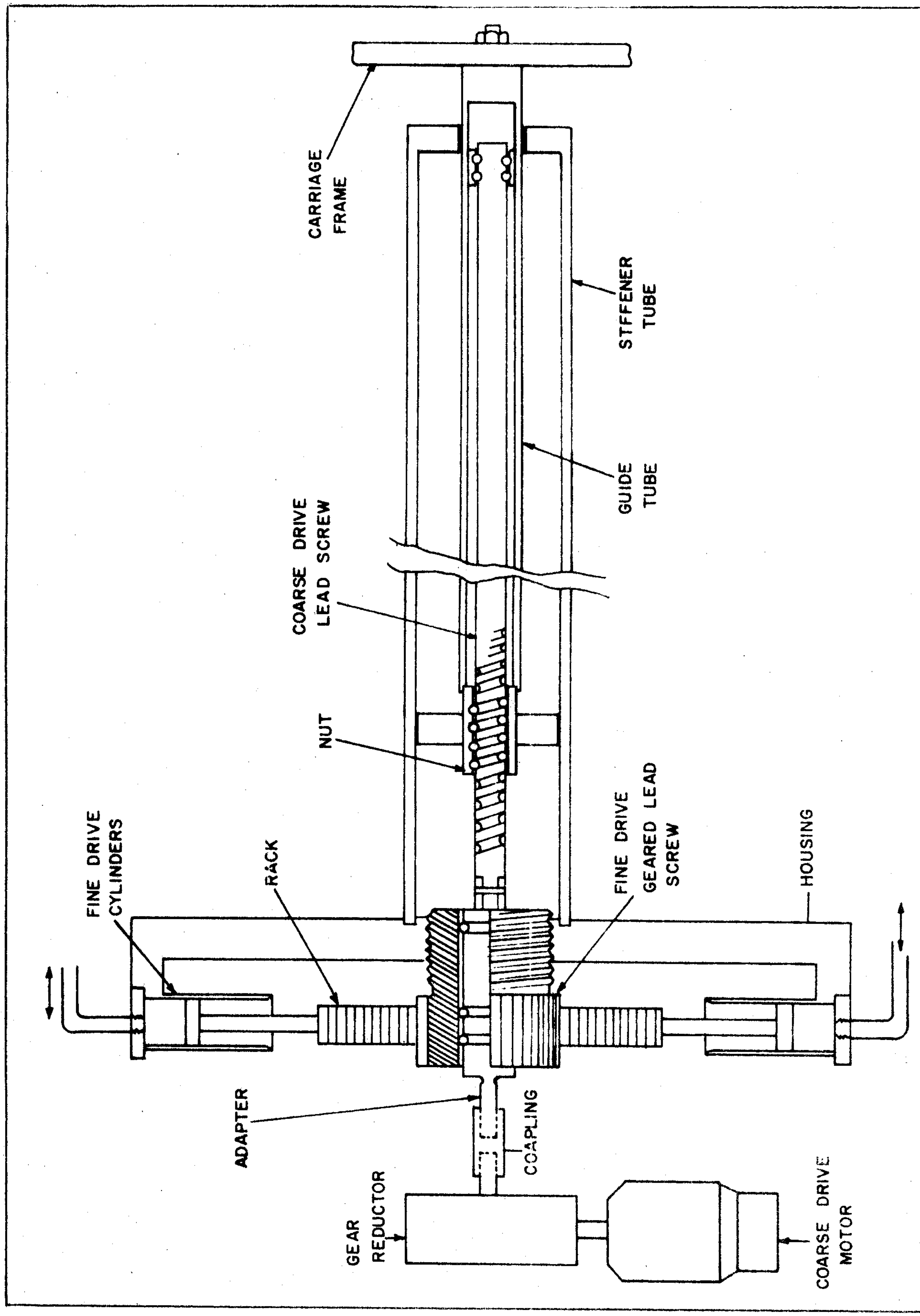


Figure 4 Horizontal Telescopic Tube and Drive Assembly

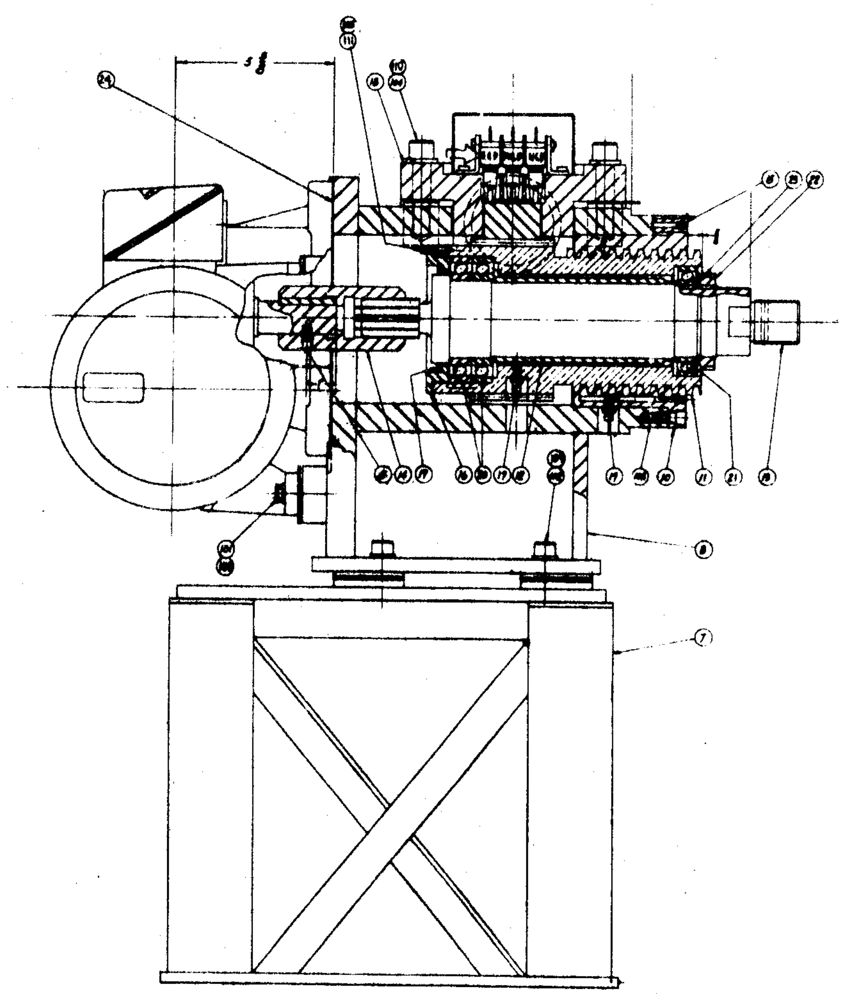


Figure 5 Horizontal Drive Assembly

approximately by the coarse Y motion, motor current is cut off and further lead screw rotation is prevented by the brake. However, the lead screw is connected to the drive coupling by a splined shaft which forms part of the vertical and fine drive assembly. The vertical and fine drive coupling assembly can move approximately 1/2 inch in each direction from its normal position.

The fine Y drive cylinder consists of a toothed rack which forms the connecting link between two opposing hydraulic cylinders. The introduction of oil to either cylinder moves the rack across the teeth of the fine Y drive screw causing the splined shaft to move in or out of the coupling and the lead screw to move up or down.

Vertical (Y) Drive Assembly (Fig. 7)

A simplified diagram of drive assembly for coarse and fine Y motion is shown in Fig. 7. As indicated some components are similar to the X motion drive assembly such as the drive coupling connecting to a splined shaft which is free to rotate inside the fine drive screw. Again, rotation of the lead screw causes a ball nut and attached shaft, termed the spline tube, to slide along the lead screw, thus lowering or raising the attached fuelling machine head.

Because of the possibility of the extended shaft flexing with the heavy fuelling machine head attached, a stiffener tube has been added to the telescopic column. This stiffener tube on the sketch, is fixed to the spline tube and both tubes slide up or down as the screw is rotated. A retaining tube is clamped to the thread at the bottom of the rotating table and the spline tube and stiffener tube telescope with respect to this retaining tube. The spline tube is inside and the stiffener tube is outside the retaining tube.

The spline tube is centered within the retaining tube by upper and lower guide rings. The upper guide ring slides along the retaining tube, moving with the spline tube and retaining tube. The lower guide ring is fixed to the retaining tube while the spline tube is located laterally and prevented from rotating by ball splines in the retaining tube. The ball splines in three grooves cut in the spline tube.

The upper guide ring carries upper and lower shock absorbers to absorb the impact at each end of the travel should the upper guide contact either the lower guide ring or the spline nut retaining tube clamping ring.

Anchor Connection

In the X drive assembly the drive coupling is attached to a splined shaft which is rigidly attached to the lead screw. In the Y drive assembly the splined shaft is connected to the lead screw through an anchor connection. This connection, item (m) in Fig. 7, transfers rotary motion to the lead screw when teeth cut in the lower end of the splined shaft engage the top ring of the anchor. However, if the lead screw and anchor are raised relative to the splined shaft the teeth are disengaged and rotation of the splined shaft does not cause the lead screw or anchor to rotate.

This provision makes it possible for the fuelling machine head to be lowered onto a solid platform or to the end of its travel without tending to drive the head through the floor lift the carriage or damage the mechanism.

A microswitch assembly is attached to the rotating table with its contact point riding just above the drive gear for the coarse Y positioning unit. At any time that the anchor becomes disengaged the contact is closed, the supply to the drive motor interrupted, the brake operated and rotation of the splined shaft stopped.

Coarse Y Positioning Unit

A drive gear is attached to the anchor and rotates with it. This drive gear drives a shaft and, through bevel gears, drives a cam shaft in the coarse positioning housing located on the rotating table. Microswitches are installed in the coarse positioning unit at locations corresponding to each horizontal row of calandria end fitting.

As the anchor and lead screw rotate for coarse Y positioning of the fuelling machine head, the cam shaft in the coarse positioning unit is turned by the drive gear bevel gear arrangement. When the cam shaft contacts the microswitch corresponding to the selected end fitting verticalplane, motor current is interrupted and the brake holds the fuelling machine head in position.

On signal from the fuelling machine snout fingers contacting the end fitting, the fine Y drive screw is rotated by the fine drive hydraulic cylinder assembly, in a manner similar to the fine X drive operation.

Y-Drive Lock Assembly

The Y-drive lock assembly provides a positive lock for the coarse Y-drive as a back-up for the Y-brake. The lock assembly is located on an extension shaft at the end of the input shaft of the Y-drive Boston Gear Reductor.

It consists of a ratchet mounted on the end of the Gear Reductor input shaft with which any one of three pawls can engage. The ratchet has six teeth and the engaging teeth on each of the pawls are equally displaced so that only one pawl engages with the ratchet at a time. This provides stops at 20° intervals of the ratchet.

The pawls are normally held out of engagement with the ratchet by a lifter driven by a hydraulic rotary actuator. Hydraulic power is taken from the elevator hydraulic pump unit, the direction of flow being controlled by a three way control valve located on top of the Y-drive lock housing. The pressure to each side of the actuator is limited by two pressure relief valves while the rate of actuator travel to the lock position is limited by a flow control valve. Two microswitch detectors YPUD and YPDD are actuated by the lifter at each end of its travel while the detector YPKD is actuated when any one of the three pawls is fully engaged with the ratchet.

Whenever the coarse Y-drive motor is operating, the pawl lifter rotary actuator is pressurized to lift the pawls clear of the ratchet. When the Y-drive motor is stopped and the brake applied, the pawl lifter is rotated to allow the pawls to engage with the ratchet. The flow control valve CF-CV 355 is adjusted to limit the rate of travel of the pawl lifter rotary actuator so that the drive has completely stopped before the pawls are engaged.

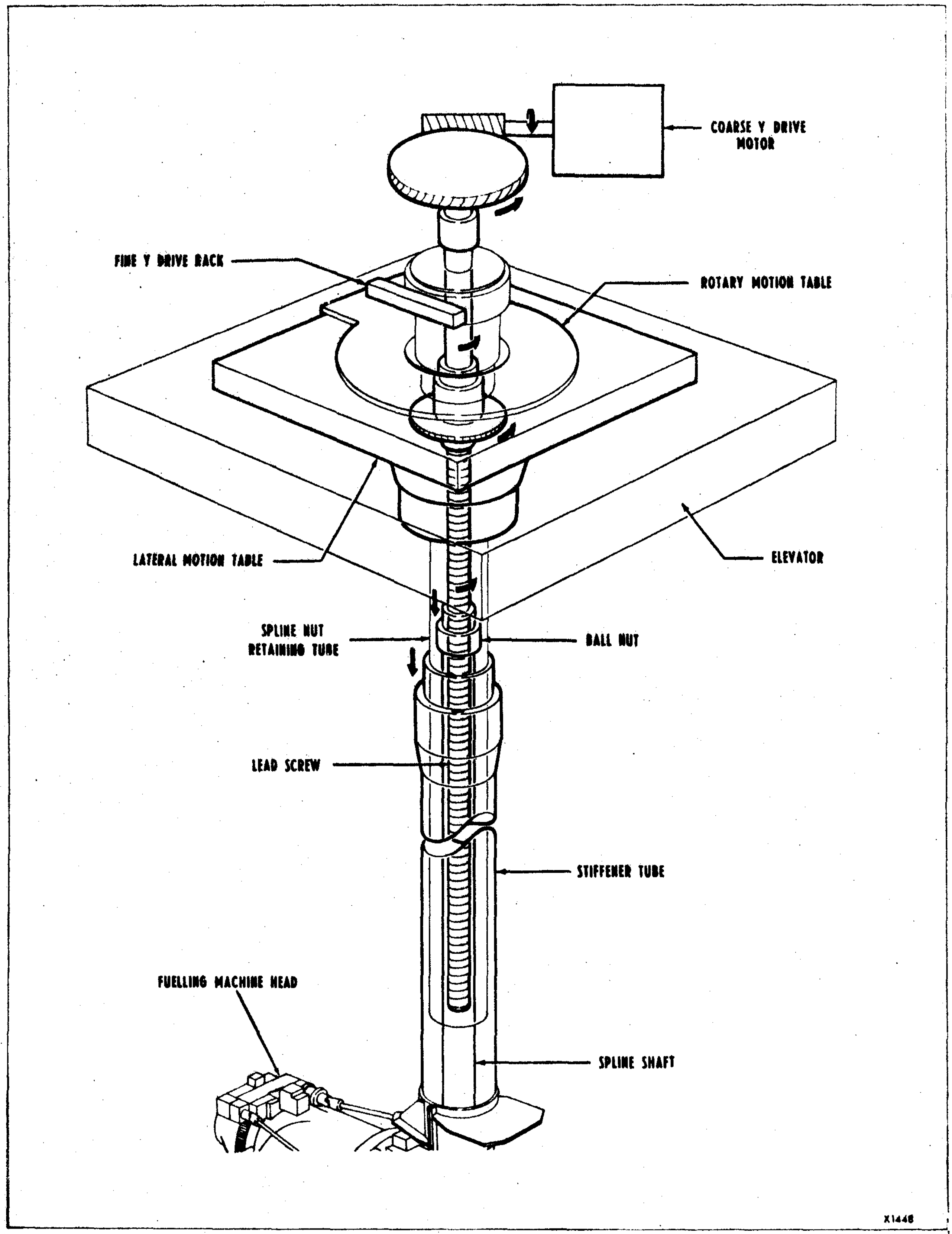


Figure 6 Coarse 'Y' Drive Motion

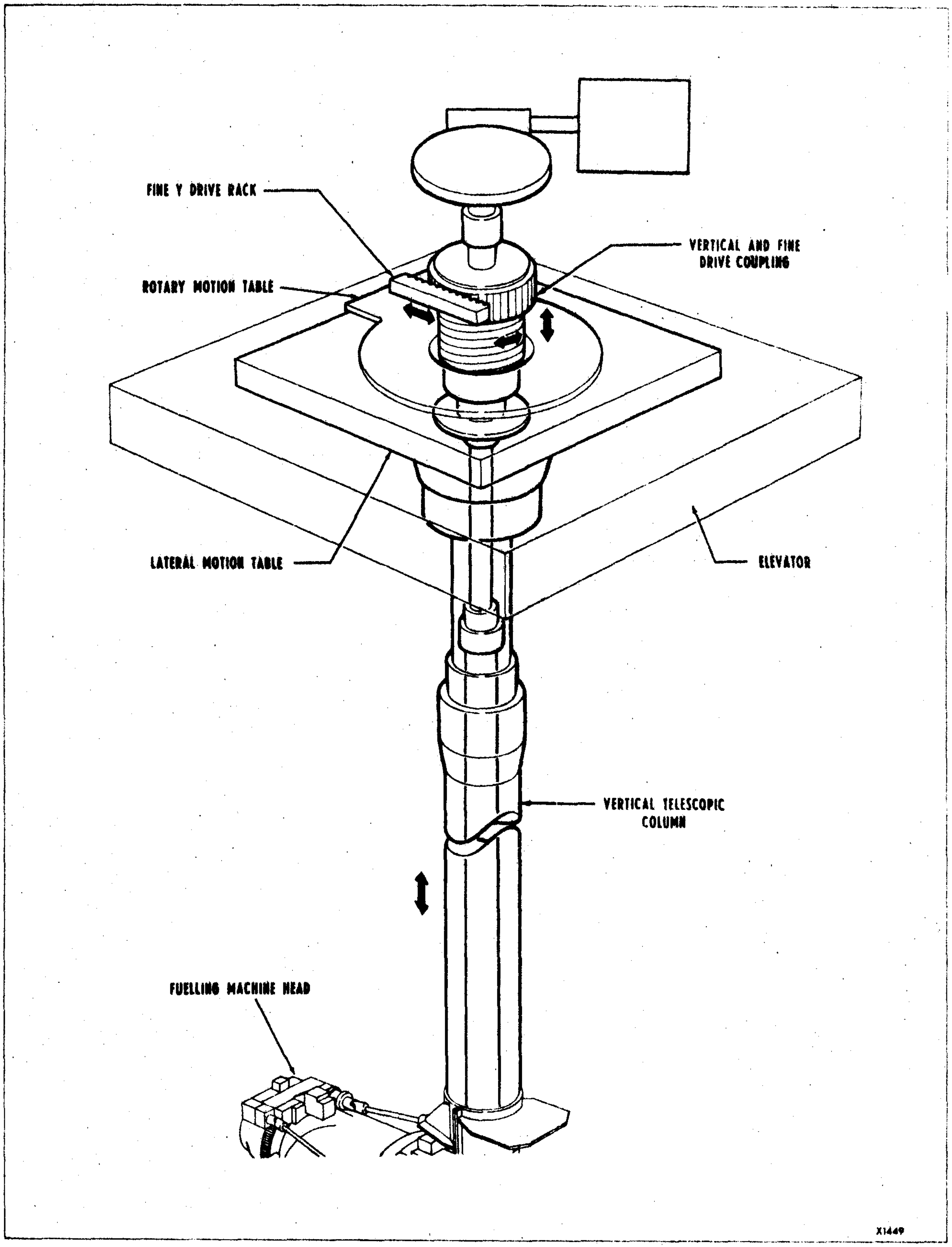


Figure 7 Fine 'Y' Drive Motion

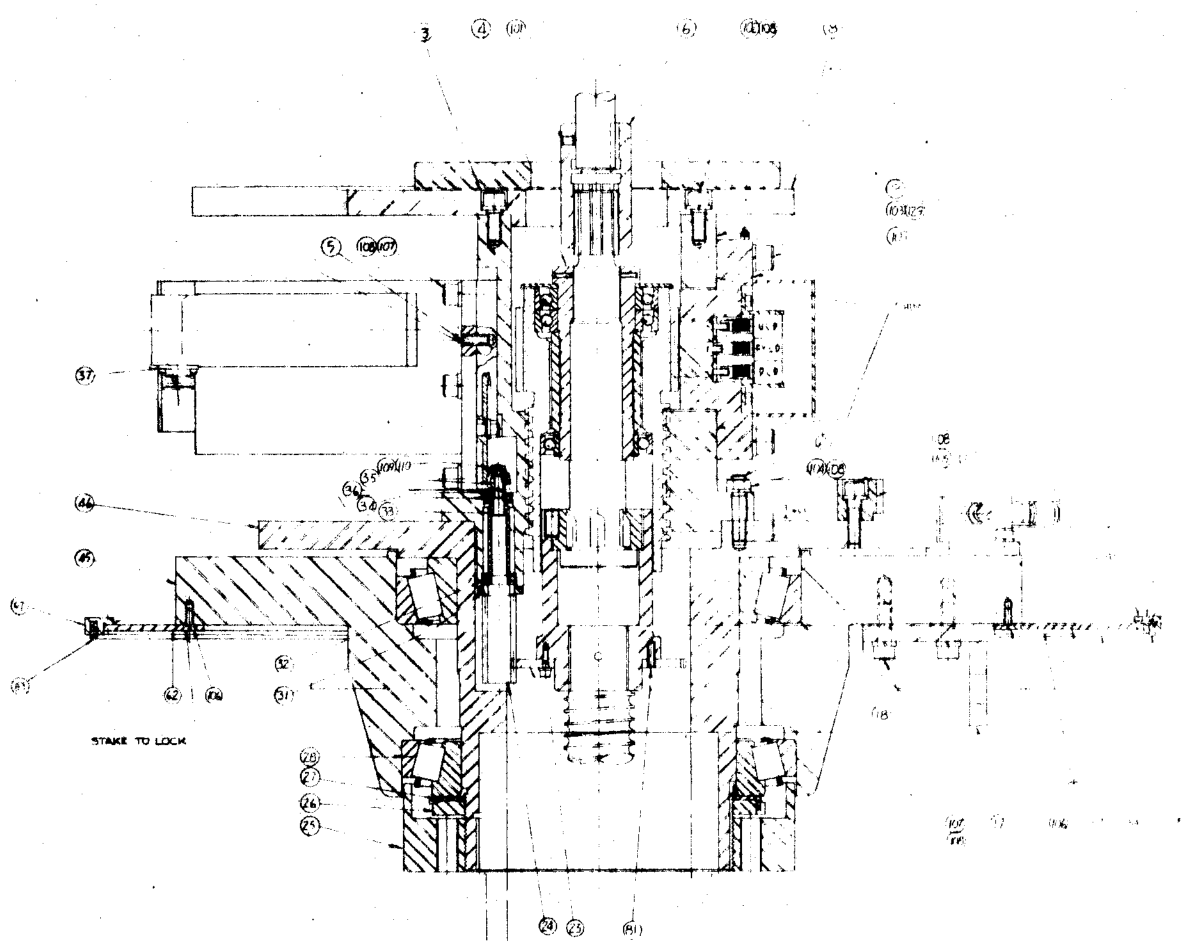


Figure 8 Vertical and Azimuth Drive Assembly

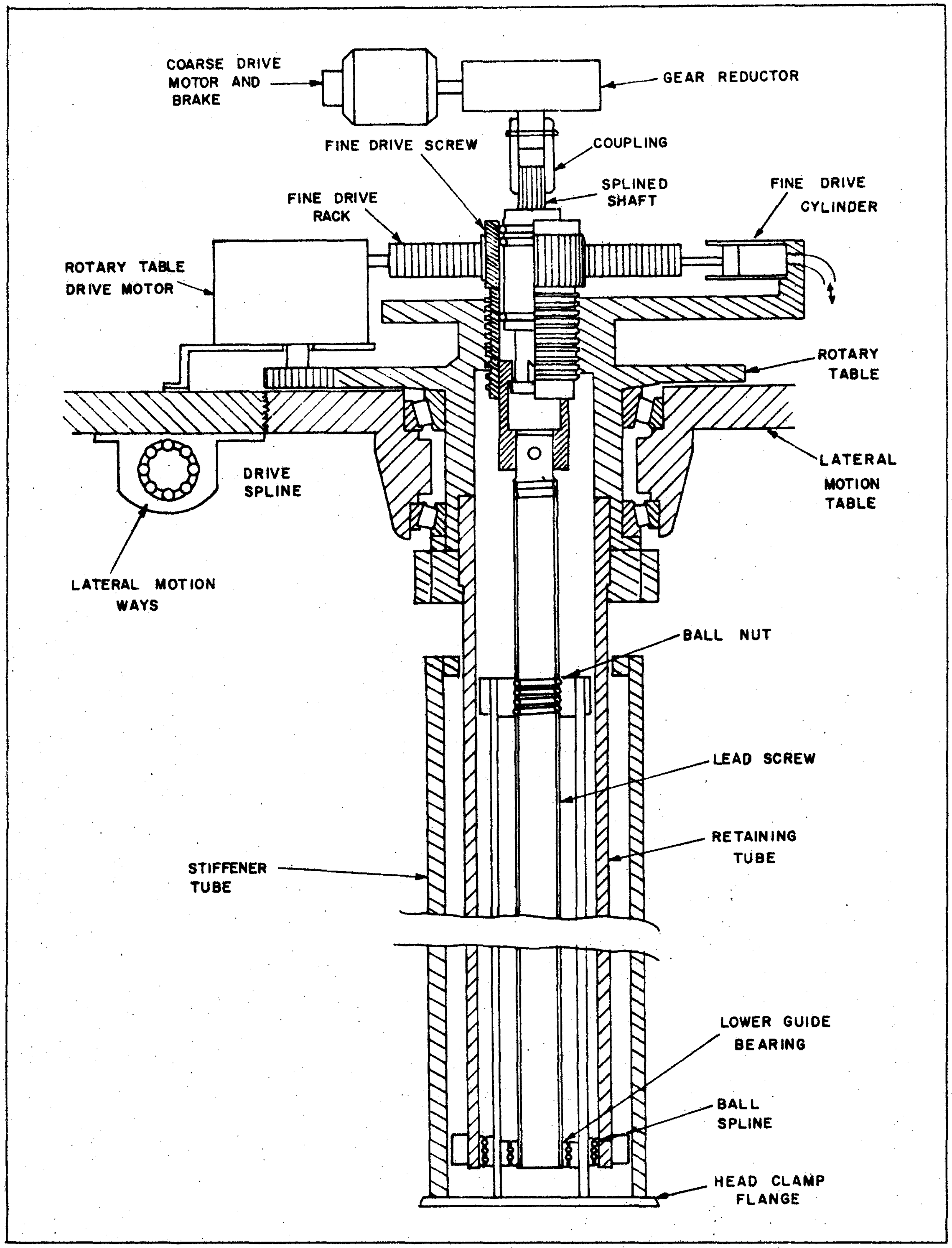


Figure 9 Vertical Telescopic Tube and Drive Assembly

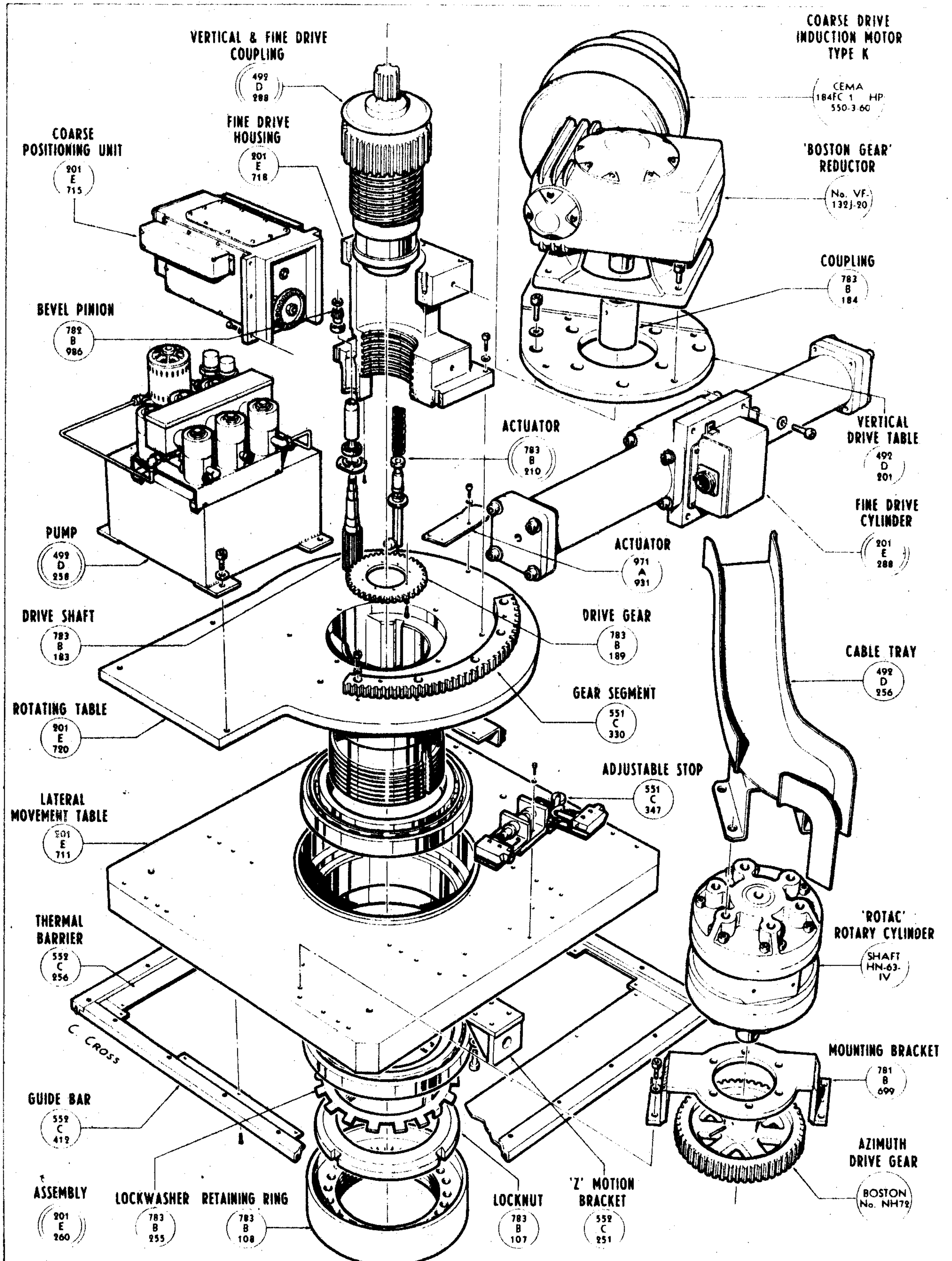


Figure 10 Vertical and Azimuth Drive

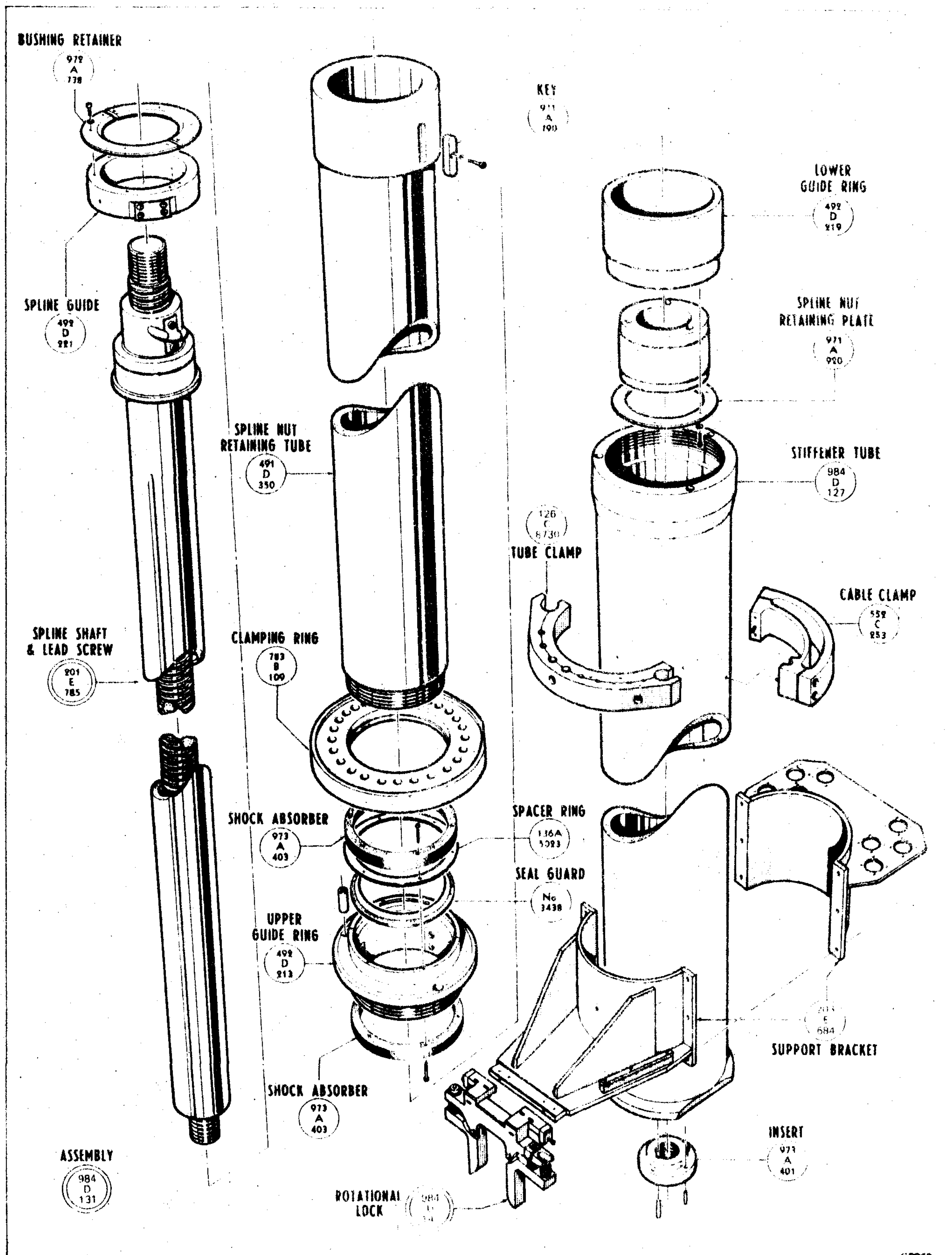


Figure 11 Vertical Screw and Telescopic Tube

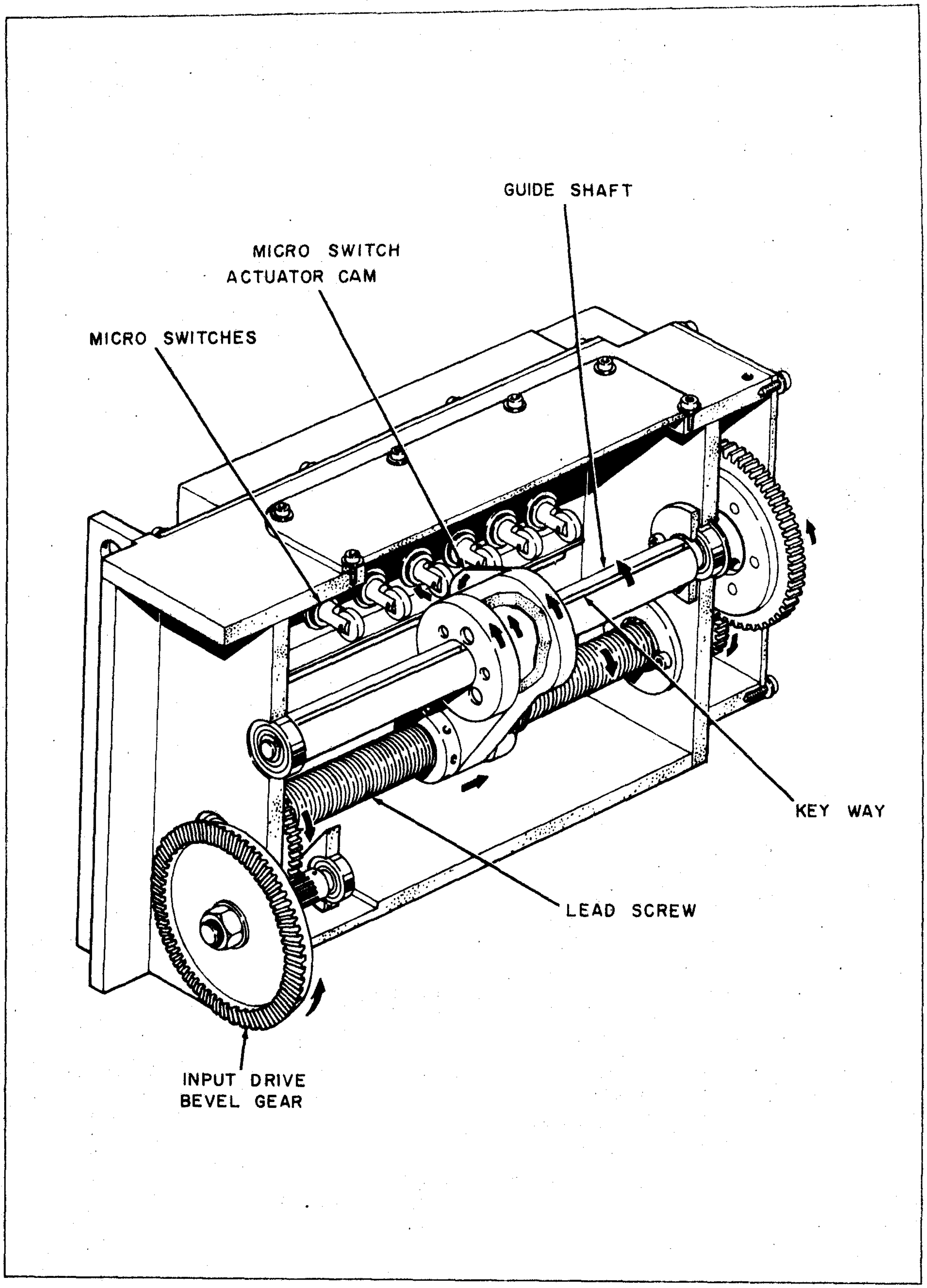


Figure 12 Coarse 'Y' Positioning Unit

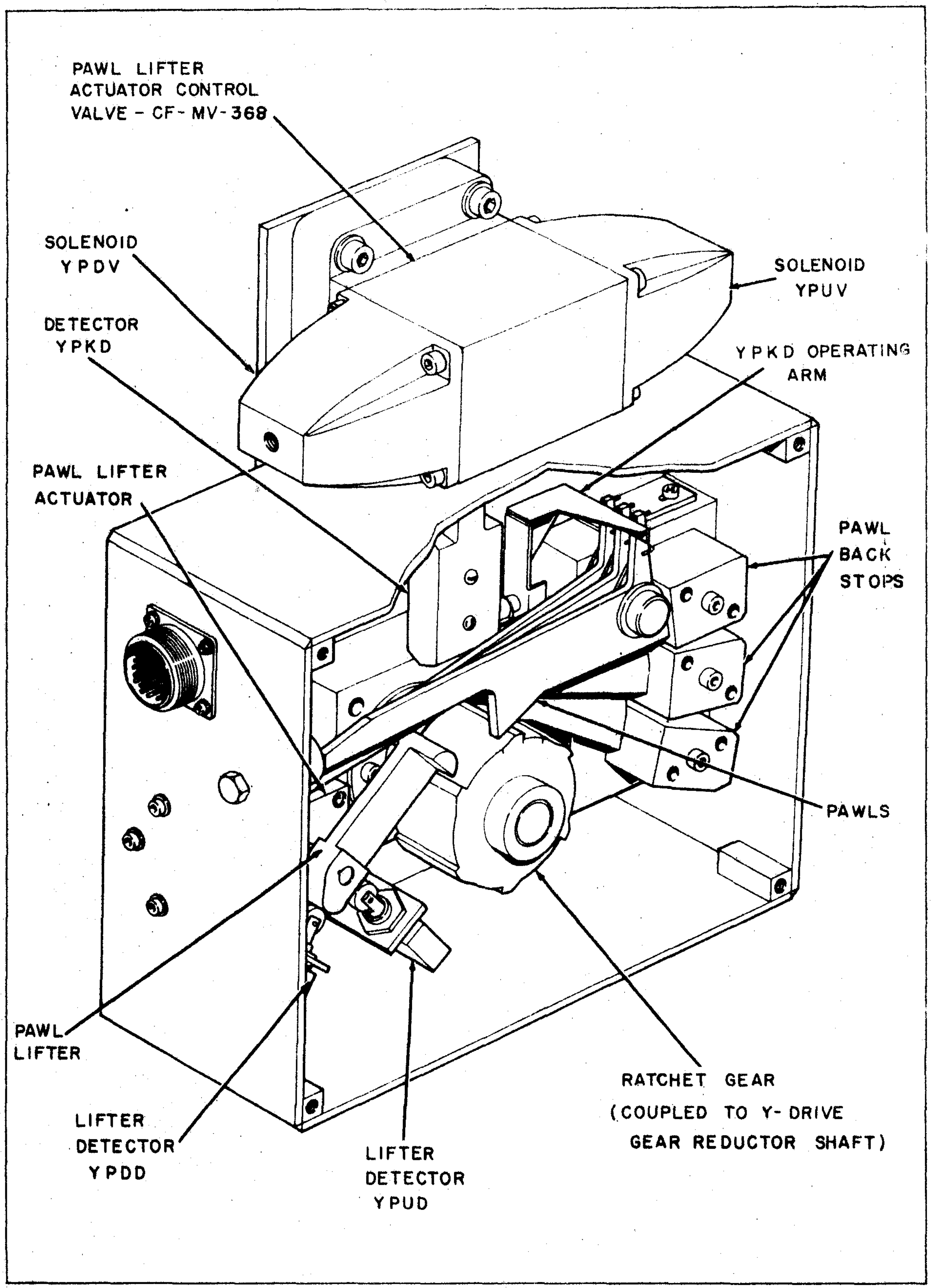


Figure 13 'Y' Drive Lock Assembly

NPD Systems - Reactor Boiler and Auxiliaries

Fuel Handling Systems

FUELLING MACHINE ELEVATOR, AXIMUTH AND Z-MOTION DRIVES

In lesson 530-352.3, the carriage assembly was described and the major drives of the carriage, horizontal (x axis), Vertical (y axis) elevator, azimuth and z motion were discussed. The horizontal and vertical drives were described in detail in lesson 530-352.4. In this lesson, the elevator, azimuth and z motion drives will be described.

ELEVATOR DRIVE

The elevator drive system provides two positions for the elevator, fully up (EU) or fully down (ED). The drive system consists of two ball-nut lead screws driven by a 3 horsepower motor through two mitre gearboxes and two worm gear speed reducers. The motor is reversible, for up and down motion. A spring - actuated, solenoid-release brake is installed on one of the motor output shafts and is automatically applied by spring pressure whenever power to the drive motor and brake is shut-off. See Figure 1.

Each lead screw is suspended at its upper end by a ball bearing assembly mounted in the carriage top frame. The lead screw is coupled to the speed reducer by a splined coupling which will automatically disengage if the lead screw is lifted. This can occur if the elevator jams during lowering or if the drive motor continues to run after the elevator has reached the bottom of its travel. The spline will automatically re-engage when motor direction is reversed. See Figure 2.

In addition, when the lead screw is lifted, the lower ball bearing which is sleeve mounted, is also lifted. Initial movement of the bearing actuates a limit switch EDLD to cut off the motor. If the drive continues to run, a second switch ELSUD is actuated when the bearing has been lifted 1-1/8 inches. At this point, the splined coupling at the speed reducer will be disengaged to prevent any possibility of damage to the carriage or drive systems.

The south lead screw on each carriage has five detectors: the elevator up limit detector, EULD; elevator up detector, EUD; elevator down limit detector, EDLD; elevator down detector EDD and elevator lead screw up detector ELSUD. The north lead screw on each carriage has four detectors, all the above except EUD.

The detectors EDD1, EDD2, EDLD1 and EDLD2 operate to ensure positive bottoming of the elevator on the carriage frame and operate to stop the drive system if the elevator tilts.

Detectors EDD1 and EDD2 are operated by the elevator when it reaches the bottom of its travel. Detectors EDLD1 and EDLD2 are each operated when the sleeve mounted ball bearings are lifted relative to the carriage frame. When the elevator is fully seated on the carriage at the bottom of its travel, EDD1, EDD2 and either EDLD1 or EDLD2 must be operated to give a DONE condition.

If during lowering of the elevator it becomes tilted, either EDLD1 or EDLD2 will be operated as that particular lead screw is lifted. This will cause a STOP and is detected by the control system logic if either EDLD1 or EDLD2 is actuated without both EDD1 and EDD2 being actuated.

During elevator up operation, if either EDLD1 or EDLD2 are actuated with the opposite EDD detector not actuated, this also indicates a tilted elevator condition and gives a STOP. The upper limit of elevator travel is detected by two limit detectors on the south side of the elevator, EUD and EULD1 and one on the north side, EULD2.

AZIMUTH DRIVE

The fuelling machine is rotated, when in the vault, through 90° between the azimuth service and normal positions. This is achieved by a rotory hydraulic drive motor which drives the rotary motion table through a pinion gear on the motor output shaft and a gear segment on the rotary motion table. See Figure 3.

The motor is supplied with hydraulic pressure from the elevator oil hydraulic system. See Figure 4 . The flow of oil to and from the motor is controlled by two solenoid operated control valves, CF-MV-204 (ANMV) and CF-MV-205 (ASMV). When their solenoids are de-energized, both ports of the motor are connected to the reservoir. However, if the head is in the service position and the solenoid of CF-MV-204 (ANMV) is energized, oil pressure will be directed to the motor to drive the head to the azimuth normal position, return oil being led through the de-energized valve CF-MV-205 to the reservoir. The function of the two valves is reversed when driving the head from normal to the service position.

A positive stop and two limit switches are mounted on the lateral motion table at each end of the travel. The switches and stop are contacted by a projection on the rotory motion table to provide the necessary position indication limit travel and provide a positive stop. See Figure 5.

Z MOTION DRIVE

Z motion, that is moving the fuelling machine into and away from the reactor end fittings, is achieved by moving the lateral motion table. Motion is provided by an electric motor driving the table through a lead screw. The motor is coupled to the lead screw by a worm gear double-reduction speed reducer. A slip clutch, installed between the motor and the speed reducer, limits the output torque of the motor to prevent damage to the drive system and components. See Figure 6.

Normal Z motion is indicated and limited by three limit switches, ICD, (in from centre detector), OCD (out from centre detector) and ZLD (Z limit detector). Additional out from centre travel, which is used only when it is necessary to uncouple a fuelling machine from an end fitting with the head lockring fully forward, is limited by a fourth limit switch, ZET (Z end of travel).

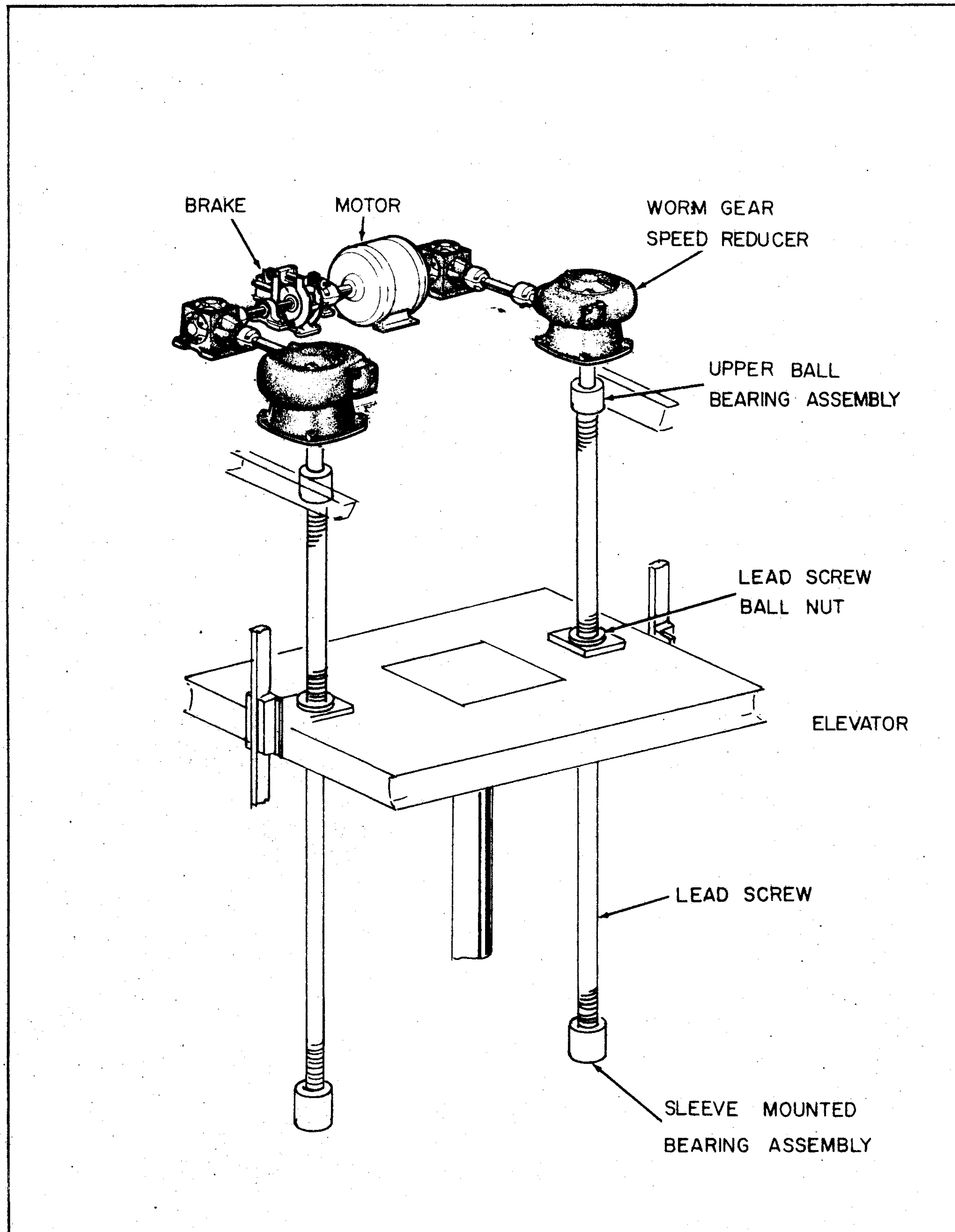


Figure 1 Elevator Drive System

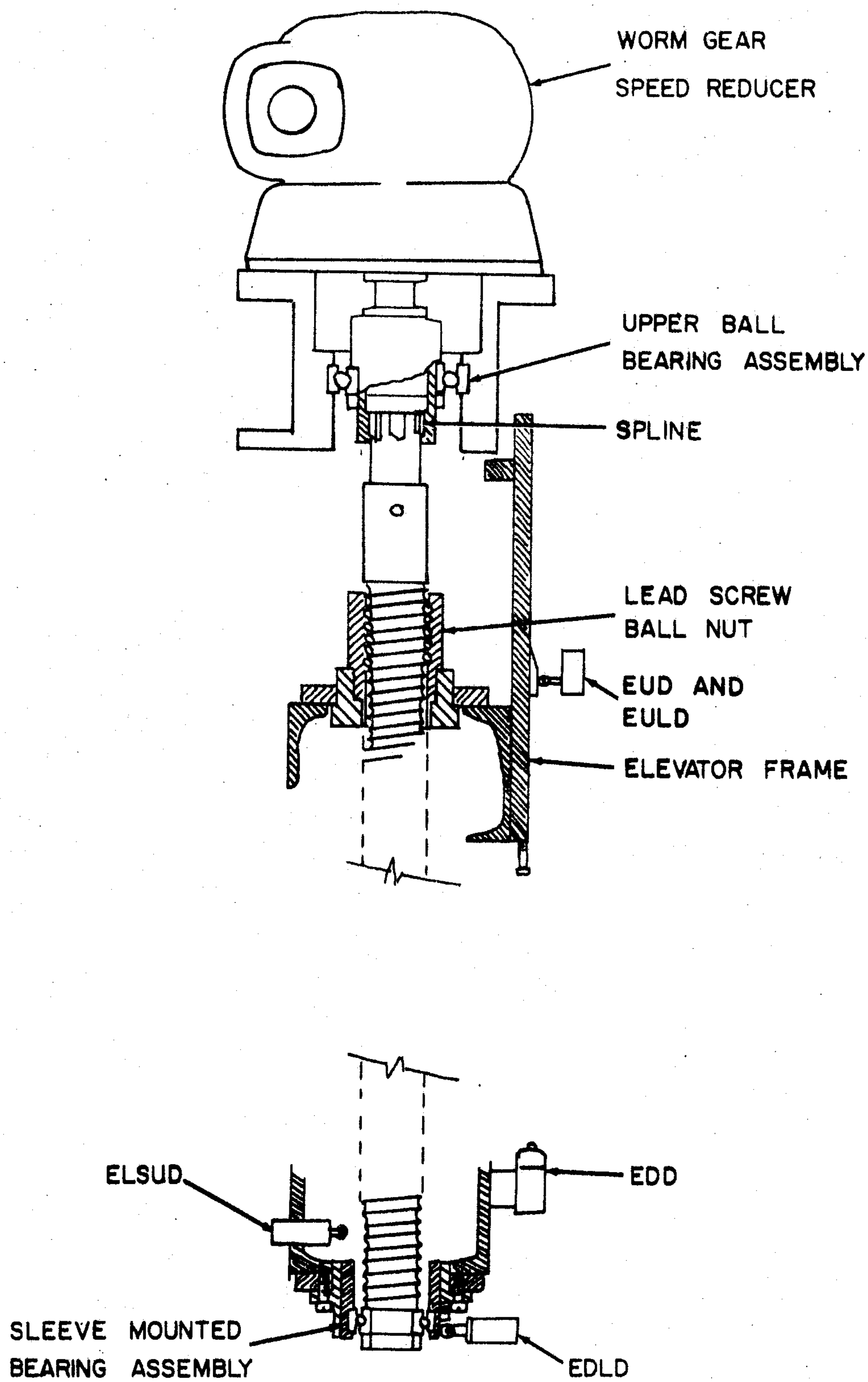


Figure 2 Elevator Ball Lead Screw Assembly

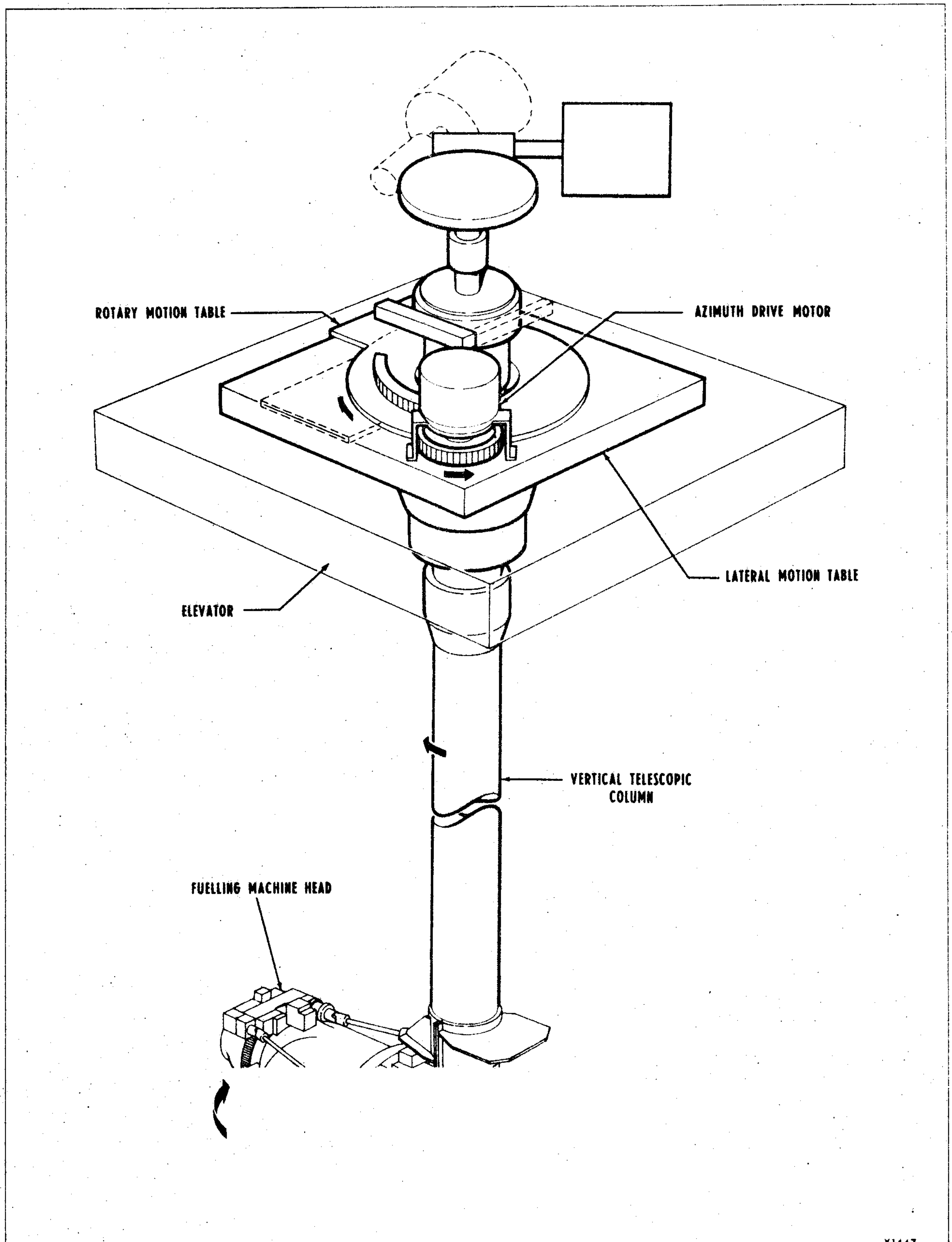


Figure 3 Azimuth Drive System

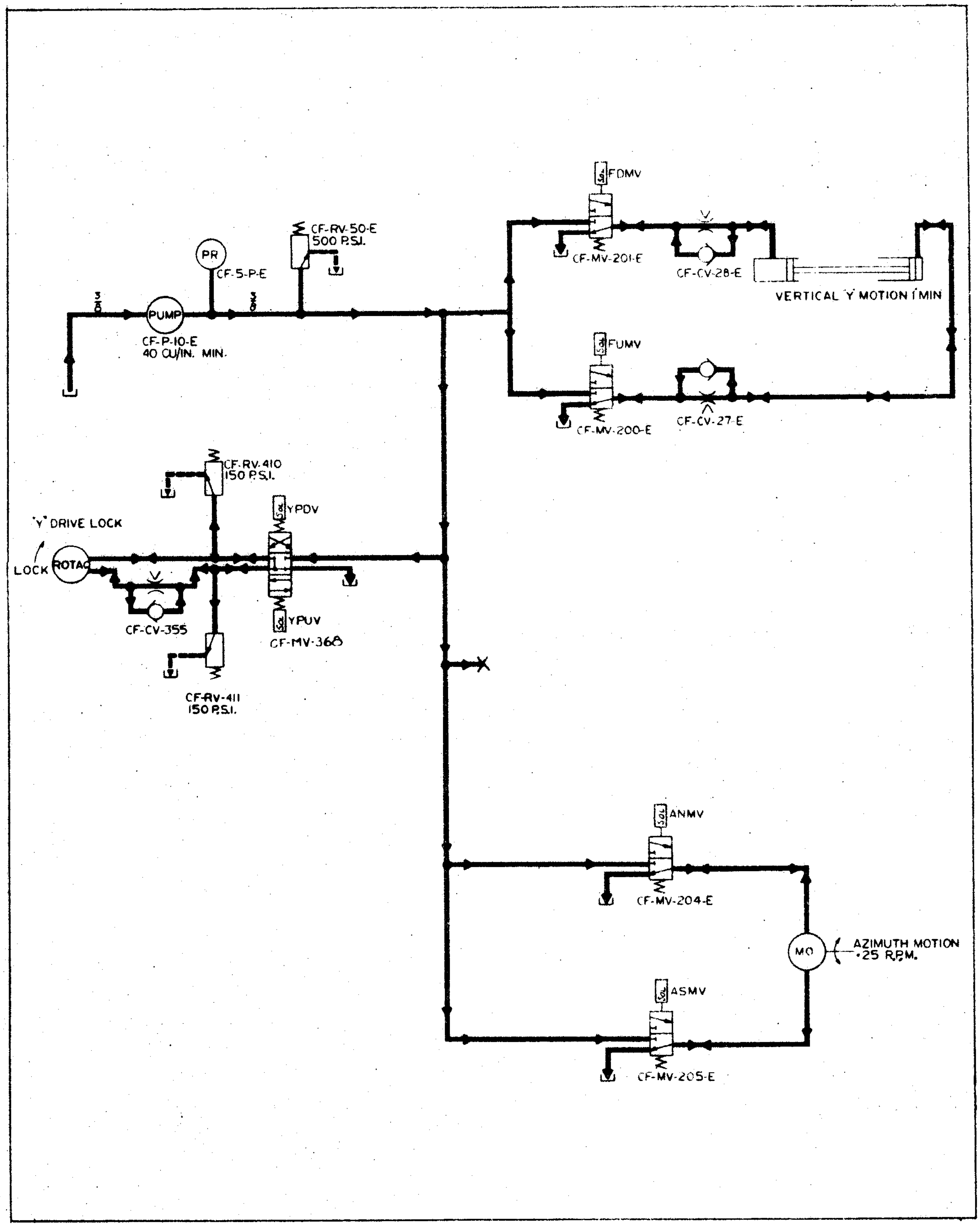


Figure 4 Oil Hydraulic Schematic - Y Fine Motion, Azimuth Motion and Y Lock

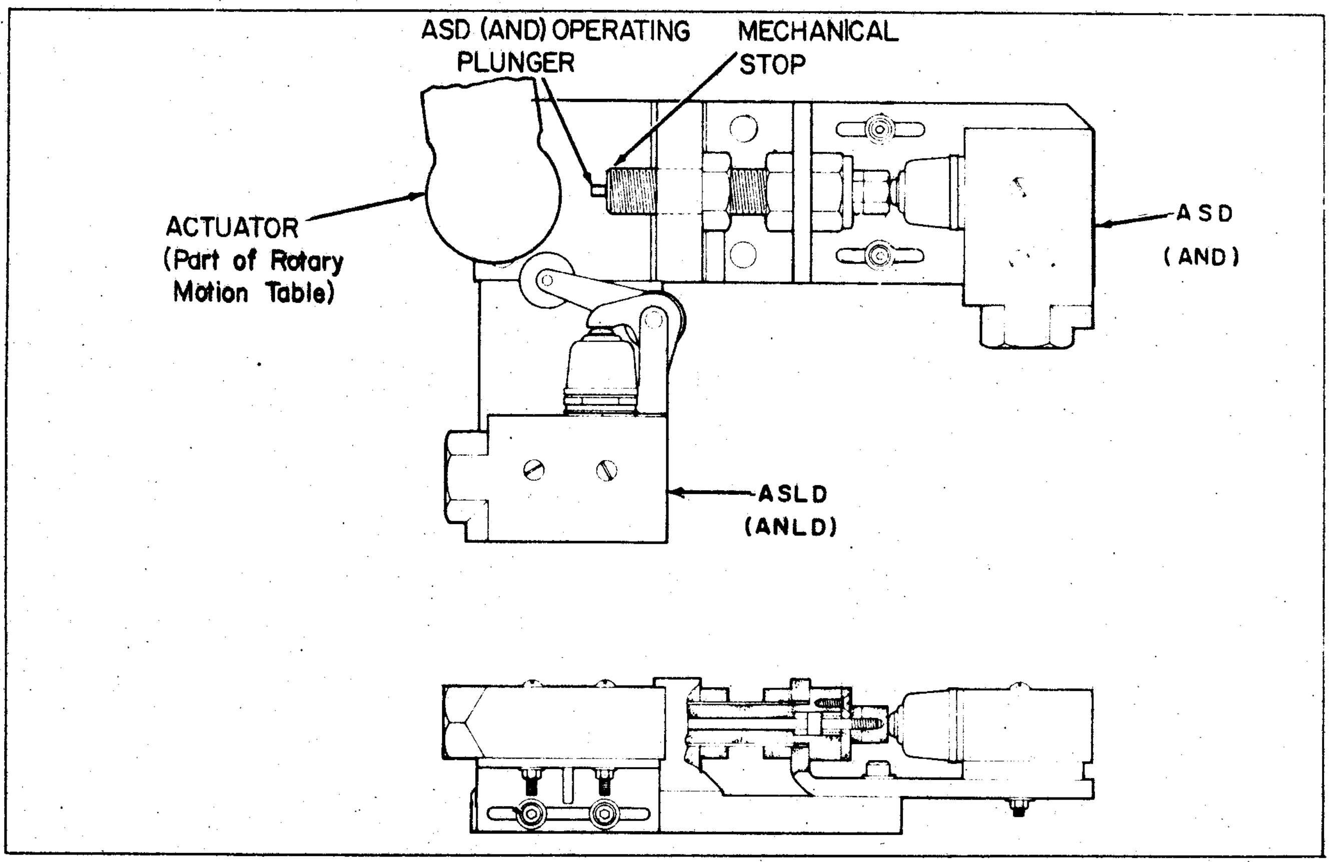


Figure 5 Azimuth Positive Stop and Detectors

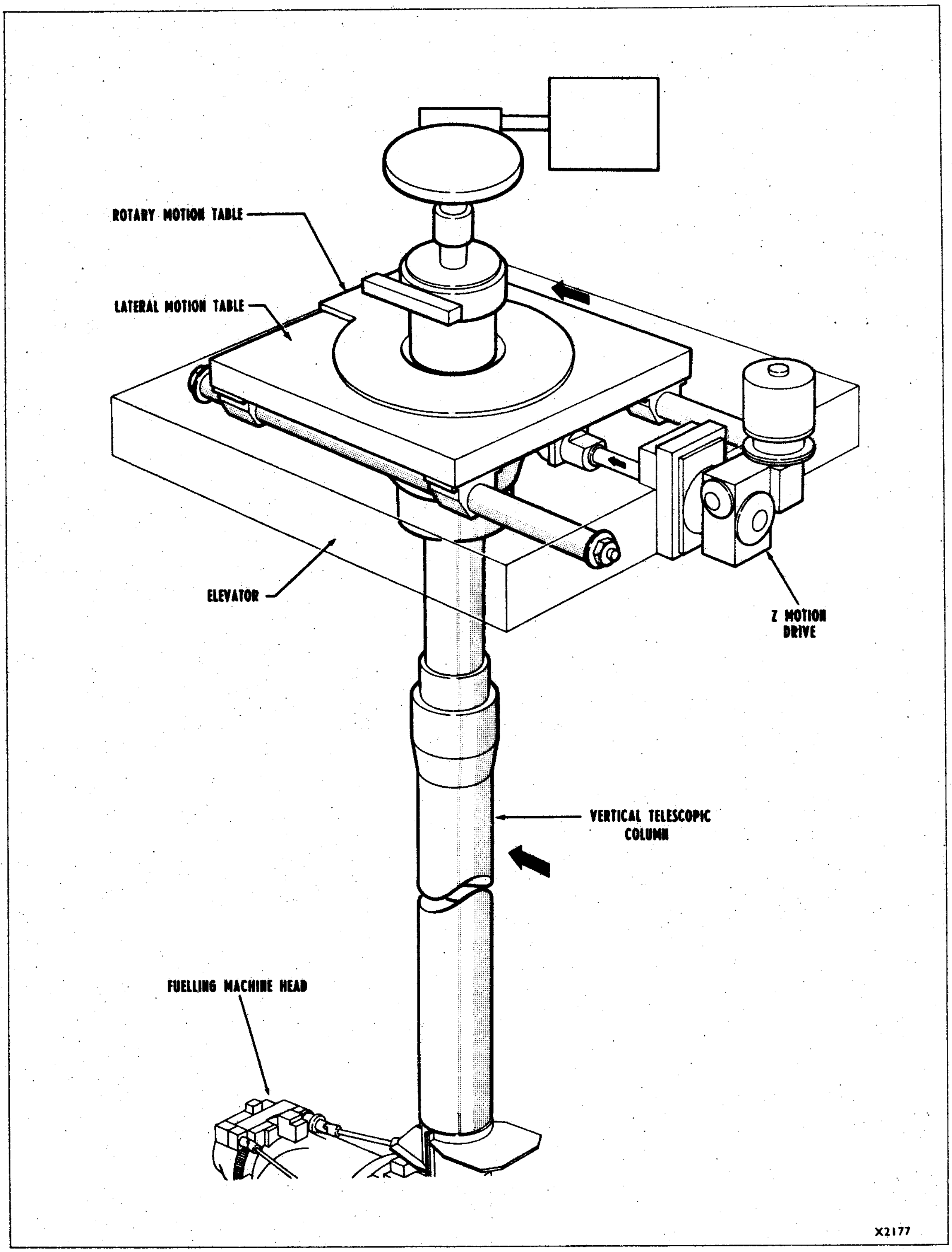


Figure 6 Z Drive System

NPD Systems - Reactor Boiler and Auxiliaries

Fuel Handling System

FUELLING MACHINE HEAD SUSPENSION AND CLAMP

The fuelling machine head suspension connects the fuelling machine head assembly to the vertical telescopic column. In performing this simple function however, there are certain requirements which must be met which add considerably to the complexity of the equipment. This lesson will define these requirements and describe the suspension mechanisms.

REQUIREMENTS OF THE HEAD SUSPENSION

The requirements of the head suspension are:

(a) When unlocked, to float the fuelling machine head in space so that the locking mechanism can pull it freely into alignment with the end fitting and so that the head will follow, with minimum restraint, the excursion of the end fitting due to temperature, pressure and weight variations of the reactor.

(b) To provide this freedom in five degrees; translation in the X,Y and Z direction, rotation about the X and Y axes.

(c) To impose no excessive out-of-balance loads on the end fitting as a result of variation in head water level, in head component position, in number of fuel bundles,plugs or adapters in the head, or as a result of friction and non-linearity in the support mechanism.

(d) To be capable of locking and unlocking so that the system can be rigid for coarse and fine homing and all traverse operations, but unlocked when locked onto an end fitting.

(e) To provide a disconnect point between the fuelling machine head and the vertical telescopic column which can be readily (mechanically) disconnected.

The first three requirements (a), (b) and (c) arise from the necessity to prevent excessive bending moments being applied to the end fittings during fuelling operations which could cause excessive stresses in the coolant tube assemblies.

The fourth requirement, (d), ensures a fixed reference position of the head with respect to the telescopic column for each homing operation so that the coarse motion position detectors will always locate the head in the same position with respect to the end fitting at every fuelling site.

The last requirement (e), arises from the fact that the fuelling machine head will have to be removed from the fuelling machine room for maintenance.

FIVE FREEDOMS OF MOVEMENT

Movement of the head with respect to the fuelling machine telescopic tube must be freely permitted with respect to the X, Y and Z axes, as shown in Figure 1.

Translation must be permitted equally in both directions from a permanent central reference point along the X and Y axes. Translation must also be permitted in the Z direction from a position in Z determined by the fine homing operation.

Rotational movement or deflection must be possible about the X and Y axes.

REASONS FOR HEAD MOVEMENT

The head must be free to move within limits, relative to the reactor, for the following reasons:

(a) To accommodate variations in the location of the reactor end fittings caused by manufacturing tolerances;

(b) To accomodate variations in the angular alignment of the end fittings relative to the plane of the reactor end face;

(c) To accommodate manufacturing tolerances in the reactor end fittings;

(d) To compensate for minor variations in the homing operation;

(e) To accomodate movement of the end fittings due to temperature fluctuations and reactor weight changes caused by reactor trips or power output changes.

Variation in Head Weight and Balancing

To provide the required vertical freedom of movement, the head is supported on two counterbalance arms. The arms are pivotted about ball spline bearings located on the centre line of the vertical column and support the head at their forward end on the head support bearings.

In the course of a fuelling operation, the head weight and centre of gravity position are affected by changing conditions, e.g., filling the head with $D_2O$from the half full condition, magazine full versus magazine empty of fuel bundles, addition of reactor end fitting plug to the magazine and moving internal components.

These changing conditions result in an unbalanced condition of the head about the head support bearings and of the head and counterweight about the ball spline bearings. This results in a vertical bending moment and a vertical reaction on the end fittings.

To minimize the effects of any unbalance, the head is balanced about the head support bearings and the counterweights adjusted to balance the head under the mean of the two extreme conditions. These two conditions are:

(a) The head half full, empty of fuel, without the end fitting plug in the magazine, but with the normal complement of fuel carriers, adapters and a spare plug in position and with all drives in their "home" position;

(b) The head full, with a full complement of fuel, the reactor end fitting plug in the magazine and all drives in their "home" position.

Movement of Head and End Fittings

During the homing process, the fuelling machine is accurately located in the X, Y and Z directions refer to Lesson 053-352.7. However, following the locking action and during the period that the head and end fitting remain rigidly connected, the end fitting position may change due to temperature changes and changes in moderator weight within the calandria.

Changes in reactor vault temperature will cause expansion and contraction of the support rods. Changes in moderator and reflector temperature will cause expansion and contraction of the calandria. These temperature changes will cause movement of the end fitting in the X and Y directions.

Temperature and pressure changes of the primary heat transport system will alter the lengths of the coolant tube, moving the end fittings in the Z direction. The end fittings can slide within their supports at the west end of the reactor.

Weight changes within the calandria, as a result of changes in moderator level, will cause varying strain in the calandria support rods causing movement of the end fittings in the Y direction.

Maximum movement of the end fittings as a result of all of these factors, has been estimated as follows:

Maximum Y displacement + 0.010* in. to -0.434 in.
Maximum X displacement ± 0.240 in.
Maximum Z displacement + 0.500 in.

*Top row only.

The fuelling machine head will also move relative to the end fittings in the Y direction as a result of the temperature differential between the atmospheres of the fuelling machine room (70°F) and the reactor vault (100°F). Following its entry into the vault and after locking on, the telescopic column will continue to expand as it assumes the higher temperature of the vault atmosphere.

HEAD SUSPENSION

The head suspension is shown exploded in Figure 2. It consists of two counterbalance arms with counterweights at their outer ends. Each arm is pivotted about the clamp housing through two ball bearings and can move sideways relative to the clamp housing on the ball spline. The ball bearings permit the complete head, including the counterweights to rotate about the X axis while the ball splines permit the complete head to move along the X axis.

The head is secured to the counterbalance arms by two spherical head support bearings at its centre of gravity. These bearings enable the head to remain level relative to the reactor face even when the counter-balance arms move. The position of these bearings on the head is fixed, the centre of gravity being adjusted by varying the mass of the weights at the front of the head.

The head including the counterbalance arms, can rotate about the vertical column or Y axis, on the main bearings located in the clamp housing. The degree of rotation is limited by stops in the suspension lock assembly which is described later in this lesson.

A pneumatic damper is installed between the end of one of the counterbalance arms and the head support structure, to damp out rapid movements of the head or counterbalance arms when the suspension is unlocked. This is necessary to prevent damage to the suspension stops and other structural components.

HEAD SUSPENSION LOCKS

The head suspension is locked whenever the head is not on an end fitting. When connecting to an end fitting, the suspension remains locked until fine homing is completed and the lockring has moved forward over the end fitting and locked. Upon completion of the fuelling operation at the end fitting, the suspension is locked up as soon as the head lockring is moved forward but before it is unlocked.

The component parts of the suspension lock assembly are shown in Figure 3. Two hydraulic actuators are mounted on the head and carry roller type cams on their shafts. The actuators rotate the cams through 90^{o} to engage the locks. In the locked position, the cams are 10^{o} beyond their perpendicular position to prevent unlocking if the hydraulic system fails. Three sets of locking plates are provided, a rotational set and a vertical set at the front and a combined horizontal and vertical set at the rear.

The front rotational set is mounted directly to the column while the front vertical and rear horizontal and vertical locking plates are bolted to the clamp housing which is in turn locked to the vertical column. Refer to the clamp and bearing assembly description later in this lesson.

Operation

The two lock actuators form part of the head oil hydraulic circuit which is described in lesson 053-352.11.

When a suspension lock selection is made by the control system, both actuators are operated to rotate their cams to engage with the locking plates. One side of each set of locking plates is spring loaded to absorb any slight misalignment in the locking system geometry and to maintain a tension on the cams and hold them in the locked position. In the rotational locking plates assembly, both sides are spring loaded. The left side plate is spring loaded for the same reasons as the other locking plates. An additional spring buffer is fitted to this side and a spring buffer is fitted to the other side to absorb rotational shocks which could occur in this plane during lock up.

The position of the rear lock actuator is adjustable to ensure the correct locking action during lock up.

SUSPENSION MANUAL LOCKS

Before the head can be removed from the column, the counterbalance arms must be locked to the head and the locking plates together with the clamp housing, locked to the counterbalance arms and the suspension locks unlocked.

The manual locks are necessary because as soon as the weight of the head is removed from the suspension, by lowering it onto its support structure, all the weight of the counterbalance arms would be transferred to the suspension locks. If this occurred, the suspension locks would be severely damaged.

The manual locks consist of two knurled pins, and a set of locking plates. See Figure 2 . The knurled pins pass through a lug on each counterbalance arm and screw into the drive housing to lock the arms.

The locking plates are mounted on thebearing housings of each counterbalance arm by a bracket. The plates are slotted and held to the bracket by capscrews. In the locked position, cutouts in the plates contact the clamp halves of the head clamp assembly to prevent the head moving relative to the column. These plates also prevent the clamp assembly moving when the head has been disconnected from the column.

HEAD DISCONNECT CLAMP

The head disconnect clamp provides a quick, positive and simple means of connecting the head to the vertical column and of disconnecting it when required. In conjunction with the fluid and electric disconnects, it enables an irradiated head to be removed from the column with a minimum of exposure of maintenance personnel. See Figure 4.

The clamp consists of two clamp halves mounted on an adapter by two threaded shafts and two guide rods. The threaded shafts are both rotated together by worm gears from a drive shaft to pull the clamp halves together and clamp up the flanges of the vertical column and the head adapter. The square section on the adapter mates with a square recess in the base of the vertical column to provide positive alignment.

The worm gears on the input drive shaft are opposite handed, i.e. one left hand and one right hand, with the threads of the threaded shafts cut to suit. By making the worm gear threads opposite handed, the axial loads applied to the drive shaft by the worm gears during tightening and loosening of the clamp oppose each other, thus preventing the transfer of these loads to the shaft bearings.

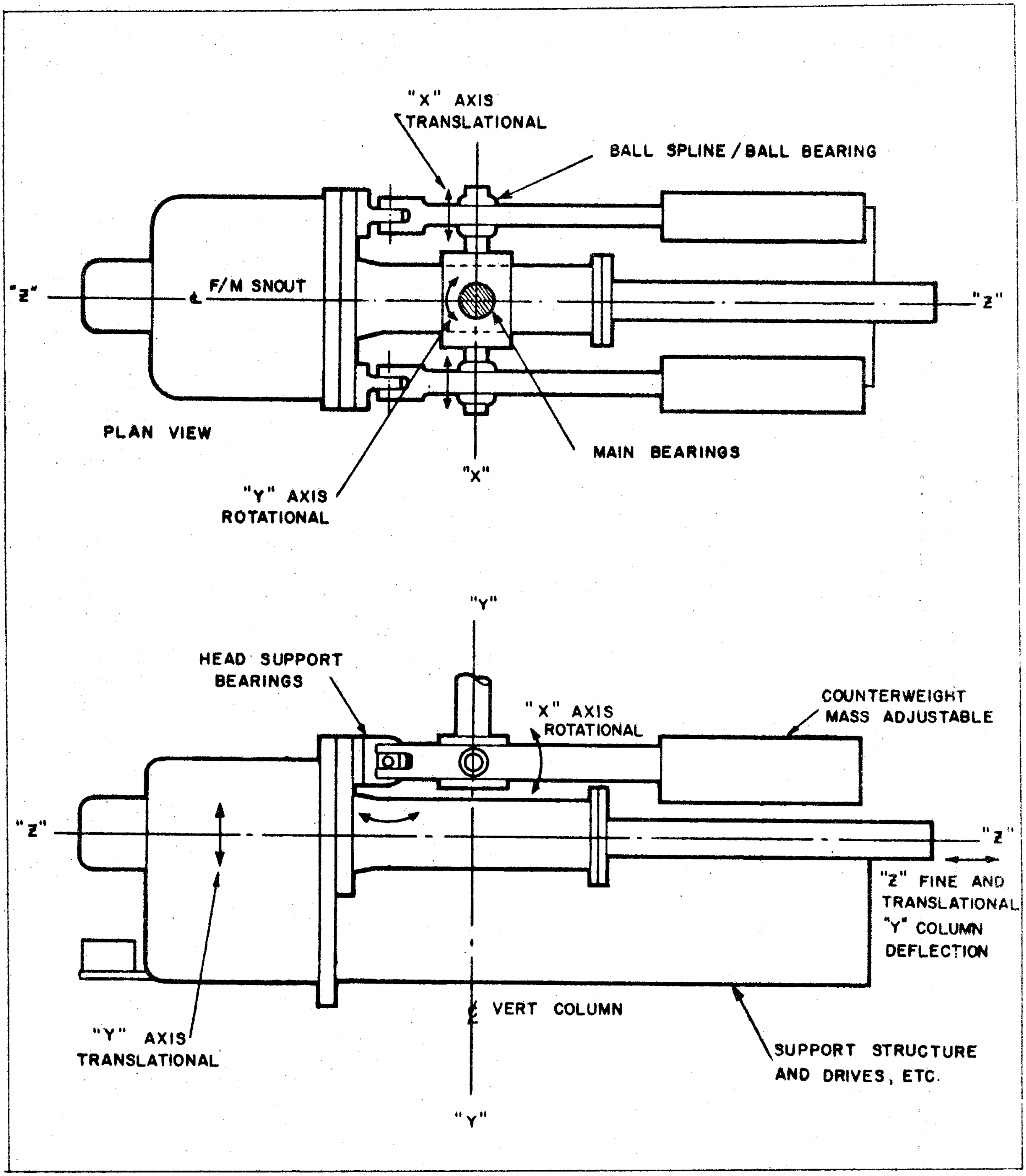


Figure 1 Head Suspension Movements

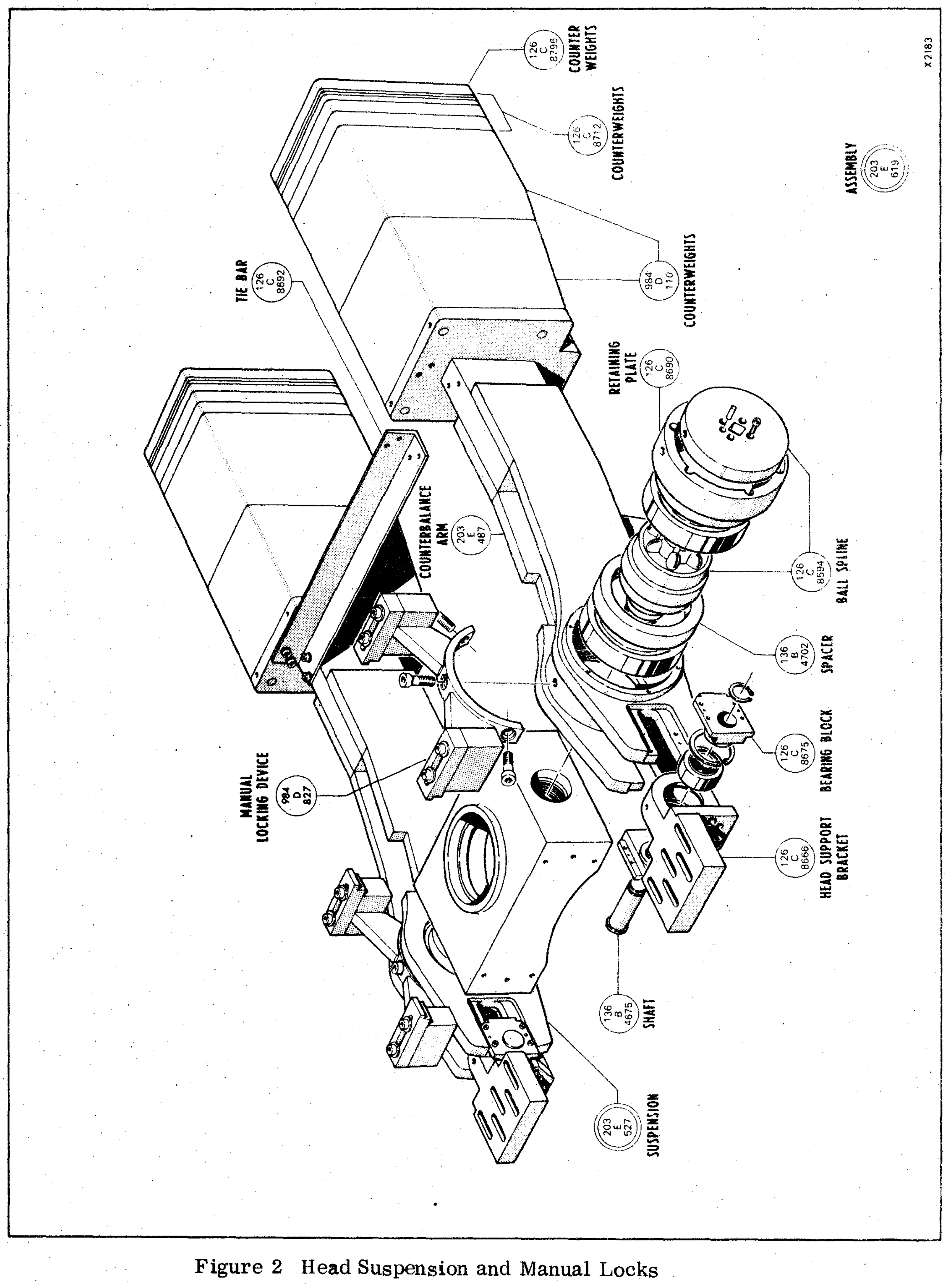


Figure 2 Head Suspension and Manual Locks

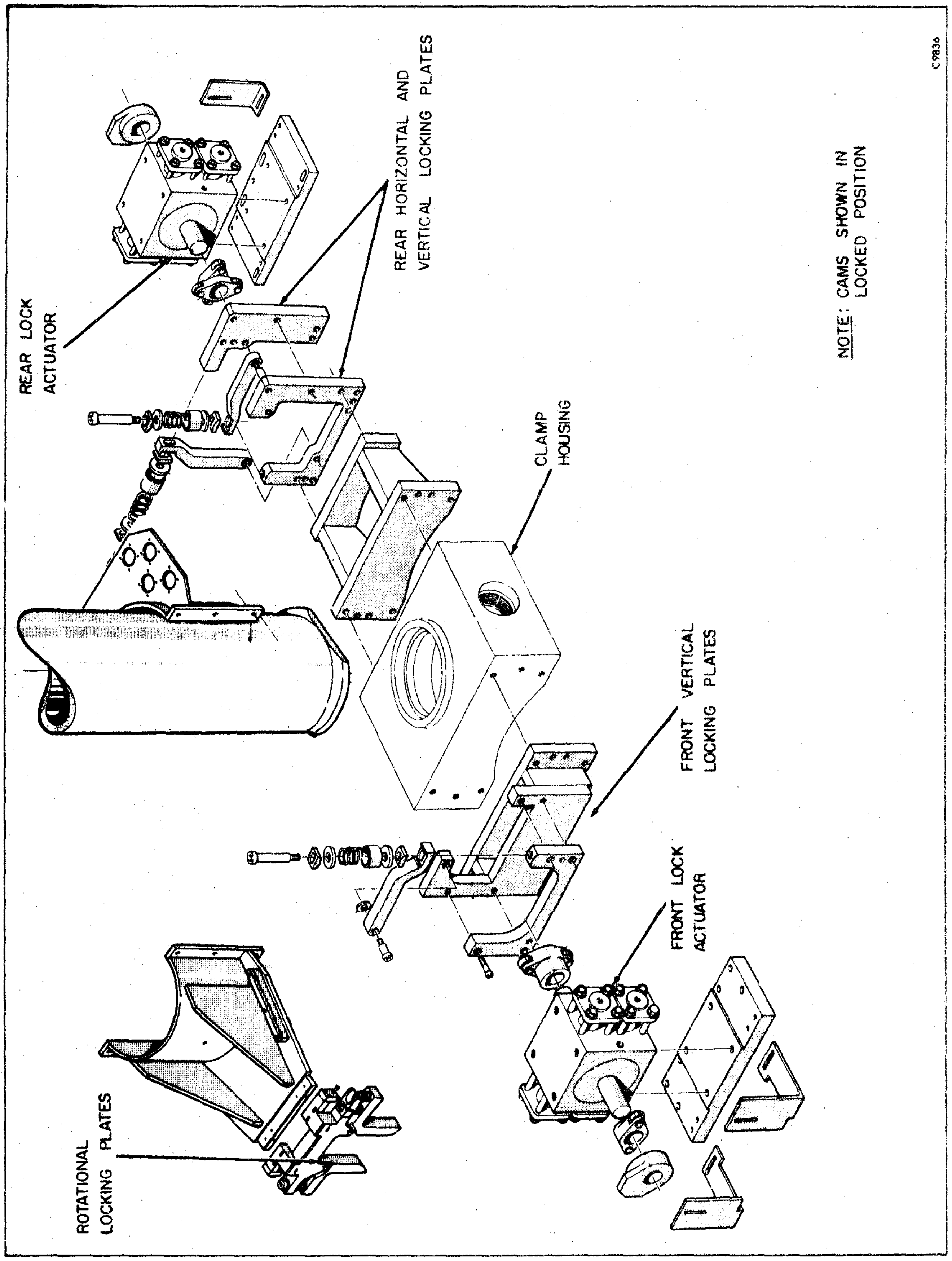


Figure 3 Suspension Lock Assembly

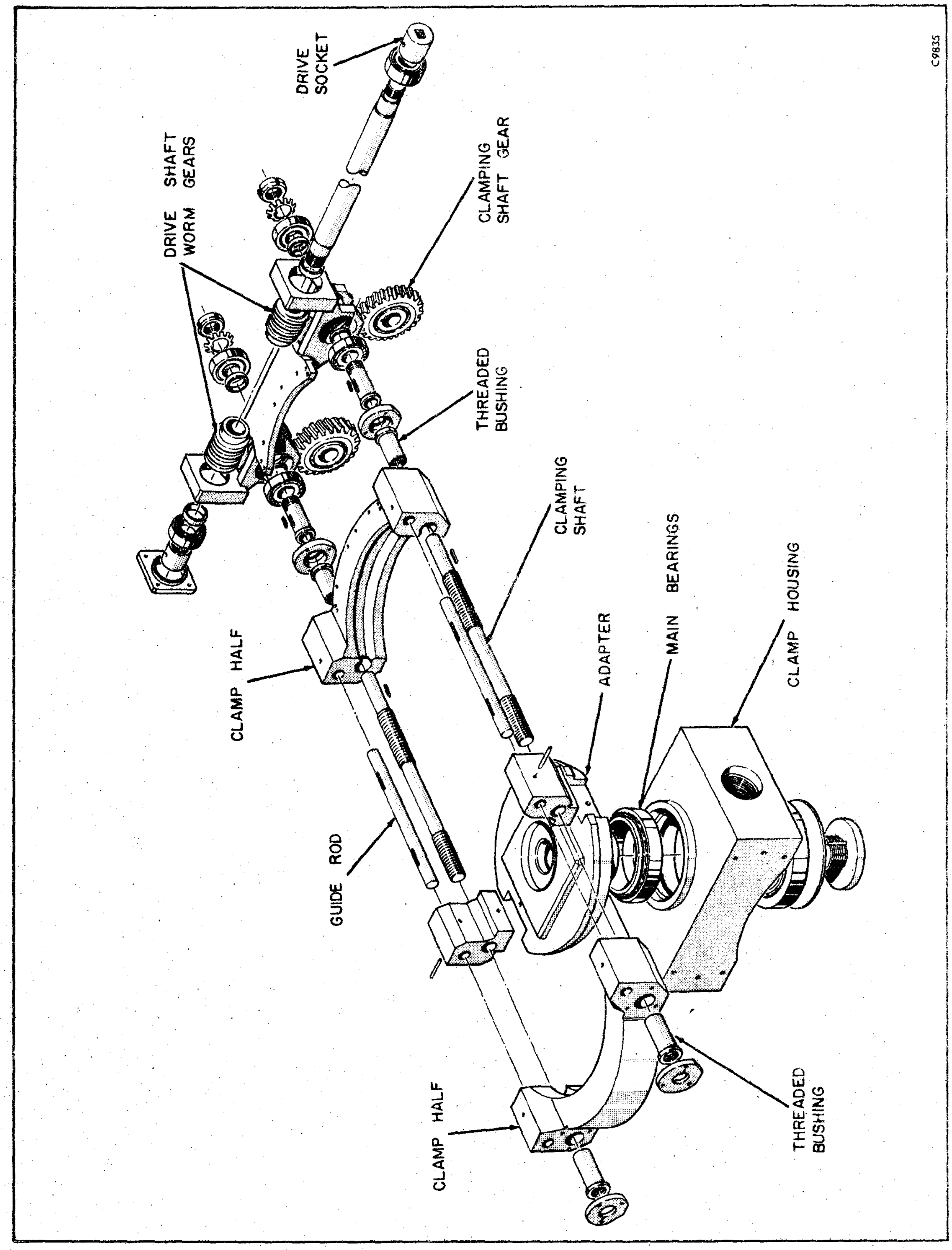


Figure 4 Head Disconnect Clamp and Bearing Assembly

NPD Systems - Reactor Boiler and Auxiliaries

Fuel Handling System

FUELLING MACHINE HOMING, LOCKING AND GAP SENSOR OPERATION

This lesson will describe the sequence of operations involved in the fine homing and locking of the fuelling machine to any end-fitting and subsequent unlocking. The unlocking and locking of the [redacted]-support hanger is one of the steps in this group of operations and is therefore included.

GENERAL

After the fuelling machine head assembly has been lowered by the elevator through the slot in the shielding, the head is rotated by the Azimuth drive mechanism 90^{o} about its vertical ("Y") axis so that the longtitudinal axis of the head is normal to the plane of the ends of the end-fittings. This is the" Azimuth Normal" position.

Immediately following the"Azimuth Normal" operation and before "coarse positioning", the head is located in the vault centrally positioned in the "X" direction with respect to the reactor lattice and Y-positioned approximately 12 inches above the topmost, or "A" row of lattice sites.

Coarse positioning to the selected lattice site follows, first in the "X" direction, then in "Y". This locates the axis of the snout of the machine within $\pm$ 1/2 inch of the axis of the end-fitting in the "X" and "Y" directions. The Z-motion drive which moves the head toward or away from the reactor face, is in the normal retracted position at this time, locating the end of the snout about 3/4 inch away from the end fitting.

The fine homing and locking operations described in detail in this lesson are now carried out. The Z-drive moves the head assembly toward the end-fitting at a very slow rate. As it moves forward in "Z", the head is simultaneously corrected ("fine homed") in "X" and "Y" to align and mate the snout with the end-fitting. Locking on then follows in which a clamping force between machine and end-fitting is exerted. This energizes an O-ring carried in the snout of the machine and seals the head assembly to the fuel channel.

During fine homing, the head suspension is locked in a "zeroed" or reference position. However, before the final clamping force is applied to make the seal at the end-fitting, the head suspension is released to allow the head to match its alignment with that of the channel without imposing excessive bending moments on the end-fitting.

FINE HOMING

Start Position

A typical fine homing operation is illustrated in Figure 1 which shows the four major steps.

Step A shows the snout of the fuelling machine at the start of fine homing. The Z-drive on the elevator platform is at the Z-out position, placing the snout approximately 3/4 inch away from the fitting. The fine "X" and fine "Y" drive pistons, which are oil-operated, are at the centres of their respective travel ranges. Motion of an "X" or "Y" drive piston from its mid-position to its travel-limit in either direction produces about 1/2 inch of fine motion of the head assembly in the related direction.

Four sensing fingers are set around the snout pressure-sleeve 90^{o} apart. See Figure 2. Each finger has an outer contacting face profiled to match a corresponding face on the end-fitting, and operates in conjunction with two micro-switches. See Figure 1. As the finger is pushed back against a spring, one micro-switch operates before the other. Each finger and its switches are mechanically independent of the other three sets.

Figure 2 shows the positions of the fingers around the pressure sleeve as viewed from the front of the machine. The code "UND", "DND", etc. relates to the first micro-switch, or detector, to be operated when its associated finger is pushed back. The code "USID", "DSID", etc. relates to the second microswitch to be operated.

When "UND" is actuated, fine Y drive in the up direction is initiated. "DND" when operated results in fine Y drive downward. Similarly "RND" selects fine X drive to the right and "LND" to the left. The contacts in these detectors are normally closed but areheld open by spring pressure on the fingers.

Machine Advances Toward End-Fitting in "Too-Low" Position

(Step B, Figure 1).

Fine homing begins with the Z-drive moving the head towards the reactor end-fitting at a rate of approximately one inch per minute.

It the snout is too low with respect to the end-fitting, Z-motion continues until the top finger contacts the end-fitting and is depressed to allow the contacts in the "UND" micro-switch to close. This cuts off the Z-drive and at the same time initiates fine "Y" motion in the up direction until "UND" opens again. When this occurs, fine "Y" is stopped and Z-motion resumes. In a similar way "LND" and "RND" correct the snout left or right respectively in fine "X". Fine "X" and fine "Y" correction may proceed simultaneously and, when either of these drives is operating, Z-motion is always cut off.

Machine Centred on End-Fitting but not Fully Homed

Motion in "Z" proceeds with correction in "X" and "Y", eventually reaching a stage where alignment in either "X" or "Y" is achieved but the machine has still some way to go in "Z" before contact between the conical sealing faces of end-fitting and snout is made.

Assume that at this intermediate stage of fine homing the machine is aligned in the "Y" direction but not in "X". This means that "UND" and "DND" micro-switches are both actuated but only one of "LND" and "RND" is actuated. When any diametrically opposite pair of switches are actuated at the same time, their effects on the related fine drive cancel one another and no fine correction in that direction takes place. Therefore, under the conditions stated above, correction would only take place along the "X"-axis in the direction of the actuated switch, "LND" or "RND".

Fine Homing

At some later stage in fine homing, both pairs of switches will be actuated, i.e. "UND" - "DND" and "LND" - "RND". Step C in Figure 1. This means that the snout is aligned with the end-fitting in both "X" and "Y" within limits corresponding to the closing and opening points on the micro-switches. The difference between these points on the actual switch represents approximately 0.003" of travel of its sensing finger and so the snout is very close to exact concentricity with the end-fitting. Under these conditions Z-motion proceeds until one of the four snout-in detectors USID, DSID, RSID or LSID, associated with the four fingers operates Step D, Figure 1. The operation of any one of these four detectors cuts off the Z-drive and signals the completion of fine homing.

LOCKING

The head is locked to the end fitting by lugs on the inner surface of a lockring which engage with mating lugs on the end fitting. When the lugs are fully engaged, the lockring is retracted to pull the head up tight against the end fitting and prevent leaks. See Figure 3.

The lockring is internally threaded and screwed on to a locking gear which is in turn mounted on the pressure sleeve by three thrust ball bearings. The gear is rotated to move the lockring axially

GAP SENSOR SYSTEM

The gap between the snout sealing surface and the coolant tube end fitting is continuously monitored during fine homing and when the head is locked on.

The gap sensor consists of four nozzles located in the snout of the head which are supplied with air at a constant pressure through restrictors. The air is tapped from the station air supply through a manual shut-off valve and a pressure reducer where it is reduced to 55 psi. See Figure 4.

The air from the pressure reducer flows through the four restrictors and the four nozzles to atmosphere. Pressure sensing lines are connected into the lines between the restrictors and the nozzles and are led back to a series of pressure switches and a four position Scanivalve located in the New Fuel Room. The output line from the Scanivalve is led to a pressure transducer which converts the air pressure into an electrical signal. This signal registers on a gap indicator meter on the Control Console. The pressure switches are connected three to each gap sensor line and each switch is set to actuate at a certain gap. These switches each operate an indicator lamp on the Control Console.

As the head snout approaches an end fitting during a homing operation the flow of air from the nozzles is restricted by the end fitting. This causes a pressure to build up in the sensing lines to the pressure switches and Scanivalve. When the gap reaches 0.010 inch, the gap cold switches are actuated, at 0.007 inch the gap large switches are actuated all at 0.003 inch the gap small switches are actuated.

If the gap increases during any part of the fuelling operation, the approximate gap size can be judged by the lights on the Console. If a more accurate gap measurement is required the Scanivalve control handle can be rotated to select any of the nozzles and that particular gap registered in the meter.

The air flow through the nozzles is normally left on at all times to keep the nozzles clean.

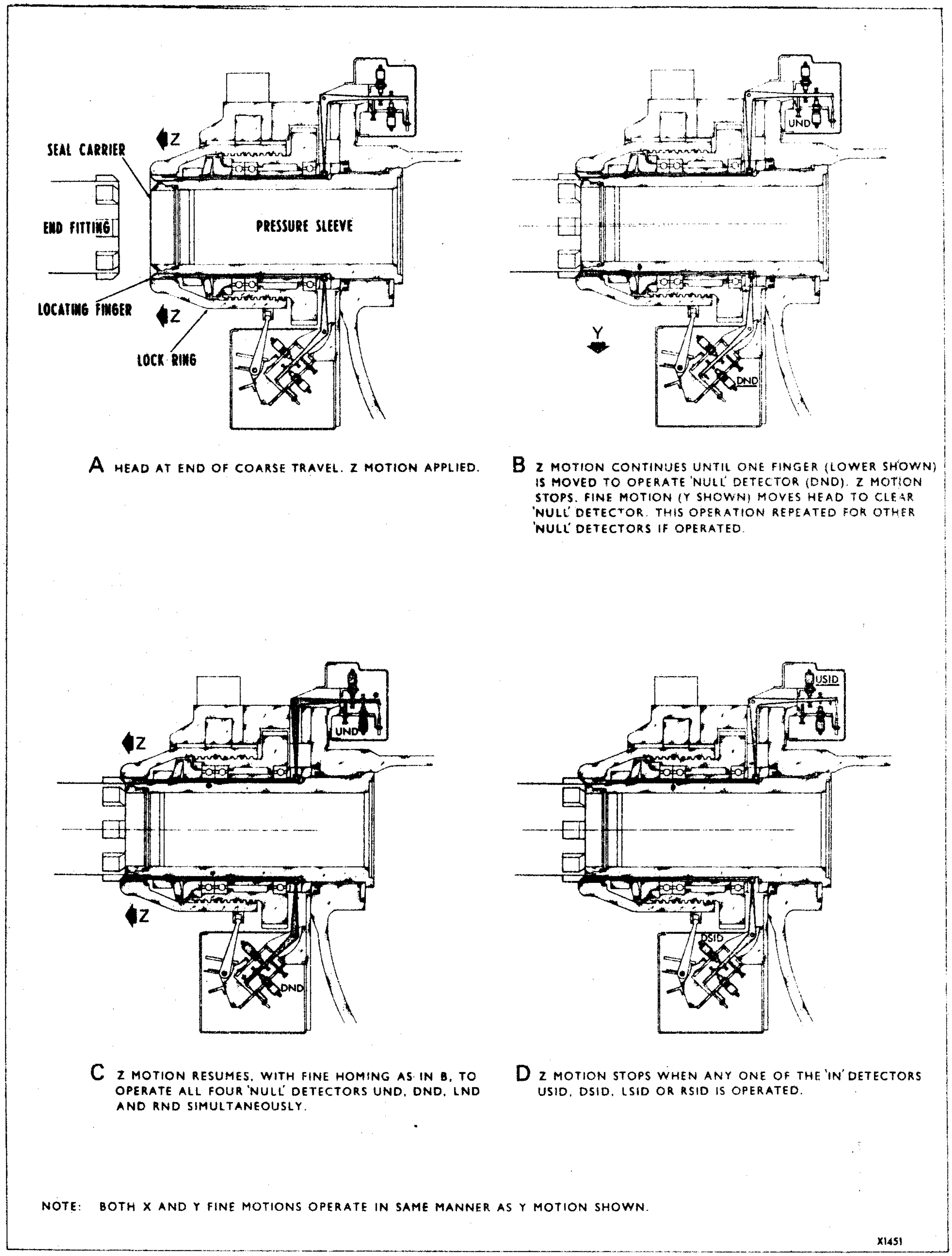


Figure 1 Fine Homing Operations

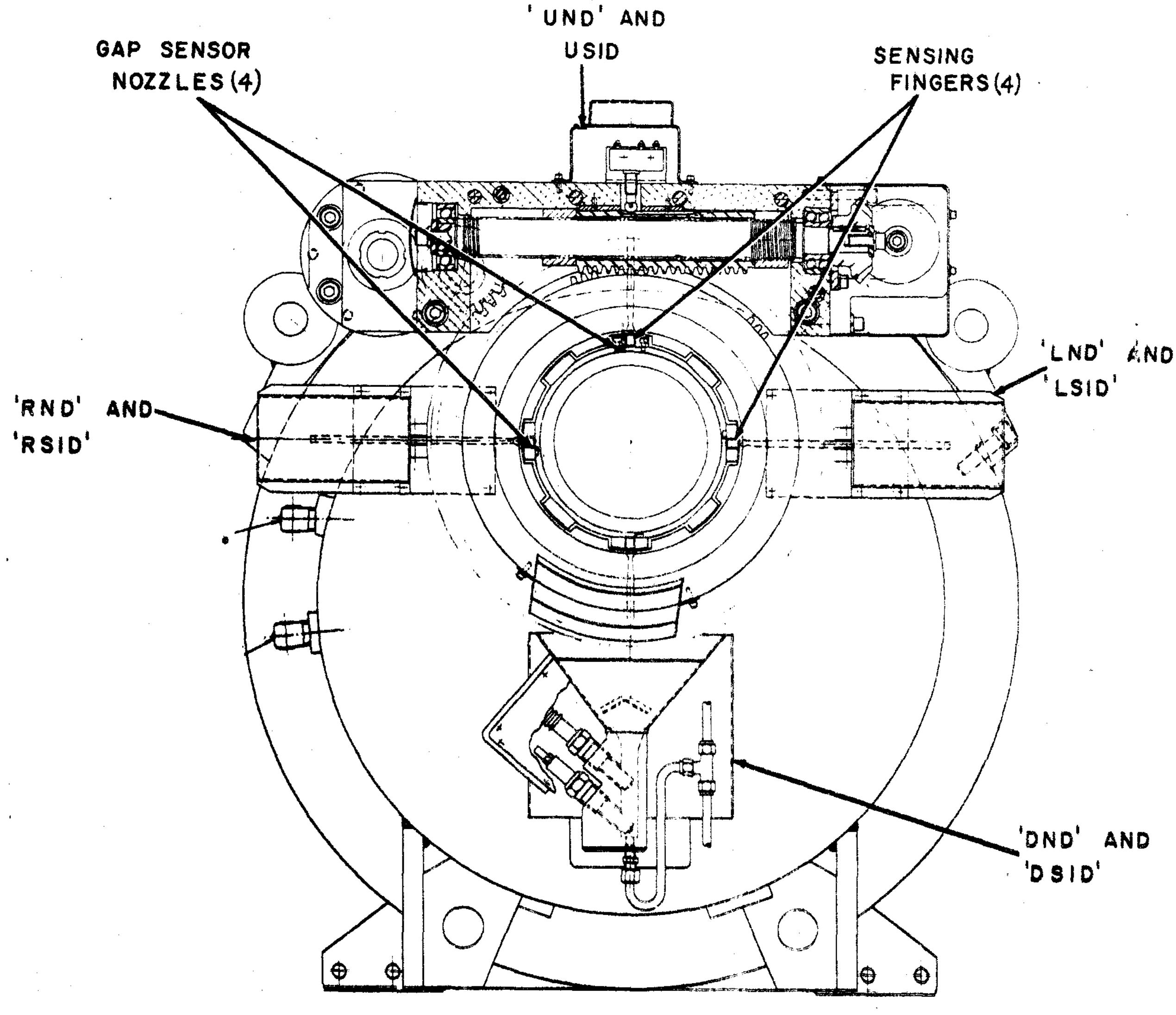


Figure 2 Sensing Fingers and Detectors

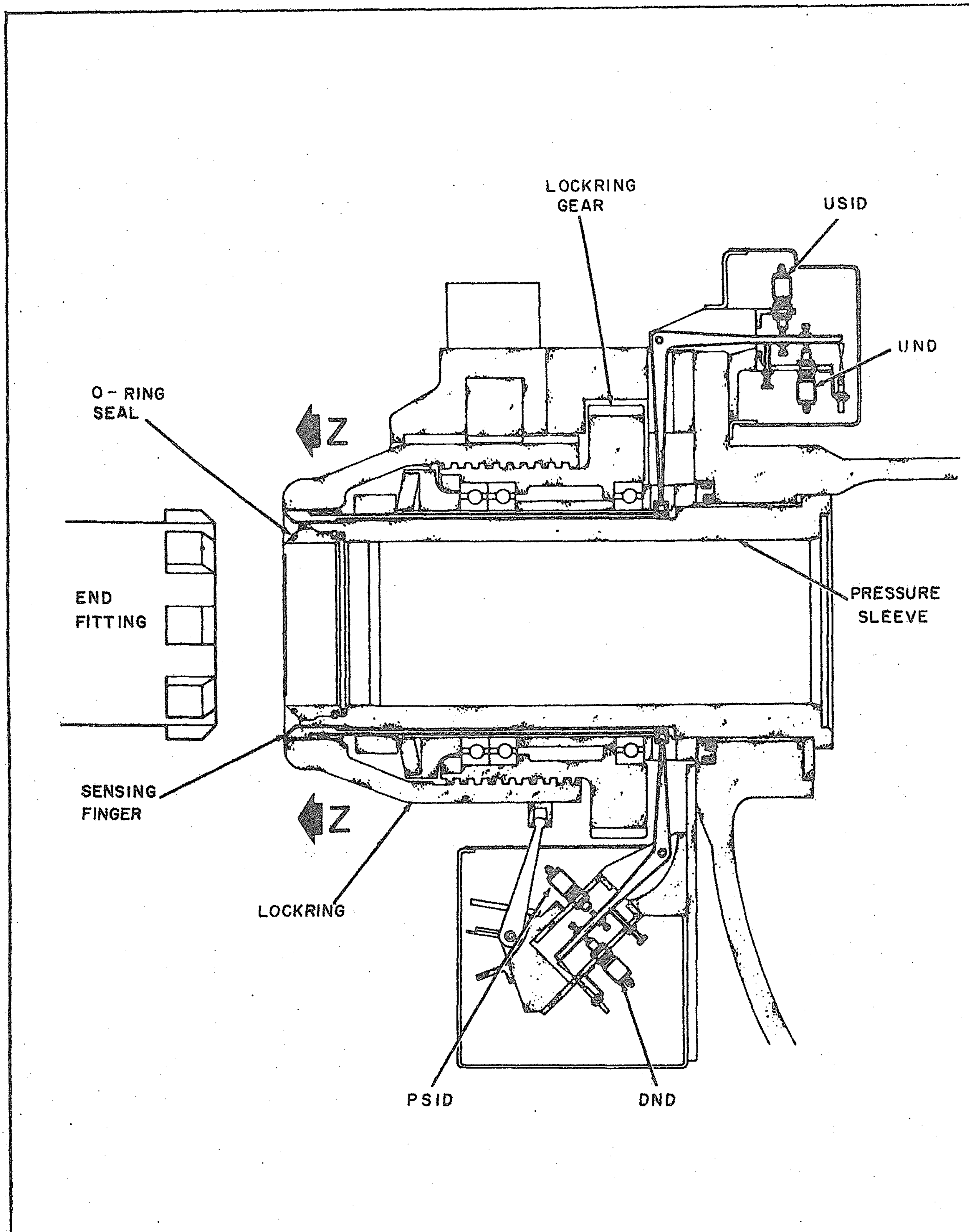


Figure 3 Homing and Locking Mechanism

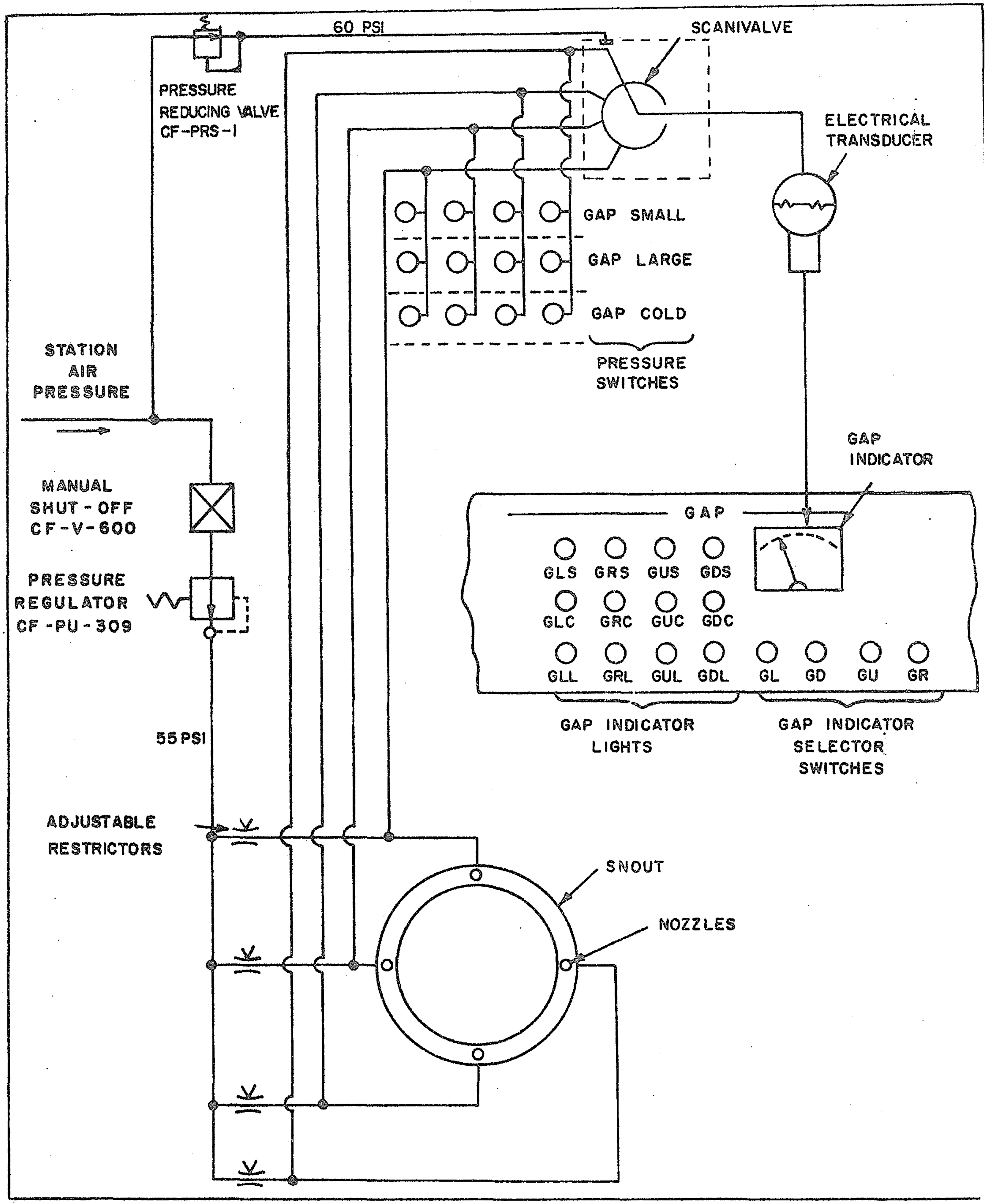


Figure 4 Gap Sensor System Schematic

NPD System - Reactor Boiler and Auxiliaries

Fuel Handling System

FUELLING MACHINE TRAVERSE OPERATIONS

The various drives of the fuelling machine and carriage which are involved in transporting the head between the several possible fuel changing sites and the spent and new fuel ports, as well as the mechanism for locking and sealing the head to the end-fittings, have been the subjects of previous lessons. In this lesson the operation of these components is discussed with respect to the way in which they are integrated into several programs referred to under the general term, "TRAVERSING".

Traversing, as it applies to the fuelling machine and its associated equipment, refers to those operations involved in taking the head assembly from any one of four defined positions to any other of these positions. Traversing may include all, or a certain number of the following component operations:

1. Coarse X and Coarse Y drives.
2. Elevator drive.
3. Azimuth drive.
4. Shielding gate drive.
5. Fine X and Fine Y drives.
6. Z drive.
7. Locking mechanism operation.
8. Suspension locking and unlocking.

The operations to be included depend upon the position the head at the start and the ordered location.

FUEL HANDLING CONTROL DATA

There are three levels of organization of the control data:

(a) Sequences, which consist of lists of operations.
(b) Steps, which consist of one or more operations and are listed numerically within each sequence.
(c) Operations, which consist of lists of detectors giving permissives, branch conditions, operation 'done' conditions, outputs to be turned on or off and setting or resetting indicators in the processor core memory.

Sequence

Machine tasks are subdivided into SEQUENCES. In general terms, a Sequence approximates a stepping switch programme on the original system. Typical Sequences are PLUG OUT, PLUG IN, MOVE FUEL, TRAVERSE. Traverse, for example, with six basic locations, could involve up to thirty traverse Sequences. The six basic locations are: Home, New Fuel, Lattice, Spent Fuel #1, Spent Fuel #2, Manipulator.

Step and Operation

Each Sequence is subdivided into a series of STEPS and each Step comprises one or more OPERATIONS. A Step, in general terms, approximates a step (of a stepping switch) on the existing system. Steps are numbered within the range $1\text{-}77_8$ and Operations $100\text{-}777_8$. Operations are not limited in application to one Step within one Sequence. An Operation may be applied in any Step where its logical function is appropriate.

Operations

An Operation is a list of detectors that define permissive(s), branch condition(s) and the DONE condition of a particular operation. Operations have DECtape block numbers from $100\text{-}777_8$ and are transferred into the processor core as required.

SYSTEM OPERATION

Each system is controlled from the console in the control room, the operator selecting the mode of operation and the sequence, step or operation required. Refer to Lesson 053-352.12 for a description of the control system.

COMPONENT POSITIONING

During fuelling machine operations, the drive mechanisms are required to assume certain definite positions within their range of travel. For example, the coarse X drive must be capable of locating the carriage at any one of 12 vertical lattice positions. Each drive mechanism is therefore equipped with position detectors which are either microswitches, pressure switches, temperature sensors or rotary encoders.

The output signal of each of these detectors is monitored by the computer, the detectors which are monitored during any particular operation being selected by the computer program.

The detectors are used to perform one or more of the following functions:

(a) Act as limit switches.
(b) Display position.
(c) Signify completion of the motion.

Shielding Gate

The shielding gate is normally fully open or fully closed. The gate open detector (GOD) contacts are closed when the gate is fully open and open when the gate is in any other position. The gate closed detector (GCD) contacts are closed when the gate is closed and open at all other positions.

The pneumatic seal is normally pressurized with air only when the gate is in the closed position. It is vented to atmosphere during gate travel to prevent rubbing. Pressurizing of the gate seal while gate is open is prevented by electrical and mechanical interlocks.

The seal pressure is indicated by a pressure switch (SPP), the contacts of which are closed when the gate seal is pressurized.

Elevator

There are only two defined positions for the elevator, fully up and fully down. The detectors for the up position are the elevator up detector EU and the elevator up limit detector EULD.

When the elevator is being raised, detector EU is operated first followed by either EULD1 on EULD2 to stop the drive system and indicate elevator up.

The primary detectors for the elevator down position are ED1 and ED2 and EDL1 and EDL2. Detectors ED1 and ED2 are actuated just before the elevator contacts the carriage frame. Limit detectors EDL1 or EDL2 are actuated when the ball lead screw lower bearing assembly is lifted approximately 1/8 inch. This stops the drive system and indicates elevator down.

If, when the elevator is moving either up or down, either EDL1 or EDL2 are actuated without ED1 or ED2 being actuated, this indicates that one of the ball screw bearings has lifted although the elevator is not fully down. The only way this can happen is for the elevator to be tilted. If this occurs, the system is stopped.

Coarse X Drive

The Coarse X drive locates the carriage at any one of seventeen positions along its rails. From South to North the positions are defined as follows:

XND (XNLD) - New Fuel Port position.

XO1SD - South Service position which is used for servicing operations on the fuelling machine.

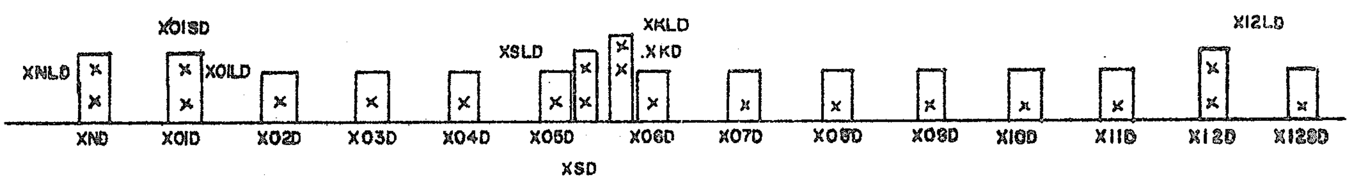
X01D to (X01LD) X05D - Reactor Lattice Row 1 to Lattice Row 5

XSD - Spent Fuel Port position.

XKD (XKLD) - Keyhole position. This is the position in Coarse X where the fuelling machine is lowered through the shield into the vault.

X06D to X12D (X12LD) - Reactor Lattice Row 6 to Lattice Row 12.

X12SD - North Limit of travel for the carriage. This position is required for fuelling machine servicing operations.



Coarse Y Drive

The Coarse Y drive can locate the fuelling machine head at any one of thirteen vertical locations. From top to bottom, the defined positions and detectors are:

YTD - Y Top position - which locates the fuelling machine head approximately 12 inches above the top row of reactor fuel channels.

YAD - Reactor Lattice Row A

YBD - Reactor Lattice Row B

YCD - Reactor Lattice Row C

YDD - Reactor Lattice Row D

YED - Reactor Lattice Row E

YFD - Reactor Lattice Row F

YGD - Reactor Lattice Row G

YHD - Reactor Lattice Row H

YJD - Reactor Lattice Row J

YKD - Reactor Lattice Row L

YMD - Reactor Lattice Row M

Fine Y Drive

There are three detectors associated with the Fine Y drive. They work in combination to define three intermediate positions and two limits of Fine Y drive.

The detectors are:

FYLD - Fine Y limit detector.

FYUD - Fine Y Up from centre .

FYDD - Fine Y Down from centre.

The defined positions of the drive are:

- Fine Down Limit.
- Fine Down from centre.
- Fine Y centre.
- Fine Up from Centre
- Fine Up Limit

Fine X Drive

There are three detectors associated with the Fine X drive. They are:

FXLD - Fine X Limit detector .

F12CD - Fine X Toward X12 from centre detector.

FNCD - Fine X Toward N.F.P. from centre detector.

These detectors operate in combination to define three intermediate and two limit positions of the Fine X drive.

These positions are:

- Fine ~~North~~ 12 Limit.
- Fine ~~North~~ 12 from centre.
- Fine X centre.
- Fine ~~South~~ N from centre.
- Fine ~~South~~ N Limit.

Fine Z Drive

Three Z motion detectors define normal Z motion positions. These detectors are:

FICD - Fine in from centre

FOCD - Fine out from centre

FZLD - Z limit detector.

These detectors operate in combination to define three intermediate and two limit positions which are:

- Five out limit
- Five out from centre
- Five Z centre
- Five in from centre
- Five in limit

A fourth detector, FZET, is used to detect on additional out from centre position beyond FOL. This position is used during breakdown operations to permit the head to be backed off from an end fitting if the head snout lockring cannot be retracted.

In addition to this, there are four detectors associated with the Z drive that cut it off when the snout has entered the end-fitting during the homing operation. They are microswitches operated by the snout sensing fingers. Operation of these fingers was described in lesson 053-352.7.

Azimuth Drive

There are only two defined azimuth positions, Azimuth Normal and Azimuth Service. These and the azimuth drive system were described in lesson 053-352.5. The detectors for these two positions are AND and ASD respectively while the limit detectors are ANLD and ASLD.

Suspension Locks

These are two separate locking mechanisms for the suspension, front and rear, and each has a detector for the locked and unlocked positions. The front detectors are FSUD and FSLD while the rear detectors are RSUD and RSLD. Both detectors for each motion FSUD and RSUD or FSLD and RSLD must be actuated before a DONE condition can exist. This ensures both locks are locked or unlocked before the next operation.

Lockring Axial

The limits of lockring forward and lockring retract motion are detected by two switches located in a housing below the head snout and operated by a lever from a U-section cam on the lockring.

The lockring forward position is detected by LFD. When the head is not on an end fitting, the lockring retract position is detected by LRD. However, during the homing operation when the lockring is retracted to pull up the head on to the end fitting, the pull up force is limited by a pressure switch, LRHP which gives a DONE condition for the control system when the required pressure is achieved. A pressure relief valve functions as a back-up for the pressure switch.

Lockring Rotary

There are only two detected positions for the lockring rotary motion, locked and unlocked. These two positions are detected by two position detectors, LLD and LUD; operated by cams on the lockring gear rack.

SHAFT ENCODERS

The position of the charge tube in axial and rotary motions, the ram and the magazine are detected by rotary shaft encoders which indicate component position by electrical signals in Gray code. These signals are amplified before being used by the control system. Refer to the control system description, lesson 053-352.12 for a description of the shaft encoders.

PRESSURE SWITCHES

If no stall condition exists at the selected position, ie. the component does not contact a solid stop, then the position is detected by the encoder only. A tolerance of a certain number of bits is permitted at each encoder detected position both for stopping the motion and for further operation checks.

However, if a stall condition does exist at the selected position, i.e. the component contacts a solid stop, then the AND ing of the shaft encoder position with the operation of the pressure switch gives a DONE condition for the logic.

In addition, the switches are also used as trips in the logic to stop the operation if the switch is actuated before the component reaches the selected position as indicated by the encoder or if excessive pressure is required to move a component. This could occur if a component jammed at some intermediate position. A hydraulic system pressure build-up would occur and the switch would be tripped to stop the operation. This prevents the possibility of damage to the head components or a fuel bundle in the event of relief valve failure and also tells the operator that a fault exists.

RELIEF VALVES

Relief valves are installed in the head hydraulic sub systems to limit the load which can be applied in the sub-system drive motors. The relief valves back-up the pressure switches to prevent excessive pressure and therefore drive force if a pressure switch fails to signal a DONE or STOP condition.

Charge Tube Axial

The axial position of the charge tube is continuously monitored by a shaft encoder mounted on the input drive. The encoder is driven through a 24:1 speed reducer mounted with it. The encoder output is used in conjunction with four pressure switches CFHP, CFLP, CRHP and CRLP for control logic and is also used as to operate the decimal read out on the control panel.

CRLP is looked at by the control system during tube retract operations and is used to give a STOP condition if the switch is actuated.

CRHP is looked at by the control system when an end fitting plug with an orifice is being withdrawn from the end fitting. When the plug is out of the orifice, only CRLP is used.

CFLP is looked at by the control system during forward motion of the charge tube and is used to give a STOP condition if the switch is actuated by an over pressure. It is also used, in conjunction with the encoder reading, to show a stall condition when the head springs are compressed when disengaging the charge tube head from a fuel carrier or adapter. It is used in conjunction with the fast speed valve (FSPV) to compress the head springs when the head is unpressurized e.g. on a spent or new fuel port.

CFHP is used in conjunction with the encoder position to show a stall condition when the head springs are compressed during the release of the charge tube head from a fuel carrier or adapter while on a reactor end fitting.

Charge Tube Rotary

The charge tube rotary position is monitored by an encoder which is used in conjunction with three pressure switches in a similar manner to the charge tube axial. The three pressure switches are ACCLP (A-motion, counter-lockwise,low pressure), ACWLP and ACWHP (A motion counter-clockwise, low and high pressure).

ACCLP is looked at during all counter-clockwise motion and is used to give a STOP to the system if tripped. All counter-clockwise positions are detected by the encoder.

ACWLP is looked at during most counter-clockwise motions and is used to give a STOP to the system if it is tripped.

ACWHP is looked at during plug replacement on a reactor end fitting. It is used to give a STOP condition if tripped before the required encoder position is reached and is ANDed with the encoder position to give a DONE condition when the plug is fully in.

Ram

Four pressure switches are used in conjunction with an encoder to detect ram force and position RFLP and RFHP (ram forward low and high pressure) and RRLP and RRHP (ram retract low and high pressure). The pressure switches and encoder work in conjunction to detect force and position in a similar manner to those in the charge tube axial system.

RRLP is used as a STOP detector during ram retract after deflecting the plug disc and is ANDed with the encoder output to detect a stall at the home position R003 when the head is not pressurized, i.e. on a spent or new fuel port.

RRHP is looked at during the ram retract motion to R003 to give a STOP if the set pressure of the switch is reached before the required encoder position is reached. The encoder position and switch operation are ANDed to give a DONE condition when the ram has compressed the charge tube springs and collapsed the head fingers to release the fuel carrier or plug adapter.

RFLP is looked at by the control system during ram forward motion when locking or unlocking a fuel carrier or adapter from the charge tube head, when locking or unlocking a plug from the new or spent fuel ports and when moving fuel into the reactor. When moving fuel, RFLP senses a stall at the end of the stroke and together with the encoder output, gives a DONE condition when the fuel string is fully in the reactor.

RFHP is used in reactor end fitting plug removal and replacement motions. It is ANDed with the ram encoder position at the stall condition which occurs when the plug disc is fully deflected. It is looked at during other plug disc deflection motions to give a STOP if an overpressure condition occurs.

Magazine

The magazine position is controlled entirely by the encoder.

The requirements for the magazine drive are to provide indexing to any of the six magazine channels, locking and aligning each magazine channel with the snout centerline and charge tube, with sufficient accuracy to permit reliable fuelling operations. This is accomplished with a Ferguson indexing drive, the cam of which makes 6 revolutions to rotate the magazine 60 degrees, that is, from one channel position to an adjacent position. The cam has a helix over 270 degrees and a dwell over 90 degrees of rotation; consequently the roller gear and shaft which is driven by the cam, will rotate 10 degrees during each 270 degrees of cam rotation and remain stationary during the remaining 90 degrees of cam rotation. The magazine encoder positions are set at the middle of a cam dwell thus effectively locking the magazine in each position.

The motor output shaft (Ferguson drive input shaft) rotates 72 revolutions for 2 revolutions of the magazine. During this number of revolutions the encoder goes through 4096 bits. Therefore 1 revolution of the Ferguson input shaft represents 56-8/9 bits (4096/72) on the encoder. One quarter of the revolution is a dwell which represents 14-2/9 (56-8/9 x 1/4) bits on the encoder. Because the magazine makes two revolutions to cover the total encoder bits of 4096, there are two unique encoder readings for each magazine channel.

SEQUENCES

The sequences used in the control system form the major level of organization of the control data. The sequences are on tape to be called up when the required mode and sequence number are selected. A single step or a single operation can also be selected if required. All sequences, steps and operations are numbered using octal numbering system. For a full description of the control system, refer to lesson 053-352.12. A list of the sequences supplied with the system follows:

SEQUENCES

Number	Title
01	Home to New fuel Port
02	Home to Lattice
03	Home to Spent Fuel Port #1 or #2
04	New Fuel Port to Home
05	New Fuel Port to Lattice
06	New Fuel to Spent Fuel Port #1 or #2
07	Lattice to Home
10	Lattice to New Fuel Port
11	Lattice to Lattice
12	Lattice to Spent Fuel Port #1 or #2
13	Spent Fuel Port #1 to Spent Fuel Port #2
14	Spent Fuel Port #1 or #2 to Lattice
15	Spent Fuel Port #1 or #2 to New Fuel Port
16	Spent Fuel Port #1 or #2 to Home
17	Spent Fuel Port #2 to Spent Fuel Port #1
20	Plug Removal on Reactor (Inlet)
21	Plug Removal on Reactor (Outlet)
22	Plug Removal at New Fuel Port and Spent Fuel Ports
23	Plug Replacement on Reactor (Outlet)
24	Plug Replacement on Reactor (Inlet)
25	Plug Replacement on New Fuel Port and Spent Fuel Ports
26	Fuel Eject into Reactor
27	Fuel Eject into Spent Fuel Ports #1 and #2
30	Fuel Accept from Reactor
31	Accept Fuel from New Fuel Port
35	Plug Removal on Reactor Orifice Dia. .0255 inch
36	Plug Replacement on Reactor - Orifice Dia. .2055 inch

NPD Systems - Reactor Boiler and Auxiliaries

Fuel Handling System

FUELLING MACHINE HEAD DESCRIPTION AND DRIVES

This lesson describes the general construction of the head and the operation of the head drive systems and internal components. A description of a complete fuelling operation, after locking on to an end fitting, is included at the end of the lesson.

CONSTRUCTION

The replacement NPD fuelling machine head support structure is of aluminum channel section with a bolted on frame at the rear carrying the gearboxes and hydraulic pressure switch assembly. The pressure vessel is built around a flat-head. This is a circular plate which forms the rear of the magazine housing and to which the forged magazine housing, the magazine support shaft and the drive housing are bolted. It is also the main member for the transfer of structural loads between the support structure, the pressure vessel and the vertical column. See Figures 1 and 16.

DRIVE SYSTEMS

The drive system consists of six hydraulic motors mounted on two gearboxes with drive shafts, and gears connecting the gearboxes to the various driven components. The oil hydraulic system is described in Lesson 530-352.10.

The drives, with the exception of the magazine drive, consist of an oil hydraulic motor and a worm and worm gear which provide the necessary gear reduction and change the drive direction. See Figures 13 and 14. The drive outputs from the gearboxes are led to the various input drives through drive shafts, using universal couplings and intermediate support bearings where necessary.

Electrically actuated brakes are installed in the charge tube rotary, charge tube axial and ram axial drive systems to provide a positive lock when in their selected positions. The brakes are disengaged when de-energized.

The drive to the magazine incorporates a Ferguson index drive which, in conjunction with the encoder, ensures positive indexing of the magazine. The overall magazine drive system results in a 36:1 reduction gear ratio between the hydraulic motor and the magazine, the index drive indexing six times to rotate the magazine one position. The encoder is driven at the same speed as the magazine.

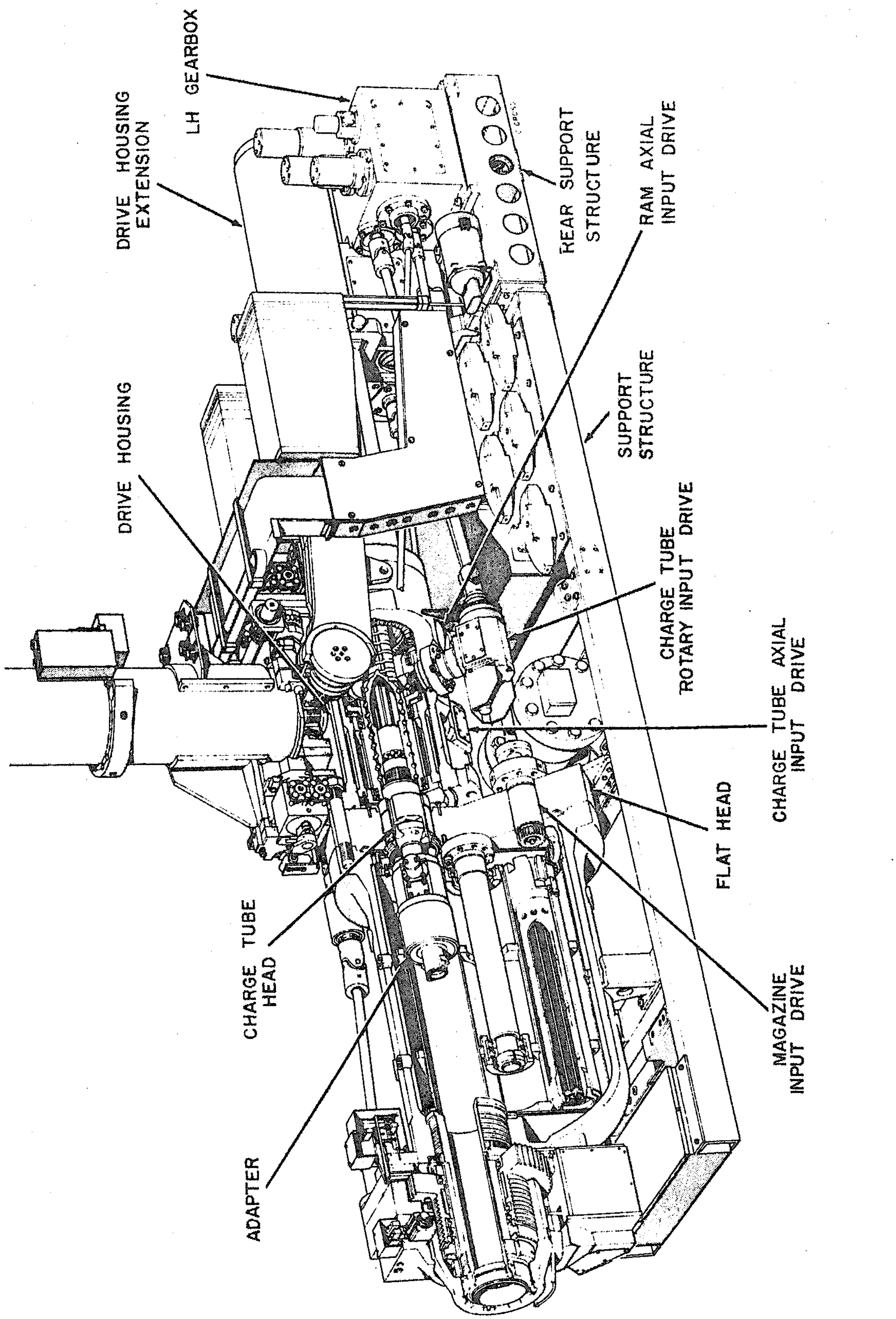


Figure 1 Head Construction and Drive Systems

Encoders are installed in the drive systems for the charge tube axial and rotary motion, the ram axial and the magazine. The magazine encoder is installed adjacent to the magazine hydraulic motor on the left hand gearbox assembly, the other three encoders being located on the input drives. The encoders provide digital information of the position of the various systems to the computer. This information is used to provide the control console readout, the printout information and control program permissives.

Drive shaft motion is transferred through the pressure vessel boundary for the ram axial, charge tube axial, charge tube rotary and magazine drives by four input drives. The input drives contain the gearing required to change direction where necessary and also contain the pressure seals.

The pressure seals each consists of a carbon-stellite rotary shaft seal which is cooled by a flow of D_2O from the D_2O cooling circuit. See Figure 2. A labyrinth seal is interposed between the rotary shaft seal and the interior of the pressure vessel boundary and a standard lip seal is located on the other side of the rotary seal. The space between the rotary seal and the lip seal is vented and connected to a D_2O drain system. Refer to Lesson 053-352.11.

LOCKRING AND LOCKRING GEAR DRIVES

The drive system and method of operation of these two components are shown in Figures 3,4,5 and 6.

The lockring is driven from the hydraulic motor on the LH gearbox through mitre gears and a screw-operated gear rack on the snout. Rotation of the motor drives the lockring through $22\text{-}1/2^{\circ}$ in each direction, anticlockwise when viewed from the front to lock and clockwise to unlock. Lockring rotary position is detected by limit switches actuated by cams on the gear rack.

The lockring gear is rotated to retract the lockring and move it forward. The lockring gear drive motor is located on the RH gearbox and drives the lockring gear through a pinion gear and idler at the snout. A LH thread on the lockring gear mates with a thread in the lockring so that as the gear is rotated, the lockring is moved axially. Lockring position is detected by a detector located under the snout. See the inset detail on Figure 5.

MAGAZINE

The magazine has six channels, four for the fuel carriers and two for the end fitting plug adapters one of which contains a spare plug. Normally only three of the fuel positions can be used for irradiated fuel bundles, the fourth position being above the water level when the head is traversing. However, the magazine can be slowly rotated, if necessary, to overcome this restriction. The magazine is mounted on and rotates around a shaft, cantilever mounted to the flathead. It is driven by a spur gear which engages with a gear ring on the rear of the magazine.

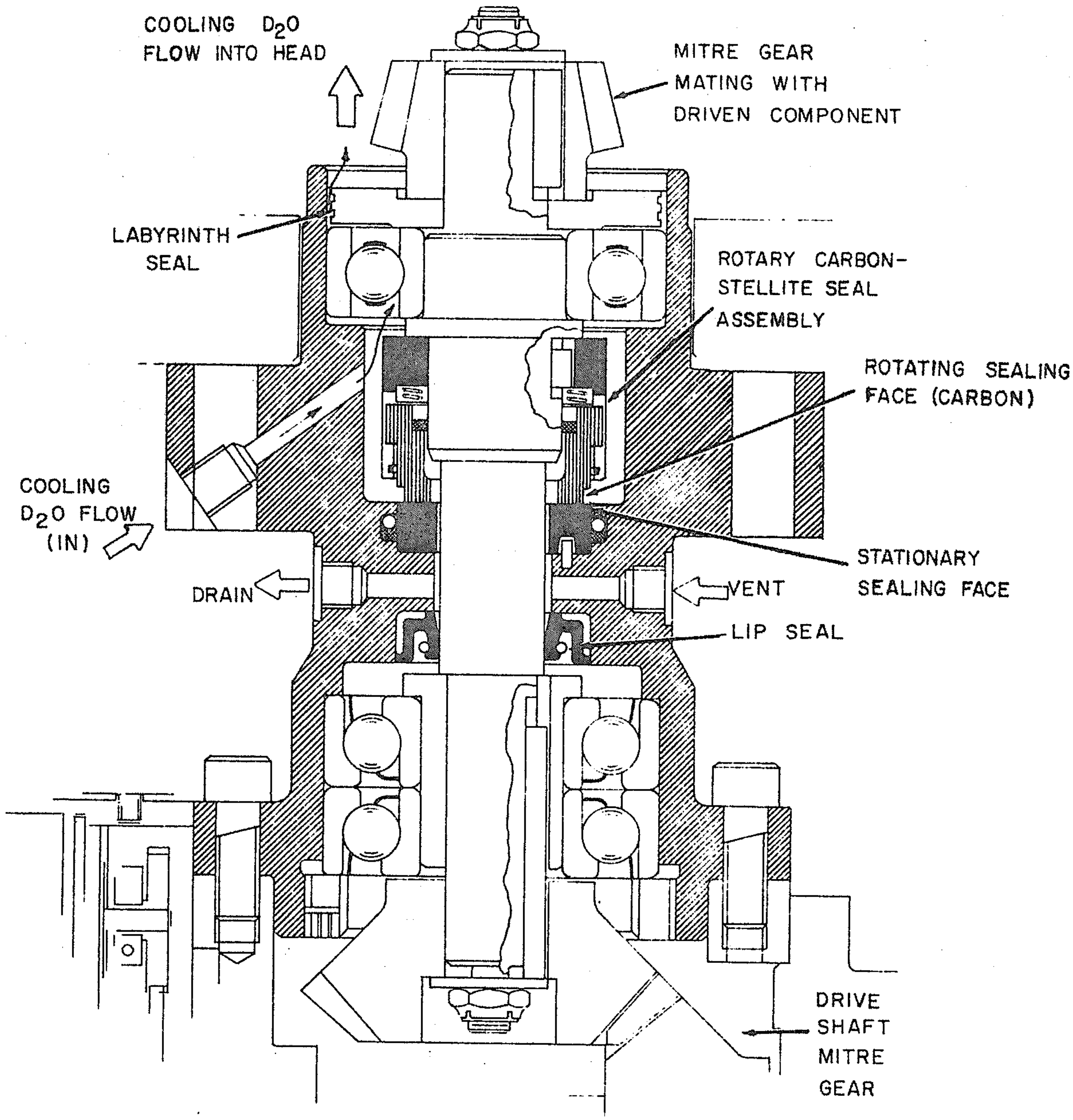


Figure 2 Typical Input Drive Shaft Seal Assembly

The drive for the spur gear passes through the flat head where it is sealed by a carbon-stellite rotary shaft seal and a labyrinth seal. See Figure 7.

To provide accurate indexing of the magazine at any one of its six channel positions, a Ferguson indexing drive is incorporated in the gearbox. See inset detail in Figure 7. The Ferguson indexing drive cam makes six revolutions to rotate the magazine 60 degrees, that is, from one channel position to the adjacent position. The cam has a helix over 270 degrees and a dwell over 90 degrees of rotation, consequently the roller and gear shaft, which is driven by the cam, will rotate 10 degrees during each 270 degrees of cam rotation and remain stationary during the remaining 90 degrees of cam rotation. The magazine encoder positions are set at the middle of a cam dwell to ensure effective locking of the magazine in each position.

The magazine housing contains a thermal barrier which forms an annular space adjacent to the inner surface of the magazine housing.

A similar thermal barrier is located directly in front of the flat head. Cooling D_2O is directed between the thermal barriers and the surrounding components to reduce the transfer of heat from the hot D_2O to the structure.

The two plug adapters for the reactor end fitting plugs and the fuel carriers are retained and located in the magazine channels by spring-loaded plungers and lock buttons or projections, in the magazine channels. The lock buttons are fixed and engage with L-shaped slots in the fuel carriers and plug adapters to prevent axial movement.

The spring-loaded plungers engage indentations to prevent rotation of the fuel carriers and plug adapters except through the positive drive of the charging tube. Positive locking of the fuel carriers and plug adapters prevents movement during traversing of the fuelling machine head and ensures positive engagement of the charge tube head.

CHARGE TUBE AND RAM ASSEMBLY

Fuel bundle movement, and axial and rotary movement of the fuel carriers, reactor end fitting plugs and adapters are provided by the charge tube and ram assembly. This assembly consists of two coaxial recirculating ball screw assemblies, the outer assembly being the charge tube and the inner assembly the ram.

The charge tube and ram assembly is supported and housed by a tubular assembly which is secured to the rear face of the flathead. This assembly is manufactured in three sections, a drive housing, an extension tube and an end cap and forms part of the pressure vessel. It is pierced in three places by the ram and charge tube input drives. A flow of cooling D_2O

is passed through the drive housing assembly and the flat head to limit the temperature rise and reduce temperature fluctuation.

Charge Tube Rotary Drive System

This drive system is illustrated in Figure 8. It consists of a Baldrive hydraulic motor, a worm shaft and gear reduction gear in the left-hand gearbox, an input drive and a bevel gear on the charge tube screw.

The bevel gear is connected to the charge tube screw by keys which engage in keyways in the outer surface of the screw. The charge tube can be rotated in either direction. An encoder is installed on the input drive to provide the necessary signals for the control system.

Charge Tube Axial Drive System

The charge tube axial drive system is shown in Figure 9. The hydraulic motor speed is reduced by a worm shaft and gear in the gearbox and is transmitted to the input drive by a universally mounted drive shaft. The bevel gear on the inner end of the input drive couples with a second bevel gear mounted in the charge tube ball nut. The ball nut is mounted on bearings within the extension housing. When the ball nut is rotated, the charge tube is moved axially.

An encoder is mounted on the input drive housing and is driven from the input drive shaft to provide the necessary signals for the control system.

Ram Drive System

The ram is driven from a hydraulic motor located on the right hand gearbox. A worm shaft and gear in the gearbox provide the necessary speed reduction and the drive is transmitted to the input drive by a universal mounted drive shaft. A bevel gear on the inner end of the input drive meshes with a bevel gear mounted on an outer drive sleeve assembly. Keys secured to the inner surface of this drive sleeve engage keyways in a ram drive guide which is in turn connected through a drive sleeve to the ram ball nut. As the ball nut is rotated, the ram spline and head are moved axially. See Figure 10.

The ram spline engages with a mating ball spline housed in the charge tube to prevent rotation of the ram. The ram drive guide is coupled to the rear end of the charge tube to support the charge tube and couple the charge tube with the ram. This means that axial and rotary movement of the charge tube are transmitted to the ram so that when either of these drives are selected, the ram head and charge tube head remain in the same relative positions.

Rotary motion of the charge tube also results in some axial movement of the charge tube and ram heads because the charge tube rotates within the charge tube ball screw nut. However, this movement has been compensated for in the design of the head.

RAM AND CHARGE TUBE OPERATION

The charge tube head and the ram head operate together to connect the charge tube head with and disconnect it from the fuel carriers and reactor end fitting plug adapters. See Figure 11. The charge tube head is made in two sections which are under spring pressure and incorporates two latching fingers. The ram head moves the fingers into or out of engagement with the fuel carrier or adapter. When the fingers are engaged, they are held engaged by spring pressure applied by the charge tube head springs. The fingers remain engaged until the charge tube head is compressed to remove spring pressure and the ram head is retracted to withdraw the fingers.

The operation of the ram and charge tube when removing a plug from an end fitting is shown in Figure 12.

In view A, the adapter is driven forward to contact the end fitting sealing plug. The charge tube brake is applied to prevent movement. In view B, the ram is advanced to push the adapter ram rod and deflect the plug sealing disc.

The charge tube and adapter are then rotated. During the first 115^{o} of rotation, the two cams on the adapter engage with two lugs on the plug locking plate to disengage the plate from the end fitting. The cams then contact two lugs on the inner surface of plug body and the next 45^{o} of movement rotates the plug to unlock it from the end fitting. See Figure 15.

The ram is then retracted so that the head of the adapter ram rod pushes the two balls in the adapter out and locks them. This in turn locks the plug to the adapter because the lugs on the plug cannot pass the extended locking balls. During plug replacement, initial movement of the adapter ram rod by the ram releases the balls to allow the adapter cams to disengage from the plug.

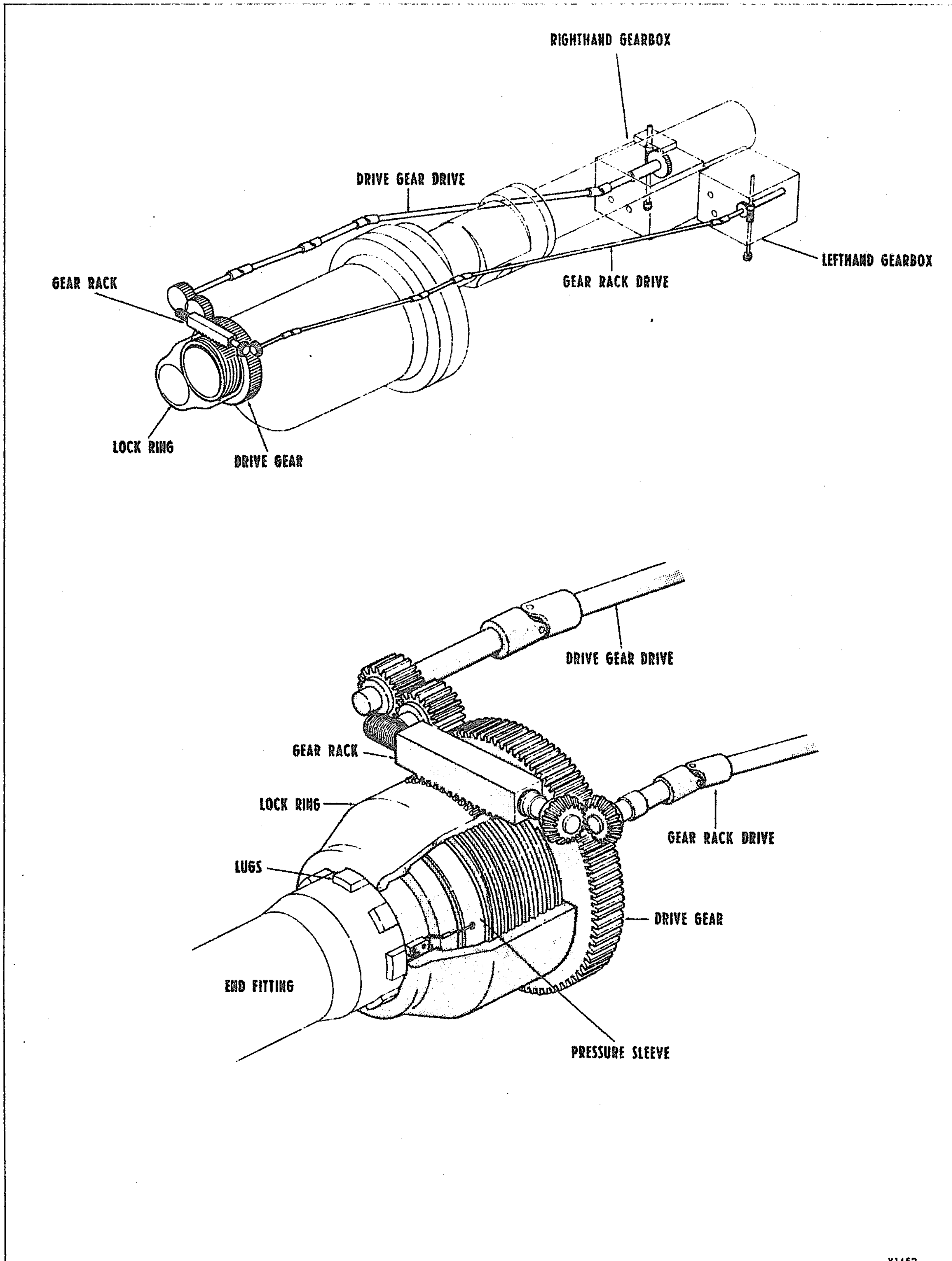


Figure 3 Locking Operation, Ready to Lock On to an End Fitting

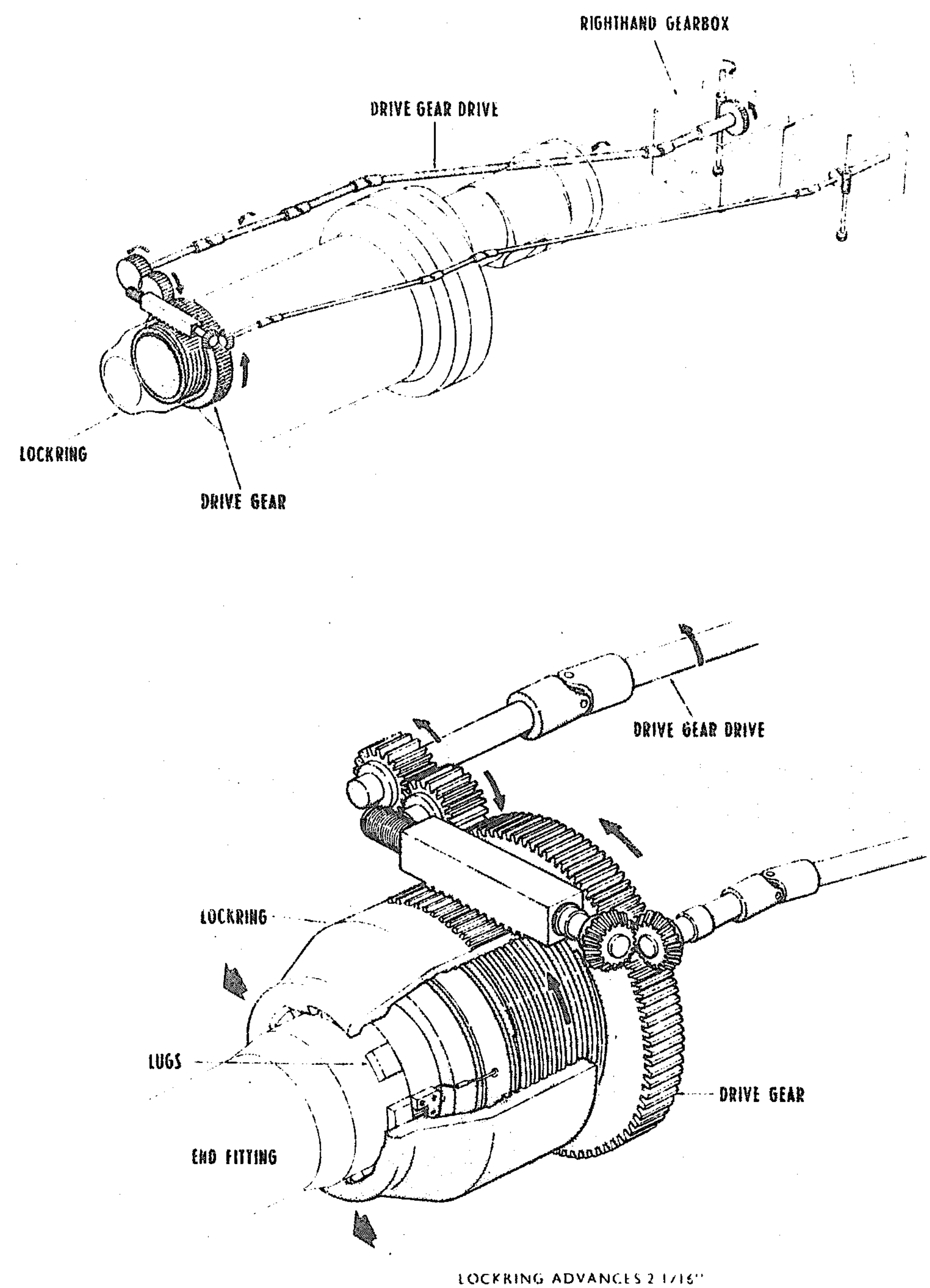


Figure 4 Locking Operation, Lockring Forward

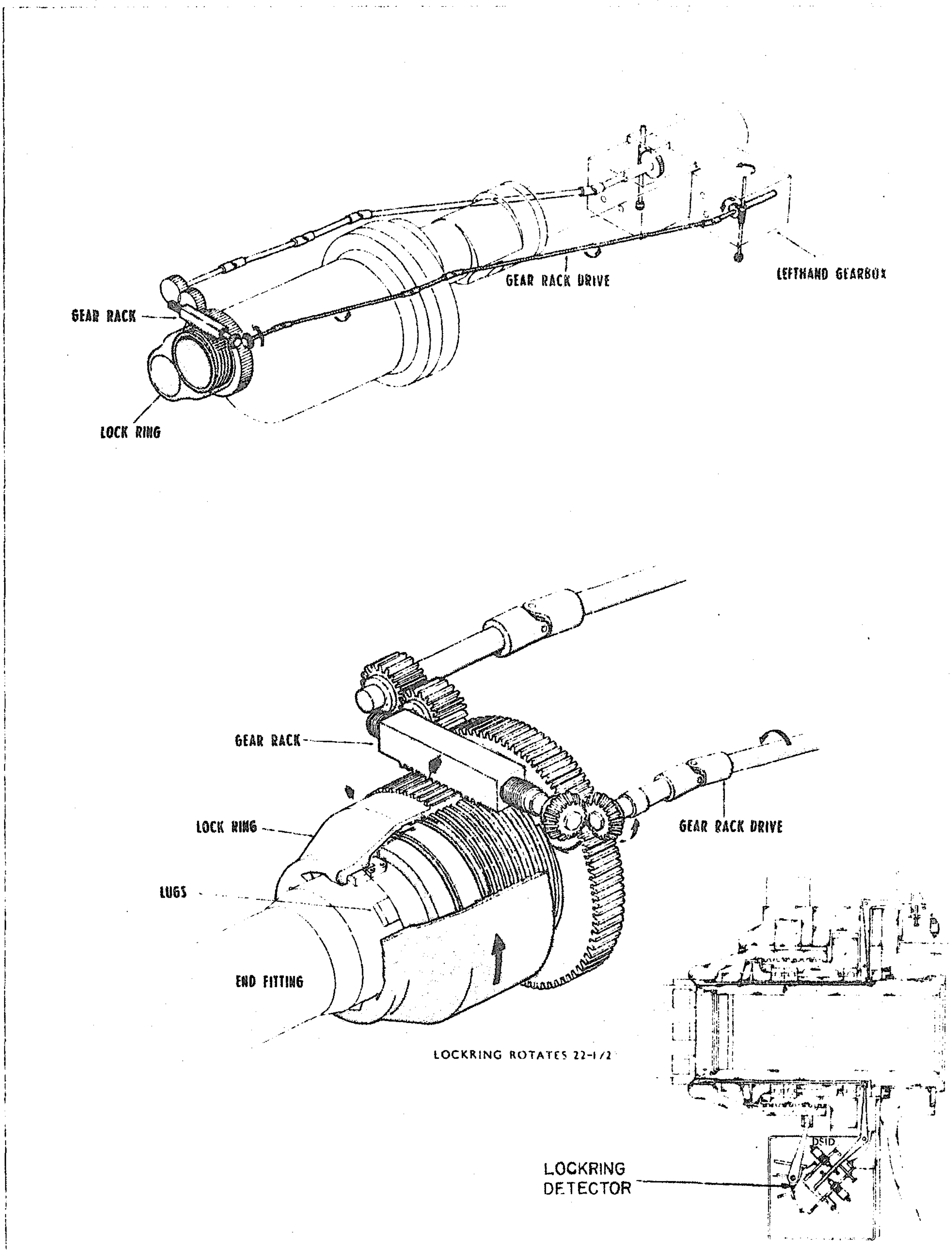


Figure 5 Locking Operation, Lockring Rotated

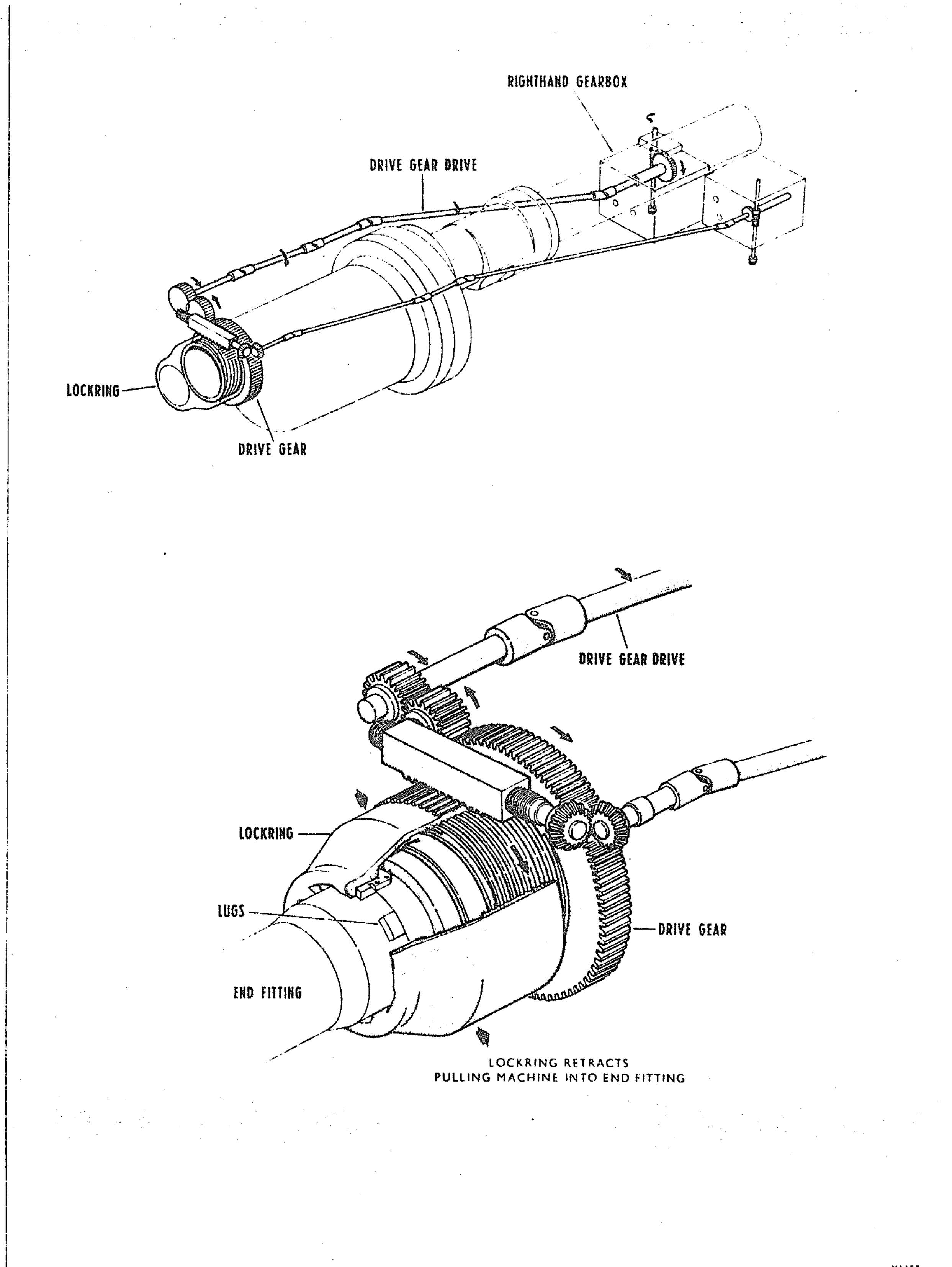


Figure 6 Locking Operation, Lockring Retracted, Machine Locked On

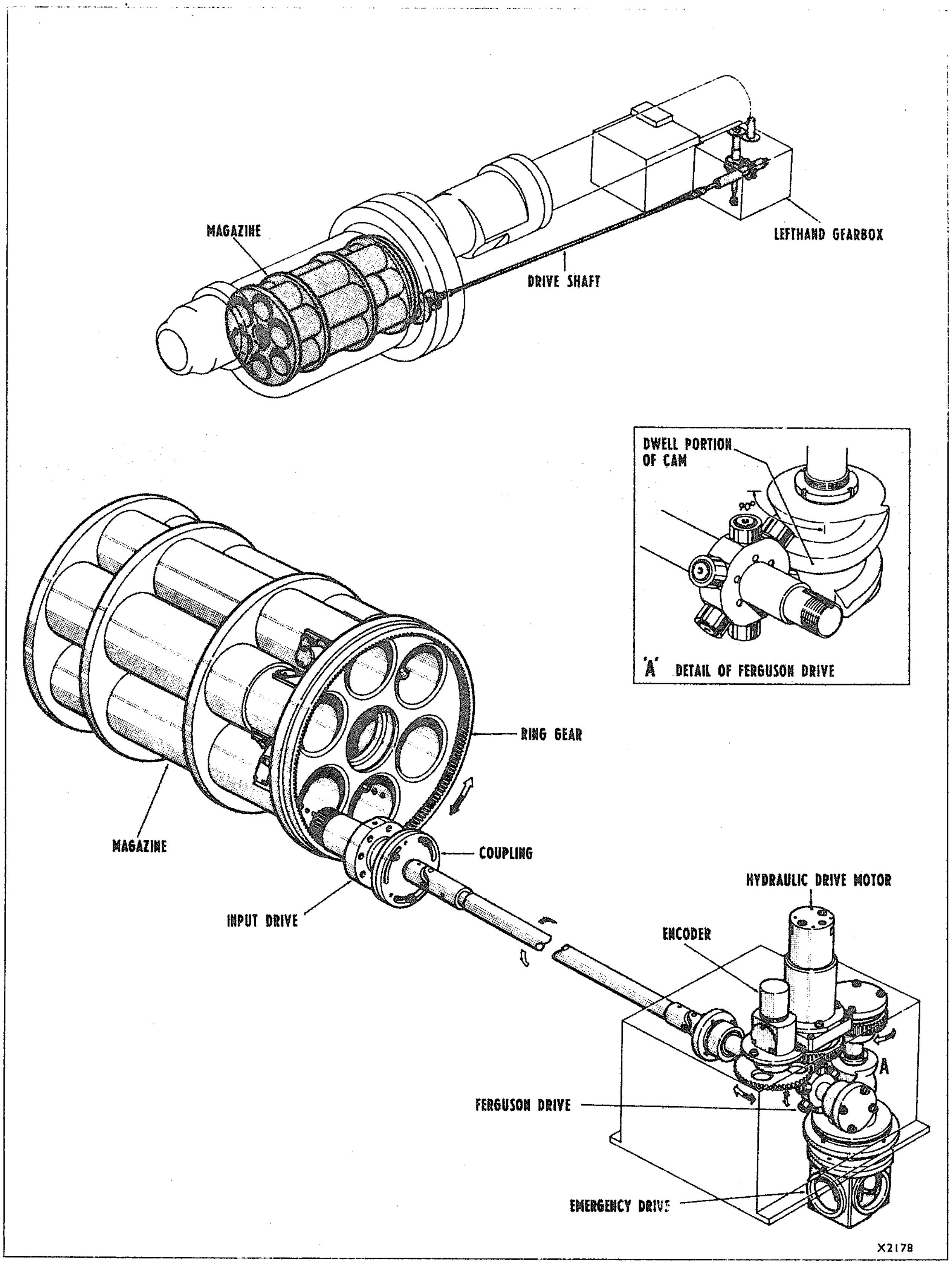


Figure 7 Magazine and Drive System

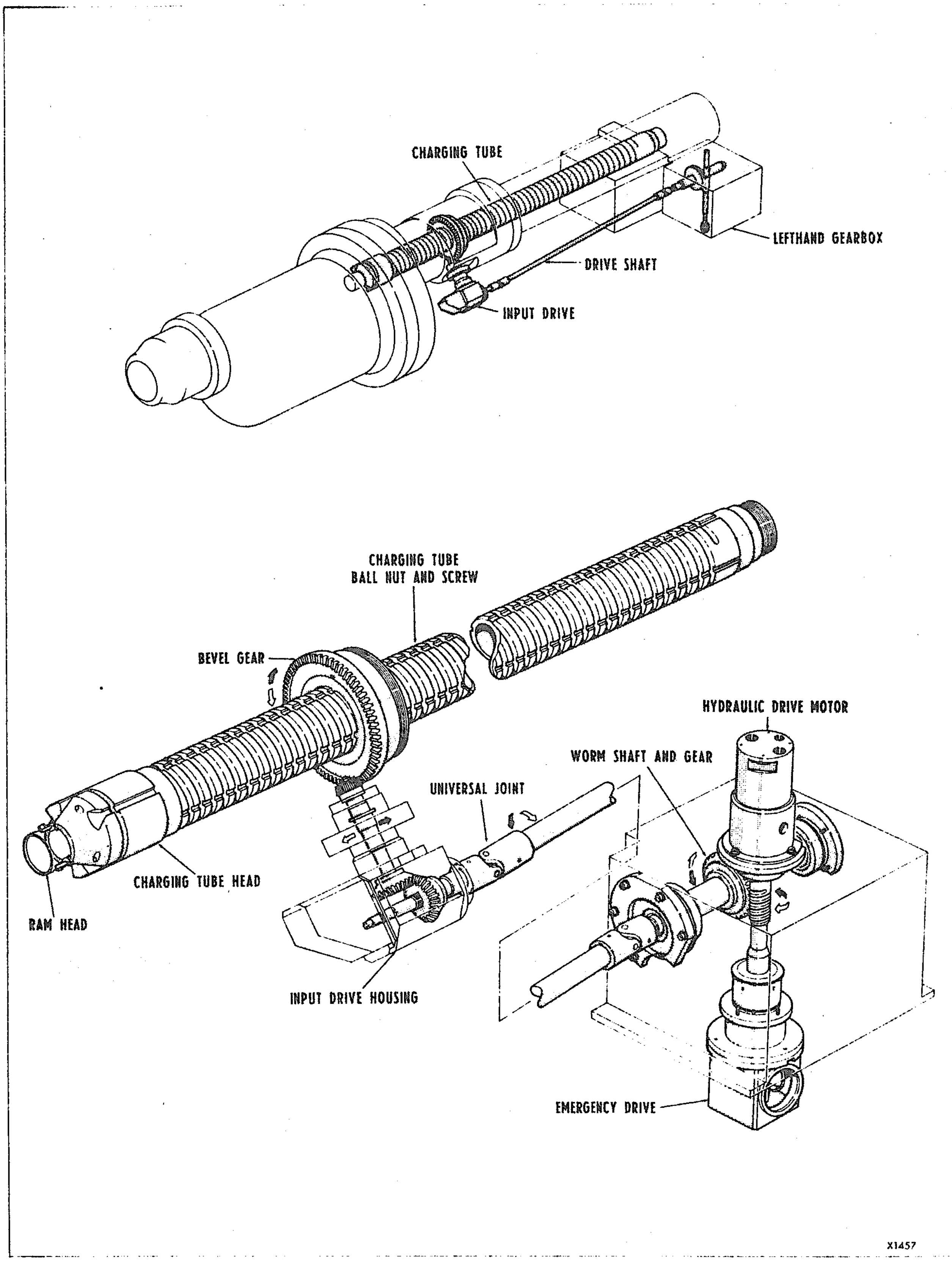


Figure 8 Charge Tube Rotary Drive System

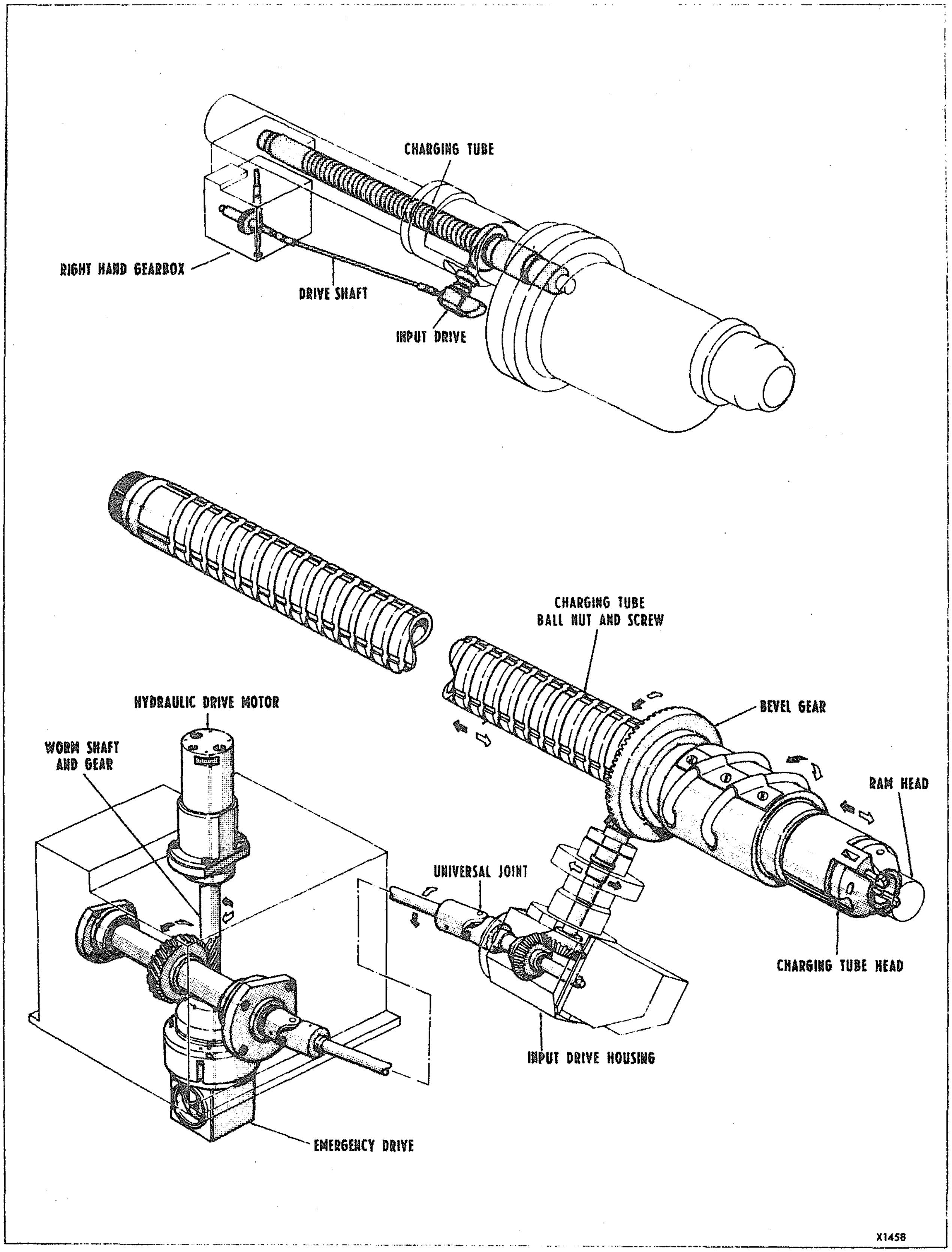


Figure 9 Charge Tube Axial Drive System

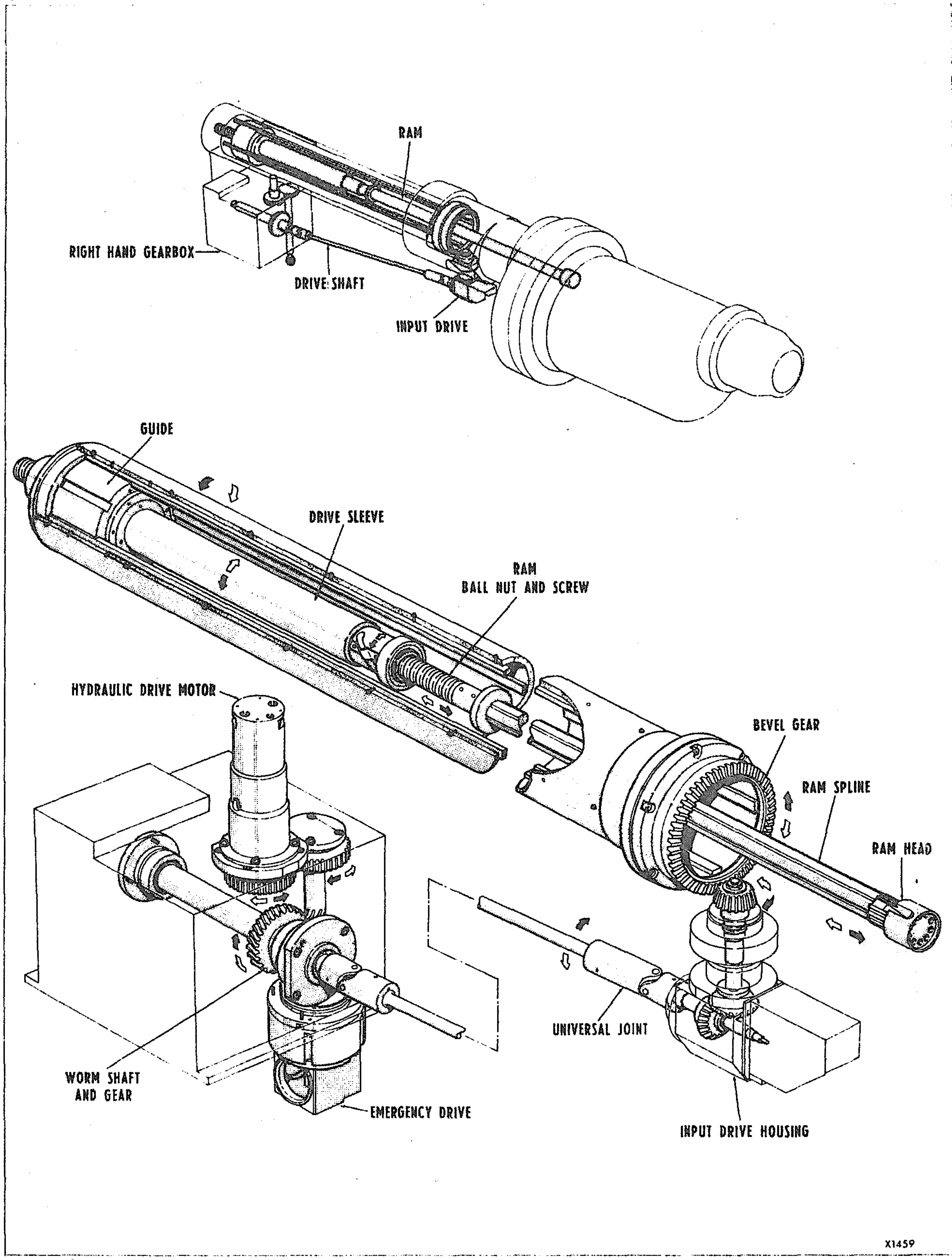


Figure 10 Ram Drive System

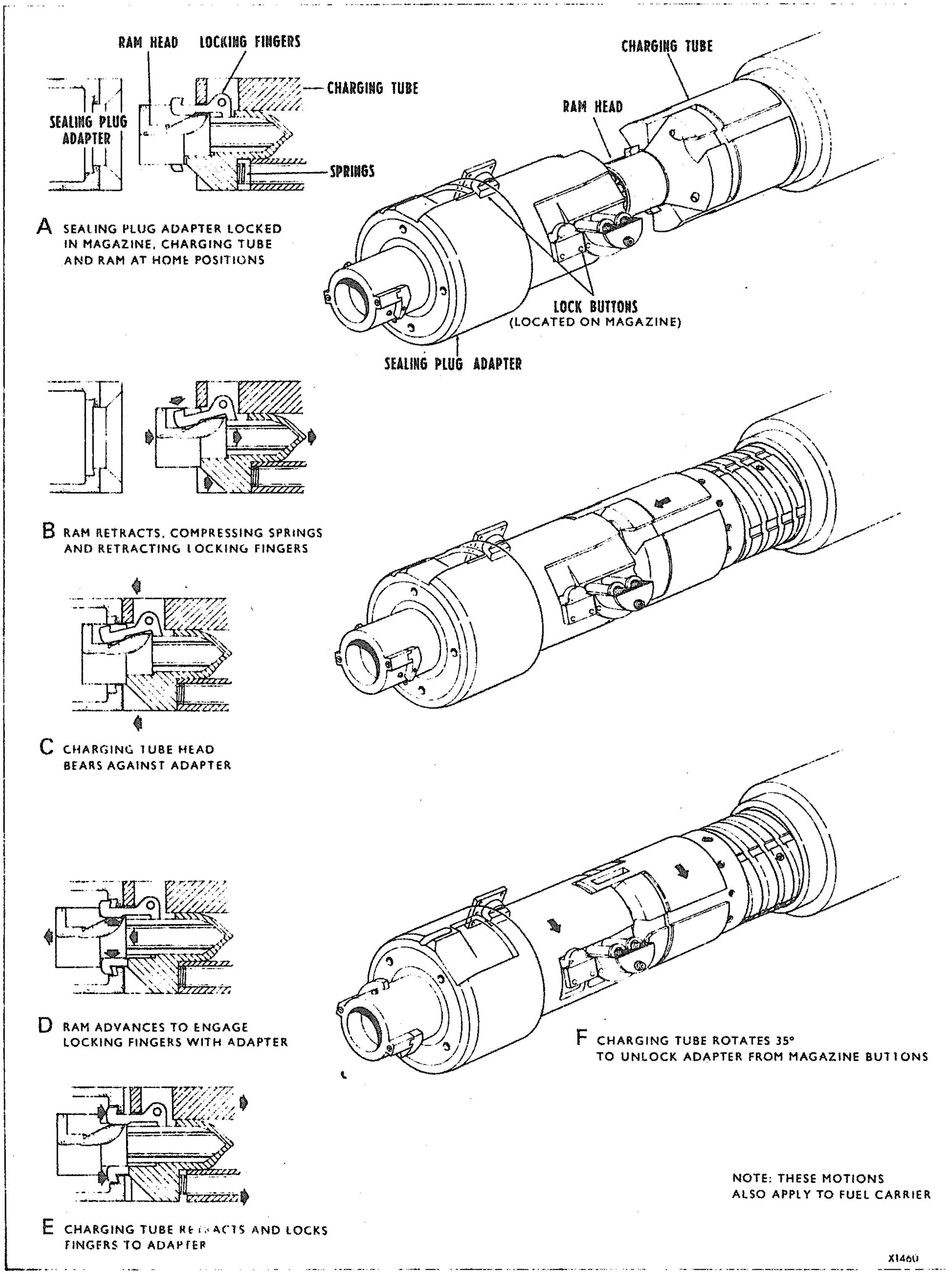


Figure 11 Ram and Charge Tube Operation (Unlocking Adapter From Magazine)

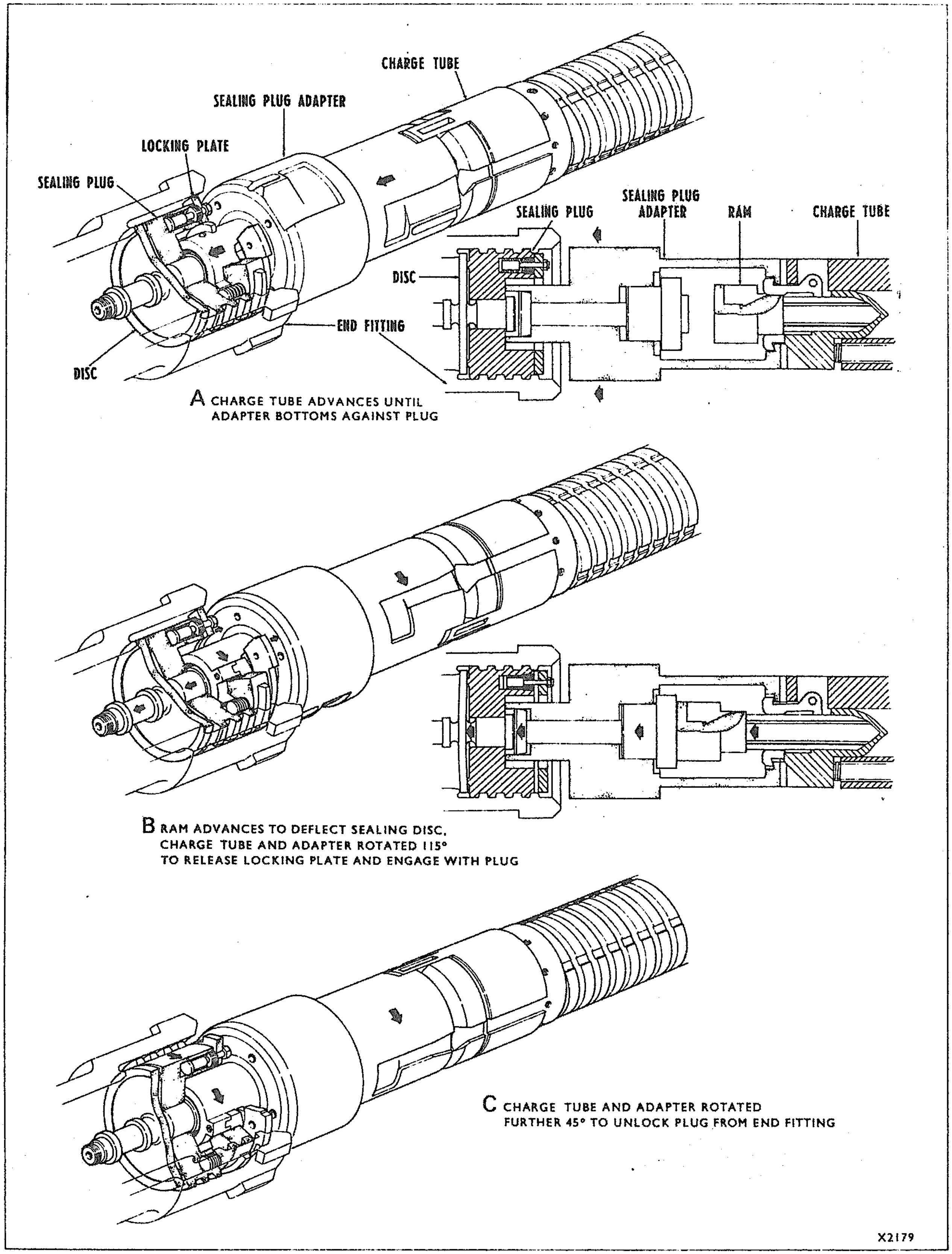


Figure 12 Ram and Charge Tube Operation (Unlocking Plug from End Fitting)

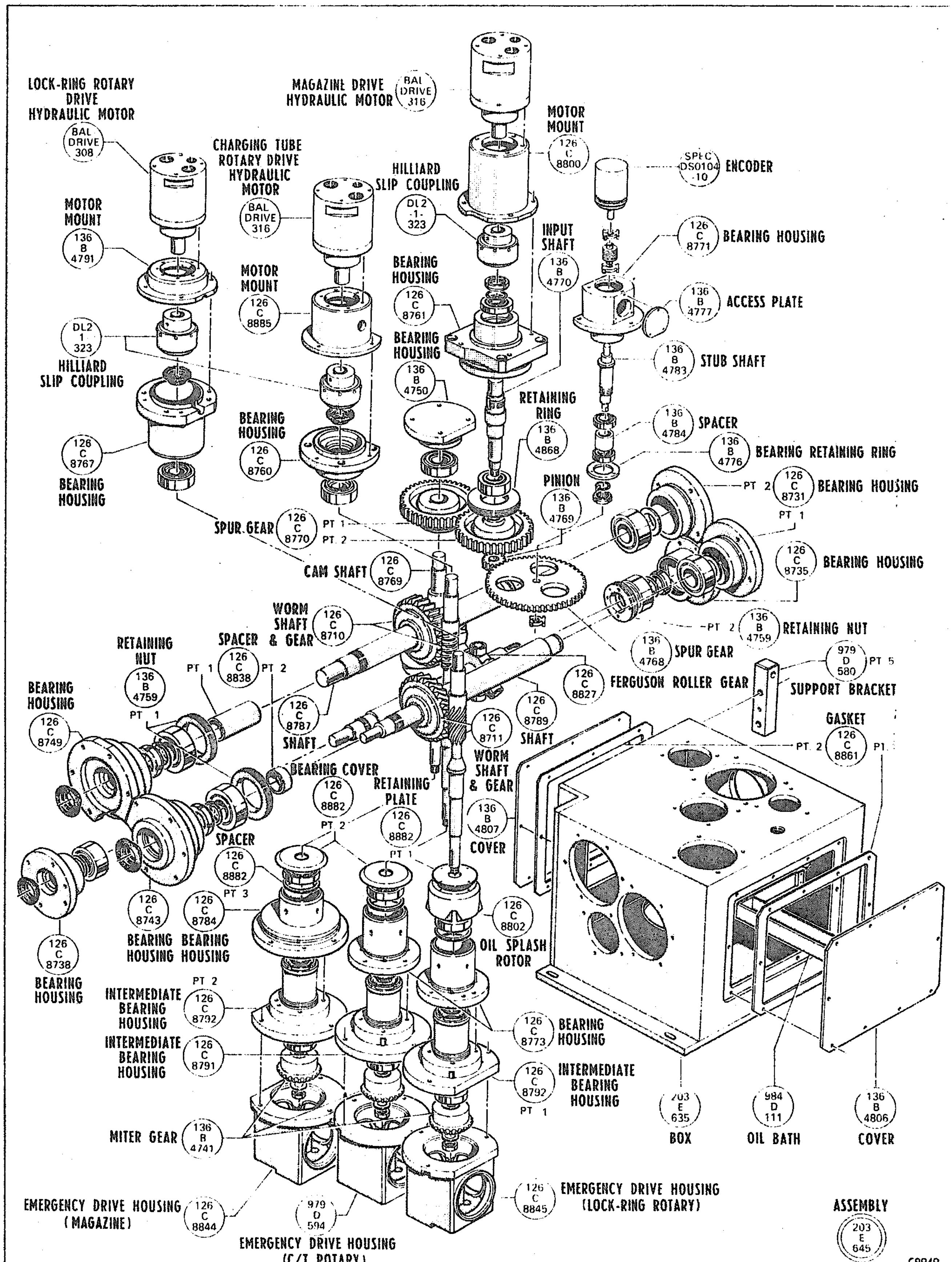


Figure 13 Left Hand Gearbox

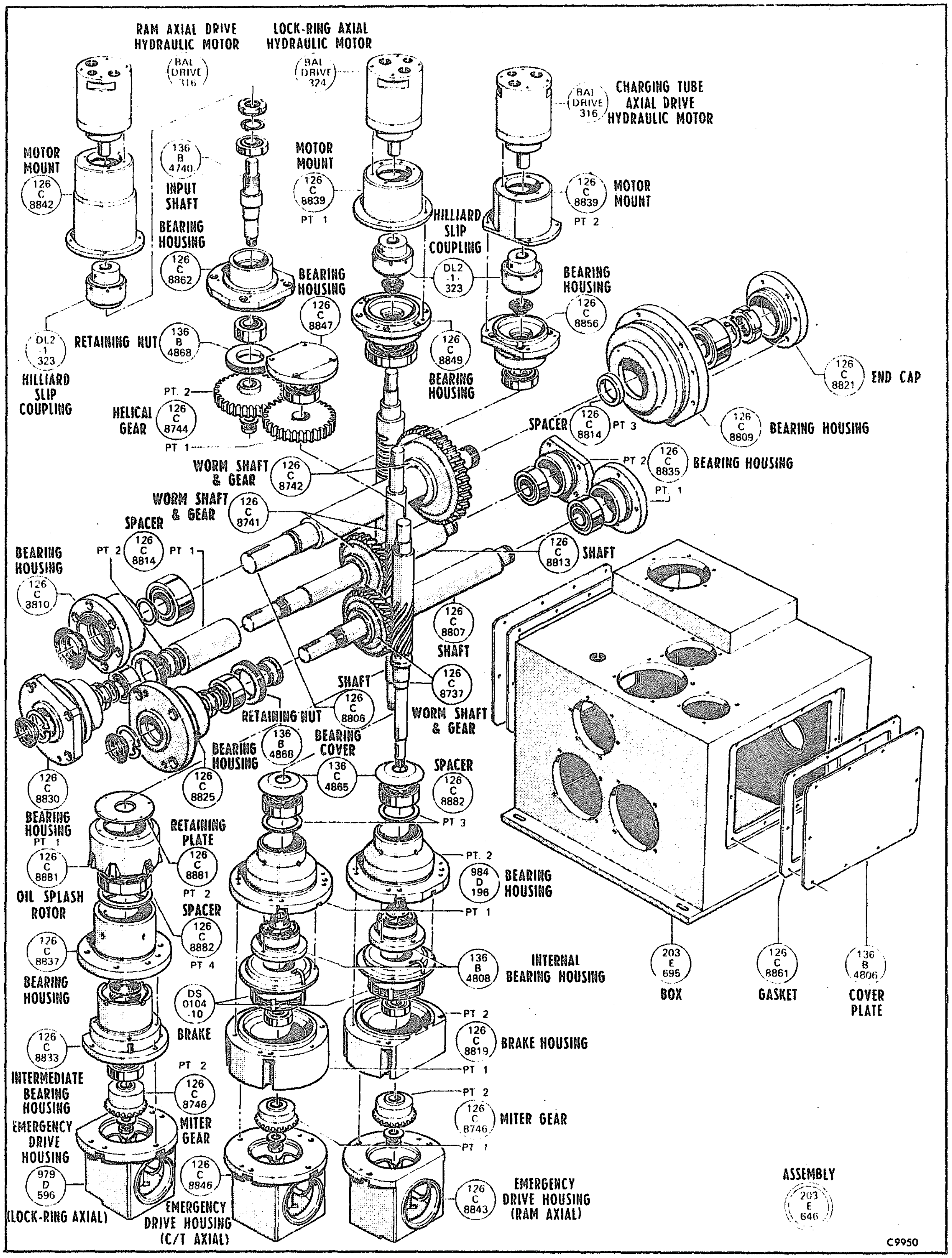


Figure 14 Right Hand Gearbox

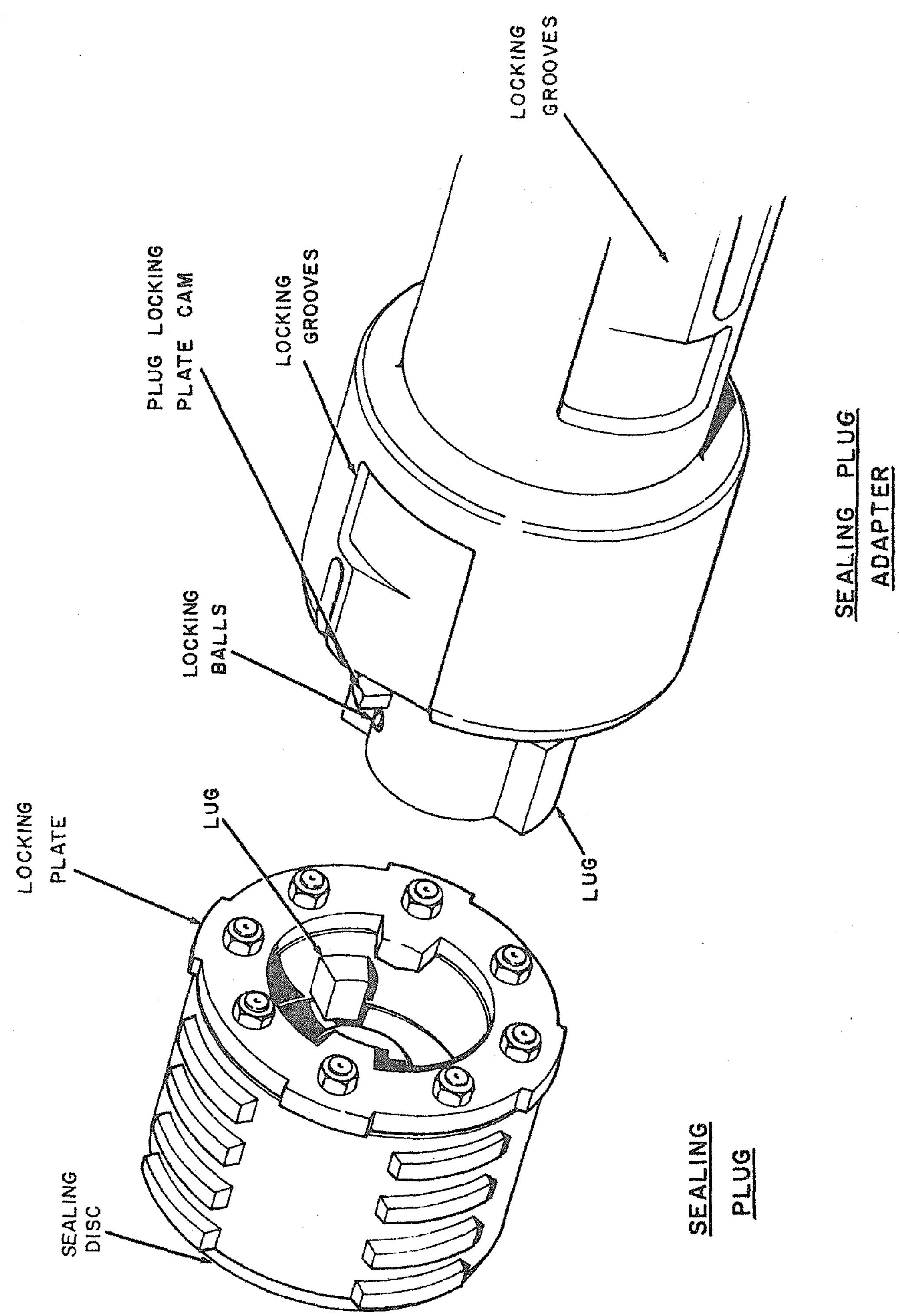


Figure 15 End Fitting Plug and Adapter

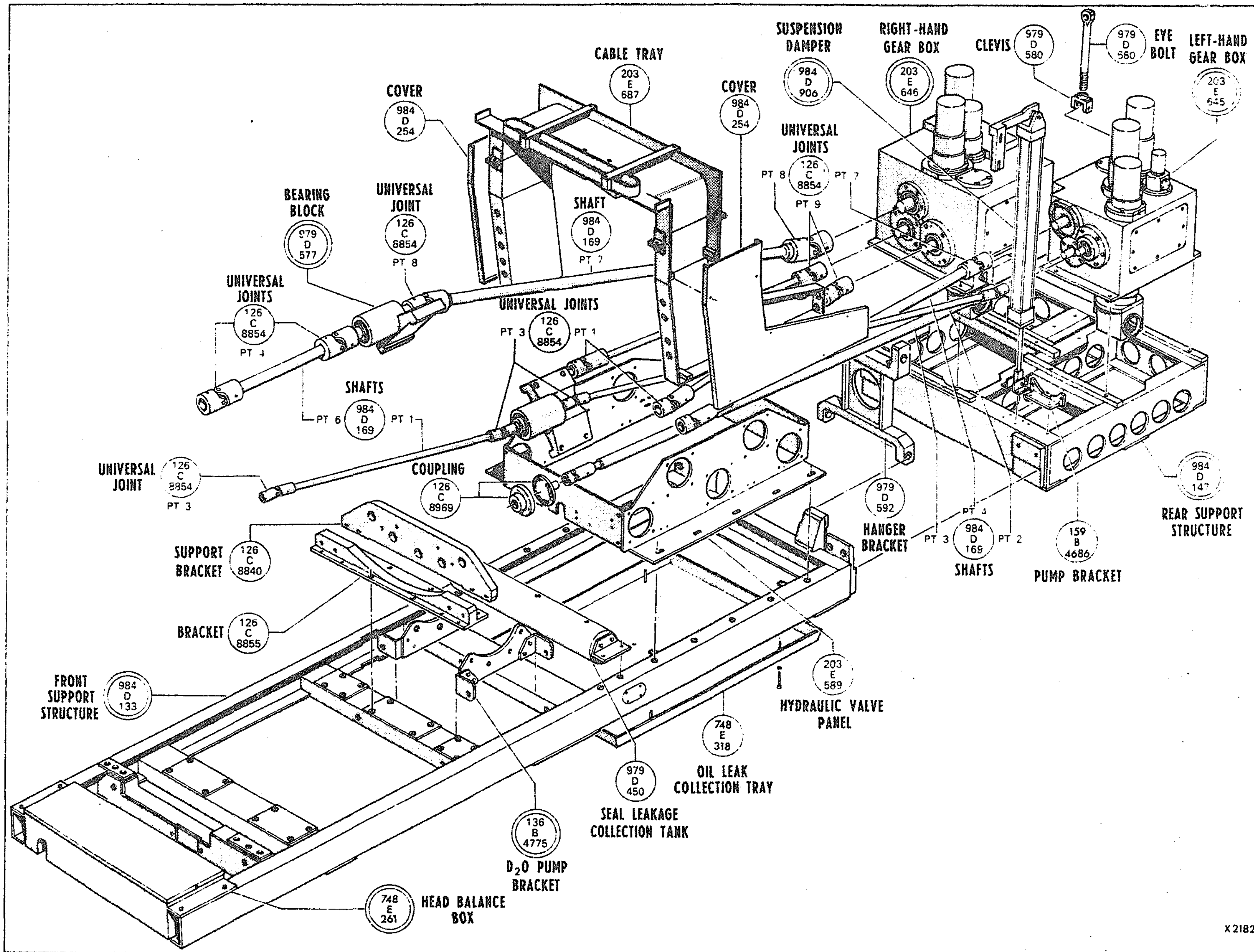


Figure 16 Head Support Structure, Gearboxes and Related Equipment

NPD Systems - Reactor Boiler and Auxiliaries

Fuel Handling System

OIL HYDRAULIC SYSTEM

This lesson describes the oil hydraulic system which operates all services on the fuelling machine head. Hydraulic power is provided by an oil hydraulic power unit, two power units being installed, one for each of the two heads, and they are located one in each of the two new fuel rooms. Hydraulic pressure, return oil and drain oil are transmitted between the power unit and the head through rigid piping and flexible hoses via the carriage.

Operation of the various functions of the head are controlled by conventional electro-hydraulic spool-type control valves. These valves direct pressure fluid to operate the hydraulic motors and cylinders. The speed of each operation and the output torque are limited by pressure relief valves and restrictors in each circuit. Operation of the suspension lock is by hydraulic cylinders through gear racks and pinions while all other operations are performed by hydraulic motors, the drives from the motors being transmitted by drive shafts, gear racks and pinions and screw jacks to the various components.

HYDRAULIC POWER UNIT

The hydraulic power unit consists of an electrically-driven variable-delivery, pressure-compensated pump mounted on a tank, as a complete unit.

The power unit is operating at all times from the start of a fuelling sequence until it is completed. The variable displacement pump is adjusted to provide 800 psig and will maintain this pressure up to the rated flow of 10 gpm (U.S.). Hydraulic fluid used in the system is Shell X-100, SAE 10W, AP-1 Rating for M.S. Service, a mineral oil. The approximate capacity of the system, including the tank is 25 Imperial gallons. See Figure 2.

All of the hydraulic system components for the head, with the exception of the suspension lock actuators, are located at the drive tube end of the fuelling machine. The control valves and manifolds are mounted on panels located on each side of the fuelling machine and below the drive housing. See Figure 1.

The six hydraulic motors are mounted three on the right hand gearbox and three on the left hand gearbox, located at the rear of the machine. The motors drive the various services through the gearboxes and rotary drive shafts. On the left hand gearbox are mounted the magazine, lockring rotary and the charge tube rotary motor together with an encoder for the magazine. Mounted on the right hand gearbox are the motors for the ram, lockring and charge tube axial drives. Encoders for the charge tube axial, ram axial and charge tube rotary drives are

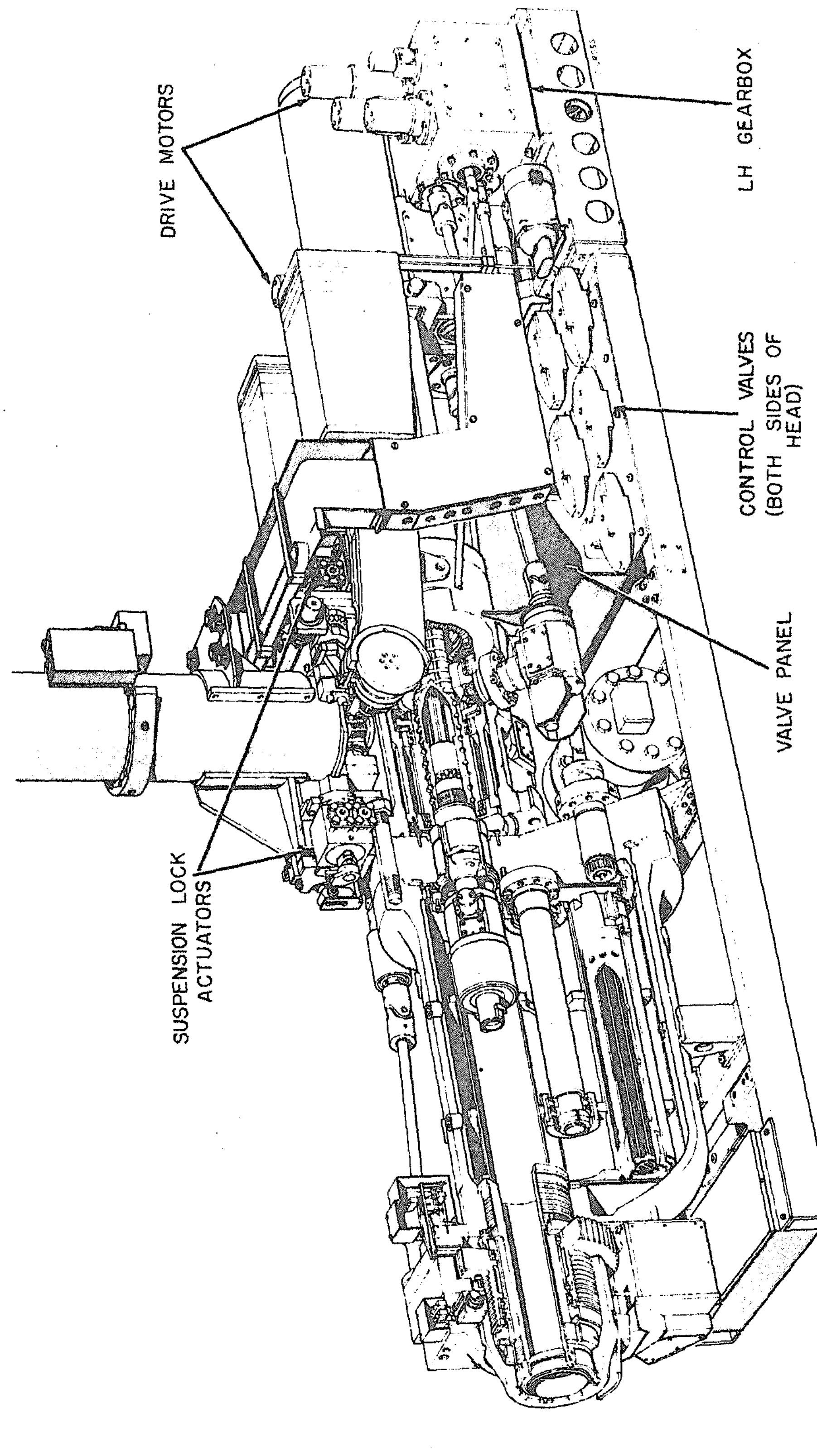


Figure 1 Oil Hydraulic Components on Head

installed on the input drives on the drive tube housing.

LOCKRING AXIAL (See Figure 3)

Axial movement of the lockring is controlled by the solenoid-operated three-position control valve CF-MV-LR/LF. Pressure fluid from the pressure manifold is directed by the valve to the lockring axial drive motor, and suction fluid is directed to the return manifold.

In the LR (retract) selection, the operating pressure is limited by relief valve CF-RV-10 while in the LF (forward) selection full system pressure may be applied. Flow control valve CF-FTV-20 limits the rate of fluid flow in both directions. In addition, CF-MV-FSP also controls the rate of flow, depending upon whether the head is on a cold end fitting, N.F.P. or S.F.P., or on a hot end fitting.

LOCKRING ROTATION (See Figure 3)

The three position solenoid-operated control valve CF-MV-LL/LU controls pressure and return flow to and from the hydraulic motor CF-MF3. When solenoid LL is energized, the valve directs pressure to lock the lockring and when solenoid LU is energized, to unlock the lockring. When both solenoids are de-energized, the valve returns to the neutral position and all four ports are closed. Flow control valve CF-FTV-22 limits the circuit flow in both directions.

CHARGE TUBE ROTATION (See Figure 3)

Charge tube rotation is controlled by the three-position solenoid-operated control valve CF-MV-ACC/ACW. Counter-clockwise rotation of the charge tube (e.g. plug unlock) occurs when solenoid ACC is energized, pressure being limited in this selection by pressure relief valve CF-RV-17. Solenoid ACW is energized for clockwise rotation (e.g. plug lock) with the pressure limited in this operation by relief valve CF-RV-11. The flow rate in both directions is limited by the flow control valve CF-FTV-21.

The control valve is spring-loaded to the neutral position so that when both solenoids are de-energized, both ports of the motor are closed. Three pressure switches are incorporated in this circuit, ACCLP, ACWLP, and ACWHP and signal the control system when a limiting pressure is reached.

When the valve spool is in the neutral (de-energized) position, any leakage past the spool tends to drive the motor and move the charge tube off position. To prevent this, bleed valves are connected from the motor ports to the drain line to prevent any pressure build-up. This small bleed off does not affect normal operation.

FAST SPEED SELECTOR VALVE (See Figure 3)

This two-position, solenoid-operated control valve, CF-MV-FSP, gives two speed operation of the ram axial, charge tube axial and lockring axial drives. When the solenoid FS is de-energized, the valve spool is spring-loaded to direct pressure through restrictor CF-FTV-27 to the three sub-systems. When the valve is energized, the restrictor is by-passed to provide maximum speed of operation.

CHARGE TUBE AXIAL (See Figure 3)

The three-position solenoid-operated control valve CF-MV-CF/CR controls the rotation of the charge tube motor CF-MF-5. Two operating pressures, in addition to the two operating speeds controlled by CF-MV-FSP, are provided by the two-position solenoid-operated control valve CF-MV-CHP and two pressure relief valves in forward operation. With the solenoid de-energized, the operating pressure is limited by relief valve CF-RV-12. When the solenoid is energized, the two relief valves CF-RV-12 and CF-RV-13 are connected in series to provide a higher operating pressure.

In retract operation, the pressure is limited by relief valve CF-RV-18.

Four pressure switches limit the pressure applied to the motor, two in the forward direction, CFHP and CFLP and two in the retract direction CRHP and CRLP. The signals from these switches are connected into the control system.

Leakage passed the control valve, CF-MV-CF/CR, when the spool is in the neutral position, is led into the drain line through two bleed valves CF-EV4 and CF-EV5

RAM AXIAL (See Figure 3)

Operation of the ram axial drive motor CF-MF-6 is controlled by the three-position solenoid-operated control valve CF-MV-RF/RR. In the same manner as the charging tube axial operation, two operating speeds are selected by CF-MV-FSP. In addition, two operating pressures in each direction are selected by CF-MV-RHP.

In the ram forward operation, pressure is controlled by relief valve CF-RV-14 for low pressure operation, exhausting into the suction manifold through CF-MV-RHP when it is de-energized. When CF-MV-RHP is energized, relief valve CF-RV-14 is by-passed and CF-RV-15 provides high pressure operation. In the ram retract cycle, relief valve CF-RV-16 limits the operating pressure.

Four pressure switches, RFLP, RFHP, RRLP and RRHP are installed in the system and provide control system signals at certain operating pressures.

SUSPENSION LOCK CLAMPS (See Figure 3)

Each of the two suspension lock is driven by two gear racks which mesh with a pinion on the lock shaft. The gear racks are each operated by two single-acting hydraulic cylinders, the pistons of which are integral with the gear racks.

Hydraulic pressure from the pressure manifold is directed to the cylinders through the two-position solenoid-operated control valve CF-MV-SL/SU. The valve position is solenoid controlled and remains in the position last selected when electrical power is removed. When energized, solenoid SL directs pressure to lock the suspension while with solenoid SU energized, the suspension is unlocked. Restrictor CF-FTV-23 limits the speed of operation in both directions.

MAGAZINE (See Figure 3)

Magazine rotation is controlled by a three-position, solenoid-operated control valve. With solenoid MCC energized, the magazine rotates in a counter-clockwise direction while with solenoid MCW energized, clockwise rotation results. Speed of magazine rotation is controlled by restrictor CF-FTV-4.

MANIFOLDS

Hydraulic pressure from the hydraulic power unit is distributed to the various services on the head through a pressure manifold. Return fluid from the control valves is collected in a return manifold which is connected to the suction side of the hydraulic power unit pump. The two manifolds are integral.

OIL DRAIN(See Figure 2)

Drain oil consists of internal leakage from the hydraulic motors, leakage from control valve vent connections and the bleed flows from the bleed valves in the charge tube rotation, charge tube axial and ram axial system. This drain oil is collected in a small reservoir at the base of the column. An electrically-driven pump, adjacent to the reservoir, pumps the fluid through the catenary hose to the reservoir of the main hydraulic power unit. The pump is controlled by two level detectors in the drain reservoir which start the pump when a pre-set level is reached CF-D-ODHUD, and switch it off when the level has dropped, CF-D-ODHUD. A third detector, CF-D-ODHTD, is set at a higher level than CF-D-ODHUD and controls the three-position solenoid-operated control valve CF-MV-ODVV. This valve is operated only as a two position valve. It controls the tank vent line and is normally open.

If the oil reaches the third detector CF-D-ODHTD, because of pump failure or any other cause, control valve CF-MV-ODVV is energized to close off the vent to prevent the oil being deposited in the vault and forces the oil up the catenary hose back to the power unit reservoir. This detector also warns the operator that a fault exists.

BREAKDOWN OPERATION

All of the control functions of the fuelling machine head, except the suspension locks, can be performed manually. A mitre gear, at the bottom of each of the hydraulic motor drive worm shafts in the two gearboxes, is accessible from three positions, from the left and right sides and the rear of the fuelling machine head.

Holes cut in the fuelling machine frame, enable a tool with a matching mitre gear to be inserted and engaged with the mitre gear in each drive system. When the shaft is rotated, the drive system is operated. See Figure 1.

Internal leakage in the motors is sufficient to permit their rotation without the control valve being selected if a control system failure makes this necessary.

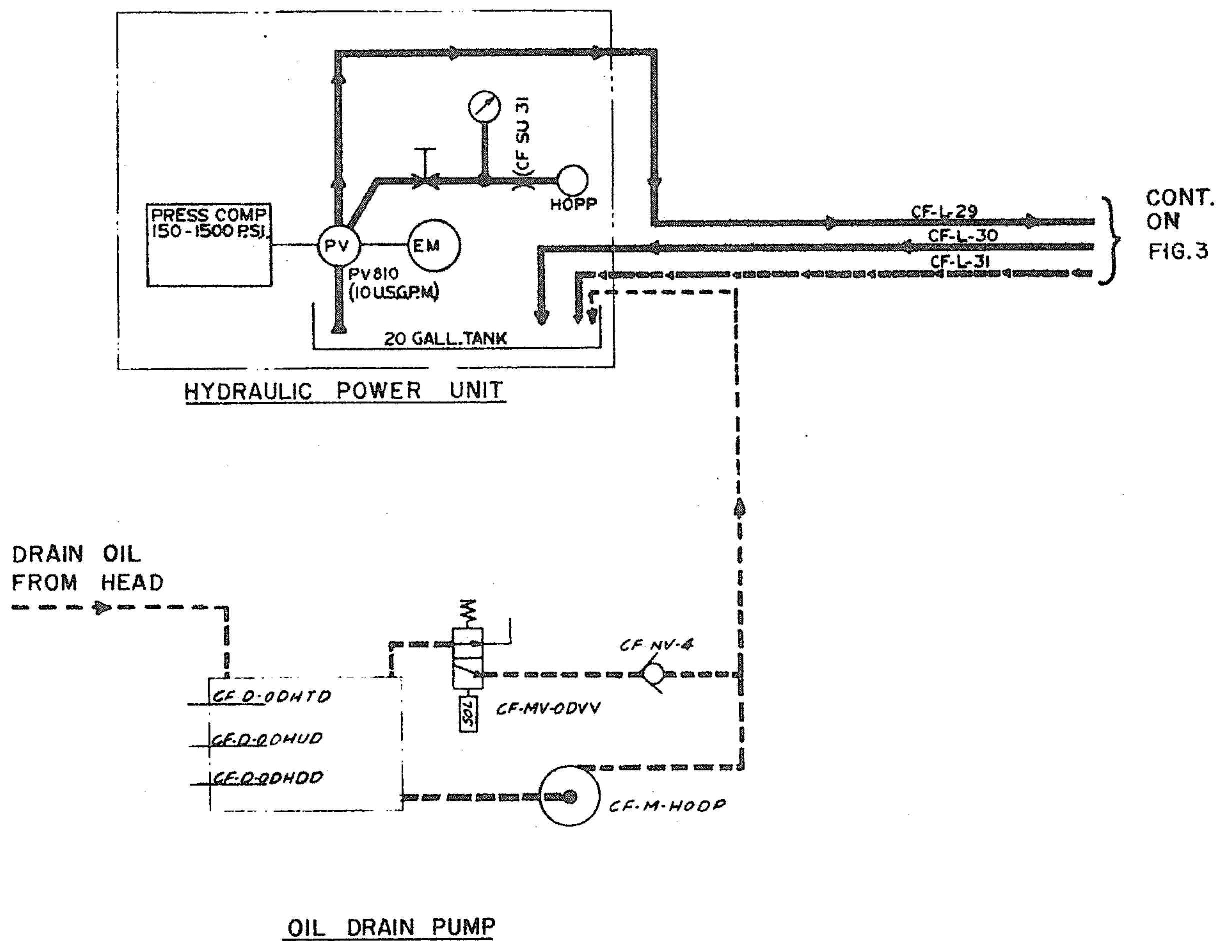
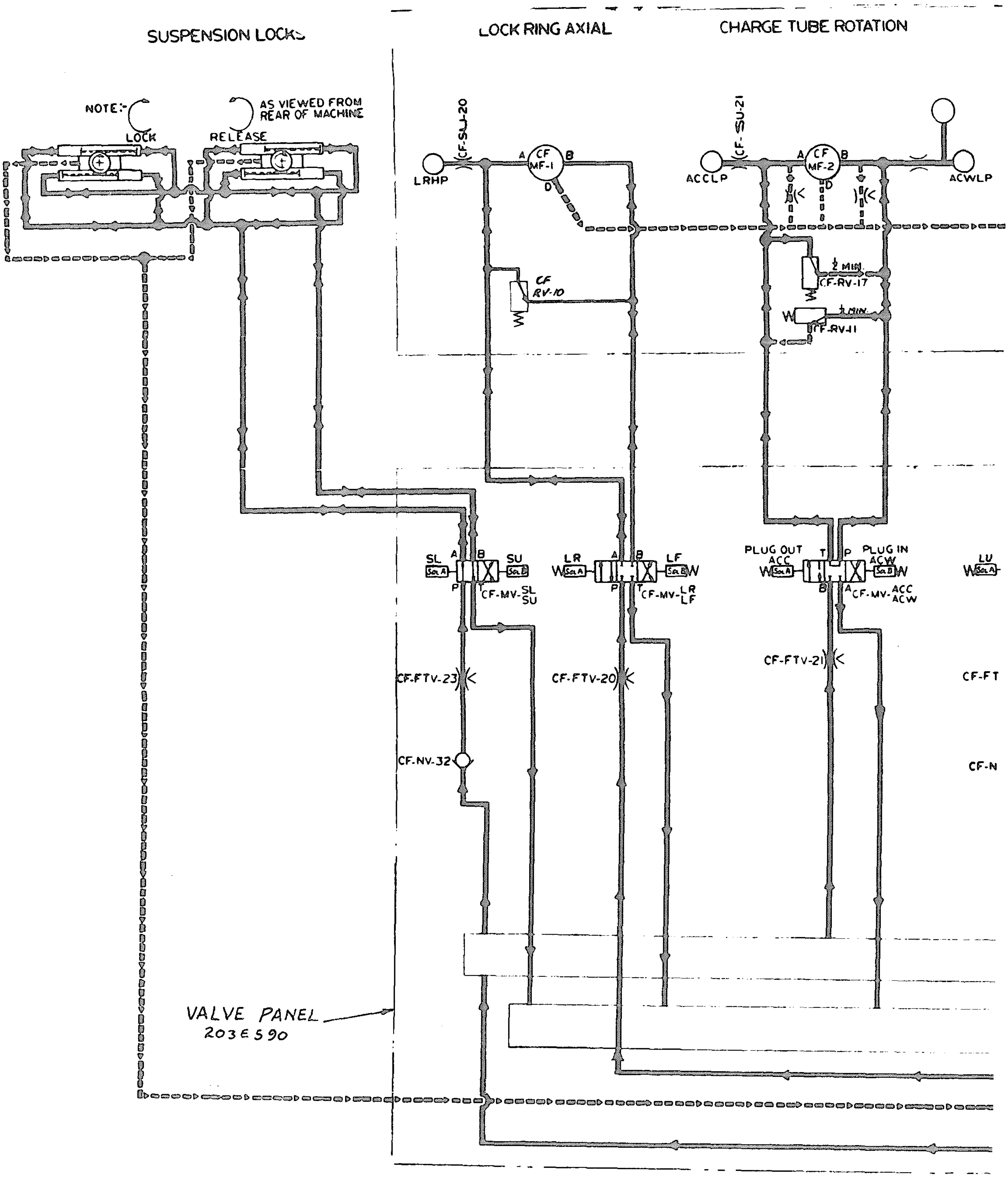
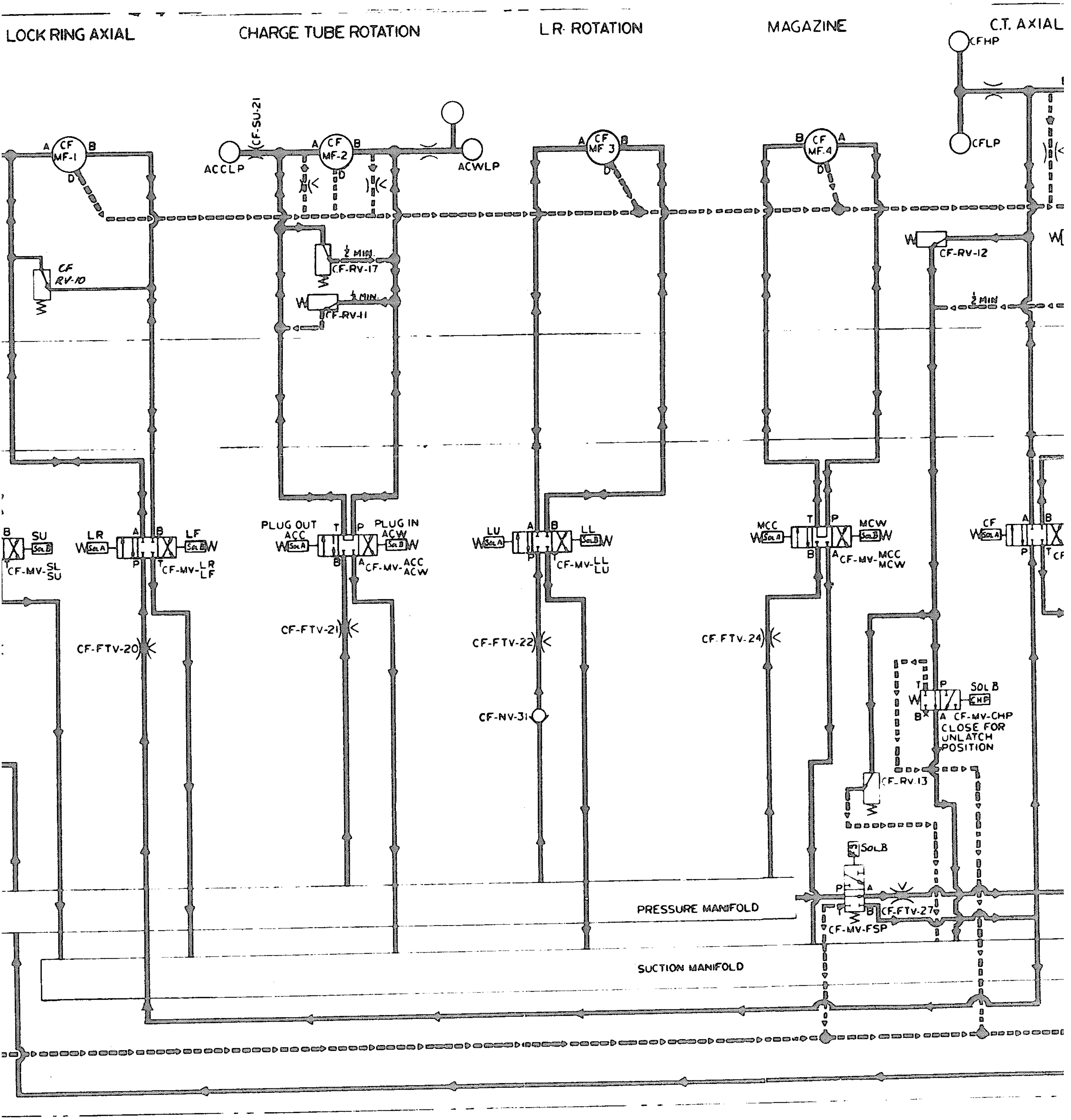


Figure 2 Hydraulic Power Unit and Drain Oil Pump Schematic


SUSPENSION LOCKS
LOCK RING AXIAL
CHARGE TUBE ROTATION
NOTE:- AS VIEWED FROM REAR OF MACHINE
LOCK
RELEASE
CF-SU-20
LRHP
CF MF-1
CF RV-10
CF-SU-21
ACCLP
CF MF-2
ACWLP
1/2 MIN.
CF-RV-17
1/4 MIN.
CF-RV-11
SL
SU
CF-MV-SL SU
LR
LF
CF-MV-LR LF
PLUG OUT ACC
PLUG IN ACW
CF-MV-ACC ACW
LU
CF-FTV-23
CF-FTV-20
CF-FTV-21
CF-FT
CF-NV-32
CF-N
VALVE PANEL
203E590


LOCK RING AXIAL
CHARGE TUBE ROTATION
L.R. ROTATION
MAGAZINE
C.T. AXIAL
CF MF-1
CF RV-10
CF-SU-21
ACCLP
ACWLP
CF MF-2
CF-RV-17
CF-RV-11
CF MF 3
CF MF-4
CFHP
CFLP
CF-RV-12
SU
LR
LF
CF-MV-SL SU
CF-MV-LR LF
PLUG OUT ACC
PLUG IN ACW
CF-MV-ACC ACW
LU
LL
CF-MV-LL LU
MCC
MCW
CF-MV-MCC MCW
CF-FTV-20
CF-FTV-21
CF-FTV-22
CF-FTV-24
CF-NV-31
SOL B
CF-MV-CHP
CLOSE FOR UNLATCH POSITION
CF-RV.13
CF-FTV-27
CF-MV-FSP
PRESSURE MANIFOLD
SUCTION MANIFOLD

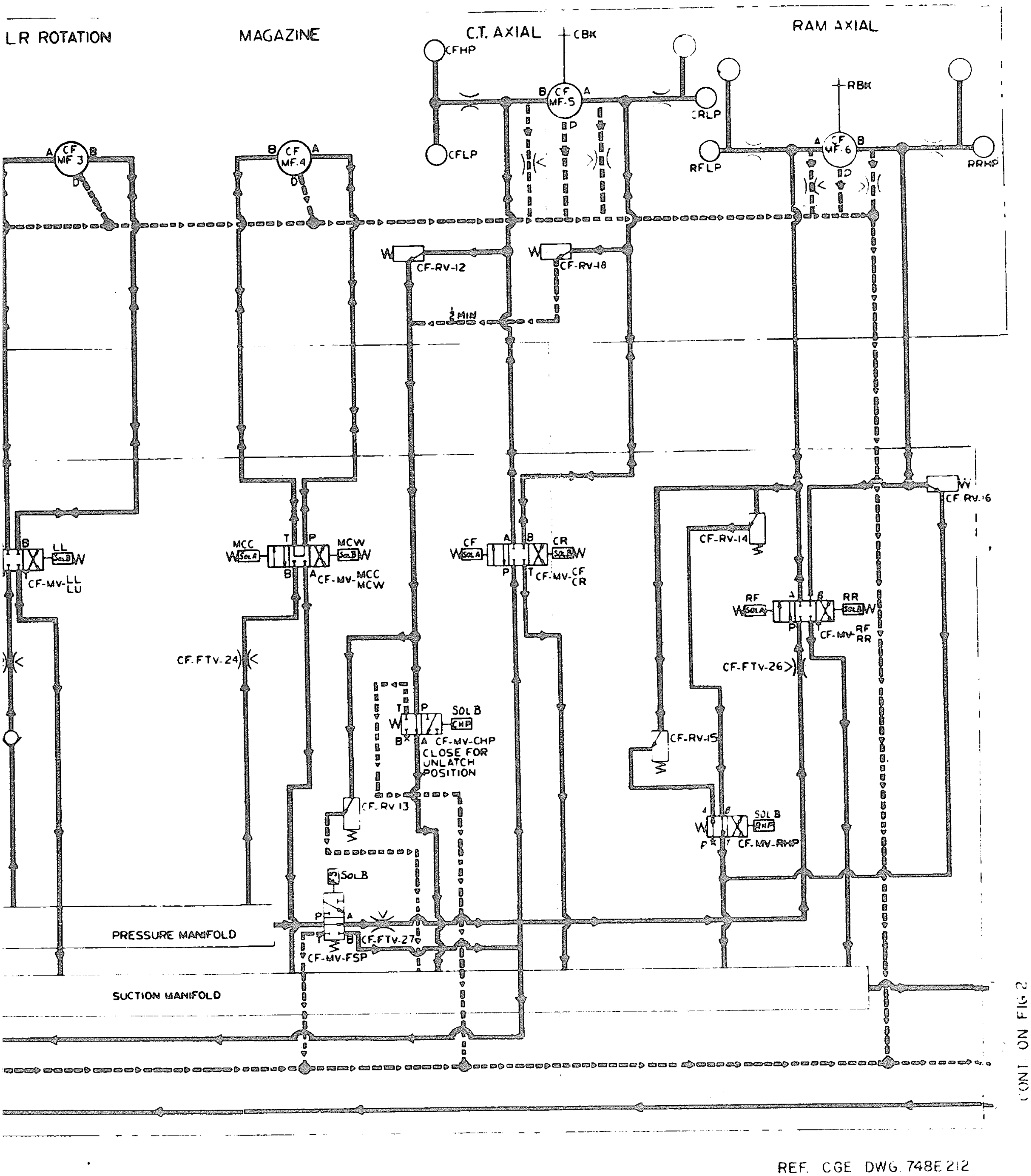


Figure 3 Oil Hydraulic Circuit on Head

NPD Systems - Reactor Boiler and Auxiliaries

Fuel Handling System

FUELLING MACHINE PRESSURIZING AND RECIRCULATING SYSTEM

In order to load fuel into the Reactor, the Fuelling Machines must break into the pressure boundary of the Primary Heat Transfer System which may be under the full reactor pressure and temperature of 1050 psig (7239494.85 N/m^2 (g)) and 530 ^{0} F(549.8^{0}K) The irradiated fuel discharged into the "accept" machine in intensely radioactive and generates considerable heat even after removal from the reactor flux. This heat will cause damage to the fuel if adequate cooling is not maintained on the fuel bundle after removal. The bundle is eventually transferred to the Spent Fuel Storage Bay where it is stored under water, the water acting as both a coolant and a radiation shield.

From these requirements, it is apparent that the Fuelling Machines must include filling, pressurizing and recirculation cooling systems. The system is filled with reactor grade heavy water.

This lesson describes the hardware and the method of operation of the Pressurizing and Cooling System.

REQUIREMENTS OF THE SYSTEM

The Pressurizing and Cooling System provides the following:

1. Filling the Fuelling Machine Head with heavy water.

2. Emptying the Head of heavy water.

3. Correcting the heavy water level in the Head to prevent the overflow of D_2O from the snout and prevent the uncovering of irradiated fuel in the magazine.

4. Pressurizing the Head with heavy water.

5. Cooling the irradiated fuel, and the Fuelling Machine Head components to prevent too rapid temperature rise with the consequent risk of failure.

6. Cooling and depressurizing the Head after the end fitting plug has been replaced.

7. Leak testing the seal made by the Snout of the Fuelling Machine with an end-fitting after the locking-on operation is complete.

8. Adding heavy water to the machine system from the Moderator System when the water level in the Reservoir of the machine drops below a pre-set level.

9. Leak testing of the reactor end fitting plug after it is replaced before the Fuelling Machine Head is unlocked.

DESCRIPTION OF THE SYSTEM AND COMPONENTS

The Pressurizing and Cooling System is shown in Figures 1 and 2.

The Fuelling Machines are each filled with heavy water which is contained partly in the head, partly in the D_2O Reservoir and partly in the piping in the remainder of the system. The Overflow Tank does not normally contain heavy water.

When the Fuelling Machines are on a reactor end-fitting with the plug removed, there is a flow from each Fuelling Machine into the reactor and this is periodically made up from the moderator pumps, through a flexible hose to each Fuelling Machine carriage from terminals on the North Wall of the Fuelling Machine Room. Apart from losses, there is no other means of transferring heavy water to or from the Fuelling Machines during normal operation.

Head Cooling System

The fuelling machine head is cooled by D_2O circulated through the space between the thermal barrier and the magazine housing. The hot D_2O is extracted from the bottom of the housing through two extraction lines by the circulating pump CF-P-1.

From the pump, the D_2O is cooled in a heat exchanger before being returned to the head through two penetrations in the top of the magazine housing which discharge into the area between the thermal barrier and the magazine housing.

The circulating pump is a canned-rotor pump with a capacity of 30 U.S. gpm (1.893×10^{-3} m^3/sec) and is mounted on the head support structure just behind the magazine housing flat head.

The heat exchanger is cooled by standby water on the tube side, with the D_2O passing through the shell side. The heat exchanger is mounted on the north side of the carriage.

Two lines are taken off the discharge side of the pump. One line passes through a filter to supply a flow of D_2O to purge each of the input drive assemblies. A second line connects to a control valve, CF-MV-CTCV, which controls the flow of D_2O to cool the drive housing and flat head.

Light water cooling to the heat exchanger is supplied by the standby water system. This water is supplied from standby water header and passes through a pneumatically controlled valve CFIT-SW- CVI before entering the tube side of the heat exchanger. It then leaves the heat exchanger to be exhausted into a process drain header. The H_2O flow can be controlled between zero and 30,000 lbs/hr (3.778 Kg/sec).

Instrumentation and Control

When the F/M is at any position other than home, the D_2O circulating pump (CF-P1) will be running. A flow detector (CF-HFD)* will indicate operation of CF-P1. If CF-HFD does not indicate flow, then further fuelling operations cannot commence on Computer control until head flow is established.

The small extraction D_2O flow to the drive housing and flat head is controlled on or off by a control valve (CF-MV-CTCV)*. This valve is programmed to open when the head is at azimuth normal and close when at azimuth service.

Cooling of the D_2O in the heat exchanger is either on or off as controlled by CFIT-SW-CVI*. The operator for this valve is controlled by a Bailey Controller so that it may be operated manually by hand, or automatically by digital computer control . The automatic signal to the Bailey Controller is determined by HJT (CFIT-D)*.

When the F/M head is away from the home position, HJT will be controlled between 90^{0}F (299.81^{0}K) and 130 ^{0}F (327.6^{0}K) as sensed by CFIT-D, and controlled automatically by the Computer. Upon rising temperature of HJT through 130 ^{0}F, a signal will be sent by the computer to the Bailey Controller to open CFIT-SW-CVI. Upon falling temperature of HJT through 90 ^{0}F a signal will be sent by the computer to the Bailey Controller to close CFIT-SW-CVI. ~~Also, CFIT-SW-CVI is programmed to open and remain open by the Bailey Controller when a plug is out of the reactor regardless of the temperature at HJT.~~

* SEE APPENDIX

HCT* as sensed by CF3T-D is a permissive which allows blow-off when the head center temperature falls at 190 ^{0}F (~~355.37~~ 361° ^{0} K).

After a successful blow-off operation cooling is left on during the leak test to prevent the pressure from building up in the head through stored heat to give a false leak indication.

3. Alarms

If the D_2O temp. of the head reaches 220^0 F (377.59^0 K) and the cam on recorder HJT reaches 200 ^{0} F (366.481 ^{0} K) an alarm, CF-HHTD *, will sound in the control room.

If the D_2O temp. of the head reaches 50^0 F an alarm, CF-HXTD, will sound in the control room.

4. Power Failure (Class IV)

Upon Class IV power failure the circulating pump will remain running as its source of power is Class III. CFIT-SW-CVI will go full open as the air control pressure to the valve operator will bleed off in approximately one minute.

Head Fill and Vent System

When the head is locked on to a reactor end fitting, the head must be filled with D_2O and all air vented prior to pressurizing the head to reactor heat transfer system pressure.

The head fill pump CF-P8 draws D_2O from the reservoir and delivers it through the filter CF-FR-9 to the head circulating system through the valve CF-MV-HID. As D_2O leaves the reservoir and enters the head, both vessels are vented to the vault D_2O recovery line CF-L-14 through CF-MV-HVV and CF-MV-OTVV. The filling continues until D_2O is forced up the head vent line CF-L-17 into the overflow tank. The overflow tank drain valve is closed. As soon as the overflow tank level probe CF-OTHD comes in, the head is considered to be full and CF-MV-HID, CF-MV-HVV and CF-MV-OTVV are closed and the head fill pump, CF-P-8 is shut down.

The circulating pump CF-P-1 continues to operate.

The following valves are energized:

OTVV - Overflow tank vent valve - open.
OTDV - Overflow tank drain valve - closed.
HVV - Head vent valve - open.
HIDV - Head in drain valve - open.

* SEE APPENDIX

D_2O Top Up System

The machine D_2O system is topped up before traversing from the new fuel port. It consists of topping up the reservoir until the level detector RUHD comes in.

If, when the top-up operation is called, the reservoir detector RUHD is not in, top-up is initiated. This consists of opening valves CF-MV-TUV and CF-MV-OTVV. This admits D_2O from line CF-L-4 through the overflow tank and via the normally open valve CF-MV-OTDV to the reservoir. The reservoir is vented through the overflow tank vent valve CF-MV - OTVV.

When RUHD comes in, CF-MV-TUV and CF-MV-OTVV are closed to stop the flow of D_2O and CF-MV-OTVV closes the vent line.

Top-up can also be initiated whenever required by the operator.

Pressurize Head with D_2O

After the head is locked on to the reactor and filled and vented, and before the reactor end fitting plug is removed, the fuelling machine must be pressurized to approximately the pressure in the reactor.

This is achieved by the pneumatically operated, piston-type intensifier pump CF-P-7. This pump is controlled by a solenoid operated and a pneumatically operated control valve which controls the flow of lubricated air.

The intensifier pump CF-P-7 draws D_2O from the reservoir and delivers it at increased pressure to the head. Note that this pressure propagates into CF-L17 right up to HVV, which is closed. While D_2O is being transferred from the reservoir, that vessel and the overflow tank are both venting. Two in-line check valves, prevent any possibility of high pressure D_2O leaking back to the reservoir.

CF-RV-1 is a pressure relief valve set to about 1250 psi (8618446.25 N/m^2) to the D_2O reservoir. The purpose of this valve to protect against over-pressure and blow - off results in circulation from the pump to the head via CF-RV-1 to the tanks and return. When the fuelling machine is on the reactor, the relief valve in the primary circuit (PRH-SV1) will protect the fuelling machine as well as the primary circuit against an overpressure.

An instrument line connected to CF-L17, the head side of CF-MV-HVV, transmits the prevailing system pressure to a differential pressure switch referenced to the surge tank pressure. This switch, RMLP/RMHP, (reactor to machine low/high differential pressure) will sense the ascending head and system pressure during pressurization, shutting down CF-P-7 and de-energizing the control valves when a pressure balance between the head and the reactor has been achieved. The RMPL/RMHP switch keeps the fuelling machine head at a pressure between 10 and 40 psi (68947.57 and 275790.28 N/m^2) greater than the surge tank pressure. This switch controls the fuelling machine pressure prior to plug removal and after plug replacement during the pre-cool operation.

A leak test is performed for 90 seconds after the head is pressurized before removing the plug to test the fuelling machine for excessive leaks. This is performed by monitoring RMLP for 90 seconds after the pressurizing pump has been turned off. If RMLP does not drop out, the next operation is brought in. If RMLP does drop out, denoting a leak, the sequence is stopped and operator action is required.

Depressurize Head (Blow-off) and Leak Tests

Upon completion of the fuelling operation after the end fitting plug has been replaced, the head is depressurized and cooled. The head is depressurized by opening valves CF-MV-HVV and CF-MV-OTVV.

When blow-off is selected, temperature detector HCT is looked at by the control system. If the switch is still on, the head temperature is above 180 ^{0} F (355.37 ^{0} K) and rapid cooling is maintained until HCT drops out.

As soon as HCT drops out, HVV and OTVV are opened to release the pressure from the head. D_2O is returned to the overflow tank through HVV, the tank being vented through OTVV. The pressure in the head should drop rapidly and should be less than 15 pisg (103421.355 N/m^2(g)) in less than four seconds. This pressure drop is checked by the pressure switch BHP, the contacts of which are set to open at 15 psig (103421.355 N/m^2 (g)) pressure falling. If this switch does not drop out within four seconds, it indicates a gross leak from the end fitting plug and the control system selects another operation to repressurize the head.

Blow-off is considered to be completed when BLP drops out. This pressure is set so that the contacts open when the head pressure is below 5 psig, (34473.385 N/m^2(g)) pressure falling.

A leak test is then performed by closing HVV and OTVV. If BLP is not actuated within 90 seconds, the leak test is considered satisfactory and the next operation is brought in. At the same time, if HJLTP has dropped out, ie. HJT is below 80 ^{0} F (299.81 ^{0}K),the low (off) cooling mode is selected, LCV energized, and HCV de-energized.

If during this leak test BLP is actuated, indicating a pressure rise above 5 psig (34473.785 N/m^2 (g)), then an operation is brought in to pressurize the head until RMHPD comes in at surge tank pressure plus 40 psi (275790.28N/m^2). Operator action is necessary to cure any leak.

Head Level Conditions, Detection and Correction

Head level is detected by two level detectors located in a housing on the side of the magazine housing. The output signals of the detectors are amplified by resistance sensitive relays which provide the output for the control system.

There are four occasions during fuelling machine operations when the head level is adjusted:

(a) Head water level is lowered at the new fuel port before accepting fuel to prevent spillage when the fuel bundles are inserted in the magazine.

(b) Head water level is raised when the machine is at the spent fuel port to ensure the irradiated fuel bundles are not uncovered by the drop in level caused by removing the fuel bundles.

(c) Head water level is lowered, prior to traversing, to a point where the fuel bundles are just covered but the level is not high enough to spill from the snout during any motions of the head. This includes lowering the water level from a head full condition before unlocking from a reactor end fitting.

(d) Head water level is raised or lowered whenever either detector changes its state from its last selected position. This is performed by the Permanent List of the Control System.

To reach the head down height level, which is approximately 3 to 3 1/2 inches below the snout, the water level is lowered until the detector HDHD just drops out. Head fill is then selected, by the next operation, and the head level is raised until HDHD just comes in at which time all valves are de-energized and the pump turned off.

However, to reach the head up height level, approximately 3/4 to 1 - 1/4 inches below the snout, the water level is raised until HUHD just comes in at which time head level is lowered until HUHD just drops out. All valves are then de-energized.

Water level is lowered by energizing CF-MV-OTVV, CF-MV-HVV and CF-MV-RHUV. The discharge pressure of the head cooling loop circulating pump forces the D_2O through RHUV into the reservoir. The reservoir and head are vented through OTV and HVV respectively.

The water level is raised by operating the head fill pump CF-P-8. The control valve CF-MV-HID is energized to allow the D_2O from the pump to enter the head cooling circuit. The head is again vented through CF-MV-HVV and the reservoir through CF-MV-OTVV.

System Drains

A manual valve CF-V-58 is connected into the inlet side of the heat exchanger. This valve is located on the D_2O valve panel at the lowest point on the carriage and is used to drain the D_2O from the carriage when required.

A drain valve CF-V-42 is fitted at the bottom of the magazine housing to permit the magazine to be drained for maintenance.

Remote Drainage of D_2O Reservoir

NOTE System to be used only after the head has been depressurized.

When the head has been depressurized, the cabinet door of the Reservoir Drain - Valve Control Unit is unlocked. This unit is located in the New Fuel Room. An instrument air line is connected to the coupling of valve CF-V-406. In the normal valve position, air is fed to CF-L-23, maintaining the carriage mounted valve CF-MV-80 in the closed position.

The valve handle of CF-V-406 is lifted to effect the opening of CF-MV-80, and handswitch RDH (Reservoir Drain) is depressed, thus energizing the carriage mounted valve CF-MV-RDV in the open position, to expose the carriage D_2O system to the drain system via CF-L-33.

The handswitch APH (Air Pressurize) is depressed to energize the pilot solenoid valve CF-MV-APV, which causes CF-MV-72 to open and allow instrument air to pressurize the D_2O circuitry on the carriage, thereby forcing out the water in the system through CF-L-33.

These three valves are energized until the system is sufficiently drained.

Leak Collection and Detection (See Figure 2)

Two leak collection and detection systems are fitted to the head, one to collect heavy water leaking from the snout and the other to collect heavy water leaking through the input drive mechanical seals.

Snout Leak Collection and Detection

Heavy water leaking from the snout is collected in a vessel located under the snout. Two level probes, CF-MLUD and CF-MLDD, signal vessel full, and vessel empty.

When the vessel is full, as indicated by MLUD coming in, a solenoid operated shut-off valve CF-MV-MLP, is energized to direct a flow of instrument air to a siphon for approximately 5 seconds. The air flow starts the siphon which drains the vessel. The difference in levels between MLDD and MLUD is equivalent to 10 cm^3 so that by monitoring the frequency of operation of MLDD and MLUD, the leak rate from the snout can be estimated.

Input Drive Seal Leak Collection

Any heavy water which leaks by the input drive seals, is collected in a vessel located just behind the circulating pump on the head.

When the level of D_2O reaches the level probe CF-SSLD in the vessel, a siphon drain is initiated by energizing the solenoid operated control valve CF-MV-LVP. An "empty drain vessel" operation is initiated each time before the head leaves the vault. If the vessel should fill up when the head is out of the vault, with the gate closed, SSLD will indicate on the control console and the operator will have to manually initiate draining so that the D_2O can be dumped into a suitable container.

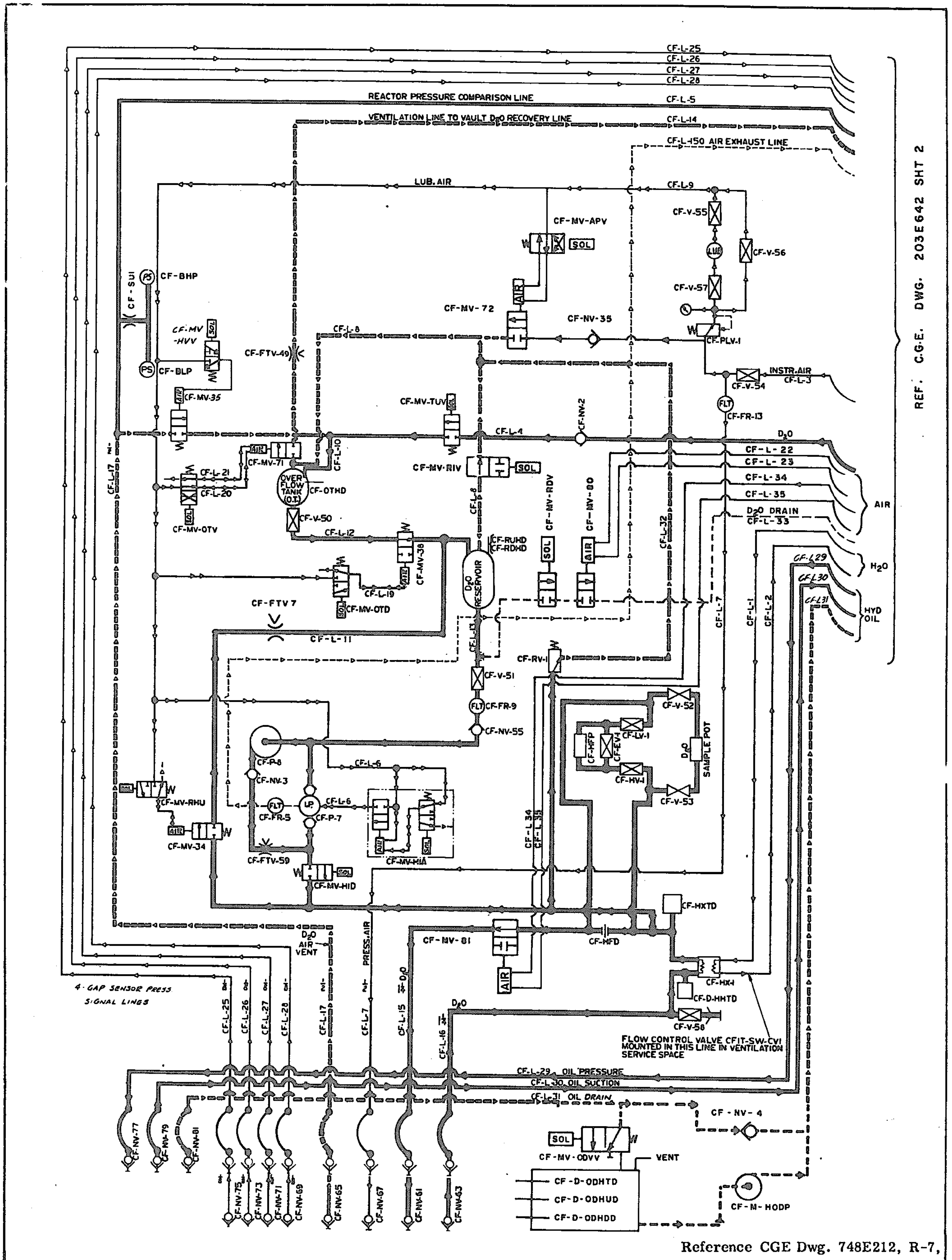


Figure 1 D_2O Systems on Carriage

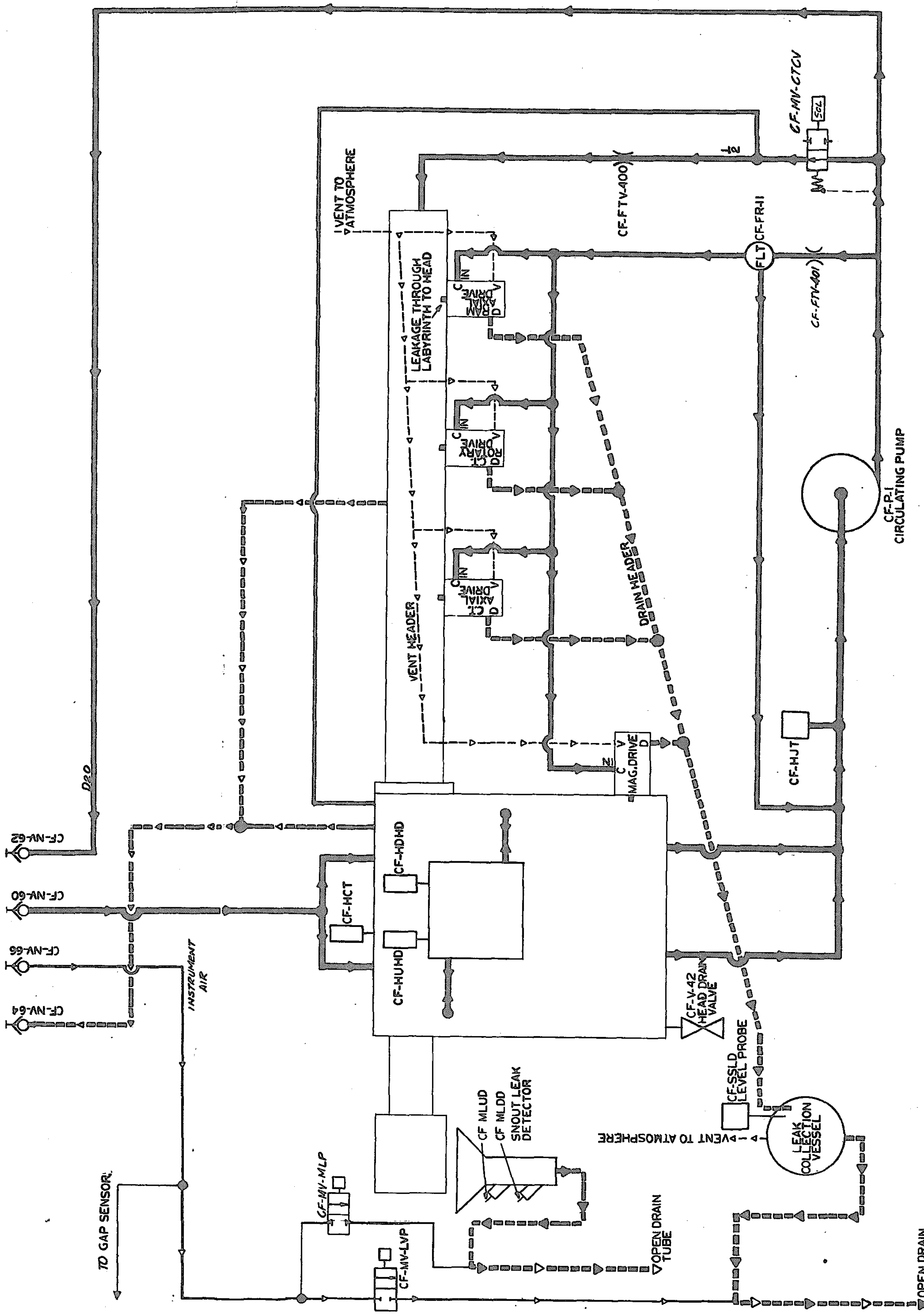


Figure 2 D_2O Systems in Head

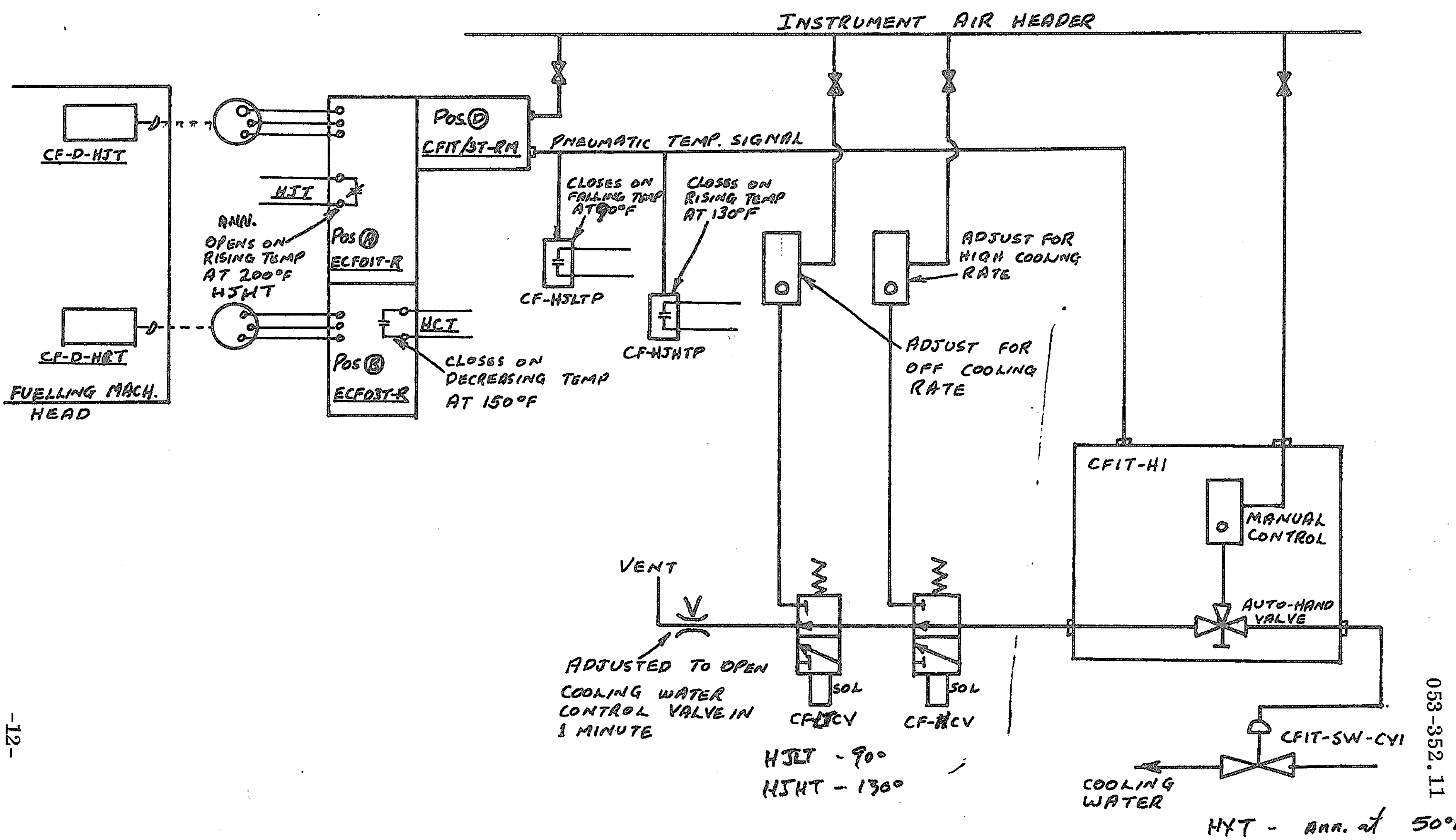


Figure 3 Head Temperature Detection and Cooling Controls

APPENDIX

HJT(CFIT-D)	An R.T.D. probe located in the pump suction line downstream of the head.
HCT(CF3T-D)	An R.T.D. probe located on the front upper portion of the magazine housing. The probe pentrates the magazine thermal barrier and senses the actual temperature of D_2O that is in intimate contact with the magazine chamber.
CF-HXTD	A capillary temperature bulb located on the outside of the D_2O line leaving the heat exchanger.
CF-HHTD	A capillary temperature bulb located on the outside of the D_2O line entering the heat exchanger,
CF-HFD	An orifice section located in return D_2O line from the heat exchanger to the F/M Head.
CF-MV-CTCV	An Aktomatic normally-open valve designed for pressure systems up to 1500 psig (10 342 135.5 $N/m_2(g)$). It is located on the left hand side of the F/M head just to the rear of the flat head.
CFIT-SW-CVI	A normally-open two inch, Fisher Governor globe valve with a pneumatic operator. It is located in the Ventilation Service Space in the H_2O supply line to the heat exchanger.

5 - Station Systems

3 - Reactor, Boiler and Auxiliaries

352 - Fuel Handling System

.12 - Control System

This lesson describes the function and operation of the fuelling machine control system. It is not intended to discuss the control of any system, such as the new fuel port or manipulator which are not covered by these lessons. The lesson consists of a general description of the system followed by a detailed description of a set of sequences covering a complete fuelling operation.

GENERAL

Two identical and complete control systems are provided, one for the East fuelling machine and one for the West. There is no communication between the two systems, except when plugs are being removed and replaced, and when fuel is being moved. Each system operates independently under the control of the operator.

Interconnections between the control system components and the mechanical equipment are shown in the Block Diagram, Figure 1.

All signals to and from the machine go first to the control console. In addition to containing all the system main controls and indicators, the console also acts as the "clearing house" for all control signals. It will be noted that a small portable control panel is provided. This portable control panel can be placed in any one of several positions near the fuelling machines for operation control during maintenance.

The control room operator has a choice of four modes of control; automatic, interrupted automatic (single step), manual operation with interlocks or manual operation without interlocks. A logging printer keeps the operator continuously advised of both machine and control status, when on automatic or single step.

An interface converts the input signals to a form compatible with the computer and converts the computer output signals so that they can drive the necessary relays.

A magnetic tape storage system (DEC tape) contains additional programs and control data on magnetic tapes which are called up as required. The programs can be modified through the communication Teletype.

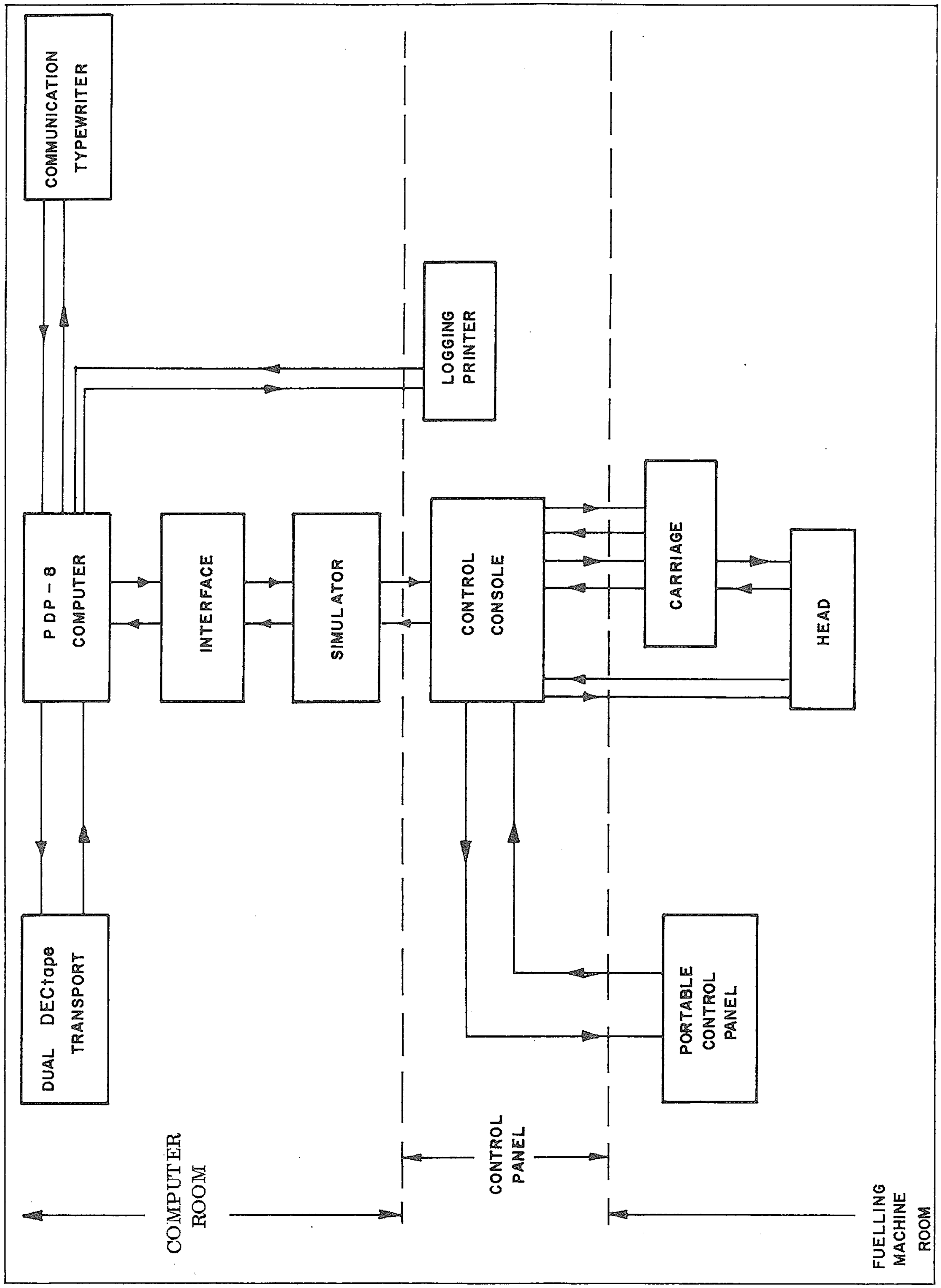


Figure 1 Control System - Block Diagram

OPERATOR CONTROLS

These controls are shown in Figure 2 , and consist of two opposite handed assemblies, one for each machine. Each assembly contains;

-an automatic operations control panel,
-a manipulator control panel,
-a logging printer,
-manual operation and detector indication panels,
-a subpanel of interlock override switches.

A small portable control station enables operations to be controlled from locations adjacent to the machine. This permits "stop","operate" and "jog" functions to be initiated locally. The motion to be controlled is selected from the main control panel, communication between the operator at the portable control panel and the control room being by telephone.

Normal Operation of the system is performed at the sloping control panel. This accepts and provides the following:

(a) The choice of operating mode (auto sequence, auto operation, single step etc.) sequence (traverse, move fuel etc.), and the location (lattice, home, new fuel etc.), all selected by pushbuttons.

(b) The current sequence number, current step number and current operation number displayed continuously by digital readouts.

(c) Ram, charge tube axial, charge tube rotary or magazine rotary position in tenths of an inch or degrees, as applicable, continuously displayed on a digital readout. Pushbuttons adjacent to the readout permit the current moving component or any selected component to be displayed as required.

(d) Numerical data selection, such as the sequence number, operation number or re-enter step number, selected by rotating thumbwheels and by depressing various insert and selector pushbuttons. These controls enable a sequence or operation to be entered at any selected point, for maintenance or in the event of a breakdown.

Pushbutton switches on the vertical panels enable abnormal conditions to be corrected or maintenance operations to be performed. Indicator lights, adjacent to the switches, show the operator the status of any particular system or detector at a glance. The control panel switches also allow selection of X and Y lattice positions, fuelling machine magazine position, adapter position etc. Indicator lights indicate if the control system has accepted the order and also indicate when the selected position has been reached or function accomplished.

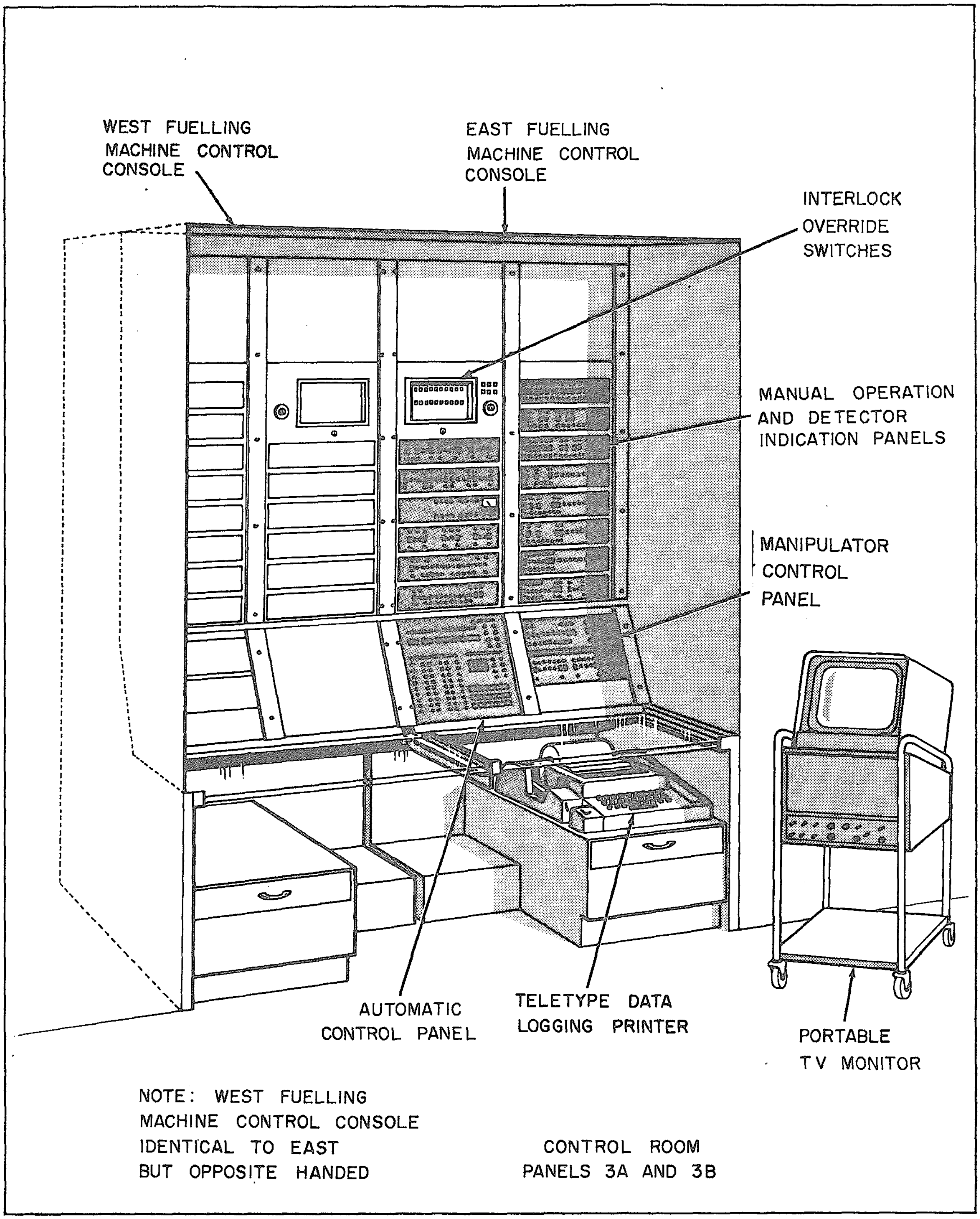


Figure 2 Fuelling Machine Control Console

AUTOMATIC OPERATIONS

Normal operation of the system is carried out from this control panel, which is divided into the following sections:

1. Mode Select - On this section, the operator selects the operating mode by depressing one of the following illuminated momentary contact pushbuttons.

   1. ASQMH - (Auto Sequence Mode, for future use).

   2. AOMH - (Auto Operation Mode) - When selected in this mode, the control system will process a sequence of operations automatically to completion, with operator action required only at start.

   3. SSMH - (Single Step Mode) - When selected to this mode, the control system will process a sequence to completion, one step at a time, with operator action required to restart after completion of each step.

   4. SMH - (Special Mode) - When selected in this mode, the control system will accept DATA INPUT from the thumbwheels and pushbuttons on the Data Input section of the panel and will carry out operations one operation at a time. (Some steps consist of carrying out several operations such as seal release and gate open motion).

   5. MMH - (Monitor Mode) - This is the mode that the control system will revert to on completion of any sequence. When in this mode, the control system monitors certain system sensors, annunciates and/or takes corrective action as required.

2. Sequence Select - The operator selects the sequence to be carried out by pressing one of the following handswitches:

   TRKH - (Traverse) - When selected, the control system will prepare to transfer the appropriate traverse sequence select program from tape into core for processing.

   Similarly, the control system will prepare for transfer of the appropriate sequence select program when one of the following handswitches is pressed:

POKH	-	Plug Out Sequence
PIKH	-	Plug In Sequence
MFKH	-	Move Fuel (Eject or Accept) Sequence
MPKH	-	Manipulator Sequence
LNFKH	-	Load New Fuel Sequence

3. Location Select - Pressing the appropriate handswitch in this section is required for the control system to transfer the required sequence from tape storage into core for processing. This action identifies where the machine is traversing to. The locations that can be selected are:

HMKH	-	Home. When at the Home position, the location indicator light (HMN) will be on.
NFKH	-	New Fuel and NFN
LTKH	-	Reactor Lattice and LTN
SFØ1KH	-	Spent Fuel Port Ø1 and SFØ1N
SFØ2KH	-	Spent Fuel Port Ø2 and SFØ2N
MNKH	-	Manipulator and MNN

4. Data Input - When the control system is selected to SM (Special Mode), the operator can insert sequences, steps and operations from this panel.

   In addition to the four thumbwheel selector switches, operation of the following handswitches is required:

INSH	-	Insert Sequence handswitch
INOH	-	Insert Operation handswitch
INRH	-	Insert step Re-enter handswitch
INIH	-	Insert handswitch

5. Status Display - As the processor executes an operation with a step of a particular sequence, the display of Sequence #, Step # and Operation # is continuous. In the case of the shaft encoder readout, a display of the encoder reading in engineering units is given.

   Five selector switches allow the operator to select a particular shaft encoder:

DMPH	-	Display Magazine Position Handswitch
DAPH	-	Display Charge Tube Rotary Position Handswitch
DCPH	-	Display Charge Tube Axial Position Handswitch
DRPH	-	Display Ram Position Handswitch
DCOH	-	Display current operation handswitch

6. Control Location Section - This is the section of the control system which indicates to the operator the current status of the control system, whether it is operating or stopped, whether the control is from the portable panel or control room, etc. This section contains only illuminated handswitches or colored window indicators. Their identification and purpose are as follows:

   OPH - Illuminated white window handswitch with the word OPERATE inscribed. When this window is on, the control system is operating. In order to start any operations from this console, this handswitch must be pressed.

   POCN - Permanent Operation Current (indication only) indicates that the current operation has been temporarily suspended and a "Permanent Op" has been loaded for processing. This "Op" could be head water level correction.

NWN - Normal Watchdog (indication only) when illuminated (green) indicates that the control system hardware timer used to check the fuel handling program, is operating properly. In the event that the fuel handling program has not carried out the instruction to re-set this timer, the operation will be stopped when the "watchdog" times out, indicating that a program fault has occurred.

ADWN - Auto Disconnect Watchdog (Red). This window comes on as a result of watchdog timing out. This results in a.c. to all drives (except circulating pump) being shut off.

ADDN - Auto Disconnect Diagnostic (Red). When this window comes on, it indicates that the output interface is not functioning correctly. This would be caused by faulty modules and/or power supplies within the interface.

JOGH - Jog Handswitch. Allows jog control of motions which will be maintained only while JOGH is depressed; as soon as it is released the motion will stop. Operations are processed through the computer and are protected by the interlock system.

OKH - This is a pushbutton indicator light to indicate that operator confirmation is required. For example, during manipulator operation, the operation will come to a point where the OK? light will come on, at which time the operator will confirm that operations may proceed by pressing OKH.

PDN - Processor Delay - This window is turned on whenever the processor is causing a delay in operating (e.g. when going out to tape to transfer an OP or Sequence into core).

PEN - Processor Error - This window is turned on when the control system has identified errors such as not having the same tube permissive when selecting a move fuel sequence. A table of Processor Errors, description and action required is given in Section 352.0.5.2 of the Operating Manual.

ION - Interlock Override - This window is turned on when any of the interlock override switches are operated. This action automatically disconnects the AC auto power supply, except STPKH - refer to "Operation of Controls" on page 9.

STPH - STOP Handswitch - Depressing this handswitch stops all automatic and manual operations, except the following: In automatic mode, the D_2O circulating pump, head oil pump, elevator oil pump and new fuel port pump are not switched off and the brakes on all head drives are applied. In manual mode, only the D_2O circulating pump remains running.

CH - CONTROL ROOM Handswitch is used to transfer control back to the control room. Portable OK is depressed and held while CH is depressed. This action isolates the portable station. Illuminated when control is at the control room.

PH - PORTABLE Handswitch - is used to transfer control from control room console to portable station. Depressing PH de-energizes the control console handswitch and energizes the portable station. Illuminated when control is at the portable station.

NT1H and NT2H - LAMP TEST - depressing either of these handswitches energizes a number of relays which connect the console indicator lamps directly to - 24 V D.C. power supply for lamp testing.

PMSTPH - PERMANENT STOP PUSHBUTTON. This is illuminated when a "permanent stop" exists. Annunciation will also occur on unit 3105 (West), 3107 (East). Refer to Section 352.0.5.1. of the OM for the procedure to clear this condition.

OPERATION FROM PORTABLE CONTROL STATION

The system can be controlled from the Portable Control Station under the supervision of the automatic control panel operator. The four control handswitches on the portable control station function in a similar manner to those on the automatic control panel and the same start-up procedures must be performed before the system can be operated.

POPH - Operate Handswitch. Equivalent to OPH on the control console. When pressed, will start the function selected at the control console.

PJOGH - Jog Handswitch. Allows jog control of machine motions. Motion will be maintained only while PJOGH is pressed and will stop as soon as it is released. The motion required must be selected at the control console.

PHOKH - This blue illuminated handswitch has two functions. If control is at the portable control station,it must be pressed in conjunction with CH on the control console to transfer control back to the control console. If the handswitch is on, indicating that operator confirmation of a system function is required, this switch can be pressed to give this confirmation. If the system accepts the confirmation, the light goes off.

PSTPH - This red handswitch will stop the system whether control is at the console or at the portable control station. If used, control must be transferred to the portable control station before the system can be restarted.

PHN - A white indicator light which is on when control is at the portable control station.

Operation of Controls Including Portable Control Station

The Fuelling Machine System cannot normally be operated without the portable control station connected to the system.

Control of the JOG, OP and STP functions can be made at either the control console or the portable control station depending upon where the control is placed. Control can only be transferred to the portable control station by the operator at the control console and can only be transferred back by combined action of both operators. See Figure 3.

The stop buttons at both the control console and the portable control station will stop the system regardless of where control is at that time. If the stop button at the console is pushed with control at the portable control station, control must be transferred to the console by the portable control station operator before the system can be restarted. In the same way, if the stop button at the portable control station is pushed with control at the console, the console operator must transfer control to the portable control station operator for system restart.

Control can always be regained by the console operator by placing the override switch, STPKH to ON. This overrides any previous selection and permits normal operation.

On system start-up, control is always at the console and the portable control station should be connected into the system prior to start-up to complete the circuitry. If the portable control station becomes disconnected or the cable is damaged, the system will stop.

In brief, the system operates as follows. See Figure 3.

Stop on Portable Control Station during Operation from Console

If the STP pushbutton at the portable control station is operated when control is at the console, all systems stop. (STP3X and STP1X drop out). The OP and JOG controls are cut out at both stations. Control can only be regained by transferring control to the portable control station. This picks up STP3X but STP1X remains out.

Operation from Portable Control Station

On system start-up, control is always at the console. If control transfer is required, either because STP on the portable control station is operated or for operational reasons, PH at the control console must be operated. This brings in PHX through the computer which turns on indicator PN on the simulator, PH on the console and PHN on the portable control station. Power is then on the OP and JOG controls at the portable control station. Refer to page 8 for a description of control functions.

Stop on Console during Operation from the Portable Control Station

If the STP control is operated at the console when control is at the portable control station, all systems' stop (STP2X drops out). The OP and JOG controls are cut out at both station and control must be transferred back to the console before control can be regained.

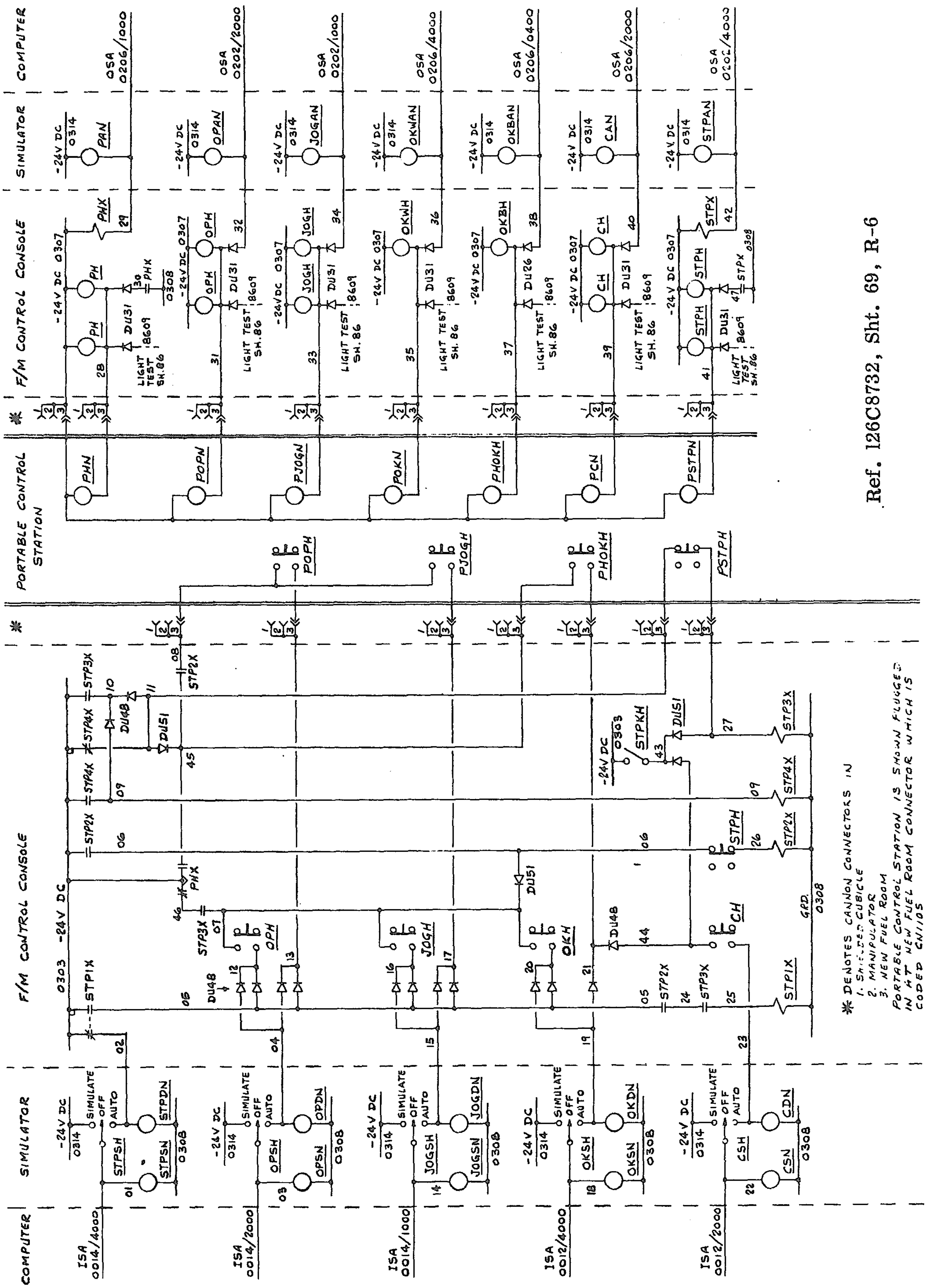
Transfer Control back to the Console

To transfer control back to the console, both the illuminated OK pushbutton on the portable control station and CH at the control console must be operated simultaneously. This drops out PHX through computer control, which resets the OP and JOG controls at the console and cuts out the OP and JOG controls at the portable control station.

Moving the Portable Control Station

If the portable control station is disconnected from its receptacle when control is at the console or at the portable control station and the system is operating, the system will stop. When the portable control station is reconnected, control will always be at the control console and must be transferred if required.

The system can be operated from the console with the portable control station disconnected, if required, by operating the override switch STPKH to ON.



Ref. 126C8732, Sht. 69, R-6

Figure 3 Portable Control Station Elementary Diagram

CONTROL SYSTEM EQUIPMENT

The equipment shown at rear of the control room in Figure 1 is housed in a four-cabinet assembly for each machine. See Figure 4. A separate communciation Teletype is provided for each system.

Computer

The PDP-8 used for fuel handling operations is a high-speed, stored-program digital computer with a 12-bit word length. It has two 4096-word, random-access, magnetic core memories one designated as field 0 and the other as field 1. Cycle time is 1.5 microseconds. Power failure hardware (Automatic Restart Type KR01) is part of the PDP-8 computer and senses a drop in the processor logic dc voltage caused by ac frequency or voltage fluctuations beyond defined limits or by power supply failure. If a drop in dc voltage is sensed, the computer stores the important registers and prepares the program for a restart on restoration of power. It will then halt the program, the whole process taking 1 millisecond.

The power supplies for the DECtape system, the Teletypes and the Digital Input/Output Multipl exer are also monitored to ensure that any power supply failure is noticed and to prevent automatic re-start until all power supplies are up to voltage.

Digital Input/Output Multiplexer (Interface)

The basic PDP-8 computer is not capable of direct inclusion in a control system without the addition of external hardware to enable the computer to sense and control the machine.

The digital input/output multiplexer or interface performs this function. It consists of three major circuit groups, a strobe generator, input gates and output drivers. It permits the operation of 360 digital outputs each capable of driving 200 milliampere of lamp load and sensing the state of 504 digital inputs. Of these 504 digital inputs, input filters are available for 432 and of these, 384 are provided with input switches on the simulator panel. Sixty independent output drivers are available. This circuitry is contained in 11 mounting panels housed in the cabinet adjacent to the computer.

Simulator

An integral part of the interface circuitry, but mounted in panels in a cabinet to the right of the interface panels, is the simulator. The simulator contains a three-position switch and two lights for every input, and an indicating light for every output. The three positions of the switches are marked AUTO, OFF and SIMULATE. With the switch in the AUTO position, both input lights are on when the detector on the fuelling machine is actuated. That is to say, the detector input is direct into the interface.

Only one input light is turned on when the switch is moved to SIMULATE showing that a signal, simulating detector operation, has been supplied to the computer for test purposes.

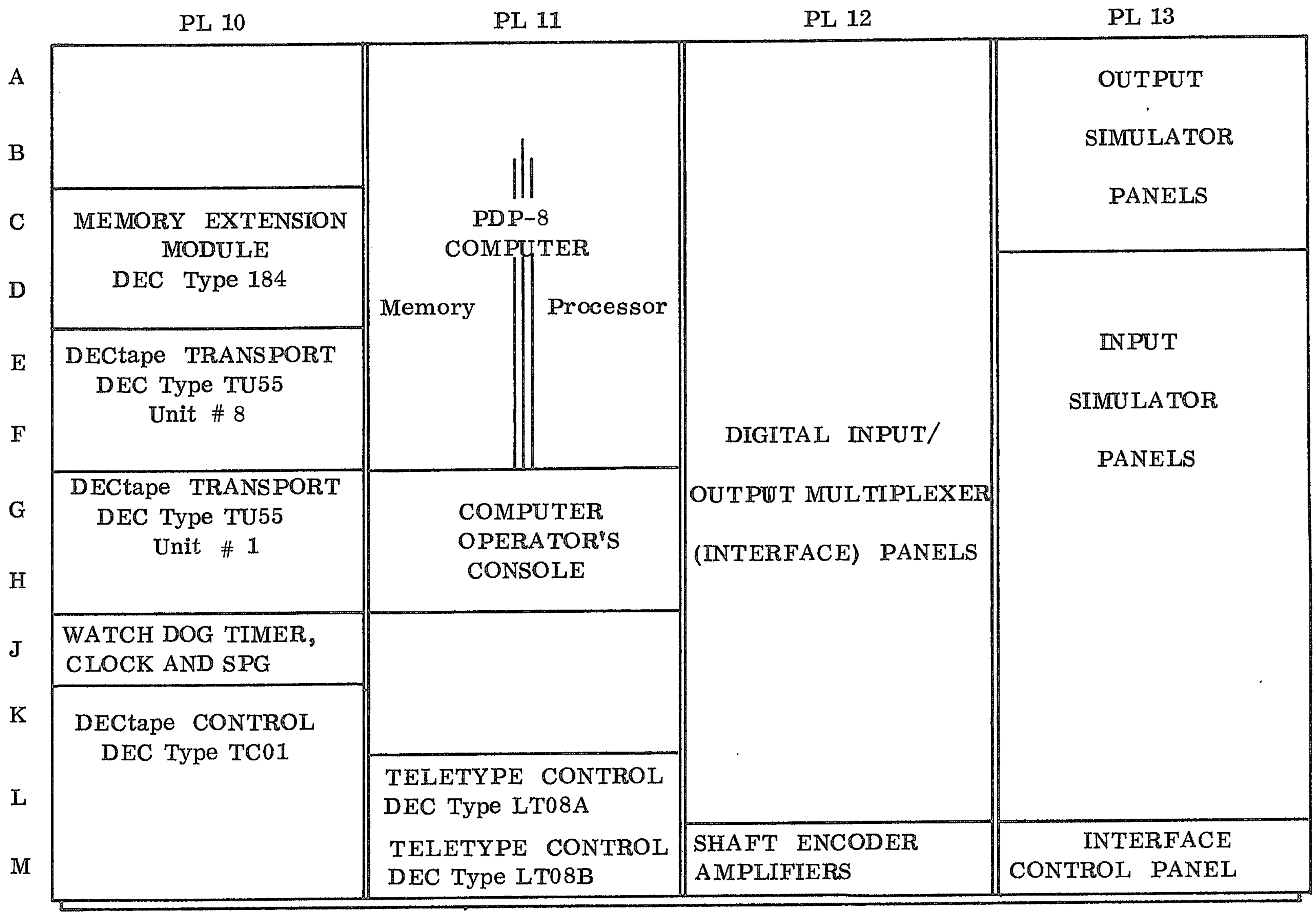


Figure 4 Control System Equipment Location

Interface Control Panel

This panel is located below the simulator panels and provides a controlled 6.3 volt signal for the Sample Pulse Generator and the Hardware Clock and provides an indication that the signal is available. It also provides an indication of the status of the Sample Pulse Generator, the - 24 volt supplies, the Watchdog Timer and the charge tube axial permissive signal. It also houses the two - 24 volt control relays FX and LX.

DECtape System Transports and Control

Two type TU55 DECtape Transports are provided with each system. The magnetic tapes each provide 190,146 words of storage. One unit, No. 8, contains the programs while the other unit, No. 1 is used to store the operating sequences and operations. Tape movement for data access is normally controlled by commands originating in the computer through the TC01 DECtape Control. However, tape movement can also be controlled by manual operation of rocker switches on the front of each transport.

One DECtape Control - Type TC01, operates both tape transports and is located in a panel below the lower tape transport.

It controls tape motion and assembles and disassembles the 12-bit computer words during transfer between the tape and the computer. Data transfers use the three cycle data break facility of the computer. In writing on the tape, the control disassembles the 12-bit words so that they are written at four consecutive lines on tape. Data read from four consecutive lines of tape are assembled into 12-bit words by the control for transfer to the computer. The 12-bit words are transferred between the control and the computer in parallel.

Teletype and Control - Model 33ASR

Two standard Teletypes Model 33 ASR (automatic send-receive) are used in each control system. One, for communication directly with the processor, is located adjacent to the computer. The other functions as a logging printer and is mounted below the glass desk top at the control console. Both machines have the usual keyboard and printing mechanisms and tape punch and tape reader mechanism. The logging printer communication with the computer is limited to a signal to the processor requesting real time printout using FHTASK with the modified log program.

The Teletype machines can type in or print out information at a rate of up to ten characters per second or to read in or punch out perforated paper tape at the same rate.

The PDP-8 processor is provided with input and output registers for one Teletype machine. These registers are used as buffers between the processor logic which processes information in 12-bit words in parallel and the Teletype machine which processes information serially, 8 bits at a time.

This Teletype system makes provision for the addition of up to five more Teletype machines to the processor using control unit LT08A as the common control unit. LT08B is a line unit, of which one is required for each additional Teletype up to five. One is used in this system and is located in control unit LT08A.

An additional G809 module for extending the Automatic Restart option KR01, is installed in this panel to monitor the -15 volt supply.

Sample Pulse Generator

The sample pulse generator is located in a panel directly below the DECtape transports, together with the hardware clock and the watchdog timer. It provides the pulses required by the hardware clock and the watchdog timer and the sample pulse interrupt to the processor.

Hardware Clock (Real Time Clock)

A real time clock, synchronized to 60 cycle hydro frequency, is provided for logging under program control. The operator can set the clock from the communications Teletype at start-up or whenever corrections are necessary.

Watchdog Timer

The watchdog timer is a separate hardware timer used as a check on the software. The watchdog is normally "kicked" every 1/60th of a second to check that the Fuel Handling Program is being performed correctly. If the watchdog is not "kicked" within approximately 1/30th of a second, indicating that a fault has occurred in the program, an indicator light will light up on the control panel and the 110 V a-c auto bus will trip and cut off the power to all drives except the D_2O circulating pump. Operator action is required to restart the system.

Back-up Interlock System

To improve the protection to the fuelling machine and the reactor against physical damage, a back-up protective interlock system with separate circuitry is provided. A typical circuit is shown in Figure 5. This is in addition to the protection provided by the control system. It consists of a conventional relay system and is intended to give back-up protection as follows:

The circuits provided with back-up interlocks are shown in Table 1. The by-pass switches associated with each circuit together with the detectors by-passed are also included:

Circuit	By-pass Switch	Detectors/Relays
Lockring Unlock	LUVKH	BLP
Lockring Forward	LFVKH	BLP
Fine Z Out Drive	FOMKH	FOCD, FZLD
Y-Pawl Up	YPUKH	TCK3X
Coarse Y-Drive Down	YMMKH	EDD, GCD, YMLD, YPUD, YBRC, TCK2X
Coarse Y-Drive Up	YTMKH	EDD, GCD, YTLD, YPUD, TCK1X
Coarse Y Brake	YBRKH	EDD, GCD, YMLD, YPUD, TCK2X
Coarse X-Drive	X12MKH	AND, XKLD, X12LD, TCK1X
Coarse X-Drive	XNMKH	EDD, EUD, XSLD, AND, YTD, X01LD, XNLD, W21/27D, S31/34D, W37D, X02D, TCK1X
Elevator Drive Down	EDMKH	FOCD, FZLD, XKD, GOD, ASD, EBRC, TCK3X
Elevator Drive Up	EUMKH	FOCD, FZLD, YKD, GOD, ASD, TCK2X
Head Vent Valve	HVVKH	POL, HCT
Over Flow Tank Vent Valve	OTVKH	POL, HCT
Manipulator Vertical Up	V01MKH	W01LD, W11D, V01LD, S01LD, W31D
Manipulator Vertical Down	V04MKH	W01LD, W11D, V04LD, V31/34D, S01LD, W21/27D
Manipulator Wall E	W01MKH	V01LD, S01LD, S21/24D, W01LD, W37D, XKD
Manipulator Wall W	W07MKH	V01LD, S01LD, S21/24D, W07LD
Manipulator Slot N	S01MKH	W01LD, W11D, S01LD, V04LD, W21/27D, V01LD
Manipulator Slot S	S04MKH	W01LD, W11D, S04LD, S31/34D, V04LD, W21/27D, V01LD
Gate Closed	GCMKH	SPP, EUD, YTD
Gate Open	GOMKH	SPP, EUD, YTD, SDD, AB-LK8, AB-LK9, AB-LK11

Table 1 System Interlocks

POWER SUPPLIES

There are two types of power supplies for the system, 110 Va-c and -24 V d-c. The 110 V a-c is supplied by Class IV power distribution, except for the power supplying the fuelling machine circulating pump motor which is Class III. The - 24 V d-c is available from two sources, the computer interface power supply and the -24V d-c Battery/Rectifier, which normally supplies the computer interface the control console and all detector circuits.

A.C. Power Supply

The a-c power supply is controlled by two switches on the console, adjacent to the interlock override switches, ACAH for the automatic bus and ACMH for the manual bus. Both switches control the common bus. The power for these two switches is supplied through contacts of relay DCCC, which means that the d-c common bus must be energized, (DCCH on), before the a-c buses can be energized.

Switch ACAH energizes two relays ACA3C and ACA1C. Two contacts of ACA1C together with contacts of ADD1X, ADWX, DCAC, STP1X and IOX act as permissives for relay ACA2C. Relay ACA2C controls the power to the 110 V a-c automatic bus and to the 110 V a-c common bus. This relay, together with ADD1X, ADWX, DCAC, STP1X and IOX form a control circuit which stops all system operations in the event of a computer stop, a manual stop at the console or the operation of any interlock override switch.

Relay ADD1X (Automatic Disconnect Diagnostic) is energized while the Watchdog Timer is being "kicked". However if the Watchdog Timer is not kicked every 1/60th second, relay ADD1X is de-energized so that relay ACAC2 is dropped out disconnecting power from the 110 V a-c common and auto buses.

Relay ADD2X is normally de-energized with its normally closed contacts forming a permissive for relay ADD1X. Five unused output drivers are connected to relay ADD2X. If a defect occurs which could cause any of the system output drivers to turn on spuriously, one or more of the five drivers connected to ADD2X may be turned on. This will de-energize ADD1X which in turn will remove automatic 110 V a-c power from all fuelling machine drives except the circulating pump. This could occur if + 10 V d-c logic power to the output drivers is lost.

Relay ACA3C, also controlled by switch ACAH, controls power to the motor control circuits, the logging Teleprinter and paper winder, the floodlight control circuits and the X and Y drive relay contacts for the ultrasonic leak detector signal conditioning unit.

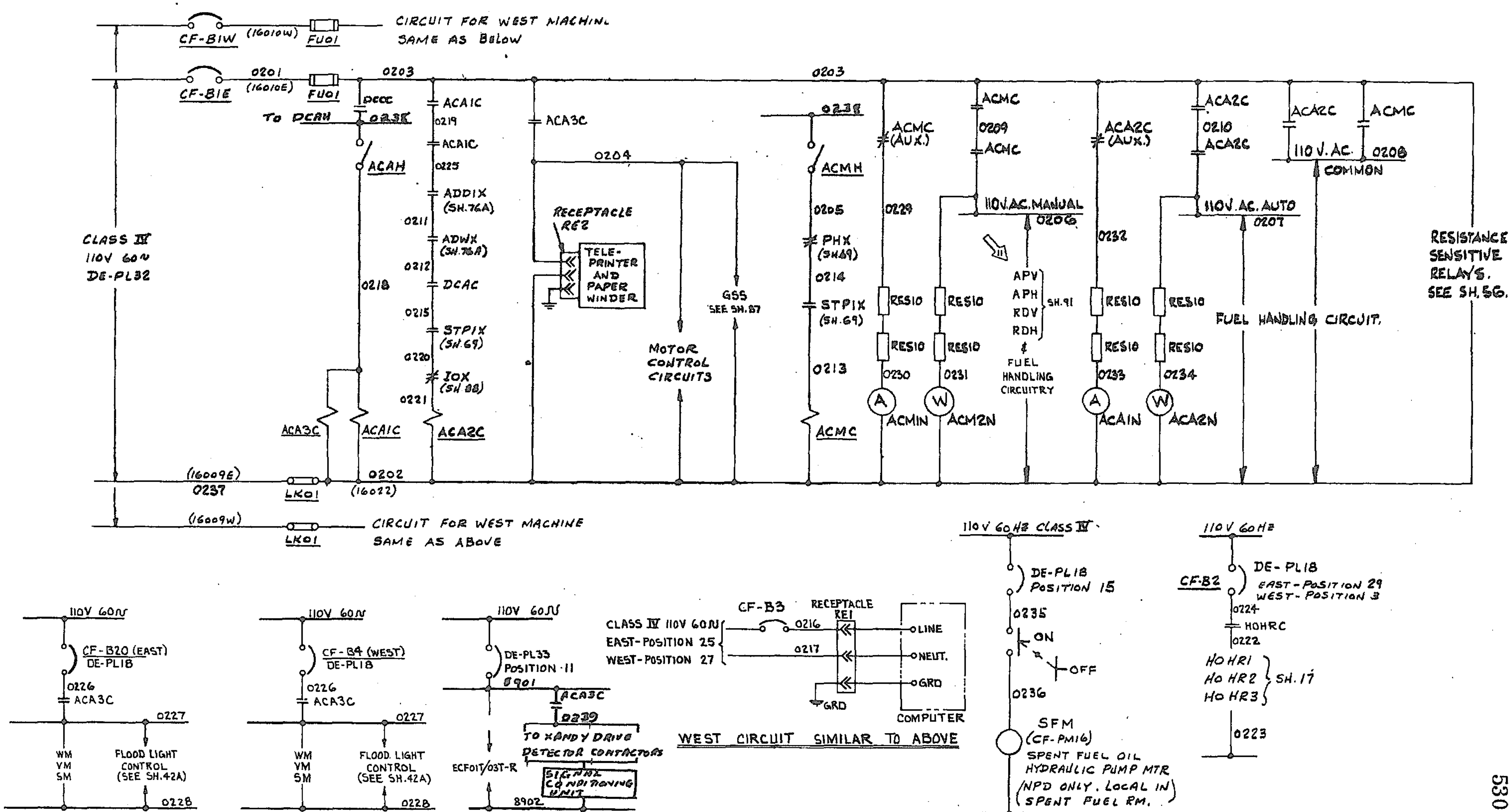


Figure 6 AC Power Supplies - Elementary Diagram (Ref. 126C8732, Sht.2, R-12)

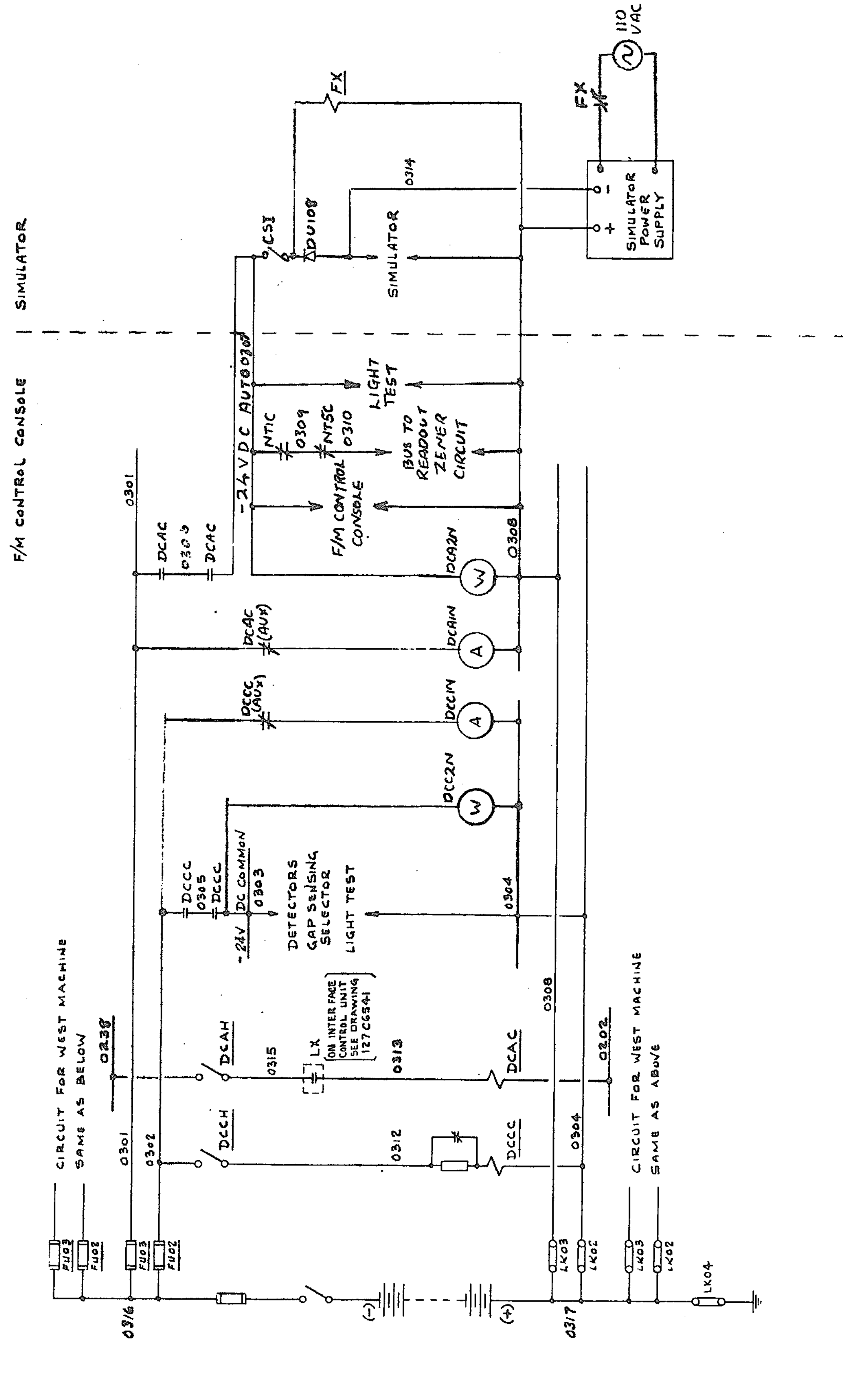


Figure 7 DC Power Supplies - Elementary Diagram (Ref. 126C8732, Sht. 3, R-10)

Switch ACMH controls relay ACMC and is a key operated switch. This relay energizes the 110 V a-c manual bus which enables manual control of the fuelling machine system drives through the MAN position of the control switches on the control console. The 110 V a-c common bus is also energized by this relay.

D.C. Power Supply

Two switches control the d-c power to the system, DCCH controlling the - 24 V d-c common bus and DCAH the - 24 V d-c automatic bus. See Figure 7.

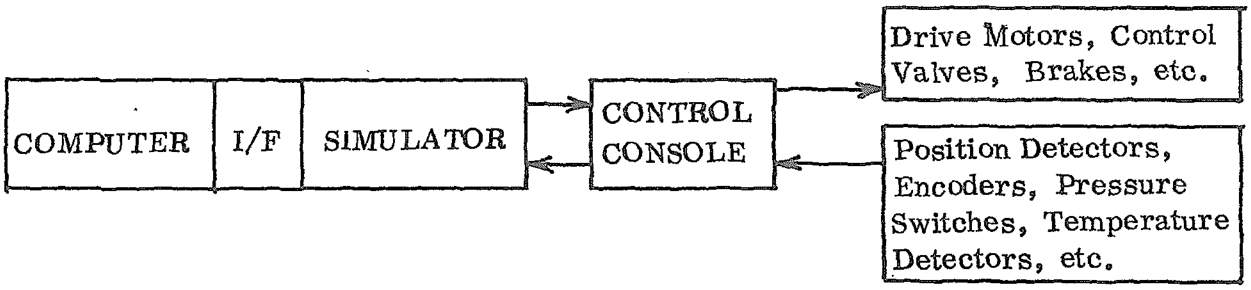
Switch DCCH energizes relay DCCC from the - 24 V d-c power supply. A resistor in series with the contactor coil limits the holding current through the coil to prevent overheating. With this relay energized, - 24 V d-c power is supplied through two sets of N.O. contacts in series to power the - 24 V d-c common bus. Services powered from this bus include the fuelling machine detectors, gap sensing selector and light test circuits. Another N.O. contact on this relay controls the 110V a-c power to switches DCAH, ACAH and ACMH. This means that d-c common bus must be energized before the d-c automatic, a-c automatic, a-c common and a-c manual buses can be energized.

Switch DCAH takes power from the 110 V a-c bus, controlled by DCCH, to energize relay DCAC. Two sets of N.O. contacts wired in series in this relay control the power to energize the - 24 V d-c auto bus, while one set of N.O. contacts acts as a permissive in the ACA2C relay circuit. Relay LX prevents relay DCAC being energized, or drops it out, if a power failure occurs in the PL12- 15 V d-c power supply. This prevents improper operation of the memory relays and other output relays on the fuel handling control console. The - 24 V d-c bus supplies power to the fuelling machine control console, the read out circuits and the light test circuits. The - 24 V d-c auto bus, through the console/simulator isolation switch (CSI) also supplies power to the simulator.

Relay FX switches off the simulator power supply when the simulator is being supplied with power from the -24 V d-c auto bus. If the -24 V d-c auto bus fails, or switch CSI is opened, relay FX will be de-energized and the simulator power supply will be turned on. Diode DU108 prevents the simulator power supply from energizing the -24 V d-c automatic bus. Switch CSI also controls the power from the -24 V d-c common bus to the shaft encoder amplifiers. This switch allows the -24 V d-c auto and common bus supplies to the computer and simulator to be shut down for servicing while still maintaining power to the control console.

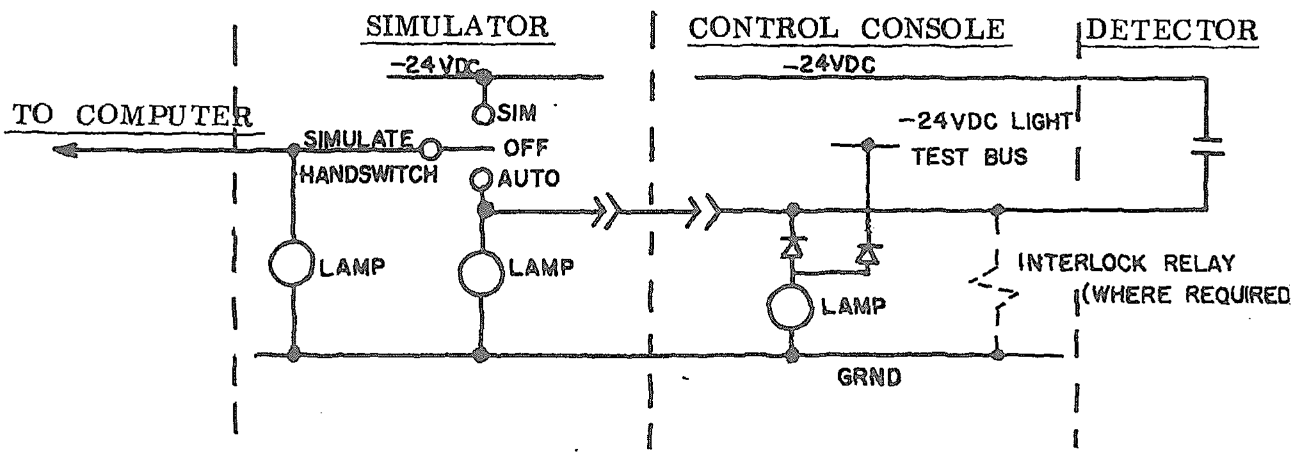
INPUT/OUTPUT CIRCUITS

An understanding of the arrangement of the communication circuitry between the computer/simulator unit and the console, and between the console and the detectors and drives is necessary before system operation can be fully understood.



The fuelling machine console provides both automatic and maintenance (manual) control of the machine drives. All control connections from the detectors , pressure switches, etc. are brought back to the console. Automatic control connections are made from the computer/simulator via the console to the machine drives etc.

Input Circuits

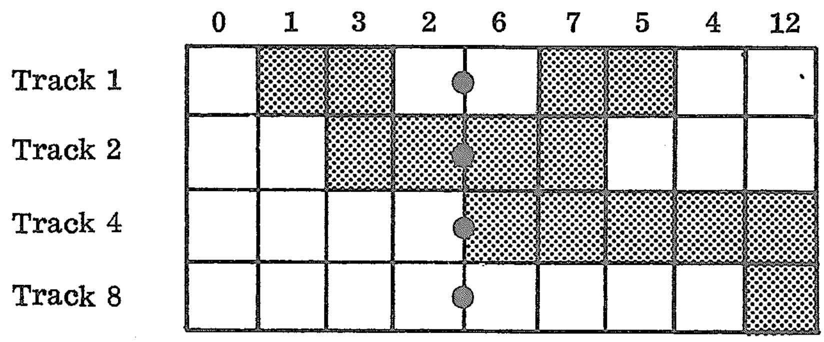


A detector contact is connected via the console to the simulator. The simulator handswitch permits the selection of three states to the input: actual detector status (AUTO), simulated "OFF" status and simulated "ON" status. Indication of the actual detector status is provided both on the simulator and the console by indicator lamps. Indication of simulated input status is provided only on the simulator.

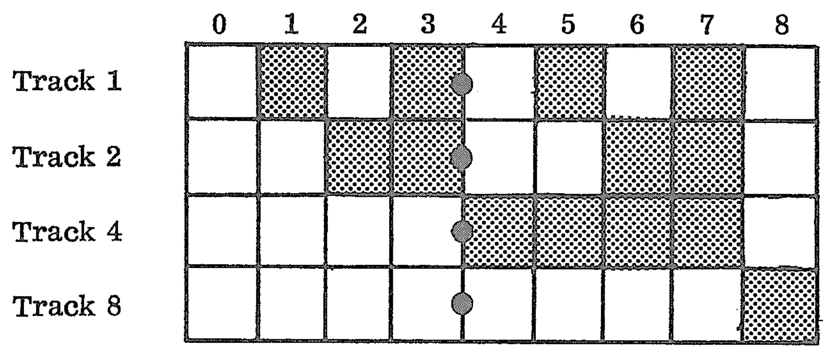
Each detector signal connection between the console and the simulator is allocated to one bit of a 12-bit input word. The input cables between the console and the simulator are 12 conductor cables and each cable is therefore related to an input word.

Shaft Encoders

The input signals from the charge tube rotary and axial, ram motion and magazine rotation are provided by shaft encoders. Shaft encoders are devices which produce a unique code for a given shaft position. The encoders chosen for the NPD fuelling machines are brush type, Gray encoders producing 2^{12} = 4096 discrete codes for a full count and require 16 turns to produce the complete 4096 discrete positions. The code is produced by brushes sliding over discs with concentric tracks coded with conducting and non-conducting segments. These are fed out on lines and into the computer interface. The reason for using Gray code is to prevent ambiguity of the read out.



GRAY



BINARY

In the example , the dots ● represent the brush contacts sliding over the coded discs which are shown expanded linearly rather than on a circular representation, and with the brushes moving in this example so as to increase the count. Due to manufacturing tolerances in the brushes and disc contacts, it is impossible for all the brushes to change from one digit to the next at the same instant. In the binary code, the output could be 3 or 4 or 6 or 5 or 1, depending upon the exact brush position at any instant during the transition across the switching point. However, in the Gray code the transition from 2 to 6 can only produce either a 2 or 6, track 4 being the only track to change.

It is practical to put only a limited number of tracks on a single disc because of the tolerance buildup, brush size etc. Hence, a 2^{12} encoder is made up of two discs geared together with a gear ratio of some power of two between them.

To ensure that the backlash in the gears and any misalignment between the brushes for one disc and the other is kept to a minimum, the low speed disc has two identical disc patterns, lead and lag. At all times, either the lead or lag pattern is energized by a switching track on the high speed disc.

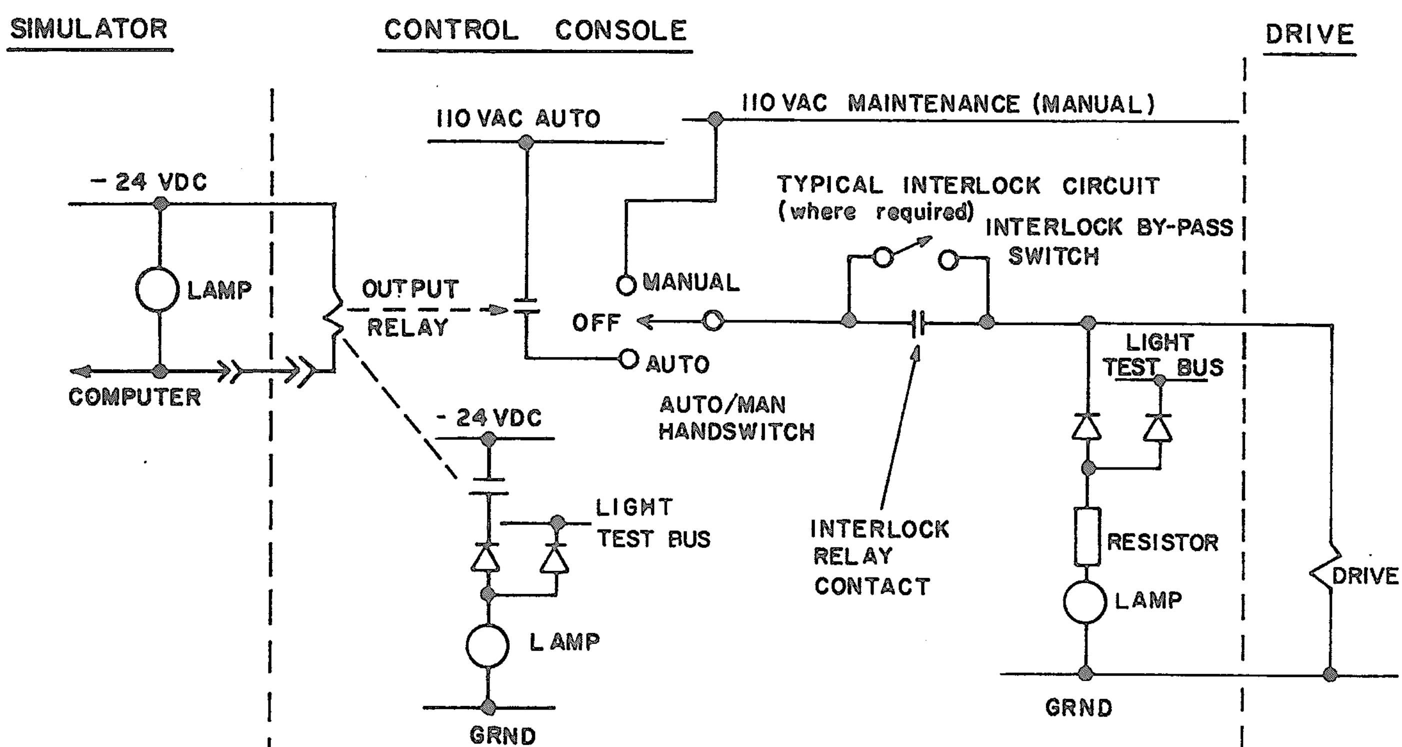
The 12-bit Gray shaft encoders used at NPD have lead and lag outputs for the computer word bits 0 to 4 inclusive and single outputs for the remaining bits. A switching track output is provided and inputs for the lead and lag buses are required.

Shaft encoder amplifiers provide two separate outputs, one for the simulator and computer, and one for the lights on the fuel handling control console.

The Fuel Handling Display Program (FDISP), a sub-program of the Fuel Handling Executive Program (FHEX) provides the engineering units display on the console.

There are a total of 32 input words and each word is allocated an input strobe address (ISA) number.

Output Circuits



An output circuit is connected from the simulator to an interposing output relay in the control console. The relay controls the drive from the 110 V a-c system through a selector handswitch mounted on the console.

The handswitch permits selection of three states to the drive; off, automatic control and manual operations. Indication of output status is provided both on the simulator and on the console. Indication of actual drive status is provided only on the console.

Each output connection between the console and the simulator is allocated to one bit of a 12-bit output word. The output cables between the console and the simulator are 12 conductor cables and each cable is therefore related to an output word.

There are 30 output words. To each word two output strobe address (OSA) numbers are allocated, even OSA numbers control the output "on" condition and odd OSA numbers control the output "off" condition.

PROGRAMMING

The programs are inserted into the computer and DECtape system through the communication Teletype which can be used to type in or print out information, or read in or punch out perforated paper tape at a rate of ten characters per second. The information inserted is stored in the computer memory and on the magnetic tape (DECtape) to be called up by selection of the required function at the control console and the communication Teletype.

DECtape Format

DECtape utilizes a 10 - track recording head to read and write five duplexed channels. Three of these track pairs are available for data; the remaining two pairs are used for timing and mark information. Duplication of each track by non-adjacent read/write heads wired in series eliminates most drop-outs which could occur due to noise and dust and minimizes the effect of skew.

The timing and mark channels control the timing of operations within the TC01 control unit and establish the format of the data contained on the information channels. These channels are recorded prior to all normal data writing on the information channels. The mark channel is used during reading and writing of data to indicate the beginning and end of data blocks and determine the functions to be performed by the system.

Each tape is approximately 260 feet long and contains 849,036 usable lines. This is equivalent to 190,000 12 - bit words in blocks of 129 words, giving a maximum of 1462 addressable blocks per reel.

The temperature of the tapes must not be allowed to exceed 80^{o} F (300 ^{o}K) otherwise the data may not be reliable.

The Automatic Control System Programs

The fuelling operation consists of many steps which must follow each other in strict sequence if fuelling is to be accomplished successfully and without damage to the machines.

The heart of the F/M control system is the high speed stored-program digital computer. The computer performs many tasks such as operating the logging printer, the communications teletype, the magnetic tape transports, monitoring line voltage, inputs and outputs, and keeping track of operations, steps and sequences, etc. These functions are executed by computer program. These programs are normally stored on magnetic tape called Library System Tapes. When required, these programs are transferred from tape storage into the processor core for operation .

In addition to programs, large amounts of data are required by these programs to carry out fuel handling operations. This data, which is information on fuelling machine operations and sequences, is stored on a separate magnetic tape called a Data Service Tape. Relevant data is "read" from tape as required by the operational programs.

The operational programs that are used in the fuelling machine control system and are stored on the Library System Tape.

1. Main Executive (MNEX) - the program which is used to execute the fuel handling program and controls all peripheral gear such as teletypes, tape transports, etc.

2. Fuel Handling Task (FHTASK) - The program which is "called in " by MNEX (i.e., from tape to core memory) from the communications teletype keyboard. Once transferred into core, FHTASK has four main functions:

    1. To use the following sub-programs in a definite order to process data related to fuel handling control:

        FHEX - Fuel Handling Executive Program
        FHOP - Fuel Handling Operate Program
        FDCD - Fuel Handling Decode Program
        FLOG - Fuel Handling Logging Program
        FDATIN - Fuel Handling Data Insert Program
        FDISP - Fuel Handling Display Program

    2. To keep track of operations, steps and sequences ensuring that they are processed automatically and in correct order.

3. To execute instructions initiated by FHOP and FDCD enabling fuel handling operations and sequences to be brought into core for processing.

4. To keep the "watchdog" timer from timing out by resetting it after each computer pass through the Fuel Handling Executive program.

Within the fuel handling program, the sequences of fuelling machine operations are arranged as data that can be read in from magnetic tape as required. A series of operations performed sequentially define a SEQUENCE such as "traverse". An OPERATION consists of certain inputs to be watched (such as pressure and component position) and certain outputs to be turned on or off (such as electric motors or drive brakes). The computer does not monitor all inputs from the fuelling machine at once. Only those sensors related to the operation in progress as well as certain permanent inputs such as the position of the fuelling machine gate are looked at by the program. This latter group of sensors is referred to as the PERMANENT LIST.

At the beginning of the fuelling cycle and at certain defined points throughout, the operator must "feed in" certain instructions to the control system via pushbuttons. Each of the two machines (east and west) has its own control system and each system functions independently of the other over the fuelling cycle except for the operation where both machines are locked to the fuel channel and fuel is being moved, and during replace and remove plug sequences when the plug at the coolant outlet end of the of the fuel channel is required to be installed before the plug with the flow control orifice.

During these operations, the two machines are co-ordinated through their interlocked control systems. The control systems for the two machines are identical, differing in their control function only as a result of the different operating instructions which are "fed in" at the beginning of the cycle.

The actual progress of each machine through the fuelling sequence can be followed by means of the logging printer and the digital readout display of the sequence, step and operation numbers.

DECtape Organization

The programs on DECtape are organized in blocks of 128 words on tape hence each block read in to the processor will occupy one page of memory. Each block is preceded by a block number and this number is used by the Task Library Table in MNEX to identify the program. A program may consist of more than one block on tape; in this case, the DECtape Read Program automatically reads in the correct number of blocks, limited to a maximum of seven for tasks.

The programs are: (In order of appearance on DECtape)

DECtape Library System (LIBSYS) consisting of INDEX, ESCAPE, UPDATE,
DELETE and GETSYS.
Fuel Handling Clock Set Task (SCSLR)
Fuel Handling Fetch Task (SFFTSK)
Fuel Handling Task (FHTASK), which includes:
- Fuel Handling Executive (FHEX)
- Fuel Handling Operate (FHOP)
- Fuel Handling Decode (FDCD)
- Fuel Data Insert (FDATIN)
- Fuel Handling Display (FDISP)
- Fuel Handling Log (FLOG)

Main Executive (MNEX)
Fuel Handling Compiler (FCOMP)
129 Word Block Duplicator (DUP 129)

OPERATIONAL PROGRAMS

DECtape Library System (LIBSYS)

The DEC Library System allows each of the system programs to be called into memory field 0 by the communications Teletype by its file name. FHTASK resides in memory field 1 and part of field 0 and must be called by the Main Executive program, which resides in field Ø.

The DECtape Library system is standard DEC software and can be used to add or delete programs from a program tape. It also keeps a directory or index of all programs and can be used to call any program into core using the Keyboard/Reader. At present, the DECtape library system can only be used in an off-line mode, i.e. when no other programs are operating.

Main Executive (MNEX)

The computer is required to perform many tasks such as operating the logging printer, the communication Teletype, the DECtape transport, watching for low-line voltage and so on. The main executive program, MNEX, looks after all these programs as required and is called from tape by the operator using the communication Teletype.

Main Executive (MNEX) is a system for performing selected tasks in a predefined priority. The operator selects the desired task(s) by keyboard entries. The task is then inserted into a task queue by the program. A task can also be queued internally by program.

The program operates as a priority interrupt system. Since only one hardware interrupt is used, the priority assignment is handled by the software.

The program has been designed for the later addition of other tasks. The present system includes the executive and its subroutines, as well as the following tasks:

1. Task to Decode a Task Request - SDKCO
2. Task to Turn a Task On/Off - STOFT
3. Task to Alter a Core Location - SALTT
4. Task to Print a Message - SPTSK
5. Fuel Handling Task - FHTASK
6. Task to Set/Read Clock - SCLSR
7. Task to Fetch F/H Task from Tape - SFFTSK
8. Task to Reset Errors - SRSTE

The executive will handle a task which uses up to 4096 core locations.

General Sequence of Operation

Information is set into the computer through the Communications Teletype keyboard. This information is stored in a buffer as it is read (SKBST). When all information for a particular task has been typed in, the task (SKDCO) checks the first four characters against an index list to ensure that it is a valid request. If valid, the task code is queued into the task queue according to its priority number in the task library table, and any parameters are stored in the task library table (SKCON and SQUEU). The tasks specified in the queue are then executed in sequence (SEAR). If the requested task is not in core, it is read in from DECtape.

For example, the parameters to alter an instruction in a location in core, are as follows:

2612, 10212/7200/CR

Defines the Task, in this case SALTT - Task to Alter a Core Location.

Defines the memory field (first digit) and location to be altered.

Defines the parameter to be inserted, in this case the instruction CLA - Clear the Accumulator. Note: A slash after the parameter defines it as octal. A comma would define it as a decimal number.

Tasks may be interrupted by various devices connected to the Interrupt Bus. Upon an interrupt (except sample pulse) the Executive returns to the interrupted program immediately after it has serviced the device/devices causing the interrupt/interrupts. Upon a sample pulse interrupt, various active registers of the Task currently being performed are stored with the Task. The executive then searches the task queue to perform tasks according to their priority. Task(s) interrupted by sample pulse are continued from the point of interrupt. When all the tasks in the queue have been done, the program shifts the tasks in the queue to fill in any completed tasks (SHIFT), and then waits in an idle loop for the next interrupt (DIAG).

Fuel Handling Task (FHTASK)

Fuel Handling Task (FHTASK) program is a task of Main Executive (MNEX) and comprises FHEX and its sub-programs as well as a number of Lists and Buffers. It is called via the communications Teletype Keyboard and, once queued, it is performed every 1/60th of a second under the control of MNEX program. FHTASK may be interrupted by any of the peripherals connected to the interrupt bus including the sample pulse. After calling the program, complete Fuel Handling Functions may be performed from the automatic section of the control console or from the simulator, for simulation purposes.

The system is capable of performing a single operation, a single step or a single sequence at a time, as well as monitoring Permanent List. Generally a number of sequences would be required to perform a particular Fuel Handling Job. FHTASK, through its sub-program FLOG, will log all sequences, steps and operations on the logging Teletype. During this logging operation, the operator may stop an operation currently being performed at any time.

FHTASK is designed to handle power failure safely. Upon power return after a power failure, the system is set in STOP state, with Special Mode set. Essential displays on the control console are not lost. However, the operator may have to perform a special operation or operations to turn on a certain output or outputs which were turned on by OUTSRT/OUTRST IODAT (s) in some previous operation.

To ensure that FHTASK is performed properly, five check points are built into the program. If the program fails to pass through certain check points, FHTASK will signal this to MNEX, which will take it out of the Task Queue. As a result of this, Watchdog will not be kicked and it will time out removing power from the a-c and d-c Automatic buses. If the program passes through all the check points, Watchdog is kicked, by generating and then executing WKK (Watchdog Kick) instruction. This would prevent Watchdog from timing out. The WKK instruction is blanked out of core immediately after being executed so that it will not be inadvertently executed on possible system failure.

Fuel Handling Executive Program (FHEX)

Fuel Handling Executive (FHEX) program, as the name implies, is executive portion of the Fuel Handling Task. Briefly, FHEX performs the following housekeeping functions of the Fuel Handling Task.

a. Keep Watchdog alive if the program passes through a number of check points (5 to be exact) in FHEX.

b. Set Fuel Handling Task in safe condition upon power restart after a power failure.

c. Keep track of the operations to be performed during the current pass and their retrieval from tape in advance where possible.

d. Perform sequence and step housekeeping, and retrieval of next sequence from tape when required to do so.

In addition to the housekeeping functions described above, FHEX calls up a number of sub-programs to perform the following functions:

- Monitor Permanent List - Perform a Sequence; a Step or an Operation automatically	FHOP
- Decode Valid Operation Inputs from the Automatic section of the control console and/or other flags set by other programs	FDCD
- Display Sequence, Step, Operation, Status etc	FDISP
- Log Sequences, Steps and Operations	FLOG

Fuel Handling Operate Program (FHOP)

This is a program which processes various lists of control data by means of its sub-programs. In the fuel handling system it processes the following lists:

PERML (Permanent List)

This is a list of specific sensors which must be monitored on a continuous basis. The IODATS in this list are only Input type and no outputs are turned On/Off by this list directly. Also there is no DONE condition associated with the Permanent List.

CIOL (Current Input/Output List)

This list consists of a number of sensors and/ or flags to be monitored, outputs to be turned on/off, and/or flags to be set/reset, in order to perform various machine functions.

CONL (Console List)

This list consists of four IODATS associated with the operators console. Permanently in core, it has a number of groups which are acted upon in different ways by FHOP according to the Instruction code and can be turned on/off by program. The CONL sub-programs in general look at various console inputs and set/reset flags and turn console outputs on/off according to operator actions.

In processing these lists, FHOP sequentially enters a number of its sub-programs depending upon the type of IODATS (Input /Output Data) in that list. The input IODAT sub-programs examine digital inputs/flags and make logical decisions based upon their present state. They also set up conditions for the output IODAT sub-programs to turn outputs on or off to control various motions of the fuelling machine or lights on the operators console. FHOP also sets a number of flags which are sensed by:

FHEX - to do certain housekeeping
FDCD - to set various console conditions
FLOG - for logging purposes

Fuel Handling Decode Program (FDCD)

Fuel Handling Decode (FDCD) Program is a subroutine of Fuel Handling Executive (FHEX) Program and is entered every pass through FHEX. This program decodes the flags set by Fuel Handling Operate (FHOP) program or/and by other programs (including itself) and sets/resets flags sensed by FHOP and/or FHEX programs.

In a broad sense two kinds of flags are examined and decoded by FDCD program. They are:

1. Internal Stop Flag (INSTPF) - This flag is set by FHOP program when processing Permanent List (PERML) or Current Input/Output List (CIOL). FDCD program, upon finding INSTPF set, inhibits setting of OPERATE Flag (OPRFLG) and/or JOG Flag (JOGFLG) in Console List for 5 seconds to give the operator time to identify the STOP condition before operating again.

2. Console List Flags - These flags in general are set/reset by FHOP program when it is processing Console List. Some of the flags may be set/reset by other programs (including FDCD program) as well.

Fuel Handling Data Insert Program (FDATIN)

The Data Insert Program is used to insert a fuel handling sequence or special operation or to re-enter at a different step in a sequence.

The data insert program is entered by pushing the insert pushbutton on the fuelling machine console. The program first tests for a definition of the data to be inserted - whether it is an operation, a step or a sequence. If the data is not defined,the remainder of the program is bypassed.

If the insertion is a valid operation number, the number is loaded into OPHLD, provided OPHLD is clear. OPHLD may not be clear if there is a GO TO from the permanent list. In this case the operator will have to complete the permanent operation and then re-insert the operation he wishes to perform.

If the insertion is a valid sequence number the new sequence is loaded. If the insertion was a valid step number, the step pointer is set for starting at the step inserted.

When the sequence, step or operation number is finally accepted, DATFLG is cleared causing the console data definition light to be turned off, indicating to the operator that the information was accepted.

Fuel Handling Display Program (FDISP)

FDISP sets the digital displays at the console for sequence, step and operation numbers. It calculates the engineering units for magazine or charge tube rotation, ram or charge tube axial motion as selected,and sets the digital display. It also sets the discrete magazine position indicators.

FDISP examines the appropriate pointer for sequence, (SEQP), step (STEPP) or operation number (OPSTKP) and reduces the word to the desired octal number. The octal number is coded so that each digit forms a six bit word (4 BCD characters and 2 special characters). This word is used as the mask with the appropriate OSA to drive the digital display.

Magazine discrete position is determined by calculation from the magazine shaft encoder position. If the encoder indicates that the magazine is at one of its six possible positions, a mask is used with OSA0404 to indicate the appropriate position.

Status display is an output in engineering units of the physical position of the magazine, ram or charge tube axial or charge tube rotary. Degrees are displayed for magazine and charge tube rotary. Inches and tenths of inches are displayed for ram and charge tube axial. The operator selects the component whose position he wishes to be displayed and the corresponding shaft encoder will be read and the component position calculated and displayed.

The operator may select current status in which case the position of the component which is currently moving is displayed. To determine which component is moving, a flag, set by FHOP is examined by FDISP. If none of the drives are operating, the status of the last component selected will be displayed.

Fuel Handling Log Program (FLOG)

This routine loads a circular print buffer with formatted information pertinent to the sequence, steps and operations carried out by the fuel handling control program. The information includes start and finish times for each operation, the duration and exit code for the operation.

On the first pass i.e. at start-up time, FLOG initializes a printout of log headings and sets a one-pass block for the initializing sub-routine. This section of the program must be loaded freshly into core before it can be used since it is overwritten with other information on a subsequent pass.

FLOG then tests for a branch condition. On a branch condition the program loads the finish time, duration and branch code. If there has been a branch condition other than while performing an operation, the branching time will be logged as a finish time and the appropriate code will be logged.

When there is a stop condition due either to the operator pushing the STOP button or a program stop, a "STOP" flag is set in log so that the bulk of the program is not processed on subsequent passes.

If there has not been a branch condition FLOG tests for a sequence number. If there is no sequence being performed FLOG bypasses this sub-routine. If a sequence is being performed it is logged as "SEQ#NM", where NM is the number of the sequence.

After logging the sequence the step number is logged. If there is no step being performed or if it is the same as the last step logged, the program proceeds to log the operation number.

If the current operation is not being processed, the program bypasses logging the sequence, step and operation until processing has started. If a new step is being processed the step number is stored for checking on subsequent passes and is loaded into the print buffer with appropriate formatting spaces. The program then proceeds to log the operation number.

Fuel Handling Clock (SCLSR)

This routine is a task which is used to set the real time clock and/or to check its time against the station clock. The clock runs only when the processor is turned on.

The clock is read by the fuel handling log portion of FHEX to calculate the duration of any given operation and printout the start, finish and duration times of the operation.

Fuel Handling Compiler/Assembler (FCOMP)

This program provides the means of changing or deleting operations within a sequence, or creating new operations or sequences. It resides on magnetic tape and can be called via the DECtape Library System. This is an 'off-line' operation, in that the fuel handling program cannot operate while the DECtape Library System is being used.

This program also allows changes to be made in any sequence of operations. Because any change to a program may modify the interlocking of the fuel handling system, any program change must be adequately supervised. The programs supplied with the system will result in the current operation being stopped and the fault logged in the event that the operation is not successfully completed. This can be modified after operating experience has been gained, so that the correct remedial action can be automatically applied.

FUEL HANDLING CONTROL DATA

There are two levels of information.

Sequences - which consist of lists of operation. See OM 352.0

Operations - which consist of lists of detectors giving permissives, branch conditions, operation 'done' conditions, outputs to be turned on or off and flags to be set or reset. See OM 352.0.

Sequence

Machine tasks are subdivided into SEQUENCES. In general terms, a Sequence approximates a stepping switch program on the original system. Typical Sequences are TRAVERSE, PLUG OUT, PLUG IN, MOVE FUEL. Traverse, for example, with six basic locations, could involve up to thirty traverse Sequences. The six basic locations are: Home, New Fuel, Lattice, Spent Fuel # 1, Spent Fuel # 2, Manipulator. Sequences are numbered within the range $1\text{-}77_8$.

Sequence numbers are really block numbers on tape. When ordered they are transferred into core memory (field 1 in this case). Sequences occupy blocks $1\text{-}77_8$ and are octal numbers. See Figure 9 for a typical fuelling machine sequence.

Processing a Sequence

The Sequence pointer points to the current sequence number. This is in core (transferred from tape) in the Sequence List. A pointer called STEP pointer (STEPP) keeps track of the current step being processed.

Step and Operation

Each Sequence is subdivided into a series of STEPS and each Step comprises one or more OPERATIONS. Steps are numbered within the range $1\text{-}77_8$ and Operations $100\text{-}777_8$. Operations are not limited in application to one Step within one Sequence. An Operation may be applied in any Step where its logical function is appropriate.

Operations

An Operation is a list of detectors that define permissive(s), branch condition(s) and the DONE condition of a particular operation. Operations have DECtape block numbers from 100 - 777_8 and are transferred into core either into the current IOLIST (CIOL) or the next IOLIST (NIOL) as required by Step pointer, or as a result of a GOTO operation # .

Each logical operation on a detector, flag or shaft encoder is described by an IODAT. Refer to page 38. The IODAT # (for example, SWCTST is 4025) is the key indicating to the program what should be done with the pieces of data which follow. See Figure 8 for a typical fuelling machine operation.

Processing an Operation

To keep track of the order in which the operations are performed, there is one further list (called a Stack) namely OPSTACK (OPSTK). There are only three ways an operation gets into OPSTACK and two ways it is removed. To get into OPSTACK, an operation must;

a. be the first operation required for a given step,
b. be the result of a GO TO from a current operation (or a GO TO from the permanent list),
c. be inserted by placing the control system in 'Special Mode' and using the insert button (INIH).

The only ways an operation can be removed from OPSTACK are for the operation to be completed (DONE), or by inserting a step re-enter or a new sequence. An operation called up by the Permanent List must be completed to be removed from OPSTACK.

Each IODAT is processed (according to the first piece of data, e.g. SWCTST, ANTST2 etc) in the order in which it occurs in the list. Any action required by an IODAT (STOP, GO TO OP # or DONE) is taken on a first come, first serve basis. On any given pass through the data, every IODAT is processed regardless of whether STOP, GO TO or DONE has occurred previously or not. However, if STOP, GO TO OP # or DONE has occurred, it is this action that is taken. On an operation that has a time delay on its outputs, these hold off the DONE condition until the time delay is complete.

Preferential Order of IODATS in an Operation

Because of the method of getting operations into OPSTACK and removing them on a DONE, it is preferable to put the DONE condition (as defined in the IODAT (S)) as the first IODAT. In this way, as a GO TO OP # is put into

OPSTACK, performed, completed and OPSTACK Pointer has returned to the original operation, the DONE condition will be found first. If other IODATS are placed before it, there is the possibility that the GO TO operation may change their state making it impossible for the DONE condition in the original operation to be found FIRST (branch conditions are handled FIRST COME, FIRST SERVED).

If there are two possible GO TO OP # IODATS in an operation, the one that it is desired to have the program 'see' first, should be in the list ahead of the other. FLGSET's or FLGRST's on the DONE condition should be placed at the end of any operation with a time delayed output IODAT. The time delay IODATS set an operation "not done" flag which is monitored by the FLGSET or FLGRST's.

Because output action is taken each pass through an operation, should a STOP, GO TO or DONE occur, outputs and flag set/reset IODATS must be at the bottom of the list.

Action taken on:

NO BRANCH - turns off/on outputs, sets/resets flags per IODATS at end of list to perform current operation,

STOP - as above except to stop current operation, that is, to turn the outputs to the off state,

Note: for OUTRST which turns outputs off during the operation and on at the DONE, these outputs are left off on a STOP

GO TO OP # - as for STOP,

DONE - reverses state of outputs in the operation, but with the time delay outputs determining when operation is done, except for OUTSRT in which the outputs are left in the condition to which they were turned.

Permanent List

To eliminate the necessity of each operation having in it various other sensors which must be monitored more or less continuously, another list, called the PERMANENT LIST, is used to perform this function. Its format is similar to an operation except that all IODATS are input and have a branch condition associated with them, GO TO OP #, STOP (this is a Permanent STOP) but not DONE.

If PERMANENT STOP occurs, all outputs in the current operation are turned off immediately, according to the IODAT associated with it, and the Instruction on the Permanent List causing the STOP is turned off, allowing the rest of the permanent list to be scanned undisturbed.

If GO TO OP # occurs, the operation # is put into OPSTACK, the current operation is stopped and this "Permanent GO TO Operation" is processed. During this, permanent list is no longer scanned. On completion, scanning of this list resumes. Individual IODATS can be turned on (to say they require processing) or off (to say they do not require processing) by setting bit Ø of the first word in each IODAT (SWCTST, ANTST2 etc.,) to Ø for off and to a 1 for on. This is done by means of flag set/reset IODATS in any particular operation.

Preparation of Control Data

Sequence data is carried on a sequence data sheet which lists the title of the Sequence, the Sequence #, the Steps involved (together with an English description of the function of each step) and the number of the Operation(s) used in each Step.

Operations are written onto operation data sheets which show the devices to be operated together with OSA/Mask and type of operation test to be applied (i.e. OUTSET, OUTSRT, etc.). Also shown are permissive conditions - test - ISA/Mask and next action (i.e. DONE, STOP, GO TO). The preparation of the operation data sheets resembles the preparation of a computer program. The work involves simultaneous application of program-type logic and plant operating work characteristics. For instance, constant consideration must be given to computer cycle times versus machine response times. With experience and a full understanding of IODATS, special operations can be made or old operations modified. The program FCOMP is used for this.

DESCRIPTION OF IODATS

IODATS (Input/Output Data) are the "mechanisms" which define the program action to be taken on inputs or outputs. They are sub-programs of the Fuel Handling Operate Program (FHOP).

There are in general two types: Those with a branch condition (generally inputs) and those without a branch condition (generally outputs). Those with GO TO OP #, STOP or DONE are detectors (contact closure and shaft encoder), flags and combinations of the above. These are always at the top of the list in an operation.

The IODATS without branch condition are output turn on or off, time delay output and flag setting or resetting.

The following is a list of all IODATS used.

Branch conditions

STOP	-	7000
DONE	-	1000
GO TO	-	7 (OP#) ie. 7436 is GO TO OP # 436

IODAT constants

OFF	-	0000
ON	-	(2's complement of the mask ie. if the mask is 0020 the ON constant is 7760 .

<u>COMTST</u> (Compare Test)

4001	-	IODAT #
0020	-	ISA
2000	-	mask
2533	-	core location
1000	-	DONE

It compares the bit(s) of input with corresponding bit(s) of the core location and if they are the same it will go to a branch condition. In this case it is a DONE.

<u>TIMTST</u> (Time Test)

4003	-	IODAT #
7704	-	basic counter (increments every 1/60 sec; overflows in 1 sec)
7766	-	seconds counter (reset on branch condition)
7766	-	counter reset
7000	-	STOP

It times the operation and if the set time (in this case, 10 sec) is exceeded, it achieves its own branch condition (in this case, it is a STOP). However, if the set time is not exceeded before completion of the operation, a normal branch condition will be achieved.

<u>FLGRST</u> (Flag Reset)

4005	=	IODAT #
0000	=	PASS 1
3652	=	core location
0010	=	mask

It sets the bit(s) of the core location to a 0 either on the first pass through the operation or else whenever a DONE condition is achieved. In this case bit 8 of core location 3652 is set to 0 on PASS 1.

<u>FLGRST</u> (Flag Reset)

4005	-	IODAT #
7777	-	DONE
3652	-	core location
0010	-	mask

It sets the bit(s) of the core location to a 0 either on the first pass through the operation or else whenever a DONE condition is achieved. In this case bit 8 of core location 3652 is set to 0 on a DONE.

<u>FLGSET</u> (Flag Set)

4007	-	IODAT #
0000	-	PASS 1
2543	-	core location
0100	-	mask

It sets the bit(s) of the core location to a 1 either on the first pass through the operation or else whenever a DONE condition is achieved. In this case, bit 5 of core location 2543 is set to a 1 on PASS 1.

<u>FLGSET</u> (Flag Set)

4007	-	IODAT #
7777	-	DONE
2543	-	core location
0100	-	mask

It sets the bit(s) of the core location to 1 either on the first pass through the operation or else whenever a DONE condition is achieved. In this case, bit 5 of core location 2543 is set to a 1 on a DONE.

<u>OUTSET</u> (Output Set)

4011	-	IODAT #
0506	-	OSA
2000	-	mask

It turns on the specified output immediately upon entering the operation and when the operation goes to a branch condition it turns the output off.

OUTRST (Output Reset)

4013	-	IODAT #
0306	-	OSA
0400	-	mask

It turns OFF the specified output immediately upon entering the operation and when the operation goes to a DONE branch condition it turns the output ON.

OUTSRT (Output Set-Reset)

4015	-	IODAT #
0400	-	OSA
2000	-	mask

It turns the specified output ON or OFF and leaves the output in that state at the end of the operation. If the OSA is even, the output is turned ON; if the OSA is odd, the output is turned OFF.

TDOUT1 (Time Delay Output 1)

4017	-	IODAT #
7704	-	basic counter (increments every 1/60 sec; overflows in 1 sec)
7776	-	seconds counter(reset on branch condition)
7776	-	counter reset
0504	-	OSA
0200	-	mask

It turns ON the specified output immediately upon entering the operation, and turns OFF the addressed output a specified time delay after a DONE condition. On a STOP or GO TO the output is turned OFF immediately.

TDOUT2 (Time Delay Output 2)

4021	-	IODAT #
7704	-	basic counter
7777	-	seconds counter
7777	-	counter reset
0604	-	OSA
4000	-	mask

It turns ON the addressed output a specified time delay after entering the operation, and turns it OFF immediately on a branch condition.

TDOUT 3 (Time Delay Output 3)

4023	-	IODAT #

7704	-	basic counter
7775	-	seconds counter
7775	-	counter reset
7704	-	basic counter
7776	-	seconds counter
7776	-	counter reset
0306	-	OSA
0040	-	mask

It turns ON the addressed output a specified time delay after entering the operation and turns OFF the output a specified time delay after a DONE condition. On a STOP or GO TO, the output is turned OFF immediately.

SWCTST (Switchtest)

4025	-	IODAT #
0024	-	ISA
0400	-	mask
7400	-	ON
7000	-	STOP

It samples the state of a single detector and if it is in its anticipated position it will go to the branch condition. In this case if bit 3 (mask 0400) of ISA 0024 is ON a STOP condition occurs.

ANTST2 (And Test # 2)

4027	-	IODAT #
0026	-	ISA
2000	-	mask
6000	-	ON
0026	-	ISA
1000	-	mask
7000	-	ON
7000	-	STOP

Logically AND's two inputs. It compares the condition of the inputs, and if they are both in their respective anticipated position it will go to a branch condition. In this case it is a STOP.

ANTST3 (And Test # 3)

4031	-	IODAT #
0026		ISA
4000	-	mask
4000	-	ON
0026	-	ISA
2000	-	mask
6000	-	ON
0026	-	ISA
1000	-	mask
7000	-	ON
7000	-	STOP

Logically AND's three inputs. It compares the conditions of the inputs and if they are all in their respective anticipated position it will go to a branch condition. In this case if bit 0, bit 1, and bit 2 of ISA 0026 are all ON a STOP condition is achieved.

ANTST4 (And Test # 4)

4033	-	IODAT #
0026	-	ISA
4000	-	mask
0000	-	OFF
0026	-	ISA
2000	-	mask
6000	-	ON
0026	-	ISA
1000	-	mask
0000	-	OFF
0026	-	ISA
0400	-	mask
7400	-	ON
7000	-	STOP

Logically AND's four inputs and compares the conditions of the inputs and if they are all in their respective anticipated position it will go to a branch condition. In this case it is a STOP.

FLGTST (Flag Test)

4035	-	IODAT #
7254	-	core location
0001	-	mask
7777	-	ON
1000	-	DONE

Checks status of specified bit in the specified core location and if it is in its anticipated position it will go to a branch condition. In this case if bit 11 of word 7254 is ON,a DONE is achieved.

FLTST 2 (Flag Test # 2)

4037	-	IODAT #
6503	-	core location
0100	-	mask
0000	-	OFF
6510	-	core location
0040	-	mask
0000	-	OFF
7000	-	STOP

It logically AND's two flags in the core and if both conditions are met it will go to a branch condition. In this case it is a STOP.

FLTST3 (Flag Test # 3)

4041	-	IODAT #
4632	-	core location
0020	-	mask
7760	-	ON
5412	-	core location
0200	-	mask
0000	-	OFF
4352	-	core location
0400	-	mask
7740	-	ON
1000	-	DONE

It logically AND's three flags in the core and if the conditions are met it will go to a branch condition. In this case it is a DONE.

SETST1 (Shaft Encoder Test # 1)

4043	-	IODAT #
0031	-	ISA
7777	-	mask
5715	-	desired position (2's complement)
1000	-	DONE

Compares shaft encoder reading with desired position. If it is ≤ than the desired position then it will go to a branch condition. In this case it is a DONE.

0010	-	mask
0000	-	OFF
1000	-	DONE

It logically AND's a SETST4 and a FLGTST and if both conditions are met it will go t a branch condition. In this case it is a DONE.

<u>SEDTST</u> (Shaft Encoder Detector Test)

4055	-	IODAT #
0035	-	ISA
7777	-	mask
4357	-	desired position (2's complement)
0010	-	(+) tolerance in # of bits
0005	-	(-) tolerance in # of bits
0000	-	OFF
0041	-	ISA
0020	-	mask
0000	-	OFF
7000	-	STOP

It logically AND's a SETST4 and a SWCTST and if both conditions are met it will go to a branch condition. In this case it is a STOP.

<u>DFLTST</u> (Detector Flag Test)

4057	-	IODAT #
0020	-	ISA
0100	-	mask
7700	-	ON
5342	-	core location
0100	-	mask
7700	-	ON
1000	-	DONE

It logically AND's the state of the detector with the state of a flag in core. If both conditions are met it will go to a branch condition. In this case it is a DONE.

DESIGN C.

CANADIAN GENERAL ELECTRIC COMPANY LIMITED
ATOMIC POWER DEPARTMENT

NPD F/M REPLACEMEN

530-352.12

OPERATION NO. 240

RAM ADVANCE TO R02.650

INPUT OUTPUT	TYPE OF TEST	ISA / MASK OSA / MASK	CONSTANT	ON OFF	GO TO
RPD 0246	SEDTST	0037 / 7777	+ 07 − 07	ON	
RFHP		0041 / 4000		ON	Done
CPD 3223	SETST 4	0033 / 7777	+ 02 − 02	OFF	Stop
APD 0530	SETST 4	0035 / 7777	+ 07 − 07	OFF	Stop
RPD 0234	SEDTST	0037 / 7777	+ 02 − 02	ON	
RFHP		0041 / 4000		ON	Stop
0015	TIMTST				Stop
RBK	TDOUT 1	0504 / 0400	0005		
RHPV	TDOUT 1	0504 / 4000	0005		
RFV	TDOUT 3	0504 / 2000	0001 / 0006		

TOLERANCES

IODATs

TIME DELAY

Figure 8 Typical Operation Sheet

SEQUENCE: Lattice to New Fuel Port

SEQUENCE NO. 10

Step	Operation	Description	Operation Details (Not on Sequence Sheets)
1	156	Blow Off	OTVV, HTV Energized.BLP comes in when pressure down to 1 psig.
2	106	Lower D_2O Level	HVV, RHUV energized. When HDHD goes off on second pass, DONE, HVV, RHUV de-energized.
3	107	Raise D_2O Level	HVV, HLUPM, OTVV, HIDU energized, until HDHD comes in D_2O level raised.
4	110	Locking Ring Forward	LFV energized. Lockring moves forward until LFD comes in.
5	123	Suspension Lock	SLV energized. Suspension locked. FSLD and RSLD come in and ANDed.
6	111	Locking Ring Unlock	LVV energized. Lockring rotated to unlock until LUD comes in.
7	112	Locking Ring Retract	LRU energized. Lockring retracted until LRD comes in.
10	133	Fine Retract in Azimuth Normal	FOMU energized. Fine retract stops when FOCD and FZLD come in and ANDed.
11	134/135/136	Fine - X - Centre	NPBU and F12MU on FNMU energized. Fine X motion stop when FNCD and F12CO come in and ANDed.
12	137/140/141	Fine - Y - Centre	FUMV or FDMV energized. Fine Y motion stops when FUCO and FDCD come in and ANDed.
13	160/164	Y - Top	} YPUV energized to lift Y-pawls up. YTM energized to drive to Y top. YPDD energized to lower Y-pawls.
	157/161	Y - Top	}
14	162/163	X - Keyhole	X12M or XNM energized to drive carriage to XKD.

Figure 9 (Sheet 1 of 3) Example of Typical Sequence with Operation Details

SEQUENCE: Lattice to New Fuel Port

SEQUENCE NO. 10

Step	Operation	Description	Operation Details (Not on Sequence Sheets)
15	165	Azimuth Service	ASMV energized to drive head to service position. CTCV energized to shut-off cooling D_2O to head extension. Valves de-energized when ASD comes in.
16	113/237	Fine Retract	NPBV and F12MV energized to fine retract head until FXLD and F12CD come in and ANDed.
17	166/130/ 206	Elevator Up	FOMV energized to move head to 2 fire out and ANDed. EUM energized to raise elevator until EUD, FICD and FOCD come in and ANDed. LVPV is energized for 10 seconds to purge seal leak tank before leaving vault.
20	167	Gate Closed	SRV energized to deflate seal, NPBV and GCMV energized to close gate until GCO comes in. SRV de-energized when op. DONE.
21	170	X - New Fuel	XNM drives carriage until XND comes in.
22	171	Fine Retract and Fine Centre Check	Operation checks all necessary detectors to determine head is in required position.
23	172/173/174	Fine Home	Head fine homes onto N.F.P.
	175/176/177	Fine Home	
	255	Fine Home	
24	151	Locking Ring Forward	LFV energized to drive lockring forward until LFD comes in.
25	153	Locking Ring Lock	LLV energized to rotate lockring until LLD comes in.
26	154	Suspension Release	SUV energized to unlock suspension DONE when FSUD and RSUD come in and ANDed.

Figure 9 (Sheet 2 of 3) Example of Typical Sequence with Operation Details

FORM NO.
CAP 7150

DESIGN ...

CANADIAN GENERAL ELECTRIC COMPANY LIMITED
ATOMIC POWER DEPARTMENT

NPD F/M REPLACEMENT

530-352.12

SEQUENCE: Lattice to New Fuel Port

SEQUENCE NO. 10

Step	Operation	Description	Operation Details (Not on Sequence Sheets)
27	155	Locking Ring Retract	LRV energized to retract lockring until LRHP comes in.
30	502	Turn ON NF Location Light	If all necessary detectors are in required condition, light is on.

Figure 9 (Sheet 3 of 3) Example of Typical Sequence with Operation Details

GLOSSARY OF TERMS

AC	- Accumulator - The Arithmetic Unit of the central processor.
Address	- The number which identifies a particular core location.
BCD	- Binary Coded Decimal - A decimal notation in which the individual decimal digits are represented by a pattern of ones and zeroes.
Bit	- Binary Digit - a numeral in the binary scale of notation, either Ø or 1. Used to describe a signal into or out of the computer which can be either Ø = Reset or 1 = Set.
Branch	- The selection of one of two or more possible paths in the flow of control.
Buffer	- An internal portion of the computer or system used as an intermediary storage.
CIOL	- Current Input/Output List - Contains the operation being or to be processed by FHOP program.
CONL	- Console List - Contains data for inputs and outputs related to the operator's console.
Core	- Internal magnetic memory.
Core Location	- The address of a particular 12-bit word in the computer memory which can have an address from 0 to 7777_8.
Core Locations	- 12-Bit hardware registers, capable of storing binary information (instructions and/or data), and which can be addressed i.e. an address is associated with each core location.
Data	- Basic elements of information which can be processed or produced by the computer.
Data Field	- Defines the particular memory from which data will be used if addressed indirectly, Field Ø or Field 1.
DECtape	- The magnetic tape system used on the Digital Equipment PDP-8 computer.
DECtape Library System (LIBSYS)	- A system of programs residing on tape (written for Unit 8) enabling the storage and retrieval of used programs by name.
DFR	- Data Field Register - Defines the particular bank of memory from which data will be used for indirectly addressed memory reference instructions AND, TAD, ISZ and DCA.

DI/OM	- Digital Input/Output Multiplexer.
FCOMP	- Fuel Handling Compiler Program - An off-line program used to assemble fuel handling data in the form of Sequences and Operations on DECtape.
FDATIN	- Fuel Handling Data Insert Program - A sub-program of FHTASK which interprets data from the F/H control console when inserting a sequence, a step re-enter or a special program.
FDCD	- Fuel Handling Decode Program - A sub-program of FHEX which decodes flags set by FHOP, including operator inputs, sets/resets flags and selects sequences automatically using the sequence select programs.
FDISP	- Fuel Handling Display Program - A sub-program of FHTASK which provides a display of sequences, steps and operation numbers and the Fuelling Machine drive status.
FHEX	- Fuel Handling Executive Program - Performs the housekeeping functions of FHTASK as well as the various fuel handling functions by using a number of sub-programs.
FHOP	- Fuel Handling Operate Program - A sub-program of FHEX which processes various lists of control data including Permanent List, Current Input/Output List and Console List.
FHTASK	- Fuel Handling Task - A Task of MNEX and comprises FHEX, its sub-programs and a number of Lists, Buffers and F/H control data.
Flag	- An indicator in core memory. The Flag is generally considered set when = non-zero (1) and reset when = zero (Ø).
FLGA	- Flag Address - Defines a particular flag word in core memory.
FLOG	- Fuel Handling Log Program - A sub-program of FHEX which logs fuel handling operations on the logging Teletype
FOPLP	- FHOP List Pointer - This pointer is initialized by FHEX program to various lists and is used subsequently by FHOP to process the list to which the pointer is initialized.
Gray Code	- A binary code used in the rotary encoders in which sequential outputs are represented by expressions which are different in only one place and in that place differ by one unit.

Hardware	- The transistor circuits etc. which interpret the software. A general term for circuitry.
IFR	- Instruction Field Register - Defines the particular memory bank from which instructions will be used.
Instruction Field	- Defines the particular memory from which instructions will be executed on the fuel handling system. There are two fields in this system, Field Ø and Field 1.
Interface	- The hardware which is between the computer circuits proper and the process being controlled. (Digital Input/Output Multiplexer)
IODAT	- Input/Output Data - A number of pieces of data representing an Input Sensor, Flag or their combination, or an Output.
IOTST	- A sub-program of FHOP- Tests the instruction part of an IODAT.
ISA	- Input Strobe Address - Number(s) meaningful to the Digital Input/ Output Multiplexer and, when used with specific software instructions, strobes the status of the 12-bit field input into the computer accumulator.
JOBL	- Job List - Contains Sequences(s) to be performed for a particular job.
LIBSYS	- See DECtape Library System.
Mask	- A number which allows the program to look at the state of a particular bit(s) in a word.
MNEX	- Main Executive Program - The program which is used to execute the fuel handling program and controls all devices such as Teletypes and DECtapes.
NIOL	- Next Input/Output List - Contains the operation generally to be processed next.
OBRC	- Output Branch Control
OPSTKP	- OPSTACK Pointer - Is used by FHEX program to perform Operation Housekeeping.
OSA	- Output Strobe Address - A number(s) meaningful to DI/OM and, when used with specific software instructions, sets the condition for the turning ON or OFF of Output(s) according to whether the number is even or odd respectively.

PASS1	- First Pass through a particular operation.
PERML	- Permanent List - A list of sensors to be monitored more or less on a continuous basis.
Pointer	- A programming term which generally means a core location which contains an address pointing to data in another list or buffer and is used for processing a list of data.
Program	- A complete plan for performing a particular function of the computer control system. Uses fuel handling data to control the fuelling machine.
Reset	- Place a binary digit in the zero state.
Routine	- A sub-division of a program consisting of two or more related instructions.
S.A.	- Starting address
SEQL	- Sequence List - Contains a Sequence being/or to be processed by FHEX program.
SEQP	- Sequence Pointer - Used by FHEX program to process a sequence.
Set	- Place a binary digit in the one state.
Software	- Programs. Those instructions which, when interpreted by the computer hardware, enable the computer to manipulate data and/or make logical decisions.
Sub-program	- A sub-division of a program.
Sub-routine	- A sub unit of a routine..
Task	
Word	- An ordered set of characters which occupies one storage location Inserted by the computer as a unit and transferred as such.
YOP	- Branch Condition - This is the last data word of the Input type IODATS.