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FFTF FUEL HANDLING EXPERIENCE

(1979 - 1986)

DM Romrell, DM Art,
RD Redekopp, JB Waldo

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P.O. Box 1970
Richland, WA 99352

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D. M. Romrell
D. M. Art
R. D. Redekopp
J. B. Waldo

FFTF Engineering
Westinghouse Hanford Company
Richland, Washington 99352

INTRODUCTION

The Fast Flux Test Facility (FFTF) is a 400 MW (th) sodium-cooled fast flux test reactor located on the Hanford Site in southeastern Washington State. The FFTF is operated by the Westinghouse Hanford Company for the United States Department of Energy.

The FFTF is a three loop plant designed primarily for the purpose of testing full-scale core components in an environment prototypic of future liquid metal reactors. The plant design emphasizes features to enhance this test capability, especially in the area of the core, reactor vessel, and refueling system. Eight special test positions are provided in the vessel head to permit contact instrumented experiments to be installed and irradiated. These test positions effectively divide the core into three sectors. Each sector requires its own In-Vessel Handling Machine (IVHM) to access all the core positions. Since the core and the in-vessel refueling components are submerged under sodium, all handling operations must be performed blind. This puts severe requirements on the positioning ability and reliability of the refueling components. This report addresses the operating experience with the fuel handling system from initial core loading in November, 1979 through 1986. This includes 9 refueling cycles.

FUEL HANDLING SEQUENCE

The fuel handling operations for refueling the FFTF reactor are illustrated in Figure 1. The new assemblies (green fuel) are received in the reactor containment building packaged in a shipping container. The polar crane is used to move the new assemblies from the shipping container to the Core Component Conditioning Station (CCCS) where each assembly is inerted and preheated prior to entry into a sodium system.

The Bottom Loading Transfer Cask (BLTC) interfaces with the CCCS, grapples the fuel assembly and raises it into a heated and argon inerted cask. The BLTC then transports the assembly to the sodium filled Interim Decay Storage (IDS) vessel and inserts it into a sodium filled Core Component Pot (CCP) within the IDS Vessel basket.

The Closed Loop Ex-Vessel Machine (CLEM) interfaces with the IDS Vessel, picks up the CCP that contains the new assembly, moves to the reactor vessel, and lowers the CCP to a transfer position within the vessel. The In-Vessel Handling Machine (IVHM) removes the new assembly from the CCP and inserts it into a pre-selected core position. Spent (irradiated) fuel is removed from the reactor core by the IVHM and is inserted into a storage location within the reactor vessel where it can radiologically cool for at least one reactor operating cycle. Subsequently, CLEM is again used to move the spent fuel assembly in a CCP to the IDS Vessel. After a year, the decay heat is sufficiently low to permit moving the assembly to a storage facility outside of the reactor containment utilizing the BLTC.

REFUELING EQUIPMENT AND EXPERIENCE

The major fuel handling equipment utilized at FFTF are described and significant operating experience noted as follows:

CCCS The Core Component Conditioning Station consists of a tubular vessel located adjacent to the IDS vessel with a blower and heater that is capable of circulating hot argon gas to inert and preheat a core component. With the core component heated and in an argon atmosphere, it is ready to transfer into a sodium filled pot in IDS. This system is very simple and consequently no significant problems have occurred with this facility.

BLTC The Bottom Loading Transfer Cask is illustrated in Figure 2. This machine consists of a shielded cask mounted on a rail transporter. The cask is equipped with a grapple, a closure valve, and a heating/cooling system. It is designed to handle normal core components having a decay heat value of less than 1.4 KW. Argon gas is circulated through the cask at nominally 204°C (400°F) with an atmospheric purity of less than 40 PPM oxygen. A computer control system monitors all operations of the grapple, closure valve, and cooling system and will halt any of these operations if the related permissive parameters are not met. Problems encountered with the BLTC are as follows. (These problems have not extended the reactor downtime.)

- The most severe problems with the BLTC have been related to sodium oxide contamination of the grapple and lower closure assembly. To minimize sodium oxide contamination, the inert gas system was modified to operate at a positive pressure in all portions of the machine. The grapple was redesigned to eliminate close fitting sliding surfaces. These changes have made this machine much more reliable.

- Problems with sodium drippage in the lower enclosure have required major disassembly for cleaning on two occasions. The drippage from the grapple and the assemblies is normally collected in drip pot containers which are exchanged with clean containers when full. Unfortunately, some of the drippage misses the pot and deposits sodium on the drip pot rotor where it cannot be removed without disassembling the machine. The radiation level of the spilled sodium has remained sufficiently low to permit hands-on maintenance with minimal exposure to personnel.

- The computer input/output modules have failed more frequently than expected. Additional cooling fans were installed to keep computer modules at a cooler temperature. This effort was partially successful in reducing failures. The existing computer system is outdated and future upgrades are being planned.

- A failure of the BLTC argon blower caused over heating of the argon heater and failure of adjacent heater lead wires. The failed wires were replaced with high temperature wiring and an interlock was installed to turn the heater off if argon flow is reduced.

IDS The IDS vessel contains a large basket that can be rotated to index with the vessel access ports. The IDS basket is capable of storing 122 core components in a sodium pool that is maintained at a normal temperature of 204°C (400°F). New core components are loaded into sodium filled core component pots that were previously inserted into the IDS Vessel. The new components are then transferred in the pots to the reactor vessel.

The IDS vessel has had two significant problems:

- The IDS basket indexing control system does not compensate for the filled basket inertia and as a result, the basket coasts by the intended position. The operator is required to jog the basket into the desired position. A planned upgrade of this system will utilize a reduced drive speed when the basket is approaching the desired position.

- Sodium vapor in the upper IDS vessel collects on an auxiliary position-viewing window and also deposits contaminants on the basket rotation bearing. The sodium vapor problem has been mitigated by keeping the sodium temperature in the IDS vessel below 218°C (425°F).

CLEM The ex-vessel fuel handling machine (Figure 3) consists of a 15.85 meters (52 ft) high shielded cask mounted on a "straddle crane" rail transporter. The cask is equipped with a grapple and closure valve and is capable of handling long test assemblies (12.192 meters [40 ft]) as well as normal core components (3.657 meters [12 ft]) in an argon atmosphere. The normal core components are handled in sodium filled pots to achieve a decay heat removal capability of up to 10 kW. The inner cask wall is maintained at approximately 204°C (400°F) by heating or cooling as appropriate.

All of the CLEM cask interfaces and penetrations are sealed with two sets of O-rings and the buffer area between the O-rings is pressurized and monitored for leaks. The closure valve is sealed with sets of two inflatable seals (upper and lower seals) where the buffer area between the seals is also pressurized and monitored for leaks.

Two computers are linked together to monitor and control all CLEM operations. The following is a typical control function. A load limiter (Pneumatic cylinder) is mounted on the top of the cask and supports the grapple load. The computer positions the load limiter, to provide a cushion or slack-chain-take-up if the grapple load exceeds the expected weight or is hung up while it is being lowered. The computer monitors the load limiter position and halts the grapple drive if the load limiter moves from the designated position (either up or down).

The most significant problems with the CLEM have been related to sodium oxide accumulation, seal integrity and frequent failures of the computer input/ output modules. The CLEM problems are detailed as follows:

- Sodium vapor generated from handling high decay heat assemblies collects on cold surfaces inside the cask and has caused friction in the grapple load measuring system. The computer program was modified to allow for the friction caused hysteresis in the grapple load measuring system. The sodium vapor also collects on a TV viewing port in the CLEM cask making it difficult to identify the serial number of the core component pot being transferred. The view port window was modified with a window shutter that covers and protects the window except while viewing an item in the cask. Additionally, an argon purge was directed over the inner window area to sweep the sodium vapor away from the window surface. This has significantly reduced the sodium vapor collection on the view port window. Emphasis has also been placed on limiting the handling of high decay heat assemblies (greater than 6 KW) to minimize sodium vapor generation.

- Several of the buffered seals on the CLEM have developed leaks making it difficult to keep the buffer areas pressurized. In some of these cases, a constant argon purge is fed into the seal buffer area to assure that the leaking seal will not let contaminated gas within the cask bleed out.

- Failure of the computer input/output modules has been reduced by installing varistors across computer input or output terminals where inductive loads such as solenoid valves are used. Future plans include a total upgrade of the control system to replace out-dated computer components.

The CLEM problems have caused approximately 11 days of reactor downtime.

IVHM Three IVHM's are used to make the in-vessel core component transfers. Each unit consists of a rotating plug with a rotating arm/grapple under the rotating plug. Figure 4 illustrates a cut-a-way of the FFTF reactor vessel with an IVHM arm assembly located just above the reactor core. Figure 5 illustrates the IVHM and its various components.

The IVHM is a very complicated robotic machine that is totally computer controlled (even when performing manual moves). Numerous hardware (limit switches) and software limits are incorporated into the IVHM system to ensure that the machine does not collide with other in-vessel components. After a desired move is entered into the control console, the computer calculates the travel path, which is displayed to the operator on a video monitor, and then controls the drive of one or two functions to follow the calculated travel path. Toes are extended to cover surrounding core assemblies while grappling and pulling the designated component from the reactor core. The toes ensure that surrounding assemblies are not lifted with the extraction of the desired assembly. The computer monitors the withdrawal and insertion forces to prevent possible damage to components or equipment in the event of an interference fit. The IVHM is used to identify each assembly that is handled by rotating the assembly while a feeler arm follows binary coded notches on the radial surface of the component handling socket. A second computer is used to verify the projected travel path of the IVHM and to generate a video display illustrating the IVHM position. Mechanical mimics and position registers in the control console also indicate the IVHM position. The IVHM operating experience has been as follows:

- The operation of the IVHM rotating plugs have been excellent. The plugs are lowered onto a ledge in the reactor vessel cover during reactor operation to prevent migration of sodium vapors into the plug bearing. After the reactor is shutdown and cooled, the rotating plug is raised a small amount to permit plug rotation. Argon purge gas is applied to the plug annulus areas both during the refueling and reactor operation. The trouble free operating experience with rotating plugs at FFTF is almost unique for sodium reactor plants since they have required no maintenance in the first seven years of operation.

- The operation of the under sodium portion of the IVHMs have been relatively trouble free. Movement of the sliding hold down toes located in each arm has exceeded the design limit of the electric drives and manual operation is now required. Operating procedure changes have been made to minimize the use of these toes. At the start of each refueling period, high friction is also noted in the grapple drive systems but decreases to normal levels after a few drive cycles.

- The IVHM computer program is written in assembly language, has been modified many times and is difficult to maintain and modify. The computer systems have become obsolete and are not vendor supported for spare parts and maintenance. Consequently, an IVHM control system upgrade is in progress. Figure 6 illustrates the current IVHM control console which utilizes numerous "thumb-wheel" switches and digital meters. The new control system is being designed using touch screen control on video monitors. Figure 7 illustrates a video screen that is used for controlling vertical drives and Figure 8 illustrates a video representation of the arm jack and grapple positions. The vertical bar graphs on each side illustrate the acceptable push and withdrawal forces applied to the arm jacks and the grapple. The development of this new touch screen control system has been significantly simplified by using a "Drawbridge" computer/user interface system that was developed by Westinghouse Hanford engineers.

IVHM problems have caused approximately 25 days of reactor downtime.

Control Rod Disconnect (CRD) Special tools are used to disconnect the CRD drive lines and permit rotation of the upper internals for refueling access with the IVHMs. After refueling, the internals are rotated back to the over-core position and the CRDs are reconnected for reactor operation. The CRD latching system is manually operated and is very complicated. As a result, they require special operator training and operator attention when disconnecting or reconnecting drive lines.

Problems experienced with the CRD system include the following:

- On two occasions, there was bonding (possible self-welding) between the upper and lower Inconel R position indicator rods. Bonding between the rods can cause a partial withdrawal of the lower rod, thereby preventing reconnecting the CRD driveline. Current disconnecting procedures include an inspection to detect and free any bonded rods. A coating of chromium carbide was applied to the lower end of the last replacement rods to prevent further bonding between the rods.

- Several CRDs were replaced after bellows cracked and permitted oxygen to enter the disconnect shaft annuli. The oxygen reacted with sodium creating products that restricted disconnect motion.

The CRD problems have caused approximately 12 days of reactor downtime.

SYSTEM UTILIZATION

The refueling system has been successfully used to perform eleven major refueling outages and six short outages. Typically, two major refueling outages occur each year. To date, core management activities have required over 1500 IVHM moves, over 1000 CLEM transfers, and over 300 BLTC transfers.

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[a]R. Huntington Alloy Inc., Huntington, VA.

System transfer time has decreased dramatically as experience with the system increases. Transfer of a new assembly from the shipping strongback to the IDS with the BLTC takes six hours. A CLEM transfer from IDS to the reactor vessel takes two hours. Return of an assembly to IDS requires two to four hours depending on the decay heat of the assembly being transferred. IVHM replacement of an assembly in the core with a "green" assembly from the fuel transfer port requires four and a half hours for the round trip. The coordination of the equipment moves has been refined to develop the shortest refueling critical path.

The FFTF outage strategy is to maintain the refueling activity as the critical path. Detailed statistics on equipment failure and other delays are gathered to permit effective outage length scheduling. The statistics are also used to identify failure trends and problem areas. Each major piece of equipment is assigned an availability goal which is used to monitor machine performance and our ability to repair it when it fails.

CONCLUSIONS

In general, the fuel handling system has operated as designed although attention must be given to problems related to sodium vapor deposition. Replacement of major components has not been required. Utilization of the system has been higher than originally intended due to the varied requirements of the irradiation program. The reliability of computers for machine control continues to be an area for improvement with system upgrades either planned or in progress.

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(2) NEIL B. CORRIGAN and J. DENBIGH STARKEY, "A Concurrent General Purpose Operating Interface," IEEE Transactions, Volume SE-10 No. 6, November 1984.

FUEL HANDLING OPERATIONS AT FFTF

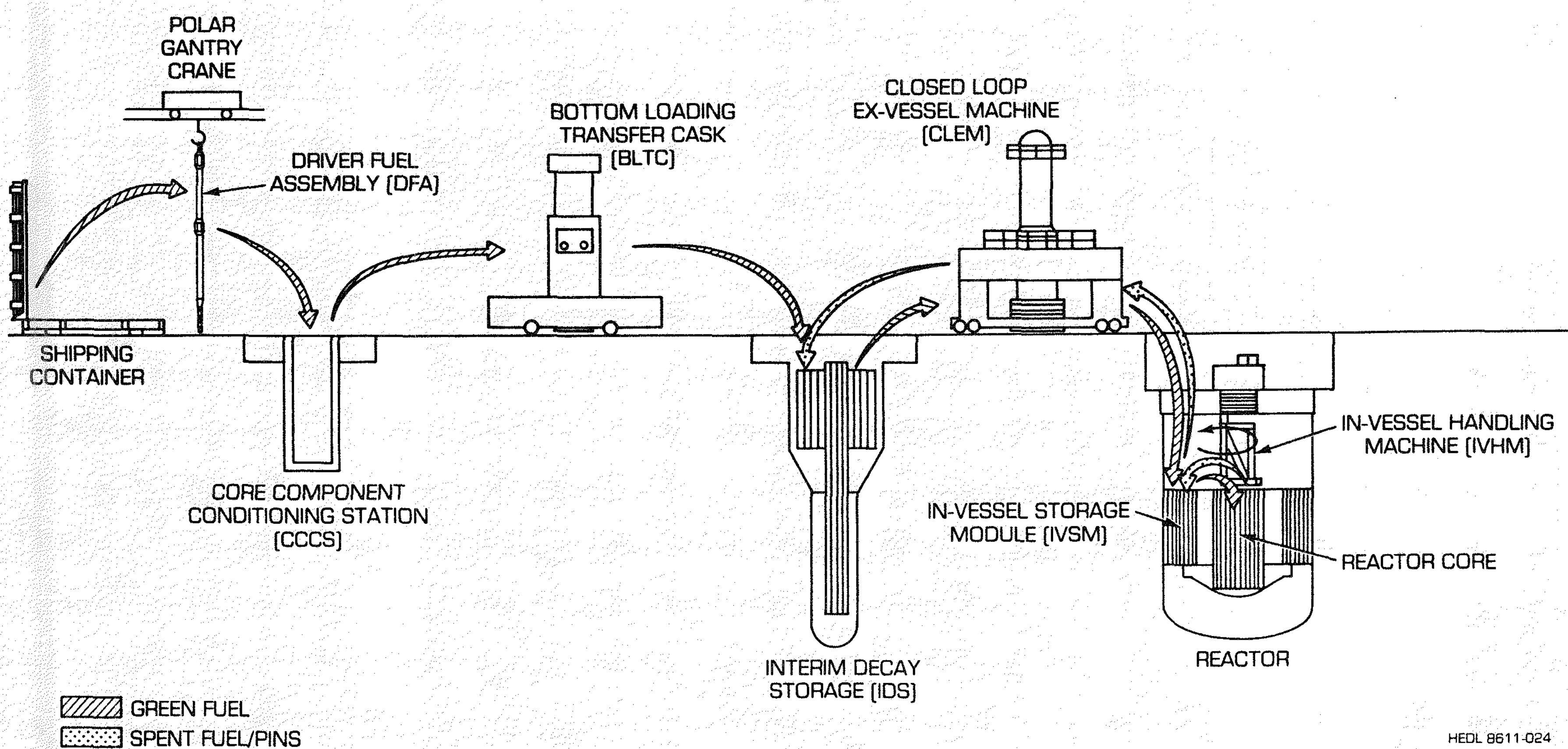

FIGURE 1

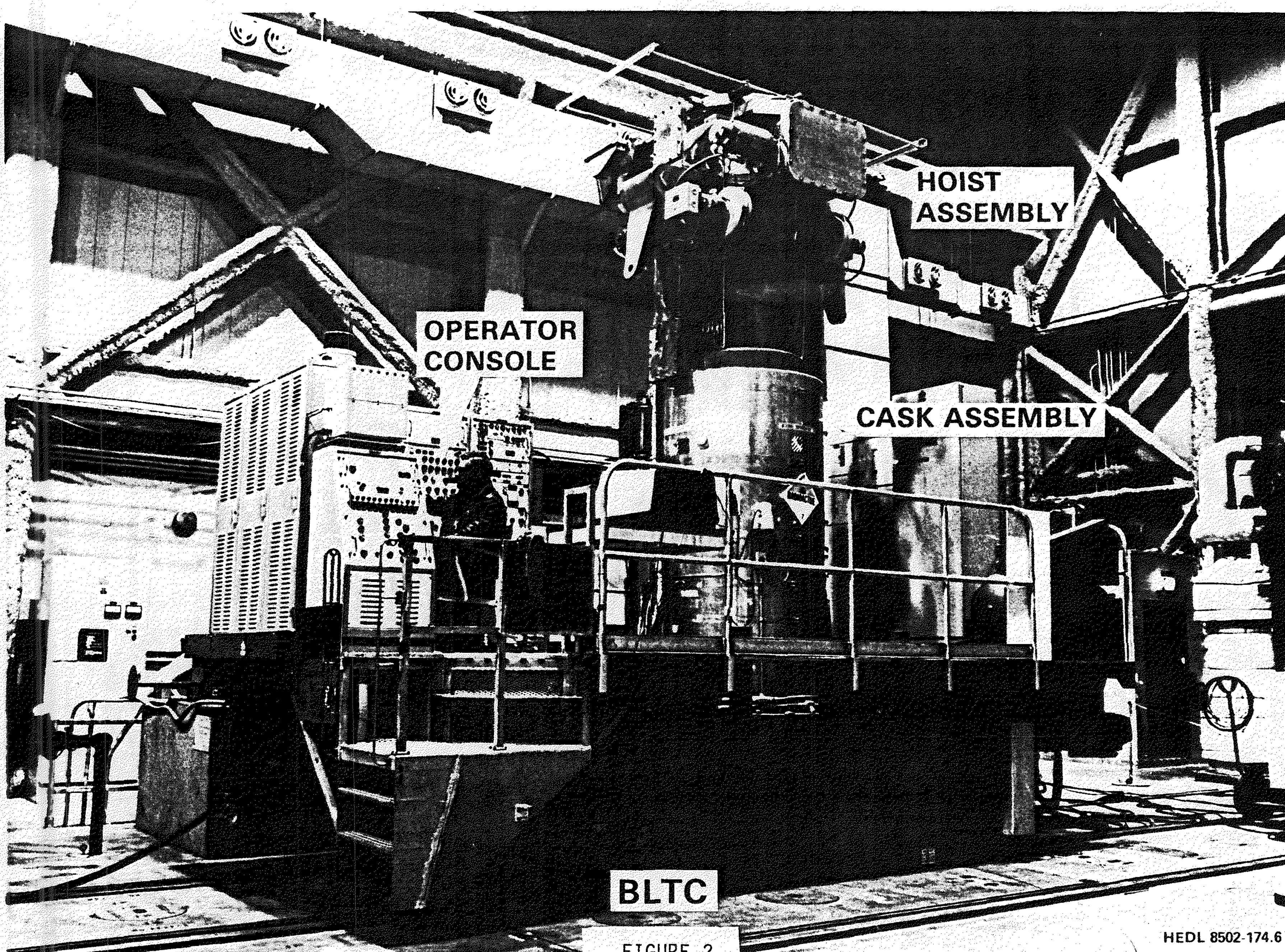

FIGURE 2

HEDL 8502-174.6

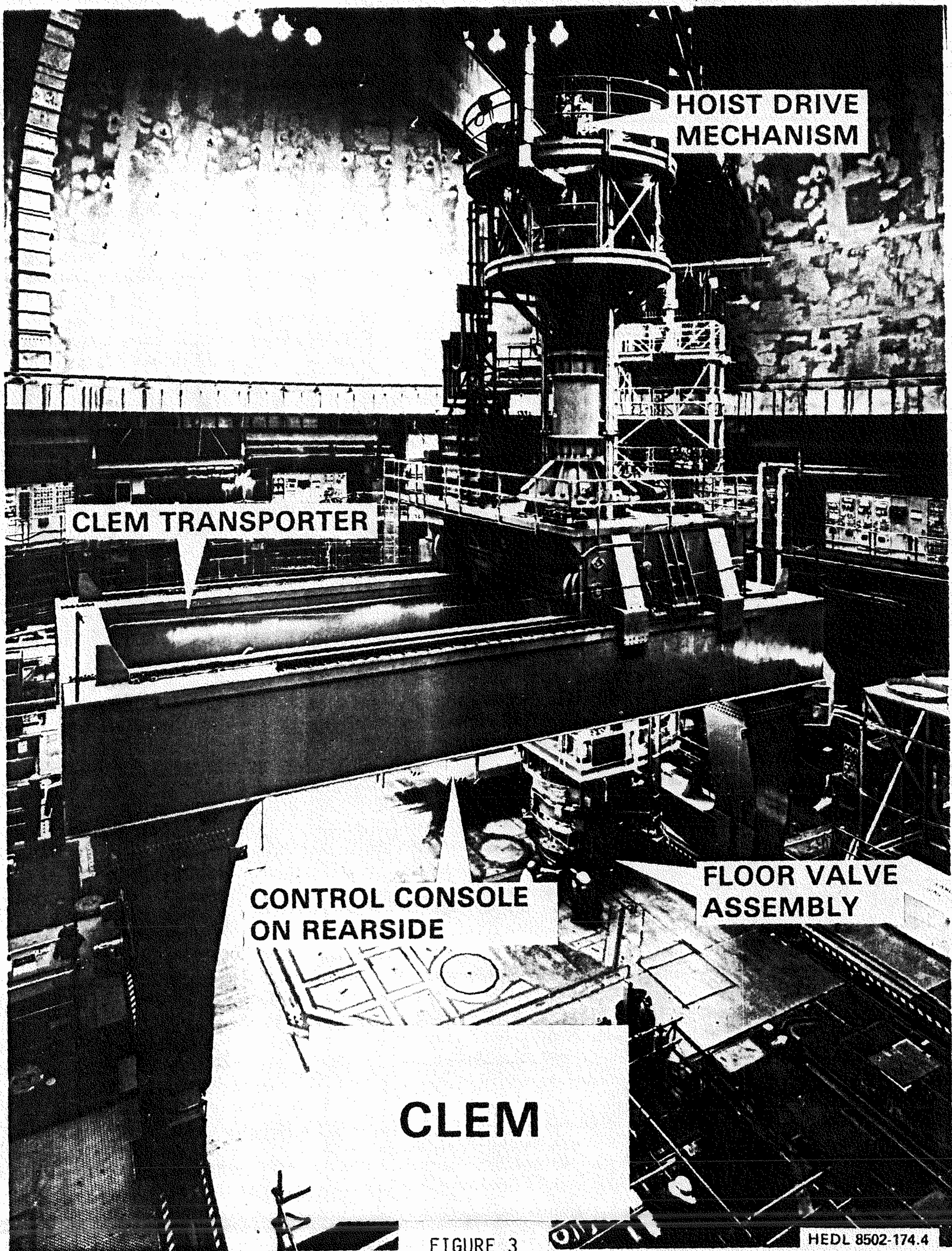
HOIST DRIVE
MECHANISM
CLEM TRANSPORTER
CONTROL CONSOLE
ON REARSIDE
FLOOR VALVE
ASSEMBLY
CLEM
HEDL 8502-174.4

FIGURE 3

FFTF REACTOR CUTAWAY

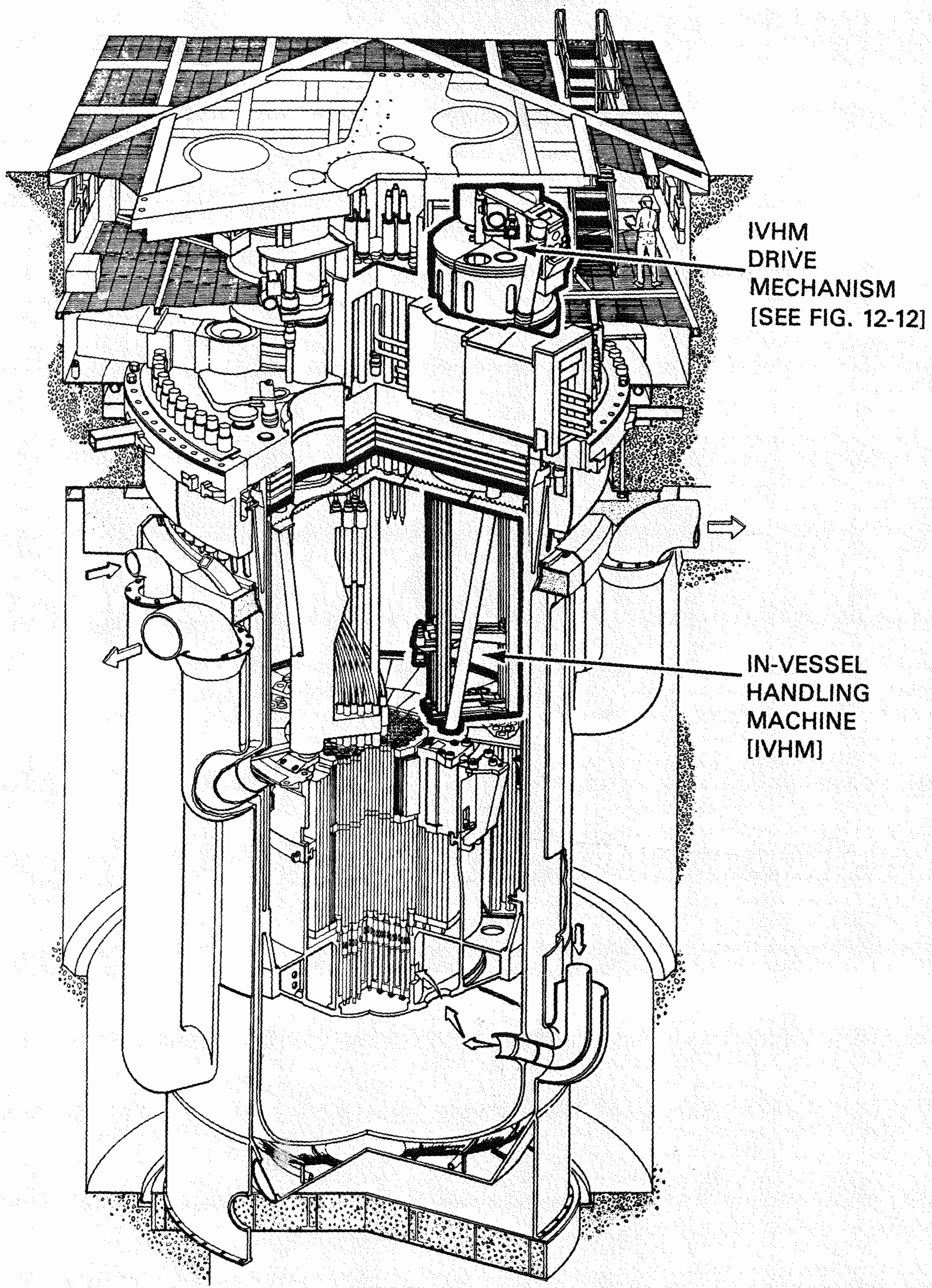

FIGURE 4

IN-VESSEL HANDLING MACHINE

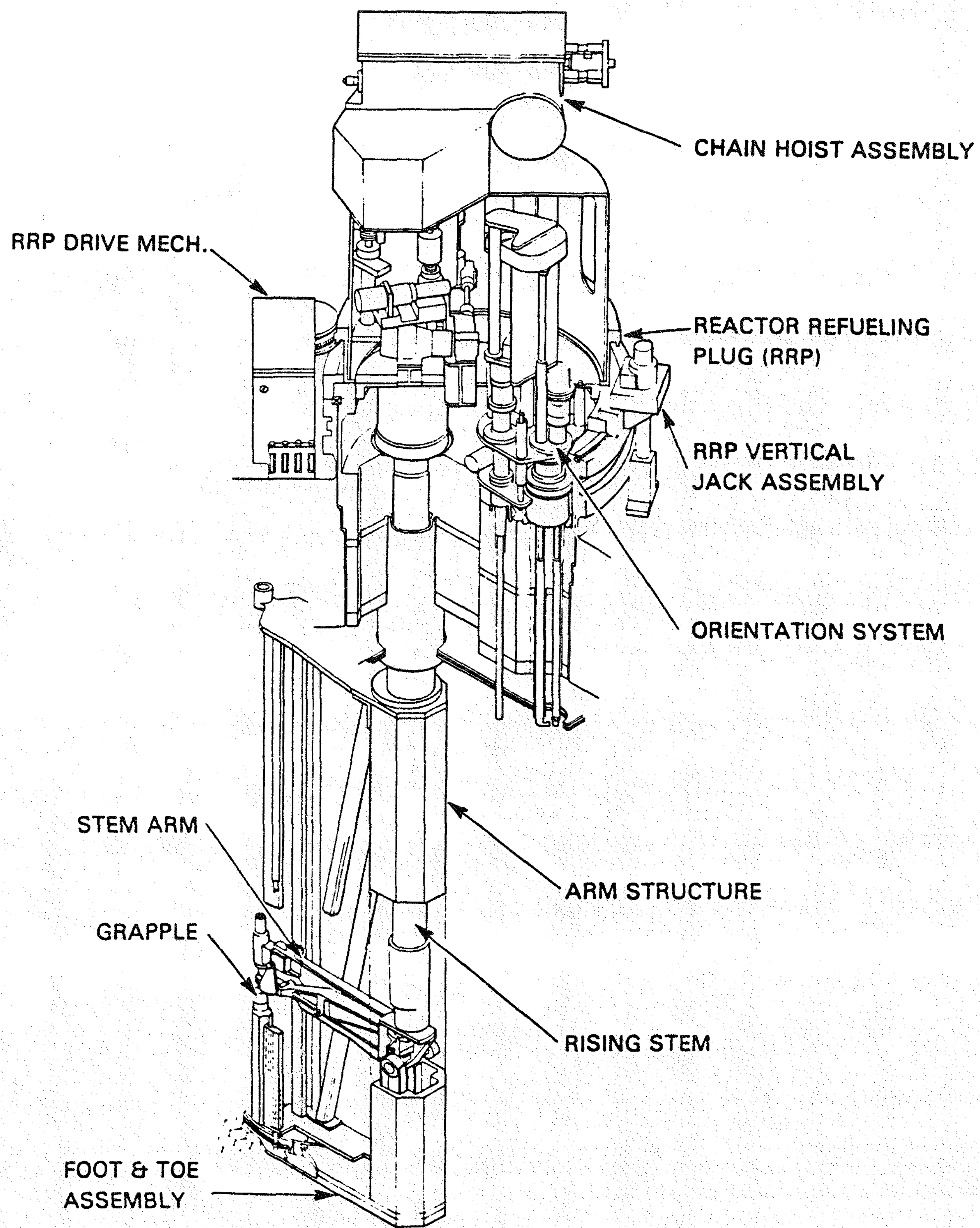

FIGURE 5

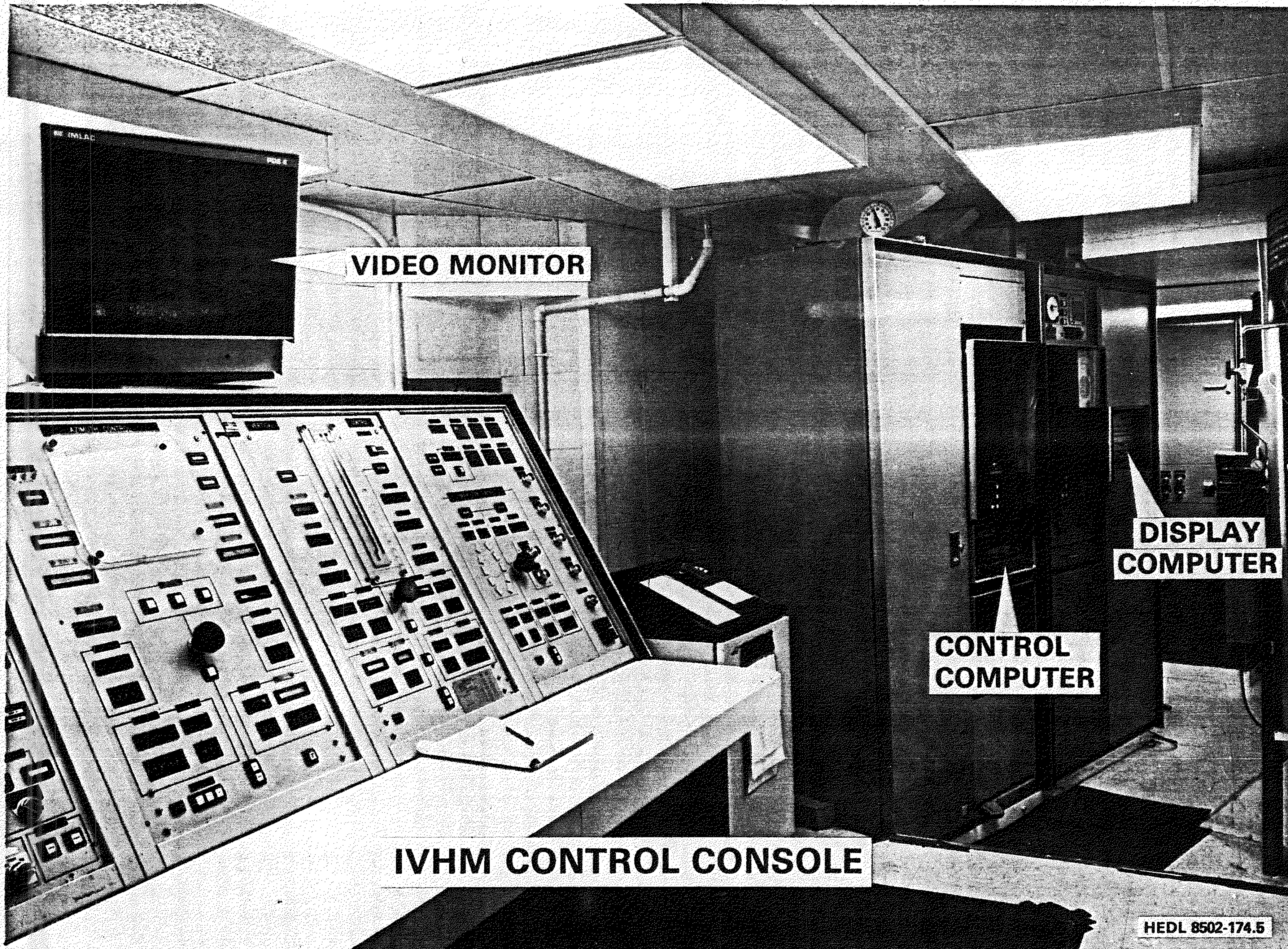
VIDEO MONITOR
DISPLAY COMPUTER
CONTROL COMPUTER
IVHM CONTROL CONSOLE
HEDL 8502-174.5

FIGURE 6

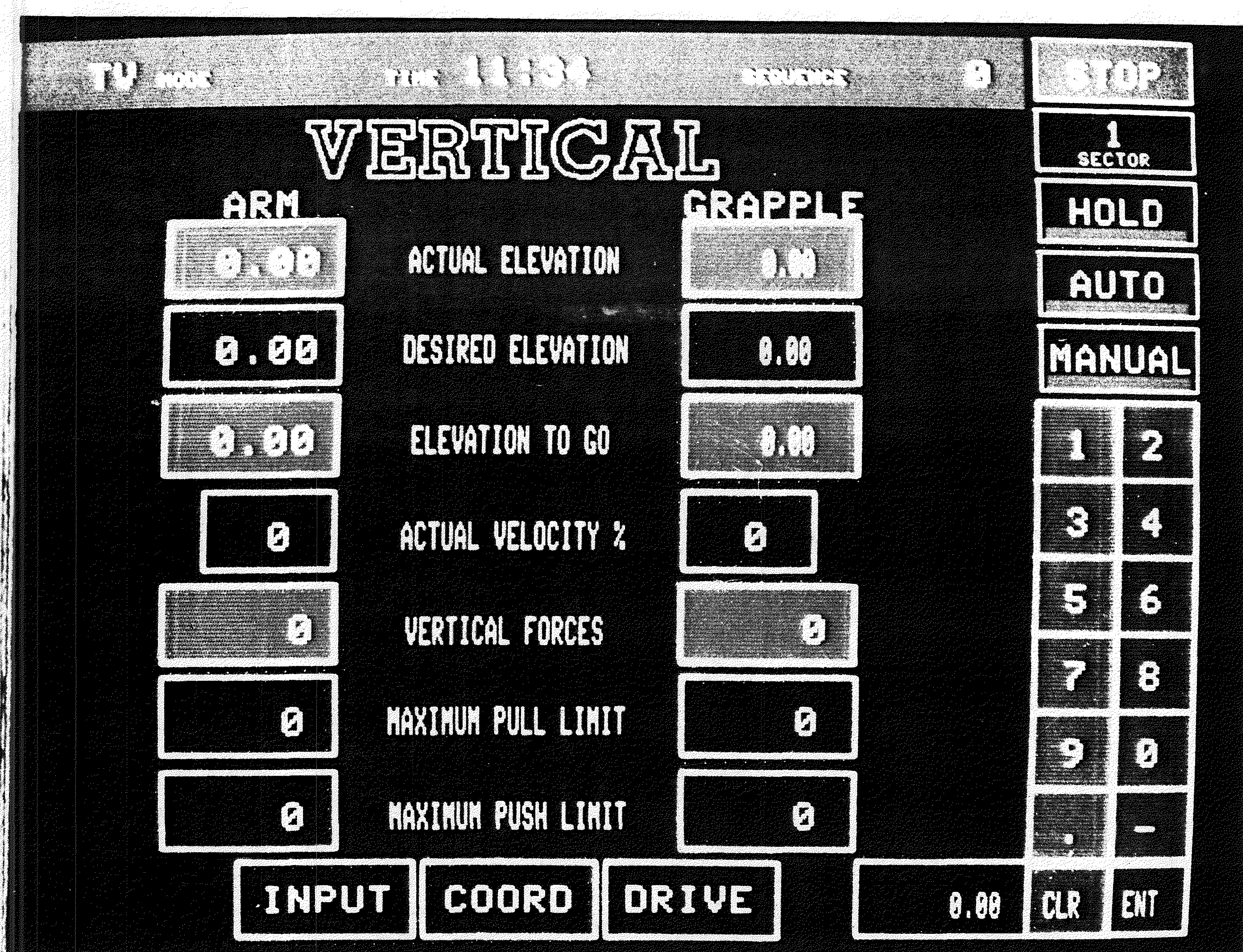
STOP
VERTICAL
1
SECTOR
HOLD
AUTO
MANUAL
ARM
GRAPPLE
ACTUAL ELEVATION
DESIRED ELEVATION
ELEVATION TO GO
ACTUAL VELOCITY %
VERTICAL FORCES
MAXIMUM PULL LIMIT
MAXIMUM PUSH LIMIT
0.00
0.00
0.00
0.00
0.00
0.00
0
0
0
0
0
0
0
0
1 2
3 4
5 6
7 8
9 0
. -
CLR ENT
0.00
INPUT
COORD
DRIVE

FIGURE 7

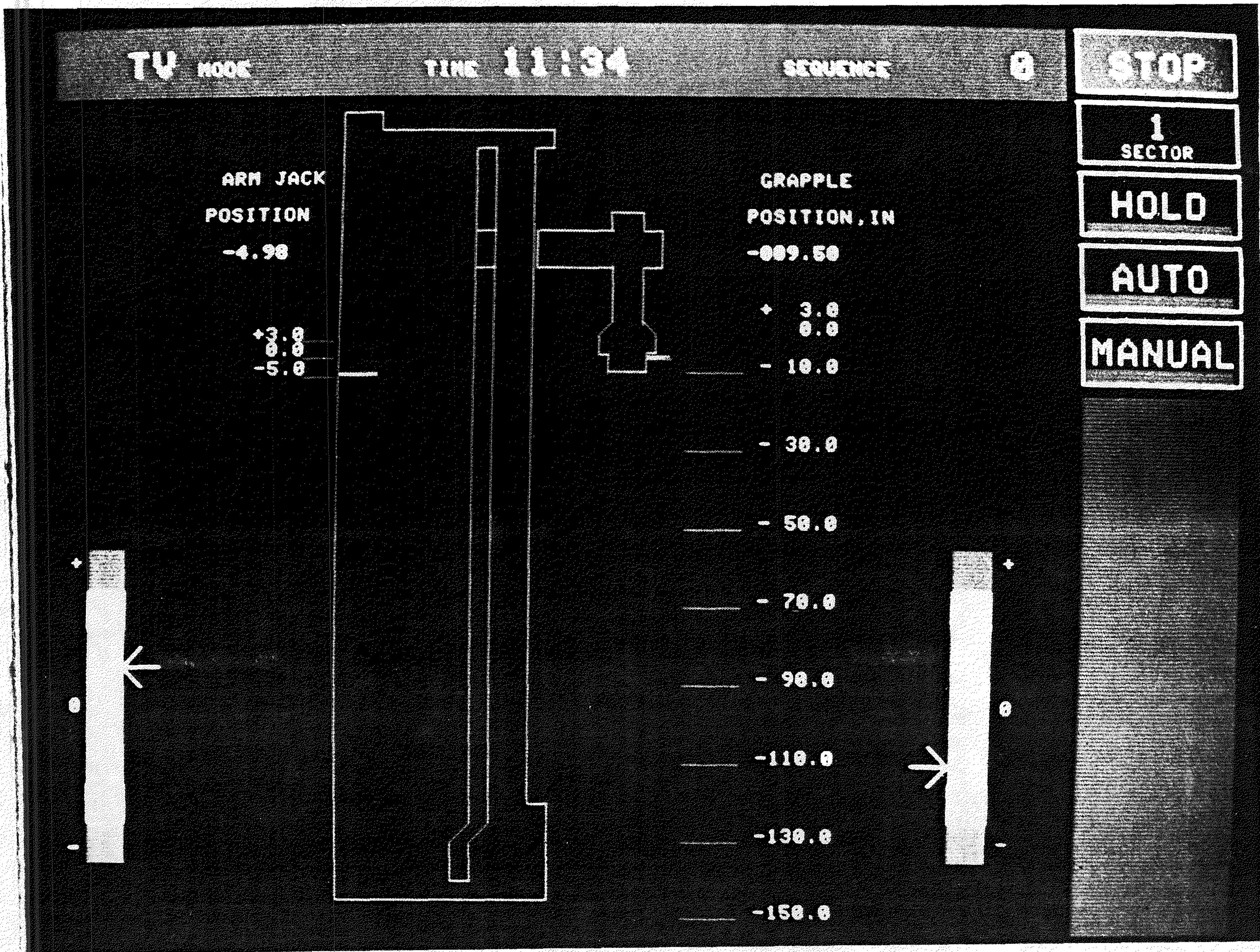
TV MODE
TIME 11:34
SEQUENCE 0
STOP
1
SECTOR
HOLD
AUTO
MANUAL
ARM JACK
POSITION
-4.98
+3.0
0.0
-5.0
GRAPPLE
POSITION, IN
-009.50
+ 3.0
0.0
- 10.0
- 30.0
- 50.0
- 70.0
- 90.0
-110.0
-130.0
-150.0
+
0
-
+
0
-

FIGURE 8