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CLASS I
MARCH 1985

LA SALLE UNIT 1
FINE MOTION CONTROL ROD DRIVE
DEMONSTRATION TEST DESCRIPTION

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1. INTRODUCTION

A fine motion control rod drive (FMCRD) has been designed jointly by General Electric, Hitachi, and Toshiba for BWR application. It utilizes an electrically driven, screw actuated drive for shim motion with hydraulic action (i.e., accumulator supplied) for scram motion. It is proposed that an FMCRD demonstration in a reactor environment be performed at LaSalle County Station Unit 1. The FMCRD's performance demonstration will be for one fuel cycle of an 18-month duration.

The FMCRD design has received considerable development and experience. It has passed extensive 40-yr equivalent life qualification tests. The FMCRD concept is currently in use in European BWR reactors. The particular FMCRD intended for use at LaSalle Unit 1 will have received a 7.5-yr equivalent life qualification before installation at the site.

For the FMCRD demonstration, a single FMCRD will be placed in a peripheral location of the LaSalle Unit 1 core. In this low reactivity worth location, a rod withdrawal error or a rod drop accident of this control rod will result in peak fuel enthalpies less than the licensing basis 170 cal/gm and 280 cal/gm safety limits, respectively. Since the FMCRD position indicating system is not compatible with the plant's locking piston control rod drive (LPCRD) position indicating system, the FMCRD position will be bypassed from the plant's rod pattern controls. When the rod pattern control system is enforcing rod pattern constraints, the FMCRD will be fully inserted. By taking these administrative actions, the plant's rod drop accident analysis will not be affected.

Although the FMCRD will have SCRAM capability and receive the plant's scram signal, its scram performance will be affected by the limitations of the site's CRD hydraulic supply system. For this reason, it has been determined that the FMCRD's peripheral location has a negligible impact on the plant's scram reactivity insertion rate. The "All Rod's Blocked" signal, such as from refueling interlocks, will be enforced on the FMCRD.

The preceding highlighted FMCRD design development and plant precautions are some of the measures taken to assure a successful and safe FMCRD in-plant demonstration. The following is a further description of the FMCRD, its supporting equipment, and plant safety/operational evaluations.

2. FMCRD DESCRIPTION

The FMCRD features low maintenance/high reliability and added plant operational flexibilities. The FMCRD is electrically driven for shim motion and hydraulically driven for scram motion. The main components of the FMCRD are the hollow piston, buffer springs, screw shaft, ball nut, unweighing detection assembly, drive motor, and position synchros. These major components of the FMCRD are shown in Figure 1.

Normal drive motion (or shim motion) is accomplished through an electrically powered stepping motor. Normal drive motion speed is 1 inch per second. The stepping motor turns a screw shaft and a ball-nut assembly translates the screw shaft's rotational motion to linear motion. The hollow piston, which is coupled to the control rod, rests on the ball-nut assembly. The ball-nut assembly is not coupled to the hollow piston to allow the hollow piston to scram freely on demand. The ball nut's translational motion will lift the hollow piston when rod insertion is desired. When rod withdrawal is desired, the ball-nut is retracted which allows the hollow piston to withdraw by its own weight.

Upon receipt of a scram signal, high pressure water from the scram accumulator lifts the FMCRD hollow piston away from the ball-nut assembly and rapidly inserts the hollow piston and coupled control rod. Water in the CRD is discharged into the reactor vessel. Disc springs buffer the rapid insertion at the end of rod travel. When the hollow piston leaves the ball-nut assembly, two latches are cammed out. These latches will latch into notches located every 8 inches on the CRD guide tube when the CRD comes to rest. Therefore, after scram completion the latches will hold the control rod in place at the full-in position. A drive-in signal is also received by the drive motor upon receipt of a scram signal. Within 2 minutes following scram

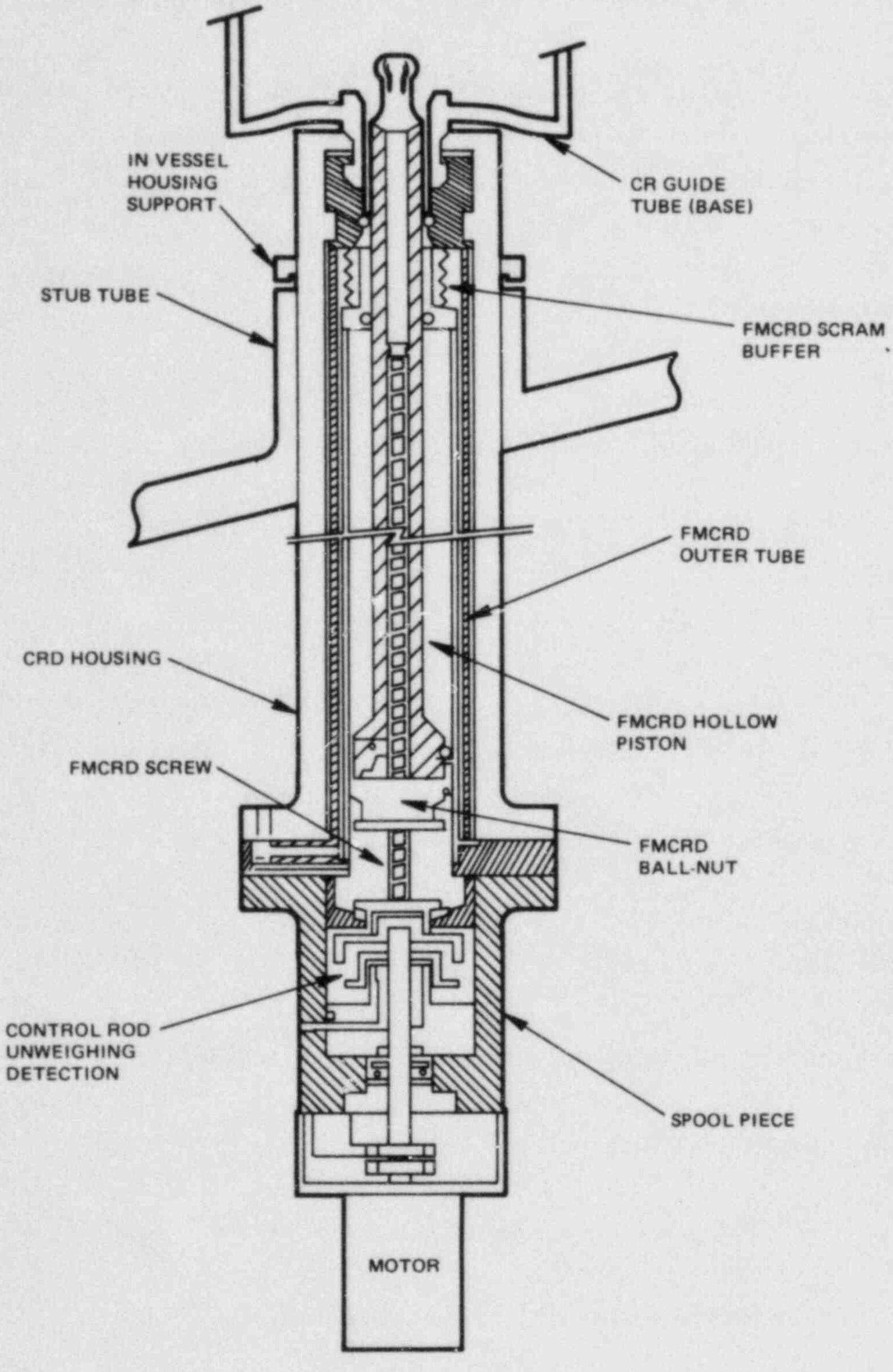

Figure 1. FMCRD Schematic

initiation, the ball-nut assembly will: (a) catch-up with the drive piston; (b) cam-in the latches; and (c) support the control rod's weight.

An unweighing detection assembly will detect the loss of weight due to a stuck control rod and enforce a rod withdrawal block signal. The unweighing detection assembly consists of a magnet attached to a spring. When the spring rises because of a loss of control rod weight, the magnet's movement changes the state of an external reed switch and causes a rod withdrawal block signal to be enforced.

The FMCRD uncoupling is achieved through actuation of permissive logic which will allow CRD withdrawal overtravel. A plug located in the coupling spud will then move and allow the spud to decouple from the control rod.

The FMCRD pressure boundary components comply with the ASME Class I requirements. This is analogous to the LPCRD design conformance.

Fundamentally, the LPCRD differs from the FMCRD by utilizing (a) hydraulic action for normal drive motion; (b) an external scram discharge for scram motion; and (c) scram capability with reactor pressure as a backup to the scram accumulators.

In summary, utilization of the FMCRDs offers the following plant features:

a. Diverse means of rod insertion (electrical/hydraulic)

b. Control rod separation detection

c. Improved plant maneuverability

d. Reduced CRD maintenance requirement

3. FMCRD SUPPORTING EQUIPMENT DESCRIPTION

The FMCRD utilizes both electric and hydraulic power sources. Normal drive motion is achieved through a stepping motor. The stepping motor is powered by normal plant ac power via an inverter and its motor controls. Rod position information is supplied by redundant synchro transmitters. The scram motion is achieved through the stored energy of a hydraulic accumulator. The hydraulic accumulator's charge is maintained by the existing plant's CRD hydraulic supply system. A description of the FMCRD's normal drive and scram controls is given in the following subsections.

3.1 FMCRD ELECTRICAL CONTROLS

The FMCRD electrical control for the plant demonstration consists of three major panels and information links between the FMCRD, its hydraulic control unit (HCU), the plant's Control Rod Drive System (CRDS) and the plant's Reactor Protection System (RPS). The discrete hardware and the information which passes between them is schematically illustrated in Figure 2.

The Operation Panel provides the operator interface. From this panel, the operator makes FMCRD movement requests and receives indication of the system's status.

The Control Panel is the main controller of information. It communicates with the FMCRD Operation Panel, the FMCRD Local Panel, the plant's RPS and the plant's CRDS. All logic operations are performed at this panel. In addition to operating on incoming signals, the Control Panel receives power from the plant and distributes it to the Operation and Local Panels.

The Local Panel receives incoming control signals and ac power from the Control Panel. The ac power is converted into appropriately modulated dc power to drive the stepping motor. The Local Panel also passes FMCRD position and other sensor data to the Control Panel.

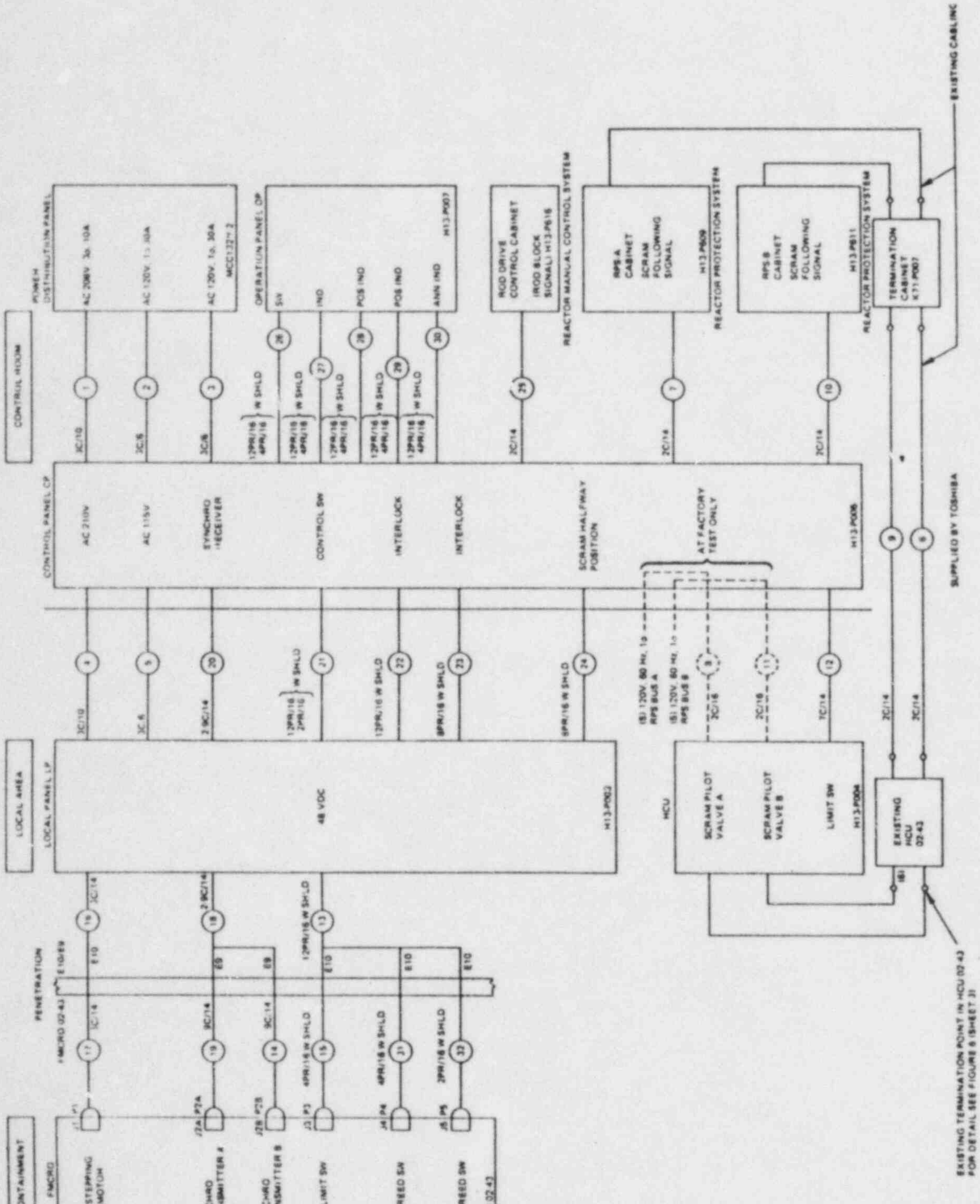

Figure 2. FMCRD Controls

3.1.1 Operation Panel

The Operation Panel's layout is illustrated in Figure 3. From this panel, the operator selects and initiates step or continuous rod movement commands. The LED indicators display both the current and target positions. In addition to accepting operator commands, several annunciators notify the operator of the system's status.

The FMCRD is capable of moving in multiples of 1, 5, 25, 50, and 100 of the 3-mm base increment. To operate the drive, select the desired increment from the "Step Number Set," depress and hold the "Insert" or "Withdraw" pushbuttons and select the "Continue" pushbutton. When insertion is required and it is necessary to override the system timer, an "Emergency Insert" switch is available. If the rod needs to be decoupled for maintenance then the keylocked overtravel switch must be turned to "Permit" to allow operation of the drive in the overtravel region.

The Operation Panel contains several indicators designed to give the operator a complete picture of the FMCRD's status. The most important of these are described below.

a. Current Position Indicator. An LED indicator displays the rod's current position in millimeters as obtained from the synchro transmitter. During continuous driving, the indicator follows the rod's movement.

b. Target Position Indicator. A similar LED indicator displays the operator selected target position. The target position is the sum of the current position and the selected step. When the rod is stationary or is following a scram, this indicator does not display any values.

c. Accumulator Trouble. An "Accumulator Trouble" indicator activates when the accumulator's nitrogen pressure is low or its water level is high.

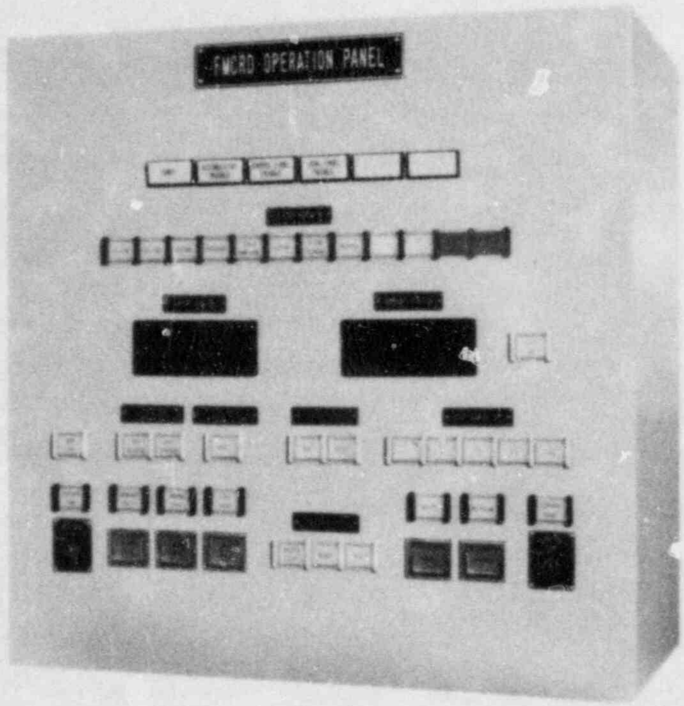

Figure 3. FMCRD Operation Panel

d. Drift. If the drive moves without receiving an insert, withdraw, or scram signal, then the drift indicator activates.

e. Control Panel Trouble. The "Control Panel Trouble" indicator activates if a circuit fails or other abnormal condition is detected.

f. Local Panel Trouble. The "Local Panel Trouble" indicator activates if an inverter fails or other abnormal condition is detected.

g. Full-In. "Full-In" indication results when the rod reaches 0 mm.

h. Full-Out. "Full-Out" indication results when the rod reaches 3660 mm (144 inches).

i. Overtravel. An "Overtravel" indicator activates when the drive is being operated below the "Full-Out" position.

j. Separation. When the rod separates from the ball nut, the "Separation" indicator activates.

k. Scram Complete. "Scram Complete" indication occurs when a scrammed rod reaches the full-in position.

l. Scram. Following manual or automatic scram, a "Scram" indicator activates.

m. Scram Following. Until the ball nut reengages with the rod, the "Scram Following" indicator activates after a scram.

n. Uncouple. "Uncouple" indication results when the rod is decoupled in the overtravel region.

3.1.2 Control Panel

The Control Panel provides the necessary logic to execute operator commands and prevent unsafe operation.

The operator initiates drive motion from the Operation Panel. After the motor stops, the rod cannot be moved again for 3 seconds. The system automatically resets itself after the 3 seconds have elapsed.

In addition to its fine motion capability, the operator can insert or withdraw a rod continuously. Once again, when the rod stops, movement is inhibited for 3 seconds.

If at any time the "Emergency Insert" pushbutton is depressed, all other ongoing operations, with the exception of scram, are terminated, and the rod is driven into the core.

Automatic scram signals originate from the plant's RPS. Upon receipt of such a signal, the rod scrams via hydraulic pressure. Simultaneously a "Scram Follow" signal is issued to the stepping motor. The motor responds by driving the ball nut until it reengages with the rod.

When both the "Manual Scram A" and the "Manual Scram B" pushbuttons on the main control room panel are depressed simultaneously, the scram pilot valve is deenergized, and the FMCRD scrams (along with all the other CRDs). This state is held by a self-hold circuit. To reset the system, the Scram Reset Switch on the main control room panel must be sequentially rotated from its normal position to Group 1/2 and to Group 3/4 positions and back to normal.

When the rod reaches 3660 mm (144 in.), a full-out reed switch closes and issues a rod withdrawal block signal. To uncouple the rod for maintenance purposes, the drive must be moved to 3728 mm (≈147 in.). To allow such a movement, the overtravel switch is positioned to "Permit." By so doing, this switch bypasses the inhibit signal from the synchro position

transmitter and the rod withdrawal block from the full-out switch. Since the over-travel region is not a multiple of the base increment, step motion cannot be used.

3.1.3 Local Panel

The local panel modulates motor driving power according to incoming operation instruction signals. Motor driving power is processed via a converter and inverter unit. The converter unit requires 115V + 10%-15%, 60/50 Hz input voltage and outputs of 5, 15, or 24 VDC voltage to the inverter unit. The inverter unit provides pulses of variable voltage and current for stepping motor actuation according to control signal demands.

3.2 FMCRD HYDRAULIC CONTROLS

The primary function of the FMCRD hydraulic controls is to scram the control rod upon demand. A second function of the FMCRD hydraulics is to provide continuous CRD purge water flow. The FMCRD hydraulic controls are performed at its HCU.

The FMCRD HCU is similar to the present locking piston control rod drive (LPCRD) HCU. The FMCRD HCU's nitrogen and water bottles are larger than the LPCRD HCU's bottles, but the FMCRD HCU has no directional control valves, nor a scram discharge valve. Since the FMCRD is electrically driven, the FMCRD's HCU has no need for the hydraulic drive directional controls required by the LPCRD for shim motion. During scram, the FMCRD discharges into the reactor vessel. Therefore, the conventional LPCRD scram discharge valve, piping, and discharge source are not required. With the elimination of the external CRD discharge source, the FMCRD is not capable of scram with reactor pressure as the driving force. Since the FMCRD scram's against reactor pressure and allows greater CRD leakage flow, a scram accumulator that is larger than the LPCRD is required. Operation of the scram pilot solenoid valve by the RPS is identical to that of the LPCRD. The scram accumulator charging and CRD purge flow is provided by the plant's CRD

hydraulic supply system. The FMCRD purge flow rate requirements are identical to the LPCRD cooling flow rate requirements. Figure 4 illustrates the FMCRD/LPCRD HCU piping interconnections for LPCRD Position 02-43.

As previously discussed, the FMCRD requires greater scram accumulator energy than the LPCRD. The FMCRD accumulator would be charged to a higher final pressure than the typical BWR5 (LaSalle class) LPCRDs. However, the plant's CRD hydraulic supply system cannot supply the additional charging pressure desired for the FMCRD accumulator. The FMCRD hydraulic modification would include a booster pressure system (i.e., small booster pump) to charge the FMCRD accumulator up to 1700 psig at rated reactor pressures. The increased pressure would be adequate for the FMCRD to comply with the plant's scram time surveillance requirements. Further discussion of the FMCRD's scram time requirements, given its peripheral location, is presented in Section 5 of this report.

The booster pump arrangement is shown in Figure 5. This system consists of one air-operated booster pump with a maximum operating pressure of 2000 psig. The pump will operate on instrument air and will have a boost ratio of 30 to 1. In other words, a 1 psig air pressure is required to increase the charging water pressure to 30 psig. The booster pump suction water comes from the charging water line of HCU 02-43. A bypass line with a globe stop check valve will be installed to provide the initial fillup of the FMCRD HCU (FMHCU). A pressure relief valve is provided at the discharge to limit the maximum charging water pressure. In addition, a high pressure alarm connected to the FMCRD HCU low pressure alarm annunciator will inform the operator of an HCU pressure problem (high or low pressure). An air pressure regulator valve is provided to adjust supply air pressure to the booster pump.

The FMCRD's HCU piping will be tied into the present LPCRD's HCU. The LPCRD's insert and withdrawal lines will be used by the FMCRD as scram insert lines. The LPCRD's HCU accumulator charging and cooling flow functions are extended to the FMCRD's HCU. The scram pilot solenoid valve's power will also be extended in conduit to the FMCRD's HCU. The scram pilot solenoid valve's power will also be extended in conduit to the FMCRD's HCU from the LPCR's HCU.

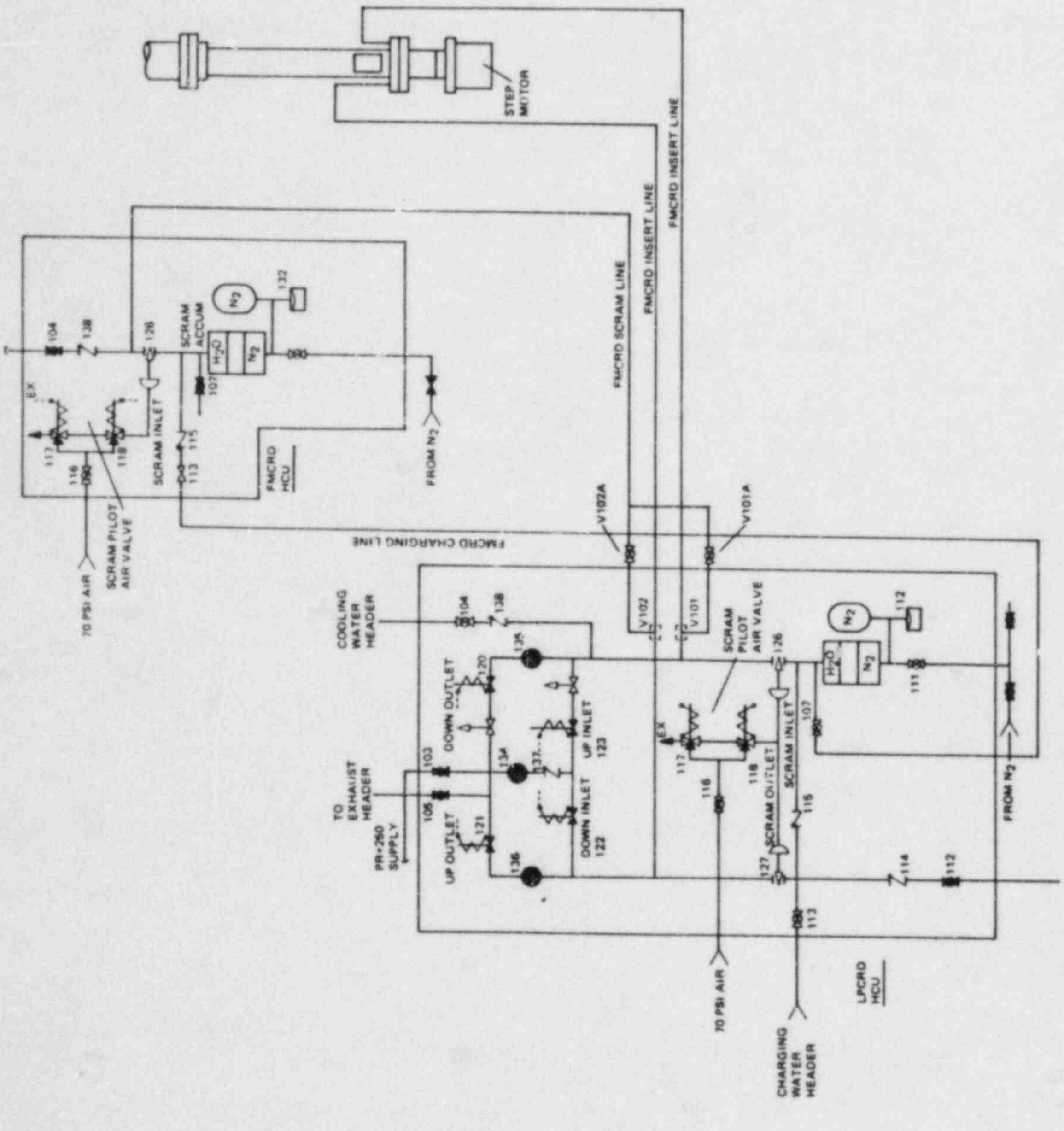

Figure 4. FMCRD/LPCRD HCU Piping Interconnections

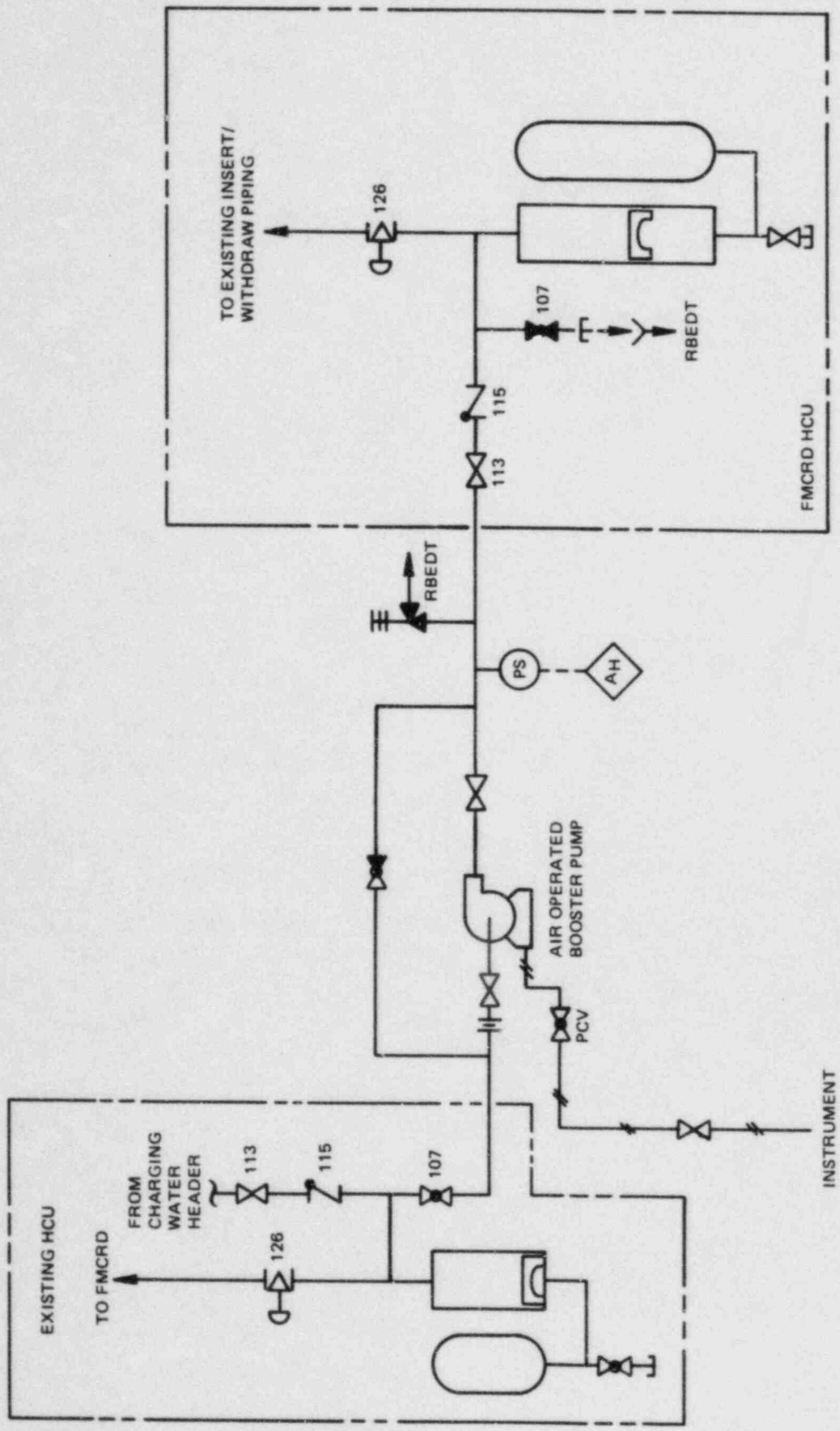

Figure 5. Booster Pump Concept

The FMCRD HCU is designed in accordance with 10CFR50, Appendix A, and manufactured under a controlled program that complies with 10CFR50, Appendix B. The accumulator and the nitrogen cylinder meets the requirements of the ASME Boiler and Pressure Vessel Code, Section VII, Division 1, and the remainder of the FMCRD hydraulic controls and piping are designed, constructed and inspected in accordance with the ANSI B31.1 codes. It will be verified by a GE San Jose test that the pipe loads created by the FMCRD scram action are bounded by the present LPCRD scram pipe loads.

4. FMCRD DEMONSTRATION TEST DESCRIPTION

It is proposed that an FMCRD and its supporting equipment be installed at LaSalle Unit 1 to observe and demonstrate the operations of the FMCRD in an operating plant environment. It is anticipated that the test will last for the duration of one plant fuel cycle. During reactor installation and removal of the FMCRD, handling methods, maintenance procedures, and radiation levels will be documented.

The following scheduled pre-operational tests will be performed following reactor installation to confirm its proper operations:

a. Friction Test

b. Coupling Test

   (1) Pull Test

   (2) Uncoupling Function

c. Functional Test

   (1) Drive Speed

   (2) Stepping

   (3) Scram

d. Interlock Test

e. Limit Switch Function

f. HCU Test

(1) "A" and "B" Circuit Test

(2) High Pressure and Low Pressure Alarm Test

During reactor operations the following data will be maintained by Plant Operations:

a. A brief statement of FMCRD operational history and reactor operating history every 6 months. Any abnormalities in FMCRD operation will be noted.

b. Typical traversing in-core probe (TIP) trace of TIP Probe nearest to FMCRD during control rod pattern change using FMCRD at least twice during the fuel cycle.

c. Reactor parameters such as thermal output, core flow rate, reactor pressure, and subcooling during the subject pattern change should be included in the preceding item (a) and during item (b).

At the conclusion of the plant demonstration, the drive shall be removed from the plant site and disassembled. All parts shall be visually examined for signs of wear, corrosion or other damage. Parts showing signs of damage or excessive wear shall be documented in a report and depicted by photograph, sketch, or dimensional inspection, if judged appropriate by the Test Director.

At the conclusion of the post-demonstration examination, radioactive portions of the drive shall be disposed of in accordance with the site

procedures. Other drive components and electrical panels shall be either retained or disposed of by mutual agreement between the Commonwealth Edison Company and the General Electric Company.

5. PLANT IMPACT

The fine motion control rod drive (FMCRD) will replace the locking piston control rod drive (LPCRD) currently in Position 02-43 in the LaSalle County Station Unit 1. Because the FMCRD operates differently and is separately instrumented from the LPCRDs, it is necessary to verify that all reactivity control requirements will be met with respect to the LaSalle FSAR and Technical Specifications and to determine procedural changes needed to accommodate the FMCRD. The reactivity control evaluations are divided into safety analyses and operational evaluations.

5.1 SAFETY ANALYSIS REVIEW

5.1.1 Control Rod Withdrawal Error

The FMCRD rod will be installed in a peripheral location at Position 02-43. Because of this location, analysis has shown its maximum worth will be less than 0.5% $\Delta k/k$ in the startup range. Therefore, withdrawal of the FMCRD rod will not significantly increase power or fuel enthalpy during startup. Under hot conditions, the LaSalle FSAR and Technical Specifications state that the Rod Block Monitor (RBM) automatically bypasses peripheral rods, confirming their unimportance in rod withdrawal error (RWE) and MCPR analyses under hot conditions. As stated in the LaSalle FSAR, a possible RWE event occurring during refueling is not considered feasible and is not evaluated. In addition, shutdown margin requirements will ensure that the reactor will remain subcritical with the highest worth rod and the FMCRD rod withdrawn, making an RWE event involving the FMCRD rod during refueling of no significance. In summary, the low reactivity worth FMCRD rod will have very little effect on peak fuel enthalpy and MCPR.

5.1.2 Control Rod Drop Accident

The design of the FMCRD System greatly reduces the probability of a control rod drop accident (CRDA). The FMCRD is equipped with a control rod separation (unweighing) detection system which detects the reduced weight on the drive should the control rod become stuck in the core. Drive withdrawal movement will be automatically terminated the instant the rod becomes stuck and, thus, prevent the control rod from potentially dropping from full-in to full-out. Analysis has shown that if the FMCRD is moved out of sequence and adjacent rods are withdrawn, the effect on the CRDA analysis is negligible.

The peripheral location of the FMCRD rod will cause it to have a very low reactivity worth such that the resulting peak fuel enthalpy in a CRDA would be far below the 280 cal/gm safety limit. Also, while the FMCRD rod will be bypassed in the Rod Sequence Control System (RSCS), it will be administratively treated as an inoperable rod. It will be moved only after the withdrawal/insert sequences of its Banked Position Withdrawal Sequence group are complete, thus staying within the analyzed rod pattern constraints for inoperable rods.

It is concluded that a CRDA event involving the FMCRD rod is of no consequence because of its peripheral location.

5.1.3 Shutdown Margin

Because the FMCRD rod is in a peripheral location, where its worth has been calculated to be less than 0.5% $\Delta k/k$, the shutdown margin of 1% $\Delta k/k$ will be easily met with the FMCRD rod withdrawn. Conservatively treating the FMCRD rod as inoperable with its position unknown for analysis purposes only, analysis has shown that the 1% $\Delta k/k$ shutdown margin can still be met with the FMCRD rod and the strongest rod fully withdrawn at the limiting point in the cycle. The 1% $\Delta k/k$ design shutdown margin provides assurance that the 0.38% $\Delta k/k$ Technical Specification shutdown margin will be met throughout the cycle. As a result, all shutdown margin requirements will be met during the second fuel cycle.

5.1.4 SCRAM Reactivity

Bounding analyses have been performed which demonstrate that the failure of the FMCRD to scram has a negligible impact on the plant's scram reactivity insertion rate. These analyses assumed that the highest worth, adjacent control rod drive also failed to scram. Therefore, the FMCRD need not be declared inoperable because of potentially excessive scram insertion times.

5.2 OPERATIONS REVIEW

The FMCRD rod will be treated as a special demonstration, and special test exceptions will be requested to exempt it from the existing Technical Specification requirements. Because of the low reactivity worth associated with the peripheral location of the FMCRD rod and the justification provided by the above evaluation, it is concluded that this special exception does not affect reactor operations or accident analyses and will not reduce the margin of safety as defined in the basis for any LaSalle Unit 1 Technical Specifications.

5.2.1 Control Rod Movement Control Systems

The FMCRD rod position, 02-43, will be bypassed in the RSCS and programmed out of the rod worth minimizer (RWM). This will free the FMCRD rod from Banked Position Withdrawal Sequence (BPWS) and notch movement restrictions. The RBM is automatically bypassed for peripheral rod locations such as 02-43 and will therefore be unaffected.

5.2.2 Rod Position Indication

The FMCRD rod position indication will be independent of the plant's Rod Position Information System (RPIS). Under normal operation, the FMCRD rod will have position indication over 100% of its range of movement at the

FMCRD Operation Panel. The FMCRD will not be moved until reactor power is greater than 25% and a rod pattern has been established. For SCRAM surveillance testing, it will have separate reed switch type position indication to verify SCRAM performance.

5.2.3 Refueling Interlocks

The refueling interlocks system will not receive a "rod-in" signal when the FMCRD rod is inserted during refueling. A special administrative procedure will be in place to ensure that the FMCRD rod is full-in before the signal to the refueling interlocks system can be jumpered to indicate full-in. The refueling interlocks system will not allow refueling bridge movement or withdrawal of any other control rod if the FMCRD rod is not indicated full-in. This procedure will make clear that the full-in signal can be jumpered only if the refueling bridge movement or control rod withdrawal is necessary. The procedure will include disarming the FMCRD by disconnecting the power supply to the electric motor to prevent inadvertent withdrawal during refueling.

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