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Tower Shielding Reactor II Design and Operation Report: Vol. 3 Assembling and Testing of the Control Mechanism Assembly

D. R. Ward
L. B. Holland

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TOWER SHIELDING REACTOR II DESIGN AND OPERATION REPORT: VOL. 3 ASSEMBLING AND TESTING OF THE CONTROL MECHANISM ASSEMBLY

D. R. Ward and L. B. Holland

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OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37830
operated by
UNION CARBIDE CORPORATION
for the
DEPARTMENT OF ENERGY

PREFACE

Information on the Tower Shielding Reactor II is contained in the TSR-II Design and Operation Report and in the Tower Shielding Facility Manual.

The TSR-II Design and Operation Report consists of three volumes:

ORNL-TM-2893, Volume 1, "Description of the Tower Shielding Reactor II and Facility," by L. B. Holland

ORNL-TM-2893, Volume 2, "Safety Analysis of the Tower Shielding Reactor II," by L. B. Holland and J. O. Kolb.

ORNL-TM-2893, Volume 3, "Assembly and Testing of the Tower Shielding Reactor II Control Mechanism Assembly," by D. R. Ward and L. B. Holland.

The material presented in Volume 3 was originally written in 1967 to serve as an informal guide for use in assembling and testing future control mechanism assemblies. The subsequent ORNL Quality Assurance (QA) Program will automatically take care of many of the inspections described here; however, Volume 3 also contains considerable material outside the scope of the routine QA procedures which should be helpful in the fabrication of future control mechanism assemblies.

CONTENTS

CONTENTS (Continued)

CONTENTS (Continued)

TOWER SHIELDING REACTOR II DESIGN AND OPERATION REPORT:
VOL. 3 ASSEMBLING AND TESTING OF THE CONTROL MECHANISM ASSEMBLY

1. INTRODUCTION

The mechanisms that are operated to control the reactivity of the Tower Shielding Reactor II (TSR-II), Fig. 1, are mounted on a Control Mechanism Housing (CMH), Fig. 2, that is centered inside the reactor core. The operation of a control mechanism is described in section 3.6 of Vol. 1 of this report. After a CMH is placed in service many parts of it become very radioactive so that, even if a CMH were accessible, it is not practical to adjust, maintain, or repair any part of it. Whenever a component of a CMH has not functioned correctly the CMH has been replaced. There is, therefore, a great incentive to make each CMH as reliable and durable as possible.

The information required to procure, fabricate, inspect, and assemble a CMH is contained in the ORNL engineering drawings listed in the appropriate sections. The components are fabricated and inspected from these drawings in accordance with a Quality Assurance Plan and a Manufacturing Plan. The material in this report describes the acceptance and performance tests of CMH subassemblies used by the Tower Shielding Facility (TSF) staff but it can also be used by personnel fabricating the components. This information which was developed and used before the advent of the formalized QA Program and Manufacturing Plans evolved during the fabrication and testing of the first five CMHs. Some of the information duplicates that covered in the shop drawings, but it is repeated here because it relates to specific problems encountered during the fabrication of previous CMHs. The numerous jigs and fixtures that have been developed specifically for use in fabricating and checking various parts and subassemblies are stored at the Tower Shielding Facility. The information concerning each CMH is tabulated in a separate bound log book. Information recorded includes deviations, nonconformances, all test results, photographs, discussions, and any information that may be useful in evaluating the performance of the CMH.

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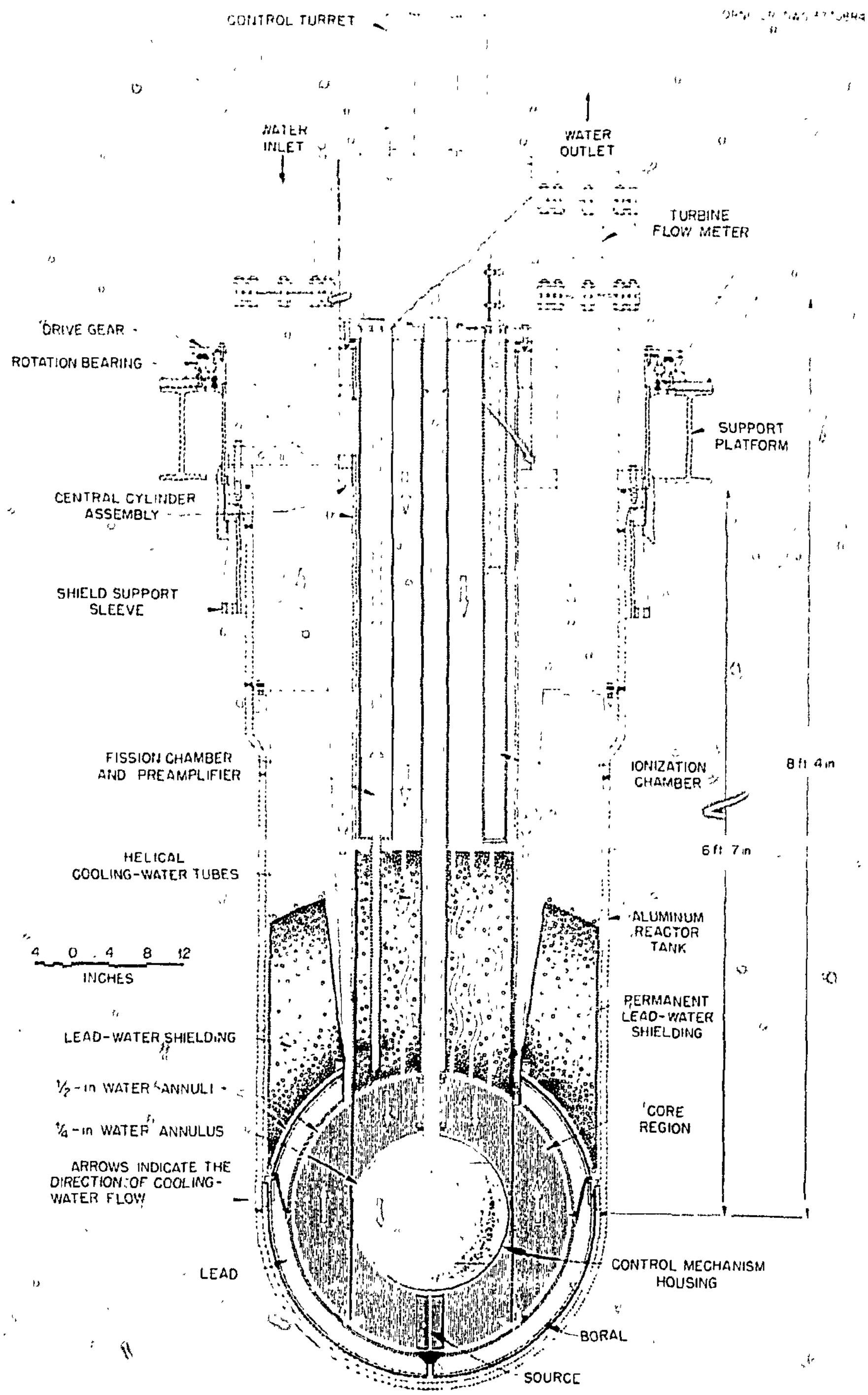

Fig. 1. Tower Shielding Reactor (Vertical Section).

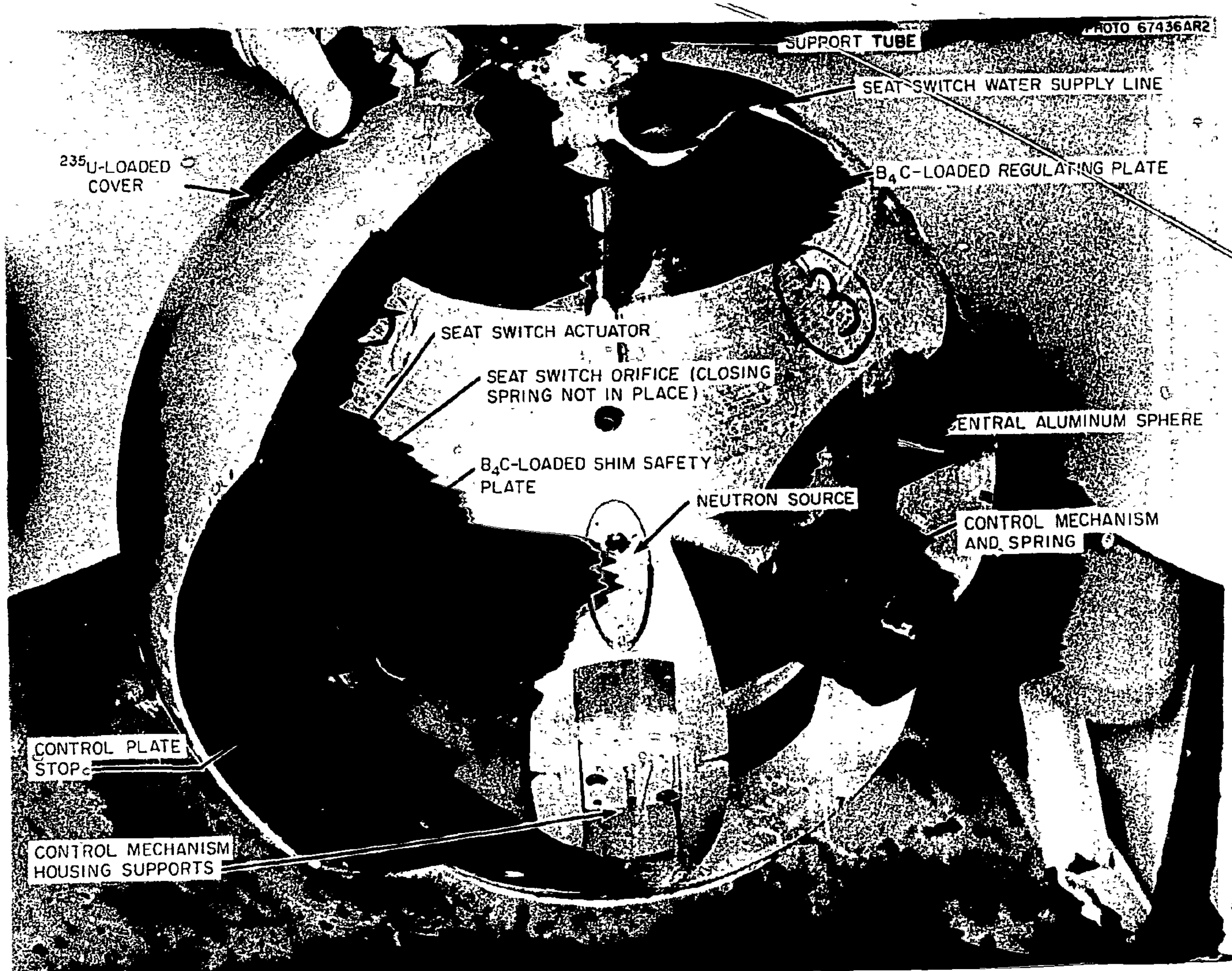

Fig. 2. Control mechanism housing.

2. CONTROL MECHANISM COMPONENT CHECKS AND ASSEMBLY SPECIFICATIONS

The control mechanisms, Figs. 3 and 4, are fabricated in accordance with ORNL Dwgs. M-20858-EM-002-D through -006-D. The procurement and fabrication have been performed by the ORNL Research Shops. Each mechanism is a custom-fitted assembly and all parts are labeled to ensure that parts from different mechanisms are not interchanged. The inspections and certifications specified in the Manufacturing Plan and in the Quality Assurance requirements result in completed components that are ready for acceptance testing with little or no modifications.

The certification and inspection reports are reviewed by TSF personnel to ensure that they meet the specifications noted in the following sections. Then the mechanisms are partially disassembled, examined, lubricated as indicated, and reassembled. When the work in this section is completed the mechanisms are ready for testing as described in subsequent sections.

2.1 Piston Rings

The piston rings used in CMH 2 through 6 were purchased on special order from Precision Piston Rings, Inc., Indianapolis, Indiana. Several dozen rings are still in stock at the TSF for use in future control mechanism housings.

2.1.1 Burrs - The piston rings are chromium plated by the supplier, and a trace of chromium buildup is sometimes noted at the 90° corners of the rings. The excess is removed by careful polishing with fine emery paper (400 to 600 grit).

2.1.2 Width - A micrometer spindle is locked 0.093 in. from its anvil and the gap is used as a gage through which each ring must pass. Special attention is given to the notched overlap section of the ring. Excessive width at this joint likely is the result of chromium buildup in the notch and this is removed by careful honing with a fine-grit stone having a corner angle of less than 90°.

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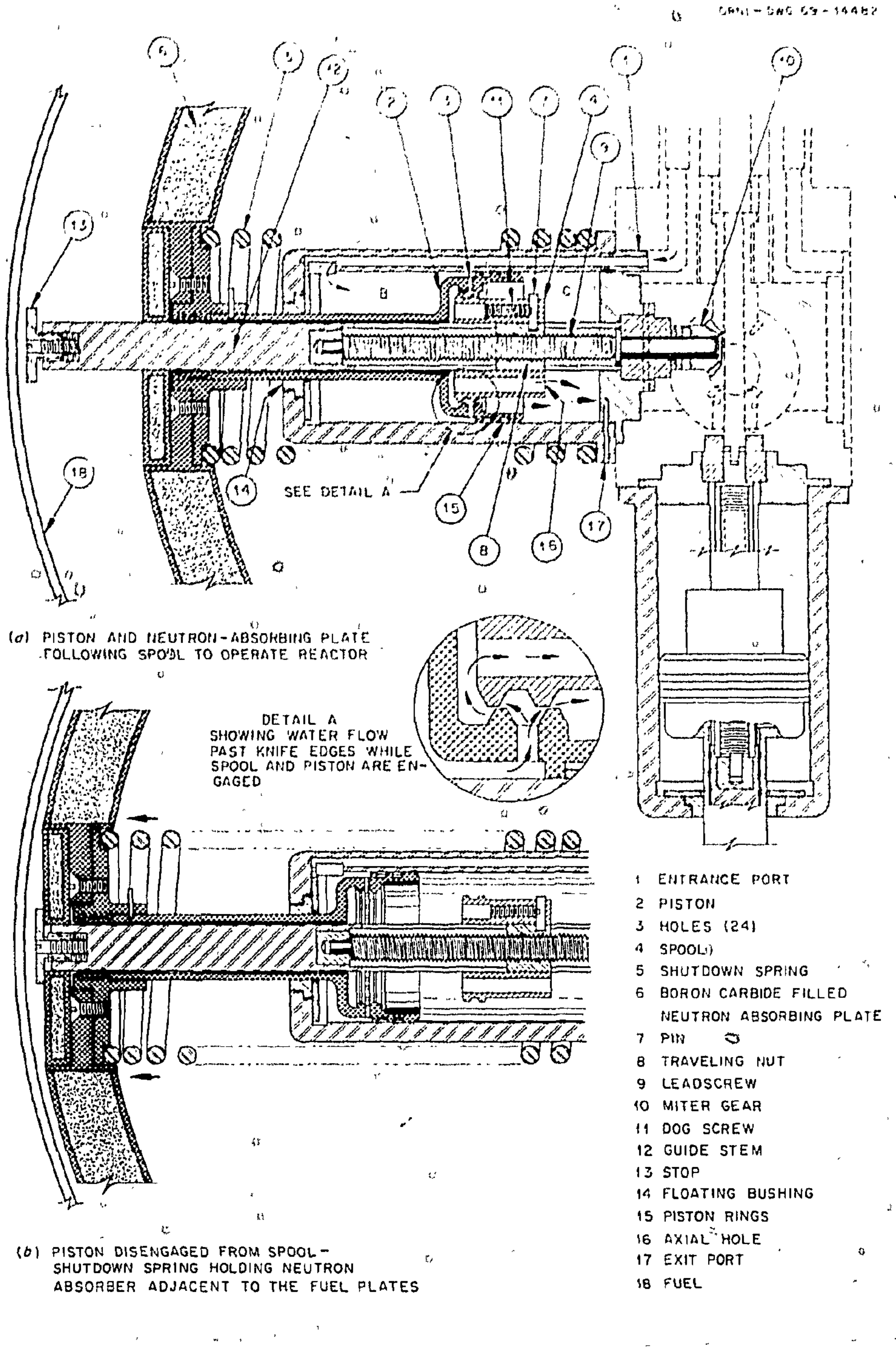


Fig. 3. Control mechanism.

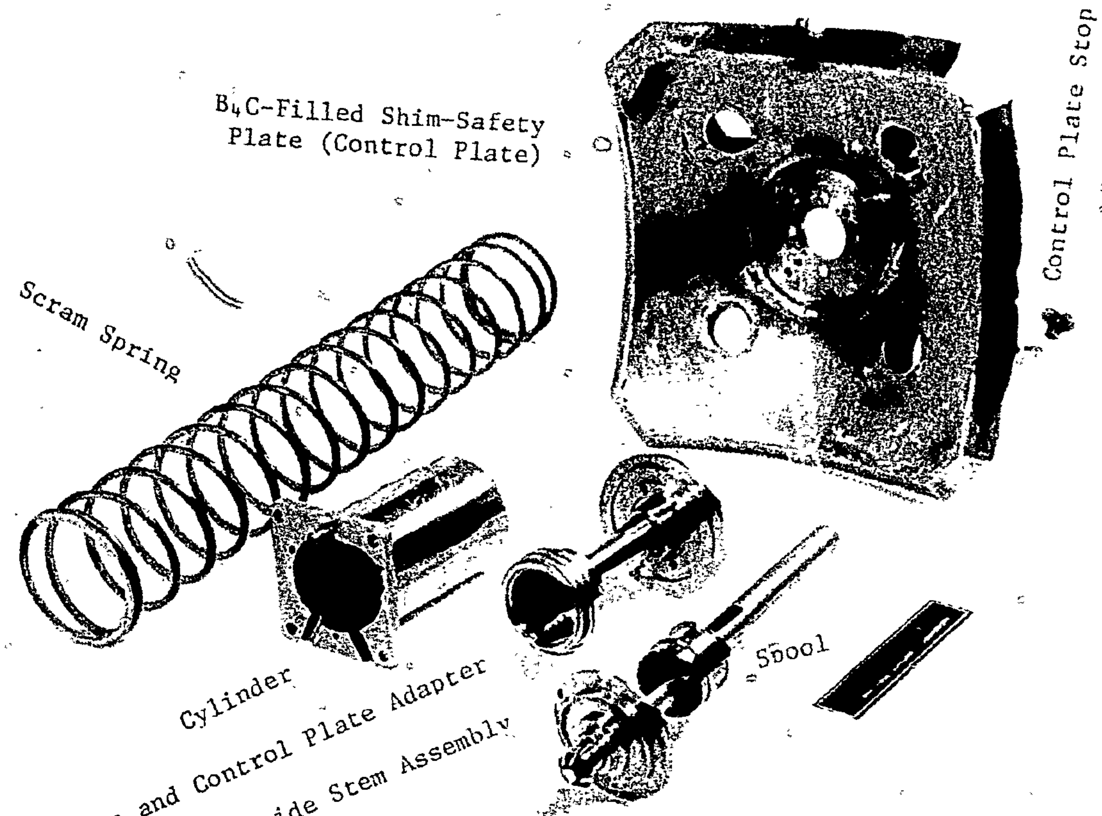


Fig. 4. Control mechanism components.

2.1.3 Radial Thickness - The rings as purchased are about 0.065 in. thick radially. A weaker ring is desired, so the rings are held in a special jig and bored in the shop to leave a radial thickness of 0.035 in. This machining leaves a burr which must be removed (see above).

2.1.4 Diameter - Go, no-go gages are used to check the diameter of each ring. Each ring must pass through a 1.757-in.-diam gage to assure its fit into the 1.760 in. cylinder bore. To date all rings have passed the 1.757 in. gage and have not passed the 1.754-in.-diam gage.

2.1.5 Roundness - Each ring is carefully fitted into the 1.760-in.-diam gage, then inspected for the leakage of light between the ring and the gage. (Alternate inspection method - A narrow feeler gage of 0.001 in. foil or plastic film is used to probe for gaps between ring and gage.) The roundness of rings has frequently been improved by judicious bending of the ring by hand or, if the defect is near the end of the ring, by very careful bending with tools. A 0.001 in. gap in ring fit looms large when compared with the 0.0006 in. to 0.0008 in. final clearance in knife edges between piston and spool piece.

2.2 Piston

2.2.1 General - The piston assembly consists of the piston body and two bronze bearings. The inspection reports are checked to ensure that the dimensions are within tolerance and checks are made to ensure that other conditions are met. The dimensions that are checked include: Maximum OD, OD of stem, ID of bearings, ID of knife edges, distance between knife edges, and width of knife edges. Sensitive diameter measurements must be accurate to 0.0001 in. as measured with a micrometer and telescoping transfer gages and they must be free of taper and out-of-roundness. The contact surfaces must be smooth, but minor pitting may be acceptable. Peaks, such as those formed by the addition of gall metal, are not acceptable.

2.2.2 Piston Ring Grooves - The groove faces are checked to ensure that they are smooth and true enough to allow the rings to form an effective seal. The rings are installed and checked to ensure that they turn freely and they can be easily depressed below the cylindrical surface of the piston. The overlap joint of each ring is examined to ensure that it fits correctly in its groove.

2.2.3 Piston Stem - The stem is checked to ensure that it is smooth and of uniform diameter so that it will seal reliably against the bronze floating seal without scratching it. The threaded end face of the piston stem is checked to ensure that it is flat and true so that it can serve as a reliable stop when the control plate adapter is screwed onto it.

2.2.4 Threads (Matching those on control plate adapter) - The threads are inspected to ensure that they are correctly made and free of chips and burrs. Any such material is removed and the threads are dressed.

2.2.5 Bearings - The bronze bearings are checked for smoothness and for tightness of staking. Stake material has been found extending inward so far that it rubbed the shaft, in which case it was shaved back with a special tool.

2.2.6 Multiple Water Holes - Burrs are formed on the inside of the piston when these radial holes are drilled. Burrs are removed with gentle scraping, using care not to damage the nearby knife-edge surfaces.

2.2.7 Knife Edges - The knife edges are inspected for smoothness and their diameter measurements are checked versus allowable tolerances.

2.3 Spool Piece

The spool piece assembly consists of the spool body, two notched pins, two dog-pointed setscrews, and two flat or cup-pointed setscrews.

2.3.1 Dimensions that are checked - OD of knife edges, distance between knife edges, width of knife edge faces, and ID of bore.

2.3.2 Bore - The bore is checked to ensure that it is smooth and that there are no burrs where the two radial anchor pin holes enter the bore.

2.3.3 Multiple Water Holes - Burrs have been found in these holes in the past. Any burrs or loose shreds of metal are removed.

2.3.4 Anchor Pins, Setscrews and Holes - The dog points of the setscrews are placed in the notches of the anchor pins to demonstrate that the dog points enter the notches freely. The dog-pointed setscrews are screwed all the way into the spool piece to demonstrate that each dog point enters its anchor pin notch far enough to hold the pin, and that no burrs are pushed into the holes. Then the pins are placed in the spool piece and the dog screws installed properly. The anchor pins are observed to extend a small distance into the central bore of the spool piece.

2.3.5 Knife Edges - Knife edges are inspected for smoothness and the measurements of their diameters are checked versus allowable tolerances and the measurements of the matching knife edges on the piston.

2.4 Control Plate Adapter

2.4.1 Threads - The threads are inspected for feathered crests which might become broken off or folded over. The surface to be contacted by the end of the piston stem is checked to ensure that it is smooth and clean so it will act as a definite stop.

2.4.2 Fit to Piston - The shim-safety control plate adapter is screwed onto the piston and checked to ensure that it comes to a definite stop without jamming.

2.5 Cylinder Assembly

The cylinder assembly consists of the cylinder body, port adapter, floating seal bushing, seal retaining ring and three screws.

2.5.1 Cylinder Body - The bore is inspected for smoothness and for freedom from taper and out-of-roundness. The water entrance passage is demonstrated to be unobstructed and free of chips and oil. The recess which receives the floating seal is inspected for smoothness to ensure that it will be an effective part of the water seal.

2.5.2 Port Adapter - The port adapter is fastened to the cylinder with a light press fit, with the protruding part rounded and highly polished so it may be pushed into the gear block and withdrawn many times later without damaging the hole in the aluminum block. It may be necessary to chamfer a corner of the port adapter if it overlaps the cylinder bore and prevents free withdrawal of the piston rings.

2.5.3 Floating Seal - Both seal faces are checked to ensure that they are smooth and free of burrs. When the seal bushing is installed and all three screws are tightened on the retaining ring, the seal bushing is checked to ensure that it can move freely to be able to align itself with the piston stem. The heads of the three screws are checked to ensure that they are flush with or recessed slightly below the surface of the retaining ring.

2.6 Guide Stem Assembly

The guide stem assembly consists of the guide stem body, lead screw, lead screw bearings, and traveling nut.

2.6.1 Body - The guide stem body is fitted to the cylinder to check the closeness of fit. The stem is checked to ensure that it is smooth, free of burrs, and without taper. The fit of the piston assembly over the guide stem is checked to ensure that it is close but free.

2.6.2 Lead Screw - The lead screw is checked to ensure that it is straight, smooth, and free of burrs.

2.6.3 Lead Screw Bearings - These bearings are pressed into the guide stem assembly, and they are checked to ensure that they fit with no radial motion when anchored in place.

2.6.4 Traveling Nut - This bronze nut is custom fitted to the lead screw. The nut is driven along the whole length of its slot and if the nut wobbles up and down in the slot as the horizontal lead screw is rotated, it indicates the lead screw is bent. A bent lead screw is straightened or replaced.

.7 Assembling of Mechanisms

2.7.1 Spool Piece to Guide Stem Assembly - The spool piece is loosely supported by the guide stem, and its location is accurately indexed in relation to the piston by their close fitting knife edges. Thus the spool piece must be free to conform to the radial position demanded by the piston knife edges. The anti-rotation wings of the traveling nut are checked to ensure that they are recessed below the surface of the guide stem to ensure noncontact between the nut and the spool piece. The two blind holes in the nut engaged by the pins which transmit axial motion from the traveling nut to the spool piece are match drilled. Care is taken to reassemble with the spool piece correctly rotated and not 180° with respect to the traveling nut. When the drive pins are dropped into the holes of the spool piece and on into the blind holes in the nut, the pins must share the load equally. The pins are withdrawn a few thousandths of an inch to permit the dog-pointed setscrews to enter the notches in the pins. The dog-pointed setscrews, in turn, are backed off a few thousandths of an inch before the second setscrews are locked tightly against the dog-pointed setscrews. When this assembly is completed, the spool piece is checked to ensure that it floats freely on the guide stem, ready to conform to the location demanded by the 0.0006 in. to 0.0008 in. radial clearance between the spool and piston knife edges. The drive pins are checked to ensure that they can be moved but a very small distance both axially and rotationally, after the other setscrews have been locked permanently in place.

2.7.2 Control Plate Adapter - A special adapter is required to connect a shim-safety plate to the piston stem. When the adapter is threaded onto the piston stem it comes to an abrupt stop at the end of its travel. A blind hole in the piston stem is match drilled through a radial hole in the sleeve portion of the adapter to receive a locking pin which eventually will be staked in place. The control plate adapter must be removed and reassembled to the piston stem several times during the testing and final assembling procedure. Care must be taken not to progressively over tighten the control plate adapter each time it is reassembled to the piston stem, as this will eventually cause misalignment of the match-drilled holes.

2.7.3 Side Load Test - In the CMH, four of the mechanisms will operate with their axes horizontal, and the weight of the control shim plate will place a side load on the guide stem (radial to the stem axis). The assembled mechanism (without the scram spring) is tested with a 5-lb side load to see if the floating seal realigns and the piston moves freely under these conditions.

2.7.4 Installing Scram Spring - This heavy spring may be dangerous if it is handled carelessly. (For spring specifications see Chapter 3.) It is assembled to the control mechanism by two men as follows:

1. Traveling nut of mechanism is moved to scrammed position (spool driven away from the miter gear).

2. Mechanism is mounted securely on mechanism test stand.

3. Scram spring is placed over cylinder of mechanism.

4. Lengths of 0.125-in.-diam nylon cord are tied 180° apart one coil back from the adapter plate end of the spring. The spring is compressed by pulling the cord loop axially toward the mounting plate.

5. While the spring is compressed the adapter plate is installed on the piston stem. It is sometimes necessary to hold the stem with a fuse puller.

6. Spring is released and made to nest in space provided on control plate adapter.

7. Lock-pin hole is inspected for alignment and adapter is shifted rotationally if necessary. Pin is installed but is not staked until the final assembly.

3. SCRAM SPRINGS

Experience has shown that springs supplied by commercial spring manufacturers are the ones most likely to meet the required specifications. Procurement of the springs has, therefore, been handled as a separate item rather than as another part of the control mechanisms. For these reasons the requirements and tests for selecting springs to be used for the control mechanisms are given in this chapter rather than as another item in Chapter 2. The requirements for the control mechanism scram spring, Figs. 2, 3, 4, and 5, are given in ORNL Drawing M-20858-EM-003D, Control Mechanism Assembly.

Additional requirements which the springs must satisfy:

1. Ends of each spring must be squared and ground so that the spring will stand erect, unsupported.

2. One end of the spring must fit into the recess provided for it on the control plate mount (item 4, Dwg. M-20858-EM-003-D) of the mechanism assembly.

3. Inside diameter of the spring must allow the spring to pass freely over the cylinder of the mechanism.

4. Outside of the spring must fit freely into the cutout provided for it in the inner ball (item 15, Dwg. M-20858-EM-013-D).

5. Each spring must register 70 ± 5 lb when compressed to 6 in. and 90 ± 5 lb when compressed to 4 in.

6. No spring will be compressed to shorter than 4 in. during testing to avoid giving it a permanent set.

Force-vs-length measurements are made at the TSF for each spring, using a Baldwin load cell to convert the load force into an electrical signal which is fed into a recorder, Fig. 5. Results are plotted and compared with similar curves of previous springs.

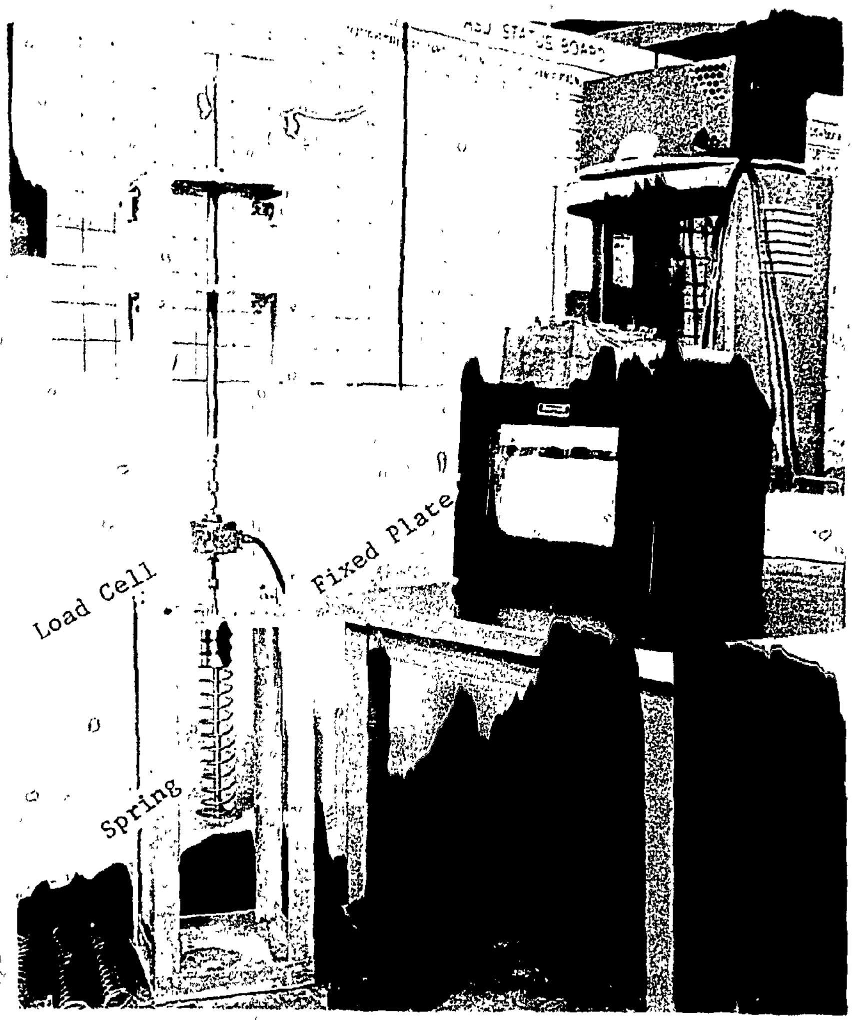


Fig. 5. Test stand for spring calibration.

4. MECHANISM BENCH TESTS

It has been found advisable to bench test each of the five shim-safety plate control mechanisms individually before installing them as a group in the final CMH assembly.

4.1 Description of Test Setup

The test setup, Fig. 6, duplicates, as nearly as possible, a water flow path through a mechanism on the reactor. The normal building water supply is used in a single-pass manner, and a pump is available to raise the water pressure above the 70 to 80 psi normally available if more pressure is desired. Water flows through a flow meter, through the scram valve (a spare scram solenoid that can be used on the reactor), through 8 ft of copper tubing representing the passage down through the stem of the CMH, into the mechanism and out into a drain. Control valves and pressure gages are strategically located.

The mechanism being tested is mounted horizontally to a brass block which simulates the aluminum block surrounding the miter gears in the center of the CMH. An extension shaft attached to the mechanism permits rotation of the mechanism lead screw manually or, as may be seen in Fig. 6, by means of an electric motor for repeated cycling tests such as for endurance runs. A refinement not shown in Fig. 6 was the addition of a spring to provide 10 lbs of lift on the scram valve shaft to simulate the effect of reactor core pressure transmitted back to the scram valve through the water bypass line.

The scram valve is powered by an ORNL magnet amplifier as shown in block diagram, Fig. 7. Pressing the scram button on the magnet control box reduces magnet current, thereby initiating the scram and simultaneously starting the timed sweep of the oscilloscope. The mechanism scram motion operates the slide of a linear transducer which alters the pattern produced by the wave generator and which is displayed on the oscilloscope. Thus the release, travel, and total scram times can be displayed and photographed for the mechanism under various test conditons of flow and pressure. Appendix D

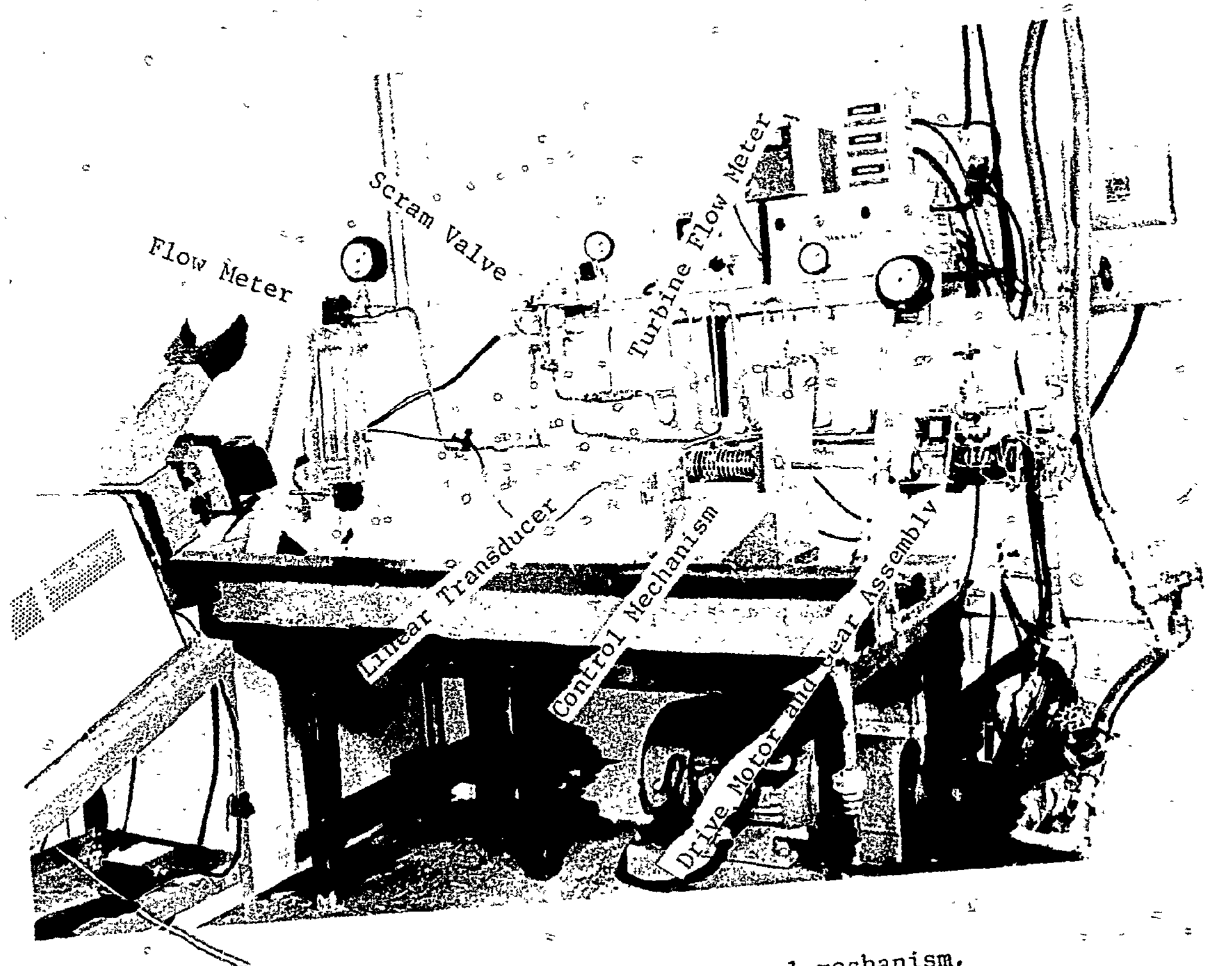


Fig. 6. Test setup for control mechanism.

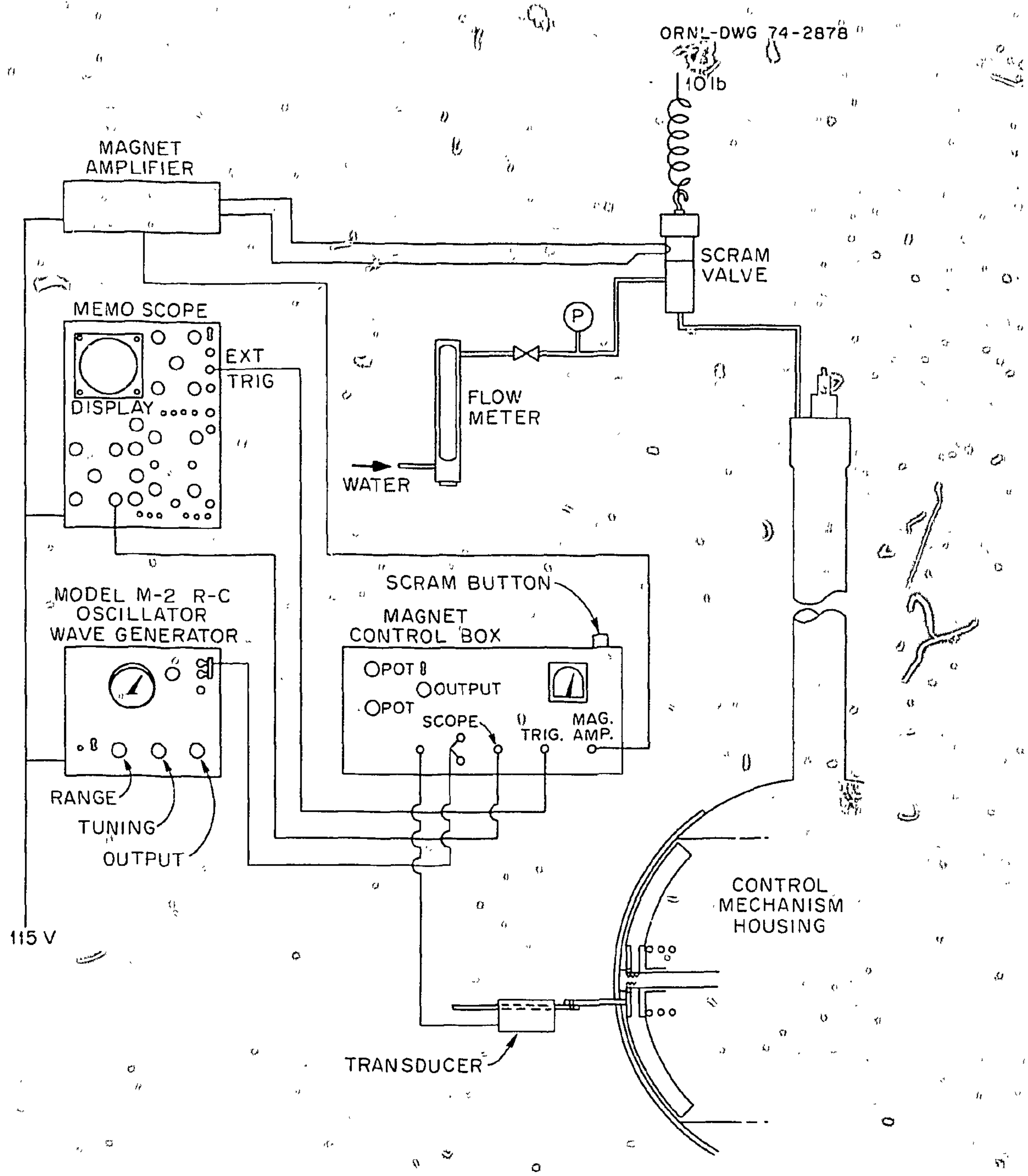


Fig. 7. Block diagram of setup to measure shim-safety plate response time.

gives information which will be helpful in setting up and operating the scram test instruments.

4.2 Test Procedure

Flows, pressures and scram times are measured with the mechanisms just picked up and withdrawn by 5, 10, 15, and 25 turns of the lead screw. Typical acceptable values for each mechanism at the time of bench testing are:

Difference in knife-edge diameters	0.0011 in. to 0.0014 in.
Minimum water flow at pick up	0.7 to 1.1 gpm
Water pressure at minimum flow	55 to 60 psig
Mechanism release time	30 to 50 msec
Mechanism travel time	20 to 40 msec
Total scram time	50 to 90 msec

It should be noted that the release, travel, and scram times are shorter for the bench tests than for the on-CMH final tests. This is because the inertial and hydraulic damping forces due to the B_4C-filled shim-safety plates are absent during the bench testing of the mechanisms. On the bench a rubber cushion is used to absorb the shock as the mechanism reaches the scrammed-out end of its travel.

It is important that the magnet amplifier supplies the proper current to the scram valve and that the scram valve is correctly adjusted mechanically, as these factors will influence the performance of the mechanism being tested.

The objective of the bench tests is to demonstrate that these mechanisms have characteristics similar to those of earlier mechanisms which have operated satisfactorily in the reactor. The set of five mechanisms should be reasonably uniform in their performance.

5. CONTROL MECHANISM HOUSING (CMH) AND SUPPORT TUBE SUBASSEMBLY

The CMH and support tube subassembly, Fig. 8, is complex and offers many opportunities for error, both in fabrication and assembly. Efforts have been made to improve the drawings with regard to accuracy and clarity but there are many places where extreme care must be used to interpret hidden lines and projected views correctly while fabricating the parts. Also, there are many places where the order of assembly is very important.

5.1 CMH Structure

The engineering details of a CMH are shown in ORNL drawings M-20858-EM-012-D through 015-D where the CMH is referred to as Control Support Ball. A photograph of an exploded layout of a CMH can be seen in Fig. 9. The inner and outer portions of the CMH are made of solid aluminum to displace as much water as possible for nuclear reasons. The outer section has several long holes drilled through it to serve as water passages for the seat switch system. One of these holes passes through a pair of structural welds. These water passages are checked to ensure that they do not leak.

5.2 Control Support Tube

The engineering details of the control support tube are shown in ORNL drawings M-20858-EM-007 through 010-D and M-20858-EM-016-D. The support tube contains ten water tubes, a solid shaft, a hollow shaft, and a total of 25 O-ring water seals. Dove-tail brackets mounted near the lower end of the tube, Fig. 10, are used to support the four upper fuel elements. Checks are made to ensure that the correct rotational orientation of the various support tube parts was maintained in assembly.

5.3 Shafts

Lack of straightness has been a problem with both shafts, Fig. 11, the solid one because it is so slender and the hollow shaft partly because it is fabricated from two pieces. The shafts sag

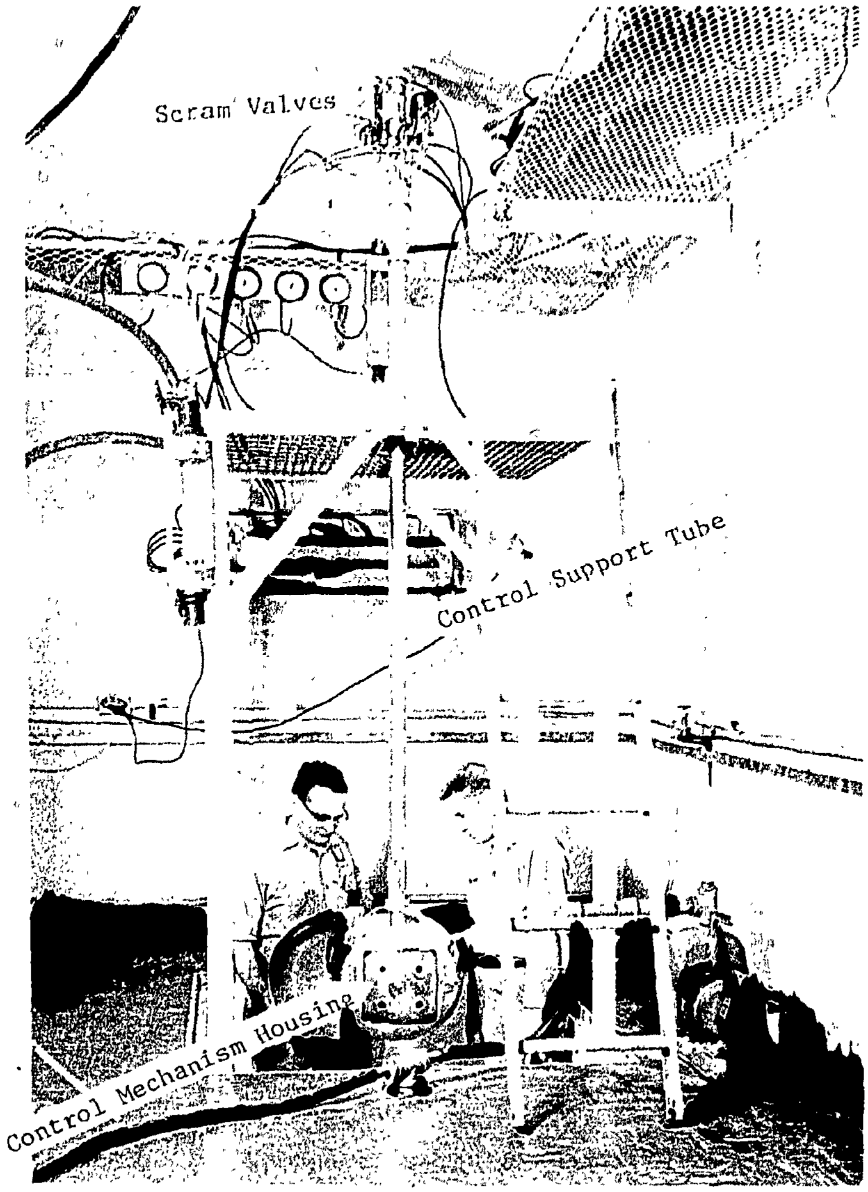


Fig. 8. Support stand for control mechanism housing.

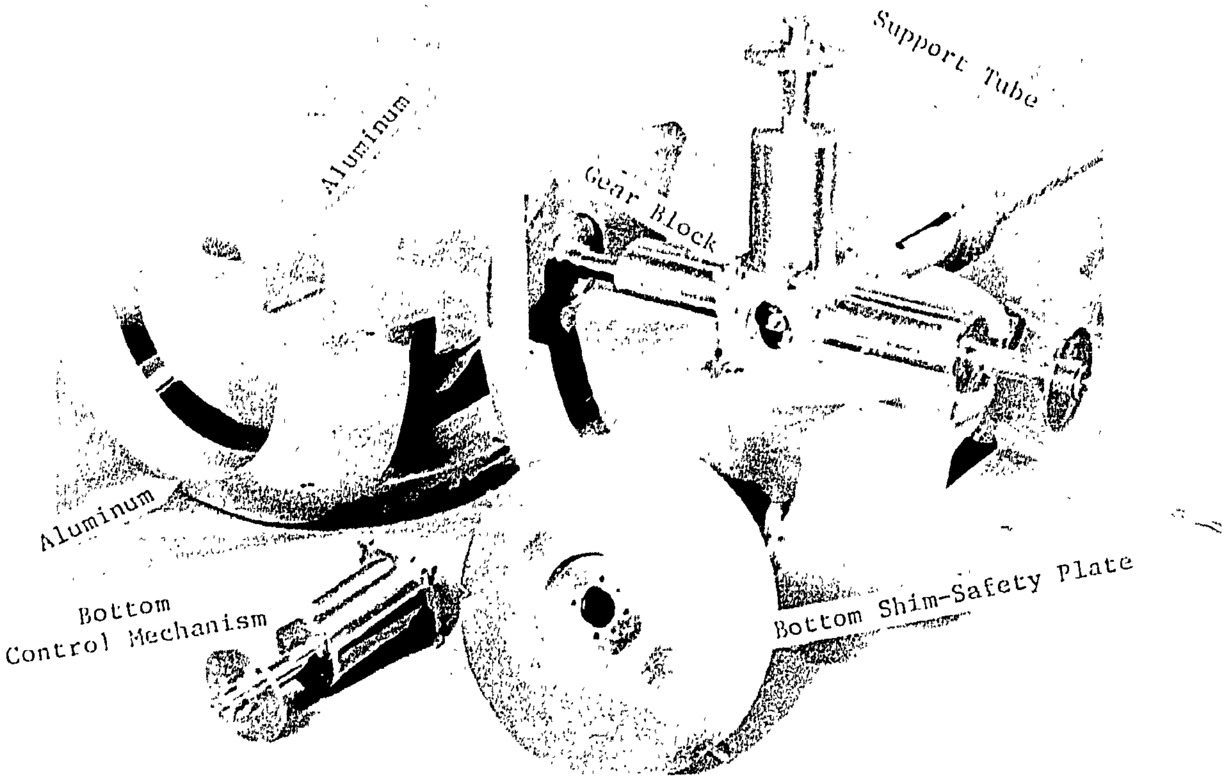


Fig. 9. Exploded view of control mechanism housing.

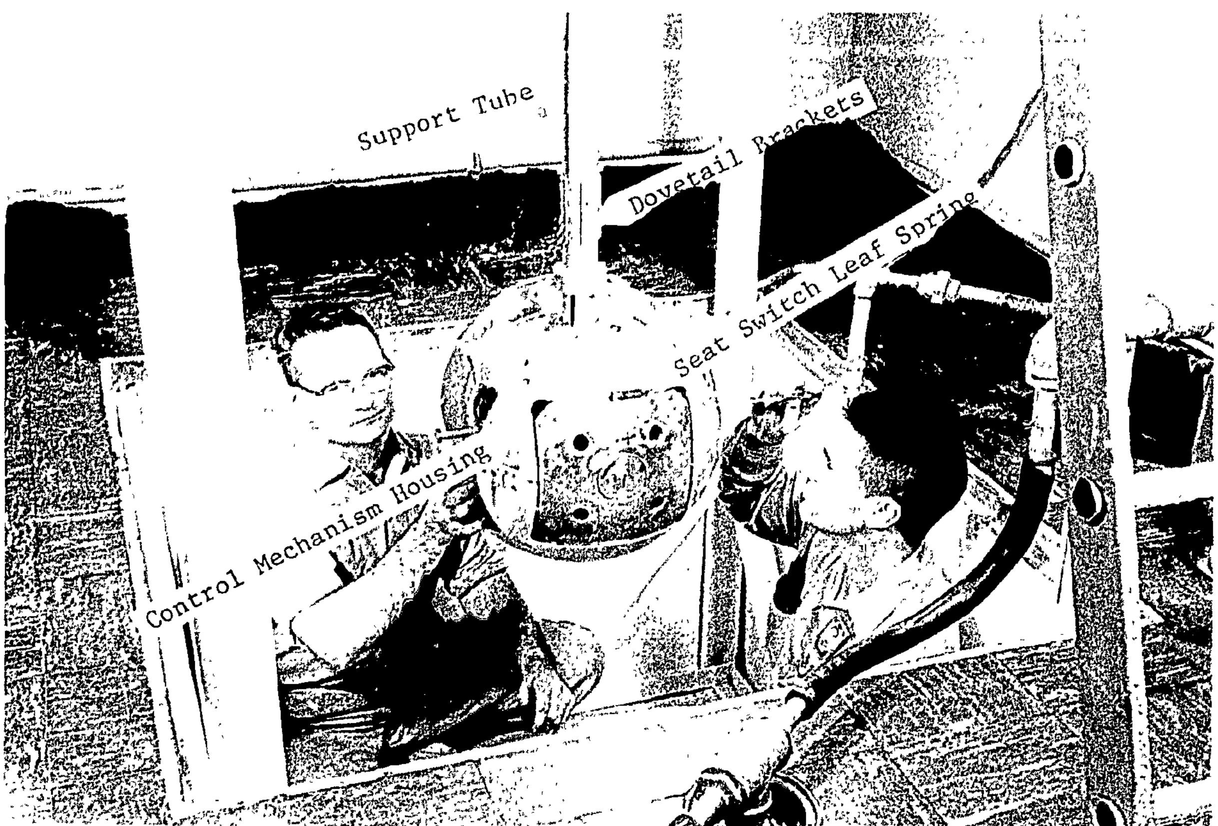


Fig. 10. Adjusting control mechanism.

under their own weight and may falsely appear to be straight when rolled horizontally across a flat surface. True straightness is assessed more accurately by supporting the ends of the shaft on V-blocks with the center barely off the table, rotating the shaft and observing any variations. Considerable improvement in straightness has been achieved in the past by careful bending and rechecking. The shaft to position the shim-safety plates is rotated inside the shaft which is driven vertically to position the regulating plate. The orientation of the shafts at the top of the support tube is shown in Fig. 11. The openings on the top of the support tube are for water lines to operate the control mechanisms and seat switches.

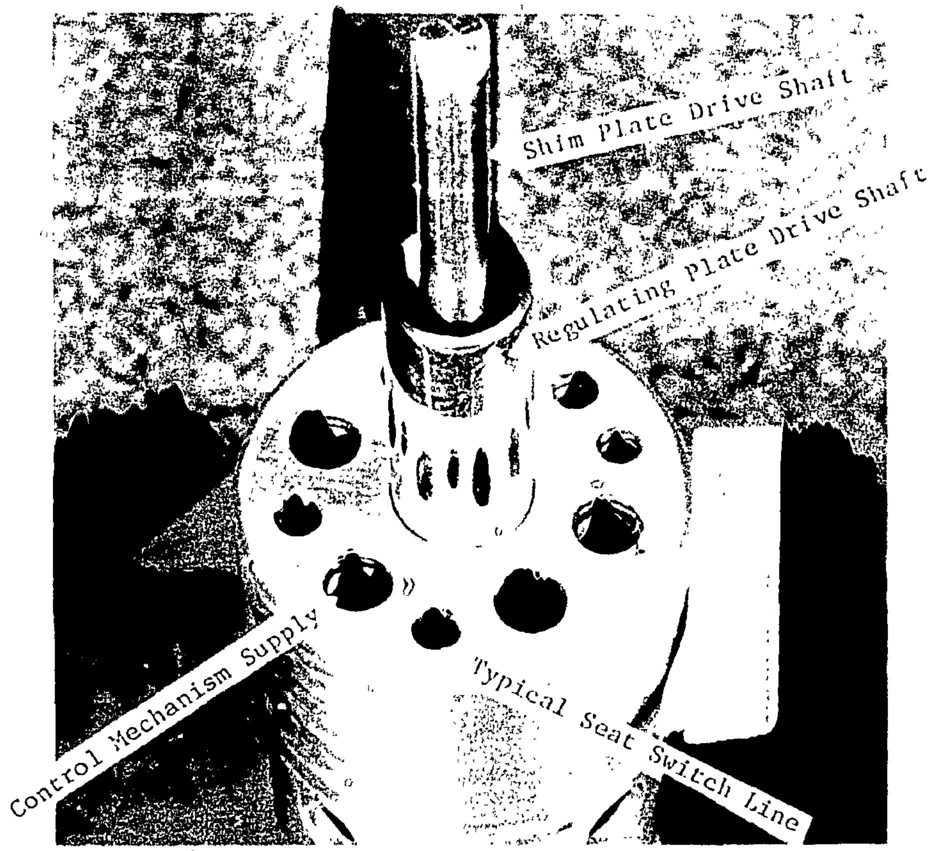
5.4 Gear Block

Because many of its surfaces mate with other parts the gear block seen in Fig. 12 is carefully checked to ensure that its dimensions are within the specified tolerances. In addition the water passages through the block, especially the tortuous one, for the No. 5 seat switch are checked to ensure that the flow passages are clear enough to permit adequate water flow and that they do not leak.

5.5 Miter Gear Pinning

When the shim rod drive shaft lower bearing is fitted to the shaft, along with the bearing washer and upper miter gear, there should be virtually no backlash because vertical motion of the shaft, either up or down, will cause binding of miter gears, Fig. 12. At first it was assumed that there would be a continuous net downward force on this long shaft due to its weight and that backlash in the upward direction could be tolerated. Then it was noted that due to water pressure in the reactor the new force on this shaft is upward and that backlash in either direction could cause binding at the miter gears.

This shaft bearing is carefully located vertically so that the tongue which terminates the lower end of the drive shaft mates properly with the slot of mechanism No. 5 lead screw shaft after mechanism



11. Drive shafts at upper end of control
sing support tube.

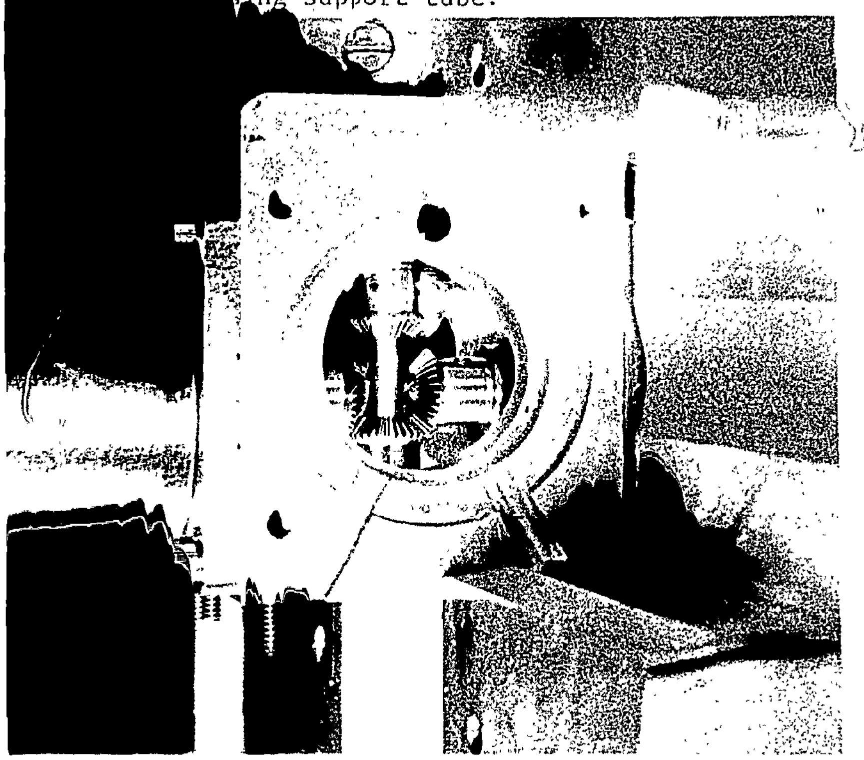


Fig. 12. Control mechanism housing gear block.

No. 5 is firmly mounted on the gear block. Then the teeth of the upper miter gear should be located so as to properly engage the mating teeth of the upper two mechanisms (No. 2 and No. 4). It should be noted that the miter gear teeth are rather sharply tapered and that even 1/32 in. of tooth-face displacement will cause poor mating of teeth (mating a large tooth section against a small one).

In a similar manner the lower shaft miter gear should be located to mate properly (full face) with mechanisms No. 1 and No. 3.

Next the spacer washers which fit between the miter gears and the lead screw outer bearings of mechanisms 1, 2, 3, and 4 are are selected. The thickness of each washer determines both the location of the mechanism miter gear, for proper depth of tooth engagement with the mating shaft gear, and also the amount of backlash (near zero is desirable) in the mechanism lead screw. It is good practice to have a wide selection of spacer washers available in many thicknesses from 0.050 to 0.075 inches for trial and error fitting. The desirable fit is that which permits about 0.004 in. of miter gear tooth separation when both the mechanism lead screw and the main drive shaft are forced into their positions of minimum backlash. During the fitting of spacer washers, the washer thickness may be reduced a few thousandths of an inch by hand polishing against emery paper if care is taken to keep their working faces smooth and parallel to each other. All miter gears are held in place by their setscrews during trial fitting operations and by taper pins only after the final locations are determined. Double drilling and repinning a miter gear in case of error seriously weakens the shaft and this should be avoided.

Because any variation in the fit between a mechanism and the gear block face will also affect the miter gear tooth fitup, removal of burrs or other trimming in this face region is completed before proceeding with the selection of spacer washers. Each mechanism is firmly bolted to the block during the final gear fitup inspection before any drilling to install taper pins in lead screw shafts is started.

5.6 Tubes and Joints

The ten water tubes are retained in an orderly array where they pass through the long support tube by a pair of spider-shaped spacers. The central holes through the spacers serve to lightly guide the hollow regulating rod shaft but are not intended to act as true bearings for this shaft.

The upper ends of the tubes are sealed by O-rings. The lower ends are attached by welding or by liquid nitrogen shrink fitting, the latter method being a later development. All tubes and joints are pressure checked to insure against leakage and flow tested to insure against plugging. If flow is inadequate, a glob of weld metal inside a passage may be the cause of trouble and this can be determined by X-rays.

All tubes and passages are cleaned with degreaser, compressed air or water to insure the removal of chips, cutting oil and dirt before the fitting and sealing of tube joints is started.

5.7 Final Assembly Suggestions

The following order of assembly of major components is presented here as a guide. It is suggested that confirmation be made that mating parts fit properly before final permanent attachment procedures are initiated.

1. Water tubes are fabricated into support tube assembly.
2. Gear block is attached to support tube assembly.
3. All O-rings are added.
4. Mechanisms are fitted to gear block and miter gear locations are determined.
5. Massive aluminum ball sections are fastened to gear block and support tube assembly.

6. Regulating rod half-plates are attached to their (hollow) drive shaft.
7. *Water tube connectors leading from support tube* assembly to ball are attached.

6. B_4C-FILLED CONTROL PLATES

B_4C-filled neutron absorbing control plates, Figs. 2, 3, 4, and 13, are used both as regulating plates and shim-safety plates in the TSR-II CMH. The fabrication and inspection of the various control plates presents considerable challenge in the field of spherical geometry. The details are given in ORNL Drawing M-20858-EM-011-D. Trouble has been experienced in the past with plates having improper curvatures, volumes, location of mounting surfaces, exterior dimensions and other faults. Techniques have been improved with time and experience, and the plates for CMH No. 6 satisfied the dimensional requirements.

6.1 Fabrication of Parts

Blanks for the major spherical surfaces are flow-turned (a form of spinning) in a tracer lathe to the approximate radius and the excess stock is removed. After being annealed in a controlled hydrogen atmosphere the blanks are final formed in a hydraulic press, using a male punch and a rubber die.

The various parts of the control plates are welded together and inspected, then annealed again in a controlled hydrogen atmosphere. Each assembly is then placed in a massive die and hydrostatically formed at 450 to 500 psi pressure. This imparts the desired shape and also serves to test the welds, both for strength and for freedom from leakage. After a final machining operation and a final weld inspection, the control plates are ready to be filled with B_4C granules.

6.2 Filling and Fill Inspection

Each control plate is carefully weighed then completely filled with B_4C (360 mesh) granules, with light tamping and vibrating used to ensure the proper compacting. If weighing reveals too much B_4C is in the control plate, the plate is emptied and the B_4C is diluted with a calculated amount of powdered graphite. Then the control plate is refilled with the mixture. If reweighing indicates that

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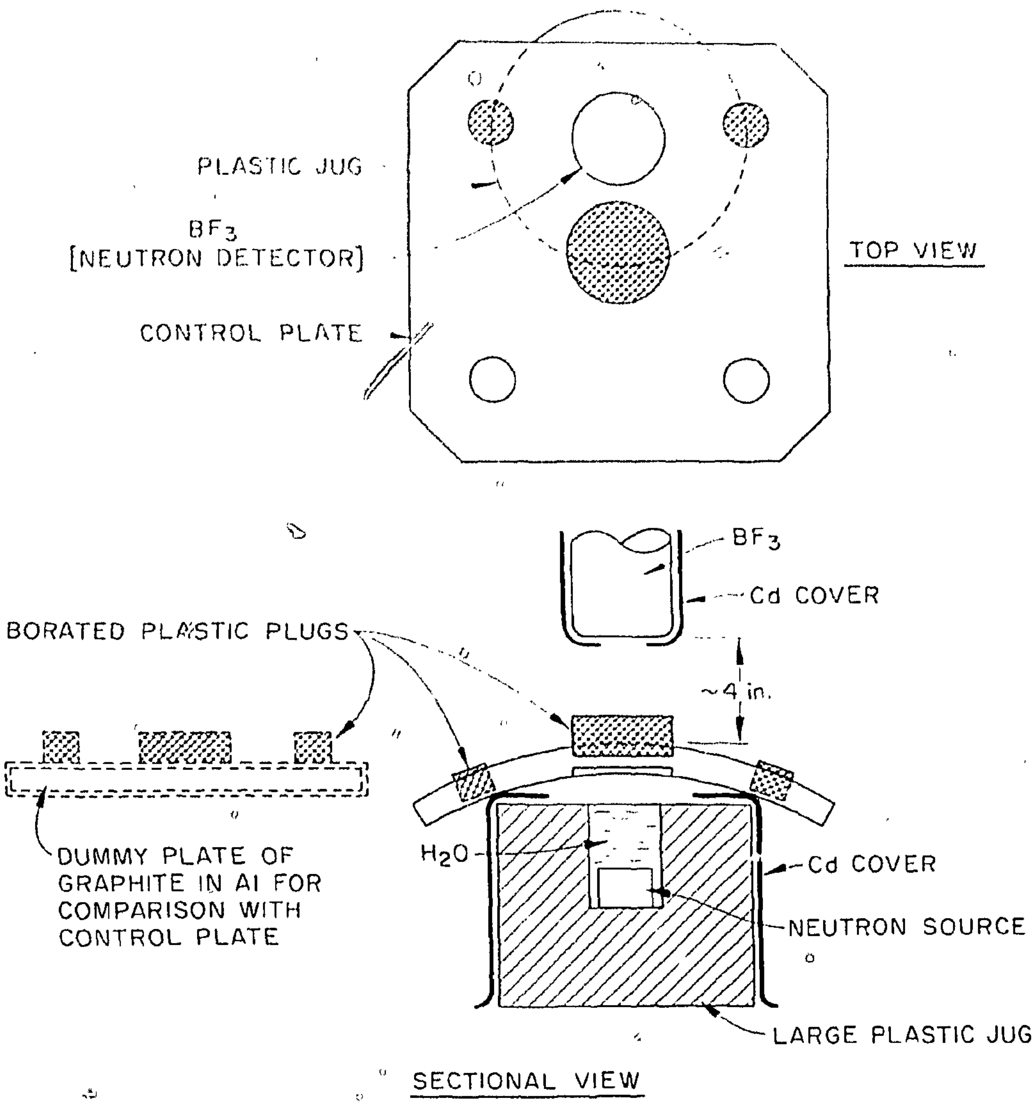

Fig. 13. Setup to check neutron absorption of control plates.

the control plate contains an acceptable amount of B_4C, the filled plate is X-rayed for voids. Finally the fill hole is closed by welding and the seal welds and nearby welds are inspected with liquid dye penetrant. All weights and other information concerning the loading of the control plates with B_4C are recorded in the bound log book.

As a final inspection against leakage the finished control plates are pressurized in an air chamber at 100 psi, then rapidly transferred into a tank of water where they are kept under observation for four hours. Leaks, if any, will be indicated by bubbles.

6.3 Confirmation of B_4C Filler Material

As a final check to ensure that the control plates have been filled with B_4C, an actual neutron absorption test is performed with each of the finished control plates. The test setup is shown in Fig. 13. Powdered graphite is perhaps the most likely material to be substituted in error for the B_4C powder, so a direct comparison is made of the transmission of neutrons from a source to a detector through each completed control plate and a dummy plate filled with powdered graphite. The numerical results are recorded in the bound log book and compared with records for previous control plates.

6.4 Fitting Control Plates to CMH

With the five control mechanisms (without scram springs) attached to the CMH, the five shim-safety control plates are mounted on the mechanisms and inspected both for uniformity of edge clearance and for proper continuity of spherical contour to match the body of the CMH. A template is provided to aid in the comparison of contours. In the past, edge clearances have been equalized by making a new set of off-center tapped holes in the control plate mounting bracket, and plate angles have been corrected by remachining the control plate hub, adding jackscrews, or by welding on shims.

Each control plate is observed as it is moved throughout its full travel to assure that its leaf switch actuator is properly guided the full distance. The leaf switch actuating tongue is trimmed to shape at this time (assuming that no reworking of the control plate is needed).

The regulating control half-plates are mounted rigidly to the vertically rising hollow shaft and are checked to ensure that there is an acceptable edge clearance and proper spherical contour. The assembled regulating plate is also checked to ensure that there is a vertical travel of at least 1-3/4 inches with no binding. The regulating rod half-plates are permanently attached to their control shaft before the seat-switch water tubes connecting stem to ball are welded in place because it is very difficult, if not impossible, to maneuver these half-plates into final position after the water tubes are installed.

7. FUEL LOADED LUNE-SHAPED PLATES

The four lune-shaped cover plates, Fig. 2, are fuel elements having enriched uranium alloy sandwiched inside aluminum. The plates are fabricated at the ORNL Rolling Mill and are shaped and inspected for integrity of fuel enclosure before delivery to the machine shop.

7.1 Inspecting and Marking

The lune plates are attached to the CMH by many small screws passing through holes in the non-fueled borders of the plates, and it is imperative that no holes penetrate the fueled region. Each plate is X-rayed and the extent of the fueled region is outlined in ink on the plate, Fig. 14. Under proper lighting conditions the dividing line between the fueled and non-fueled regions can usually be confirmed optically by noting a variation in surface texture.

7.2 Fitting and Trimming

The lune plates require considerable trimming to clear the seat switch water supply lines and at their contact with the support tube, Fig. 2. Trimming is routinely restricted to no closer than 3/8 inch from the fueled region, with 1/4 inch being the absolute minimum safe clearance. Trimming has been successfully accomplished by both filing and grinding. If grinding is used, great care must be used to prevent the grinder from grabbing the plate and distorting it.

7.3 Mounting

Starting with CMH No. 6 two sets of lune-shaped templates are available to aid in mounting the lune-shaped fuel plates to the CMH. One set of templates is designed to locate positions on the CMH for drilling and tapping. The second set of templates is designed to locate positions on each lune fuel plate for drilling holes through the edge of the plate to match those tapped in the CMH. Proper identity of fuel-loaded plates is maintained because three different fuel loadings have been made.

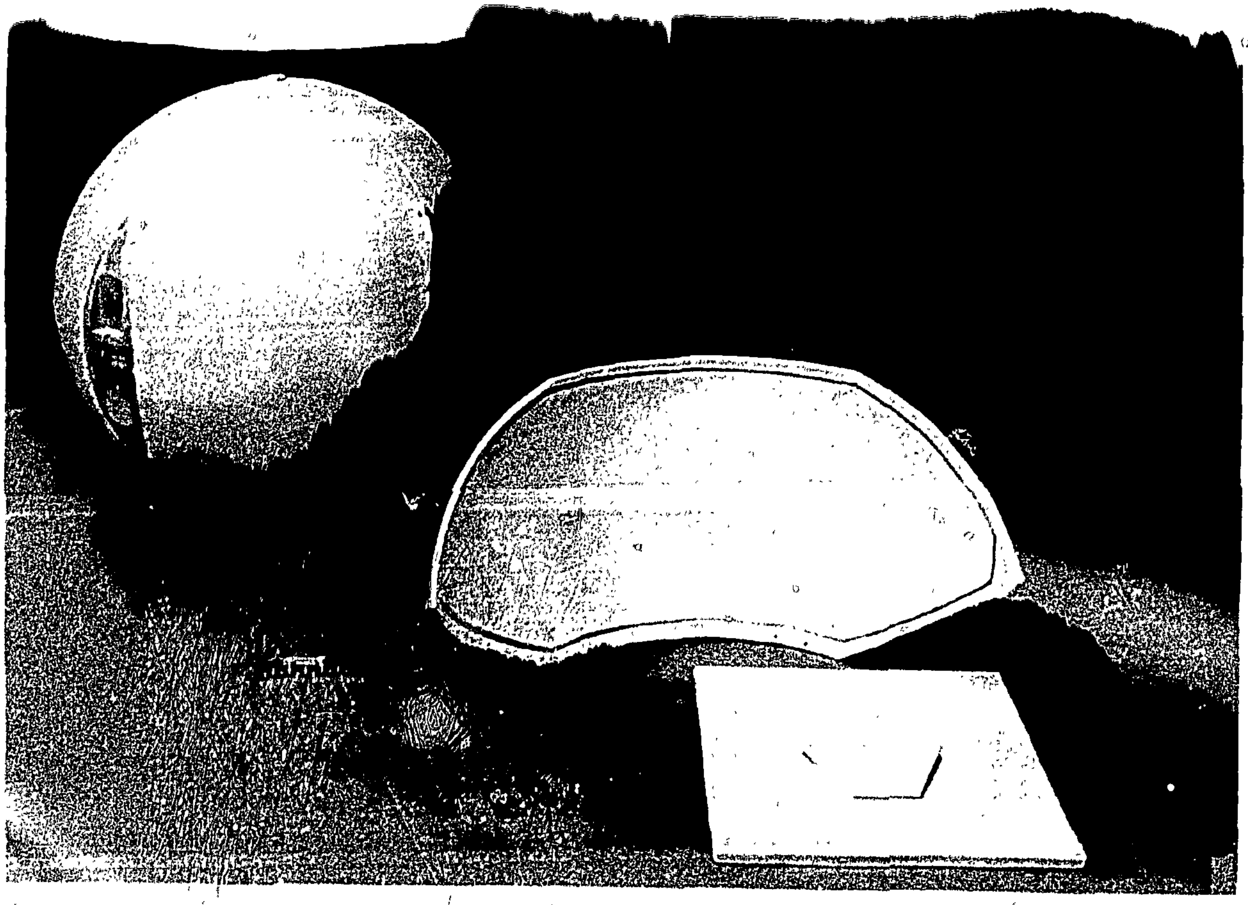

Fig. 14. Lune-shaped fuel plates: prior to rolling, shaped, and assembled.

7.4 Cleaning and Storing

After the attachment of the lune plates to the CMH has been completed, the lune plates are removed and the ball and plates are cleansed of aluminum chips and cutting oil or other lubricants applied during the drilling and tapping operation. Blind tapped holes are cleaned with blasts from an air hose.

Since the lune plates contain enriched uranium they are stored in a security safe until time for their reassembly to the CMH. If the fuel plates are not to be used for an extended period they are transferred, in accordance with security procedures, to Y-12 for storage.

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8. FINAL ASSEMBLING AND TESTING OF CONTROL MECHANISM HOUSING

The control mechanism housing is suspended above the indoor test pit at the Tower Shielding Facility for the final assembling, adjusting and testing operations, Fig. 8.

8.1 Adjusting Seat Switch Leaf Springs

The seat switch water passages are rechecked by flowing water through them with the orifice nozzles removed, then the nozzles are installed and tightened firmly.

The seat switch leaf springs, Figs. 7 and 10, are custom fitted to the CMH while the control plates are removed. One corner of each spring near the anchor screws may have to be removed (by grinding or filing) if it extends beyond the spherical contour of the CMH where it may touch a spherically shaped fuel plate.

Each leaf spring must make a reasonably tight seal over its respective orifice, so the mating surfaces are checked to ensure that they are smooth. A permanent compound bending of the leaf between the anchor portion and the orifice closure portion is often required to achieve the proper tilt, orifice closure and force. Final polishing of the assembled surfaces is sometimes required to affect a tight seal.

After all five leaf springs have been adjusted to give virtually zero seat switch leakage with the control plates absent, the leaf springs are removed until after the control mechanisms and control plates are installed and adjusted.

8.2 Assembling and Lubricating of Mechanisms

Before being placed into service the control mechanisms are disassembled for a final inspection, cleaning and lubricating. No published information has been found which lists long life lubricants, suitable for use in a high-level radiation field under water. The mechanism lead screws of the first control ball were coated with a paste mixture of powdered graphite in silicone stopcock

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grease. This apparently worked well and a postmortem examination two years later showed the lead screws were still covered with the grease.

This mixture is the standard lubricant for use on mechanism lead screws, cylinder walls, piston rings, and other exposed surfaces where the material can be applied. Silicone oil is used on O-rings and bearings where lubricants can enter only by capillary action.

No lubricant is applied to the close-fitting miter gears since friction and wear at the gear teeth is minimal. Also, the presence of grease might cause dirt and trash to cling to the teeth and this may invite trouble.

8.3 Attaching Mechanisms and Rechecking Miter Gears

The mechanisms are fastened to and removed from the gear block several times before they are mounted for the last time. Each attachment is made firmly to insure reliability of fit and care is taken not to strip the threads in the aluminum block. Damaged threads have been repaired by the use of hardened inserts (such as Helicoils). The two shallow tapped holes near the No. 5 water passage must be clearly marked so that only the 1/2-in. long rather than the 11/16-in.-long cap screws are inserted.

The mechanisms and other CMH parts undergo considerable handling after the original fitting and pinning of miter gears, and a recheck of the miter gear backlash is made at this time as follows:

1. With no mechanisms on the CMH the shim rod drive shaft is rotated to check that it turns freely and that a barely discernable vertical backlash is present.

2. The lead screw of each mechanism is rotated to about the midpoint of its travel.

3. No. 5 mechanism is mounted on the CMH to confirm that the tongue on the lower end of the shim rod drive shaft enters a safe distance into the corresponding groove in the No. 5

lead screw without bottoming. (Bottoming would create undesirable end thrust on both the mechanism lead screw and the shim rod drive shaft.)

4. The shim rod drive shaft is rotated to check that it drives No. 5 mechanism without difficulty. If trouble is encountered, the following items should be considered:

   a. The No. 5 lead screw outer (upper) bushing serves also as an outboard bearing for the shim drive shaft. If the lower end of the drive shaft is bent or out of alignment, binding may occur.

   b. If the drive shafts are not aligned so that the tongue and groove connection match correctly for 360° of rotation, the shafts will be forced into misalignment, causing binding in this bearing. If remating the tongue and groove at 180° corrects the difficulty, the parts should be carefully marked so that future mating will always be at this preferred orientation.

5. With No. 5 mechanism remaining in place, a second mechanism is mounted firmly on the CMH.

6. The shaft is rotated one turn, while both the lead screw shaft and the shim rod drive shaft are pressed axially in the direction of minimum miter gear backlash, to confirm that a small but definite backlash exists at the miter gears.

7. The second mechanism is removed and the other three mechanisms are checked in similar fashion, with No. 5 mechanism in place.

8.4 Establishing Shim-Safety Plate Stops

The stops, Fig. 2, must be adjusted to limit the outward movement of the five shim-safety plates to where they will not quite contact the fuel-loaded lune plates when the shim-safety plates are scrammed. This is best achieved by attaching the mechanisms to the

CMH one at a time without their scram springs, according to the following procedures:

1. The No. 5 mechanism lead screw is rotated exactly 10 turns above its mechanical scrammed limit and the mechanism is mounted on the CMH.

2. The No. 5 shim-safety plate, filler plug, and adjustment screw are attached.

3. The adjustment screw is turned clockwise until there is a 0.020 inch to 0.030 inch minimum clearance between the plate and the template, then the setscrew is tightened. The 8 3/8-in. radius of the template represents the inner surface of the spherically curved fuel-loaded cover plates.

4. The shim-plate drive shaft at the top of the support tube is rotated counterclockwise to count the number of turns until it stops. (Approach this stop lightly at all times so as not to damage the mechanism.) This number is subtracted from 10 (see step 1) to determine the number of turns of insert end piston loss of travel for mechanism No. 5. This value is recorded in the log book and, with a felt-tip pen, on the mechanism housing. (Typical example: 10 − 7.6 = 2.4 turns. Thus the No. 5 shim-safety plate adjustment screw will stop the outward travel at 2.4 turns of the lead screw before internal mechanical binding occurs in No. 5 mechanism.) Similar information can be determined if all measurements are made from the fully withdrawn position of the mechanism spool rather than the fully inserted position.

5. The rotational position of the adjustment screw is marked with aligned radial arrows on the screw head and on the filler plug. The adjustment screw is removed and the number of turns for removal is recorded in the log book and, with a felt-tip pen, on the No. 5 filler plug.

6. No. 5 filler plug, shim-safety plate, and mechanism are removed from the CMH. Then the other four mechanisms are checked in a similar fashion with only one mechanism on the CMH at a time.

8.5 Synchronizing Control Plate Pickup

Next a scram spring is installed on each mechanism (see precautions in Section 2.7.4), and the radial pin which locks the threaded shim-safety plate adapter to the piston stem is permanently staked in place. A check is made to ensure that the staked pin does not extend through the stem wall and rub against the guide stem.

The mechanisms are synchronized and installed for the final time according to the following procedure:

1. With the mechanisms out of the CMH, each lead screw is rotated until its spool touches its piston, then it is backed off a total of two turns plus the desired individual amount of piston loss of travel noted on the mechanism. (Left-handed lead screw threads on two mechanisms can cause confusion as to which direction to rotate lead screw to move spool toward miter gear.)

   An alternate method of setting this distance is to withdraw the spool the number of turns determined in bench tests to move the spool from position where it contacts the piston to the position where the knife edges engage plus the turns for piston loss of travel recorded in section 8.4.5.

2. The rotational angle of the No. 5 lead screw is carefully noted, then the mating tongue of the shim rod drive shaft is oriented to match. (Sometimes rotating the shim rod drive shaft at 180° improves the fit. See section 8.3.4b.)

3. No. 5 mechanism is installed and all four mounting nuts are tightened. Care is taken not to rotate the shim drive shaft until all five mechanisms have been installed.

4. The other four mechanisms are mounted on the CMH, and their mounting screws are given a final torquing. The miter gear backlash is confirmed after each mechanism is mounted, except for the last one which cannot be checked.

5. The shim-safety plates and filler plug are attached, making sure that the filler plugs cannot contact the guide stems.

6. The plate stop screws are installed and adjusted each to its proper predetermined position as recorded on its filler plug. Then the template is used to recheck the shim-safety plate surfaces for proper clearance.

7. With the plate stop screws at their proper positions their setscrews are secured. It should be noted that better binding can be achieved by bottoming the rather small setscrew, then applying the final twisting effort to the wide-headed stop screw with the T-wrench, and this technique is recommended.

8. The shim plate drive shaft is rotated counterclockwise to check that it travels approximately the two turns established in step 8.5.1 before coming to a halt, at which time the spool pieces of all five mechanisms theoretically are bottoming simultaneously against their respective pistons.

   Warnings: Shaft rotational limits must be approached cautiously and contacted gently. Control plate stops must not be readjusted while the drive shaft is in its rotational limit as this may apply stress to a mechanism and damage it.

9. Final adjustments may be necessary to more accurately synchronize the picking up of the five shim-safety plates. One method of adjustment is to remove a given mechanism, rotate its miter gear a few teeth in the proper direction (beware of left-handed lead screws), and reassemble. An easier adjustment (and the only one possible for mechanism No. 5) may be made by altering the adjustment screw stop position if this can be done without fatally shifting the stopping place for the control plate.

The following numbers will be helpful in computing correctional increments when making final adjustments:

Mechanism lead screw pitch: 14 threads per inch

Miter gear: 30 teeth

Control plate adjustable stop screw: 16 threads per inch

$\frac{1}{14}$ = 0.071 in. motion per revolution of miter gear (or per turn of shim rod drive shaft)

$\frac{1}{30 \times 14}$ = 0.0024 in. control plate motion per tooth of miter gear

$\frac{1}{16}$ = 0.0625 in. control plate motion per complete turn of adjustment screw

$\frac{1}{16 \times 8}$ = 0.0078 in. motion per 1/8 turn of adjustment screw

$\frac{0.0078}{0.0024}$ = 3.3 miter gear teeth equal 1/8 turn of adjustment screw

8.6 Preparation for Shim-Safety Plate Response Measurements on CMH

The shim rod tests require repeated turning of the shim rod drive shaft at the top of the support tube, and this can be very tiring to the hand. The addition of a temporary crank is helpful, but the greater leverage provided by a crank invites overstressing the machinery when a mechanical limit is reached. A knob instead of a crank is safer and is recommended, but even a knob must be used with care.

The five mechanisms are tested one at a time. The number of variables is minimized by testing all five mechanisms using the same flow meter, pressure gage, scram valve, and water line. The water line coming from the scram valve is transferred from one feed hole to another at the top of the support tube as the test progresses. The friction grip of the O-ring is not quite sufficient to hold the water line in place during a test, so additional tie-downs are used.

The shim-safety plates hit the adjustment screw stops with considerable force when scrammed out, and this shock should be minimized during the plate response scram tests. During much of the testing, cover plates surround the CMH and a retarding dashpot action is achieved as the shim-safety plates move through the enclosed water. This duplicates the action which occurs when the CMH is in service in the reactor. During scram tests where the cover plates are absent and there is no hydraulic cushioning, the plate movement after scram is limited to 1/8 inch, unless a supplementary rubber stop is employed.

The accuracy of mechanism pickup synchronization is measured. This is done by counting the number of turns the shim-safety plate drive shaft makes from its inserted (scrammed) mechanical limit to where each mechanism starts to pick up. Tests are made at a standardized pressure of about 50 psig. (This is the pressure with the shim-safety plate withdrawn a few mils from its scrammed position and it will be lower before the pickup starts.) For observing the approach to the mechanism pickup point, the rise in the pressure gage reading is a more accurate indicator than the reduction in the flow meter reading. If certain mechanisms pick up too early or too late, they are readjusted according to step 9 in section 8.5. A record is made in the log book, describing any adjustment and listing the number of overtravel turns from the mechanical insert stop to the position where spool and piston knife edges engage for each mechanism before and after adjusting. The various limits and overtravels are illustrated in Fig. 15, and care must be used when making log book entries to adequately describe the item measured (e.g. this piston loss of travel corresponds to the one described in item 1 of section 8.5).

The shim-safety plate drive shaft is rotated through its full range of travel without any plates being moved and the total number of turns is recorded in the log book. Then, with the plates engaged, the turns are counted from the scrammed mechanical limit to the

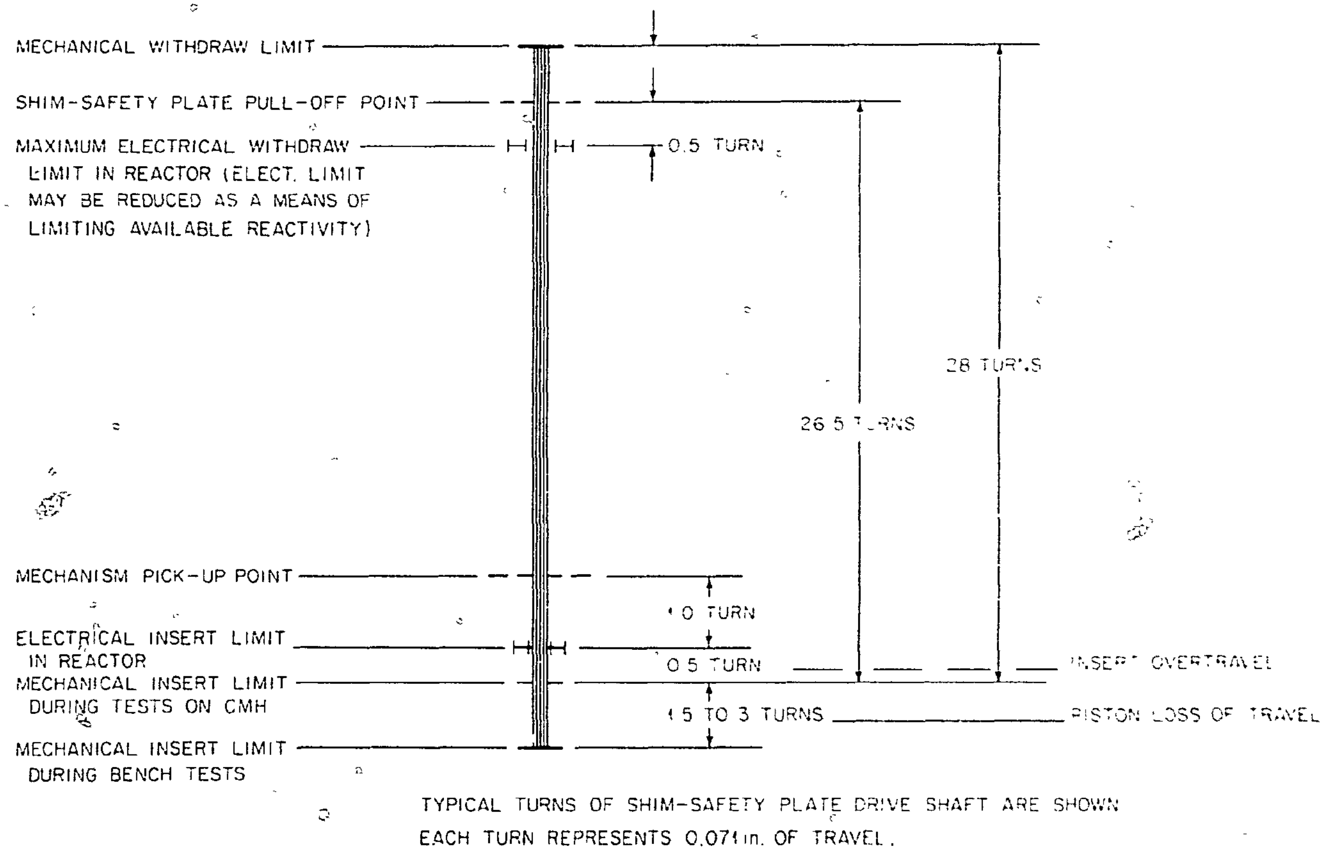

Fig. 15. Typical guide points for indicated operation of control mechanism drive.

position where each shim-safety plate is mechanically disengaged. Subtracting these numbers from the total turns will give the amount of upper end overtravel for each mechanism, and these overtravel numbers are recorded.

The minimum pressure and flow needed to keep the piston and spool engaged to 25 turns withdrawn is determined. Response tests from this position provide maximum transducer motion for the best oscilloscope pictures. This value has been chosen as a standardized location for taking pressure and flow readings. With pressure at the minimum, the shim-safety plate is withdrawn 25 turns, then the water supply is slowly throttled and the pressure and flow rates are observed at the time the plate disengages and scrams. The next step is to measure the response times of the control mechanisms, shim-safety plate response times, under simulated reactor conditions. These measurements are made with all mechanisms on the CMH and dummy lune plates on the CMH, and the CMH full of water.

8.7 <u>Shim-Safety Response Measurements with Transducer on CMH</u>

The CMH is first enclosed in a set of special dummy lune-shaped plates having holes to permit the transducer to contact the shim-safety plates for measuring their movement. The dummy plates are held in place with plastic tape, and all seams and unused holes are carefully taped shut to minimize the leakage of the water. Care must be used when setting up the transducer slide to aim the contact rod exactly in the direction of the shim-safety plate motion, otherwise the rod may get wedged between the shim-safety plate and the cover plate. Wooden posts spanning from the CMH to the opposite side of the test pit are used to brace the CMH and eliminate reactive motion due to scramming a shim-safety plate.

A garden hose is used to maintain the CMH full of water or the pit is completely filled with water to submerge the CMH. Making scram tests with the CMH less than full will result in unrealistically short travel times and may permit more shock than is desirable when a plate contacts its stop.

Scram tests are made at water pressures barely adequate to maintain the spool and piston engaged and also at a higher uniform pressure of 55 to 60 psig for all mechanisms. The higher test pressure slightly lengthens the mechanism release time. Response times are measured with the equipment shown in Fig. 7. Appendix D gives information that is used in setting up and operating the scram test instruments.

Successive scrams are made with a given mechanism under identical conditions. When repeated oscilloscope displays show little variation, a typical scope display is photographed with the Polaroid camera, resulting in a picture like that shown in Fig. 16. Each photograph is carefully marked with the data, test number, mechanism number, water pressure and other pertinent data.

The shape of the shim-safety plate for No. 5 mechanism is different from the others. The different edge clearance and the absence of water-passage holes and the fact that its scram is gravity aided results in scram performance slightly different from the others.

8.8 Seat Switch Tests

The five seat switch leaf springs were adjusted earlier (step 8.1) to stop the flow of water through the seat switch orifices. With the shim-safety plates in place and adjusted, the seat switch leaf springs are reassembled to the CMH. The contact between the leaf spring and the actuator on the plate should be established to permit the required rate of water flow when its plate is in the scrammed position.

Reshaping the leaf spring consists of bending only the end section which contacts the actuator tongue of the shim-safety plate, with care being taken not to disturb the previously shaped part of the spring which produces the seal at the orifice when the shim-safety plate is withdrawn. Metal may also be removed or added to the actuator to provide the correct contact. Experience has shown that a gap of 0.010 in. to 0.015 in. between the orifice and the

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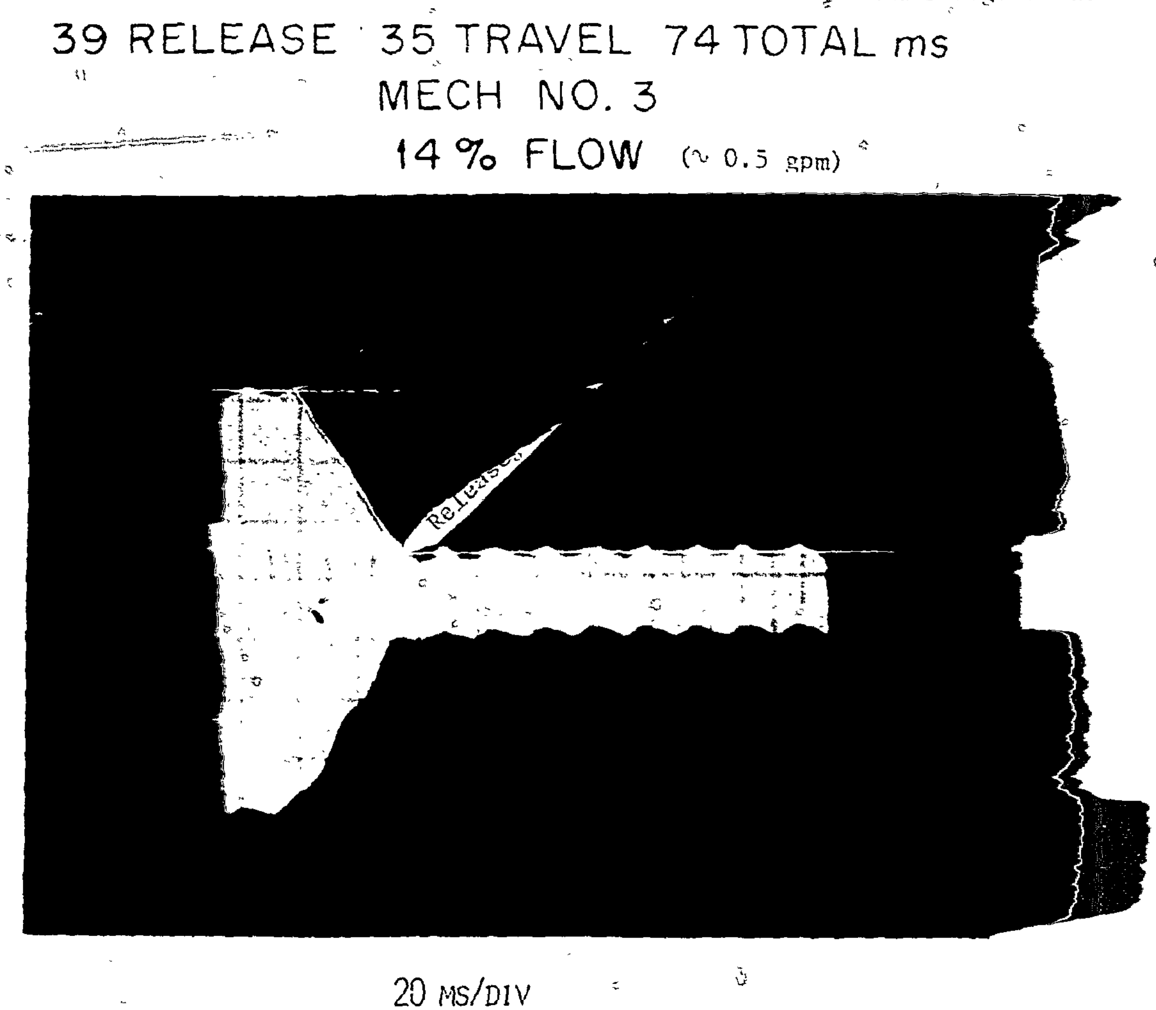

Fig. 16. Oscilloscope trace of shim-safety plate release and travel times.

leaf spring will produce a flow of approximately 0.1 gpm at 5 to 15 psig, and this flow is satisfactory for indicating that the shim-safety plate is scrammed.

During adjustment of the leaf spring the following suggestions and precautions are recommended:

1. Use feeler gages to measure the gap between the orifice and the leaf spring.
2. Avoid scratching the sealing surface of the leaf. A small toolmaker's vise is helpful in bending leaf springs.
3. Avoid bending the leaf spring beyond its elastic limit by mistake, as would happen if a shim-safety plate were removed while its seat switch leaf spring is in place.
4. Make sure the leaf spring makes reliable contact with its actuator so that it will not slip off or bind.
5. Reshape the working surface of the actuator, if necessary, by removing metal or by welding on an extension.
6. Remember that any last minute adjusting of a shim-safety plate stop will also alter the water flow gap between the seat switch orifice and its leaf spring.
7. Be alert to the possibility that a leaf spring may contact a fuel-loaded cover plate. This possibility should be investigated with the template and also when the lune plates are added to the CMH. If scratch marks are generated at the suspected locations on the inside surface of the lune plates, take corrective action.
8. Record in the log book the flow at 5 to 10 psig water pressure for each of the five seat switches with the shim-safety plates scrammed and also picked up (where the flow must be essentially zero.)

8.9 Shim-Safety Plate Response Measurements with Seat Switch

The measurements in section 8.7 are repeated in the test stand with the seat switches set up as they will be used in the reactor. For these measurements the CMH is set up as described in section 8.7 and the CMH is submerged in water. A seat switch flow transducer is connected in the flow line to each mechanism as it is tested and the signal is fed to the oscilloscope in place of the linear transducer signal. The scope is triggered by the scram signal described previously. Response times are measured and recorded of the shim-safety plate for a high seat switch flow rate, that is, in excess of 0.25 gpm with pressure of approximately 30 psig, and the results are compared to the values obtained with the transducer. The measurements are repeated with seat switch pressure and flow comparable to those encountered during reactor operation, approximately 0.1 gpm and 10 psig, and these values are recorded for future reference. The release plus travel time is shown in Fig. 17 as the elapsed time from the start of the signal trace to the point where the signal trace leaves the base line trace.

8.10 Regulating Plate (Two-Piece Plate) Test

Checks are made to demonstrate that the regulating plate will move freely throughout its full travel, without tendancy to bind. It is demonstrated that the regulating plate will move from its upper limit to its lower limit due to gravity alone and that the rotational position of the shim plate drive shaft does not affect the freedom of regulating plate motion. Likewise, it is shown that the vertical position of the regulating plates do not alter the torque required to rotate the shim drive shaft.

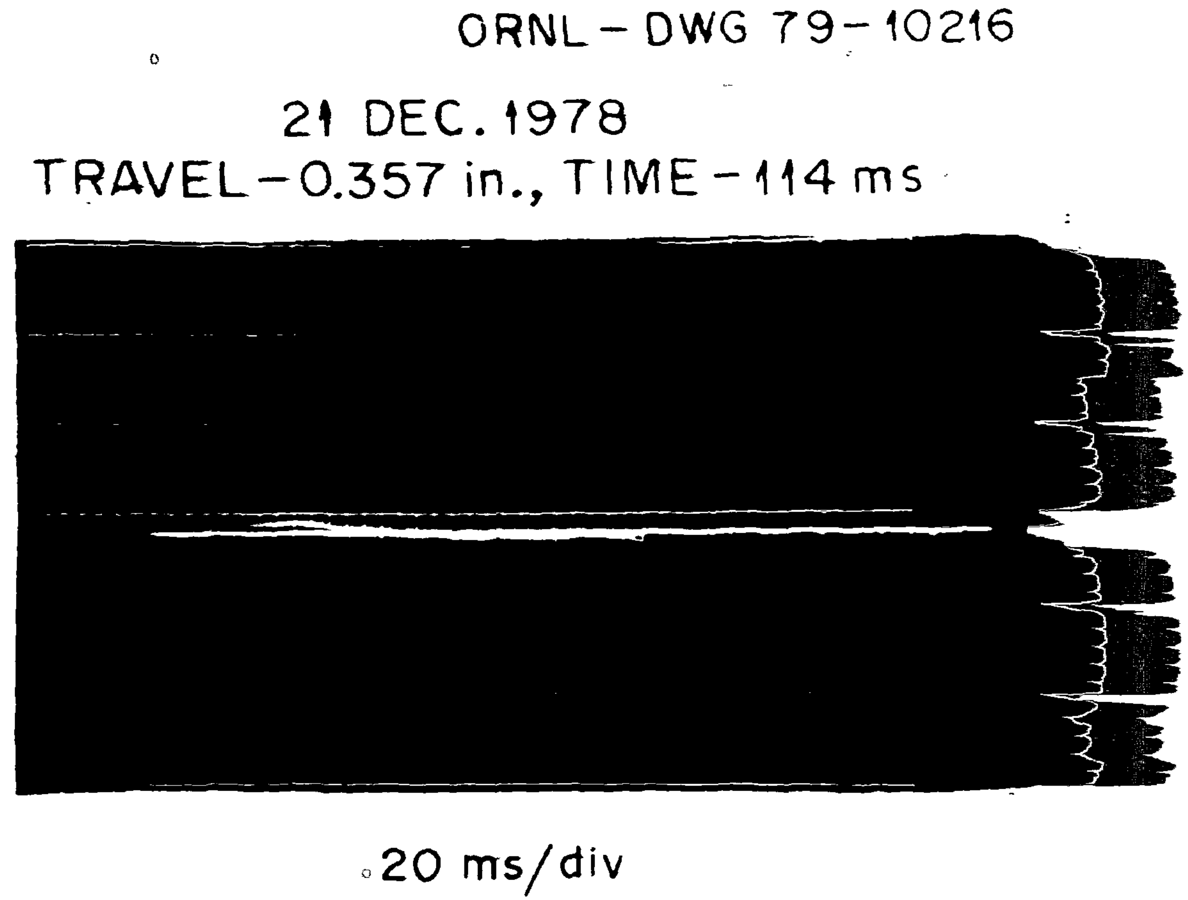

Fig. 17. Oscilloscope trace of time required for release and travel of shim-safety plate 1 during in-reactor test.

9. STORAGE OF CONTROL MECHANISM HOUSING ASSEMBLY

Tap water is normally used for testing the control mechanism assembly. If the control assembly is not to be installed in the reactor right away, steps are taken to prevent the evaporative deposition of minerals from the tap water remaining in the CMH. The control assembly is rinsed with copious amounts of demineralized water, with careful attention given to flushing the narrow passages leading to the seat switches and the control mechanisms.

Finally, the CMH is wrapped in a plastic bag to keep out dust, and the top of the support tube likewise is covered to protect the ten tube entrances and the seals for the control shafts.

APPENDIX A. SUMMARY OF FABRICATION, ASSEMBLING, AND TESTING

1. Order nonstock items from suppliers as needed, i.e. scram springs, piston rings.

2. Start simultaneous shop fabrication of five major components: mechanism, CMH, stem, B_4C-filled control plates, fuel-loaded lune plates.

3. Do bench tests of mechanisms; rework as needed.

4. Inspect B_4C-filled control plates; confirm the filler material with neutron absorption test.

5. Make trial fit of CMH to stem; do not weld.

6. Make trial fit of regulating half plates to regulating plate drive shaft in stem assembly; remove half plates.

7. Fit mechanisms to gear block in stem; locate and anchor shim drive shaft bushing; add five spacer washers needed to establish desired backlash behind five miter gears; pin two miter gears to drive shaft and four miter gears to four mechanism shafts; remove mechanisms from stem assembly.

8. Clamp CMH to stem and weld tubes to make a permanent CMH-and-stem assembly after installing regulating plate segments or after demonstrating that the segments can be installed after the tubes are welded in place.

9. Test mechanism water tubes and seat-switch tubes for possible plugging or leaks.

10. Attach mechanism and control plates to CMH; inspect shim-safety plate fit-ups; install seat switch leaf springs; trim actuators on shim-safety plates approximately to dimension.

11. Inspect fuel-loaded lune plates; trim to fit templates; attach to CMH using templates for drilling and tapping; remove lune plates and store in accordance with security plan.

12. Synchronize mechanisms for uniform time of pickup; adjust shim-safety plate stops, resynchronize if necessary.

13. Adjust seat switch leaf springs for complete closure and proper openings at nozzles.

14. Make final tests of seat switches and mechanisms on CMH.

15. Rinse water passages and whole assembly with demineralized water; cover assembly with protective plastic sheet until time for installation in reactor.

16. Bring documents up-to-date to show latest corrections and improvements.

17. Demonstrate proper performance of control assembly again immediately before installing it in the reactor.

APPENDIX B. FINAL ACCEPTANCE TESTS FOR TSR-II CONTROL MECHANISM HOUSING

Description of Test	Acceptance Test Limits
Shim-safety plate drive shaft must turn freely with plates picked up or scrammed	(Acceptable torque values have not been established)
Regulating plate shaft must move freely throughout its entire range	Must descend by gravity from any position
Shim-safety plate travel, lower mechanical stop to pull-off	25 turns min.
Shim-safety plate variation of pickup point	0.5 turn max.
Water pressure required to hold shim-safety plate at 25 turns picked up	60 psi max.
Water flow per mechanism at 25 turns picked up (at min. water pressure)	1.1 gpm max.
Photographs of response times of each mechanism at pickup and at 5, 10, 15, and 25 turns withdrawn at pressure and flow to permit withdrawal to 25 turns	Total scram time at <200 msec Total release time at <80 msec
Seat switch flow, shim-safety plates scrammed (at <10 psig water pressure)	0.10 gpm min.
Seat switch flow, shim-safety plates picked up (at <10 psig water pressure)	0.05 gpm max.
Weight of B_4C in shim-safety plates (g)	4450 ± 25
B_4C weight, total in	
Plates 1, 2, 3, 4, weight each, including filler plug	850 max. 830 nom. 810 min.
Plate 5, weight	545 max. 530 nom. 515 min.
Plates A and B, weight each	335 max. 300 nom. 285 min.
Filler plugs, each	23 max. 0 min.

Description of Test	Acceptance Test Limits
Control plate filler material	B_4C powder, 300 to 450 mesh
Confirmation of control plate filler material	Attenuation of thermal neutrons through each shim-safety plate must be measured by approved methods and must match the attenuation of previous shim-safety plates.

APPENDIX C. BRIEF HISTORY OF TSR-II CONTROL MECHANISM HOUSINGS

A review of the history of the TSR-II CMHs shows: CMH 1 was a prototype used only for early criticality studies; CMH 2 and 3 had useful lives of about one year each; CMH 4 went into service in November 1964 and was operable until April 1972 at which time CMH 5 was installed. CMHs 2 and 3 continued in service after one shim-safety plate was inoperable. Their useful life ended when the shim-safety plate drive shaft could be turned only with considerable difficulty (and with occasional shearing of drive pins) and a second shim-safety plate could not be picked up. Both CMHs required greatly increased water flows through their mechanisms during their final days of operation. The ability for the shim-safety plates to scram, an essential safety feature, remained unimpaired throughout. After two years of service, the force required to rotate the shim-safety plate drive shaft of CMH 4 increased, and the span of travel for the vertically moving regulating plate was reduced by about 0.2 inch (out of about 1.7 inches total original travel). The causes of some of these changes were not understood, even after the postmortem examination was completed.

Postmortem examinations are very difficult since early inspections are precluded because of the high radiation levels of the CMHs; and if a year or more decay time is allowed before inspection, corrosion occurs which masks the original causes of failure.

APPENDIX D. INSTRUMENT SETTINGS FOR SCRAM TESTS

The circuitry and components needed for conducting the scram tests are shown in Fig. 7. The numerical values given below are those arrived at during a former set of scram tests. They may serve as a guide in setting up for future tests but should not be regarded as rigidly fixed.

D.1 Magnet Amplifier

Set up by standard procedure.

D.2 Wave Generator (Model M-2 RC Oscillator)

Range: 10^3

Tuning: 8.6

Output: 8

Dial: 11.6

D.3 Magnet Control Box

Upper pot: 4.6

Lower pot: 6.0

Voltage: 38

D.4 Oscilloscope

Use a type oscilloscope similar to a Textronic 585-A which has a timed single sweep. Adjust amplitudes to provide the largest complete picture.

D.5 Polaroid Camera (attached to scope by special frame)

Film: Any black and white film with speed >200

Iris: Adjust to obtain best picture (F8 to F11)

Shutter: On bulb

D.6 Photographic Technique

(1) Adjust camera iris, speed, and focus; adjust oscilloscope brightness, focus, and scale illumination to give a sharp picture.

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(2) Set scope on single sweep and set time and amplitude to photograph the complete trace on scale.

(3) With shim-safety plate positioned, open camera shutter and press scram button on magnet current box, the sweep light should go out verifying a sweep occurrred. Close shutter.

(4) For pictures made using a flowmeter for the signal, after trace is made, remove signal input cable to oscilloscope, reset sweep, open shutter, press scram button again, close shutter and reconnect signal lead. This action provides a baseline trace on the photograph.