APAE Memo 106

Mechanical Lab. Reports 3036
3036-A
3036-B

CONTROL ROD DRIVE DEVELOPMENT

Contract AT (11-1) - 318

Issued Aug. 15, 1957

Authors J. P. Tully
T. F. Connolly
R. E. Anderson

ALCO PRODUCTS, INC.
P. O. Box 414
Schenectady, N. Y.

Table of Contents

List of Photographs

List of Photographs (Continued)

List of Photographs (Continued)

List of Photographs (Continued)

List of Photographs (Continued)

List of Figures

Alco Products, Incorporated
Mechanical Laboratory Report No. 3036

ORNL Test Rig. Control Rod and Control Rod Drive

Reference:	G.O. 690,001-1
Test Period:	June 1, 1955 to Jan. 30, 1956

Object:

To determine the operating and performance characteristics of the ORNL concept of control rod drive mechanism as applied to APPR-1.

Conclusion:

Operating the ORNL rig definitely indicated that design changes were necessary to provide a satisfactory rod drive and control rod combination for the APPR-1. Listed below are the changes deemed necessary.

1) Redesign of the seal to reduce leakage rate and operating temperature.

2) Shorten control rod drop time.

3) Improve method of control rod guiding.

4) Facilitate removal of rod drive and water seal components for maintenance.

5) Improve decelerating piston and dashpot.

6) Provide more reliable position indicating means.

7) Relocate drive to decrease operating temperature of driving mechanism.

8) Simplify gear train.

9) Redesign of backup roller and rack to prevent sticking.

Apparatus:

1) ORNL test rig.

Procedure and Results:

The test rig had been built and operated by the American Machine and Foundry Co., for the Oak Ridge National Laboratory as a preliminary study for the APPR to determine the feasibility of a rack and pinion control rod drive. The disassembled rig was received in the Mechanical Laboratory on April 11, 1955.

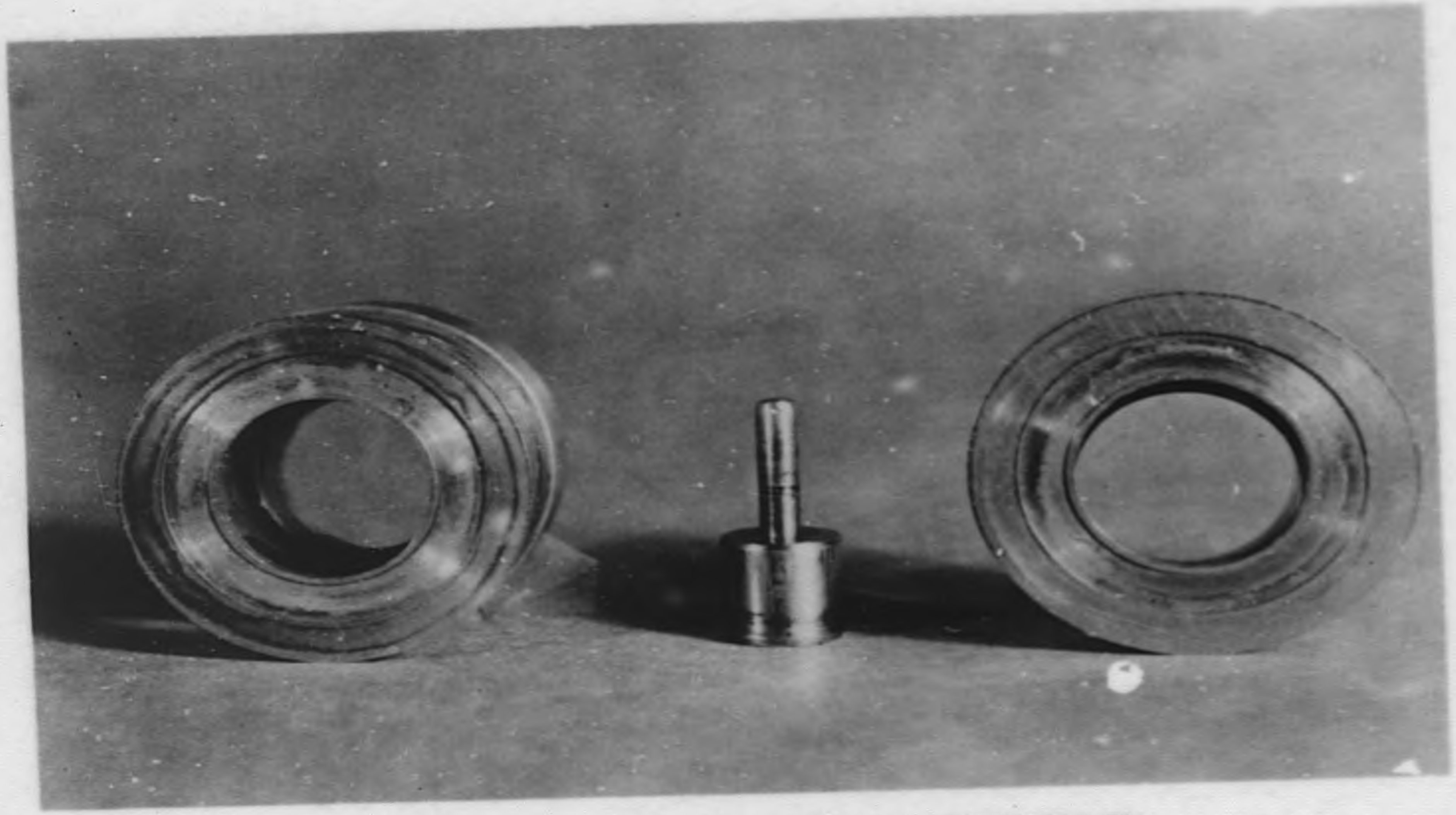
The test rig was dismantled completely and all components inspected. The attached photographs, #4725 thru 4728, indicate the condition of the water seal rings, control rod guide rollers and the control rod snubber, and are representative of the conditions found throughout the test rig.

Before reassembly of the rig the individual components were reworked as necessary, such as, lapping the water seal rings, polishing off score marks on the control rod, adjusting guide rollers, etc. A dimensional check was made of critical components.

The necessary supports and test stands were fabricated and equipment installed, ready for starting operations on September 12, 1955. Before operation the rig was pressure tested at 1775 psi and 200°F. Photographs 4754 to 4757 show the test setup shortly after starting.

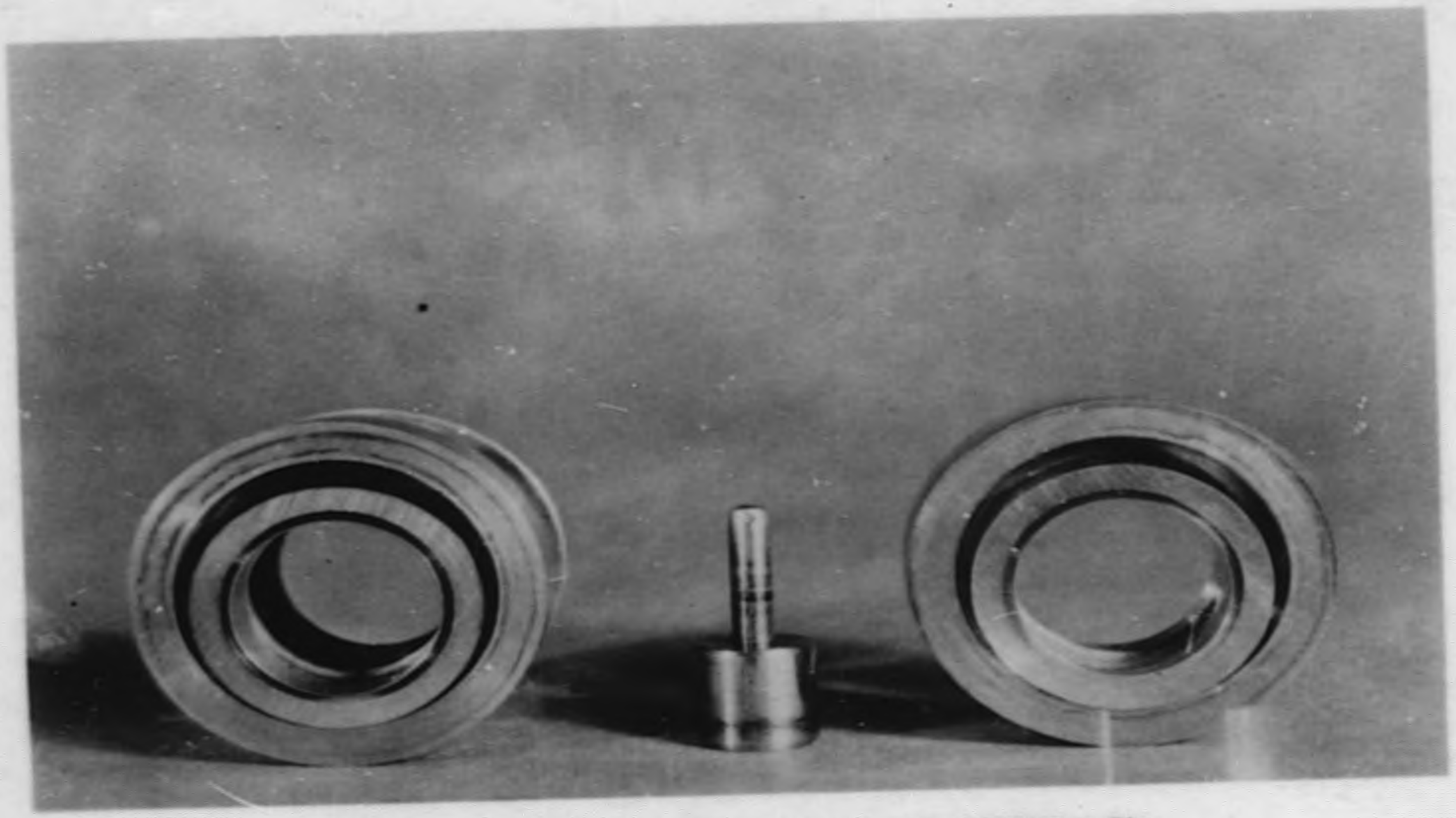
The first check of seal leakage rates was made on September 12, 1955. At this time the system pressure was held at 1100 psi with the system temperature varying from 185 - 280°F.

The coolant circulating pump used with this rig was of the conventional type using a labyrinth shaft seal. The leakage thru this seal was found to be approximately 80 #/hr. Because of this excessive seal leakage it was impossible to hold



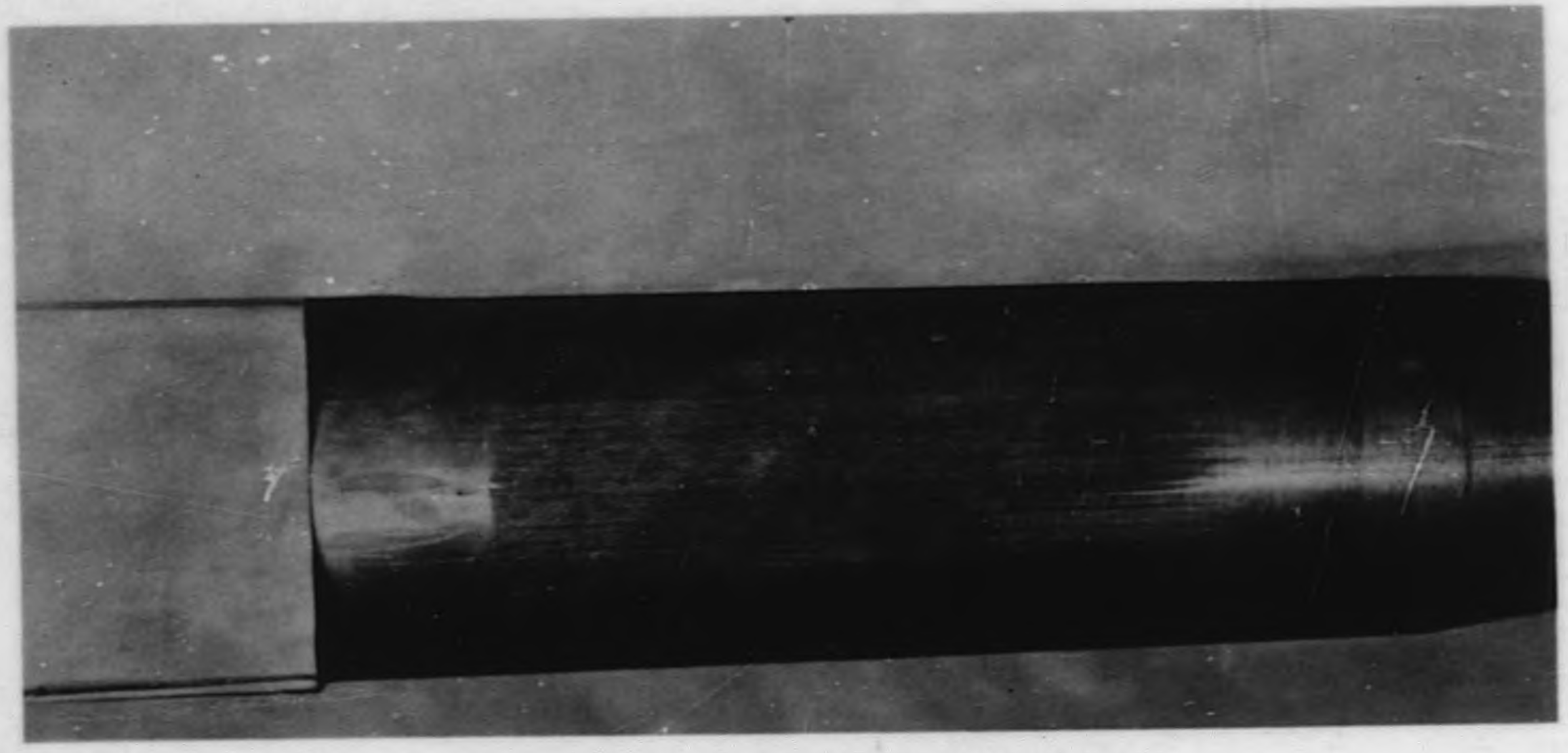
Seal Rings & Control Rod Roller as Received in ORNL Test Rig

Photo 4725



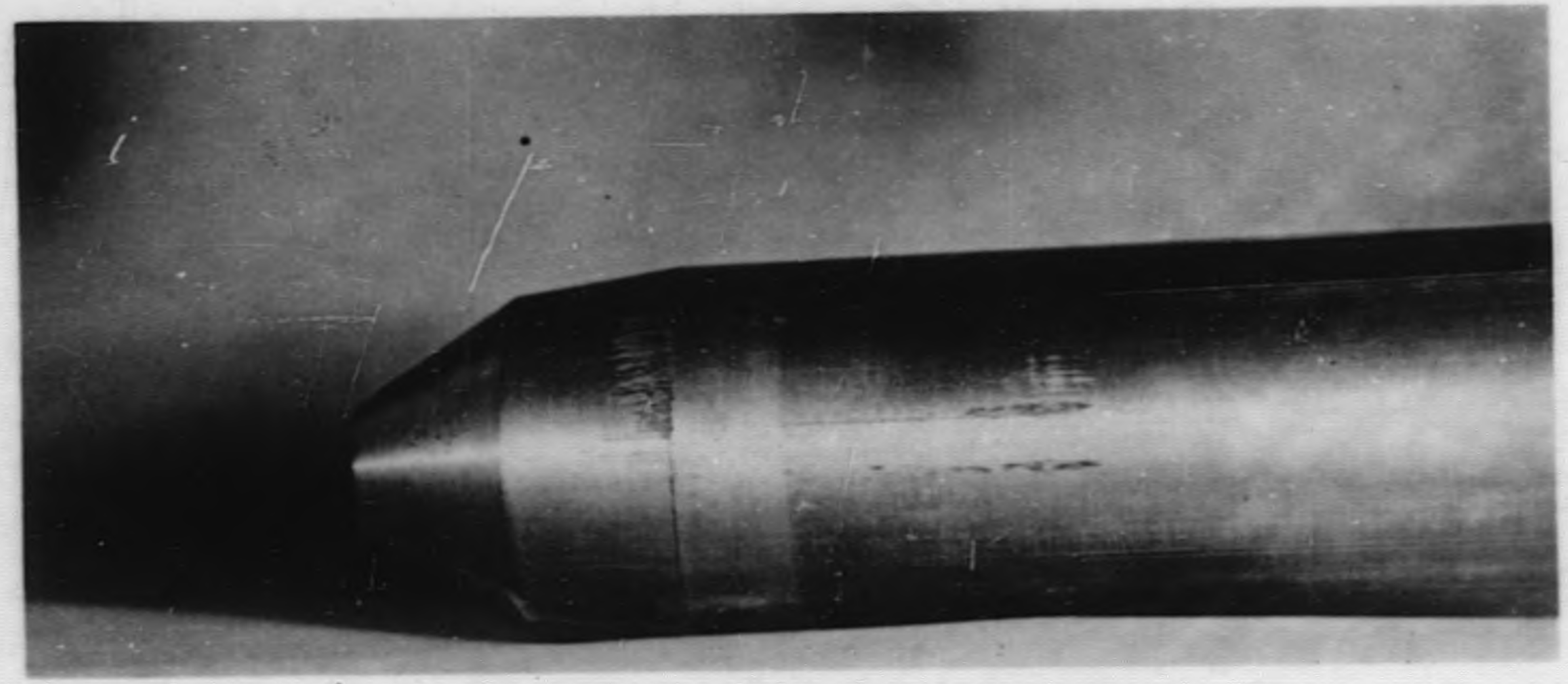
Seal Rings & Control Rod Roller as Received In ORNL Test Rig

Photo 4726



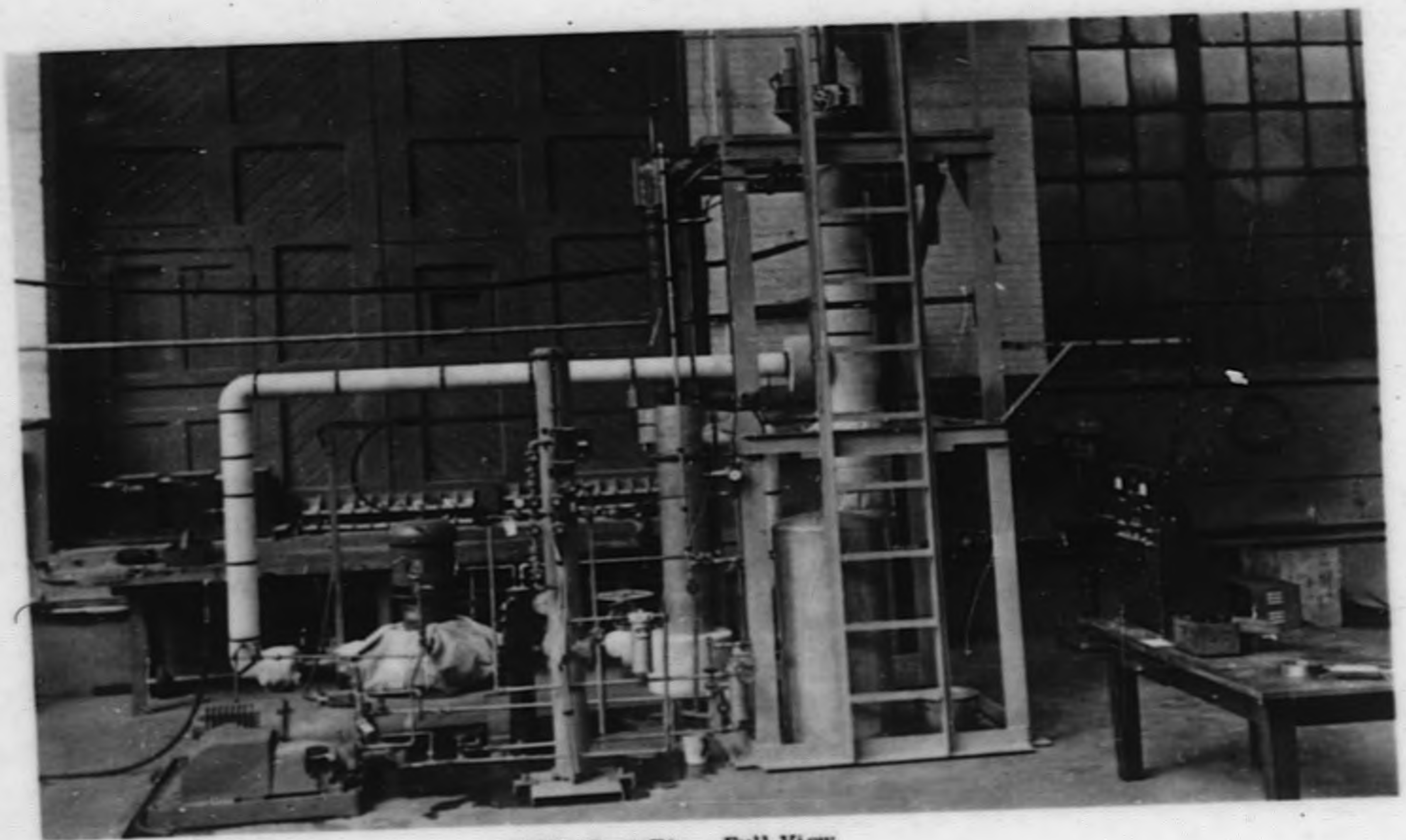
Control Rod Snubber as Received in ORNL Test Rig

Photo 4727



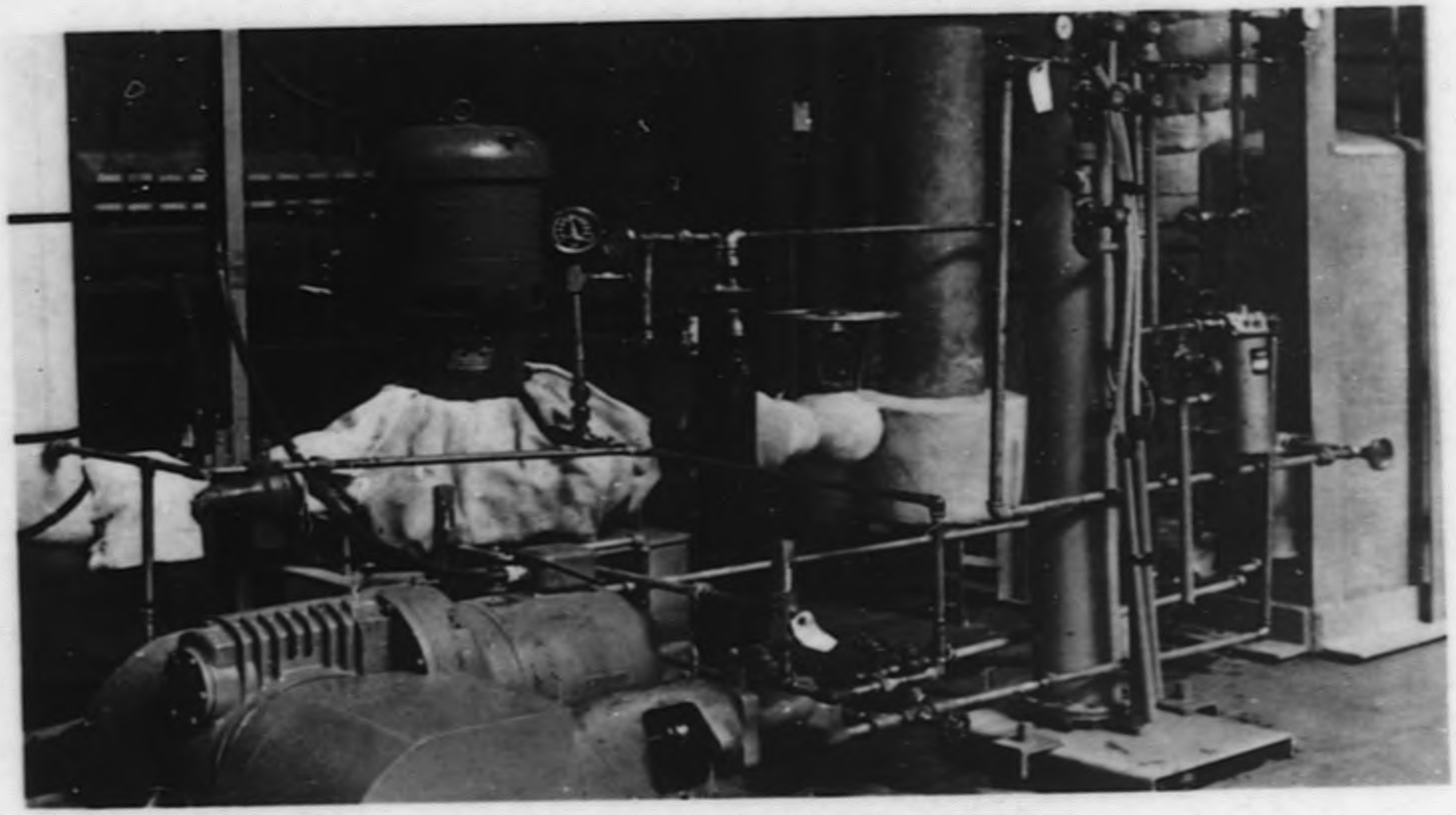
Control Rod Snubber as Received in ORNL Test Rig

Photo 4728



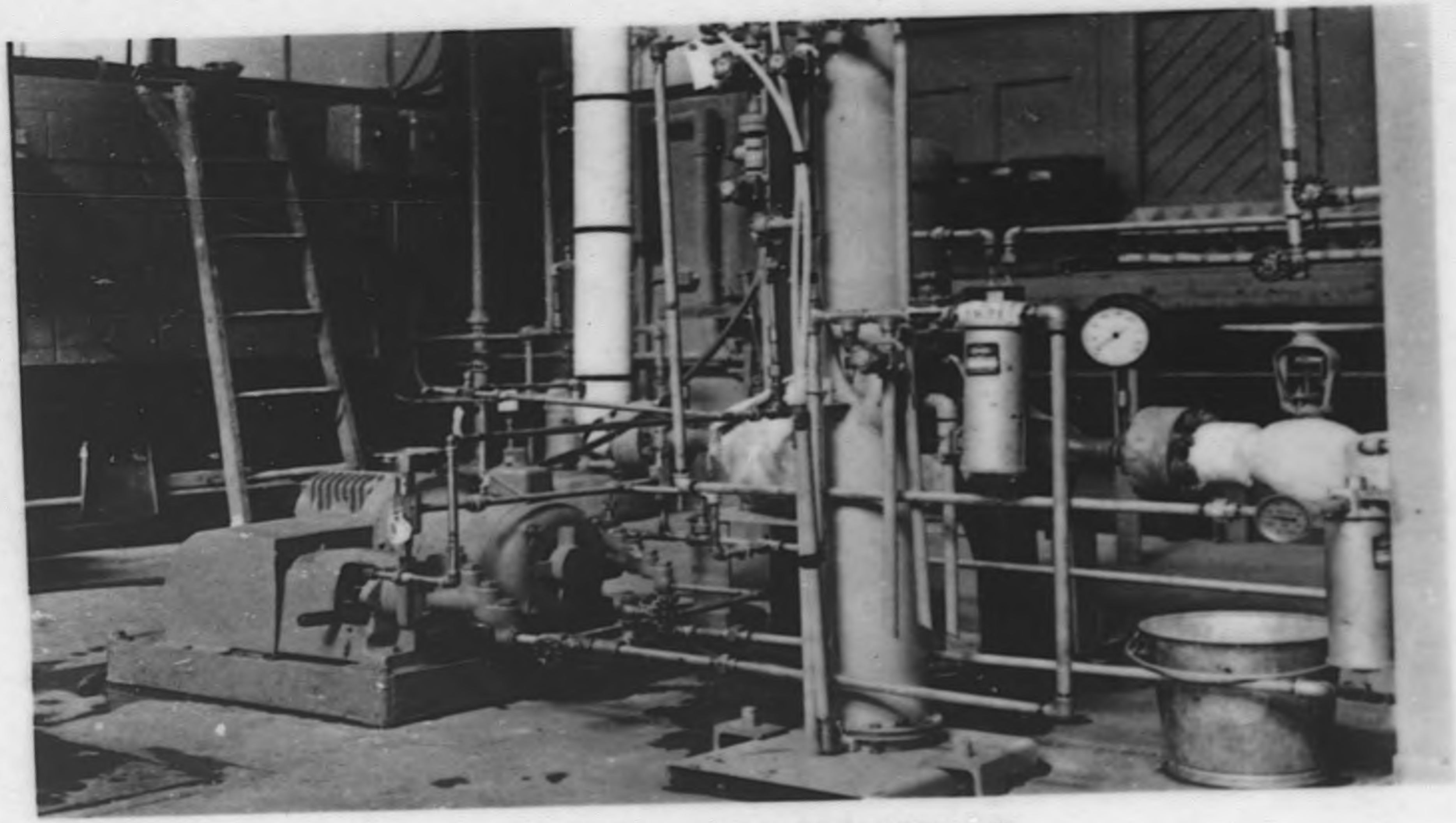
ORNL Test Rig - Full View

Photo 4754



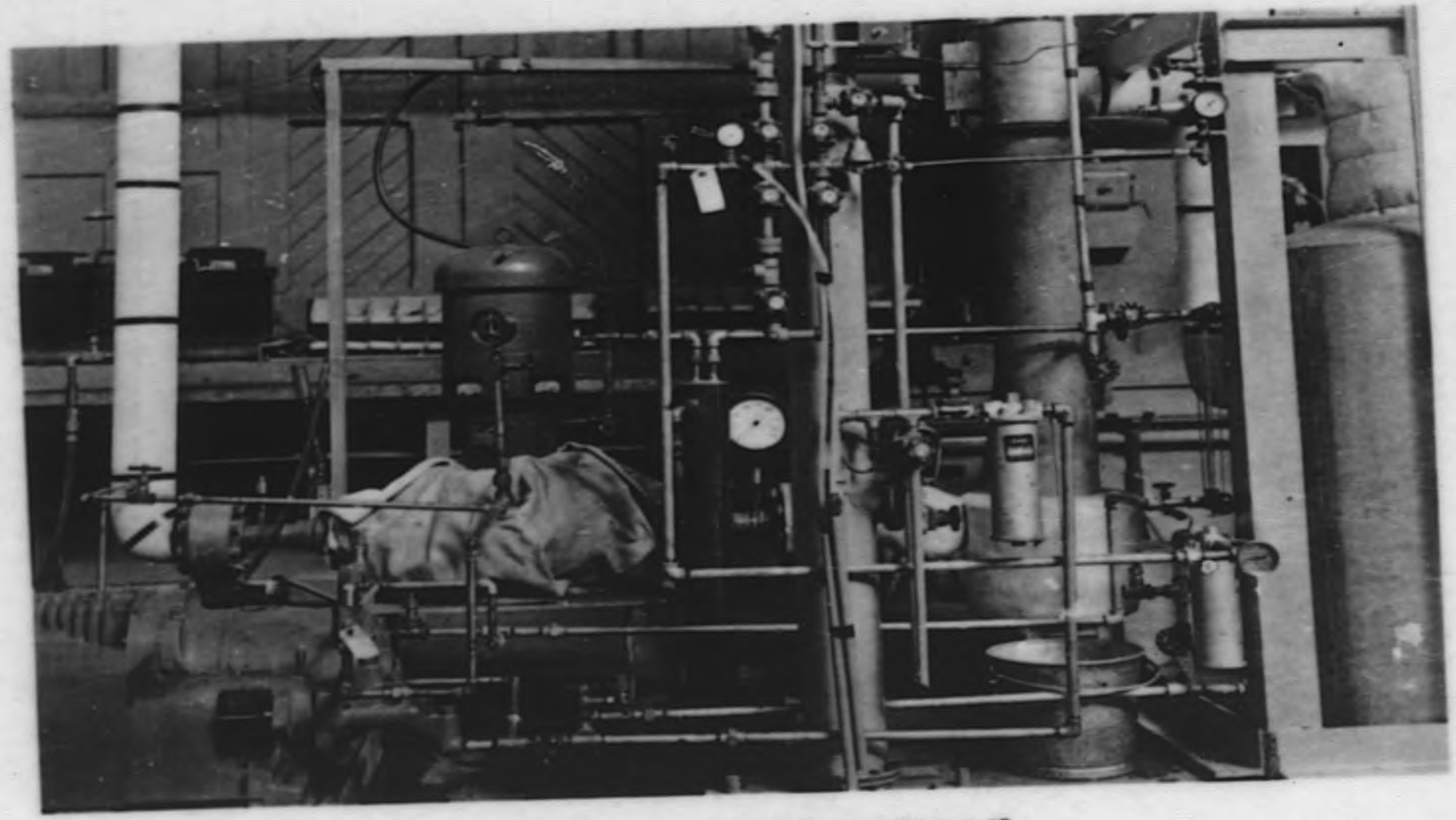
ORNL Test Rig - Select View of Piping #1

Photo 4755



ORNL Test Rig - Select View of Piping #2

Photo 4756



ORNL Test Rig - Select View of Piping #3

Photo 4757

the temperature constant or bring it to the desired operating level of 450°F. The rod drive seal leakage rate was 4.95 lbs/hr under these conditions.

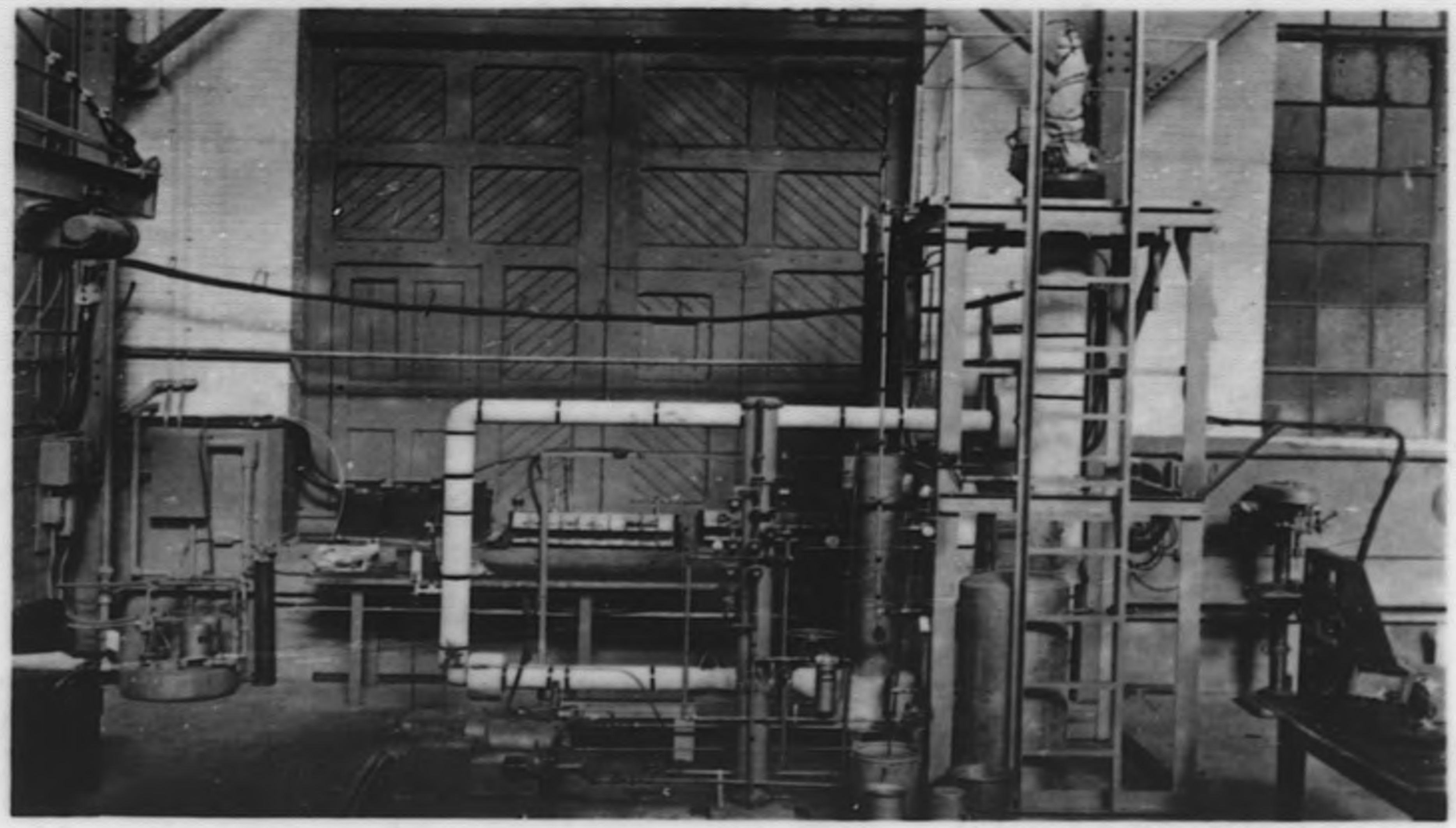
It was decided to add additional heating capacity to the system to bring it up to the desired operating temperature of 450°F. The heaters that had been previously located in the surge tank were transferred to the main tank. Due to the absence of circulation to the surge tank the heaters contributed little toward heating the system water. A total of 12 KW of heaters was added but it was still not possible to bring the system temperature above 350°F due to the pump leakage.

The circulating pump seal was removed and reworked but the leakage still could not be brought down to acceptable levels. It was decided to remove the pump from the system and depend on natural convection for circulation. A straight section of pipe was installed in place of the pump as shown in photographs #4763 to 4766. With the excessive leakage of the circulating pump seal eliminated, the rig operating temperature could be maintained. The seal leakage rate measured at 450°F and 1200 psi with the control rod drive operating was approximately 16 #/hr and with the rod stationary dropped to approximately 10 #/hr.

The test rig was placed on an operating basis which consisted of 8 hours a day continuous cycling of the control rod and 16 hours a day with the rod stationary at various points of the travel. Scrams were initiated periodically throughout the cycling period.

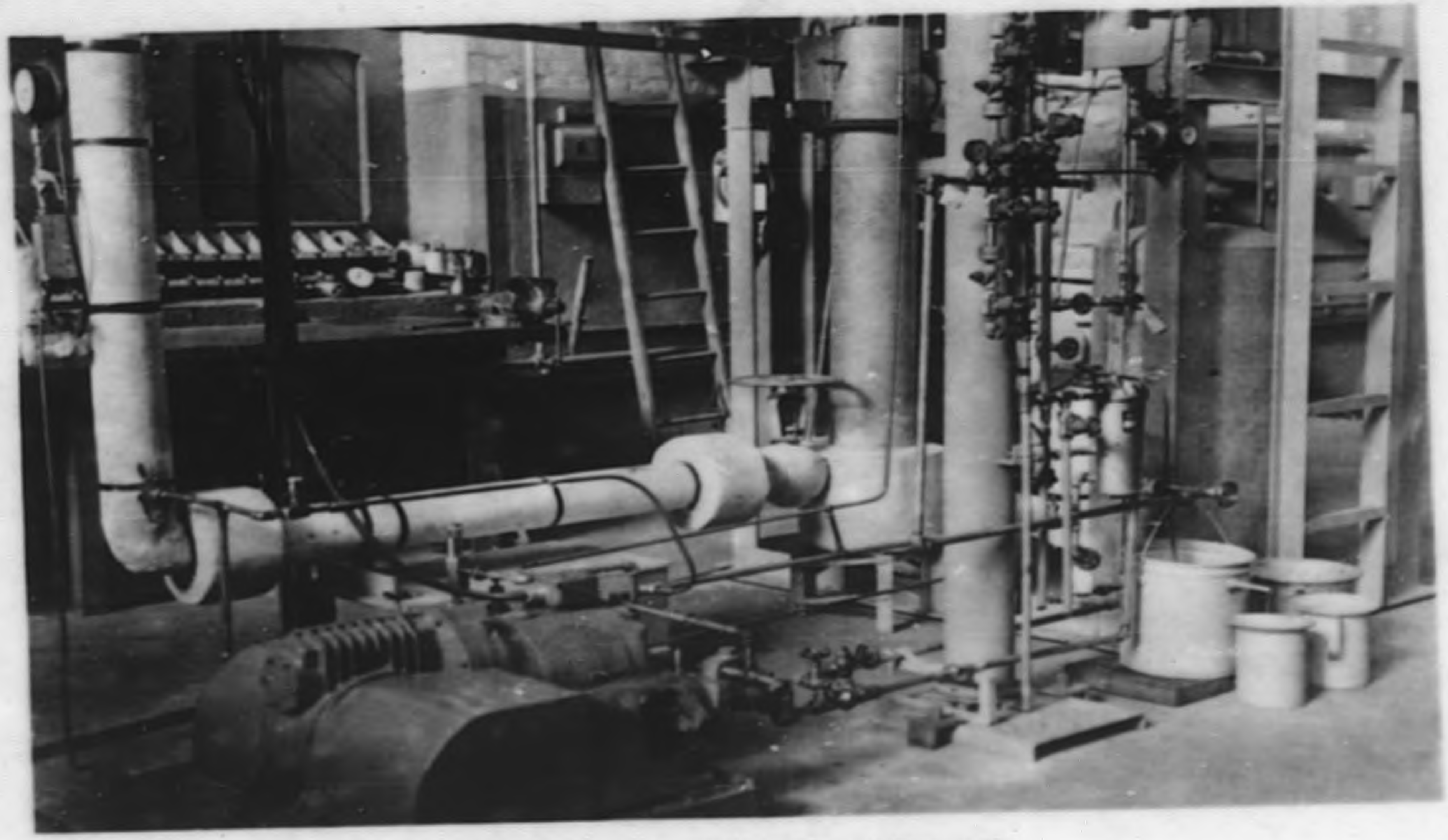
A considerable amount of the downtime during the test period was due to leaks in the system and malfunction of components such as the pressure regulating valves and heaters.

The seal leakage remained fairly constant for approximately 1200 hours of operation. A gradual rise was then noted until at 1600 hours it had risen to approxi-



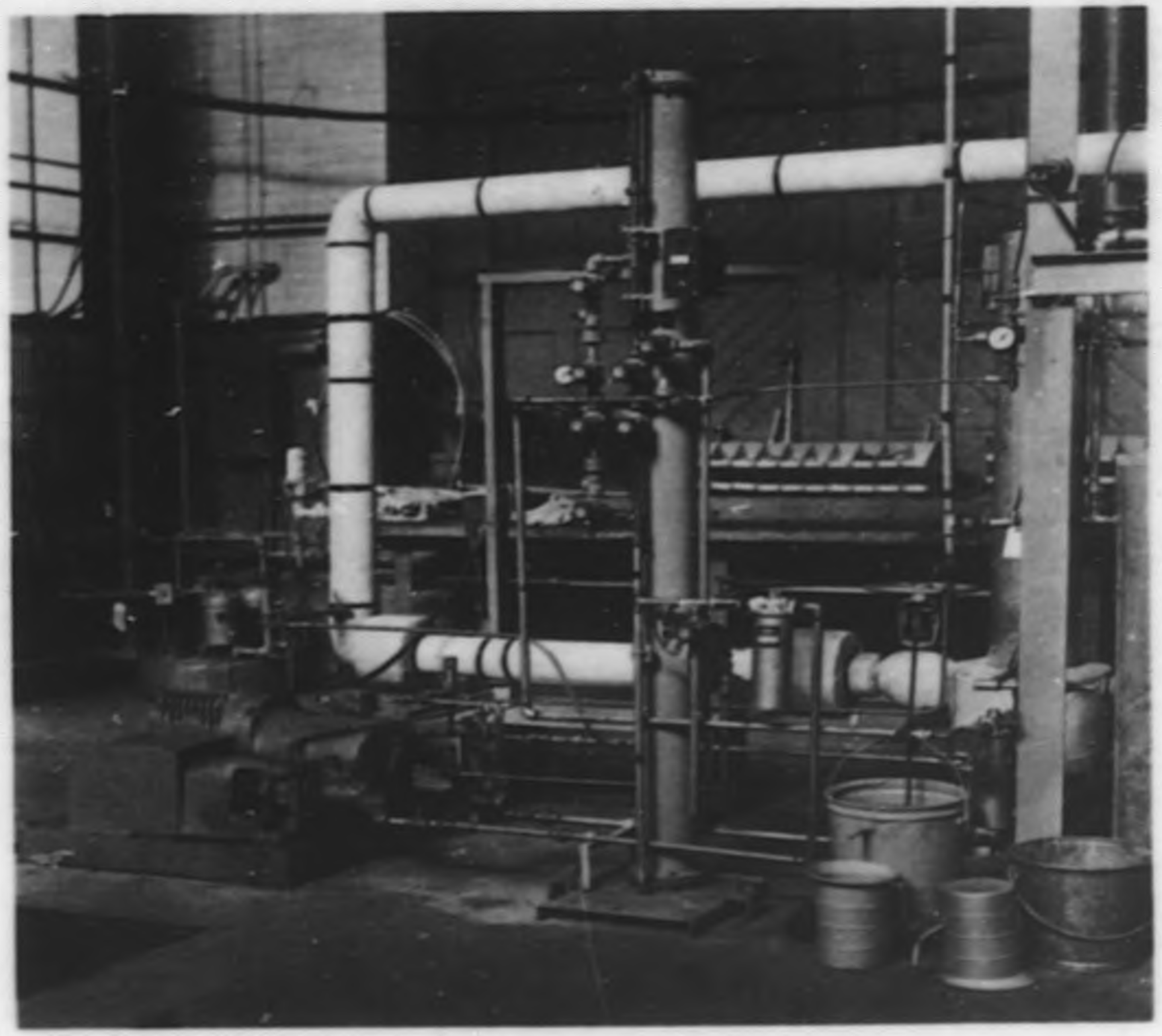
ORNL Test Rig - Full View

Photo 4763



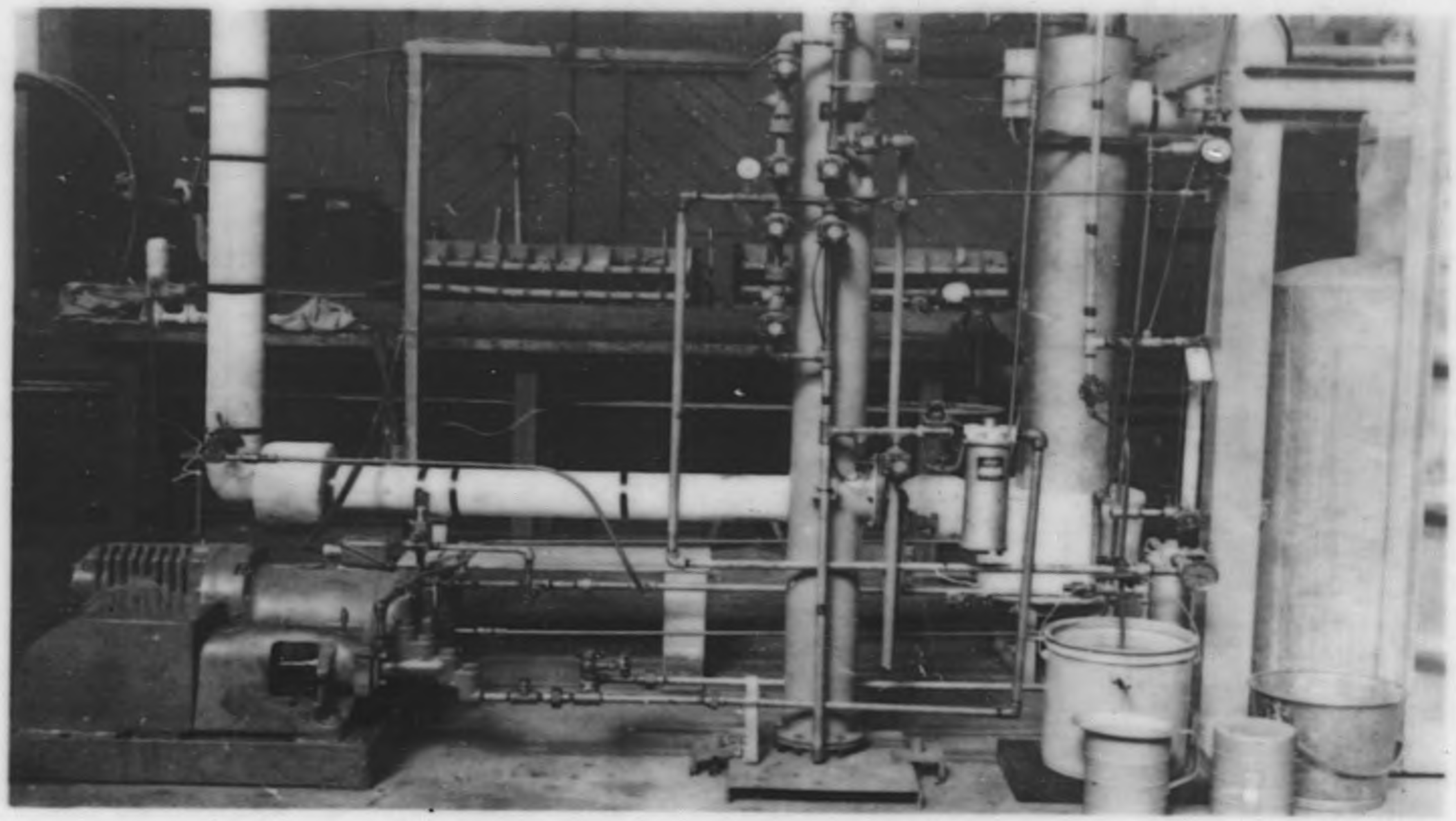
ORNL Test Rig - Select View of Piping #1

Photo 4764



ORNL Test Rig - Select View of Piping #2

Photo 4765



ORNL Test Rig - Select View of Piping #3

Photo 4766

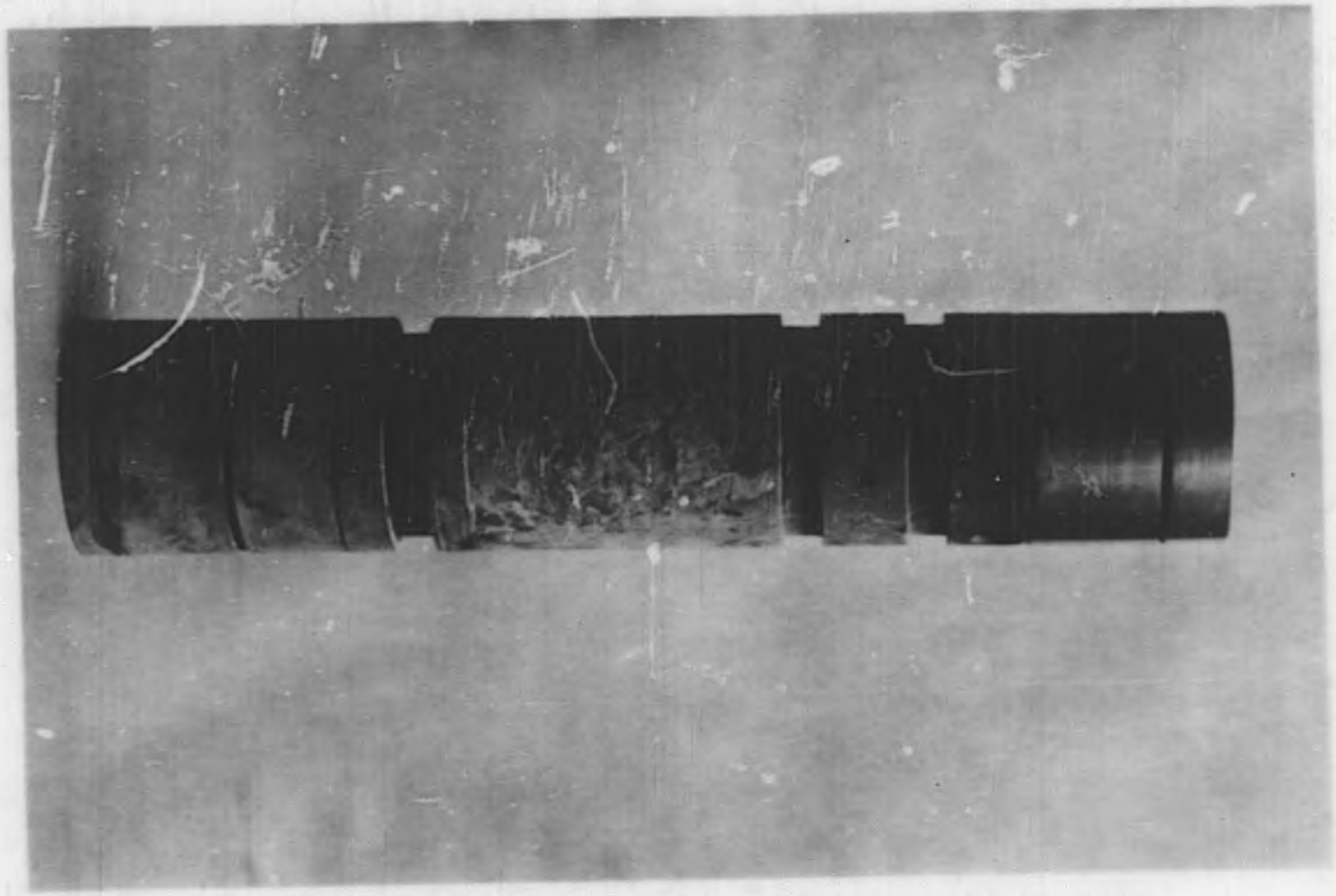
mately 36 #/hr with the rod in operation and 18 #/hr with the rod stationary. The seal ring retainer was tightened on numerous occasions but this only improved the leakage rate for short periods. Because of the inaccessibility of the seal, tightening of this retainer required an extensive dismantling of the drive components.

After 1600 hours of operation on the rig (530 hours with the rod running or 2120 cycles), the seal was disassembled for inspection. Considerable deposits of rust and scale were found on all components in contact with the primary water. The water seal components were stuck in the housing due to scale formation and corrosion. The pinion bearing was very badly worn and had to be replaced. Photographs #4872 to 4879 show the conditions of various parts of the seal and drive after 5 months of operation (1600 hours). The seal was cleaned up and reassembled, but no improvement in the seal leakage rate was apparent.

After a total of 1767 hours of operation (567 with the rod running), the system was shut down and dismantled. At this time, under standard operating conditions, the leakage rate was approximately 24 lbs/hr. Photograph #4928 shows the disassembled control rod, drive, seal and test tank.

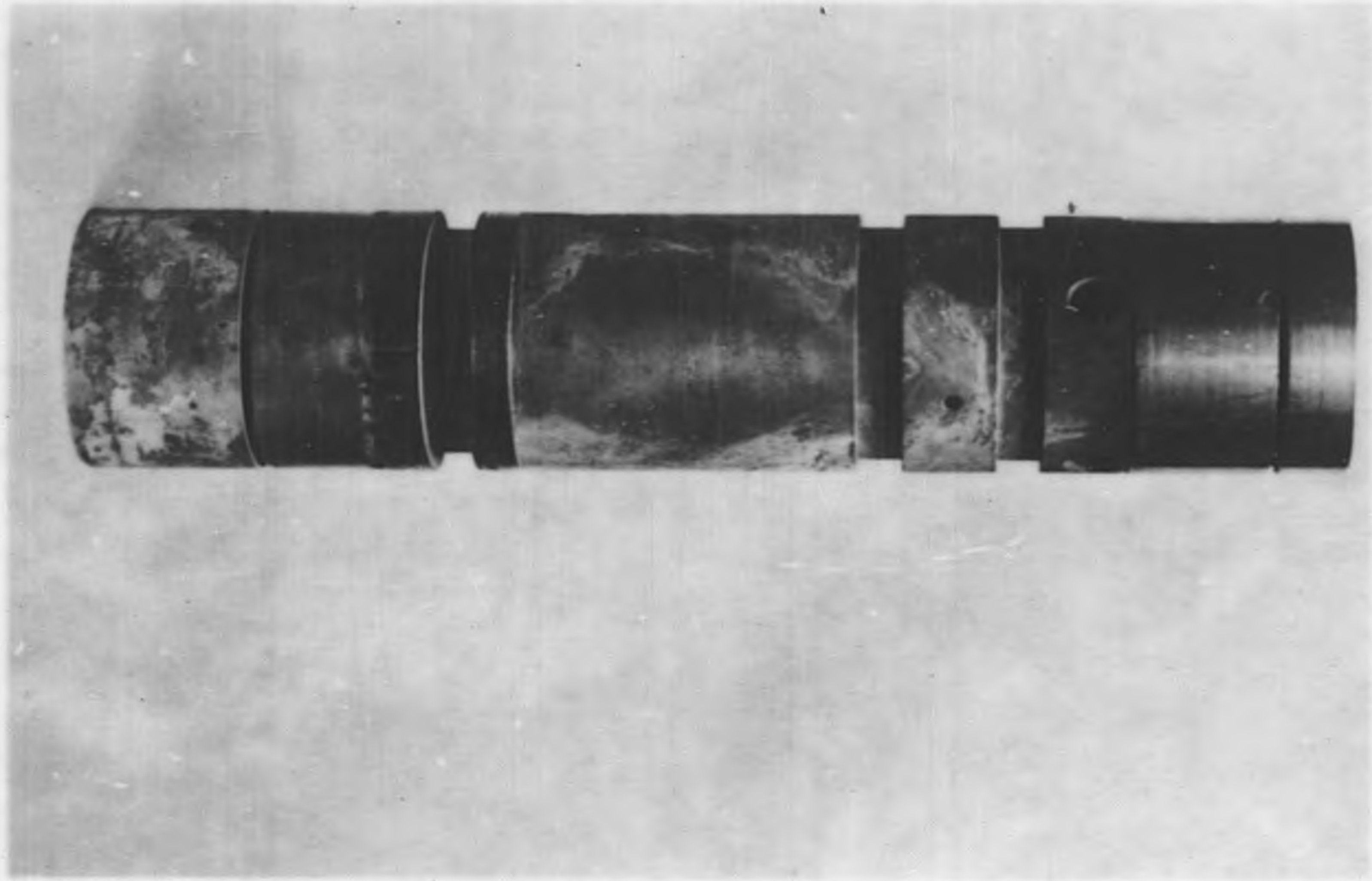
Inspection of the various parts after disassembly showed the control rod guide rollers to be practically useless. The adjustable spring mounted roller supports did not maintain their proper position. This lack of accurate guiding on the control rod caused heavy scoring of the dashpot piston and cylinder. A number of the rollers had stuck on their mounting pins resulting in flat spots due to their inability to rotate.

Throughout the entire test period the pinion showed evidence of pitting corrosion. The chrome plating on the back side of the rack had flaked off in many



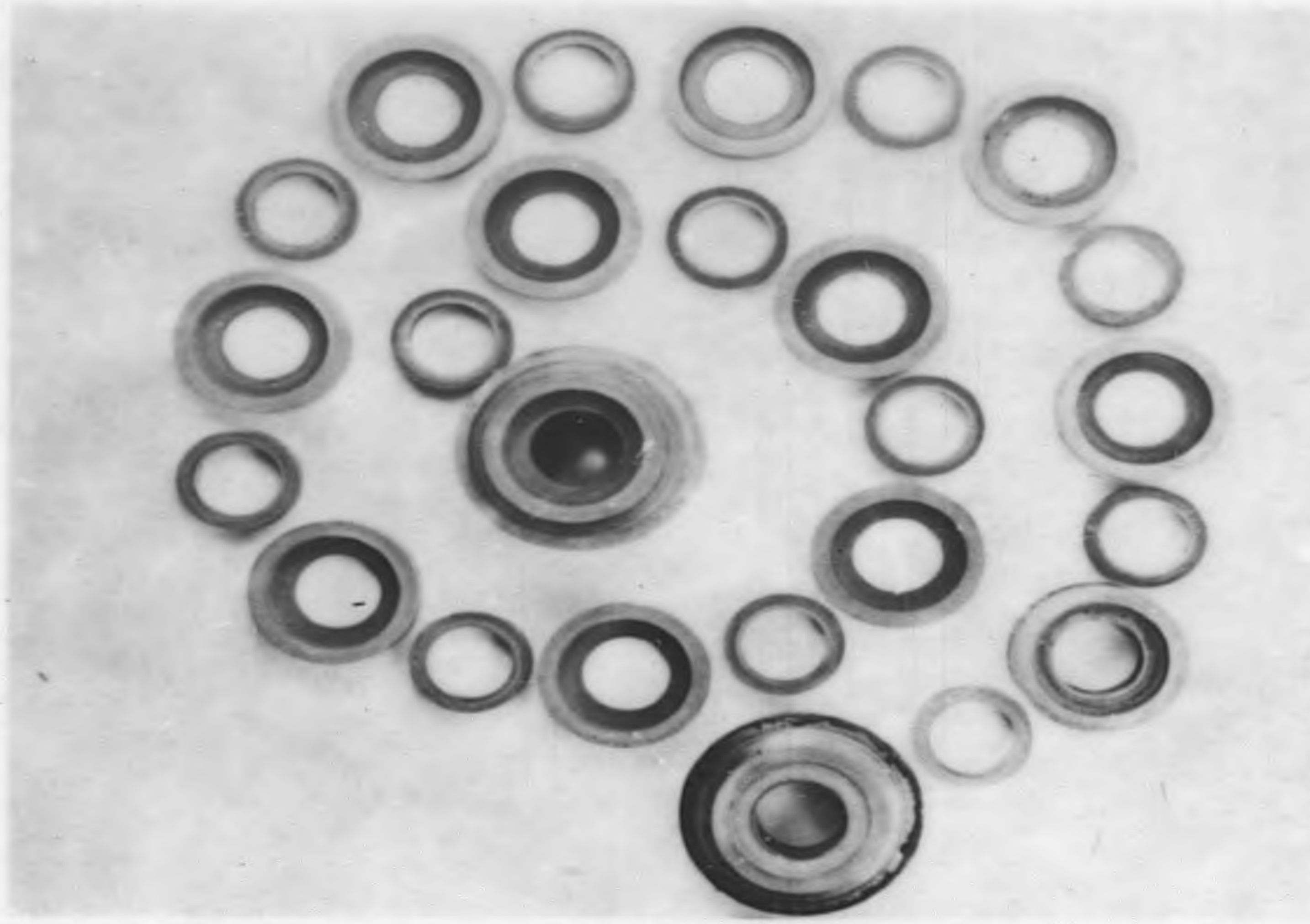
ORNL High Pressure Water Seal From Control Rod Drive After 5 Months in Use

Photo 4872



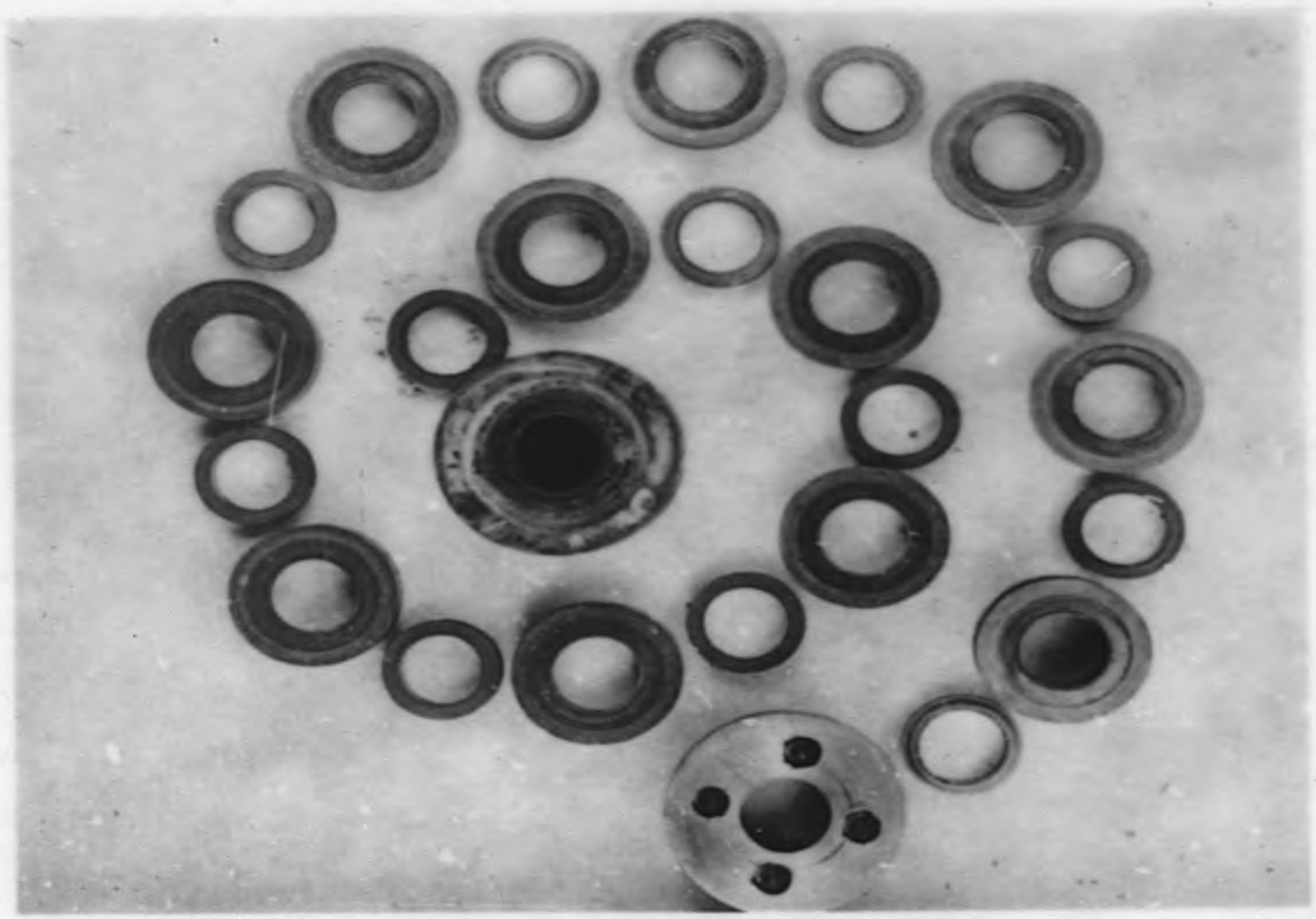
ORNL High Pressure Water Seal From Control Rod Drive After 5 Months in Use

Photo 4873



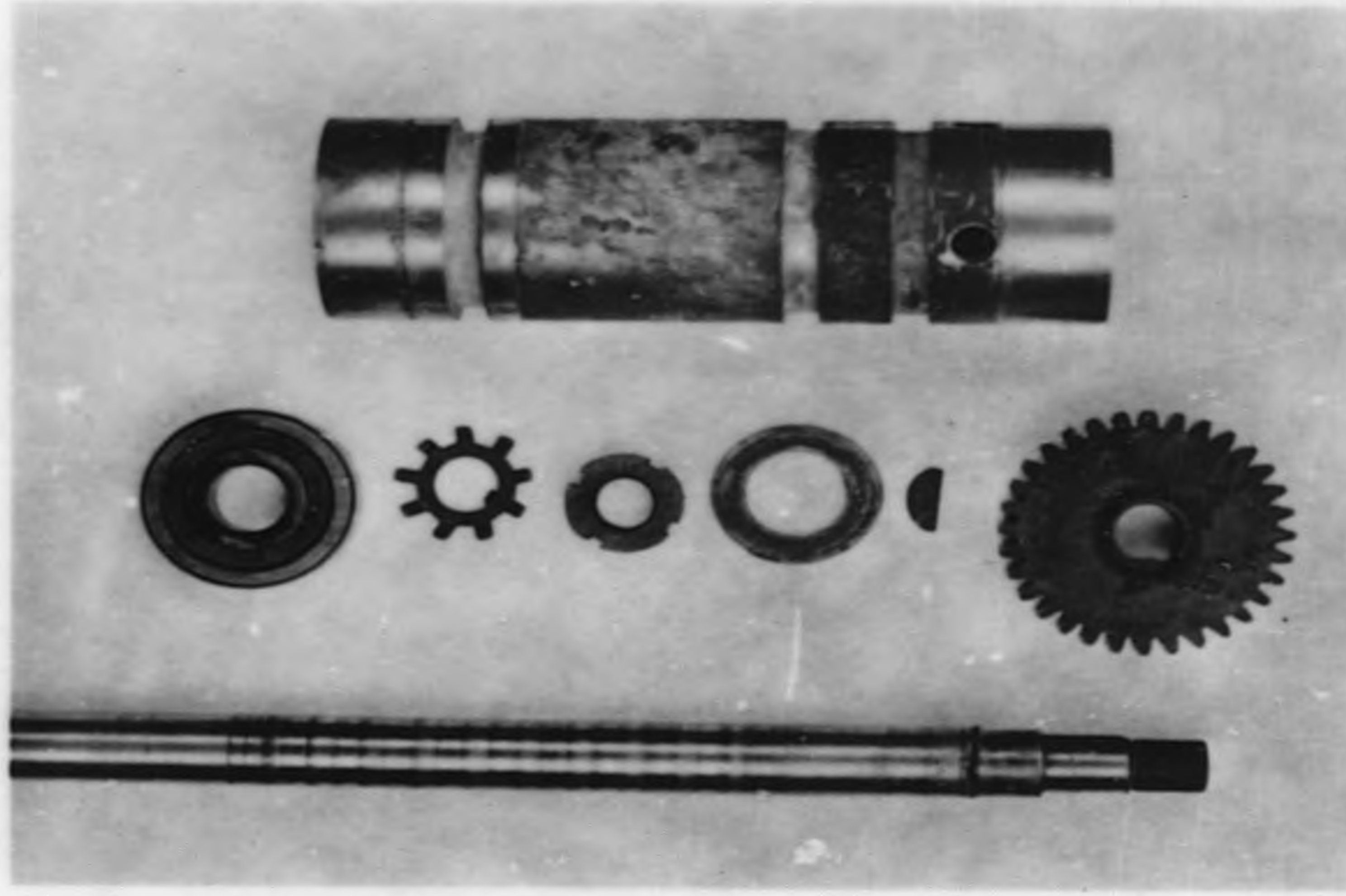
ORNL High Pressure Water Seal From Control Rod Drive After 5 Months in Use

Photo 4874



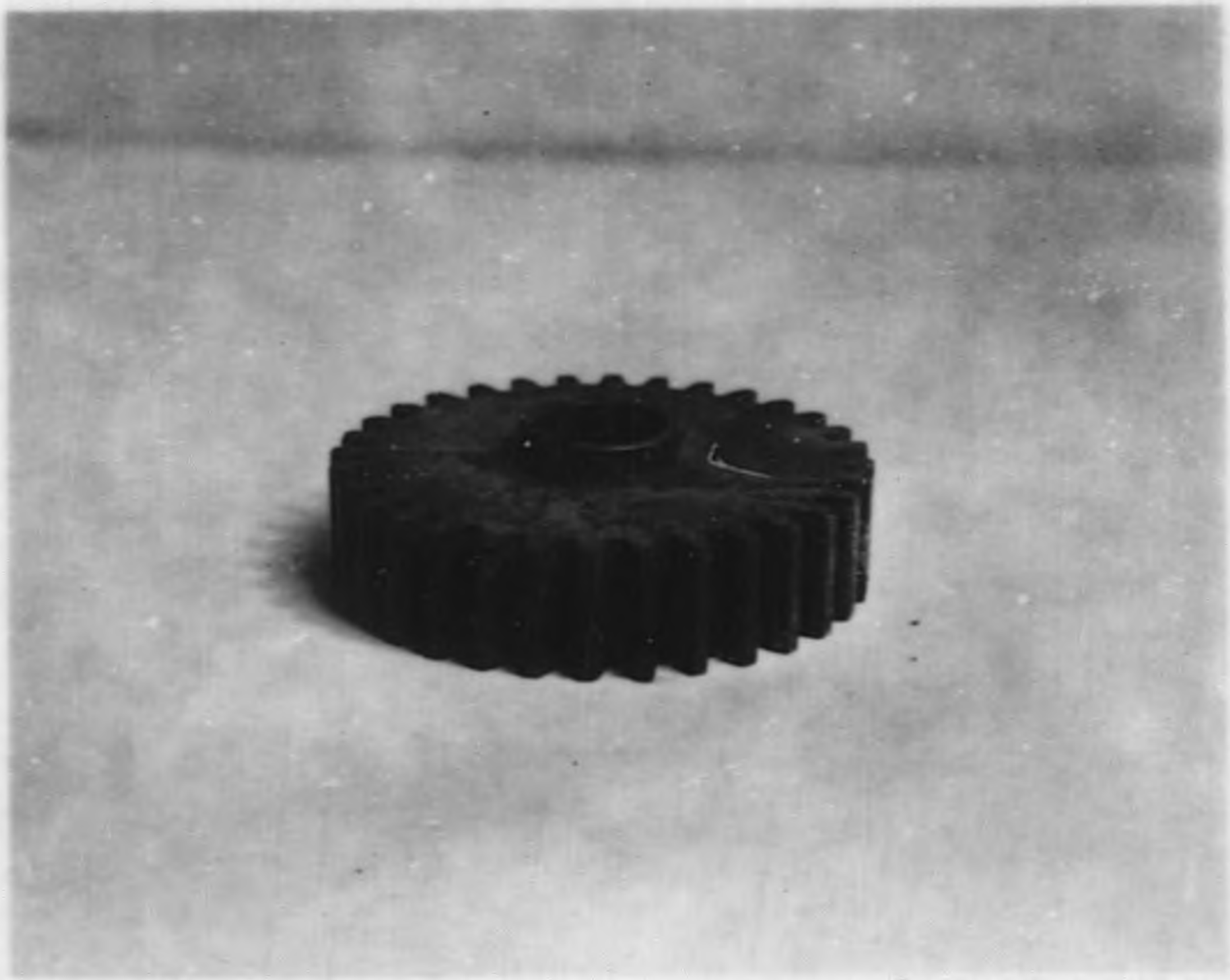
ORNL High Pressure Water Seal From Control Rod Drive After 5 Months in Use

Photo 4875



ORNL High Pressure Water Seal From Control Rod Drive After 5 Months in Use

Photo 4876

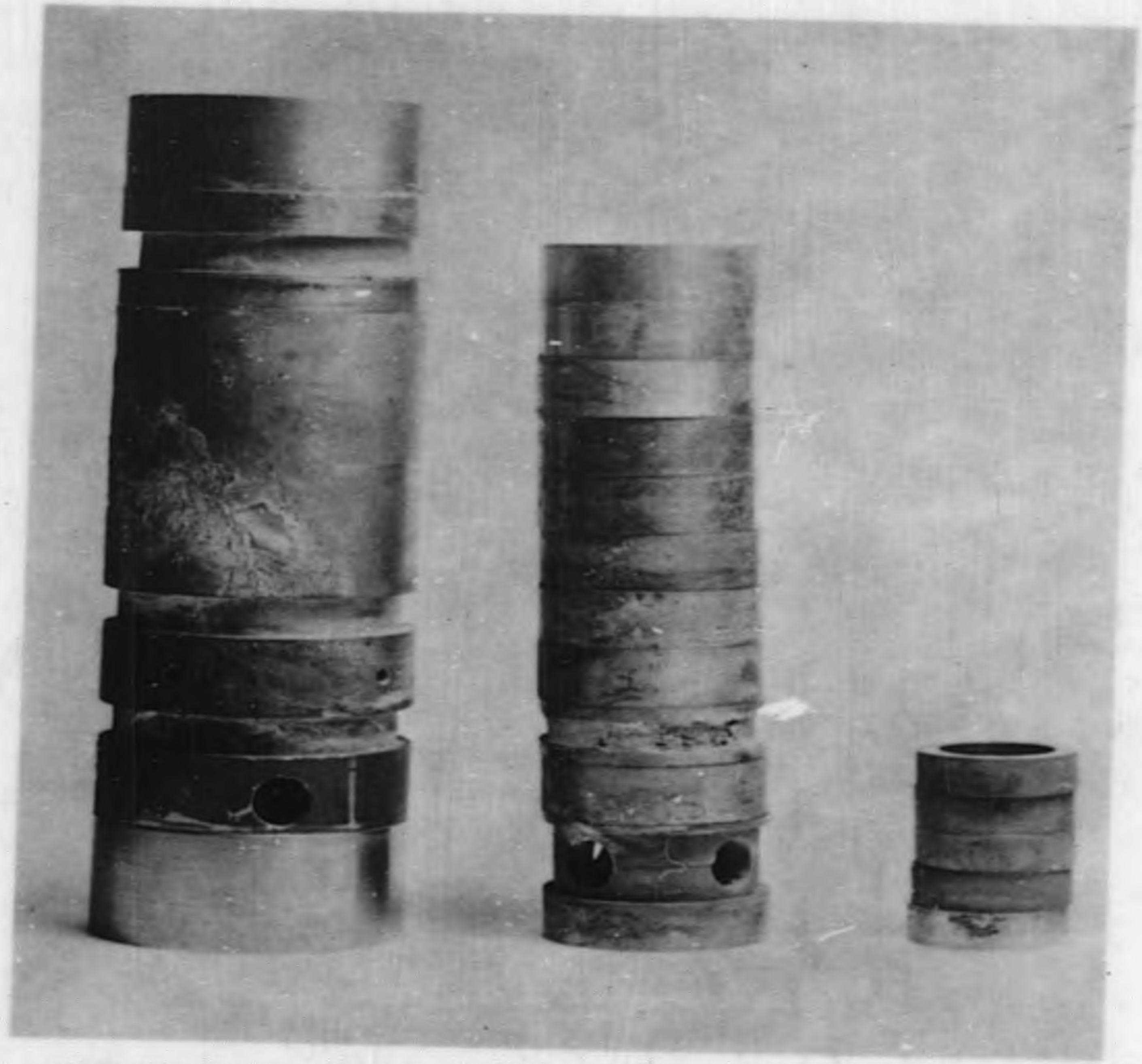


ORNL High Pressure Water Seal From Control Rod Drive After 5 Months in Use

Photo 4877

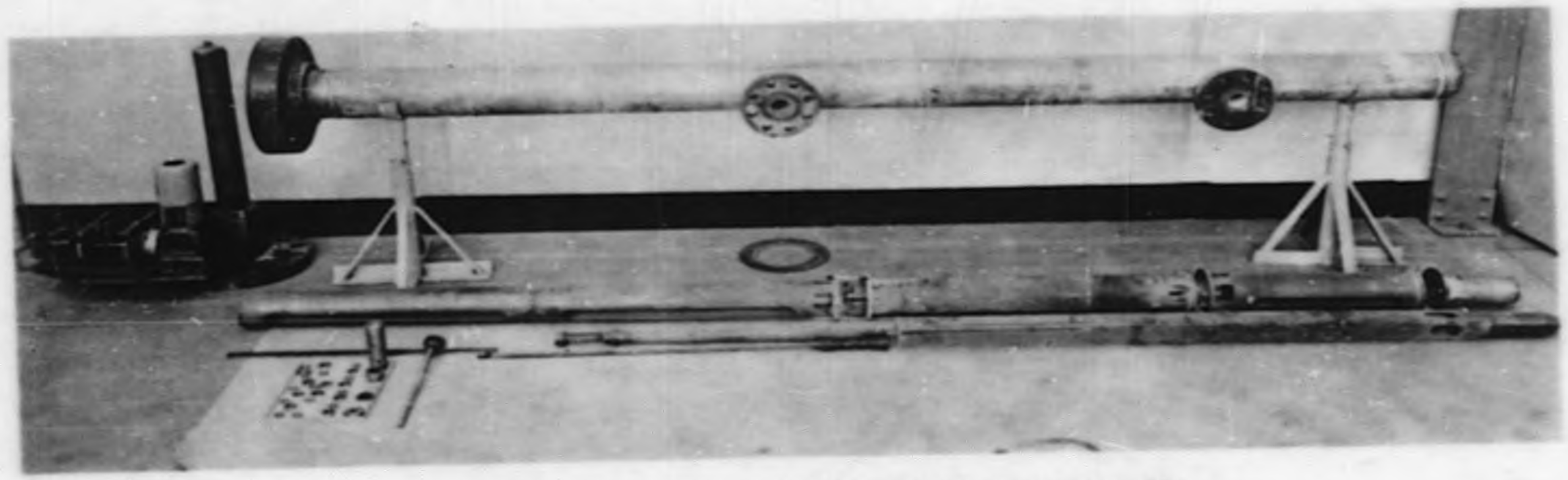
ORNL High Pressure Water Seal From Control Rod Drive After 5 Months in Use

Photo 4878



ORNL High Pressure Water Seal From Control Rod Drive After 5 Months in Use

Photo 4879



ORNL Control Rod Drive Seal & Test Tank Disassembly

Photo 4928

places particularly at the square edges. The back-up roller showed some wear at the guiding edges. The control rod showed heavy scoring at the guiding edges caused by inaccuracy of the rod section and poor guidance. Considerable trouble was encountered with the rod position indicators. The potentiometer type indicators function fairly well during normal rod operation, but fail after a few scram cycles.

The adjustment of any of the components while the rig was in operation was impossible due to the high temperature levels reached. To maintain the water seal and control rod drive mechanism it was necessary to drain the entire system requiring a great deal of down time. Adjusting the upper and lower limit switches required approximately eight (8) hours. Tightening the water seal to insure against excessive leakage requires a special wrench and can only be done after dismantling the gear train.

Acceleration tests performed on the control rod showed that the time required to scram from the full out to full in position was approximately two seconds which was entirely inadequate. The clock type spring used as an accelerating means contributed very little to the total force required to give the rod an acceptable acceleration. The inertia of reduction gearing between the seal and the magnetic clutch was of such magnitude that only by a redesign of the gear train could acceptable scram times be hoped for.

Tests were run on the piston and dashpot decelerating means used with this rig. It was found that the dashpot, because of the conical shape used on the piston and the excessive clearances required due to the inaccurate guiding of the rods, was very ineffective. When scrammed the control rods were stopped primarily by the metal to metal bottoming of the piston in the cylinder with resulting loud noise and deformation of the contact surfaces.

Because of the square section of the rack and the square guide of the backup roller extreme care had to be exercised in tightening the mounting flange capscrews. Any angularity of the flange would cause binding between the rack and roller thereby preventing the control rod from scramming.

Alco Products, Inc.

Mechanical Laboratory Report No. 3036-A

Single Test Rig, Control Rod and Control Rod Drive

Reference:	G.O. 690,001-1
Test Period:	January 24, 1956 to July 2, 1956

Object:

To determine operating and performance characteristics of the prototype APPR-1 control rod and control rod drive.

Conclusion:

The control rod and drive designed for the APPR-1 operated and performed satisfactorily and showed marked improvement over the ORNL rig as follows:

1) Greatly reduced seal leakage rate.
2) Easy to install and maintain (possible to remove the drive with system under pressure and temperature).
3) The control rod guides maintain the rod in proper position and allow it to move freely.
4) The limit switch and rod position indicator, improved somewhat over the ORNL rig, but still not entirely satisfactory.
5) Control rod drop times satisfactory.
6) Good deceleration of rod after scram.
7) Lower operating temperature of drive mechanism.
8) No indication of sticking between rack and back-up roller.

Apparatus:

Same test stand as used with the ORNL rig, with the following alterations and additions:

1) New test tank and control rod and drive mechanism.

2) Westinghouse canned motor coolant circulating pump

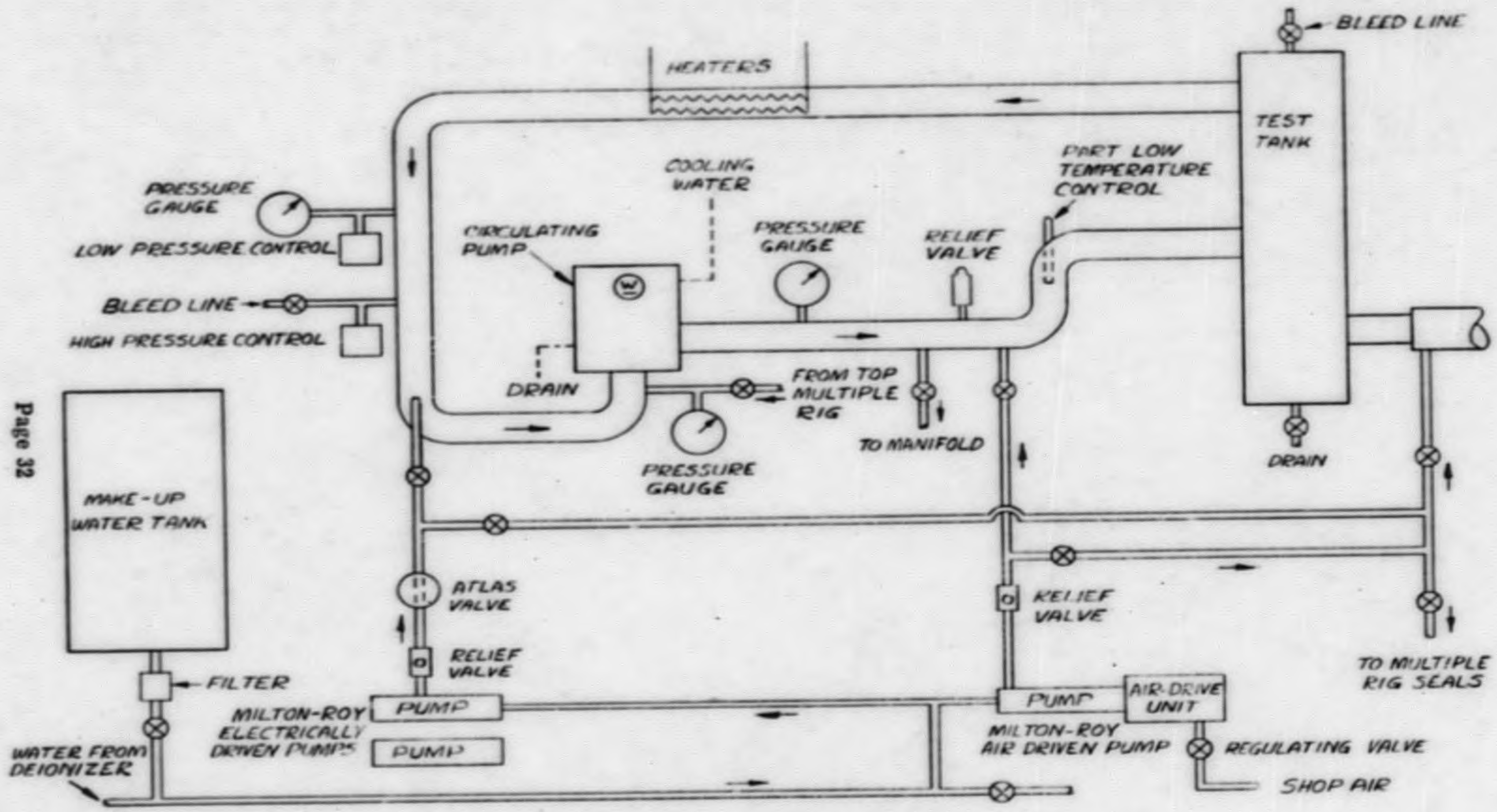
3) Air operated Milton-Roy feed water makeup pump

4) Clamshell type pipe heaters

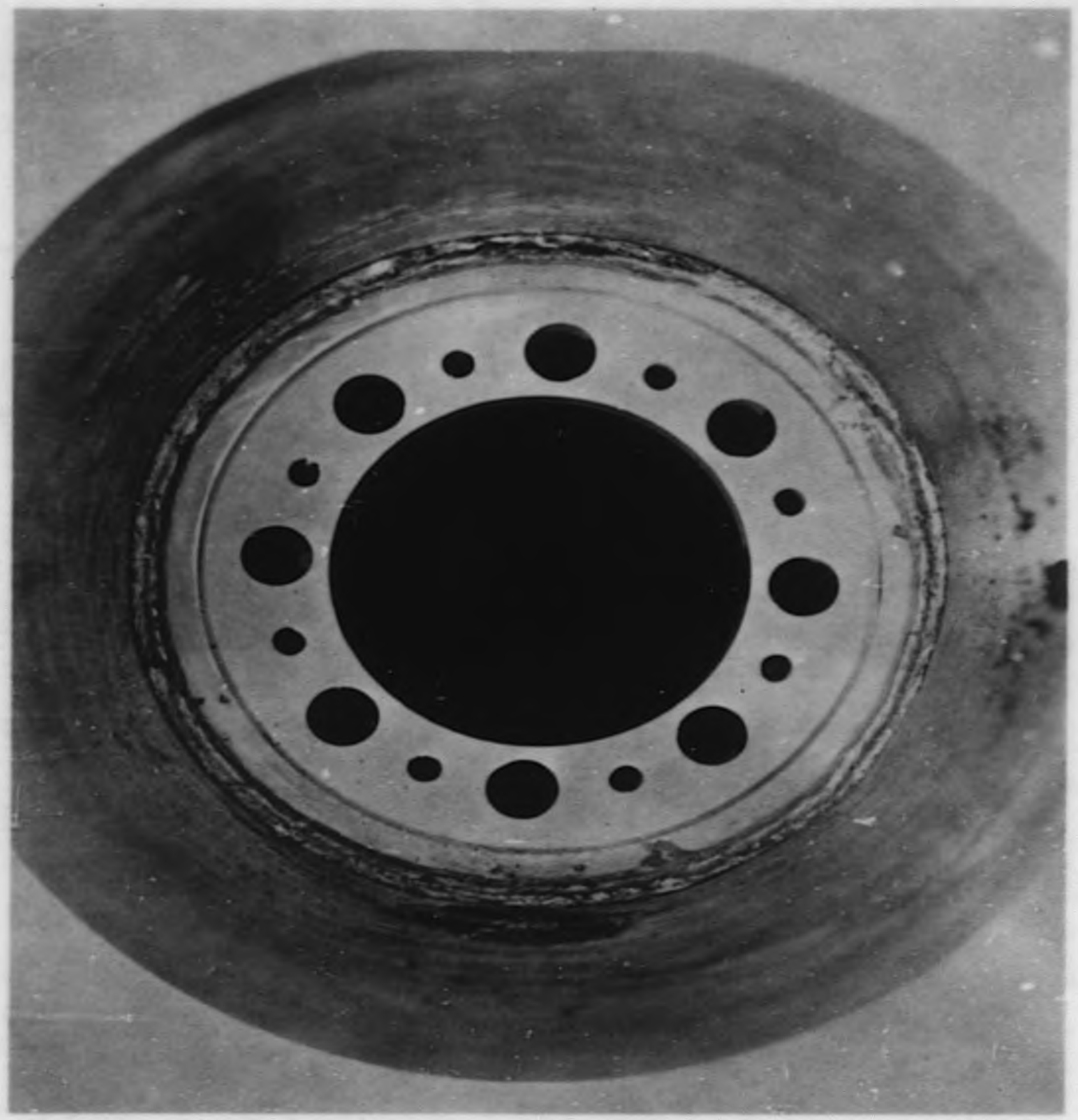
Procedure and Results

In December 1955 a decision was made to replace the ORNL test rig with a system similar to that designed for APPR-1 which used a bottom rather than a top drive. The control rod drive and seal were to be of the APPR-1 design. A new tank to house the control rod was fabricated. A Canned Rotor Pump was purchased to be used as the circulating pump to simulate actual flow conditions. Clamshell heaters were used in place of immersion heaters because of easier installation and maintenance. The same Deionizer, pressure pumps and much of the original rig piping were to be used. See Piping Diagram - Single Rig.

The ORNL test rig was removed and the new test tank installed in the support structure. The tank was fitted with an internal flange near the top to receive a yoke structure which simulated that of the APPR-1 pinion support. Photo #4867 shows the yoke support flange of the test tank drilled to allow water to flow around the control rod, simulating flow conditions to be encountered in the actual core of the APPR-1. The yoke structure was bolted on the upper end to the drilled flange and guided at its lower end by a machined bore in the test tank. This method of mounting left it free to expand thereby minimizing effects of thermal expansion. The lower end of the yoke was bored to receive the drive shaft pinion bearings and backup roller pin. The outboard drive shaft bearing was carried in a ball seat flange which was in turn bolted to a flange at the outboard end of the lower extension pipe as shown in photographs No. 4925 and 4926 of the test rig.

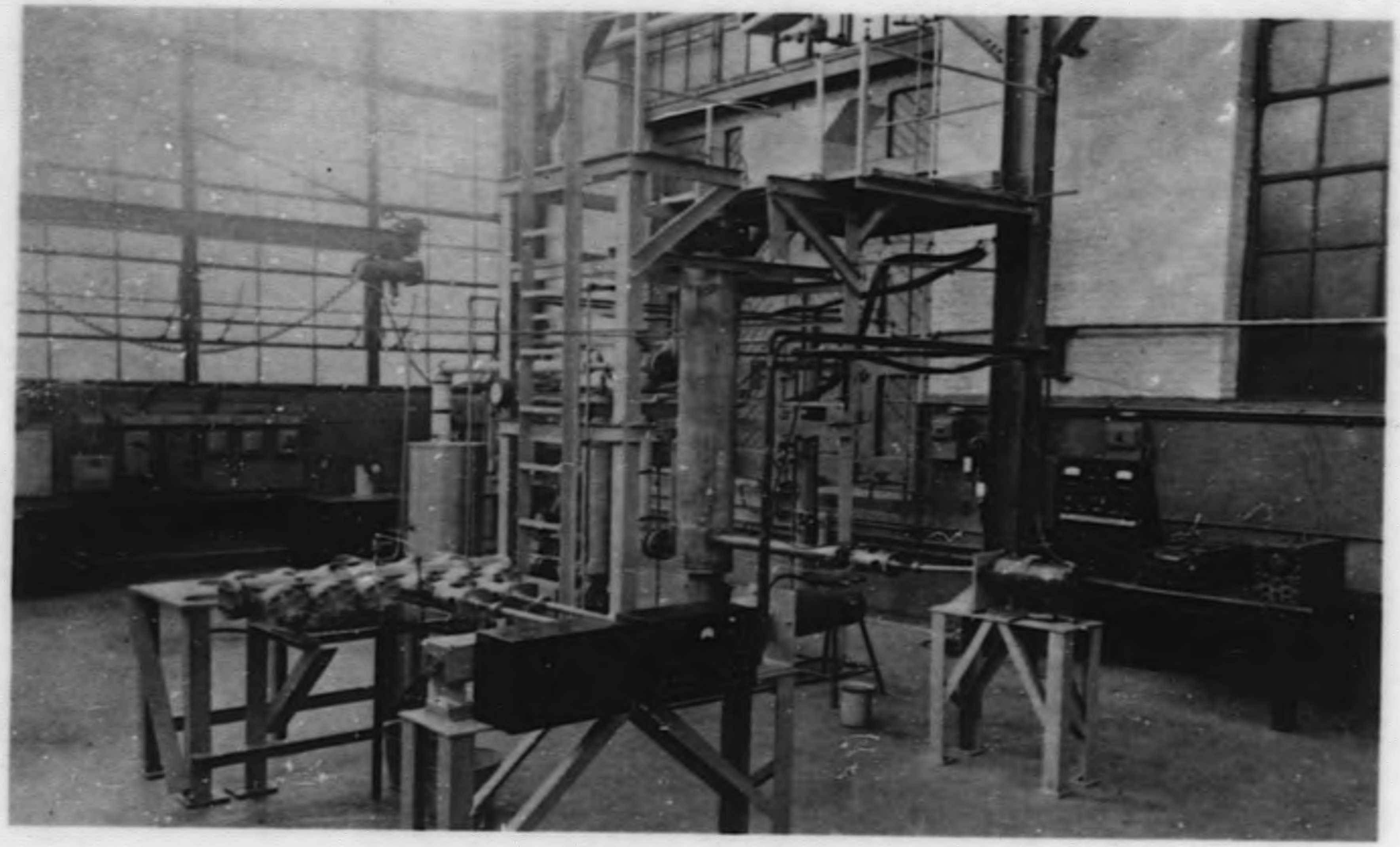


Piping Diagram - Single Rig Fig. 1



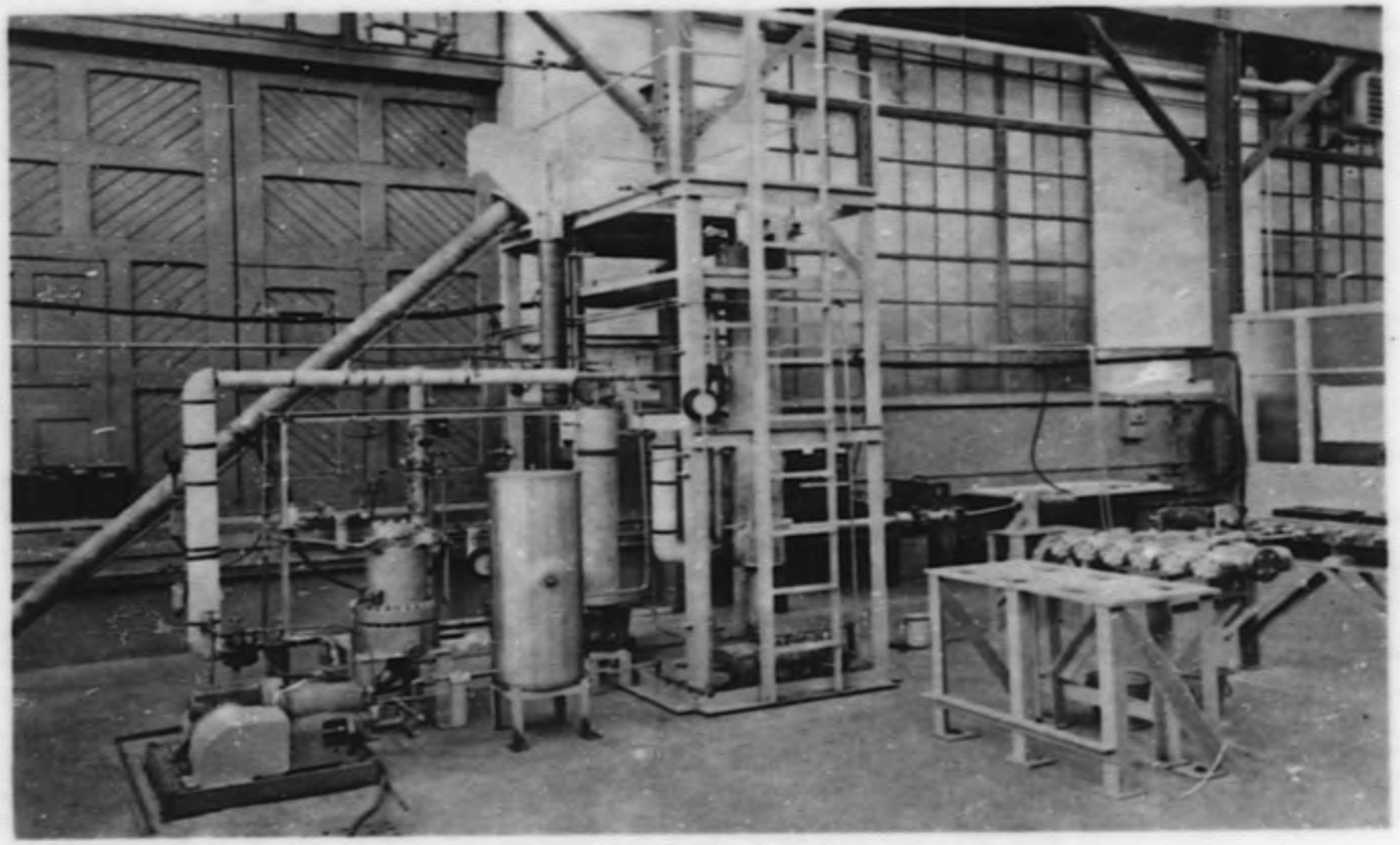
Test Tank Single Test Rig

Photo 4867



Alco Control Rod Drive & Seal Test Rig View #1

Photo 4925



Alco Control Rod Drive & Seal Test Rig View #2

Photo 4926

Photographs No. 4881, 4882 and 4886 show components of the high pressure seal assembly and control rod drive, respectively. The seal assembly was mounted on the ball seat flange and the clutch housing attached to it. The drive motor and reduction gear assembly was separately mounted and connected to the drive through a double universal joint shaft. The installation was started in January 1956 and completed in late February.

Prior to operating the single test rig under temperature and pressure, some preliminary control rod drop tests were run. Initial tests showed that friction between the control rod and the control rod guide plates was excessive, and rod drop times were not satisfactory. After the rod had stuck, once at the top and once at the bottom, it was found that slight interferences existed between the rack and the yoke housing preventing proper gear tooth contact between pinion and rack. The yoke was modified to eliminate this interference, and clearance between the rod and the guides was increased .020 inch to prevent binding.

Further testing indicated that the control rod was "bottoming" too hard after scram, due to excessive dashpot clearance, causing the rod to bounce slightly. The dashpot piston and cylinder clearance was reduced and grooves added to the piston diameter, the labyrinth adding to the efficiency. A similar arrangement on the APPR-1 proved effective.

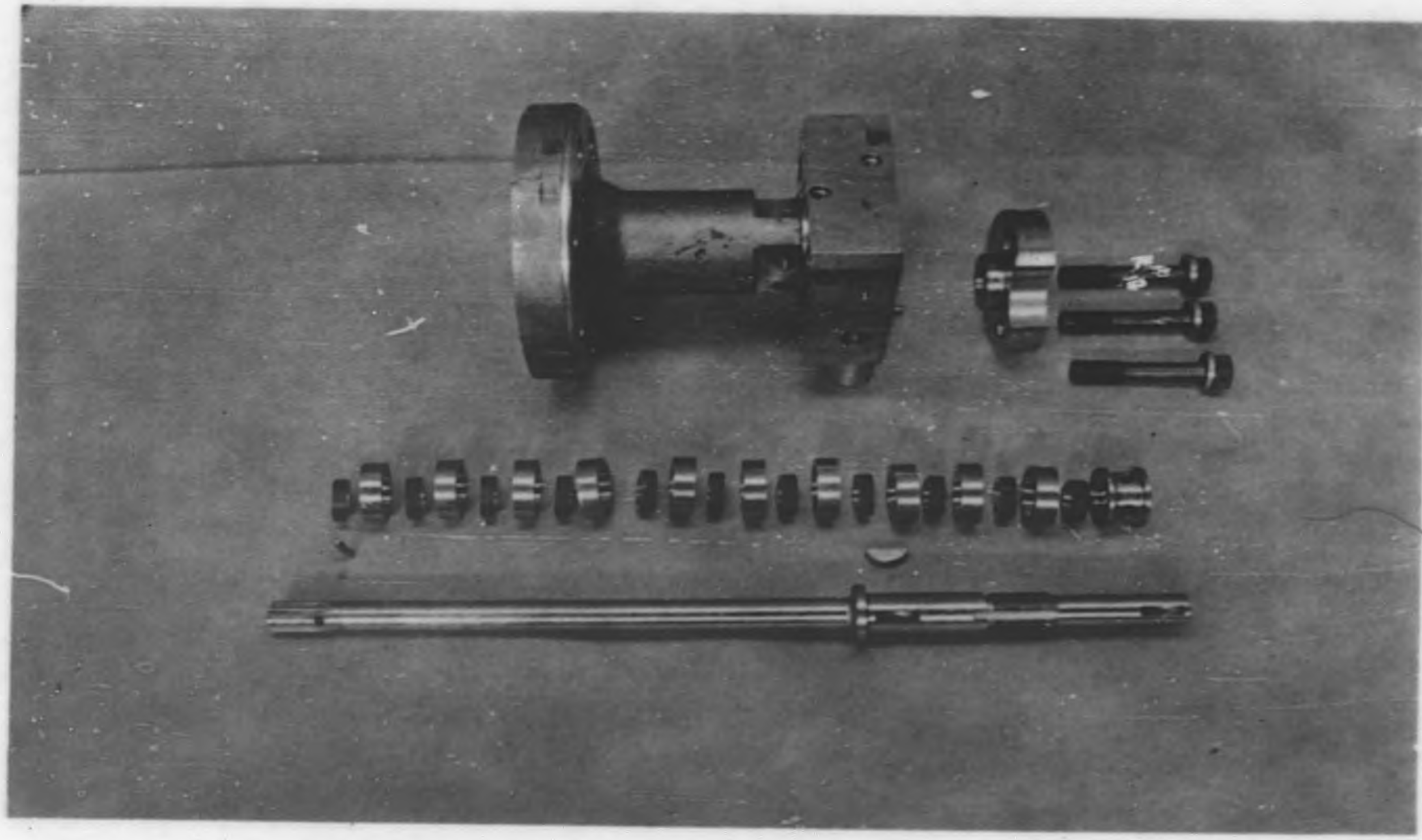
The following photographs are oscillograph records of the control rod drops under various conditions:

1) Photo #4941 - Record of 22" drop with total rod weight of 71 lbs, no flow and the top of the test tank open.

2) Photo #4942 - Same as 4941 with the top of the test tank closed.

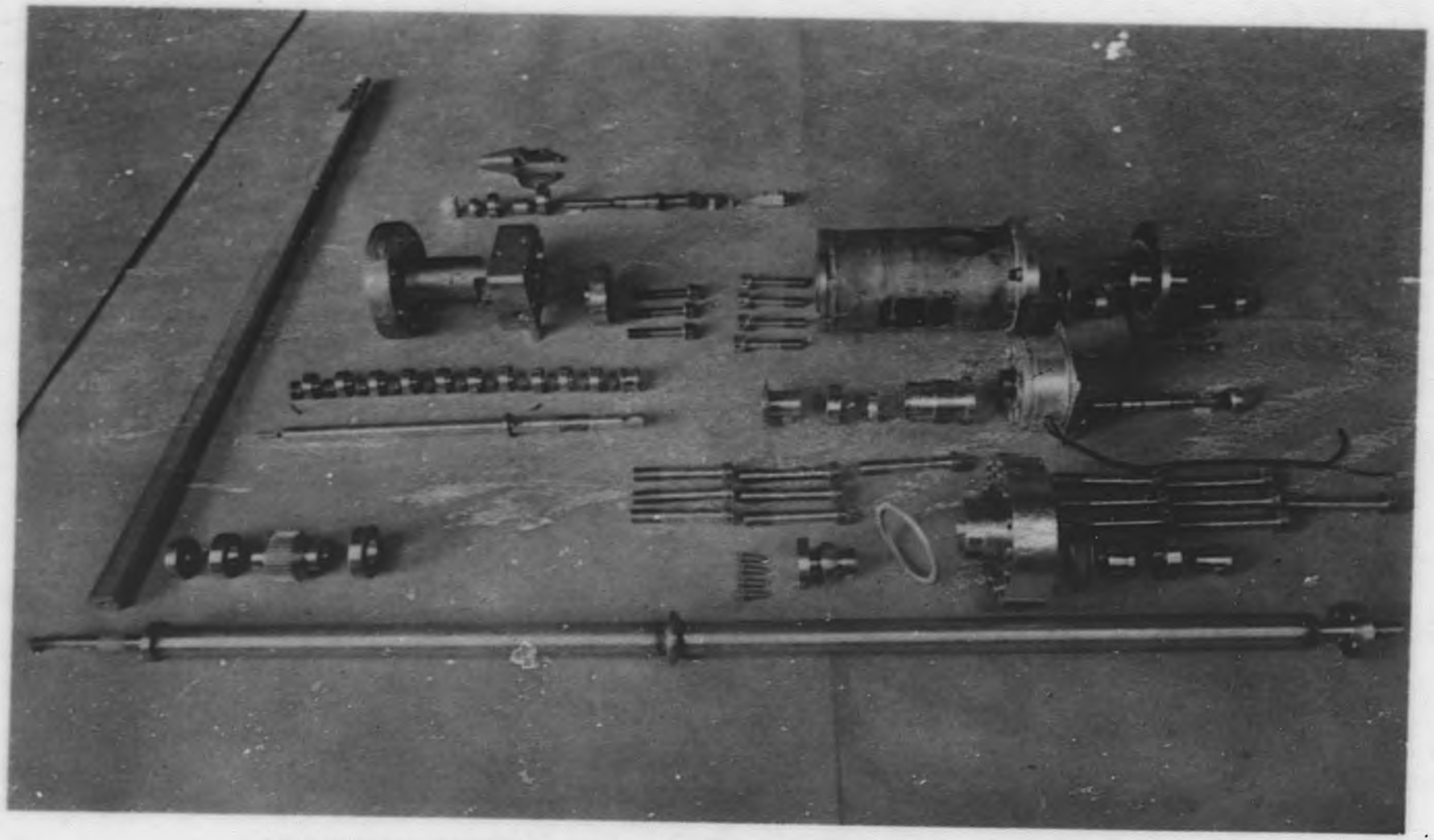
3) Photo #4952 - Record of 22" drop with the system pressurized to 1200 psi and the circulating pump operating.

4) Photo #4953 - Same as 4952 with the circulating pump off.



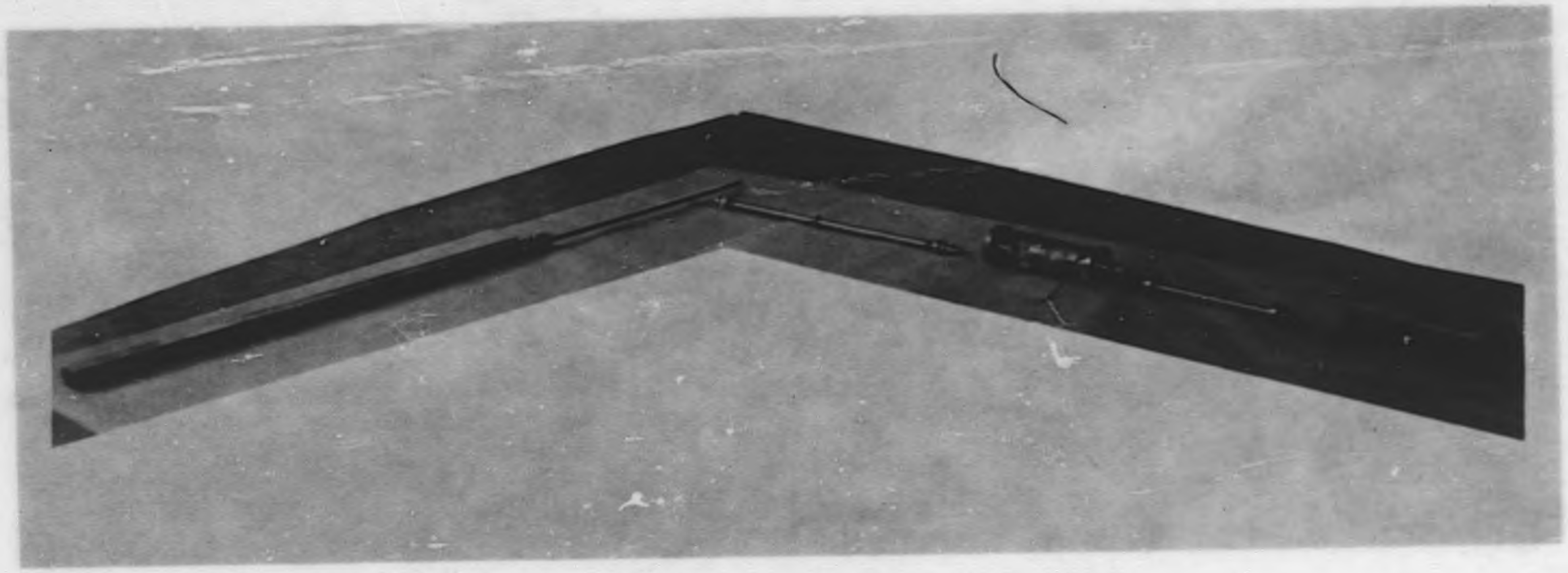
Alco Control Rod Drive Test Rig High Pressure Seal Assembly

Photo 4881



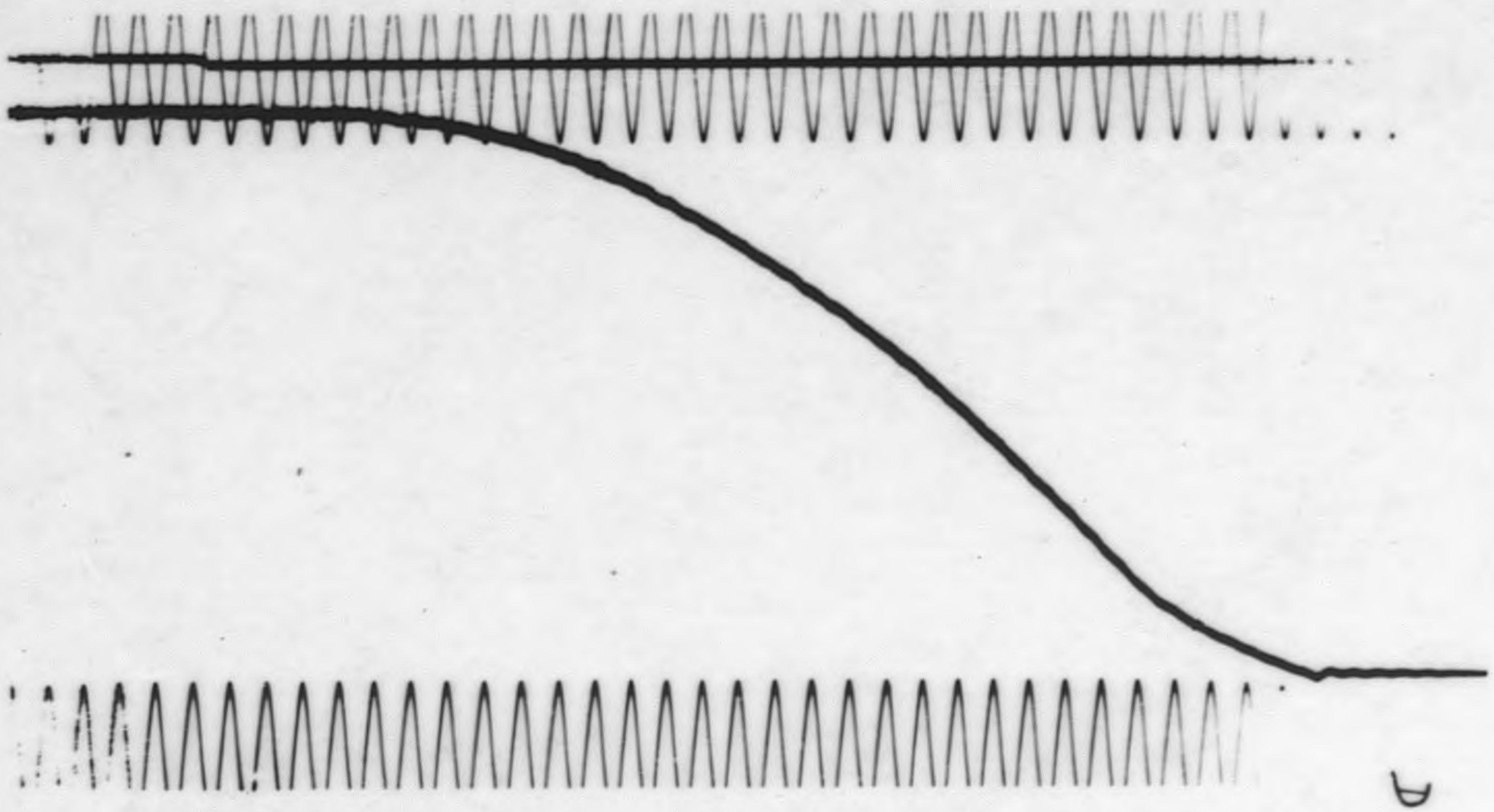
Alco Control Rod Drive Test Rig Control Rod Drive & Seal Assembly

Photo 4882



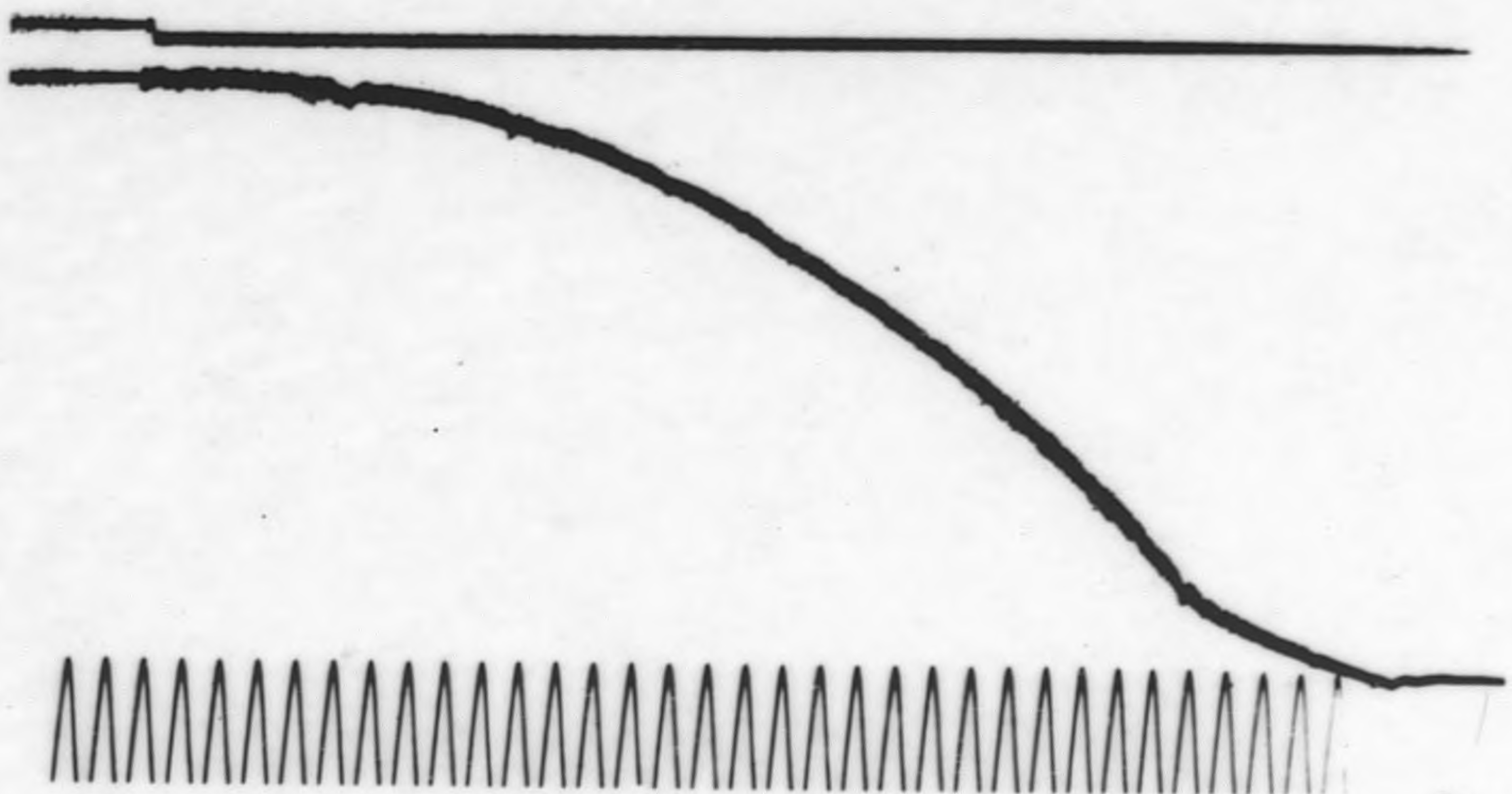
Alco Control Rod Sub-Assembly Drive Arrangement

Photo 4886



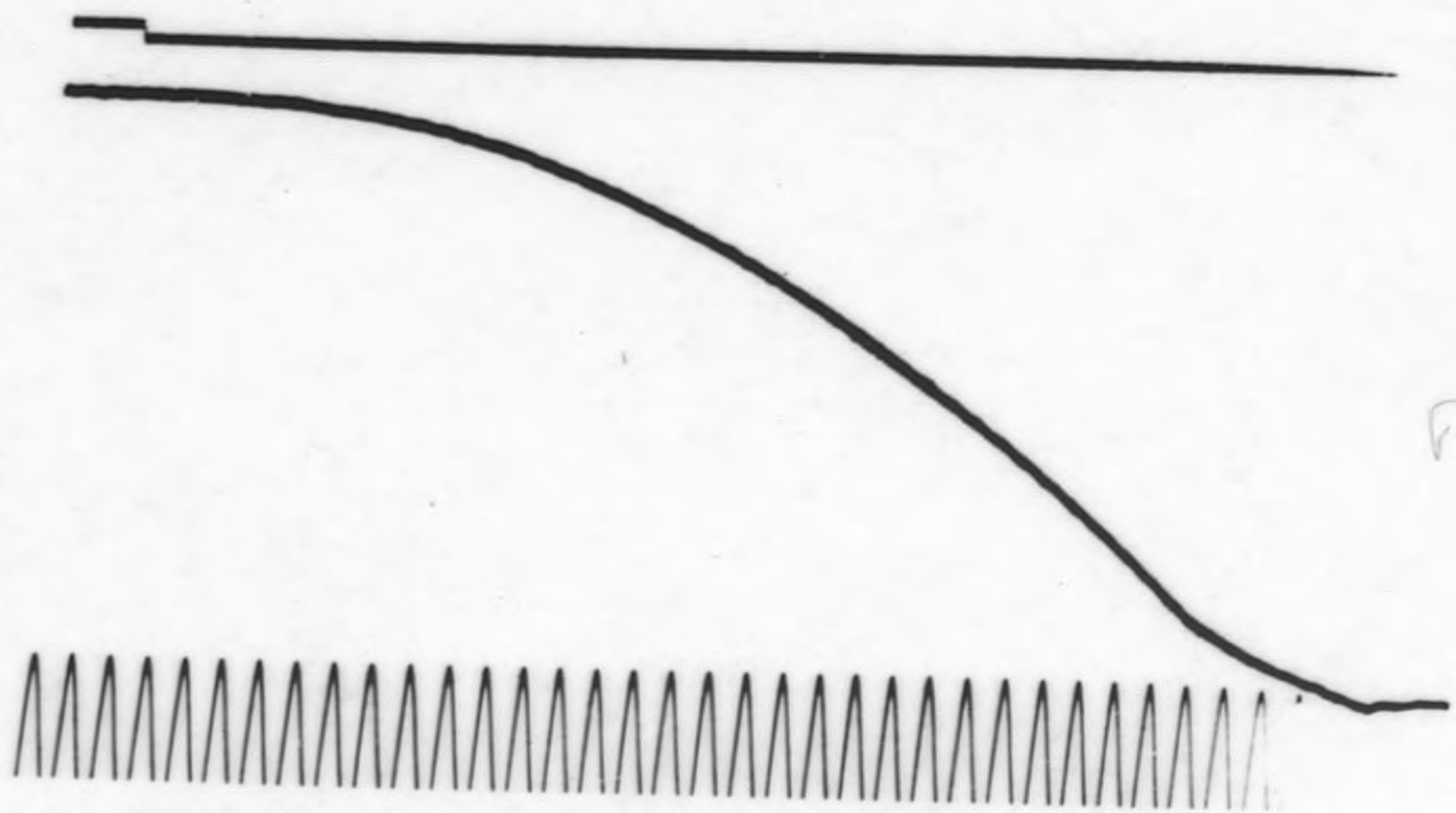
Oscillograph Record of 22" Rod Drop Total Rod Weight 71 lbs, No Flow, Top of Test Tank Open

Photo 4941



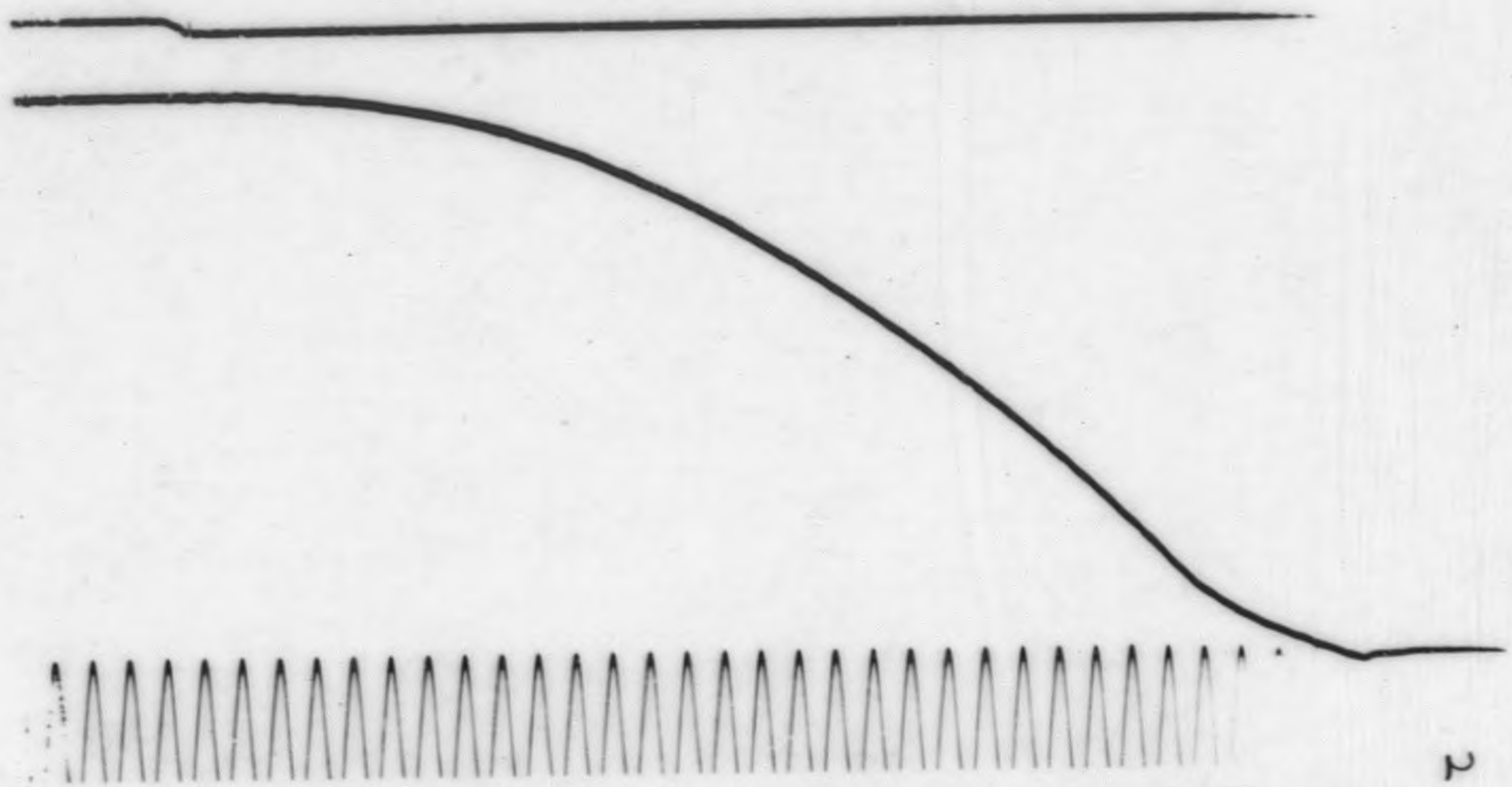
Oscillograph Record of 22" Rod Drop Total Rod Weight 71 lbs, No Flow, Top of Test Tank Closed

Photo 4942



Oscillograph Record of 22" Drop System Pressurized 1200 PSI Circulating Pump Operating

Photo 4952



Oscillograph Record of 22" Drop System Pressurized 1200 PSI Circulating Pump Off

Photo 4953

As shown in photographs 4952 and 4953, with the circulating pump on, the drop time of .562 secs is slightly slower than .530 secs without the pump in operation. The control rod used in these tests contained no simulated fuel elements or had no cap as the APPR-1 rod. Weight was provided by substituting a 1/4 inch wall square tube for the .050 thick tube of APPR-1. A plug with a hole equivalent to the open area of the APPR-1 rod was used at the top of the rod. During the period of operation with frequent scrams, the life of the potentiometer type position indicators was very short. After a few dozen scrams the indication became rough and in time the indicators would fail completely and would have to be replaced.

In March the rig was started up for extended seal and rod tests with the rod operating on a continuous up and down cycling schedule. Records of seal leakage, seal leakage temperature, system temperature and pressure were kept.

During the initial operation under pressure leakage was observed seeping out of the pilot bore around the outside of the seal ring retaining gland. This gland carries a lip type seal to prevent leakage around the seal shaft from the collecting annulus. An "O" ring was installed on the outside of the small diameter of the plate to prevent leakages around the gland. This completely eliminated any external leakage through the drive mechanism.

The first seal leakage records were not consistant, due to operating difficulties and interruptions, such as, relief valves not functioning properly, rod drop tests, etc. The first steady week of operation (beginning April 16, 1956) with the rod cycling, the leakage rate was 2.15 lbs. per hour. After 400 hours of rod operation, the leakage rate had decreased to an average of 1.2 lbs. per hour. At 620 hours of rod operation and 720 hours on the rig, the leakage averaged

1.0 lbs. per hour. The last leakage check at 960 hours of rod operation showed an average of 1.25 lbs. per hour. The above are average figures due to the difficulty in maintaining a constant pressure of exactly 1200 psi and variations in leakage associated with rod movement. Water samples were periodically taken from the deionizer and analyzed for total solids, bicarbonate and pH factor. The total solids varied from 5 ppm (just after regenerating) to 154 ppm. The bicarbonate varied from 3.6 ppm to 141 ppm. The pH factor varied from 5.1 to 7.4.

Late in June the rod was started on scramming operation. This involved running the rod from its bottom position to its top position in a normal manner, then scramming to its bottom position. The scram time averaged .530 seconds from full out to full in position. There was a slight increase in seal leakage during scramming but the overall increase is negligible. The total cycling time on the control rod was 905 hours, and total rig time was 1023 hours when the scramming operation began.

A demonstration was held, during this period, to show that the control rod drive and seal could be removed and replaced while the system was at operating pressure and temperature. Seven minutes was required to remove the drive including the seal. Approximately 15 minutes was required to replace it and put it back into operation. The seal mounting capscrews were slotted to facilitate removal by screw driver after loosening with a wrench. The ball valve on the drive shaft provides an absolutely leak tight seal when the breakdown seal assembly is removed.

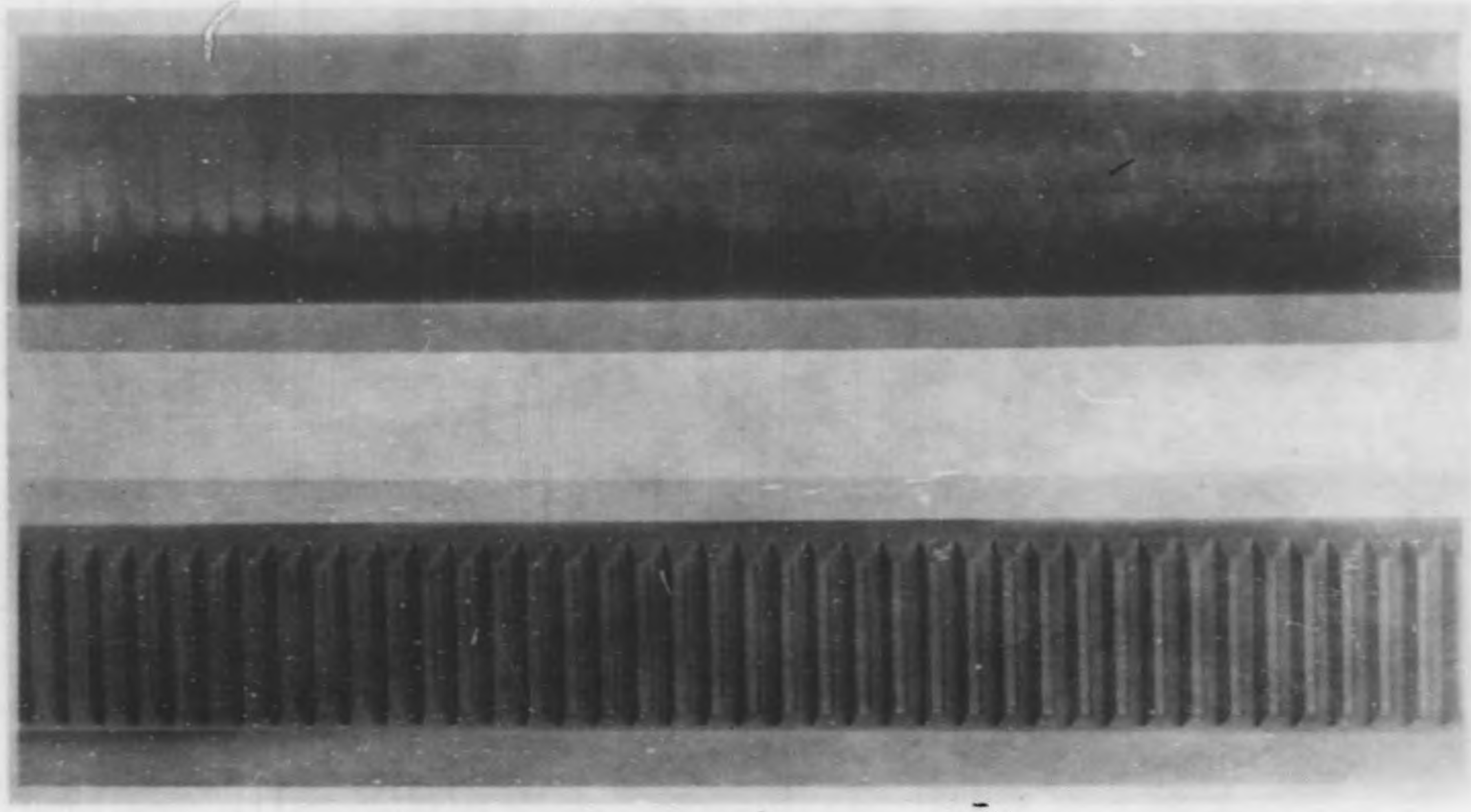
When replacing the seal, it was found advantageous to first tighten the capscrews and then connect the high pressure feed line. With pressure on both sides of the ball valve very little force is required on the seal shaft to move it to its operating position.

On threaded connections to be removed and replaced frequently better results were obtained when the mating parts were not made to the same steel specifications. Lapping of the threads gave additional improvement. Recommended compounds are; "United Lapping Compound #3805" or "Carborundum Finishing Compound #H 40 Fine". Where lubrication was necessary "Neolube" (graphite suspended in alcohol) was satisfactory. When dried the graphite, unlike grease, adhered to the surface.

On July 2, 1956 a section of the main 2" pipe loop ruptured while the rig was operating at pressure and temperature. The failure occurred in a section of the pipe encased in the electrical clamshell type heaters. A section of the ruptured pipe was sent to the Metallurgical Laboratory for inspection and testing. A separate report has been written covering this failure. Just prior to this explosion the rig had been checked and was operating normally. The morning following the control equipment was checked and found to be satisfactory. The total time on the rig at this time was 1136-1/2 hours and total rod operating time was 1035 hours (4140 cycles). For the last 130 hours (1100 cycles) the rod was on scramming cycle.

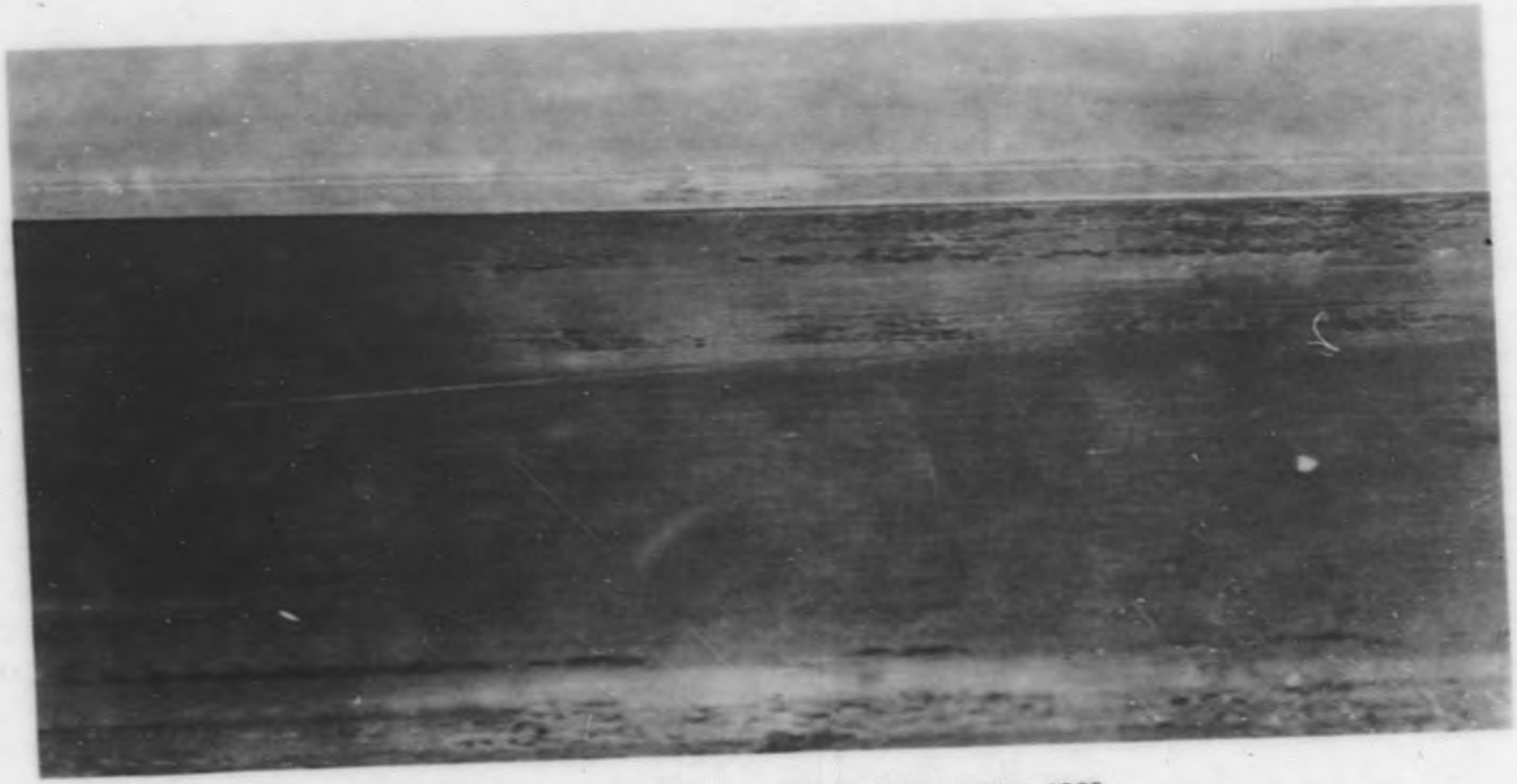
The rig was disassembled for inspection and photographing. The following photographs #5126 to 5133 indicate the condition of various parts, and the total hours of operation on each when photographed.

Some scoring and scratches were found on the rod guide pads and contact edges of the rod but these were considered insignificant as the depth was approximately .003. All bearings were free but slightly sticky due to the presence on the

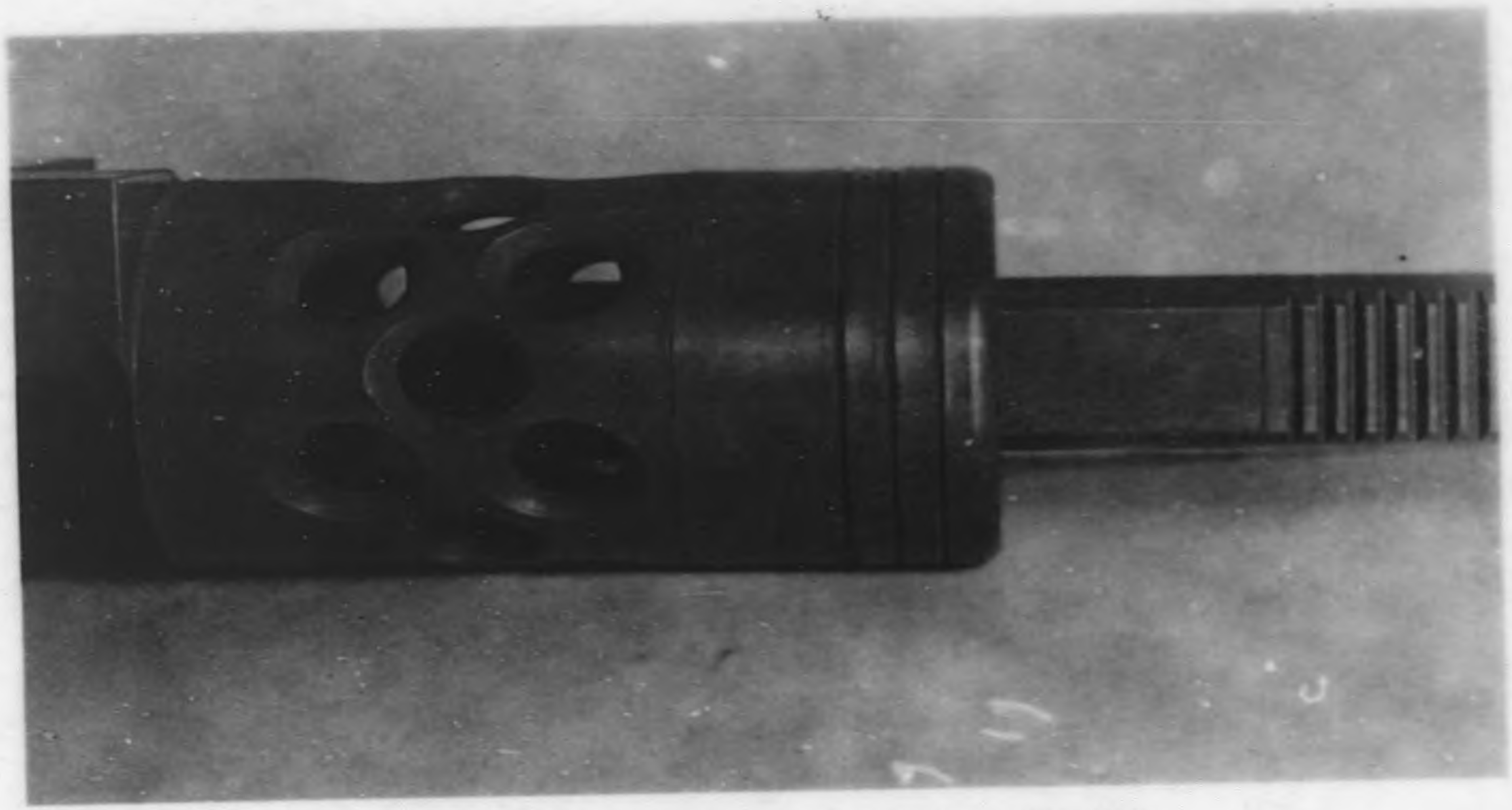


Single Rig Control Rod Rack Showing Condition of Teeth & Back - Hours of Operation 1035

Photo 5126

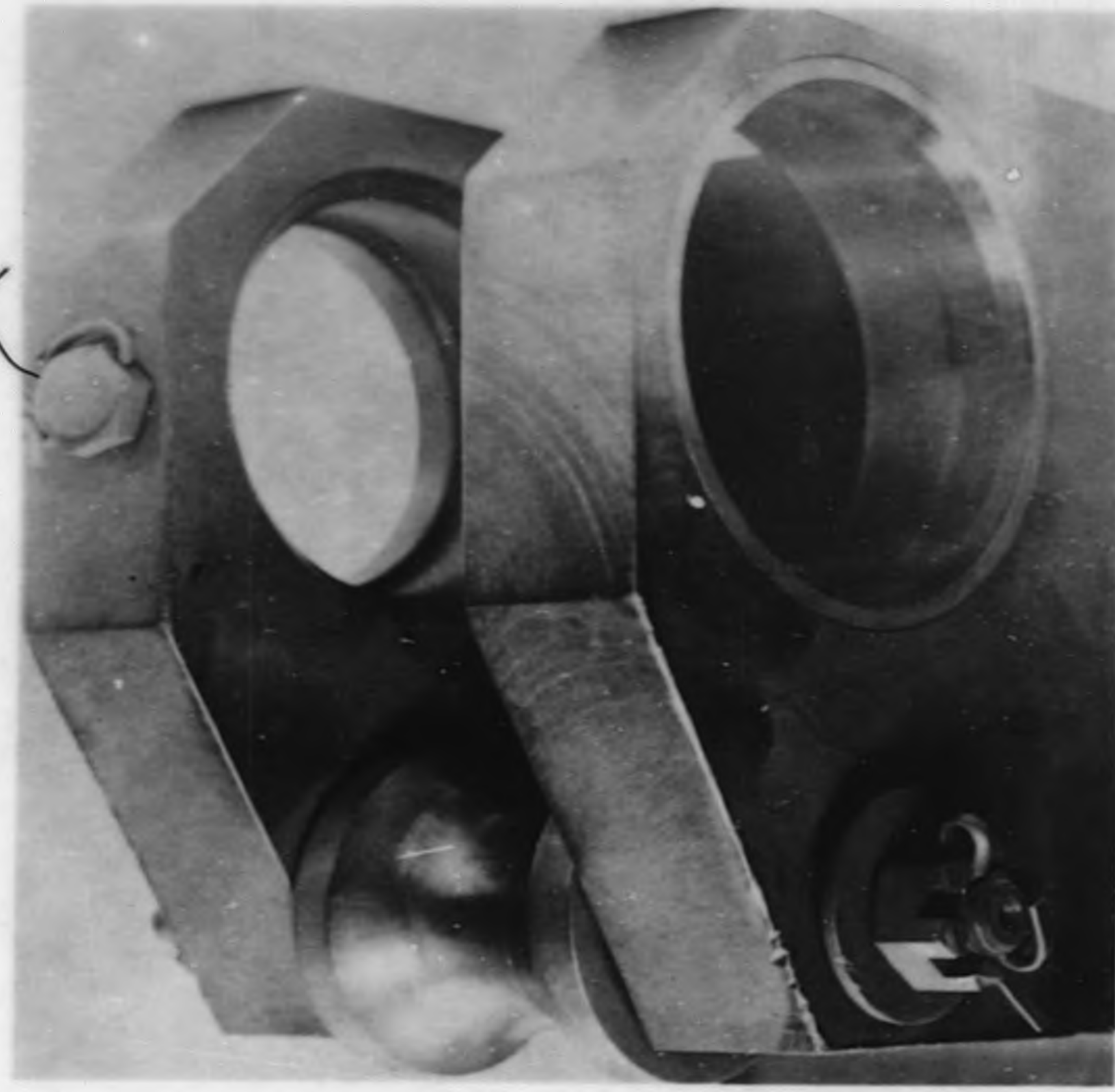


Single Rig Control Rod Showing Scoring - Hours of Operation 1035 Photo 5127



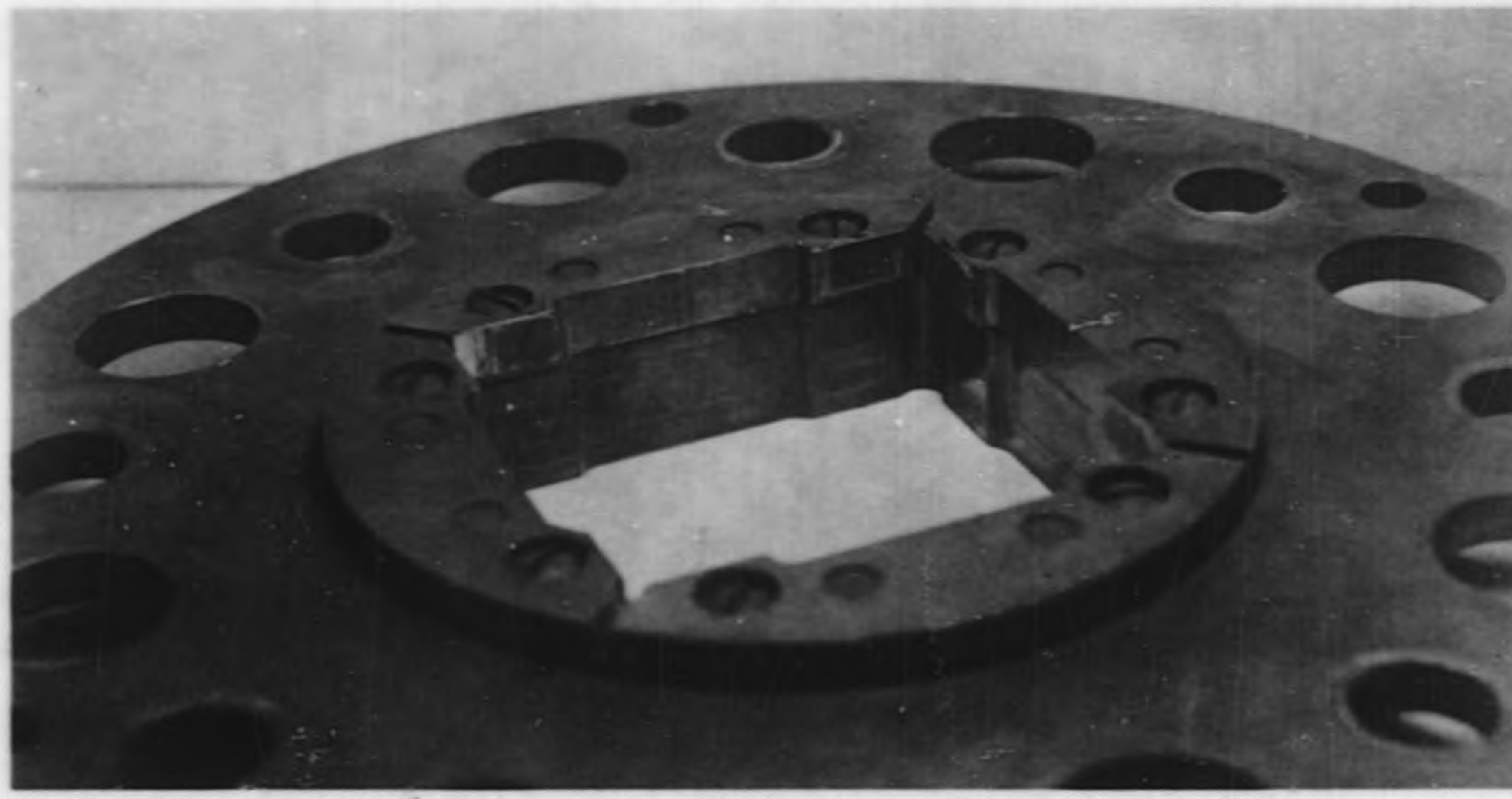
Single Rig Control Rod Piston - Hours of Operation 1035

Photo 5128



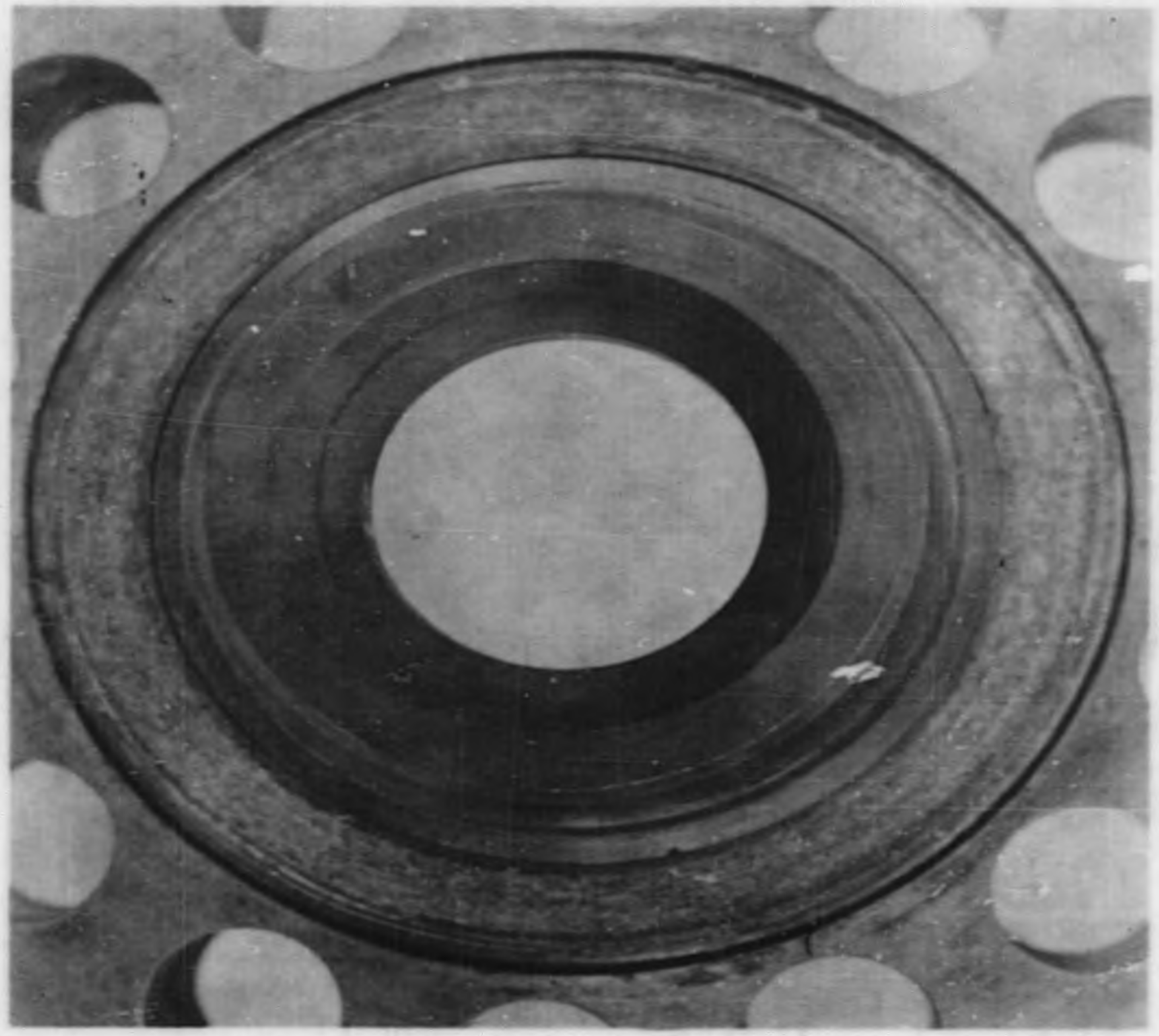
Single Rig Rack Roller - Hours of Operation 1140

Photo 5129



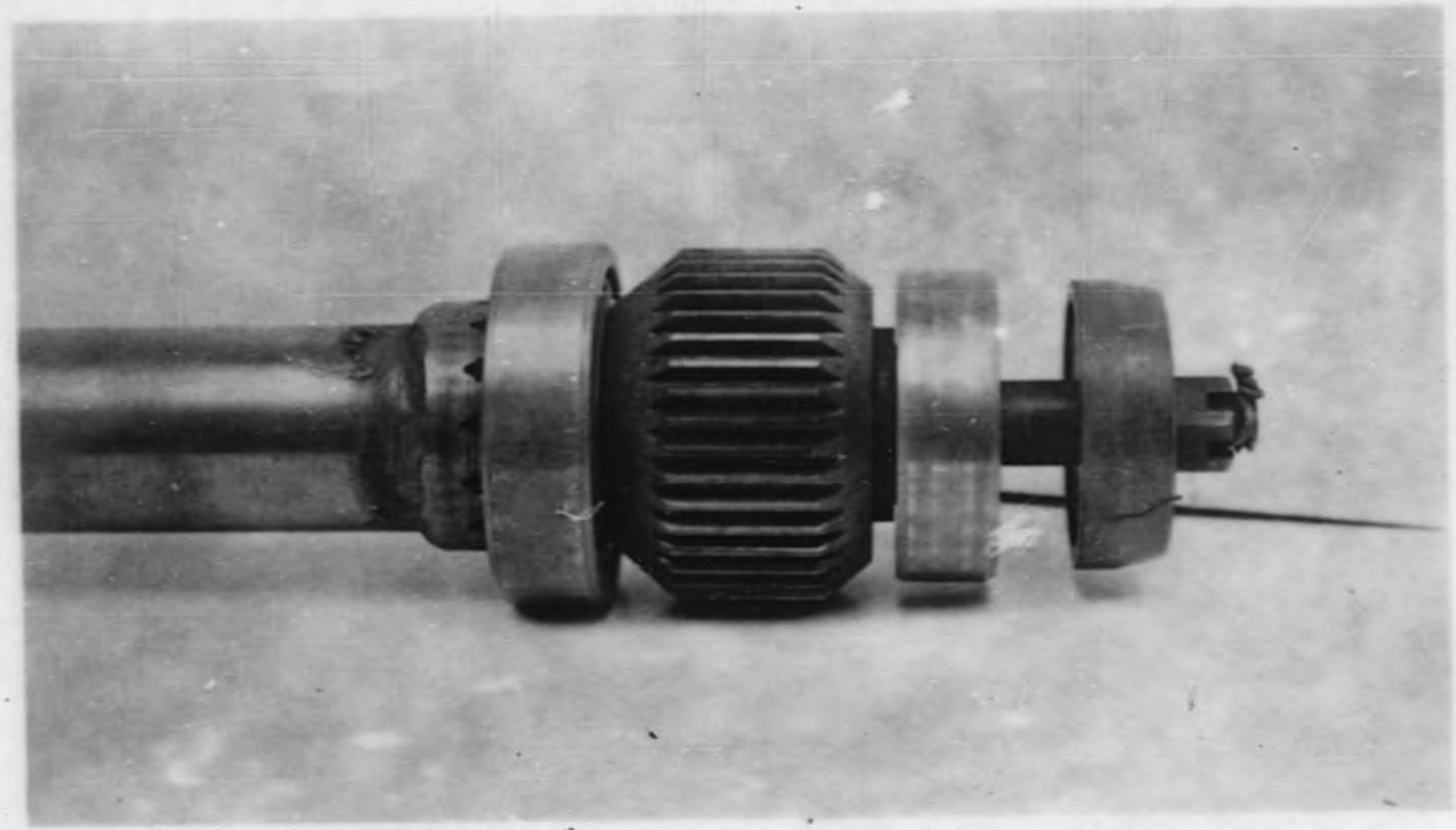
Single Rig Rod Guide Plate (Stellite Faced) Hours of Operation 1140

Photo 5130



Single Rig Flange Condition of Seat - Hours of Operation 1140

Photo 5131



Single Rig Drive Shaft Showing Condition of Rack Pinion - Hours of Operation 1140

Photo 5132

Single Rig Drive Shaft Showing Condition of Valve - Hours of Operation 1140

Photo 5133

balls and races of red oxide which was prevalent on all the surfaces in contact with water. The back of the rack showed indication of sliding on the roller. All pinion and rack teeth were in excellent condition.

The single test rig was rebuilt as a corrosion test rig and all further control rod testing was transferred to the multiple rig.

Alco Products, Inc.

Mechanical Laboratory Report No. 3036-B

Multiple Test Rig, Control Rod and Control Rod Drive

Reference: G.O. 690,001-1

Test Period: February 13, 1956 to February 28, 1957

Object:

To provide severe endurance testing of APPR-1 control rod drives and control rods on a continuous scramming cycle. To determine the effect of this operation on materials, and fits. To determine the reliability of the control rods and the control rod drives.

Conclusion:

The control rods and drives held up exceptionally well during the endurance testing. Some changes in materials and fits were necessary to improve the reliability and life of the equipment. They are:

1) Change the material of the seal shaft from 440C annealed stainless steel to 17-4 PH stainless steel.

2) Use 304 stainless steel for the rod guides.

3) Increase the clearance between rod and rod guides slightly.

4) Do not reuse gaskets.

5) Change the method of installing the drive gear on the synchro.

6) Change the keyway in the sleeve of the seal for better assembly.

7) Change machining methods on seal flange to insure against leakage of tubing connection.

Apparatus:

The single rig test stand with the following equipment connected to it:

1) 6 test tanks

2) Common manifold with heaters

3) 6 rod drives

4) Common gearbox to connect all drives to one drive motor

See piping diagram - multiple rig.

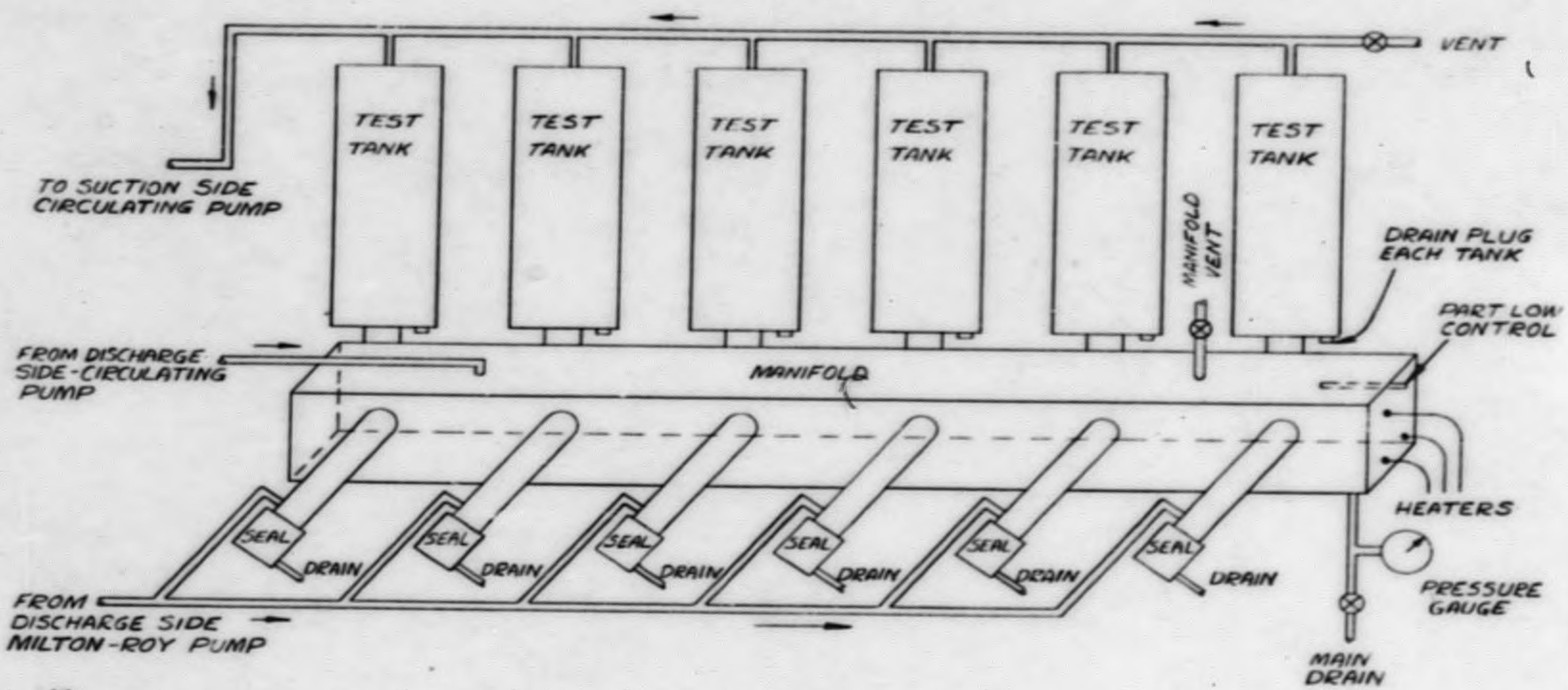
Procedure and Results:

To obtain more results and to experiment on several different projects at the same time a multiple rig was built. The rig was connected to and used the same pressurizing and water purification equipment as the single rig. Photos 5406 thru 5411 show the multiple rig and its allied equipment. As the components became available from the shop, they were cleaned and installed. All unfinished surfaces were wire brushed to remove scale and weld splatter. Further cleaning with Triclene "D", washing with a commercial detergent, flushing with clear water and blowing dry with shop air produced satisfactory results.

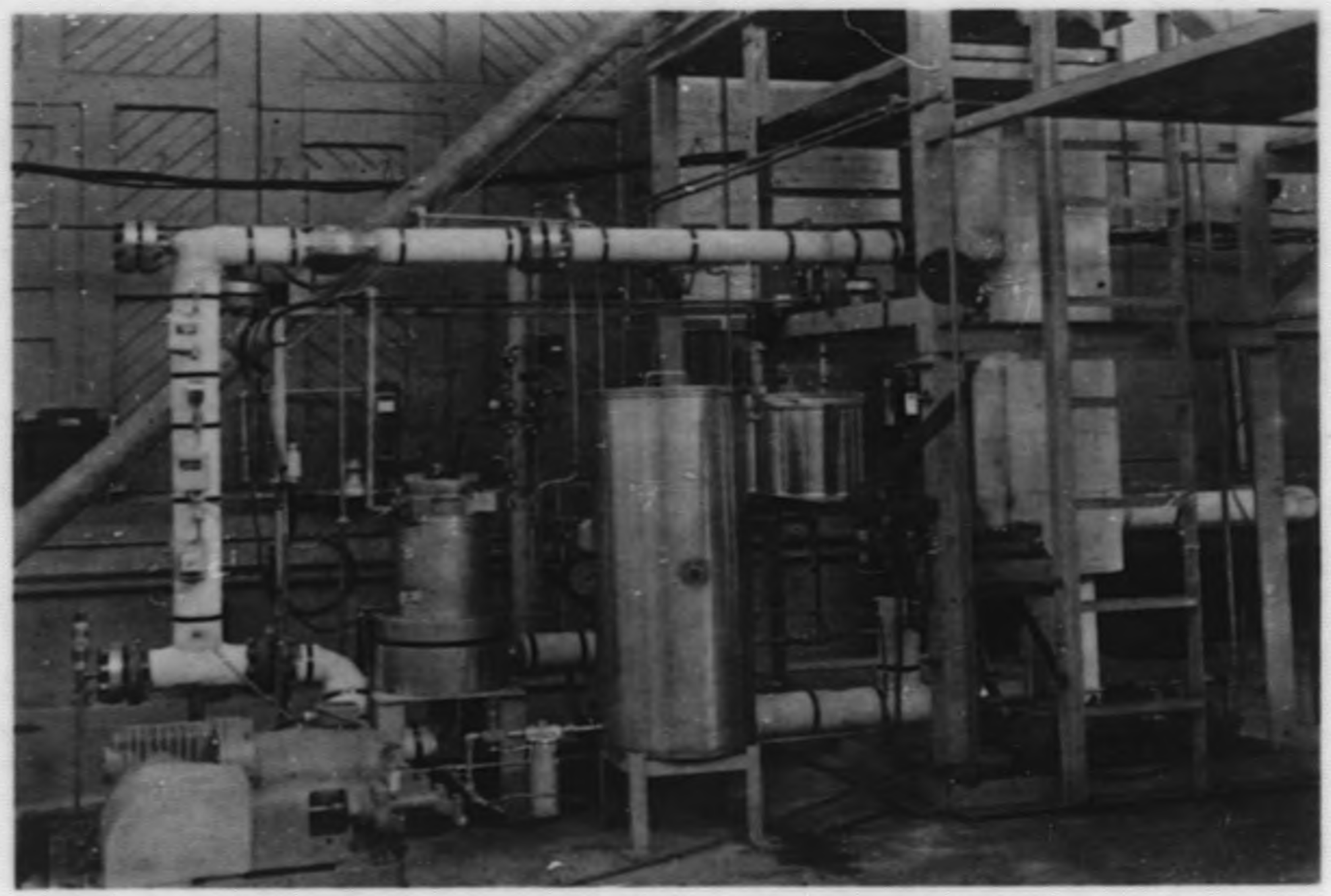
The 6 drives were connected to a common gearbox and the gearbox connected to one of the APPR-1 drive motors. This put a far greater load on the motor than it would be subjected to on the APPR-1 and no trouble was encountered during the testing period.

An aluminum shear key which would shear at 700 in lbs was installed between the motor shaft and the drive shaft, to safeguard the motor and drives in case of extreme overload.

The first tests were seal leakage tests. They were conducted at 1200 psi, and run for 40 hours. The results were:

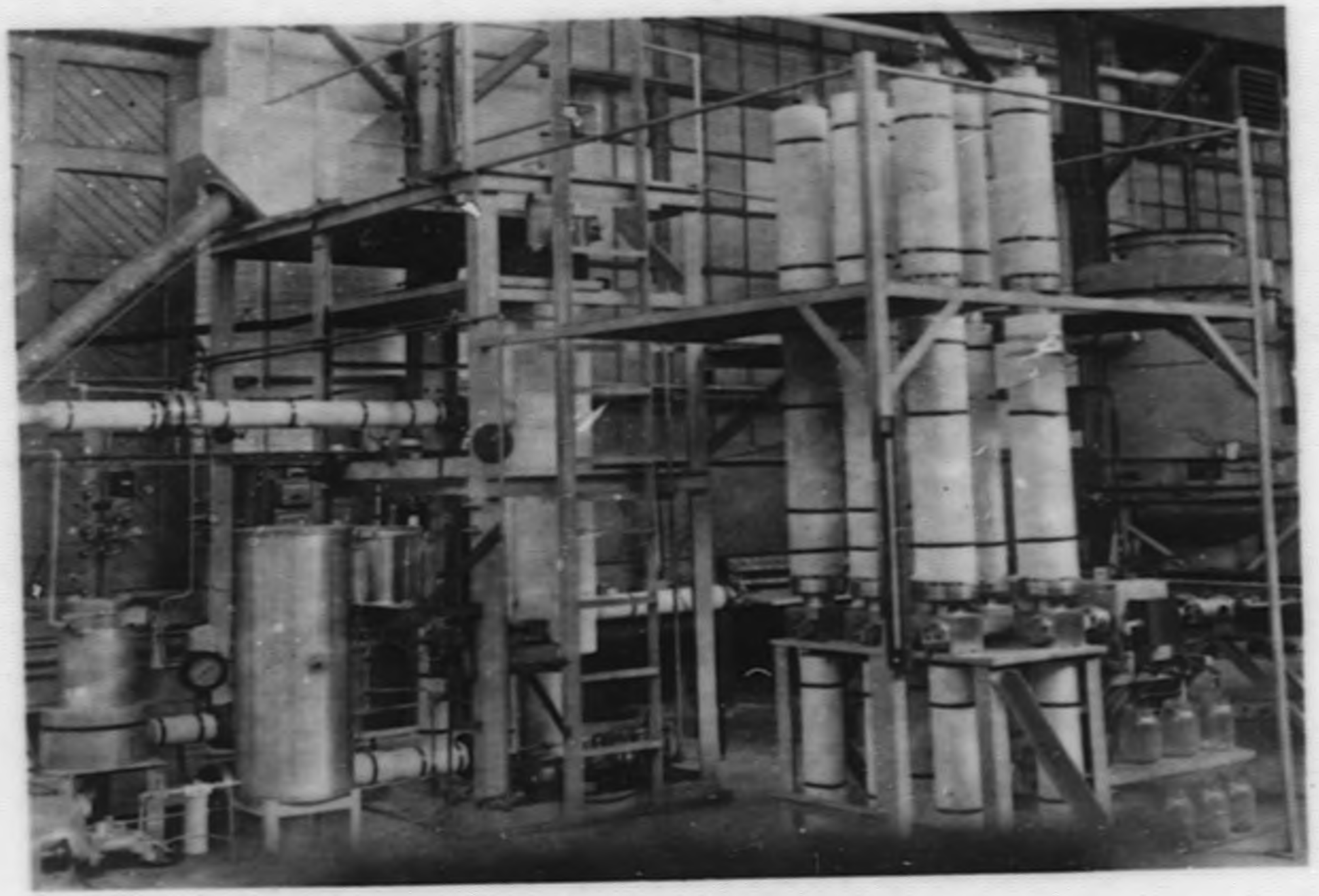


Piping Diagram - Multiple Rig **Fig. 2**



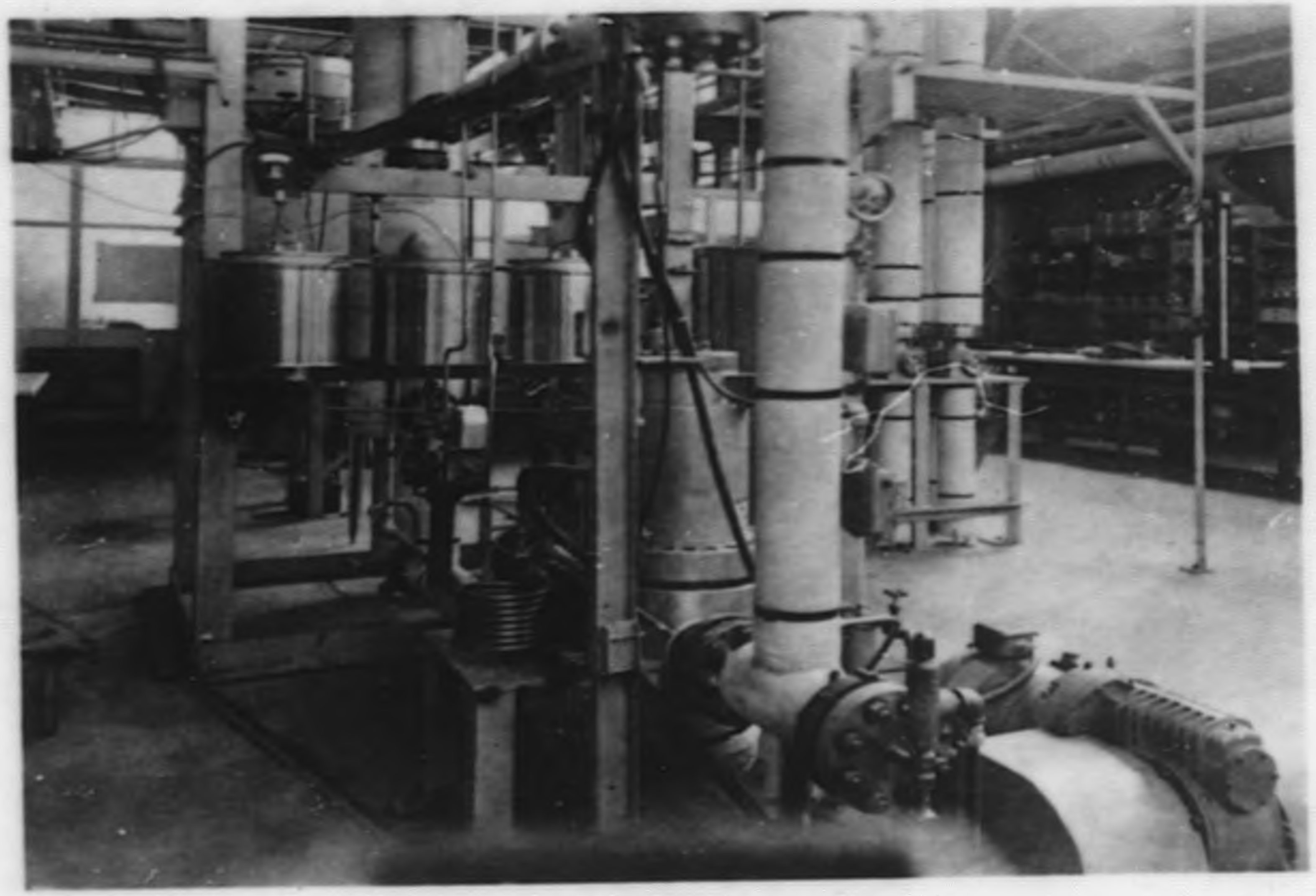
Single Rig Showing Pressure Pump and Circulating Pump

Photo 5406



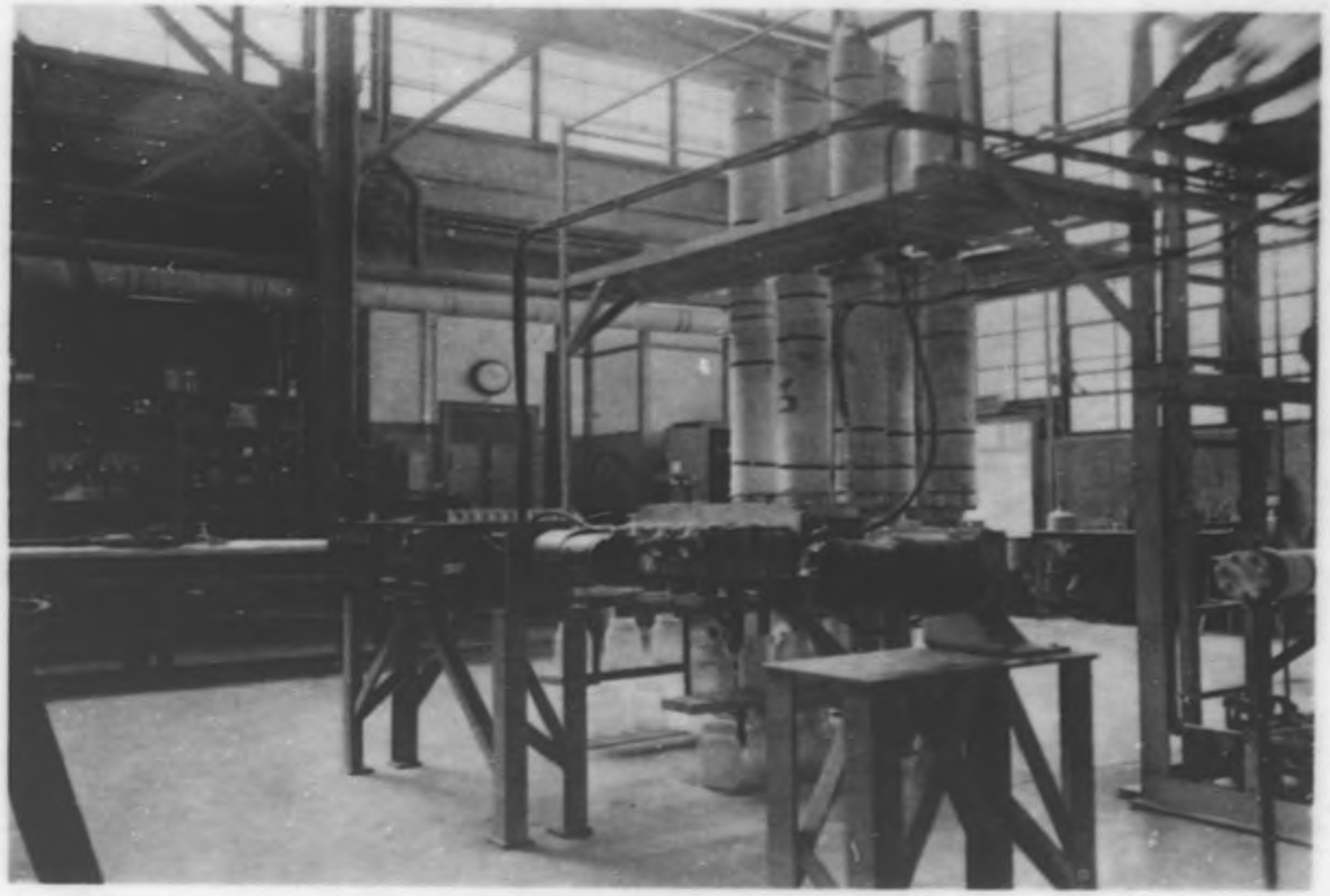
General View of Multiple and Single Rigs

Photo 5407



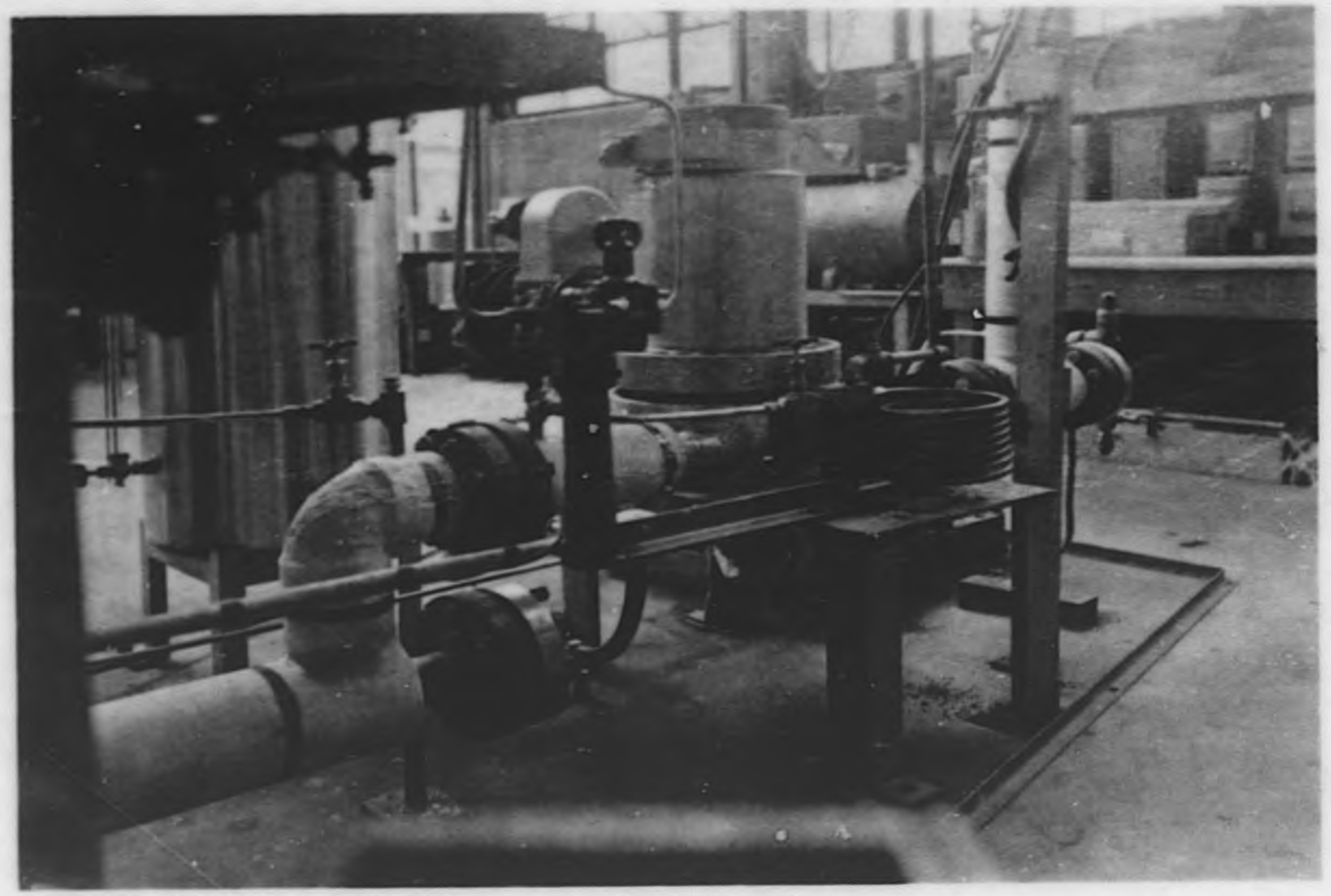
Rear View of Single Rig Showing Pumps

Photo 5408



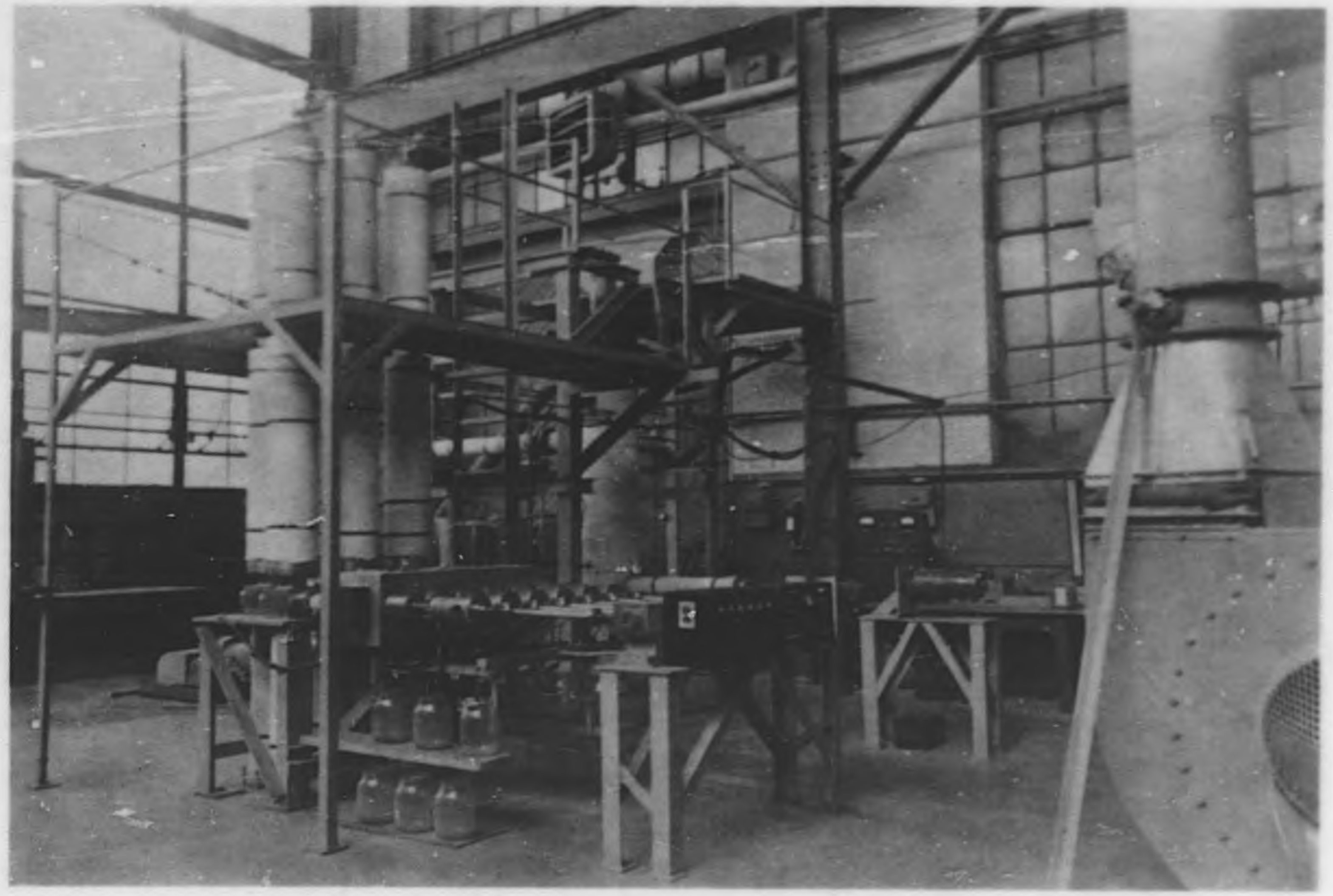
Multiple Rig Showing Seals and Control Panel

Photo 5409



Circulating Pump for Multiple and Single Rigs

Photo 5410



General View of Multiple Rig

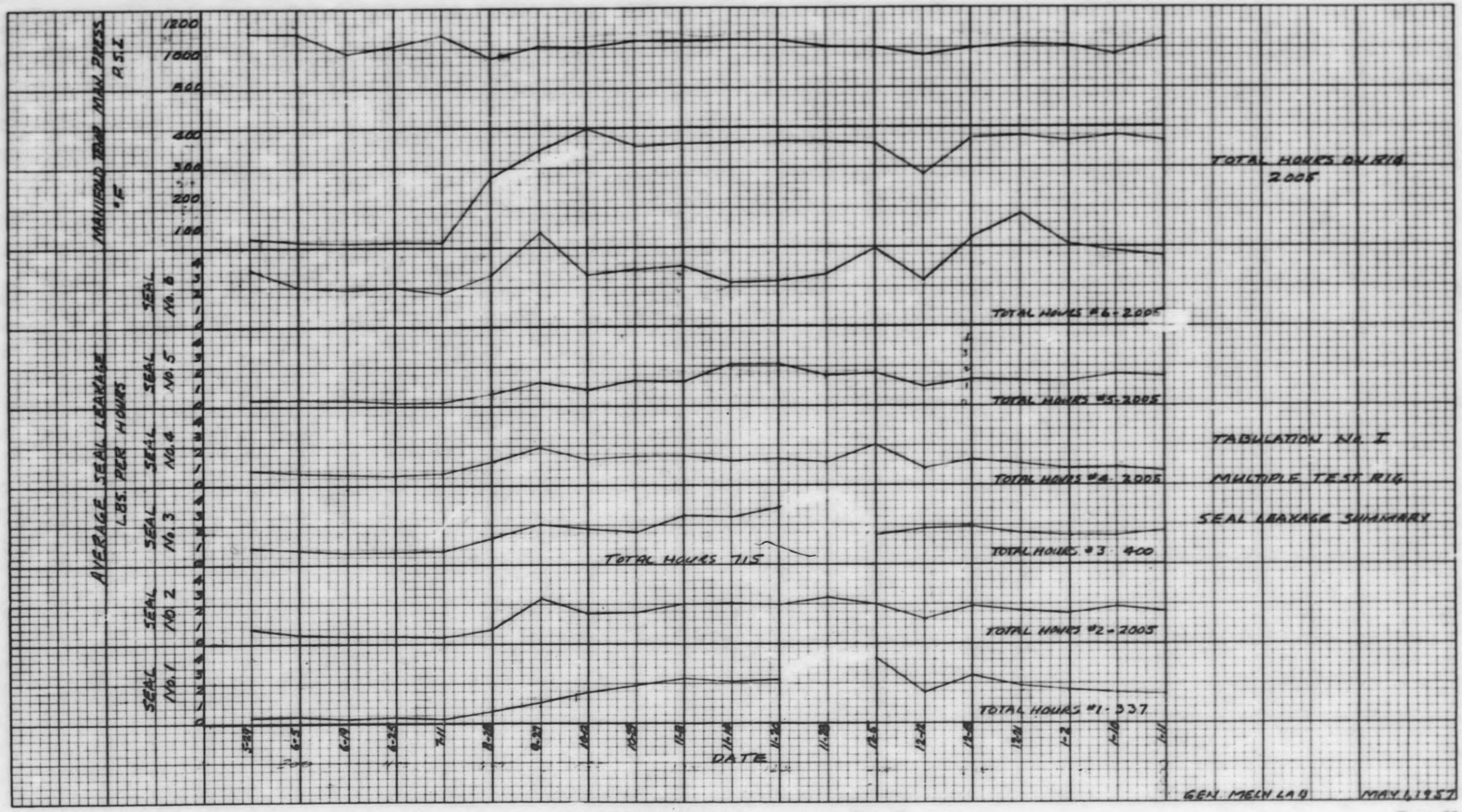
Photo 5411

Unit Number	Seal Leakage	Average Manifold Temp.
1	.36 #/hr	69°F
2	.81 #/hr	69°F
3	1.12 #/hr	69°F
4	.91 #/hr	69°F
5	.38 #/hr	69°F
6	3.30 #/hr	69°F

The number 6 seal was dismantled to check for misassembly, but none could be found. The comparatively high leakage rate was attributed to the ring and shaft clearance being on the upper limits. The seal was cleaned and reassembled and the high leakage rate remained constant. The graph (Fig. 3) shows the seal leakage over a long period.

The original rack backup rollers used became very rusty in a few days and the whole system became contaminated. Incorrect heat treatment had left iron deposits on the surface. This indicated that in addition to very close control of the materials used, the heat treatment must be also carefully controlled. The rack roller pin was stainless steel coated with Stellite #12. The rack rollers were changed from Stainless Steel #410 to Stellite #3. Stellite has excellent wear resistant qualities and good corrosion resistant qualities. The rack rollers are well below the core and the main flow of water, therefore the release of cobalt can be tolerated.

The diameter of the dashpot bores were varied to determine the best dampening effect during scram operation. The control rod pistons were made to the APPR-1 tolerance of $\frac{2.597}{2.595}$ in. The bores were varied as follows:



Graph of Seal Leakage Fig. 3

Block Number	Bore
1	2.6274 In.
2	2.6172 In.
3	2.607 In.
4	2.6065 In.
5	2.6174 In.
6	2.626 In.

This would give three different clearances of .012, .022 and .032 in. The .032 in. clearance was accepted as being the best. The deceleration qualities were satisfactory and the system reliability was better. The smaller clearances produced too rapid a deceleration and caused some scuffing on the piston and dashpot.

The roller clearances were also varied to get the best acceleration and reliability effects. The clearances are shown on the following table:

Block Number	Roller Clearance
1	.010 In.
2	.0105 In.
3	.011 In.
4	.010 In.
5	.0115 In.
6	.012 In.

* The .012 clearance gave satisfactory acceleration and maximum reliability under all operating conditions.

At the same time two types of rod guides were used. They were in the form of removable blocks, so that they could be removed and remachined as necessary.

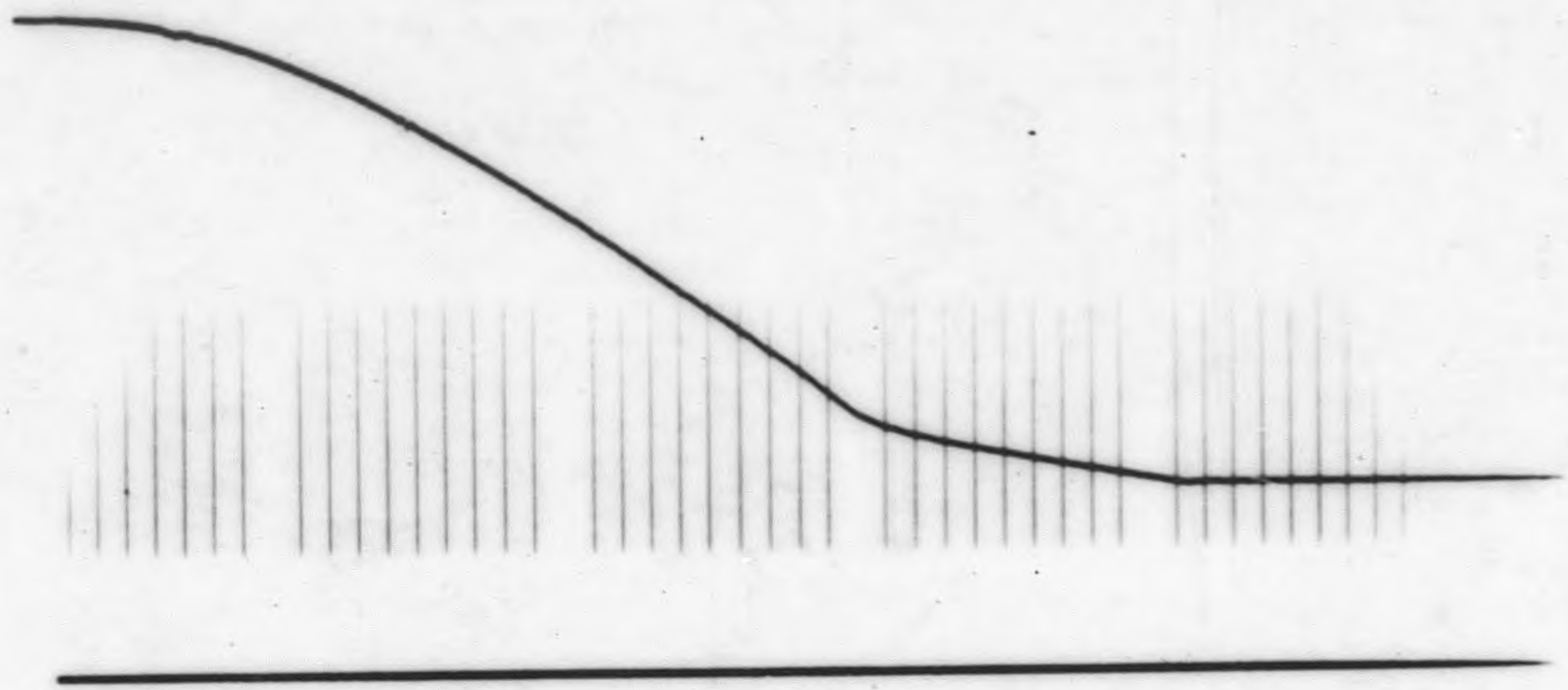
*- .012 clearance gave satisfactory performance and was preferred for reliability, so was used in APPR-1

The number 1, 2 and 6 tanks were fitted with Stellite blocks and the 3, 4 and 5 tanks fitted with Stainless Steel #304 blocks. The clearances between the guides and control rods were also varied to find the best operating conditions. A final clearance dimension of .030 in. was selected as giving the least amount of scuffing, good acceleration and minimum rod wander. The stainless steel guides were selected for the final design. The stainless steel produced slightly more scuffing on the rods, but the disadvantages of Stellite in this location (cost and difficulty of manufacture and release of cobalt to the system) outweighed its slight improvement over 304. Photos 5019 and 5020 are oscillograph recordings of rod drops without and with the system pressurized, respectively.

Rods were checked for squareness and alignment before and after operation in the test rig. After 232 hours of continuous operation no difference could be found.

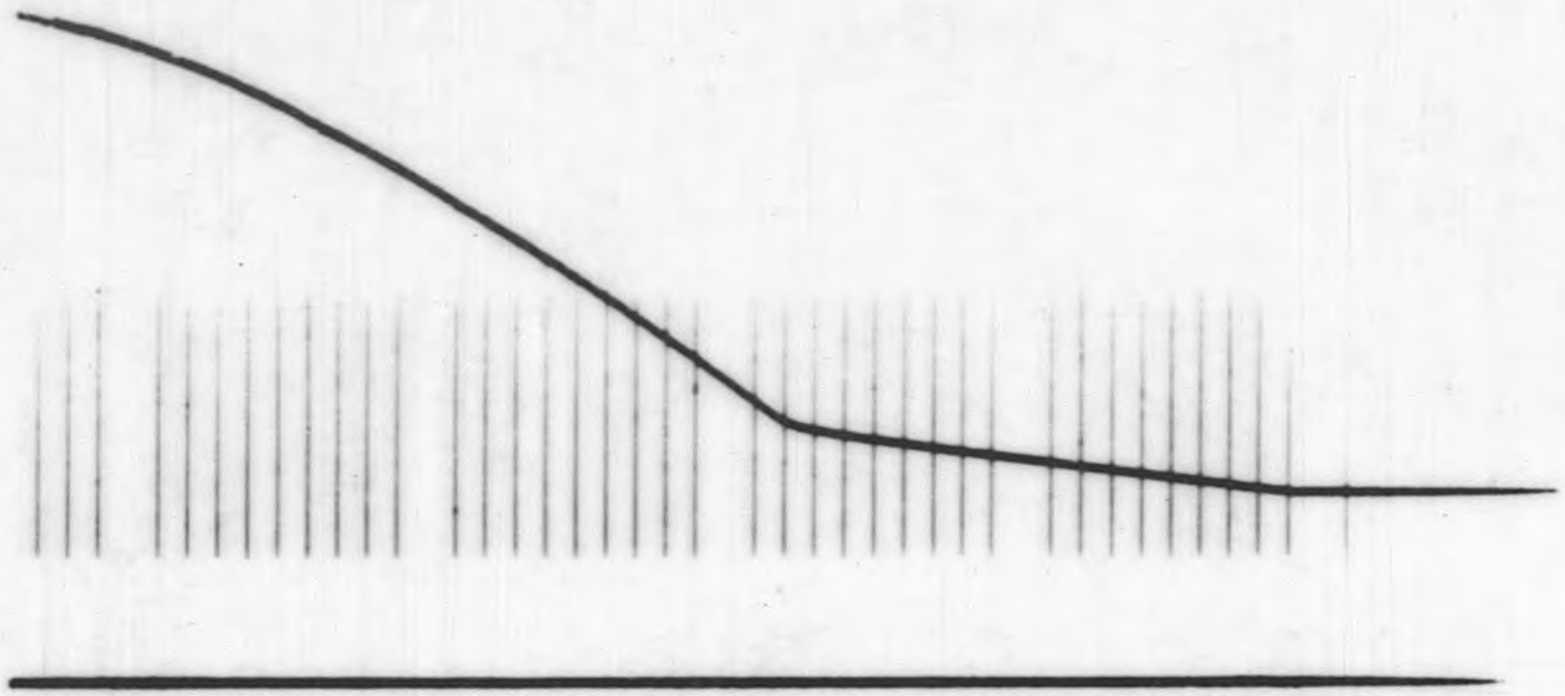
Synchros and fine position indicators were installed on the rig to determine the effect of repeated scramming. After many cycles the instruments still functioned very well indicating that a good selection had been made. The original intention was to shrink the drive gear onto the synchro shaft, but it was found that the shafts were being bent and distorted. The hole in the gear was relieved to give .0002 in. clearance and a set screw put in the gear hub. The set screw did not disturb the balance of the unit and produced very satisfactory results.

The clutches were checked for breakaway torque. All clutches were checked at 90 volts D.C. with the following results:



Oscillograph of Rod Drop #6 Tank W/No Pressure on System

Photo 5019



Oscillograph of Rod Drop #6 Tank W/1200 PSI Pressure on System

Photo 5020

1	40 ft. lb.
2	32 ft. lb.
3	45 ft. lb.
4	35 ft. lb.
5	35 ft. lb.
6	No reading taken

The manufacturing data states that the breakaway torque should be 40 ft. lbs. or greater. The low readings indicated that the friction surfaces were not sufficiently burnished. The clutches were set up and reburnished and upon a second check all readings were 40 ft. lbs. or higher.

One of the drive units could not be removed with the system pressurized as the ball valve would not contact its seat. Upon investigation it was found that the sleeve was not in its proper place. The design of this part was changed by increasing the width of the keyway thus insuring that the parts would be properly oriented at assembly. The flange bolts were also very hard to handle when the system was up to temperature, so a screw driver slot was put in the head to make assembly and removal easier.

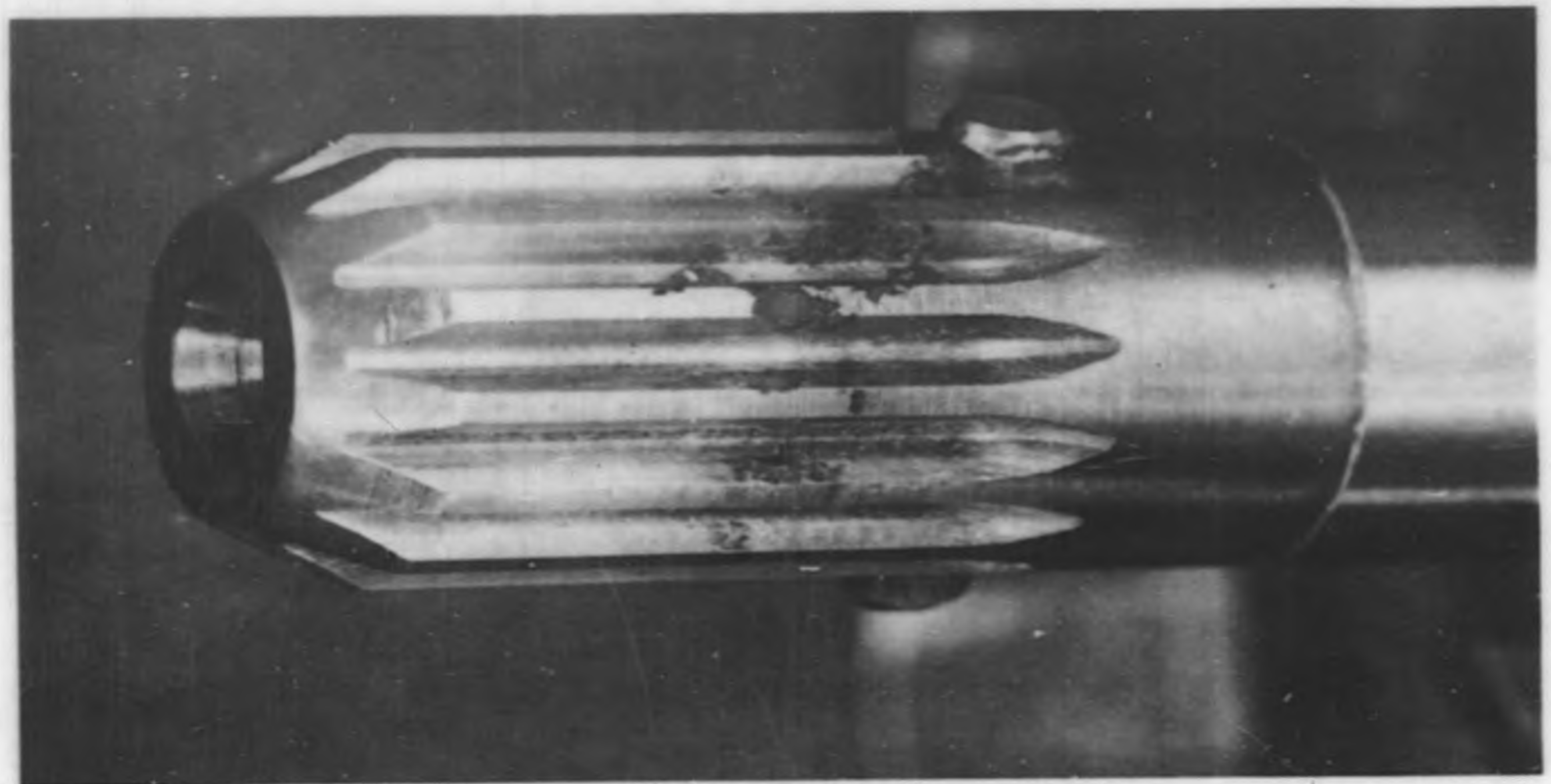
From May 29, 1956 to January 11, 1957 the rig was in operation 2005 hours. In this time 60,000 scram tests were made, and no serious malfunctions occurred during these tests. Tests were also made by raising 3 different rods to different levels and holding them for prolonged periods to find out if the rod would stick after being held stationary. The intent was to hold them in the elevated position for 3 to 4 weeks and then scram them. The power to the laboratory was accidentally cut on different occasions and due to the drive setup the rods were scrammed before any oscillograph records could be obtained. On all occasions the rods always scrammed all the way, indicating that no sticking occurred.

The APPR-1 drives were removed from the criticality facility and installed on the multiple rig for leakage tests, before being shipped to Fort Belvoir. The spline end of the seal shafts were badly pitted. Photos 5153 and 5154 show this condition. Because of the presence of this corrosion it was decided to replace all APPR-1 seal shafts with 17-4 PH Stainless Steel. The corroded shafts were made of 440C annealed stainless steel. 17-4 PH has superior corrosion resistance as well as better physical properties.

During the exchange of seals a leak developed at one of the flanged joints. This joint was sealed with a flexitalic gasket. The gasket had been reused several times and the thickness was reduced from .125 to .108 in. Because of the permanent deformation of the gasket with reuse, a new gasket should be used each time the joint is broken.

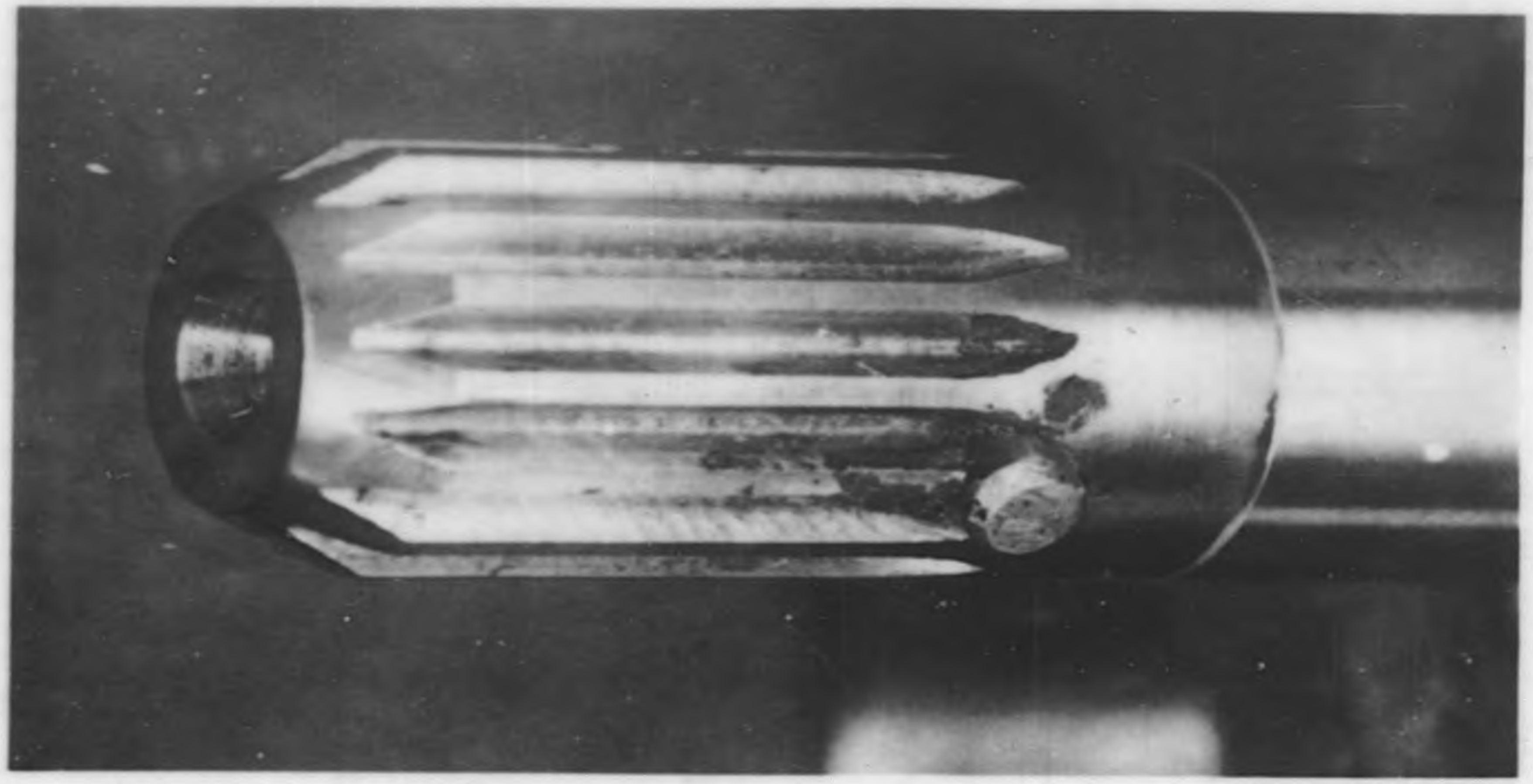
After all the seals were cleaned and new shafts installed they were checked for leakage, with the following results:

Seal Number	Leakage
1	5.35 lbs/hr
2	3.52 lbs/hr
3	4.31 lbs/hr
4	11.65 lbs/hr
5	1.50 lbs/hr
6	6.32 lbs/hr
7	5.80 lbs/hr
8	6.60 lbs/hr



Coroosion of Spline End of Water Seal Shaft

Photo 5153



Corrosion of Spline End of Water Seal Shaft

Photo 5154

To determine the reason for the comparatively high leakage rates all the shafts were measured. The new shafts averaged .0001 in. to .00025 in. smaller in diameter than the old ones. Since leakage varies as the cube of the clearance, the expected leakage increase was calculated from the measured increase in clearance and found to be in reasonably good agreement with the measured leakage increase. Leakage rates are well within the manufacturer's limits.