UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

VELOCITY AND ABRASION STUDIES OF ARMCO SMOOTH-FLO PIPE--SARGENT CANAL MISSOURI RIVER BASIN PROJECT, NEBRASKA

General Report No. R20

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DIVISION OF ENGINEERING LABORATORIES

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COMMISSIONER'S OFFICE
DENVER, COLORADO

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Commissioner's Office--Denver
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Hydraulic Laboratory Branch
Chemical Engineering Laboratory Branch
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Subject: Velocity and Abrasion studies of Armco Smooth-flo pipe--Sargent Canal--Missouri River Basin Project, Nebraska

INTRODUCTION

Flood detention dikes and reservoirs have been designed for protection of the Sargent Canal in reaches that must maintain the hydraulic gradient and yet cross low areas in the topography.

One of the higher dikes will protect an approximate 650-foot reach of the canal in the vicinity of Station 1223+70 (Figure 1). The crest of the dike at elevation 2414.3 will be 43.8 feet above the ground surface at the toe. Detained floodwater will flow through the dike in an uncontrolled 24-inch-diameter evacuation conduit 228 feet long. The invert of the concrete inlet structure to the pipe will be elevation 2373.0 and the invert of the pipe exit will be elevation 2370.5. The maximum water surface elevation behind the dike will be 2409.3 to provide a total head of 37.8 feet to the center line of the exit of the evacuation conduit. An impact-type stilling basin at the conduit exit will dissipate the energy of water flowing at an approximate maximum velocity of 30 feet per second.

The design of the evacuation conduit utilized an asphalt coated asbestos-bonded corrugated metal pipe manufactured under the trade name of Armco, Smooth-flo pipe. Since this pipe had been designed for low-velocity flow of sewage structures, velocity and abrasion tests were made to determine the resistance of the asphalt

*Cross-referenced as Laboratory Reports No. Hyd 412 and P-60 for title only.

to a water velocity of 30 feet per second and to abrasion by sand carried in the water. The velocity tests were performed in the Hydraulic Laboratory Branch and the abrasion tests in the Chemical Engineering Laboratory Branch. This report combines the results of the two studies under the headings Velocity Tests and Abrasion Tests.

VELOCITY TESTS

Asphalt Erosion by Water Velocity

A radial misalinement of the joint between sections of pipe was considered to be the most critical spot for erosion of the asphalt. This erosion could occur as the water flowed against and over a projection of the coating into the flow. A pressure equal to the velocity head against the projection would couple with a negative pressure on top to start a movement of the lining. Water penetrating between the asphalt and pipe would tend to lift the coating to cause progressive damage.

Test Pipe and Facilities

Two 4-foot-long sections of the pipe were provided for the velocity tests by the Denver office of Armco Drainage and Metal Projects, Incorporated, Figures 2 and 5. The first section of pipe was prepared without a joint and the second section with a typical joint. The coating applied to the exterior of the pipes was noted to be approximately 1/16 inch thick and uniform on the corrugations. The coating on the pipe interior was smooth and continuous but slightly wavy from the shrinkage between the corrugations. The depressions between the corrugations were approximately 0.05 inch deep. The asphalt filled the 1/2-inch valleys and covered the crests of the corrugations by approximately 1/4 inch. The inside diameter was thus reduced from a nominal 24 inches to approximately 23.5 inches. The second section of pipe differed from the first by the joint near the midpoint of length.

The laboratory pump capacity was inadequate to fill the pipe at a velocity of 30 feet per second; therefore, a nozzle was constructed to provide this velocity over a part of the circumference of the pipe, Figure 3A. A pitot tube was used to measure and determine the uniformity of the jet velocity from the nozzle, Figure 2B.

Test Procedure

To simulate a pipe joint in the first section of pipe before the second pipe section became available, the nozzle was slowly depressed into the coating to allow a 1/16-inch projection of the coating above the lower inside surface of the nozzle, Figure 3B. The nozzle radius as constructed was slightly less than the radius of the pipe coating at the test section. Therefore, at the center line of the nozzle the projection of the coating above the nozzle surface was a maximum. Approximately 4 inches to each side of the center line the coating and nozzle surfaces were coincident. Beyond these points the nozzle surface projected to a maximum of 1/16 inch above the coating surface.

To test the section of pipe which contained the joint, the nozzle was inserted into the pipe to within 10-1/2 inches of the joint, Figure 5B. A 6-inch-wide piece of 24-gage galvanized iron was formed to the radius of the pipe and placed between the lining and the underneath side of the nozzle. The metal extended 2-1/2 inches downstream from the nozzle exit on top of the coating to deflect the water in a horizontal direction along the pipe to the joint. An 8-inch length of lining was thus exposed between the end of the metal strip and the pipe joint.

Water at a temperature of 61.5° F was pumped through the nozzle until a velocity head corresponding to 30 feet per second was measured by the Pitot tube. A mercury manometer connected to a pressure tap in the 12-inch inlet pipe was then used with the measured discharge to indicate the jet velocity. Observations were made at intervals to determine if erosion of the coating occurred and to what extent.

Test Results--Continuous Interior Pipe

The velocity of the jet measured with the Pitot tube was quite uniform across the exit of the nozzle and continued so for a distance of approximately 1 foot downstream. From there to the end of the pipe the pipe curvature crowded the water toward the bottom center and the jet lost its identity. The depth of the jet in the first 1 foot was approximately 5/8 inch with a slight amount of spreading up the wall of the pipe.

Observation of the pipe coating at the end of a 2-hour and 45-minute test period disclosed no damage. In a total test time of 10 hours and 15 minutes, the coating had been eroded immediately downstream of the nozzle to cover a 3-1/2-inch length on each side of the nozzle center line. The eroded area extended downstream an average of approximately 1/2 inch and the depth of erosion varied between 1/8 and 1/4 inch but did not extend to the metal of the pipe. The coating had been torn from the area as flakes or small chunks. At the right end of the eroded area a chunk approximately 3/4 inch in diameter had been removed to a depth of 1/4 inch. No erosion occurred where the nozzle projected above or was flush with the lining. The test was continued after inspection to observe the progress of the erosion.

In a total time of 12 hours and 45 minutes the largest piece of coating was removed near the right-hand end of the eroded area,

Figure 4A and B. This piece, Figure 4B (Detail A), measured 1-3/4 inches along the nozzle and 1-11/16 inches downstream from the nozzle exit. Inspection of the piece disclosed that the water had raised the upstream edge into the flow and then peeled the piece in a downstream direction as the projected area increased. The final break of the piece from the coating gave the appearance of flakiness and left a rough edge at the downstream end of the hole.

Continuation of the test to a total time of 17 hours and 15 minutes enlarged the eroded area to 2-1/2 inches along the nozzle and to 2-1/8 inches in the downstream direction, Figure 4B. The area had been enlarged by the removal of small pieces down to the asbestos bonding layer of the pipe apparently by direct impingement of the water on and under the coating. The metal pipe was not exposed. The damage near the extreme ends of the nozzle impression was caused by the sealing material used to prevent flow from this part of the nozzle. The asphalt downstream of the eroded area showed no visible effects of the 30-foot-per-second water velocity at the end of 17 hours and 15 minutes of testing.

To obtain results more conclusive than were disclosed by tests with a simulated pipe joint, a test was made on a pipe section that contained a typical joint. This test was desired because a deformation occurred in the previous test when the nozzle was depressed into the coating. The deformation was evidenced by the cracks that opened in the asphalt under the nozzle, Figure 4B. A subsequent weakening of the coating was likely to have occurred to lower the resistance to the flow of water. To eliminate the effect of this deformation, a pipe section that contained a typical joint was installed for testing.

Test Results--Pipe with Joint

Two 2-foot-long pipe sections coupled together were provided for the test. The sections had been coated with asphalt before assembly (Figure 5A). A neoprene sponge rubber sleeve 6 inches wide and 3/8 inch thick was held in place by a steel band and hoops to cover the joint and prevent leakage. The maximum radial misalinement of the joint on the interior of the pipe was approximately 1/8 inch. The coating was slightly rounded at the ends of the pipe sections forming the joint and evidently occurred as the asphalt cooled from the fluid to plastic state after application (Figure 5B). The maximum longitudinal separation in the joint was approximately 1/4 inch and varied from this distance to direct contact around the circumference of the joint. A section of the joint separated by a 1/4-inch space with the downstream pipe surface 1/8 inch higher than the upstream surface was chosen for the test (Figure 5B).

Observation of the joint at the end of a 7-hour 55-minute test period disclosed small eroded areas similar to those that occurred in the first test. The coating was again removed as flakes or small chunks from the end of the pipe forming the downstream side of the joint. The depth of erosion was a maximum of 1/16 inch and the largest area 1/4 by 1/2 inch. Erosion was not extensive, and the test was continued for a total time of 29 hours and 50 minutes.

The erosion was progressive over the test time with the eroded areas interconnecting along the joint (Figure 5C). Erosion depth increased to approximately 1/8 inch maximum and extended downstream from the joint a distance of 1/2 inch. No large areas of erosion occurred and none penetrated through the coating to the corrugated pipe in 29 hours and 50 minutes. There was no apparent erosion except at the pipe joint. The longitudinal streaks in Figure 5C were evident in both the first and second tests. The surface of the streaks felt as very fine sandpaper and was apparently deposits of material from the air and laboratory water. The streaks were deposited on the surface and were not eroded into the coating.

The test was discontinued with the conclusion that new asphalt properly bonded to the corrugated pipe would be eroded at the joints by a water velocity of 30 feet per second, but the erosion would probably not be extensive. The erosion resistance of aged asphalt to a water velocity of 30 feet per second could not be determined in the short test period.

<u>Test Results--Pipe Joint with Mastic Asphaltic Filler</u>

To indicate the worth of protecting the pipe joint, the joint was disassembled and a mastic asphaltic filler was applied with a putty knife to the ends of the two pipe sections (Figure 6A). A circumferential section of the joint that contained both a separation and a contact of the pipe ends was chosen for the filler application. The joint was reassembled and installed in the laboratory test facilities with no attempt made to smooth out the mastic that projected into the pipe (Figure 6B and C). The height of the projections ranged from 0 to 3/8 inch. In the reassembly of the pipe joint, it was noted that a radial offset of the two pipe sections larger than that of the previous test occurred over approximately 1/4 of the pipe circumference. The offset distance was a maximum of 1/4 inch. The remaining 3/4 of the pipe circumference containing the test section was evenly alined.

Testing was started after the filler had cured for 48 hours. Observation of the joint after 7 hours 45 minutes of test at a velocity of 30 feet per second disclosed that the filler had been pushed away from the end of the upstream pipe section and had folded over the end of the downstream pipe section (Figure 7A and B). Streamers had been torn from the main body of the filler that was extruded into the pipe from the joint. The streamers alined with flow in a downstream direction and remained against the pipe coating. With a pipe flowing full in a field installation, the streamers would probably be torn free and be removed by the water. In the laboratory installation the extruded filler caused an upward deflection of the water that did not entirely recover to a horizontal flow direction downstream of the joint (Figure 7C). Therefore, the streamers were not exposed to the full 30-fps velocity, and they remained attached to the joint.

For a comparison with the results of the test on the unfilled joint, the filled joint test was continued for a total time of 30 hours. An additional small amount of filler was removed from the joint (Figures 7 and 8). A small amount of damage to the pipe was discerned on the ends of both the upstream and downstream pipe sections. On the end of the upstream section a small piece of coating 1/4 inch long by 1/16 inch maximum in width had been torn from the pipe to remain attached to the filler. The bond between the filler and coating was apparently stronger in this small area than the strength of the asphalt. Very slight damage to the end of the pipe forming the downstream side of the joint was also caused by a tearing action. In the 30-hour test period there was no apparent erosion caused by direct water impingement on the end of the pipe as had occurred in the test on the unfilled joint. The filler bridged the joint and deflected the water away from the exposed end of the downstream pipe to prevent the erosion. Thus, the filler may offer protection provided it is not torn from the joint to expose the ends of the pipe.

A curing period longer than the 48 hours previous to the laboratory test would increase the resistance of the filler to the velocity and could increase the bond strength between the filler and coating. The manufacturers usually recommend 7 to 10 days curing. The increased strength of the filler and coating-filler bond should provide protection of the joint provided the filler does not project appreciably into the pipe. If the filler projects into the pipe to provide a leverage for the flow of water, chunks of filler and coating could be torn from the pipe. This action would expose the pipe ends to further erosion.

ABRASION TESTS

Test Procedure

The specimen used in this test was prepared by pouring the asphalt (of the same quality as that applied to the pipe) heated to 400° F into an 8-inch-diameter, 8-inch-long steel pipe being rotated to 50 rpm. After pouring, the outside of the pipe was heated to cause the asphalt to smooth out. The specimen was allowed to set for 4 days, the abrasive charge introduced, the ends sealed, and rotation begun. The abrasion test was made in four separate runs under the conditions tabulated below:

Run No.	Velocity RPM	FPS	Duration Days	Revolutions	Abrasive charge
1	33	1.1	14	660,000	Sand
2	33	1.1	14	660,000	Sand
3	97	3.4	5	660,000	Sand
4	33	1.1	14	660,000	Gravel

After each run, the coating was visually inspected for damage, the pipe was weighed, and thickness measurements were made.

The abrasive charge described above as "sand" consists of 3/4 pound each of Nos. 30, 50, 100 and pan size Clear Creek sand plus 2,000 cc of water. The charge described as "gravel" consists of 3 pounds of No. 4 aggregate plus 2,000 cc of water. In either case the charge fills about one-third of the volume of the cylinder.

Results of Tests

After 2.6 million revolutions in the abrasion test, the asphalt has shown no loss in weight nor apparent loss in thickness. Weight and thickness losses are criteria for determining the performance of lining subject to abrasion.

The appearance of the asphalt surface, however, has changed considerably as may be noted by comparing Figure 9 taken before the abrasion test was started with Figure 10 taken after 660,000 revolutions (2 weeks) at 33 rpm and Figure 11 taken after an additional 660,000 revolutions at 33 rpm and 660,000 revolutions at 97 rpm and Figure 12 taken after an additional 2 weeks (660,000 revolutions) at 33 rpm using No. 4 aggregate instead of sand. In the Figure 12, note in particular the pronounced rippling effect caused by the No. 4 aggregate as compared with the effects of the sand shown in the preceding photographs. It should be noted that the craters showing in Figure 9 are not typical of the application on the pipe furnished by Armco. As shown in the photographs, the surface has been roughened considerably and has embedded in it grains of sand. The asphalt is very soft, 46 penetration as compared with 15-20 penetration for American Water Works Association coal-tar enamel, which no doubt accounts for the effect caused by the sand.

The attached Table 1 gives a comparison of test results for the asphalt used in Armco Smooth-flo pipe and two other pipe lining materials.

The test results may be unrealistic for two reasons. First, sand adhering to the coating would compensate for a weight loss in the coating. Second, asphalt is known to absorb appreciable amounts of water. This also would tend to compensate a weight loss in the coating and could also cause an increase in the volume of the asphalt, hence an increase in the thickness of the coating. Thus the apparent failure of the coating to lose any weight or thickness may not be a completely accurate representation.

In the course of general laboratory investigations this asphalt coating will be subjected to further erosion testing with different gradation of abrasive particles and revolution speeds. More data will then be available regarding the erosion resistance of this soft asphalt.

CONCLUSIONS

Velocity tests

1. The joint between the concrete inlet section of the evacuation conduit and the coated pipe should be smooth to prevent impingement of the water against any projection of the coating above the concrete.

2. All joints between sections of pipe should have a minimum of misalinement, especially those joints near the pipe inlet where the boundary velocity could be 30 feet per second.

3. A new bituminous coating properly bonded to the corrugated pipe would be eroded at the joints by a water velocity of 30 feet per second, but the erosion would probably not be extensive.

4. The maximum laboratory test time of 30 hours was insufficient to determine a long-period resistance of the coating between joints to a velocity of 30 feet per second.

5. The resistance to erosion of an aged bituminous coating to a water velocity of 30 feet per second could not be determined in the short test period.

6. A joint filler would offer protection to the ends of the pipe sections provided the filler was smoothed into the joint and did not project into the pipe flow.

Abrasion tests

1. Laboratory indications are that the material will provide satisfactory protection of the pipe, except possibly where subjected to abrasion by coarse aggregate. Only service performance will prove the durability and protective capacity of this asphalt as a coating material.

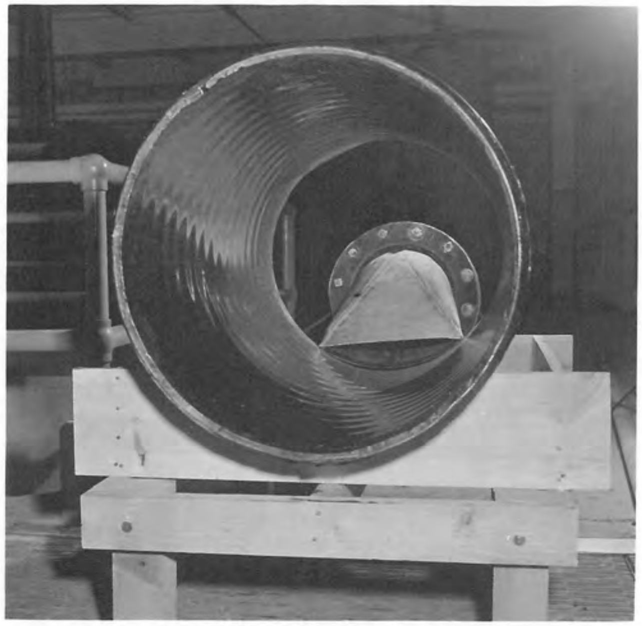
2. The laboratory test data acquired to date on the asphalt coating for the Armco Smooth-flo pipe do not indicate any adverse

effect from erosion by silt or sand except for causing surface roughness of the asphalt. Performance apparently superior to that of coal-tar enamel and asphalt enamel may, however, be misleading in that sand adherence and water absorption may have obscured erosion effects to some extent. Within the test limitations this could not be investigated fully. Also unknown is whether this surface roughness will lead to more severe damage in the presence of high-water velocities.

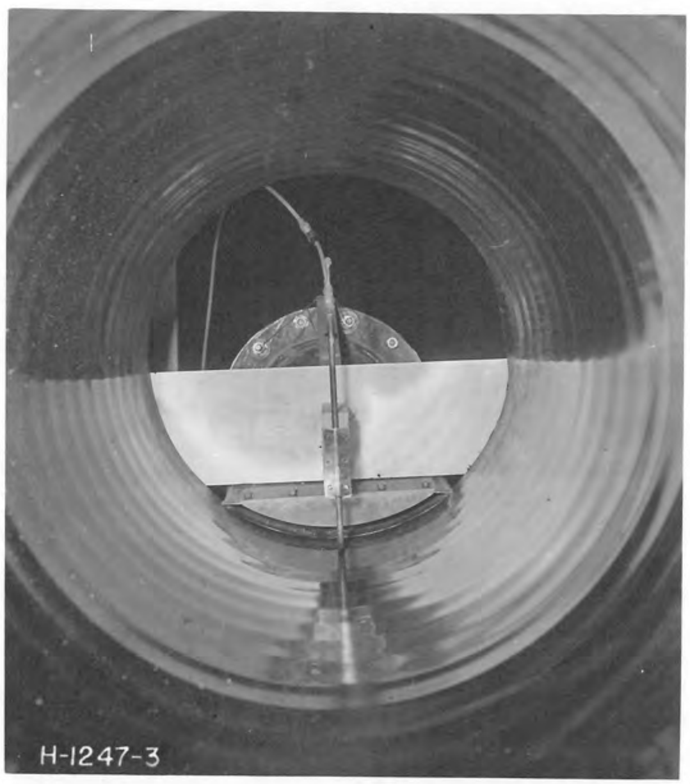
Table 1

Physical Characteristics and Performance Data
of Pipeline Coating Materials

Material	Physical properties		Abrasion test results 1,980,000 revolutions	
	Pen	Soft point	Average thickness loss	Average wt loss
Armco coating smooth-flow pipe asphalt	46	211° F	None Exact measurement hampered by roughness of coating	None
Coal-tar enamel	16	235° F	11 mils	34 grams
Asphalt enamel	6	246° F	2.5 mils	8 grams



A. Pipe interior before test and partially completed nozzle, looking upstream



B. Nozzle and Pitot Tube installation

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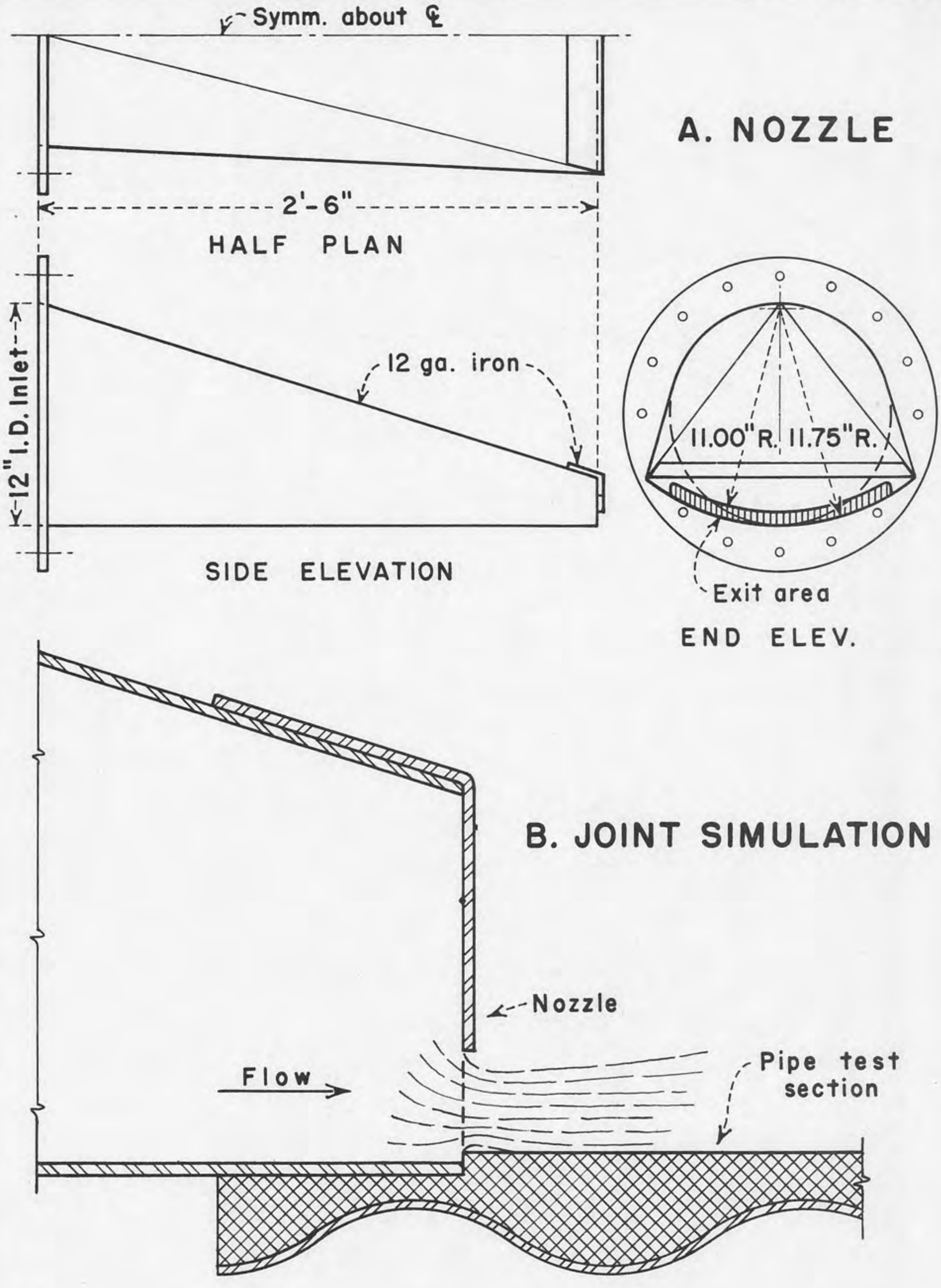
PIPE INSTALLATION IN HYDRAULIC LABORATORY
HYDRAULIC AND CHEMICAL ENGINEERING LABORATORY STUDIES



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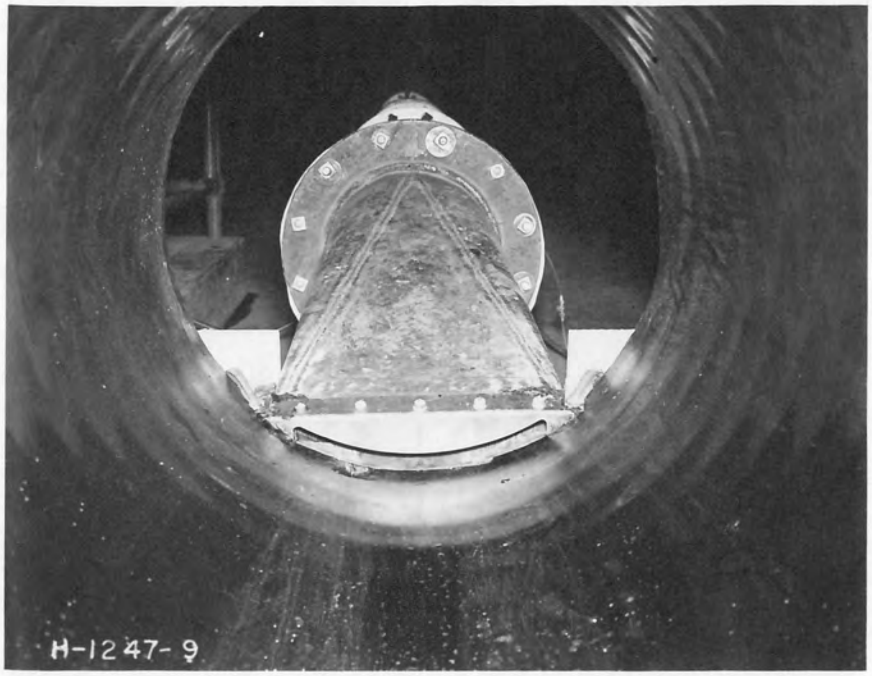
VELOCITY TEST NOZZLE

HYDRAULIC & CHEMICAL ENGINEERING LABORATORIES STUDIES



A. Erosion after total time of 12 hours-45 minutes at a velocity of 30 feet per second

B. Erosion after total time of 17 hours-15 minutes, pipe moved downstream from nozzle, damage near ends of depression caused by nozzle sealing material A as designated

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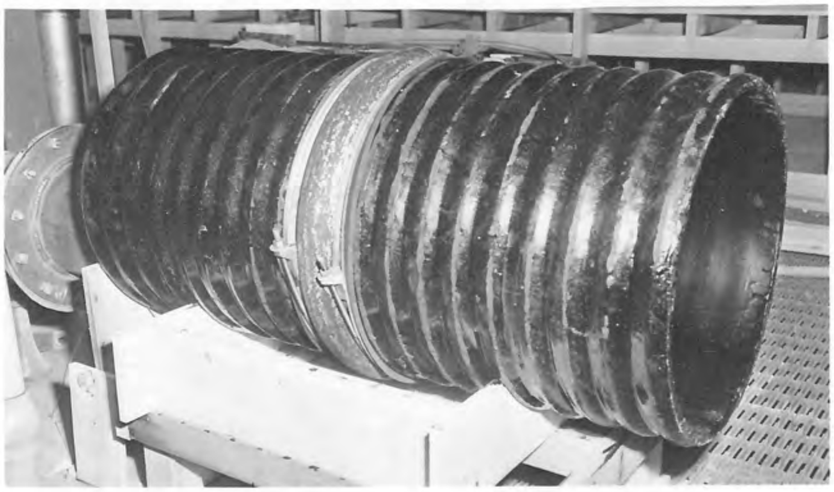
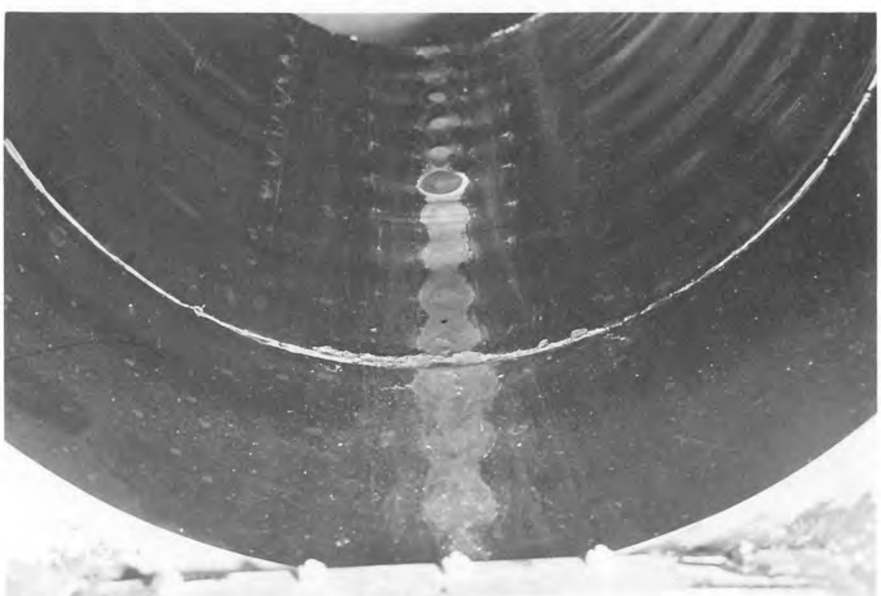
EROSION OF CONTINUOUS INTERIOR PIPE COATING
HYDRAULIC AND CHEMICAL ENGINEERING LABORATORY STUDIES



A. Exterior of pipe and coupling

B. Interior pipe joint--Maximum height of downstream surface above upstream surface approximately 1/8 inch

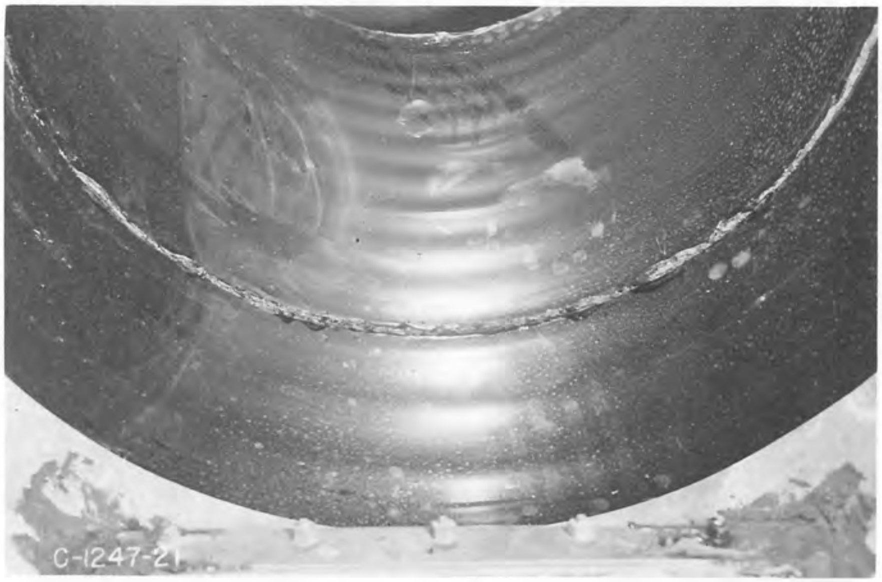


C. Erosion of coating on downstream pipe section after 29 hours 50 minutes at a velocity of 30 feet per second

SARGENT CANAL
EROSION OF COATING IN PIPE WITH JOINT
HYDRAULIC AND CHEMICAL ENGINEERING LABORATORY STUDIES

FIGURE 6
Report General. 20

A. Dissassembled joint with asphaltic filler applied to ends of pipe sections

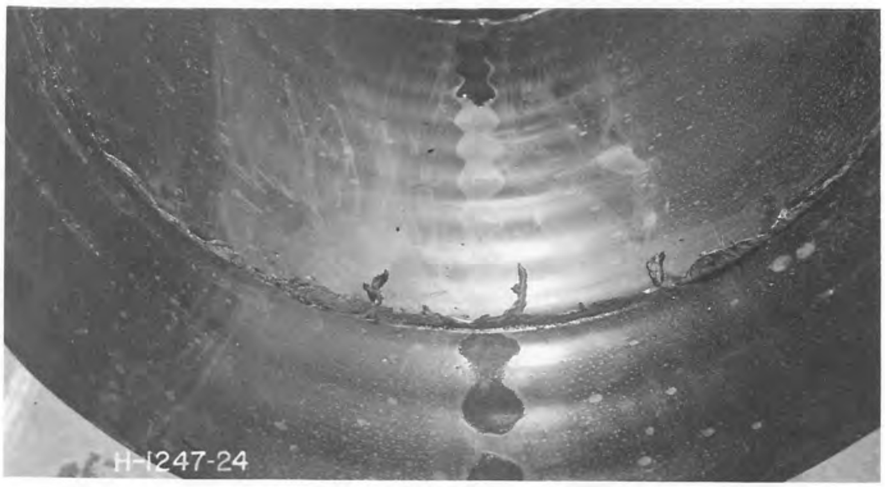


B. Appearance of re-assembled joint before test--maximum height of filler approximately 3/8 inch--looking downstream

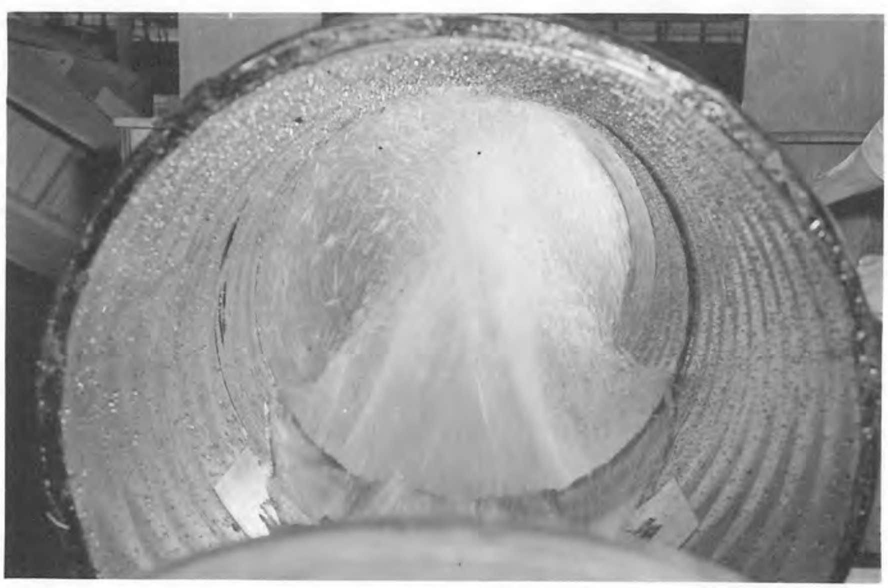
C. Appearance of joint before test--looking upstream

SARGENT CANAL
PIPE JOINT WITH ASPHALTIC FILLER BEFORE TEST
HYDRAULIC AND CHEMICAL ENGINEERING LABORATORY STUDIES

A. Joint filler torn by force of water at 30 feet per second velocity after 7 hours-55 minutes looking upstream



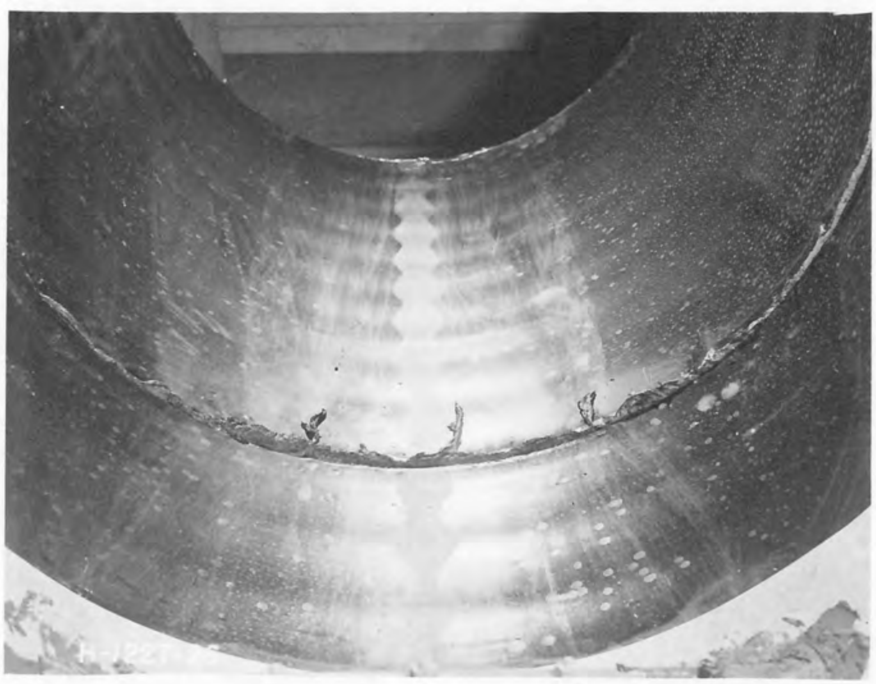
B. View of joint after 7 hours-55 minutes looking downstream



C. Flow conditions 20 minutes after start of test--velocity of jet from nozzle 30 feet per second

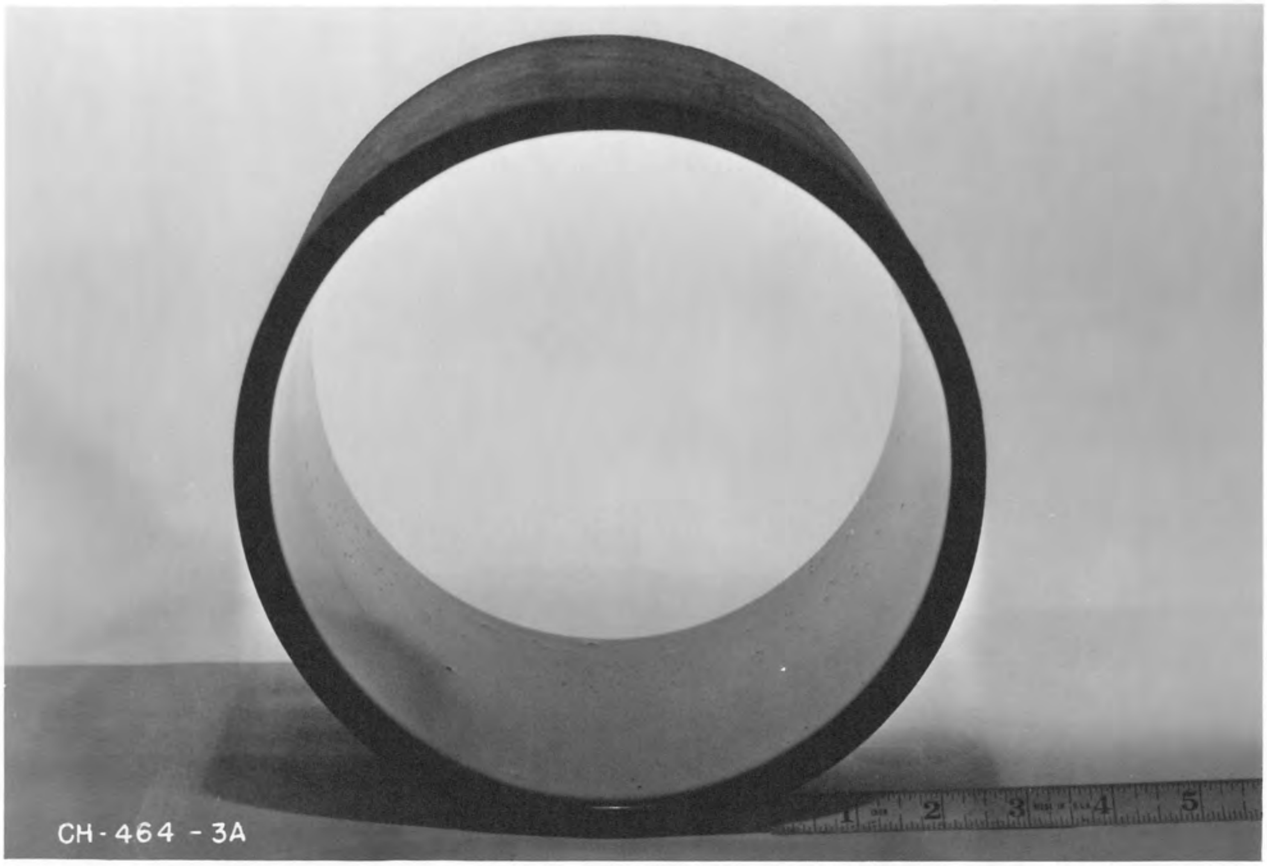
SARGENT CANAL
PIPE JOINT WITH ASPHALTIC FILLER AFTER TEST OF
7 HOURS 55 MINUTES
HYDRAULIC AND CHEMICAL ENGINEERING LABORATORY STUDIES

A. Joint appearance after total test time of 30 hours at a water velocity of 30 feet per second compare slight change with Figure 7



B. View of joint looking downstream total test time 30 hours

SARGENT CANAL
PIPE JOINT WITH ASPHALTIC FILLER AFTER TEST OF 30 HOURS
HYDRAULIC AND CHEMICAL ENGINEERING LABORATORY STUDIES



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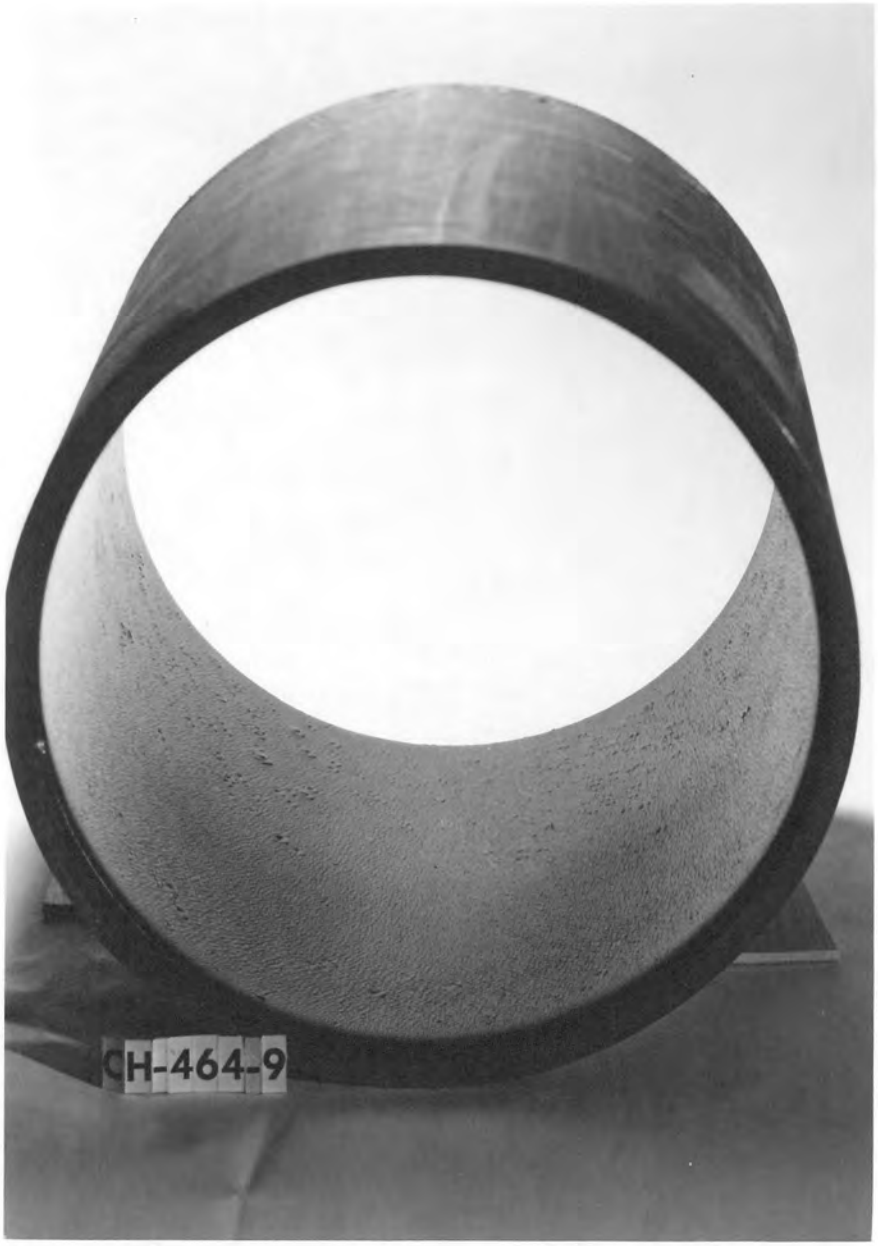
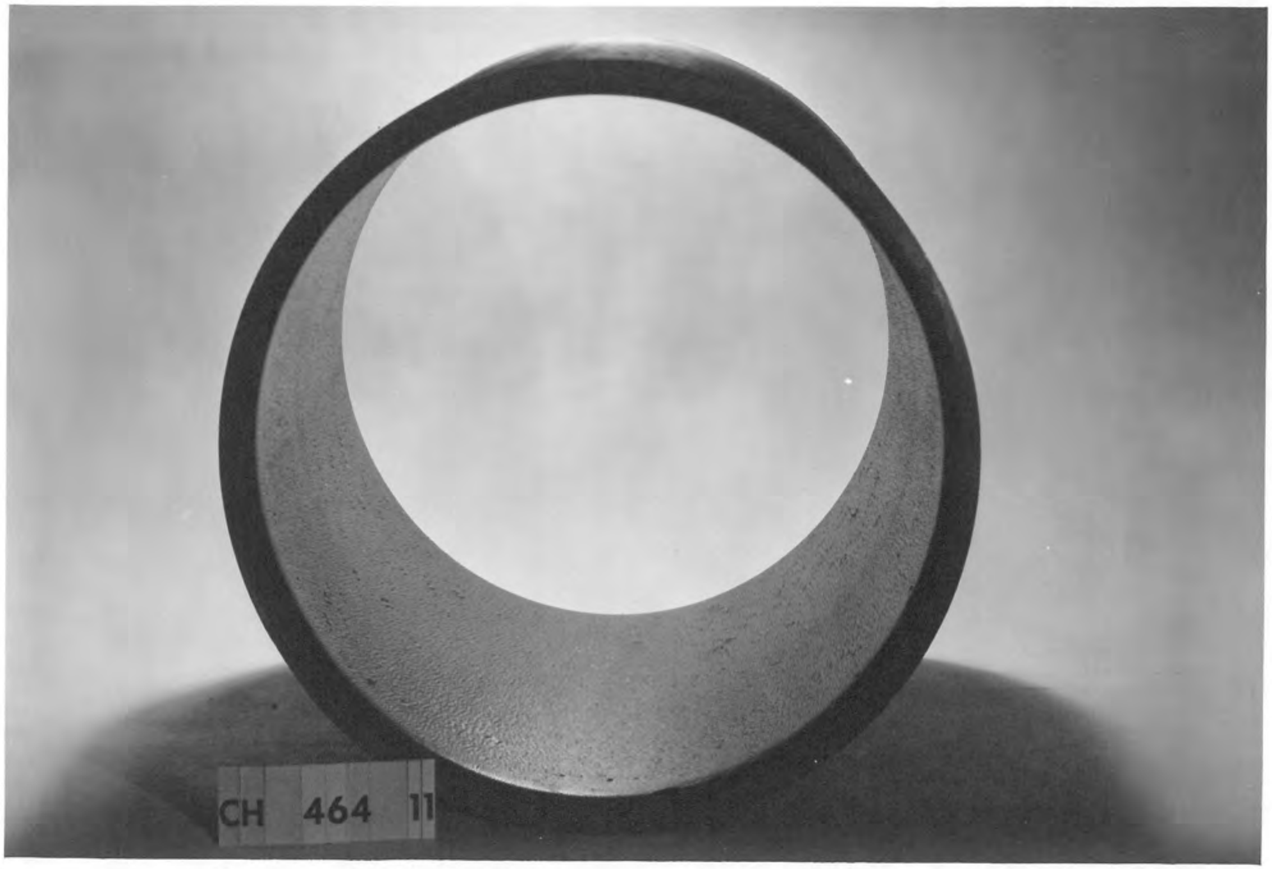
Photograph No. CH-464-3A. Showing the pipe before the abrasion test was started. The holes and craters are not typical of the usual application.



SARGENT CANAL
Photograph No. CH-464-9. Note the general roughening of the surface after 660,000 revolutions at 33 rpm, using sand as the abrasive medium.



SARGENT CANAL
Photograph No. CH-464-11. Showing the appearance of the surface after 1, 320, 000 revolutions at 33 rpm and 660, 000 revolutions at 97 rpm, using sand as the abrasive medium.

SARGENT CANAL

Photograph No. CH-464-14. Showing the appearance of the surface after 1,320,000 revolutions at 33 rpm, 660,000 revolutions at 97 rpm using sand as the abrasive medium, and 660,000 revolutions at 33 rpm using No. 4 aggregate as the abrasive medium.