TEST OF PROTECTIVE COATINGS FOR NAVY

BUREAU OF RECLAMATION
HYDRAULIC LABORATORY

Form 7-C-11
(7-52)
Bureau of Reclamation

INFORMATIONAL ROUTING

293
~~HEBERT~~
~~THOMAS (etc)~~
3 BRADLEY (etc)
~~Peterka~~
~~Schuster~~

JUN 19 1953

Commander
New York Naval Shipyard
Brooklyn 1, New York

Attention: Material Laboratory, Code 945

AUTHOR

Sir:

Ten cone specimens (two bare metal and two each of four different coating materials, identified by Numbers 1 through 10) sent to us by the New York Naval Shipyard were tested during the period March 3 to April 14, 1953, for their relative resistance to cavitation-erosion. The apparatus used for these tests is shown on Figure 1. Cavitation in this apparatus is caused by forcing water at high velocity through a throat section and an expansion in the flow passage. The velocity through the apparatus, and thus the cavitation intensity, is regulated by the differential pressure across the test section. Piezometer taps located 6 inches upstream from the upstream specimen support and 11 inches downstream from the cone tip were used to record the upstream and downstream pressure heads from which the differential pressure could be determined. The discharge and the flow area of the throat were used to indicate the average velocity through the throat section of the apparatus. The discharge from the laboratory pumps was measured by a volumetrically calibrated 8-inch venturi meter.

Each specimen was placed in the apparatus, the pump operated at full speed, and the back pressure regulated to concentrate the collapse of cavities on the specimen. This gave a cavitation envelop or "vapor pocket" about 6 inches long. The throat velocity was about 70 feet per second, the upstream pressure head 144 feet of water, and the downstream pressure head about 39 feet of water. The specimens were examined at 4-, 1-, and 1/2-hour intervals during the initial part of the test, depending upon the coating material being tested, and at shorter intervals as the tests progressed and damage of the specimens became apparent. The tests were stopped when bare metal was exposed by cavitation erosion of the coating or when rupture of the coating by pressure and velocity exposed bare metal or upset the flow conditions to interfere with further cavitation testing. With one exception, all

specimens requiring more than 8 hours' testing were left in the apparatus overnight with the water drained from the system. The metal cone, designated Specimen 4, was removed and dried with alcohol at the end of each test interval.

Summary of Results

Plans were to test two Thiokol coated cones first and use the results as a basis for comparison of the relative resistance to cavitation of the other specimens. The failure of these specimens by loosening of the bond at the upstream end of the apparatus throat section precluded their use as a standard because the loosening in this area prevented maintaining constant test conditions. The results of the tests on these two specimens necessitated a change in plans, and it was decided to test all the coatings to failure and select a standard for comparison. All coatings failed, either by cavitation-erosion to bare metal or a tearing of the loosened coating in periods of 1/4 to 11-1/4 hours. Failure occurred in three general areas on the various specimens. These areas were near the cone tip, near the cone base, and at the upstream edge of the coating in the throat of the apparatus. Cavitation-erosion was noted also in the throat area just downstream from irregularities in the coating surface of some of the specimens.

Damage near the cone tip was of two kinds, cavitation-erosion penetrating the coating and a tearing away of a portion of the coating after loosening by cavitation action. Specimens 1, 5, and 6 are good examples of the cavitation-erosion near the tip (Figures 4, 15, and 17), while Specimens 1, 7, and 8 are examples of the loosened coating being torn away (Figures 4, 18, and 21).

Damage near the base of the cone section of the specimens was by cavitation-erosion. This damage was noticeable on all except Specimens 9 and 10 (Figures 5, 7, 10, 15, 16, 19, and 21). This damage occurred at the upstream end of the cavitation envelop--an unusual location. It is believed that slight pressure surges at the cone base where the pressure gradient (throat pressure to vapor tension pressure) is practically vertical caused a collapse of some of the cavities almost as soon as they formed. This resulted in erosion of the surface at that location. This condition was not prevalent in our previous tests where the corner at the cone base was rounded as shown on Figure 1.

Test Results

Specimens 1 and 2

The coating of Specimen 1 was removed from a small area near the tip of the cone (Figure 3B) in 11-1/4 hours of operation. It appears that the coating in this area was pitted and loosened by cavitation and that pressures under the loosened coating and velocities past it caused a rupture and tearing away of a portion of the material (Figure 4A and B). There was some pitting of the coating material at the periphery of the cone base, but no metal was exposed in this region (Figure 5).

The coating of the second specimen (Number 2) became loosened and torn at the upstream edge of the coating in the throat section in 10-1/2 hours (Figure 6). The loosening and tearing of the coating at this location prevented continuing the test under controlled conditions, and the test was discontinued. There was cavitation-erosion at the base of the cone as in the case of Specimen 1, but a portion of the coating seemed to have been removed as a layer (Figure 7A). This damage seemed to be a result of cavitation and velocity on a thin layer of the coating.

Specimens 3 and 4

The two metal specimens (Numbers 3 and 4) were tested for different periods. Specimen 3 was tested for a period comparable to that for Specimen 1 (11-1/4 hours) while Specimen 4 was subjected to 40 hours' testing. The test on this specimen was continued in order to obtain sufficient damage for comparison with that obtained for the other coatings. The test was made after the tests on all other coatings were completed. A slight erosion at the base of the cone, characterized by a silvery appearance of the metal, was noted on Specimen 3 (Figure 9). No other damage could be detected. After 40 hours' testing of Specimen 4, there still seemed to be no damage other than that of the periphery at the cone base where the erosion was greater than that after 11-1/4 hours' testing of Specimen 3 (Figure 10). Photomicrographs of areas in the throat of the apparatus, at the base of the cone section, midway between the cone base and tip, and near the cone tip were taken at the end of the 40-hour test on Specimen 4. While erosion at the base of the cone is shown distinctly by the photomicrographs, there is no apparent damage in the other areas (Figure 11).

Specimens 5 and 6

The coating of Specimen 5 had been under test for 1-3/4 hours when metal became exposed at the base of the cone and considerable pitting occurred near the cone tip (Figures 12 and 13). Additional testing of 5-3/4 hours exposed metal near the tip and increased the exposed areas near the cone base (Figures 14 and 15). A change was made in the test conditions for the latter test period in order to contain more of the cavity collapses on the specimen. The back pressure was increased to about 47 feet of water to give a cavitation envelop or "vapor pocket" 4 inches long. In 1 hour of testing, cavitation-erosion exposed metal near the cone base of Specimen 6. In 4 hours, cavitation-erosion had exposed metal at numerous spots near the cone tip (Figures 16 and 17).

Specimens 7 and 8

Metal was exposed near the cone base of Specimen 7 in 2-1/2 hours of testing. The coating on the upper half of the cone was loosened by cavitation and torn away in 8-1/2 hours (Figures 18 and 19). Failure similar to that on Specimen 7 was noted on Specimen 8 after 3-1/2 hours' testing. Bare metal exposed by cavitation-erosion was noted at the cone base in about 2 hours (Figures 20 and 21).

Specimens 9 and 10

The coatings of both Specimens 9 and 10 became loosened and torn at the upstream edge of the coating in the throat section. The time in which this took place on both specimens was so short that no comparison as to cavitation-erosion resistance was possible (Figures 22 through 24). This gave further indication that a revision should be made to prevent pressure and velocity conditions damaging the coatings in this area so as to prevent further controlled cavitation studies.

Comments

From the tests made, it will be difficult to obtain any comparison of the relative resistance to cavitation of the various specimens by considering the damage at the downstream end of the cavitation envelop or "vapor pocket." Some idea as to relative resistance might be obtained by comparison of the damage at the

cone bases of the various specimens. For example, the damage at the cone bases of Specimens 1 and 2 was only slight in 11-1/4 hours of operation (Figure 5), the damage at the cone bases of Specimens 3 and 4 was slight in 11-1/4 hours and not noticeably increased in 40 hours (Figure 11), the damage at the cone bases of Specimens 5 and 6 was to bare metal in about 1 hour of operation with considerable bare metal exposed in 1-3/4 hours and much more in 5-3/4 hours (Figures 13 and 15), the damage at the cone bases of Specimens 7 and 8 was to bare metal in about 3-1/2 hours with considerable increase in area of exposed metal in 8-1/2 hours (Figures 19 and 21). The damage at the bases of the cones of Specimens 9 and 10 was negligible in 1-1/2 hours of operation. The material at the junction of the cone base and cylindrical throat section appeared to be rounded compared with the other specimens. This may account at least in part for the negligible damage at the cone bases of these specimens (Figures 22 and 24). The possibility that there were different degrees of rounding at the junction for the different coatings may make comparative results questionable.

The tests prove that some special treatment of the coating at both upstream and downstream edges of the coating materials should be considered in future test programs. This treatment should be of a nature to prevent velocity and pressure acting on loosened edges of the coating to tear them and upset the test conditions. A special undercutting or extension of the specimen at both ends might do much to solve the problem. Some degree of success was obtained by slight alterations to the cone in some of our most recent tests (Figure 1).

The ten specimens have been photographed and placed in their packing boxes for shipment. It is intended that they be returned to you when the two additional specimens mentioned in your letter of March 26, 1953, have been tested unless we are advised that you prefer their return before that time. The above specimens have been received and are scheduled for immediate testing.

Very truly yours

(SIGNED)

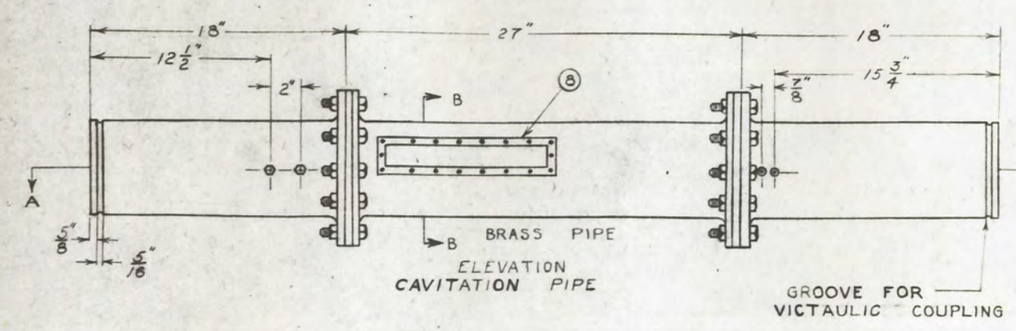
Walter H. Price, Chief
Engineering Laboratories Branch

Enclosures

Blind to: Chief, Engineering Laboratories Branch
R. M. Martin
C. B. Masin
J. C. Schuster

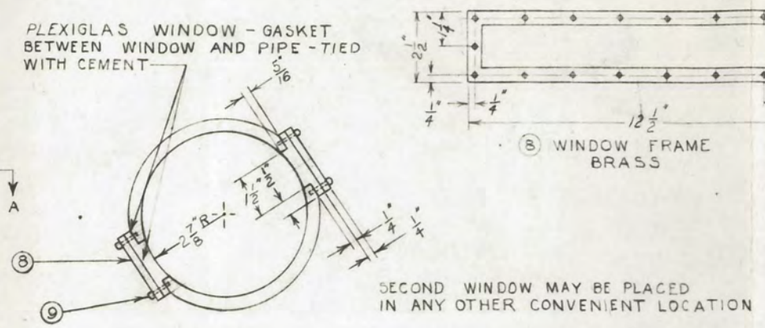
JWBall:bab-s

FIGURE 1



ELEVATION
CAVITATION PIPE

GROOVE FOR VICTAULIC COUPLING



SECTION B-B

SECOND WINDOW MAY BE PLACED IN ANY OTHER CONVENIENT LOCATION

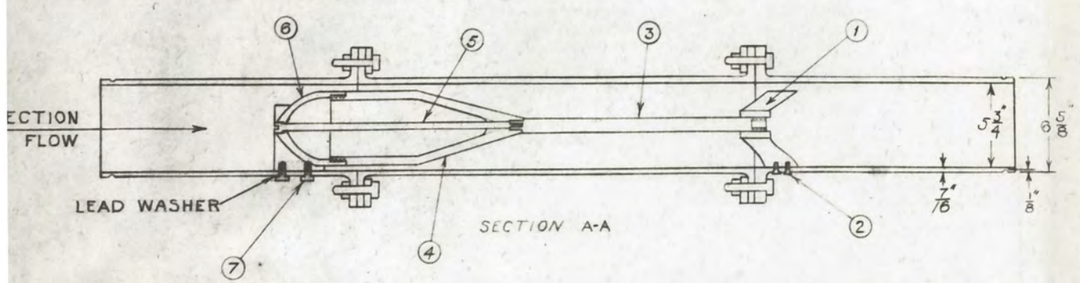
(8) WINDOW FRAME
BRASS

(9) WINDOW FRAME SCREW
STANDARD MACHINE SCREW
1/4"-20NC-2 - 3/4" LONG - FILLISTER HEAD WITH HOLE TO CONNECT WIRE TO PREVENT LOOSING - 36 REQ'D

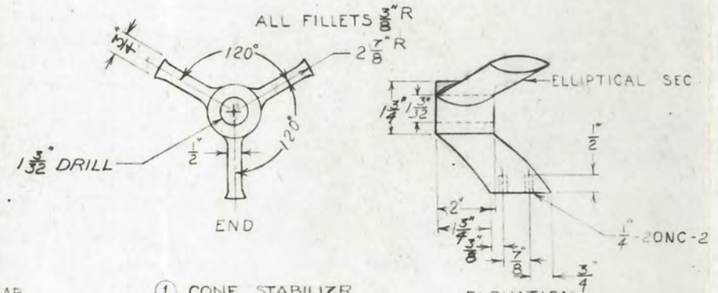
(7) CONE CAP SCREW
STANDARD CAP SCREW
3/8"-16NC-2-1" LONG - HEXAGON HEAD
6 REQ'D

(2) CONE STABILIZER SCREW
STANDARD CAP SCREW
1/4"-20NC-2-7/8" LONG - FLAT HEAD
6 REQ'D

NOTE: THROTTLING VALVE SHOULD BE INSTALLED DOWNSTREAM FROM CAVITATION UNIT TO ADJUST CAVITATION EFFECT TO DESIRED AREA ON CONE.



SECTION A-A

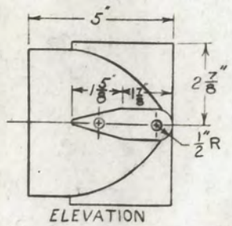


END

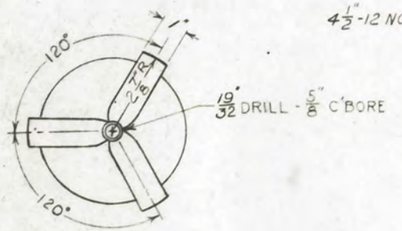
ELEVATION

(1) CONE STABILIZER
BRASS

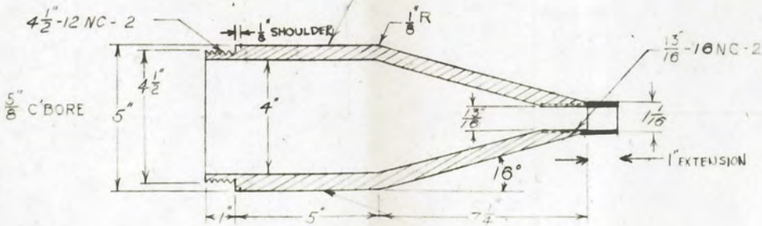
CONSTRUCT OF MATERIAL SIMILAR TO THAT WHICH WILL RECEIVE THE FINAL COATING



ELEVATION



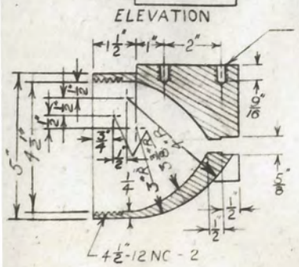
END



SECTION

(4) CONE

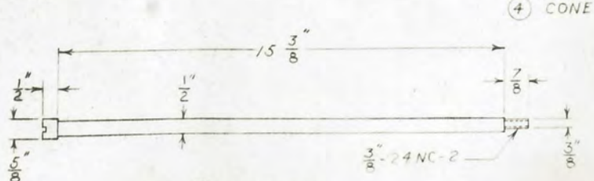
REVISION OF CONE WOULD REQUIRE SMALLER THREAD SIZE TO BE ACCOMMODATED IN TIP EXTENSION



SECTION

(6) CONE CAP
BRASS

UNDER CUT APPROXIMATE THICKNESS OF COATING



(5) TIE ROD
BRASS

END

ELEVATION SEC.

(3) CONECTING ROD
BRASS

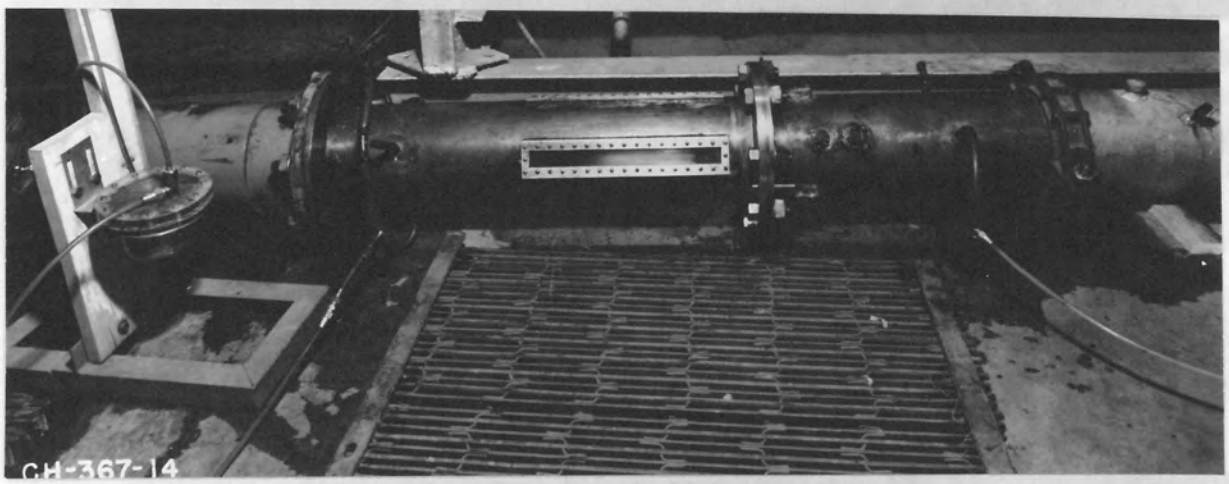
ASSEMBLY SCALE: 1" = 6"
DETAIL SCALE: 1" = 3"

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RESEARCH AND GEOLOGY DIVISION
PAINTS AND OILS LABORATORY

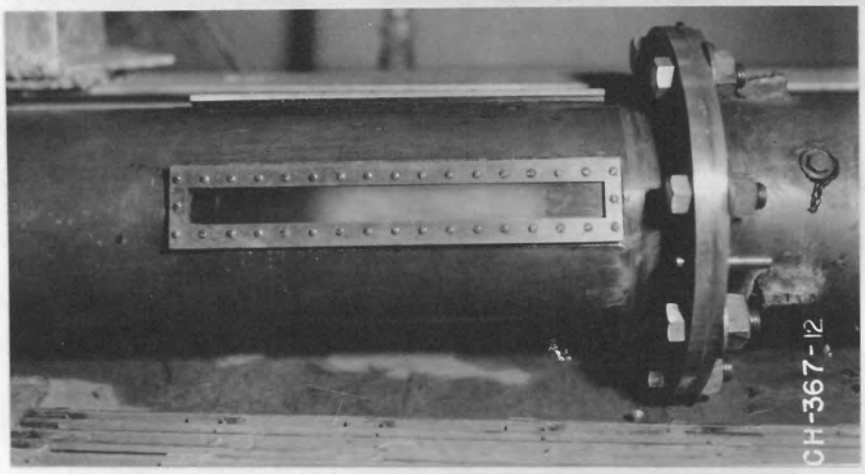
CAVITATION APPARATUS

DRAWN JAC SUBMITTED
TRACED RECOMMENDED
HELKED M.P.J. APPROVED
DENVER, COLORADO DATE FOR FILING

Figure 2



A. Flow right to left.



B. VAPOR POCKET

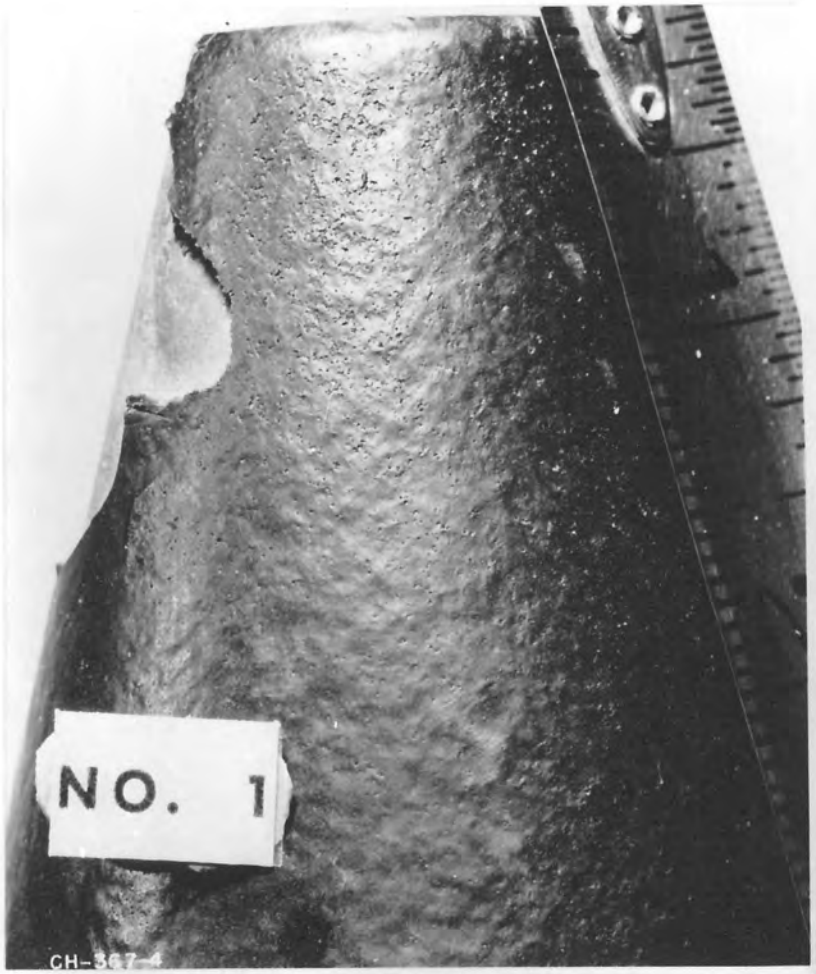
Tests of Protective Coatings
CONE CAVITATION APPARATUS

A. BEFORE TEST

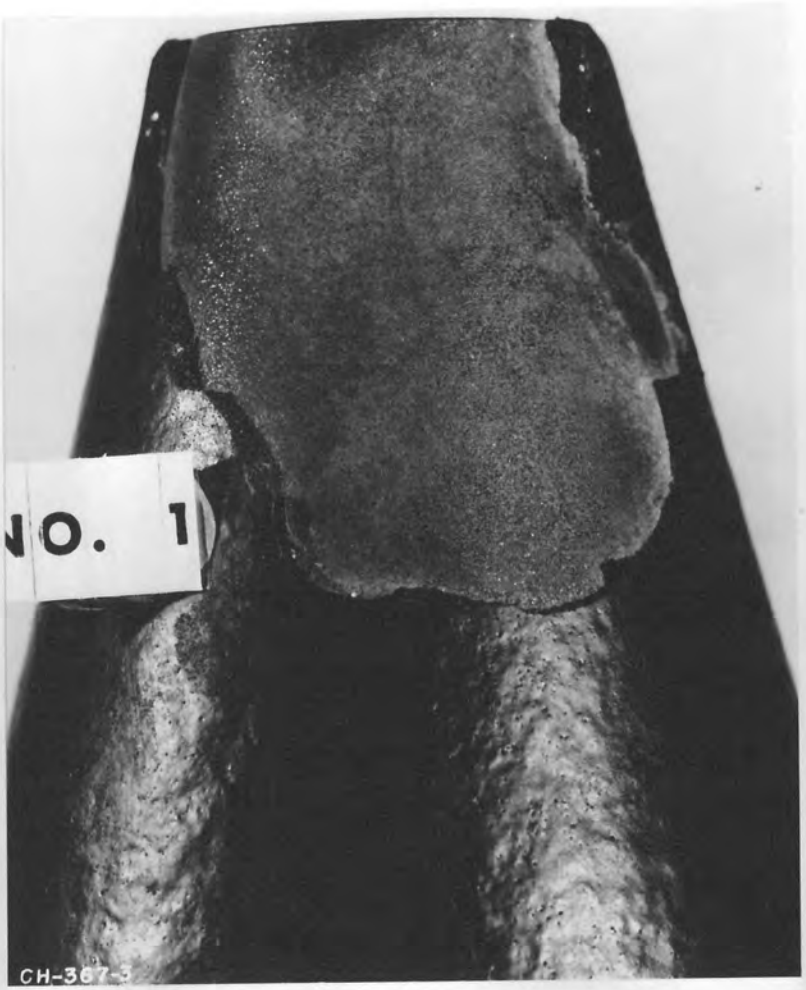
B.

Tests of Protective Coatings
SPECIMENS 1 and 2.

Figure 3



A. PITTED COATING

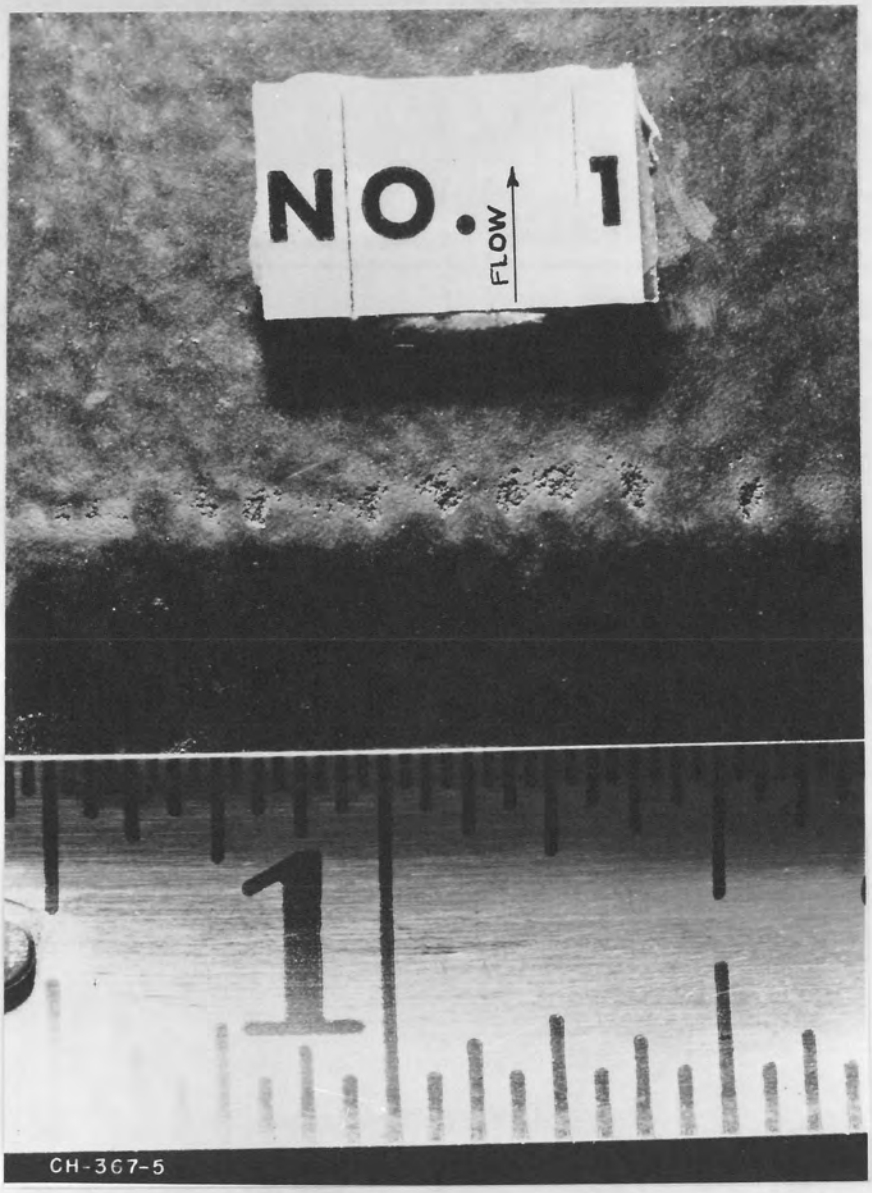


B. Exposed Metal at Cone Tip.

Tests of Protective Coatings
Tip of SPECIMEN 1 AFTER $11\frac{1}{4}$ HRS at 71.2 FT/SEC

Figure 4

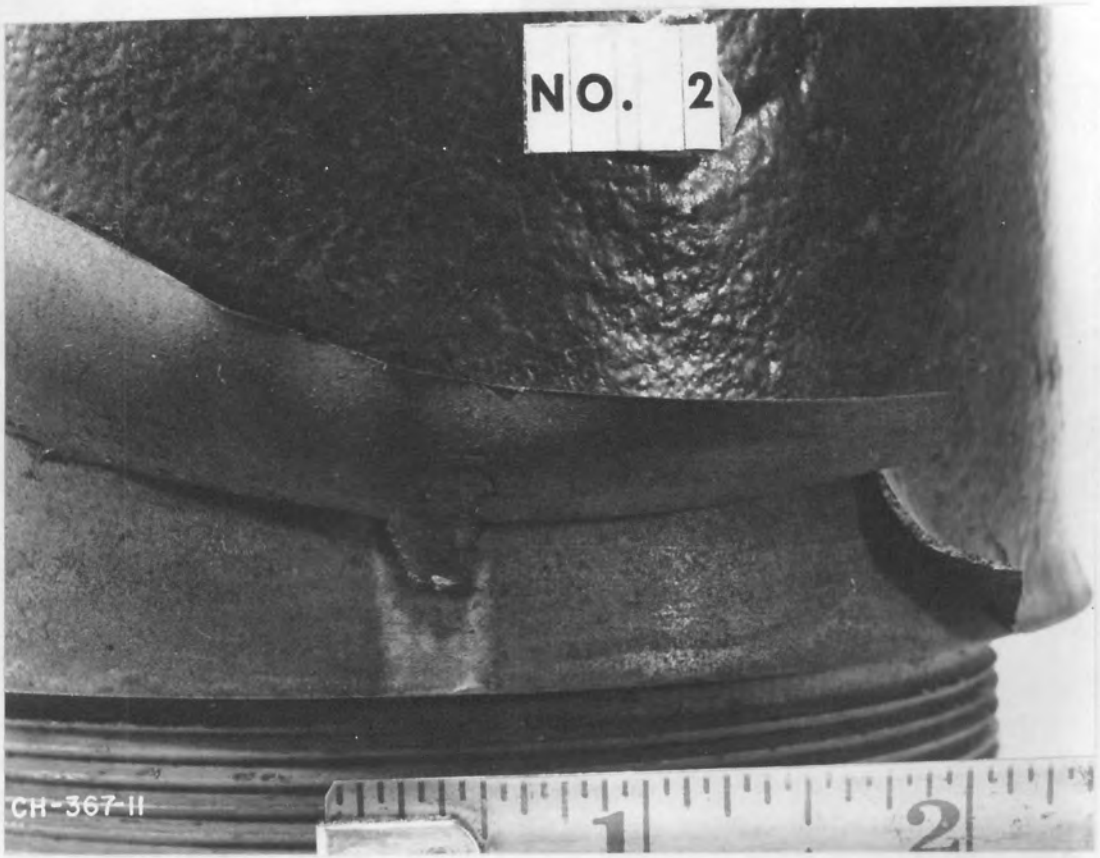
Figure 5



PITTED COATING AT CONE BASE

Tests of Protective Coatings
CONE BASE of SPECIMEN 1 after $11\frac{1}{4}$ HRS at 71.2 FT/SEC.

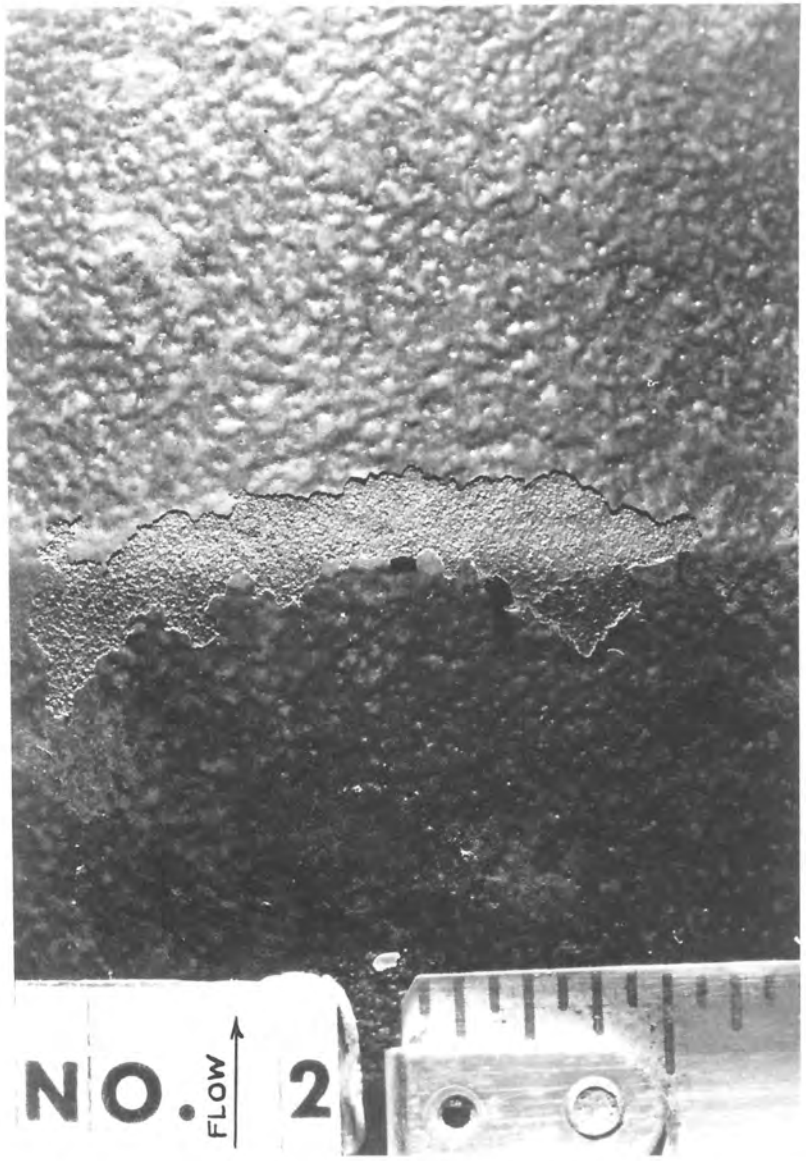
NO 2, FLAME SPRAYED THIOKOL
TESTED 10 1/2 HRS. AT 71.2 FT/SEC



B. TEAR IN UPSTREAM EDGE OF COATING CAUSED BY PRESSURE AND VELOCITY.

Figure 6

Tests of Protective Coatings
SPECIMEN 2 After $10\frac{1}{2}$ HRS at 71.2 FT/SEC.



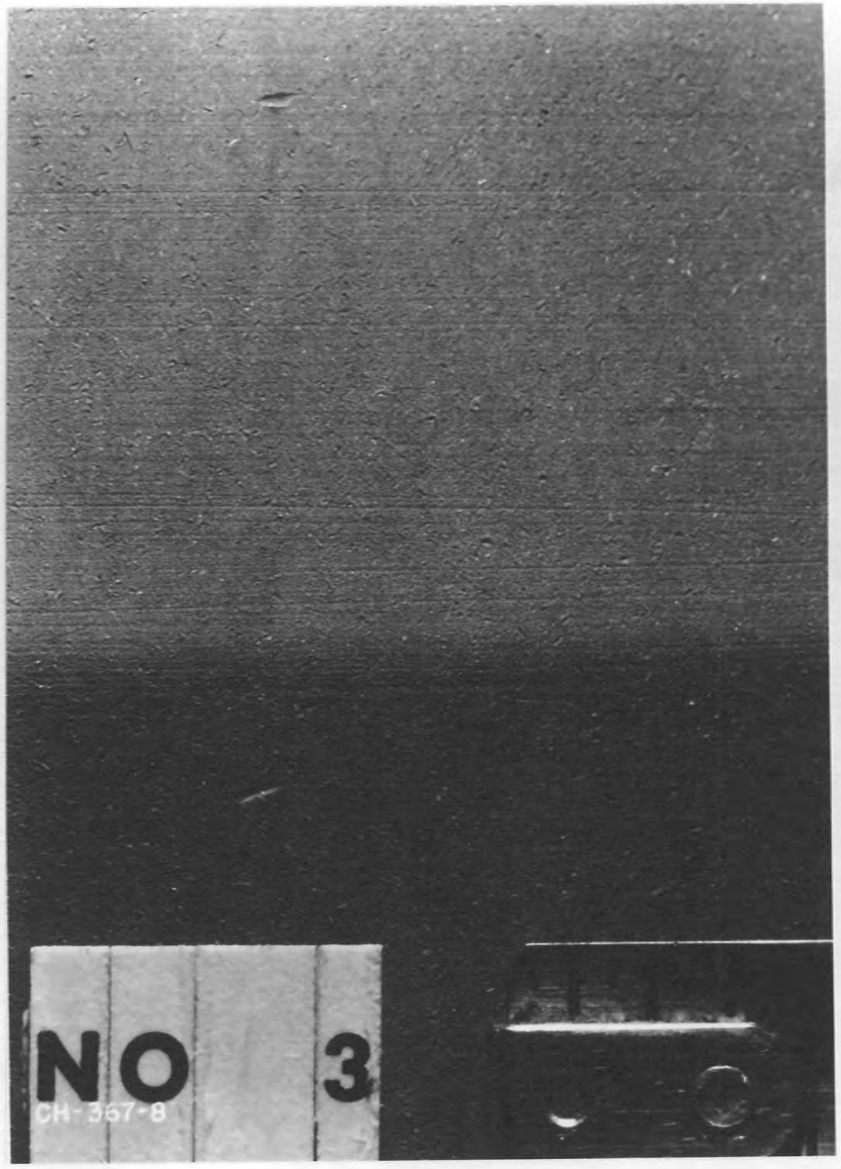
A. CONE BASE EROSION

B. CONE TIP

Figure 7

Tests of Protective Coatings
SPECIMEN 2 CONE TIP and Base After $10\frac{1}{2}$ HRS at 71.2 FT/SEC.

A. METAL CONE SPECIMEN

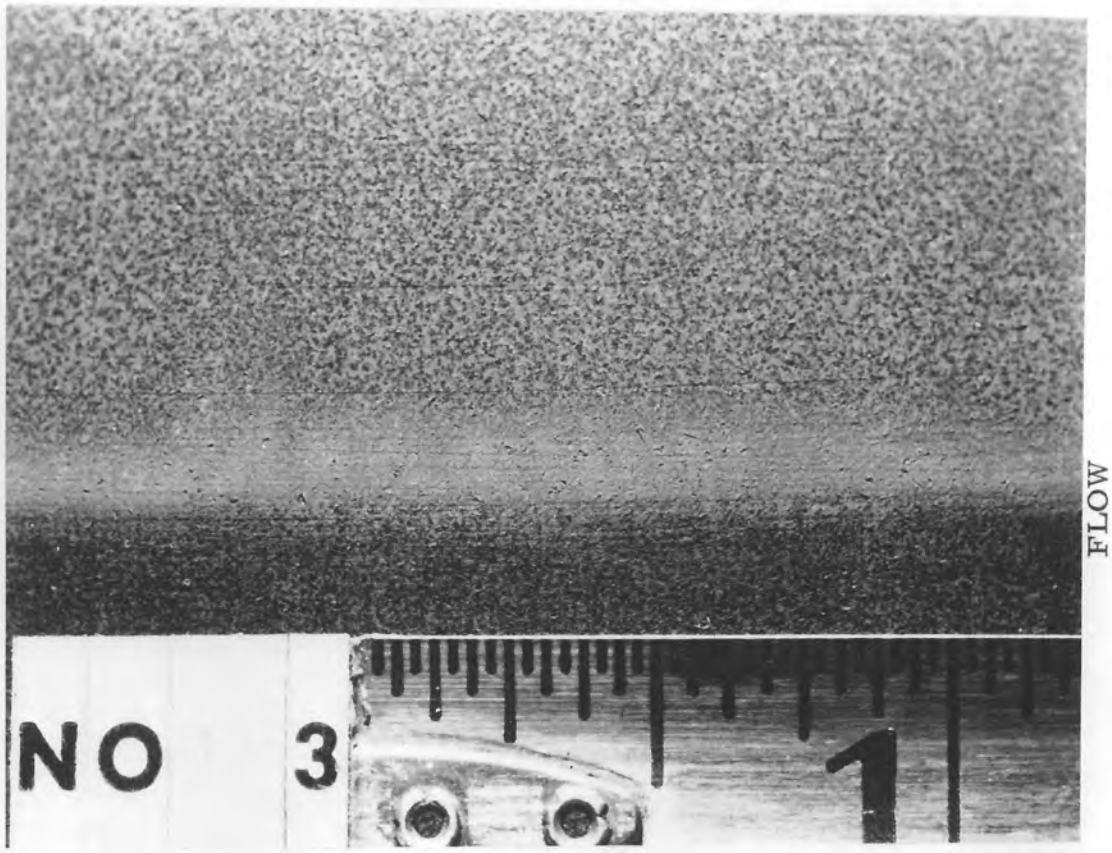


B. CONE BASE AREA

Tests of Protective Coatings
SPECIMEN 3 BEFORE TEST

Figure 8

A. METAL CONE SPECIMEN



B. SLIGHT PITTING NEAR CONE BASE - DARK SPOTS CAUSED BY RUSTING

FLOW

Figure 9

Tests of Protective Coatings
SPECIMEN 3 AFTER $11\frac{1}{4}$ HRS at 72.09 FT/SEC.

Tests of Protective Coatings
SPECIMEN 4 AFTER 40 HRS At 71.6 FT/SEC.

Figure 11

A. SURFACE AT TIP

B. SURFACE NEAR MIDDLE OF CONE

Flow

C. PITTING AT CONE BASE - NOTE REMOVAL OF MACHINE MARKS

D. SURFACE IN THROAT

Tests of Protective Coatings
PHOTO-MICROGRAPHS - MAGNIFICATION 12X
SPECIMEN 4 AFTER 40 HRS At 71.6 FT/SEC.

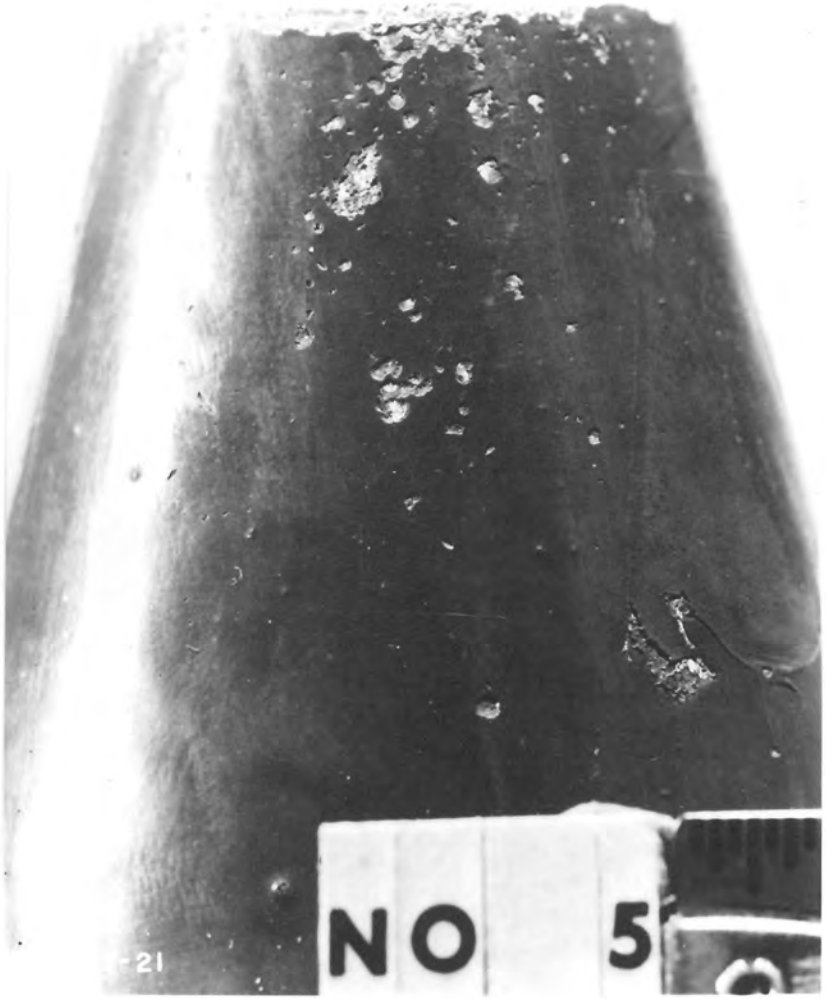
A. BEFORE TEST

B. PITTING AT CONE BASE

Tests of Protective Coatings
SPECIMEN 5 BEFORE AND AFTER TEST.

Figure 12

A. PITTING DOWNSTREAM OF COATING SAG IN STRAIGHT PART OF CONE SPECIMEN AND AT CONE BASE



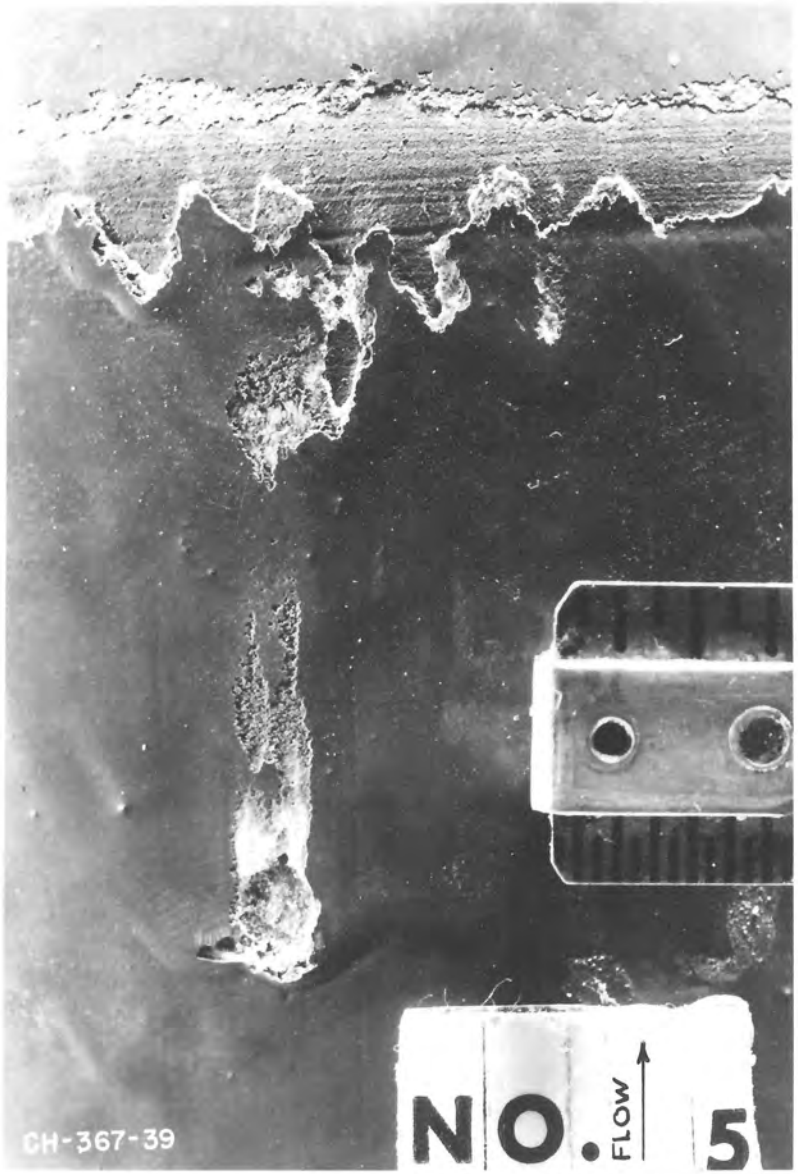
B. PITTING AT TIP

Tests of Protective Coatings
SPECIMEN 5 AFTER 1-3/4 HRS At 72.8 FT/SEC

Figure 13

PITTING at Cone Tip and BASE

Tests of Protective Coatings
SPECIMEN 5 AFTER RETEST
WITH SHORTENED VAPOR POCKET



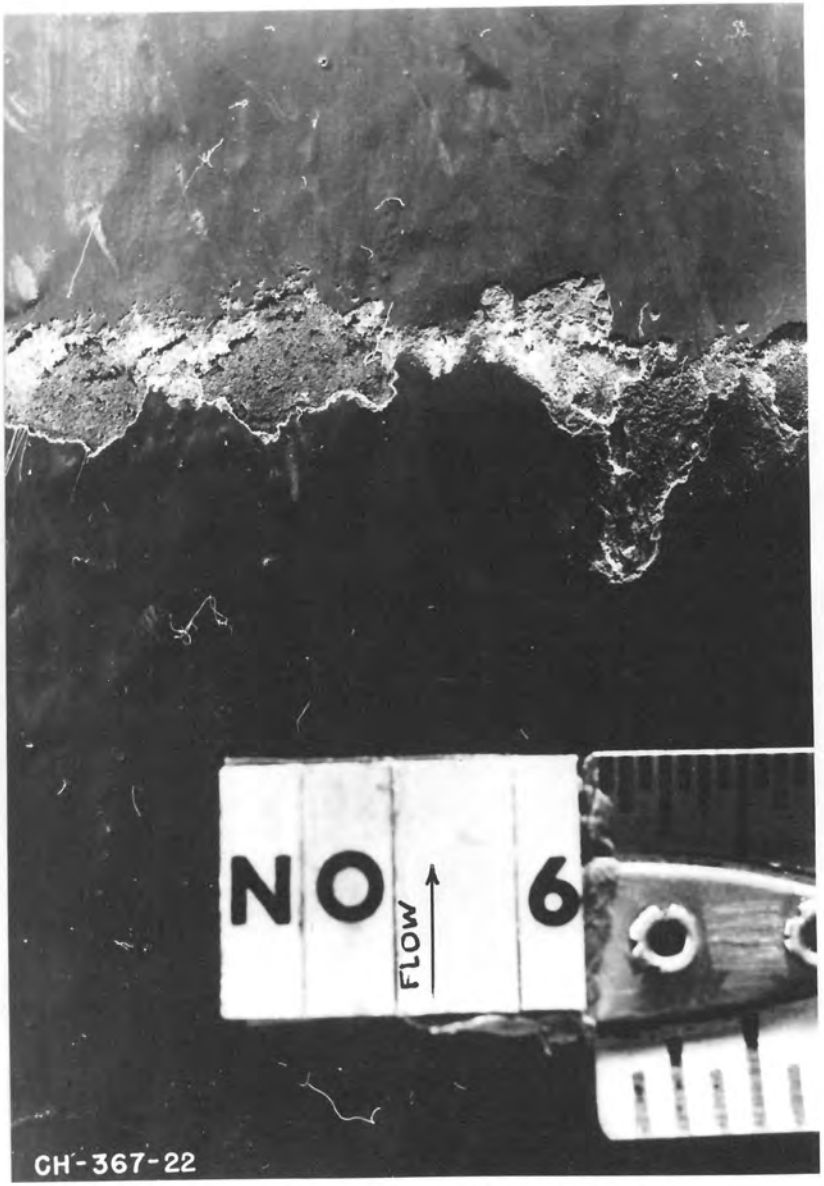
A. PITTING AT CONE BASE AND COATING SAG

B. Pitting on Cone Tip

Figure 15

Tests of Protective Coatings
SPECIMEN 5 RETEST 5-3/4 HRS At 70.4 FT/SEC SHORTENED VAPOR POCKET

A.

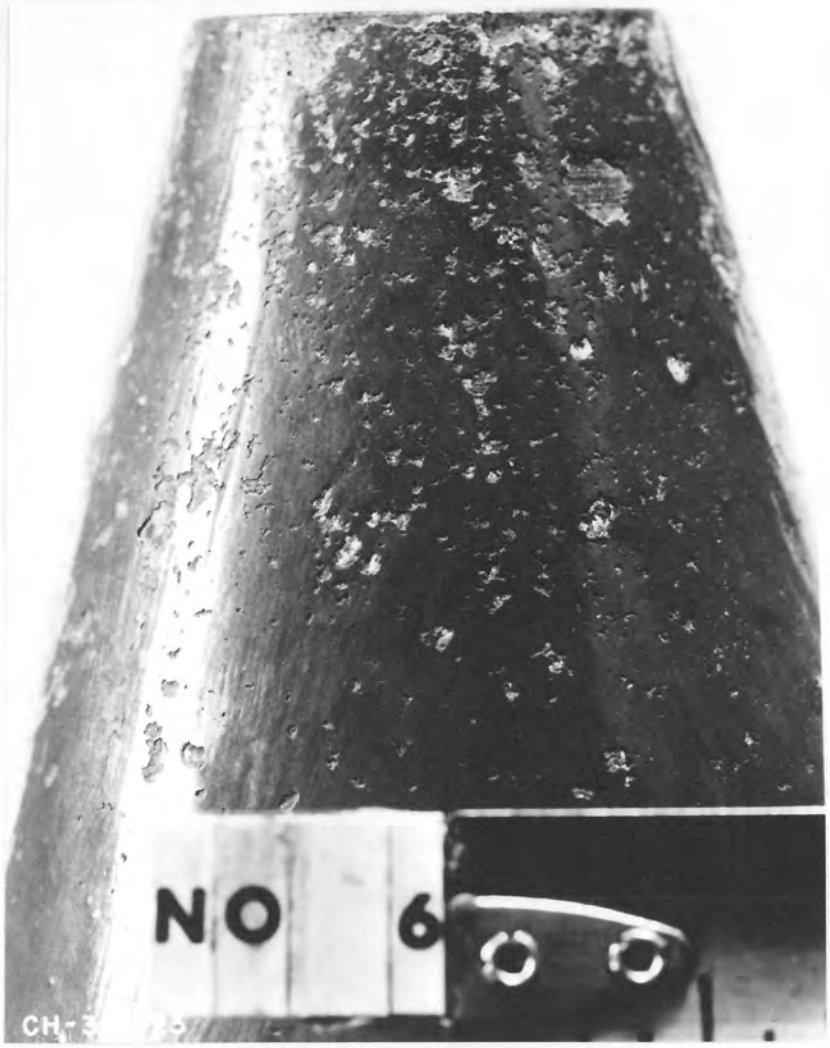


B. PITTING AT CONE BASE

Figure 16

Tests of Protective Coatings
SPECIMEN 6 AFTER 4 HRS At 70.5 FT/SEC.

Figure 17



PITTING AT TIP

Tests of Protective Coatings
Tip of SPECIMEN 6 AFTER 4 HRS
At 70.5 FT/SEC.

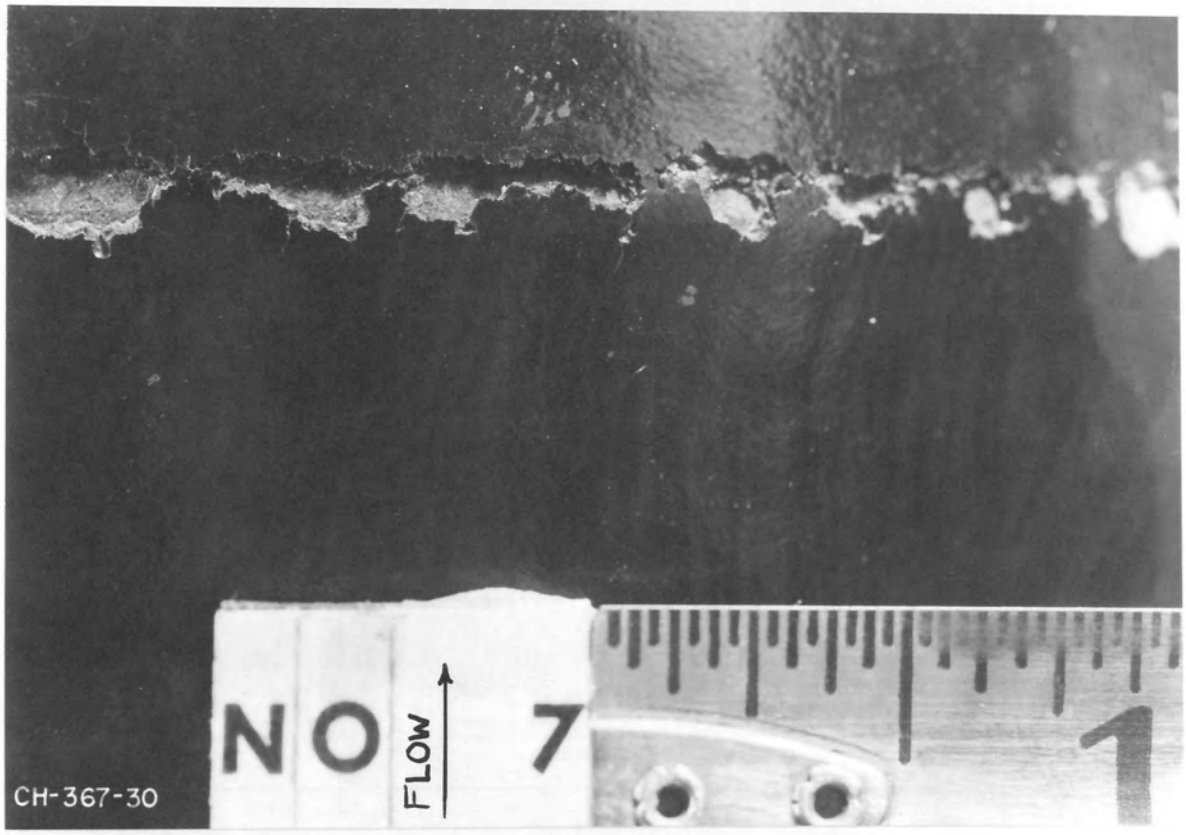
A. BEFORE TEST

B. PITTING AT BASE - TEARING AT TIP RESULTING FROM LOOSENING BY CAVITATION

Test of Protective Coatings
SPECIMEN 7 BEFORE and AFTER TEST

Figure 18

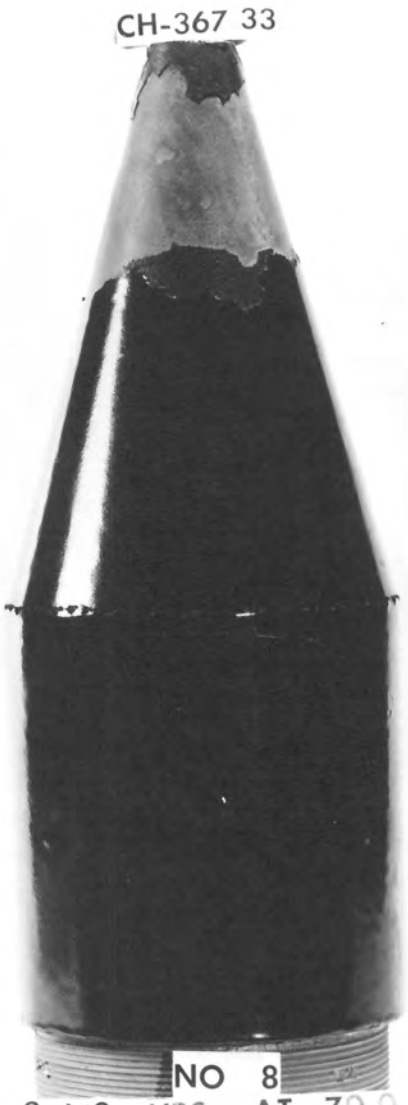
Figure 19



PITTING AT CONE BASE

Tests of Protective Coatings
CONE BASE of SPECIMEN 7
After $8\frac{1}{2}$ HRS At 71.2 FT/SEC

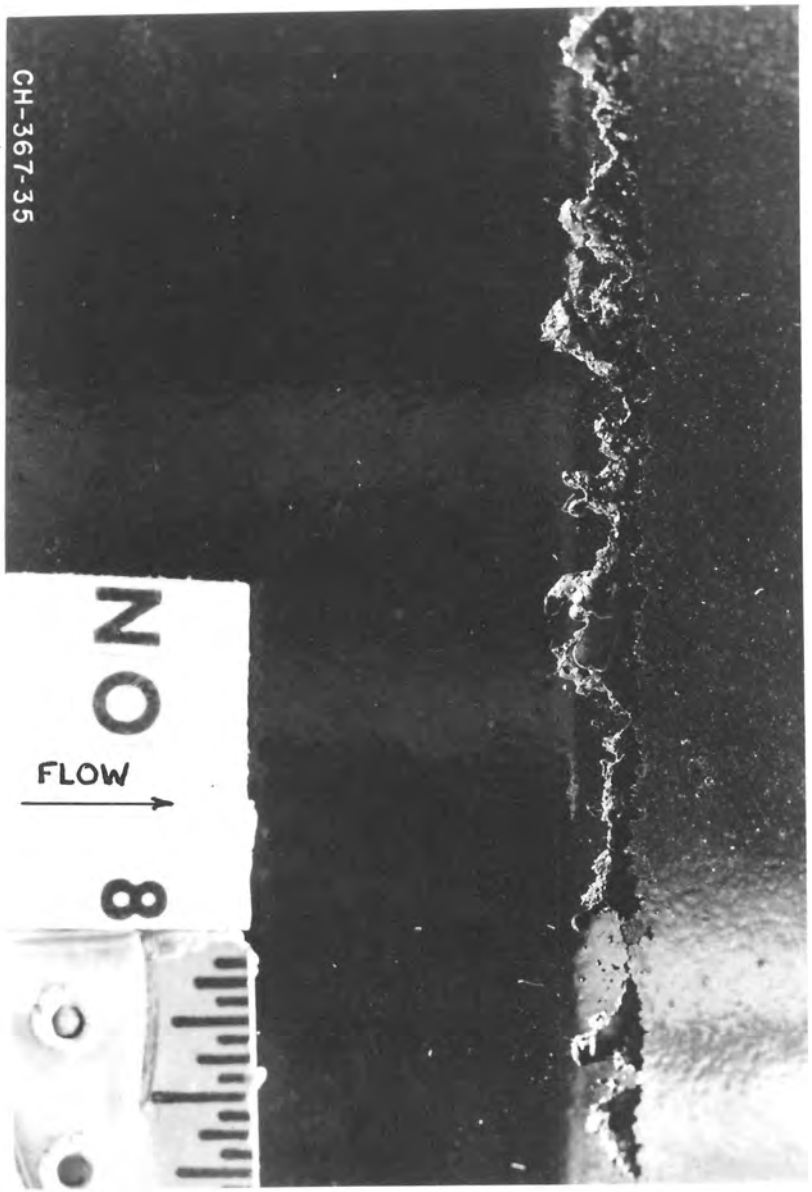
A. BEFORE TEST



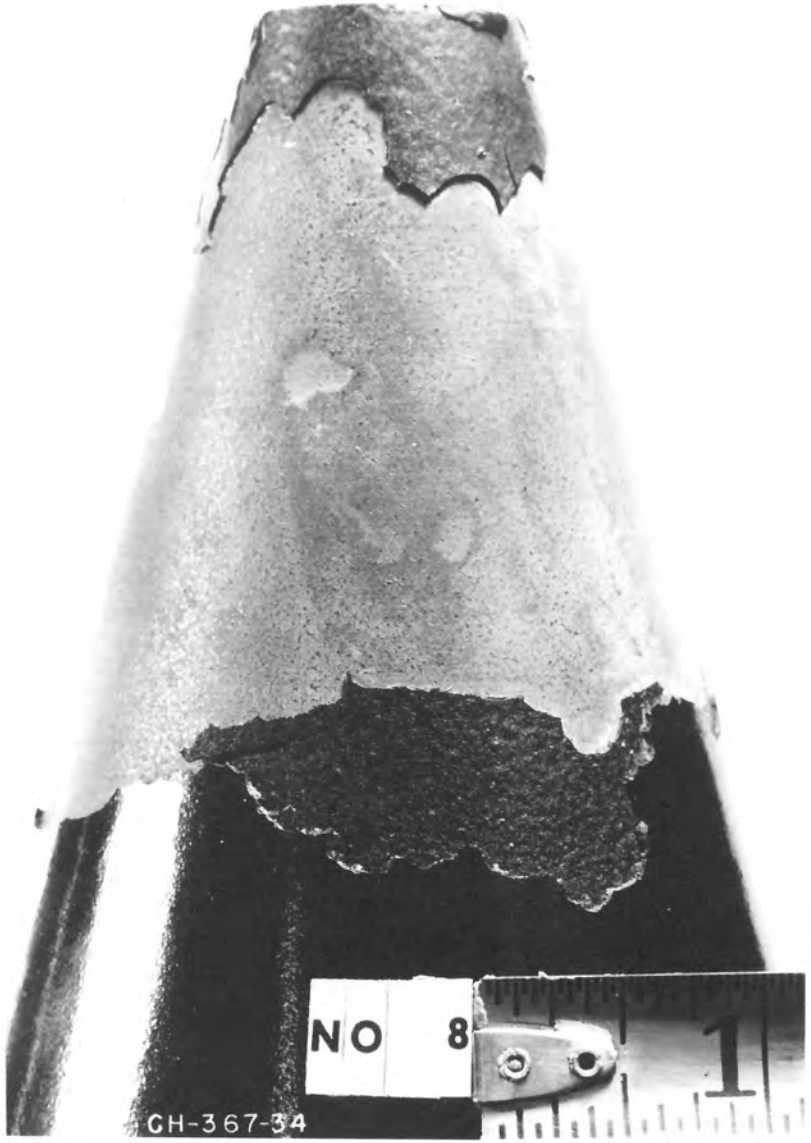
B. PITTING AT BASE AND TEAR AT TIP

Tests of Protective Coatings
SPECIMEN 8 BEFORE AND AFTER TEST

Figure 20



A. PITTING AT BASE



B. TEAR AT TIP

Figure 21

Tests of Protective Coatings
SPECIMEN 8 AFTER $3\frac{1}{2}$ HRS At 70 FT/SEC

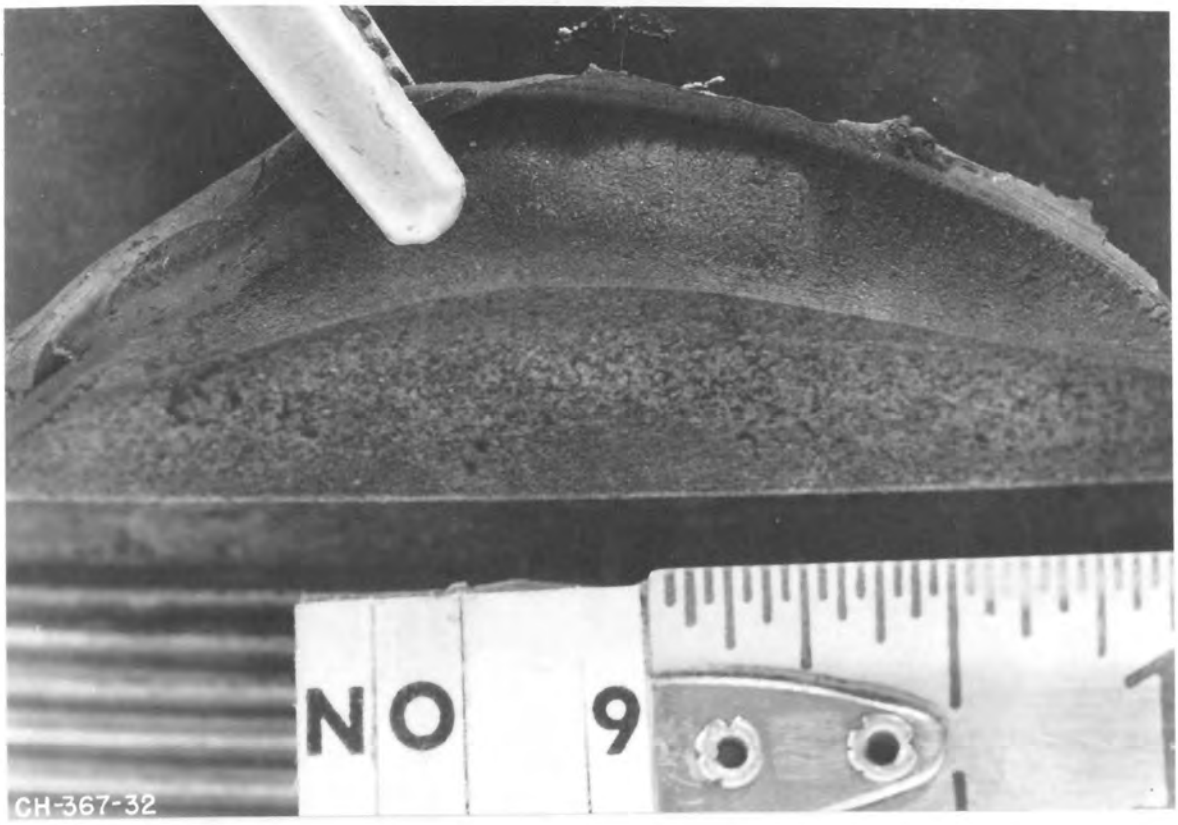
A. BEFORE TEST

B Loosened coating at upstream edge.

Tests of Protective Coatings
SPECIMEN 9 BEFORE AND AFTER TEST

Figure 22

Figure 23



TEAR AT UPSTREAM EDGE OF COATING

Tests of Protective Coatings
UPSTREAM Edge of SPECIMEN 9
AFTER $1\frac{1}{2}$ HRS At 72.1 FT/SEC

A. BEFORE TEST

B.

Loosened Coating at upstream edge

Tests of Protective Coatings
SPECIMEN 10 BEFORE AND AFTER TEST

Figure 24

Figure 25

LOOSENED COATING

Tests of Protective Coatings
UPSTREAM EDGE OF SPECIMEN 10
AFTER $\frac{1}{4}$ HR At 71.8 FT/SEC.