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UNION CARBIDE NUCLEAR COMPANY
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OAK RIDGE, TENNESSEE

1

COPY NO. 20

DATE: May 22, 1957

SUBJECT: Summary of Corrosion Data for HRT Mockup Operational Period Ending November 5, 1956.

TO: E. G. Bohlmann

FROM: R. E. Wacker and J. C. Griess

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SUMMARY OF CORROSION DATA FOR HRT MOCKUP OPERATIONAL PERIOD ENDING NOVEMBER 5, 1956.

The HRT mockup was shut down November 5, 1956 to prepare the system for operation on 300-g-of-uranium-per-liter uranyl sulfate. At this time the corrosion samples in the loop were removed and replaced and the letdown heat exchanger was removed and sectioned for examination.

I. GENERAL

During the reported period of mockup operation, August 15, 1956 to November 5, 1956, operation was on 0.042 m UO_2SO_4, 0.024 m H_2SO_4, and 0.005 m $CuSO_4$ at 280°C and 1400 psi pressure, with the oxygen content at near 500 ppm. The system was operated for 1925 hr during this period. The uranium concentration was maintained at 9.5 g of uranium per liter during most of the operation. After 120 hr it dropped to 6.7 g of uranium per liter due to a leak but was brought back to the original concentration. The over-all corrosion rate, as determined by nickel concentration, was 1.5 mpy.

Examination of the pump showed bearing wear and high corrosion on the pump. Small additions of solids were made during the run for further testing of the hydroclone system. The results of this investigation will be reported by the Engineering Development Section.

II. SAMPLES

The corrosion coupons were of the same type as previously exposed in the mockup. A titanium holder in the suction side of the main circulating line contained coupons of titanium 75A, Zircaloy-2 and types 309 SCb and 347 stainless steel. The titanium samples had a blue-black film, the Zircaloy-2 samples had a gray-black, tightly adherent film, and the stainless steel samples had a brownish-black film. Type 347 stainless steel coupons were also mounted on a stainless steel bar that extended through the vertical leg of the pressurizer. Those exposed to the vapor phase and those exposed in the water-soup interface had fairly heavy dull black films, whereas those exposed in the water region of the vertical leg had thin gray-black films. Though all samples showed small corrosion rates, the samples in the

interface region and those in the vapor phase showed rates higher by a factor of 10 to 20 than the samples in the water region. From the corrosion rates of the samples, it would appear that the bottom 3 or 4 coupons were exposed to the water-soup mixture, not just the bottom coupon. Corrosion data for all samples are presented in Tables I and II.

Photographs of the coupons before the run and after defilming are shown in Figures 2 through 53. Figures 1 through 24 show the main circulating line samples in the "as-machined" condition. Figures 25 through 36 show these same coupons after defilming at the end of the run. Figures 37 through 46 show the pressurizer leg samples as machined and Figures 47 through 52 show these same coupons as defilmed.

The appendix contains a tabulation of the negative plate numbers of all photographs.

A similar array of new samples has been inserted in the mockup for the next period of operation on 300-g-of-uranium-per-liter uranyl sulfate.

III. LETDOWN HEAT EXCHANGER

The letdown heat exchanger, which had been in the mockup since December, 1955, was cut from the system at this time for sectioning and examination. It had been in the system for a total of 5640 hr of operation on 0.04 $\underline{m}$ UO_2SO_4, 0.02 $\underline{m}$ H_2SO_4, and 0.005 $\underline{m}$ $CuSO_4$. Operation for 3710 hr of this time was at 300°C and 2000 psi, with the remainder of the time at 280°C and 1400 psi. All sections were made of type 347 stainless steel.

The letdown heat exchanger consisted of three pipes, a 1/2-in. Schedule 80 pipe inside a 1-in. Schedule 80 pipe, which in turn was inside two sections of 1-1/2-in. Schedule 80 pipe. There was one 90 degree bend in the exchanger 15 ft from the take-off from the main circulating system.

The inner pipe contained the feed stream being pumped into the system at a velocity of 1.4 fps. This stream had a temperature gradient of from 40°C at the inlet end to 220°C at the point of entry into the main circulating system. The 1/2-in. pipe was 31 ft 6 in. in length. A corrosion sample was exposed in the feed stream in the form of a 1/8-in. diameter type 347 stainless steel wire extended through the entire length of the pipe. The wire thickness was measured with a micrometer, both before and after exposure to determine the corrosion pattern along the length of the pipe and wire.

Flowing through the first annulus or through the 1-in. pipe was the letdown stream from the main circulating system, flowing at a velocity of 2 fps. This annulus had a total length of 30 ft 7 in., beginning 11 in. down from the feed stream discharge and ending 2 in. from the feed stream inlet to the exchanger. The temperature gradient in the stream was from 300 to 80°C.

Flowing through the second annulus or first section of 1-1/2-in. pipe was the purge water stream flowing at a velocity of 0.7 fps. This annulus had its outlet 15 in. from the feed stream discharge and ran for 216 in. The temperature gradient in this stream was from 40 to 280°C.

Flowing through the third annulus or the second section of 1-1/2-in. pipe was cooling water. The inlet to this stream was 5 in. from the purge stream inlet and the pipe had a length of 117 in., ending 27 in. from the inlet to the feed stream. The temperature gradient in this stream was from 15 to ~ 100°C.

The results of the examination are described below for each section of the exchanger:

a. Feed Stream Pipe. The feed or inner stream of the letdown heat exchanger showed a definite corrosion pattern over its length, with the heaviest attack occurring where the pipe wall was in the temperature range around 200°C. Beginning at the hot or discharge end of the pipe the following observations were made:

1. For the first 10 ft. 9 in. of pipe length, the walls had a heavy red-brown scale, which was flaked off in spots, and which could be easily rubbed off, leaving a brown to black film. No localized attack was found in this region. A sample of the scale was sent for spectrographic and X-ray analysis. The scale consisted mainly of a mixture of iron and chromium oxides with some zirconium oxide, which were the chief constituents of the solids added to the system during the testing of the hydroclone. Results of the analysis are shown in Table III, Sample 1.
2. The next 6-in. length had heavy pitting attack. Large irregular pits up to 3/64 in. deep along with numerous smaller pits were evident. Adjacent pits were undercut and joined at the bottom. The deepest penetration in this region corresponds to a corrosion rate of 75 mpy. Figures 53 and 54 show this pitted area. The unpitted area had the same red rust colored scale as before, while

5

the bottom of the pit areas had a brown-black film. There was a shiny line of bare metal along one side of the pitted area. This section of the pipe has been sent to metallography for examination.

3. The next 4 ft 6 in. of the pipe appeared to have been attacked at a fairly uniform rate, decreasing in attack as the temperature decreased. The first part of this region showed some localized attack, whereas the last part showed a uniform attack. Figures 55 and 56 show the beginning and end of this region, respectively. A section of the pipe from this region was sent for Huey Test and chemical analysis. The sample passed the Huey Test. Results are shown in Table IV, Sample 1.

4. At this point (15 ft 6 in. from the hot or outlet end of the feed stream) a second section of 1/2-in. pipe was welded to the first section. This section of pipe extended through the remainder of the feed stream of the exchanger. The entire length of this section of pipe had long narrow parallel grooves running lengthwise of the pipe, with some cracking between grooves. These grooves were from 1/64 in. to 1/16 in. deep. There were pits present which appeared to undercut at the bottom along the length of the pipe to form grooves. Figures 57 and 58 show that portion of the pipe adjacent to the weld and Figures 59 and 60 show the feed stream inlet or cold end of the pipe. The start of grooves through pits can be seen in the latter two photographs. It is believed that this grooving is not a result of uranyl sulfate attack but was caused by something used in the original cleaning or pickling of the metal by the manufacturer. A section of this pipe has been sent to Metallography for examination. Samples were also sent for Huey Test and for chemical analysis. The samples failed the Huey Test and chemical analysis showed it to be low in chromium content. Results are shown in Table IV, Sample 2. This section of pipe had a dark brown film which became light gray as the temperature decreased. Most of the film over the last 10 ft could be rubbed off, leaving bare metal.

Measurements were taken of the pipe wall thickness at numerous points along the entire length of the feed-stream pipe. These are tabulated in Table V and

and Figure 1 shows a plot of the wall thickness versus the pipe length. Although the exact temperature at any given point along the pipe is not known, the point of heaviest attack is believed to be at a point of approximately 200°C. This agrees with the 100A loop data which show the 200 to 225°C temperature range to be the worst region for low velocity corrosion. A dye-check of the edges of this pipe showed no evidence of cracking.

b. Letdown Stream Pipe. Examination of the letdown stream or first annulus gave about the same corrosion pattern as the feed stream. The highest attack area was in the temperature region of 200°C. Beginning at the hot or inlet end of the pipe, the following observations were made:

1. The first 11 ft 4 in. of the letdown stream pipe had a heavy brown-black scale which could easily be rubbed off leaving a black film underneath. The scale became thinner as the temperature decreased. There was a heavy deposit of scale in the stagnant region above the inlet which had the appearance of fine dried mud after cracking. No localized attack was observed. Samples of the scale were sent for spectrographic and x-ray analysis and for chemical analysis for chloride. The scale appeared to be a mixture of corrosion products and the oxides added to the system during the testing of the hydroclone. Results of the analysis are shown in Table III, Sample 2.
2. A heavier deposit of loose, rust colored scale was found over the next 5 ft of the pipe length, along with regions of localized attack. There was one large pit in the inner wall of the 1-in. pipe in the bend section of the exchanger, 14 ft 6 in. from the inlet end. This pit was just downstream from the weld in the 1/2-in. pipe on the opposite wall of the annulus and undoubtedly resulted from turbulence caused by the weld. The pit was irregular, approximately 1/4 in. wide and 1/8 in. deep. There was a smaller pit 1/2 in. from the large pit, and 2 in. of area immediately downstream from the pit had a shiny thin black film with numerous very small pits. Figure 61 shows the pit along with the localized attack found in this region. This area was in the temperature region of 200°C.

3. The remainder of the pipe had a brown scale which became lighter in color as the temperature decreased. The scale could easily be rubbed off leaving bare metal at the colder end of the pipe. No localized attack was found in this section.

c. Purge Water Stream. The purge water stream or second annulus showed no evidence of corrosion attack. A thin, red-brown scale was deposited over most of the pipe walls which could be rubbed off, leaving a blue-black tightly adherent film.

d. Cooling Water Stream. The cooling water stream, or third annulus, contained a thin yellow rust-colored film and no evidence of corrosion damage.

e. Corrosion Wire. Examination of the corrosion wire exposed in the feed stream of the letdown heat exchanger again shows the region of heaviest attack to be in the temperature range of 200 to 225°C. Beginning at the hot end of the wire, the following observations were made:

1. The first 7 ft of the wire had a heavy rust-brown colored scale which could easily be rubbed off, leaving a brown to black film. No localized attack was observed.
2. The next 10 ft of the wire showed corrosion attack, with the first 4 ft of this section indicating heavy localized attack. At the beginning of this localized attack, the wire was broken and 3 in. downstream from the break a wide deep crack went completely around the wire. Just how deep this crack extended could not be determined. This section of the wire has been sent to Metallography for examination and will be reported by that group along with their findings on the sections of the letdown heat exchanger pipe. Figure 63 shows the crack area and Figure 64 shows the heavy pitting attack just downstream from the crack.
3. The remainder of the wire showed little or no corrosion. The brown-black scale tailed off to bare metal at the cold end.

The corrosion wire had been prepared for this test by swaging a piece of 1/4-in. type 347 stainless steel rod to a diameter of approximately 1/8 in. The wire was then pickled and spot welded to each end of the feed pipe. A sample of the

original wire was sent for Huey Test and chemical analysis. Results of these are shown in Table IV, Sample 3.

Before inserting the wire in the feed pipe, mircometer measurements were taken along its length in order to determine the corrosion damage after testing. A reference notch was made in the wire at one end and measurement were taken at 1-ft intervals over the length of the wire. One measurement was taken at each point across the plane of the notch and a second 90 degrees from the plane of the notch. After removal from the exchanger measurements were again taken of the wire in the same manner. The reference notch could not be located on removal so the second set of measurements are probably not in the exact same location or plane as the original set. Therefore the average of the two measurements at each point was used in determining the penetration at that point. The wire measurements are given in Table VI and a plot of the thickness versus length is shown in Figure 1. The point of heaviest attack yielded a corrosion rate of 16 mpy.

The examination of the letdown heat exchanger shows that stainless steel has excellent corrosion resistance at low velocities to the proposed HRT fuel solution (0.04 m UO_2SO_4, 0.02 m H_2SO_2, and 0.005 m $CuSO_4$) except in the temperature range of 200 to 225°C and in regions of high turbulence.

Another letdown heat exchanger of similar design and with a wire extending through the feed stream has been installed in the mockup for operation on 300-g-of-uranium-per-liter uranyl sulfate.

APPENDIX

SAMPLE PHOTOGRAPHS*

Sample No.	Holder	Corrosion Lab. Plate No.
H-143	Main Line	1654, 1808
H-144	" "	1654, 1808
H-172	" "	1655, 1808
H-173	" "	1655, 1808
H-202	" "	1656, 1809
H-203	" "	1656, 1809
H-232	" "	1657, 1809
H-233	" "	1657, 1809
H-252	Pressurizer	1658, 1805
H-253	"	1658, 1805
H-254	"	1659, 1805
H-255	"	1659, 1806
H-256	"	1660, 1806
H-257	"	1660, 1806
H-258	"	1661, 1807
H-259	"	1661, 1807
H-260	"	1662, 1807

* Photographic plates are on file with J. L. English of the Materials Research Section, Reactor Experimental Engineering Division, Oak Ridge National Laboratory.

SAMPLE PHOTOGRAPH FIGURES

Figure No.	Corrosion Lab. Plate No.
2, 3, 4, 5, 6, 7	1654
8, 9, 10, 11, 12, 13	1655
14, 15, 16, 17, 18, 19	1656
20, 21, 22, 23, 24, 25	1657
26, 27, 28, 29, 30, 31	1808
32, 33, 34, 35, 36, 37	1809
38, 39	1658
40, 41	1659
42, 43	1660
44, 45	1661
46, 47	1662
48, 49	1805
50, 51	1806
52, 53	1807
54, 55, 56, 57	1829
58, 59	1830
60, 61	1832
62	1831
63, 64	1833

Table 1. Main Circulating Line Samples

Coupons No.	Coupons Type	Coupon Position from Flange End of Holder	Sample Area, cm^2	Weight Change, mg/cm^2 Scrubbed	Weight Change, mg/cm^2 Defilmed	Corrosion Rate, mpy Defilmed	Appearance
H-143	347 SS	3	20.7	+ 1.46	- 0.53	0.12	Brown-black film. Uniform attack.
H-144	347 SS	6	20.7	+ 2.12	- 0.60	0.14	" " " " "
H-202	309 SCb	4	20.7	+ 1.58	- 0.64	0.15	" " " " "
H-203	309 SCb	5	20.7	+ 1.52	- 0.71	0.16	" " " " "
H-172	Ti-75A	1	20.7	- 0.04	- 0.40	0.16	Blue-black film. Blue after defilming.
H-173	Ti-75A	8	20.7	+ 0.52	- 0.34	0.14	" " " " " "
H-232	Zircaloy-2	2	20.7	+ 1.37	+ 1.30	1.0*	Gray-black, tightly adherent film.
H-233	Zircaloy-2	7	20.7	+ 2.29	+ 1.97	1.6*	" " " " "

Samples exposed in uranyl sulfate solution for 1925 hr.

* Assuming the weight gain to be due entirely to ZrO_2.

Table 2. Pressurizer Vertical Leg Samples

Coupons No.	Coupons Type	Coupon Position* From Flange End of Holder	Sample Area, cm^2	mg/cm^2 Scrubbed	mg/cm^2 Defilmed	Corrosion Rate, mpy Defilmed	Appearance
H-252	347 SS	1	16.1	+ 0.06	- 0.93	0.21	Dull black film.
H-253	347 SS	2	16.1	+ 0.07	- 0.51	0.12	" " "
H-254	347 SS	3	16.1	+ 0.06	- 0.09	0.02	Thin, gray-black film.
H-255	347 SS	4	16.1	+ 0.06	- 0.08	0.02	" " " "
H-256	347 SS	5	16.1	+ 0.02	- 0.10	0.02	" " " "
H-257	347 SS	6	16.1	+ 0.04	- 1.42	0.32	Dull black film.
H-258	347 SS	7	16.1	- 0.01	- 0.09	0.02	Thin gray-black film.
H-259	347 SS	8	16.1	- 0.02	- 1.48	0.34	Dull black film.
H-260	347 SS	9	16.1	- 0.24	- 1.55	0.35	" " "

Samples exposed in uranyl sulfate solution for 1925 hr.

* Positions 1 through 3 in pressurizer vapor phase. Position 9 in water-soup interface in horizontal header to pressurizer. Others in water region of vertical leg.

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Table 3. Analysis of Sample Scales

Analysis	Weight Percent			
	Sample 1[a]		Sample 2[b]	
	Spec.	X-Ray	Spec.	X-Ray
Fe	>> 10		>> 10	
Cr	> 5		5	
Zr	> 5		4	
Ni	.2		.2	
Cu	.1		.5	
Mn	.07		.03	
Al	.1		.07	
Ti	.1		.05	
Sn	.3		.7	
Nb	1		1	
Fe_2O_3[c]		75-95		75-95
ZrO_2		5-15		5-15

a. Scale removed from feed stream pipe. No analysis for chloride.

b. Scale removed from letdown stream pipe. Chemical analysis showed presence of chloride in concentration < 200 ppm.

c. Solid solution of Cr_2O_3 with Fe_2O_3.

Table 4. Chemical and Huey Test Results

Sample	Weight Percent							
	Cr	Ni	Mn	C	Si	S	P	Nb
1	18.4	12.6	1.67	.058	.47	.026	.017	.58
2	17.8	10.8	1.33	.051	.29	.017	.013	.56
3	18.4	10.0	1.58	.065	.65	.023	.008	.73

Sample	Huey Test Values (mpm avg.)	
	Specimen 1	Specimen 2
1	1.6	1.8
2	7.2	6.5
3	0.8	0.8

Table 5. Wall Thickness of 1/2-in. Letdown Heat Exchanger Pipe

Inches from Hot End	Wall Thickness* - In.
1	.1509
6	.1546
62	.1496
123	.1455
126	.1410
130	.1416
137	.1270
141	.1358
180	.1409
208	.1434
254	.1408
300	.1390
353	.1380
379	.1381

*These thicknesses are the average of two or more measurements on opposite walls of the pipe at these locations. Measurements were made after defilming that section of the pipe. Thickness before defilming was from .002 in. larger at the hot or heavily scaled end of the pipe to .0002 in. larger at the cold end of the pipe.

Table 6. Thickness of Corrosion Wire

Feet from Hot End	Wire Thickness[a] - Inches As Swaged	After Test
0	.1398	.1375
1	.1377	.1380
2	.1395	.1385
3	.1389	.1371
4	.1381	.1366
5	.1389	.1374
6	.1386	.1382
7	.1387	.1365
8	.1381	.1181
9	.1384	.1225
10	.1395	.1263
11	.1391	.1360
12	.1388	.1381
13	.1381	.1378
14	.1385	.1385
15	.1384	.1391
16	.1390	.1385
17	.1381	.1390
18	.1385	.1388
19	.1398	.1388
20	.1400	.1387
21	.1370	.1389
22	.1397	.1385
23	.1379	.1386
24	.1389	.1392
25	.1380	.1392
26	.1384	.1391
27	.1372	.1393
28	.1393	.1393
29	.1380	.1399
30	.1389	.1378
31	.1372	.1394
32[b]	.1377	.1370

a. These values are an average of two micrometer measurements taken at each point, the second 90 degrees from the plane of the first. A reference notch was put in the wire at the time of the original measurements, but since the exact location of the notch could not be determined after testing, the second set of measurements probably vary slightly from the original as to exact location and plane of the measurement. Thicknesses after testing are given in the scrubbed measurement. Thicknesses after testing are given in the scrubbed condition. Defilming of sections of the wire showed the defilmed thickness to be 0.0001 to 0.001 in. less than the scrubbed thickness.

b. Measurement only 8 in. from previous one.

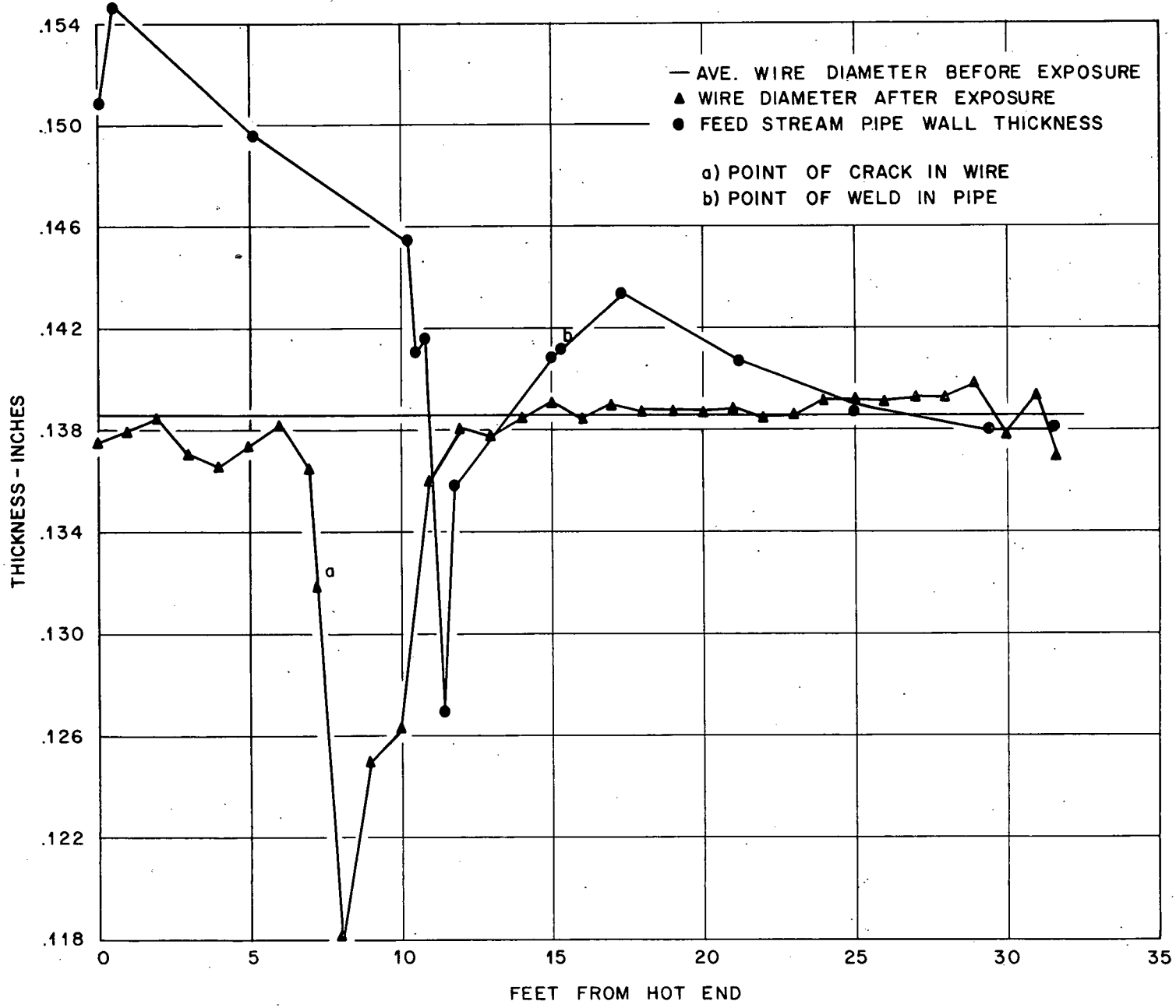

Fig. 1 Feed Pipe and Wire Thickness After Exposure in Mockup Letdown Heat Exchanger

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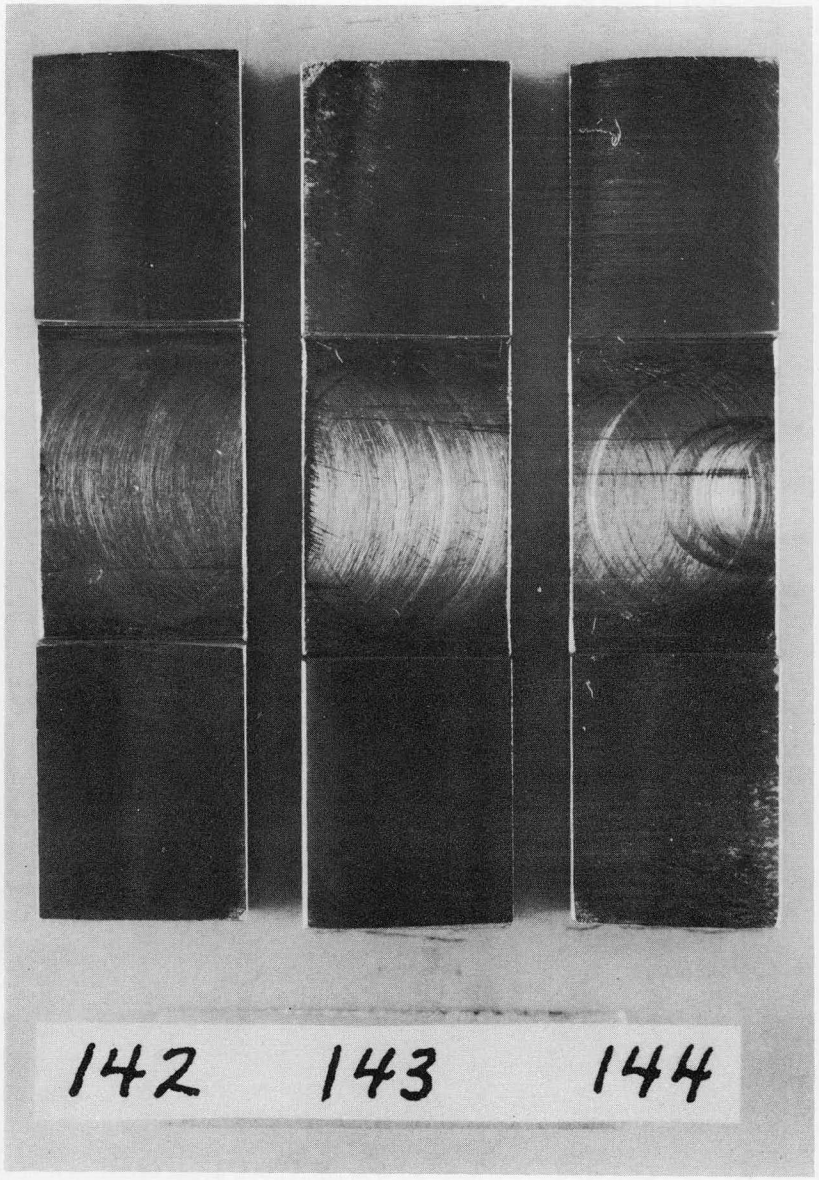

Fig. 2 Coupons as Machined (2.5X)

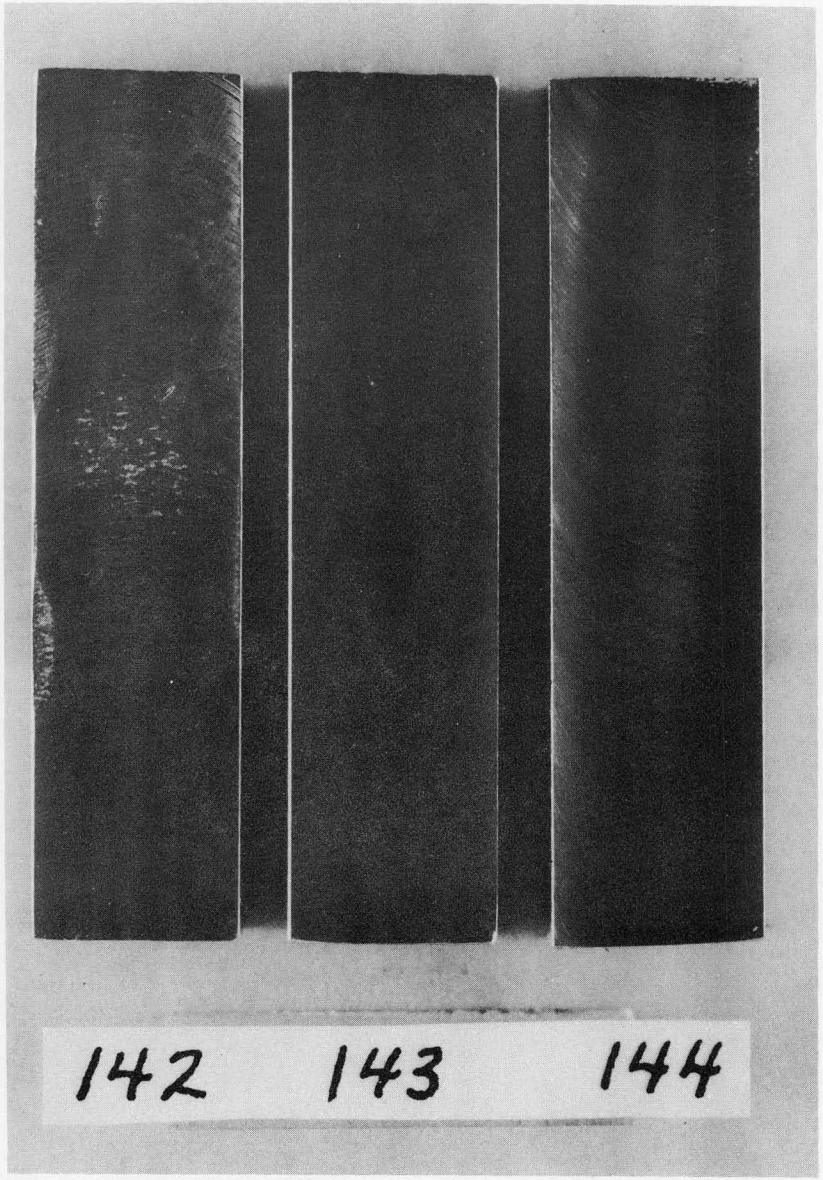

Fig. 3 Coupons as Machined (2.5X)

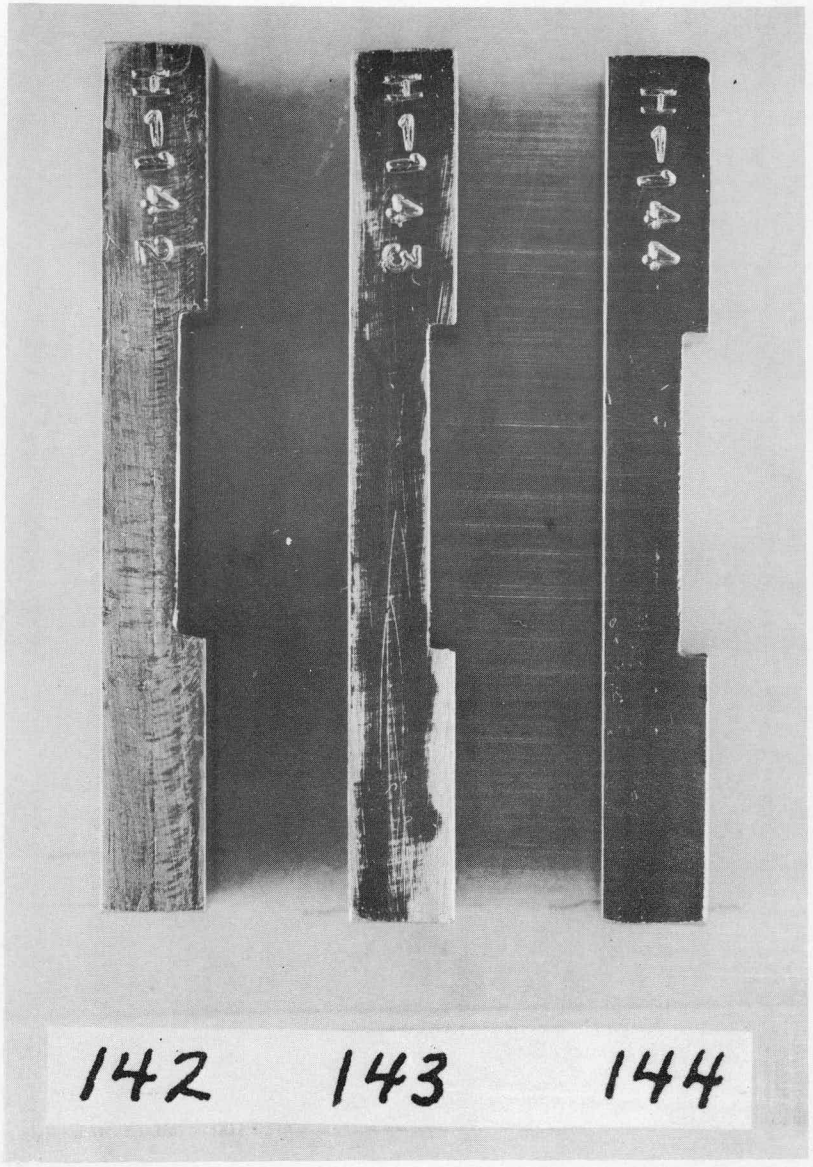

Fig. 4 Coupons as Machined (2.5X)

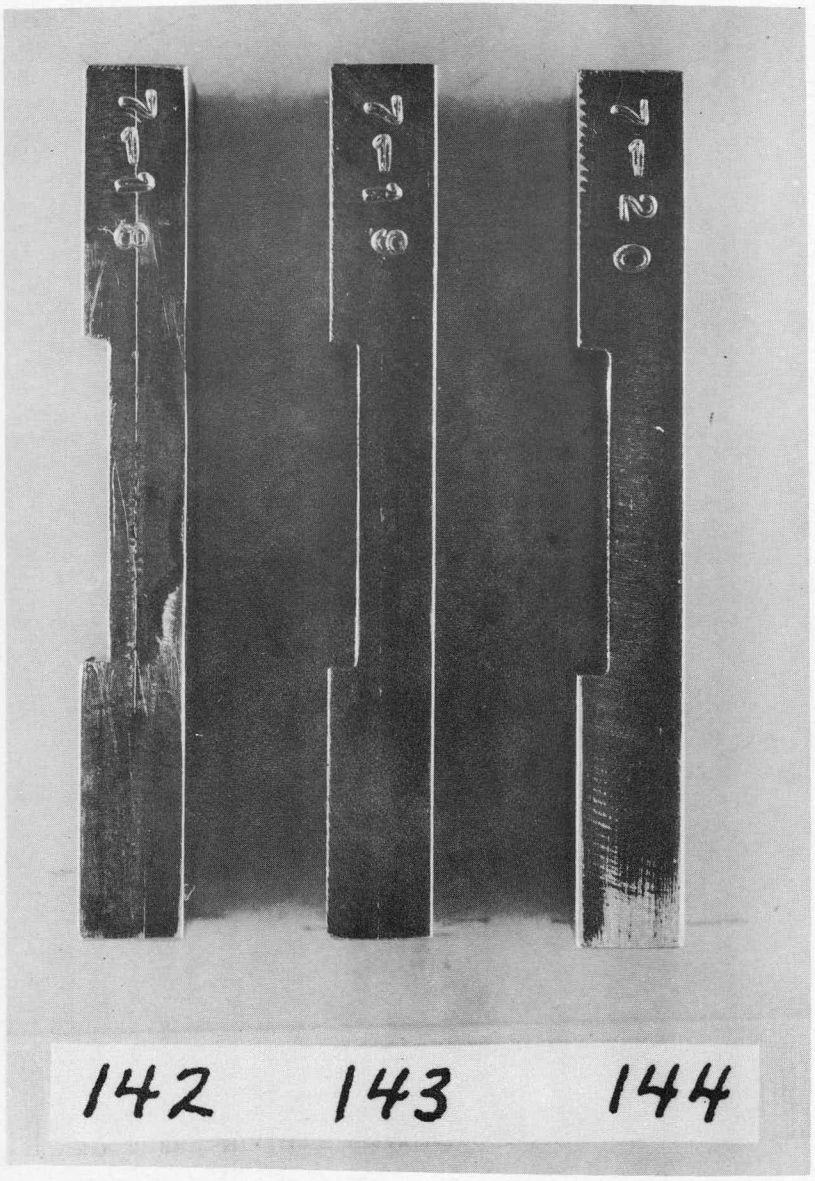

Fig. 5 Coupons as Machined (2.5X)

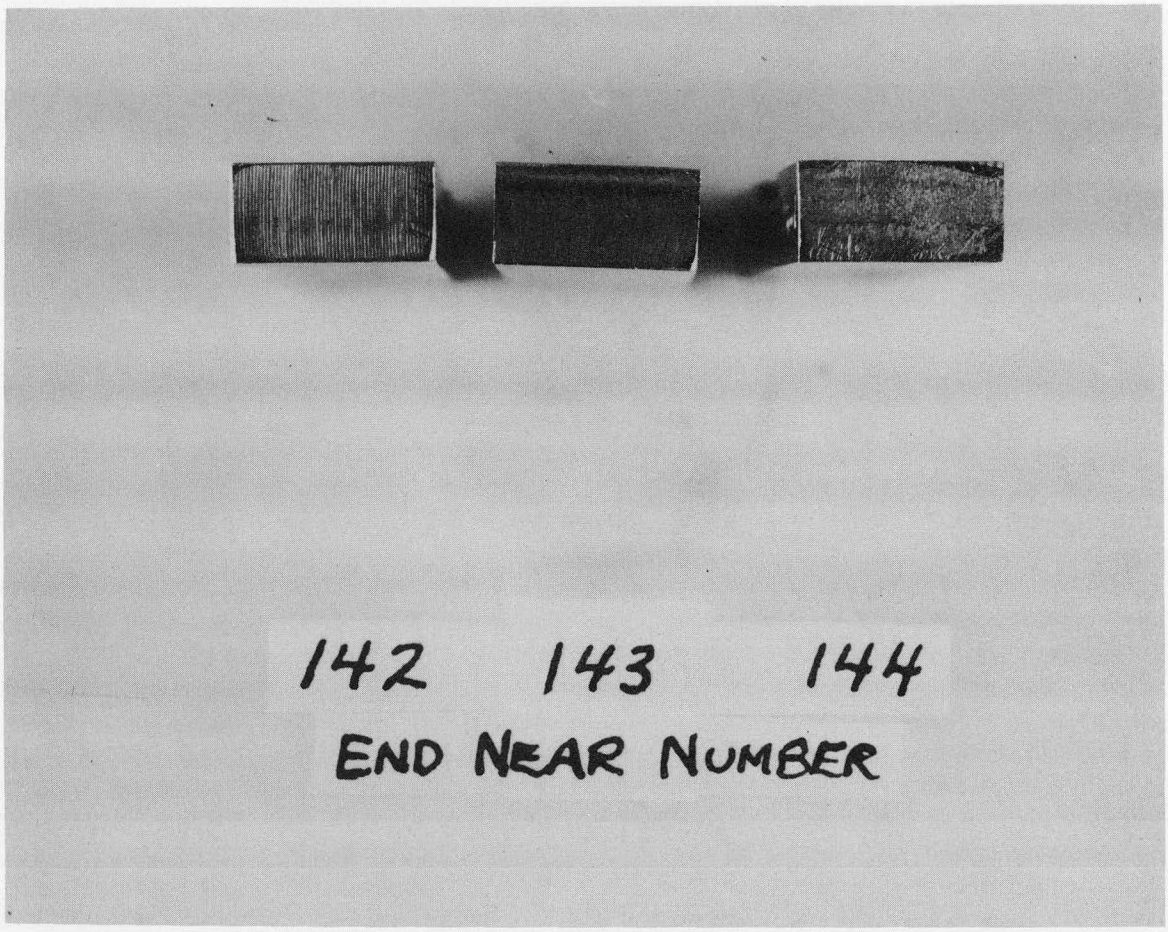

Fig. 6 Coupons as Machined (2.5X)

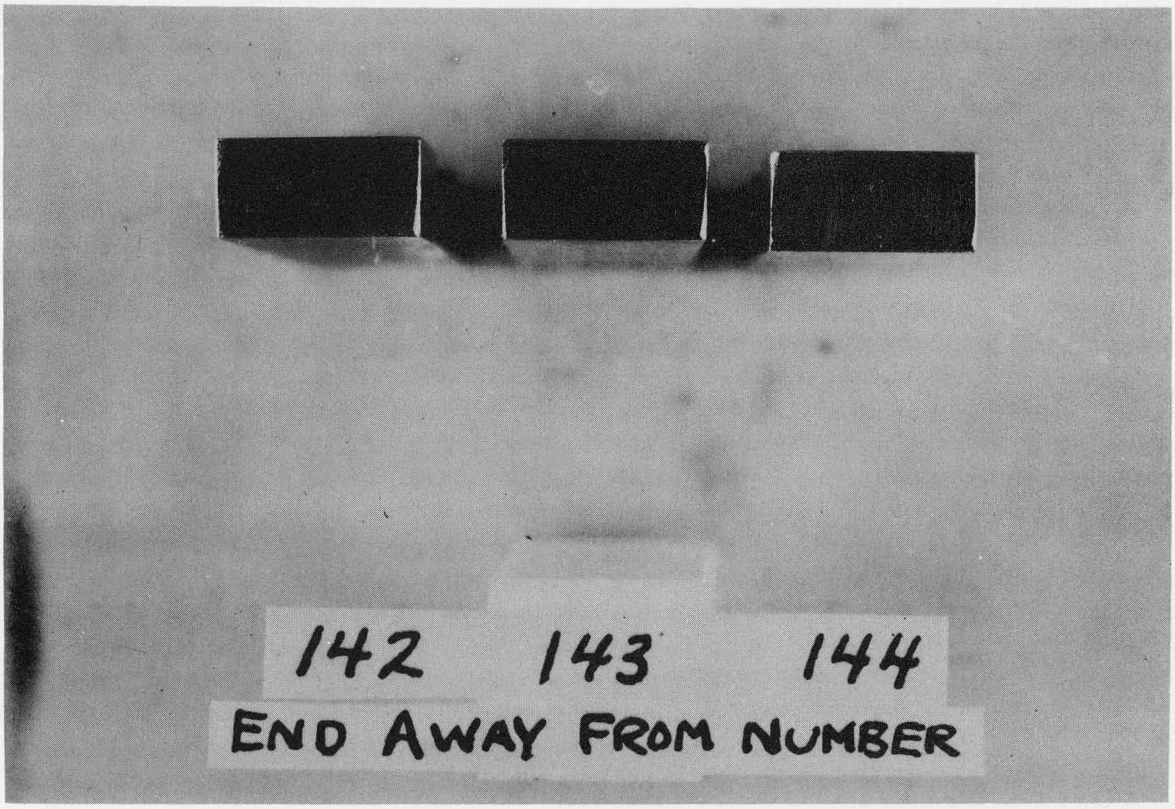

Fig. 7 Coupons as Machined (2.5X)

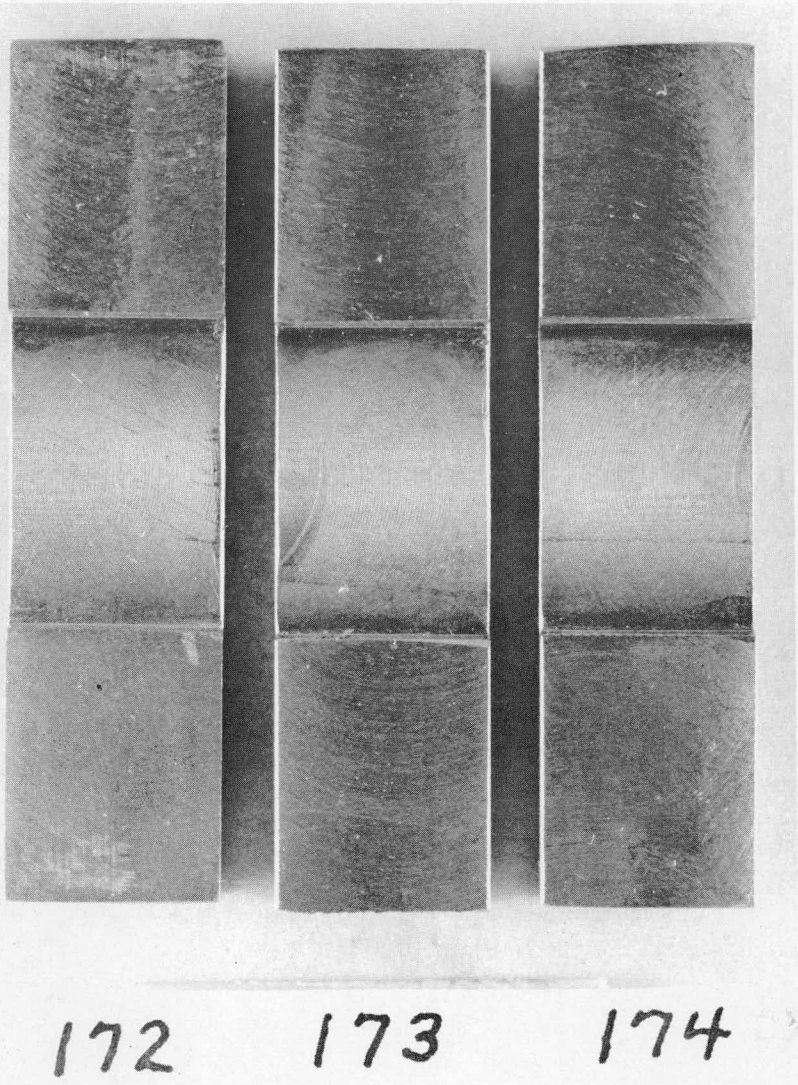

Fig. 8 Coupons as Machined (2.5X)

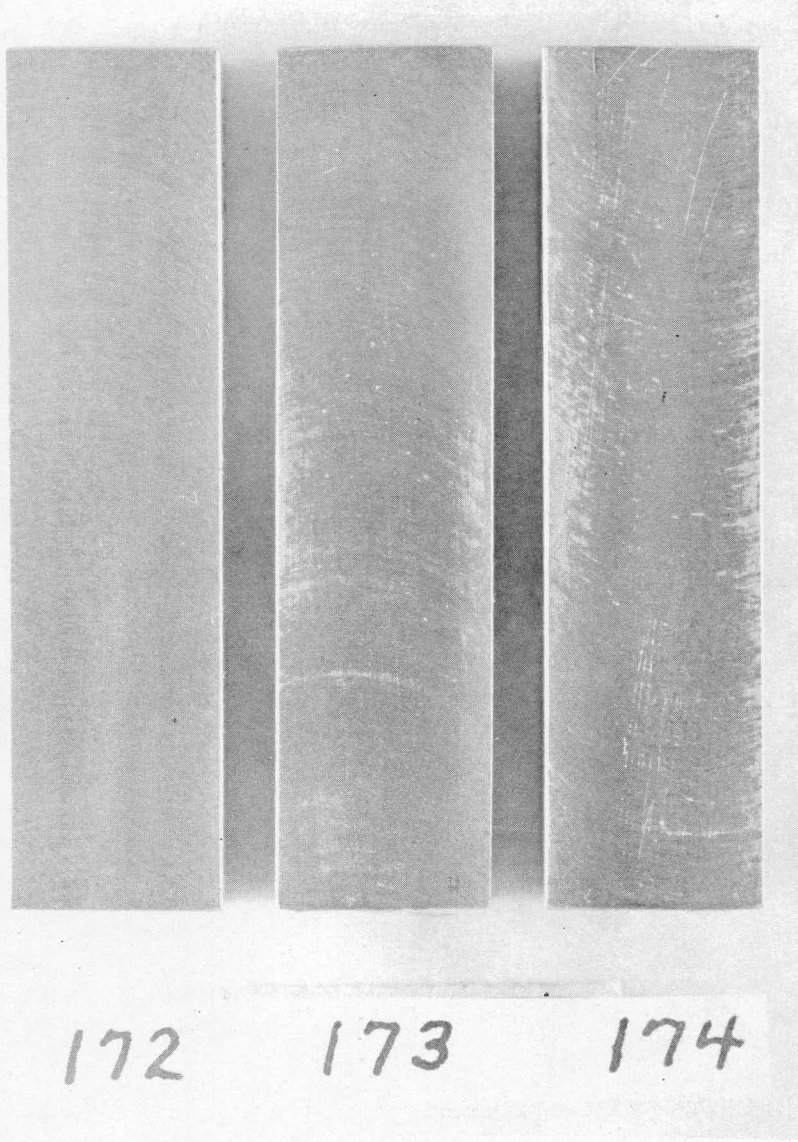

Fig. 9 Coupons as Machined (2.5X)

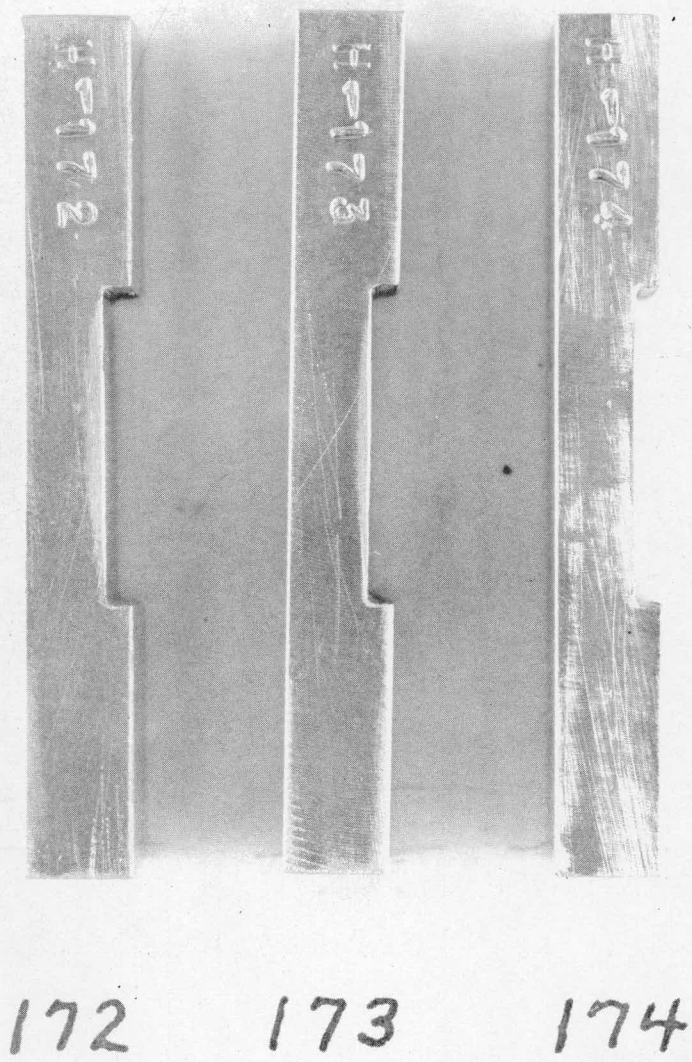

Fig. 10 Coupons as Machined (2.5X)

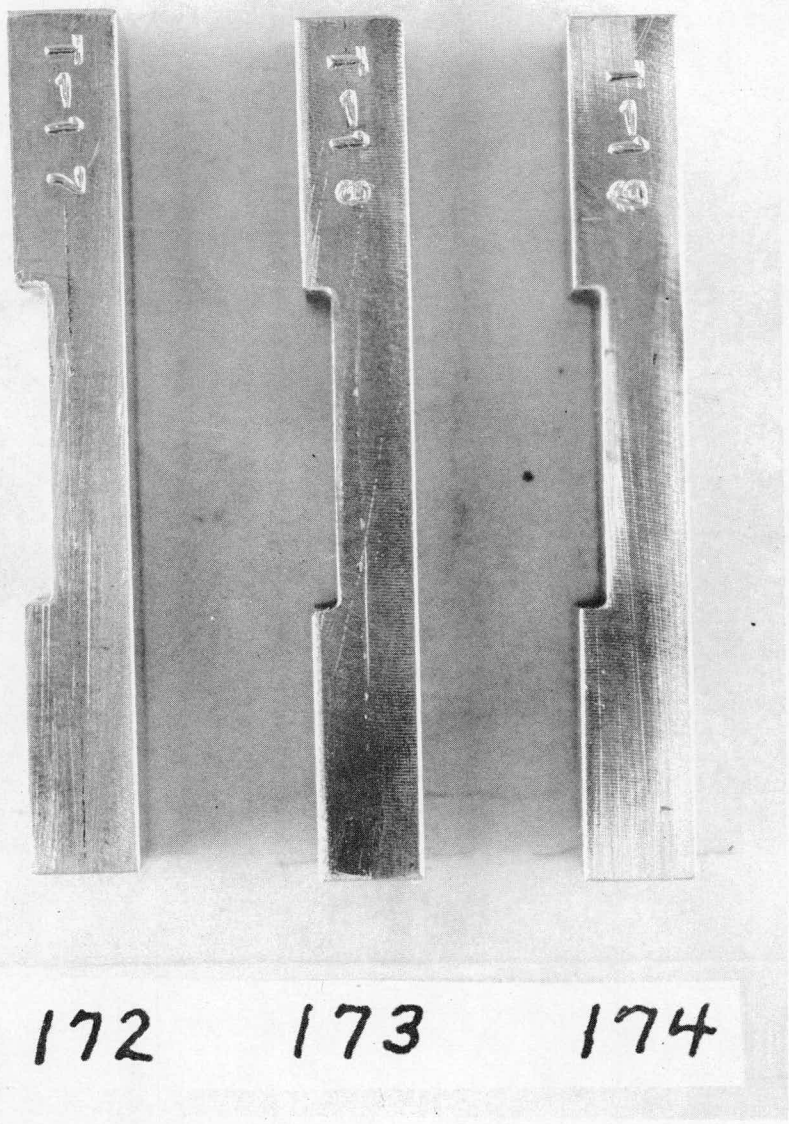

Fig. 11 Coupons as Machined (2.5X)

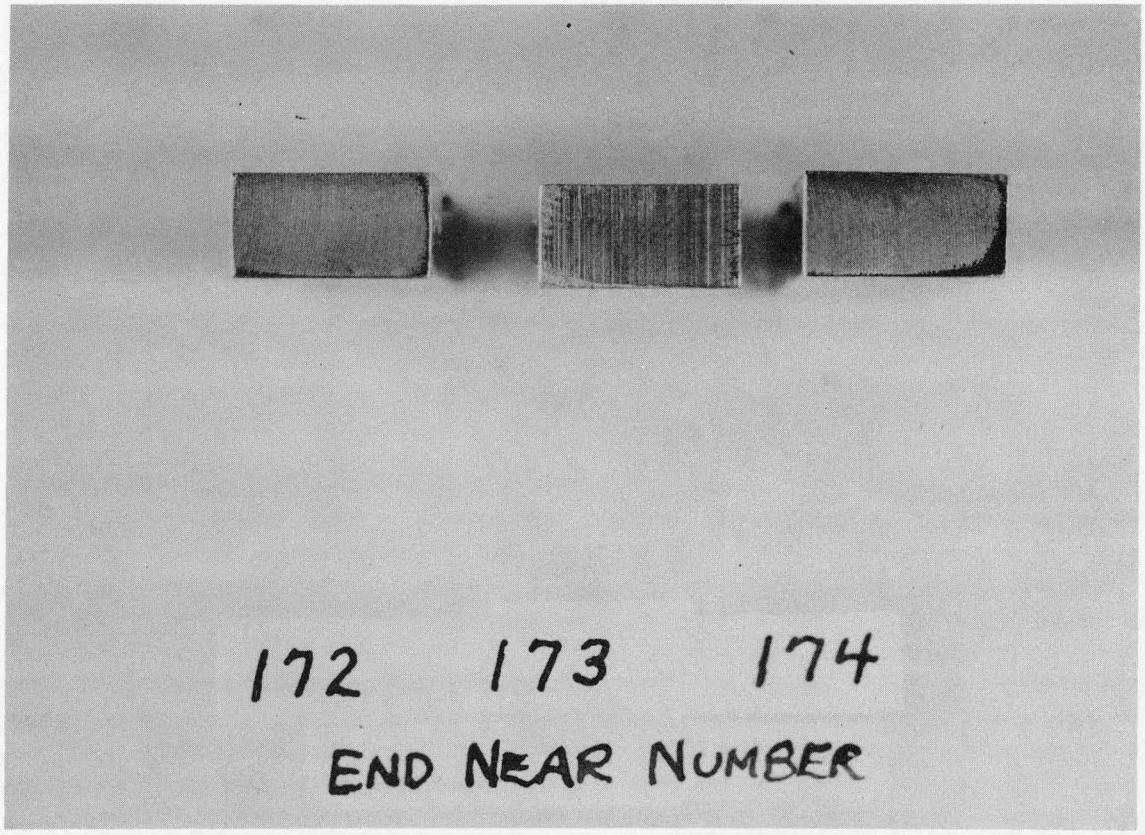

Fig. 12 Coupons as Machined (2.5X)

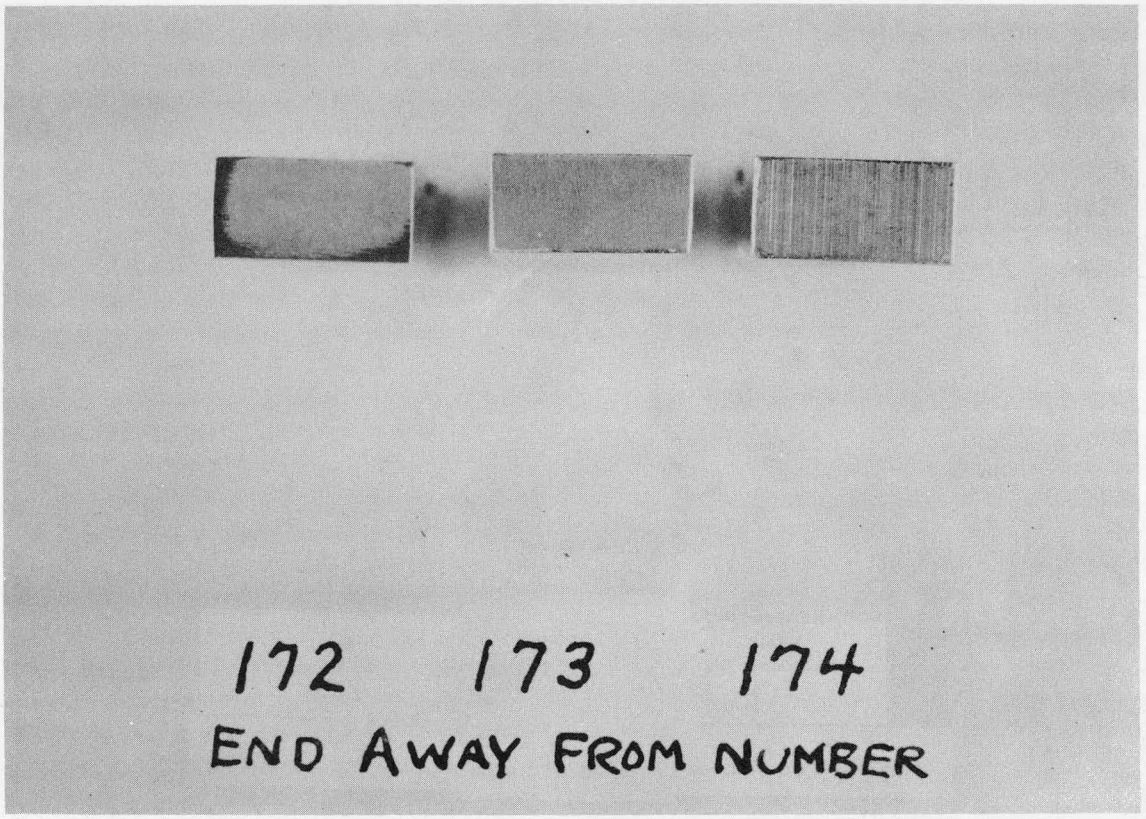

Fig. 13 Coupons as Machined (2.5X)

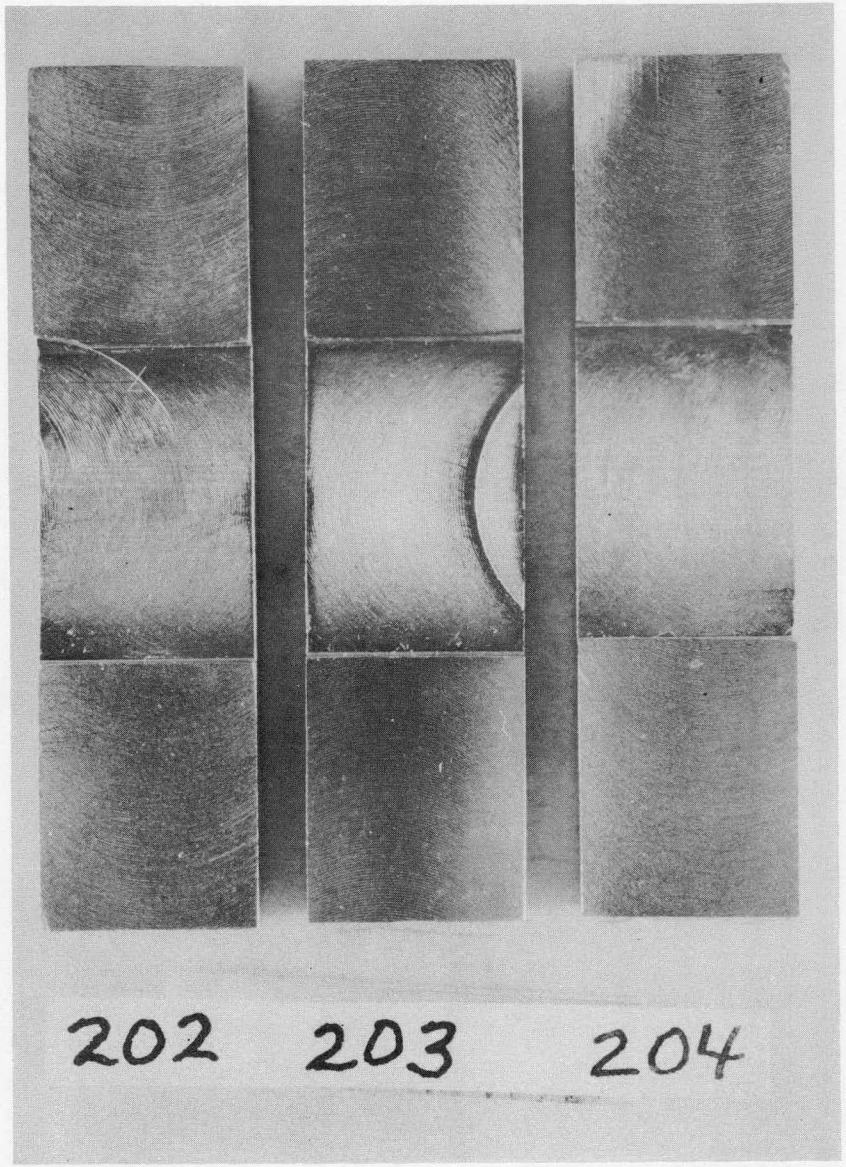

Fig. 14 Coupons as Machined (2.5X)

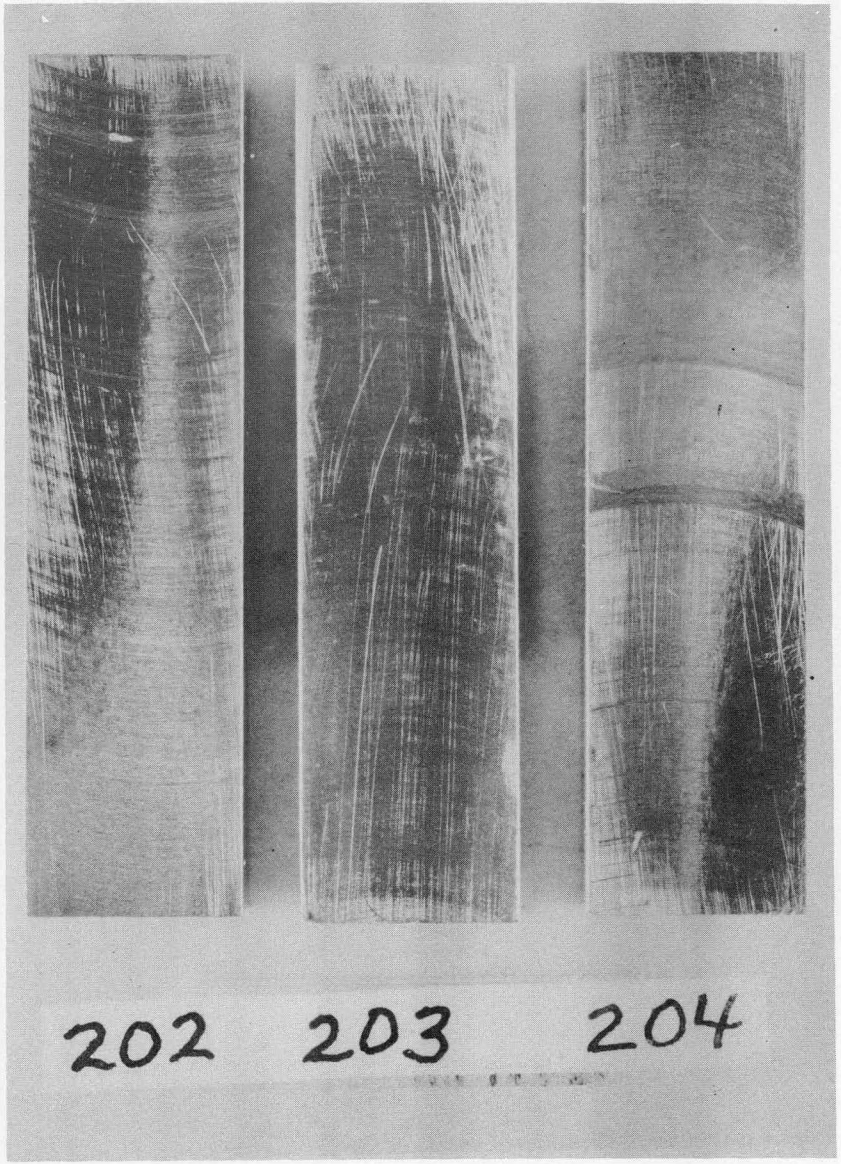

Fig. 15 Coupons as Machined (2.5X)

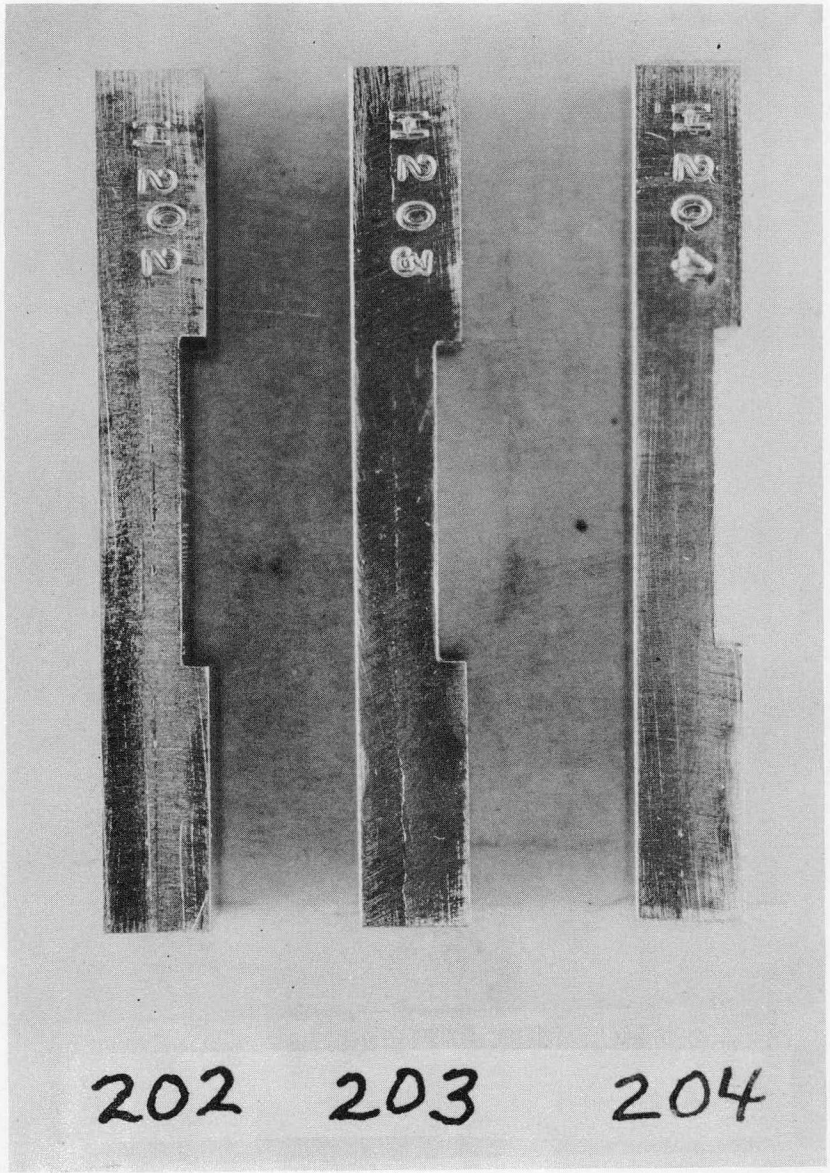

Fig. 16. Coupons as Machined (2.5X)

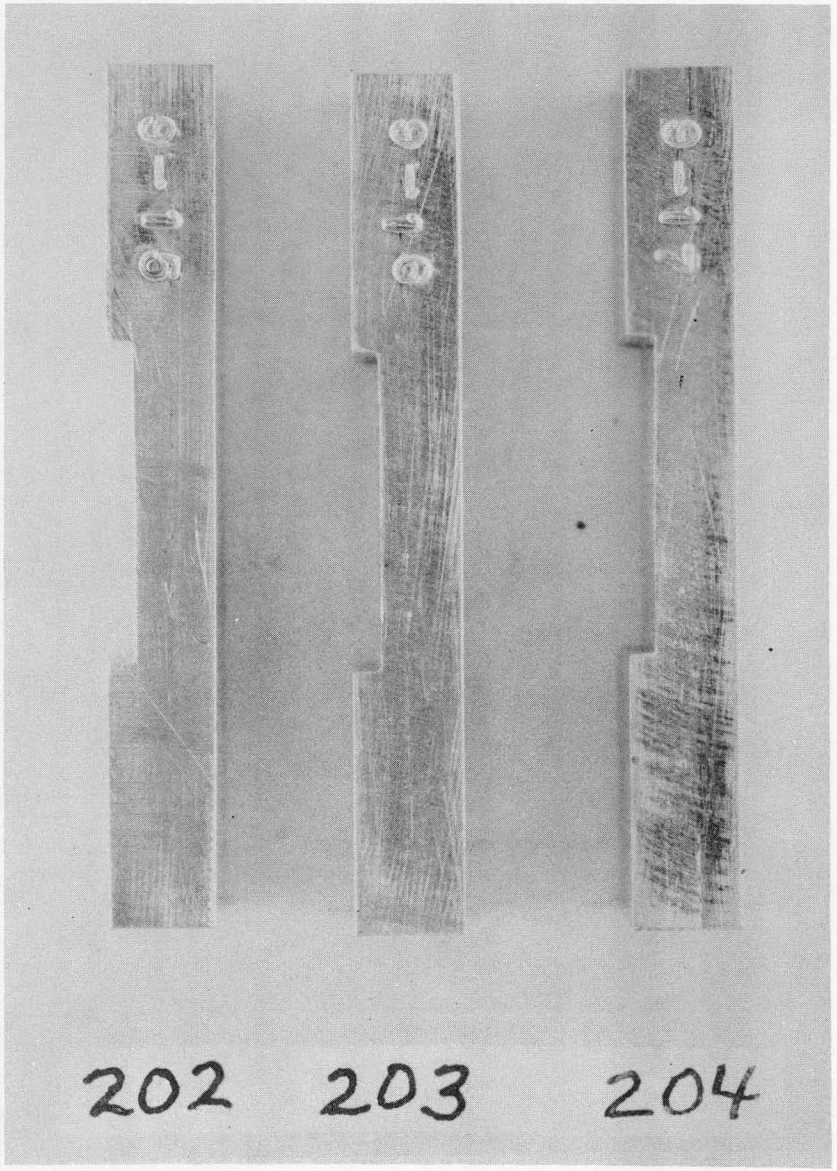

Fig. 17 Coupons as Machined (2.5X)

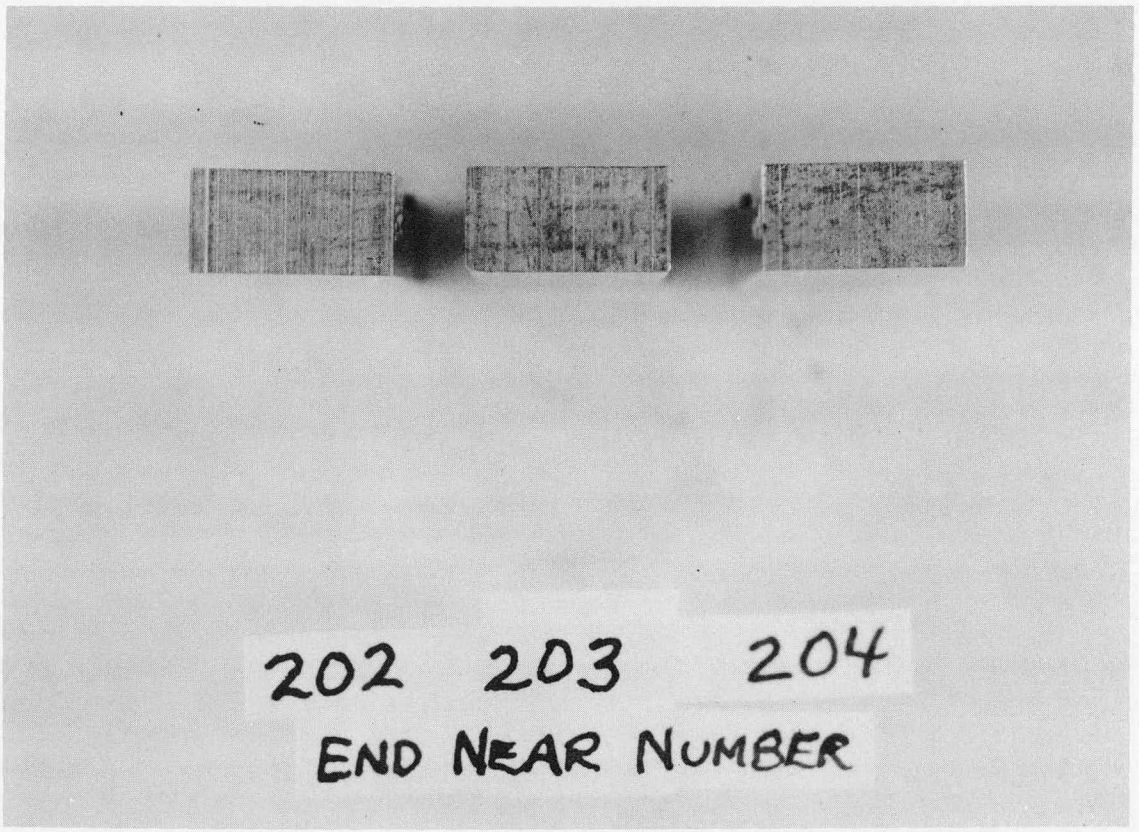

Fig. 18 Coupons as Machined (2.5X)

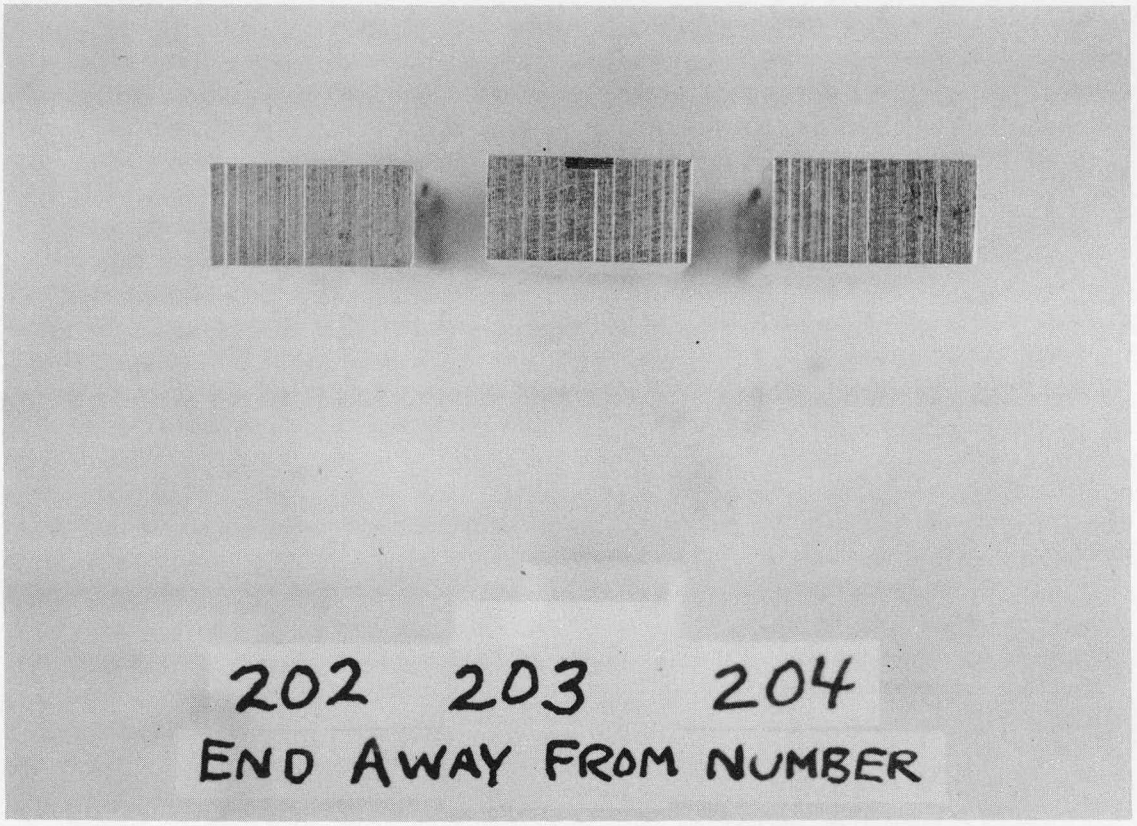

Fig. 19 Coupons as Machined (2.5X)

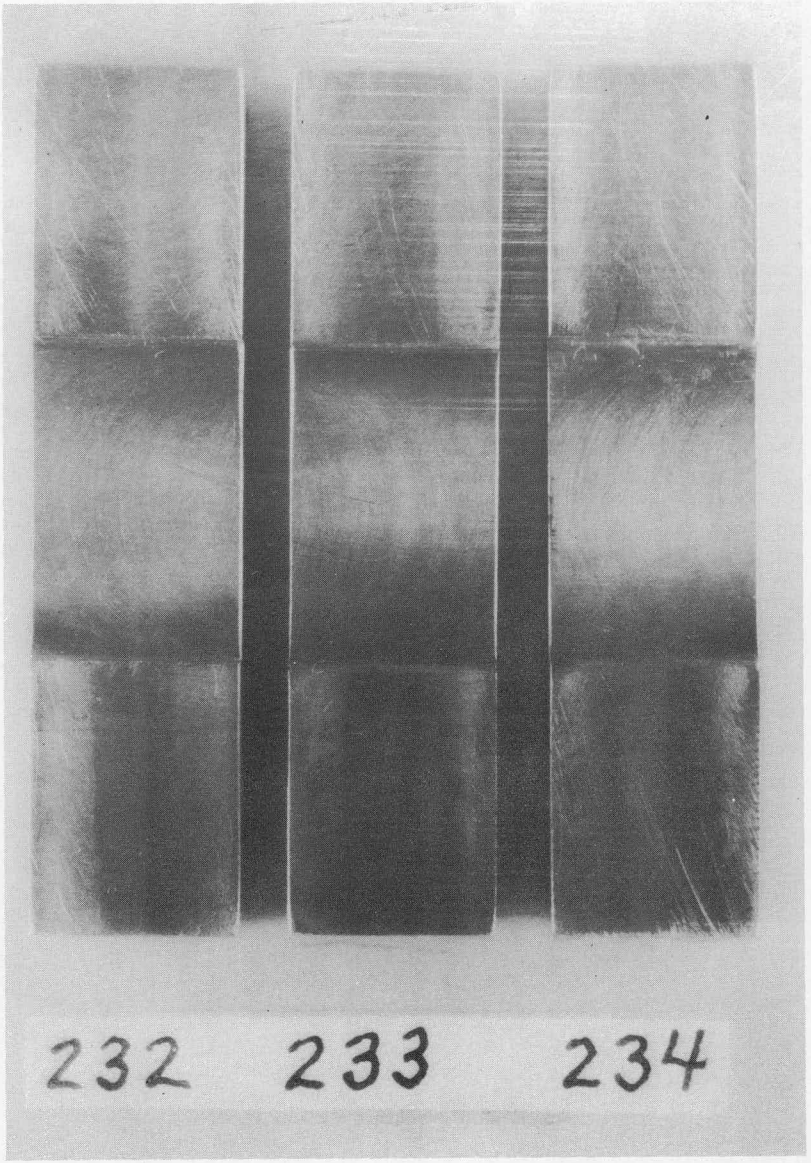

Fig. 20 Coupons as Machined (2.5X)

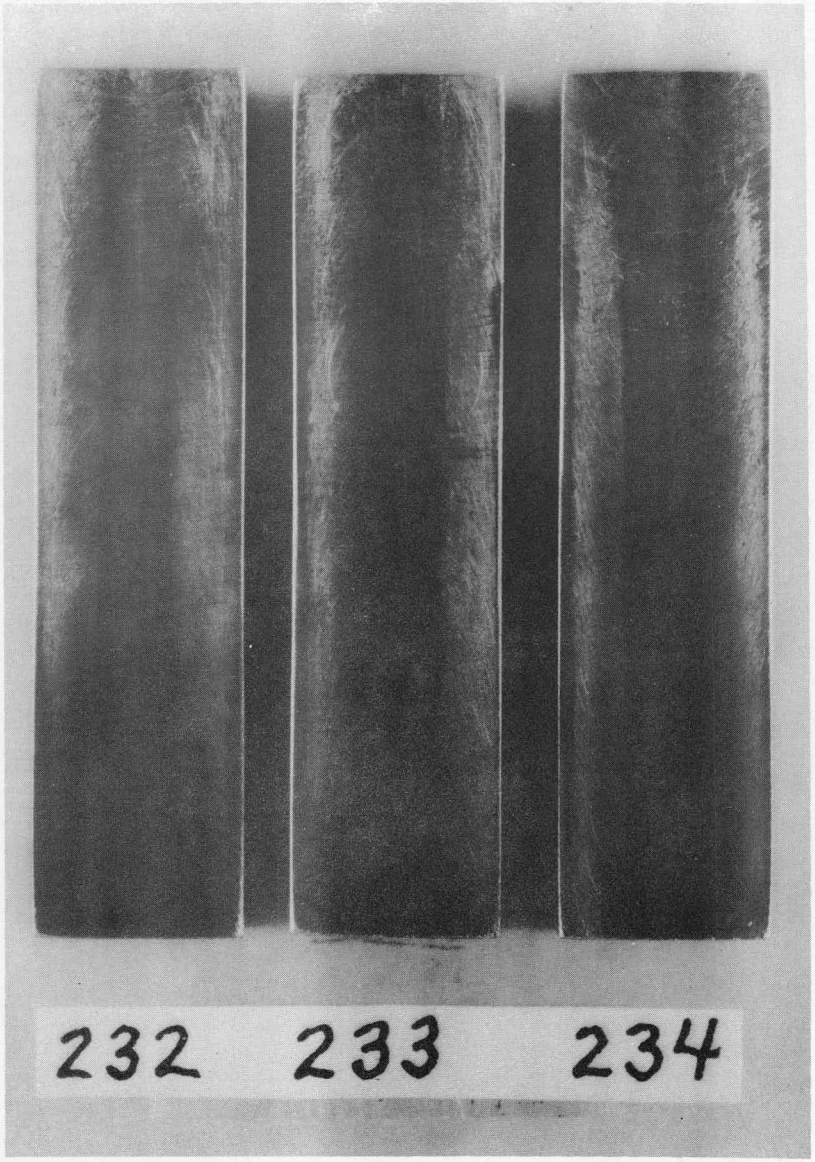

Fig. 21 Coupons as Machined (2.5X)

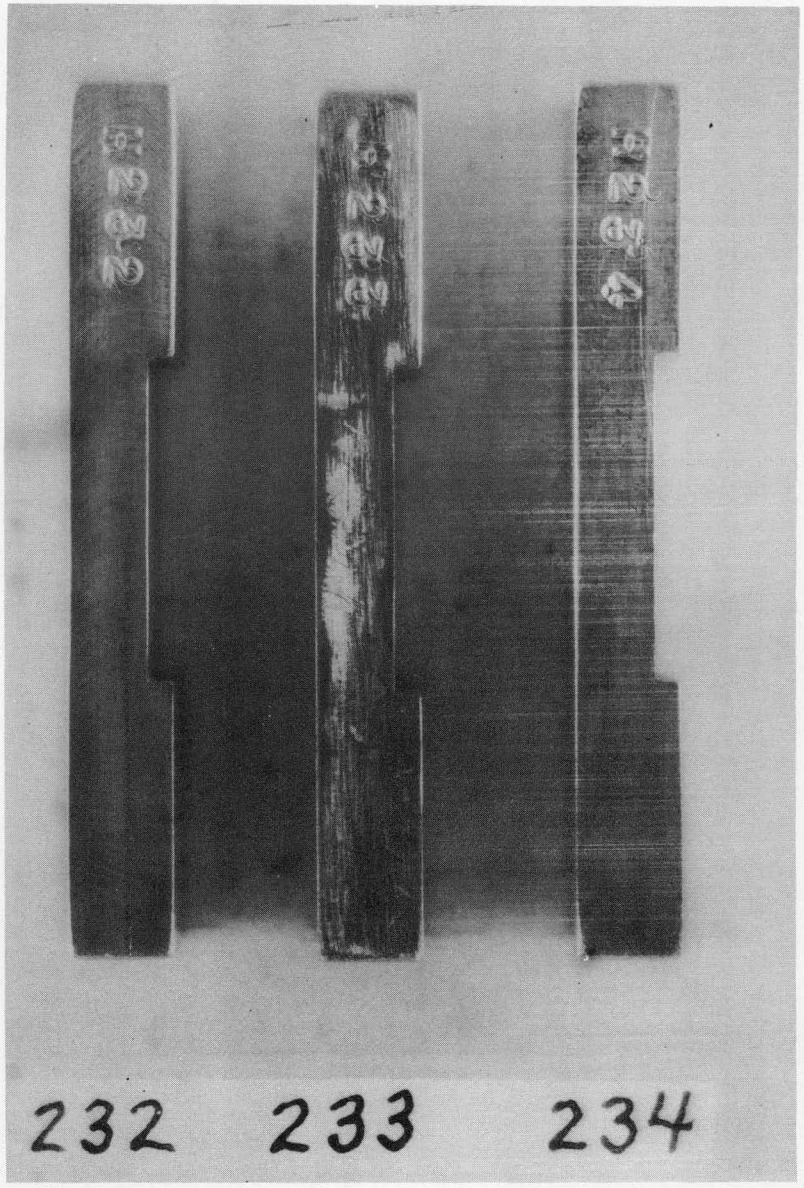

Fig. 22 Coupons as Machined (2.5X)

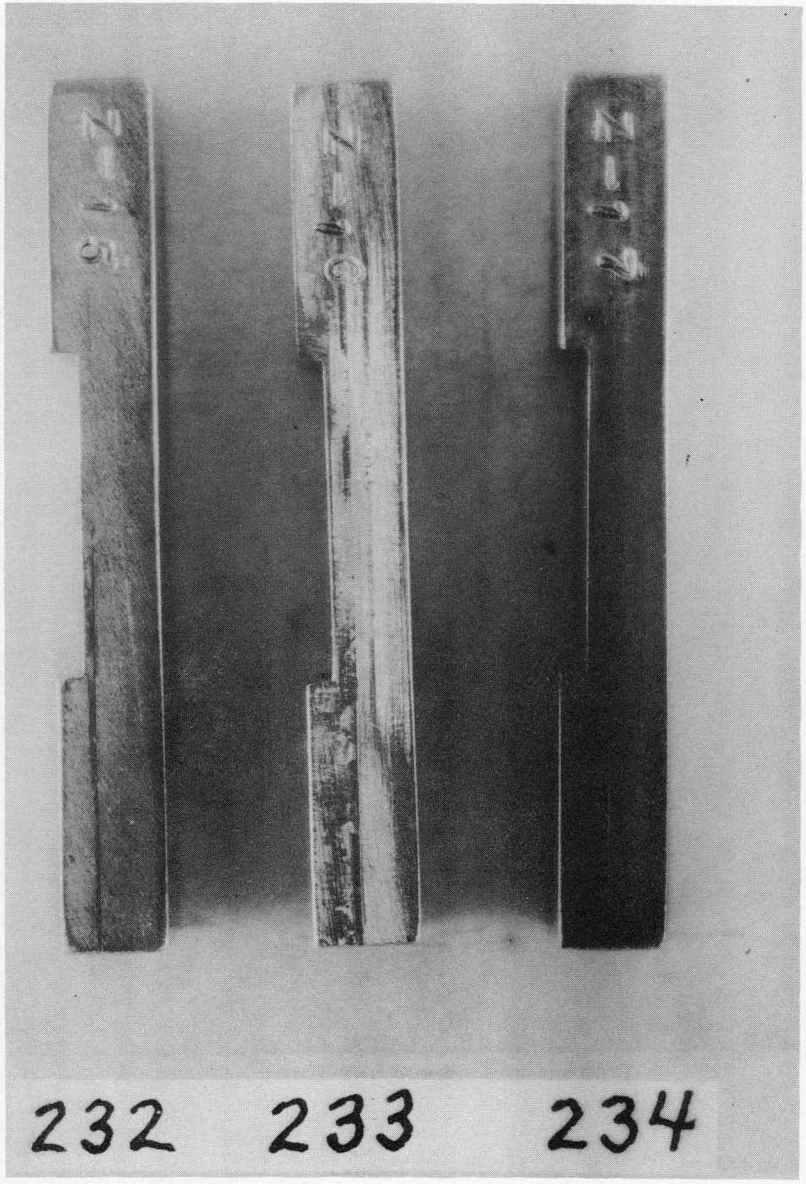

Fig. 23 Coupons as Machined (2.5X)

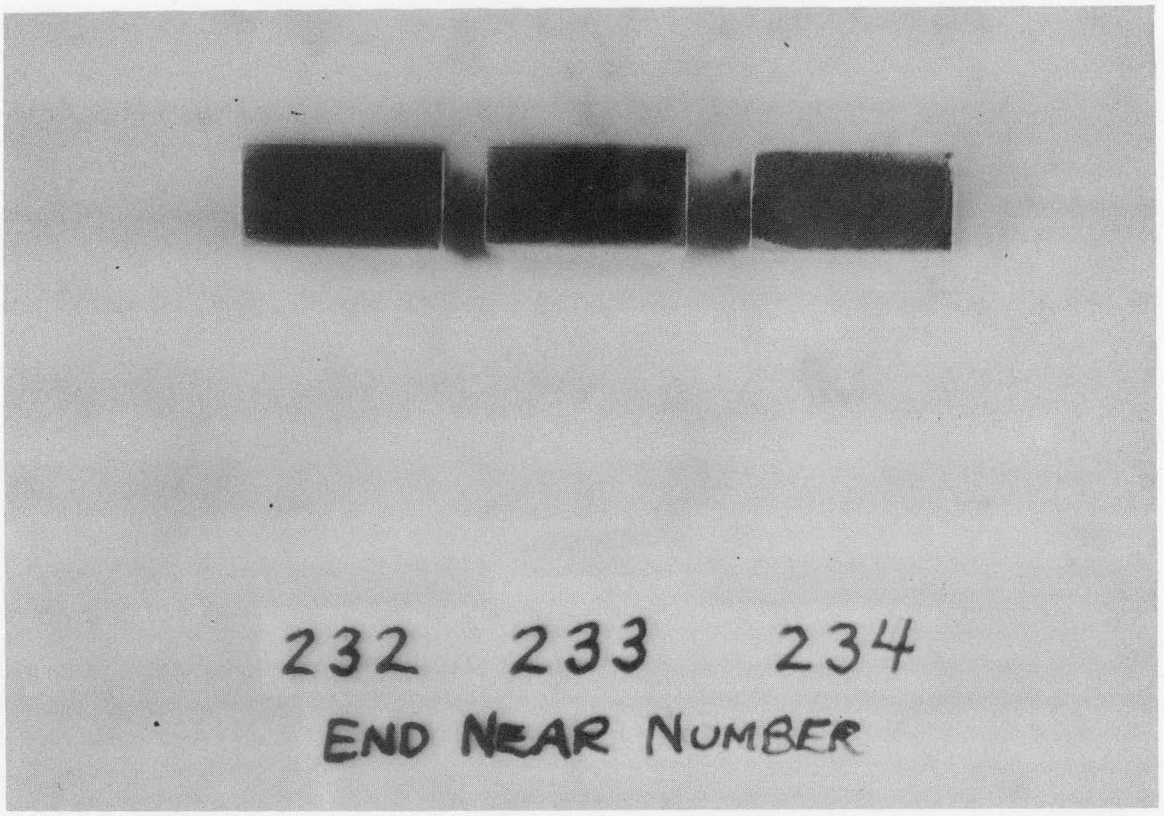

Fig. 24 Coupons as Machined (2.5X)

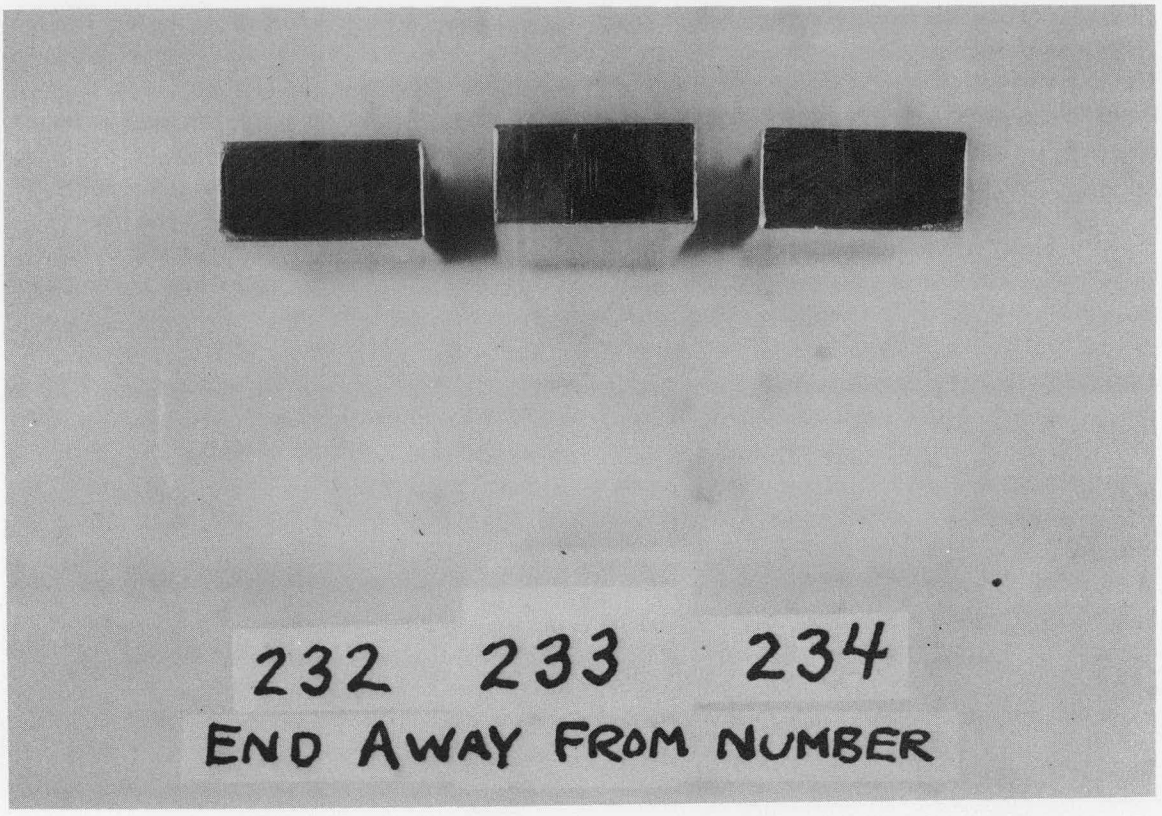

Fig. 25 Coupons as Machined (2.5X)

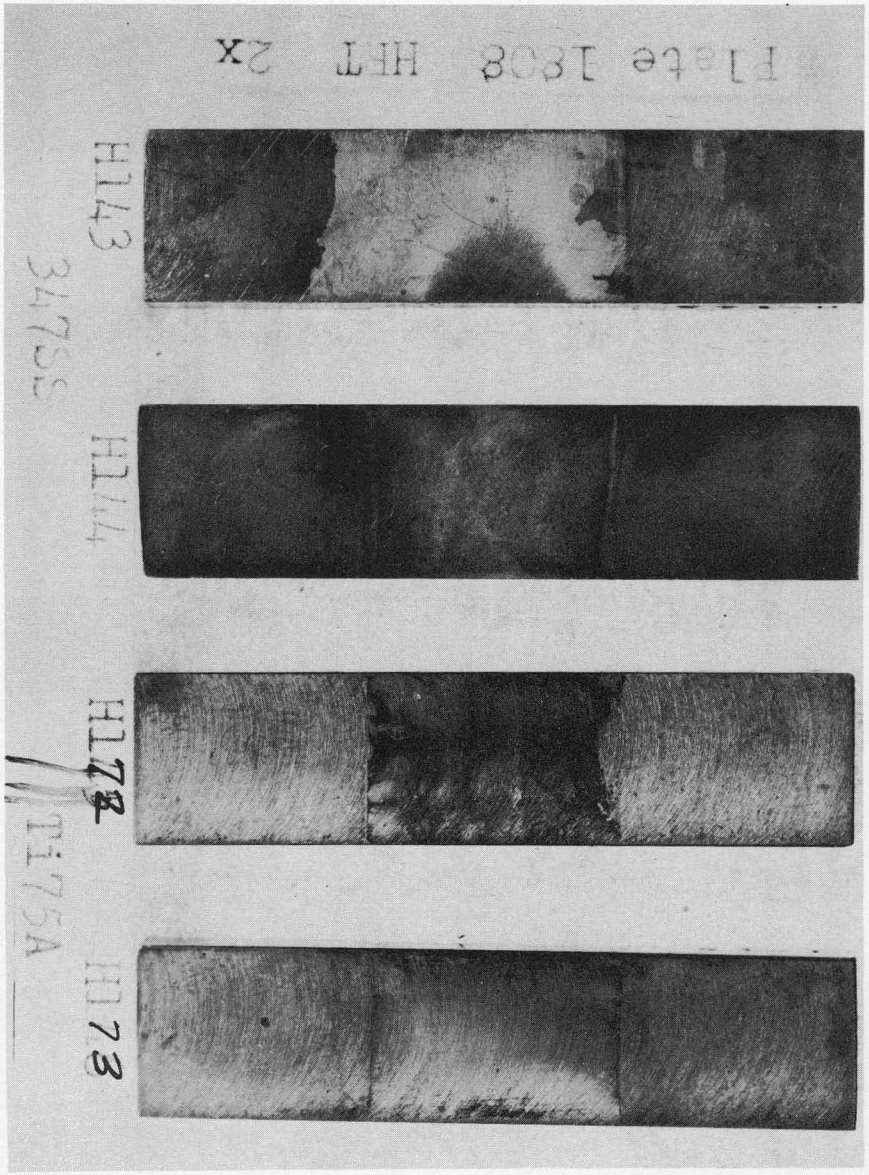

Fig. 27 Coupons Defilmed (2X)

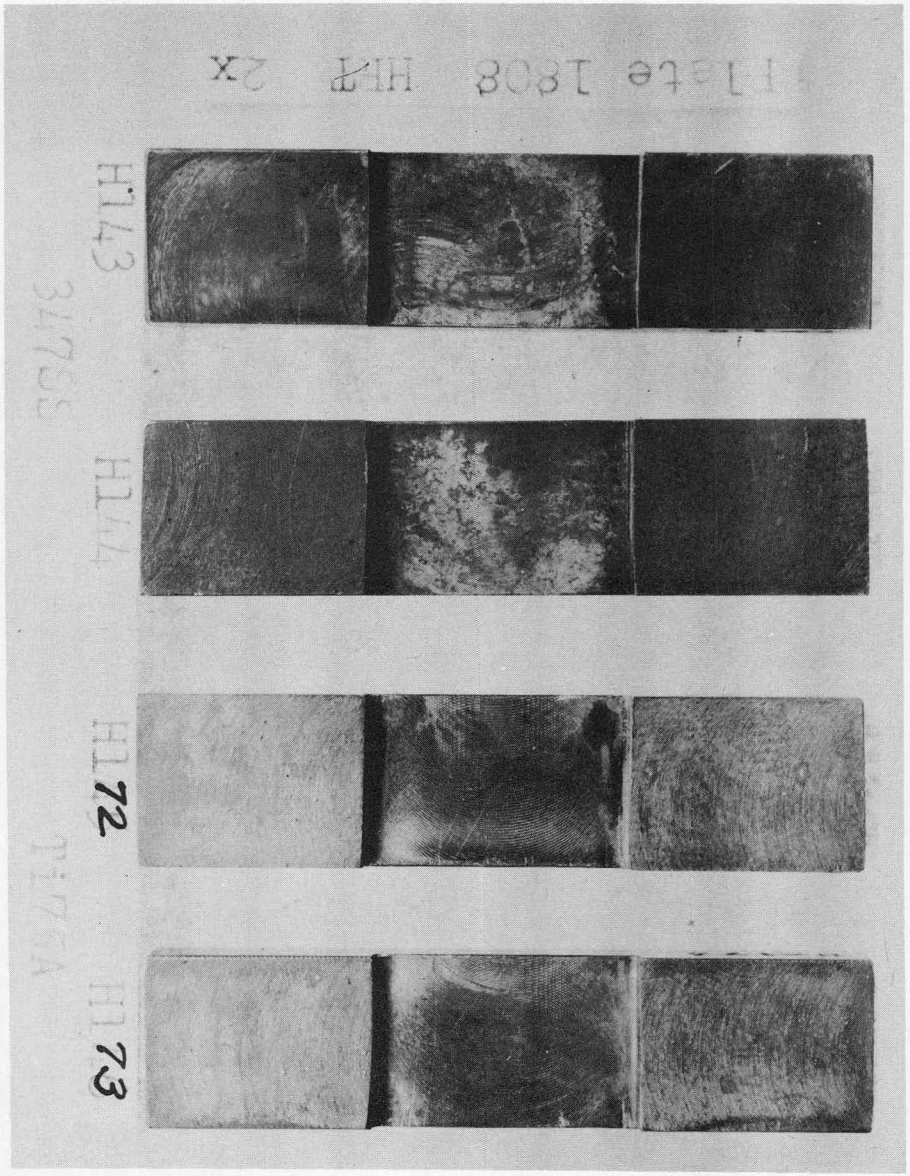

Fig. 26 Coupons Defilmed (2X)

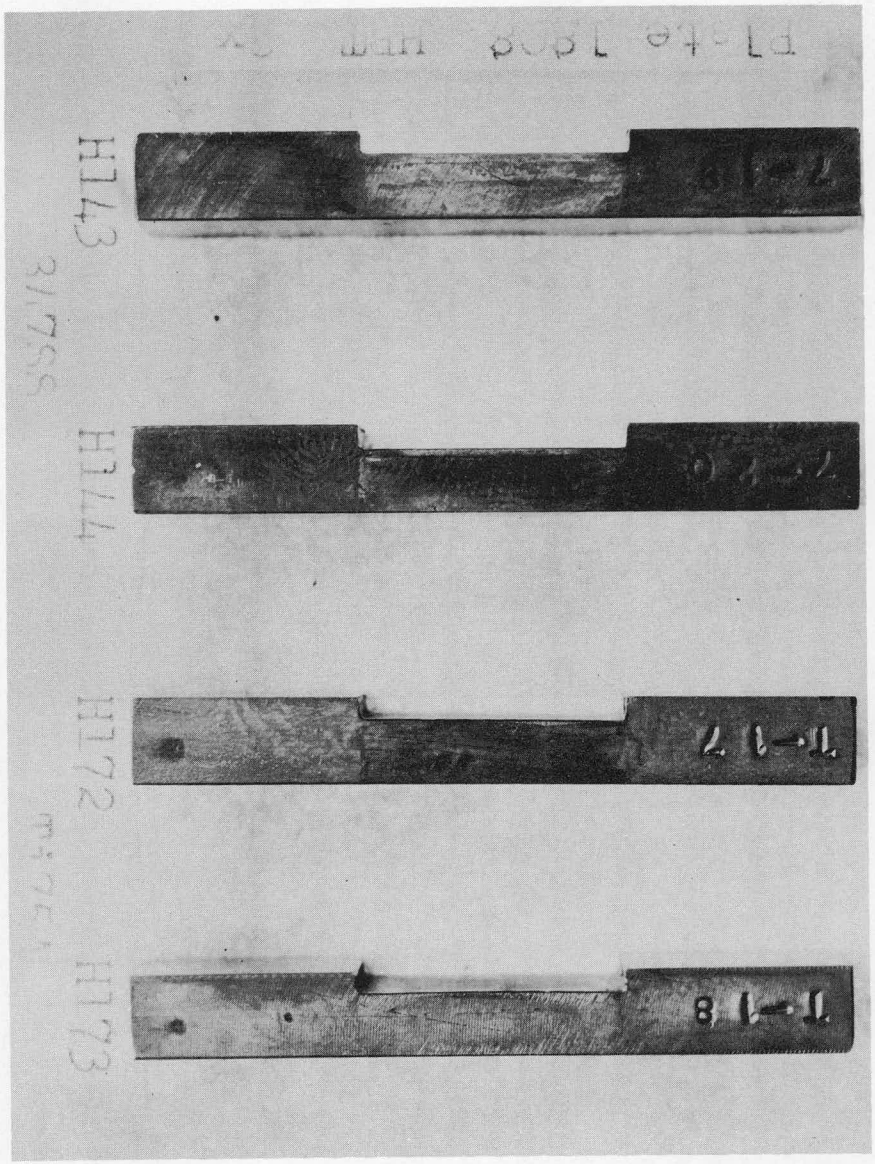

Fig. 29 Coupons Defilmed (2X)

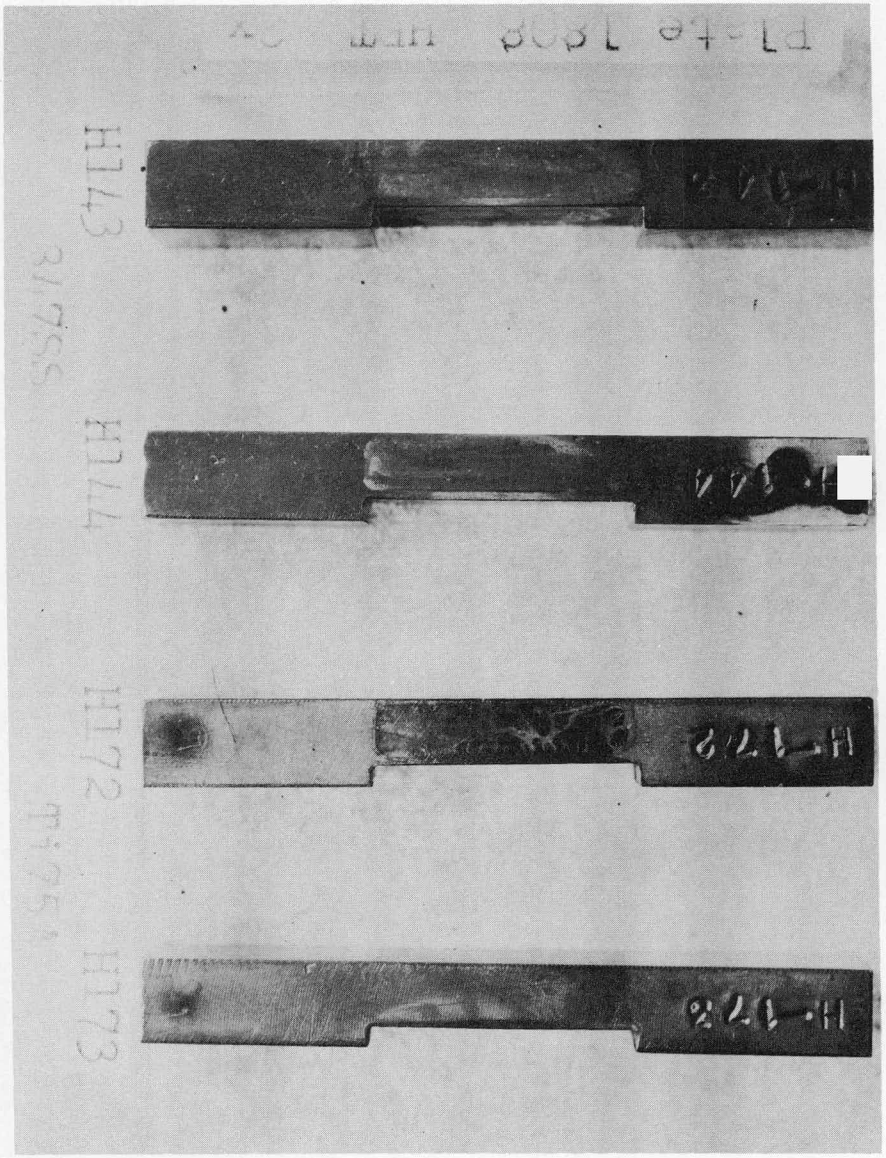

Fig. 28 Coupons Defilmed (2X)

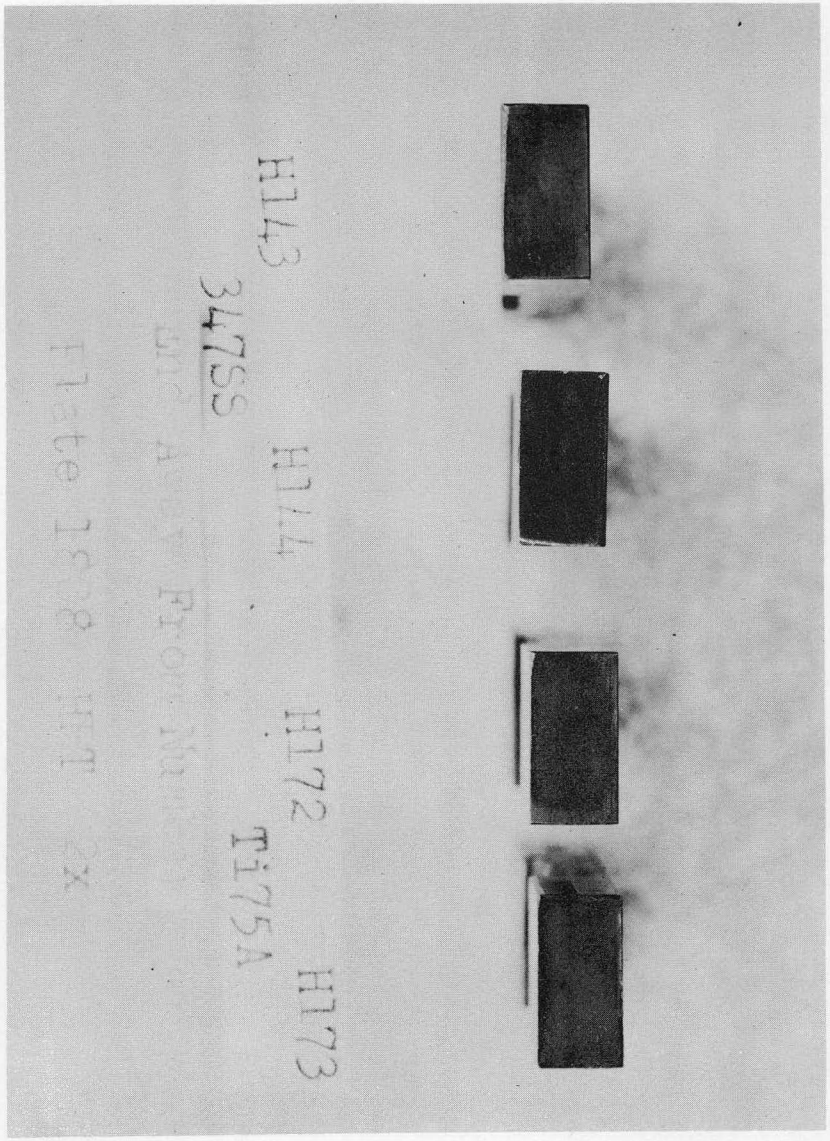

Fig. 31 Coupons Defilmed (2X)

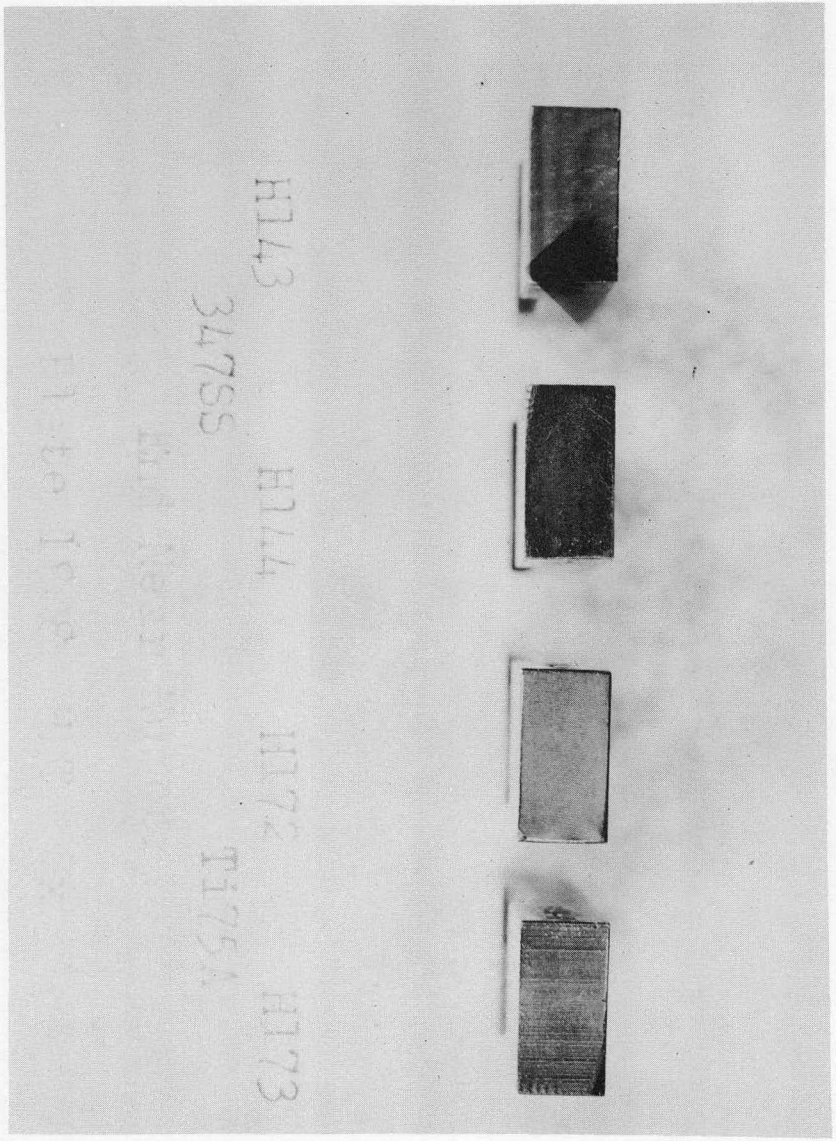

Fig. 30 Coupons Defilmed (2X)

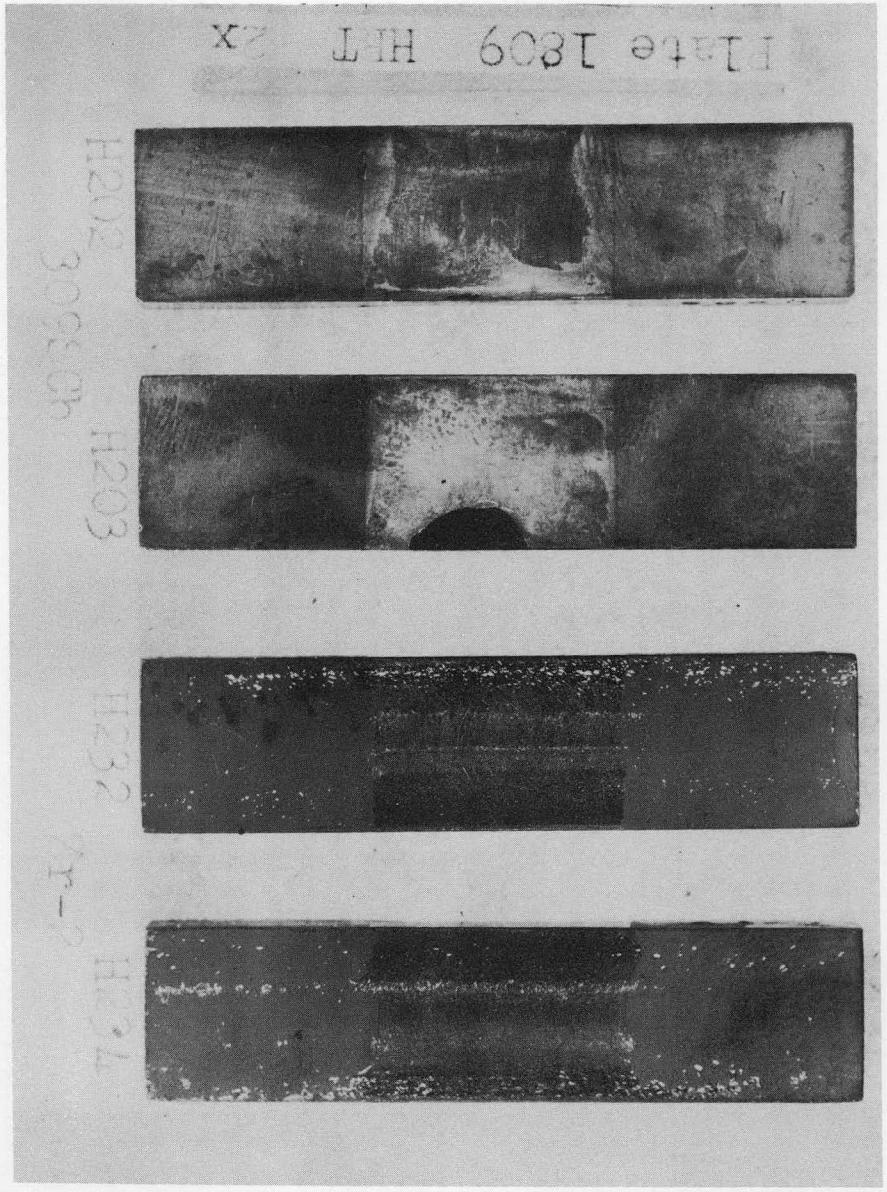

Fig. 33 Coupons Defilmed (2X)

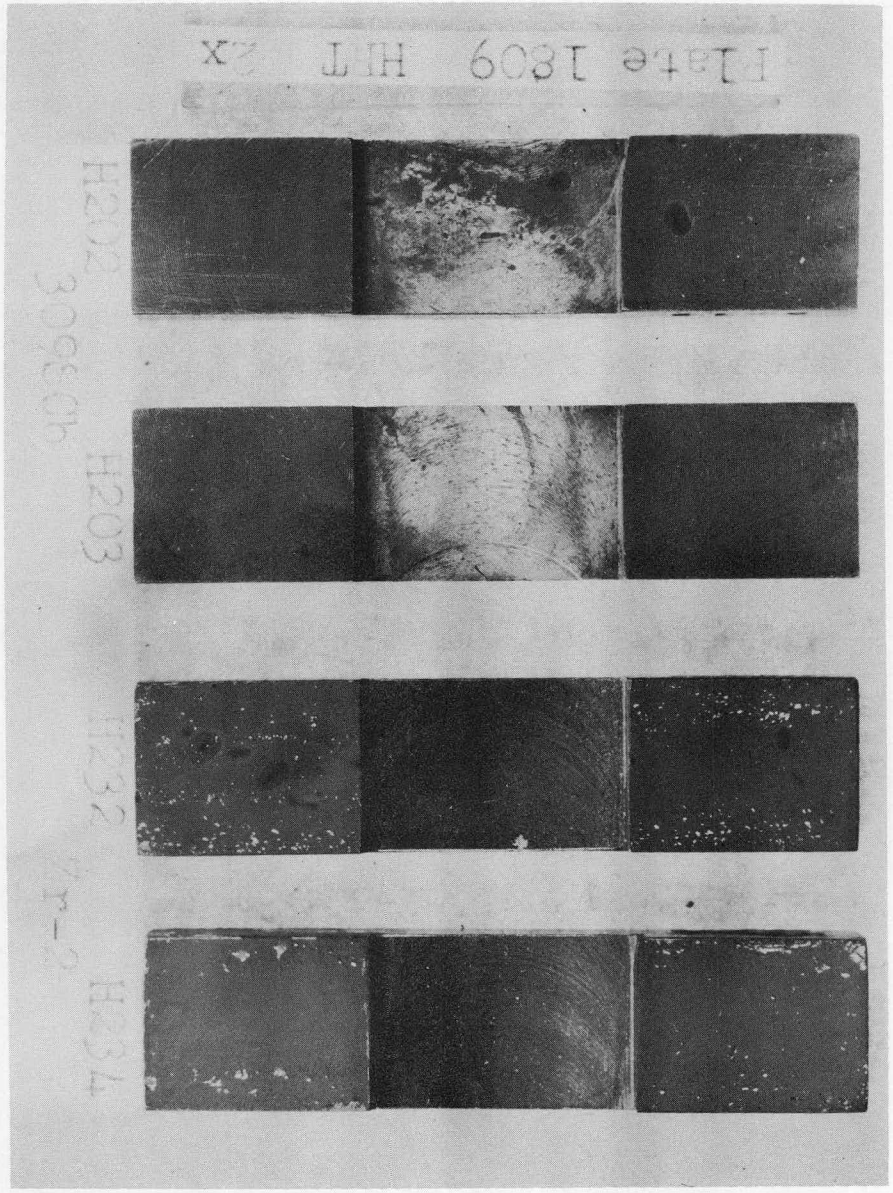

Fig. 32 Coupons Defilmed (2X)

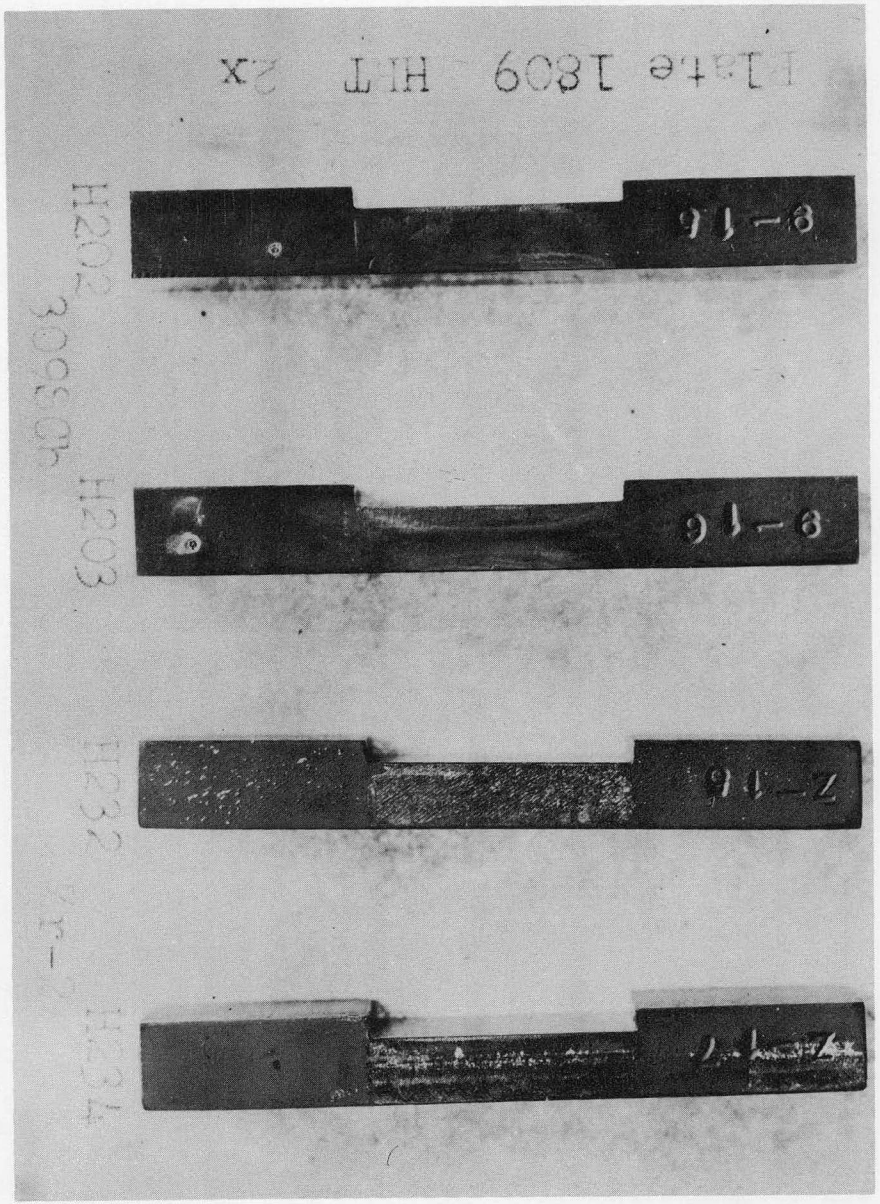

Fig. 35 Coupons Defilmed (2X)

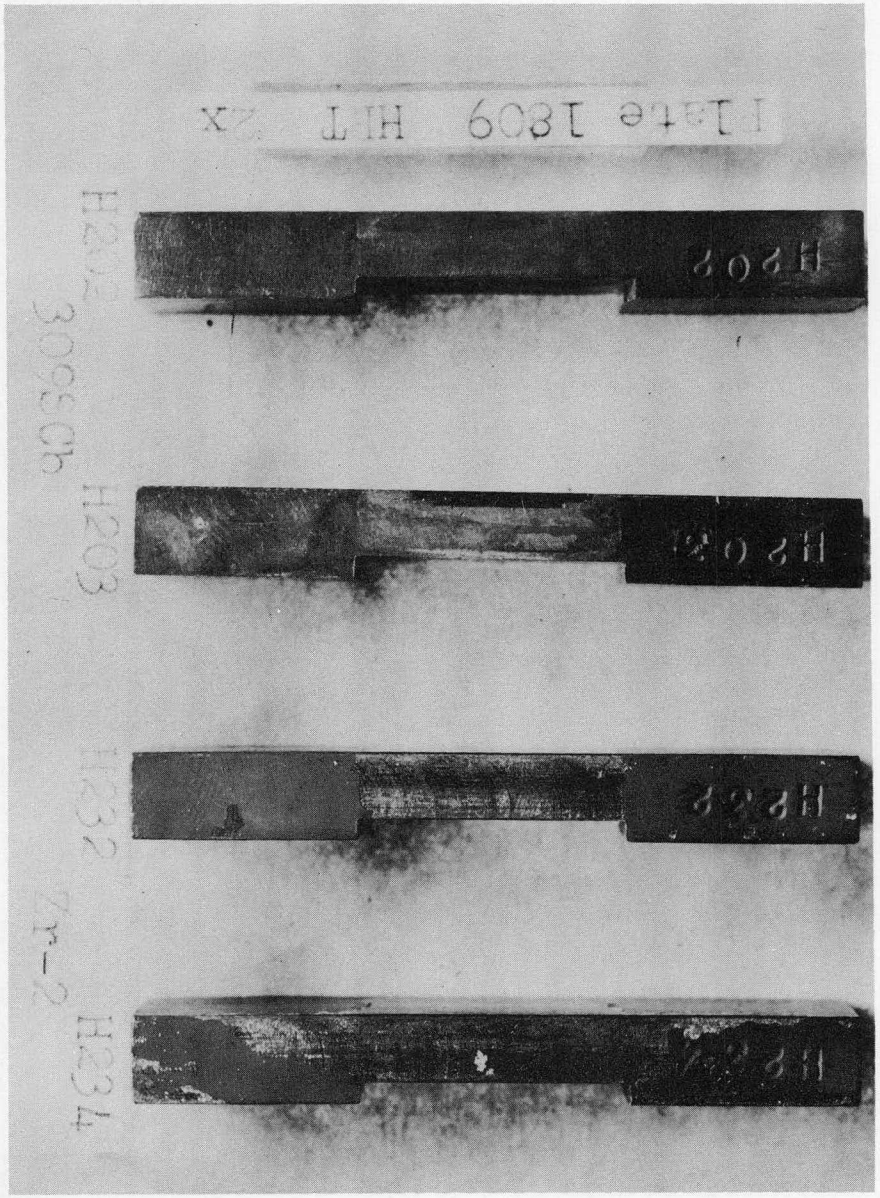

Fig. 34 Coupons Defilmed (2X)

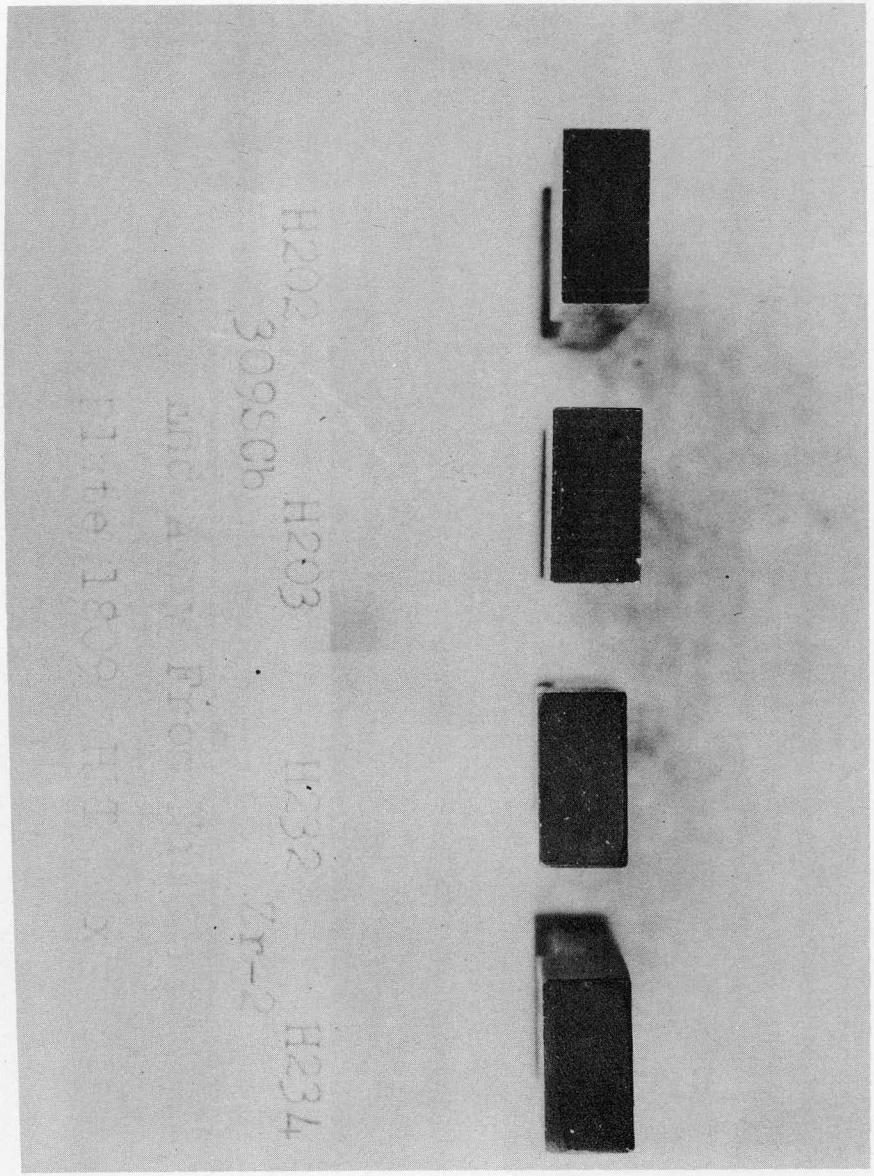

Fig. 37 Coupons Defilmed (2X)

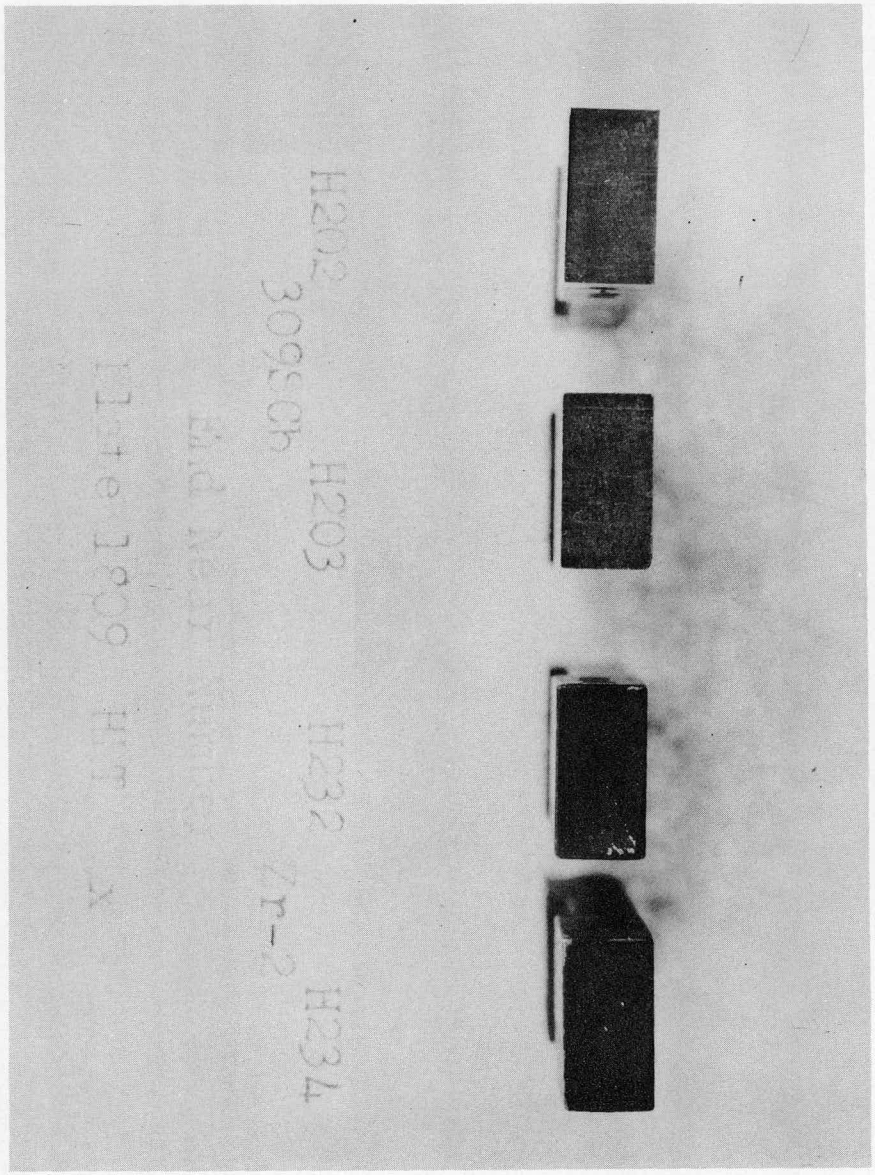

Fig. 36 Coupons Defilmed (2X)

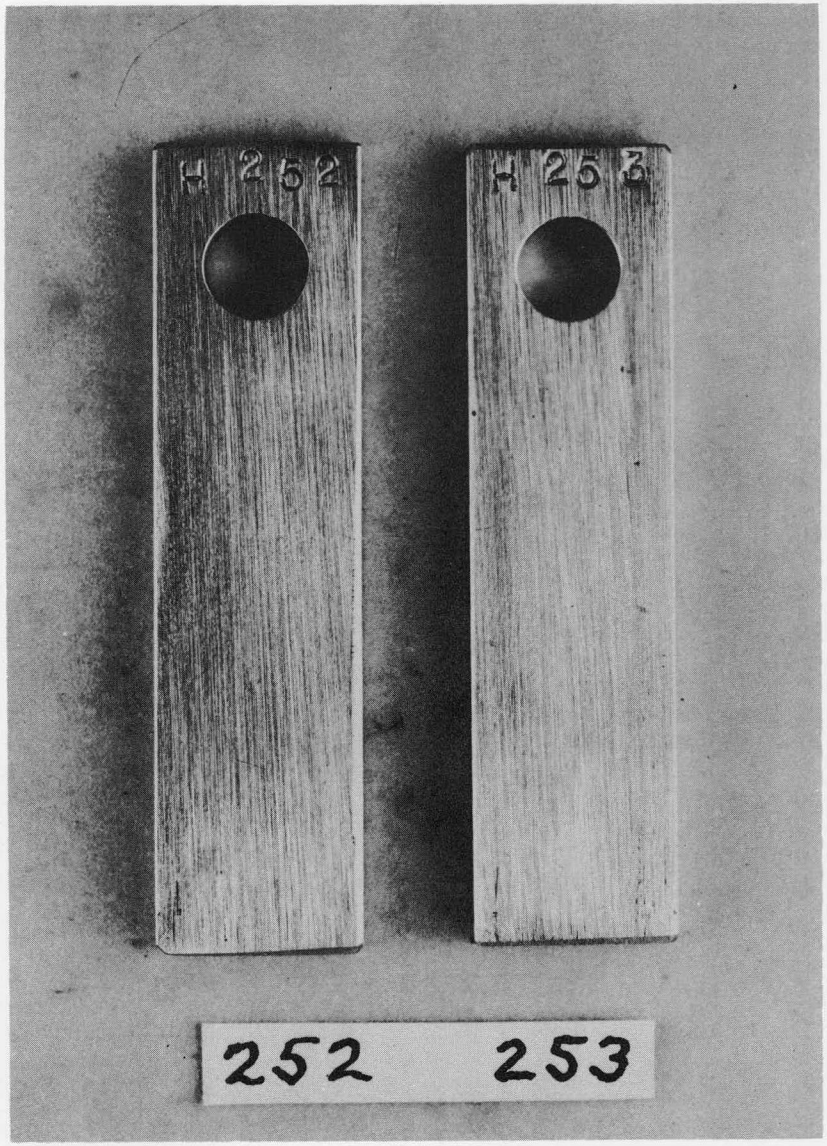

Fig. 38 Coupons as Machined (2.2X)

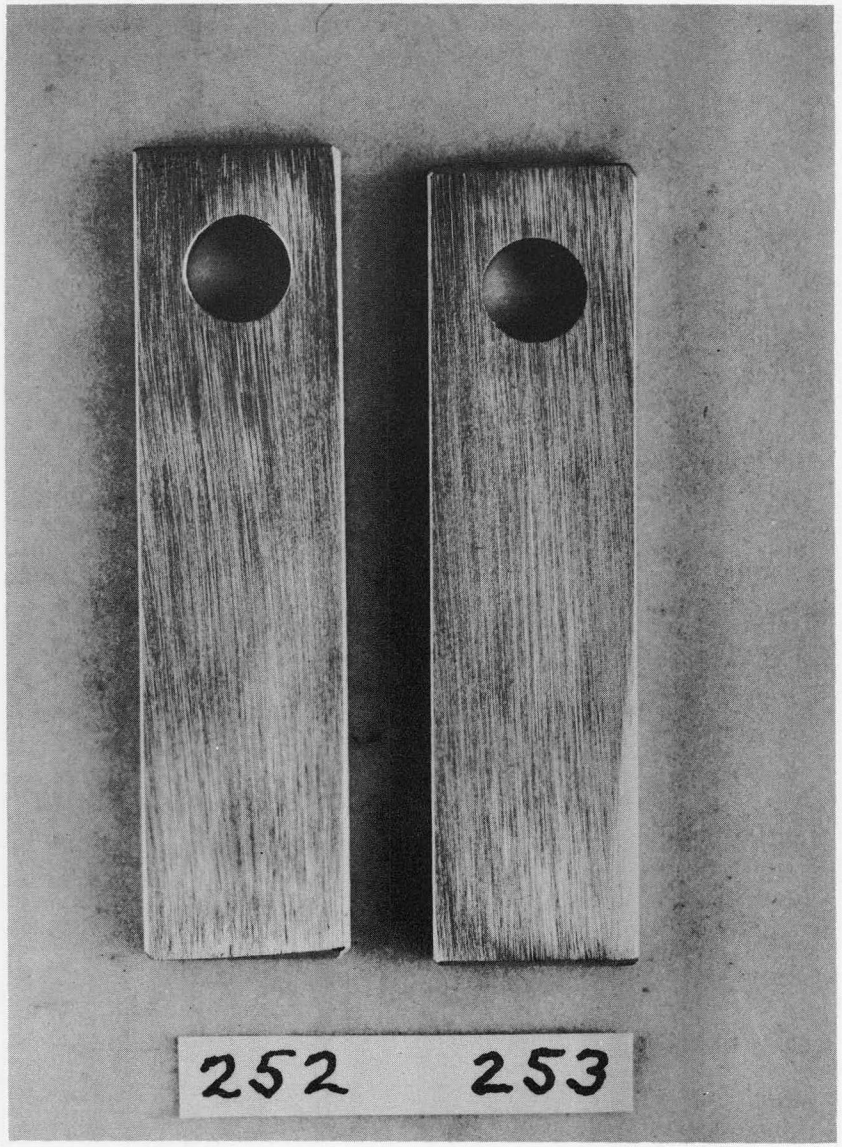

Fig. 39 Coupons as Machined (2.2X)

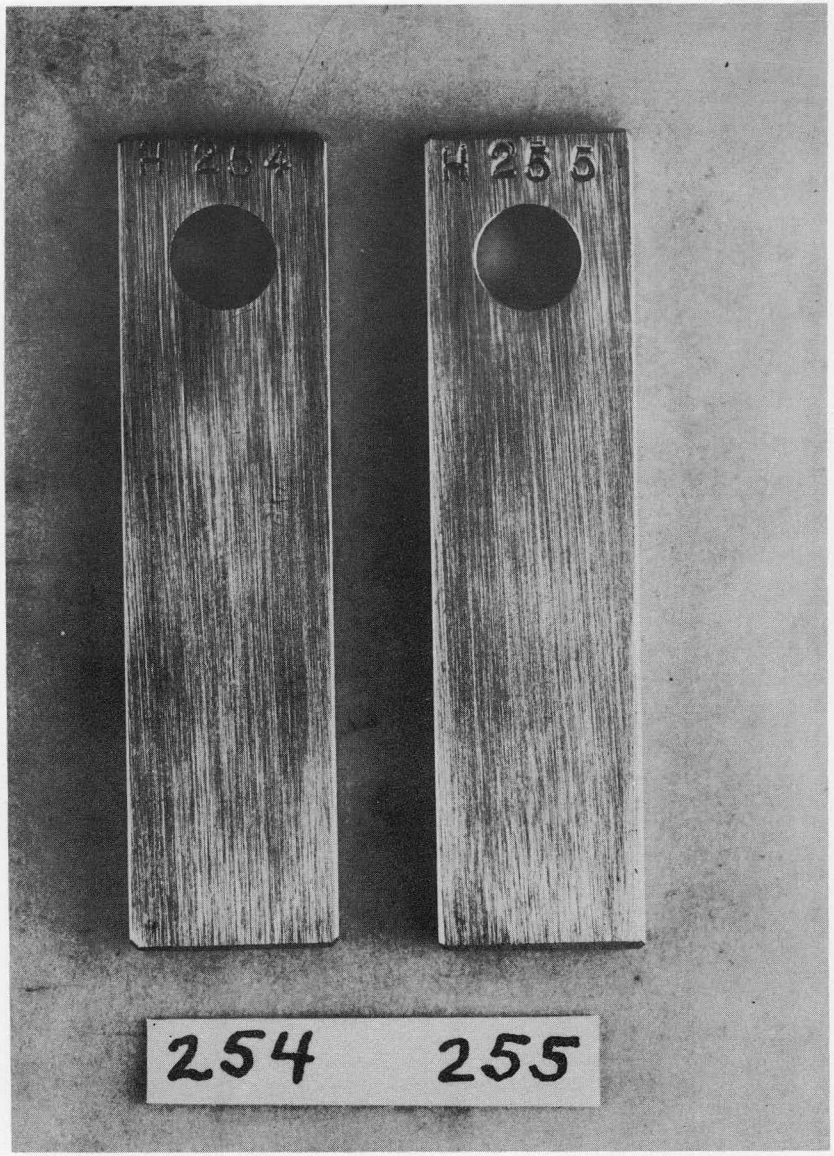

Fig. 40 Coupons as Machined (2.2X)

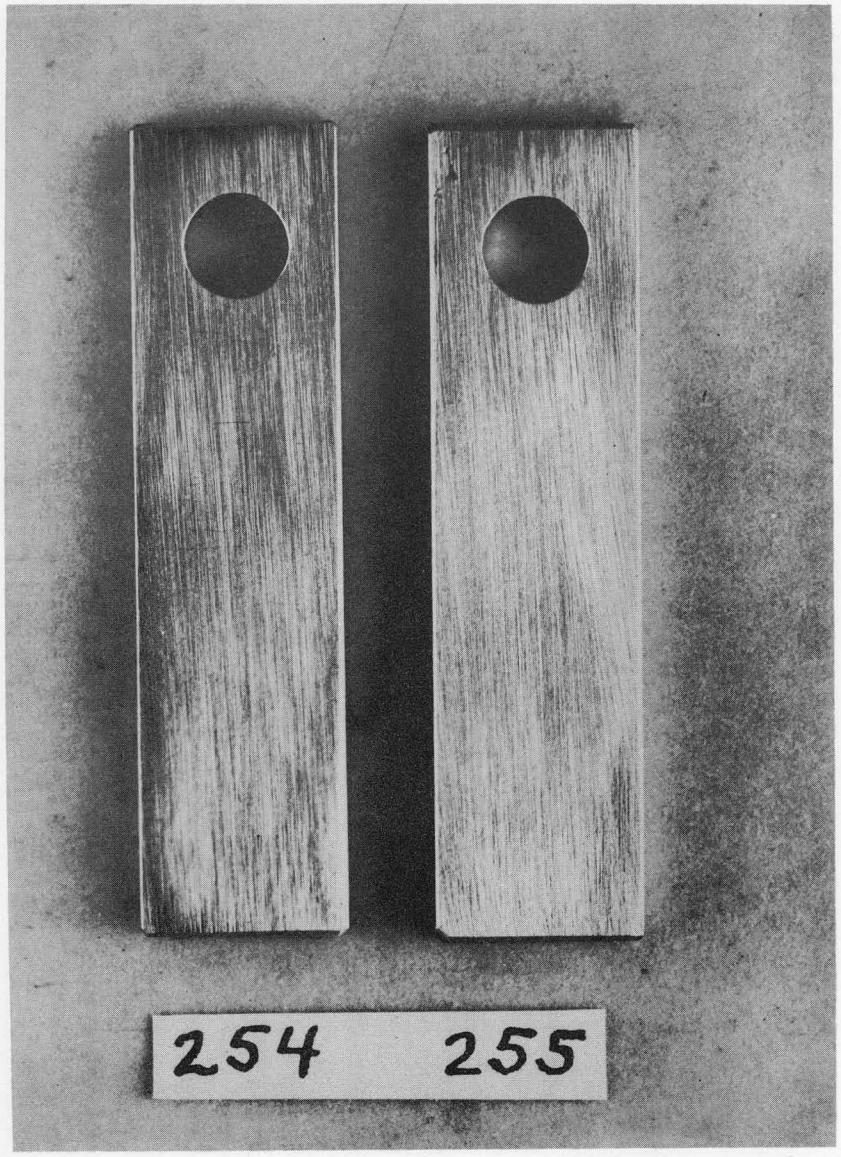

Fig. 41 Coupons as Machined (2.2X)

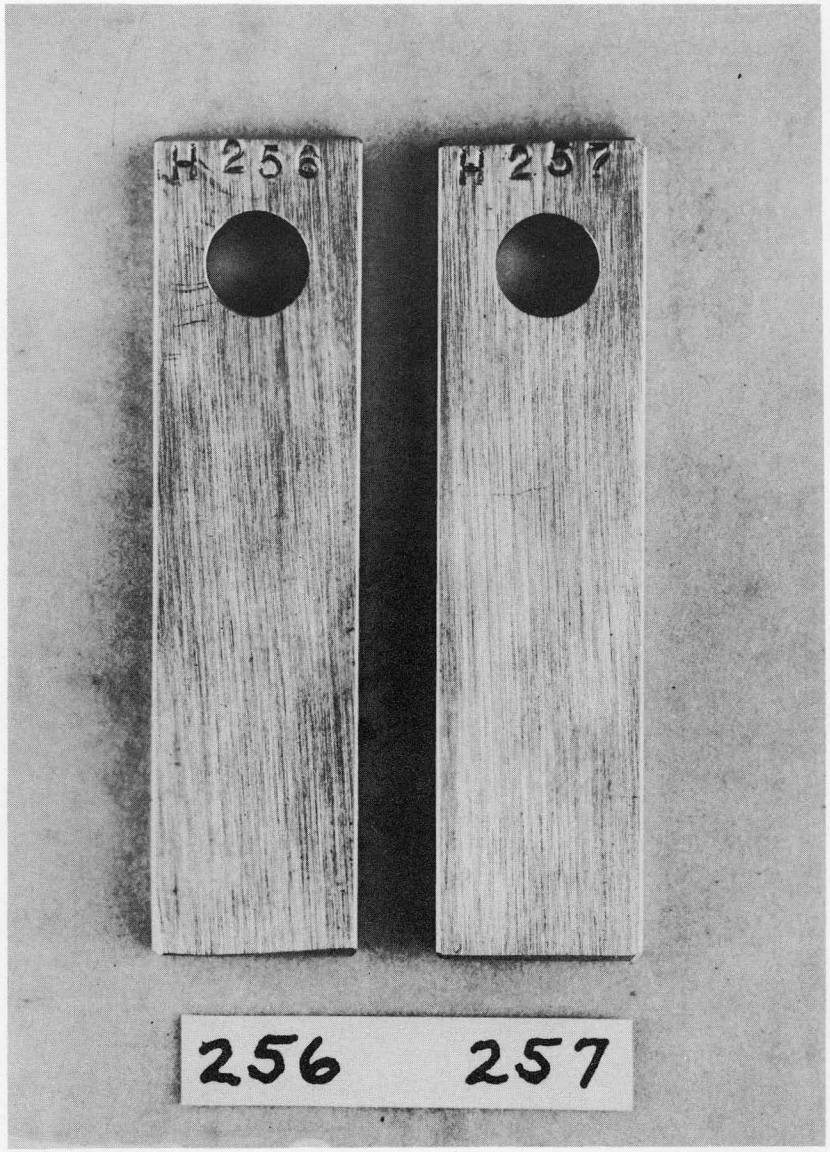

Fig. 42 Coupons as Machined (2.2X)

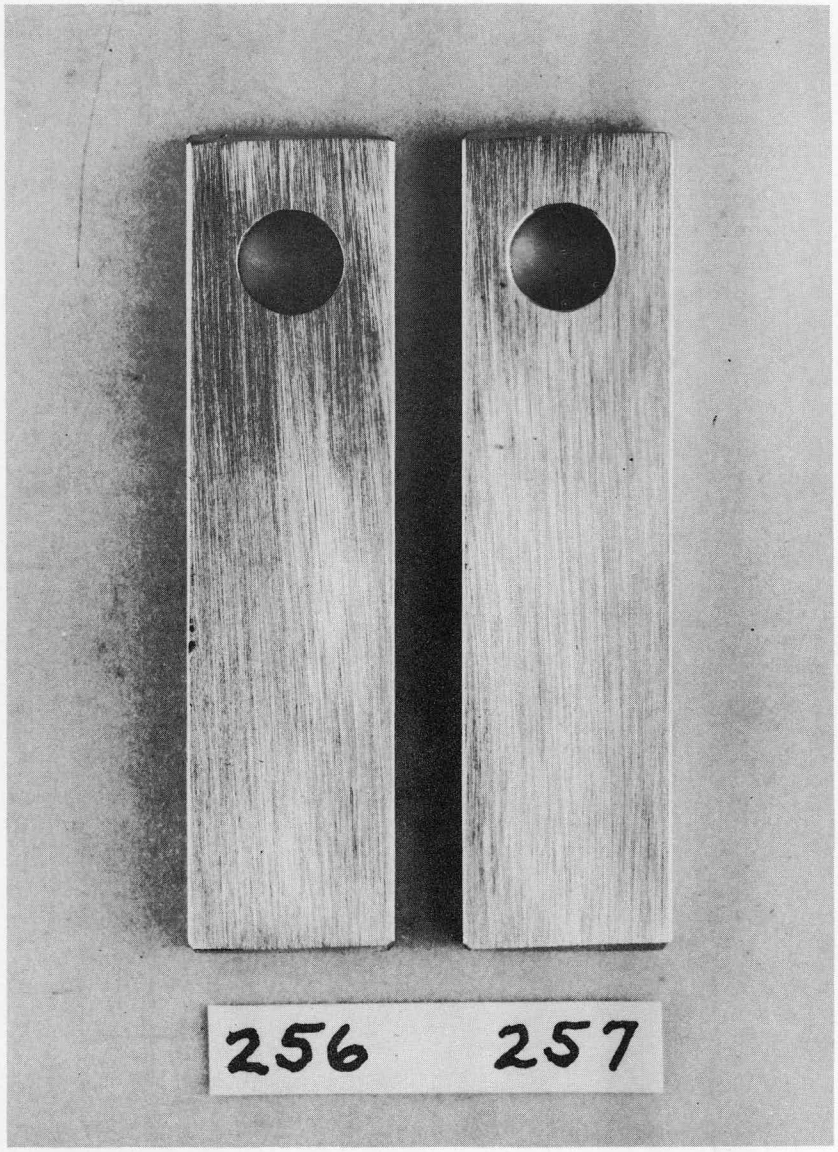

Fig. 43 Coupons as Machined (2.2X)

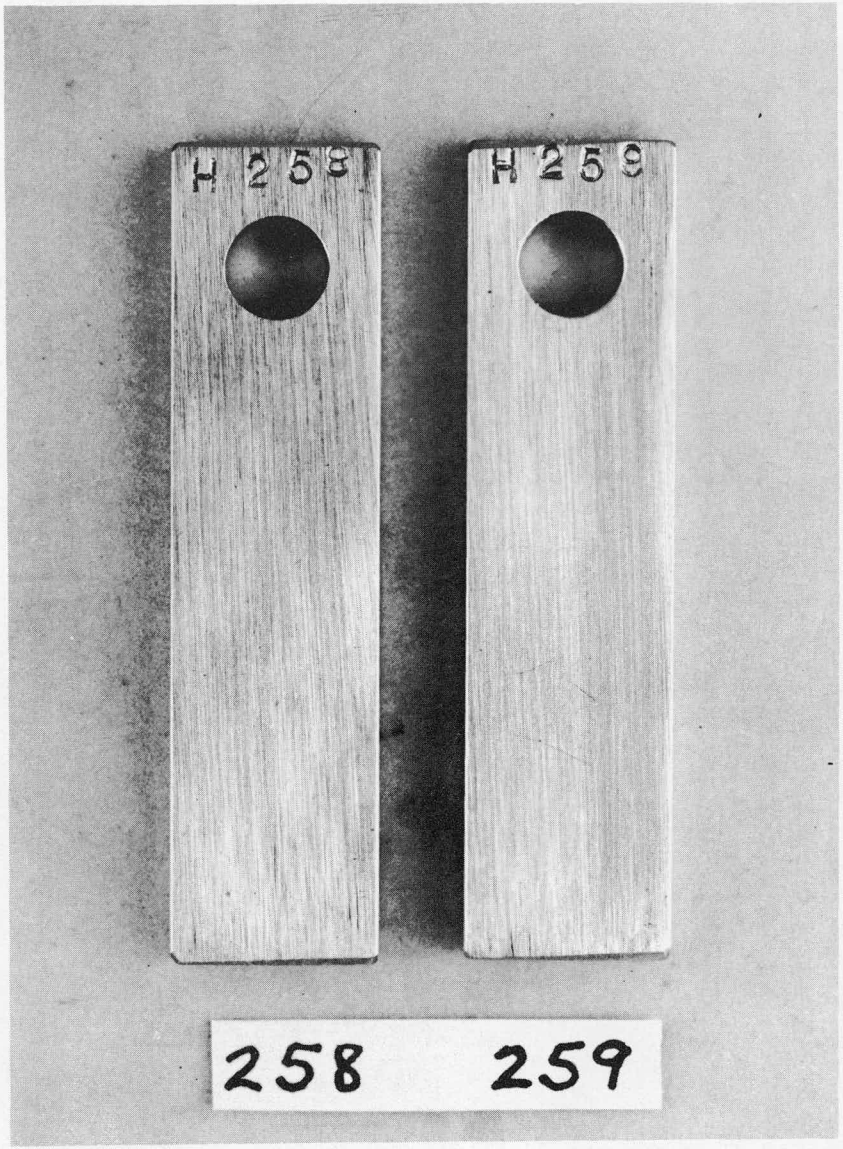

Fig. 44 Coupons as Machined (2.2X)

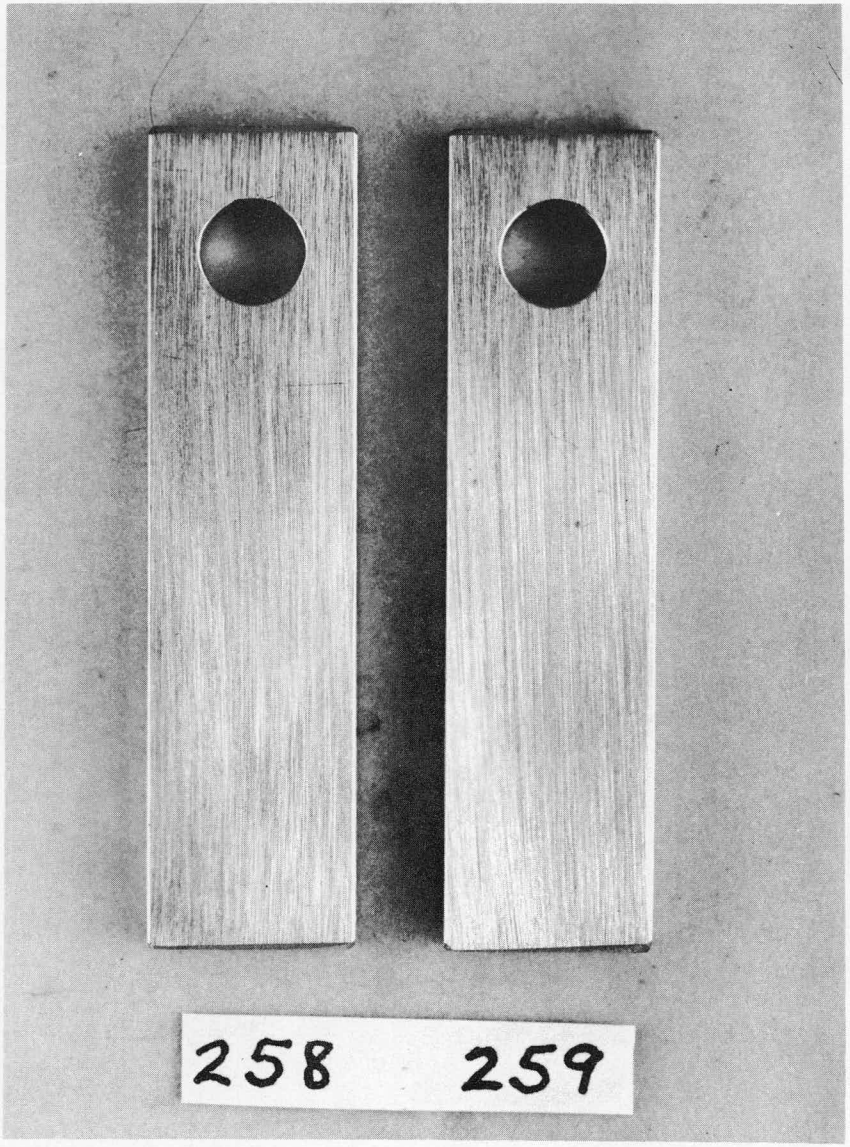

Fig. 45 Coupons as Machined (2.2X)

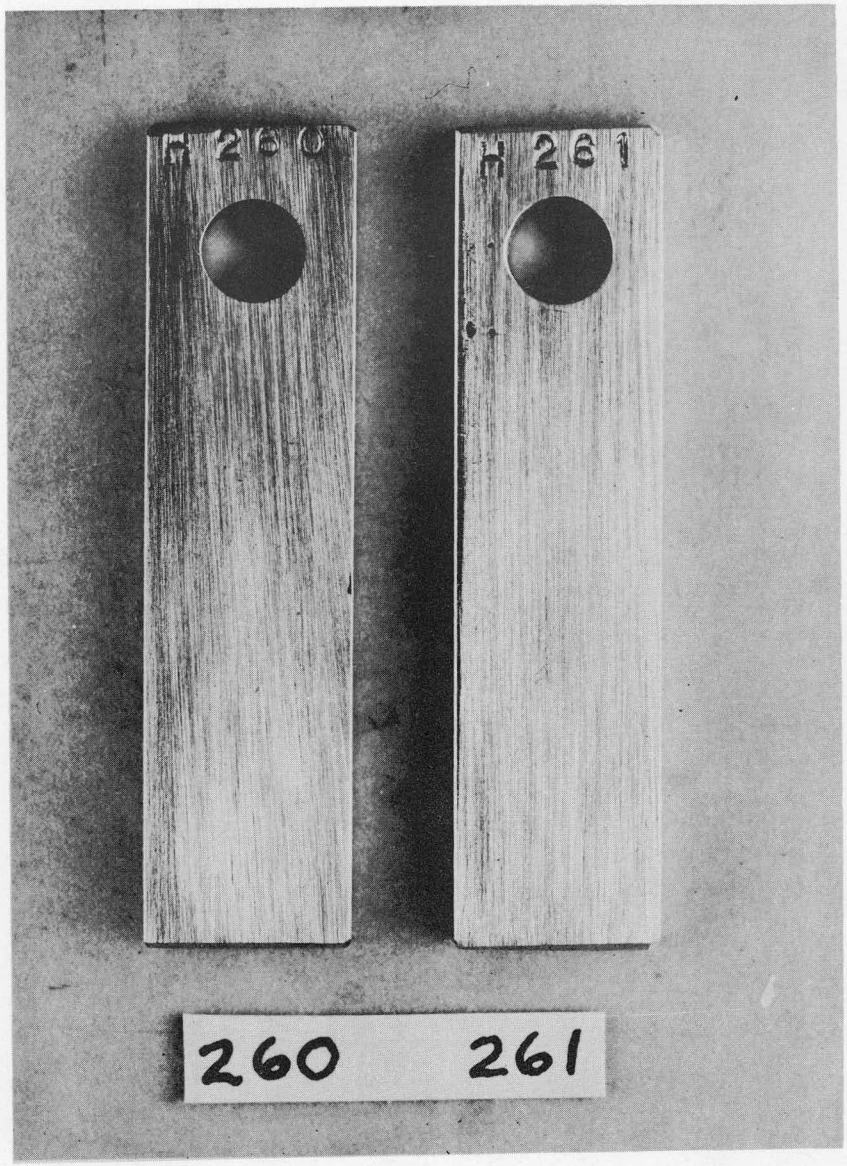

Fig. 46 Coupons as Machined (2.2X)

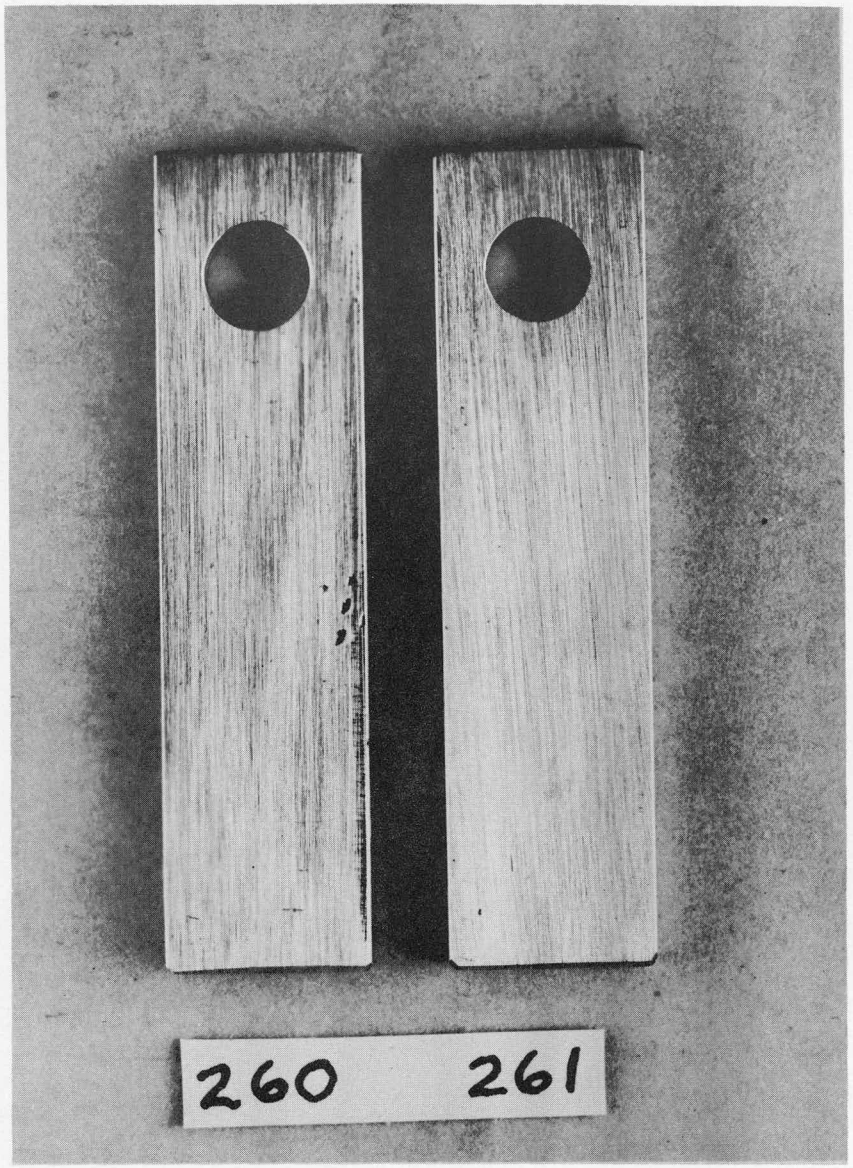

Fig. 47 Coupons as Machined (2.2X)

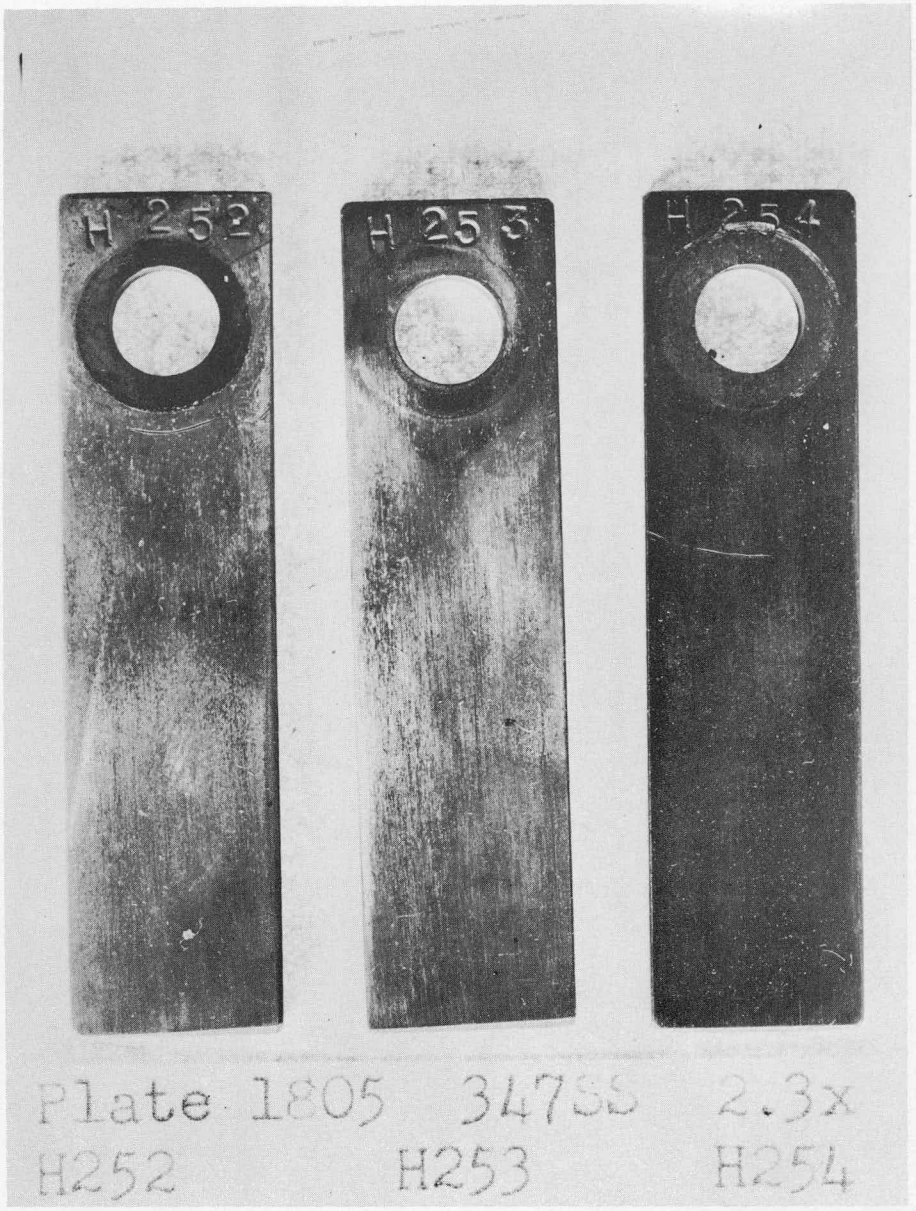

Fig. 48 Coupons Defilmed (2.3X)

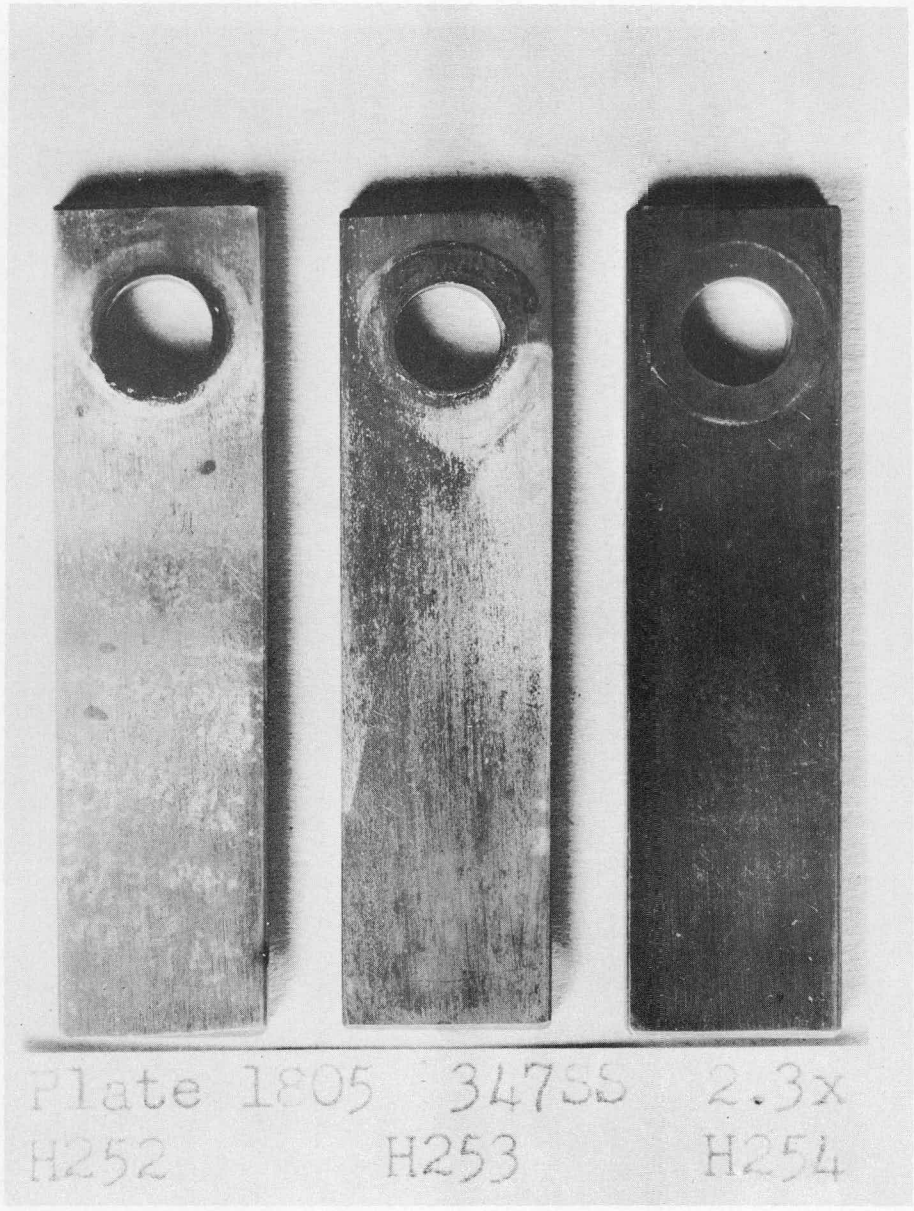

Fig. 49 Coupons Defilmed (2.3X)

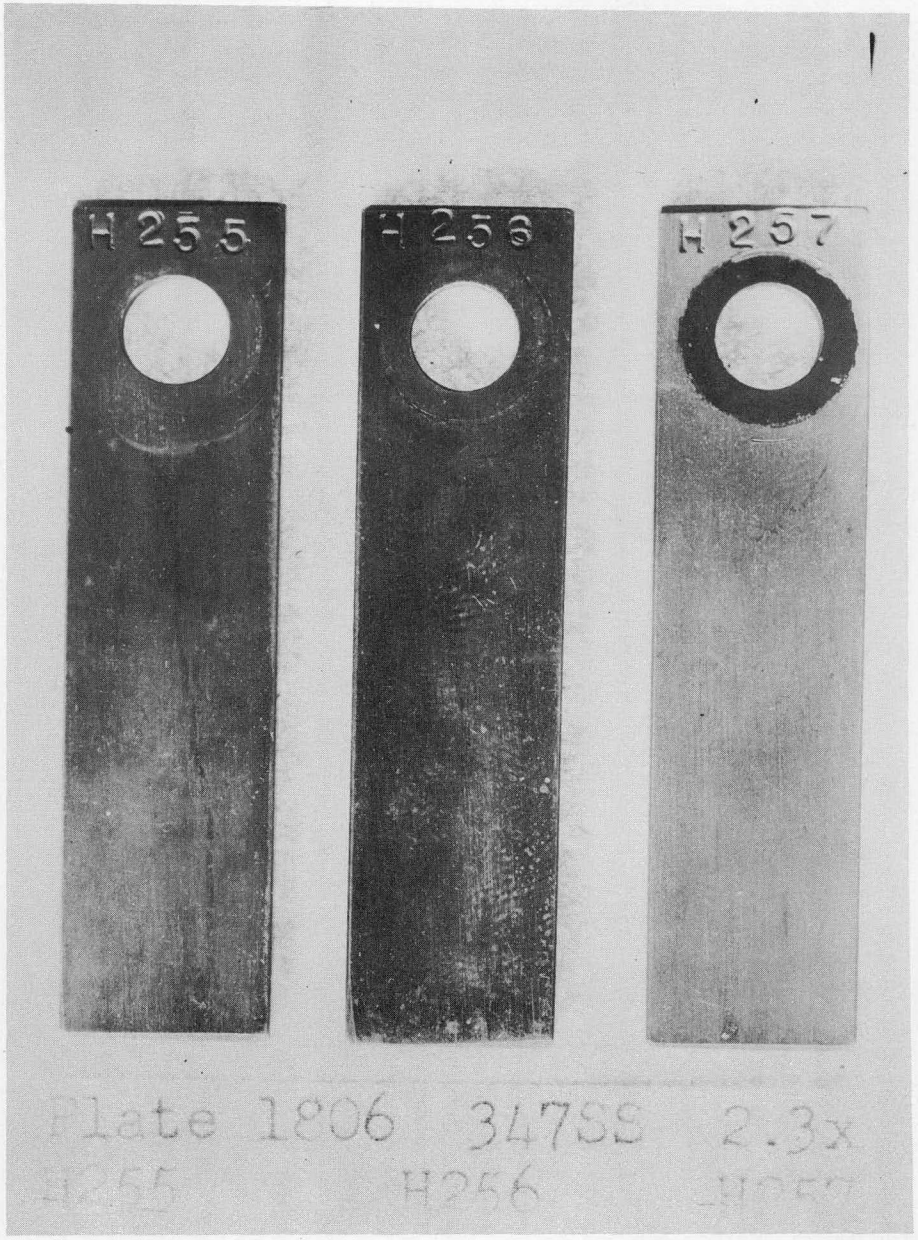

Fig. 50 Coupons Defilmed (2.3X)

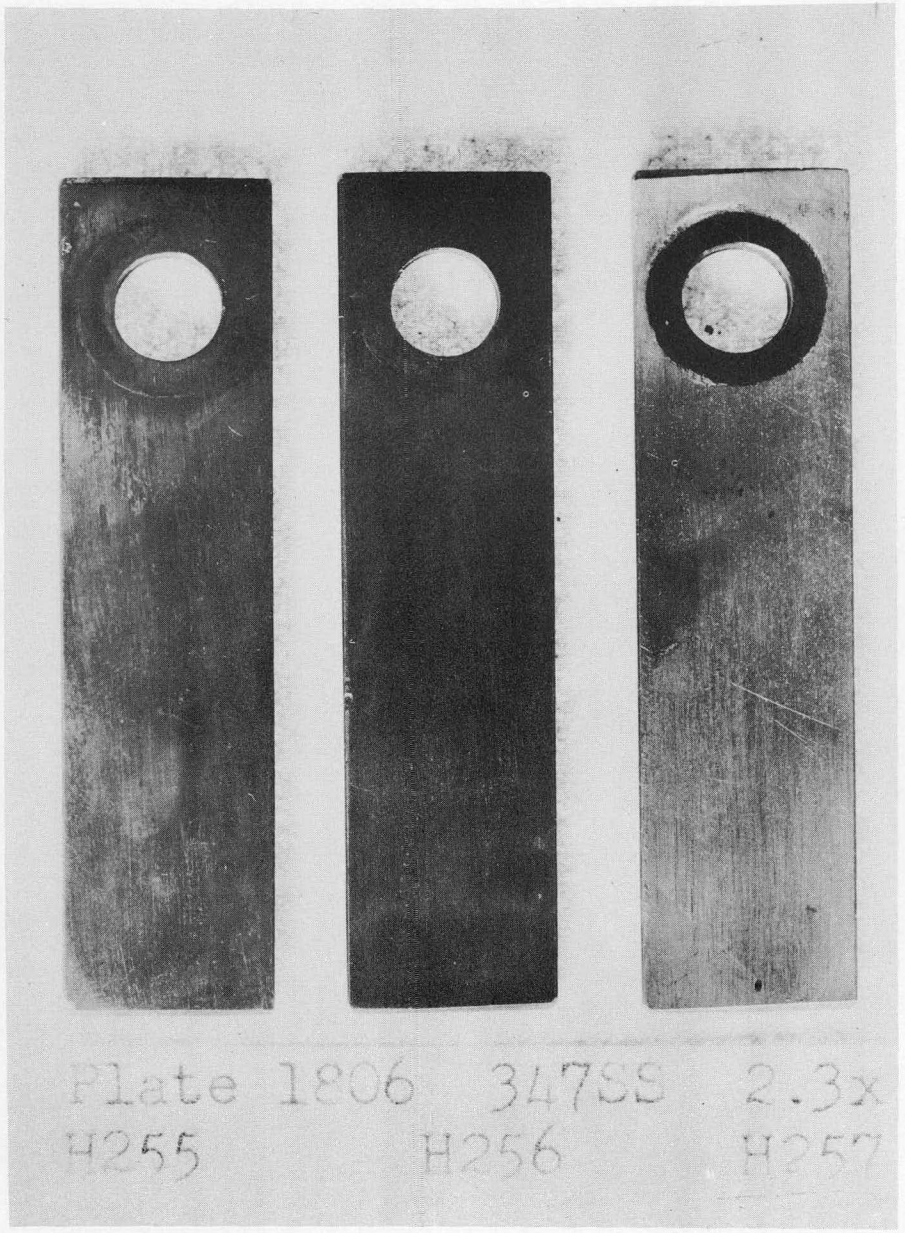

Fig. 51 Coupons Defilmed (2.3X)

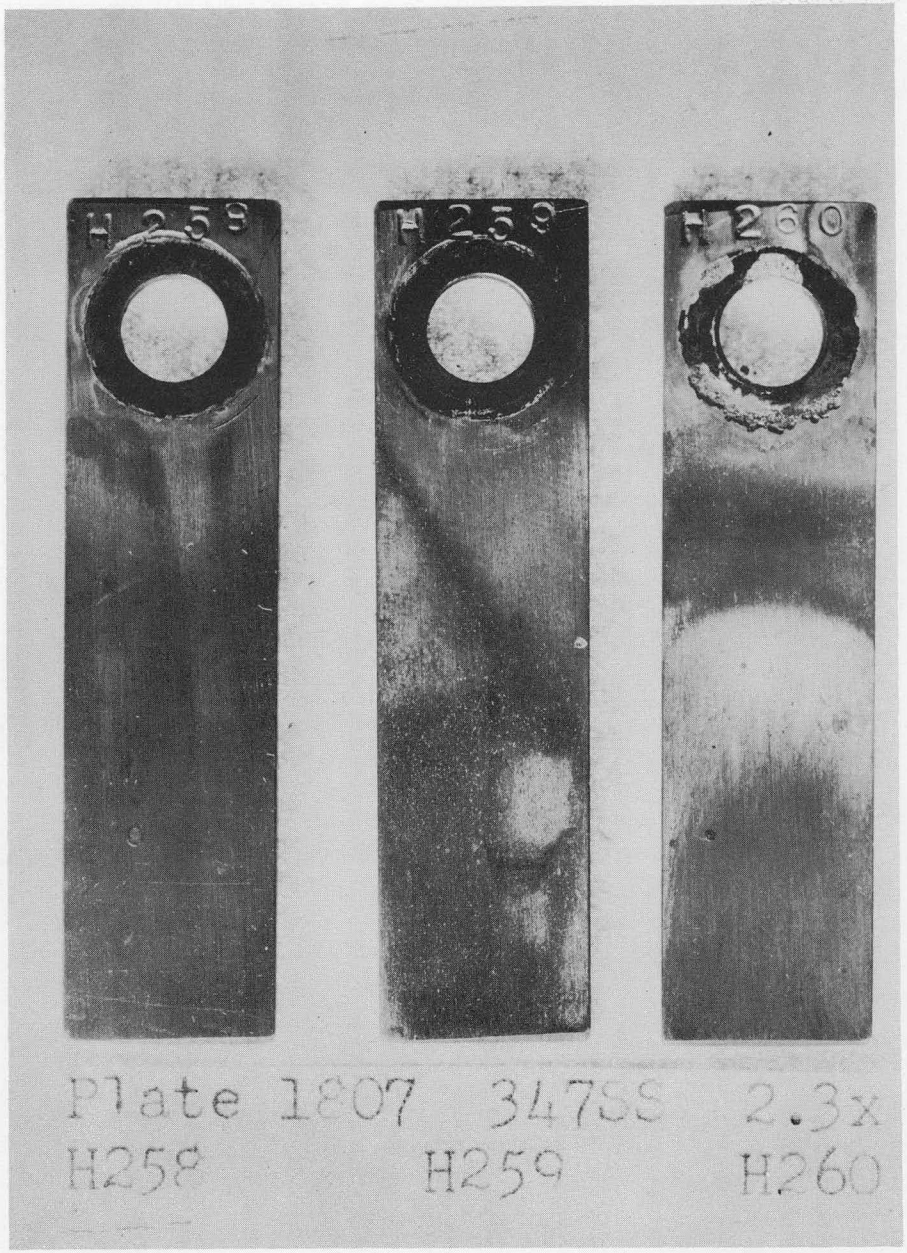

Fig. 52 Coupons Defilmed (2.3X)

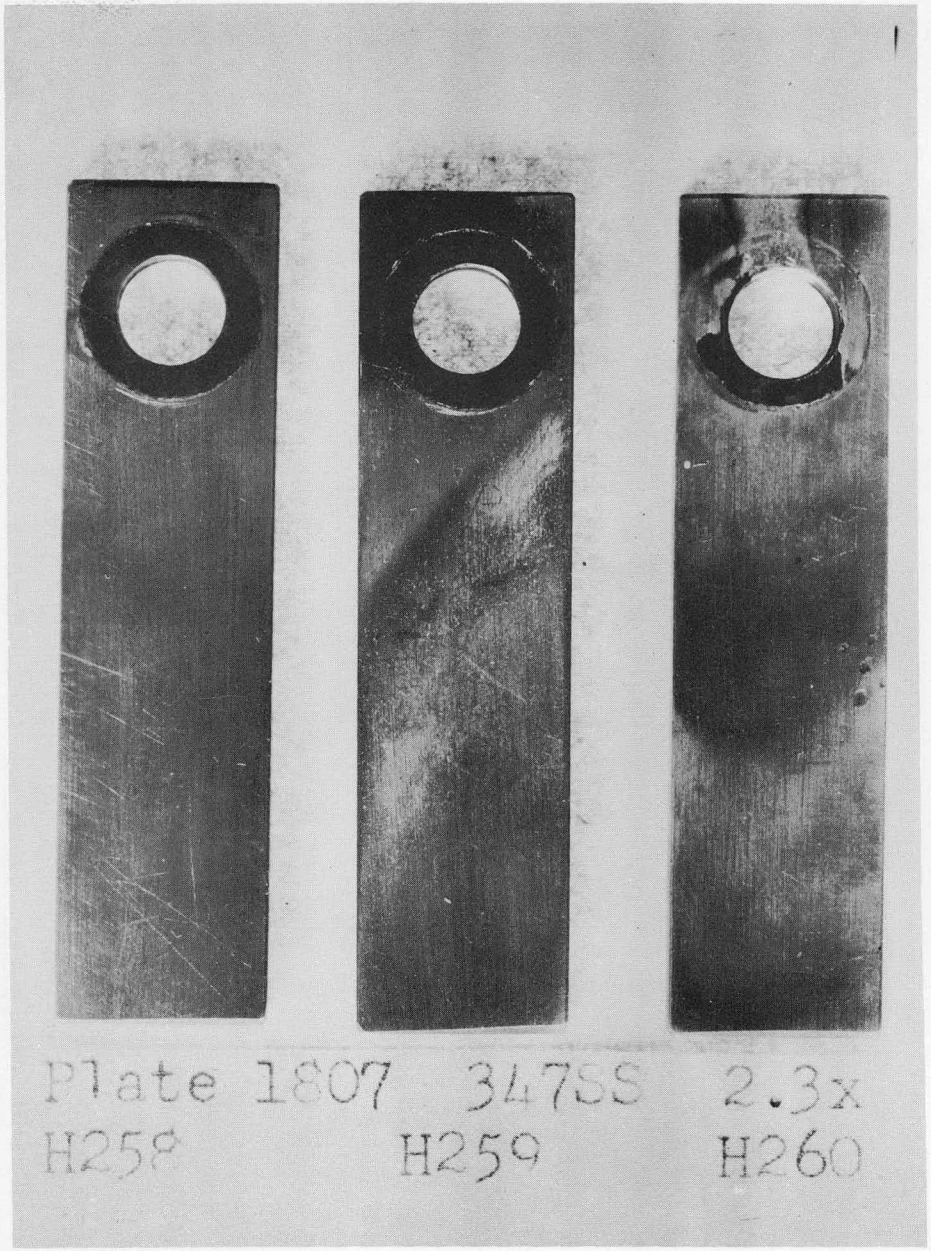

Fig. 53 Coupons Defilmed (2.3X)

Fig. 55 Feed Stream Pipe Pitted Area 11 ft from Outlet (Hot) End (15X)

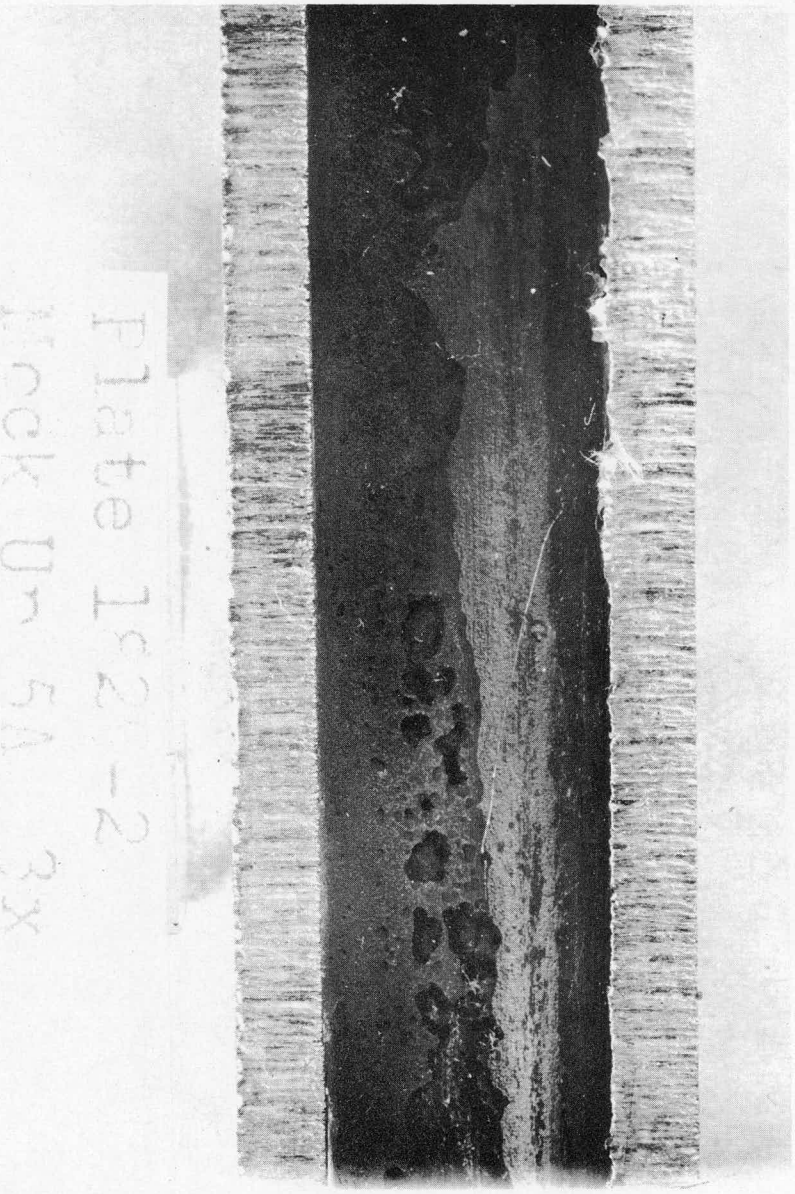

Fig. 54 Feed Stream Pipe Pitted Area 11 ft from Outlet (Hot) End (3X)

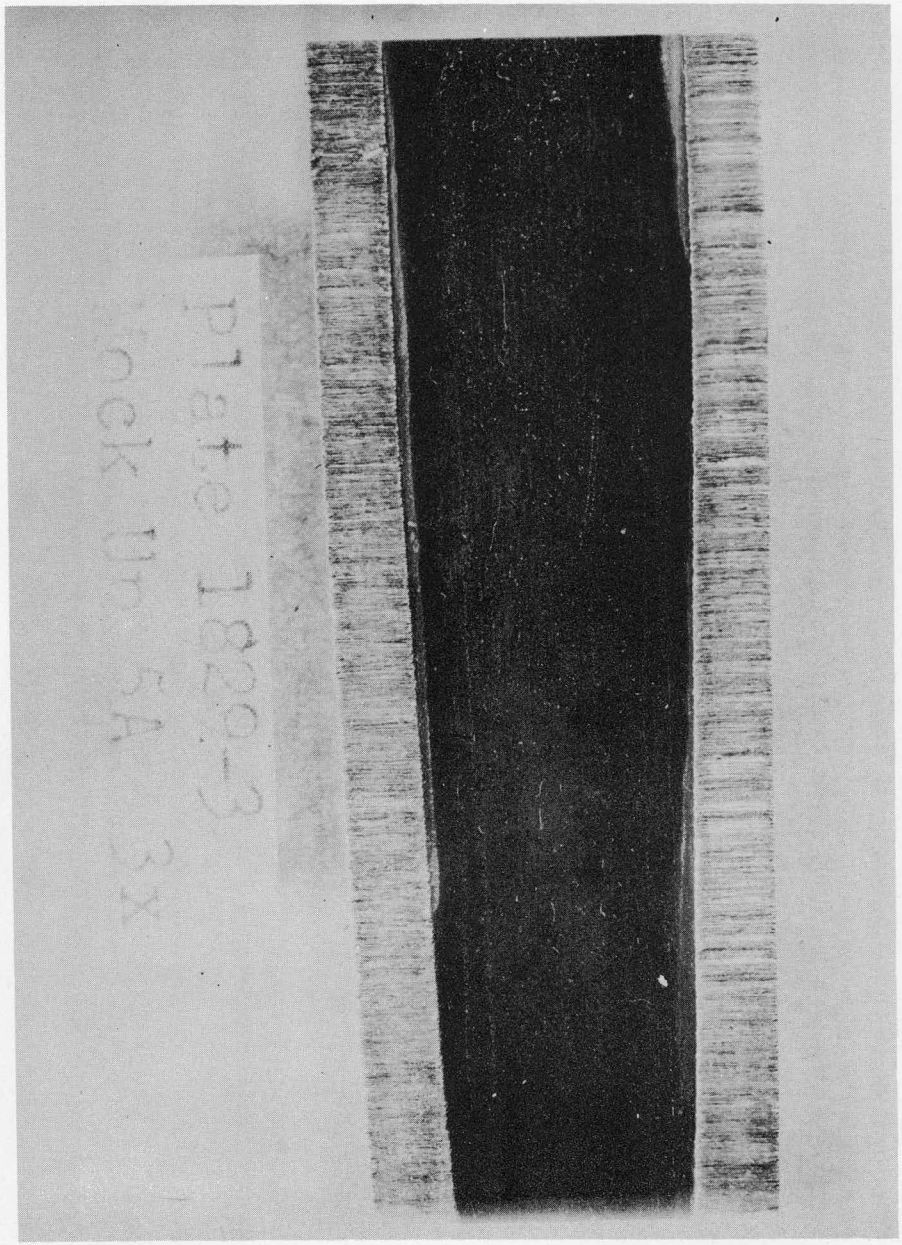

Fig. 57 Feed Stream Pipe Area 6 in. Upstream from Weld. 14-1/2 ft from Outlet (Hot) End. (3X)

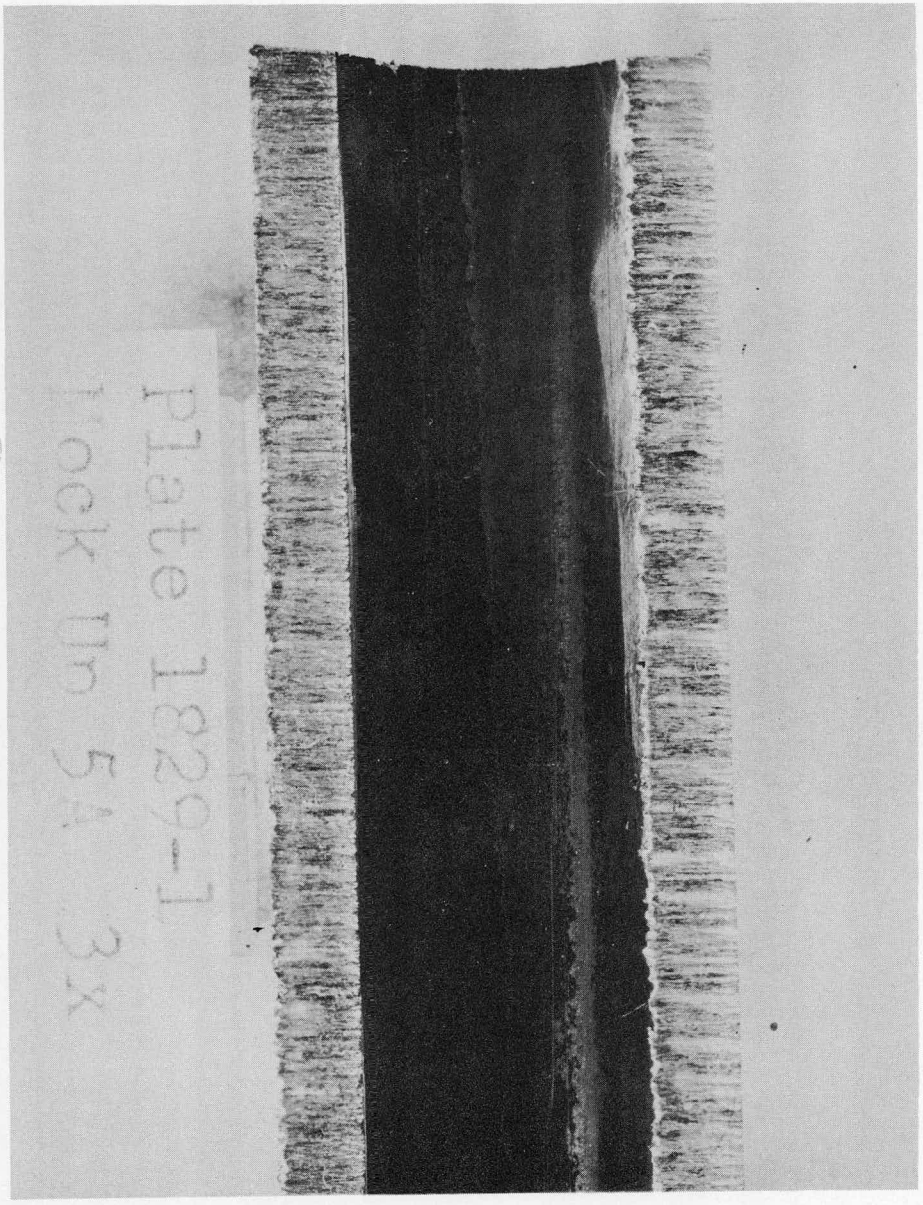

Fig. 56 Feed Stream Pipe 6 in. Downstream from Pitted Area. 12 ft from Outlet (Hot) End. (3X)

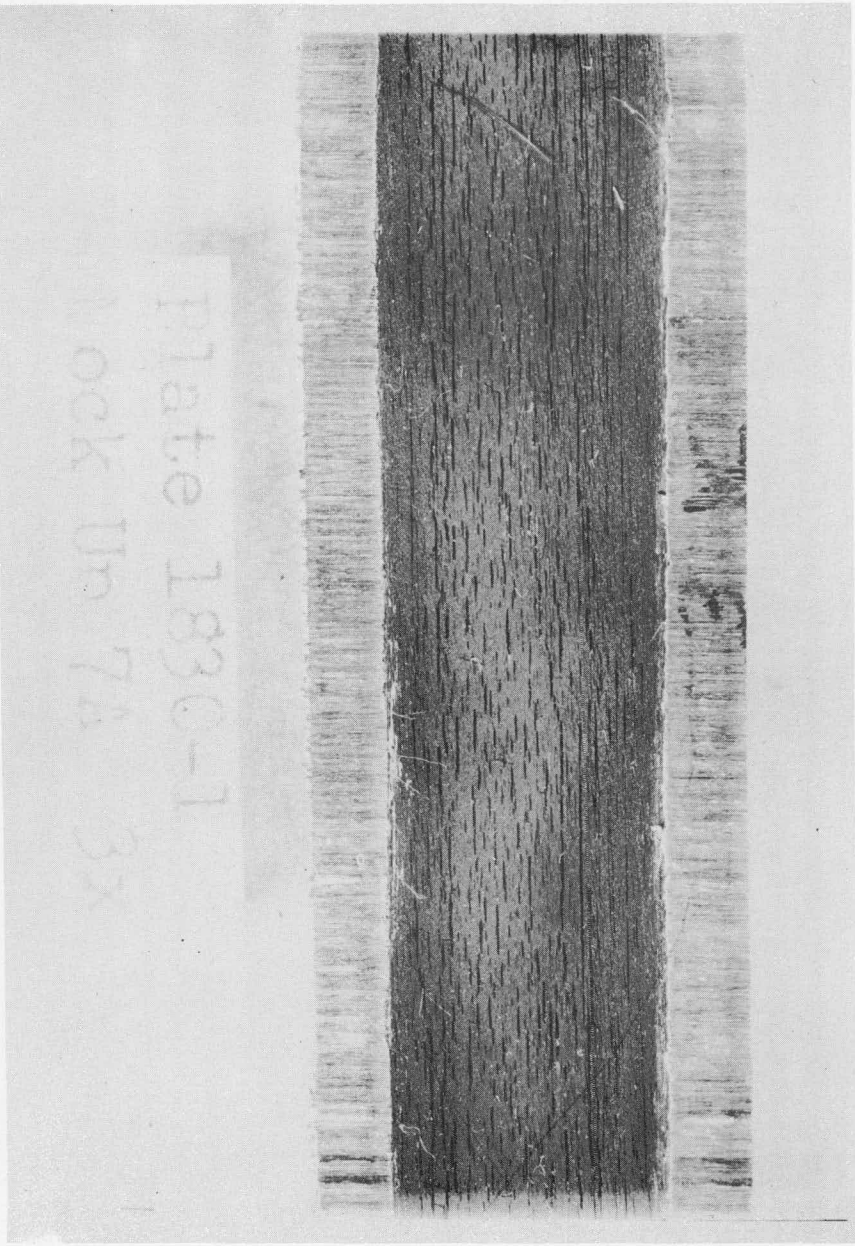

Fig. 59 Feed Stream Pipe Downstream from Weld. 16 ft from Outlet (Hot) End. (3X)

Fig. 58 Feed Stream Pipe Downstream from Weld. 15-1/2 ft from Outlet (Hot) End. (15X)

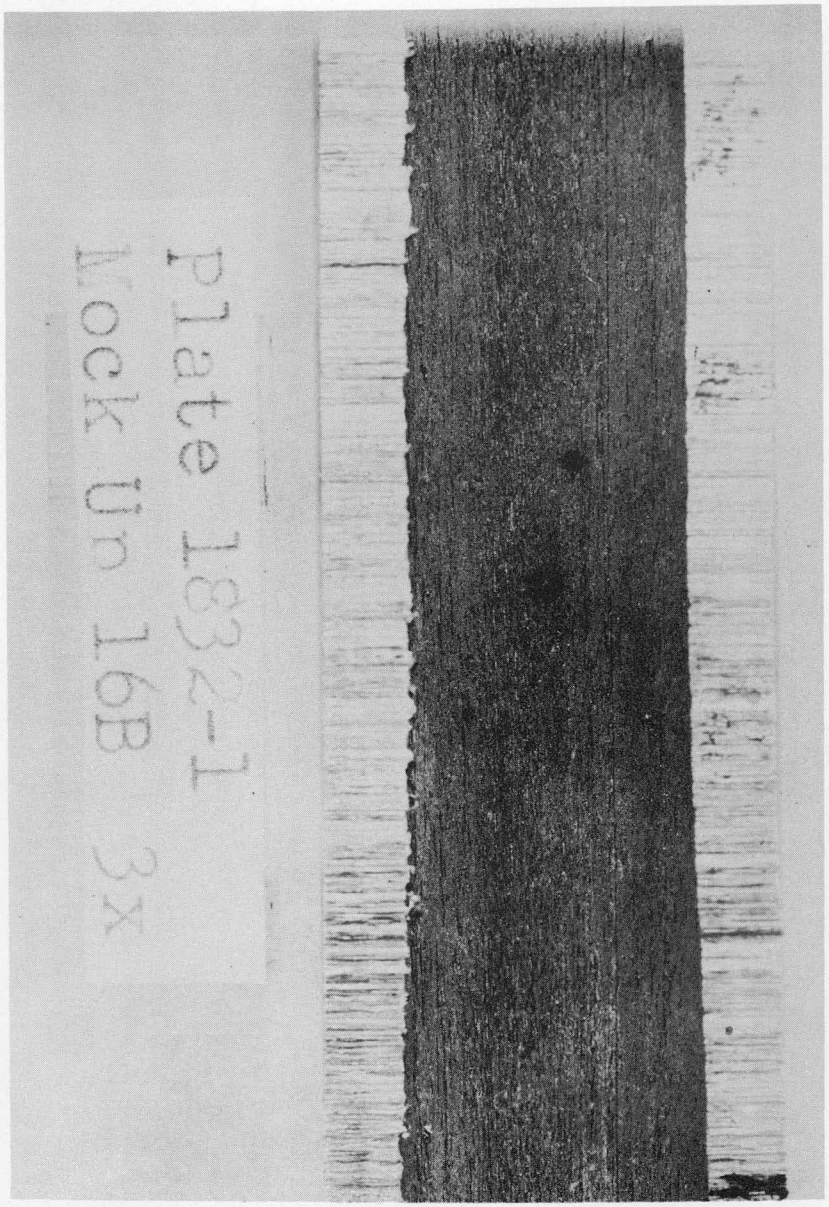

Fig. 60 Feed Stream Pipe Area 31 ft from Outlet (Hot) End. (3X)

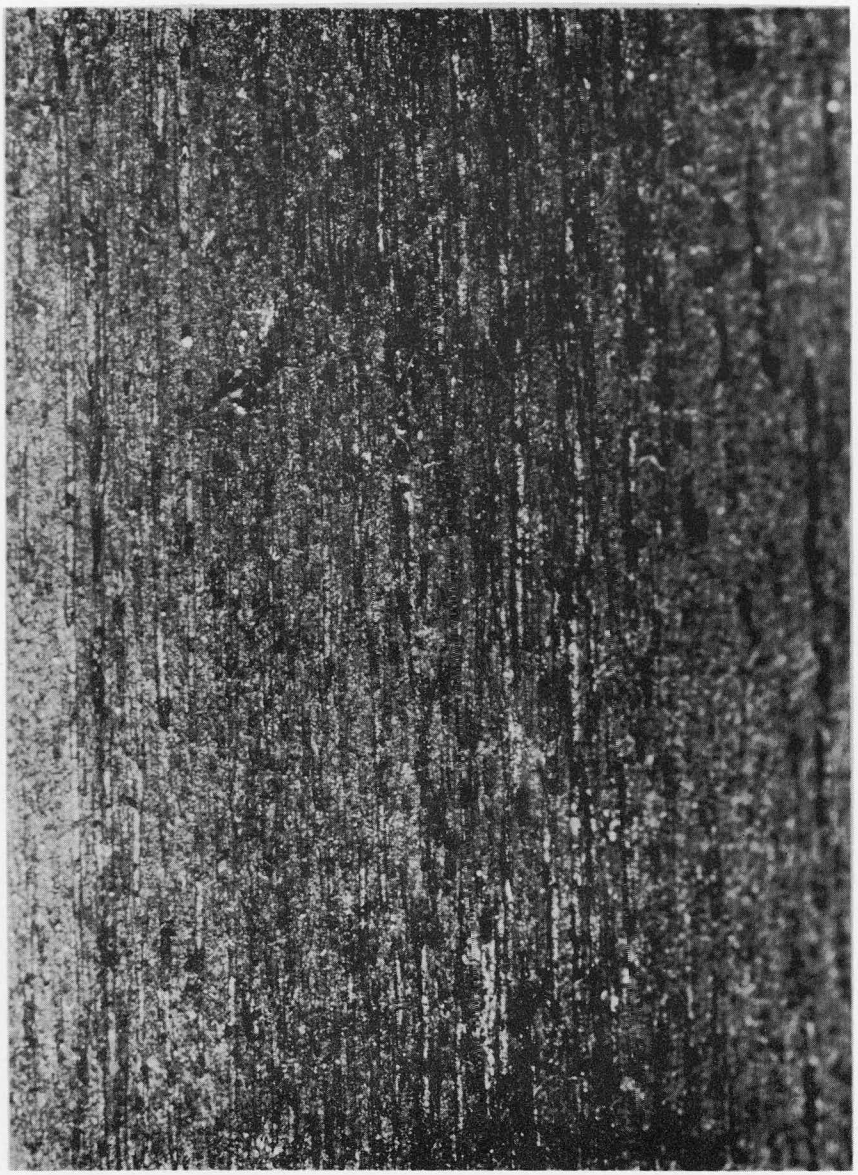

Fig. 61 Feed Stream Pipe Area 31 ft from Outlet (Hot) End. (15X)

48

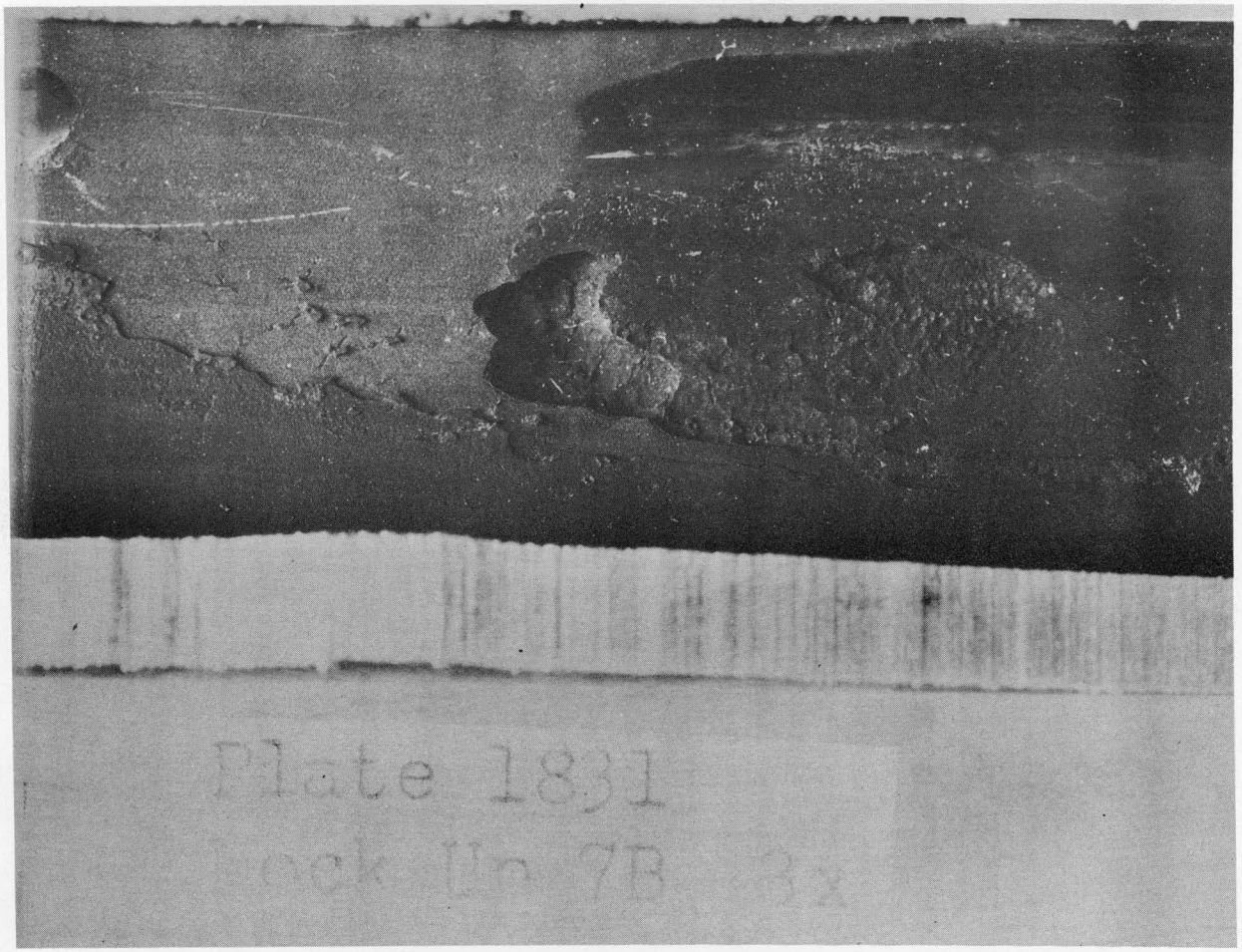

Fig. 62 Letdown Stream Pipe. 14-1/2 ft from Letdown Stream Inlet (Hot) End. (3X)

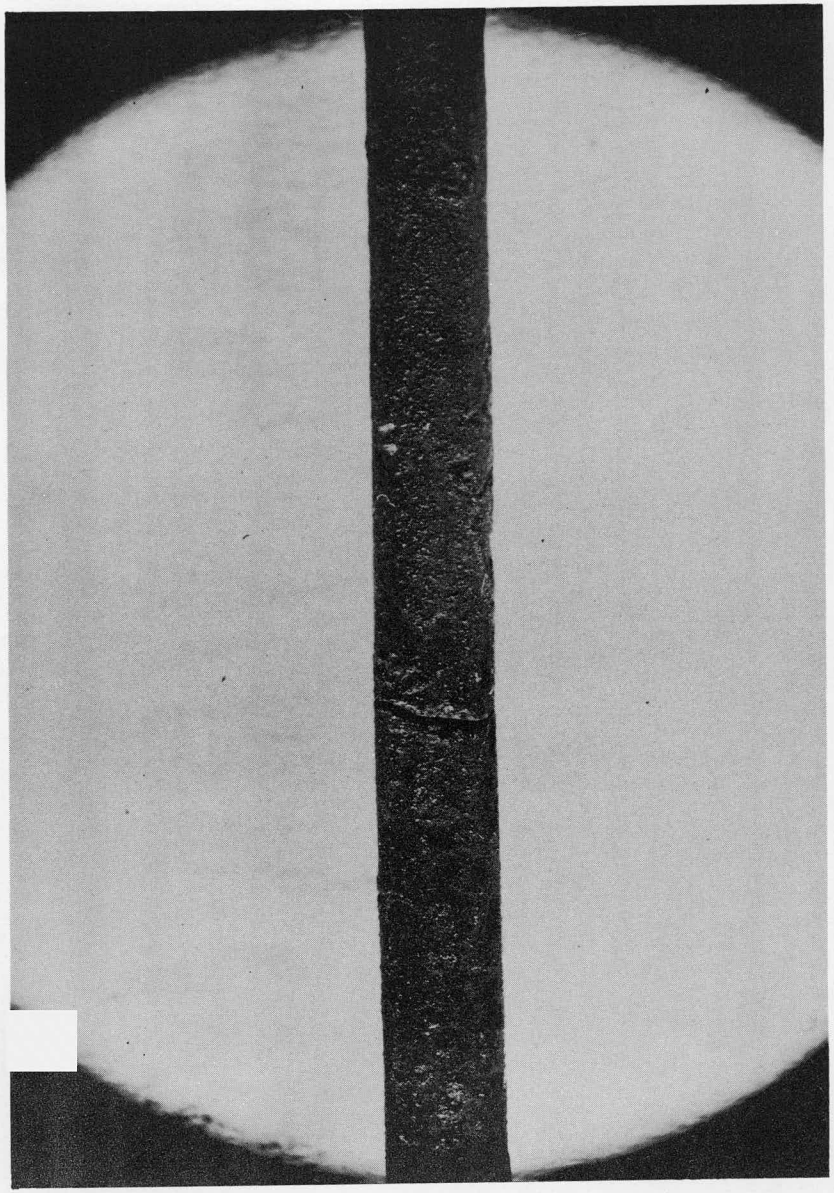

Fig. 63 Corrosion Wire from Feed Stream Pipe. Crack 7 ft 3 in. from Outlet (Hot) End. (5X)

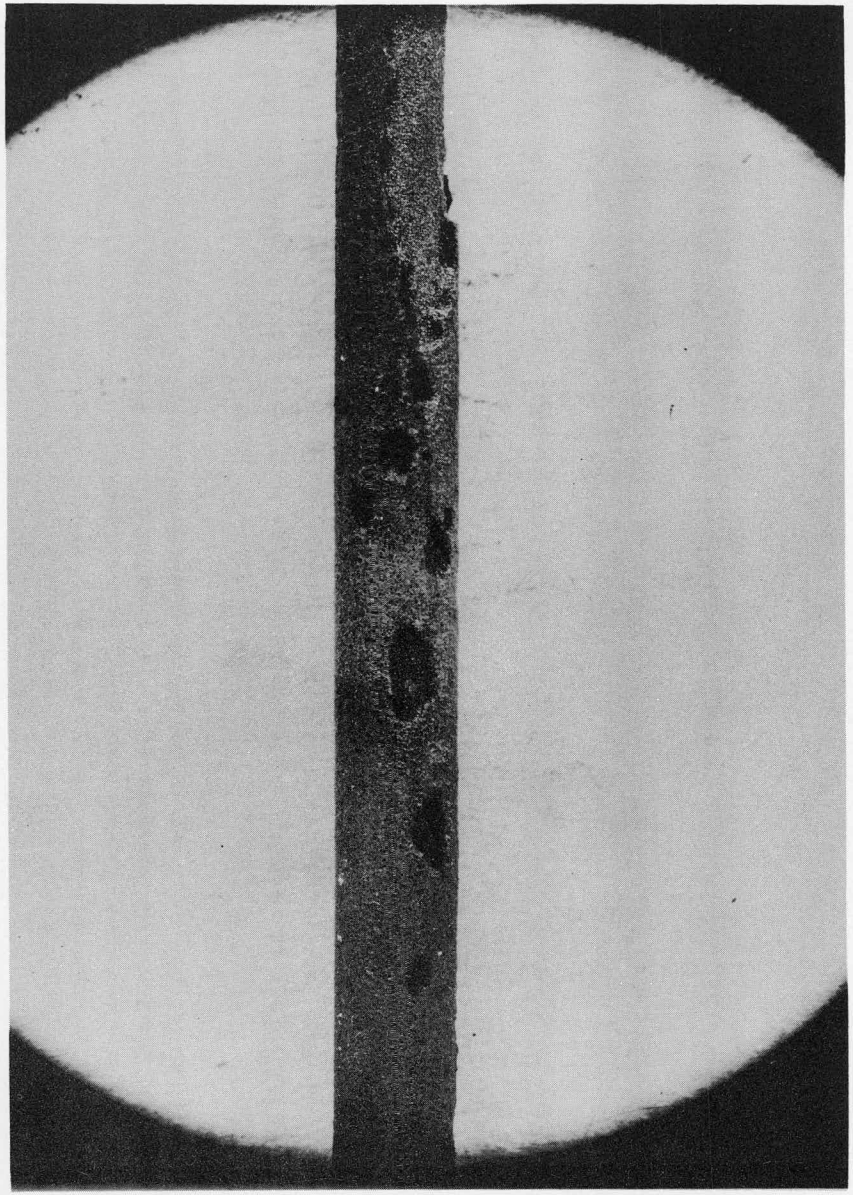

Fig. 64 Corrosion Wire from Feed Stream Pipe. Pitted Area 7-1/2 ft from Outlet (Hot) End. (5X)