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DATE: June 3, 1958

SUBJECT: Metallographic Examination of Components and Coupons from HRP In-Pile Loop L-2-19

TO: A. R. Olsen

FROM: A. E. Richt

DISCLAIMER

Intra-Laboratory Correspondence
OAK RIDGE NATIONAL LABORATORY
Solid State Division

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Introduction

Metallographic examination of representative components and coupons from HRP In-Pile Loop L-2-19 has been requested. This loop operated for a total of 1149 hours at 280°C in beam hole HB-2 of the LITR during which period the reactor logged 2705 Mwhr of operation.

Specimens from the loop components which were examined included sections from the nose of the core cap, pump outlet piping, pressurizer body, pressurizer heater lines, the sampler line capillary tubing, impeller shaft, and the thermal barrier. In addition, the following corrosion coupons were examined: SA-1607, SA-1610; SA-1615, SA-1620, SA-25 (347 S.S.); SMA-1, SMA-4, SMS-1, SMS-3 (304L S.S.); SL-75, SL-78 (430L S.S.); ZB-46, ZB-49, ZB-74, ZB-2, ZNN-2, ZNN-6 (Zircaloy II); ZZ-1, ZZ-4 (Xytl Bar Zr); TD-35, TD-43, TD-48 (Ti 110AT); and IN-2 (Incoloy). Ten stress specimens were also examined: SL-15, SL-16, SL-19, SL-20 (430L S.S.); TD-1, TD-2, TD-3, TD-4, TD-11, and TD-12 (Ti-110AT). Three corrosion coupons from In-Pile Autoclave L53Z-111 were also examined with this group of specimens: SS-111, SS-113, and SS-115 (347 S.S.).

Results

Examination of a section from the nose of the core cap revealed no evidence of corrosive attack (Fig. 1).

The surfaces of sections from the loop pressurizer body showed slight general corrosive attack at the grain boundaries on areas exposed to the vapor phase of the fuel solution (Fig. 2). Sections exposed to the fuel solution proper showed only slight general surface roughening (Fig. 3). Of particular interest is the absence of surface scale on sections from the vapor phase of the pressurizer and the peculiar "needlelike" oxide on surfaces below the liquid level.

A section of the loop piping at the pump outlet showed no evidence of corrosive attack or oxide scale formation (Fig. 4).

Sections from the pressurizer heater lines showed evidence of radial cracking such as noted in previous loops. A thin oxide scale formation on all interior surfaces with only slight general surface roughening was noted (Fig. 5).

Sections from the sampler line capillary tubing showed rather severe intergranular attack to a depth of 3-4 mils in the region within 1/4" of the pump outlet piping junction (Fig. 6). The interior surface of the capillary tubing was covered with a heavy (1 - 1-1/2 mil) oxide scale. The line itself appeared to be plugged by an oxide "wall" in the region of heaviest intergranular attack. The oxide "plug" is shown by the "open" arrow and an area showing a peculiar intergranular oxide formation of the capillary tubing material is indicated by the solid arrow. Sections slightly ($<$1/8") beyond this oxide "plug" showed only slight general surface

roughening (Fig. 7). Large spherical oxide deposits were also found inside the tubing (Fig. 8). It will be noted that they appear to consist of a lighter-colored, porous inner sphere coated with a darker, more dense outer scale.

Sections from both the impeller shaft and the thermal barrier showed heavy corrosive attack in a rather restricted region. Maximum depth of attack noted on the impeller shaft is estimated at 12 mils, and occurred in an abrupt manner toward one end of the shaft (Fig. 9). Sections from the thermal barrier also showed a similar type of attack in the most heavily corroded region (Fig. 10); however, the transition region between this area and areas showing no attack was characterized by a pitting type of attack such as shown in Fig. 11.

The new physical shape of the corrosion coupons caused numerous difficulties in remote handling and mounting of the specimens for metallographic examination. The first three groups of coupons from this series of specimens were sectioned too deeply, and, as a result, examination and dimensional measurements of the ears of these groups were not possible.

As would be expected from the weight loss data, corrosive attack on the 347 S. S. coupons varied from a heavy pitting type of attack on coupon SA-1607 (Fig. 12) to only slight general surface roughening on coupon SA-1620 (Fig. 13).

Examination of the 304L S.S. coupons revealed no evidence of localized attack for either the annealed or the sensitized specimens. The typical appearance of two of these specimens is shown in Fig. 14.

Coupons SL-75 and SL-78 showed no evidence of corrosive attack.

Coupons of the zircaloy-2 and zirconium types showed no evidence of localized attack. Typical examples of the surfaces of these coupons are shown in Figs. 15, 16, and 17.

All surfaces of the Ti-110AT specimens were smooth and even with no evidence of corrosive attack. The submitted incoloy specimen showed slight general corrosive attack near the center of the coupon (Fig. 18).

All 430L S.S. stress corrosion specimens exhibited severe localized corrosive attack at both ends and beneath the fulcrum of the specimen. A typical example of this attack is shown in Fig. 19, at the end of specimen SL-20. Maximum depth of attack was 13 mils and was characterized by a heavy scale formation on all corroded areas. Attack at the fulcrum of the specimens was of a similar nature but much less intense (2 mils maximum). Strangely, the compression face opposite the heavily corroded ends of the specimen also showed a similar, but less intense, type of corrosive attack. This was not true of the tension face opposite the fulcrum or at the exposed ends of the specimen. Except for these areas of localized attack, the remaining surfaces of the coupons were smooth and even with no evidence of corrosive attack (Fig. 20).

All surfaces of the Ti-110AT stress corrosion specimens were smooth and even, showing no evidence of corrosive attack (Fig. 21).

Corrosion coupons from the in-pile autoclave L53Z-111 showed long "canal-like" pits, however, metallographic examination of these specimens revealed no abnormal structure which could account for such a type of attack.

A summary of dimensional measurements and metallographic results is given in Tables I, II, and III.

TABLE I

Summary of Metallographic Examination of Loop L-2-19 Corrosion Coupons

Coupon No.	Mat'l	Calc.[1] Penetr.	Ear Thick. In.	Center Thick. In.	Ear Thick. In.	Surface Appearance
SA-1607	347 S.S.	3.29 mils	--	.057	--	Severe pitting attack (2 mils) on all exposed surfaces.
SA-1610	"	1.48	--	.056	--	Pitting attack (1 mil) on exposed surfaces.
SA-1615	"	Gain	--	.057	--	Slight general surface roughening.
SA-1620	"	Gain	--	.060	--	Slight general surface roughening.
SA-25	"	--	--	.058	--	Few small scattered pits on exposed surfaces.
SMA-1	304L S.S.	0.52	.057	.056	.057	Smooth, even - slight surface undulation.
SMA-4	"	Gain	.057	.057	.057	Smooth, even - no evidence of attack.
SMS-1	"	0.45	.061	.059	.061	Smooth, even - slight surface undulation.
SMS-3	"	Gain	.060	.059	.059	Smooth, even - no evidence of attack.
SL-75	430L S.S.	0.48	--	.060	--	Smooth, even - no evidence of attack.
SL-78	"	Gain	--	.058	--	Smooth, even - no evidence of attack.
ZB-46	Zr-2	1.05	--	.058	--	Smooth, even - slight surface undulation.
ZB-49	"	0.56	--	.059	--	Smooth, even - slight surface undulation.
ZB-74	"	Gain	--	.060	--	Smooth, even - no evidence of attack.
ZB-2	"	0.45	.057	.058	.059	Smooth, even - no evidence of attack.
ZNN-2	"	0.55	.058	.054	.060	Smooth, even - no evidence of attack.
ZNN-6	"	Gain	.060	.059	.061	Smooth, even - no evidence of attack.

(Continued)

TABLE I (Continued)

Summary of Metallographic Examination of Loop L-2-19 Corrosion Coupons

Coupon No.	Mat'l	Calc.[1] Penetr.	Ear Thick. In.	Center Thick. In.	Ear Thick. In.	Surface Appearance
ZZ-1	Xtyl Bar Zr	0.60 mils	.060	.059	.062	Smooth, even - no evidence of attack.
ZZ-4	"	0.11	.060	.058	.061	Smooth, even - no evidence of attack.
TD-35	Ti-110AT	0.20	--	.055	--	Smooth, even - no evidence of attack.
TD-43	Ti-110AT	Gain	--	.057	--	Smooth, even - no evidence of attack.
TD-48	Ti-110AT	Gain	--	.058	--	Smooth, even - no evidence of attack.
1N-2	Incoloy	1.22	.060	.056	.061	Slight ($<$ 1/2 mil) surface attack.

[1] Data obtained from A. R. Olsen.

TABLE II

Metallographic Results of Loop L-2-19 Stress-Corrosion Specimens

Specimen No.	Mat'l	Calc. Penetr. Mils	Thickness - In.			Surface Appearance
			End-A*	End-B**	Center	
SL-15	430L S.S.	0.31	.061	.053	.061	Severe attack at both ends of specimen with slight corrosive attack beneath fulcrum. Other areas smooth and even with no indication of attack.
SL-16	"	0.33	.061	.023	.060	
SL-19	"	0.63	.060	.046	.061	
SL-20	"	0.30	.060	.056	.061	
TD-1	Ti-110AT	0.12	.062	--	.062	Smooth, even - no evidence of attack.
TD-2	"	0.12	.060	--	.061	Smooth, even - no evidence of attack.
TD-3	"	0	.056	--	.056	Smooth, even - no evidence of attack.
TD-4	"	0	.058	--	.057	Smooth, even - no evidence of attack.
TD-11	"	--	.056	--	.055	Smooth, even - no evidence of attack.
TD-12	"	--	.051	--	.052	Smooth, even - no evidence of attack.

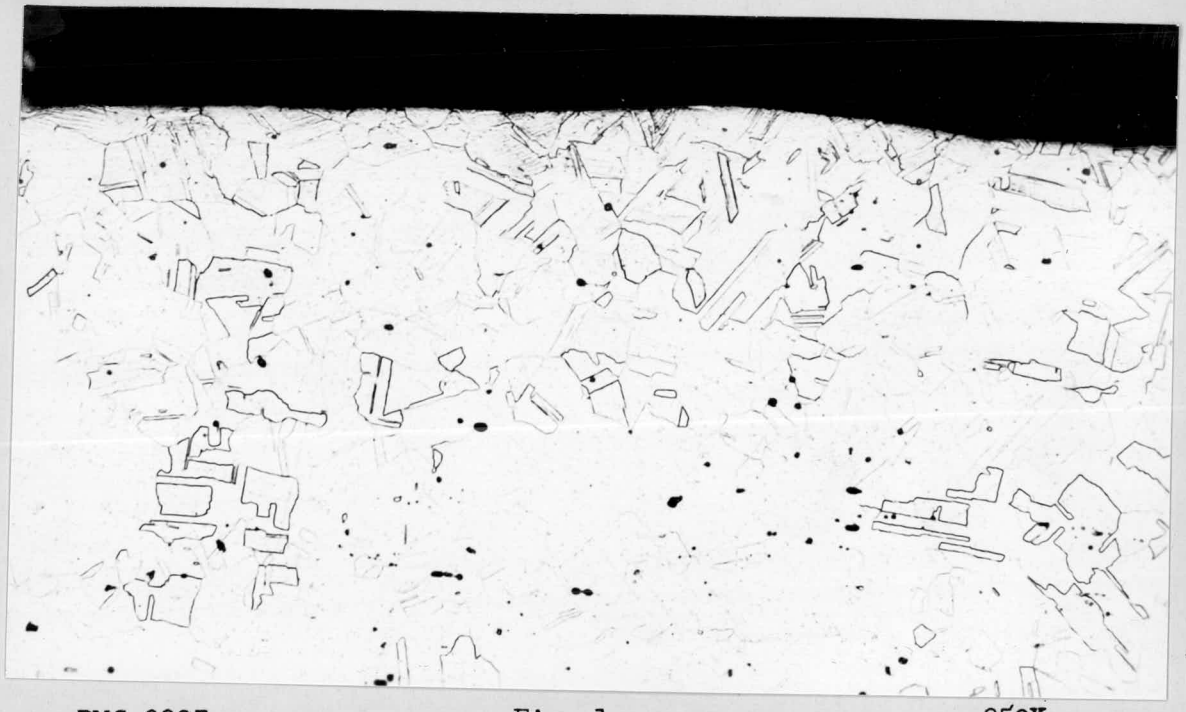
* End thickness at area exhibiting no corrosive attack.

** Minimum specimen thickness at corroded region.

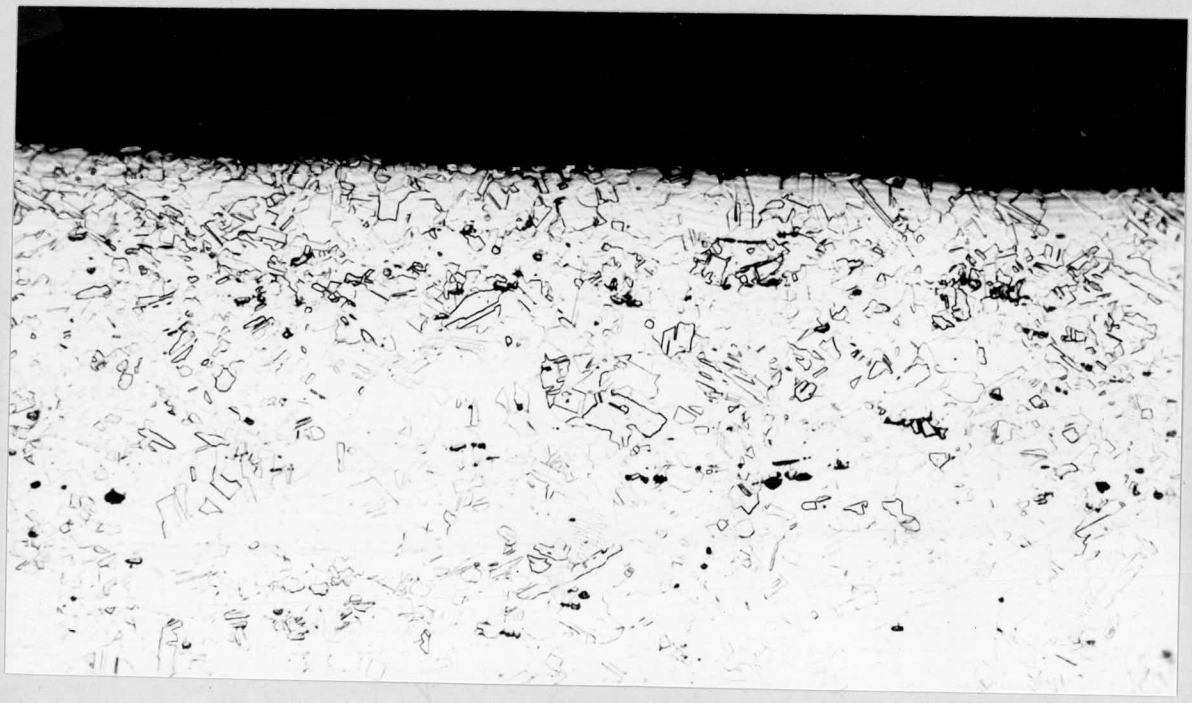
TABLE III

In-Pile Autoclave L53Z-111 Coupons

Coupon No.	Mat'l	Wt. Loss	Thickness - In.			Surface Appearance
			End	Center	End	
SS-111	347 S.S.	8.2	.062	.061	.062	Numerous canal like pits approximately 1/2 mil deep.
SS-113	"	8.6	.059	.058	.058	Numerous canal like pits approximately 3 mils deep.
SS-115	"	5.0	.061	.061	.060	No evidence of attack.



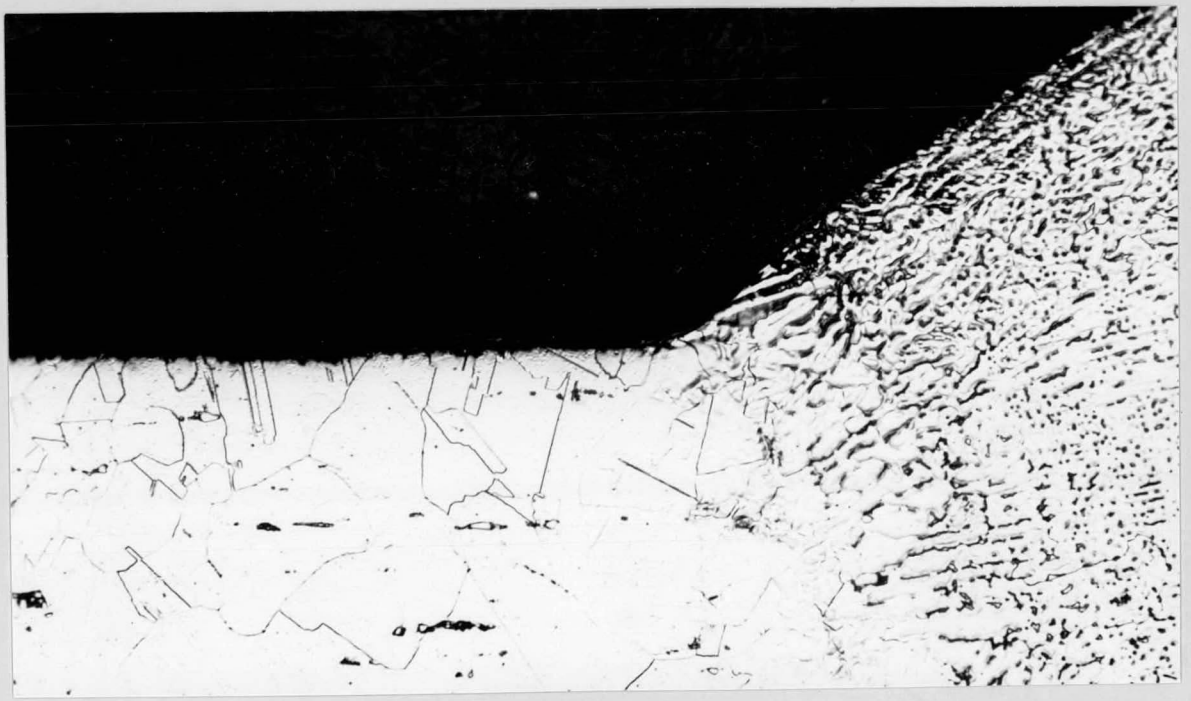
RMG 2227 — Fig. 1 Core Cap — 250X



RMG 2228 — Fig. 2 Pressurizer - Liquid Phase — 250X

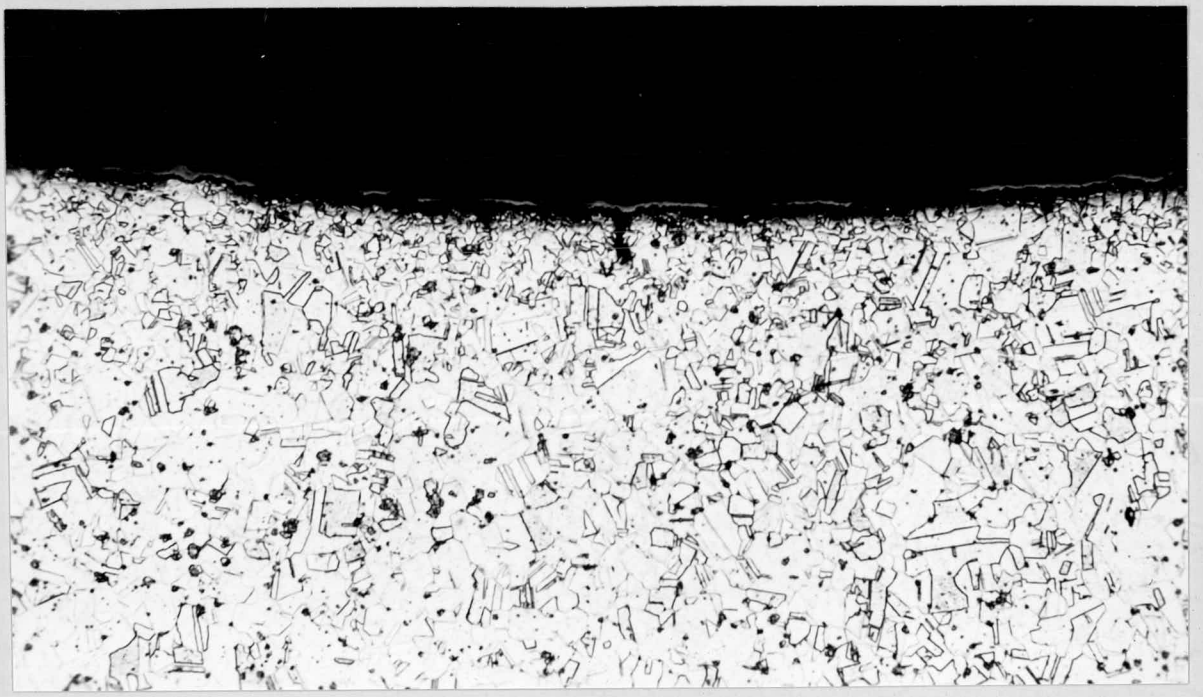
RMG 2229 — Fig. 3 — 250X

Pressurizer - Vapor Phase



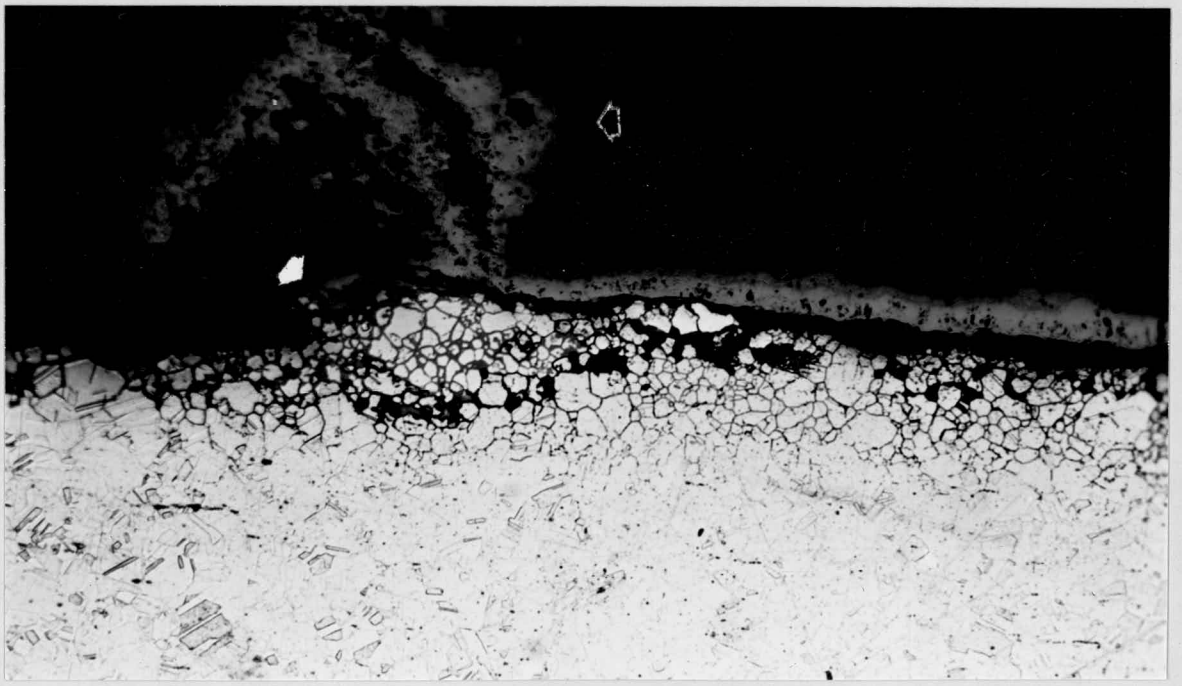
RMG 2230 — Fig. 4 — 250X

Pump Outlet



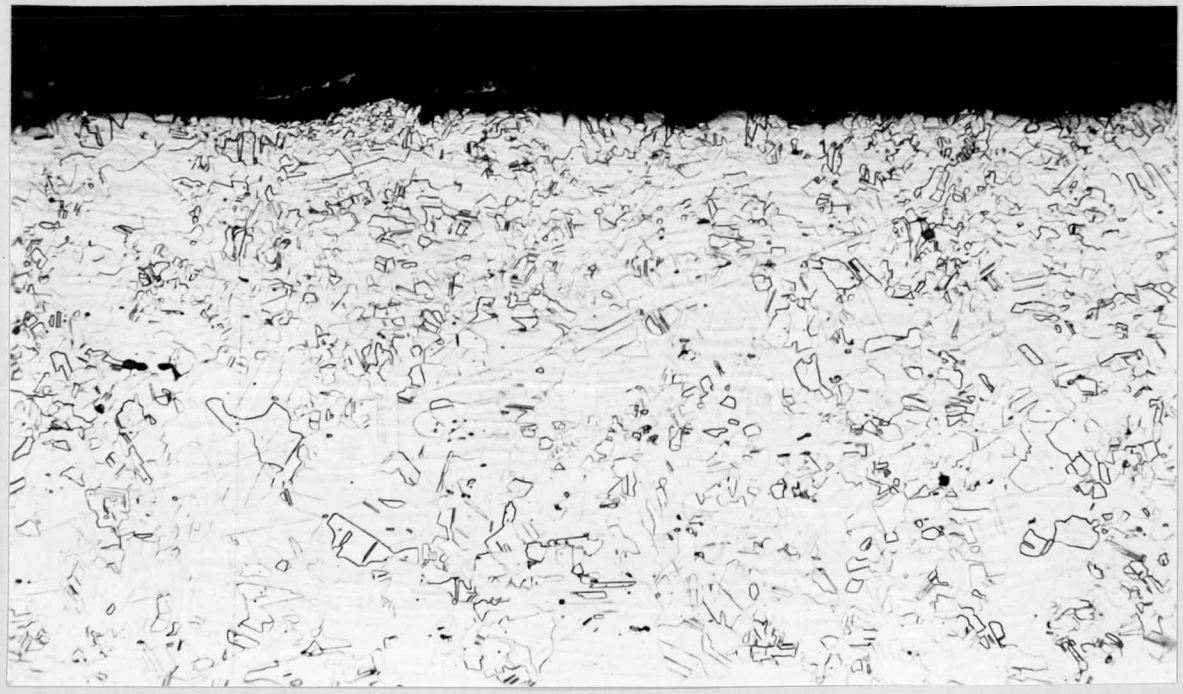
RMG 2231 — Fig. 5 — 250X

Pressurizer Heater Line



RMG 2232 — Fig. 6 — 250X

Sampler Line Capillary Tubing

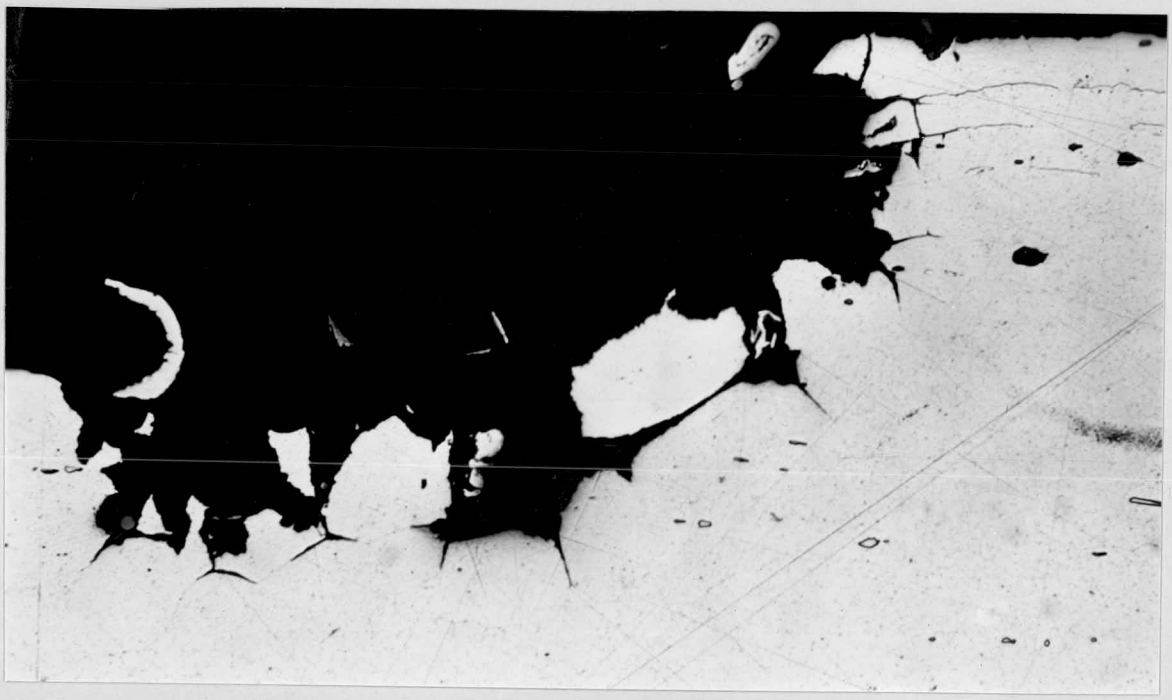


RMG 2233 — Fig. 7 — 250X

Sampler Line Capillary Tubing

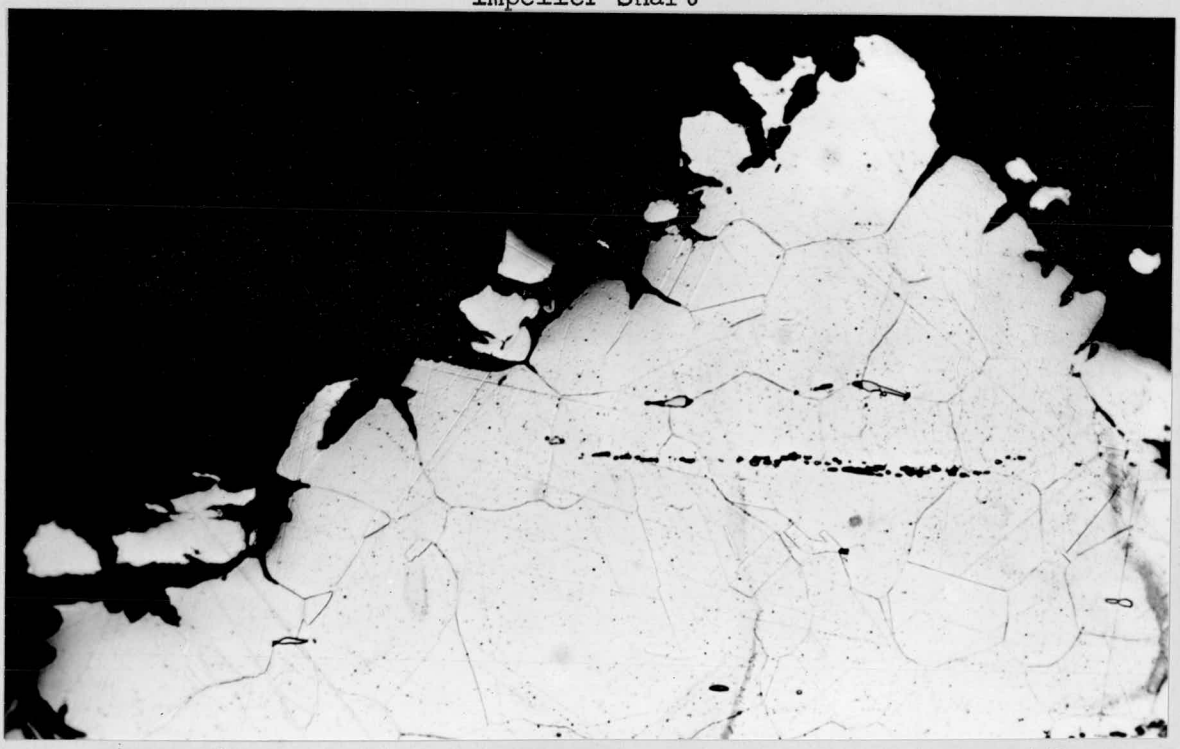
RMG 2234 — Fig. 8 — 250X

Oxides in Capillary Tubing



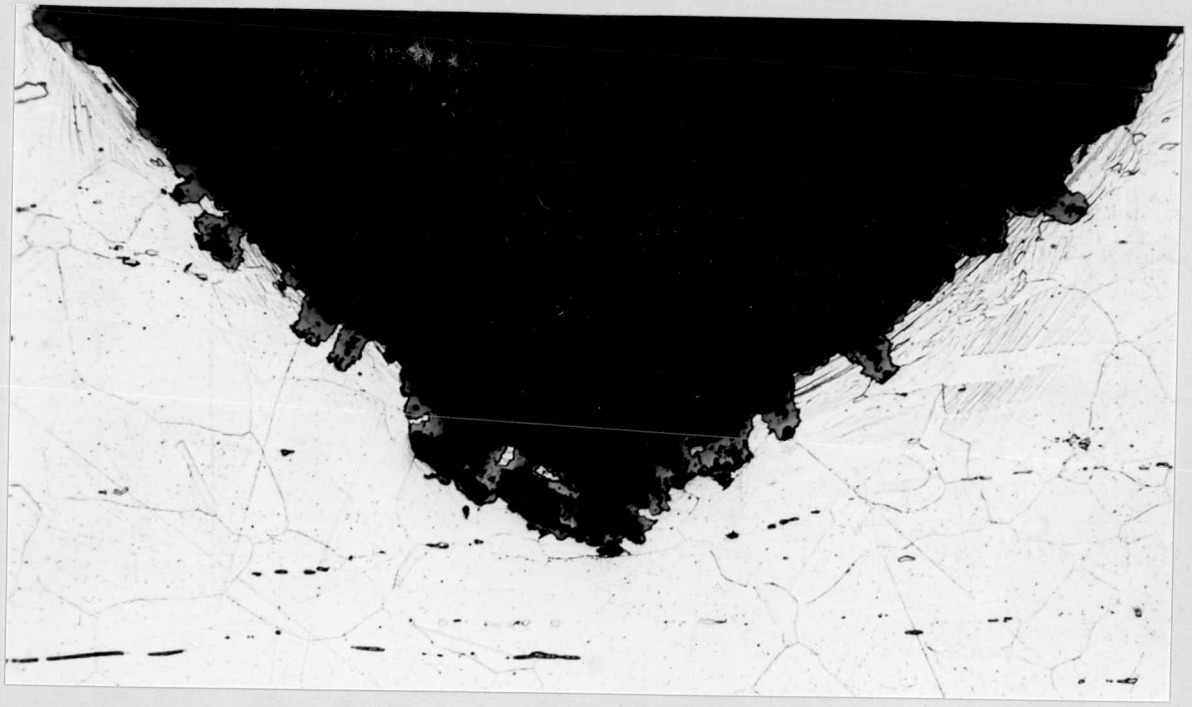
RMG 2235 — Fig. 9 — 250X

Impeller Shaft



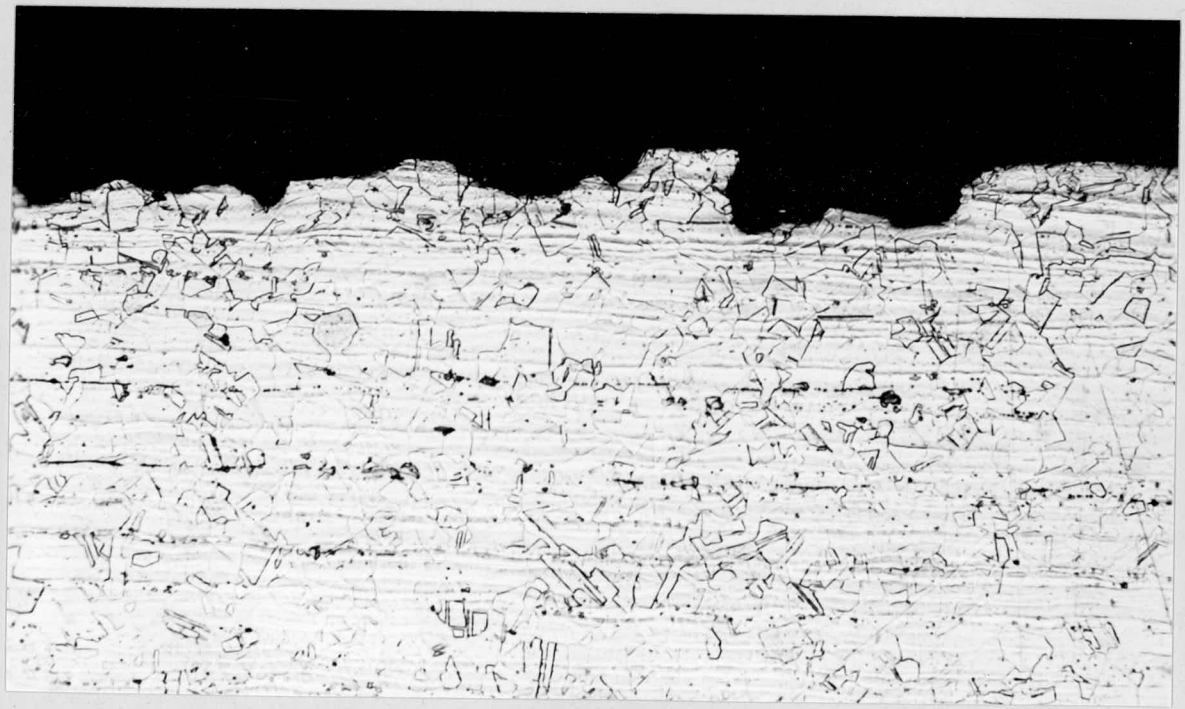
RMG 2236 — Fig. 10 — 250X

Thermal Barrier



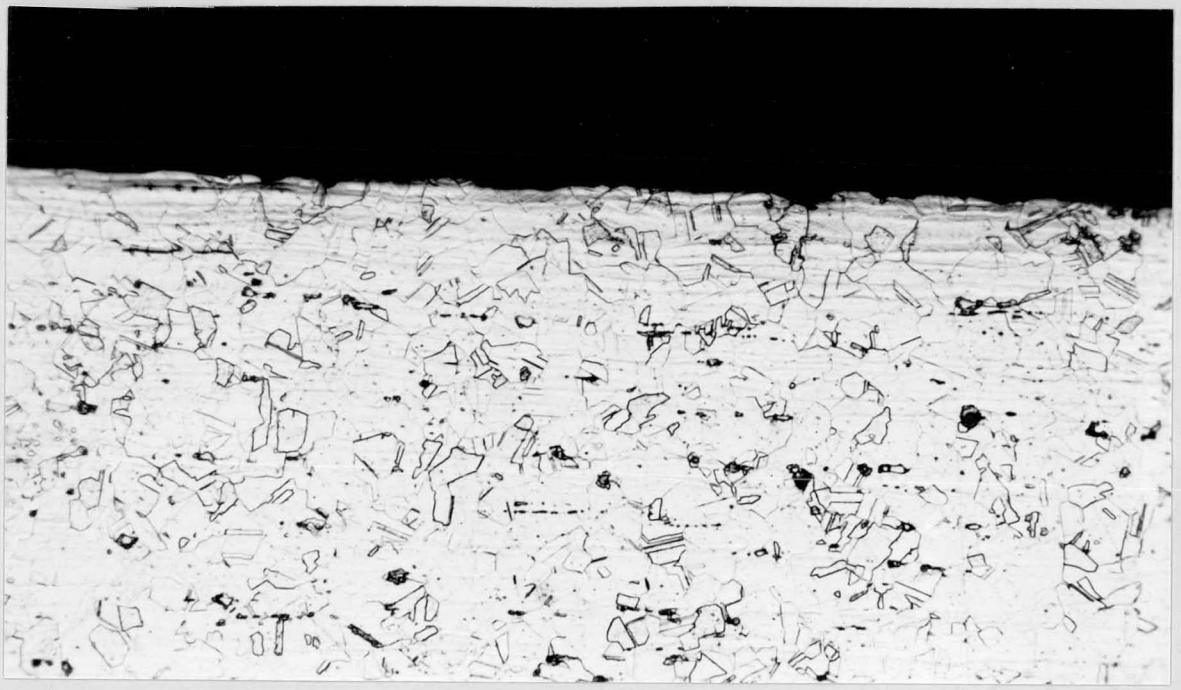
RMG 2237 — Fig. 11 — 250X

Thermal Barrier



RMG 2238 — Fig. 12 — 250X

Coupon SA-1607



RMG 2239 — Fig. 13 — 250X

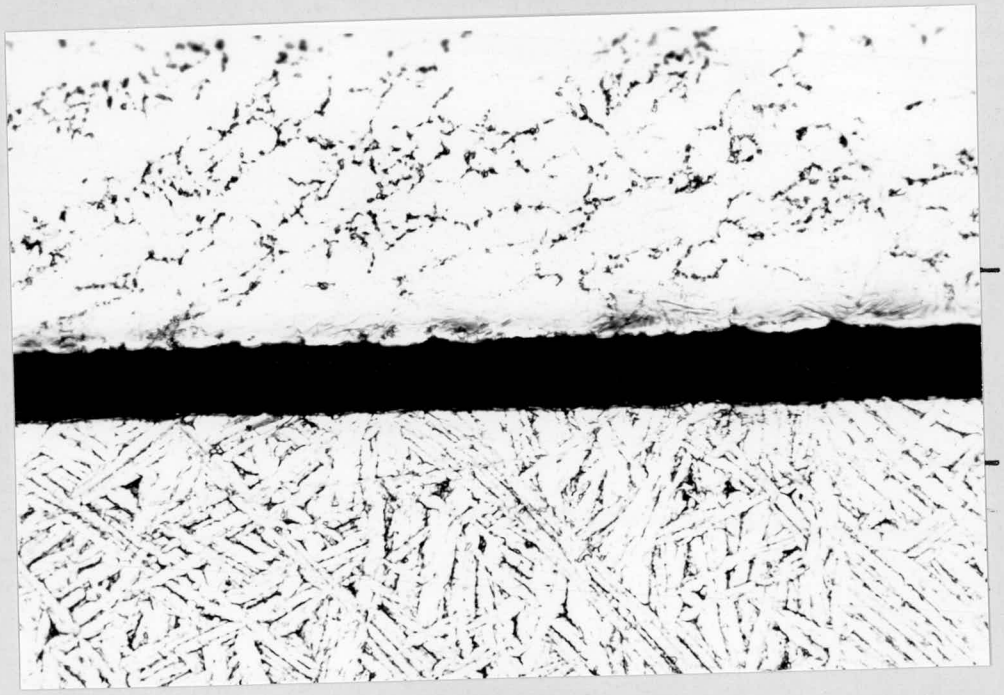
Coupon SA-1620

RMG 2240 — Fig. 14 — 250X

Coupons SMS-1 and SMA-4

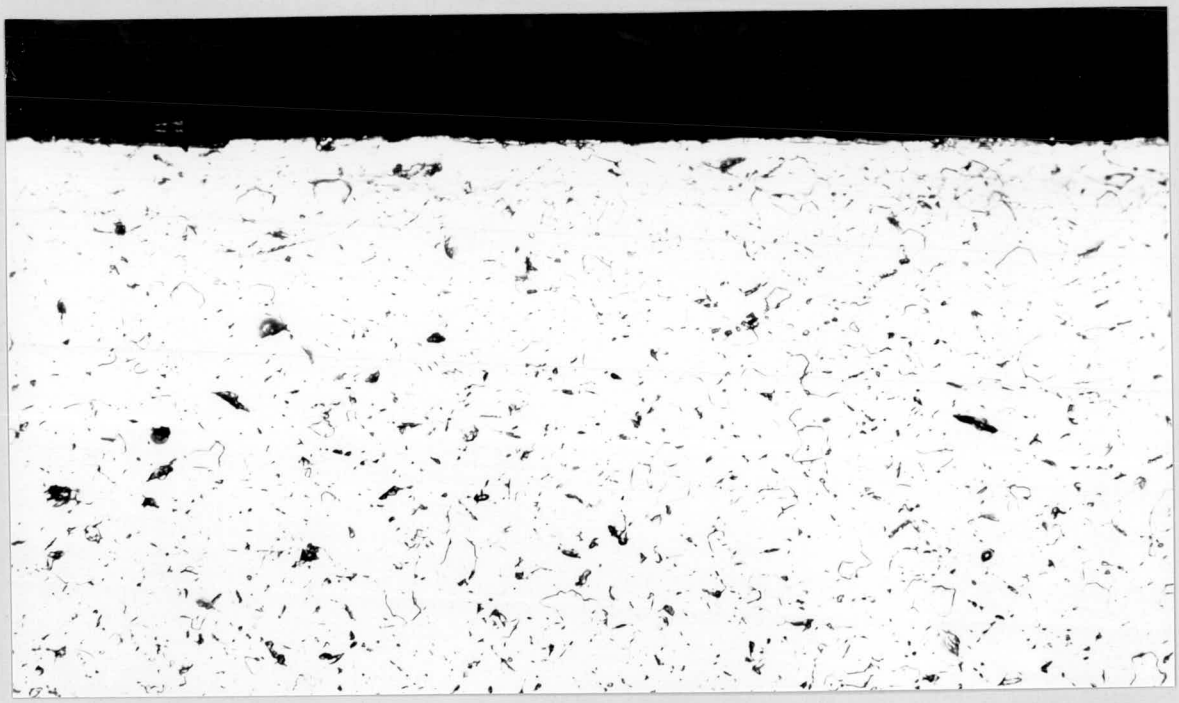
RMG 2241-2 Fig. 15 250X

Coupons ZB-46 and ZB-74

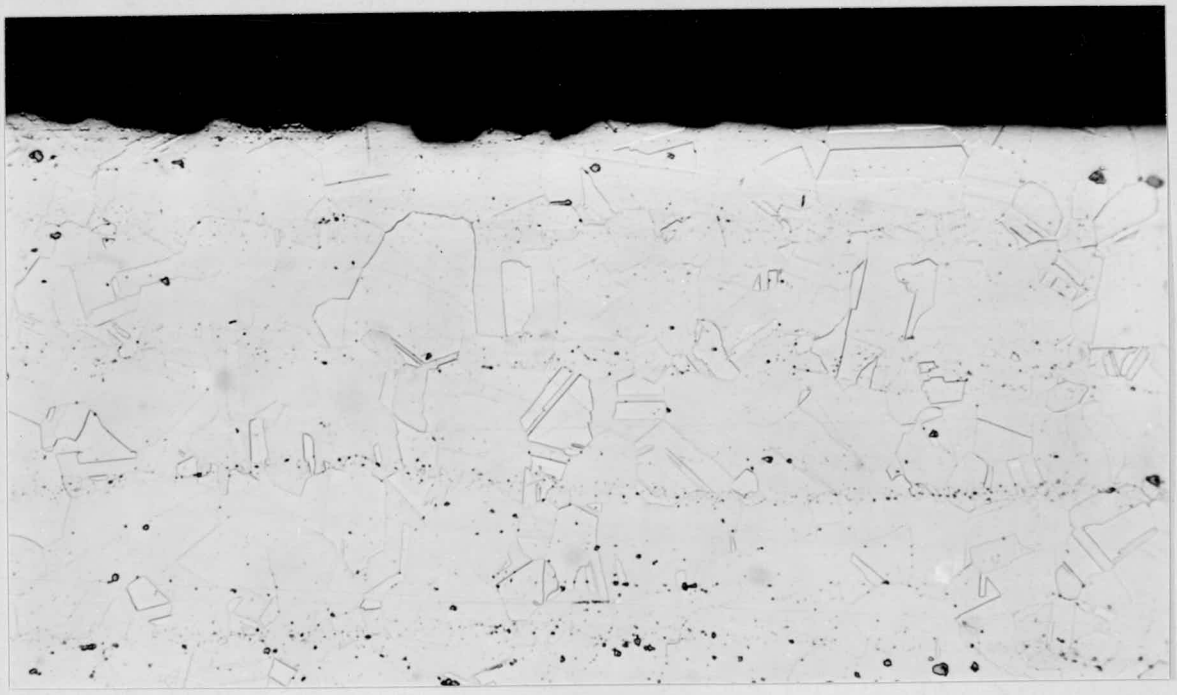


RMG 2243 Fig. 16 250X

Coupons ZB-2 and ZNN-2



RMG 2244 — Fig. 17 Coupon ZZ-1 — 250X



RMG 2245 — Fig. 18 Coupon 1N-2 — 250X

RMG 2246 — Fig. 19 — 250X

Stress Specimen SL-20 (End)

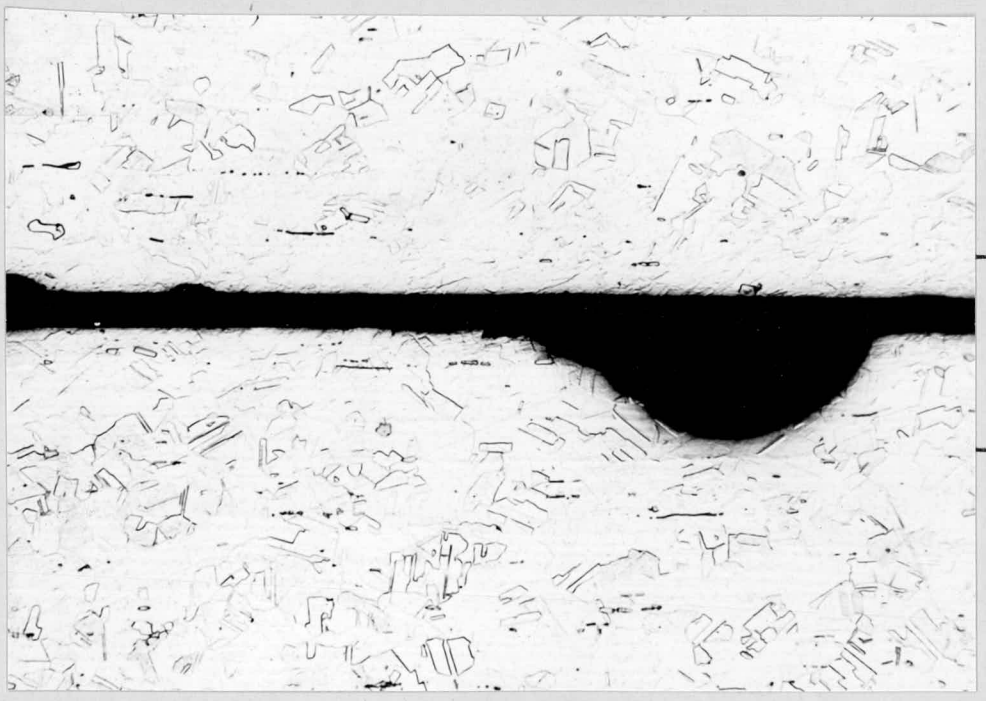
RMG 2247 — Fig. 20 — 250X

Stress Specimen SL-20

RMG 2248

Fig. 21
Typical Ti-110AT Stress Specimen

250X



RMG 2249

Fig. 22
Coupons SS-111 and SS-115

250X

Distribution

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