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DATE 10 March 1964

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ELECTROCHEMICAL DEBURRING OF MOLYBDENUM, ALUMINUM AND STAINLESS STEEL

REPORT A478 SERIAL NO. 20

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This report was prepared under Contract Number AF33(657)-11215 and BPSN: 63-6899-7381-738103. Additional information pertaining to any data contained herein may be obtained from the Directorate of Materials and Processes (ASRCEM-1), Aeronautical Systems Division, Air Force Systems Command, United States Air Force, Wright-Patterson Air Force Base, Ohio, or McDonnell Aircraft Corporation, St. Louis, Missouri

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CODE (Mo-4, Alwt-8, FeAH-2)(V1-c)

STRUCTURES LABORATORY

FINAL REPORT
(Mo-4, Alwt-8, FeAH-2) VI-c)

ELECTROCHEMICAL DEBURRING OF MOLYBDENUM, ALUMINUM AND STAINLESS STEEL

ABSTRACT

Sharp edges left after chemical milling and blanking are presently being mechanically removed at high cost. The sharp edges would be areas of high current density in electrochemical operations and could be easily removed in electrochemical solutions.

The criteria of a good electrochemical deburring solution were leveling characteristics and removal rate. Various solutions were evaluated for breaking sharp edges on molybdenum, among them being 25% by weight nitric acid, nitric-hydrofluoric acid solution for milling molybdenum and variations of Turco 105 steel etchant. These solutions were successful in a leveling action on sharp burrs, but would not round the side edges. A combination of nitric acid leveling and side edge burnishing produced the most promising results.

Aluminum and stainless steel deburring was evaluated in proprietary solutions, with good results obtained in polishing and breaking of sharp edges.

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1. OBJECT

To determine the electrochemical techniques and solutions required to remove sharp edges which result in chemical milling and blanking.

2. MATERIALS AND SOLUTIONS

(1) Molybdenum per MMS-184
(2) Aluminum 7178-T6 per MIL-A-9180
(3) Stainless Steel, 17-7 pH per MIL-S-25043,
321 per MIL-S-6721
(4) Electro-Gleam 55 (Mac Dermid Inc.)
(5) Electropolish Bs (Mac Dermid Inc.)
(6) Electropolish BA (Mac Dermid Inc.)
(7) Sulfuric acid - alcohol polish
One part concentrated sulphuric acid to seven parts methyl alcohol (95%)
(8) Nitric acid
50% by weight
25% by weight
75% by weight
Concentrated.
(9) Chromic-Sulphuric acid
11.3% by volume, concentrated sulphuric acid, chromic acid .17 lb/gal, and remainder water.
(10) Nitric acid (42°Be') 45% by volume - hydrofluoric acid (70%) 3.5% by volume - remainder water.
(11) Turco 105 steel etchant
(a) $Fe(NO_3)_3\ 9H_2O$ - 370 gms
$FeCl_3\ 6H_2O$ - 236 gms
H_3PO_4 70% - 124 mls
$CrCl_3\ .6H_2O$ - 51 gms
HCl 12.4N - 121 mls
water to make 1 liter

(b) Same as (a) adjusted to H^+ = 6.0N and NO_3 = 4.5N

(12) 4140 Steel etchant
H^+ = 6.5 N, NO_3^- 2 2.7N
(13) Inconel 718 etchant
H^+ = 3.0 N, NO_3^- = 2.5N

3. TEST PROCEDURE

Approximately 4 liters of each of the solutions listed in Section 2 were prepared. The specimens were first deburred with the mask left on. They were cleaned by immersion in Prosolve B for 5 minutes at 150°F, rinsed in hot water, then cold. A spot was bared on the specimen by scraping

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3. TEST PROCEDURE (CONT'D.)

away a portion of the mask. A clip was attached to the bare spot and the specimen lowered into the solution up to, but not including the clip. The specimen was deburred and then removed and rinsed in cold water. Examination of each specimen run was performed with the aid of a microscope.

The next step was to run a different set of specimens by removing the mask. The mask was soaked loose and removed in cold trichloroethylene. They were immersed in Prosolve B for 5 minutes at 150°F and rinsed in hot water, then cold. The specimen was clipped and immersed in the deburring solution up to, but not including the clip. It was then removed and rinsed in cold water. Examination was made for metal removed, leveling of the burr, and surface finish. At one time during the testing, production specimens were submitted for deburring. A racking procedure was devised to eliminate rack marks from the specimen. A clip was constructed in such a manner as to provide a point contact through the mask. The point contact was then remasked with KMER for protection. See Figure 2, page 45. Another method for racking (to reduce rack marks) was to spot-weld the alumel wire of a chromel-alumel thermocouple onto the edge of the specimen. The method was successful for a limited period of time until the etching action of the solution loosened the alumel wire, permitting the specimen to drop off.

4. TEST RESULTS

4.1 Nitric Acid

Deburring with and without maskant was performed in the following concentrations.

4.1.1 25% By Weight

Of all the solutions evaluated, this solution produced the best leveling. The best leveling occurred at 125°F and 8 amps per square inch. The time varies with the height of the burr. See Table 1, page 7 and Table 11, page 17, for parameter data. The one disadvantage of this solution was that it would not round the edges. In an effort to round the edges, approximately .020-inch of the mask was scraped around the edge and removed. This was not successful, in that the sides of the edges were undercut, producing more sharp edges. See Table 17, page 23, specimens 1 through 6 and specimen 14, in conjunction with Figure 1, Photographs of specimens 1 through 6, and 14, are presented on pages 25 and 26.

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4.1.2 50% by Weight

This solution produced leveling, but was not as good as the 25% by weight. Parameter data is shown in Table 2, page 8.

4.1.3 75% by Weight

There was some leveling produced, although the surface was pitted and irregular. The conduction of the solution was considerably low, which produced a slow deburring rate. See Table 3, page 9, for parameter data.

4.1.4 Concentrated

The conduction of the solution was too low to allow a reaction between the molybdenum and the solution, consequently no deburring was accomplished. See Table 3, page 9 for parameter data.

4.2 Chromic Sulphuric Acid

This solution is not satisfactory for deburring because of poor leveling action. A slight polish is produced, which is of little value. See Table 4, page 10, and Table 12, page 18, for parameter.

4.3 Alcohol - Sulphuric Acid

The inability of this solution to level the burr excludes it as a possible deburring solution. It also attacks and removes the maskant. See Table 5, page 11, and Table 13, page 19, for parameter data.

4.4 Nitric-Hydrofluoric Acid

Acceptable leveling action is produced by this solution; however, its one disadvantage is the high current density necessary for burr removal. See Table 6, page 12, for parameter data.

4.5 Electrogleam 55

There was very little leveling action produced by this solution. It also attacks the maskant. A high polish was obtained, which is of little value. See Table 7, page 13 and Table 9, page 15 for parameter data. Because the solution did have a rounding ability for sharp edges, the edge was leveled first in nitric acid and the mask completely removed. The Electrogleam 55 treatment was applied and the specimens exhibited a radius on the edges from .002-in. to .006-in. depending on current density. This method produced good results, but a satisfactory manner of racking on the bare specimen to eliminate rack marks was not achieved. See Table 17, page 23 in conjunction with Figure 1, photographs 7 through 13. The next step was to leave the mask on and rack with the point contact method, explained under section 3, but scraping away .020-in. of the maskant on the sides of

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4.5 Electrogleam 55 (Cont'd.)

the edge. This produced undercutting of the sides, which was not acceptable. See Table 17, on page 23, Specimen 27A through 29C in conjunction with Figure 1, photographs 27A through 29C on pages 33 - 35.

4.6 Electrogleam BS

This solution was not successful in leveling the burr, but did exhibit a rounding of sharp edges. See Table 8, page 14, and Table 10, page 16, for data. The same racking problem was encountered with electrogleam BS on the base specimen, as with Electrogleam 55, discussed under Section 4.5. The point contact method of racking was used with the mask left on. Approximately .020-in. of the maskant was scraped away from the sides of the edge. The specimen was leveled in nitric acid and the Electrogleam BS treatment applied. No satisfactory specimens were obtained because of undercutting of the sides of the edges. See Table 17 on page 23, and specimens 15 through 18C in conjunction with Figure 1, photographs 15 through 18C, pages 29 and 30.

4.7 Turco 105 Etchant for Steel

Turco 105 was successful in leveling the burr with current densities ranging from 5 amps per square inch to 20 amps per square inch. Rounding of the side edges was accomplished on some specimens, but was not repeatable. See Table 18, page 24, specimens 30 and 31; also see Table 17, page 23, specimens 19 and 20 in conjunction with Figure 1; photographs 19, 20, 30 and 31, pages 31 and 36.

In an effort to round the edges, approximately .020-in. of the maskant was scraped from the edges and Turco 105 treatment applied. This did not prove successful because of undercutting of the sides of the edges. See Table 17, page 23, specimens 21 through 26, in conjunction with Figure 1, and photographs 21 through 26. Burnishing of edges was tried by scraping the edges with a knife after Turco 105 treatment. This proved very successful and radii were obtained from .005-in. to .008-in. See Table 18, page 24, specimens 39 through 42, in conjunction with Figure 1 and photographs 39 through 42. Specimens were also performed without burnishing of the edges after Turco 105 treatment. This resulted in very sharp edges which were not acceptable. See Table 18, page 24, specimens 46 through 48, in conjunction with Figure 1, and photographs 46 through 48.

4.8 Variations of Turco 105 Steel Etchant

Attempts to improve leveling and rounding of edges by raising and lowering H^+ and NO_3^- were unsuccessful. There was some tendency toward faster removal rates with the higher H^+ and NO_3^- ion concentration, however, this was not substantial. Specimens were run by scraping the mask away at a 45° angle to the edge. This still produced sharp edges. See Table 18,

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4.8 Variations of Turco 105 Steel Etchant (Cont'd.)

page 24, specimens 46 through 48, 49 through 51, and 52 through 56, in conjunction with Figure 1, pages 41 - 44 and photographs 46 through 48, 49 through 51, and 52 through 56. Attempts to round the edges by burnishing with a knife after leveling were again successful, with radii ranging from .005-in. to .0058-in. See Table 18, page 24, specimens 32 through 34, 35 through 38, 43 through 45, in conjunction with Figure 1, pages 37, 38 and 40 and photographs 32 through 34, 35 through 38, 43 through 45.

5. ELECTROCHEMICAL DEBURRING OF STAINLESS STEEL AND ALUMINUM

Proprietary solution Electropolish BS produced a more satisfactory polish and rounding of edges than did the Electrogleam 55 on stainless steel 321. The Electropolish BS produced an RMS of 10 from a raw sample of RMS 60. The metal removal was much less from Electropolish BS than Electrogleam 55. See Tables 15 and 16, pages 21 and 22, in conjunction with Figure 4, page 47. Electropolish BA produced an RMS value of 25-30 from a raw sample of RMS 20-22. See Table 14, page 20, in conjunction with Figure 3, page 46.

6. CONCLUSIONS AND RECOMMENDATIONS

25% by weight nitric acid and Turco 105 steel etchant exhibit the greatest leveling characteristics. However, due to the high cost of make-up and maintenance of Turco 105 etchant, nitric acid would have the preference. Burnishing with a special tool or a pencil-type grinding wheel after leveling of the burr in nitric acid is recommended in rounding the edges to a .005-in. radius.

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TABLE 1

NITRIC ACID 25% BY WT.
WITH MASKED SPECIMENS of molybdenum

AREA (SQ. IN)	CURRENT DENSITY (AMP/SQ IN)	VOLTAGE	TIME (MIN.)	TEMP (°F)	COMMENTS
.06	3	6	12	90	SOME LEVELING OF BURR. FORMS A PRECIPITATE WHICH INHIBITS CUTTING
.05	3	6	13	90	ADJUSTED CATHODE TO ANODE AREA TO 10 to 1. NO **NOTICEABLE** DIFF IN CUTTING
.05	3	10	12	90	SOME LEVELING OF BURR. FORMS A PRECIPITATE WHICH INHIBITS CUTTING
.18	8	2	14	100	SOME LEVELING OF BURR. REQUIRES DESMUTTING
.06	8	0.1	19	125	VERY GOOD LEVELING OF BURR. REQUIRES DESMUTTING
.08	12	3	4	100	GOOD LEVELING OF BURR. SOME PITTING.
.08	25	2	5	90	DECOMPOSES ACID. NO DEBURRING

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TABLE 2

NITRIC ACID 50 % BY WT.
WITH MASKED SPECIMENS of molybdenum

AREA (SQ IN)	CURRENT DENSITY (AMP/SQ IN)	VOITAGE	TIME (MIN)	TEMP (°F)	COMMENTS
.07	4	1	12	100	SOME LEVELING OF BURR. FORMS A PRECIPITATE WHICH INHIBITS CUTTING.
.07	8	1.5	13	100	SOME LEVELING OF BURR. FORMS A PRECIPITATE WHICH INHIBITS CUTTING
.07	12	1.5	5	97	SOME LEVELING OF BURR. PITTING
.014	3.3	6	12	118	SOME LEVELING OF BURR PITTING
.01	3.0	10	12	96	SOME LEVELING OF BURR. PITTING
.06	25	2	5	125	SOME LEVELING OF BURR. SEVERE PITTING.

TABLE 3

NITRIC ACID 75% BY WT.
WITH MASKED SPECIMENS of molybdenum

AREA (SQ IN.)	CURRENT DENSITY (AMP/SQ IN)	VOLTAGE	TIME (MIN)	TEMP (°F)	COMMENTS
.077	1	10	10	112	SOME LEVELING OF BURR. SEVERE PITTING ATTACKS MASK. SLOW REACTION
.12	1	10	10	88	SOME LEVELING OF BURR SEVERE PITTING ATTACKS MASK. SLOW REACTION
.08	2	20	10	88	SOME LEVELING OF BURR. SEVERE PITTING ATTACKS MASK

NITRIC ACID CONCENTRATED

AREA (SQ IN)	CURRENT DENSITY (AMP/SQ IN)	VOLTAGE	TIME (MIN)	TEMP (°F)	COMMENTS
.08	0	10	10	88	NO DEBURRING ATTACKS MASK RAPIDLY.
.08	0	20	10	88	NO DEBURRING. ATTACKS MASK RAPIDLY

TABLE 4
CHROMIC - SULPHURIC ACID
WITH MASKED SPECIMENS of molybdenum

AREA (SQ IN)	CURRENT DENSITY (AMP/SQ IN)	VOLTAGE	TIME (MIN)	TEMP (°F)	COMMENTS
.39	4	2.0	6	110	NO LEVELING OF BURR
.39	8	3.0	2	110	SLIGHT POLISH NO LEVELING OF BURR
.39	5	3.2	6	92	SLIGHT POLISH. NO LEVELING OF BURR SOME PITTING
.39	5	5.0	6	92	SLIGHT POLISH. NO LEVELING OF BURR SOME PITTING
.39	5.5	6.0	5	92	SLIGHT POLISH. NO LEVELING OF BURR SOME PITTING
.39	15	8.0	5	92	SLIGHT POLISH. NO LEVELING OF BURR SOME PITTING

TABLE 5
ALCOHOL - SULPHURIC ACID
WITH MASKED SPECIMENS of molybdenum

AREA (SQ. IN)	CURRENT DENSITY (AMP/SQ. IN)	VOLTAGE	TIME (MIN)	TEMP (°F)	COMMENTS
.14	1.2	3.5	5	80	HIGH POLISH. NO LEVELING OF BURR. ATTACKS MASK
.14	1.2	4.5	5	80	HIGH POLISH. NO LEVELING OF BURR, ATTACKS MASK
.14	1.5	6	10	80	HIGH POLISH. NO LEVELING OF BURR. ATTACKS MASK
.17	1.0	6	30	80	HIGH POLISH. NO LEVELING OF BURR. ATTACKS MASK. Added 100 MLS. H_2SO_4. DECOMPOSES ALCOHOL
.09	1.0	6.0	9	80	ADDED 200 MLS of H_2SO_4 DECOMPOSES ALCOHOL

TABLE 6
NITRIC - HYDROFLOURIC ACID WITH MASKED SPECIMENS of molybdenum

AREA (SQ. IN)	CURRENT DENSITY (AMP/SQ IN)	VOLTAGE	TIME (MIN)	TEMP (°F)	COMMENTS
.08	50	1.5	1.5	116	GOOD LEVELING AND DEBURRING
.10	10	0	5	110	POOR DEBURRING
.09	8	0	10	80	POOR DEBURRING
.09	40	1.4	1.5	115	GOOD DEBURRING AND LEVELING
.10	20	.6	3	120	GOOD DEBURRING AND LEVELING

TABLE 7
ELECTROGLEAM 55
WITH MASKED SPECIMENS of molybdenum

AREA (SQ. IN)	CURRENT DENSITY (AMP/SQ. IN)	VOLTAGE	TIME (MIN)	TEMP (°F)	COMMENTS
.09	1.5	7	15	190	SLIGHT LEVELING OF BURR. ROUNDS EDGES. ATTACKS MASK. HIGH POLISH
.09	2	10	10	206	SLIGHT LEVELING OF BURR. ROUNDS EDGES ATTACKS MASK. HIGH POLISH
.09	3	15	10	200	SLIGHT LEVELING OF BURR. ROUNDS EDGES ATTACKS MASK. HIGH POLISH
.09	2.5	12	10	200	SLIGHT LEVELING OF BURR. ROUNDS EDGES. ATTACKS MASK. HIGH POLISH

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TABLE 8
ELECTROPOLISH BS
WITH MASKED SPECIMENS of molybdenum

AREA (SQ. IN)	CURRENT DENSITY (AMP/sq in)	VOLTAGE	TIME (MIN)	TEMP (°F)	COMMENTS
.07	1.5	7	15	190	SLIGHT LEVELING OF BURR. ROUND EDGES NOT AS BRIGHT A POLISH AS ELECTROGLEAM 55. ATTACKS MASK
.08	2	10	10	206	SLIGHT LEVELING OF BURR. ROUNDS EDGES SLIGHT POLISH ATTACKS MASK
.06	2.5	12	10	180	SLIGHT LEVELING OF BURR. ROUNDS EDGES. HIGH POLISH. ATTACKS MASK.
.09	3	15	10	200	SLIGHT LEVELING OF BURR. ROUNDS EDGES. HIGH POLISH. ATTACKS MASK.

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TABLE 9
ELECTROGLEAM 55
WITH MASK REMOVED from molybdenum

AREA (SQ. IN)	CURRENT DENSITY (AMP/SQ. IN)	VOLTAGE	TIME (MIN)	TEMP (°F)	METAL REMOVED (IN/SIDE)	RMS
3	0.8	10	10	180-190	.0008	60
2.4	0.5	5	10	180-190	.0005	60
1.1	1.6	15	10	180-190	.0015	60

TABLE 10
ELECTROPOLISH BS
WITH MASK REMOVED from molybdenum

AREA (SQ. IN)	CURRENT DENSITY (AMP/SQ IN)	VOLTAGE	TIME (MIN)	TEMP (°F)	METAL REMOVAL (IN/SIDE)	RMS
2	1.2	10	10	200-205	.0005	GREATER THAN ELECTROGLEAM 55
2	1.0	7	10	200-205	.0005	GREATER THAN ELECTROGLEAM 55
2	1.5	15	10	200-205	.0008	GREATER THAN ELECTROGLEAM 55

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TABLE 11
NITRIC ACID 25% BY WT
WITH MASK REMOVED from molybdenum

AREA (SQ IN)	CURRENT DENSITY (AMP/SQ IN)	VOLTAGE	TIME (MIN)	TEMP (°F)	METAL REMOVAL (IN/SIDE)	RMS
3	3	0.5	10	125	.0005	GREATER THAN ELECTROGLEAM 55
2.2	8	0.6	10	125	.0025	GREATER THAN ELECTROGLEAM 55
1.1	12	1.1	10	125	.006	GREATER THAN ELECTROGLEAM 55

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TABLE 12
CHROMIC - SULPHURIC ACID
WITH MASK REMOVED from molybdenum

AREA (SQ IN)	CURRENT DENSITY (AMP/SQ IN)	VOLTAGE	TIME (MIN)	TEMP (OF)	METAL REMOVAL (IN/SIDE)	RMS
2.2	4	2.5	20	110	.0035	GREATER THAN ELECTROGLEAM 55
2.2	2	1.5	20	110	.0025	GREATER THAN ELECTROGLEAM 55
2.0	8	4.5	20	105	.004	GREATER THAN ELECTROGLEAM 55

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TABLE 13
ALCOHOL-SULPHURIC ACID
WITH MASK REMOVED from molybdenum

AREA (SQ. IN)	CURRENT DENSITY (AMP/SQ IN)	VOLTAGE	TIME (MIN)	TEMP (°F)	METAL REMOVAL (IN/SIDE)	RMS
2.4	.5	3.5	20	80	.002	GREATER THAN ELECTROGLEAM 55
2.0	.1	4.5	20	80	.0025	GREATER THAN ELECTROGLEAM 55
2.2	1.2	6.0	20	80	.003	GREATER THAN ELECTROGLEAM 55

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TABLE 14
ELECTROPOLISH BA ON ALUMINUM

AREA (SQ IN)	CURRENT DENSITY (AMP/SQ IN)	VOLTAGE	TIME (MIN)	TEMP (°F)	METAL REMOVAL (IN/SIDE)	RMS	COMMENTS
4	.25	6	20	180-190	.001	25	HIGH POLISH ATTACKS MASK ROUNDS EDGES
4	.63	9	20	180-190	.0015	25	HIGH POLISH ATTACKS MASK ROUNDS EDGES
4	.83	12	20	180-190	.0015	30	HIGH POLISH ATTACKS MASK ROUNDS EDGES

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TABLE 15
ELECTROPOLISH BS
ON STAINLESS STEEL 321

AREA (SQ IN)	CURRENT DENSITY (AMP/SQ IN)	VOLTAGE	TIME (MIN)	TEMP (°F)	METAL REMOVAL (IN/SIDE)	RMS	COMMENTS
2	3.3	9	5	180-200	.001	10	HIGH POLISH ROUNDS EDGES
2.5	5.0	12	5	180-200	.0015	10	HIGH POLISH ROUNDS EDGES
1.8	8.0	15	5	180-200	.0025	10	HIGH POLISH ROUNDS EDGES

TABLE 16
ELECTROGLEAM 55 ON STAINLESS STEEL 321

AREA (SQ. IN)	CURRENT DENSITY (AMP/SQ IN)	TIME (MIN)	VOLTAGE	TEMP (°F)	METAL REMOVAL (IN/SIDE)	RMS	COMMENTS
1.12	11	5	6	180-200	.003	25	HIGH POLISH ROUNDS EDGES
1.25	15	5	9	180-200	.005	35	HIGH POLISH ROUNDS EDGES
.75	19	5	12	180-200	.0055	40	HIGH POLISH ROUNDS EDGES

TABLE

NITRIC ACID TREATMENT

SPECIMEN NO	AREA (SQ IN)	CURRENT DENSITY (AMP/SQ IN)	TIME (MIN)	TEMP (°F)	VOLTAGE
1	.04	8	10	118-128	.05
2	.11	8	6	118-128	.05
3	.14	8	6	118-128	.1
4	.14	8	20	118-128	.1
5	.18	8	20	118-128	.1
6	.08	8	20	118-128	.1
14	.11	8	20	118-128	.1

NITRIC ACID TREATMENT

7	.11	8	20	118-128	.05
8	.14	8	20	118-128	.1
9	.12	8	20	118-128	.1
10	.17	8	20	118-128	.1
11	.08	8	20	118-128	.05
12	.12	8	20	118-128	.1
13	.18	8	20	118-128	.15

NITRIC ACID TREATMENT

15	.08	8	20	118-128	1.2
16	.08	8	20	118-128	1.2
17	.17	8	20	118-128	1.5
18A					
18B	.22	8	20	118-128	.5
18C					

TURCO 105 TREATMENT

19	.16	20	5	145±5	2
20	.12	20	7	145±5	2
21	.16	20	5	145±5	2
22	.12	20	5	145±5	2
23	.10	20	5	145±5	2
24	.15	20	5	145±5	2
25	3	20	10	145±5	2
26	2		20	145±5	

NITRIC ACID TREATMENT

27A					
27B	.10	8	20	118-128	1.2
27C					
28A					
28B	.15	8	20	118-128	1.3
28C					
29A					
29B	.07	8	20	118-128	1.0
29C					

NITRIC ACID

AREA (SQ IN)	CURRENT DENSITY (AMP/SQ IN)	TIME (MIN)	T (°
.14	8	6	11
.18	8	2	11
.08	8	2.5	11
.11	8	1	11

ELECTROGLEA

3	.8	10	1
2	1	10	1
2	1	10	1
3	1.6	20	1
2	.75	20	1
1.1	1.4	20	1
.18	.6	10	1

ELECTROPOLISH

.16	3	20	2
.16	2.5	30	2
.34	3	40	2
.44	2.5	30	2

TURCO 105

.16	20	1	1
.12	20	1.5	1
.10	20	2	1
.15	23	1	1

ELECTROGLEAM

.06	3.4	10	1
.05	3.2	20	1
.05	3.2	30	1

TABLE 17

T / P	VOLTAGE	AREA (SQ IN)	CURRENT DENSITY (AMP/SQ IN)	TIME (MIN)	TEMP (°F)	VOLTAGE	METAL REMOVED (IN/SIDE)	RADIUS (IN)	COMMENT
					NITRIC ACID TREATMENT				
28	.05							NONE	Mask was scraped fro
28	.05							NONE	nitric acid treatme
28	.1							NONE	scraped from edge be
28	.1	.14	8	6	118-128	.1		NONE	Treatment on specim
28	.1	.18	8	2	118-128	.1		NONE	Figure 1 with picture
28	.1	.09	8	2.5	118-128	.1		NONE	specimen NO.
28	.1	.11	8	1	118-128	.1		.004	
ENT					ELECTROGLEAM 55 TREATMENT				
28	.05	3	.8	10	180-190	10	.0005	.002	Mask was completely
28	.1	2	1	10	180-190	10	.0005	.0026	nitric Acid treatment
28	.1	2	1	10	180-190	10	.0005	.0012	55 treatment with
28	.1	3	1.6	20	180-190	10	.0015	.006	specimen 13 where t
28	.05	2	.75	20	180-190	10	.0015	.006	scraped from the 50
28	.1	1.1	1.4	20	180-190	10	.001	.005	treatments see Figure
28	.15	.18	.6	10	180-190	10		.0035	corresponding to specim
ENT					ELECTROPOLISH BS TREATMENT				
28	1.2	.16	3	20	220-230	15		NONE	Mask was scraped from
28	1.2	.16	2.5	30	220-230	15		NONE	nitric Acid Treatment
28	1.5	.34	3	40	220-230	15		NONE	BS treatment. Specime
28	.5								respectively, raw sampl
		.44	2.5	30	220-230	15		NONE	Leveling, electropolish
									Figure 1 with pictures
									specimen No.
T					TURCO 105 TREATMENT				
5	2							.020	Mask was scraped fro
5	2							005	Treatments on specim
5	2	.16	20	1	145 ± 5	2		NONE	Mask was completely r
5	2	.12	20	1.5	145 ± 5	2		NONE	25 and 26. Specimen
5	2	.10	20	2	145 ± 5	2		NONE	current. SEE Figure 1
5	2	.15	23	1	145 ± 5	4		NONE	corresponding to specime
5	2						.001	.0037	
5							.0025	NONE	
ENT					ELECTROGLEAM 55 TREATMENT				
28	1.2	.06	3.4	10	180-190	10		NONE	Mask was scraped fro
28	1.3	.05	3.2	20	180-190	10		NONE	Treatments. Specimen 2
28	1.0	.05	3.2	30	180-190	10		NONE	raw samples. Specimen
									Nitric acid Leveling. Spe
									are electrogleam 55 tr
									27A, B, C. all represent
									one sample etc. See
									corresponding to specim

2

3

ABLE 17

RIC ACID TREATMENT

NT TY (IN)	TIME (MIN)	TEMP (°F)	VOLTAGE	METAL REMOVED (IN/SIDE)	RADIUS (IN)	COMMENT
					NONE	Mask was scraped from edge between nitric acid treatments. Mask was scraped from edge before Nitric Acid Treatment on specimens 1 thru 3. See Figure 1 with pictures corresponding to specimen No.
					NONE	
					NONE	
	6	118-128	.1		NONE	
	2	118-128	.1		NONE	
	2.5	118-128	.1		NONE	
	1	118-128	.1		.004	

TROGLEAM 55 TREATMENT

10	180-190	10	.0005	.002	Mask was completely removed between nitric Acid treatment and Electrogleam ES treatment with the exception of Specimen 13 where the mask was scraped from the edge between treatments See Figure 1 with pictures corresponding to specimen No.
10	180-190	10	.0005	.0026	
10	180-190	10	.0005	.0012	
20	180-190	10	.0015	.006	
20	180-190	10	.0015	.006	
20	180-190	10	.001	.005	
10	180-190	10		.0035	

ROPOLISH BS TREATMENT

20	220-230	15		NONE	Mask was scraped from edge between nitric Acid treatment and Electropolish BS treatment. Specimen 18A, B, C are respectively, raw sample, nitric acid leveling, Electropolish BS treatment. See Figure 1 with pictures corresponding to specimen No.
30	220-230	15		NONE	
40	220-230	15		NONE	
30	220-230	15		NONE	

105 TREATMENT

				.020	Mask was scraped from edge between Treatments on specimens 21 thru 24. Mask was completely removed on specimens 25 and 26. Specimen 26 was run without current. See Figure 1 with pictures corresponding to specimen No.
				.005	
1	145 ± 5	2		NONE	
1.5	145 ± 5	2		NONE	
2	145 ± 5	2		NONE	
1	145 ± 5	4		NONE	
			.001	.0037	
			.0025	NONE	

OGLEAM 55 TREATMENT

10	180-190	10		NONE	Mask was scraped from edge between Treatments. Specimen 27A, 28A, 29A are raw samples. Specimen 27B, 28B, 29B are Nitric acid Leveling. Specimen 29C, 28C, 29C are Electrogleam 55 treatments. Specimen 27A, B, C. all represent steps performed on one sample etc. See Figure 1 with pictures corresponding to specimen No.
20	180-190	10		NONE	
30	180-190	10		NONE	

TABLE

TURCO 105 TREATMENT

SPECIMEN NO	AREA (SQ. IN)	CURRENT DENSITY (AMP/SQ IN)	TIME (MIN)	TEMP (°F)	VOITAGE	RADIUS (IN)	COM
30	.06	20	5	145 ± 5	2	.003	Etchant A NO operat SEE Figur corresgond
31	.07	20	5	145 ± 5	2	.003	

4140 STEEL ETCHANT

32	.11	10	20	145 ± 5	2	.0058	Etchant a
33	.11	5	30	145 ± 5	1	.005	a Knife on Edge a Figure 1 to specime burnished
34	.11	20	10	145 ± 5	3	.0058	

INCONEL 718 ETCHANT

35	.088	10	10	145 ± 5	1	.0058	a Knife E Edge and with pictu
36	.088	5	15	145 ± 5	.5	.0054	
37	.088	20	5	145 ± 5	2.5	.0046	No. Etch 2.7 NO_3^-.
38	.088	10	30	75-85	1.5	NONE	with a Kn

TURCO 105 TREATMENT

39	.053	20	10	145 ± 5	1	.0058	a Knife Edge and mask burnished w deburring.
40	.053	10	15	145 ± 5	.5	.0058	
41	RAW SPECIMEN FOR 35 thru 40						
42	RAW SPECIMEN FOR 32 thru 34						

TURCO $H^+ = 6.0$ $NO_3^- = 4.5$

43	.192	5	30	145 ± 5	1.5	.007	a Knife Edge and mask sc burnished wit deburring. Se
44	.2	10	15	145 ± 5	3.2	NONE	
45	.2	20	8	145 ± 5	6.0	NONE	

TURCO 105 TREATMENT

46	.12	5	10	145 ± 5	.5	.008	a Knife Edg a mask scra Figure 1 with specimen NO
47	.12	10	10	145 ± 5	1.5	NONE	
48	.12	20	5	145 ± 5	2.0	NONE	

INCONEL 718 ETCHANT

49	.04	5	20	145 ± 5	.25	.008	a Knife Edge and mask sc Figure 1 wit to specimen
50	.08	10	15	145 ± 5	2.0	NONE	
51	.10	20	10	145 ± 5	3.0	NONE	

4140 STEEL ETCHANT

52	.07	5	40	145 ± 5	.5	NONE	a Knife Edge and mask s Figure 1 with Specimen NO
53	.07	10	20	145 ± 5	3.0	NONE	
54	.14	20	9	145 ± 5	5.0	NONE	
55	RAW SPECIMEN FOR 46 and 49						
56	RAW SPECIMEN FOR 47, 48, 50, 51, 52, 53 and 54						

TABLE 18

O 105 TREATMENT					COMMENT
CURRENT DENSITY (AMP/SQ IN)	TIME (MIN)	TEMP (°F)	VOITAGE	RADIUS (IN)	
20	5	145 ± 5	2	.003	Etchant Analyzed 4.5 H^+ and 2.7 NO_3^- NO operation performed on mask. See Figure 1 with pictures corresponding to specimen No.
20	5	145 ± 5	2	.003	
STEEL ETCHANT					Etchant analyzed 3.0 H^+ and 2.5 NO_3^-
10	20	145 ± 5	2	.0058	a Knife Edge was placed 45° on edge and mask scraped. See Figure 1 with pictures corresponding to specimen No. Specimens were burnished with a Knife edge after deburring.
5	30	145 ± 5	1	.005	
20	10	145 ± 5	3	.0058	
L 718 ETCHANT					
10	10	145 ± 5	1	.0058	a Knife Edge was placed 45° on edge and mask scraped. See Figure 1 with pictures corresponding to specimen No. Etchant Analyzed 6.5 H^+ and 2.7 NO_3^-. Specimens were burnished with a Knife edge after deburring.
5	15	145 ± 5	.5	.0054	
20	5	145 ± 5	2.5	.0046	
10	30	75-85	1.5	NONE	
105 TREATMENT					a Knife Edge was placed 45° on Edge and mask scraped. Specimens were burnished with a Knife Edge after deburring. See Figure 1 with pictures corresponding to specimen No.
20	10	145 ± 5	1	.0058	
10	15	145 ± 5	.5	.0058	
ECIMEN FOR 35 thru 40					
ECIMEN FOR 32 thru 34					
H^+ = 6.0 NO_3^- = 4.5					a Knife Edge was placed 45° on Edge and mask scraped. Specimen 43 was burnished with a Knife Edge after deburring. See Figure 1 with pictures corresponding to specimen No.
5	30	145 ± 5	1.5	.007	
10	15	145 ± 5	3.2	NONE	
20	8	145 ± 5	6.0	NONE	
05 TREATMENT					a Knife Edge was placed 45° on Edge a mask scraped. No burnishing. See Figure 1 with pictures corresponding to specimen No.
5	10	145 ± 5	.5	.008	
10	10	145 ± 5	1.5	NONE	
20	5	145 ± 5	2.0	NONE	
718 ETCHANT					a Knife Edge was placed 45° on Edge and mask scraped. No burnishing. See Figure 1 with pictures corresponding to specimen No.
5	20	145 ± 5	.25	.003	
10	15	145 ± 5	2.0	NONE	
20	10	145 ± 5	3.0	NONE	
EL ETCHANT					a Knife Edge was placed 45° on Edge and mask scraped. No burnishing. See Figure 1 with pictures corresponding to Specimen No.
5	40	145 ± 5	.5	NONE	
10	20	145 ± 5	3.0	NONE	
20	9	145 ± 5	5.0	NONE	
CIMEN FOR 46 and 49.					
CIMEN FOR 47, 48, 50, 51, 52, 53 and 54					

2

TABLE 18

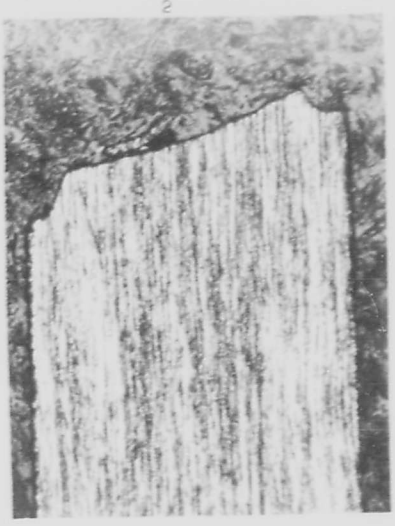
COMMENT

Etchant Analyzed 4.5 H^+ and 2.7 NO_3^- NO operation performed on mask. See Figure 1 with pictures corresponding to specimen No.	
Etchant analyzed. 3.0 H^+ and 2.5 NO_3^- a knife edge was placed 45° on edge and mask scraped. See Figure 1 with pictures corresponding to specimen No. SPECIMENS WERE burnished with a knife edge after deburring.	
a knife edge was placed 45° on edge and mask scraped. See Figure 1 with pictures corresponding to specimen No. Etchant Analyzed 6.5 H^+ and 2.7 NO_3^-. SPECIMENS WERE burnished with a knife edge after deburring.	
a knife edge was placed 45° on edge and mask scraped. Specimens were burnished with a knife edge after deburring. See Figure 1 with pictures corresponding to specimen No.	
a knife edge was placed 45° on edge and mask scraped. Specimen 43 was burnished with a knife edge after deburring. See Figure 1 with pictures corresponding to specimen No.	
a knife edge was placed 45° on edge a mask scraped. No burnishing. See Figure 1 with pictures corresponding to specimen No.	
a knife edge was placed 45° on edge and mask scraped. No burnishing. See Figure 1 with pictures corresponding to specimen No.	
a knife edge was placed 45° on edge and mask scraped. No burnishing. See Figure 1 with pictures corresponding to specimen No.	

FIGURE 1 - DEBURRED SPECIMENS - 25% NITRIC ACID MAG. 75X

1

2



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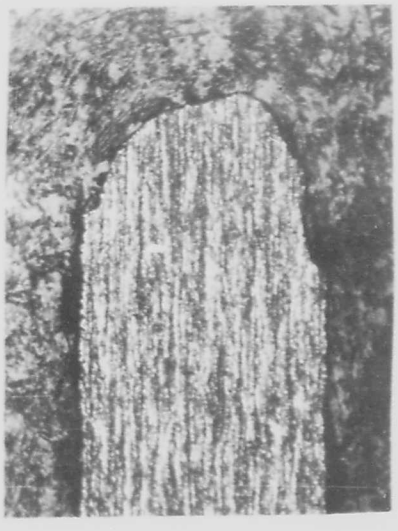

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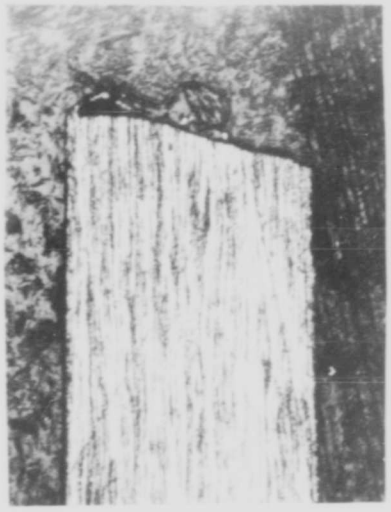
FIGURE 1 - DEBURRED SPECIMENS - 25% NITRIC ACID MAG. 75X

5



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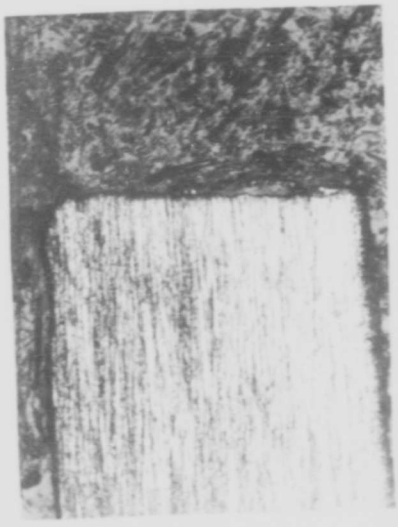
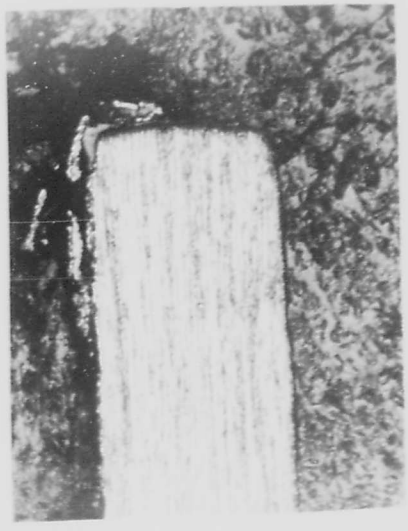


FIGURE 1 - DEBURRED SPECIMENS LEVELED IN 25% NITRIC ACID AND POLISHED IN ELECTROGLEAM 55. MAG. 75X

7



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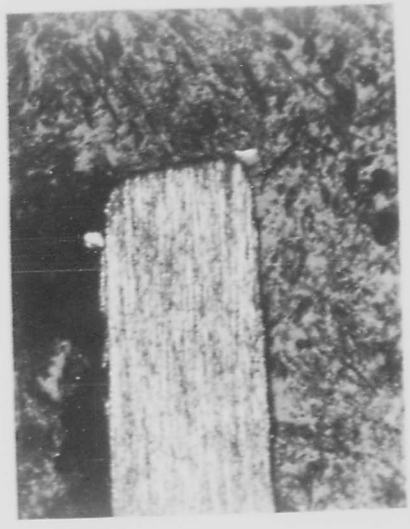

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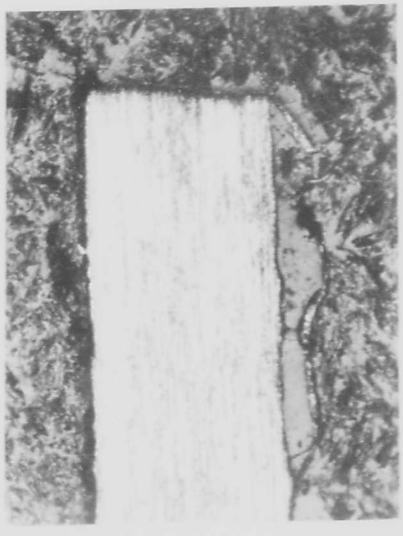

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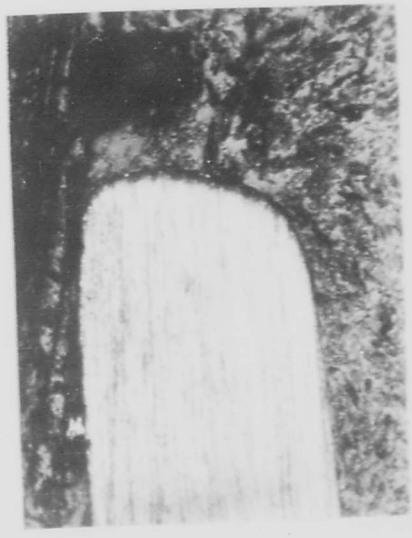
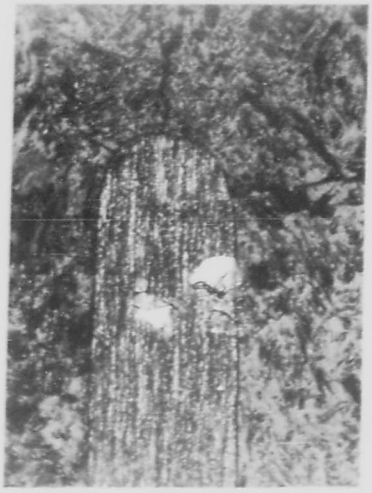


FIGURE 1 - DEBURRED SPECIMENS LEVELED IN 25% NITRIC ACID AND POLISHED IN ELECTROGLEAM 55

MAG. 75X

11



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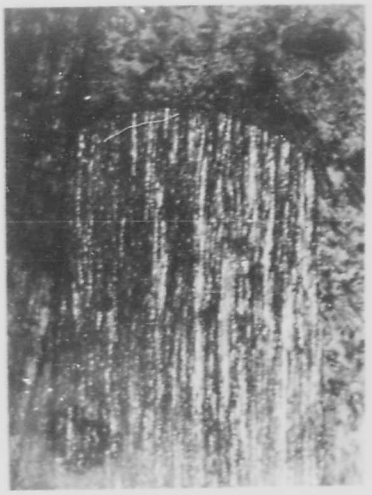

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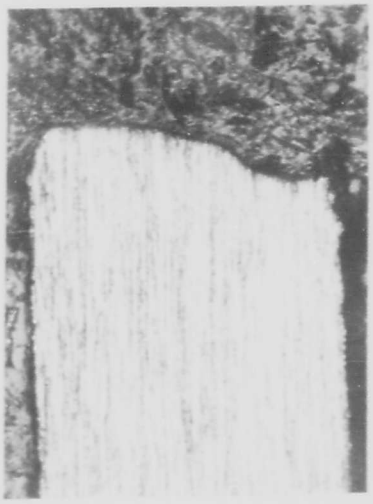

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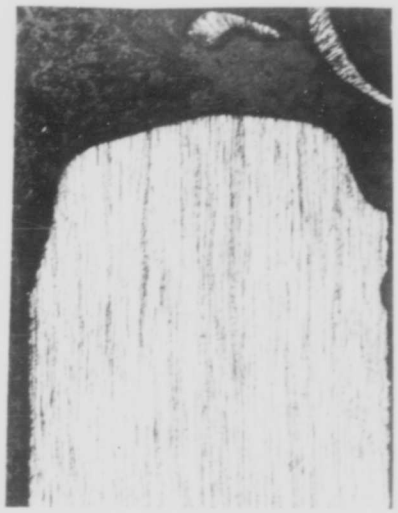
FIGURE 1 - DEBURRED SPECIMENS LEVELED IN 25% NITRIC ACID AND POLISHED IN ELECTROPOLISH B.S. MAG. 75X

15



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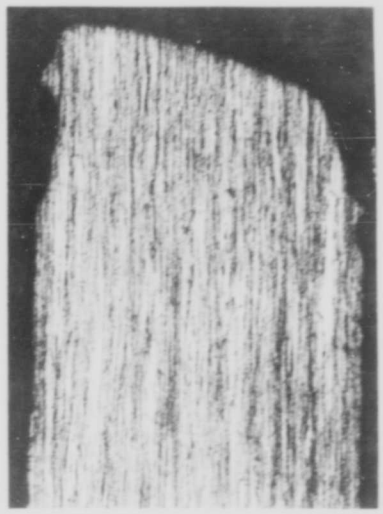

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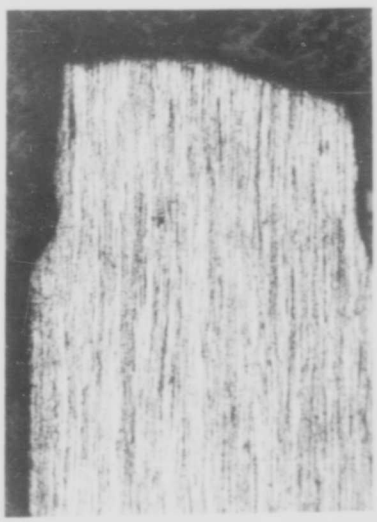

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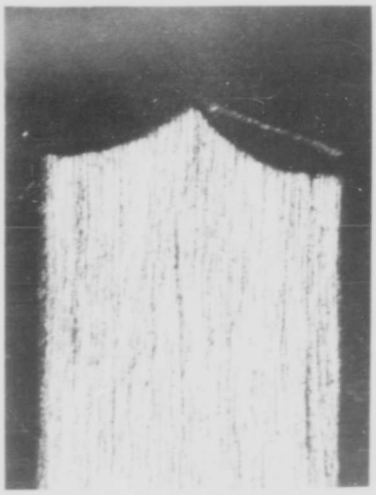
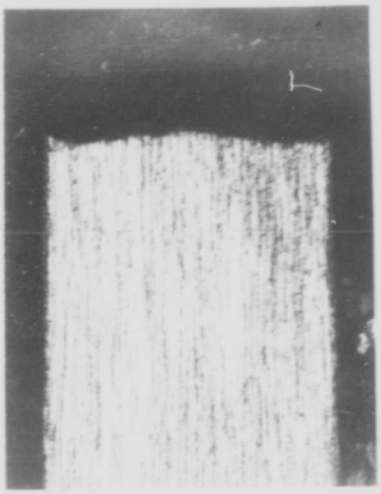
FIGURE 1 - DEBURRED SPECIMENS LEVELED IN 25% NITRIC ACID AND POLISHED IN ELECTROPOLISH B.S. MAG. 75X

18A



18B



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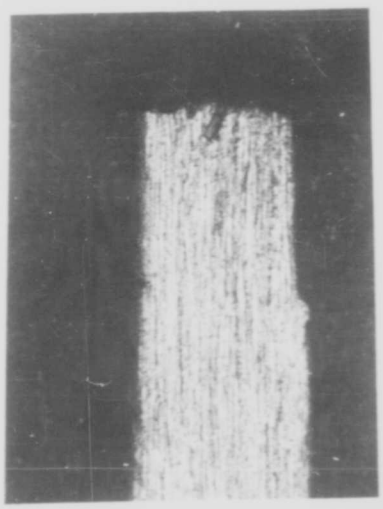

FIGURE 1 - DEBURRED SPECIMENS. TUROO 105 PTCHANT

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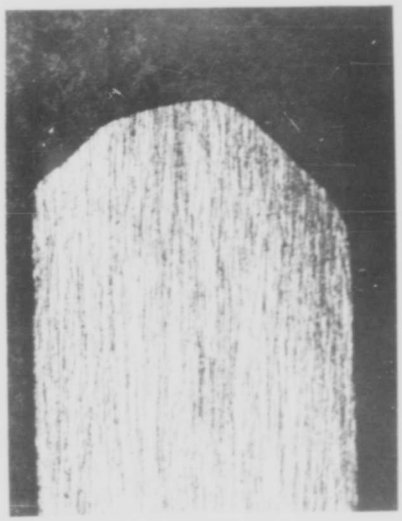
MAG. 75X

19



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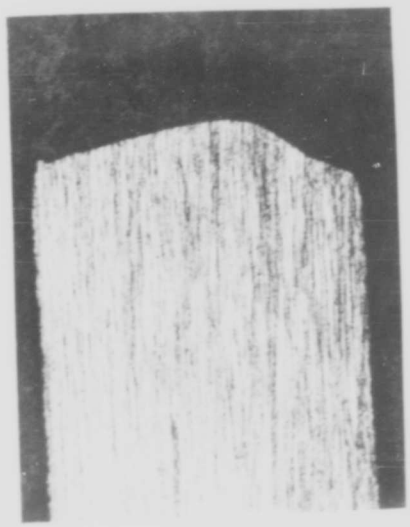

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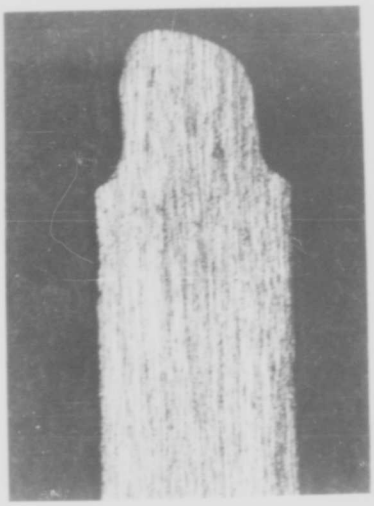
FINAL REPORT

FIGURE 1 - DEBURRED SPECIMENS. TURCO 105 TREATMENT

MAG. 75X

23

24



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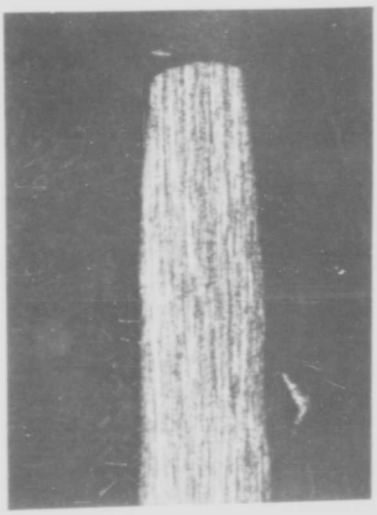

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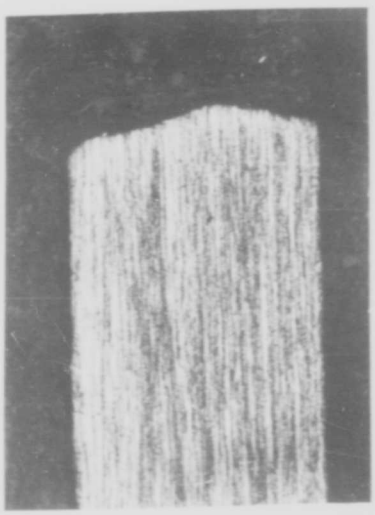
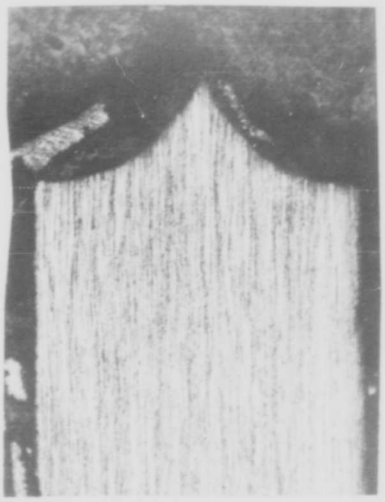


FINAL REPORT

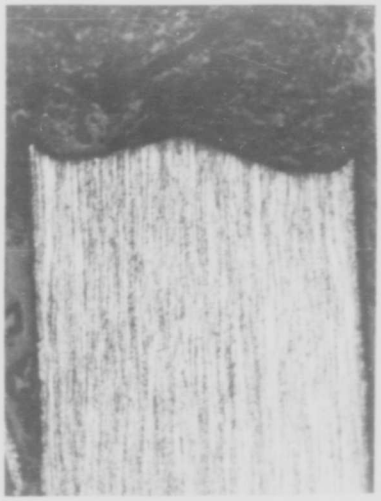
FIGURE 1 - DEBURRED SPECIMENS. LEVELED IN 25% NITRIC ACID AND POLISHED IN ELECTROGLEAM 55.

MAG. 75X

27A



27B



27C

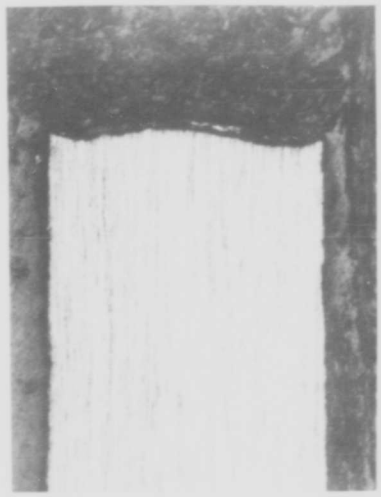
FINAL REPORT

FIGURE 1 - DEBURRED SPECIMEN LEVELED IN 25% NITRIC AND POLISHED IN ELECTROGLEAM 55

MAG. 75X

28A

28B



28C

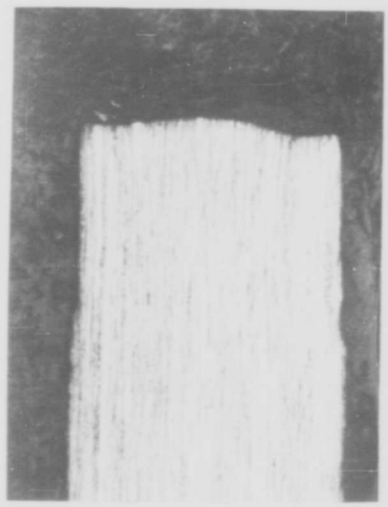


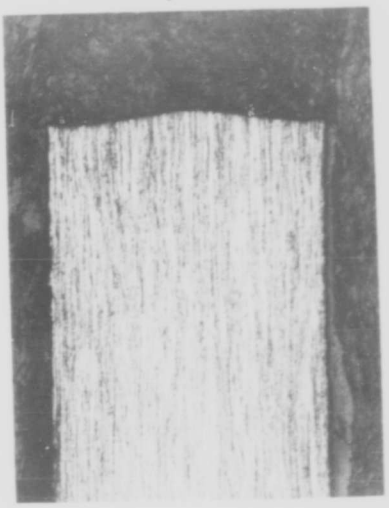
FIGURE 1 - DEBURRED SPECIMENS LEVELED IN 25% NITRIC ACID AND POLISHED IN ELECTROGLEAM 55

FINAL REPORT

MAG. 75X

29A

29B



29C

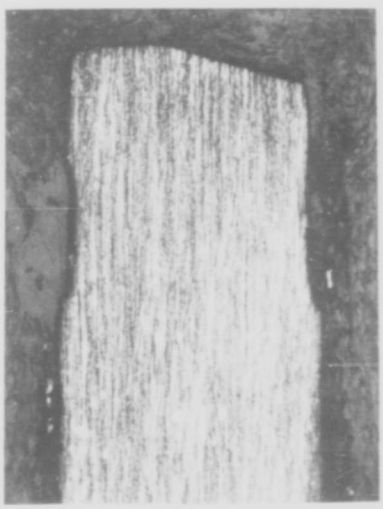


FIGURE 1 - DEBURRED SPECIMENS TURCO 105 ETCHANT FINAL REPORT

MAG. 75X

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FIGURE 1 - DEBURRED SPECIMENS - 4140 STEEL ETCHANT FINAL REPORT

32

MAG. 75X

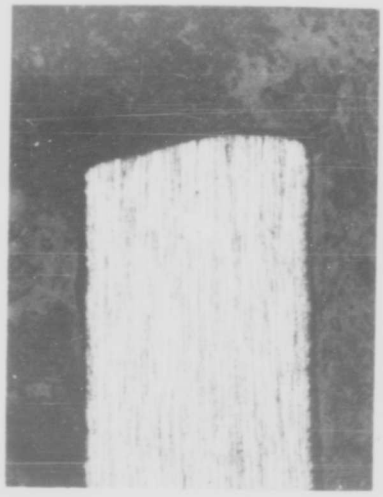
33

34

FIGURE 1 - DEBURRED SPECIMENS INCONEL 718 ETCHANT

FINAL REPORT
MAG. 75X

35



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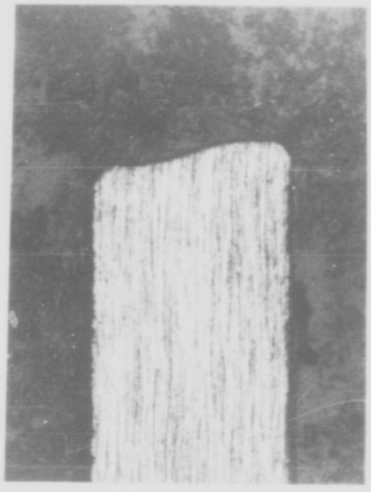

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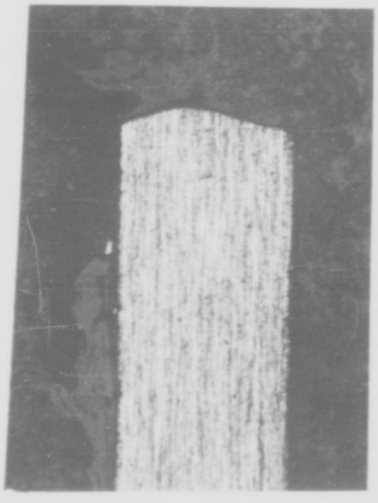

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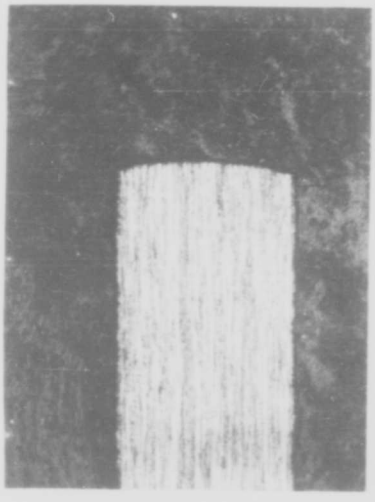

FIGURE 1 - DEBURRED SPECIMENS TURCO 105 ETCHANT

FINAL REPORT
MAG. 75X

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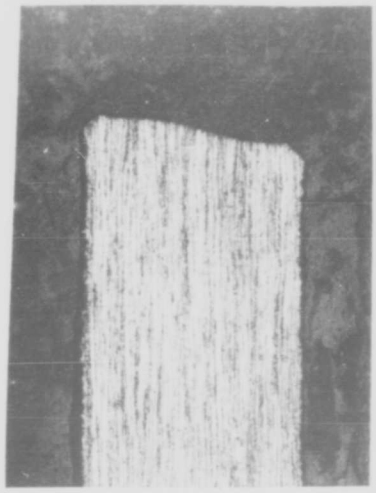

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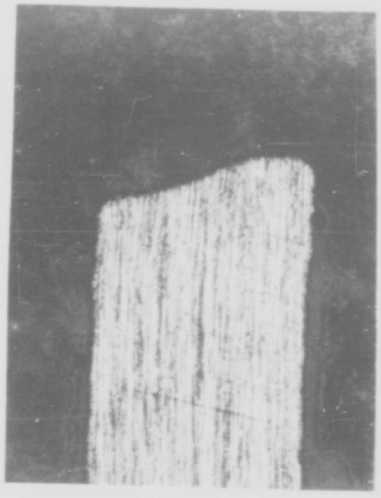

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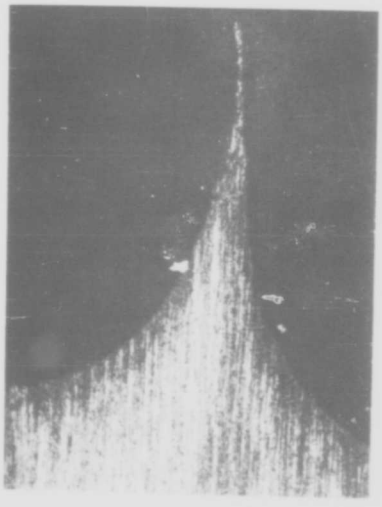

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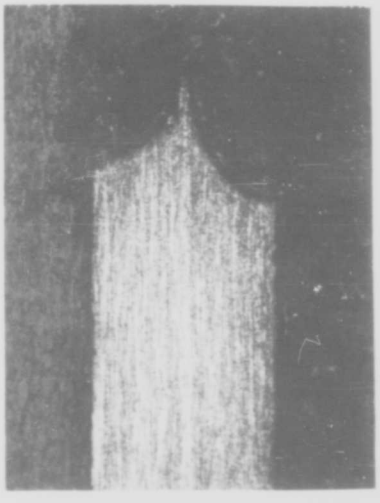
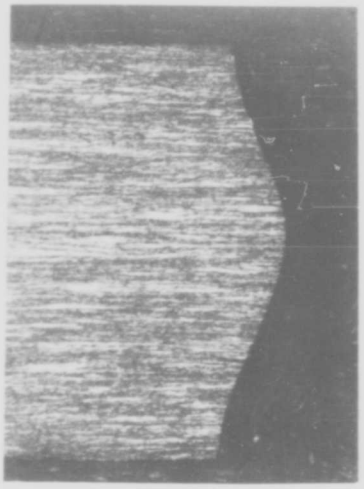


FIGURE 1 - DEBURRED SPECIMENS. TURCO 105 ETCHANT
$H^+ = 6.0$, $NO_3^- = 4.5$
43

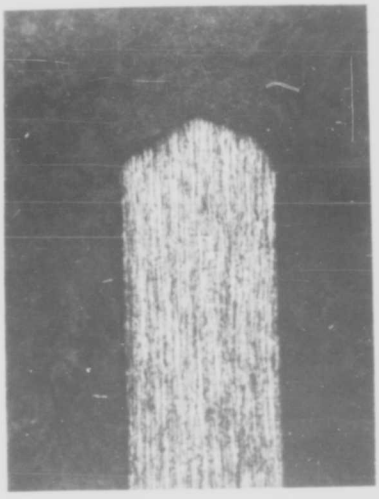
FINAL REPORT
MAG. 75X
44



45

FIGURE 1 - DEBURRED SPECIMENS - TURCO 105 ETCHANT FINAL REPORT
MAG. 75X

46



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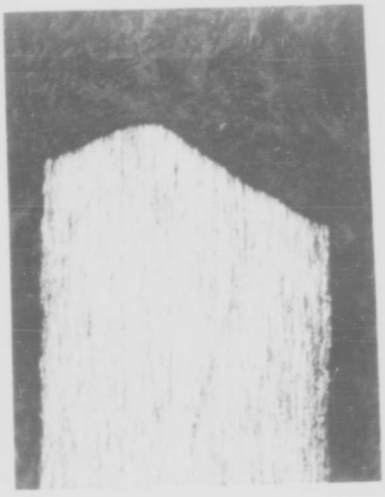

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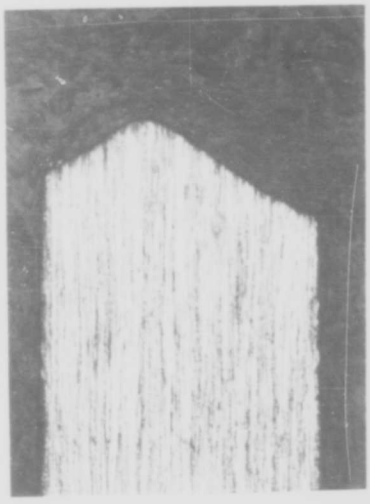

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FIGURE 1 - DEBURRED SPECIMENS - INCONEL 718 ETCHANT

FINAL REPORT
MAG. 75X

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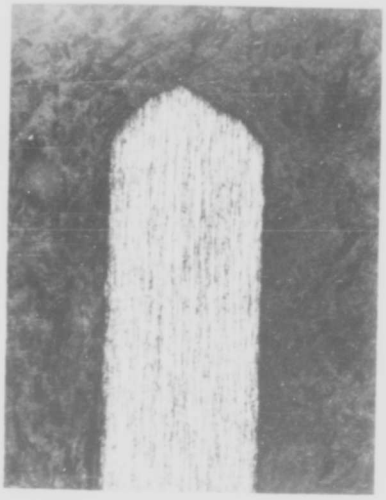

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51

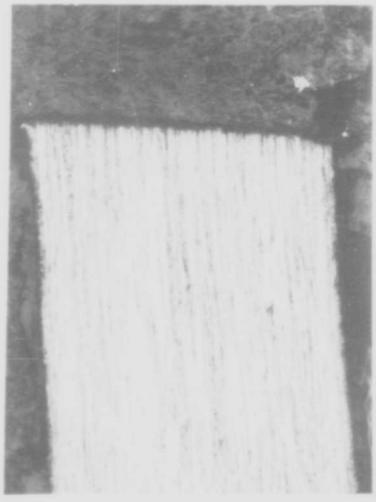

FIGURE 1 - DEBURRED SPECIMENS - 4140 STEEL ETCHANT

FINAL REPORT

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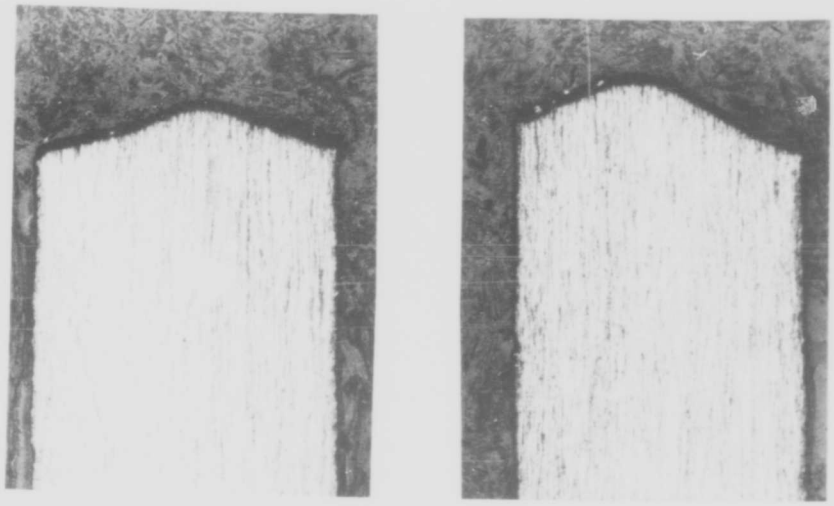
MAG. 75X



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FINAL REPORT

FIGURE 1 - RAW SPECIMENS

MAG. 75X

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FINAL REPORT

FIGURE 1

METHOD OF RACKING

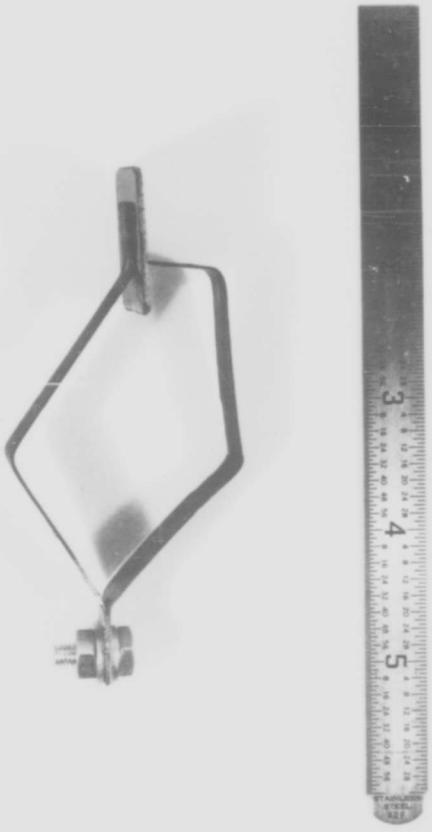
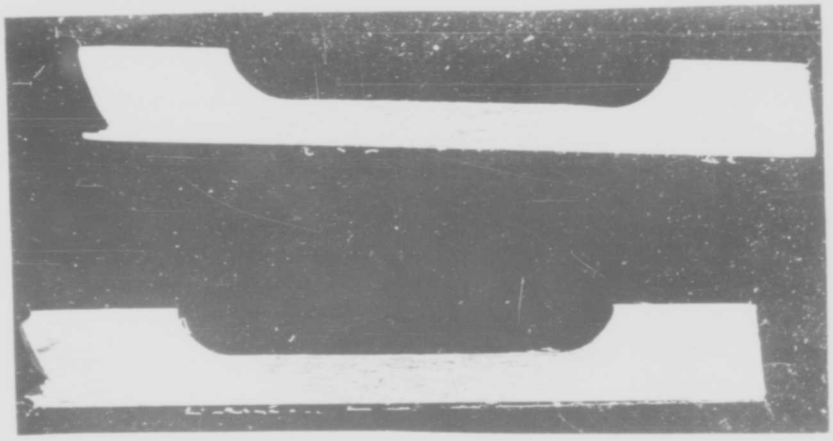


FIGURE 3 - ELECTROPOLISH AND ELECTRO -DEBURRING OF ALUMINUM FINAL REPORT

AFTER ELECTROPOLISH

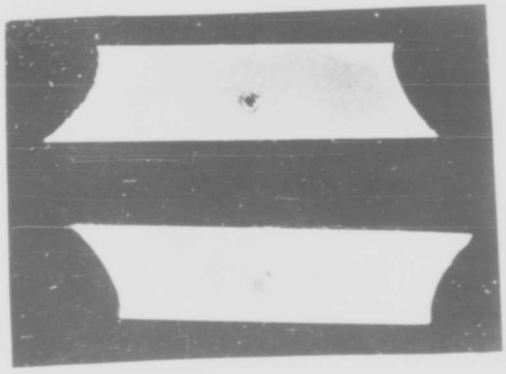


BEFORE ELECTROPOLISH

FINAL REPORT

FIGURE 4 - ELECTROPOLISH AND ELECTRO-DEBURRING OF STAINLESS STEEL

BEFORE ELECTROPOLISH



AFTER ELECTROPOLISH

MAC 1008 (REV. 28 JAN. 59)
PAGE 1 OF 3

TEST REQUEST

TITLE Electrochemical Deburring of Molybdenum, Aluminum and Stainless Steel

LABORATORY OR DEPT. RESPONSIBLE FOR TEST	MODEL
Dept 253 (BC)	Misc.
TEST PARTS ON IBM ☐: ON TPL NO. ____ PRODUCTION PARTS FOR TEST NOT REQUIRED ☒	APL/EPL None

OK for IDEP

WORK REQUESTED

OBJECTIVE (GIVE PURPOSE OF TEST, WORK AND DATA REQUIRED INCLUDING SERVICE HISTORY AND BACKGROUND INFORMATION)

REV. A Rmr
F6575-068

1.0 OBJECT

To determine the electrochemical techniques and solutions required to remove sharp edges which result in chemical milling and blanking.

2.0 HISTORY AND JUSTIFICATION

Sharp edges left after chemical milling and blanking are presently being mechanically removed at high cost. During mechanical removal delamination may occur, particularly with molybdenum and its alloys. Some parts are also complicated in geometrical shape adding to the high cost of removal.

The sharp areas would be areas of high current density in electro-chemical operations and should be easily reduced in electrochemical solutions. It is necessary to test various solutions for breaking sharp edges and to select the solution most suitable for each material.

3.0 MATERIALS AND SOLUTIONS

3.1 Molybdenum per MMS-184.
3.2 Aluminum 7178-T6 per MIL-A-9180.
3.3 Stainless Steel, 17-7PH per MIL-S-25043, 321 per MIL-S-6721.

NOTE: Chem-blanked parts of molybdenum and chem-milled parts of aluminum and stainless will be furnished by Dept. 272.

3.4 Electro-Gleam 55 (MacDermid Inc.)
3.5 Electropolish BS (MacDermid Inc.)
3.6 Electropolish BA (MacDermid Inc.)

REFERENCES OR ENCLOSURES

Equipment $50 — REV B ADDS ACTUALS 11-7-62 CMT

NOTE: The above solutions will be furnished by Department 272.

3.7 Sulfuric acid - alcohol electro polish.

3.8 Chromic-sulfuric acid electro polish.

4.0 PROCEDURE

4.1 Make up one gallon of each solution as follows:

4.1.1 Solutions of paragraph 3.4 through 3.6 will be made up per vendors literature furnished by Dept. 272.

4.1.2 Sulfuric acid-alcohol polish:

One part concentrated sulfuric acid to seven parts methyl alcohol (95%). Anode current density - 4 ASI. Cathode - Stainless Steel. Temperature - Room Temperature.

4.1.3 Nitric acid 50 percent (by weight). Temperature 80-105 F.

4.1.4 Chromic-Sulfuric Acid - 11.3%, by volume, concentrated sulfuric acid, Chromic acid, 17 lb./gal., and the remainder water. Cathode - Stainless Steel.

4.2 Chemical Deburring Tests

4.2.1 Chem-deburr the sharp edges of the following masked materials in listed solutions as follows:

Solution	Materials
Electro-Gleam 55	Molybdenum Stainless Steel Aluminum
Electropolish BA	Aluminum
Electropolish BS	Stainless Steel Molybdenum
Paragraph 4.1.2	Molybdenum
4.1.3	Molybdenum
4.1.4	Molybdenum

4.2.2 Immerse the part (anodic) in solution and apply amperage at the middle of the range suggested by vendor literature or rate specified in 4.1.2 for solutions of paragraph 4.1.2 through 4.1.4.

NOTE: Use copper clips for attachment of parts in MacDermid solutions and stainless clips for remainder of solutions. If clips are immersed in solution, a maskant shall be applied to prevent attack of clip.

4.2.3 Vary the amperage, length of chem-deburring time, and concentration of solution until a minimum chem-deburr time requirement is obtained for breaking all sharp edges to an approximate 0.005 inch radius with minimum undercut.

4.2.4 Repeat the test as listed in paragraph 4.2 with the maskant removed. Chem-polish the surface until a maximum smoothness is obtained by varying the amperage and solution concentration.

5.0 RESULTS

5.1 Current density, temperature, concentration, time, voltage, and calculated area used to produce 0.005 inch radius of each metal, surface finish of unmasked chem-polish surfaces (RMS reading) and metal removal rate.

5.2 List any unusual characteristics of solutions noticed while chem-polishing which might produce detrimental effect in production such as temperature increase and effect of materials on maskant. Also, state effective life of solutions without additions.

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