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ELECTROCHEMICAL
DEBURRING OF MOLYBDENUM,
ALUMINUM AND
STAINLESS STEEL

REPORT A478 SERIAL NO. 20

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

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

ELECTROCHEMICAL DEBURRING OF MOLYBDENUM,
ALUMINUM AND STAINLESS STEELABSTRACT

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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REPORT A478**FINAL REPORT****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) $\text{Fe}(\text{NO}_3)_3 \cdot 9\text{H}_2\text{O}$ - 370 gms
 $\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$ - 236 gms
 H_3PO_4 70% - 124 mls
 $\text{CrCl}_3 \cdot 6\text{H}_2\text{O}$ - 51 gms
 HCl 12.4N - 121 mls
water to make 1 liter
 - (b) Same as (a) adjusted to $\text{H}^+ = 6.0\text{N}$ and $\text{NO}_3^- = 4.5\text{N}$
- (12) 4140 Steel etchant
 $\text{H}^+ = 6.5\text{N}$, $\text{NO}_3^- = 2.27\text{N}$
- (13) Inconel 718 etchant
 $\text{H}^+ = 3.0\text{N}$, $\text{NO}_3^- = 2.5\text{N}$

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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FINAL REPORT4.1.2 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 Electroglean 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 Electroglean 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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FINAL REPORT4.5 Electroglean 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 Electroglean 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 electroglean BS on the base specimen, as with Electroglean 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 Electroglean 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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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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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.)	VOLTAGE	TIME (MIN.)	TEMP (OF)	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.

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TABLE 3
NITRIC ACID 75% BY WT. OF molybdenum
WITH MASKED SPECIMENS

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

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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	

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TABLE 5 ALCOHOL - SULPHURIC ACID WITH MASKED SPECIMENS OF molybdenum						COMMENTS
AREA (SQ. IN.)	CURRENT DENSITY (AMP/SQ. IN.)	VOLTAGE	TIME (MIN.)	TEMP (°F)		
.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 ₂ SO ₄ . DECOMPOSES ALCOHOL
.09	1.0	6.0	9	80		ADDED 200 MLS OF H ₂ SO ₄ DECOMPOSES ALCOHOL

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TABLE 6
NITRIC - HYDROFLUORIC 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	110	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

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TABLE 7
ELECTROGLEAM SS
WITH MASKED SPECIMENS OF molybdenum

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

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TABLE 9
ELECTRODE AM SS
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

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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 SS
2	1.0	7	10	200-205	.0005	GREATER THAN ELECTROGLEAM SS
2	1.5	15	10	200-205	.0008	GREATER THAN ELECTROGLEAM SS

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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 SS
2.2	8	0.6	10	125	.0025	GREATER THAN ELECTROGLEAM SS
1.1	12	1.1	10	125	.006	GREATER THAN ELECTROGLEAM SS

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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 SS
2.2	2	1.5	20	110	.0025	GREATER THAN ELECTROGLEAM SS
2.0	8	4.5	20	105	.004	GREATER THAN ELECTROGLEAM SS

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TABLE 13 ALCOHOL-SULPHURIC ACID WITH MASK REMOVED FROM MOLYBDENUM							RMS
AREA (SQ. IN)	CURRENT DENSITY (AMP/SQ IN)	VOLTAGE	TIME (MIN)	TEMP (°F)	METAL REMOVAL (IN /SIDE)		
2.4	.5	3.5	20	80	.002		GREATER THAN ELECTROGLEAM SS
2.0	.1	4.5	20	80	.0025		GREATER THAN ELECTROGLEAM SS
2.2	1.2	6.0	20	80	.003		GREATER THAN ELECTROGLEAM SS

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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

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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			
AREA (SQ IN)	CURRENT DENSITY (AMP/SQ IN)	TIME (MIN)	TEMP (°F)
.14	8	6	118
.18	8	2	118
.08	8	2.5	118
.11	8	1	11

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

ELECTROGLEAM

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

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					

ELECTROPOLISH

.16	3	20	22
.16	2.5	30	22
.34	3	40	22
.44	2.5	30	22

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	

TURCO 105

.16	20	1	14
.12	20	1.5	14
.10	20	2	14
.15	23	1	14

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					

ELECTROGLEAM

.06	3.4	10	18
.05	3.2	20	18
.05	3.2	30	18

1

TABLE 17

		NITRIC ACID TREATMENT								COMMENT	
P	VOLTAGE	AREA (SQ IN)	CURRENT DENSITY (AMP/SQ IN)	TIME (MIN)	TEMP (°F)	VOLTAGE	METAL REMOVED (IN/SIDE)	RADIUS (IN)			
28	.05							NONE		MASK WAS SCRAPED FROM NITRIC ACID TREATMENT. SCRAPED FROM EDGE BE TREATMENT ON SPECIM Figure 1 with pictures. Specimen NO.	
28	.05							NONE			
28	.1							NONE			
28	.1	.14	8	6	118-128	.1		NONE			
28	.1	.18	8	2	118-128	.1		NONE			
28	.1	.08	8	2.5	118-128	.1		NONE			
28	.1	.11	8	1	118-128	.1		.004			
ENT		ELECTROGLEAM SS TREATMENT									
28	.05	3	.8	10	180-190	10	.0005	.002		MASK WAS COMPLETELY NITRIC ACID TREATMENT SS TREATMENT WITH SPECIMEN 13 WHERE + SCRAPED FROM THE ED TREATMENTS SEE Figure corresponding to specim	
28	.1	2	1	10	180-190	10	.0005	.0026			
28	.1	2	1	10	180-190	10	.0005	.0012			
28	.1	3	1.6	20	180-190	10	.0015	.006			
28	.05	2	.75	20	180-190	10	.0015	.006			
28	.1	1.1	1.4	20	180-190	10	.001	.005			
28	.15	.18	.6	10	180-190	10		.0035			
ENT		ELECTROPOLISH BS TREATMENT									
28	1.2	.16	3	20	220-230	15		NONE		MASK WAS SCRAPED FROM NITRIC ACID TREATMENT BS TREATMENT. SPECIMEN 25 AND 26. SPECIMEN 27A, B, C. ALL REPRESENT ONE SAMPLE ETC. SEE Figure 1 with pictures. Specimen No.	
28	1.2	.16	2.5	30	220-230	15		NONE			
28	1.5	.34	3	40	220-230	15		NONE			
28	.5	.44	2.5	30	220-230	15		NONE			
T		TURCO 105 TREATMENT									
5	2							.020		MASK WAS SCRAPED FROM TREATMENTS ON SPECIMEN 25 AND 26. SPECIMEN 27A, B, C. ALL REPRESENT ONE SAMPLE ETC. SEE Figure 1 with pictures. Specimen No.	
5	2							.005			
5	2	.16	20	1	145 ± 5	2		NONE			
5	2	.12	20	1.5	145 ± 5	2		NONE			
5	2	.10	20	2	145 ± 5	2		NONE			
5	2	.15	23	1	145 ± 5	4		NONE			
5	2						.001	.0037			
5	2						.0025	NONE			
ENT		ELECTROGLEAM SS TREATMENT									
28	1.2	.06	3.4	10	180-190	10		NONE		MASK WAS SCRAPED FROM TREATMENTS. SPECIMEN 27A, B, C. ALL REPRESENT ONE SAMPLE ETC. SEE Figure 1 with pictures. Specimen No.	
28	1.3	.05	3.2	20	180-190	10		NONE			
28	1.0	.05	3.2	30	180-190	10		NONE			

2

3

NITRIC ACID TREATMENT

NT ITY (IN)	TIME (MIN)	TEMP (°F)	VOLTAGE	METAL REMOVED (IN/SIDE)	RADIUS (IN)
				NONE	
				NONE	
				NONE	
6	118-128	.1		NONE	
2	118-128	.1		NONE	
2.5	118-128	.1		NONE	
1	118-128	.1		NONE	
				.004	

COMMENT

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.

ELECTROGLEAM SS TREATMENT

10	180-190	10	.0005	.002
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

MASK WAS COMPLETELY REMOVED BETWEEN NITRIC ACID treatment and ELECTROGLEAM SS 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.

ELECTROPOLISH BS TREATMENT

20	220-230	15	NONE
30	220-230	15	NONE
40	220-230	15	NONE
30	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.

105 TREATMENT

			.020
			.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

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.

ELECTROGLEAM SS TREATMENT

10	180-190	10	NONE
20	180-190	10	NONE
30	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, 27C are ELECTROGLEAM SS treatments. Specimen 27A, B, C. all represent steps performed on one sample etc. SEE Figure 1 with pictures corresponding to Specimen No.

TABLE

TURCO 105 TREATMENT

SPECIMEN NO	AREA (SQ. IN)	CURRENT DENSITY (AMP/SQ IN)	TIME (MIN)	TEMP (°F)	VOLTAGE	RADIUS (IN)
30	.06	20	5	145 ± 5	2	.003
31	.07	20	5	145 ± 5	2	.003

ETCHANT
NO OPERA
SEE FIGURE
CORRESPOND

4140 STEEL ETCHANT

32	.11	10	20	145 ± 5	2	.0058
33	.11	5	30	145 ± 5	1	.005
34	.11	20	10	145 ± 5	3	.0058

Etchant a
a knife
on edge a
Figure 1
to specimens
burnished

INCONEL 718 ETCHANT

35	.088	10	10	145 ± 5	1	.0058
36	.088	5	15	145 ± 5	.5	.0054
37	.088	20	5	145 ± 5	2.5	.0046
38	.088	10	30	75 - 85	1.5	NONE

a knife edge and
with picture
No. Etch
2.7 NO₃⁻.
with a knife

TURCO 105 TREATMENT

39	.053	20	10	145±5	1	.0058
40	.053	10	15	145±5	.5	.0058
41	RAW SPECIMEN FOR 35 thru 40					
42	RAW SPECIMEN FOR 32 thru 34					

A knife edge
and mask:
burnished w/
deburring.
corresponding

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

43	.192	5	30	145 ± 5	1.5	.007
44	.2	10	15	145 ± 5	3.2	NONE
45	.2	20	8	145 ± 5	6.0	NONE

a knife edge
and mask so
burnished with
deburring. See
corresponding

TURCO 105 TREATMENT

46	.12	5	10	145 ± 5	.5	.008
47	.12	10	10	145 ± 5	1.5	NONE
48	.12	20	5	145 ± 5	2.0	NONE

a knife edge
a mask scrap
Figure 1 with
specimen NO

INCONEL 718 ETCHANT

49	.04	5	20	145 ± 5	1.25	100%
50	.08	10	15	145 ± 5	2.0	NONE
51	.10	20	10	145 ± 5	3.0	NONE

a knife edge
and mask
Figure 1 with
to specimen

4140 STEEL ETCHANT

52	.07	5	40	145 ± 5	.5	NONE
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					

a knife edge
and mask S
Figure 2 with
specimen NO

TABLE 18

105 TREATMENT

CURRENT DENSITY (AMP/50 IN)	TIME (MIN)	TEMP (°F)	VOLTAGE	RADIUS (IN)
20	5	145 ± 5	2	.003
20	5	145 ± 5	2	.003

COMMENT

Etchant Analyzed 4.5 H⁺ and 2.7 NO₃⁻
NO operation performed on mask.
SEE Figure 1 with pictures corresponding to specimen NO.

STEEL ETCHANT

10	20	145 ± 5	2	.0058
5	30	145 ± 5	1	.005
20	10	145 ± 5	3	.0058

Etchant analyzed 3.0 H⁺ and 2.5 NO₃⁻

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.

L 718 ETCHANT

10	10	145 ± 5	1	.0058
5	15	145 ± 5	.5	.0054
20	5	145 ± 5	2.5	.0046
10	30	75-85	1.5	NONE

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 NO₃⁻. SPECIMENS WERE burnished with a knife edge after deburring.

105 TREATMENT

20	10	145 ± 5	1	.0058
10	15	145 ± 5	.5	.0058

SPECIMEN FOR 35 thru 40
SPECIMEN FOR 32 thru 34

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.

H⁺ = 6.0 NO₃⁻ = 4.5

5	30	145 ± 5	1.5	.007
10	15	145 ± 5	3.2	NONE
20	8	145 ± 5	6.0	NONE

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.

105 TREATMENT

5	10	145 ± 5	.5	.008
10	10	145 ± 5	1.5	NONE
20	5	145 ± 5	2.0	NONE

A knife edge was placed 45° on edge and mask scraped. NO burnishing. SEE Figure 1 with pictures corresponding to specimen NO.

718 ETCHANT

5	20	145 ± 5	.25	.008
10	15	145 ± 5	2.0	NONE
20	10	145 ± 5	3.0	NONE

A knife edge was placed 45° on edge and mask scraped. NO burnishing. SEE Figure 1 with pictures corresponding to specimen NO.

EL ETCHANT

5	40	145 ± 5	.5	NONE
10	20	145 ± 5	3.0	NONE
20	9	145 ± 5	5.0	NONE

SPECIMEN FOR 46 and 49
SPECIMEN FOR 47, 48, 50, 51, 52, 53 and 54

A knife edge was placed 45° on edge and mask scraped. NO burnishing. SEE Figure 1 with pictures corresponding to specimen NO.

2

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.

3

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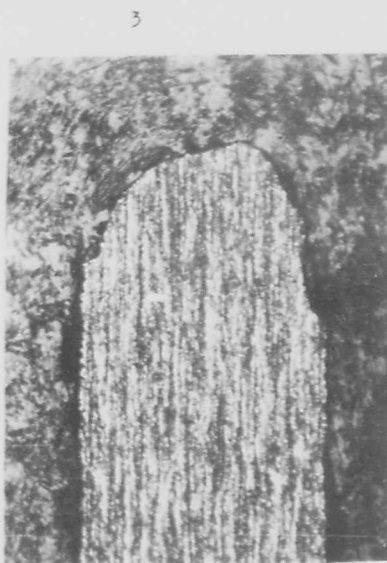
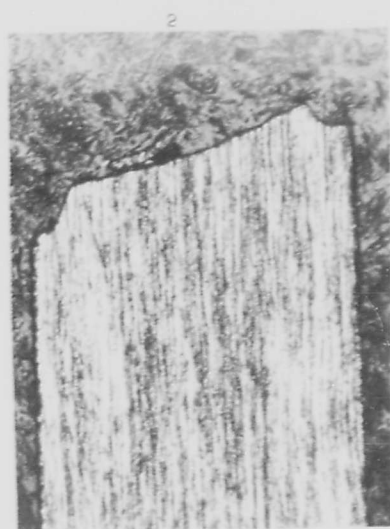
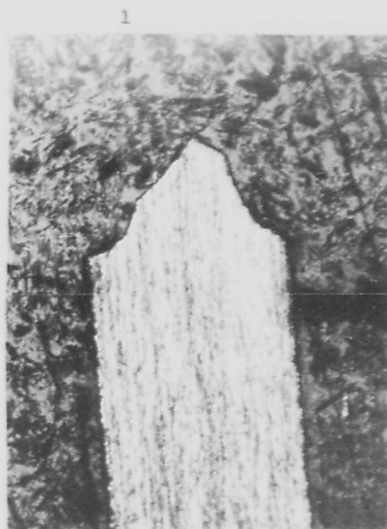
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FIGURE 1 - DEBURRED SPECIMENS - 25% NITRIC ACID

MAG. 75X



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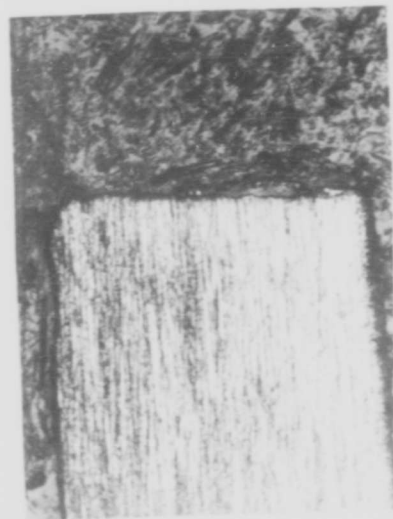
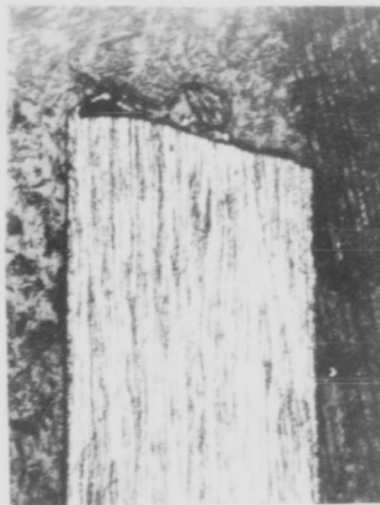
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FIGURE 1 - DEBURRED SPECIMENS - 25% NITRIC ACID

MAG. 75X

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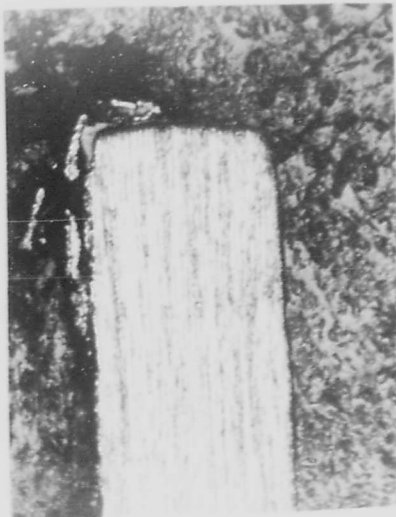
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FIGURE 1 - DEBURRED SPECIMENS LEVELED IN 25% NITRIC ACID AND POLISHED IN ELECTROGLEAM 55. MAG. 75X

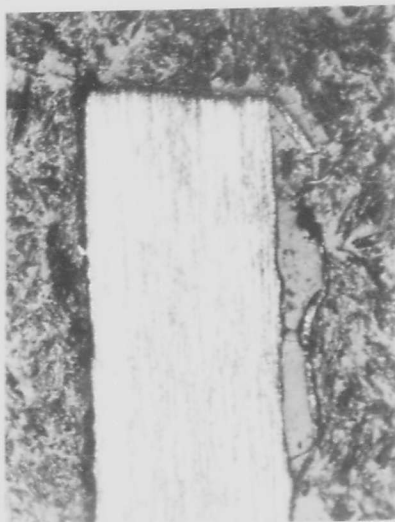
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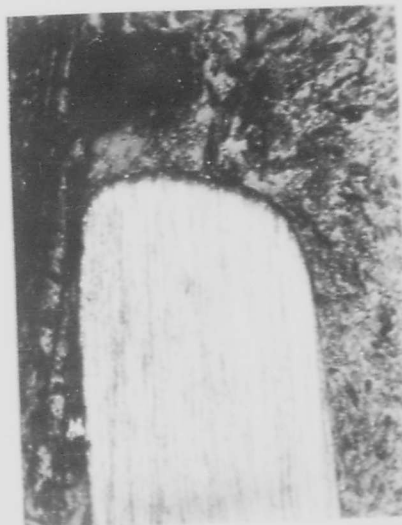
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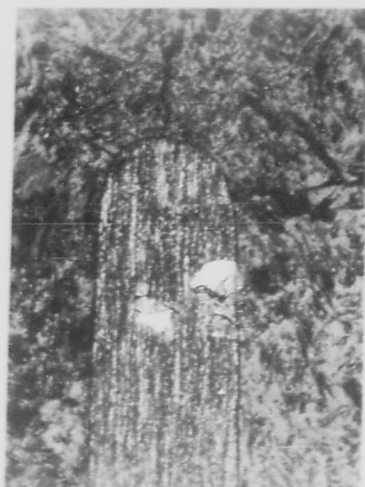
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FIGURE 1 - DEBURRED SPECIMENS LEVELED IN 25% NITRIC ACID AND POLISHED
IN ELECTROGLEAM 55

MAG. 75X

11



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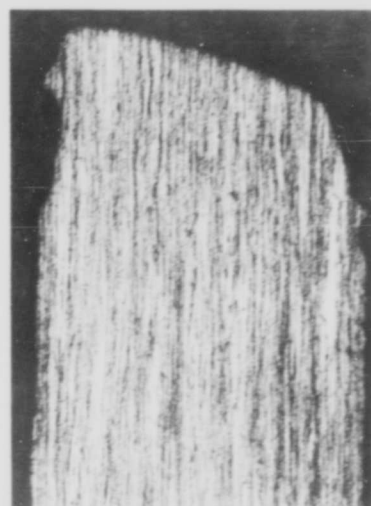
FIGURE 1 - DEBURRED SPECIMENS LEVELED IN 25% NITRIC ACID AND POLISHED
IN ELECTROPOLISH B.S.

MAG. 75X

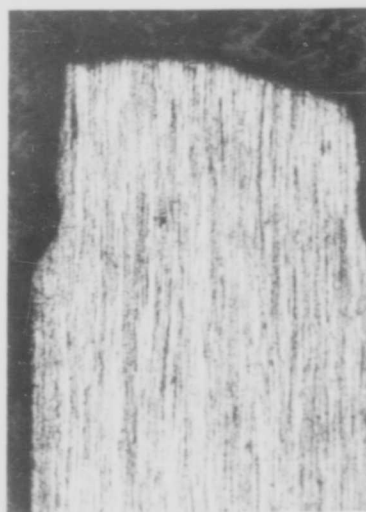
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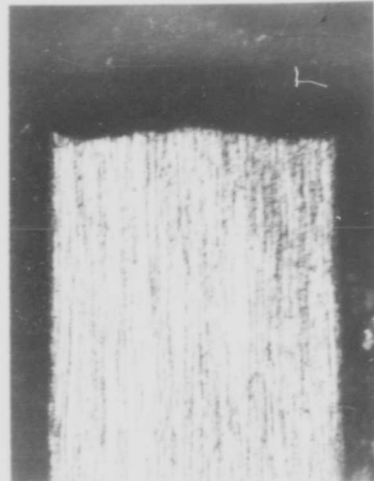
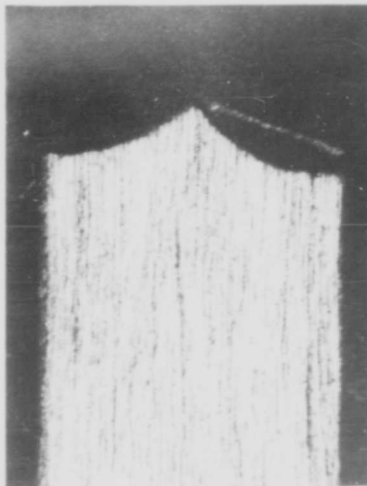
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FIGURE 1 - DEBURRED SPECIMENS LEVELED IN 25% NITRIC ACID
AND POLISHED IN ELECTROPOLISH B.S.

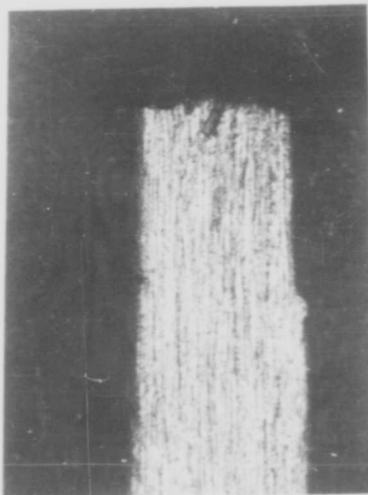
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18A

18B



18C



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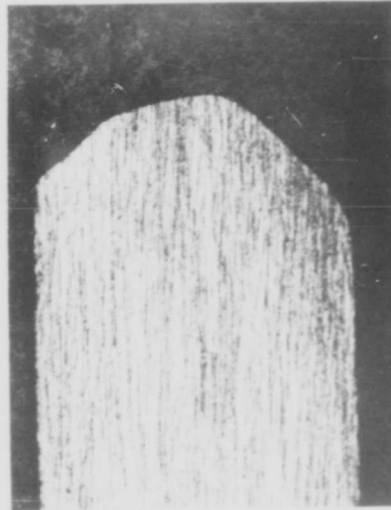
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FIGURE 1 - DEBURRED SPECIMENS. TURCO 105 ETCHANT

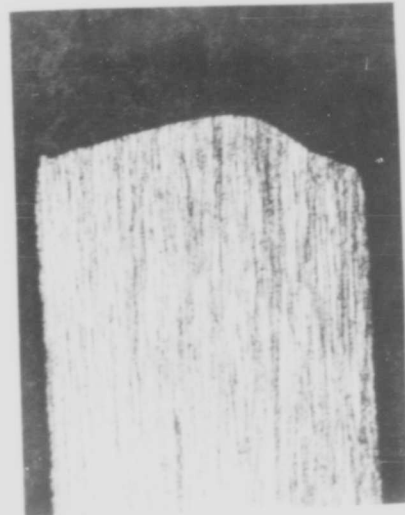
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MAG. 75X

19



20



21



22



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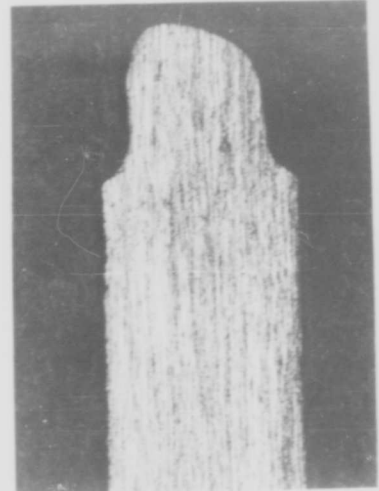
FIGURE 1 - DEBURRED SPECIMENS, TURCO 105 TREATMENT

MAG. 75X

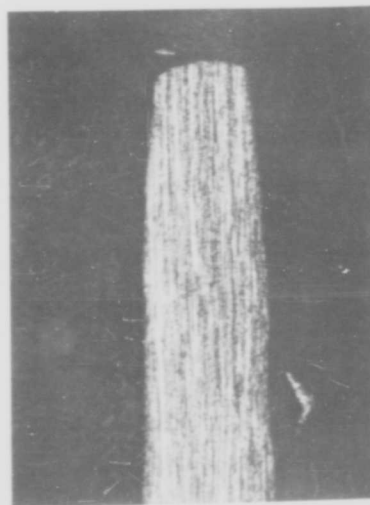
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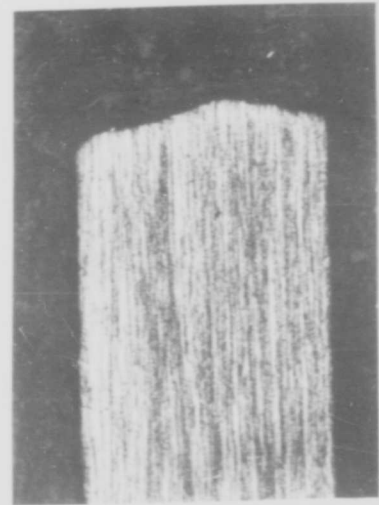
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25



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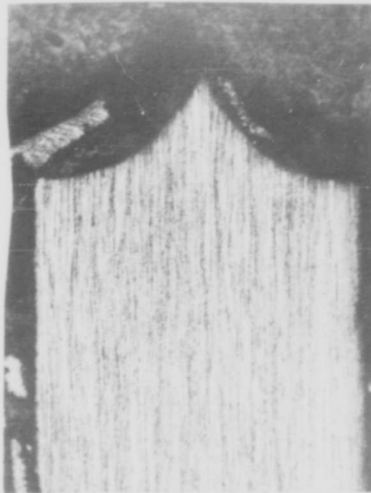
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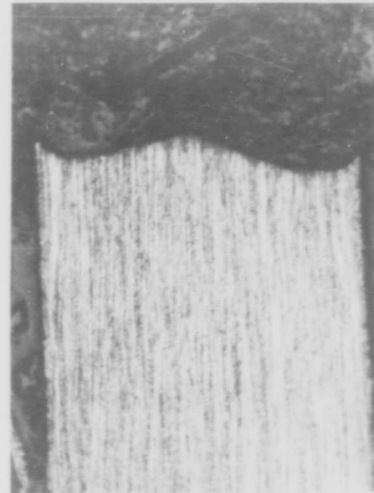
REPORT A478REVISED D4E-255995FINAL REPORTFIGURE 1 - DEBURRED SPECIMENS. LEVELED IN 25% NITRIC ACID
AND POLISHED IN ELECTROGLEAM 55.

MAG. 75X

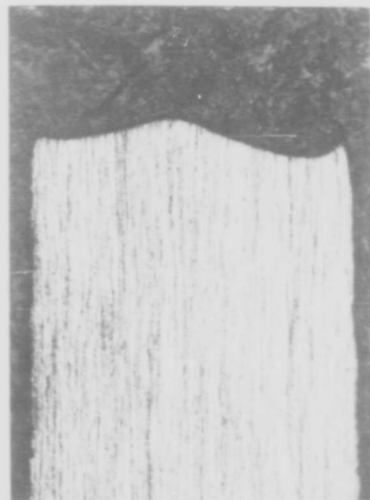
27A



27B



27C



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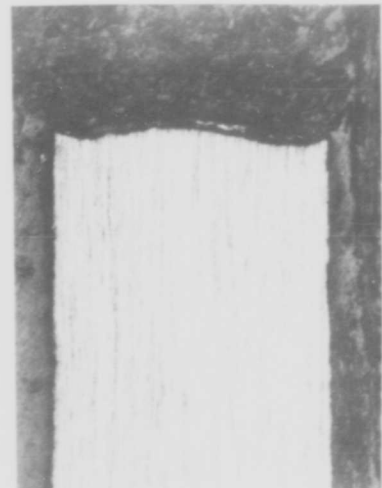
FIGURE 1 - DEBURRED SPECIMEN LEVELED IN 25% NITRIC AND
POLISHED IN ELECTROGLEAM 55

MAG. 75X

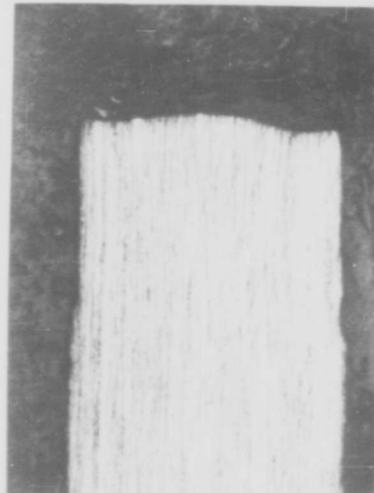
28A



28B



28C



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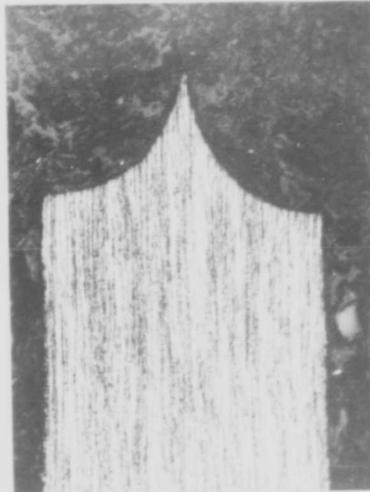
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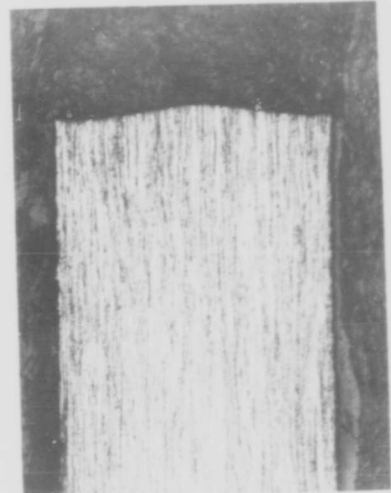
MAG. 75X

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

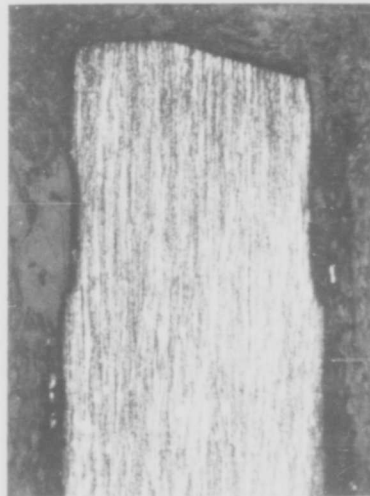
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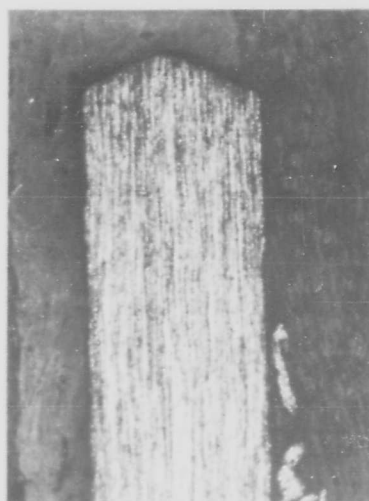
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FIGURE 1 - DEBURRED SPECIMENS TURCO 105 ETCHANT

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FIGURE 1 - DEBURRED SPECIMENS - 4140 STEEL ETCHANT

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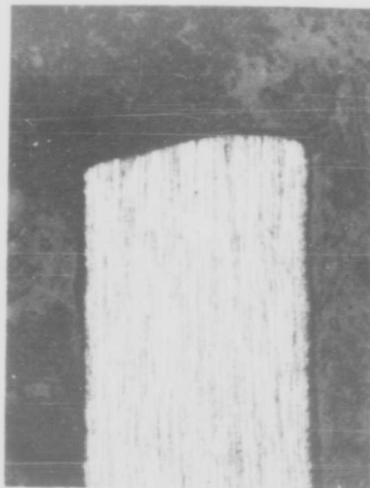
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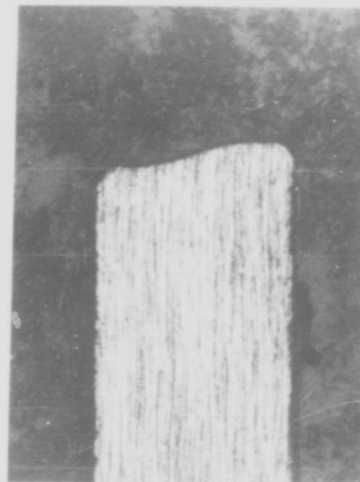
FIGURE 1 - DEBURRED SPECIMENS INCONEL 718 ETCHANT

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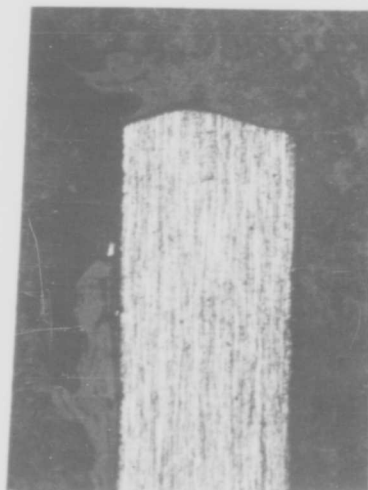
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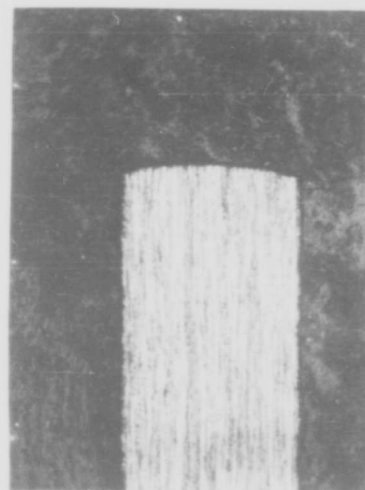
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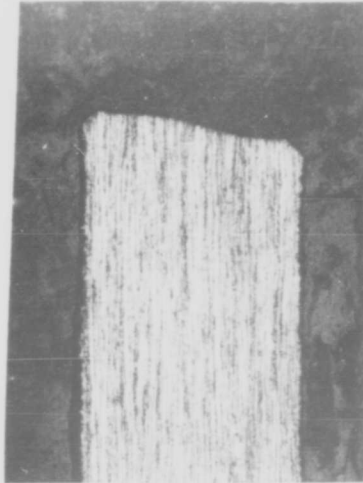
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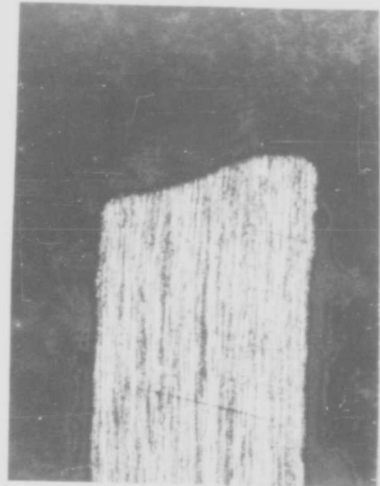
FIGURE 1 - DEBURRED SPECIMENS TURCO 105 ETCHANT

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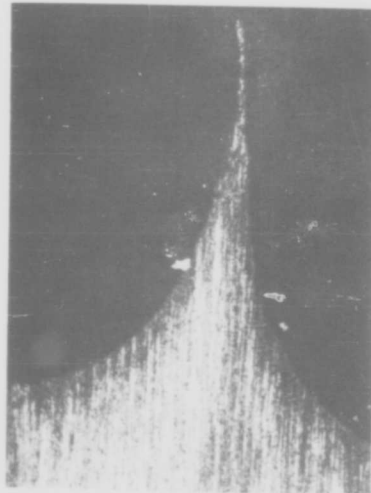
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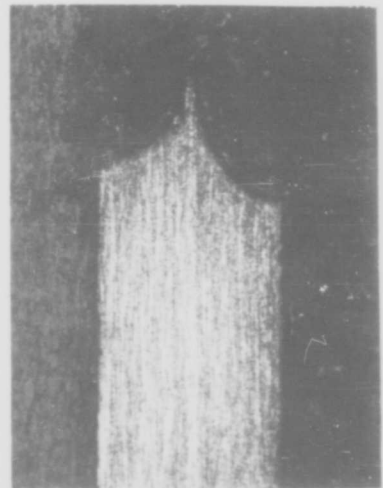
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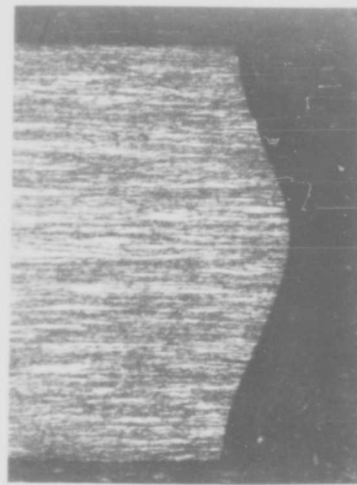
REVISED D4E-257302**LABORATORY REPORT**PAGE 40REPORT A478**FIGURE 1 - DEBURRED SPECIMENS. TURCO 105 ETCHANT** $H^+ = 6.0, NO_3^- = 4.5$

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MAG. 75X

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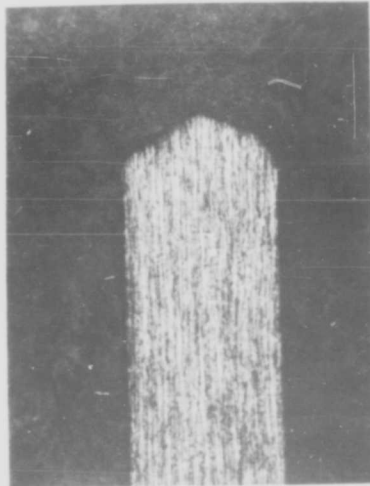
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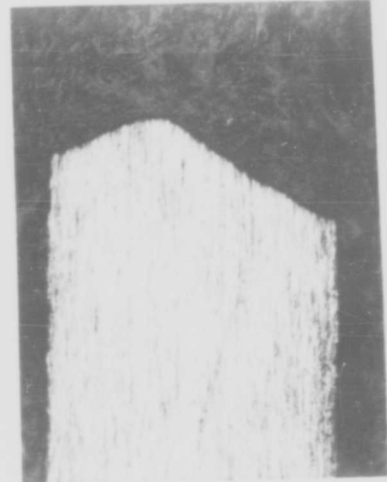
FIGURE 1 - DEBURRED SPECIMENS - TURCO 105 ETCHANT

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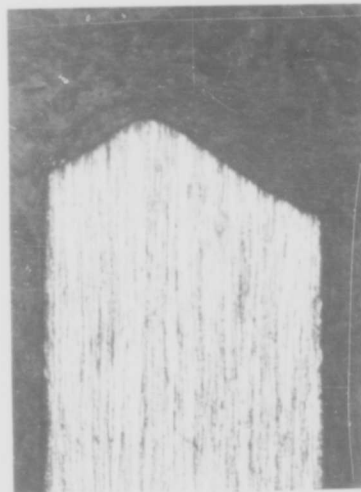
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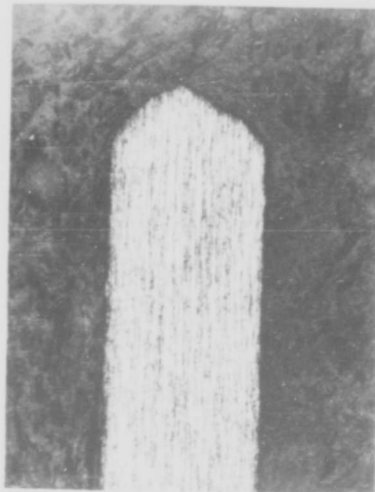
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FIGURE 1 - DEBURRED SPECIMENS - INCONEL 718 ETCHANT

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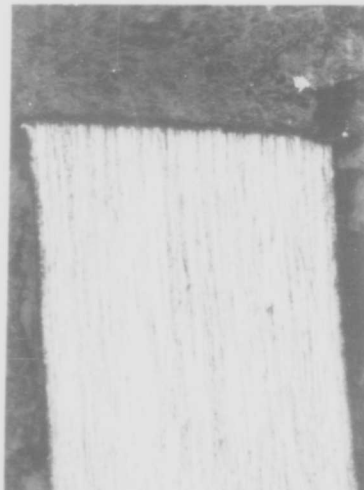
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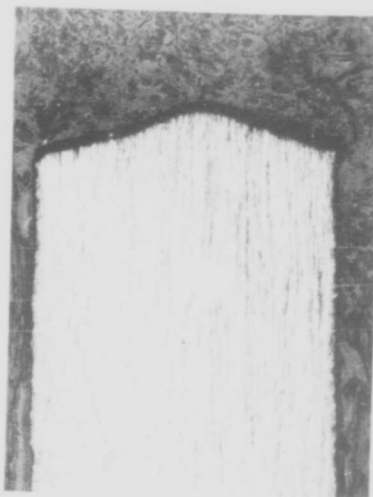
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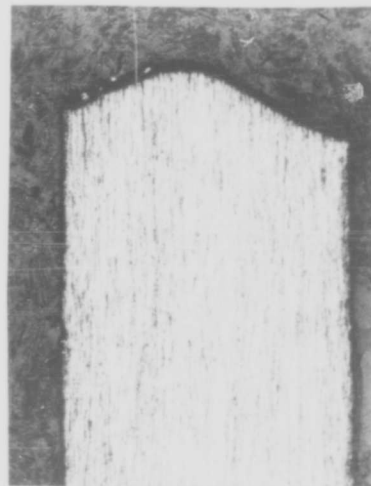
FIGURE 1 - DEBURRED SPECIMENS - 4140 STEEL ETCHANT

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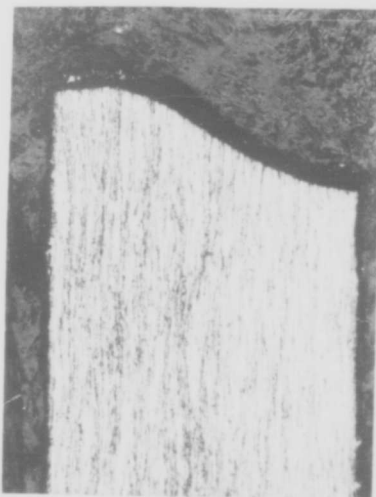


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FIGURE 1 - RAW SPECIMENS

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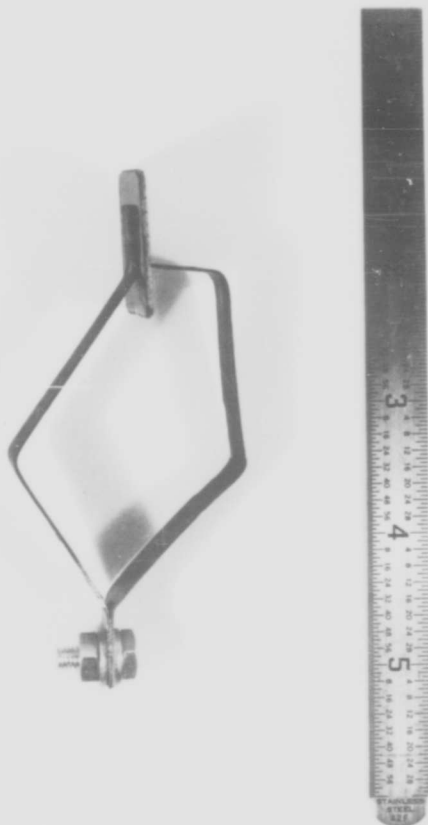
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FIGURE 1

METHOD OF RACKING



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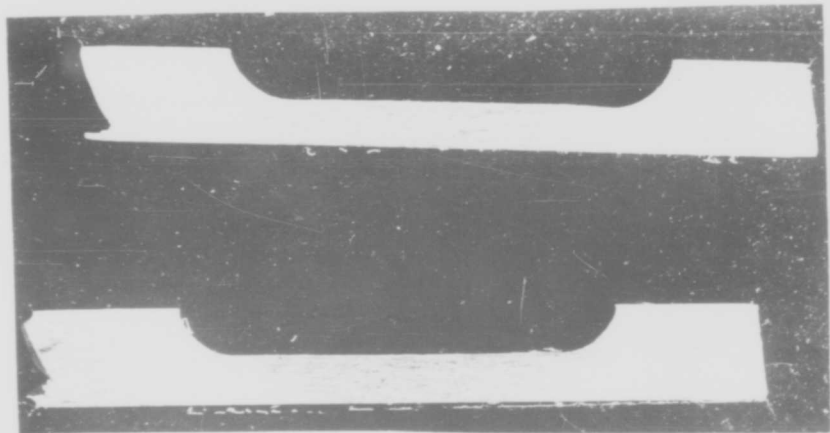
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FIGURE 3 - ELECTROPOLISH AND ELECTRO-DEBURRING OF ALUMINUM

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AFTER ELECTROPOLISH



BEFORE ELECTROPOLISH

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FIGURE 4 - ELECTROPOLISH AND ELECTRO-DEMURRING OF STAINLESS
STEEL

BEFORE ELECTROPOLISH



AFTER ELECTROPOLISH

TEST REQUEST

TITLE Electrochemical Deburring of Molybdenum, Aluminum
and Stainless Steel

LABORATORY OR DEPT. RESPONSIBLE FOR TEST

Dept 253

MODEL

Misc.

TEST PARTS ON IBM ☐ : ON TPL NO.PRODUCTION PARTS FOR TEST NOT REQUIRED ☒

APL/EM

None

WORK REQUESTED

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

1.0 OBJECT

REV. A Rm

F6575-C68

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

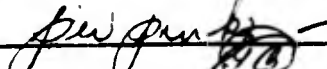
Equipment

\$50-

REV B ADDS ACTUAL

14-7-62

CMT

pin pin


OK for IDEP

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:

<u>Solution</u>	<u>Materials</u>
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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