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THE BOEING COMPANY
AERO-SPACE DIVISION
SATURN BOOSTER BRANCH

DOCUMENT NO. T5-6539-2

VOLUME _____ OF _____

TITLE AN ANALYSIS OF ETCHANT EFFECTS ON PENETRANT PERFORMANCE

MODEL NO. Saturn V/S-IC CONTRACT NO. NAS8-5608

ISSUE NO. M-5 ISSUED TO ~~SRS Method~~ Scientific & Tech Inf Facility College Pk. Md.

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ABSTRACT

26265

This report summarizes studies to determine the need for etching as welded, burnished, shaved, and/or sanded welds prior to penetrant inspection. Discussions are also presented of studies which were performed to develop a process for manually etching welds and to determine if the "crack-like fissures" observed in the heat affected zone of machined Y-ring to bulkhead weld were the result of preferential grain boundary etch or created during welding.

KEY WORDS

Heat affected zone

Penetrant

Etch

Cornstarch

Fissure

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1.0 OBJECT

The objective of this investigation was threefold:

1.1 To demonstrate the necessity of etching prior to penetrant inspection of welds.

1.2 To develop a process for manually etching welds.

1.3 To determine if the "crack-like fissures" observed in the heat-affected zone of machined Y-ring to bulkhead weld were the result of preferential grain boundary etch or created during welding.

2.0 BACKGROUND

"Crack-like fissures" were observed in Y-ring base metal in the heat affected zone adjacent to the Y-ring to bulkhead weld on the "S" bulkhead. These "fissures" were not evident until after the bulkhead was etched in the production etch facility and occurred only in Y-ring material.

Two possible causes of the fissures were: 1) that the fissures were created during welding and were uncovered by the etch or 2) that the fissures were evidence of preferential grain boundary etching occurring in the production facility.

It was necessary to demonstrate the necessity of etching prior to penetrant inspection because this requirement was questioned by Manufacturing, Project, and Quality Control personnel. If the penetrant inspection could be satisfactorily accomplished without a prior etch, the etch step could simply be excluded.

It was also required to develop an etchant which would not preferentially attack the weld heat affected zone. Further, it would be desirable to develop a technique for manually applying the etchant to local areas to preclude reducing gore membranes below drawing tolerance by repeated etch cycles in the production facility.

3.0 CONCLUSIONS

3.1 Etching prior to penetrant inspection of welds which are either burnished, hand sanded, machine sanded, or shaved is mandatory to assure adequate detection of discontinuities using penetrant methods. Note that in Figure 3 the weld crater cracks were not detected on the shaved surface prior to etch.

3.2 Two techniques have been developed for manual application of etchants to local areas such as weldments without inducing preferential grain boundary etching.

3.3 Results of attempts to intentionally induce "crack-like fissures" in weld heat affected zones with various etches were inconclusive, as no fissures were observed on any of the test panels treated in the laboratory.

4.0 RECOMMENDATIONS

It is recommended that:

4.1 All welds be etched prior to penetrant inspection.

4.2 Manual etching be accomplished by one of the two following methods:

4.2.1 Use of 24 oz/gal, room temperature Turco 13-B applied with an open cell sponge. Suitable tooling to prevent spillage, runoff, or dripping must be provided, and the pad must be moved slightly every minute or so in order not to transfer the sponge surface pattern to the part.

4.2.2 Use of artifically thickened 24 oz/gal room temperature Turco 13-B (maximum 7.0 oz/gal corn starch or equivalent) which is continuously reapplied during etching time. Spillage, run-offs and dripping must be controlled by suitable masking and careful attention to applicator loading.

4.3 Welded panels simulating the bulkhead to Y-ring weld be exposed to cleaning and etching cycles in the production facility and in the laboratory to provide additional correlations of results from these sources.

5.0 PENETRANT INSPECTION STUDY

5.1 OBJECTIVE

This study was conducted to determine the need for etching as-welded, burnished, shaved, and/or sanded welds prior to penetrant inspection.

5.2 CONCLUSIONS

Etching of burnished, shaved, and/or sanded welds is mandatory in order to assure adequate detection of discontinuities using penetrant methods. This is particularly true where tight cracks are present in the weld. In the panels used for this study 17 of 44, or about 40%, of the discontinuities present would not have been marked as rejectable without the inclusion of an etch step prior to the penetrant inspection.

5.3 DISCUSSION OF PENETRANT RESULTS

Three welded panels were prepared per memo 5-7512-M-1-420 dated 9-4-64 (see Appendix A) and used for the penetrant studies. The various treatments to which these panels were subjected are outlined in the Procedures Section (5.4).

Figures 1 through 5 are photographs ("black light" illumination) of the penetrant indications observed at the stages specified in the procedures. The three panels were first processed per Procedure I (Figures 1 through 3). This procedure was outlined in the above mentioned memo. However, since the sanding operations in this procedure were followed immediately by an etch, it was not possible to isolate the effects of sanding. Procedure II was followed to more clearly define the effects of sanding by penetrant inspecting after sanding and prior to etching.

Indications 1 and 7 (from left) in Figure 1; 1, 2, 3, 5, 6, 8 and 9 (from left) in Figure 2; and both indications in Figure 3 demonstrate the increased sensitivity of penetrant to detect certain surface discontinuities after etching. Even though two small porosity type indications were "opened up" by etching this is not sufficient evidence to indicate that as-welded beads must be etched prior to penetrant inspection.

Bead shaving of panels 24-2 and 24-3 after processing per Procedure I above was apparently accomplished with a very sharp tool because little metal smear was evident and the "remains" of the crater cracks were still visible to the unaided eye.

The following observations were made from Figures 4 and 5:

Hand sanding tends to obscure discontinuities to penetrant detection. Four of five indications in panel 24-2 were almost completely obscured. All five indications in panel 24-3 were partially obscured.

Etching subsequent to hand sanding "opened" these discontinuities sufficiently to be detected by the penetrant.

Power sanding also tends to obscure discontinuities to penetrant inspection although as indicated in these particular panels, apparently not to the degree that hand sanding does. The panels were previously etched, however, and the discontinuities were probably "wider open" than normal. If the panels had been power sanded after shaving - prior to etching - the discontinuities would probably have been obscured to the same degree as in hand sanding.

Etching subsequent to power sanding "re-opened" the discontinuities giving much larger indications as shown in the figures and in some cases reopening discontinuities completely closed by the power sanding operation (see discontinuities 4 and 5 from the left in Figure 4).

5.4 PROCEDURES

The welded panels were treated per the following procedures:

5.4.1 Procedure I (Figures 1,2 and 3)(Outlined in memo 5-7512-M-1-420)

Penetrant inspect and photograph
Etch (sponge technique)
Penetrant inspect and photograph
Manually sand (180 grit)
Etch (sponge technique)
Penetrant inspect and photograph
Mechanical sand (150 grit)
Etch (sponge technique)
Penetrant inspect and photograph

5.4.2 Procedure II (Figures 4 and 5)

Shave panels 24-2 and 24-3
Penetrant inspect and photograph
Manually sand (180 grit)
Penetrant inspect and photograph
Etch (sponge technique)
Penetrant inspect and photograph
Mechanical sand (180 grit)
Penetrant inspect and photograph
Etch (sponge technique)
Penetrant inspect and photograph

All the above penetrant steps were accomplished using ZL-44B penetrant (diluted 1 to 3 with water) and ZP-45 wet developer as specified in 60B32002.

6.0 ETCHANT STUDIES

6.1 OBJECTIVE

These studies were performed to develop a process for manually etching welds and to determine if the "crack-like fissures" observed in the heat-affected zone of machined Y-ring to bulkhead weld were the result of preferential grain boundary etch or created during welding.

6.2 CONCLUSIONS

6.2.1 It is possible to manually etch welds removing 0.0002" to 0.0003" metal (per side) using 24 oz/gal Turco 13-B etchant. This may be applied either as a thickened paste (maximum 7 oz/gal corn starch or equivalent) or with a soaked open cell polyurethane sponge.

6.2.2 No positive evidence of "crack-like preferential etching" was observed on any test panel treated in the lab. This may be somewhat misleading, however, because the violent agitation produced by the spray heads in the production etch facility could not be duplicated in the lab. Should preferential etch start, the local areas of attack would retain depleted solution after a certain initial etch time and would not etch further unless the depleted solution was forcibly replaced (by adequate agitation) with fresh solution. Section 3.3 - Recommendations, suggests that tests be performed to provide additional correlations between laboratory and production facility etchant results.

6.3 DISCUSSION OF PROCEDURES & RESULTS

6.3.1 Manual Technique

Small (approximately 1.5" x 1.5" x 1/4") 2219 test panels were prepared, numbered, cleaned, measured (for surface area of one side) and weighed. These panels were then subjected to various etching mixtures, recleaned and reweighed. Etch depth was calculated on the basis of weight loss using the following formula.

$$\text{Density of 2219} = 0.102\#/in^3$$

$$1 \text{ lb.} = 453.59g$$

$$\text{Weight Change} = (\text{Density 2219})(\text{Value removed})$$

$$W_1 - W_2 = (\text{Density})(\text{Area})(\text{Depth})$$

$$\text{Etch Depth} = \frac{W_1 - W_2, g}{(\text{Density, lbs/in}^3)(\text{Area, in}^2)\left(\frac{453.59g}{1b}\right)}$$

$$= \frac{W_1 - W_2, g}{(46.27)\quad(\text{Area, in}^2)}$$

$$= \frac{W_1 - W_2, g}{\text{Area, in}^2}\ (0.0216)$$

It was determined in these tests that both Wyandotte Mil-Etch and Turco 13-B, at 24 oz/gal, sponge applied or in a diatemaceous earth-asbestoes fiber paste, would etch 0.0002 to 0.0003 inches (per side) in less than 10 minutes (the arbitrarily established criteria for acceptability of etch rate). Thick corn starch pastes, however, would not. It was also noted that both types of pastes tended to fall off as soon as gassing started, and had to be constantly reapplied. Moreover, removal of the great amount of particulate contamination generated by the diatomaceous earth was recognized as being a potentially serious problem in cleaning propellant tanks to meet MSFC requirements. Therefore, testing of paste materials was discontinued. However, it should be noted that previous work with corn starch thickened solution indicated that satisfactory etch rates could be obtained provided the corn starch concentration was kept below about 7 oz/gal. Manufacturing Development has established 5 oz/gal corn starch paste as a satisfactory concentration.

During the sponge tests, it was noted that the sponge surface pattern transferred to the test panel face. Accordingly, different materials with smoother surfaces were tried. All these materials transferred a pattern, with the possible exception of felt. The felt,however, was so severly attacked (wrinkled and dissolved) by the etchant that no conclusive results could be obtained. Approximately 0.5 lbs/in^2 pressure was applied to press the part more firmly into the sponge, and a pattern was still transferred. The problem was resolved by shifting the sponge slightly every minute - no pattern transferred. Graphs of etch rates for the above three techniques are shown in Figures 6, 7 and 8.

6.3.2 Preferential Etching (Manual Technique)

Two welded 2219 panels were etched, one with Mil Etch and one with 13-B, both at 24 oz/gal, sponge applied per above. Severe preferential etching of the heat affected zone was noted on the panel exposed to Mil Etch. Three end grain specimens (panels whose faces are normal to the longitudinal axis of a "Y" ring billet) were prepared and etched to an average depth of 0.00026" in 7 minutes 9 seconds with 24 oz/gal Turco 13-B. These panels showed no evidence of preferential attack. The percent deviation from average etch depth for the 3 panels was 1.0% for one, 1.62% for another, and 11.23% for another (the latter panel was etched on both sides due to a splash which resulted in an erroneous value for etch depth due to greater weight loss).

At this point, Turco 13-B at 24 oz/gal, room temperature, sponge applied, was considered as satisfactory and further testing of etchants was discontinued.

Various welded panels were then etched with the 13-B solution prior to penetrant inspection for the program described in Section 5.0 of this report. In no case did serious preferential etching occur, although the larger grain size of the heat affected zone was revealed by the etchant.

6.3.3 Preferential Etching ("Crack-like Fissures")

The final portion of the program concerned the possible development of "crack-like" preferential etching in the heat affected zones of 2219 weldments. Four panels with about 18 inches of weld bead each were prepared as follows: A plate was cut from a "Y" ring billet end in the T37 condition on a plane rotated 15 degrees from the long transverse axis, and welded to a 2219 T851 plate. Two two inch repair welds were made in each plate. The plates were then cut into 2 inch wide specimens, with the repair welds centered on one specimen each. A total of 29 panels were prepared.

These panels were then exposed to each of the solutions used in the etch cycle, for various lengths of time. Several control panels were left "as welded" (i.e. not exposed to solution).

No cracks developed in the control panels, one of which was repaired welded.

After 1 hour in the alkaline cleaner (Turco 4215S) noticable smut was formed, but no preferential attack was identified.

After 1 hour in the deoxidizer (Turco Smut-Go) very mild etching action was noted with an apparent slight preference for the heat affected zones. After 40 hours in the deoxidizer, severe etching was noted, with the base metal - weld bead interface area, and the weld bead itself, preferentially attacked. No "crack-like" attack was generated.

A number of panels were exposed to a laboratory approximation of the production facility etch cycle, with individual panels removed after each successive step. While preference for the heat affected zone and weld bead was noted when the panels reached the etching step, there was no indication of any "crack-like" preferential etching, nor was there any apparent difference in the degree of attack on repair welded versus welded panels.

In no case during this whole test program were any "crack-like" fissures developed as a result of preferential etching.

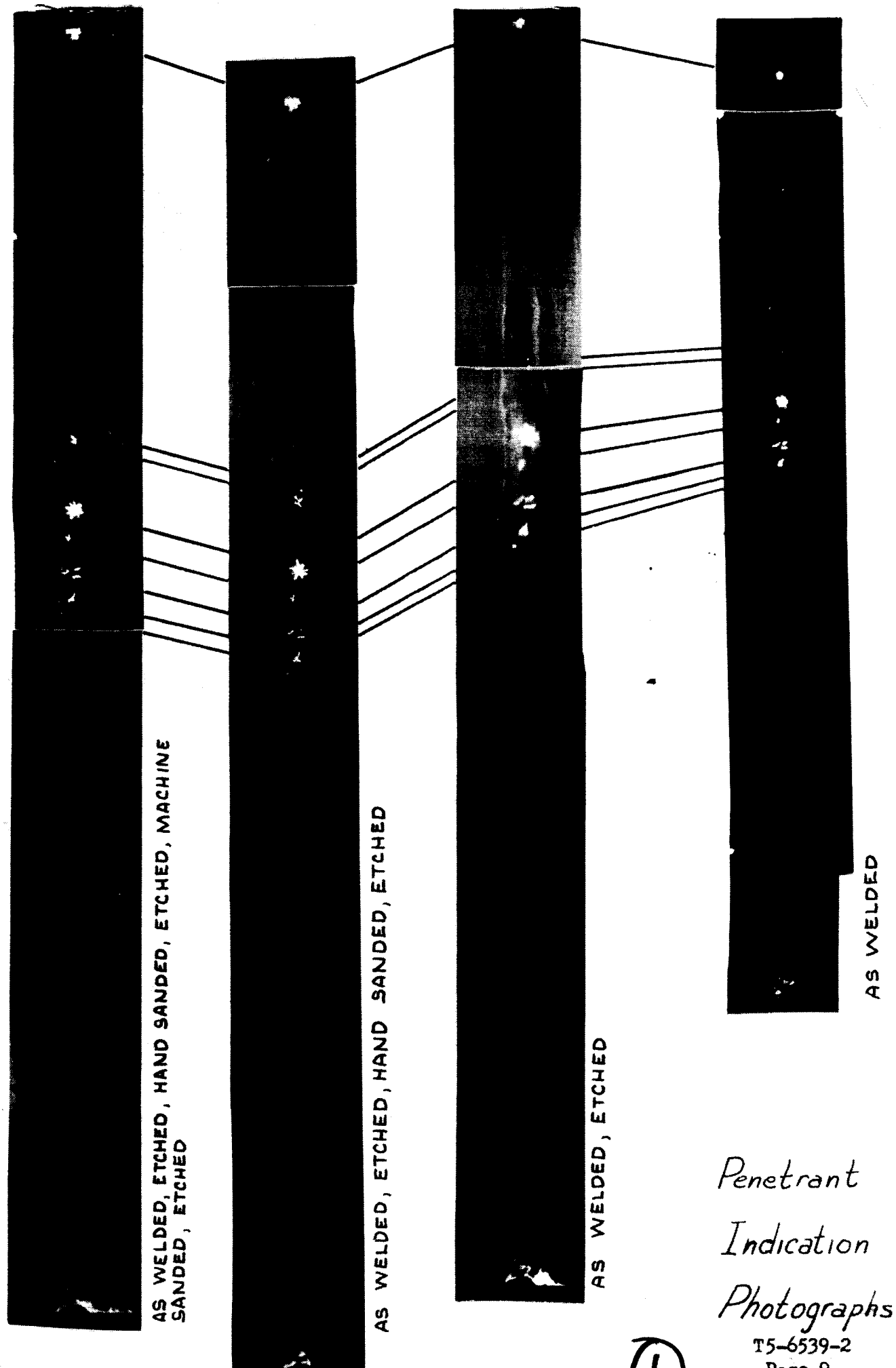
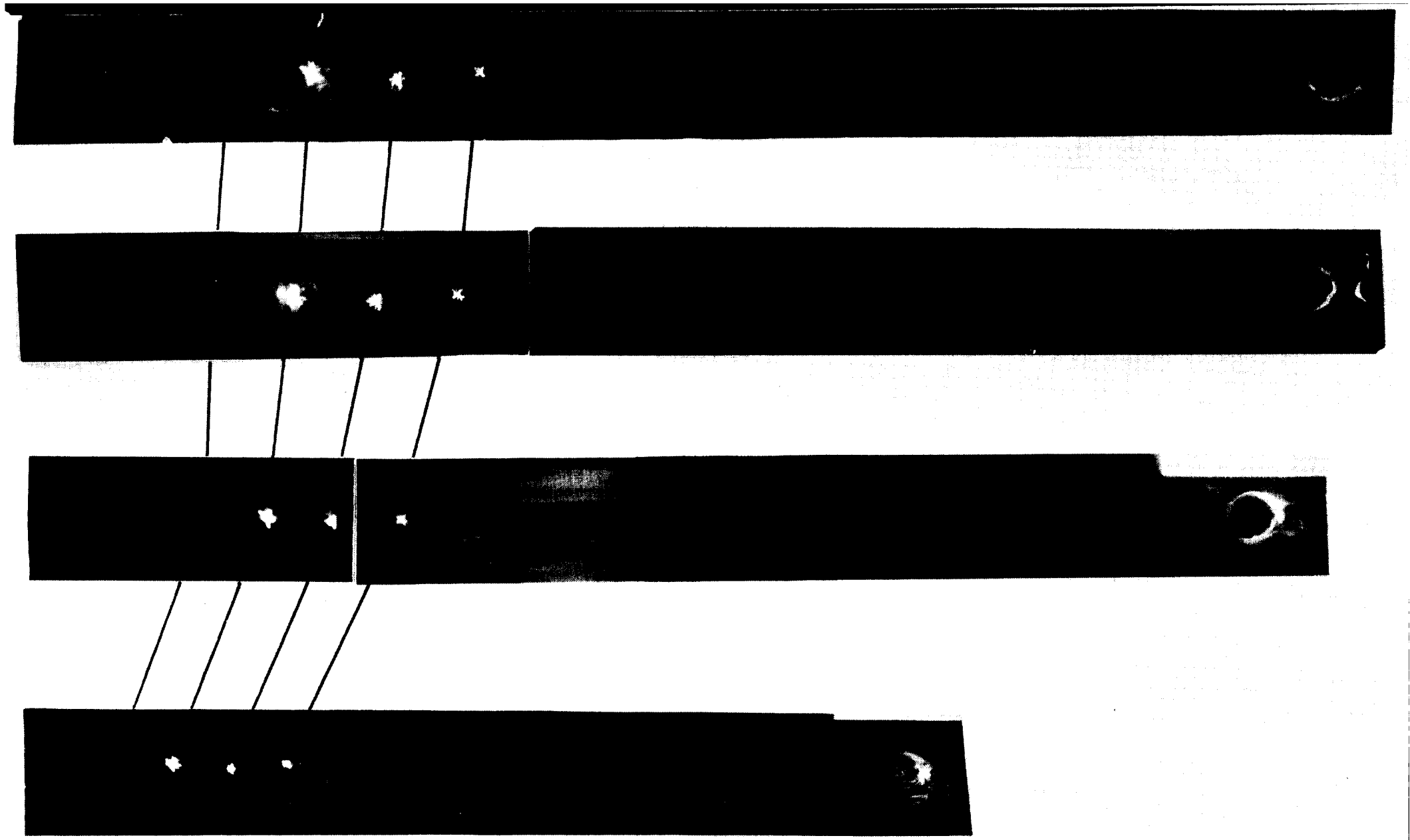


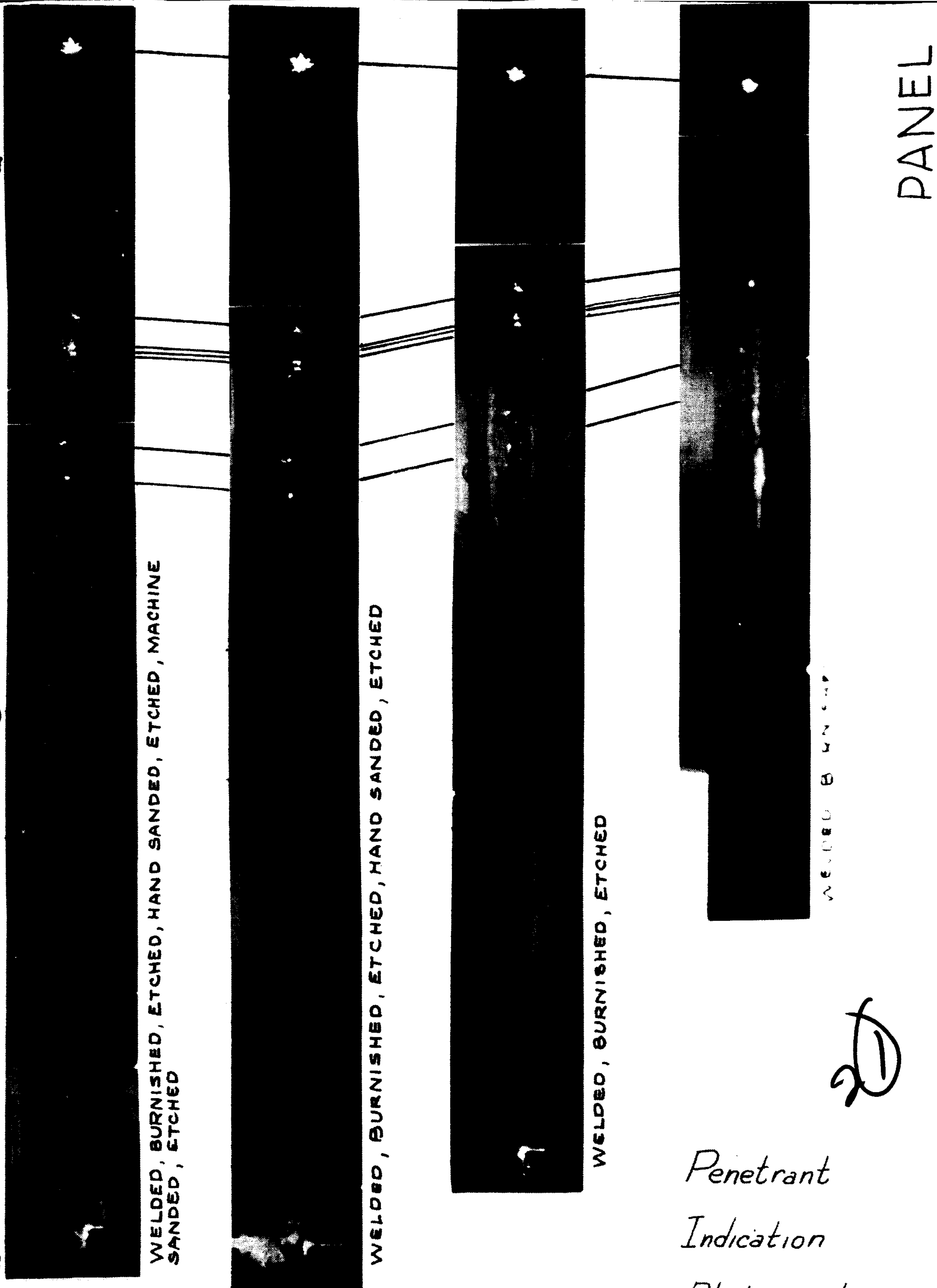
FIGURE 1

Penetrant Indication Photographs

T5-6539-2



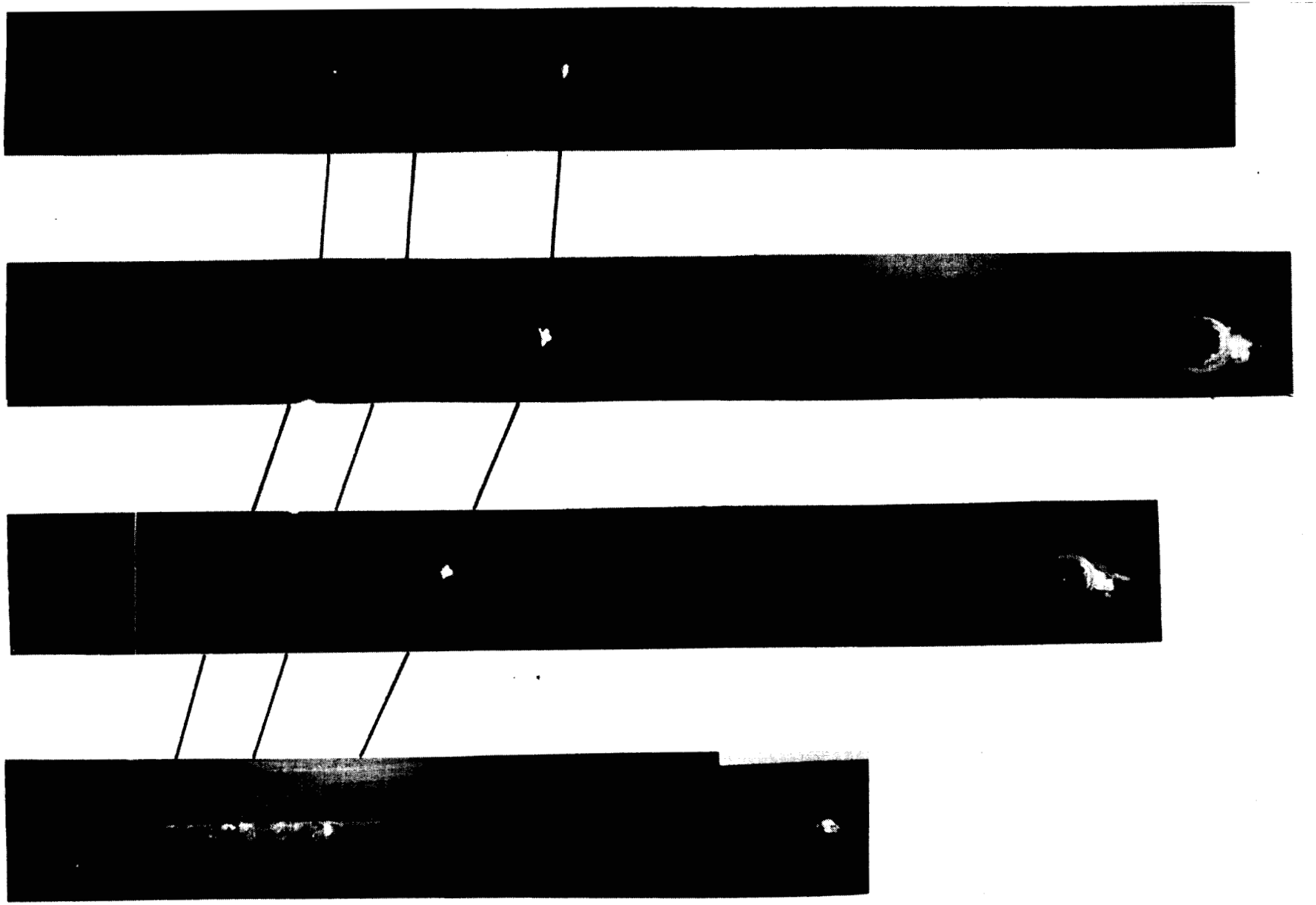
24-2



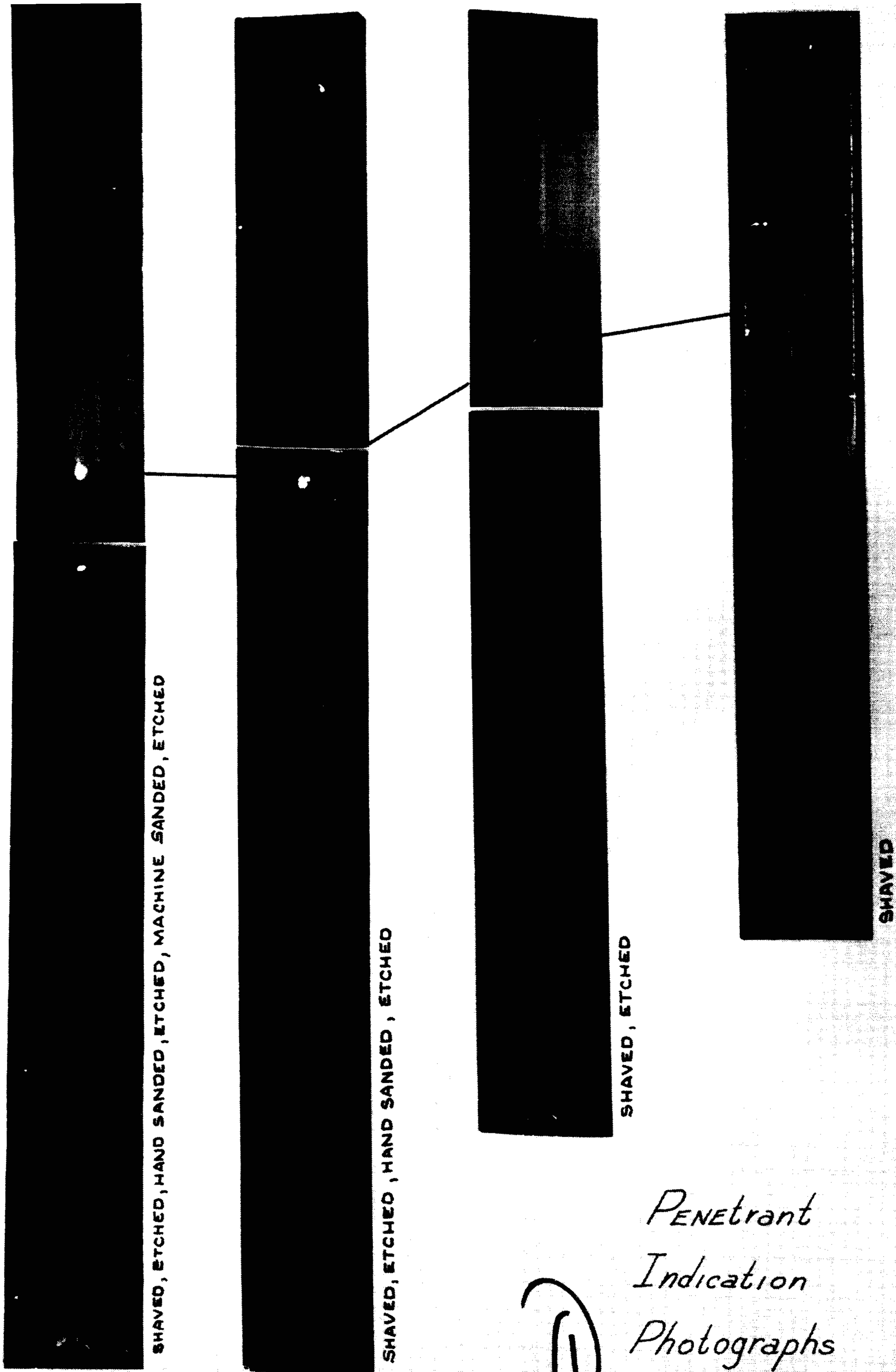
20

Penetrant Indication Photographs

FIGURE 2



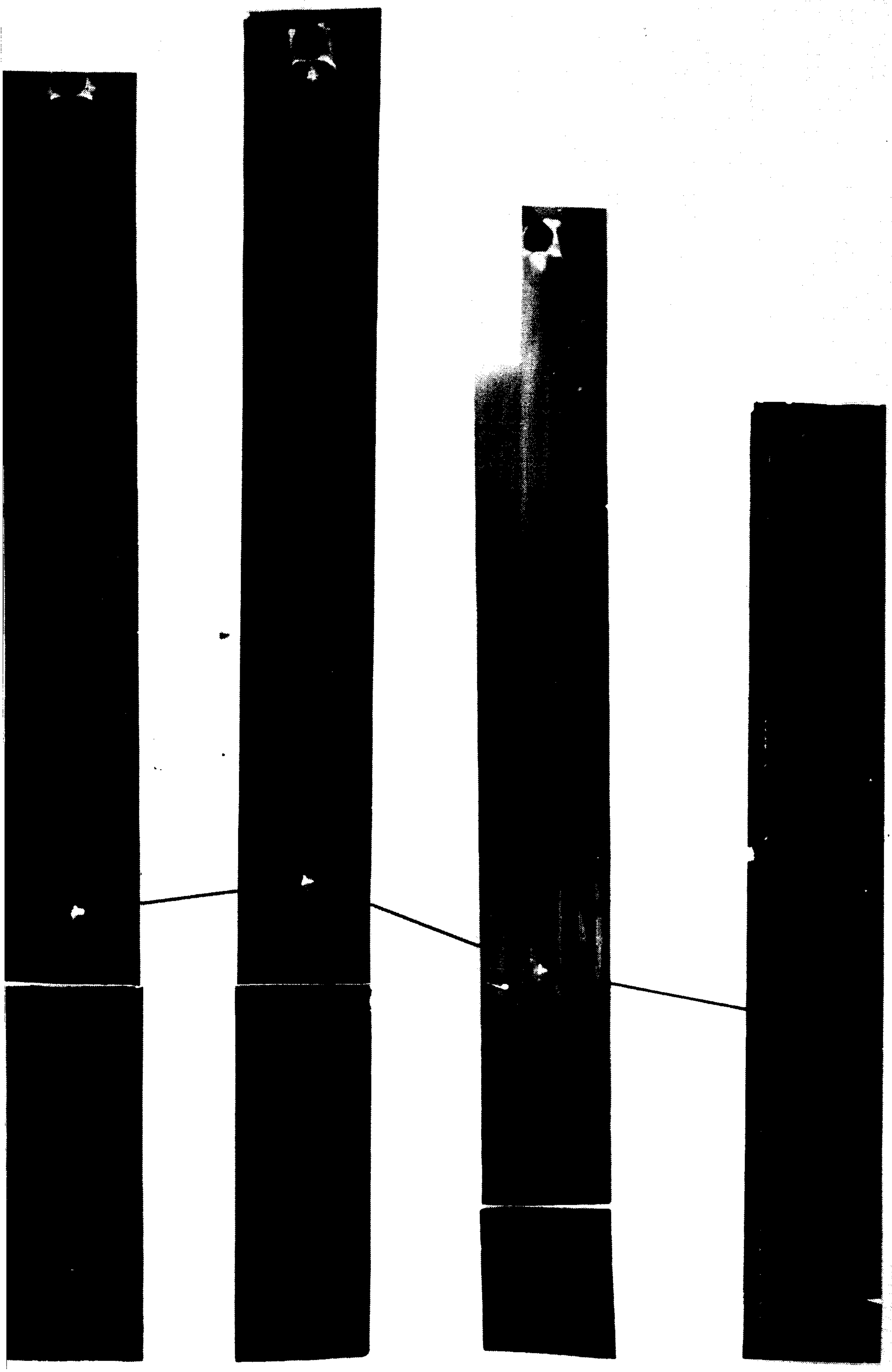
24-3



Penetrant Indication Photographs

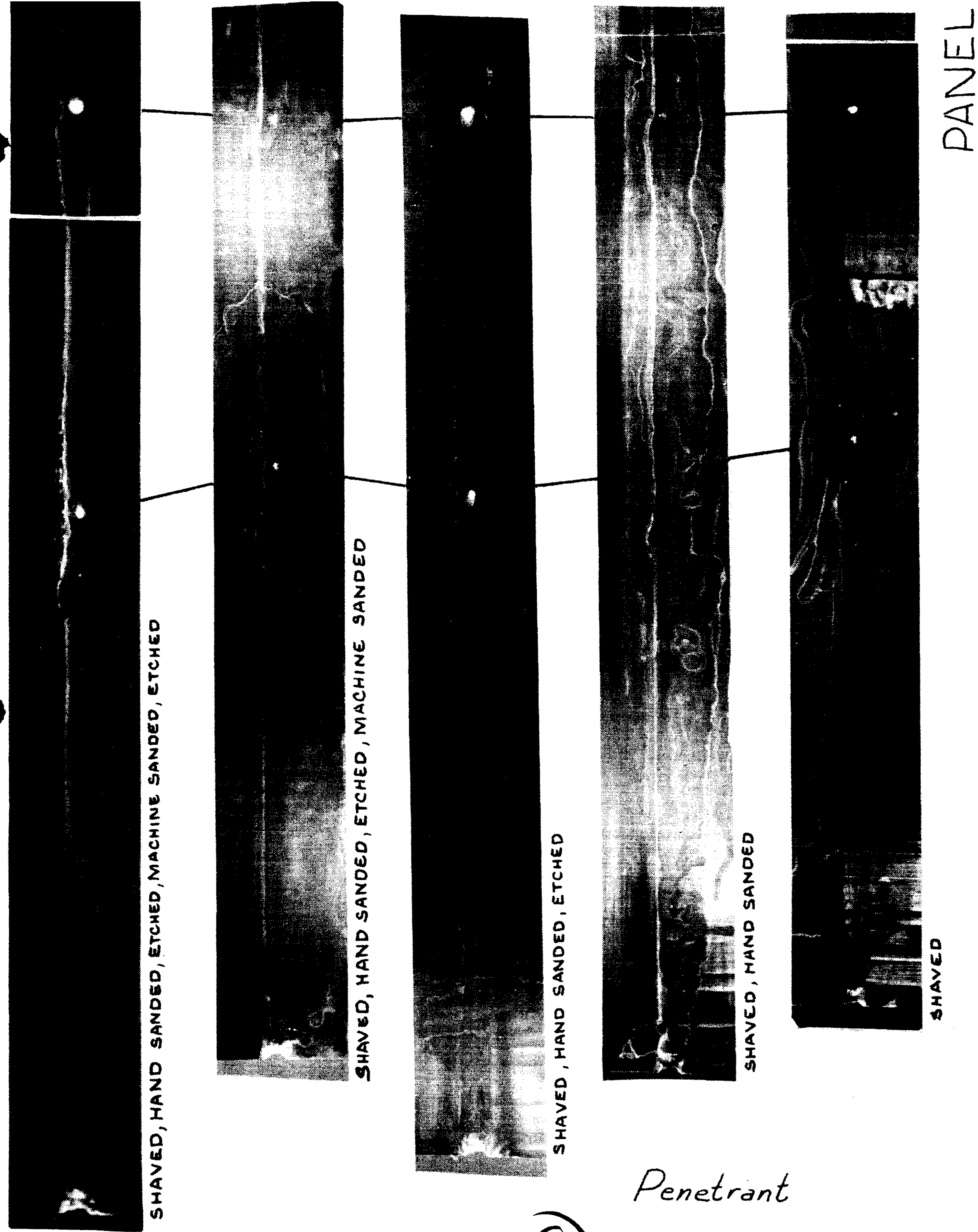
(1)

FIGURE 3



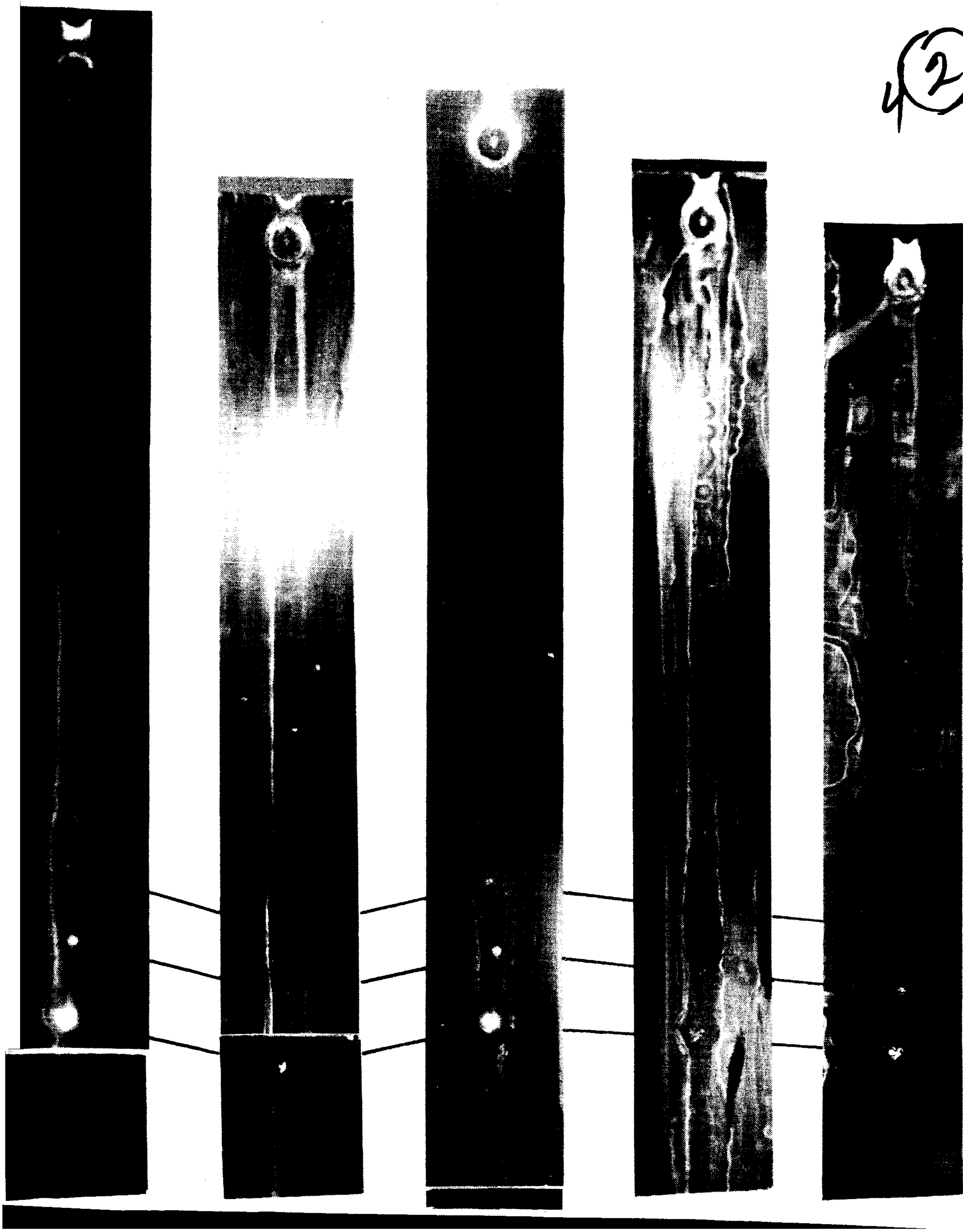
3 (2)

24-4



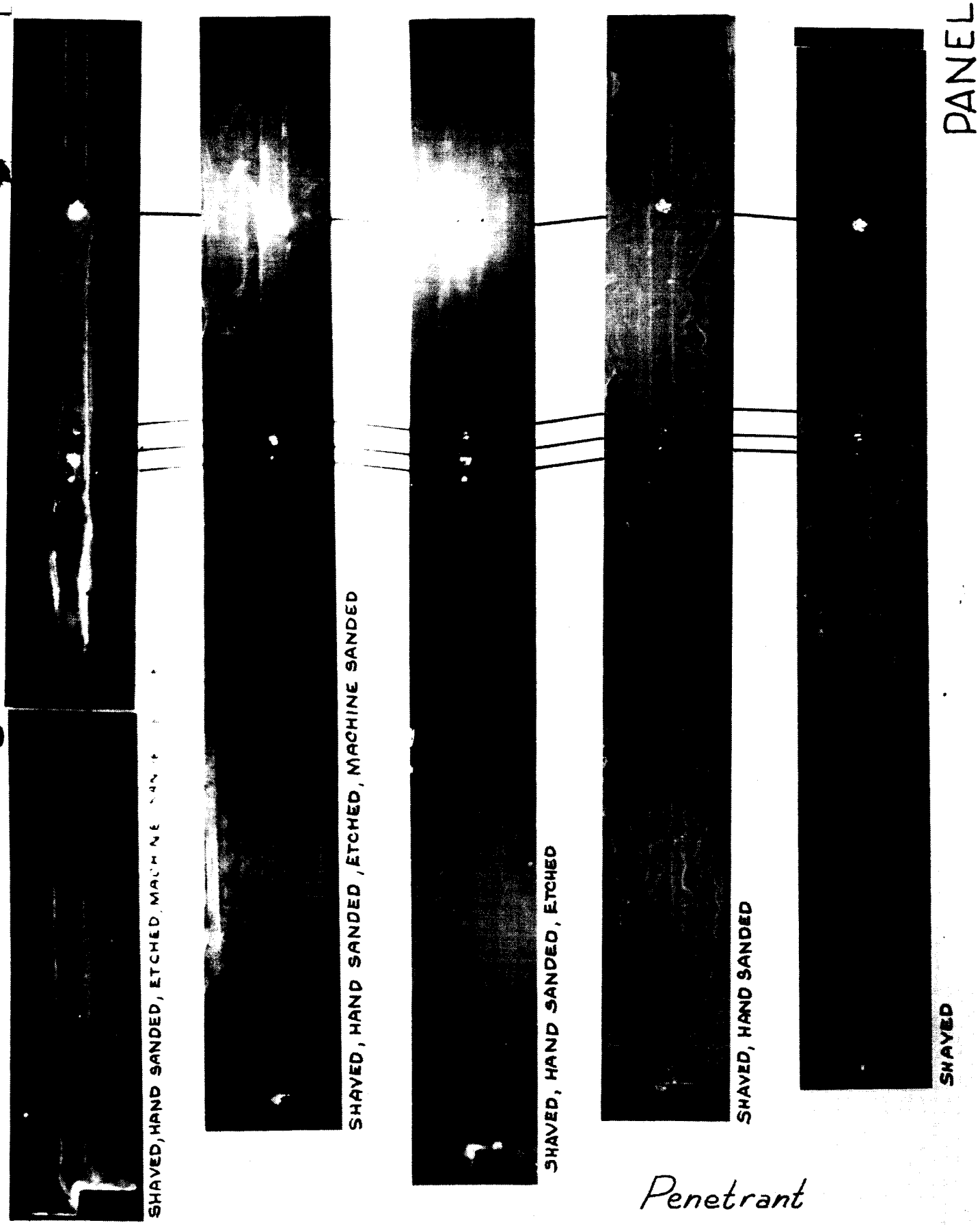
(1) Penetrant Indication Photographs

FIGURE 4



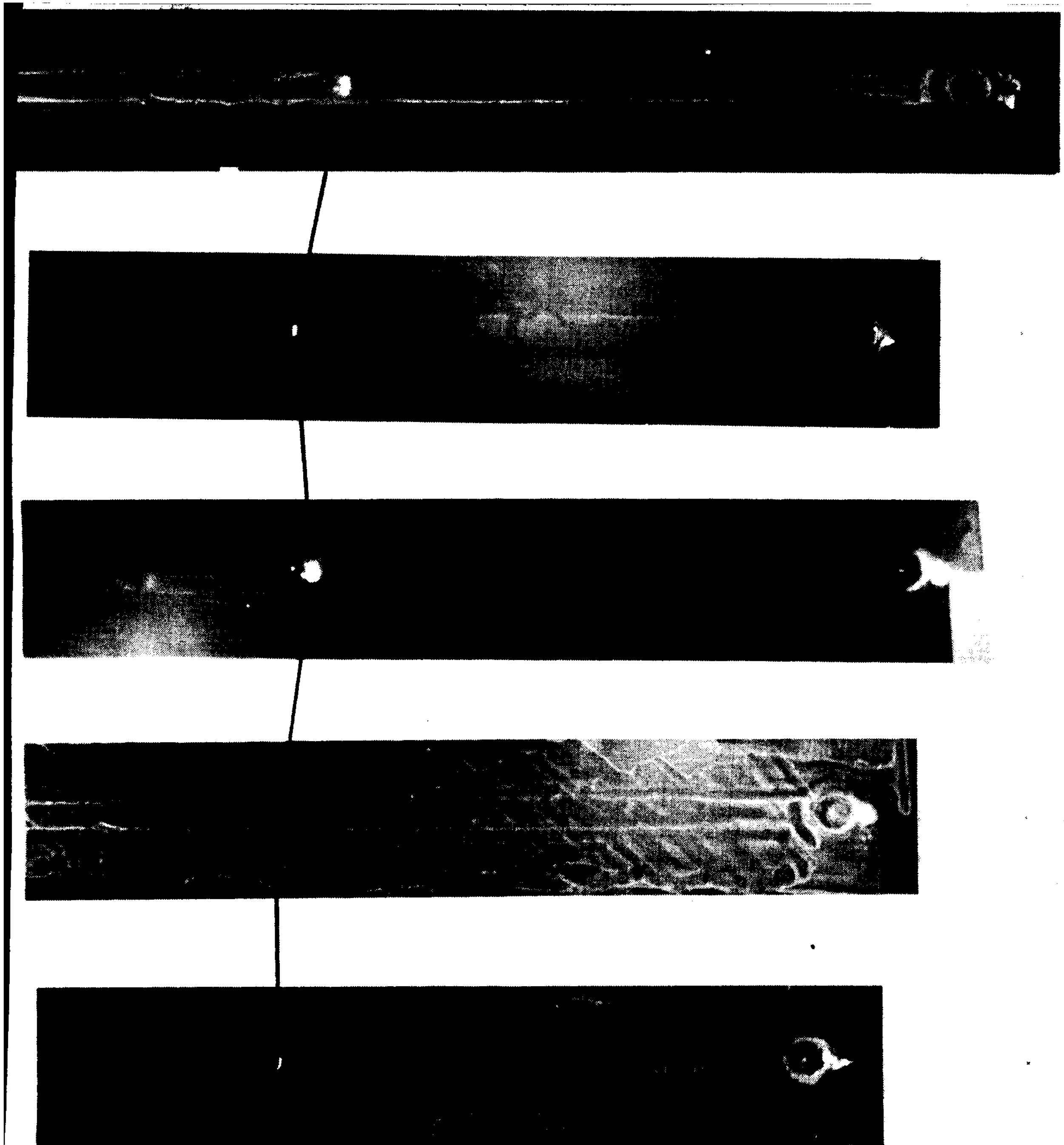
4(2)

#24-2



Penetrant Indication Photographs

FIGURE 5



#24-3

5-(2)

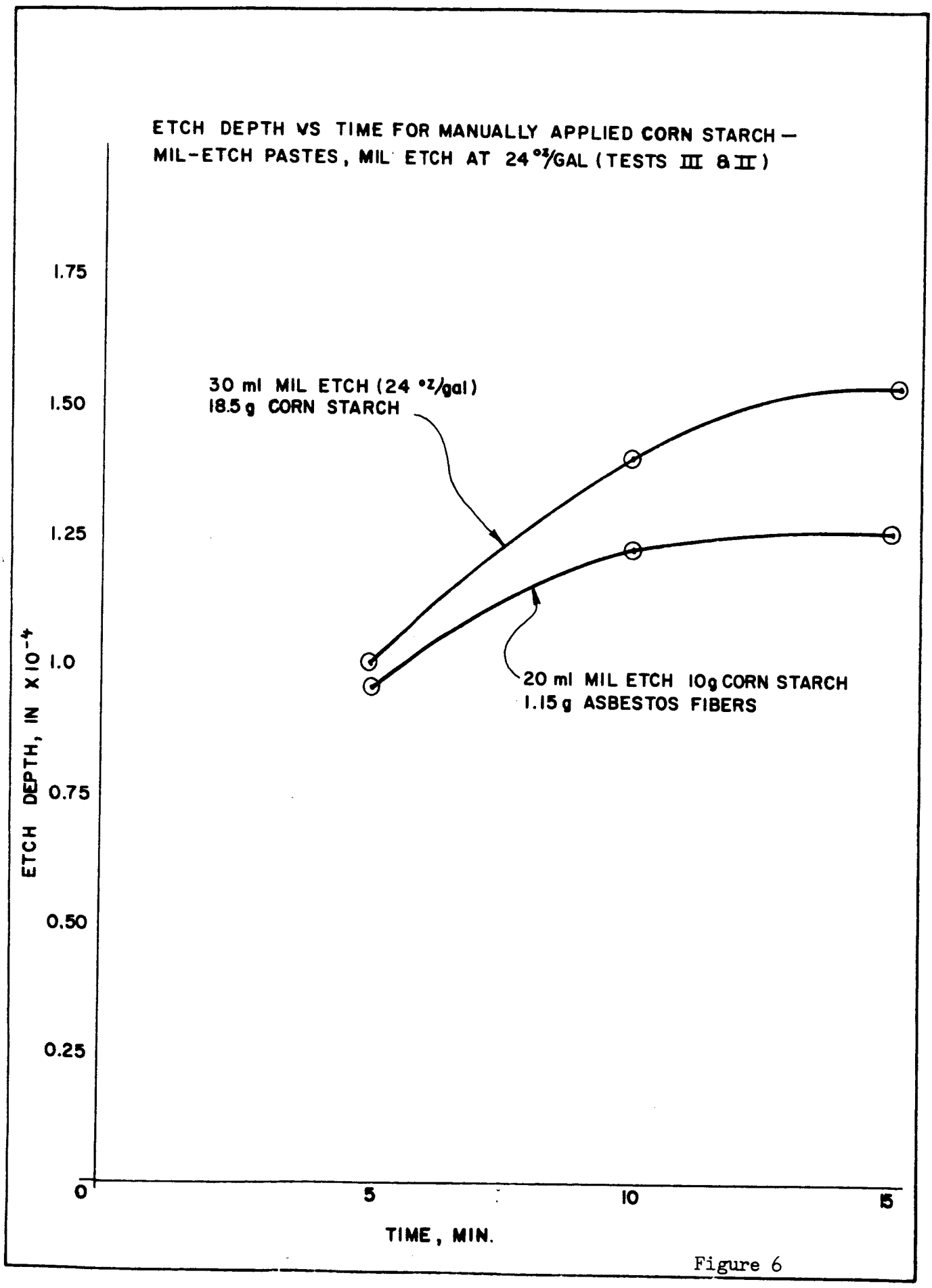

ETCH DEPTH VS TIME FOR MANUALLY APPLIED CORN STARCH – MIL-ETCH PASTES, MIL ETCH AT 24 °Z/GAL (TESTS III & II)
1.75
1.50
1.25
1.0
0.75
0.50
0.25
0
5
10
15
ETCH DEPTH, IN X 10⁻⁴
TIME, MIN.
30 ml MIL ETCH (24 °Z/gal)
18.5 g CORN STARCH
20 ml MIL ETCH 10g CORN STARCH
1.15 g ASBESTOS FIBERS

Figure 6

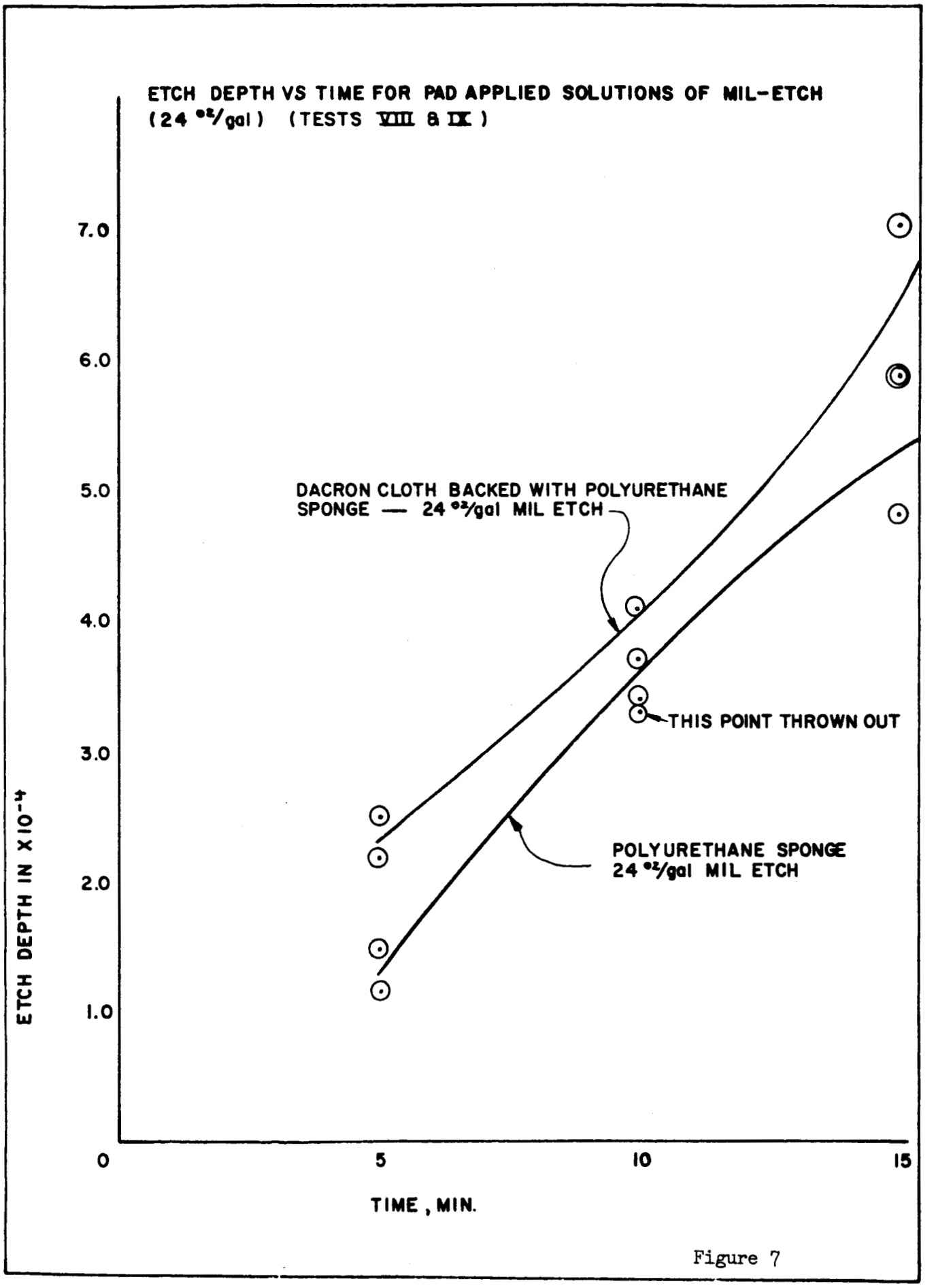

ETCH DEPTH VS TIME FOR PAD APPLIED SOLUTIONS OF MIL-ETCH
(24 oz/gal) (TESTS VIII & IX)
DACRON CLOTH BACKED WITH POLYURETHANE SPONGE — 24 oz/gal MIL ETCH
THIS POINT THROWN OUT
POLYURETHANE SPONGE 24 oz/gal MIL ETCH
ETCH DEPTH IN X 10⁻⁴
TIME, MIN.
0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
5
10
15

Figure 7

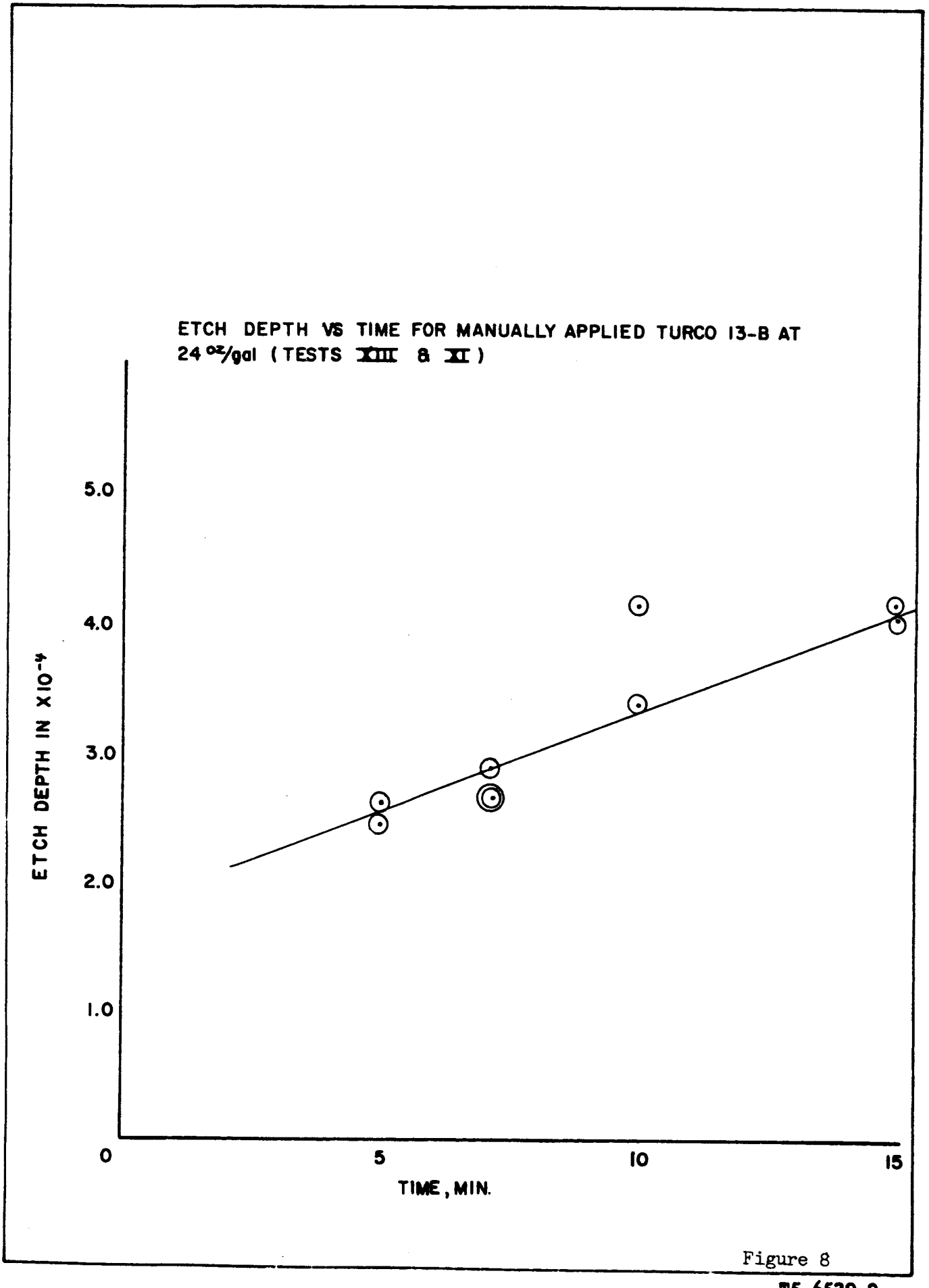

ETCH DEPTH VS TIME FOR MANUALLY APPLIED TURCO 13-B AT 24 oz/gal (TESTS XIII & XI)
ETCH DEPTH IN X10⁻⁴
5.0
4.0
3.0
2.0
1.0
0
5
10
15
TIME, MIN.

Figure 8

APPENDIX A

The following is a reproduction of memo 5-7512-M-1-420, outlining the preparation of the three welded panels used in the work described in Section 2.0 of this report.

September 4, 1964
5-7512-M-1-420

To:	W. B. Addiston	5-2500	LA-34
	A. D. Martin	5-2397	AZ-43
	W. B. Snyder	5-7552	LD-05
	E. L. Stone	5-2570	LC-28
	C. A. Wilkinson	5-7000	LA-43

Subject: Development of Etching Procedures Prior to Penetrant Inspection of 2219 Welds.

The following procedure is proposed to evaluate the need of etching shaved, burnished and/or sanded welds prior to penetrant inspection. Because this inspection must be performed while the parts are on the welding fixture, part of the program will consist of an evaluation of etchants and methods of application.

Four test panels will be prepared containing intentionally induced weld cracks. (see Attachment 1)

Panel #1 will be used to evaluate possible etchants. Items to be checked are:

Rate of metal removal
Degree of preferential attack (if any)
Amount of pitting
Surface roughness
Feasability of Application

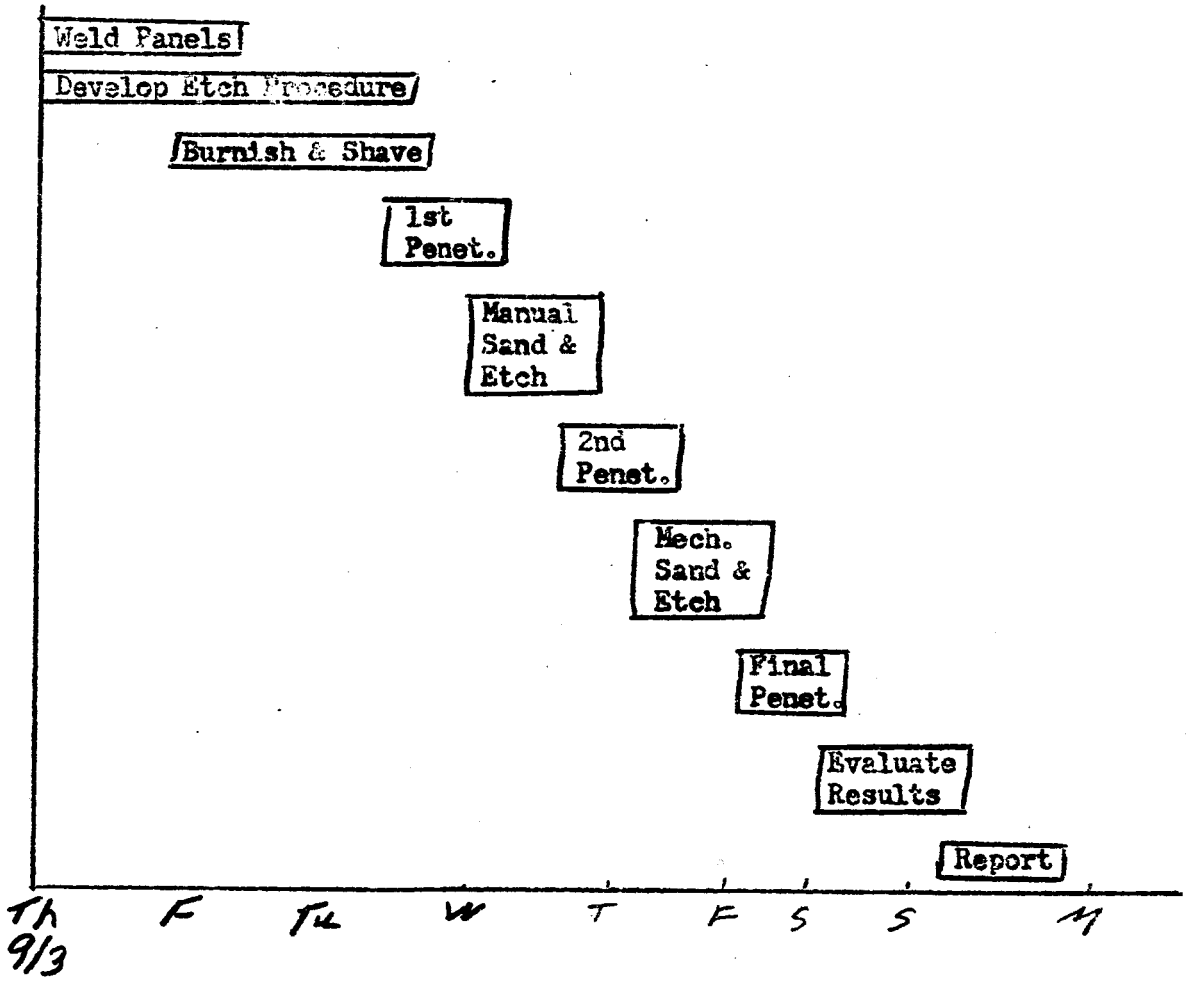
Panel #2 will be as welded
Panel #3 will be as welded plus burnished
Panel #4 will be as welded plus shaved to +.015"

Processing of these three panels will be as follows:

Penetrant inspect and photograph any indications
Manually sand
Etch (as developed from panel #1)
Penetrant inspect and photograph any indications
Mechanical sand
Etch (as developed from panel #1)
Penetrant inspect and photograph any indications.

At the conclusion of this work a 60B specification will be issued covering the required processing of production welds.

The anticipated schedule is:

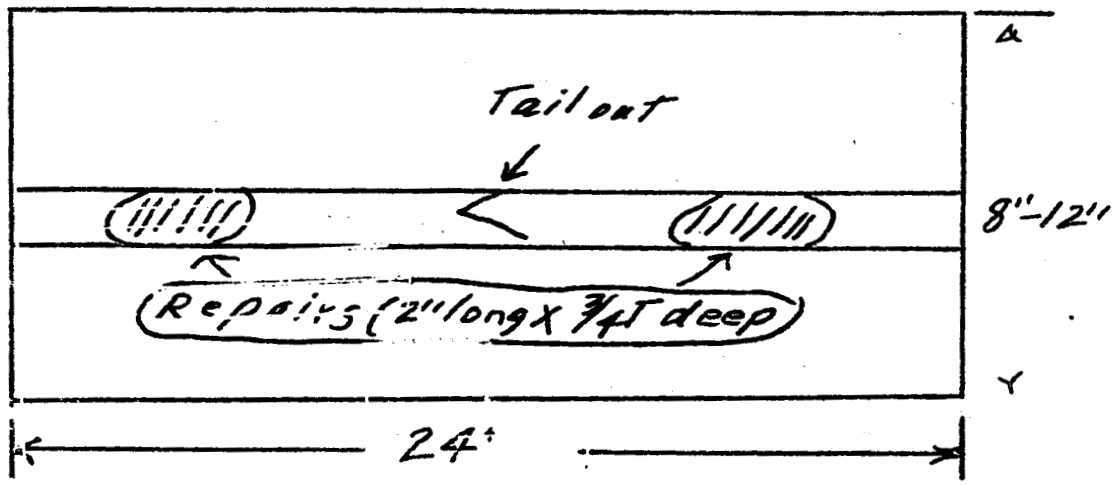


JGJ:nn
090364
Attachment: #1
2219 -T87 Plate

R. Wayne McAllister
R. W. McAllister
5-7510 LH-24

26

2219 -T87 PLATE



1. Need three panels per the above sketch by Tuesday morning 9-8-64. One in "as welded" and burnished (steel brush polished) and one with weld bead machined off.

2. No inspection required and crater cracks (small) are needed.