# NASL MECHANICAL PEENING PROCEDURE FOR IMPROVEMENT OF FATIGUE PROPERTIES OF HY-80 BUTT WELDS

Lab. Project 9300-1, Technical Memorandum #34

SF 020-01-01, Task 0722

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MATERIAL SCIENCES DIVISION

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## TABLE OF CONTENTS

| | Page |
|---|---|
| ADMINISTRATIVE INFORMATION | 4 |
| OBJECTIVE | 4 |
| NASL MECHANICAL PEENING PROCEDURE (FOR BUTT WELDS) | 5 |
| DESCRIPTION OF SPECIMENS | 5 |
| FATIGUE TESTING PROCEDURE | 6 |
| RESULTS | 6 |
| SUPPLEMENTARY TESTS | 7 |
| CONCLUSIONS | 7 |
| RECOMMENDATIONS | 8 |
| FUTURE WORK | 8 |

FIGURES

1 - NASL Peening Procedure for the Improvement of Fatigue Properties (For Steel Butt Welds) - NASL SK.N-1886 of 21 Jan 1965

2 - Photo L19985-1 - Macro-Section of Peened HY-80 Butt Weld

3 - Welding Procedure and Joint Design

4 - Variation of Deflection with Number of Fatigue Cycles - 80 KSI Nominal Stress

5 - Comparison of Fatigue Results for HY-80 Tee-Fillet Welds and Butt Welds

6 - Photo L19985-2 - Base Plate Fatigue Failure in Peened Weldment

7 - Photo L19985-3 - Explosion Bulge Results of "As Peened" Butt Weld after 180,000 Cycles in Fatigue at 80 KSI

## TABLE OF CONTENTS
(Continued)

TABLES

1 - Chemical Analysis and Mechanical Properties of HY-80 Specimen Material

2 - Results of Fatigue Tests on HY-80 Butt Welds

## ADMINISTRATIVE INFORMATION

Ref: (a) NAVAPLSCIENLAB Program Summary of 1 May 1965, SF 020-01-01, Task 0722, Fabrication of High Strength Steel Alloys
(b) NAVAPLSCIENLAB Lab. Project 9300-1, Progress Report 1 of 15 Apr 1964
(c) NAVAPLSCIENLAB Lab. Project 9300-1, Tech Memo #11 of 8 Jul 1964
(d) NAVAPLSCIENLAB Lab. Project 9300-1, Tech Memo #15 of 25 Aug 1964
(e) NAVAPLSCIENLAB Lab. Project 9300-1, Tech Memo #18 of 30 Sep 1964
(f) NAVSHIPYDNYK Lab. Project 6160-2, Progress Report 3 of 17 Jul 1961

1. In connection with its high strength steel program, outlined in reference (a), the U. S. Naval Applied Science Laboratory is investigating the effects of welding on the fatigue properties of HY-80 steel and methods for improving these properties. The NASL mechanical peening procedure was shown to be an effective post weld treatment for improving the bending fatigue properties of HY-80 tee-fillet welds in reference (b). The results of other fatigue improvement procedures applied to HY-80 tee-fillet welds were reported as follows:

reference (c) - grinding

reference (d) - shot peening

reference (e) - grinding and shot peening

This memorandum presents a description of and the results obtained with the NASL tee-fillet weld peening procedure which has been modified for application to HY-80 butt welds.

## OBJECTIVE

2. The primary objectives of the work reported herein were as follows:

a. Modify the NASL mechanical peening procedure (previously developed for HY-80 tee-fillet welds) for application to HY-80 butt welds.

b. Determine the degree of improvement in the bending fatigue properties of HY-80 butt welds obtained through the use of this procedure.

3. Additional objectives were:

a. To determine the effects of weld reinforcement removal after peening on the bending fatigue properties of HY-80 butt welds.

b. To determine the explosion bulge properties of a peened HY-80 butt weld that had been subjected to extensive bending fatigue.

## NASL MECHANICAL PEENING PROCEDURE (FOR BUTT WELDS)

4. The mechanical peening procedure developed for the improvement of the fatigue properties of HY-80 butt welds is illustrated in Figure 1. It involves the use of three separate peening tools:

a. A hemispherical nose contouring tool for major metal movement.

b. A dressing tool for removing spherical impressions and increasing the width of the peened area.

c. A flattening tool for removing any sharp ridge that may appear at the base plate edge of the peened area.

This procedure is similar to the procedure for tee-fillet welds described in reference (b), differing principally in the following aspects:

a. The shape of the dressing tool.

b. The additional use of a flattening tool.

c. The angle used between the tool and the plate surface.

A macro-section of a peened HY-80 butt weld illustrating the contour produced by peening is shown in Figure 2.

## DESCRIPTION OF SPECIMENS

5. To determine the degree of improvement in bending fatigue properties obtained through the use of mechanical peening, six 1-1/2" x 28" x 32" HY-80 butt welded plate type fatigue specimens were prepared. The chemical analysis and mechanical properties of the HY-80 material used for these specimens are shown in Table 1. Each specimen was machined from a separate 32" x 40" weldment; the welding procedure and joint design for which are shown in Figure 3. After welding, the following treatments were applied.

a. Two weldments were left in the "as welded" condition.

b. Two weldments were peened (on all weld toes) using the procedure illustrated in Figure 1.

c. Two weldments were peened as in (b) above and then ground to remove weld reinforcement on both sides of each weldment.

The grinding for removal of weld reinforcement was done with hand-held compressed air grinders to simulate shipyard conditions. A horizontal grinder with a 7" x 1" straight wheel was used for rough grinding and a vertical grinder with a 6" cup wheel was used for finishing.

## FATIGUE TESTING PROCEDURE

6. The specimens were tested in the NASL Plate Fatigue Machine described in reference (f). This machine supports the specimen as a simply supported plate along two opposite edges and applies a pulsating, uniformly distributed pressure to the lower face of the specimen, thus producing cyclic stresses which vary from zero to a specified maximum. Nominal equivalent elastic stress is used for stresses greater than the yield strength of the test material. The test is conducted at a constant cyclic rate (12 cycles/min) and in an ambient environment. The fatigue life of a specimen is taken to be the number of cycles to a 10% increase in maximum deflection. Normally the test is continued until the maximum deflection has increased by 100% over the initial maximum deflection.

## RESULTS

7. The fatigue results obtained from the six butt welded specimens tested are presented in Table 2 and Figure 4, and are compared to those of tee-fillet welds in Figure 5. All specimens were initially fatigue tested at a maximum nominal stress of 80,000 psi. A brief summary of the results obtained at this stress level is as follows:

a. "As Welded" specimens - Fatigue lives of 18,000 and 17,100 cycles; major crack at toe of weld in both specimens.

b. "As Peened" specimens - Subjected to fatigue for more than 10 times the fatigue life of the "as welded" specimens with no significant increase in deflection and no major cracks; tests stopped so that specimens could be used for supplementary tests.

c. "Peened-Reinforcement Removed" specimens - Fatigue lives approximating 30 times and 10 times "as welded"; major crack in weld deposit and toe of weld respectively.

## SUPPLEMENTARY TESTS

8. Since the "as peened" specimens did not fail during fatigue testing at 80,000 psi, supplementary tests were performed. These tests and the subsequent results are as follows:

a. "As Peened" Specimen #58B2MP (after 250,000 cycles at 80,000 psi) - subjected to additional bending fatigue at 100,000 psi.
Results: (1) Reached 10% increase in deflection after 120,800 cycles and 100% after 131,780 cycles.

(2) Cracking occurred in base plate away from weld - no cracks in weld area - see Figure 6.

b. "As Peened" Specimen #58B5MP (after 180,000 cycles at 80,000 psi) - explosion bulge tested at 0°F.
Results: (1) Explosion bulge properties were below the expected performance of "as welded" unfatigued welds; however, an appreciable degree of toughness was retained (see Figure 7).

NOTE: Supplementary work to be reported at a later date indicates that two mechanically peened HY-80 butt welds, which were not subjected to fatigue, showed explosion bulge properties equivalent to current requirements.

## CONCLUSIONS

9. A modification of the NASL mechanical peening procedure (previously developed for HY-80 tee-fillet welds) has been developed for application to HY-80 butt welds. This procedure is capable of increasing the bending fatigue life of an HY-80 butt weld to a significant degree. In addition, the procedure is rapid, inexpensive and readily applicable with current shipyard skills and equipment.

10. The occurrence of a weld deposit fatigue crack in a "peened-reinforcement removed" specimen (noted in paragraph 7), suggests that removal of weld reinforcement after peening increases the possibility that the fatigue crack, which eventually occurs during fatigue testing, will form in the weld deposit rather than at the toe of the weld. This may be attributed to the changes in stress concentration and residual stresses and the reduction in weld section thickness caused by removal of weld reinforcement.

11. The explosion bulge test of a peened HY-80 butt weld which had been subjected to extensive bending fatigue showed some loss of toughness.

## RECOMMENDATIONS

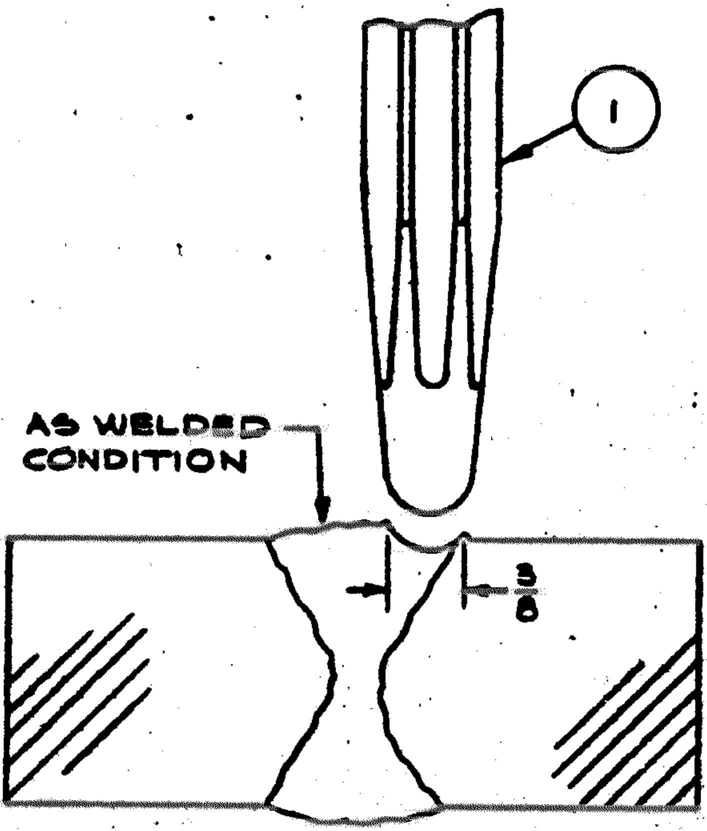
12. It is recommended that the NASL mechanical peening procedure (for butt welds) described herein be considered as a practical and effective method for increasing the fatigue life of HY-80 butt welds. However, final recommendations relative to application of the NASL mechanical peening procedure to butt and fillet welds will be deferred until all scheduled work is completed relative to determination of any possible deleterious effects on toughness due to peening.

## FUTURE WORK

13. Information relative to possible deleterious effects on HY-80 toughness due to mechanical peening will be forwarded in August 1965.

14. The application of the NASL mechanical peening procedure to HY-130/150 welds will be evaluated after basic fatigue data for welds in this material is acquired.

15. Axial fatigue tests of mechanically peened butt and fillet welds are currently being conducted at the University of Illinois under BUSHIPS contract NObs-92240.

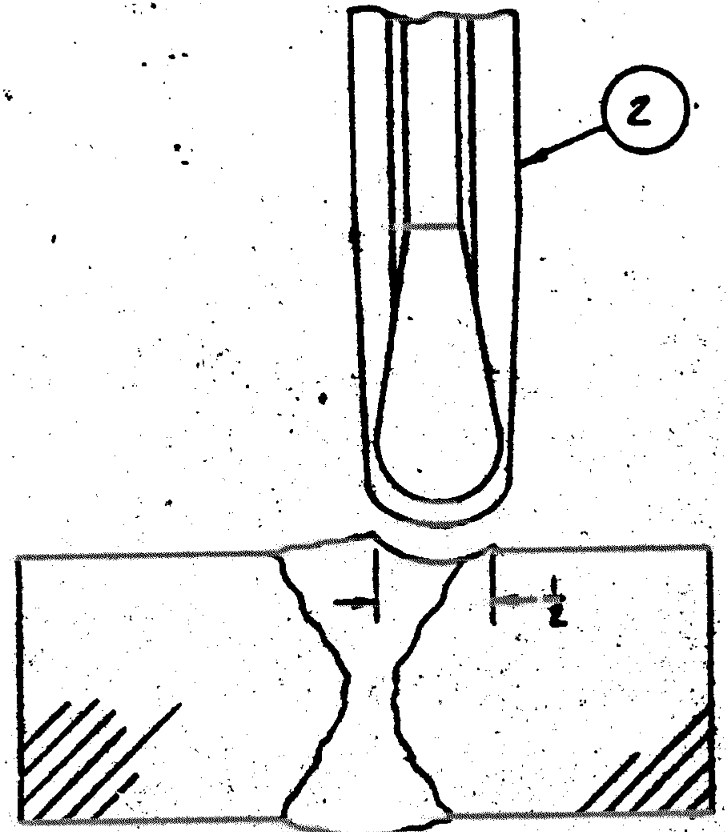


SECTION A-A

FIRST PASS: USE CONTOUR TOOL ①

SECO
THIS
IMPR
PEEN

ABOVE PASSES N
PLATE SURFACE &
FED. SPEC. OO-H-



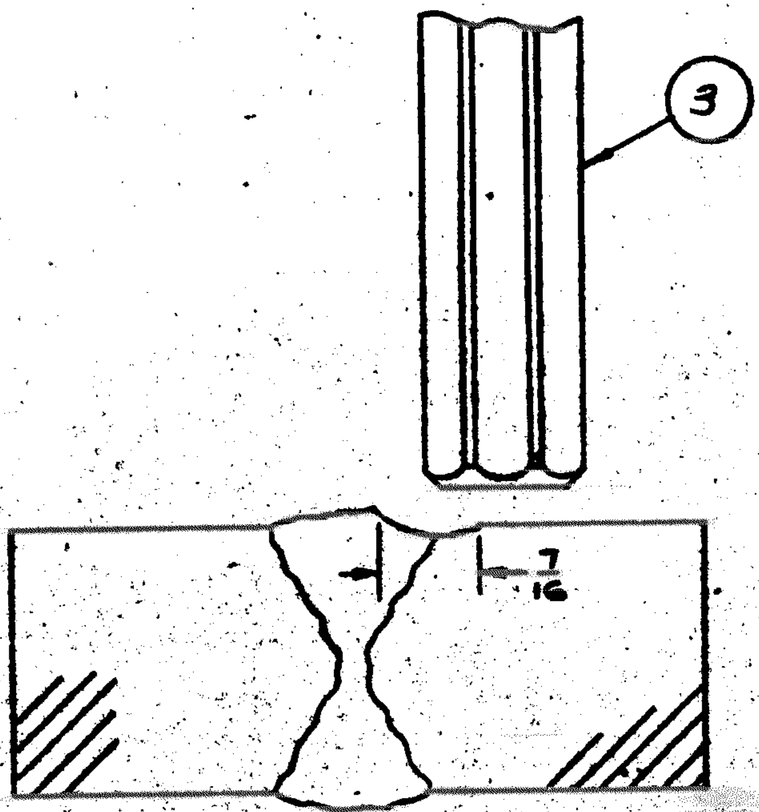
SECTION B-B

SECOND PASS: USE DRESSING TOOL ②
THIS OPERATION REMOVES SPHERICAL
IMPRESSIONS & INCREASES WIDTH OF
PEENED AREA.

SECTIO

THIRD PASS: US
THIS OPERATIO
CROWN".

SES MADE WITH TOOLS HELD PERPENDICULARLY TO
ACE & ATTACHED TO PNEUMATIC HAMMER,
OO-H-116a, SIZE 2, TYPE 2, & 90 P.S.I. AIR SUPPLY

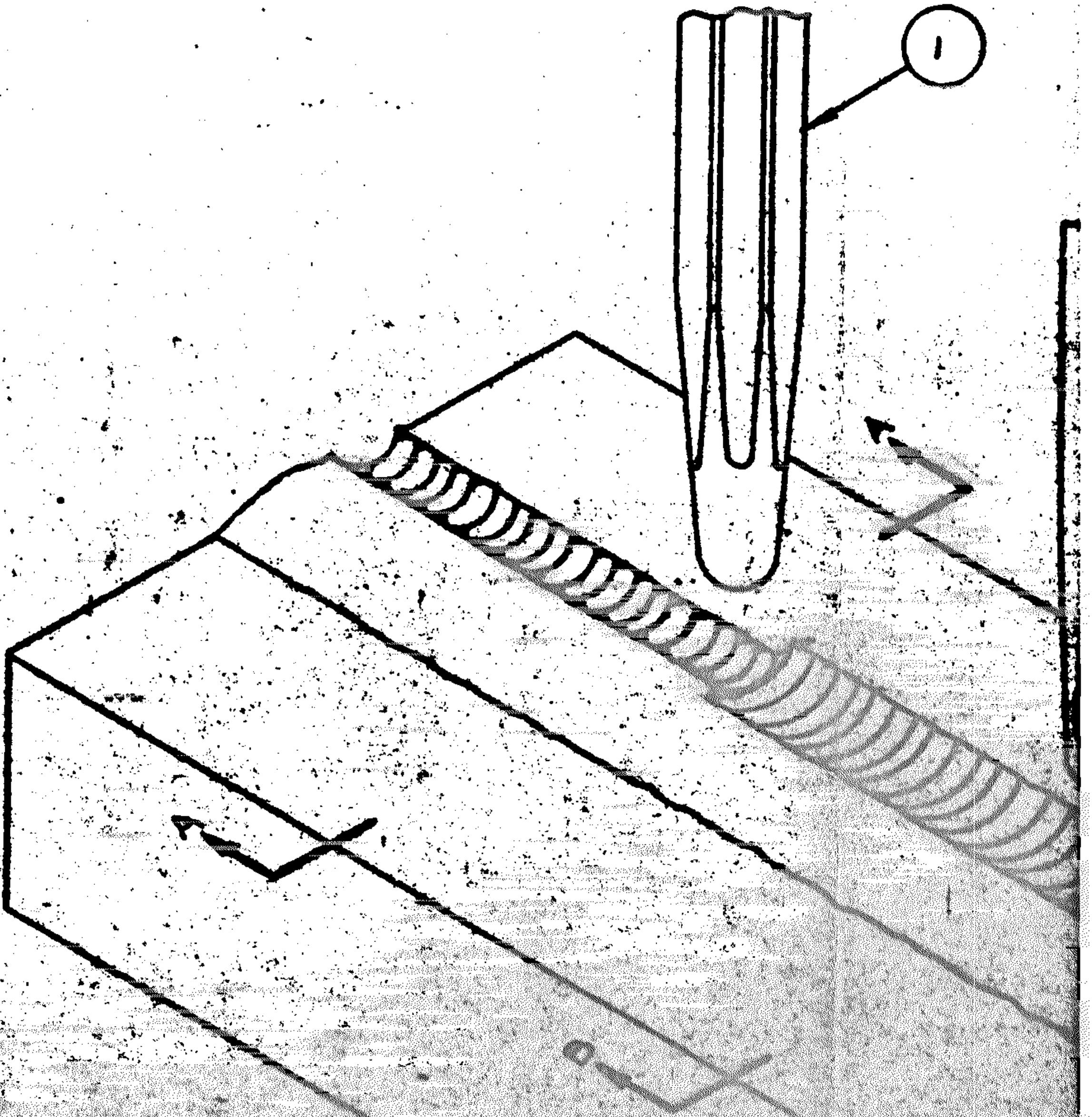


SECTION C-C

②
RICAL
H OF

THIRD PASS: USE FLATTENING TOOL ③
THIS OPERATION REMOVES "RAISED
CROWN".

PENDICULARLY TO
AMMER,
P.S.I. AIR SUPPLY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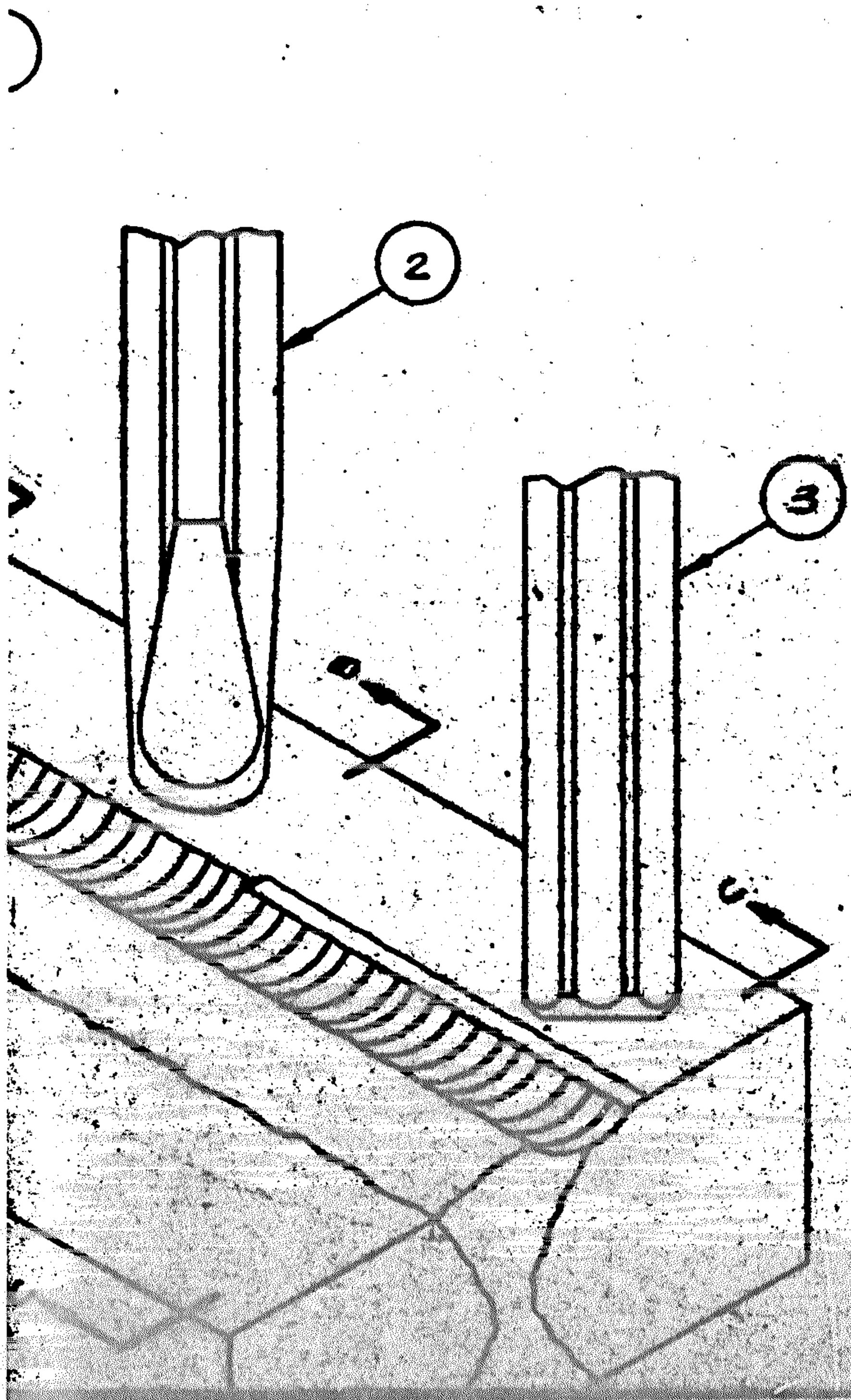


NASL PEENING PROCEDU
FATIGUE PROPERTIES

INS

I EQUIPMENT:
(a) 90 P.S.I. AIR SUP
(b) PNEUMATIC HAMMER
① CONTOURING TOOL
② DRESSING TOOL
③ FLATTENING TOOL

II PROCEDURE:
(a) DIRECT CONTOURING
(b) FOLLOW TOE OF WEL
TO APPROXIMATE CO
(c) DIRECT DRESSING T
THIS OPERATION. WI
OF CONTOURING TO
UPSET METAL: ONE
AS IN SECTION B-B
(d) DIRECT FLATTENING
RIDGE OF UPSET
THIS WILL BRING
PLATE AS IN SEC

NOTE: ALL DIMENSIO
APPROXIMATE.
SOME VARIATI

## NASL PEENING PROCEDURE FOR THE IMPROVEMENT OF FATIGUE PROPERTIES (AS SHOWN FOR BUTT WELDS)

## INSTRUCTIONS

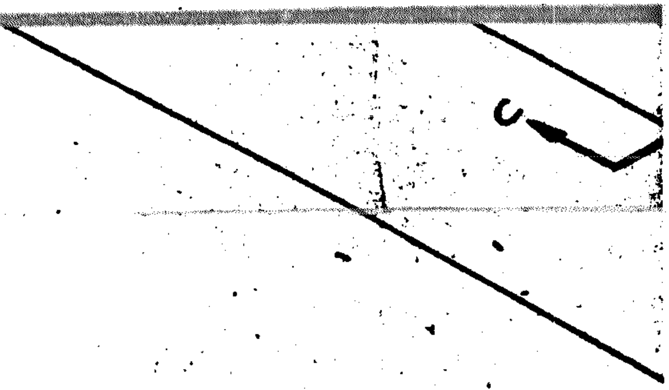
I **EQUIPMENT:**

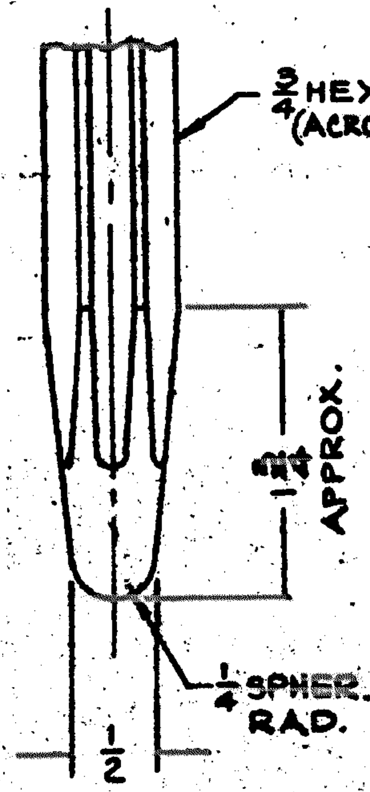
(a) 90 P.S.I. AIR SUPPLY.
(b) PNEUMATIC HAMMER, FED. SPEC. 00-H-116a, SIZE 2, TYPE 2
① CONTOURING TOOL
② DRESSING TOOL } CHISEL BLANK, HARDEN TO Rc 58-62
③ FLATTENING TOOL

II **PROCEDURE:**

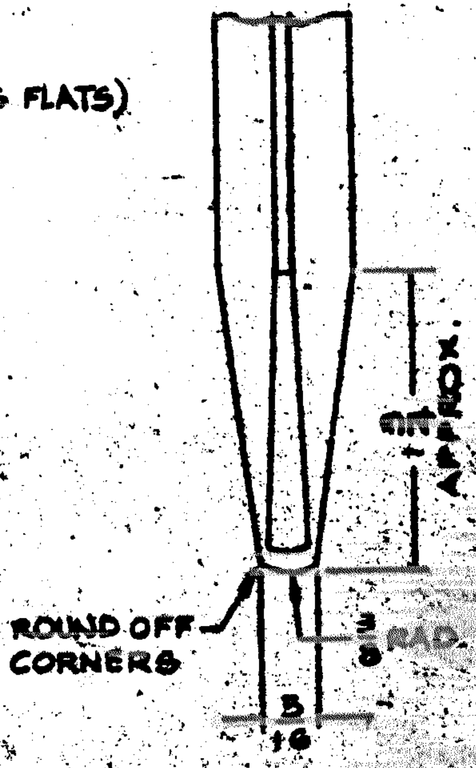
(a) DIRECT CONTOURING TOOL ① AS SHOWN IN SECTION A-A.
(b) FOLLOW TOE OF WELD AT A SPEED OF 15 INCHES/MINUTE TO APPROXIMATE CONTOUR SHOWN IN SECTION A-A.
(c) DIRECT DRESSING TOOL ② AS IN SECTION B-B. THIS OPERATION WILL REMOVE SPHERICAL IMPRESSIONS OF CONTOURING TOOL ① AND LEAVE TWO RIDGES OF UPSET METAL: ONE ON EACH SIDE OF PEENED LENGTH, AS IN SECTION B-B.
(d) DIRECT FLATTENING TOOL ③ AS IN SECTION C-C ALONG RIDGE OF UPSET METAL ON BASE METAL SIDE. THIS WILL BRING RIDGE BACK TO LEVEL OF BASE PLATE AS IN SECTION C-C.

**NOTE:** ALL DIMENSIONS AND SPEEDS ARE APPROXIMATE. JOB CONDITIONS MAY MAKE SOME VARIATIONS ADVISABLE.



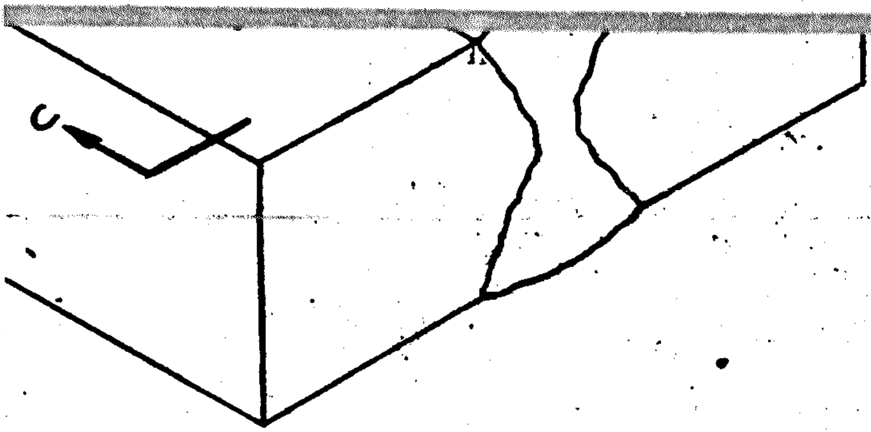


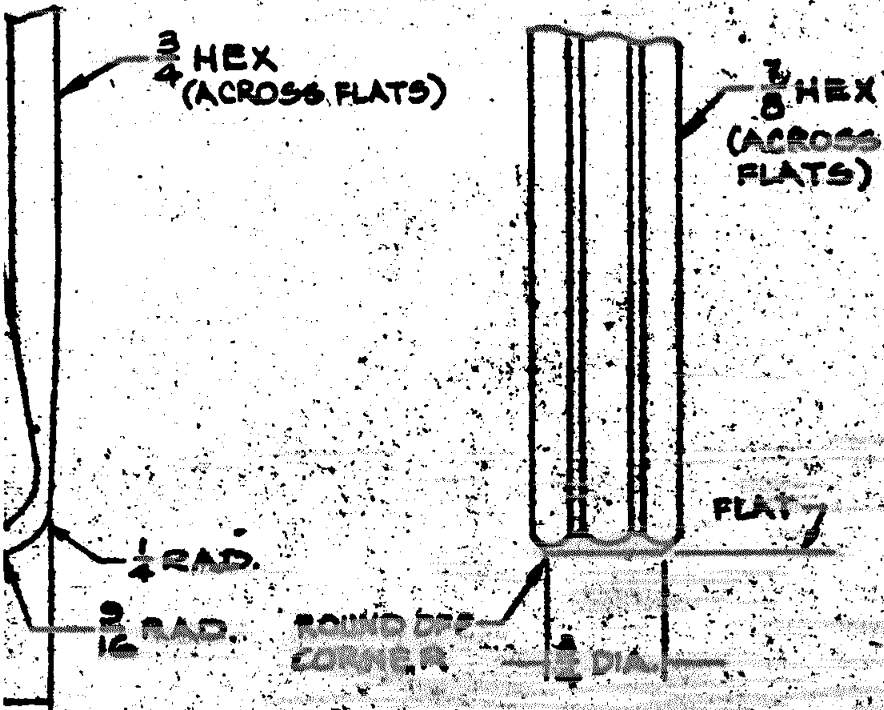
① CONTOUR TOOL



② DRESSING TOOL

TOOL ① ② & ③: MAKE FROM CHISEL BLANK
HARDEN TO Rc 58-62





③ FLATTENING TOOL

OL

LANKS.

SATISFACTORY TO CODE [illegible]
DATE [illegible]
[illegible] HEAD [illegible]

| ALT. | DESCRIPTION |
|---|---|
| | |

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PROCEDURE
OF FATIGUE
(FOR STEEL

D.C.

SCALE 1/1 (12 IN. = 1 FT.)
DRAWN BY A. FREY
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CHECKED BY T.C.
INSPECTED
IN CHARGE [illegible]

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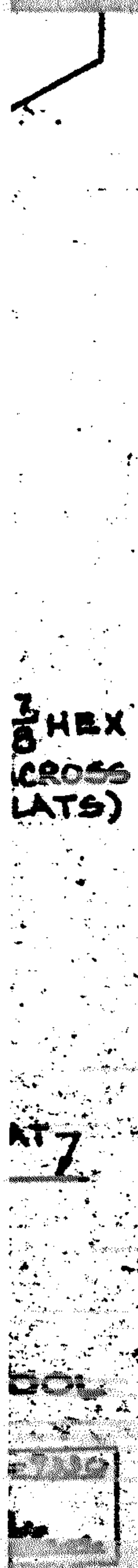

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ALTERATIONS

# NASL PEENING PROCEDURE FOR THE IMPROVEMENT OF FATIGUE PROPERTIES (FOR STEEL BUTT WELDS)

U.S. NAVAL APPLIED SCIENCE LABORATORY
U.S. NAVAL BASE, BROOKLYN, NEW YORK [illegible]

SCALE 1/1 (12 IN. = 1 FT.)
DATE 1 DEC. 1964

DRAWN BY A. FREY
TRACED BY
CHECKED BY T.C.
INSPECTED
IN CHARGE T. Cyman

APPROVED
DATE 1/21/65
INDUSTRIAL DEPARTMENT HEAD
APPROVAL LETTER

SKETCH NUMBER
SK.N-1886
SHEET 1 OF 1 SHEET

BUREAU SHIPS FILE NUMBER

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**ALTERATIONS**

# NASL PEENING
# PROCEDURE FOR THE IMPROVEMENT OF FATIGUE PROPERTIES (FOR STEEL BUTT WELDS)

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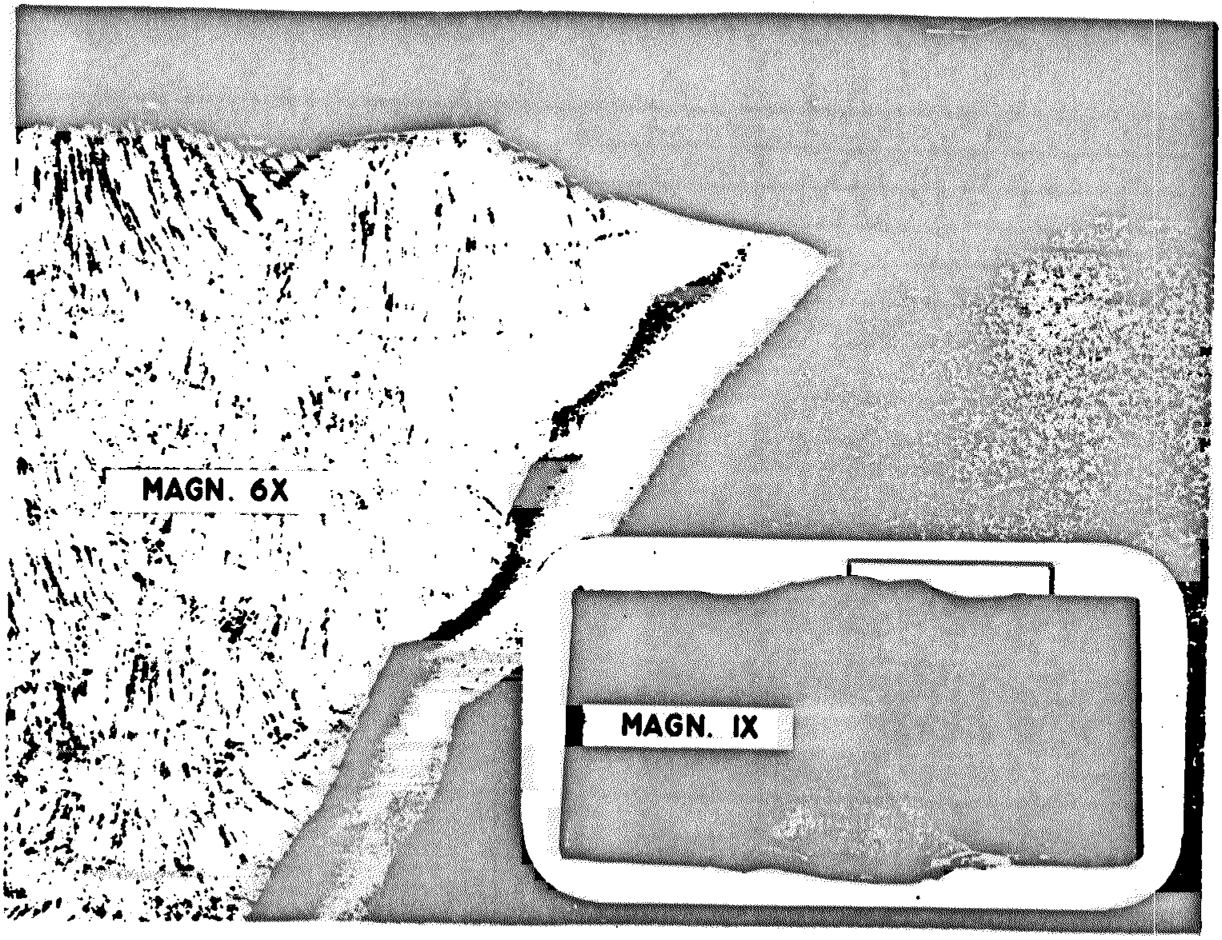

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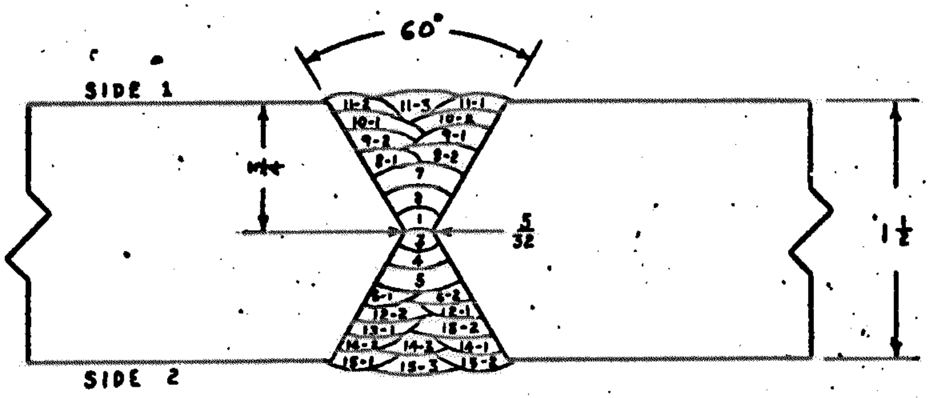
FIGURE 2 - MACRO-SECTION OF PEENED HY-80 BUTT WELD

**PHOTO** L19985-1



**Base Metal:** HY-80 steel

**Electrode:** MIL-11018, 5/32" & 3/16" dia.

**Preheat:** 200°F

**Interpass Temperature:** 200-300°F

**Current & Polarity:** Direct current, reversed polarity

**Position:** Flat

**Heat Input:** 5/32" dia. electrodes - heat input to suit
3/16" dia. electrodes - 45,000 ±5,000 joules/inch

**Sequence:**

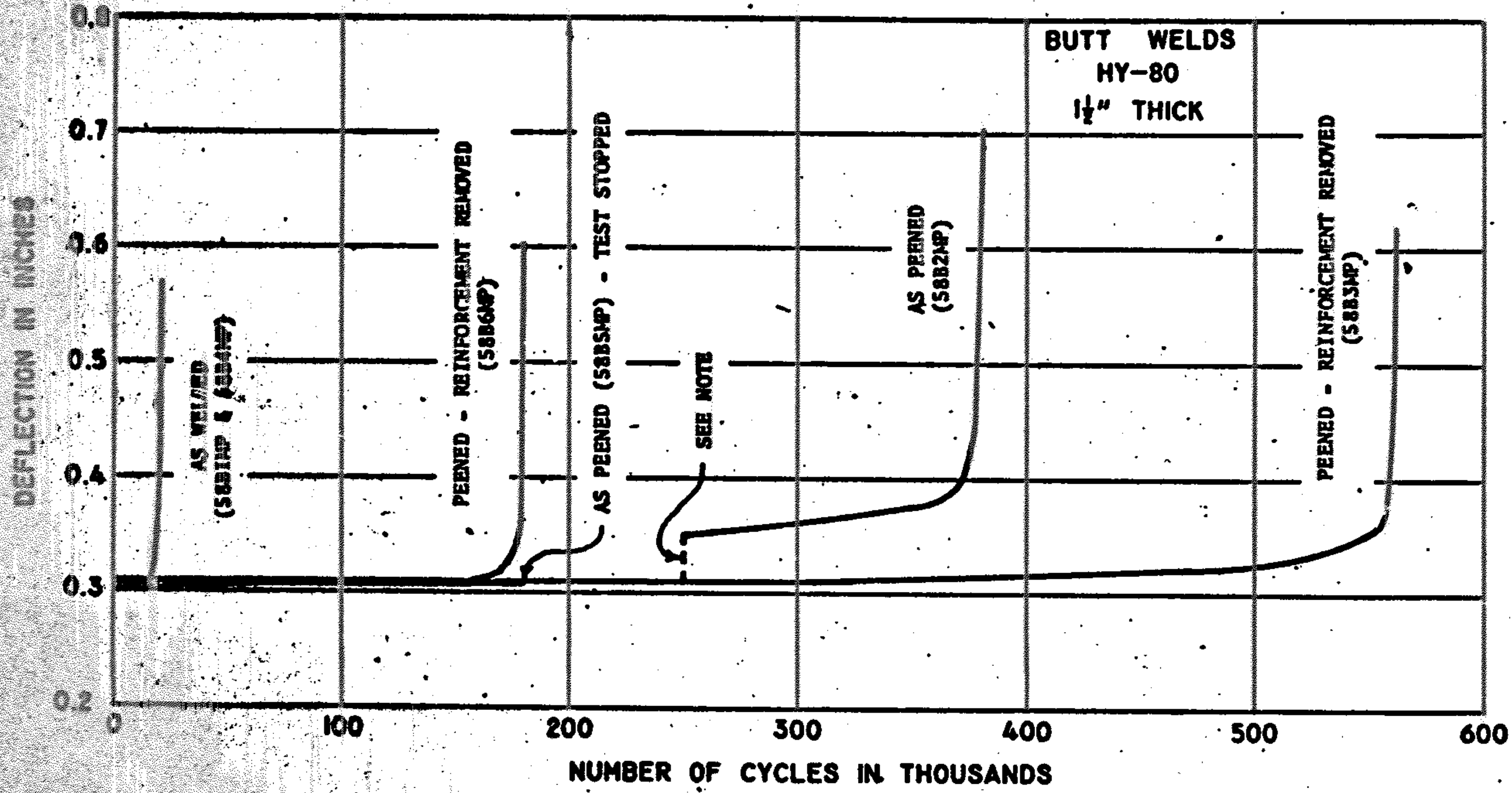
**Side 1**
Two layers, 5/32" dia. electrodes, block technique

**Side 2**
Grind root
Two layers, 5/32" dia. electrodes, continuous welding
Two layers, 3/16" dia. electrodes, continuous welding

**Side 1**
Finish welding side 1 using 3/16" dia. electrodes & continuous welding

**Side 2**
Finish welding side 2 using 3/16" dia. electrodes & continuous welding

FIGURE 3 - WELDING PROCEDURE AND JOINT DESIGN



NOTE: AS PEENED (58B2MP) - Stress raised to 100 ksi after 250,000 cycles at 80 ksi

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FIGURE 4 - VARIATION OF DEFLECTION WITH NUMBER OF FATIGUE CYCLES - 80 KSI NOMINAL STRESS

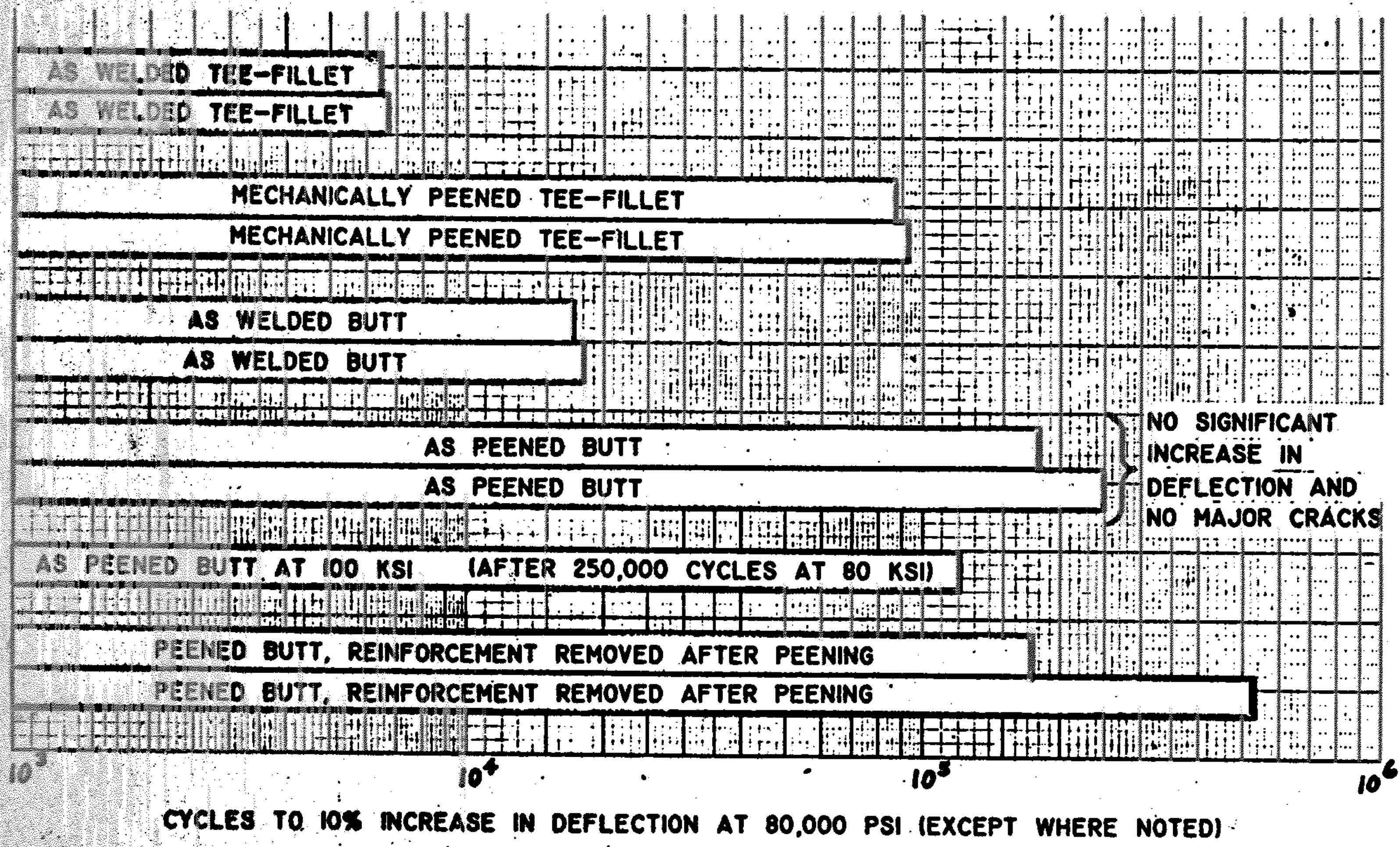

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FIGURE 5 - COMPARISON OF FATIGUE RESULTS FOR HY-80 TEE-FILLET WELDS AND BUTT WELDS

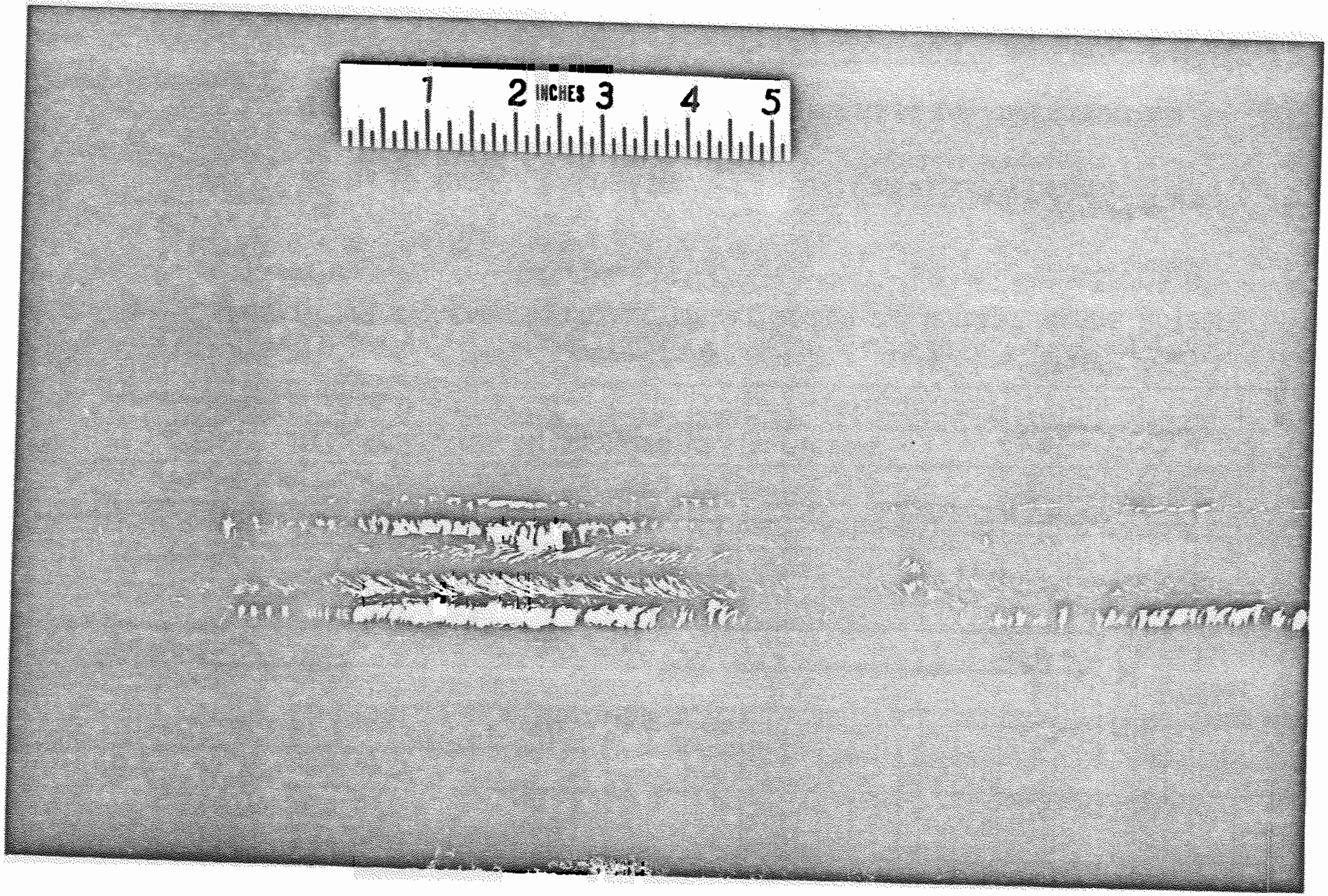

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FIGURE 6 - BASE PLATE FATIGUE FAILURE IN PEENED WELDMENT

**PHOTO L19985-2**

SHOT #1

| | SIDE A | SIDE B |
|---|---|---|
| % REDUCTION IN THICKNESS | 6.56 | 5.55 |
| DEPTH OF BULGE | 3.34 | 3.125 |
| LENGTH OF CRACKS | 11" | 5-3/8"<br>2-1/4" |

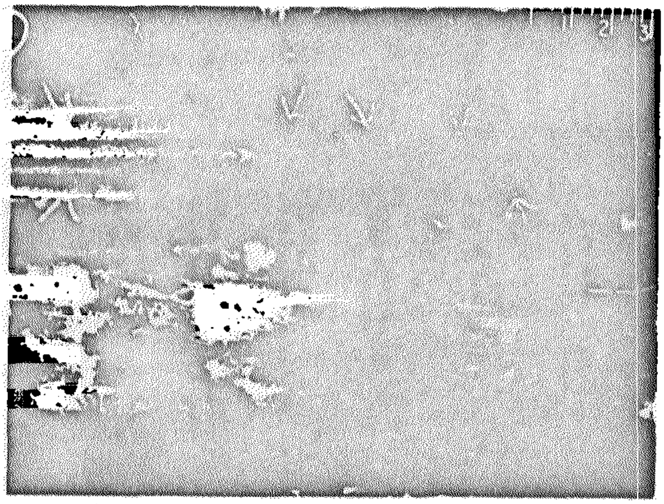

FIG. 7a - Close-up of specimen after first shot showing cracks at toe of weld

SHOT #2

| | SIDE A | SIDE B |
|---|---|---|
| % REDUCTION IN THICKNESS | 11.72 | 11.70 |
| DEPTH OF BULGE | 6.15 | 6.00 |
| LENGTH OF CRACKS | 23" | 10-3/4" |

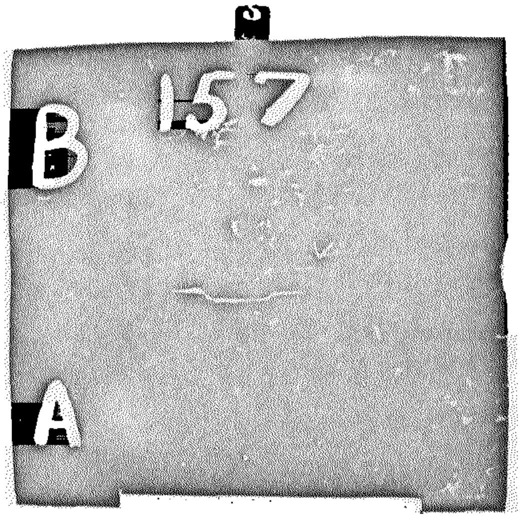

FIG. 7B - Specimen after second shot

TEST CONDITIONS: Stand-off distance, 17"; Pentolite charge, 24 lb; Temperature of specimen, 0°F

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FIGURE 7 - EXPLOSION BULGE RESULTS OF "AS PEENED" BUTT WELD AFTER 180,000 CYCLES IN FATIGUE AT 80 KSI

**PHOTO L-19985-3**

## TABLE 1

## CHEMICAL ANALYSIS AND MECHANICAL PROPERTIES OF HY-80 SPECIMEN MATERIAL

| Chemical Analysis Element % | | Determined by NAVAPLSCIENLAB | Specification MIL-S-16216G |
|---|---|---|---|
| Maximum Unless a Range is Shown | C | 0.14 | 0.18 |
| | Mn | 0.27 | 0.10-0.40 |
| | P | 0.009 | 0.025 |
| | S | 0.021 | 0.025 |
| | Si | 0.23 | 0.15-0.35 |
| | Ni | 2.72 | 2.00-3.25 |
| | Cr | 1.47 | 1.00-1.80 |
| | Mo | 0.41 | 0.20-0.60 |
| | Ti | 0.002 | 0.02 |
| | V | 0.00 | 0.03 |
| | Cu | 0.14 | 0.25 |
| **Mechanical Properties** | | | |
| Yield Strength 0.2% Offset (psi) | | 91,100 (L)<br>90,400 (T) | 80,000-95,000 |
| Ultimate Tensile Strength (psi) | | 107,900 (L)<br>107,000 (T) | - |
| Elongation in 2 inches (%) | | 27.5 (L)<br>25.5 (T) | 20 |
| Reduction in Area (%) | | 72.1 (L)<br>65.1 (T) | 55 (L)<br>50 (T) |
| Charpy V-Notch Impact at -120°F (ft-lbs) | | 98.3 (L)<br>62.8 (T) | 50 |

(L) Longitudinal (parallel to direction of roll).

(T) Transverse (perpendicular to direction of roll).

## TABLE 2

## RESULTS OF FATIGUE TESTS ON HY-80 BUTT WELDS

| Specimen No. | Type of Specimen | Calculated Nominal Cyclic Stress (psi) | | Avg Thickness at Critical Section (in.) | | Applied Uniform Pressure (psi) | Initial Deflection (in.) | No. of Stress Cycles To | | | | Location of | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 1st Observation of Crack | | 10% Increase in Deflection | 100% Increase in Deflection | | |
| | | Side B | Side D | Side B | Side D | | | Side B | Side D | | | Initial Crack | Major Crack |
| S8B1MP | As Welded | 80,000 | 79,600 | 1.497 | 1.499 | 305 | 0.302 | 5,000 | 5,000 | 18,000 | 19,160 | Side B 2-1/2" From End C | Toe of Weld |
| S8B4MP | As Welded | 79,900 | 80,000 | 1.499 | 1.499 | 306 | 0.302 | 4,500 | 9,400 | 17,100 | 18,630 | Side B 3" From End A | Toe of Weld |
| S8B5MP | As Peened | 80,000 | 80,000 | 1.485 | 1.485 | 301 | 0.307 | 30,000 | 36,000 | * | * | Side B 1/2" From End C | * |
| S8B2MP | As Peened | 80,000 | 79,400 | 1.485 | 1.492 | 301 | 0.307 | 8,300 | 8,300 | ** | ** | Sides B & D 3" From End A | ** |
| ** | ** | 100,000 | 99,900 | 1.485 | 1.492 | 376 | 0.352 | 54,000 | 8,000 | 120,800 | 131,780 | Side D 8" From End A | Base Plate |

## TABLE 2

| Specimen No. | Type of Specimen | Calculated Nominal Cyclic Stress (psi) |  | Avg Thickness at Critical Section (in.) |  | Applied Uniform Pressure (psi) | Initial Deflection (in.) | No. of Stress Cycles to |  |  |  | Location of |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  |  |  |  | 1st Observation of Crack |  | 10% Increase in Deflection | 100% Increase in Deflection | Initial Crack | Major Crack |
|  |  | Side B | Side D | Side B | Side D |  |  | Side B | Side D |  |  |  |  |
| S8B3MP | Peened Reinforcement Removed | 79,200 | 80,000 | 1.475 | 1.469 | 294 | 0.310 | 37,500 | 39,000 | 537,100 | 561,700 | Side B 15" From End C | Weld Deposit |
| S8B6MP | Peened Reinforcement Removed | 80,000 | 79,800 | 1.487 | 1.490 | 302 | 0.302 | 13,000 | 14,400 | 175,200 | 180,000 | Side B 17" From End A | Toe of Weld |

*Less than 1% increase in deflection and no major crack after 180,000 cycles - fatigue test stopped and specimen subjected to explosion bulge test.

**Less than 1% increase in deflection and no major crack after 250,000 cycles - specimen subjected to additional bending fatigue at 100,000 psi.