MFS-19019 110053

ADD118400

CARD (CC 1-3): 2 3

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

NEW TECHNOLOGY TRANSMITTAL

(See Instructions on Reverse)

Approved Through January 1970
Budget Bureau No. 10-R0046

NT CONTROL NUMBER (CC 4-11): M F S - 1 9 0 1 9

1. TITLE

Fatigue Properties of Ti-5Al-2.5Sn ELI in Smooth, Shot Peened and Notched Surface Conditions at 70F and -423F

2. INNOVATOR(S) (Name and Social Security No.)

Peter T. Jarocewicz S/S 081-38-2181
Edwin F. Green S/S 551-05-2131

3. EMPLOYER (Organization and division)	4. ADDRESS (Place of performance)
Rocketdyne, a division of North American Rockwell Corporation	6633 Canoga Avenue Canoga Park, Calif. 91304

5. DOCUMENTATION (Full and complete disclosure must be enclosed, the contents of which are discussed in NHB 2170.3, Documentation Guidelines for New Technology Reporting. Place an "X" to the left of those items of documentation which are available but NOT enclosed with this transmittal)

	ENGINEERING SPECIFICATIONS		OPERATING MANUALS		COMPUTER TAPES/CARDS
	ASSEMBLY/MFG DRAWINGS		TEST DATA		
	PARTS OR INGREDIENTS LIST		ASSEMBLY-MFG PROCEDURES		

6. PREVIOUS PUBLICATION OR PUBLIC DISCLOSURE

PUBLICATION

TYPE: ☐ JOURNAL ☒ REPORT ☐ CONFERENCE OR SEMINAR

BY: ☐ NASA ☐ OTHER GOVT. ☒ CONTRACTOR ☐

VOLUME NO.	PAGE	DATE	STATUTORY BAR ESTABLISHED (Date)
MPR 70-305		25 March, 1970	

TITLE: Fatigue Properties of Ti-5Al-2.5Sn ELI in Smooth, Shot Peened and Notched Surface Conditions at 70F and -423F

PATENT

STATUS: ☐ APPLICATION FILED ☐ ISSUED

NO.	DATE

7. STATE OF DEVELOPMENT

☐ CONCEPT ONLY ☐ DESIGN ☐ PROTOTYPE ☐ MODIFICATION ☐ PRODUCTION MODEL ☒ USED IN CURRENT WORK

8. ORIGIN (CC 12): P

9. NASA PRIME CONTRACT NO. (CC 13-23): N A S 8 - 1 9
M SFC

10. SUBCONTRACT TIER (CC 24):

11. CONTRACTOR REPORTABLE ITEM NO. (CC 25-33): N A R 8 1 1 6 1

12. CONTRACTOR/GRANTEE NEW TECHNOLOGY Not SUBMITTED PURSUANT TO NT/PRI CLAUSE PROVISION (CC 34) ☐

For Internal Use Only

13. SUBCONTRACTOR CIC (CC 35-41):

14. NT RECEIPT DATE (CC 42-47): MO 0 6 DAY 1 7 YR 7 0

15. PROJ. NO. (CC 48-51):

16. EVALUATION ORGANIZATION (CC 52-54):

17. NT FORWARDED FOR EVALUATION (Date) (CC 55-60): MO DAY YR

18. COMMENTS

	NAME AND TITLE	SIGNATURE	DATE
19. PREPARED BY	S.W. Winquist Rocketdyne Patent Review By	S.W. Winquist	4-24-70
20. APPROVED (Center TUO)	H. L. Martin		7/2/70

NASA FORM 666 SEP 68 PREVIOUS EDITIONS ARE OBSOLETE.

Ref. 134

110053

TECHNOLOGY ITEM DESCRIPTION
(Drawing and Description Sheet)

(14) MFS-19019

NAR 81161

(6)

Title Fatigue Properties of Ti-5Al-2.5Sn ELI in Smooth, Shot Peened, and Notched Surface Conditions at 70F and -423F

Provide the following information concerning the disclosed item in the sequence indicated:

1. Problem the item solved.
2. Advantages of the item over presently known solutions.
3. Specifically describe the item and its operation.
4. List features that are believed to be novel, new, or significant.
5. List as specifically as possible potential applications.

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1. In order to design turbopump components for adequate fatigue life; properties were required for the subject material in smooth, shot peened, and notched conditions at room and -423F. None were available.

2. Design information, not previously available, was obtained

3. Tests were performed as described in attached report MPR 70- 305, with results as shown in data attached thereto.

4. Quantitative effects of shot peening on increasing the fatigue life, and of notching decreasing it, especially at cryogenic temperatures, are believed to be highly novel and significant, for the titanium alloy in question.

5. Potential applications are for all users of this titanium alloy in the temperature ranges from room down to as low as -423F, and who are concerned with fatigue properties.

(8) U
(9) Inventions
(10) See Cover
(11) Mar 70
(12) J
(20)
(21) MPDC - 70006
(22) APP
(33) I
(35) 390199-

MPR No. 70-305
25 March 1970

SUBJECT: Fatigue Properties of Ti-5Al-2.5Sn ELI in Smooth, Shot Peened and Notched Surface Conditions at 70°F and -423°F

INTRODUCTION

In order to furnish design information for proper fatigue life of turbopump components, Materials and Processes (M&P) initiated a program to determine the fatigue properties of forged Ti-5Al-2.5Sn ELI in the smooth, notched and shot peened conditions at both room temperature and -423°F. The effect of variations in microstructure was also investigated.

CONCLUSIONS

1. The fatigue properties of Ti-5Al-2.5Sn ELI are significantly affected by the surface roughness conditions of the material.
2. Shot peening increased the average fatigue limit by 13.8% at 70°F and 10.1% at -423°F.
3. Notching decreased the average fatigue limit by 23.1% at 70°F and 21.5% at -423°F.
4. The S-N curves for this material are typical in shape for titanium alloys, exhibiting a "knee" and a fatigue limit.

Procedure and Results

A sample forging of Ti-5Al-2.5Sn ELI was obtained from the same billet as the material of the concerned components. The material producer was Reactive Metals, Inc. (See Table I for heat number on mill analysis) The raw material was forged by Reisner into a 8.85 inch diameter by 3.83 inch high

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To: G. J. Basl
From: Metallurgical and Chemical Lab
Subject: Fatigue Properties of Ti-5Al-2.5Sn ELI in Smooth, Shot Peened and Notched Surface Conditions at 70°F and -423°F

D/596-175 AC10 MPR 70-305
D/596-175 PA36 25 March 1970

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cylindrical shape. (S/N 33657 P/N 461679-5). The forging was vacuum annealed to 1400°F ± 25°F for four hours.

Specimen Size

Both tensile (TR-250) and fatigue (FF-155 .080 in. thick) specimens were removed from the forging. The locations of the test specimens are shown in Figure 1.

Specimen Preparation

The fatigue specimens were carefully prepared so as not to contaminate the surface. They were processed by wet hand grinding with 320 grit, ultrasonic cleaning in acetone, and stress relieving. The stress relieving was done in a tube furnace at 1150°F ± 10° for 60 ± 5 minutes in an argon atmosphere. The specimens were cooled in the cold zone of the furnace under an argon atmosphere to room temperature.

The tensile properties of the forging were determined at both 70°F and -423°F. The results of the individual tests are given in Table II.

These tensile values were used to set the starting points in the fatigue testing. The modulus of elasticity used for each test was 16X10° psi for room temperature (70°F) and 17X10⁶ psi for -423°F. The fatigue testing was then performed on a Krouse Flexural Fatigue Testing Machine, Model 150, as shown in fig. 6, page 14.

Surface Condition

Fatigue of Surface Notch 4

The fatigue specimens were tested under three different surface conditions, smooth, shot peened, and notched. All specimens had a 32 RMS or better finish before the surface conditions were changed for testing. The smooth specimens retained the 32 RMS or better finish and were tested in that unaltered condition. The shot peened specimens were peened at Metal Improvement Company using glass beads of .009 in. to .016 in. in diameter. The intensity was .004A with eight passes on each side. The notched specimens were notched with a scribe in the constant stress area of the specimen. The notch was .0005 inch deep and .002 inch wide, and the notch was placed directly opposite to the strain gage. (See Figure 2 for location of strain gage).

The room temperature fatigue tests were set up with strain gages and a strain indicator read out box. The graphic results of the tests are shown in Figure 3. All of the three conditions are plotted on the same chart for comparison.

The cryogenic fatigue testing was performed at the Santa Susana Field Laboratories. The specimen set up was done at room temperature with a strain gage and a strain indicator read out box. A Type Q plug-in unit and oscilloscope were used to check the strain levels during testing. Allowances were made at set up for contraction during chilldown. The graphic results of the cryogenic testing are shown in Figure 3. (The raw data for the fatigue testing appears in Tables 3 and 4).

To: G. J. Basl — D/596-175 AC10 — MPR 70-305
From: Metallurgical and Chemical Lab — D/596-175 BA36 — 25 March 1970
Subject: Fatigue Properties of Ti-5Al-2.5Sn ELI in Smooth, Shot Peened and Notched Surface Conditions at 70°F and -423°F

Photomicrographs were taken of the typical microstructures encountered in this test, and they appear as Figures 5a and 5b. Figure 5a is a photomicrograph of the structure at the center of the forging showing the typical platelike structure encountered. Figure 5b shows the typical equiaxed structure observed in the test specimens.

Discussion

The Ti-5Al-2.5Sn ELI exhibited the typical-shape fatigue curve for titanium alloys, with the curved portion at high stress levels and a knee and flat portion at the lower stress levels. The effects of the two surface conditions imposed on the fatigue specimens were significant on the position of the curve. The smooth curve at both 70°F and -423°F was between the shot peened and the notched curves.

Shot peening was beneficial to the endurance limit of the material. At 70°F shot peening raised the endurance limit from 66 KSI (smooth condition) to 74 KSI (shot peened). At -423°F shot peening increased the endurance limit from 78.5 KSI (smooth) to 86.5 KSI (shot peened).

The notching of the fatigue specimens was significantly detrimental to the fatigue properties. At 70°F the notched specimen had an endurance limit of 50 KSI as compared to 66 for the smooth specimens. At -423°F the notching of the specimens reduced the fatigue limit from 78.5 KSI (smooth) to 62 KSI (notched).

These results indicated that shot peening did improve the fatigue limit, however, the effect of notching was of a much greater magnitude. Shot peening increased the fatigue limit only 13.8% at 70°F while notching decreased the fatigue limit by 23.1%. At -423°F almost the same degree of change was observed. Shot peening increased the fatigue limit by 10.1% and notching reduced the limit by 21.5%.

Therefore, caution should be taken with this material to minimize the occurrence of any machine marks or other scratches which ccould cause a notch effect on the part.

The major types of grain structures encountered were equiaxed and plates, with some overlapping of the two structures. Approximately 80% of the specimens tested had a predominantly platelike structure, and 25% had appreciable amounts of equiaxed alpha. The effect of microstructure on fatigue life was not significant in the limited testing which was done. However, due to the limited number of specimens tested, no conclusive trends could be determined to show whether a significant effect was present or not.

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Attachment to: MPR 70-305
25 March 1970

TABLE I

8-030

MILL ANALYSIS OF HEAT NO. 293722 OF
Ti-5Al-2.5Sn (ELI) FROM REACTIVE METALS, INC.

ELEMENT	%
Al	5.1
Sn	2.4
O_2	.080
H_2	.006
N_2	.007
C	.02
Fe	.09
Mn	.01

Attachment to: MPR 70-305
25 March 1970

TABLE II

TENSILE PROPERTIES OF Ti-5Al-2.5Sn ELI FORGING

TEST TEMP.	BAR NO.	Y.S. KSI	U.T.S. KSI	ELONG. % - 4D	RED. OF AREA %
70°F	1	110.4	117.1	14.0	32.9
	3	109.6	117.9	17.0	42.8
	5	108.0	117.4	16.0	38.5
	AVG.	109.3	117.5	15.7	38.1
-423°	2	184.8	213.6	10.0	11.7
	4	189.7	213.0	11.0	22.4
	6	187.0	212.8	14.0	22.3
	AVG.	187.2	213.1	11.7	18.8

Round Specimen (see pg. S-3410)

Attachment to: MPR 70-305
25 March 1970
(Page 1 of 2 for this ...

TABLE III

ROOM TEMPERATURE FATIGUE TEST RESULTS

CONDITION	SPEC. NO.	STRAIN μ in/in.	STRESS PSI	CYCLES TO FAILURE
SMOOTH	01 1-5	4068	65,000	2,517,900 DNF*
	02 5-2	3949	63,200	125,300
	03 5-5	5357	85,700	30,200
	04 5-6	4394	70,300	122,500
	05 5-8	4634	74,250	66,000
	06 6-3	4145	66,250	79,000
	07 10-1	4065	65,000	137,600
	08 12-1	4097	65,500	159,400
SHOT PEENED	01 7-2	4357	69,700	482,600
	02 7-7	5075	81,200	681,600
	03 8-5	4690	75,040	820,800
	04 8-6	6010	96,000	56,200
	05 8-7	4500	72,000	1,001,200 DNF*
	06 13-2	4175	66,800	1,840,700 DNF*
	07 13-3	5487	87,790	123,400
	08 13-4	4880	78,080	96,500
	09 13-6	4817	77,070	432,400
NOTCHED	01 3-1	3275	52,400	410,600
	02 3-3	3482	55,700	261,800
	03 3-7	4072	65,000	239,400

*DNF - DID NOT FAIL

TABLE III (Cont'd)

ROOM TEMPERATURE FATIGUE TEST RESULTS

CONDITION	SPEC. NO.	STRAIN μ in/in.	STRESS PSI	CYCLES TO FAILURE
NOTCHED (Cont'd)	3-8	2830	45,300	1,034,600 * DNF
	12-3	3085	49,360	2,077,800 * DNF

* DNF - DID NOT FAIL

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March 25, 1970

TABLE IV

CRYOGENIC FATIGUE TEST RESULTS

CONDITION	SPEC. NO.	STRAIN μ in/in	STRESS PSI	CYCLES TO FAILURE
SMOOTH	01 1-3	4800	81,600	736,900
	02 1-4	5300	90,000	135,500
	03 1-7	4610	78,400	1,003,000 DNF *
	04 6-6	4400	74,800	1,000,000 DNF *
	05 6-8	6000	102,000	50,500
SHOT PEENED	01 7-3	6420	109,000	88,400
	02 7-4	5665	96,400	191,200
	03 7-8	5080	86,400	1,000,500 DNF *
	02 8-2	7008	119,100	49,900
	05 8-3	5247	89,000	116,300
NOTCHED	01 3-2	3550	60,400	1,000,100 DNF *
	02 3-5	4157	70,700	149,900
	03 12-2	3750	63,800	618,900
	04 12-8	3490	59,400	1,403,200 DNF *

* DNF - DID NOT FAIL

Written By: P. T. Jarocewicz
Member Technical Staff
Metallurgical and
Chemical Laboratory
Materials and Processes

Approved By: E. F. Green - Manager
Metallurgical and
Chemical Laboratory
Materials and Processes

Attachments

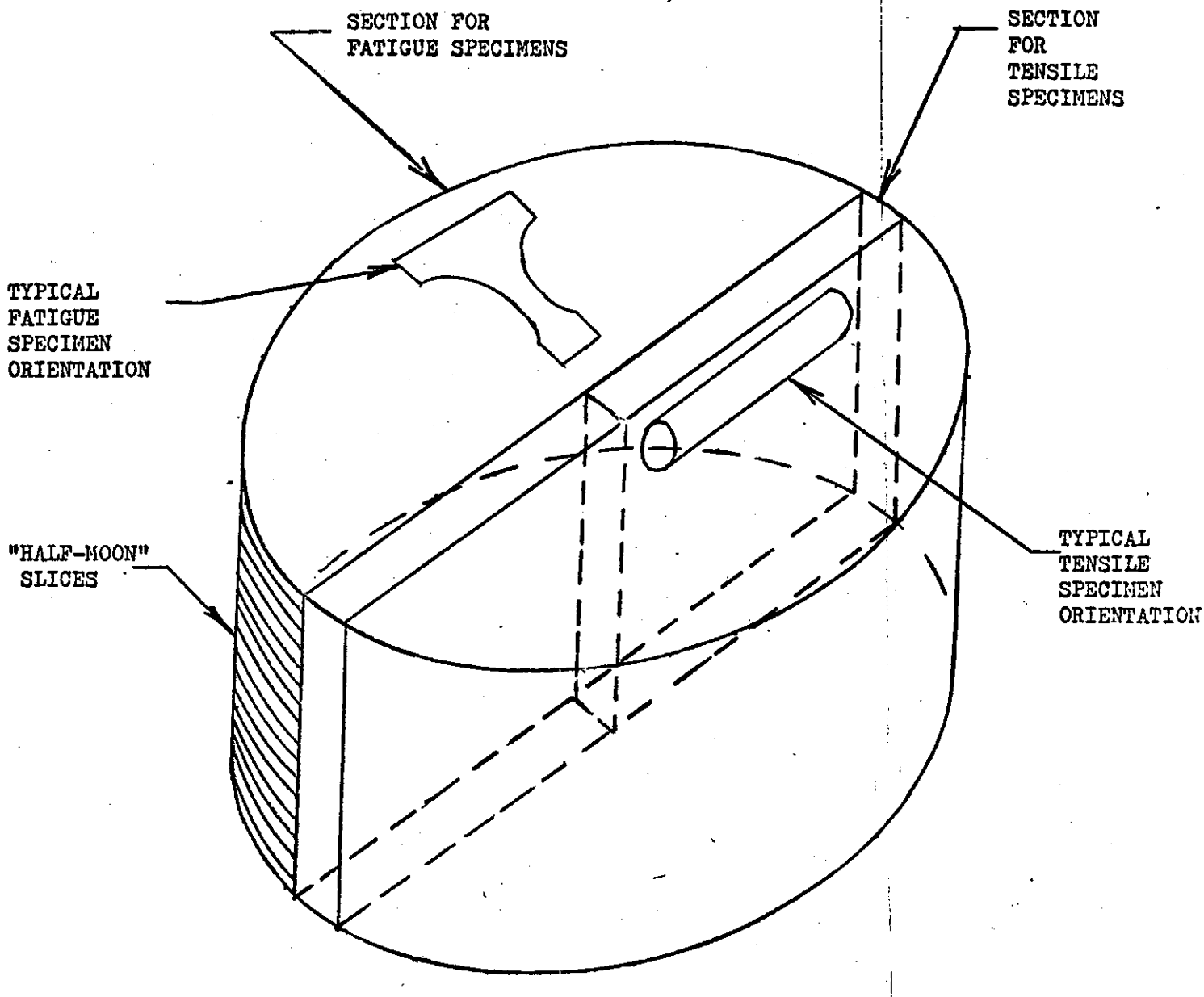


FIGURE 1

SECTIONING OF FORGING FOR TEST SPECIMENS

Fatigue section was sliced into 16 "Half-Moon" slices and 8 fatigue specimens removed from each slice pointing toward center of forging.

Six tensile specimens were removed in a radial orientation.

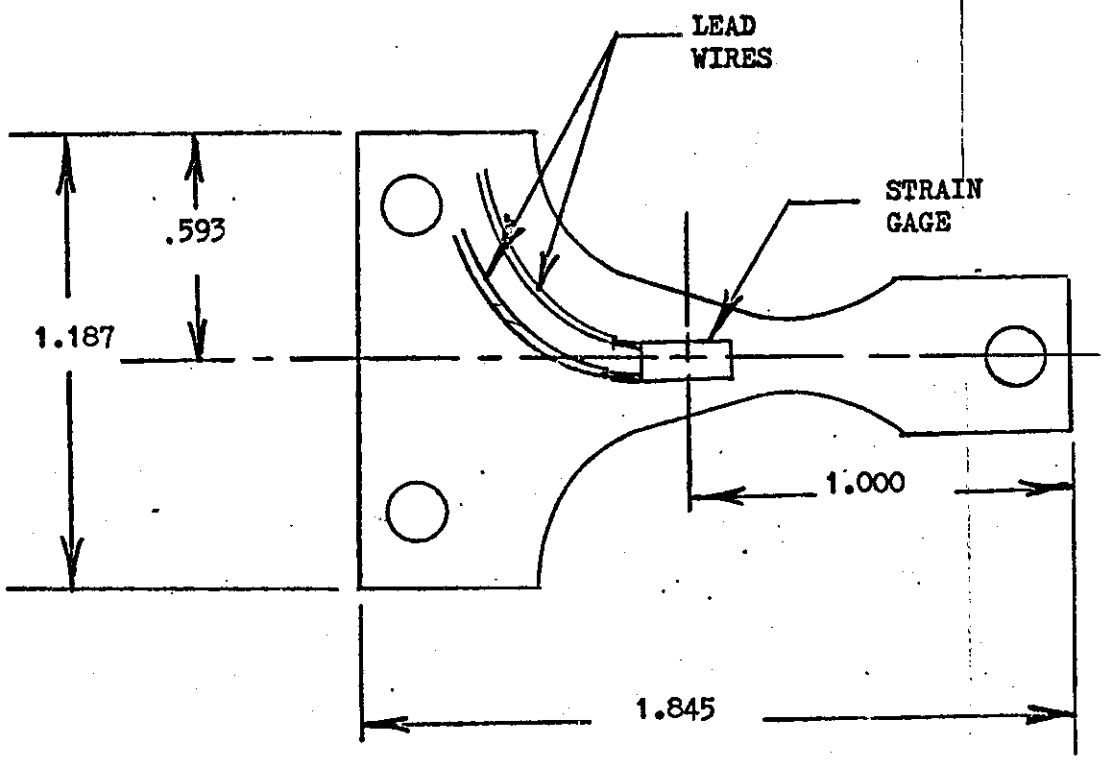


FIGURE 2

LOCATION OF STRAIN GAGE

FIGURE 3

MPR 70-305 3-25-70

70°F
FLEXURAL
2000 CPM
-1
8

FATIGUE PROPERTIES

ROCKETDYNE

CHART NO.
MATERIAL Ti-5Al-2.5Sn(E.L.)
FORM SHEET
CONDITION NOTED
FINISH 32 RMS
F_{tu} 117.5 KSI

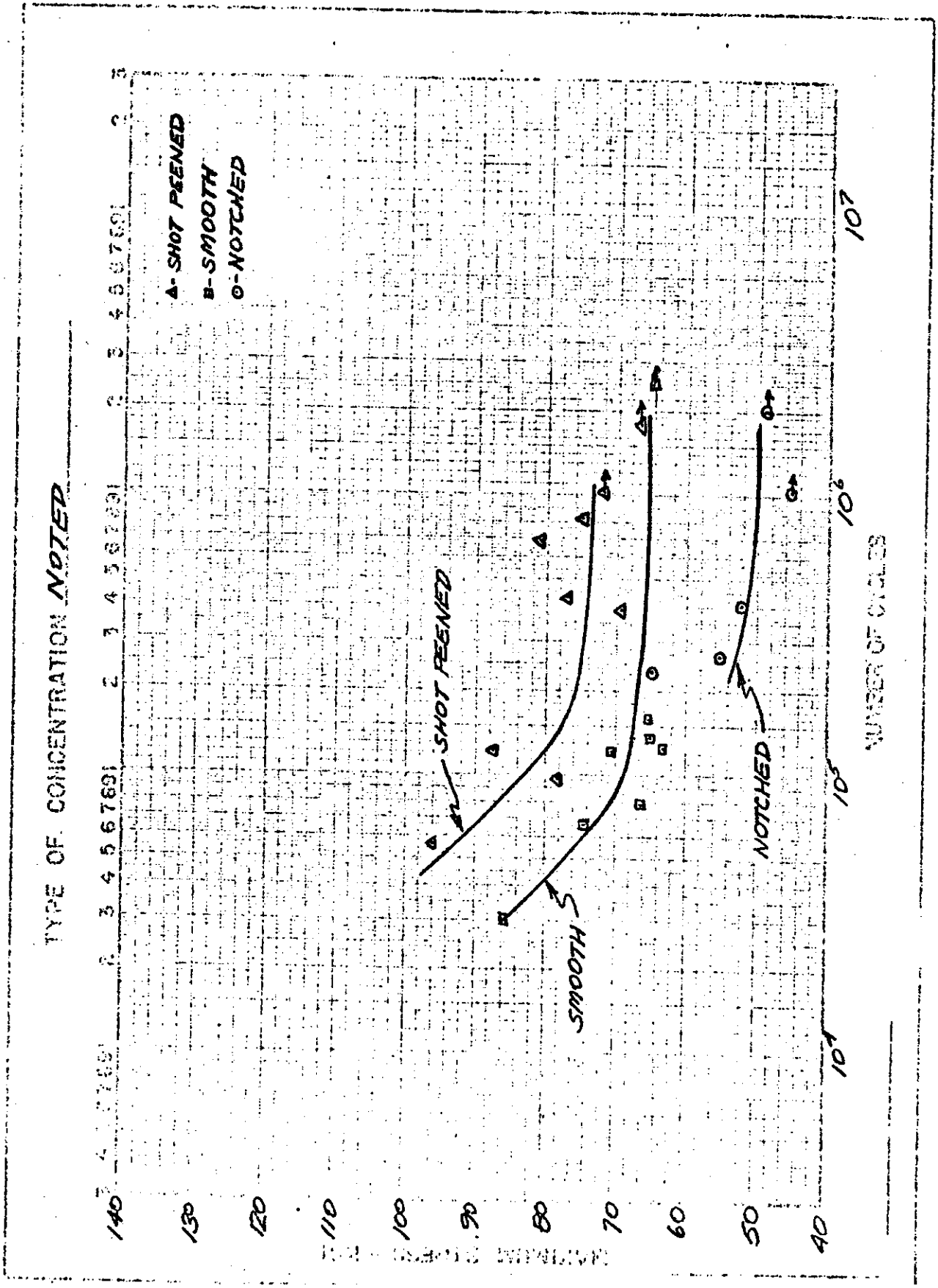


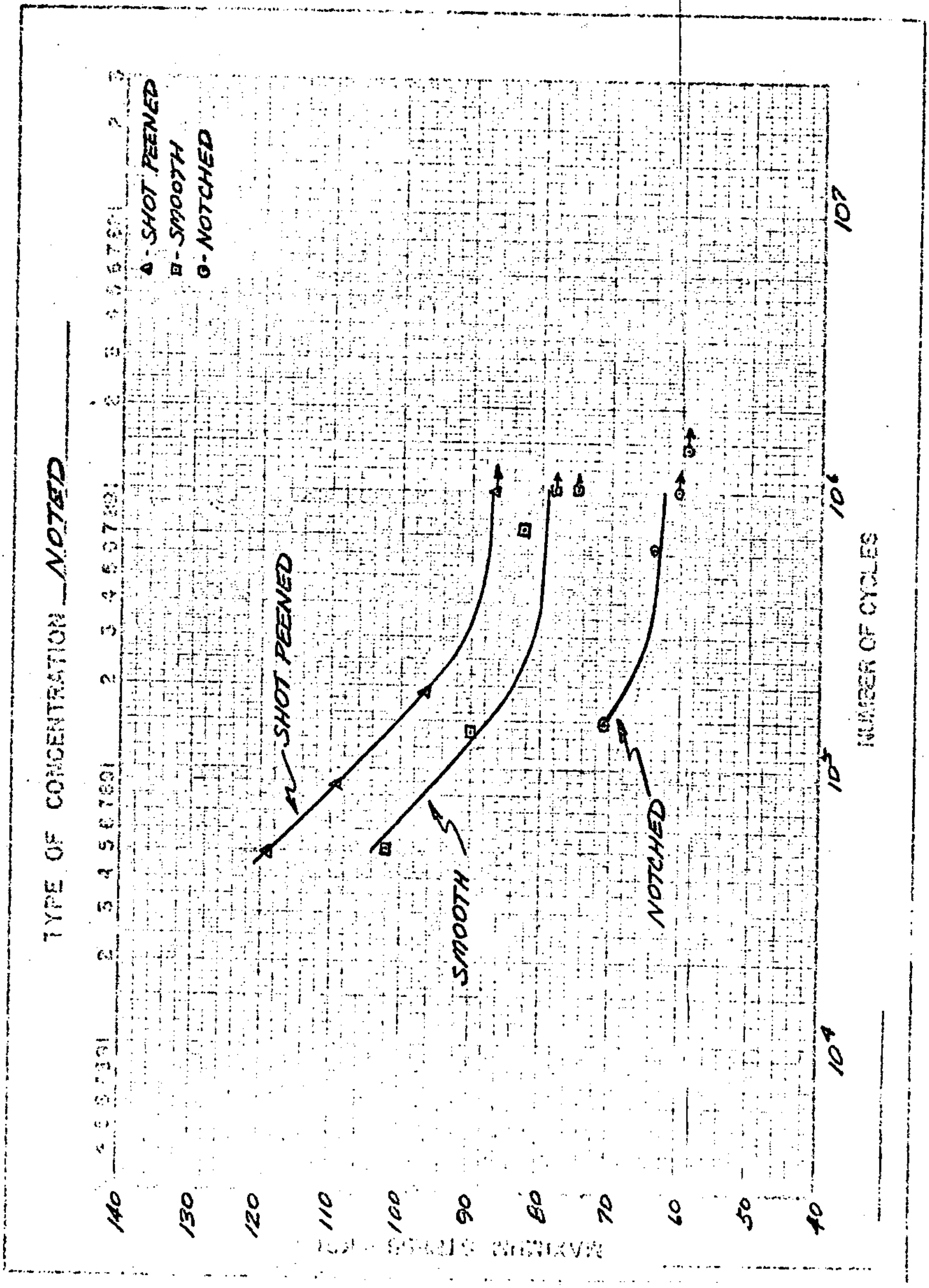
FIGURE 4

TEMPERATURE -423°F
LOADING FLEXURAL
FREQUENCY 2000 CPM
R(MIN/MAX) -1
A(ALT/MEAN) ∞

FATIGUE PROPERTIES

SOURCE ROCKETDYNE
APPROVED ______ DATE ______

CHART NO. MPR 70-305 3-25-70
MATERIAL Ti-5Al-2.5Sn (ELI)
FORM SHEET
CONDITION NOTED
FINISH 32 RMS
Ftu 213.1 KSI



Keller's Etch 100X

a

Keller's Etch 100X

b

FIGURE 5

a - Typical platelike structure

b - Typical equiaxed structure

KROUSE FATIGUE MACHINE MODEL NO 150 MK VI 503

SCHEMATIC

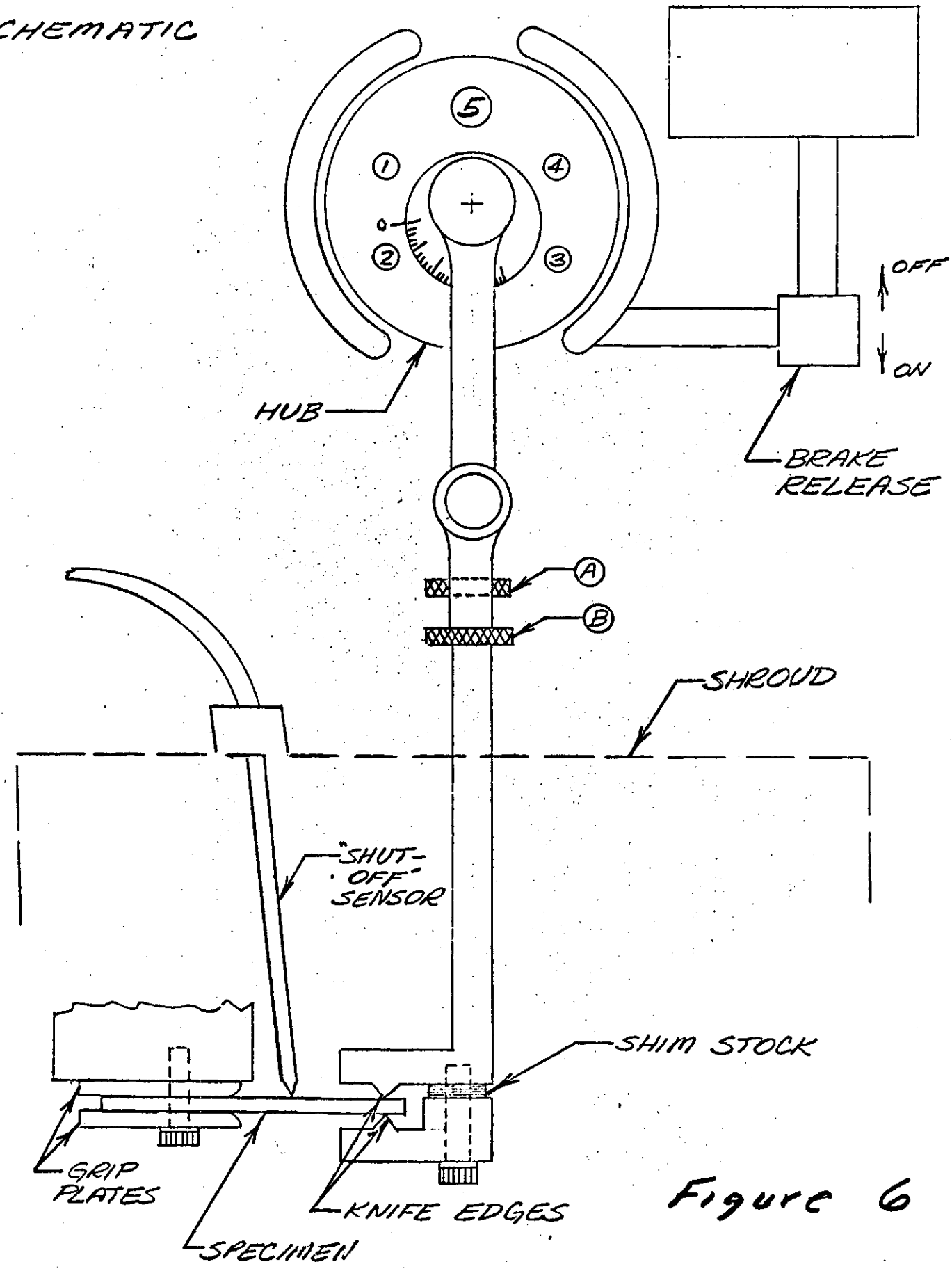


Figure 6

JAROCEWICZ 2/12/

DISCLOSURE OF INNOVATION OR INVENTION

NAR 81161
Page 16 of 16

Title Fatigue Properties of Ti-5Al-2.5Sn ELI in Smooth, Shot Peened, and Notched Surface Conditions at 70F and -423F

Docket No. _____

INNOVATOR OR INVENTOR	DEPT. NO.	SERIAL NO.	PHONE NO.	MAIL ADDRESS	SUPERVISOR
Peter T. Jarocewicz	596	326992	3761	BA 69	E.F.Green
Edwin F. Green	596	301736	3761	BA 69	W.J. Kappen

THE PROBLEM: In order to design turbopump components for adequate fatigue life, smooth, shot peened and notched fatigue properties of subject material were required. None were available

DESCRIPTION OF SOLUTION: (Succinct statement of broad solution together with detailed description, illustrated by sketches where appropriate, of the structure, operation, physical characteristics -- electrical, chemical, mechanical -- describing the new result. Attach additional material, preferably on Form 74-S.)

Test were performed as described in attached report MPR 70-305, with results as shown in data attached thereto.

Inventor: Edwin F Green (FIRST NAME) F. (INITIAL) (LAST NAME) 19615 Bryant St Northridge (HOME ADDRESS) 4-24-70 (DATE)

Peter T. Jarocewicz (FIRST NAME) T. (INITIAL) (LAST NAME) 6534 Winnetka Ave Canoga Pk (HOME ADDRESS) 4-24-70 (DATE)

Witnesses: (Read and Understood By:)

(1) _____ 4-24-70

(2) _____ (FIRST NAME) (INITIAL) (LAST NAME) (DATE)

FORM 74-S-1 REV. 12-69

(OVER)

17