

UNCLASSIFIED

AD 287 545

*Reproduced
by the*

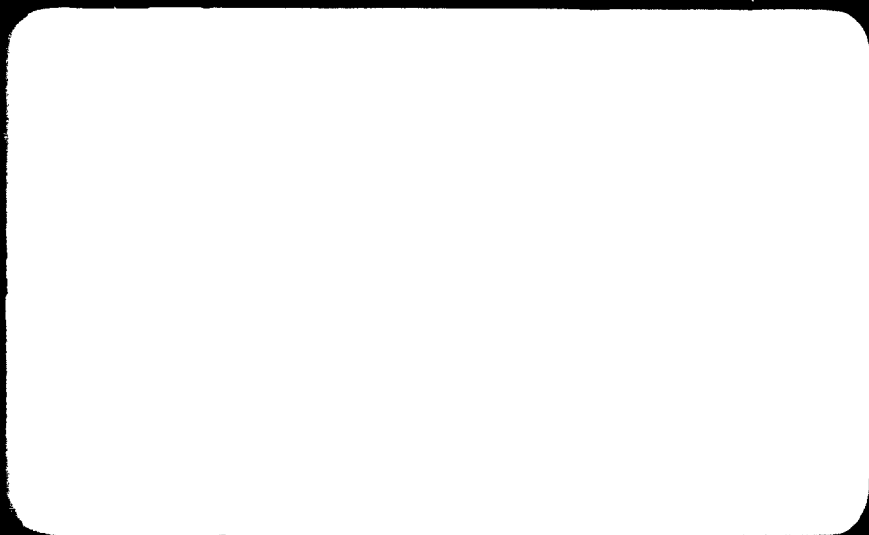
**ARMED SERVICES TECHNICAL INFORMATION AGENCY
ARLINGTON HALL STATION
ARLINGTON 12, VIRGINIA**



UNCLASSIFIED

NOTICE: When government or other drawings, specifications or other data are used for any purpose other than in connection with a definitely related government procurement operation, the U. S. Government thereby incurs no responsibility, nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use or sell any patented invention that may in any way be related thereto.

287 545



File No. _____

Report No. NA57H-527-18

NORTH AMERICAN AVIATION, INC.
COLUMBUS DIVISION COLUMBUS 16, OHIO
ENGINEERING DEPARTMENT

DOD HIGH STRENGTH TITANIUM
ALLOY SHEET RESEARCH PROGRAM

1 August 1962

PREPARED UNDER NAVY BUREAU OF WEAPONS

CONTRACT NOas 57-785d

PROGRESS REPORT NO. 18

Released to ASTIA by the
Bureau of **NAVAL WEAPONS**
without restriction.

PREPARED BY D. E. Myers
D. E. Myers
Metals-Application

APPROVED BY J. R. Macaulay
J. R. Macaulay
Engineering Group Leader
Metals

V. L. Beals
V. L. Beals
Engineering Manager
Struct Mech & Mat'ls Res

No. of Pages 16 and Appendix I

REVISIONS

Date 31 August 1962

DATE	REV. BY	PAGES AFFECTED	REMARKS

NORTH AMERICAN AVIATION, INC.
COLUMBUS DIVISION
COLUMBUS 16, OHIO

NA57H-527-18

ABSTRACT

This report contains data obtained from evaluations conducted on the 5Al-5Sn-5Zr and 7Al-12Zr alloys to determine the precautions necessary to prevent stress corrosion cracking problems during forming.

Normal precautions during manufacturing to prevent contamination of the 5Al-2 $\frac{1}{2}$ Sn titanium alloy details are adequate for the super alpha titanium alloys. A range of 1300F for two and one half hours to 1500F for one half hour produces 88 to 100% stress relief of both alloys.

NORTH AMERICAN AVIATION, INC.
COLUMBUS DIVISION
COLUMBUS 16, OHIO

NA57H-527-18

TABLE OF CONTENTS

	PAGE NO.
INTRODUCTION	3
OBJECTIVE	3
SCOPE	3
SUMMARY	3
TEST PROGRAM	4
GENERAL COMMENTS	15
FUTURE WORK	15
<u>FIGURE NO.</u>	
1. Typical Examples Stress Corrosion Cracking	6
2. Photomicrographs of Typical Examples of Stress Corrosion Cracking	7
3. Effects of Time and Temperature on Relief of Applied Stress 7Al-12Zr Alloy	10
4. Effects of Time and Temperature on Relief of Applied Stress 5Al-5Sn-5Zr Alloy	11
5. Photograph of Formed Specimen	14
<u>TABLE NO.</u>	
I Results of Corrosion Tests Conducted on Both Alloys	8
II Maximum Stress Relief Obtained on 7Al-12Zr Titanium	12
III Maximum Stress Relief Obtained on 5Al-5Sn-5Zr	12
REFERENCES	16
CONTRIBUTORS	16
APPENDIX NO. I-DISTRIBUTION LIST	17

NORTH AMERICAN AVIATION, INC.
COLUMBUS DIVISION
COLUMBUS 16, OHIO

NA57H-527-18

1. INTRODUCTION: North American Aviation, Inc., Columbus Division is evaluating the quality, uniformity, creep properties, thermal stability and fabrication characteristics of the 5Al-5Sn-5Zr and 7Al-12Zr super alpha titanium sheet alloys under the Department of Defense Titanium Sheet Rolling Program. This, the Eighteenth Progress Report under BuWeps Contract NOas 57-785d contains fabrication stress corrosion and contamination data obtained during the period of 31 May 1962 to 31 August 1962.
2. OBJECTIVES: The objectives of this program are to obtain design criteria and to determine fabrication characteristics of the materials being tested.
3. SCOPE: The program includes receiving inspection of materials, determination of mechanical properties at room and elevated temperatures, creep properties (welded and unwelded), thermal stability, formability, fabrication stress and contamination studies, machinability, dimpling, fusion and resistance welding tests.
4. SUMMARY: Data obtained from tests conducted to determine the stress and contamination levels which would produce stress corrosion cracking during forming and the precautions necessary revealed;

The alloys are susceptible to stress corrosion cracking when contaminated with chlorides.

NORTH AMERICAN AVIATION, INC.
COLUMBUS DIVISION
COLUMBUS 16, OHIO

NA57H-527-18

Stress corrosion cracking can be prevented by cleaning with uninhibited heavy duty alkaline cleaner prior to elevated temperature forming and the use of interstage stress relief operations.

Stress relief of both alloys can be accomplished as low as 1300F for times to 2½ hours and optimum stress relief is obtained at 1500F for ½ hour.

Recommended forming sequences to avoid stress corrosion and contamination problems are to prepare blanks, clean, form, clean, hot size, stress relieve, and pickle.

5. TEST PROGRAM: The 5Al-5Sn-5Zr and 7Al-12Zr alloy sheet were evaluated to determine;

If the alloys were susceptible to stress corrosion cracking when contaminated with materials known to cause cracking in the 5Al-2.5Sn alloy.

The handling procedures necessary to prevent contamination.

The stress relief necessary to prevent cracking.

- 5.1 Material Tested: Both the stress corrosion and stress relief tests were conducted on laboratory samples and specimens formed in production departments taken from .040 gage sheet from two heats of each of the two alloys.

<u>Supplier</u>	<u>Alloy</u>	<u>Heat #</u>	<u>Sheet #</u>	<u>NAA #</u>
TMCA	7-12	V1787M	A7325-5	63
RMI	7-12	32558	3175-7	65
TMCA	5-5-5	V1813M	A7129-5	76
TMCA	5-5-5	V1785M	A7558-8	77

NORTH AMERICAN AVIATION, INC.
COLUMBUS DIVISION
COLUMBUS 16, OHIO

NA57H-527-18

5.2 Test Samples: Strap type, .040 X 3/4 X 8" lg, longitudinal samples were used for laboratory stress corrosion & stress relief testing. (The longitudinal direction was selected because yield strengths are normally lower in this direction). Test samples were prepared by shearing, burring and then cleaned with methyl ethyl ketone. All samples were given the white glove treatment during handling. Thermal processing of the two groups of samples was accomplished in an electric, stagnant air, furnace.

5.3 Stress Corrosion Samples - Testing: Stress corrosion tests were conducted by contaminating the laboratory samples from two heats of both alloys with a paste composed of 20 percent sodium chloride solution and infusorial earths. (Residual inactive elements). The samples were preloaded from 12 ksi to 108 ksi and exposed at 1200F for one hour in the furnace. Examination of each sample was done at room temperature using a 50X magnification and dye penetrant to determine if cracking had occurred.

5.3.1 Results - The results obtained from the stress corrosion samples (Reference Figures 1 & 2 and Table I) are summarized below:

Complete fracture developed in all samples of both alloys when preloaded to 72 ksi or higher.

Visual cracks developed in all samples of both alloys which were preloaded from 48 ksi to 60 ksi.

NORTH AMERICAN AVIATION, INC.
COLUMBUS DIVISION
COLUMBUS 16, OHIO

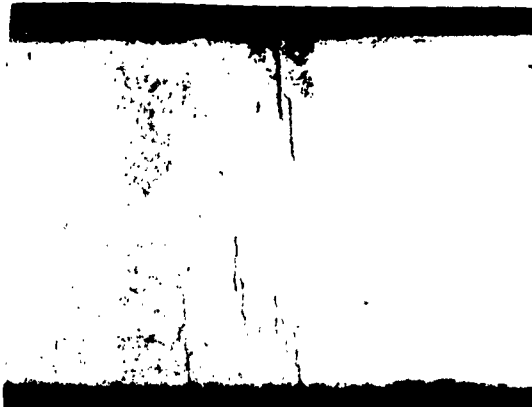
NA57H-527-18

Macroscopic cracks (5X) developed in all samples
preloaded at 36 ksi.

No cracks were detected in any sample of either
alloy when the preload was less than 36 ksi.

FIGURE 1

Typical Examples of Stress Corrosion Cracking



Cracks in Sample Preloaded to 36 ksi
5Al-5Sn-5Zr Alloy (5X)



Cracks in Sample
Preloaded to 72 ksi
7Al-12Zr Alloy
(5X)



Failure of Sample
Preloaded to 108 ksi
7Al-12Zr Alloy
(5X)

NORTH AMERICAN AVIATION, INC.
COLUMBUS DIVISION
COLUMBUS 16, OHIO

NA57H-527-18

FIGURE 2.

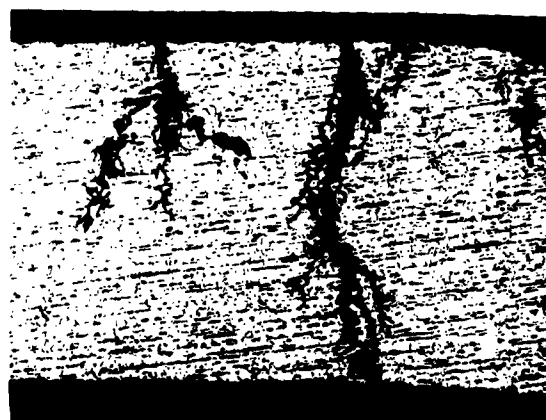
Photomicrographs of Typical Examples of Stress Corrosion Cracking



Stress Corrosion Cracks in 5Al-5Zr-5Sn
Alloy Preloaded to 72 ksi (50X)



Stress Corrosion Cracks in
7Al-12Zr Alloy Preloaded to
108 ksi (50X)



Stress Corrosion Cracks in
5Al-5Zr-5Sn Alloy Preloaded to
108 ksi (50X)

NORTH AMERICAN AVIATION, INC.
COLUMBUS DIVISION
COLUMBUS 16, OHIO

NA57H-527-18

TABLE I

Results of Stress Corrosion Tests
Conducted on Both Alloys

<u>Sample*</u> <u>Number</u>	<u>Preload</u> <u>(ksi)</u>	<u>Results</u>
1	108	Complete failure
2	96	Complete failure
3	84	Complete failure
4	72	Complete failure
5	60	Visual cracks
6	40	Visual cracks
7	36	Macroscopic cracks
8	24	No cracks
9	12	No cracks

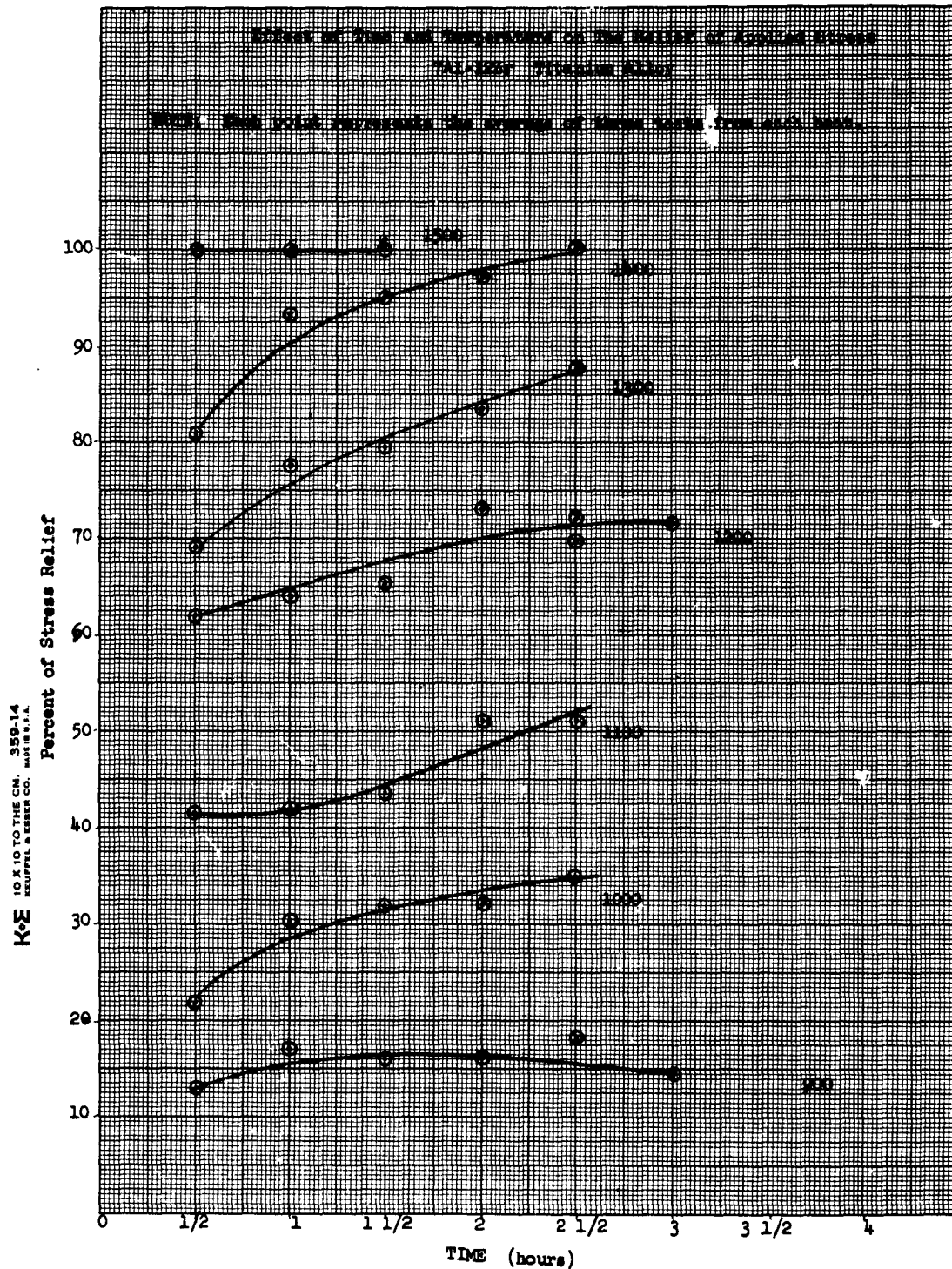
* Each sample represents three pieces of each alloy of each heat. The degree of cracking was most severe with the 7Al-12Zr alloy, however, the difference is not considered significant.

5.3.2 Discussion: A minimum stress level of 36 ksi was required to produce stress corrosion cracking under conditions of extreme contamination. The stress level required to cause cracking under lesser degrees of contamination is expected to be much higher and would not be encountered under normal manufacturing conditions. Special precautions such as white gloves will be necessary when the parts are subjected to higher stresses resulting from severe cold work in localized areas or in welding.

5.4 Stress Relief Samples - Testing:- Stress relief tests were conducted using the beam relaxation method described in AIME Transactions 1942 "Relief of Residual Stresses in Some Aluminum Alloys." This test involved preloading laboratory samples from two heats of each alloy to 95 percent of the yield strength and expose at 900, 1000, 1100, 1200, 1300, 1400 and 1500F for 30 to 210 minutes at 30 minute intervals. To determine the percent of relaxation the method described in the "Investigation of Stress Relief Procedures for Titanium Alloys" under WADC Report KB-955-M-2, Contract No AF33(616)2688 were used.

5.4.1 Results:- Test results indicate that a 88% stress relief can be obtained at 1300F for two and one half hours with the optimum 100% stress relief obtained at 1500F for one half hour for both alloys. Results of the beam relaxation tests are shown in Figures 3 & 4 and the maximum stress relief obtained at each temperature is listed in Tables II and III.

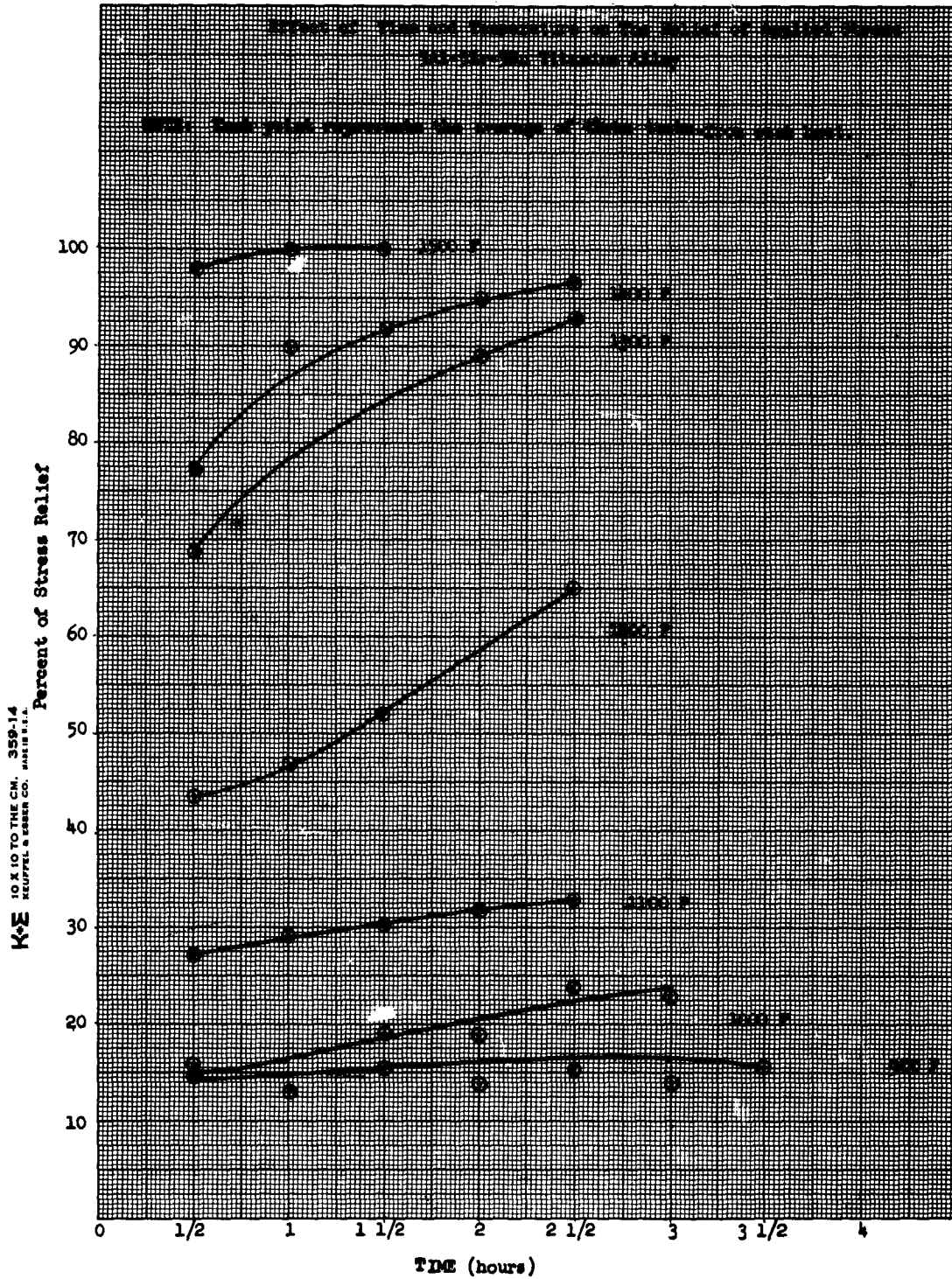
FIGURE 3.



NORTH AMERICAN AVIATION, INC.
COLUMBUS DIVISION
COLUMBUS 16, OHIO

NA57B-527-18

FIGURE 4.



NORTH AMERICAN AVIATION, INC.
COLUMBUS DIVISION
COLUMBUS 16, OHIO

NA57H-527-18

TABLE II

MAXIMUM STRESS RELIEF OBTAINED ON 7Al-12Zr TITANIUM

<u>Temperature</u> <u>(F)</u>	<u>Time</u> <u>(Hrs)</u>	<u>Percent</u> <u>Relief</u>
900	3.5	15.0
1000	2.5	35.0
1100	2.5	50.0
1200	2.5	72.0
1300	2.5	87.0
1400	2.5	100.0
1500	0.5	100.0

TABLE III

MAXIMUM STRESS RELIEF OBTAINED ON 5Al-5Zr-5Sn TITANIUM

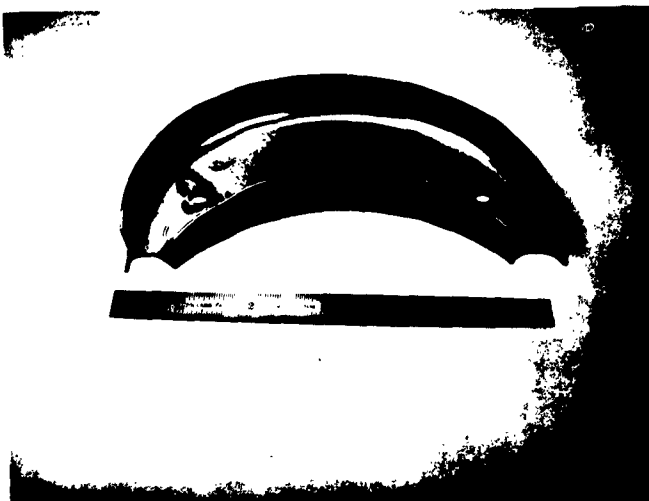
<u>Temperature</u> <u>(F)</u>	<u>Time</u> <u>(Hrs)</u>	<u>Percent</u> <u>Relief</u>
900	4.0	15.0
1000	3.0	22.0
1100	2.5	37.0
1200	2.5	65.0
1300	3.0	94.0
1400	2.5	97.0
1500	1.0	100.0

- 5.4.2 Discussion:- The data obtained indicates that the time required to obtain stress relief at a temperature lower than 1300F may be impractical for production purposes. Furthermore, it is questionable whether satisfactory stress relief can be obtained at a lower temperature. Depending on the production tooling and equipment available and/or necessary to obtain final dimensions during stress relief, the time and temperature required to obtain stress relief for both alloys appears adjustable within the indicated range.

5.5 Formed Specimens Testing:- In addition to the formability sequence specimens data, reported on Progress Report #17, eight (8) specimens were subjected to the processing indicated by the laboratory samples. The specimens were made by sawing, edges prepared, cleaned in an uninhibited heavy duty alkaline cleaner, formed at room temperature on a hydro press, cleaned, benched at elevated temperatures of 800 to 900 F for approximately 10 minutes each, cleaned, hot sized, stress relieved and pickled. One set of four (4), one specimen from each heat of each alloy were stress relieved at 1300 F for two and one half hours and a similar set stressed relieved at 1500 F for a half hour. As with the formability specimens, previously reported, no special precautions were taken with these specimens to prevent contact with chloride materials during this test.

5.5.1 Specimen Data: The configuration used for formed specimens was a hydro press specimen made from .040 gage sheet with a 15% stretch flange and a 12% shrink flange for both alloys. Specimens were longitudinal and identical in general configuration and preparation to the "formability specimens" previously reported. Figure 5, is a photograph of a typical formed specimen.

FIGURE 5
TYPICAL FORMABILITY SEQUENCE SPECIMEN



- 5.5.2 Results: - Macroscopic examination (50X) and dye penetrant inspection of the specimens revealed no cracks at any stage of the test sequences.
- 5.5.3 Discussion:- Based on the results of these formability processing sequence tests and the data obtained from the formability tests conducted earlier in the program it is recommended that production parts be cleaned prior to elevated temperature forming and that interstage stress relief operations be used as dicatated by the fabrication operations. The processing of formed specimens as presented in paragraph 5.5 is recommended for producing parts from these alloys. However, adjustments to accommodate cold worked welded or dimpled parts immediately preceding assembly may require special control of cleaning and

NORTH AMERICAN AVIATION, INC.
COLUMBUS DIVISION
COLUMBUS 16, OHIO

NA57H-527-18

stress relief conditions in order to prevent stress corrosion cracking.

6. GENERAL: The stress corrosion and contamination data contained in this progress report complete these evaluations under this program.
7. FUTURE WORK: Creep properties determinations at 900 and 1100 F from 10 to 1000 hours are virtually complete and data will be reported in the Final Report.

NORTH AMERICAN AVIATION, INC.

COLUMBUS DIVISION

COLUMBUS 16, OHIO

NA57H-527-18

REFERENCES

(Relative to the super alpha titanium sheet alloys evaluations)

Progress Report #14, Letter, 61CL4785, dated 24 July 1961, reporting no progress due to lack of material.

Progress Report #15, Letter, 61CL7332, dated 20 October 1961 reporting no progress due to delay in receiving material.

Progress Report #16, NA57H-527-16, dated 31 January 1962.

Progress Report #17, NA57H-527-17, dated 31 May 1962.

CONTRIBUTORS

NAA Columbus personnel responsible for specific evaluations and/or contributing data under this program are:

<u>Name</u>	<u>Title</u>	<u>Responsibility</u>
M. C. Clapp	Welding Engineer	Fusion Welding
D. E. Conklin	Welding Engineer	Fusion Welding
C. C. Lawson	Development Engineer	Machinability
J. E. Lott	Welding Engineer	Resistance Welding
R. M. Potter	Research Engineer	Fabrication Processes
R. R. Richison	Associate Engineer	Dimpling
D. M. Rosenbaum	Research Engineer	Metallurgical Lab.
R. W. Steur	Specialist Metallurgical	Mechanical Testing
L. P. Streett	Industrial Engineer	Mfg. Liaison

NORTH AMERICAN AVIATION, INC.
COLUMBUS DIVISION
COLUMBUS 16, OHIO

NA57H-527-18

APPENDIX I
Distribution List

NORTH AMERICAN AVIATION, INC.
COLUMBUS DIVISION
COLUMBUS 16, OHIO

NA57H-527-18

DISTRIBUTION LIST

	<u>No. of Copies</u>
1. National Academy of Sciences, Materials Advisory Board 2101 Constitution Avenue, Washington 25, D. C. Attn: Dr. W. J. Harris, Jr., Mr. L. L. Gould	2
2. Convair San Diego, California Att: Mr. S. R. Carpenter	1
3. New York University, College of Engineering University Heights, New York 53, New York Attn: Dr. George Gerard	1
4. Boeing Aircraft Company Seattle, Washington Attn: Mr. T. H. Gray	1
5. Armour Research Foundation, Technology Center Chicago 16, Illinois Attn: Dr. Donald J. McPherson	1
6. United Aircraft Corporation Pratt & Whitney Division, East Hartford, Connecticut Attn: Mr. N. Winston Sharp	1
7. North American Aviation, Incorporated Inglewood, California Attn: Mr. L. P. Spalding	1
8. Republic Aviation Corporation, Farmingdale Long Island, New York Attn: Mr. Robert Wichser	1
9. National Bureau of Standards Connecticut Avenue and Van Ness Street, N. W. Washington 25, D. C. Attn: Dr. William Youden	1
10. CO Watertown Arsenal Watertown 72, Massachusetts Attn: Mr. S. V. Arnold	1
11. WADC (WCLTC) Attn: Mr. Howard Middendorp	1
12. Air Material Command (ASC) Wright Patterson Air Force Base, Ohio Attn: Mr. R. Jameson (LMBM)	1
13. Titanium Metals Corporation of America Toronto, Ohio Attn: Mr. Harold Kessler	1

NORTH AMERICAN AVIATION, INC.
COLUMBUS DIVISION
COLUMBUS 16, OHIO

NA57H-527-18

DISTRIBUTION LIST

- | | |
|--|---|
| 14. Mallory Sharon Titanium Corporation
Niles, Ohio
Attn: Dr. Dillon Evers | 1 |
| 15. Crucible Steel Company of America
Midland, Pennsylvania
Attn: Dr. Howard Clark | 1 |
| 16. Battelle Memorial Institute
Columbus, Ohio
Attn: Mr. H. R. Ogden, Dr. R. I. Jaffee | 2 |
| 17. WADC, Wright Patterson Air Force Base, Ohio
Materials Laboratory
Attn: Mr. Edward Dugger | 1 |
| 18. Grumman Aircraft Engineering Corporation
Bethpage, L. I., New York
Attn: Mr. Francis X. Drumm | 1 |
| 19. University of Syracuse, Research Institute
Attn: Dr. George Sachs | 1 |
| 20. Chance-Vought Aircraft, Inc.
Dallas, Texas
Attn: Mr. John W. Seeger | 1 |
| 21. Aircraft Industries Association
7660 Beverly Boulevard
Los Angeles, California
Attn: Mr. H. D. Moran | 7 |
| 22. Office of Assistant Secretary of Defense
Attn: Research and Engineering | 1 |
| 23. Commanding Officer, Diamond Ordnance Fuse Laboratory
Washington 25, D. C.
Attn: Technical Reference Section - ORDTL-012 | 1 |
| 24. Naval Air Material Center
Aeronautical Materials Laboratory
Philadelphia 12, Pennsylvania | 1 |
| 25. Commander, Quartermaster Research & Engineering Command
U. S. Army
Quartermaster Research and Engineering Center
Mechanical Engineering Division
Natick, Massachusetts | 1 |

NORTH AMERICAN AVIATION, INC.
COLUMBUS DIVISION
COLUMBUS 16, OHIO

NA57H-527-18

DISTRIBUTION LIST

- | | |
|--|---|
| 26. Bureau of Ordnance (RE-c) Dept. of Navy
Washington 25, D. C. | 1 |
| 27. Bureau of Ships (Code 343) Dept. of Navy
Washington 25, D. C. | 1 |
| 28. Office of Naval Research (Code 423)
Washington 25, D. C. | 1 |
| 29. Naval Research Laboratory
Metallurgy Division
Washington 25, D. C. | 1 |
| 30. National Aviation and Space Agency
Washington 25, D. C. | 2 |
| 31. Harvey Aluminum Company
19200 Southwestern Avenue
Torrence, California | 1 |
| 32. Lockheed Aircraft Corporation
Structural Research Laboratory
Marietta, Georgia
Attn: Mr. P. J. Hughes | 1 |
| 33. Convair Astronautics Division
General Dynamics Corporation
San Diego 12, California
Attn: A. Hurlich (Mail Zone 595-20) | 1 |
| 34. Convair
A Division of General Dynamics Corporation
Fort Worth, Texas
Attn: Mr. W. O. Sunafrank (Dept. 23-2) | 1 |
| 35. Republic Steel Corporation
Central Alley District
Massilon, Ohio
Attn: Mr. Tom Perry | 1 |
| 36. Titanium Metals Corporation of America
New York 7, New York
Attn: Mr. E. F. Erbin | 1 |
| 37. Lockheed Missiles and Space Division
3251 Hanover Street
Palo Alto, California
Attn: Mr. W. A. Kozumplik, Manager | 1 |

NORTH AMERICAN AVIATION, INC.
COLUMBUS DIVISION
COLUMBUS 16, OHIO

NA57H-527-18

DISTRIBUTION LIST

38. Douglas Aircraft Company, Incorporated
3855 Lakewood Boulevard
Long Beach, California
Attn: Mr. E. Harpoothian, Cl-250

1