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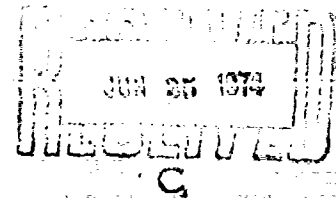
AD919994

AFML-TR-74-10  
Volume II

## SLEEVE COLDWORKING FASTENER HOLES

Volume II—Appendixes

Joseph L. Phillips  
Manufacturing Research and Development  
Boeing Commercial Airplane Company



TECHNICAL REPORT AFML-TR-74-10, VOLUME II

February 1974

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Air Force Materials Laboratory  
Manufacturing Technology Division  
Air Force Systems Command  
Wright-Patterson Air Force Base, Ohio

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# **SLEEVE COLDWORKING FASTENER HOLES**

Volume II—Appendixes

Joseph L. Phillips

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## FOREWORD

This technical report covers all work performed under Contract F33615-72-C-1630 from 1 June 1972 to 30 November 1973. This manuscript was released for publication by the author in February 1974.

This contract with The Boeing Commercial Airplane Company was initiated under Manufacturing Methods Project 746-2, "Sleeve Coldworking Fastener Holes." It was conducted under the technical direction of Captain Carlan Silha, Metals Branch (AFML/LTM), Manufacturing Technology Division, Air Force Materials Laboratory, Wright-Patterson Air Force Base, Ohio.

This program was accomplished at The Boeing Commercial Airplane Company in Seattle, Washington, with Mr. Richard G. Christner as program manager, Mr. Joseph L. Phillips as principal investigator, and Mr. Ray Hendricks as primary coordinator and director of the testing program. Other personnel that supported the program in Boeing were DeVere Lindh, Dave Reese, Tom Kane, Burke Dykes, Walt Swift, and Merrell Christianson.

Publication of this final technical report does not constitute Air Force approval of the report's findings or conclusions. It is published only for the exchange and stimulation of ideas. Your comments are solicited on the potential utilization of the information contained herein as applied to your present and/or future production and/or your maintenance rework. Suggestions concerning additional manufacturing methods on this or other subjects will be appreciated.

This program was accomplished as part of the Air Force Manufacturing Technology Program, the primary objective of which was to develop on a timely basis, manufacturing processes and techniques for use in economical production of USAF materials and components for aircraft production.

This technical report has been reviewed and approved for publication.



H. A. JOHNSON  
Chief, Metals Branch  
Manufacturing Technology Division

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H. A. JOHNSON  
Chief, Metals Branch  
Manufacturing Technology Division

## ABSTRACT

In this 21-month program, optimized process parameters for sleeve coldworking of fastener holes have been developed, and the effects of process and application parameters on structural performance have been defined for selected aluminum, titanium, and high-strength steel alloys. The sleeve coldworking process for fastener holes is a process that uses a tapered mandrel in conjunction with a disposable, prelubricated sleeve to compressively prestress a significant size zone around each hole which offsets the stress concentration of the hole itself. The sleeve method allows higher degrees of prestressing than possible with other methods and offers potential for significant improvements in fatigue performance. In addition, it does not require precision controls germane to other fatigue-rated hole preparation/fastener installation systems. This technical report covers the results of this 21-month program. In addition to definition of optimized methods and the effects of process and application variations upon structural performance, the results include performance and economics comparisons for the process with other fatigue-rated hole preparation/fastener systems.



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**APPENDIX I**

**MATERIAL PROCUREMENT TEST REPORTS**

0.010 - 0.249

*1/4" thick* TYPICAL TEST REPORT 0.250 - 0.499  
 2024-T81 Flat Alum Sheet  
 (T851) Plate

SPECIFICATION QQA 250/4 Latest Revision  
 PRODUCING MILL Alcoa HEAT/LOT No.

CHEMICALS								
	SI	FE	CU	MN	MG	CA	Z	Ti
MIN			3.8	.30	1.2			
MAX	.50	.50	4.9	.9	1.8	.10	.25	
	NI	PR	AL	OTHER	CARBON	PHOS	SUL	TIN
MIN								
MAX				Bal	.15			

MECHANICAL PROPERTIES				
	TENSILE	YIELD	ELONGATION	HARDNESS
MIN	67,000	58,000	5% - 2"	
MAX				

**TESTS & INSPECTION**

THE ABOVE TEST DATA CONFORMS TO THE REQUIREMENTS OF THE SPECIFICATION AS NOTED. THE MATERIAL HAS BEEN INSPECTED AND FOUND IN COMPLIANCE TO THIS SPECIFICATION.

By *[Signature]*  
 TEST REPORT DEPT.

Mill Test Report - 2024 T851 Strength Test Data and Chemistry

111  
 REGISTRATION  
 SF-29-1432  
 LICENSE NUMBER

**G.O. CARLSON Inc**  
 Producers of Stainless Steel  
 Nickel Alloys and Titanium  
 THORNDALE, PA 19378

NC TEST REPORT  
 8/1/72  
 DATE

SOLD TO  
 The Boeing Company  
 Commercial Airplane Group  
 P.O. Box 3707  
 Seattle, Washington, 98124

INVOICE

SHIP TO  
 Same Co.  
 Boeing Field  
 Bldg. 3-304 Door 8, Gate C-39  
 Seattle, Washington, 98124

ROUTING  
 (ACTUAL) United Parcel Service-Blue Label

DOC 32547  
 CREDIT ALL INCL. OF PHYSICALS

CURT NO 6-966576-41351  
 DATE OF SPMT 8/1

MARK 6-966576-41351  
 NO COPIES 4

NOTARIZED TEST REPORTS  
 4 CHEMS. & MECHANICAL PROPS.  
 (1) WITH SHIPMENT

ATTN Pur. Dept.  
 TYPED BY ssd

STN TO CUST 2  
 STN TO CONT 2

TYPE CARLSON C6 AL-4V TITANIUM HRA & DESCALED MIL-T-9046F TYPE III COMP. C ANNEALED, DESCALED #1 FINISH

STRENGTH REQUIREMENTS Try 7-28 or Sooner

QTY	SIZE	REMARKS	REQ BY	QTY	PRICE	AMOUNT
2	3/4 x 2-3/4 x 15-1/2		1	2	11	
2	3/4 x 3-1/2 x 15-1/2		2	2	14	
2	3/4 x 2 x 15-1/2		3	2	8	
1	3/4 x 12-1/2 x 12-1/2		4	1	20	
					53	

ALL ITEMS: ABRASIVE CUT GRAIN TO RUN DIRECTION OF ROLLING

PRIORITY BUYING DO-A1  
 CONTRACT # 3615-72-C-1630

Item	Qt	Heat No	CHEMICAL ANALYSIS								HYDROGEN CHECK			
			C	N	Fe	O <sub>2</sub>	H <sub>2</sub>	Vf	Al	Sn	V <sub>6</sub>	CHECK		
1	7	A41531-18	.024	.015	.20	.16	.0010			BAL	5.82		4.08	.0054

MECHANICAL TESTS	HEAT NO	YIELD STG. PSI		TENSILE		% ELONG		% RED		BRINELL		BEND	
		TS	YS	STR	UTS	IN 2"	IN 4"	OF AREA	PERFORM	TEMP	TEMP		
3/4	A41531-18	134,100	113,000	146,800	148,000	12.0	11.0	33.0	34.0	302	302	---	---

SHOWN TO AND S. BEC. BEC. BEFORE METHOD. 1 COPY OF AUG 72

HEREBY CERTIFY THE ABOVE FIGURES ARE CORRECT AS CONTAINED IN THE REPORT

G. O. CARLSON, INC.

Mill Test Report - Ti-6Al-4V Titanium Strength Test Data and Chemistry

# FRIEND METALS CO. INC.

1650 SO. SINCLAIR STREET

ANAHEIM, CALIFORNIA 92805

(714) 639-5610

**CERTIFICATE OF TESTS — MILL PRODUCTS**

Date October 2, 1972

S  
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D

Boeing Comm'l Airplane Co.  
P.O. Box 3707  
Seattle, Wash.

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P  
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O

Boeing, C.A.G. Revg.  
Bldg. #3-304, Door 8  
Boeing Field  
Seattle, Wash.

Customer Order No <b>6-966563-5835F</b>	Our Order No <b>7542</b>	Specification <b>AMS-6519A</b>
Heat Number <b>C23761</b>	Quantity <b>4 pcs.</b>	Size <b>22# 1/4" x 4" x 17" lg. each</b>

Description of Material: **300 M, normalized & sub-critical annealed to R/c 33 Max per BAC-5617 & blanchard ground on 2 sides to (+.100"-0")**

Heat Number	CHEMICAL ANALYSIS												
	C	MN	P	S	SI	CR	NI	MO	V	TI	AL	CU	CO
C23761	.41	.78	.005	.004	1.54	.79	1.80	.42	.09				
	B	CB	TA	CS & TA		SN	N	W	O	FE			

Heat Number	MECHANICAL PROPERTIES									Grain Size
	Tensile PSI	2% Yield PSI	% Elong in	% Red Area	BHN	Stress PSI	Temp °F	Hours	% Elong in	
	289,000	250,000	10.3	31.8	302					7-9
	292,000	251,000	10.0	30.4						
	291,000	246,000	10.0	33.2						
	293,000	247,000	9.8	31.8						

AMS-2300-F/S=0/0

Jominy: 56.5 @ 8/16  
55.5 @ 20/16

Macro: OK

Mill: Latrobe

THIS IS TO CERTIFY TO THE BEST OF OUR KNOWLEDGE AND BELIEF, THAT THE VALUES SHOWN ARE CORRECT AND TRUE AND THAT THE MATERIAL COMPLIES WITH THE REQUIREMENTS OF THE SPECIFICATIONS SHOWN

D. Allan Chase

24 7 77 0728

**APPENDIX II**

**PHASE I DATA**

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PHASE I TASK 1 - MANDREL TAPER DETERMINATION

TEST NUMBER: IB1 TEST PLATE NUMBER: 1  
 MANDREL: ST 5300 C8M-(1)-O-N NOMINAL SIZE: 3/8" (.12)  
 MAX. DIA. MANDREL: .3538" MANDREL MATERIAL: H-11 nitrided MANDREL TAPER: .015 inch/inch  
 PULL: X PUSH: \_\_\_\_\_ LUBRICATION: Fel Pro 300 (on sleeve)

SLEEVE THICKNESS: .010" MANDREL DIA. +2xSLEEVE THICKNESS: .3738

TEST MATERIAL: Aluminum COMPOSITION: 2024-T851 STACK UP: 3/8"

Hole no.	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after C.V.*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole* expansion (calc.)		
	Top	Mid.	Bot.			Top	Mid.	Bot.						Top	Mid.	Bot.
D-1	3545	3545	3550	75	.0193	3655	3655	3660	-	-	-	2090	None	011C	0110	0110
D-2	3545	3550	3550	50	.0188	3670	3660	3660	-	.0040"	.0055"	1915	None	0125	0110	0110
D-3	3550	3550	3550	85	.0188	3640	3645	3650	-	-	-	1800	None	0090	0095	0100
D-4	3550	3550	3550	90	.0188	3640	3645	3645	40	-	-	1730	None	0090	0095	0095
D-5	3545	3550	3550	85	.0188	3640	3645	3650	-	-	-	1765	None	0095	0095	0100
D-6	3550	3550	3550	75	.0188	3640	3645	3650	-	-	-	1785	None	0090	0095	0100

\* To nearest 0.0005 inch

PHASE I TASK I - MANDREL TAPER DETERMINATION

TEST NUMBER: 1B2 TEST PLATE NUMBER: 1  
 MANDREL: ST 5300 CBM (1) O.N. NOMINAL SIZE: 3/8" (12)  
 MAX. DIA. MANDREL: .3538" MANDREL MATERIAL: H18 extruded MANDREL TAPER: .030 inch/inch  
 P.U.L.: X PUSH: LUBRICATION: Fel Pro 300 (on sleeve)  
 SLEEVE THICKNESS: .010" MANDREL DIA.: .2x SLEEVE THICKNESS .3738  
 TEST MATERIAL: Aluminum COMPOSITION: 2024-T851 STACK UP: 3/8"

Hole no	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW*	Upper entrance of hole	Upper exit of hole	Force required for Mandrel	Sleeve thin out	Retained hoop expansion (calc.)		
	Top	Mid.	Bot.			Top	Mid.	Bot.						Top	Mid.	Bot.
E-1	3560	3550	3550	85	.0188	3660	3660	3665	---	---	---	1460	None	0100	0110	0115
E-2	3545	3545	3555	85	.0193	3655	3655	3665	---	---	---	1385	None	0100	0110	0110
E-3	3545	3545	3545	85	.0193	3640	3645	3645	---	.0040	---	1275	None	0095	0100	0100
E-4	3545	3550	3550	100	.0188	3660	3660	3665	45	---	.0055	1325	None	0115	0110	0115
E-5	3545	3545	3545	85	.0193	3635	3635	3645	---	---	---	1300	None	0090	0090	0100
E-6	3550	3550	3550	75	.0193	3640	3640	3650	---	.0040	.0055	1240	None	0090	0090	0100

\*To nearest 0.0005 inch



PHASE I TASK I MANDREL TAPER DETERMINATION

TEST NUMBER IB3 TEST PLATE NUMBER 1  
 MANDREL ST 5300 CBM-( )-ON NOMINAL SIZE 3/8" (-12)  
 MAX DIA MANDREL 3539" MANDREL MATERIAL H-II-nitrided MANDREL TAPER .045 inch/inch  
 PULL X PUSH \_\_\_\_\_ LUBRICATION Fel Pro 300 (on sleeve)  
 SLEEVE THICKNESS .010" MANDREL DIA 1.2xSLEEVE THICKNESS 3739"  
 TEST MATERIAL Aluminum COMPOSITION: 2024-T851 STACK UP: 3/8"

Hole no.	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out			Retained hole expansion (calc.)			
	Top	Mid.	Bot			Top	Mid.	Bot.					Top	Mid.	Bot.				
E-7	3550	3550	3550	60	.0189	3660	3660	3670				1200	None	0110	0110	0120			
E-8	3545	3545	3550	65	.0194	3640	3640	3645	30			1110	None	0095	0095	0095			
F-2	3545	3660	3545	80	0179	3660	3665	3670		.0025"	0060"	1245	None	0115	0105	0125			
F-3	3545	3545	3545	80	0194	3660	3660	3670				1235	None	0115	0115	0125			
F-4	3545	3545	3545	85	0194	3640	3640	3645				1195	None	0095	0095	0100			
G-1	3560	3550	3550	35	0189	3660	3660	3665				1215	None	0100	0100	0115			

\*To nearest 0.0005 inch

PHASE I - TASK I - MANDREL TAPER DETERMINATION

TEST NUMBER: IC1 TEST PLATE NUMBER: II  
 MANDREL: ST 5300 CBM (J-O-N) NOMINAL SIZE: 3/8" (-12)  
 MAX. DIA. MANDREL: .3538" MANDREL MATERIAL: H-II-nitrided MANDREL TAPER: .015 inch/inch  
 PULL: X PUSH: LUBRICATION: Fel Pro 300 (on sleeve)  
 SLEEVE THICKNESS: .010" MANDREL DIA. +2xSLEEVE THICKNESS: .3738"  
 TEST MATERIAL: Aluminum COMPOSITION: 2024-T851 STACK UP: 3/8"

Hole no.	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole* expansion (calc.)		
	Top	Mid.	Bot.			Top	Mid.	Bot.						Top	Mid.	Bot.
A-1	3615	3610	3610	50	.0128	3655	3660	3670	--	--	--	1375	None	0050	0050	0050
A-2	3605	3610	3605	35	.0128	3665	3670	3675	--	.0015	.0035	--	None	0060	0060	0070
A-3	3605	3605	3610	55	.0133	3655	3655	3665	25	--	--	1315	None	0050	0050	0055
A-4	3605	3605	3605	75	.0133	3645	3645	3660	--	--	--	1265	None	0040	0040	0055
A-5	3605	3605	3605	45	.0133	3670	3670	3675	--	--	--	1425	None	0065	0065	0070
A-6	3605	3605	3605	80	.0133	3670	3670	3675	--	--	--	1550	None	0065	0065	0070

\*To nearest 0.0005 inch

PHASE I TASK I MANDREL TAPER DETERMINATION

TEST NUMBER IC2 TEST PLATE NUMBER 11  
 MANDREL ST 5300 CBM (J.O.N) NOMINAL SIZE 3/8" (12)  
 MAX DIA MANDREL 3538" MANDREL MATERIAL H-II-nitrided MANDREL TAPER 030 inch/inch  
 PULL X PUSH \_\_\_\_\_ LUBRICATION Fel Pro 300 (on sleeve)

SLEEVE THICKNESS .010" MANDREL DIA. +2xSLEEVE THICKNESS .3738"

TEST MATERIAL Aluminum COMPOSITION 2024-T851 STACK UP 3/8"

Hole no	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole* expansion (calc.)		
	Top	Mid	Bot			Top	Mid	Bot						Top	Mid	Bot
A-7	3605	3600	3600	80	.0138	3665	3660	3670	---	---	---	1400	None	0060	0060	0070
A-8	3600	3600	3600	50	.0138	3675	3665	3665	20	---	---	1290	None	0075	0065	0065
B-1	3605	3635	3605	45	.0133	3650	3650	3660	---	---	---	1170	None	0045	0045	0055
B-2	3605	3605	3605	40	.0133	3650	3650	3655	---	0020	0040	1115	None	0045	0045	0050
B-3	3605	3605	3605	25	.0133	3665	3665	3675	---	---	---	1300	None	0060	0060	0070
B-4	3605	3605	3605	45	.0133	3665	3665	3665	---	---	---	1225	None	0060	0060	0060
B-5	3605	3605	3605	70	.0133	3650	3650	3660	---	---	---	1160	None	0045	0045	0055

\*To nearest 0.0005 inch

PHASE I - TASK I - MANDREL TAPER DETERMINATION

TEST NUMBER: IC3 TEST PLATE NUMBER: 11  
 MANDREL: ST 5300 CBM-(J)-O-N NOMINAL SIZE: 3/8" (-12)  
 MAX. DIA. MANDREL: .3539" MANDREL MATERIAL: H-II-nitrided MANDREL TAPER: .045 inch/inch  
 PULL: X PUSH: \_\_\_\_\_ LUBRICATION: Fel Pro 300 (on sleeve)  
 SLEEVE THICKNESS: .010" MANDREL DIA. +2xSLEEVE THICKNESS: .3739"  
 TEST MATERIAL: Aluminum COMPOSITION: 2024-T851 STACK UP: 3/8"

Hole no.	Size prior to CW*		Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole* expansion (calc.)		
	Top	Mid.			Bot.	Top	Mid.						Bot.	Top	Mid.
B-6	3605	3605	3605	.0134	3670	3670	3675	--	--	1120	None	0065	0065	0070	
B-7	3605	3605	3605	.0134	3670	3670	3675	--	--	1145	None	0065	0065	0070	
C-1	3605	3605	3600	.0134	3650	3655	3655	--	--	1025	None	0045	0050	0055	
C-2	3605	3605	3605	.0134	3665	3665	3675	30	.0030"	1065	None	0060	0060	0070	
C-3	3605	3605	3605	.0134	3655	3655	3655	--	--	1030	None	0050	0050	0050	
C-4	3605	3605	3605	.0134	3670	3670	3675	--	--	1540	None	0065	0065	0070	

\*To nearest 0.0005 inch

PHASE I - TASK I - MANDREL TAPER DETERMINATION

TEST NUMBER            ID1            TEST PLATE NUMBER            II             
 MANDREL            ST 5300 CBM-( ) O-N            NOMINAL SIZE            3/8" (-12)  
 MAX. DIA MANDREL            MANDREL MATERIAL:            H-II-nitrided            MANDREL TAPER:             
 PULL            X            PUSH:            LUBRICATION:            Fel Pro 300 (on sleeve)

SLEEVE THICKNESS:            .010"            MANDREL DIA. +2xSLEEVE THICKNESS:            .3738"

TEST MATERIAL:            Aluminum            COMPOSITION:            2024-T851            STACK UP:            3/8"

Hole no	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole* expansion (calc.)		
	Top	Mid.	Bot.			Top	Mid.	Bot.						Top	Mid.	Bot.
E-1	3650	3650	3645	50	.0088	3670	3670	3670	--	--	--	1235	None	0020	0020	0025
E-2	3650	3650	3650	65	.0088	3685	3685	3685	--	.0010	.0030	1275	None	0035	0035	0035
E-3	3655	3655	3660	55	.0083	3685	3685	3690	--	--	--	1260	None	0030	0030	0030
E-4	3650	3655	3655	60	.0083	3670	3675	3680	25	--	--	1045	None	0020	0020	0025
E-5	3655	3655	3655	60	.0083	3685	3685	3690	--	--	--	1200	None	0030	0030	0035
E-6	3655	3655	3655	50	.0083	3685	3685	3690	--	--	--	1190	None	0030	0030	0035

\*To nearest 0.0005 inch

PHASE I - TASK I - MANDREL TAPER DETERMINATION

TEST NUMBER: ID2 TEST PLATE NUMBER: II  
 MANDREL: ST 5300 CBM-I JON NOMINAL SIZE: 3/8" (-12)  
 MAX. DIA. MANDREL: .3538" MANDREL MATERIAL: H-II-nitrided MANDREL TAPER: .030 inch/inch  
 PULL: X PUSH: \_\_\_\_\_ LUBRICATION: Fel Pro 300 (on sleeve)  
 SLEEVE THICKNESS: .010" MANDREL DIA. +2XSLEEVE THICKNESS: .3738"  
 TEST MATERIAL: Aluminum COMPOSITION: 2024-T851 STACK UP: 3/8"

Hole no.	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole expansion (calc.)	
	Top	Mid.	Bot.			Top	Mid.	Bot.						Top	Bot.
E-7	3655	3650	3650	70	.0088	3670	3670	3670	--	--	215	None	0015	0015	0020
E-8	3655	3655	3655	50	.0083	3680	3680	3685	--	--	1045	None	0025	0025	0030
F-1	3650	3650	3650	50	.0088	3670	3670	3670	--	--	990	None	0020	0020	0020
F-2	3655	3655	3650	80	.0083	3685	3685	3685	35	--	1025	None	0030	0030	0030
F-3	3655	3655	3655	60	.0083	3680	3680	3680	--	.0005	1030	None	0025	0025	0025
F-4	3655	3660	3655	65	.0078	3685	3685	3685	--	--	995	None	0030	0025	0030

\* To nearest 0.0005 inch

PHASE I - TASK I - MANDREL TAPER DETERMINATION

TEST NUMBER ID3 TEST PLATE NUMBER II  
 MANDREL ST 5300 CBM (I) O-N NOMINAL SIZE 3/8" (.12)  
 MAX. DIA. MANDREL .3539" MANDREL MATERIAL H-II-nitrided MANDREL TAPER: .045 inch/inch  
 PULL: X PUSH \_\_\_\_\_ LUBRICATION: Fel Pro 300 (on sleeve)

SLEEVE THICKNESS .010" MANDREL DIA. +2xSLEEVE THICKNESS .3739"  
 TEST MATERIAL Aluminum COMPOSITION: 2024-T851 STACK UP: 3/8"

Hole no.	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole* expansion (calc.)		
	Top	Mid.	Bot.			Top	Mid	Bot.						Top	Mid.	Bot.
F-5	3655	3655	3655	55	.0084	3675	3675	3675	--	--	--	820	None	0020	0020	0020
F-6	3655	3655	3655	60	.0084	3680	3680	3685	--	--	--	950	None	0025	0025	0030
F-7	3650	3650	3645	50	.0089	3675	3670	3670	--	--	--	865	None	0025	0020	0025
F-8	3655	3655	3650	40	.0084	3670	3670	3670	--	--	--	810	None	0015	0015	0020
G-1	3655	3655	3655	70	.0084	3685	3685	3685	35	--	--	950	None	0030	0030	0030
G-2	3655	3655	3655	75	.0084	3685	3685	3685	--	0015	0035	945	None	0030	0030	0030

\*To nearest 0.0005 inch

PHASE I - TASK I - MANDREL TAPER DETERMINATION

TEST NUMBER: IF1 TEST PLATE NUMBER: III  
 MANDREL: ST 5300 CBM (ION) NOMINAL SIZE: 3/8" (-12)  
 MAX. DIA. MANDREL: .3538 MANDREL MATERIAL: H.H-nitrided MANDREL TAPER: .015 inch/inch  
 PULL: X PUSH: \_\_\_\_\_ LUBRICATION: Fel Pro 300 (on sleeve)

SLEEVE THICKNESS: .010" MANDREL DIA. (2xSLEEVE THICKNESS): .3738"

TEST MATERIAL: Aluminum COMPOSITION: 2024-T851 STACK UP: 1-1/2"

Hole no	Size prior to CW*		Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole expansion (calc.)		
	Top	Mid.			Bot.	Top	Mid.						Bot.		
C-1	3540	3545	45	.0193	3685	3680	3680	20	--	--	3500	None	0145	0135	0135
C-2	3540	3545	--	.0193	3685	3675	3680	--	0030	0070	3365	None	0145	0130	0135
C-3	3540	3545	--	.0193	3685	3665	3670	--	--	--	3370	None	0145	0120	0125
C-4	3540	3540	--	.0198	3685	3680	3685	--	--	--	3185	None	0145	0135	0145
C-5	3540	3540	--	.0198	3590	3680	3685	--	--	--	3200	None	0150	0135	0140

\*To nearest 0.0005 inch



PHASE I - TASK I - MANDREL TAPER DETERMINATION

TEST NUMBER IF2 TEST PLATE NUMBER 111  
 MANDREL ST 5300 CBM (-) ON NOMINAL SIZE 3/8" (-.12)  
 MAX. DIA. MANDREL .3538" MANDREL MATERIAL H II-nitrided MANDREL TAPER .030 inch/inch  
 PULL X PUSH: \_\_\_\_\_ LUBRICATION: Fel Pro 300 (on sleeve)

SLEEVE THICKNESS: .010" MANDREL DIA. +2xSLEEVE THICKNESS: .3738"

TEST MATERIAL Aluminum COMPOSITION 2024-T851 STACK UP: 1-1/2"

Hole no.	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole* expansion (calc.)		
	Top	Mid.	Bot.			Top	Mid.	Bot.						Top	Mid.	Bot.
C-6	3540	3550	3540	-	.0188	3685	3675	3680	-	-	-	2810	None	0145	0125	0140
C-8	3545	3540	3540	-	.0198	3690	3680	3665	-	-	.0070	2640	None	0145	0140	0125
D 1	3540	3545	3545	40	.0193	3690	3680	3665	15	-	-	2550	None	0145	0135	0120
D-2	3540	3540	3545	-	.0198	3685	3685	3680	-	-	-	2785	None	0145	0140	0135
D 3	3540	3540	3545	-	.0198	3685	3675	3665	-	.0030	.0045	2815	None	0145	0135	0125

\* To nearest 0.0005 inch

PHASE I-TASK I-MANDREL TAPER DETERMINATION

TEST NUMBER: IF3 TEST PLATE NUMBER: III  
 MANDREL: ST 5300 CBM ( ) O-N NOMINAL SIZE: 3/8" (.12)  
 MAX DIA. MANDREL: .3539" MANDREL MATERIAL: H-11-nitrided MANDREL TAPER: .045 inch/inch  
 PULL: X PUSH: \_\_\_\_\_ LUBRICATION: Fel Pro 300 (on sleeve)

SLEEVE THICKNESS: .010" Nom. MANDREL DIA. +2xSLEEVE THICKNESS: .3739"

TEST MATERIAL: Aluminum COMPOSITION: 2024-T851 STACK UP: 1-1/2"

Hole no.	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole expansion (calc.)		
	Top	Mid.	Bot.			Top	Mid.	Bot.						Top	Bot.	
D-4	3540	3540	3540	30	.0199	3690	3680	3690	15	-	-	2360	None	0150	0140	0150
D-5	3540	3545	3540	-	.0194	3695	3680	3685	-	-	-	2450	None	0155	0135	0145
D-6	3540	3540	3545	-	.0199	3695	3680	3680	-	0030	0045	2475	None	0155	0140	0135
D-7	3540	3540	3540	-	.0199	3685	3665	3665	-	-	-	2225	None	0145	0125	0125
D-8	3540	3540	3540	-	.0199	3690	3680	3685	-	-	-	2455	None	0155	0140	0145

\*To nearest 0.0005 inch

PHASE I - TASK I - MANDREL TAPER DETERMINATION

TEST NUMBER: IG1 TEST PLATE NUMBER: III  
 MANDREL: ST 5300 CBM-I J-O-N NOMINAL SIZE: 3/8" (-12)  
 MAX. DIA. MANDREL: .3538" MANDREL MATERIAL: H-II-nitrided MANDREL TAPER: .015 inch/inch  
 PULL: X PUSH: Fel Pro 300 (on sleeve)

SLEEVE THICKNESS: .010" Nom. MANDREL DIA. +2xSLEEVE THICKNESS: .3738"

TEST MATERIAL: Aluminum COMPOSITION: 2024-T851 STACK UP: 1-1/2"

Hole no.	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole expansion (calc.)		
	Top	Mid.	Bot.			Top	Mid.	Bot.						Top	Mid.	Bot.
F-3	3620	3620	3620	-	.0118	3695	3680	3690	-	-	-	2525	None	0075	0060	0070
F-4	3620	3620	3620	25	.0118	3675	3670	3690	10	-	-	2485	None	0055	0050	0070
F-5	3620	3620	3620	-	.0118	3675	3670	3675	-	-	-	2385	None	0055	0050	0055
F-6	3620	3620	3620	-	.0118	3690	3685	3695	-	.0030	.0045	2565	None	0070	0065	0075
F-7	3620	3620	3620	-	.0118	3680	3680	3690	-	-	-	2375	None	0060	0060	0070
F-8	3620	3620	3620	-	.0118	3690	3685	3675	-	-	-	2500	None	0070	0065	0055

\*To nearest 0.0005 inch

PHASE I-TASK I-MANDREL TAPER DETERMINATION

TEST NUMBER: IG2 TEST PLATE NUMBER: III  
 MANDREL: ST 5300 CBM-I J-O-N NOMINAL SIZE: 3/8" (12)  
 MAX. DIA. MANDREL: .3538" MANDREL MATERIAL: H-II-nitrided MANDREL TAPER: .030 inch/inch  
 PULL: X PUSH: \_\_\_\_\_ LUBRICATION: Fel Pro 320 (on sleeve)  
 SLEEVE THICKNESS: .010" MANDREL DIA.: 2xSLEEVE THICKNESS: .3738"  
 TEST MATERIAL: Aluminum COMPOSITION: 2024-T851 STACK UP: 1-1/2"

Hole no.	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole* expansion (calc.)		
	Top	Mid.	Bot.			Top	Mid.	Bot.						Top	Mid.	Bot.
E-6	3620	3620	3620	-	.0188	3680	3665	3680	-	.0030	.0045	1955	None	0060	0045	0060
E-7	3620	3620	3620	-	.0118	3690	3685	3695	-	-	-	2070	None	0070	0065	0075
E-8	3620	3620	3620	-	.0118	3690	3685	3690	-	-	-	1965	None	0070	0065	0070
F-1	3620	3620	3620	45	.0118	3690	3685	3670	20	-	-	1710	None	0070	0065	0050
F-2	3620	3620	3620	-	.0118	3675	3665	3690	-	-	-	1990	None	0055	0045	0070

\*To nearest 0.0005 inch

PHASE I - TASK I - MANDREL TAPER DETERMINATION

TEST NUMBER: IG3 TEST PLATE NUMBER: III  
 MANDREL: ST 5300 CBM-I J-O-N NOMINAL SIZE: 3/8" (-12)  
 MAX. DIA. MANDREL: .3539" MANDREL MATERIAL: H-11-nitrided MANDREL TAPER: .045 inch/inch  
 PULL: X PUSH: \_\_\_\_\_ LUBRICATION: Fel Pro 300 (on sleeve)  
 SLEEVE THICKNESS: .010" Nom. MANDREL DIA. +2xSLEEVE THICKNESS: .3739"  
 TEST MATERIAL: Aluminum COMPOSITION: 2024-T851 STACK UP: 1-1/2"

Hole no.	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole* expansion (calc.)	
	Top	Mid.	Bot.			Top	Mid.	Bot.						Top	Mid.
E-1	3620	3620	3620	35	.0119	3680	3670	3695	20	-	-	1660	None	0060	0075
E-2	3620	3620	3620	-	.0119	3695	3675	3675	-	-	-	1520	None	0075	0055
E-3	3620	3620	3620	-	.0119	3695	3670	3675	-	.0040	.0040	1460	None	0075	0055
E-4	3620	3620	3620	-	.0119	3695	3670	3675	-	-	-	1445	None	0075	0055
E-5	3620	3620	3620	-	.0119	3695	3690	3690	-	-	-	1475	None	0075	0070

\* To nearest 0.0005 inch

PHASE I TASK I MANDREL TAPER DETERMINATION

TEST NUMBER IHI TEST PLATE NUMBER III  
 MANDREL ST 5300 CBM (10-N) NOMINAL SIZE 3/8" (-12)  
 MAX DIA. MANDREL .3538" MANDREL MATERIAL: H-II nitrided MANDREL TAPER: .015 inch/inch  
 PULL: X PUSH: \_\_\_\_\_ LUBRICATION: Fel Pro 300 (on sleeve)  
 SLEEVE THICKNESS: .010" Nom. MANDREL DIA. +2xSLEEVE THICKNESS .3738"  
 TEST MATERIAL: Aluminum COMPOSITION: 2024-T851\* STACK UP: 1-1/2"

Hole no.	Size prior to CW*		Finish prior to CW	Maximum expansion (calc.)	Size after CW*		Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Returned hole expansion (calc.)			
	Top	Mid.			Bot.	Top						Mid.	Bot.		
G-1	3650	3650	3650	16	.0088	3700	3695	3700	10	-	1750	None	0050	0045	0050
G-2	3650	3650	3650	-	.0088	3700	3695	3705	-	-	2060	None	0050	0045	0050
G-3	3650	3650	3650	-	.0088	3685	3685	3680	-	-	1165	None	0035	0035	0037
G-4	3650	3650	3650	-	.0088	3685	3680	3685	-	-	1380	None	0035	0030	0035
G-5	3650	3650	3650	-	.0088	3690	3685	3685	-	.0020	1240	None	0040	0035	0035

\*To nearest 0.0005 inch

PHASE I-TASK I-M: DREL TAPER DETERMINATION

TEST NUMBER: IH2 TEST PLATE NUMBER: 111  
 MANDREL: ST 5300 CBM-( )-O-N NOMINAL SIZE: 3/8" (-.12)  
 MAX. DIA. MANDREL: .3538" MANDREL MATERIAL: H-II-nitrided MANDREL TAPER: .030 inch/inch  
 PULL: X PUSH: \_\_\_\_\_ LUBRICATION: Fel Pro 300 (on sleeve)

SLEEVE THICKNESS: .010" Nom. MANDREL DIA. +2xSLEEVE THICKNESS: .3738"  
 TEST MATERIAL: Aluminum COMPOSITION: 2024-T851 STACK UP: 1-1/2"

Hole no.	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole expansion (calc.)		
	Top	Mid.	Bot.			Top	Mid.	Bot.						Top	Mid.	Bot.
G-6	3650	3650	3650	20	.0088	3705	3695	3700	10	--	--	--	None	0055	0045	0050
G-7	3650	3650	3650	--	.0088	3700	3680	3685	--	--	--	1240	None	0050	0030	0035
G-8	3650	3650	3650	--	.0088	3685	3680	3685	--	.0015	.0095	1160	None	0035	0030	0035
H-1	3650	3650	3650	16	.0088	3685	3685	3705	--	--	--	1360	None	0035	0035	0055
H-2	3650	3650	3650	--	.0088	3700	3695	3685	--	--	--	1195	None	0050	0045	0035
H-3	3650	3650	3650	--	.0088	3700	3695	3685	--	--	--	1195	None	0050	0045	0035

\*To nearest 0.0005 inch

PHASE I - TASK I - MANDREL TAPER DETERMINATION

TEST NUMBER: IH3 TEST PLATE NUMBER: III  
 MANDREL: ST 5300 CBM (-) O-N NOMINAL SIZE: 3/8" (-12)  
 MAX. DIA. MANDREL: .3539" MANDREL MATERIAL: H-II-nitrided MANDREL TAPER: .045 inch/inch  
 PULL: X PUSH: \_\_\_\_\_ LUBRICATION: Fel Pro 300 (on sleeve)  
 SLEEVE THICKNESS: .010" Nom. MANDREL DIA. +2xSLEEVE THICKNESS: .3739"  
 TEST MATERIAL: Aluminum COMPOSITION: 2024-T851 STACK UP: 1-1/2"

Hole no.	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole* expansion (calc.)		
	Top	Mid.	Bot.			Top	Mid.	Bot.						Top	Bot.	
H-4	3650	3650	3650	40	.0089	3690	3680	3685	15	.0015	--	975	None	0040	0030	0035
H-5	3650	3650	3650	--	.0089	3685	3680	3685	--	--	.0035	930	None	0035	0030	0035
H-6	3650	3650	3650	--	.0089	3705	3695	3700	--	--	--	1150	None	0055	0045	0055
H-7	3650	3650	3650	--	.0089	3685	3680	3685	--	--	--	925	None	0035	0030	0035
H-8	3650	3650	3650	--	.0089	3700	3695	3700	--	--	--	1200	None	0050	0045	0050

\*To nearest 0.0005 inch



PHASE I - TASK I - MANDREL TAPER DETERMINATION

TEST NUMBER: IJ1 TEST PLATE NUMBER: IV  
 MANDREL: ST 5300 CBM (J-O-N) NOMINAL SIZE: 3/4" (-24)  
 MAX. DIA. MANDREL: 7163" MANDREL MATERIAL: H-II-nitrided MANDREL TAPER: .020 inch/inch  
 PULL: X PUSH: \_\_\_\_\_ LUBRICATION: Fel Pro 300 (on sleeve)  
 SLEEVE THICKNESS: .015" MANDREL DIA. +2xSLEEVE THICKNESS: .7463"  
 TEST MATERIAL: Aluminum COMPOSITION: 2024-T851 STACK UP: 2.50"

Hole no.	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole* expansion (calc.)		
	Top	Mid.	Bot.			Top	Mid.	Bot.						Top	Mid.	Bot.
B-3	7145	7140	7140	40	.0323	7355	7320	7350	-	-	-	22,250	.0005" typ	0210	0180	0210
B-4	7145	7140	7140	50	.0323	7350	7320	7355	-	-	-	20,580	.0005" typ	0205	0180	0215
C-1	7145	7140	7145	50	.0323	7355	7325	7340	20	.0060	.0090	18,340	.0005" typ	0210	0185	0195
C-2	7145	7140	7140	40	.0323	7355	7325	7340	-	-	-	15,800	.0005" typ	0210	0185	0200
C-3	7145	7140	7140	40	.0323	7355	7320	7340	-	-	-	18,400	.0005" typ	0210	0180	0200

\* To nearest 0.0005 inch

PHASE I-TASK I-MANDREL TAPER DETERMINATION

TEST NUMBER: IJ2 TEST PLATE NUMBER: V  
 MANDREL ST 5300 CRM (ION) NOMINAL SIZE: 3/4" (.24)  
 MAX DIA. MANDREL: 7165" MANDREL MATERIAL: H-11-nitrided MANDREL TAPER: .030 inch/inch  
 PULL: X PUSH: Fel Pro 300 (on sleeve)  
 SLEEVE THICKNESS: .015" MANDREL DIA. 2xSLEEVE THICKNESS 7465"  
 TEST MATERIAL: Aluminum COMPOSITION: 2024-T851 STACK UP: 1-1/8"

Hole no	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force remained for Mandrel	Sleeve thin out		Retained hole expansion (inches)		
	Top	Mid	Bot.			Top	Mid	Bot.					Top	Bot.	Top	Bot.	
C-4	7135	7130	7130	-	.0335	7360	7335	7365	-	.0025	.0070	9.960	-	-	0225	0205	0235
D-1	7130	7130	7130	-	.0335	7350	7320	7370	-	-	-	10.070	-	-	0220	0190	0240
D-2	7135	7130	7130	8-10	.0335	7360	7315	7370	5	-	-	10.100	-	-	0225	0185	0240
D-3	7135	7130	7130	-	.0335	7370	7330	7365	-	-	-	10.180	-	-	0235	0200	0235
D-4	7135	7135	7130	-	.0330	7365	7330	7360	-	-	-	10.330	-	-	0230	0195	0230

\*To nearest 0.0005 inch

PHASE I-TASK I-MANDREL TAPER DETERMINATION

TEST NUMBER: IJ3 TEST PLATE NUMBER: VI  
 MANDREL: ST 5300 CBM-( )-O-N NOMINAL SIZE: 3/4" (.24)  
 MAX. DIA. MANDREL: .7165" MANDREL MATERIAL: H-II-nitrided MANDREL TAPER: .045 inch/inch  
 PULL: X PUSH: \_\_\_\_\_ LUBRICATION: FelPro 300 (on sleeve)

SLEEVE THICKNESS: .015" MANDREL DIA. +2xSLEEVE THICKNESS: .7465"

TEST MATERIAL: Aluminum COMPOSITION: 2024-T851 STACK UP: 1-1/8"

Hole no.	Size prior to CW*		Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole* expansion (calc.)		
	Top	Mid.			Bot.	Top	Mid.						Bot.	Top	Mid.
C-4	7135	7135	7140	.0330	7335	7325	7355	-	-	-	7700	-	0220	0190	0215
D-1	7135	7130	7130	.0335	7370	7350	7340	-	-	-	7260	-	0235	0220	0210
D-2	7135	7135	7130	.0330	7360	7345	7340	-	.0030	.0095	8080	-	0225	0210	0210
D-3	7130	7130	7130	.0335	7365	7335	7345	10	-	-	8200	-	0235	0205	0215
D-4	7135	7130	7130	.0335	7360	7325	7360	-	-	-	8660	-	0225	0185	0230

\*To nearest 0.0005 inch

PHASE I - TASK I - MANDREL TAPER DETERMINATION

TEST NUMBER: IK1 TEST PLATE NUMBER: IV  
 MANDREL: ST 5300 CBM ( ) ON NOMINAL SIZE: 3/4" (-24)  
 MAX. DIA. MANDREL: .7163" MANDREL MATERIAL: H-II-nitrided MANDREL TAPER: .020 inch/inch  
 PULL: X PUSH: \_\_\_\_\_ LUBRICATION: Fel Pro 300 (on sleeve)  
 SLEEVE THICKNESS: .015" MANDREL DIA. +2xSLEEVE THICKNESS: .7463"  
 TEST MATERIAL: Aluminum COMPOSITION: 2024-T851 STACK UP: 2.50"

Hole no.	Size prior to CW*		Finish prior to CW	Maximum expansion (calc.)	Size after CW*		Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole* expansion (calc.)		
	Top	Mid.			Bot.	Top						Mid.	Bot.	Top
A-1	7205	7200	7195	.0263	7390	7340	7390	-	-	13,020	None	0185	0140	0195
A-2	7205	7200	7195	.0263	7390	7350	7395	-	-	11,900	None	0185	0150	0200
A-3	7205	7200	7195	.0263	7395	7345	7420	.0050	.0080	11,440	None	0190	0145	0225
A-4	7205	7200	7195	.0263	7390	7340	7395	-	-	11,260	None	0185	0140	0200
B-1	7205	7200	7195	.0263	7380	7335	7385	-	-	11,020	None	0175	0135	0190
B-2	7205	7200	7195	.0263	7390	7340	7390	-	-	13,080	None	0185	0140	0195

\*To nearest 0.0005 inch

PHASE I-TASK I-MANDREL TAPER DETERMINATION

TEST NUMBER: IK2 TEST PLATE NUMBER: V  
 MANDREL: ST 5300 CBM-1 J-O-N NOMINAL SIZE 3/4" (-24)  
 MAX O/A, MANDREL: .7165" MANDREL MATERIAL: H-II-nitrided MANDREL TAPER: .030 inch/inch  
 PULL: X PUSH: \_\_\_\_\_ LUBRICATION: Fel Pro 300 (on sleeve/

SLEEVE THICKNESS: .015" MANDREL DIA. +2xSLEEVE THICKNESS: .7465"  
 TEST MATERIAL: Aluminum COMPOSITION: 2024-T851 STACK UP: 1-1/8"

Hole no.	Size prior to CW*		Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out			Retained hole* expansion (calc.)	
	Top	Mid.			Bot.	Top	Mid.					Bot.	Top	Mid.	Bot.	
A-1	7195	7200	7190	.0265	7360	7330	7360	-	-	-	8270	-	-	-	0165	0170
A-2	7195	7195	7195	.0270	7370	7345	7370	5	-	-	8270	-	-	-	0175	0175
A-3	7195	7195	7195	.0270	7365	7340	7370	-	-	-	8260	-	-	-	0170	0175
A-4	7195	7195	7190	.0270	7365	7330	7370	-	-	-	7860	-	-	-	0170	0160
B-1	7195	7195	7195	.0270	7370	7335	7380	-	.0025	.0065	7800	-	-	-	0175	0185
B-2	7195	7195	7195	.0270	7380	7340	7380	-	-	-	7760	-	-	-	0185	0185

\*To nearest 0.0005 inch

PHASE I - TASK I - MANDREL TAPE DETERMINATION

TEST NUMBER: IK3 TEST PLATE NUMBER: VI  
 MANDREL: ST 5300 CBM (1.0N) NOMINAL SIZE: 3/4" (-24)  
 MAX. DIA. MANDREL: 7165 MANDREL MATERIAL: H-12 nitrided MANDREL TAPER: .045 inch/inch

PULL: X PUSH: \_\_\_\_\_  
 SLEEVE THICKNESS: .015 MANDREL DIA.: 2X SLEEVE THICKNESS 7465  
 LUBRICATION: Fel Pro 300 (on sleeve)

TEST MATERIAL: Aluminum COMPOSITION: 2024-T351 STACK UP: 1-1/8"

Hole no	Size prior to CW*		Finish prior to CW	Maximum expansion (Tab. 1)	Size after CW*		Finish after CW	Upset diameter of hole	Force required for mandrel	Sleeve thru out	Retain hole expansion (Tab. 1)		
	Top	Mid.			Bot.	Top					Mid.	Bot.	
A-1	7210	7215	7195	.0250	7370	7335	7360	-	7500	-	0160	0120	0155
A-2	7195	7195	7190	.0270	7370	7340	7365	-	6750	-	0175	0145	0175
A-3	7195	7195	7190	.0270	7370	7340	7365	5	6660	-	0175	0145	0175
A-4	7200	7215	7190	.0250	7365	7335	7360	-	6320	-	0165	0120	0170
B-1	7195	7200	7195	.0265	7375	7345	7385	-	6080	-	0180	0145	0190
B-2	7195	7195	7195	.0270	7380	7340	7375	-	6200	-	0185	0145	0180

\*To nearest 0.0005 inch

PHASE I-TASK I-MANDREL TAPER DETERMINATION

TEST NUMBER: IL1 TEST PLATE NUMBER: IV  
 MANDREL: ST 5300 CBM-( )-O-N NOMINAL SIZE: 3/4" (-24)  
 MAX. DIA. MANDREL: .7163" MANDREL MATERIAL: H-II-nitrided MANDREL TAPER: .020 inch/inch  
 PULL: X PUSH: \_\_\_\_\_ LUBRICATION: Fel Pro 300 (on sleeve)

SLEEVE THICKNESS: .015" MANDREL DIA. +2x-SLEEVE THICKNESS: .7463"

TEST MATERIAL: Aluminum COMPOSITION: 2024-T851 STACK UP: 2.50"

Hole no.	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole* expansion (calc.)		
	Top	Mid.	Bot.			Top	Mid.	Bot.						Top	Mid.	Bot.
C-4	7250	7250	7250	40	.0213	7395	7350	7380	-	-	-	10,200	.0005" typ	0145	0100	0130
D-1	7250	7250	7250	30	.0213	7400	7340	7380	-	-	-	9,440	.0005" typ	0150	0090	0130
D-2	7250	7250	7245	30	.0213	7405	7335	7385	-	-	-	8,740	.0005" typ	0155	0085	0140
D-3	7250	7250	7245	40	.0213	7400	7345	7385	15	.0035	.0075	-	.0005" typ	0150	0085	0140
D-4	7250	7245	7245	30	.0218	7385	7335	7380	-	-	-	-	.0005" typ	0135	0090	0135

\*To nearest 0.0005 inch

PHASE I - TASK I - MANDREL TAPER DETERMINATION

TEST NUMBER 112 TEST PLATE NUMBER V  
 MANDREL ST 5300 CBM (J)-ON NOMINAL SIZE 3/4" (-24)  
 MAX DIA MANDREL .7165" MANDREL MATERIAL H-II-nitrided MANDREL TAPER .030 inch/inch  
 PULL X PUSH \_\_\_\_\_ LUBRICATION Fel Pro 300 (on sleeve)  
 SLEEVE THICKNESS: .015" MANDREL DIA. + 2 x SLEEVE THICKNESS .7465"  
 TEST MATERIAL Aluminum COMPOSITION 2024-T851 STACK UP 1-1/8"

Hole no	Size prior to CW*			Finish prior to CW	Maximum expansion (calc)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole* expansion (calc.)		
	Top	Mid.	Bot.			Top	Mid.	Bot.						Top	Mid.	Bot.
B-3	7240	7240	7240	-	.0225	7380	7350	7380	-	-	-	6440	-	0140	0110	0140
B-4	7240	7240	7235	-	.0225	7375	7340	7380	-	-	-	6260	-	0135	0100	0145
C-1	7240	7235	7235	-	.0230	7385	7355	7385	-	-	-	6160	-	0145	0125	0150
C-2	7240	7235	7235	8-10	.0230	7380	7355	7385	5	.0015	.0055	6150	-	0140	0120	0150
C-3	7240	7240	7235	-	.0225	7385	7350	7385	-	-	-	6250	-	0145	0110	0150

\*To nearest 0.0005 inch



PHASE I - TASK I - MANDREL TAPER DETERMINATION

TEST NUMBER: IL3 TEST PLATE NUMBER: VI  
 MANDREL: ST 5300 CBM ( ) ON NOMINAL SIZE: 3/4" (-12)  
 MAX. DIA. MANDREL: .7165" MANDREL MATERIAL: H-II-nitrided MANDREL TAPER: 0.45 inch/inch  
 PULL: X PUSH: \_\_\_\_\_ LUBRICATION: Fel Pro 300 (on sleeve)

SLEEVE THICKNESS: .015" MANDREL DIA. +2xSLEEVE THICKNESS: .7465

TEST MATERIAL: Aluminum COMPOSITION: 2024-T851 STACK UP: 1-1/8"

Hole no.	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole* expansion (calc.)		
	Top	Mid.	Bot.			Top	Mid.	Bot.						Top	Mid	Bot.
B-3	7240	7240	7240	20	.0225	7380	7350	7365	10	-	-	5240	-	0140	0110	0125
B-4	7240	7240	7240	-	.0225	7380	7350	7370	-	-	-	5300	-	0140	0110	0130
C-1	7235	7240	7235	-	.0225	7370	7345	7365	-	.0020	.0065	5220	-	0145	0105	0130
C-2	7240	7240	7240	-	.0225	7375	7345	7370	-	-	-	5360	-	0135	0105	0130
C-3	7235	7235	7235	-	.0230	7380	7.50	7365	-	-	-	5290	-	0145	0115	0130

\*To nearest 0.0005 inch

PHASE I - TASK I - MANDREL TAPER DETERMINATION

TEST NUMBER: 1A1T TEST PLATE NUMBER: VII  
 MANDREL: ST 5300 CBM (-) O-N NOMINAL SIZE: 3/8 inch (-12)  
 MAX. DIA. MANDREL: 0.3538 inch MANDREL MATERIAL: H-II-nitrided MANDREL TAPER: 0.015 inch/inch  
 PULL: X PUSH: LUBRICATION: Fel Pro 300 (on sleeve)

SLEEVE THICKNESS: 0.010 inch MANDREL DIA. + 2 x SLEEVE THICKNESS: 0.3738 inch

TEST MATERIAL: Titanium COMPOSITION: 6Al-4V STACK UP: 3/8 inch

Hole no.	Size prior to CW*			Finish, prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sieve thin out		Retained hole expansion (calc.)		
	Top	Mid.	Bot.			Top	Mid.	Bot.					Top	Mid.	Bot.		
A1	3555	3555	3555	--	.0168	3660	3650	3660	--	--	--	2190	.0010	.0010	0105	0095	0105
B1	3555	3555	3555	40	.0166	3660	3650	3660	20	--	--	2190	.0010	.0010	0105	0095	0105
C1	3555	3555	3555	--	.0165	3660	3655	3670	--	.0045	.0050	2270	.0010	.0010	0105	0100	0115
D1	3555	3555	3555	--	.0165	3660	3650	3665	--	--	--	2275	.0010	.0010	0105	0095	0110
E1	3555	3555	3555	--	.0165	3645	3640	3655	--	--	--	2235	.0010	.0010	0090	0085	0100

\* To nearest 0.0005 inch  Mandrel diameter progressively reduced to 0.3531 inch in 5 holes

PHASE I - TASK I - MANDREL TAPER DETERMINATION

TEST NUMBER: 1A2T TEST PLATE NUMBER: VII  
 MANDREL: ST 5300 CBM-( )-O-N NOMINAL SIZE: 3/8 inch (12)  
 MAX DIA. MANDREL: 0.3538 inch MANDREL MATERIAL: H-II-nitrided MANDREL TAPER: 0.030 inch/inch  
 PULL: X PUSH: \_\_\_\_\_ LUBRICATION: Fel Pro 300 (on sleeve)  
 SLEEVE THICKNESS: 0.010 inch MANDREL DIA.: 2 x SLEEVE THICKNESS: 0.3738 inch  
 TEST MATERIAL: Titanium COMPOSITION: 6Al-4V STACK UP: 3/8 inch

Hole no.	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole expansion (calc.)		
	Top	Mid	Bot.			Top	Mid	Bot.						Top	Mid	Bot.
F1	3555	3555	3555	-	.0168	3665	3655	3665	-	-	-	1720	.0010	0110	0100	0110
G1	3555	3555	3555	-	.0166	3660	3650	3660	-	-	-	1670	.0010	0105	0095	0105
H1	3555	3555	3555	-	.0165	3660	3650	3660	-	.0048	.0052	1615	.0010	0105	0095	0105
A2	3555	3555	3555	-	.0165	3660	3650	3665	-	-	-	1770	.0010	0105	0095	0110
B2	3555	3555	3555	25	.0165	3660	3650	3660	10	-	-	1660	.0010	0105	0095	0105

To nearest 0.0005 inch Mandrel diameter progressively reduced to 0.3531 inch in 5 holes

PHASE I - TASK I - MANDREL TAPER DETERMINATION

TEST NUMBER: 1A3T TEST PLATE NUMBER: VII  
 MANDREL: ST 5300 CBM-( )-O-N NOMINAL SIZE: 3/8 inch (-12)  
 MAX. DIA. MANDREL: 0.3539 inch MANDREL MATERIAL: H-II-nitrided MANDREL TAPER: 0.045 inch/inch  
 PULL: X PUSH: Fel Pro 300 (on sleeve)  
 LUBRICATION: \_\_\_\_\_

SLEEVE THICKNESS: 0.010 inch MANDREL DIA. + 2 x SLEEVE THICKNESS: 0.3739 inch

TEST MATERIAL: Titanium COMPOSITION: 6Al-4V STACK UP: 3/8 inch

Hole no.	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out			Retained hole* expansion (calc.)	
	Top	Mid.	Bot.			Top	Mid.	Bot.					Top	Mid.	Bot.		
C2	3555	3555	3555	-	.0172	3660	3650	3660	-	-	-	1635	.0010	.0095	0105	0095	0105
D2	3555	3555	3555	-	.0172	3660	3655	3660	-	-	-	1425	.0010	0100	0105	0095	0105
E2	3555	3555	3555	30	.0172	3650	3650	3665	12	-	-	1440	.0010	0095	0110	0095	0110
F2	3555	3555	3555	-	.0172	3660	3650	3660	-	-	-	1400	.0010	0095	0105	0095	0105
G2	3555	3555	3555	-	.0172	3660	3650	3660	-	0.005	0.0054	1435	.0010	0105	0095	0095	0105

\* To nearest 0.0005 inch

△ Mandrel diameter progressively reduced to 0.3537 inch in 5 holes

PHASE I TASK I MANDREL TAPER DETERMINATION

TEST NUMBER 181T TEST PLATE NUMBER VII  
 MANDREL ST 5300 CBM-I)-O-N NOMINAL SIZE 3/8 inch (-12)  
 MAX DIA MANDREL 0.3531 inch MANDREL MATERIAL H-II-nitrided MANDREL TAPER: 0.015 inch/inch  
 PULL X PUSH \_\_\_\_\_ LUBRICATION: Fel Pro 300 (on sleeve)

SLEEVE THICKNESS 0.010 inch MANDREL DIA. + 2 x SLEEVE THICKNESS: 0.3731 inch

TEST MATERIAL Titanium COMPOSITION 6Al-4V STACK UP 3/8 inch

Hole no	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out			Retained hole* expansion (calc.)		
	Top	Mid	Bot			Top	Mid	Bot.					Top	Mid	Bot.			
A3	3600	3600	3600	-	.0126	3665	3665	3670	-	-	-	1925	.0005	.0065	.0055	.0070	.0065	.0070
B3	3600	3600	3600	20	.0126	3660	3655	3665	10	-	-	1930	.0005	.0060	.0055	.0065	.0060	.0065
C3	3600	3600	3600	-	.0126	3660	3650	3665	-	.0020	.0024	1880	.0005	.0060	.0055	.0065	.0060	.0065
D3	3600	3600	3600	-	.0126	3660	3660	3665	-	-	-	1835	.0005	.0060	.0060	.0065	.0060	.0065
E3	3600	3600	3600	-	.0126	3670	3660	3670	-	-	-	1780	.0005	.0070	.0060	.0070	.0060	.0070

\* To nearest 0.0005 inch

PHASE I - TASK 1 - MANDREL TAPER DETERMINATION

TEST NUMBER 1B2T TEST PLATE NUMBER VII  
 MANDREL ST 5300 CBM-( )-O-N NOMINAL SIZE 3/8 inch (.12)  
 MAX DIA. MANDREL 0.3531 inch MANDREL MATERIAL H-II-nitrided MANDREL TAPER: 0.030 inch/inch  
 PULL: X PUSH: \_\_\_\_\_ LUBRICATION: Fel Pro 300 (on sleeve)

SLEEVE THICKNESS: 0.010 inch MANDREL DIA. + 2 x SLEEVE THICKNESS: 0.3731 inch

TEST MATERIAL Titanium COMPOSITION: 6Al-4V STACK UP: 3/8 inch

Hole no.	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole expansion (calc.)		
	Top	Mid.	Bot.			Top	Mid.	Bot.						Top	Mid.	Bot.
F3	3600	3600	3600	-	.0121	3660	3660	3665	-	-	-	1460	.0005	0060	0060	0065
G3	3600	3600	3600	-	.0121	3600	3655	3665	-	.0025	.0025	1400	.0005	0060	0055	0065
H3	3600	3600	3600	-	.0121	3665	3660	3670	-	-	-	1420	.0005	0065	0060	0070
A4	3600	3600	3600	-	.0121	3665	3660	3665	-	-	-	1390	.0005	0065	0060	0065
B4	3600	3600	3600	25	.0121	3665	3660	3665	12	-	-	1440	.0005	0065	0060	0065

\* To nearest 0.0005 inch

PHASE I - TASK I - MANDREL TAPER DETERMINATION

TEST NUMBER: 1B3T TEST PLATE NUMBER: VII  
 MANDREL: ST 5300 CBM-(J)-ON NOMINAL SIZE: 3/8 inch (-12)  
 MAX DIA. MANDREL: 0.3537 inch MANDREL MATERIAL: H-II-nitrided MANDREL TAPER: 0.045 inch/inch  
 PULL: X PUSH: \_\_\_\_\_ LUBRICATION: Fel Pro 300 (on sleeve)  
 SLEEVE THICKNESS: 0.010 inch MANDREL DIA. + 2 x SLEEVE THICKNESS: 0.3737 inch  
 TEST MATERIAL: Titanium COMPOSITION: 6Al-4V STACK UP: 3/8 inch

Hole no.	Size prior to CW*		Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole expansion (calc.)		
	Top	Mid			Bot.	Top	Mid						Bot.		
C4	3600	3600	3600	.0132	3665	3660	3670	-	-	-	1255	.0005	0065	0060	0070
D4	3600	3600	3600	.0132	3665	3660	3665	-	.0026	.0026	1245	.0005	0065	0060	0065
E4	3600	3600	3600	.0132	3665	3660	3665	8	-	-	1300	.0005	0065	0060	0065
F4	3600	3600	3600	.0132	3665	3660	3665	-	-	-	1255	.0005	0065	0060	0065
G4	3600	3600	3600	.0132	3670	3665	3670	-	-	-	1215	.0005	0070	0065	0070

\* To nearest 0.0005 inch

PHASE I - TASK I - MANDREL TAPER DETERMINATION

TEST NUMBER 1C1T TEST PLATE NUMBER VII  
 MANDREL: ST 5300 CBM-4 J-O-N NOMINAL SIZE 3/8 inch (.12)  
 MAX. DIA. MANDREL: 0.3531 inch MANDREL MATERIAL: H-II-nitrided MANDREL TAPER: 0.015 inch/inch

PULL: X PUSH: \_\_\_\_\_ LUBRICATION: Fel Pro 300 (on sleeve)

SLEEVE THICKNESS: 0.010 inch MANDREL DIA. + 2 x SLEEVE THICKNESS: 0.3731 inch

TEST MATERIAL: Titanium COMPOSITION: 6Al-4V STACK UP: 3/8 inch

Hole no.	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole* expansion (calc.)		
	Top	Mid	Bot.			Top	Mid	Bot.						Top	Mid	Bot.
A5	3660	3660	3660	-	.0071	3685	3685	3690	-	-	-	1440	None	0025	0025	0030
P5	3660	3660	3660	20	.0071	3680	3680	3685	.0020	.0025	-	1320	None	0020	0020	0025
C5	3660	3660	3660	-	.0071	3685	3685	3690	-	-	-	1375	None	0025	0025	0030
D5	3660	3660	3660	-	.0071	3685	3685	3690	-	-	-	1285	None	0025	0025	0030
E5	3660	3660	3660	-	.0071	3685	3685	3690	-	-	-	1300	None	0025	0025	0030

\* To nearest 0.0005 inch



PHASE I - TASK I - MANDREL TAPER DETERMINATION

TEST NUMBER 1C2T TEST PLATE NUMBER VII  
 MANDREL ST 5300 CBM-I J-O-N NOMINAL SIZE 3/8 inch (-12)  
 MAX DIA. MANDREL 0.3531 inch MANDREL MATERIAL H-II-nitrided MANDREL TAPER: 0.030 inch/inch  
 PULL X PUSH \_\_\_\_\_ LUBRICATION: Fel Pro 300 (on sleeve)

SLEEVE THICKNESS 0.010 inch MANDREL DIA. + 2 x SLEEVE THICKNESS 0.3731 inch

TEST MATERIAL Titanium COMPOSITION: 6Al-4V STACK UP 3/8 inch

Hole no	Size prior to CW*		Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole* expansion (calc.)		
	Top	Mid.			Bot.	Top	Mid.						Bot.	Top	Mid.
F5	3660	3660	3660	.0071	3685	3685	3690	-	-	-	1100	None	0025	0025	0030
G5	3660	3660	3660	.0071	3685	3685	3690	-	.0020	.0026	1080	None	0025	0025	0030
H5	3660	3660	3660	.0071	3685	3685	3690	8	-	-	1125	None	0025	0025	0030
A6	3660	3660	3660	.0071	3685	3685	3685	-	-	-	1105	None	0025	0025	0025
B6	3660	3660	3660	.0071	3685	3685	3690	-	-	-	1105	None	0025	0025	0030

\* To nearest 0.0005 inch

## PHASE I - TASK I - MANDREL TAPER DETERMINATION

TEST NUMBER 1C3T TEST PLATE NUMBER VII  
 MANDREL: ST 5300 CBM (-) O-N NOMINAL SIZE 3/8 inch (-12)  
 MAX DIA. MANDREL: 0.3537 inch MANDREL MATERIAL H-II-nitrided MANDREL TAPER 0.045 inch/inch  
 PULL X PUSH \_\_\_\_\_ LUBRICATION: Fel Pro 300 (on sleeve)

SLEEVE THICKNESS: 0.010 inch MANDREL DIA. + 2 x SLEEVE THICKNESS: 0.3737 inch

TEST MATERIAL: Titanium COMPOSITION: 6Al-4V STACK UP: 3/8 inch

Hole no.	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole expansion (calc.)		
	Top	Mid.	Bot.			Top	Mid.	Bot.						Top	Mid.	Bot.
C6	3660	3660	3660	-	.0077	3685	3685	3690	-	-	-	1040	None	0025	0025	0030
D6	3660	3660	3660	-	.0077	3690	3685	3690	-	-	-	1030	None	0030	0025	0030
E6	3660	3660	3660	20	.0077	3685	3685	3690	10	.0023	.0027	1000	None	0025	0025	0030
F6	3660	3660	3660	-	.0077	3690	3685	3690	-	-	-	985	None	0030	0025	0030
G6	3660	3660	3660	-	.0077	3685	3685	3690	-	-	-	1020	None	0025	0025	0030

\*To nearest 0.0005 inch

PHASE I - TASK I - MANDREL TAPER DETERMINATION

TEST NUMBER: 1D1T TEST PLATE NUMBER: VIII

MANDREL: ST 5300 CBM-( J)-O-N NOMINAL SIZE: 3/8 inch (.12)

MAX. DIA. MANDREL: 0.3538 inch MANDREL MATERIAL: H-II-nitrided MANDREL TAPER: 0.015 inch/inch

PULL: X PUSH: LUBRICATION: Fel Pro 300 (on sleeve)

SLEEVE THICKNESS: 0.010 inch MANDREL DIA. + 2 x SLEEVE THICKNESS: 0.3738 inch

TEST MATERIAL: Titanium COMPOSITION: 6Al-4V STACK UP: 1-1/2 inches

Hole no.	Size prior to CW*		Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out		Retained hole* expansion (calc.)	
	Top	Mid.			Bot.	Top	Mid.					Bot.	Top	Mid.	Bot.
A2	3555	3550	3550	.0157	3650	3625	3650	10	-	-	8400	.001	.0095	.0075	0100
A3	3555	3550	3550	.0155	3650	3625	3650	-	.0069	-	7550	.001	.0095	.0075	0100
A4	3555	3550	3550	.0153	3645	3625	3650	-	-	.0070	6540	.001	.0090	.0075	0100
A5	3555	3555	3550	.0152	3650	3625	3650	-	-	-	6050	.001	.0095	.0070	0100

\*To nearest 0.0005 inch  Mandrel diameter progressively reduced to 0.3522 inch in 4 holes

PHASE I - TASK 1 - MANDREL TAPER DETERMINATION

TEST NUMBER: 1D2T TEST PLATE NUMBER: VIII  
 MANDREL: ST 5300 CBM-( )-ON NOMINAL SIZE: 3/8 inch (.12)  
 MAX DIA. MANDREL: 0.3531 inch MANDREL MATERIAL: H-II-nitrided MANDREL TAPER: 0.030 inch/finch  
 PULL: X PUSH: \_\_\_\_\_ LUBRICATION: Fel Pt o 300 (on sleeve)  
 SLEEVE THICKNESS: 0.010 inch MANDREL DIA. + 2 x SLEEVE THICKNESS: 0.3731 inch  
 TEST MATERIAL: Titanium COMPOSITION: 6Al-4V STACK UP: 1-1/2 inches

Hole no	Size prior to CW*		Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole* expansion (calc.)		
	Top	Mid.			Bot.	Top	Mid.						Bot.		
A6	3550	3545	3550	.0162	3645	3620	3650	-	.0068	-	4760	.001	0095	0075	0100
A7	3550	3545	3545	.0161	3650	3625	3650	-	-	-	4800	.001	0100	0080	0105
A8	3545	3545	3545	.0161	3650	3625	3650	-	-	.0072	4780	.001	0105	0080	0105
B1	3550	3550	3550	.0156	3645	3620	3650	-	-	-	4840	.001	0095	0070	0100
B2	3550	3550	3550	.0155	3645	3620	3645	12	-	-	4840	.001	0095	0070	0095

\*To nearest 0.0005 inch  Mandrel diameter progressively reduced to 0.3525 inch in 5 holes

PHASE I - TASK I - MANDREL TAPER TERMINATION

TEST NUMBER 1D3T TEST PLATE NUMBER VIII

MANDREL ST 5300 CBM-1 / O-N NOMINAL SIZE 3/8 inch (.12)

MAX DIA MANDREL 0.3537 inch MANDREL MATERIAL H-II-nitrided MANDREL TAPER 0.045 inch/inch

PULL X PUSH LUBRICATION Fel Pro 300 (on sleeve)

SLEEVE THICKNESS 0.010 inch MANDREL DIA 2 x SLEEVE THICKNESS 0.3737 inch

TEST MATERIAL Titanium COMPOSITION 6Al-4V STACK UP 1-1/2 inches

Hole no	Size prior to CW			Finish prior to CW	Maximum expansion (cale)	Size after CW			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thru out			Retained minor expansion (cale)	
	Top	Mid	Bot			Top	Mid	Bot					Top	Mid	Bot		
B3	3550	3550	3550	-	.0165	3640	3625	3650	-	-	-	4700	.001	.0090	.0075	.0100	.0100
B4	3550	3550	3550	-	.0165	3640	3625	3660	-	-	-	5180	.001	.0090	.0075	.0110	.0110
B5	3550	3550	3550	18	.0164	3650	3625	3650	8	0070	-	4500	.001	.0100	.0075	.0100	.0100
B6	3550	3550	3545	-	.0163	3640	3620	3645	-	-	-	4760	.001	.0090	.0070	.0100	.0100
B7	3550	3550	3545	-	.0163	3640	3630	3655	-	-	.0070	5000	.001	.0090	.0080	.0110	.0110

△ Mandrel diameter progressively reduced to 0.3533 inch in 5 holes

△ Mandrel 0.0005 inch

PHASE I - TASK 1 MANDREL TAPER DETERMINATION

TEST NUMBER 1E1T TEST PLATE NUMBER VIII  
 MANDREL: ST 5300 CBM (-) O-N NOMINAL SIZE: 3/8 inch (-12)  
 MAX DIA MANDREL: 0.3538 inch MANDREL MATERIAL: H-II-nitrided MANDREL TAPER: 0.015 inch/inch  
 PULL: X PUSH: \_\_\_\_\_ LUBRICATION: Fel Pro 300 (on sleeve)  
 SLEEVE THICKNESS: 0.010 inch MANDREL DIA. + 2 x SLEEVE THICKNESS: 0.3738 inch  
 TEST MATERIAL: Titanium COMPOSITION: 6Al-4V STACK UP: 1-1/2 inches

Hole no.	Size prior to CW*		Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole* expansion (calc.)		
	Top	Mid.			Bot.	Top	Mid.						Bot.	Top	Mid.
C1	3605	3605	3605	.0115	3645	3640	3650	-	-	-	7320	.0005	0040	0035	0050
C2	3605	3605	3605	.0110	3650	3640	3655	-	-	.0045	7520	.0005	0045	0035	0055
C3	3605	3605	3605	.0108	3555	3640	3655	10	.0035	-	5540	.0005	0050	0035	0050
C4	3605	3605	3605	.0108	3650	3630	3650	-	-	-	4220	.0005	0045	0025	0045

\* To nearest 0.0005 inch

△ Mandrel diameter progressively reduced to 0.3523 inch in 4 holes

PHASE I - TASK I - MANDREL TAPER DETERMINATION

TEST NUMBER: 1E2T TEST PLATE NUMBER: VIII  
 MANDREL: ST 5300 CBM-I J-O-N NOMINAL SIZE: 3/8 inch (-12)  
 MAX. DIA. MANDREL: 0.3520 inch MANDREL MATERIAL: H-II-nitrided MANDREL TAPER: 0.030 inch/inch  
 PULL: X PUSH: LUBRICATION: Fel Pro 300 (on sleeve)

SLEEVE THICKNESS: 0.010 inch MANDREL DIA. + 2 x SLEEVE THICKNESS: 0.3720 inch  
 TEST MATERIAL: Titanium COMPOSITION: 6Al-4V STACK UP: 1-1/2 inches

Hole no	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole* expansion (calc)		
	Top	Mid.	Bot.			Top	Mid.	Bot.						Top	Mid.	Bot.
C6	3605	3605	3600	-	.0105	3650	3640	3660	-	-	-	3380	.0005	0045	0035	0060
C7	3605	3605	3605	-	.0105	3645	3635	3660	-	.0038	-	3180	.0005	0040	0030	0055
C8	3605	3600	3605	-	.0105	3645	3640	3660	-	-	.0045	3300	.0005	0040	0040	0055
D1	3605	3605	3605	-	.0105	3645	3640	3660	-	-	-	3940	.0005	0040	0035	0055
D2	3605	3605	3605	18	.0105	3650	3640	3665	10	-	-	3400	.0005	0045	0035	0060

\*To nearest 0.0005 inch

PHASE I - TASK I - MANDREL TAPER DETERMINATION

TEST NUMBER 1E3T TEST PLATE NUMBER VIII  
 MANDREL ST 5300 CBM ( )-ON NOMINAL SIZE 3/8 inch (-12)  
 MAX DIA. MANDREL 0.3539 inch MANDREL MATERIAL H-II-nitrided MANDREL TAPER: 0.045 inch/inch  
 PULL: X PUSH: \_\_\_\_\_ LUBRICATION: Fel Pro 300 (on sleeve)  
 SLEEVE THICKNESS: 0.010 inch MANDREL DIA. + 2 x SLEEVE THICKNESS: 0.3739 inch  
 TEST MATERIAL: Titanium COMPOSITION: 6Al-4V STAGI UP: 1-1/2 inches

Hole no.	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole expansion (calc.)		
	Top	Mid.	Bot.			Top	Mid.	Bot.						Top	Mid.	Bot.
D3	3605	3605	3605	-	.0119	3660	3645	3660	-	-	-	3280	.0005	0055	0040	0055
D4	3605	3605	3605	-	.0119	3665	3640	3660	-	.0038	-	2760	.0005	0050	0035	0055
D5	3605	3600	3600	-	.0119	3650	3640	3665	-	-	-	3060	.0005	0045	0040	0065
D6	3605	3605	3605	15	.0117	3650	3640	3665	8	-	.0045	3120	.0005	0045	0040	0060
D7	3605	3605	3605	-	.0114	3650	3640	3660	-	-	-	2920	.0005	0045	0040	0055
D8	3605	3605	3605	-	.0122	3650	3640	3660	-	-	-	3450	.0005	0045	0040	0055

\* To nearest 0.0005 inch  
 Mandrel diameter progressively reduced to 0.3529 inch in 5 holes.  
 AISI 9260 mandrel; used for hole D8. Maximum diameter = 0.3537 inch.



PHASE I TASK I MANDREL TAPER DETERMINATION

TEST NUMBER 1F11 TEST PLATE NUMBER VIII  
 MANDREL ST 5300 CBM-I JON NOMINAL SIZE 3/8 inch (.12)  
 MAX DIA MANDREL 0.3623 inch MANDREL MATERIAL H-II nitrided MANDREL TAPER 0.015 inch/inch  
 PULL X PUSH \_\_\_\_\_ LUBRICATION Fel-Pro 300 (on sleeve)

SLEEVE THICKNESS 0.010 inch MANDREL DIA 2 x SLEEVE THICKNESS: 0.3723 inch  
 TEST MATERIAL Titanium COMPOSITION 6Al-4V STACK UP 1-1/2 inches

Hole no	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole expansion (calc.)		
	Top	Mid	Bot			Top	Mid	Bot						Top	Mid	Bot
E1	3655	3655	3655	-	.0068	3660	3660	3665	-	-	-	5340	None	0005	0005	0010
E2	3655	3655	3660	18	.0068	3660	3650	3670	10	.0024	.0032	4260	None	0005	0005	0010
E3	3655	3655	3655	-	.0068	3660	3660	3670	-	-	-	4800	None	0005	0005	0015
E4	3660	3655	3655	-	.0068	3675	3660	3675	-	-	-	3500	None	0015	0005	0020
E5	3655	3655	3655	-	.0068	3670	3665	3675	-	-	-	3400	None	0015	0010	0020

\*To nearest 0.0005 inch

## PHASE I TASK I MANDREL TAPER DETERMINATION

TEST NUMBER 172 TEST PLATE NUMBER VIII  
 MANDREL ST 5300 CBM ION NOMINAL SIZE 3/8 inch (.12)  
 MAX. DIA MANDREL 0.3520 inch MANDREL MATERIAL H-II-nitrided MANDREL TAPER: 0.030 inch/inch  
 PULL X PUSH      LUBRICATION Fel Pro 300 (on sleeve)

SLEEVE THICKNESS 0.010 inch MANDREL DIA 2 x SLEEVE THICKNESS 0.3720 inch

TEST MATERIAL Titanium COMPOSITION 6Al-4V STACK UP: 1-1/2 inches

Hole no	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole* expansion (calc.)		
	Top	Mid.	Bot.			Top	Mid.	Bot.						Top	Mid.	Bot.
E6	3660	3655	3655	-	.0065	3680	3670	3685	-	-	-	1630	None	0020	0015	0030
E7	3655	3655	3656	-	.0065	3680	3675	3685	-	.0025	-	1600	None	0025	0020	0030
E8	3655	3655	3650	15	.0065	3680	3570	3685	8	-	.0030	1495	None	0025	0015	0035
F1	3655	3655	3655	-	.0065	3665	3665	3670	-	-	-	1925	None	0010	0010	0015
F2	3655	3655	3655	-	.0065	3665	3665	3670	-	-	-	1910	None	0010	0010	0015

\*To nearest 0.0005 inch

PHASE I - TASK I - MANDREL TAPER DETERMINATION

TEST NUMBER 1F3T TEST PLATE NUMBER VIII

MANDREL ST 5300 CBM-I (ION) NOMINAL SIZE 3/8 inch (12)

MAX DIA. MANDREL 0.3537 inch MANDREL MATERIAL H-II-nitrided MANDREL TAPER: 0.045 inch/inch

PULL: X PUSH: \_\_\_\_\_ LUBRICATION Per Proc 400 (for sleeve)

SLEEVE THICKNESS: 0.010 inch MANDREL DIA + 2 x SLEEVE THICKNESS 0.3737 inch

TEST MATERIAL: Titanium COMPOSITION 6Al-4V STACK UP 1.12 inches

Hole no	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thickness	Retained hole expansion (calc.)		
	Top	Mid.	Bot			Top	Mid.	Bot						Top	Bot.	
F3	3655	3655	3655	-	.0082	3675	3670	3685	-	-	-	2000	None	0020	0015	0030
F4	3655	3655	3655	-	.0082	3675	3670	3685	-	-	-	2220	None	0020	0015	0030
F5	3655	3655	3655	20	.0082	3680	3675	3690	12	-	-	2040	None	0025	0020	0035
F6	3655	3655	3655	-	.0082	3680	3675	3690	-	-	-	2000	None	0025	0020	0035
F7	3655	3655	3655	-	.0082	3680	3670	3690	-	.0025	.0035	2040	None	0025	0015	0035

\*To nearest 0.0005 inch

PHASE I - TASK I - MANDREL TAPER DETERMINATION

TEST NUMBER 1G1T TEST PLATE NUMBER IX  
 MANDREL ST 5300 CBM-( )-O-N NOMINAL SIZE 3/4 inch (F-24)  
 MAX DIA. MANDREL 0.7158 inch MANDREL MATERIAL H-II-nitrided MANDREL TAPER 0.020 inch/inch  
 PULL X PUSH \_\_\_\_\_ LUBRICATION Fel Pro 300 (on sleeve)

SLEEVE THICKNESS 0.015 inch MANDREL DIA. + 2 x SLEEVE THICKNESS 0.7458 inch  
 TEST MATERIAL Titanium COMPOSITION 6Al-4V STACK UP 2 inches

Hole no.	Size prior to CW*			Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole expansion (calc.)		
	Top	Mid.	Bot.		Top	Mid	Bot.						Top	Mid	Bot.
A1	7140	7140	7140	.0295	7295	7280	7335	-	-	-	26,600	.001	0155	0140	0195
A2	7140	7140	7140	.0294	7295	7280	7335	20	-	-	18,000	.001	0155	0140	0195
A3	7140	7140	7140	.0293	7300	7285	7335	-	.0070	.0135	19,200	.001	0160	0145	0195
A4	7140	7140	7140	.0291	7295	7280	7335	-	-	-	17,100	.001	0155	0140	0195

\* To nearest 0.0005 inch

1 Mandrel progressively reduced to 0.7150 inch in 4 holes

PHASE I TASK 1 MANDREL TAPER LEAK TEST

TEST NUMBER 1G2T TEST PLATE NUMBER 1X  
 MANDREL ST 5300 CBM-I ION 3.4 inch (24)  
 MAX DIA MANDREL 0.7158 inch MANDREL MATERIAL H-11 nitrided MANDREL TAPER 0.030 inch/inch  
 PULL X PUSH \_\_\_\_\_ LUBRICATION Fel Pro 300 (on sleeve)

SLEEVE THICKNESS: 0.015 inch MANDREL DIA. + 2 x SLEEVE THICKNESS: 0.7458 inch

TEST MATERIAL Titanium COMPOSITION 6Al-4V STACK UP: 2 inch

Hole no.	Size prior to CW		Finish prior to CW	Platinum deposition (leak)	Size after CW		Finish after CW	Upset entrance of hole	Upset exit of hole	Force required (lb)	Sleeve thin out	Retired hole expansion (leak)			
	Top	Mid			Bot	Top						Bot	Top	Bot	
83	7140	7140	7145	-	6298	7337	7310	7340	0030	0115	18,000	.001	0190	0.70	0155
84	7140	7145	7145	30	6297	7320	7303	7.740	-	-	18,800	.001	0120	0150	0155

Top Mid Bot

PHASE I - TASK I - MANDREL TAPER DETERMINATION

TEST NUMBER 1G3T TEST PLATE NUMBER IX  
 MANDREL ST 5300 CBM(-) J-O-N NOMINAL SIZE 3/4 inch (-12)  
 MAX DIA. MANDREL 0.7148 inch MANDREL MATERIAL H-II-nitrided MANDREL TAPER 0.045 inch/inch  
 PULL X PUSH          LUBRICATION Fel Pro 300 (on sleeve)  
 SLEEVE THICKNESS: 0.015 inch MANDREL DIA. + 2 x SLEEVE THICKNESS: 0.7448 inch  
 TEST MATERIAL Titanium COMPOSITION 6Al-4V STACK UP 2 inch

Hole no	Size prior to CW*		Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Returned hole* expansion (calc.)		
	Top	Mid.			Bot	Top	Mid.						Bot.		
C3	7140	7140	1740	-.0288	7295	7275	7335	-	-	-	14,500	.001	0155	0135	0195
C4	7140	7140	7140	-.0283	7295	7275	7335	-	-	-	12,600	.001	0155	0135	0195
D1	7140	7140	7140	-.0282	7295	7275	7335	-	.0065	.0090	14,100	.001	0155	0135	0195
D2	7140	7140	7140	-.0282	7295	7275	7335	18	-	-	14,000	.001	0155	0135	0195
D3	7140	7140	7140	-.0280	7295	7275	7335	-	-	-	13,600	.001	0155	0135	0195

\* To nearest 0.0005 inch.  Mandrel diameter progressively reduced to 0.7140 inch in 5 holes.

PHASE I - TASK I - MANDREL TAPER DETERMINATION

TEST NUMBER: 1H1T TEST PLATE NUMBER: X  
 MANDREL: ST 5300 CBM-( )-O-N NOMINAL SIZE: 3/4 inch (.24)  
 MAX DIA. MANDREL: 0.7158 inch MANDREL MATERIAL: H-II-nitrided MANDREL TAPER: 0.020 inch/inch  
 PULL: X PUSH: \_\_\_\_\_ LUBRICATION: Fel Pro 300 (on sleeve)  
 SLEEVE THICKNESS: 0.015 inch MANDREL DIA. + 2 x SLEEVE THICKNESS: 0.7458 inch  
 TEST MATERIAL: Titanium COMPOSITION: 6Al-4V STACK UP: 2 inch

Hole no.	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole* expansion (calc.)		
	Top	Mid.	Bot.			Top	Mid.	Bot.						Top	Mid.	Bot.
A1	7195	7195	7195	-	.0243	7345	7310	7335	-	-	-	15,500	.001	0150	0115	0140
A2	7195	7195	7195	50	.0243	7350	7315	7335	25	-	-	16,500	.001	0155	0120	0140
A3	7195	7195	7195	-	.0243	7340	7310	7335	-	.0025	.0085	16,800	.001	1045	0115	0140
A4	7195	7195	7195	-	.0243	7345	7310	7335	-	-	-	15,400	.001	0150	0115	0140
B1	7195	7195	7195	-	.0243	7345	7310	7330	-	-	-	16,700	.001	0150	0115	0135

\*To nearest 0.0005 inch







PHASE I - TASK I - MANDREL TAPER DETERMINATION

TEST NUMBER 1J1T TEST PLATE NUMBER: XI  
 MANDREL ST 5300 CBM-I J-O-N NOMINAL SIZE: 3/4 inch (.24)  
 MAX. DIA. MANDREL: 0.7164 inch MANDREL MATERIAL: H-II-nitrided MANDREL TAPER: 0.020 inch/inch  
 PULL: X PUSH: Fel Pro 300 (os sleeve) LUBRICATION: \_\_\_\_\_

SLEEVE THICKNESS: 0.015 inch MANDREL DIA. + 2 x SLEEVE THICKNESS: 0.7464 inch

TEST MATERIAL: Titanium COMPOSITION: 6Al-4V STACK UP: 2 inch

Hole no.	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole expansion (calc.)		
	Top	Mid.	Bot.			Top	Mid.	Bot.						Top	Mid.	Bot.
A1	7250	7250	7250	-	.0194	7340	7320	7345	-	-	-	15,700	.001	0090	0070	0095
A2	7250	7250	7250	-	.0188	7335	7320	7345	-	.0035	.0125	11,800	.001	0085	0070	0095
A3	7250	7245	7245	-	.0188	7330	7320	7345	-	-	-	15,300	.001	0080	0070	0095
A4	7250	7250	7250	-	.0188	7330	0320	7345	-	-	-	15,600	.001	0080	0070	0095
B1	7250	7245	7250	45	.0188	7330	7320	7355	20	-	-	11,900	.001	0080	0070	0105

\* To nearest 0.0005 inch ▷ Mandrel diameter reduced to .7158 inch in first hole.



PHASE I - TASK I - MANDREL TAPER DETERMINATION

TEST NUMBER: 1J3T TEST PLATE NUMBER: XI  
 MANDREL: ST 5300 CBM-( J)-O-N NOMINAL SIZE: 3/4 inch  
 MAX DIA. MANDREL: 0.7162 inch MANDREL MATERIAL: H-11-nitr.ded MANDREL TAPER: 0.045 inch/inch  
 PULL: X PUSH: Fel Pro 300 (on sleeve) LUBRICATION:   
 SLEEVE THICKNESS: 0.015 inch MANDREL DIA. + 2 x SLEEVE THICKNESS: 0.7462 inch  
 TEST MATERIAL: Titanium COMPOSITION: 6Al-4V STACK UP: 2 inch

Hole no.	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upsat entrance of hole	Upsat exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole* expansion (calc.)		
	Top	Mid.	Bot.			Top	Mid.	Bot.						Top	Mid.	Bot.
C4	7250	7250	7250	-	.0192	7355	7315	7345	-	-	-	8300	.001	0085	0065	0095
D1	7250	7250	7245	-	.0184	7335	7315	7345	-	.0035	.0135	8500	.001	0085	0065	0010
D2	7250	7245	7245	30	.0183	7335	7320	7355	18	-	-	9800	.001	0085	0075	0105
D3	7245	7245	7245	-	.0182	7335	7315	7355	-	-	-	8200	.001	0085	0065	0105
D4	7250	7245	7245	-	.0185	7335	7315	7345	-	-	-	8700	.001	0085	0065	0100

\*To nearest 0.0005 inch \*Mandrel diameter progressively reduced to .7150 inch in 5 holes.

PHASE I - TASK I - MANDREL TAPER DETERMINATION

TEST NUMBER: 1A15 TEST PLATE NUMBER: XII  
 MANDREL: Push (Design per BAC 5972) NOMINAL SIZE: 3/8 inch  
 MAX. DIA. MANDREL: 0.3580 inch MANDREL MATERIAL: Carboly 883 (GE)  
 MANDREL TAPER: 0.015 inch/inch LUBRICATION: Fel Pro 300  
 TEST MATERIAL: 300 'M' Steel (280/300 ksi) STACK UP: 3/8 inch

Hole no.	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole expansion (calc.)		
	Top	Mid.	Bot.			Top	Mid.	Bot.						Top	Mid.	Bot.
A1	3445	3450	3455	-	.0130	3525	3520	3530	-			7060		0080	0070	0075
A2	3445	3445	3450	-	.0135	3525	3520	3535	-			4100		0080	0075	0080
A3	3440	3440	3445	-	.0140	3525	3515	3535	-			4200		0085	0075	0090
A4	3440	3440	3440	-	.0140	3525	3520	3535	-			3650		0085	0080	0085
A5	3450	3450	3450	50	.0130	3525	3520	3535	25			3520		0075	0070	0085

\*To nearest 0.0005 inch

PHASE I - TASK I - MANDREL TAPER DETERMINATION

TEST NUMBER: 1A2S TEST PLATE NUMBER: XII  
 MANDREL: Push (Design per BAC 5972) NOMINAL SIZE: 3/8 inch  
 MAX. DIA. MANDREL: 0.3580 inch MANDREL MATERIAL: Carboloy 883 (GE)  
 MANDREL TAPER: 0.030 inch/inch LUBRICATION: Fel Pro 300  
 TEST MATERIAL: 300 'M' Steel (280/300 ksi) STACK UP: 3/8 inch

Hole no.	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole* expansion (calc.)		
	Top	Mid	Bot.			Top	Mid	Bot.						Top	Mid	Bot.
A6	3450	3450	3450	-	.0130	3525	3520	3535	-			6040		0075	0070	0085
A7	3445	3445	3445	-	.0135	3525	3520	3535	-			4880		0080	0075	0090
A8	3450	3450	3450	50	.0130	3520	3515	3535	20			4550		0070	0065	0085
B1	3445	3450	3455	-	.0130	3525	3520	3535	-			4760		0080	0070	0080
B2	3445	3455	3455	-	.0125	3520	3515	3535	-			4920		0075	0060	0080

\*To nearest 0.0005 inch

PHASE I - TASK 1 - MANDREL TAPER DETERMINATION

TEST NUMBER: 1A3S TEST PLATE NUMBER: X11  
 MANDREL: Push (Design per BAC 5972) NOMINAL SIZE: 3/8 inch  
 MAX. DIA. MANDREL: 0.3580 inch MANDREL MATERIAL: Carboloy 883 (GE)  
 MANDREL TAPER: 0.045 inch/inch LUBRICATION: Fel Pro 300  
 TEST MATERIAL: 300 'M' Steel (280/300 ksi) STACK UP: 3/8 inch

Hole no.	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole* expansion (calc.)		
	Top	Mid.	Bot.			Top	Mid.	Bot.						Top	Mid.	Bot.
B3	3445	3445	3455	-	.0125	3525	3520	3535	-			4860		0780	0065	0080
B4	3445	3455	3455	-	.0130	3525	3520	3535	-			4280		0080	0065	0080
B5	3445	3450	3455	-	.0130	3525	3520	3535	-			4860		0080	0070	0080
B6	3450	3455	3455	-	.0125	3525	3520	3535	-			4940		0075	0065	0080
B7	3445	3450	3455	50	.0130	3525	3520	3535	20			4820		0080	0070	0080

\*To nearest 0.0005 inch

PHASE I - TASK I - MANDREL TAPER DETERMINATION

TEST NUMBER: 1B1S TEST PLATE NUMBER: X11  
 MANDREL: Push (Design per BAC 5972) NOMINAL SIZE: 3/8 inch  
 MAX. DIA. MANDREL: 0.3580 inch MANDREL MATERIAL: Carboloy 883 (GE)  
 MANDREL TAPER: 0.015 inch/inch LUBRICATION: Fel Pro 300  
 TEST MATERIAL: 300 'M' Steel (280/300 ksi) STACK UP: 3/8 inch

Hole no	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sieve thin out	Retained hole* expansion (calc.)		
	Top	Mid.	Bot			Top	Mid.	Bot.						Top	Mid.	Bot
C1	3395	3395	3395	-	.0185	3510	3505	3525	-			5260		0115	0110	0130
C2	3395	3395	3395	-	.0185	3515	3510	3520	-			5200		0120	0115	0125
C3	3395	3395	3395	80	.0185	3515	3510	3525	35			5500		0120	0115	0130
C4	3395	3395	3395	-	.0185	3515	3510	3525	-			5880		0120	0115	0130
C5	3395	3395	3395	-	.0185	3515	3510	3525	-			7360		0120	0115	0130

\*To nearest 0.0005 inch



PHASE I - TASK I - MANDREL TAPER DETERMINATION

TEST NUMBER: 1B2S TEST PLATE NUMBER: XII  
 MANDREL: Push (Design per BAC 5972) NOMINAL SIZE: 3/8 inch  
 MAX. DIA MANDREL: 0.3580 inch MANDREL MATERIAL: Carbolloy 883 (GE)  
 MANDREL TAPER: 0.030 inch/inch LUBRICATION: Fel Pro 300  
 TEST MATERIAL: 300 'M' Steel (280/300 ksi) STACK UP: 3/8 inch

Hole no	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole* expansion (calc.)		
	Top	Mid	Bot			Top	Mid	Bot						Top	Mid	Bot
C6	3395	3395	3395	-	.0185	3515	3510	3525	-			7000		0120	0115	0130
C7	3395	3395	3395	80	.0185	3315	3510	3525	35			6420		0120	0115	0130
C8	3395	3395	3395	-	.0185	3515	3510	3525	-			6000		0120	0115	0130
D1	3395	3395	3395	-	.0185	3515	3510	3525	-			5780		0120	0115	0130
D2	3395	3395	3395	-	.0185	3515	3510	3525	-			7480		0120	0115	0130

\* To nearest 0.0005 inch

PHASE I - TASK I - MANDREL TAPER DETERMINATION

TEST NUMBER: 1B3S TEST PLATE NUMBER: XII  
 MANDREL: Push (Design per BAC 5972) NOMINAL SIZE: 3/8 inch  
 MAX. DIA. MANDREL: 0.3580 inch MANDREL MATERIAL: Carboly 883 (GE)  
 MANDREL TAPER: 0.045 inch/inch LUBRICATION: Fel Pro 300  
 TEST MATERIAL: 300 'M' Steel (280/300 ksi) STACK UP: 3/8 inch

Hole no	Size prior to CW*		Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole* expansion (calc.)		
	Top	Mid.			Bot.	Top	Mid.						Bot.	Top	Mid.
D3	3395	3395	3395	.0185	3515	3510	3525	-			5980		0120	0115	0130
D4	3395	3395	3395	.0185	3515	3510	3525	-			6040		0120	0115	0130
D5	3395	3395	3395	.0185	3515	3510	3525	30			7660		0120	0115	0130
D6	3395	3395	3395	.0185	3515	3510	3525	-			6900		0120	0115	0130
D7	3395	3395	3395	.0185	3515	3510	3525	-			5880		0120	0115	0130

\* To nearest 0.0005 inch

PHASE I - TASK I - MANDREL TAPER DETERMINATION

TEST NUMBER: 1C1S TEST PLATE NUMBER: XII  
 MANDREL: Push (Design per BAC 5972) NOMINAL SIZE: 3/8 inch  
 MAX. DIA. MANDREL: 0.3580 inch MANDREL MATERIAL: Carboloy 883 (GE)  
 MANDREL TAPER: 0.015 inch/inch LUBRICATION: Fel Pro 300  
 TEST MATERIAL: 300 'M' Steel (280/300 ksi) STACK UP: 3/8 inch

Hole no	Size prior to CW*		Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole expansion (calc.)		
	Top	Mid			Bot.	Top	Mid						Bot.	Top	Mid
E3	3345	3345	3345	.0235	3530	3500	3515	-			19,260		0185	0155	0170
E4	3345	3345	3345	.0235	3530	3505	3515	5			23,800		0185	0160	0170
E5	3345	3345	3345	.0235				-			29,000	Mandrel froze in hole - Broke on removal			

\* To nearest 0.0005 inch

PHASE I - TASK I - MANDREL TAPER DETERMINATION

TEST NUMBER: 1D1S TEST PLATE NUMBER: XIII  
 MANDREL: Push (Design per BAC 5972) NOMINAL SIZE: 3/8 inch  
 MAX. DIA. MANDREL: 0.3580 inch MANDREL MATERIAL: Carboloy 883 (GE)  
 MANDREL TAPER: 0.030 inch/inch LUBRICATION: Fel Pro 300  
 TEST MATERIAL: 300 'M' Steel (280/300 ksi) STACK UP: 3/8 inch

Hole no.	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole* expansion (calc.)		
	Top	Mid.	Bot.			Top	Mid.	Bot.						Top	Mid.	Bot.
A2	3440	3440	3445	-	.0140	3535	3510	3535				6080		0085	0070	0095
A3	3440	3440	3440	40	.0140	3525	3515	3535				5220		0075	0075	0095
B1**	3435	3534	3445	45	.0145	3505	3500	3515				5200	.0010	0070	0065	0070
B2**	3455	3440	3445	-	.0140	3510	3505	3520				4800	.0010	0055	0065	0075

\* To nearest 0.0005 inch

\*\* Sleeve used; maximum expansion does not include sleeve thinout.

PHASE I - TASK I - MANDREL TAPER DETERMINATION

TEST NUMBER: 1E1S TEST PLATE NUMBER: XIII  
 MANDREL: Push (Design per BAC 5972) NOMINAL SIZE: 3/8 inch  
 MAX. D/A. MANDREL: 0.3580 inch MANDREL MATERIAL: Carboloy 883 (GE)  
 MANDREL TAPER: 0.030 inch/inch LUBRICATION: Fel Pro 300  
 TEST MATERIAL: 300 'M' Steel (280/300 ksi) STACK UP: 3/8 inch

Hole no.	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Retained hole* expansion (calc.)		
	Top	Mid.	Bot.			Top	Mid.	Bot.					Top	Mid.	Bot.
C1	3395	3390	3395	80	.0190	3515	3500	3535				6,640	0120	0110	0140
C2	3395	3380	3390	-	.0200	3515	3500	3535				6,680	0120	0120	0135
D1**	3395	3390	3395	90	.0190	3495	3485	3515				13,100	0010	0095	0120
D2**	3390	3385	3385	-	.0195	3495	3485	3515				9,200	0105	0100	0130

\*\* Sleeve used; maximum expansion does not include sleeve thinout.

\* To nearest 0.0005 inch

PHASE I - TASK I - MANDREL TAPER DETERMINATION

TEST NUMBER: 1F1S TEST PLATE NUMBER: XIII  
 MANDREL: Push (Design per BAC 5972) NOMINAL SIZE: 3/8 inch  
 MAX. DIA. MANDREL: 0.3580 inch MANDREL MATERIAL: Carboloy 883 (GE)  
 MANDREL TAPER: 0.015 inch/inch LUBRICATION: Fel Pro 300  
 TEST MATERIAL: 300 'M' Steel (280/300 ksi) STACK UP: 1-3/8 inch

Hole no	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole* expansion (calc.)		
	Top	Mid	Bot.			Top	Mid.	Bot.						Top	Mid.	Bot.
A8	3450	3440	3425	40	.0140	3520	3505	3535				9,900	Mandrel Broke	0070	0065	0090
A5**	3495	3450	3440	40	.0130	3500	3475	3505				22,600	Sleeve tore	0055	0025	0065

\* To nearest 0.0005 inch \*\* Sleeve used; maximum expansion does not include sleeve thinout

PHASE I - TASK I - MANDREL TAPER DETERMINATION

TEST NUMBER: 1F2S TEST PLATE NUMBER: XIII  
 MANDREL: Push (Design per BAC 5972) NOMINAL SIZE: 3/8 inch  
 MAX. DIA. MANDREL: 0.3580 inch MANDREL MATERIAL: Carboly 883 (GE)  
 MANDREL TAPER: 0.030 inch/inch LUBRICATION: Fel Pro 300  
 TEST MATERIAL: 300 'M' Steel (280/300 ksi) STACK UP: 1-3/8 inch

Hole no.	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole* expansion (calc.)		
	Top	Mid.	Bot.			Top	Mid.	Bot.						Top	Mid	Bot.
A6	3440	3440	3440	-	.0140	3525	3510	3530				7000		0085	0070	0090
A7	3445	3440	3445	-	.0140	3530	3515	3530				6230		0085	0075	0085
A1	3455	3445	3440	45	.0140	3525	3520	3530				7780		0075	0075	0095

\* To nearest 0.0005 inch

PHASE I - TASK I - MANDREL TAPER DETERMINATION

TEST NUMBER: 1F3S TEST PLATE NUMBER: XIII  
 MANDREL: Push (Design per BAC 5972) NOMINAL SIZE: 3/8 inch  
 MAX. DIA. MANDREL: 0.3580 inch MANDREL MATERIAL: Carboloy 883 (GE)  
 MANDREL TAPER: 0.0045 inch/inch LUBRICATION: Fel Pro 300  
 TEST MATERIAL: 300 'M' Steel (280/300 ksi) STACK UP: 1-3/8 inch

Hole no.	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole* expansion (calc.)		
	Top	Mid.	Bot.			Top	Mid.	Bot.						Top	Mid.	Bot.
83	3445	3440	3445	-					Mandrel Broke in Hole							
84	3440	3445	3435	-	.0145	3520	3515	3535				6000		0080	0075	0100
85	3440	3440	3440	40	.0140	3520	3515	3535				5400		0075	0075	0095

\*To nearest 0.0005 inch



PHASE I - TASK I MANDREL TAPER DETERMINATION

TEST NUMBER: 1G2S TEST PLATE NUMBER: X111  
 MANDREL: Push (Design per BAC 5972) NOMINAL SIZE: 3/8 inch  
 MAX. DIA. MANDREL: 0.3580 inch MANDREL MATERIAL: Carboloy 883 (GE)  
 MANDREL TAPER: 0.030 inch/inch LUBRICATION: Fel Pro 300  
 TEST MATERIAL: 300 'M' Steel (280/300 ksi) STACK UP: 1-3/8 inch

Hole no.	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole expansion (calc.)		
	Top	Mid.	Bot.			Top	Mid.	Bot.						Top	Mid.	Bot.
C6	3380	3385	3390	-	.0195	3520	3495	3530				9520		0140	0110	0140
C7	3380	3385	3390	-	.0195	3515	3495	3530				9600		0135	0110	0140
C8	3395	3380	3390	100	.0200	3515	3495	3530				9700		0130	0115	0140

\* To nearest 0.0005 inch





PHASE I - TASK I - MANDREL TAPER DETERMINATION

TEST NUMBER: 1J2S TEST PLATE NUMBER: XIV  
 MANDREL: Push (Design per BAC 5972) NOMINAL SIZE: 3/4 inch  
 MAX. DIA. MANDREL: 0.7280 inch MANDREL MATERIAL: Carboloy 883 (GE)  
 MANDREL TAPER: 0.030 inch/inch LUBRICATION: Fel Pro 300  
 TEST MATERIAL: 300 'M' Steel (280/300 ksi) STACK UP: 2 inch

Hole no.	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole* expansion (calc.)		
	Top	Mid.	Bot.			Top	Mid.	Bot.						Top	Mid.	Bot.
B3	7080	7080	7080	-	.0200	7185	7170	7200				20,700		0105	0090	0120
B4	7080	7080	7080	25	.0200	7180	7170	7200				26,100		0100	0090	0120
C2	7080	7080	7080	-	.0200	7180	7170	7200				18,350		0100	0090	0120
C3	7080	7080	7080	-	.0200	7185	7175	7200				17,050		0100	0095	0120

\* To nearest 0.0005 inch

PHASE I - TASK 1 - MANDREL TAPER DETERMINATION

TEST NUMBER: 1J3S TEST PLATE NUMBER: XIV  
 MANDREL: Push (Design per BAC 5972) NOMINAL SIZE: 3/4 inch  
 MAX. DIA. MANDREL: 0.7280 inch MANDREL MATERIAL: Carboloy 883 (GE)  
 MANDREL TAPER: 0.045 inch/inch LUBRICATION: Fel Pro 300  
 TEST MATERIAL: 300 'M' Steel (280/300 ksi) STACK UP: 2 inch

Hole no.	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole* expansion (calc.)		
	Top	Mid.	Bot.			Top	Mid.	Bot.						Top	Mid.	Bot.
CA	7080	7080	7080	-	.0020	7180	7175	7200				14,900		0100	0095	0120
D2	7080	7080	7080	25	.0200	7180	7175	7200				14,900		0100	0095	0120
D3	7080	7080	7080	-	.0200	7180	7175	7200				14,600		0100	0095	0120
D4	7080	7080	7080	-	.0200	7190	7180	7205				14,850		0110	0100	0125

\* To nearest 0.0005 inch

PHASE I - TASK I - MANDREL TAPER DETERMINATION

TEST NUMBER: 1K1S TEST PLATE NUMBER: XVI  
 MANDREL: Push (Design per BAC 5972) NOMINAL SIZE: 3/4 inch  
 MAX. DIA. MANDREL: 0.7280 inch MANDREL MATERIAL: Carboloy 863 (GE)  
 MANDREL TAPER: 0.015 inch/inch LUBRICATION: Fel Pro 300  
 TEST MATERIAL: 300 M' Steel (280/300 ksi) STACK UP: 2 inch

Hole no	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole* expansion (calc.)		
	Top	Mid.	Bot			Top	Mid.	Bot.						Top	Mid.	Bot.
A1	7030	7030	7035	-	.0250	7155	7150	7200	-			23,000		0125	0120	0165
A2	7035	7035	7035	50	.0245	7160	7155	7195	25			32,900		0125	0120	0160
A3	7030	7035	7030	-	.0245	7165	7155	7200	-			43,300		0135	0120	0170
A4	7030	7035	7040	-	.0245	7160	7155	7200	-			40,000		0130	0120	0160
B2	7030	7030	7030	-	.0245	7170	7160	7210				45,800		0140	0130	0180

\*To nearest 0.0005 inch

PHASE I - TASK I - MANDREL TAPER DETERMINATION

TEST NUMBER: 1K25 TEST PLATE NUMBER: XVI  
 MANDREL: Push (Design per BAC 5972) NOMINAL SIZE: 3/4 inch  
 MAX. DIA. MANDREL: 0.7280 inch MANDREL MATERIAL: Carboloy 883 (GE)  
 MANDREL TAPER: 0.030 inch/inch LUBRICATION: Fel Pro 300  
 TEST MATERIAL: 300 'M' Steel (280/300 ksi) STACK UP: 2 inch

Hole no	Size prior to CW*			Finish prior to LW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole* expansion (calc.)		
	Top	Mid	Bot.			Top	Mid	Bot.						Top	Mid	Bot.
B3	7030	7035	7030	60	.0245	7165	7155	7195	25			27,350		0135	0120	0165
B4	7030	7035	7035	-	.0245	7165	7155	7200	-			20,800		0135	0120	0165
C1	7035	7035	7030	-	.0245	7165	7160	7200	-			22,500		0130	0125	0170
C2	7035	7035	7045	-	.0245	7175	7160	7205	-			40,500		0140	0125	0160
C3	7030	7035	7035	-	.0245	7175	7165	7205	-			45,900		0145	0130	0170

\* To nearest 0.0005 inch

PHASE I - TASK I - MANDREL TAPER DETERMINATION

TEST NUMBER: 1K3S TEST PLATE NUMBER: XVI  
 MANDREL: Push (Design per BAC 5972) NOMINAL SIZE: 3/4 inch  
 MAX. DIA. MANDREL: 0.7280 inch MANDREL MATERIAL: Carboloy 883 (GE)  
 MANDREL TAPER: 0.045 inch/inch LUBRICATION: Fel Pro 300  
 TEST MATERIAL: 300 'M' Steel (280/300 ksi) STACK UP: 2 inch

Hole no	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve thin out	Retained hole* expansion (calc.)		
	Top	Mid.	Bot.			Top	Mid.	Bot.						Top	Mid.	Bot.
C4	7030	7030	7030	-	.0250	7170	7155	7210	-			24,300	Mandrel Broke	0140	0125	0180
D1	7030	7035	7030	-	.0245	7165	7160	7200	-			17,000		0135	0125	0170
D2	7030	7030	7030	75	.0250	7170	7160	7205	30			17,000		0140	0130	0175
D3	7030	7035	7030	-	.0245	7170	7160	7200	-			20,800		0140	0125	0170
U4	7030	7030	7030	-	.0250	7170	7160	7215	-			24,400		0140	0130	0185

\* To nearest 0.0005 inch







PHASE I - TASK I - MANDREL TAPER DETERMINATION

TEST NUMBER: 1L3S TEST PLATE NUMBER: XV  
 MANDREL: Push (Design per BAC 5972) NOMINAL SIZE: 3/4 inch  
 MAX. DIA. MANDREL: 0.7280 inch MANDREL MATERIAL: Carboloy 883 (GE)  
 MANDREL TAPER: 0.045 inch/inch LUBRICATION: Fel Pro 300  
 TEST MATERIAL: 300 'M' Steel (280/300 ksi) STACK UP: 2 inch

Hole no	Size prior to CW*			Finish prior to CW	Maximum expansion (calc.)	Size after CW*			Finish after CW	Upset entrance of hole	Upset exit of hole	Force required for Mandrel	Sleeve in/out	Retained hole* expansion (calc.)		
	Top	Mid.	Bot.			Top	Mid.	Bot.						Top	Mid.	Bot.
C3	6960	6960	6960	-	.0320	7170	7145	7180				19,800		0210	0185	0220
C4	6960	6960	6960	125	.0320	7170	7145	7180				21,500		0210	0185	0220
D1	6965	6965	6970	-	.0315	-	-	-	Mandrel Broke In Hole							

\* To nearest 0.0005 inch

PHASE I - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER: IIA

NOMINAL EXPANSION VALUE: 0.025 in.

GENERAL TEST CONDITIONS

DATE: 11/2/72

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 2  
 Width: 1.50 in.  
 Hole spacing: 1.50 in.  
 Edge margin: 0.75 in.  
 Material: 2024 T-851  
 Material gauge: 0.250 in.  
 Surface Treatment: Shot peen  
 Fastener: None

3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: 0.010 in.  
 Sleeve orientation: 0°  
 CW Mandrel: ST 5300-CBM-12 -0-N  
 CW Mandrel Taper: 0.045 inch/inch  
 CW Mandrel Major Dia.: 0.3540 in.  
 Lubrication: Fel Pro 300 (on sleeve)









2. Hole Preparation

Nominal hole size: 3/8 in.  
 Process: Drill, ream, CW & ream (1/64 in.)

4. Fatigue Conditions

Net stress: 30 ksi max.  
 Test load: 8650 lb  
 Load ratio: (R) = 0.1  
 Test Frequency: 6200/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibraphore (36 kip)

2024  
 0.025-in. interference  
 30 ksi

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches) 	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
II A1	1	.3500	.3635	.3735	10	6	-	.0240	.0135	200+	 .028 in. Bow  (Counter didn't work) cw
	2	.3500	.3635	.3735	15	12	-	.0240	.0135		
II A2	1	.3500	.3655	.3735	15	10	5	.0240	.0155	353	 .022 in. Bow  cw
	2	.3500	.3655	.3735	20	12	-	.0240	.0155		
II A3	1	.3500	.3635	.3735	20	14	-	.0240	.0135	451	 .024 in. Bow  cw
	2	.3500	.3635	.3735	12	7	-	.0240	.0135		

 Taken at Minimum (midpoint)

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PHASE I - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER: IIA

NOMINAL EXPANSION VALUE: 0.025 in.

GENERAL TEST CONDITIONS

DATE: 11/2/72

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 2  
 Width: 1.50 in.  
 Hole spacing: 1.50 in.  
 Edge margin: 0.75 in.  
 Material: 2024 T-851  
 Material gauge: 0.250 in.  
 Surface Treatment: Shot peen  
 Fastener: None

3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: 0.010 in.  
 Sleeve orientation: 0°  
 CW Mandrel: ST 5300-CBM-12 -0-N  
 CW Mandrel Taper: 0.045 inch/inch  
 CW Mandrel Major Dia.: 0.3530 in.  
 Lubrication: Fel Pro 300 (on sleeve)




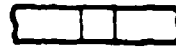

2. Hole Preparation

Nominal hole size: 3/8 in.  
 Process: Drill, ream, CW & ream (1/64 in.)

2024  
 0.025-in. interference  
 30 ksi

4. Fatigue Conditions

Net stress: 30 ksi max  
 Test load: 8650 lb  
 Load ratio: (R) = 0.1  
 Test Frequency: 6200/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibraphore (36 kip)

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches) 	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
II A 4	1	.3505	.3650	.3740	55	20	30	.0225	.0145	275	
	2	.3505	.3660	.3740	50	25	35	.0225	.0150		
											
											

 Taken at Minimum (midpoint)

PHASE I - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER: 11B

NOMINAL EXPANSION VALUE: 0.020 in.

GENERAL TEST CONDITIONS

DATE: 11/2/72

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 2  
 Width: 1.50 in.  
 Hole spacing: 1.50 in.  
 Edge margin: 0.75 in.  
 Material: 2024 T-851  
 Material gauge: 0.250 in.  
 Surface Treatment: Shot peen  
 Fastener: None

3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: 0.010 in.  
 Sleeve orientation: 0°  
 CW Mandrel: ST 5300-CBM-12 -0-N  
 CW Mandrel Taper: 0.045 inch/inch  
 CW Mandrel Major Dia.: 0.3540  
 Lubrication: Fel Pro 300 (on sleeve)









2. Hole Preparation

Nominal hole size: 3/8 in.  
 Process: Drill, ream, CW & ream (1/64 in.)

4. Fatigue Conditions

Ner stress: 30 ksi max  
 Test load: 8650 lb  
 Load ratio: (R) = 0.1  
 Test Frequency: 6200/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibraphore (36 kip)

2024  
 0.020 in. interference  
 30 ksi

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches) 	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
B1	1	.3550	.3655	.3735	8	6	-	.0190	.0105	422	 .020 in. Bow 
	2	.3550	.3655	.3735	10	8	-	.0190	.0105		
B2	1	.3545	.3640	.3735	10	8	-	.0195	.0095	206	 .038 in. Bow 
	2	.3545	.3640	.3735	10	8	10	.0195	.0095		
B3	1	.3550	.3665	.3735	8	6	-	.0190	.0105	256	 16 in Bow 
	2	.3550	.3660	.3735	12	10	-	.0190	.0110		

 Taken at Minimum (midpoint)

PHASE I - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER: IIB

NOMINAL EXPANSION VALUE: 0.020 in.

GENERAL TEST CONDITIONS

DATE: 11/2/72

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 2  
 Width: 1.50 in.  
 Hole spacing: 1.50 in.  
 Edge margin: 0.75 in.  
 Material: 2024 T-851  
 Material gauge: 0.250 in.  
 Surface Treatment: Shot peen  
 Fastener: None

3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: 0.010 in.  
 Sleeve orientation: 0°  
 CW Mandrel: ST 5300-CBM- 12 -0-N  
 CW Mandrel Taper: 0.045 inch/inch  
 CW Mandrel Major Dia.: 0.3539 in.  
 Lubrication: Fel Pro 300 (on sleeve)




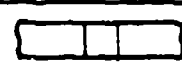
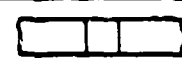
2. Hole Preparation

Nominal hole size: 3/8 in.  
 Process: Drill, ream, CW & ream (1/64 in.)

2024  
 0.020-in. interference  
 30 ksi

4. Fatigue Conditions

Net stress: 30 ksi max  
 Test load: 8650 lb  
 Load ratio: (R) = 0.1  
 Test Frequency: 6200/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibraphore (36 kip)

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches) 	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
IIB 4	1	.3550	.3660	.3740	45	18	30	.0189	.0110	310	
	2	.3550	.3645	.3735	50	20	35	.0189	.0095		
											
											

 Taken at Minimum (midpoint)

PHASE I - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER: IIC

NOMINAL EXPANSION VALUE: 0.015 in.

GENERAL TEST CONDITIONS

DATE: 11/2/72

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 2  
 Width: 1.50 in.  
 Hole spacing: 1.50 in.  
 Edge margin: 0.75 in.  
 Material: 2024 T-851  
 Material gauge: 0.250 in.  
 Surface Treatment: Shot peen  
 Fastener: None

3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: 0.010 in.  
 Sleeve orientation: 0°  
 CW Mandrel: ST 5300-CBM-12 -0-N  
 CW Mandrel Taper: 0.045 inch/inch  
 CW Mandrel Major Dia.: 0.3540 in.  
 Lubrication: Fel Pro 300 (on sleeve)






2. Hole Preparation

Nominal hole size: 3/8 in.  
 Process: Drill, ream, CW & ream (1/64 in.)

2024  
 0.015-in. interference  
 30 ksi

4. Fatigue Conditions

Net stress: 30 ksi max  
 Test load: 8650 lb  
 Load ratio: (R) = 0.1  
 Test Frequency: 6200/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibraphore (36 kip)

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches) 	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
C4	1	.3600	.3665	.3740	5	4	-	.0140	.0065	113	 .026 in. Bow <span style="float: right;">↑ cw</span>
	2	.3600	.3650	.3735	8	5	-	.0140	.0065		
C2	1	.3600	.3665	.3735	10	8	10	.0140	.0065	148	 .010 in. Bow <span style="float: right;">↑ cw</span>
	2	.3600	.3650	.3740	10	8	-	.0140	.0050		
C3	1	.3600	.3650	.3740	8	5	-	.0140	.0050	105	 .016 in. Bow <span style="float: right;">↑ cw</span>
	2	.3600	.3650	.3735	10	6	-	.0140	.0050		

 Taken at Minimum (midpoint)



PHASE I - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER: IID

NOMINAL EXPANSION VALUE: 0.010 in.

GENERAL TEST CONDITIONS

DATE: 11/2/72

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 2  
 Width: 1.50 in.  
 Hole spacing: 1.50 in.  
 Edge margin: 0.75 in.  
 Material: 2024 T-851  
 Material gauge: 0.250 in.  
 Surface Treatment: Shot peen  
 Fastener: None

3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: 0.010 in.  
 Sleeve orientation: 0°  
 CW Mandrel: ST 5300-CBM- 12 -0-N  
 CW Mandrel Taper: 0.045 inch/inch  
 CW Mandrel Major Dia.: 0.3540 in.  
 Lubrication: Fel Pro 300 (on sleeve)






2. Hole Preparation

Nominal hole size: 3/8 in.  
 Process: Drill, ream, CW & ream (1/64 in.)

4. Fatigue Conditions

Net stress: 30 ksi max  
 Test load: 8600 lb  
 Load ratio: (R) = 0.1  
 Test Frequency: 6200/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibraphore (36 kip)

2024  
 0.010-in. interference  
 30 ksi

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (inches)	Retained Diametrical Expansion (inches) 	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
II D1	1	.3650	.3680	.3735	15	10	-	.0090	.0030	50	 .002 in. Bow <span style="float: right;">↑ cw</span>
	2	.3650	.3680	.3735	18	12	-	.0090	.0030		
II D2	1	.3650	.3670	.3735	24	15	10	.0090	.0020	68	 .004 in. Bow <span style="float: right;">↑ cw</span>
	2	.3650	.3680	.3735	20	14	-	.0090	.0030		
II D3	1	.3650	.3680	.3735	18	10	-	.0090	.0030	73	 .011 in. Bow <span style="float: right;">↑ cw</span>
	2	.3650	.3680	.3735	25	14	-	.0090	.0030		

 Taken at Minimum (midpoint)

PHASE I - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER: 11E

NOMINAL EXPANSION VALUE: 0.035 in.

GENERAL TEST CONDITIONS

DATE: 11/2/72

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 3  
 Width: 3.00 in.  
 Hole spacing: 3.00 in.  
 Edge margin: 1.50 in.  
 Material: 2024 T-851  
 Material gauge: 0.375 in.  
 Surface Treatment: Shot peen  
 Fastener: None

3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: 0.015 in.  
 Sleeve orientation: 0°  
 CW Mandrel: ST 5300-CBM - 24 -0-N  
 CW Mandrel Taper: 0.045 inch/inch  
 CW Mandrel Major Dia.: 0.7164 in.  
 Lubrication: Fel Pro 300 (on sleeve)






2. Hole Preparation

Nominal hole size: 3/4 in.  
 Process: Drill, ream, CW & ream (1/64 in.)

2024 0.035-in. interference 30 ksi
--

4. Fatigue Conditions

Net stress: 30 ksi max  
 Test load: 25,400 lb  
 Load ratio: (R) - 0.1  
 Test Frequency: 6500/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibraphore (36 kip)

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (inches)	Retained Diametrical Expansion (inches) 	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
E4	1	.7115	.7320	.7480	25	15	25	.0349	.0205	394	
	2	.7115	.7320	.7480	30	18	20	.0349	.0205		
E5	1	.7120	.7320	.7485	35	18	25	.0344	.0200	431	
	2	.7125	.7320	.7475	45	20	25	.0339	.0195		
											

 Taken at Minimum (midpoint)

PHASE I - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER: 11E

NOMINAL EXPANSION VALUE: 0.035 in.

GENERAL TEST CONDITIONS

DATE: 11/2/72

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 3  
 Width: 3.00 in.  
 Hole spacing: 3.90 in.  
 Edge margin: 1.50 in.  
 Material: 2024 T-851  
 Material gauge: 0.375 in.  
 Surface Treatment: Shot peen  
 Fastener: None

3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: 0.015 in.  
 Sleeve orientation: 0°  
 CW Mandrel: ST 5300-CBM-24 -0-N  
 CW Mandrel Taper: 0.045 inch/inch  
 CW Mandrel Major Dia.: 0.7164 in.  
 Lubrication: Fel Pro 300 (on sleeve)





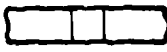
2. Hole Preparation

Nominal hole size: 3/4 in.  
 Process: Drill, ream, CW & ream (1/64 in.)

2024  
 0.035 in. interference  
 40 ksi

4. Fatigue Conditions

Net stress: 40 ksi max  
 Test load: 33,777 lb  
 Load ratio: (R) = 0.1  
 Test Frequency: 8000/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibraphore (36 kip)

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches) 	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
11 E-1	1	.7115	.7335	.7480	45	16	30	.0349	.0220	49	 .034 in. Bow <span style="float: right;">↑ cw</span>
	2	.7115	.7340	.7480	45	14	25	.0349	.0225		
											
											

 Taken at Minimum (midpoint)

PHASE I - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER: 11E

NOMINAL EXPANSION VALUE: 0.035 in.

GENERAL TEST CONDITIONS

DATE: 11/2/72

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 3  
 Width: 3.00 in.  
 Hole spacing: 3.00 in.  
 Edge margin: 1.50 in.  
 Material: 2024 T-851  
 Material gauge: 0.375 in.  
 Surface Treatment: Shot peen  
 Fastener: None

3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: 0.015 in.  
 Sleeve orientation: 0°  
 CW Mandrel: ST 5300-CBM- 24 -0-N  
 CW Mandrel Taper: 0.045 inch/inch  
 CW Mandrel Major Dia.: 0.7164 in.  
 Lubrication: Fel Pro 300 (on sleeve)






2. Hole Preparation

Nominal hole size: 3/4 in.  
 Process: Drill, ream, CW & ream (1/64 in.)

2024  
 0.035-in. interference  
 35 ksi

4. Fatigue Conditions

Net stress: 35 ksi max  
 Test load: 29,500 lb  
 Load ratio: (R) = 0.1  
 Test Frequency: 8000/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibraphore (36 kip)

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches) 	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
11	1	.7115	.7340	.7480	35	16	35	.0349	.0225	112	 .029 in. Bow Grip failure
E2	2	.7115	.7340	.7480	35	12	32	.0349	.0225		
11	1	.7115	.7340	.7480	40	10	28	.0349	.0225	107	 .027 in. Bow <span style="float: right;">↑ cw</span>
E3	2	.7115	.7335	.7480	45	12	30	.0349	.0220		
											

 Taken at Minimum (midpoint)

PHASE I - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER: IIF

NOMINAL EXPANSION VALUE: 0.0315 ± 0.0015 in.

GENERAL TEST CONDITIONS

DATE: 11/2/72

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 3  
 Width: 3.00 in.  
 Hole spacing: 3.00 in.  
 Edge margin: 1.50 in.  
 Material: 2024 T-851  
 Material gauge: 0.375 in.  
 Surface Treatment: Shot peen  
 Fastener: None

3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: 0.015 in.  
 Sleeve orientation: 0°  
 CW Mandrel: ST 5300-CBM- 24 -0-N  
 CW Mandrel Taper: 0.045 inch/inch  
 CW Mandrel Major Dia.: 0.7164 in.  
 Lubrication: Fel Pro 300 (on sleeve)

2. Hole Preparation

Nominal hole size: 3/4 in.  
 Process: Drill, ream, CW & ream (1/64 in.)

4. Fatigue Conditions

Net stress: 30 ksi max  
 Test load: 25,400 lb  
 Load ratio: (R) = 0.1  
 Test Frequency: 6500/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibraphore (36 kip)

2024  
 0.032-in. interference  
 30 ksi

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW	After ream	Before CW	After CW	After Ream				
II F-1	1	.7140	.7340	.7480	44	20	30	.0324	.0200	392	.012 in. Bow  cw
	2	.7140	.7340	.7480	50	25	35	.0324	.0200		
II F-2	1	.7165	.7345	.7480	40	20	12	.0304	.0180	285	.009 in. Bow  cw
	2	.7140	.7340	.7480	45	20	15	.0324	.0200		
II F-3	1	.7150	.7345	.7480	45	20	25	.0314	.0195	360	.022 in. Bow  cw
	2	.7140	.7340	.7480	45	25	30	.0324	.0200		

Taken at Minimum (midpoint)

PHASE I - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER: 11G

NOMINAL EXPANSION VALUE: 0.0265 ± 0.0055 in.

GENERAL TEST CONDITIONS

DATE: 11/2/72

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 3  
 Width: 3.00 in.  
 Hole spacing: 3.00 in.  
 Edge margin: 1.50 in.  
 Material: 2024 T-851  
 Material gauge: 0.375 in.  
 Surface Treatment: Shot peen  
 Fastener: None

3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: 0.015 in.  
 Sleeve orientation: 0°  
 CW Mandrel: ST 5300-CBM- 24 -0-N  
 CW Mandrel Taper: 0.045 inch/inch  
 CW Mandrel Major Dia.: .7164 in.  
 Lubrication: Fel Pro 300 (on sleeve)


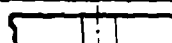
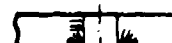



2. Hole Preparation

Nominal hole size: 3/4 in.  
 Process: Drill, ream, CW & ream (1/64 in.)

4. Fatigue Conditions

Net stress: 30 ksi max  
 Test load: 25,500 lb  
 Load ratio: (R) = 0.1  
 Test Frequency: 6500/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibraphore (36 kip)

2024  
 0.027 in. interference  
 30 ksi

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
G1	1	.7195	.7345	.7480	20	12	28	.0269	.0150	245	 Grip failure .020 in. Bow
	2	.7195	.7345	.7480	14	8	25	.0269	.0150		
G2	1	.7195	.7345	.7480	10	8	75	.0269	.0150	297	 .020 in. Bow  cw
	2	.7195	.7350	.7480	23	10	70	.0269	.0155		
G3	1	.7195	.7350	.7480	26	12	20	.0269	.0155	297	 .010 in. Bow  cw
	2	.7195	.7345	.7480	16	10	25	.0269	.0150		

 Taken at Minimum (midpoint)

PHASE I - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER: 11H

NOMINAL EXPANSION VALUE: 0.025 in.

GENERAL TEST CONDITIONS

DATE: 11/2/72

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 3  
 Width: 3.00 in.  
 Hole spacing: 3.00 in.  
 Edge margin: 1.50 in.  
 Material: 2024 T-851  
 Material gauge: 0.375 in.  
 Surface Treatment: Shot peen  
 Fastener: None

3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: 0.015 in.  
 Sleeve orientation: 0°  
 CW Mandrel: ST 5300-CBM- 24 -0-N  
 CW Mandrel Taper: 0.045 inch/inch  
 CW Mandrel Major Dia.: 0.7164 in.  
 Lubrication: Fel Pro 300 (on sleeve)





2. Hole Preparation

Nominal hole size: 3/4 in.  
 Process: Drill, ream, CW & ream (1/64 in.)

2024  
 0.025-in. interference  
 35 ksi

4. Fatigue Conditions

Net stress: 35 ksi max  
 Test load: 29,800 lb  
 Load ratio: (R) = 0.1  
 Test Frequency: 6500/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibraphore (36 kip)

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
11H 1	1	.7235	.7355	.7480	50	20	55	.0229	.0120	55	 ↑ .015 in. Bow cw
	2	.7235	.7350	.7480	32	15	40	.0229	.0125		
											
											

 Taken at Minimum (midpoint)

PHASE I - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER:    JH   

NOMINAL EXPANSION VALUE:    0.025 in.   

GENERAL TEST CONDITIONS

DATE:    11/2/72   

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration:    Fig. 3     
 Width:    3.00 in.     
 Hole spacing:    3.00 in.     
 Edge margin:    1.50 in.     
 Material:    2024 T-851     
 Material gauge:    0.375 in.     
 Surface Treatment:    Shot peen     
 Fastener:    None   

3. CW Process

Sleeve type:    Axial Split     
 Sleeve thickness:    0.015 in.     
 Sleeve orientation:    0°     
 CW Mandrel:    ST 5300-CBM- 24 -0-N     
 CW Mandrel Taper:    0.045 inch/inch     
 CW Mandrel Major Dia.:    0.7164 in.     
 Lubrication:    Fel Pro 300 (on sleeve)   





2. Hole Preparation

Nominal hole size:    3/4 in.     
 Process:    Drill, ream, CW & ream (1/64 in.)   

2024  
 0.025-in. interference  
 30 ksi

4. Fatigue Conditions

Net stress:    30 ksi max     
 Test load:    25,400 lb     
 Load ratio:    (R) = 0.1     
 Test Frequency:    6500/minute     
 Test Laboratory:    Materials     
 Test Engineer:    D. Reese     
 Test Machine:    Vibraphore (36 kip)   

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
II H 2	1	.7235	.7355	.7480	32	17	45	.0229	.0120	164	 .015 in. Bow cw
	2	.7235	.7355	.7480	50	25	42	.0229	.0120		
II H 3	1	.7235	.7355	.7480	50	23	45	.0229	.0120	274	 .025 in. Bow cw
	2	.7235	.7355	.7480	40	16	30	.0229	.0120		
II H 4	1	.7230	.7340	.7480	35	15	20	.0234	.0110	181	
	2	.7230	.7340	.7480	30	12	25	.0234	.0110		

 Taken at Minimum (midpoint)



PHASE I - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER: 11J

NOMINAL EXPANSION VALUE: 0.025 in.

GENERAL TEST CONDITIONS

DATE: 11/10/72

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 2  
 Width: 1.50 in.  
 Hole spacing: 1.50 in.  
 Edge margin: 0.75 in.  
 Material: 6Al-4V Ti  
 Material gauge: 0.250 in.  
 Surface Treatment: Shot peen  
 Fastener: None

3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: 0.010 in.  
 Sleeve orientation: 0°  
 CW Mandrel: ST 5300-CBM- 12 -0-N  
 CW Mandrel Taper: 0.045 inch/inch  
 CW Mandrel Major Dia.: 0.3530 in.  
 Lubrication: Fel Pro 300 (on sleeve)






2. Hole Preparation

Nominal hole size: 3/8 in.  
 Process: Drill, ream, CW & ream (1/64 in.)

6Al-4V  
 0.025-in. interference  
 60 and 70 ksi

4. Fatigue Conditions

Net stress: See remarks  
 Test load: 20,200 lb  
 Load ratio: (R) = 0.1  
 Test Frequency: 6500/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibraphore (36 kip)

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches) 	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
11	1	.3500	.3625	.3735	70	30	25	.0220	.0125	2,197 591	 60 ksi (1st run) 70 ksi (cont'd run) ↑ CW
J1	2	.3500	.3625	.3735	60	25	20	.0220	.0125		
											
											

 Taken at Minimum (midpoint)

PHASE I - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER: 11J

NOMINAL EXPANSION VALUE: 0.026 in.

GENERAL TEST CONDITIONS

DATE: 11/10/72

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 2  
 Width: 1.50 in.  
 Hole spacing: 1.50 in.  
 Edge margin: 0.75 in.  
 Material: 6Al-4V Ti  
 Material gauge: 0.0250 in.  
 Surface Treatment: Shot peen  
 Fastener: None

3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: 0.010 in.  
 Sleeve orientation: 0°  
 CW Mandrel: ST 5300-CBM- 12 -0-N  
 CW Mandrel Taper: 0.045 inch/inch  
 CW Mandrel Major Dia.: 0.3530 in.  
 Lubrication: Fel Pro 300 (on sleeve)



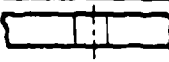


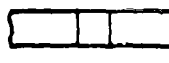
2. Hole Preparation

Nominal hole size: 3/8 in.  
 Process: Drill, ream, CW & ream (1/64 in.)

6Al-4V  
 0.025-in. interference  
 70 ksi

4. Fatigue Conditions

Net stress: 70 ksi max  
 Test load: 20,200 lb  
 Load ratio: (R) = 0.1  
 Test Frequency: 6500/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibraphore (36 kip)

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches) 	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
11	1	.3505	.3625	.3735	60	35	25	.0215	.0120	932	
J2	2	.3505	.3625	.3735	70	30	20	.0215	.0120		
11	1	.3495	.3645	.3730	20	10	15	.0225	.0150	181	 Different mandrel used—dia = .3540 in.  CW
J4	2	.3495	.3645	.3730	-	-	-	.0225	.0150		
											

 Taken at Minimum (midpoint)

PHASE I - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER: 11J

NOMINAL EXPANSION VALUE: 0.025 in.

GENERAL TEST CONDITIONS

DATE: 11/10/72

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 2  
 Width: 1.50 in.  
 Hole spacing: 1.50 in.  
 Edge margin: 0.75 in.  
 Material: 6Al-4V Ti  
 Material gauge: 0.250 in.  
 Surface Treatment: Shot peen  
 Fastener: None

3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: 0.010 in.  
 Sleeve orientation: 0°  
 CW Mandrel: ST 5300-CBM- 12 -0-N  
 CW Mandrel Taper: 0.045 inch/inch  
 CW Mandrel Major Dia.: 0.3530 in.  
 Lubrication: Fel Pro 300 (on sleeve)





2. Hole Preparation


Nominal hole size: 3/8 in.  
 Process: Drill, ream, CW & ream (1/64 in.)

6Al-4V  
 0.025-in. interference  
 80 ksi

4. Fatigue Conditions

Net stress: 80 ksi max  
 Test load: 23,100 lb  
 Load ratio: (R) = 0.1  
 Test Frequency: 6500/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibraphore (36 kip)

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (inches)	Retained Diametrical Expansion (inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
11	1	.3505	.3625	.3735	60	30	20	.0215	.0120	77	 ↑ CW
J3	2	.3505	.3625	.3735	55	25	25	.0215	.0120		
											
											

 Taken at Minimum (midpoint)

PHASE I - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER: 11J

NOMINAL EXPANSION VALUE: 0.025 in.

GENERAL TEST CONDITIONS

DATE: 11/10/72

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 2  
 Width: 1.50 in.  
 Hole spacing: 1.50 in.  
 Edge margin: 0.75 in.  
 Material: 6Al-4V Ti  
 Material gauge: 0.250 in.  
 Surface Treatment: Shot peen  
 Fastener: None

3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: 0.010 in.  
 Sleeve orientation: 0°  
 CW Mandrel: ST 5300-CBM- 12 -0-N  
 CW Mandrel Taper: 0.045 inch/inch  
 CW Mandrel Major Dia.: 0.3540 in.  
 Lubrication: Fel Pro 300 (on sleeve)



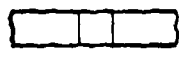
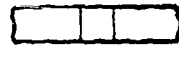
2. Hole Preparation


Nominal hole size: 3/8 in.  
 Process: Drill, ream, CW & ream (1/64 in.)

6Al-4V  
 0.025-in. interference  
 75 ksi

4. Fatigue Conditions

Net stress: 75 ksi max  
 Test load: 20,100 lb  
 Load ratio: (R) 0.1  
 Test Frequency: 6500/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibraphore (36 kip)

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diometrical Expansion (Inches)	Retained Diometrical Expansion (Inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
11	1	.3495	.3645	.3730	15	10	15	.0225	.0150	110	 CW
J5	2	.3495	.3645	.3730	-	-	-	.0225	.0150		
											
											

 Taken at Minimum (midpoint)

PHASE I - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER: 11K

NOMINAL EXPANSION VALUE: 0.016 in.

GENERAL TEST CONDITIONS

DATE: 11/10/72

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 2  
 Width: 1.50 in.  
 Hole spacing: 1.50 in.  
 Edge margin: 0.75 in.  
 Material: 6Al-4V Ti  
 Material gauge: 0.250 in.  
 Surface Treatment: Shot peen  
 Fastener: None

3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: 0.010 in.  
 Sleeve orientation: 0°  
 CW Mandrel: ST 5300-CBM-12 -0-N  
 CW Mandrel Taper: 0.045 inch/inch  
 CW Mandrel Major Dia.: 0.3540 in.  
 Lubrication: Fel Pro 300 (on sleeve)






2. Hole Preparation


Nominal hole size: 3/8 in.  
 Process: Drill, ream, CW & ream (1/64 in.)

6Al-4V  
 0.016-in. interference  
 70 ksi

4. Fatigue Conditions

Net stress: 70 ksi max  
 Test load: 20,200 lb  
 Load ratio: (R) = 0.1  
 Test Frequency: 6500/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophone

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches) 	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
11 K 4	1	.3560	.3655	.3730	15	10	15	.0170	.0096	196	
	2	.3560	.3660	.3730	-	-	-	.0170	.0100		
11 K 5	1	.3560	.3655	.3730	15	10	15	.0170	.0096	94	
	2	.3560	.3655	.3730	-	-	-	.0170	.0096		
											

 Taken at Minimum (midpoint)

PHASE I - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER: IIK

NOMINAL EXPANSION VALUE: 0.020 in.

GENERAL TEST CONDITIONS

DATE: 11/10/72

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 2  
 Width: 1.50 in.  
 Hole spacing: 1.50 in.  
 Edge margin: 0.75 in.  
 Material: 6Al-4V Ti  
 Material gauge: 0.250 in.  
 Surface Treatment: Shot peen  
 Fastener: None

3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: 0.010 in.  
 Sleeve orientation: 0°  
 CW Mandrel: ST 5300-CBM- 12 -G-N  
 CW Mandrel Taper: 0.045 inch/inch  
 CW Mandrel Major Dia.: 0.3530 in.  
 Lubrication: Fel Pro 300 (on sleeve)




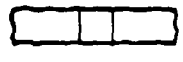
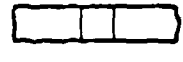
2. Hole Preparation


Nominal hole size: 3/8 in.  
 Process: Drill, ream, CW & ream (1/64 in.)

6Al-4V  
 0.020-in. interference  
 80 ksi

4. Fatigue Conditions

Net stress: 80 ksi max  
 Test load: 23,000 lb  
 Load ratio: (R) 0.1  
 Test Frequency: 6500/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibraphore (36 kip)

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches) 	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
II	1	.3560	.3635	.3730	60	30	20	.0160	.0075	58	 ↑ CW
K1	2	.3560	.3635	.3730	70	35	16	.0160	.0075		
											
											

 Taken at Minimum (midpoint)

PHASE I - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER: IHK

NOMINAL EXPANSION VALUE: 0.020 in.

GENERAL TEST CONDITIONS

DATE: 11/10/72

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 2  
 Width: 1.50 in.  
 Hole spacing: 1.50 in.  
 Edge margin: 0.75 in.  
 Material: 6Al-4V Tj  
 Material gauge: 0.250 in.  
 Surface Treatment: Shot peen  
 Fastener: None

3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: 0.010 in.  
 Sleeve orientation: 0°  
 CW Mandrel: ST 5300-CBM-12 -0-N  
 CW Mandrel Taper: 0.045 inch/inch  
 CW Mandrel Major Dia.: 0.3530 in.  
 Lubrication: Fel Pro 300 (on sleeve)

2. Hole Preparation

Nominal hole size: 3/8 in.  
 Process: Drill, ream, CW & ream (1/54 in.)

6Al-4V  
 0.020 in. interference  
 75 ksi

4. Fatigue Conditions

Net stress: 75 ksi max  
 Test load: 21,800 lb  
 Load ratio: (R) = 0.1  
 Test Frequency: 6500/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibraphore (36 kip)

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After C/V	After Ream				
11 K2		.3655	.3635	.3730	80	45	20	.0185	.0080	113	CW
		.3365	.3635	.3730	75	35	15	.0160	.0075		

Taken at Minimum (midpoint)

PHASE I - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER: IIK

NOMINAL EXPANSION VALUE: 0.020 in.

GENERAL TEST CONDITIONS

DATE: 11/10/72

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig 2  
 Width: 1.50 in.  
 Hole spacing: 1.50 in.  
 Edge margin: 0.75 in.  
 Material: 6Al-4V Ti  
 Material gauge: 0.250 in.  
 Surface Treatment: Shot peen  
 Fastener: None

3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: 0.010 in.  
 Sleeve orientation: 0°  
 CW Mandrel: ST 5300-CBM- 12 -0-N  
 CW Mandrel Taper: 0.045 inch/inch  
 CW Mandrel Major Dia.: 0.3530 in.  
 Lubrication: Fel Pro 300 (on sleeve)






2. Hole Preparation

Nominal hole size: 3/8 in.  
 Process: Drill, ream, CW & ream (1/64 in.)

6Al-4V  
 0.020 in. interference  
 70 ksi

4. Fatigue Conditions

Net stress: 70 ksi max  
 Test load: 20,200 lb  
 Load ratio: (R) = 0.1  
 Test Frequency: 6500/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibraphore (36 kip)

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches) 	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
II	1	.3565	.3635	.3730	60	30	15	.0155	.0070	224	 ↑ CW
K3	2	.3555	.3635	.3730	75	40	20	.0165	.0080		
II	1	.3560	.3655	.3730	15	10	15	.0170	.0095	196	 ↑ CW
K4	2	.3560	.3655	.3730	-	-	-	.0170	.0100		Different mandrel used—dia = .3540 in.
											

 Taken at Minimum (midpoint)



PHASE I - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER: III

NOMINAL EXPANSION VALUE: 0.015 in.

GENERAL TEST CONDITIONS

DATE: 11/10/72

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 2  
 Width: 1.50 in.  
 Hole spacing: 1.50 in.  
 Edge margin: 0.75 in.  
 Material: 6Al-4V Ti  
 Material gauge: 0.250 in.  
 Surface Treatment: Shot peen  
 Fastener: None

3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: 0.010 in.  
 Sleeve orientation: 0°  
 CW Mandrel: ST 5300-CBM- 12 -0-N  
 CW Mandrel Taper: 0.045 inch/inch  
 CW Mandrel Major Dia.: 0.3530 in.  
 Lubrication: Fel Pro 300 (on sleeve)






2. Hole Preparation

Nominal hole size: 3/8 in.  
 Process: Drill, ream, CW & ream (1/64 in.)

6Al-4V  
 0.015-in. interference  
 70 ksi

4. Fatigue Conditions

Net stress: 70 ksi max  
 Test load: 20,200 lb  
 Load ratio: (R) = 0.1  
 Test Frequency: 6500/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibraphore (36 kip)

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (KHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches) 	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
II L1	1	.3615	.3650	.3730	80	45	15	.0105	.0035	102	 ↑ CW
	2	.3615	.3650	.3730	70	45	20	.0105	.0035		
II L2	1	.3615	.3650	.3730	80	50	10	.0105	.0035	140	 ↑ CW
	2	.3610	.3650	.3730	60	40	15	.0110	.0040		
II L3	1	.3610	.3650	.3730	50	35	20	.0110	.0040	95	 ↑ CW
	2	.3615	.3650	.3730	60	40	15	.0105	.0035		

 Taken at Minimum (midpoint)

PHASE I - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER: 11M

NOMINAL EXPANSION VALUE: 0.010 in.

GENERAL TEST CONDITIONS

DATE: 11/10/72

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 2  
 Width: 1.50 in.  
 Hole spacing: 1.50 in.  
 Edge margin: 0.75 in.  
 Material: 6Al-4V Ti  
 Material gauge: 0.250 in.  
 Surface Treatment: Shot peen  
 Fastener: None

3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: 0.010 in.  
 Sleeve orientation: 0°  
 CW Mandrel: ST 5300-C8M- 12 -0-N  
 CW Mandrel Taper: 0.045 inch/inch  
 CW Mandrel Major Dia.: 0.3530  
 Lubrication: Fel Pro 300 (on sleeve)


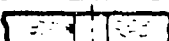
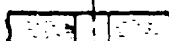
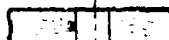
2. Hole Preparation


Nominal hole size: 3/8 in.  
 Process: Drill, ream, CW & ream (1/64 in.)

6Al-1V  
 0.010-in. interference  
 70 ksi

4. Fatigue Conditions

Net stress: 70 ksi max  
 Test load: 20,100 lb  
 Load ratio: (R) = 0.1  
 Test Frequency: 6500/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibraphore (36 kip)

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
M1	1	.3665	.3675	.3735	70	40	20	.0055	.0010	53	 ↑ CW
	2	.3660	.3675	.3735	60	30	25	.0060	.0015		
M2	1	.3660	.3675	.3735	60	35	18	.0060	.0015	57	 ↑ CW
	2	.3660	.3675	.3735	70	40	25	.0060	.0015		
M3	1	.3660	.3675	.3735	70	35	15	.0060	.0015	48	 ↑ CW
	2	.3660	.3675	.3735	75	45	20	.0060	.0015		

 Taken at Minimum (midpoint)

PHASE I - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER: IIN

NOMINAL EXPANSION VALUE: 0.035 in

GENERAL TEST CONDITIONS

DATE: 11/10/72

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 3  
 Width: 3.00 in.  
 Hole spacing: 3.00 in.  
 Edge margin: 1.50 in.  
 Material: 6Al-4V Ti  
 Material gauge: 0.375 in.  
 Surface Treatment: Shot peen  
 Fastener: None

3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: 0.015 in.  
 Sleeve orientation: 0°  
 CW Mandrel: ST 5300-CBM- 24 -0-N  
 CW Mandrel Taper: 0.045 inch/inch  
 CW Mandrel Major Dia.: 0.7140  
 Lubrication: Fel Pro 300 (on sleeve)


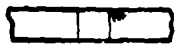


2. Hole Preparation

Nominal hole size: 3/4 in.  
 Process: Drill, ream, CW & ream (1/64 in.)

6Al-4V  
 0.035-in. interference  
 70 ksi

4. Fatigue Conditions

Net stress: 70 ksi max  
 Test load: 60,300 lb  
 Load ratio: (R) : 0.1  
 Test Frequency: 4500/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibraphore (100 kip)

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
II	1	.7095	.7290	.7485	100	45	20	.0325	.0195	105	 ↑ CW
N1	2	.7095	.7290	.7485	-	-	-	.0325	.0195		
II	1	.7095	.7290	.7485	-	-	-	.0325	.0195	65	 ↑ CW
N2	2	.7095	.7290	.7485	-	-	-	.0325	.0195		
II	1	.7095	.7290	.7485	100	50	20	.0325	.0195	30	 ↑ Discolored ↑ CW
N3	2	.7095	.7290	.7485	-	-	-	.0325	.0195		

 Taken at Minimum (midpoint)

PHASE I - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER: 110

NOMINAL EXPANSION VALUE: 0.030 in.

GENERAL TEST CONDITIONS

DATE: 11/10/72

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 3  
 Width: 3.00 in.  
 Hole spacing: 3.00 in.  
 Edge margin: 1.50 in.  
 Material: 6Al-4V Ti  
 Material gauge: 0.375 in.  
 Surface Treatment: Shot peen  
 Fastener: None

3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: 0.015 in.  
 Sleeve orientation: 0°  
 CW Mandrel: ST 5300-CBM- 24 -(-)-N  
 CW Mandrel Taper: 0.045 inch/inch  
 CW Mandrel Major Dia.: 0.7140  
 Lubrication: Fel Pro 300 (on sleeve)






2. Hole Preparation

Nominal hole size: 3/4 in.  
 Process: Drill, ream, CW & ream (1/64 in.)

6Al-4V  
 0.030-in. interference  
 70 ksi

4. Fatigue Conditions

Net stress: 70 ksi max  
 Test load: 60,200 lb  
 Load ratio: (R) = 0.1  
 Test Frequency: 4500/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibraphore (100 kip)

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (inches)	Retained Diametrical Expansion (inches) 	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
11	1	.7130	.7295	.7485	80	35	10	.0290	.0165	95	
	01	2	.7145	.7295	.7485	-	-	-	.0275		
11	1	.7130	.7295	.7485	-	-	-	.0290	.0165	78	
	02	2	.7140	.7295	.7485	-	-	-	.0280		
11	1	.7130	.7295	.7485	90	45	15	.0290	.0165	60	
	03	2	.7140	.7295	.7485	-	-	-	.0280		

 Taken at Minimum (midpoint)

PHASE I - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER: 110

NOMINAL EXPANSION VALUE: 0.030 in.

GENERAL TEST CONDITIONS

DATE: 11/10/72

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 3  
 Width: 3.00 in.  
 Hole spacing: 3.00 in.  
 Edge margin: 1.50 in.  
 Material: 6Al-4V Ti  
 Material gauge: 0.375 in.  
 Surface Treatment: Shot peen  
 Fastener: None

3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: 0.015 in.  
 Sleeve orientation: 0°  
 CW Mandrel: ST 5300-CBM- 24 -0-N  
 CW Mandrel Taper: 0.045 inch/inch  
 CW Mandrel Major Dia.: 0.7140  
 Lubrication: Fel Pro 300 (on sleeve)






2. Hole Preparation

Nominal hole size: 3/4 in.  
 Process: Drill, ream, CW (not postreamed)

6Al-4V  
 0.030-in. interference  
 70 ksi

4. Fatigue Conditions

Net stress: 70 ksi max  
 Test load: 60,100 lb  
 Load ratio: (R) = 0.1  
 Test Frequency: 4500/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibraphore (100 kip)

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches) 	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
04	1	.7140	.7290	-	20	15	-	.0290	.0150	95	 ↑ CW
	2	.7140	.7290	-	25	20	-	.0290	.0150		
05	1	.7140	.7290	-	25	20	-	.0290	.0150	95	 ↑ CW
	2	.7140	.7290	-	25	20	-	.0290	.0150		
											

 Taken at Minimum (midpoint)

PHASE I - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER: IIP

NOMINAL EXPANSION VALUE: 0.025 in.

GENERAL TEST CONDITIONS

DATE: 11/10/72

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 3  
 Width: 3.00 in.  
 Hole spacing: 3.00 in.  
 Edge margin: 1.50 in.  
 Material: 6Al-4V Ti  
 Material gauge: 0.375 in.  
 Surface Treatment: Shot peen  
 Fastener: None

3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: 0.015 in. (thin out .001 in.)  
 Sleeve orientation: 0°  
 CW Mandrel: ST 5300-CBM- 24 -0-N  
 CW Mandrel Taper: 0.045 inch/inch  
 CW Mandrel Major Dia.: 0.7140 in.  
 Lubrication: Fel Pro 300 (on sleeve)





2. Hole Preparation

Nominal hole size: 3/4 in.  
 Process: Drill, ream, CW & ream (1/64 in.)

6Al-4V  
 0.025-in. interference  
 70 ksi

4. Fatigue Conditions

Net stress: 70 ksi max  
 Test load: 60,300 lb  
 Load ratio: (R) 0.1  
 Test Frequency: 4500/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibraphore (100 kip)

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
II P 1	1	.7190	.7305	.7485	80	35	20	.0230	.0115	52	 ↓ CW
	2	.7185	.7305	.7485	-	-	-	.0235	.0120		
II P 2	1	.7185	.7305	.7485	-	-	-	.0235	.0120	71	 ↑ CW
	2	.7190	.7305	.7485	-	-	-	.0230	.0115		
II P 3	1	.7190	.7305	.7485	80	35	20	.0230	.0115	53	 ↑ CW
	2	.7185	.7305	.7485	-	-	-	.0235	.0120		

 Taken at Minimum (midpoint)

PHASE I - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER: 110

NOMINAL EXPANSION VALUE: 0.020 in.

GENERAL TEST CONDITIONS

DATE: 11/10/72

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 3  
 Width: 3.00 in.  
 Hole spacing: 3.00 in.  
 Edge margin: 1.50 in.  
 Material: 6Al-4V Ti  
 Material gauge: 0.375 in.  
 Surface Treatment: Shot peen  
 Fastener: None

3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: 0.015 in.  
 Sleeve orientation: 0°  
 CW Mandrel: ST 5300-CBM- 24 -0-N  
 CW Mandrel Taper: 0.045 inch/inch  
 CW Mandrel Major Dia.: 0.7140 in.  
 Lubrication: Fel Pro 300 (on sleeve)






2. Hole Preparation

Nominal hole size: 3/4 in.  
 Process: Drill, ream, CW & ream (1/64 in.)

6Al-4V  
 0.020-in. interference  
 70 ksi

4. Fatigue Conditions

Net stress: 70 ksi max.  
 Test load: 60,100 lb  
 Load ratio: (R) = 0.1  
 Test Frequency: 4500/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibraphore (100 kip)

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches) 	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
11 Q 1	1	.7235	.7315	.7485	8	5	15	.0185	.0080	25	 ↓ CW
	2	.7240	.7315	.7485	-	-	-	.0180	.0075		
11 Q 2	1	.7235	.7315	.7485	-	-	-	.0185	.0080	47	 ↑ CW
	2	.7240	.7315	.7485	-	-	-	.0180	.0075		
11 Q 3	1	.7235	.7315	.7485	8	5	20	.0185	.0080	44	 ↑ CW
	2	.7240	.7315	.7485	-	-	-	.0180	.0075		

 Taken at Minimum (midpoint)

PHASE I - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER: 11R

NOMINAL EXPANSION VALUE: NONE

GENERAL TEST CONDITIONS

DATE: 11/17/72

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 3  
 Width: 3.00 in.  
 Hole spacing: 3.00 in.  
 Edge margin: 1.50 in.  
 Material: 6Al-4V Ti  
 Material gauge: 0.375 in.  
 Surface Treatment: Shot peen  
 Fastener: None

3. CW Process (not used)

Sleeve type: \_\_\_\_\_  
 Sleeve thickness: \_\_\_\_\_  
 Sleeve orientation: \_\_\_\_\_  
 CW Mandrel: \_\_\_\_\_  
 CW Mandrel Taper: \_\_\_\_\_  
 CW Mandrel Major Dia.: \_\_\_\_\_  
 Lubrication: \_\_\_\_\_





2. Hole Preparation

Nominal hole size: 3/4 in.  
 Process: Drill and ream only

6Al-4V  
 Reamed only  
 70 ksi

4. Fatigue Conditions

Net stress: 70 ksi max  
 Test load: 59,300 lb  
 Load ratio: (R) = 0.1  
 Test Frequency: 4500/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibraphore (100 kip)

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
R 1	1	-	-	.7510	-	-	25	-	-	38	 Cv
	2	-	-	.7500	-	-	20	-	-		
R 2	1	-	-	.7500	-	-	25	-	-	28	
	2	-	-	.7500	-	-	25	-	-		
											

 Taken at Minimum (midpoint)



PHASE I - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER: IIS

NOMINAL EXPANSION VALUE: 0.025 in.

GENERAL TEST CONDITIONS

DATE: 12/7/72

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 2  
 Width: 1.50 in.  
 Hole spacing: 1.50 in.  
 Edge margin: 0.75 in.  
 Material: 300 M steel  
 Material gauge: 0.250 in.  
 Surface Treatment: Shot peen  
 Fastener: None

3. CW Process

Sleeve type: None used  
 Sleeve thickness: -  
 Sleeve orientation: -  
 CW Mandrel: Push (design per BAC 5972)  
 CW Mandrel Taper: 0.030 in./in.  
 CW Mandrel Major Dia.: 0.3580  
 Lubrication: Fel Pro 300

2. Hole Preparation





Nominal hole size: 3/8 in.  
 Process: Drill, ream, CW & ream (1/64 in.)

300M  
 0.025 in. interference  
 110 ksi

Edges cupped on fracture surface from effect of shot peen; hole edges similar

4. Fatigue Conditions

Net stress: 110 ksi max  
 Test load: 31,400 lb  
 Load ratio: (R) = 0.1  
 Test Frequency: 7000/min  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibraphore (36 kip)

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
S1	1	0.3335	0.3505	0.3725	90	75	20	0.0245	0.0170	253	 ↑ cw
	2	0.3335	0.3505	0.3725	-	-	-	0.0245	0.0170		
S2	1	0.3330	0.3505	0.3725	85	70	25	0.0250	0.0170	249	 ↑ cw
	2	0.3335	0.3505	0.3725	-	-	-	0.0245	0.0170		
S3	1	0.3335	0.3505	0.3730	90	75	60	0.0245	0.0170	135	 ↑ cw Hole not cleaned up
	2	0.3335	0.3510	0.3725	-	-	-	0.0245	0.0175		

 Taken at Minimum (midpoint)

PHASE I - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER: IISA

NOMINAL EXPANSION VALUE: 0.021 in.

GENERAL TEST CONDITIONS

DATE: 11/27/72

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 2  
 Width: 1.50 in.  
 Hole spacing: 1.50 in.  
 Edge margin: 0.75 in.  
 Material: 300 M steel  
 Material gauge: 0.250  
 Surface Treatment: Shot peen  
 Fastener: None

3. CW Process

Sleeve type: None used  
 Sleeve thickness: -  
 Sleeve orientation: -  
 CW Mandrel: Push (design per BAC 5972)  
 CW Mandrel Taper: 0.045 in./in.  
 CW Mandrel Major Dia.: 0.3580  
 Lubrication: Fel Pro 300




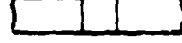
2. Hole Preparation

Nominal hole size: 3/8 in.  
 Process: Drill, ream, CW & ream (1/64 in.)

4. Fatigue Conditions

Net stress: 110 ksi max  
 Test load: 31,300 lb  
 Load ratio: (R) = 0.1  
 Test Frequency: 4000/min  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibraphore (100 kip)

300M  
 0.021 in. interference  
 110 ksi

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
II S4A	1	0.3370	0.3510	0.3720	35	17	20	0.0210	0.0140	55	 ↑ c/w
	2	0.3370	0.3510	0.3725	-	-	-	0.0210	0.0140		
II S5A	1	0.3370	0.3515	0.3720	30	15	20	0.0210	0.0145	44	 ↑ c/w
	2	0.3370	0.3515	0.3720	-	-	-	0.0210	0.145		
											

 Taken at Minimum (midpoint)

PHASE I - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER: II SB

NOMINAL EXPANSION VALUE: 0.023 in.

GENERAL TEST CONDITIONS

DATE: 11/27/72

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 2  
 Width: 1.50 in.  
 Hole spacing: 1.50 in.  
 Edge margin: 0.75 in.  
 Material: 300 M steel  
 Material gauge: 0.250 in.  
 Surface Treatment: Shot peen  
 Fastener: None

3. CW Process

Sleeve type: None used  
 Sleeve thickness:                       
 Sleeve orientation:                       
 CW Mandrel: Push (design per BAC 5972)  
 CW Mandrel Taper: 0.045 in./in.  
 CW Mandrel Major Dia.: 0.3580  
 Lubrication: Fel Pro 300





2. Hole Preparation

Nominal hole size: 3/8 in.  
 Process: Drill, ream, CW & ream (1/64 in.)

4. Fatigue Conditions

Net stress: 110 ksi max  
 Test load: 31,300 lb  
 Load ratio: (R) = 0.1  
 Test Frequency: 4000/min  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibraphore (36 kip)

300M  
 0.023-in. interference  
 110 ksi

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
II S6A	1	0.3350	0.3510	0.3720	30	15	20	0.0230	0.0160	Malfunction	 ↑ CW
	2	0.3350	0.3500	0.3720	-	-	-	0.0230	0.0150		
II S7A	1	0.3350	0.3500	0.3720	35	18	20	0.0230	0.0150	144	 ↑ CW
	2	0.3350	0.3505	0.3720	-	-	-	0.0230	0.0155		
											

 Taken at Minimum (midpoint)

PHASE I - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER: 11T

NOMINAL EXPANSION VALUE: 0.020

GENERAL TEST CONDITIONS

DATE: 12/7/72

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig 2  
 Width: 1.50 in  
 Hole spacing: 1.50 in.  
 Edge margin: 0.75 in.  
 Material: 300 M steel  
 Material gauge: 0.250 in.  
 Surface Treatment: Shot peen  
 Fastener: None

3. CW Process

Sleeve type: None used  
 Sleeve thickness: -  
 Sleeve orientation: -  
 CW Mandrel: Push (design per BAC 5972)  
 CW Mandrel Taper: 0.030 in./in.  
 CW Mandrel Major Dia.: 0.3580  
 Lubrication: Fel Pro 300

2. Hole Preparation






Nominal hole size: 3/8 in.  
 Process: Drill, ream, CW & ream (1/64 in.)


300M  
 0.020 in. interference  
 110 ksi

Failure edges corniced from shot peen effect

4. Fatigue Conditions

Net stress: 110 ksi max  
 Test load: 31,400 lb  
 Load ratio: (R) = 0.1  
 Test Frequency: 6000/4000/min  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrature (36 & 100 kip)

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches) 	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
11	1	0.3390	0.3505	0.3725	60	50	15	0.0190	0.0115	77	 CW 100 kip machine
11	2	0.3390	0.3505	0.3725	-	-	-	0.0190	0.0115		
11	1	0.3390	0.3510	0.3725	60	50	20	0.0190	0.0120	75	 CW 36 kip machine
12	2	0.3390	0.3510	0.3725	-	-	-	0.0190	0.0120		
11	1	0.3390	0.3510	0.3725	60	45	15	0.0190	0.0120	70	 CW 36 kip machine
13	2	0.3390	0.3510	0.3725	-	-	-	0.0190	0.0120		

 Taken at Minimum (midpoint)

PHASE I - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER: 11U

NOMINAL EXPANSION VALUE: 0.015 in.

GENERAL TEST CONDITIONS

DATE: 12/7/72

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 2  
 Width: 1.50 in.  
 Hole spacing: 1.50 in.  
 Edge margin: 0.75 in.  
 Material: 300 M steel  
 Material gauge: 0.250 in.  
 Surface Treatment: Shot peen  
 Fastener: None

3. CW Process

Sleeve type: None used  
 Sleeve thickness: -  
 Sleeve orientation: -  
 CW Mandrel: Push (design per BAC 5972)  
 CW Mandrel Taper: 0.030 in./in.  
 CW Mandrel Major Dia.: 0.3580  
 Lubrication: Fel Pro 300

2. Hole Preparation






Nominal hole size: 3/8 in.  
 Process: Drill, ream, CW & ream (1/64 in.)

300M 0.015-in. interference 110 ksi
---

Failure edges corniced from shot peen effect

4. Fatigue Conditions

Net stress: 110 ksi max  
 Test load: 31,400 lb  
 Load ratio: (R) = 0.1  
 Test Frequency: 7000/4000/min  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibraphore (36 & 100 kip)

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches) 	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
11U1	1	0.3435	0.3515	0.3730	85	70	25	0.0145	0.0080	100	 c/w 36 kip machine
	2	0.3435	0.3515	0.3730	-	-	-	0.0145	0.0080		
11U2	1	0.3435	0.3515	0.3725	85	70	20	0.0145	0.0080	52	 c/w 36 kip machine
	2	0.3435	0.3515	0.3725	-	-	-	0.0145	0.0080		
11U3	1	0.3435	0.3515	0.3730	90	75	15	0.0145	0.0080	55	 c/w 36 & 100 kip machine
	2	0.3430	0.3515	0.3730	-	-	-	0.0150	0.0085		

 Taken at Minimum (midpoint)

PHASE I - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER:     IIV    

NOMINAL EXPANSION VALUE:     0.010 in.    

GENERAL TEST CONDITIONS

DATE:     12/7/72    

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration:     Fig. 3      
 Width:     1.50 in.      
 Hole spacing:     1.50 in.      
 Edge margin:     0.75 in.      
 Material:     300 M steel      
 Material gauge:     0.250 in.      
 Surface Treatment:     Shot peen      
 Fastener:     None    

3. CW Process

Sleeve type:     None used      
 Sleeve thickness:     -      
 Sleeve orientation:     -      
 CW Mandrel:     Push (design per BAC 5972)      
 CW Mandrel Taper:     0.030 in./in.      
 CW Mandrel Major Dia.:     0.3580      
 Lubrication:     Fel Pro 300    

2. Hole Preparation




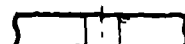
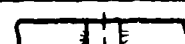
Nominal hole size:     3/8 in.      
 Process:     Drill, ream, CW & ream (1/64 in.)    

300M  
 0.010 in. interference  
 110 ksi

Failure edges corniced from shot peen

4. Fatigue Conditions

Net stress:     110 ksi max      
 Test load:     31,400 lb      
 Load ratio:     (R) = 0.1      
 Test Frequency:     6500/min      
 Test Laboratory:     Materials      
 Test Engineer:     D. Reese      
 Test Machine:     Vibraphore (36 kip)    

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches) 	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
II V1	1	0.3480	0.3525	0.3725	35	30	20	0.0100	0.0045	37	 ↑ c/w
	2	0.3480	0.3525	0.3725	-	-	-	0.0100	0.0045		
II V2	1	0.3495	0.3525	0.3725	30	25	25	0.0085	0.0030	33	 ↑ c/w Hole edge corniced one side
	2	0.3495	0.3525	0.3725	-	-	-	0.0085	0.0030		
II V3	1	0.3490	0.3530	0.3725	30	25	40	0.0090	0.0040	33	 ↑ c/w
	2	0.3495	0.3525	0.3725	-	-	-	0.0085	0.0030		

 Taken at Minimum (midpoint)

PHASE I - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER: II W

NOMINAL EXPANSION VALUE: 0.035 in.

GENERAL TEST CONDITIONS

DATE: 12/7/72

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 3  
 Width: 3.00 in.  
 Hole spacing: 3.00 in.  
 Edge margin: 1.50 in.  
 Material: 300 M steel  
 Material gauge: 0.375 in.  
 Surface Treatment: Shot peen  
 Fastener: None

3. CW Process

Sleeve type: None used  
 Sleeve thickness: -  
 Sleeve orientation: -  
 CW Mandrel: Push (design per BAC 5972)  
 CW Mandrel Taper: 0.030 in./in.  
 CW Mandrel Major Dia.: 0.7280  
 Lubrication: Fel Pro 300






2. Hole Preparation

Nominal hole size: 3/4 in.  
 Process: Drill, ream, CW & ream (1/64 in.)

4. Fatigue Conditions

Net stress: 110 ksi max  
 Test load: 93,600 lb  
 Load ratio: (R) = 0.1  
 Test Frequency: 5000/min  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibraphore (100 kip)

300M  
 0.035-in. interference  
 110 ksi

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches) 	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
II W1	1	0.6920	0.7140	0.7495	35	30	10	0.0360	0.0220	53	 c/w
	2	0.6925	0.7140	0.7495	-	-	-	0.0355	0.0215		
II W2	1	0.6920	0.7140	0.7495	30	25	15	0.0360	0.0220	80	 c/w
	2	0.6925	0.7140	0.7495	-	-	-	0.0355	0.0215		
II W3	1	0.6920	0.7140	0.7495	40	35	10	0.0360	0.0220	59	 c/w
	2	0.6925	0.7140	0.7495	-	-	-	0.0355	0.0215		

 Taken at Minimum (midpoint)

PHASE I - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER: 11 X

NOMINAL EXPANSION VALUE: 0.030 in.

GENERAL TEST CONDITIONS

DATE: 12/7/72

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 3  
 Width: 3.00 in.  
 Hole spacing: 3.00 in.  
 Edge margin: 1.50 in.  
 Material: 300 M steel  
 Material gauge: 0.375 in.  
 Surface Treatment: Shot peen  
 Fastener: None

3. CW Process

Sleeve type: None used  
 Sleeve thickness: -  
 Sleeve orientation: -  
 CW Mandrel: Push (design per BAC 5972)  
 CW Mandrel Taper: 0.030 in./in.  
 CW Mandrel Major Dia.: 0.7280  
 Lubrication: Fel Pro 300





2. Hole Preparation

Nominal hole size: 3/4 in.  
 Process: Drill, ream, CW & ream (1/64 in.)

4. Fatigue Conditions

Net stress: 110 ksi  
 Test load: 93,500 lb  
 Load ratio: (R) = 0.1  
 Test Frequency: 5000/min  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibraphore (100 kip)

300M  
 0.030 in. interference  
 110 ksi

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
11 X1	1	0.6985	0.7165	0.7495	40	35	10	0.0295	0.0180	41	 ↑ c/w
	2	0.6985	0.7165	0.7495	-	-	-	0.0295	0.0180		
11 X2	1	0.6985	0.7165	0.7495	40	35	15	0.0295	0.0180	43	 ↑ c/w
	2	0.6980	0.7165	0.7495	-	-	-	0.0300	0.0185		
11 X3	1	0.6985	0.7165	0.7495	35	30	15	0.0295	0.0180	48	 ↑ c/w
	2	0.6980	0.7165	0.7495	-	-	-	0.0300	0.0185		

 Taken at Minimum (midpoint)



PHASE I - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER: II Y

NOMINAL EXPANSION VALUE: 0.025 in.

GENERAL TEST CONDITIONS

DATE: 12/7/72

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig.3  
 Width: 3.00 in.  
 Hole spacing: 3.00 in.  
 Edge margin: 1.50 in.  
 Material: 300 M steel  
 Material gauge: 0.375 in.  
 Surface Treatment: Shot peen  
 Fastener: None

3. CW Process

Sleeve type: None used  
 Sleeve thickness: -  
 Sleeve orientation: -  
 CW Mandrel: Push (design per BAC 5972)  
 CW Mandrel Taper: 0.030 in./in.  
 CW Mandrel Major Dia.: 0.7280  
 Lubrication: Fel Pro 300






2. Hole Preparation

Nominal hole size: 3/4 in.  
 Process: Drill, ream, CW & ream (1/64 in.)

4. Fatigue Conditions

Net stress: 110 ksi max  
 Test load: 93,400 lb  
 Load ratio: (R) = 0.1  
 Test Frequency: 5000/min  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibraphore (100 kip)

300M  
 0.025-in. interference  
 110 ksi

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches) 	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
II Y1	1	0.7025	0.7170	0.7495	50	45	10	0.0255	0.0135	36	 ↑ c/w
	2	0.7040	0.7165	0.7495	-	-	-	0.0240	0.0125		
II Y2	1	0.7020	0.7165	0.7495	45	40	15	0.0260	0.0145	39	 ↑ c/w
	2	0.7040	0.7170	0.7495	-	-	-	0.0240	0.0130		
II Y3	1	0.7035	0.7170	0.7495	45	40	10	0.0245	0.0135	31	 ↑ c/w
	2	0.7025	0.7170	0.7495	-	-	-	0.0255	0.0145		

 Taken at Minimum (midpoint)

PHASE I - TASK 2 - OPTIMUM EXPANSION DEFINITION

TEST NUMBER: 11Z

NOMINAL EXPANSION VALUE: 0.0

GENERAL TEST CONDITIONS

DATE: 12/7/72

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 3  
 Width: 3.00 in.  
 Hole spacing: 3.00 in.  
 Edge margin: 1.50 in.  
 Material: 300 M steel  
 Material gauge: 0.375 in.  
 Surface Treatment: Shot peen  
 Fastener: None

3. CW Process

Sleeve type: None used  
 Sleeve thickness: -  
 Sleeve orientation: -  
 CW Mandrel: Push (design per BAC 5972)  
 CW Mandrel Taper: 0.030 in./in.  
 CW Mandrel Major Dia.: 0.7280  
 Lubrication: Fel Pro 300






2. Hole Preparation

Nominal hole size: 3/4 in.  
 Process: Drill, ream, CW & ream (1/64 in.)

300M 0.020-in. interference 110 ksi
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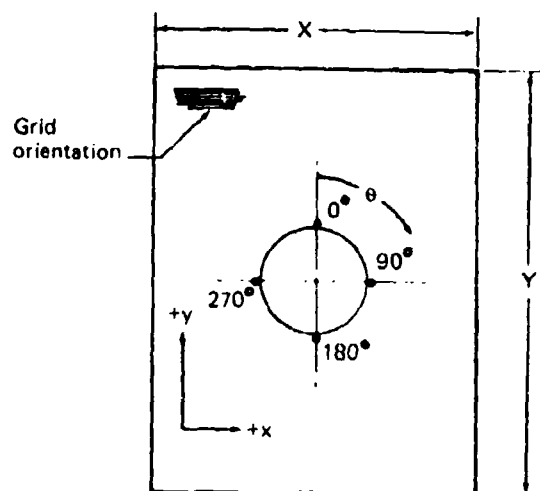
4. Fatigue Conditions

Net stress: 110 ksi max  
 Test load: 93,500 lb  
 Load ratio: (R) : 0.1  
 Test Frequency: 5000/min  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibraphore (100 kip)

Specimen No.	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches) 	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
11 Z1	1	0.7080	0.7175	0.7495	40	35	10	0.0200	0.0095	32	 c/w
	2	0.7080	0.7175	0.7495	-	-	-	0.0200	0.0095		
11 Z2	1	0.7080	0.7180	0.7495	40	35	10	0.0200	0.0100	64	 c/w
	2	0.7080	0.7180	0.7495	-	-	-	0.0200	0.0100		
11 Z3	1	0.7080	0.7175	0.7495	35	30	10	0.0200	0.0095	44	 c/w
	2	0.7080	0.7175	0.7495	-	-	-	0.0200	0.0095		

 Taken at Minimum (midpoint)

PHASE I-TASK 2-MOIRE DATA



Specimen Configuration

View looking at exit side  
 Same reference maintained both sides, i.e., 90° on entrance side  
 is opposite 90° on exit side  
 All strains are  $\epsilon_y$  component

- Area where strain was measured

Specimen no.	Material	Hole size	X (in.)	Y (in.)	<sup>a</sup> $\theta$ (deg)	Affected zone (in.)			
						(Exit face)		(Entrance face)	
						-Y	+Y	-Y	+Y
1	Al	Large	2.3	4.3	18	0.55	0.55	0.60	0.55
2	Al	↑	2.3	4.3	232	0.80	0.50	0.80	0.50
3	Ti	↑	2.8	3.0	38	0.65	0.65	0.65	0.65
4	Ti	↓	2.8	3.0	35	0.90	0.90	0.90	0.90
5	Al	Small	1.5	4.3	180	0.45	0.35	0.45	0.30
6	Al	↑	1.5	4.3	265	0.45	0.35	(b)	
7	Ti	↑	1.5	1.9	45	0.45	0.40	0.40	0.40
8	Ti	↑	1.5	1.9	50	0.40	0.35	0.35	0.35
9	Stl	↓	1.5	1.7	Not visible	0.40	0.35	0.35	0.30

Specimen no.	$\epsilon_y$ (exit face)				$\epsilon_y$ (entrance face)			
	0°	90°	180°	270°	0°	90°	180°	270°
1	.094	.018	.020	.016	.063	.010	.029	.010
2	.025	.018	.110	.028	.030	.012	.048	.011
3	.125	.022	.078	.025	.050	.016	.054	.010
4	.094	.020	.055	.022	.032	.021	.031	.010
5	.016	.036	.068	.023	.028	.018	.090	.020
6	(b)							
7	.034	.034	.065	(b)	.045	.016	.062	.022
8	.064	.029	.085	.011	.029	.015	.055	.019
9	.082	.015	.066	.028	.071	.018	.059	.018

= Questionable because of split discontinuity effect

<sup>a</sup> Location of discontinuity from split in sleeve

<sup>b</sup> Damaged; did not read

PHASE I - TASK 3 - COLDWORK PROCESS FOR STEEL

SPECIMEN 3F1 TEST 1 DATE 10/26/72

MATERIAL: 300 M steel (280/300 ksi) MANDREL MATERIAL: Vascojet 'MA'

MATERIAL STACKUP: 3/8 inch MANDREL TAPER (IN./IN.): 0.015

NOMINAL HOLE SIZE (IN.): 0.364 and 0.358 MANDREL MAX DIA (IN.): 0.3538 (start)

COLDWORK PROCESS: Pull SLEEVE THICKNESS (IN.) 0.0105

LUBRICATION (SLEEVE): Fel-Pro 300

Hole no.	Hole diameter (in.)		Theoretical coldwork diameter expansion (in.) <sup>a</sup>	Pull force (lb)	Sleeve thirout (in.)	Retained coldwork diameter expansion (in.)	Mandrel diameter loss (in.)	Remarks (tool life, operational success, etc.)
	Before coldwork	After coldwork						
A1	0.3635	0.3670	0.0113	2600	0.0004	0.0035	None	Mandrel had deep center.  Difficulty removing sleeve
A2	0.3635	0.3660	0.0113	2340	0.0004	0.0025	None	
A3	0.3635	0.3660	0.0113	2520	0.0004	0.0025	0.0002	
E1	0.3580	0.3635	0.0166	2620	0.0006	0.0045	0.0004	
E2	0.3585	0.3635	0.0157	2630	0.0010	0.0045	0.0004	
E3	0.3585	0.3635	0.0153	2560	0.0015	0.0045	None	

<sup>a</sup> Does not include allowance for mandrel diameter decrease or sleeve thirout

PHASE I - TASK 3 - COLDWORK PROCESS FOR STEEL

SPECIMEN 3F1 TEST 2 DATE 10/26/72

MATERIAL: 300 M steel (280/300 ksi) MANDREL MATERIAL: Vascojet 'MA'  
 MATERIAL STACKUP: 3/4 inch MANDREL TAPER (IN./IN.): 0.015  
 NOMINAL HOLE SIZE (IN.): 0.364 and 0.3580 MANDREL MAX DIA (IN.): 0.3528 (start)  
 COLDWORK PROCESS: Pull SLEEVE THICKNESS (IN.): 0.0105  
 LUBRICATION (SLEEVE): Fel Pro 300

Hole no.	Hole diameter (in.)		Theoretical coldwork diameter expansion (in.) <sup>a</sup>	Pull force (lb)	Sleeve throat (in.)	Retained coldwork diameter expansion (in.)	Mandrel diameter loss (in.)	Remarks (tool life, operational success, etc.)
	Before coldwork:	After coldwork						
A4	0.3630	0.3650	0.0108	3600	0.0010	0.0020	None	(Sleeve could not be removed from hole)
A5	0.3630	0.3655	0.0108	3230	0.0005	0.0025	None	
A6	0.3630	0.3655	0.0108	3280	0.0005	0.0025	None	
E4	0.3580	See remarks	0.0158	4670			0.0006	
E5	0.3580	0.3625	0.0152	5670	0.0010	0.0045	0.0001	
E6	0.3575	0.3630	0.0151	5140	0.0010	0.0045	None	

<sup>a</sup> Does not include allowance for mandrel diameter decrease or sleeve throat

PHASE I - TASK 3 - COLDWORK PROCESS FOR STEEL

SPECIMEN 3F1 TEST 3 DATE 10/26/72

MATERIAL 300 M steel (280,300 ksi) MANDREL MATERIAL A1S1 9260

MATERIAL STACKUP: 3/4 inch MANDREL TAPER (IN /IN.): 0.015

NOMINAL HOLE SIZE (IN.): .3640 and .3580 MANDREL MAX DIA (IN.): 0.3538 (start)

COLDWORK PROCESS: Pull SLEEVE THICKNESS (IN.) 0.0105

LUBRICATION (SLEEVE): FelPro 300

Hole no.	Hole diameter (in.)		Theoretical coldwork diameter expansion (in.) <sup>a</sup>	Pull force (lb)	Sleeve throught (in.)	Retained coldwork diameter expansion (in.)	Mandrel diameter loss (in.)	Remarks (tool life, operational success, etc.)
	Before coldwork	After coldwork						
A7	0.3630	0.3655	0.0118	3940	0.0010	0.0025	0.0004	
A8	0.3630	0.3660	0.0114	3420	0.0010	0.0030	0.0004	
B1	0.3630	0.3650	0.0110	3740	0.0010	0.0020	0.0001	
E7	0.3580	0.3625	0.0159	4320	0.0015	0.0045	0.0007	
E8	0.3585	0.3625	0.0147	4800	0.0015	0.0050	0.0002	
F1	0.3580		0.0150	4460			None	Sleeve could not be removed

<sup>a</sup> Does not include allowance for mandrel diameter decrease or sleeve throught

PHASE 1-TASK 3-COLDWORK PROCESS FOR STEEL

SPECIMEN 3F1 TEST 4 DATE 10/26/72

MATERIAL: 300 M steel (280/300 ksi) MANDREL MATERIAL: H-11 (nitrided)  
 MATERIAL STACKUP: 3/4 inch MANDREL TAPER (IN./IN.): 0.015  
 NOMINAL HOLE SIZE (IN.): 0.3580 MANDREL MAX DIA (IN.): 0.3540 (start)  
 COLDWORK PROCESS: Pull SLEEVE THICKNESS (IN.) 0.0105  
 LUBRICATION (SLEEVE): Fel-Pro 300

Hole no.	Hole diameter (in.)		Theoretical coldwork diameter expansion (in.) <sup>a</sup>	Pull force (lb)	Sleeve thinout (in.)	Retained coldwork diameter expansion (in.)	Mandrel diameter loss (in.)	Remarks (tool life, operational success, etc.)
	Before coldwork	After coldwork						
F2	0.3580	0.3510	0.0170	4900	None	0.0030	0.0058	

<sup>a</sup> Does not include allowance for mandrel diameter decrease or sleeve thinout

PHASE I - TASK 3 - COLDWORK PROCESS FOR STEEL

SPECIMEN      Fatigue coupon      TEST      5      DATE      11/6/72

MATERIAL:      4340 'M' (270/360 ksi)      MANDREL MATERIAL:      Vascojet 'MA'

MATERIAL STACKUP      0.20 inch      MANDREL TAPER (IN./IN.):      0.015

NOMINAL HOLE SIZE (IN.)      3/8      MANDREL MAX DIA (IN.):      0.3521 (at start)

COLDWORK PROCESS      Pull      SLEEVE THICKNESS (IN.)      0.0105

     LUBRICATION (SLEEVE):      FeI Pro. 300

Hole no.	Hole diameter (in.)		Theoretical coldwork diameter expansion (in.) <sup>a</sup>	Pull force (lb)	Sleeve thimout (in.)	Retained coldwork diameter expansion (in.)	Mandrel diameter loss (in.)	Remarks (tool life, operational success, etc.)
	Before coldwork	After coldwork						
1	0.3630	0.3656	0.0101	1880	0.0013	0.0026	None	Mandrel previously used for steel pull testing.
2	0.3540	0.3605	0.0191	3000	0.0035	0.0065	None	
3	0.3540	0.3615	0.0190	2175	0.0025	0.0075	None	
4	0.3540	0.3606	0.0190	2220	0.0025	0.0066	None	

<sup>a</sup> Does not include allowance for mandrel diameter decrease or sleeve thimout



PHASE I - TASK 3 - COLDWORK PROCESS FOR STEEL

SPECIMEN Fatigue coupon TEST 6 DATE 11/6/72

MATERIAL 4340 M' (270-300 ksi) MANDREL MATERIAL AISI 9260

MATERIAL STACKUP 0.20 inch MANDREL TAPER (IN./IN.) 0.015

NOMINAL HOLE SIZE (IN.) 3/8 MANDREL MAX DIA (IN.) 0.3520

COLDWORK PROCESS Pull SLEEVE THICKNESS (IN.) 0.0105

LUBRICATION (SLEEVE) Fel Pro 300

Hole no.	Hole diameter (in.)		Theoretical coldwork diameter expansion (in.) <sup>a</sup>	Pull force (lb)	Sleeve thimout (in.)	Retained coldwork diameter expansion (in.)	Mandrel diameter loss (in.)	Remarks (tool life, operational success, etc.)
	Before coldwork	After coldwork						
1	0.3540	0.3605	0.0190	2335	0.0030	0.0065	None	Sleeve slid in jaws & crippled part of sleeve failed
2	0.3530	0.3573	0.0200	2875	0.0035	0.0043	0.0002	
3	0.3530	0.3600	0.0198	2700	0.0030	0.0070	None	

<sup>a</sup> Does not include allowance for mandrel diameter decrease or sleeve thimout

PHASE 1 - TASK 3 - COLDWORK PROCESS FOR STEEL

SPECIMEN 3F1 TEST 7 DATE: 11/21/72

MATERIAL: 300 M steel (280/300 ksi) MANDREL MATERIAL: Vascojet 'MA'  
 MATERIAL STACKUP: 3/4 inch MANDREL TAPER (IN./IN.): 0.015  
 NOMINAL HOLE SIZE (IN.): 3/8 MANDREL MAX DIA (IN.): 0.3520 (start)  
 COLDWORK PROCESS: Pull SLEEVE THICKNESS (IN.) 0.0105  
 LUBRICATION (SLEEVE): Fel Pro 300

Hole no.	Hole diameter (in.)		Theoretical coldwork diameter expansion (in.) <sup>a</sup>	Pull force (lb.)	Sleeve thimout (in.)	Retained coldwork diameter expansion (in.)	Mandrel diameter loss (in.)	Remarks (tool life, operational success, etc.)
	Before coldwork	After coldwork						
1	0.3500	-	0.0230	10,840	-	-	-	Mandrel tang broke before it reached maximum diameter

<sup>a</sup> Does not include allowance for mandrel diameter decrease or sleeve thimout

PHASE I - TASK 3 - COLDWORK PROCESS FOR STEEL

SPECIMEN 3F1 TEST 8 DATE 11/21/72

MATERIAL: 300 M steel (280/300 ksi) MANDREL MATERIAL: AISI 9260  
 MATERIAL STACKUP: 3/8 inch MANDREL TAPER (IN./IN.): 0.015  
 NOMINAL HOLE SIZE (IN.): 3/8 MANDREL MAX DIA (IN.): 0.3518  
 COLDWORK PROCESS: Pull SLEEVE THICKNESS (IN.) 0.0105  
 LUBRICATION (SLEEVE): Fel Pro 300

Hole no.	Hole diameter (in.)		Theoretical coldwork diameter expansion (in.) <sup>a</sup>	Pull force (lb)	Sleeve thinout (in.)	Retained coldwork diameter expansion (in.)	Mandrel diameter loss (in.)	Remarks (tool life, operational success, etc.)
	Before coldwork	After coldwork						
1	0.3500	-	0.0230	4080	-	-	0.0050	Mandrel diameter decreased too much for production process

<sup>a</sup> Does not include allowance for mandrel diameter decrease or sleeve thinout

### ALLOY 300M\* (Ultra-High Strength Steel)

ALLOY 300M is an alloy steel offering a combination of hardenability, ductility and toughness at tensile strengths from 280000 to 320000 psi.

\* U.S. Pat. 2,791,500

#### Composition:

Carbon	0.40-0.45
Manganese	0.65-0.90
Silicon	1.45-1.80
Nickel	1.65-2.00
Chromium	0.65-0.90
Molybdenum	0.30-0.45
Vanadium	0.05 min.
Phosphorus	0.025 max.
Sulphur	0.025 max.
Iron	Remainder

#### Physical Constants:

Density, lb./cu. in.	0.283
Thermal coef. expansion/°F. x 10 <sup>-6</sup> (0-200°F)	6.3
Thermal conductivity, BTU./ft <sup>2</sup> /in./hr./°F.	260
Specific heat, BTU./lb./°F.	0.107
Modulus of elasticity, psi x 10 <sup>6</sup>	29.30

#### PROPERTIES

Table 1—EFFECT OF TEMPERING TEMPERATURE

(1" rd., oil quenched from 1575°F.)

Tempering Temperature °F	Tensile Strength psi	Yield Strength psi (0.2%)	Charpy Impact ft. lbs.	Elongation % in 2"	Reduction of Area %	Brinell Hardness
200	340000	180000	13.0	6.0	10.0	575
400	310000	240000	16.0	7.0	27.0	555
500	297000	242000	18.0	8.0	32.0	540
600	289000	245500	22.0	9.5	34.0	525
700	280000	235000	17.5	9.0	32.0	500
800	260000	215000	10.0	8.5	23.0	425

Table 2—TYPICAL MECHANICAL PROPERTIES—FORGING

(Quenched in oil and tempered at 500°F.)

	Longitudinal	Transverse
Tensile strength, psi	297000	296000
Notch tensile strength, psi	303000	262000
Yield strength, psi (0.2%)	242000	239000
Elongation, % in 2"	8.0	4.0
Reduction of area, %	23.0	9.4
Charpy impact, ft. lbs. (V-notch)		
at room temp.	18	9
at -65°F.	15	7
Bend test*		
Load, lbs.	10200	9650
Outside angle, deg.	35	25

\* Load applied at center of 7/16" dia. x 5" long specimen supported near end.

Table 3—TYPICAL PROPERTIES OF WELDED TUBES

(5 1/2" dia. x 1/4" wall, flash butt welded tubes, oil quenched and tempered at 400°F.)

	Parent Metal	Across the Weld
Tensile strength, psi	302500	285600
Notch strength, psi	270000	246000
Elongation, % in 2"	9	3
Reduction of area, %	18	7
Charpy impact, ft. lbs. (V-notch)		
at room temp.	20	19
at -65°F.	18	14
Bend Test*		
Max. load, lbs.	9800	8900
Outside bend angle, deg.	35	25

\* Load applied to the center of 7/16" dia. by 5" long rounds supported near ends.

Table 4—EFFECT OF MASS ON TENSILE PROPERTIES\*

(Heat treated by normalizing at 1700°F., oil quenching from 1575°F. and tempering at 600°F.)

Bar Diameter inches	Tensile Strength psi	Yield Strength psi (0.2%)	Elongation % in 2"	Reduction of Area %
1	289000	245500	9.5	34.1
3	281000	236000	9.5	35.0
5 1/4	308000	261000	7.3	22.3

\* Heat treated in full section

**Table 5 -- EFFECT OF MASS ON IMPACT PROPERTIES\***  
(Heat treated by normalizing at 1650°F., oil quenching from 1575°F. and tempering at 600°F.)

Bar Diameter inches	Izod Impact ft. lbs. at +70°F.	Charpy Impact V-Notch, ft. lbs.		
		+70°F.	-50°F.	-100°F.
1	23	72	19	18
3	15	19	14	9
3 3/4	12	9	7	5

\* Heat treated in full section.

**Table 6 -- NOTCH TENSILE TESTS**  
(4 1/2" squares, oil quenched and tempered at 600°F.)

K factor	Orientation	0.3" Diameter		0.5" Diameter	
		Tensile	Yield	Tensile	Yield
10	Longitudinal	320000	275000	275000	262000
	Transverse	315000	245000	245000	221750
5	Longitudinal	345000	307000	307000	262000
	Transverse	312000	312000	312000	262000
3	Longitudinal	385000	358000	358000	335000
	Transverse	385000	335000	335000	335000

(Stress concentration "K" factors were varied by control of notch root radius. The factor for the sharp notch—less than 0.001" radius—is 10.)

**Table 7 -- TYPICAL MECHANICAL PROPERTIES -- CAST**  
(0.36C sand cast keel blocks 1" x 1" x 6")

	Heat Treat A	Heat Treat B
Tensile strength, psi	257500	262000
Yield strength, psi (0.1%)	221250	221750
Elongation, % in 2"	5.8	5.9
Reduction of area, %	10.6	10.8
Charpy impact, ft. lbs. (V-notch) R. T.	10.5	11
	0°F.	10
	-50°F.	10
	-100°F.	8

Heat Treat A—Austenitized at 1650°F. for one hour, transferred to a furnace at 1350°F., held at 1350°F. for 30 minutes, quenched in oil and double tempered at 600°F. for 6 hours.

Heat Treat B—Austenitized at 1650°F. for one hour, transferred to a furnace at 1350°F., held at 500°F. for 5 minutes, air cooled, double tempered at 600°F. for 6 hours.

**Heat Treatment:**

**CRITICAL POINTS:** Ac<sub>1</sub> 1400°F. Ar<sub>1</sub> 650°F.  
Ac<sub>2</sub> 1480°F. Ar<sub>2</sub> 785°F.

(400°F./hr. heating and cooling rate)

**ANNEALING:** Heat to about 1430°F. and equalize, cool 10°F./hr. to 1200°F., 20°F./hr. to 900°F. and air cool for 241 Brinell maximum. (Produces a spheroidized structure.)

**NORMALIZING:** Heat to about 1700°F., air cool. Recharge in furnace before reaching room temperature.

**HARDENING:** Heat to about 1600°F., quench in oil, temper at 500-600°F. Double tempering is advisable.

(It is not recommended for any other tempering temperature. This range produces maximum yield strength and maximum impact strength simultaneously. Tempering on either side of the recommended range results in a serious deterioration of mechanical properties.)

**Machinability:**

Machinability rating of annealed material is 45% of cold-rolled B1112 screw machine stock. Can be machined without difficulty up to 250 Brinell. A partially spheroidized structure obtained by normalizing and drawing at 1200 deg. F. is best for optimum machinability.

High speed steel cutting tools should be ground to R-12 deg. side rake, 6-10 deg. back rake, 7-9 deg. side relief, 7-9 deg. end relief, R-12 deg. end cutting-edge angle, about 15 deg. side cutting-edge angle, and a nose radius of about 10% of depth of cut. Sintered carbide cutting tools should be ground to 4-9 deg. side rake, 0-10 deg. back rake, 6-10 deg. side relief, 6-12 deg. end relief, 8-13 deg. end cutting-edge angle, 0-20 deg. side cutting-edge angle, and a nose radius equal to 1/32 inch.

When machining stock around 200 Brinell hardness with high speed steel cutting tools use cutting speeds of 70 sfpm with feed of 0.060 in. rev. and depth of cut of 1/32 inch; 120 sfpm with feed of 0.015 in. rev. and depth of cut of 1/32 inch. 60 sfpm with feed of 0.030 in. rev. and 1/4 inch depth of cut. With sintered carbide cutting tools use cutting speeds of 260 sfpm with feed of 0.060 in. rev. and depth of cut of 1/32 inch, 470 sfpm with feed of 0.015 in. rev. and depth of cut of 1/32 inch. 205 sfpm with feed of 0.030 in. rev. and depth of cut of 1/4 inch.

**Manufacturers:**

Various alloy steel mills (licensed).

**Workability:**

Forge at 1950-2200°F. and allow to cool in air in a dry place. Forging should not be continued below 1700°F.

**Weldability:**

Good welding characteristics. Can be readily gas or arc welded. Welding rod of the same composition shall be used. In arc welding use a coated welding rod. The retarded grain growth during welding minimizes the normal ill-effects produced by grain coarsening. As the steel has air hardening properties the part after the welding shall be either annealed or normalized and drawn.

**General Characteristics:**

Tough, shock and impact resistant. Has best combination of ductility, toughness, and strength. High fatigue and creep resistant. This steel has air hardening properties and is especially free of temper-brittleness. Maintains good strength properties at elevated temperatures. Wear and abrasion resistant in hardened condition. The high depth hardness is reflected in excellent torque properties. Recommended for heavy duty, high-strength applications.

The most desirable properties of this steel are obtained by using a 600°F. temper after the oil quench. This treatment produces the best yield to tensile strength ratio and the best impact strength for all sizes tested. As shown by the impact data, the steel as tempered at 600°F. does not show any definite transition temperature range. There is a regular decrease in impact strength with decreasing temperature in the manner of 9% nickel steel.

Since tempering above 600°F. is not recommended, this steel should not be employed for service at higher temperatures.

The hardenability of 300-M is so great that it may be heat treated in heavy sections without impairment of its properties. The Jominy hardenability curve, being essentially horizontal for its full length, indicates that the hardenability is too great to be usefully evaluated by this test.

**Forms Available:**

Billets, bars, rods, forgings, sheet, strip, plate and castings

**Applications:**

Aircraft landing gears, airframe parts, high strength bolts, fittings, wing fasteners and pylon parts, carbide-bit bodies, drop forgings for various applications, axles, gears, shafting, pressure vessels, oil-well perforating guns.

**AISI 9260  
(Spring Steel)**

 Published by  
 Engineering Alloys Digest, Inc.  
 Upper Montclair, New Jersey

AISI 9260 is an oil-hardening type of spring steel and tool steel recommended for repeated and severe impact service. It is also used for heavy duty, shock resistant machine parts.

**Composition:**

	9260	9260H
Carbon	0.56-0.64	0.55-0.65
Manganese	0.75-1.00	0.65-1.10
Silicon	1.80-2.20	1.70-2.20
Phosphorus*	0.035 max	0.040 max
Sulphur*	0.040 max	0.040 max
Iron	Remainder	Remainder

\*Phosphorus and sulphur are 0.040 max in open hearth steel and 0.025 max in electric furnace steel.

**Physical Constants:**

Density, lb/cu.in.	0.283
Thermal conductivity, Btu/ft <sup>2</sup> /hr/°F (212°F)	27
Thermal coef. expansion, °F (70-1200°F) x 10 <sup>-6</sup>	8.1
Specific heat, Btu/lb/°F	0.10-0.11
Electrical resistivity, microhm-cm (68°F)	20
Modulus of elasticity, psi x 10 <sup>6</sup> (in tension)	29.0
(in torsion)	10.7

**PROPERTIES**
**Table 1 — TYPICAL MECHANICAL PROPERTIES**

	Normalized	Annealed
Tensile strength, psi	150000	118000
Yield strength, psi (0.2%)	80000	68000
Elongation, % in 2"	15	22
Reduction of area, %	30	46
Brinell hardness	311	241
1000 impact, ft. lbs.	5	5

**Table 2 — TYPICAL HEAT TREATED PROPERTIES**  
 (1" Rd., normalized 1600°F., quenched in oil 1575°F., tempered)

Tempering Temperature °F.	Tensile Strength psi	Yield Strength psi (0.2%)	Elongation % in 2"	Reduction of Area %	Brinell Hardness	1000 Impact ft. lbs.
400	355000	330000	5	19	653	6
500	350000	330000	7	21	655	7
600	340000	325000	9	25	627	7
700	325000	280000	9.5	28	601	8
800	260000	228000	10	30	514	12
900	215000	195000	11	31	429	13
1000	187000	166000	12	32.5	368	14
1100	165000	144000	15	35	341	24
1200	148000	125000	17	40	311	35
1300	130000	105000	20	47	269	59

**Table 3 — MASS EFFECT DATA**

 (5.7 Grain Size, 0.61C, 0.82Mn, 2.11Si, 0.23Cr, 0.08Ni, 0.02Mo)  
 (Bethlehem—Single best results)

Size Inches	Tensile Strength psi	Yield Point psi	Elongation % in 2"	Reduction of Area %	Brinell Hardness	1000 Impact ft. lbs.
Annealed—(Heated to 1575°F., furnace cooled 20°F. hr. to 1280°F., air cooled)						
1	132250	67250	14.5	20.2	262	2.5
Normalized—(Heated to 1600°F., air cooled)						
1/2	166750	98250	15.3	35.8	331	4.0
1	161000	90750	14.7	25.5	321	4.0
2	159500	87250	13.7	30.5	311	4.0
4	144000	86750	4.2	5.9	295	5.0
Oil quenched from 1575°F., tempered at 900°F.						
1/2	230500	207000	10.7	25.7	441	5.7
1	224500	200750	9.2	24.6	444	6.0
2	202000	168250	9.5	22.7	401	6.5
4	173250	105500	4.5	4.5	341	5.5
Oil quenched from 1575°F., tempered at 1100°F.						
1/2	177750	155000	14.2	30.0	352	5.0
1	174250	147500	14.7	34.5	351	8.7
2	160250	130500	16.0	36.0	321	8.2
4	149000	94250	10.5	19.2	321	5.2

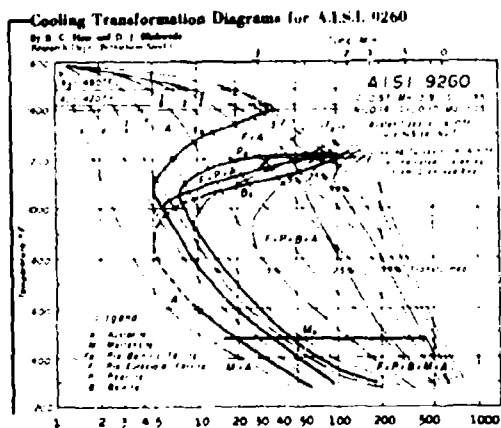
**Table 4 — AS-QUENCHED HARDNESS DATA**

(Oil quenched from 1575°F.)

	Rockwell "C" Hardness			
	1/2" Rd.	1" Rd.	2" Rd.	4" Rd.
Surface	64	62	60	42
1/2" Radius	64	62	55	58
Center	64	62	50	57

**Table 3 - JOMINY HARDENABILITY - 9260H**  
(1/2" distance in 1/16 inch)

"J" distance	1	2	3	4	5	6	7	8	10	12	16	20	24	32
Re max.	-	-	65	64	63	62	60	58	52	47	40	37	36	34
Re min.	60	60	57	53	46	41	38	36	35	34	32	31	30	28



**Heat Treatment:**

Critical Points: Ac<sub>1</sub>, 1440°F  
Ac<sub>3</sub>, 1490°F  
Ar<sub>1</sub>, 1345°F  
Ar<sub>3</sub>, 1330°F

Anneal: Heat to 1525-1575°F, furnace cool.  
Normalize: Heat to 1600-1650°F, quench.  
Harden: Heat to 1575-1625°F, quench in oil, temper to desired hardness.

**Machinability:**

Machinability rating of mill annealed stock (187-255 Brinell) is about 45% of AISI B1112 steel. To obtain best machining properties, heat to 1400-1450°F, cool slowly to 1000°F, then air cool.

Cobalt high-speed steel or carbide-tipped cutting tools are recommended. High-speed steel turning tools should be ground to 8-10° side rake, 6-8° back rake, 7-9° side relief, 7-9° end relief, 10-14° end cutting-edge angle, 12-16° side cutting-edge angle, and a nose radius equal to 10% of depth of cut. Carbide-tipped tools should be ground to 6-10° side rake, 2-6° back rake, 8-10° side relief, 8-10° end relief, 8-10° end cutting-edge angle, 8-14° side cutting-edge angle, and a nose radius of 1/32 inch. For high-speed steel cutters use sulphurized or chlorinated cutting oils, but no cutting oil for carbide-tipped tools.

**Specification Equivalents:**

SAE 9260  
QQ-S-624, F59260  
QQ-S-674, Comp. F  
ASTM A59, Gr. 9260  
ASTM A331 Gr. 9260  
ASTM A304, Gr. 9260H  
MIL-S-6410 Comp. 5

**Workability:**

Forge from 2175°F. to 1750°F. It is subject to decarburization and should therefore not be held at the forging temperature longer than is necessary. After forging, the steel should be cooled slowly by burying in ashes, dry lime, silocel or other dry heat-insulation material.

**Weldability:**

The high carbon and silicon contents of this steel introduces difficulty in welding, which is, therefore, not recommended normally.

**Corrosion Resistance:**

This steel is better than plain carbon steel in industrial atmosphere and about the same when continuously exposed to moisture. If salts are present, corrosion is increased. It is attacked readily by acids, but resistant to alkalis at ordinary temperatures.

**General Characteristics:**

AISI 9260 is recommended for heavy duty springs and for shock resisting parts in which a combination of high ductility with hardness is required. The combined qualities of extremely high strength together with toughness gives this steel the ability to withstand repeated and severe impacts. It is primarily an oil-hardening steel. It may be quenched in water with satisfactory results, but care should be taken if the part has drastic dimensional change or sharp corners. The higher oil-quenching temperature improves the strength, ductility, and shock-resistance. It has good wear-resistance and maximum shock-resistance for hardnesses under Rockwell C58.

Although it is not classed as a non-deforming steel, it will hold size and shape reasonably well during heat treatment, if normal precautions are used in its application and treatment. Where freedom from distortion is of primary importance, the parts should always be oil-quenched rather than water-quenched.

It decarburizes more freely than other tool steels when heated for forging, annealing, or heat treating. This is due to its high silicon and molybdenum content. Care should be exercised during heating to protect it from decarburization. This steel is less notch sensitive than either carbon steel or chromium-vanadium alloy steel.

**Form Available:**

Billets, bars, rods, forgings.

**Applications:**

Heavy duty springs, shear blades, pneumatic tool, punches, shanks for carbide tools, machine parts subject to shock, chisels, caulking tools and all types of severe or unusual service involving drastic or repeated impact at atmospheric temperatures.

**Manufacturers:**

Practically all alloy steel mills.

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Upper Merion, New Jersey

### VASCOJET M-A (CVM) (Ultra High Strength Steel)

Vascojet M-A (CVM) is an ultra high-strength alloy steel capable of reaching tensile strength values up to 360,000 psi and maintaining high strength levels at operating temperatures to 1000 deg. F. It combines extremely high strength with ductility, toughness, fatigue and heat resistance.

#### Composition:

Carbon	0.50-0.55	} Total	12.0
Tungsten			
Molybdenum			
Chromium			
Vanadium			
Iron	Remainder		

#### Physical Constants:

Specific gravity	7.92
Density, lb/cu.in.	0.285
Thermal coef. expansion/°F x 10 <sup>-6</sup> (80-1000°F)	6.4
Modulus of elasticity, psi x 10 <sup>6</sup>	
at 70°F	31.0
at 400°F	28.8
at 1000°F	24.0

### PROPERTIES

**Table 1 - TYPICAL HEAT TREATED PROPERTIES**  
(Standard 0.250" round buttonhead tensile specimens quenched from 2050 deg. F. in salt at 1050 deg. F. and triple tempered (2+2+2 hours) as indicated.)

Tempering Temperature °F	Tensile Strength psi	Yield Strength psi (0.2%)	Elongation % in 2"	Reduction of Area %	Rockwell Hardness "C"	True Fracture Stress psi
975	361700	292600	6.0	20.0	60.9	430500
1000	351600	292600	8.0	33.4	59.9	453500
1025	345800	292400	7.0	34.1	59.5	440200
1050	344400	277700	7.8	33.2	58.6	435200
1075	321800	280200	6.5	31.0	57.3	398500
1100	305200	266500	6.5	28.5	56.1	378700
1150	253400	215500	7.0	25.2	50.4	311200
1200	200900	158500	9.0	33.0	40.9	259200
1300	144000	105400	14.0	48.4	33.5	226700

**Table 2 - TYPICAL TENSILE PROPERTIES AT 350 ksi T.S.**  
(Bar heat treated to 350000 psi (tensile strength))

Tensile strength, psi	350000
Yield strength, psi (0.2%)	290000
Elongation, % in 2"	8
Reduction of area, %	33
Rockwell hardness	C60

**Table 3 - TYPICAL AUSFORMED PROPERTIES\***  
(Austenite deformed 91% at 1100°F before conventional quenching and tempering)

Tempering Temperature °F	Tensile Strength psi	Yield Strength psi (0.2%)	Elongation % in 2"	Reduction of Area %
700	465000	425000	7	22
800	460000	425000	7	25
1000	455000	410000	7	33
1100	435000	390000	9	39

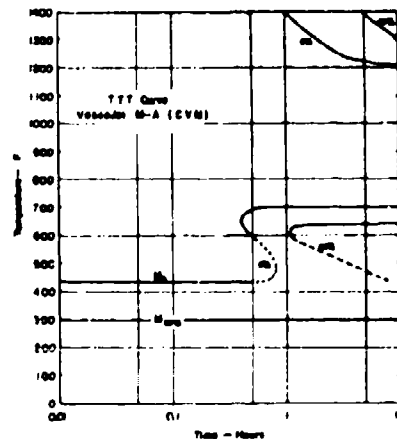
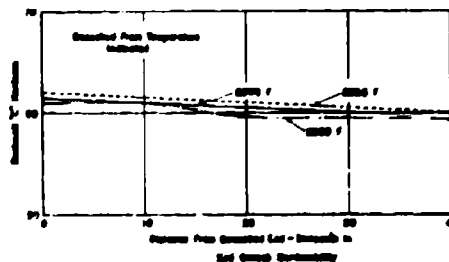
\*From Justsson and Zackay

**Table 4 - IMPACT PROPERTIES**

Rockwell Hardness "C"	Izod Unnotched ft. lbs.	Charpy Unnotched ft. lbs.	Charpy V-Notch ft. lbs.
57.5	120 + (stops beam)	264 + (stops beam)	13
59.0	120 + (stops beam)	264 + (stops beam)	12
61.0	120 + (stops beam)	264 + (stops beam)	8

**Table 5 - TYPICAL ANNEALED PROPERTIES**

Tensile strength, psi	95000
Yield strength, psi (0.2%)	48000
Elongation, % in 2"	23
Reduction of area, %	55
Rockwell hardness	B87-93





**Table 6 - FATIGUE PROPERTIES**

Stress, psi	No. of Cycles
210,000	33,000
170,000	332,000
160,000	768,000
150,000	1,167,000
145,000	2,457,000
140,000	Stopped at 106,000,000

**Table - EFFECT OF TEST TEMPERATURE ON THE TENSILE PROPERTIES**  
(Standard 0.505" round tensile specimens austenitized in salt at 2050°F for 5 minutes, salt quenched at 1050°F, and triple tempered (2 x 2 1/2 hours) as indicated. Average of two tests per condition.)

Testing Temperature °F	Tempering Temperature °F	Yield Strength psi (0.2%)	Tensile Strength psi	Reduction of Area %	Elongation % in 2"
500	1000	249200	417400	37.8	6.3
600	1000	255200	408600	37.2	5.8
800	1000	241600	292900	28.7	5.4
900	1000	221400	278600	30.9	5.9
1000	1000	204300	259000	24.9	5.4
500	1075	245000	289200	39.5	6.0
600	1075	229700	280500	41.7	6.3
800	1075	233500	264200	40.5	6.1
900	1075	206200	251300	38.2	5.7
1000	1075	183000	230100	28.8	6.3

**Heat Treatment:**

**Anneal:** Heat to 1600-1650 deg. F, cool slower than 50 deg. F per hour to 1000 deg. F, then more rapidly to room temperature.

**Hardening:** Preheat at 1550 deg. F, raise temperature rapidly to 2025-2050 deg. F in a protective atmosphere, hold 5-10 minutes at temperature, quench in air, salt, or oil, temper at 950-1150 deg. F. Double or triple tempering is recommended (2 x 2 x 2 hours).

(Phase changes: The steel transforms on slow cooling from austenite to spheroidite, A<sub>1</sub>-1380 to 1430°F.

Martensite start temperature, Ms, is 430°F)

**Stress Relief:** Heat at 875-950°F for 2-4 hours; for finished heat treated parts after grinding, machining or straightening.

**Machinability:**

Rough machining is generally performed on material in the fully annealed condition in much the same manner as any 0.50% C alloy steel.

Single point turning tools of high speed steel should be ground to 8-12° side rake, 6-10° back rake, 7-10° side relief, 7-10° end relief, 8-15° end cutting-edge angle, 12-18° side cutting-edge angle and a nose radius equal to 10% of cut depth. Sintered carbide-tipped tools should be ground to 4-12° side rake, 2-5° back rake, 5-10° side relief, 5-10° end relief, 8-12° end cutting-edge angle, 10-16° side cutting-edge angle and a 1/32" nose radius.

Use sulphurized or chlorinated oils containing sulphur as lubricants with high speed steel cutters.

**Workability:**

**Forging:** Start at 1950 to 1900°F and finish at 1650°F. It should be reheated as often as necessary to prevent forging too cold. Because of its air-hardening properties, it is very necessary that this steel be cooled slowly after forging to prevent the formation of stress cracks. After forging, the material may be returned to a hot furnace and cooled slowly with the furnace, or may be buried in some insulating material such as lime, mica or silocel.

**Forming:** This alloy in the fully annealed condition can be readily formed by all common methods. Straightening can be performed either during cooling from austenitizing or during heating for tempering.

**Weldability:**

Preheat at 500-1000°F, weld with inert gas shielded arc or coated electrodes; maintain temperature above 600°F, cool slowly in furnace or insulating medium. Welded parts have shown excellent weldability with weld metal strength and ductility equal to or greater than the parent metal. Because of its hardenability, welding requires preheating and post-heating and generally is followed by an anneal.

Welded parts are usually slowly cooled to 200°F, followed by immediate tempering to 1250-1400°F, for softening, to permit final straightening and sizing without cracking.

**Corrosion Resistance:**

General corrosion resistance of this steel is low and surface protection is required. For room temperature applications, conventional paint, plating, vapor deposition, and other coatings

may be used. For elevated temperature applications, aluminum silicone paint, nickel-cadmium diffusion plating, nickel-zinc plate, etc. may be used.

Hydrogen embrittlement may occur after hydrogenating treatment of the high strength conditions at high strength levels. Approved plating methods should be followed by baking at temperatures ranging from 375°F for 24 hours (for low heat resistant plate) to 950°F for heat resisting plate. At the upper end of the operating temperature range, protection is required if slight oxidation to a tight scale is not permissible.

**Pickling:**

Heat treated parts should be cleaned by mechanical methods. Pickling or cathodic cleaning are not permissible.

**General Characteristics:**

Vascojet M-A (CVM) is a consumable vacuum arc melted, high strength alloy steel providing more ductility and a smaller differential between longitudinal and transverse mechanical properties. It can be air, salt or oil hardened depending on the section thickness. Triple tempering produces stress relief combined with maximum hardness because tempering is done in the secondary hardening temperature range, i.e., the range in which the steel develops a higher hardness than at a lower temperature; hydrogen, which can cause embrittlement when tensile strength exceeds 200,000 psi, is rapidly removed and strength is not lowered; retained austenite is transformed, reducing the danger of subsequent transformation to martensite with accompanying high stresses during service.

Vascojet M-A (CVM) is a high-strength structural steel offering tensile strength values up to 360,000 psi at room temperature and high strength levels at operating temperatures to 1000°F. It is readily machined and can be formed by all standard methods of fabrication. In order to achieve maximum strength and ductility, it is recommended that this alloy be ordered in the CVM (consumable vacuum melted) grade. Experience indicates that CVM melting, with subsequent removal of dissolved gases and reduction of inclusions to a minimum, improves transverse type properties by factors of two or three to one. This alloy assures outstanding fatigue strength due to the fact that it offers the full advantage of secondary hardening phenomena.

This steel is highly magnetic, but becomes nonmagnetic at temperatures above 1400 to 1500°F. The damping capacity is  $1.3 \times 10^{-4}$  logarithmic decrement.

Vascojet M-A has been found to respond quite satisfactorily to the ausforming process. Tensile strength levels in excess of 450,000 psi with quite respectable ductility are possible.

The deformation of metastable austenite before quenching and tempering enhances strength and hardness.

**Forms Available:**

Billets, forgings, sheet, plate, bars and wire.

**Applications:**

Fasteners, airframes, rocket motor cases, high speed rotors, lightweight axles, gears, shafting, pressure vessels, helicopter rotors, engine mounts, turbine components, and nuclear applications.

**Manufacturer:**

Vanadium Alloys Steel Corp.  
Latrobe, Pennsylvania

Best Available Copy

PHASE I-TASK 4A-EDGE MARGIN AND HOLE SPACING DATA

SPECIMEN NUMBER: 1A DATE: 1/4/73

TEST CONDITIONS

Specimen Description

Material: <u>2024-T851</u>	Hole spacing (in.): <u>1-1/8</u>
Material gage (in.): <u>0.375</u>	Nominal hole size (in.): <u>3/8</u>
Size (L x W)(in.): <u>15 x 1.5</u>	Edge margin: <u>0.75 in.</u>
Numer of holes: <u>12</u>	

Coldwork Information

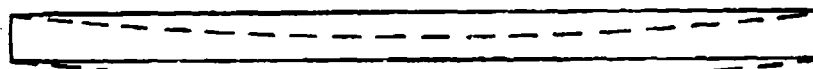
Coldwork process: <u>Sleeve</u>
Mandrel taper (in./in.): <u>0.045</u>
Mandrel diameter (in.): <u>0.3537</u>
Expansion (in.): <u>0.0185</u>

RESULTING DATA

Edge bulge at holes, average (in.):	<u>0.0017</u>
Edge bulge between holes, average (in.):	<u>0.001</u>
<sup>a</sup> Bow after coldwork (in.):	<u>+0.025</u>
<sup>a</sup> Bow after ream and countersink (in.):	<u>+0.0085</u>
<sup>b</sup> Edge distortion after coldwork (in.):	<u>None</u>
<sup>c</sup> Specimen growth after coldwork (in.):	<u>0.0085 in 12.375</u>
Specimen growth after ream (in.):	<u>0.0085 in 12.375</u>
Specimen growth after countersink (in.):	<u>0.0080 in 12.375</u>

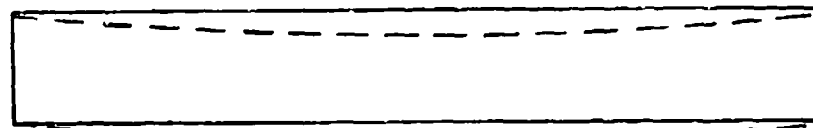
<sup>a</sup>Bow direction

↓ Direction of coldwork



(+) Indicates bow as shown in sketch  
 (-) Indicates bow in opposite direction

<sup>b</sup>Edge distortion:



Value indicates amount of side bow

<sup>c</sup>Measurements taken after each operation indicated. Some of the difference may be contributed to reamer wander and temperature variance

PHASE I--TASK 4A--EDGE MARGIN AND HOLE SPACING DATA

SPECIMEN NUMBER: 2A DATE: 1/4/73

TEST CONDITIONS

Specimen Description

Material:	<u>2024-T851</u>	Hole spacing (in.):	<u>1-1/2</u>
Material gage (in.):	<u>0.375</u>	Nominal hole size (in.):	<u>3/8</u>
Size (L x W)(in.):	<u>15 x 1.5</u>	Edge margin:	<u>0.75 in.</u>
Number of holes:	<u>9</u>		

Coldwork information

Coldwork process:	<u>Sleeve</u>
Mandrel taper (in./in.):	<u>0.045</u>
Mandrel diameter (in.):	<u>0.3537</u>
Expansion (in.):	<u>0.0185</u>

RESULTING DATA

Edge bulge at holes, average (in.):	<u>0.0015</u>
Edge bulge between holes, average (in.):	<u>0.0005</u>
<sup>a</sup> Bow after coldwork (in.):	<u>+0.025</u>
<sup>a</sup> Bow after ream and countersink (in.):	<u>+0.018</u>
<sup>b</sup> Edge distortion after coldwork (in.):	<u>None</u>
<sup>c</sup> Specimen growth after coldwork (in.):	<u>0.0090 in 12</u>
Specimen growth after ream (in.):	<u>0.011 in 12</u>
Specimen growth after countersink (in.):	<u>0.010 in 12</u>

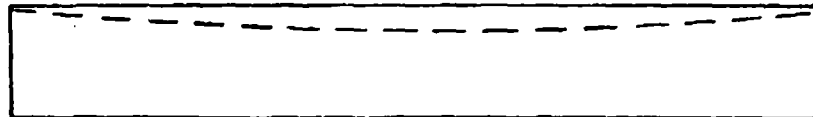
<sup>a</sup>Bow direction

↓ Direction of coldwork



(+) Indicates bow as shown in sketch  
 (-) Indicates bow in opposite direction

<sup>b</sup>Edge distortion



Value indicates amount of side bow

<sup>c</sup>Measurements taken after each operation indicated. Some of the difference may be contributed to reamer wander and temperature variance.

PHASE I-TASK 4A-EDGE MARGIN AND HOLE SPACING DATA

SPECIMEN NUMBER: 3A DATE: 1/4/73

TEST CONDITIONS

Specimen Description

Material: <u>2024-T851</u>	Hole spacing (in.): <u>1-1/8</u>
Material gage (in.): <u>0.375</u>	Nominal hole size (in.): <u>3/8</u>
Size (L x W)(in.): <u>15 x 1-1/8</u>	Edge margin: <u>0.563 in.</u>
Numer of holes: <u>12</u>	

Coldwork Information

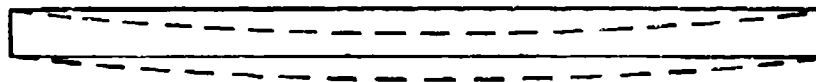
Coldwork process: <u>Sleeve</u>
Mandrel taper (in./in.): <u>0.045</u>
Mandrel diameter (in.): <u>0.3537</u>
Expansion (in.): <u>0.0185</u>

RESULTING DATA

Edge bulge at holes, average (in.):	<u>0.0020</u>
Edge bulge between holes, average (in.):	<u>0.0007</u>
<sup>a</sup> Bow after coldwork (in.):	<u>+0.055</u>
<sup>a</sup> Bow after ream and countersink (in.):	<u>+0.045</u>
<sup>b</sup> Edge distortion after coldwork (in.):	<u>0.003</u>
<sup>c</sup> Specimen growth after coldwork (in.):	<u>0.0165 in 12.375</u>
Specimen growth after ream (in.):	<u>0.0150 in 12.375</u>
Specimen growth after countersink (in.):	<u>0.0150 in 12.375</u>

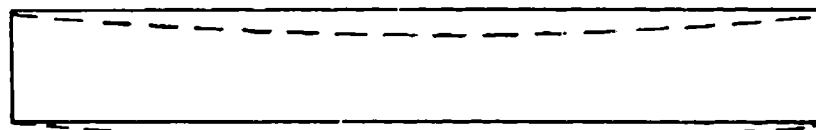
<sup>a</sup>Bow direction

↓ Direction of coldwork



(+) Indicates bow as shown in sketch  
 (-) Indicates bow in opposite direction

<sup>b</sup>Edge distortion



Value indicates amount of side bow

<sup>c</sup>Measurements taken after each operation indicated. Some of the difference may be contributed to reamer wander and temperature variance

PHASE I--TASK 4A--EDGE MARGIN AND HOLE SPACING DATA

SPECIMEN NUMBER: 4A DATE: 1/4/73

TEST CONDITIONS

Specimen Description

Material: <u>2024-T851</u>	Hole spacing (in.): <u>1-1/2</u>
Material gage (in.): <u>0.375</u>	Nominal hole size (in.): <u>3/8</u>
Size (L x W)(in.): <u>15 x 1-1/8</u>	Edge margin: <u>0.563 in.</u>
Numer of holes: <u>9</u>	

Coldwork Information

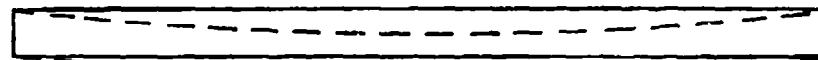
Coldwork process: Sleeve  
 Mandrel taper (in./in.): 0.045  
 Mandrel diameter (in.): 0.3537  
 Expansion (in.): 0.018

RESULTING DATA

Edge bulge at holes, average (in.): 0.0022  
 Edge bulge between holes, average (in.): 0.0005  
<sup>a</sup>Bow after coldwork (in.): +0.051  
<sup>a</sup>Bow after ream and countersink (in.): +0.040  
<sup>b</sup>Edge distortion after coldwork (in.): 0.010  
<sup>c</sup>Specimen growth after coldwork (in.): 0.0165 in 12  
 Specimen growth after ream (in.): 0.0150 in 12  
 Specimen growth after countersink (in.): 0.0145 in 12

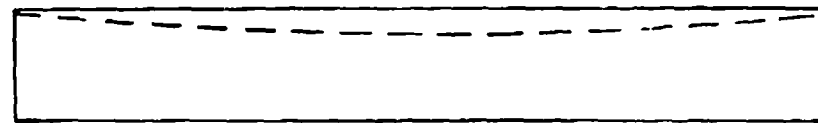
<sup>a</sup>Bow direction

↓ Direction of coldwork



(+) Indicates bow as shown in sketch  
 (-) Indicates bow in opposite direction

<sup>b</sup>Edge distortion



Value indicates amount of side bow

<sup>c</sup>Measurements taken after each operation indicated. Some of the difference may be contributed to reamer wander and temperature variance

PHASE I--TASK 4A--EDGE MARGIN AND HOLE SPACING DATA

SPECIMEN NUMBER: 7A DATE: 1/4/73

TEST CONDITIONS

Specimen Description

Material: <u>2024-T851</u>	Hole spacing (in.): <u>2-1/4</u>
Material gage (in.): <u>0.750</u>	Nominal hole size (in.): <u>3/4</u>
Size (L x W)(in.): <u>15 x 2-1/4</u>	Edge margin: <u>1.125 in.</u>
Numer of holes: <u>6</u>	

Coldwork Information

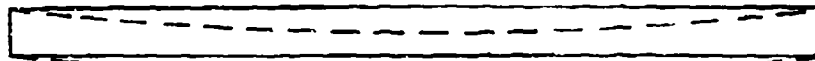
Coldwork process: <u>Sleeve</u>
Mandrel taper (in./in.): <u>0.045</u>
Mandrel diameter (in.): <u>0.7145</u>
Expansion (in.): <u>0.030</u>

RESULTING DATA

Edge bulge at holes, average (in.):	<u>0.0035</u>
Edge bulge between holes, average (in.):	<u>0.0015</u>
<sup>a</sup> Bow after coldwork (in.):	<u>+0.009</u>
<sup>a</sup> Bow after ream and countersink (in.):	<u>+0.006</u>
<sup>b</sup> Edge distortion after coldwork (in.):	<u>None</u>
<sup>c</sup> Specimen growth after coldwork (in.):	<u>0.011 in 11.25</u>
Specimen growth after ream (in.):	<u>0.013 in 11.25</u>
Specimen growth after countersink (in.):	<u>0.013 in 11.25</u>

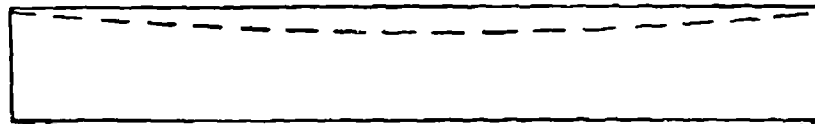
<sup>a</sup>Bow direction

↓ Direction of coldwork



(+) Indicates bow as shown in sketch  
 (-) Indicates bow in opposite direction

<sup>b</sup>Edge distortion



Value indicates amount of side bow

<sup>c</sup>Measurements taken after each operation indicated. Some of the difference may be contributed to reamer wander and temperature variance

PHASE I--TASK 4A--EDGE MARGIN AND HOLE SPACING DATA

SPECIMEN NUMBER: 8A DATE: 1/4/73

TEST CONDITIONS

Specimen Description

Material: <u>2024-T851</u>	Hole spacing (in.): <u>3.00</u>
Material gage (in.): <u>0.750</u>	Nominal hole size (in.): <u>3/4</u>
Size (L x W)(in.): <u>15 x 2-1/4</u>	Edge margin: <u>1.125 in.</u>
Numer of holes: <u>4</u>	

Coldwork Information

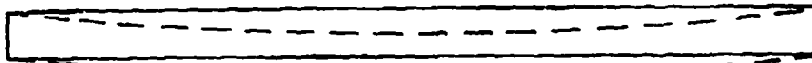
Coldwork process: <u>Sleeve</u>
Mandrel taper (in./in.): <u>0.045</u>
Mandrel diameter (in.): <u>0.7142</u>
Expansion (in.): <u>0.030</u>

RESULTING DATA

Edge bulge at holes, average (in.):	<u>0.004</u>
Edge bulge between holes, average (in.):	<u>None</u>
<sup>a</sup> Bow after coldwork (in.):	<u>+0.008</u>
<sup>a</sup> Bow after ream and countersink (in.):	<u>+0.008</u>
<sup>b</sup> Edge distortion after coldwork (in.):	<u>None</u>
<sup>c</sup> Specimen growth after coldwork (in.):	<u>0.0095 in 9</u>
Specimen growth after ream (in.):	<u>0.0115 in 9</u>
Specimen growth after countersink (in.):	<u>0.0120 in 9</u>

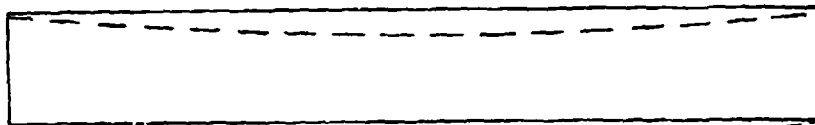
<sup>a</sup>Bow direction

↓ Direction of coldwork



(+) indicates bow as shown in sketch  
 (-) indicates bow in opposite direction

<sup>b</sup>Edge distortion



Value indicates amount of side bow.

<sup>c</sup>Measurements taken after each operation indicated. Some of the difference may be contributed to reamer wander and temperature variance

PHASE I--TASK 4A--EDGE MARGIN AND HOLE SPACING DATA

SPECIMEN NUMBER: 9A DATE: 1/4/73

TEST CONDITIONS

Specimen Description

Material: <u>2024-T851</u>	Hole spacing (in.): <u>2-1/4</u>
Material gage (in.): <u>0.750</u>	Nominal hole size (in.): <u>3/4</u>
Size (L x W)(in.): <u>15 x 3</u>	Edge margin: <u>1.50 in.</u>
Numer of holes: <u>6</u>	

Coldwork Information

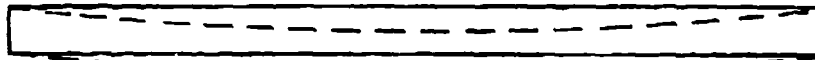
Coldwork process: <u>Sleeve</u>
Mandrel taper (in./in.): <u>0.045</u>
Mandrel diameter (in.): <u>0.7142</u>
Expansion (in.): <u>0.030</u>

RESULTING DATA

Edge bulge at holes, average (in.):	<u>0.003</u>
Edge bulge between holes, average (in.):	<u>0.0015</u>
<sup>a</sup> Bow after coldwork (in.):	<u>+0.006</u>
<sup>a</sup> Bow after ream and countersink (in.):	<u>+0.004</u>
<sup>b</sup> Edge distortion after coldwork (in.):	<u>None</u>
<sup>c</sup> Specimen growth after coldwork (in.):	<u>0.0063 in 11.25</u>
Specimen growth after ream (in.):	<u>0.0065 in 11.25</u>
Specimen growth after countersink (in.):	<u>0.0070 in 11.25</u>

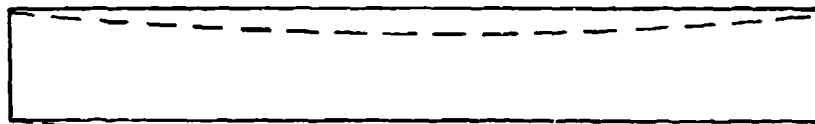
<sup>a</sup>Bow direction

↓ Direction of coldwork



(+) Indicates bow as shown in sketch  
 (-) Indicates bow in opposite direction

<sup>b</sup>Edge distortion



Value indicates amount of side bow

<sup>c</sup>Measurements taken after each operation indicated. Some of the difference may be contributed to reamer wander and temperature variance.



PHASE I- TASK 4A-EDGE MARGIN AND HOLE SPACING DATA

SPECIMEN NUMBER: 10A DATE: 1/4/73

TEST CONDITIONS

Specimen Description

Material: <u>2024-T851</u>	Hole spacing (in.): <u>3.00</u>
Material gage (in.): <u>0.750</u>	Nominal hole size (in.): <u>3/4</u>
Size (L x W)(in.): <u>15 x 3</u>	Edge margin: <u>1.50 in.</u>
Number of holes: <u>4</u>	

Coldwork Information

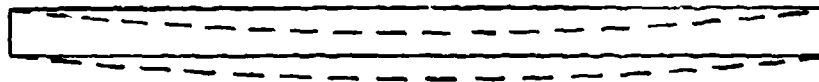
Coldwork process: <u>Sleeve</u>
Mandrel taper (in./in.): <u>0.045</u>
Mandrel diameter (in.): <u>0.7142</u>
Expansion (in.): <u>0.030</u>

RESULTING DATA

Edge bulge at holes, average (in.):	<u>0.0025</u>
Edge bulge between holes, average (in.):	<u>None</u>
<sup>a</sup> Bow after coldwork (in.):	<u>+0.006</u>
<sup>a</sup> Bow after ream and countersink (in.):	<u>+0.004</u>
<sup>b</sup> Edge distortion after coldwork (in.):	<u>None</u>
<sup>c</sup> Specimen growth after coldwork (in.):	<u>0.0045 in 9</u>
Specimen growth after ream (in.):	<u>0.0036 in 9</u>
Specimen growth after countersink (in.):	<u>0.0035 in 9</u>

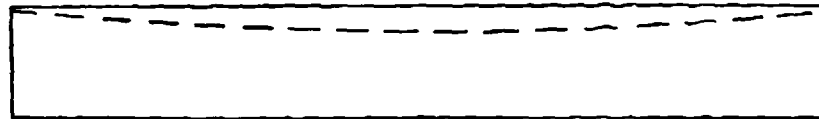
<sup>a</sup>Bow direction

↓ Direction of coldwork



(+) Indicates bow as shown in sketch  
 (-) Indicates bow in opposite direction

<sup>b</sup>Edge distortion



Value indicates amount of side bow

<sup>c</sup>Measurements taken after each operation indicated. Some of the difference may be contributed to reamer wander and temperature variance.

PHASE I - TASK 4A-EDGE MARGIN AND HOLE SPACING DATA

SPECIMEN NUMBER: 1T DATE: 1/6/73

TEST CONDITIONS

Specimen Description

Material: <u>Ti-6Al-4V</u>	Hole spacing (in.): <u>1-1/8</u>
Material gage (in.): <u>0.375</u>	Nominal hole size (in.): <u>3/8</u>
Size (L x W)(in.): <u>15 x 1.5</u>	Edge margin: <u>0.75 in.</u>
Number of holes: <u>12</u>	

Coldwork Information

Coldwork process: <u>Sleeve</u>
Mandrel taper (in./in.): <u>0.045</u>
Mandrel diameter (in.): <u>0.3537</u>
Expansion (in.): <u>0.018</u>

RESULTING DATA

Edge bulge at holes, average (in.):	<u>0.0015</u>
Edge bulge between holes, average (in.):	<u>0.0010</u>
<sup>a</sup> Bow after coldwork (in.):	<u>+0.035</u>
<sup>a</sup> Bow after ream and countersink (in.):	<u>None</u>
<sup>b</sup> Edge distortion after coldwork (in.):	<u>0.001</u>
<sup>c</sup> Specimen growth after coldwork (in.):	<u>0.016 in 12.375</u>
Specimen growth after ream (in.):	<u>0.018 in 12.375</u>
Specimen growth after countersink (in.):	<u>0.0175 in 12.375</u>

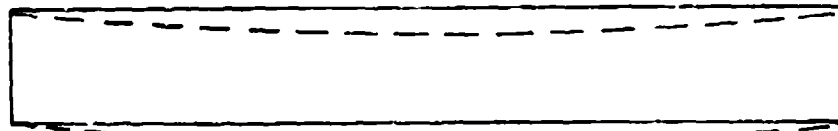
<sup>a</sup>Bow direction

↓ Direction of coldwork



(+) Indicates bow as shown in sketch  
 (-) Indicates bow in opposite direction

<sup>b</sup>Edge distortion



Value indicates amount of side bow

<sup>c</sup>Measurements taken after each operation indicated. Some of the difference may be contributed to reamer wander and temperature variance

PHASE I - TASK 4A - EDGE MARGIN AND HOLE SPACING DATA

SPECIMEN NUMBER: 2T DATE: 1/8/73

TEST CONDITIONS

Specimen Description

Material: <u>Ti-6Al-4V</u>	Hole spacing (in.): <u>1.5</u>
Material gage (in.): <u>0.375</u>	Nominal hole size (in.): <u>3/8</u>
Size (L x W)(in.): <u>15 x 1.5</u>	Edge margin: <u>0.75 in.</u>
Number of holes: <u>9</u>	

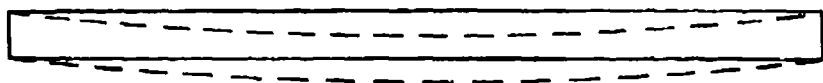
Coldwork Information

Coldwork process: <u>Sleeve</u>
Mandrel taper (in./in.): <u>0.045</u>
Mandrel diameter (in.): <u>0.3537</u>
Expansion (in.): <u>0.018</u>

RESULTING DATA

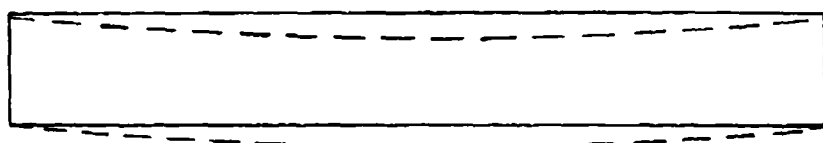
Edge bulge at holes, average (in.):	<u>0.0010</u>
Edge bulge between holes, average (in.):	<u>0.0005</u>
<sup>a</sup> Bow after coldwork (in.):	<u>+0.017</u>
<sup>a</sup> Bow after ream and countersink (in.):	<u>-0.005</u>
<sup>b</sup> Edge distortion after coldwork (in.):	<u>0.002</u>
<sup>c</sup> Specimen growth after coldwork (in.):	<u>0.016 in 12</u>
Specimen growth after ream (in.):	<u>0.017 in 12</u>
Specimen growth after countersink (in.):	<u>0.017 in 12</u>

<sup>a</sup>Bow direction ↓ Direction of coldwork



(+) Indicates bow as shown in sketch  
 (-) Indicates bow in opposite direction

<sup>b</sup>Edge distortion



Value indicates amount of side bow

<sup>c</sup>Measurements taken after each operation indicated. Some of the difference may be contributed to reamer wander and temperature variance.

PHASE I- TASK 4A-EDGE MARGIN AND HOLE SPACING DATA

SPECIMEN NUMBER: 3T

DATE: 1/8/73

TEST CONDITIONS

Specimen Description

Material: Ti-6Al-4V  
 Material gage (in.): 0.375  
 Size (L x W)(in.): 15 x 1-1/8  
 Number of holes: 12

Hole spacing (in.): 1-1/8  
 Nominal hole size (in.): 3/8  
 Edge margin: 0.563 in.

Coldwork Information

Coldwork process: Sleeve  
 Mandrel taper (in./in.): 0.045  
 Mandrel diameter (in.): 0.3537  
 Expansion (in.): 0.018

RESULTING DATA

Edge bulge at holes, average (in.): 0.0032  
 Edge bulge between holes, average (in.): 0.0010  
<sup>a</sup>Bow after coldwork (in.): +0.042  
<sup>a</sup>Bow after ream and countersink (in.): +0.016  
<sup>b</sup>Edge distortion after coldwork (in.): 0.001  
<sup>c</sup>Specimen growth after coldwork (in.): 0.0145 in 12.375  
 Specimen growth after ream (in.): 0.0130 in 12.375  
 Specimen growth after countersink (in.): 0.0130 in 12.375

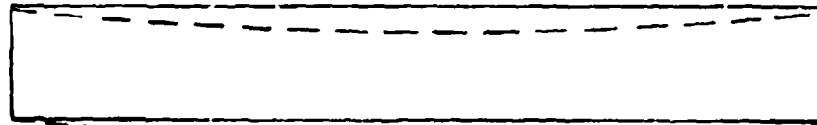
<sup>a</sup>Bow direction

↓ Direction of coldwork



(+) Indicates bow as shown in sketch  
 (-) Indicates bow in opposite direction

<sup>b</sup>Edge distortion



Value indicates amount of side bow

<sup>c</sup>Measurements taken after each operation indicated. Some of the difference may be contributed to reamer wander and temperature variance

PHASE I--TASK 4A--EDGE MARGIN AND HOLE SPACING DATA

SPECIMEN NUMBER: 4T DATE: 1/8/73

TEST CONDITIONS

Specimen Description

Material: <u>Ti-6Al-4V</u>	Hole spacing (in.): <u>1.5</u>
Material gage (in.): <u>0.375</u>	Nominal hole size (in.): <u>3/8</u>
Size (L x W)(in.): <u>15 x 1-1/8</u>	Edge margin: <u>0.563 in.</u>
Number of holes: <u>9</u>	

Coldwork Information

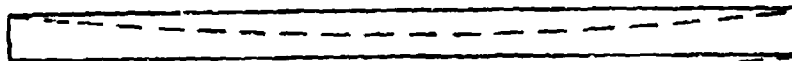
Coldwork process: <u>Sleeve</u>
Mandrel taper (in./in.): <u>0.045</u>
Mandrel diameter (in.): <u>0.3537</u>
Expansion (in.): <u>0.018</u>

RESULTING DATA

Edge bulge at holes, average (in.):	<u>0.0024</u>
Edge bulge between holes, average (in.):	<u>0.0005</u>
<sup>a</sup> Bow after coldwork (in.):	<u>+0.055</u>
<sup>a</sup> Bow after ream and countersink (in.):	<u>+0.028</u>
<sup>b</sup> Edge distortion after coldwork (in.):	<u>0.003</u>
<sup>c</sup> Specimen growth after coldwork (in.):	<u>0.0145 in 12</u>
Specimen growth after ream (in.):	<u>0.0160 in 12</u>
Specimen growth after countersink (in.):	<u>0.0155 in 12</u>

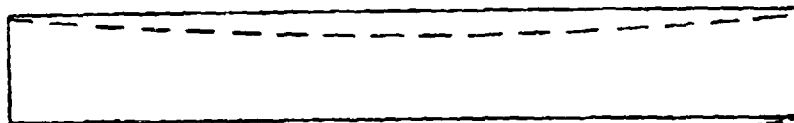
<sup>a</sup>Bow direction

↓ Direction of coldwork



(+) Indicates bow as shown in sketch  
 (-) Indicates bow in opposite direction

<sup>b</sup>Edge distortion



Value indicates amount of side bow

<sup>c</sup>Measurements taken after each operation indicated. Some of the difference may be contributed to reamer wander and temperature variance

PHASE I--TASK 4A--EDGE MARGIN AND HOLE SPACING DATA

SPECIMEN NUMBER: 7T DATE: 1/8/73

TEST CONDITIONS

Specimen Description

Material: <u>Ti-6Al-4V</u>	Hole spacing (in.): <u>2-1/4</u>
Material gage (in.): <u>0.75</u>	Nominal hole size (in.): <u>3/4</u>
Size (L x W)(in.): <u>15 x 2-1/4</u>	Edge margin: <u>1.125 in.</u>
Number of holes: <u>6</u>	

Coldwork Information

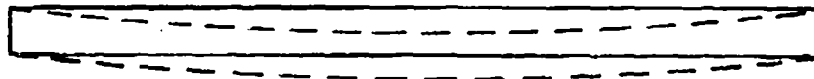
Coldwork process: <u>Sleeve</u>
Mandrel taper (in./in.): <u>0.045</u>
Mandrel diameter (in.): <u>0.714</u>
Expansion (in.): <u>0.029</u>

RESULTING DATA

Edge bulge at holes, average (in.):	<u>0.003</u>
Edge bulge between holes, average (in.):	<u>0.001</u>
<sup>a</sup> Bow after coldwork (in.):	<u>+0.003</u>
<sup>a</sup> Bow after ream and countersink (in.):	<u>-0.030</u>
<sup>b</sup> Edge distortion after coldwork (in.):	<u>None</u>
<sup>c</sup> Specimen growth after coldwork (in.):	<u>0.0110 in 11.25</u>
Specimen growth after ream (in.):	<u>0.0120 in 11.25</u>
Specimen growth after countersink (in.):	<u>0.0115 in 11.25</u>

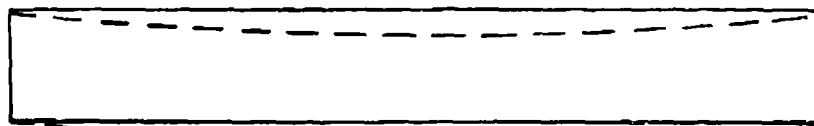
<sup>a</sup>Bow direction

↓ Direction of coldwork



(+) Indicates bow as shown in sketch  
 (-) Indicates bow in opposite direction

<sup>b</sup>Edge distortion



Value indicates amount of side bow

<sup>c</sup>Measurements taken after each operation indicated. Some of the difference may be contributed to reamer wander and temperature variance.

PHASE I-TASK 4A-EDGE MARGIN AND HOLE SPACING DATA

SPECIMEN NUMBER: 8T DATE: 1/8/73

TEST CONDITIONS

Specimen Description

Material: <u>Ti-6Al-4V</u>	Hole spacing (in.): <u>3</u>
Material gage (in.): <u>0.75</u>	Nominal hole size (in.): <u>3/4</u>
Size (L x W) (in.): <u>15 x 2-1/4</u>	Edge margin: <u>1-1/8 in.</u>
Number of holes: <u>4</u>	

Coldwork Information

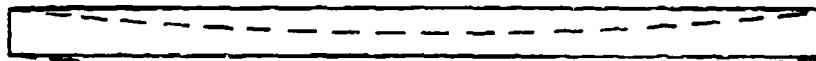
Coldwork process: Sleeve  
 Mandrel taper (in./in.): 0.045  
 Mandrel diameter (in.): 0.714  
 Expansion (in.): 0.029

RESULTING DATA

Edge bulge at holes, average (in.): 0.003  
 Edge bulge between holes, average (in.): 0.0005  
<sup>a</sup>Bow after coldwork (in.): +0.017  
<sup>a</sup>Bow after ream and countersink (in.): +0.011  
<sup>b</sup>Edge distortion after coldwork (in.): None  
<sup>c</sup>Specimen growth after coldwork (in.): 0.006 in 9  
 Specimen growth after ream (in.): 0.006 in 9  
 Specimen growth after countersink (in.): 0.006 in 9

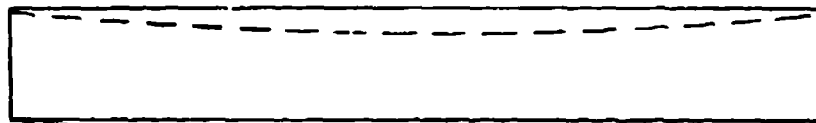
<sup>a</sup>Bow direction

↓ Direction of coldwork



(+) Indicates bow as shown in sketch  
 (-) Indicates bow in opposite direction

<sup>b</sup>Edge distortion



Value indicates amount of side bow

<sup>c</sup>Measurements taken after each operation indicated. Some of the difference may be contributed to reamer wander and temperature variance.

PHASE I-TASK 4A-EDGE MARGIN AND HOLE SPACING DATA

SPECIMEN NUMBER: 9T DATE: 1/8/73

TEST CONDITIONS

Specimen Description

Material: <u>Ti-6Al-4V</u>	Hole spacing (in.): <u>2-1/4</u>
Material gage (in.): <u>0.75</u>	Nominal hole size (in.): <u>3/4</u>
Size (L x W) (in.): <u>15 x 3</u>	Edge margin: <u>1.50 in.</u>
Number of holes: <u>6</u>	

Coldwork Information

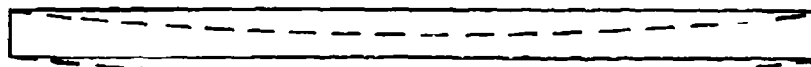
Coldwork process: Sleeve  
 Mandrel taper (in./in.): 0.045  
 Mandrel diameter (in.): 0.714  
 Expansion (in.): 0.029

RESULTING DATA

Edge bulge at holes, average (in.): 0.0025  
 Edge bulge between holes, average (in.): 0.0010  
<sup>a</sup>Bow after coldwork (in.): +0.012  
<sup>a</sup>Bow after ream and countersink (in.): +0.003  
<sup>b</sup>Edge distortion after coldwork (in.): None  
<sup>c</sup>Specimen growth after coldwork (in.): 0.0085 in 11.25  
 Specimen growth after ream (in.): 0.0075 in 11.25  
 Specimen growth after countersink (in.): 0.0075 in 11.25

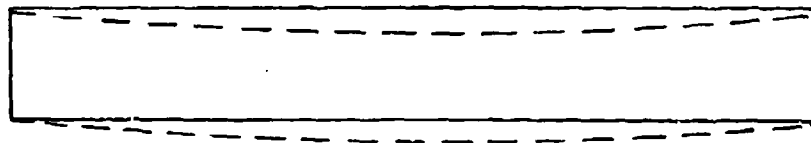
<sup>a</sup>Bow direction

↓ Direction of coldwork



(+) indicates bow as shown in sketch  
 (-) Indicates bow in opposite direction

<sup>b</sup>Edge distortion



Value indicates amount of side bow

<sup>c</sup>Measurements taken after each operation indicated. Some of the difference may be contributed to reamer wander and temperature variance



PHASE I - TASK 4A - EDGE MARGIN AND HOLE SPACING DATA

SPECIMEN NUMBER: 10T DATE: 1/8/73

TEST CONDITIONS

Specimen Description

Material: <u>Ti-6Al-4V</u>	Hole spacing (in.): <u>3</u>
Material gage (in.): <u>0.75</u>	Nominal hole size (in.): <u>3/4</u>
Size (L x W)(in.): <u>15 x 3</u>	Edge margin: <u>1-1/2 in.</u>
Number of holes: <u>4</u>	

Coldwork Information

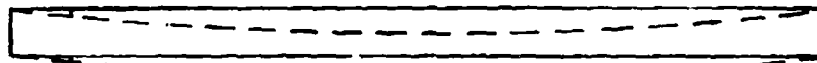
Coldwork process: <u>Sleeve</u>
Mandrel taper (in./in.): <u>0.045</u>
Mandrel diameter (in.): <u>0.714</u>
Expansion (in.): <u>0.029</u>

RESULTING DATA

Edge bulge at holes, average (in.):	<u>0.0025</u>
Edge bulge between holes, average (in.):	<u>0.0010</u>
<sup>a</sup> Bow after coldwork (in.):	<u>None</u>
<sup>a</sup> Bow after ream and countersink (in.):	<u>-0.010</u>
<sup>b</sup> Edge distortion after coldwork (in.):	<u>None</u>
<sup>c</sup> Specimen growth after coldwork (in.):	<u>0.0030 in 9</u>
Specimen growth after ream (in.):	<u>0.0020 in 9</u>
Specimen growth after countersink (in.):	<u>0.0020 in 9</u>

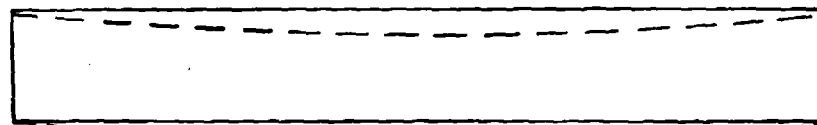
<sup>a</sup>Bow direction

↓ Direction of coldwork



(+) Indicates bow as shown in sketch  
 (-) Indicates bow in opposite direction

<sup>b</sup>Edge distortion



Value indicates amount of side bow

<sup>c</sup>Measurements taken after each operation indicated. Some of the difference may be contributed to reamer wander and temperature variance

PHASE I--TASK 4A--EDGE MARGIN AND HOLE SPACING DATA

SPECIMEN NUMBER: 1S

DATE: 6/1/73

TEST CONDITIONS

Specimen Description

Material: <u>300 M steel</u>	Hole spacing (in.): <u>1.50</u>
Material gage (in.): <u>0.375</u>	Nominal hole size (in.): <u>3/8</u>
Size (L x W)(in.): <u>15 x 1.125</u>	Edge margin: <u>9/16 in.</u>
Number of holes: <u>9</u>	

Coldwork Information

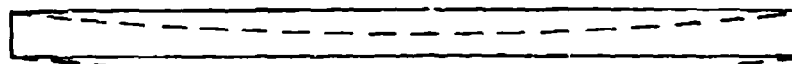
Coldwork process: Push, no sleeve  
 Mandrel taper (in./in.): 0.045  
 Mandrel diameter (in.): 0.358  
 Expansion (in.): 0.023

RESULTING DATA

Edge bulge at holes, average (in.): 0.0031  
 Edge bulge between holes, average (in.): 0.0007  
<sup>a</sup>Bow after coldwork (in.): 0.103  
<sup>a</sup>Bow after ream and countersink (in.): 0.101  
<sup>b</sup>Edge distortion after coldwork (in.): 0.013  
<sup>c</sup>Specimen growth after coldwork (in.): 0.032 in 15  
 Specimen growth after ream (in.): 0.032 in 15 (no change)  
 Specimen growth after countersink (in.): 0.032 in 15 (no change)

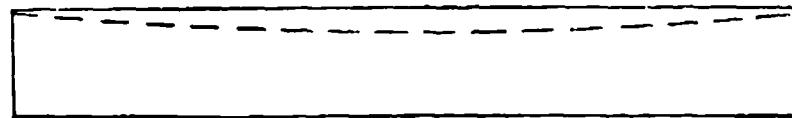
<sup>a</sup>Bow direction

↓ Direction of coldwork



(+) Indicates bow as shown in sketch  
 (-) Indicates bow in opposite direction

<sup>b</sup>Edge distortion



Value indicates amount of side bow

<sup>c</sup>Measurements taken after each operation indicated. Some of the difference may be contributed to reamer wander and temperature variance.

PHASE I-TASK 4A-EDGE MARGIN AND HOLE SPACING DATA

SPECIMEN NUMBER: 2S DATE: 6/14/73

TEST CONDITIONS

Specimen Description

Material: <u>300 M steel</u>	Hole spacing (in.): <u>1.125</u>
Material gage (in.): <u>3/8</u>	Nominal hole size (in.): <u>3/8</u>
Size (L x W)(in.): <u>15 x 1.125</u>	Edge margin: <u>9/16 in.</u>
Number of holes: <u>12</u>	

Coldwork Information

Coldwork process: Push, no sleeve  
 Mandrel taper (in./in.): 0.045  
 Mandrel diameter (in.): 0.3580  
 Expansion (in.): 0.0230

RESULTING DATA

Edge bulge at holes, average (in.): 0.0030  
 Edge bulge between holes, average (in.): 0.0010  
<sup>a</sup>Bow after coldwork (in.): +0.102  
<sup>a</sup>Bow after ream and countersink (in.): +0.102  
<sup>b</sup>Edge distortion after coldwork (in.): None  
<sup>c</sup>Specimen growth after coldwork (in.): 0.030 in 15  
 Specimen growth after ream (in.): 0.030 in 15 (no change)  
 Specimen growth after countersink (in.): 0.030 in 15 (no change)

<sup>a</sup>Bow direction

↓ Direction of coldwork



(+) Indicates bow as shown in sketch  
 (-) Indicates bow in opposite direction

<sup>b</sup>Edge distortion



Value indicates amount of side bow

<sup>c</sup>Measurements taken after each operation indicated. Some of the difference may be contributed to reamer wander and temperature variance.

PHASE I - TASK 4A - EDGE MARGIN AND HOLE SPACING DATA

SPECIMEN NUMBER: 3S DATE: 6/14/73

TEST CONDITIONS

Specimen Description

Material: <u>300 M steel</u>	Hole spacing (in.): <u>1.125</u>
Material gage (in.): <u>3/8</u>	Nominal hole size (in.): <u>3/8</u>
Size (L x W) (in.): <u>15 x 1.50</u>	Edge margin: <u>0.750 in.</u>
Number of holes: <u>12</u>	

Coldwork Information

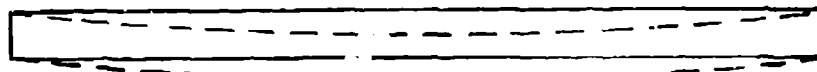
Coldwork process: <u>Push, no sleeve</u>
Mandrel taper (in. in.): <u>0.045</u>
Mandrel diameter (in.): <u>0.358</u>
Expansion (in.): <u>0.023</u>

RESULTING DATA

Edge bulge at holes, average (in.):	<u>0.0017</u>
Edge bulge between holes, average (in.):	<u>0.0012</u>
<sup>a</sup> Bow after coldwork (in.):	<u>0.0525</u>
<sup>a</sup> Bow after ream and countersink (in.):	<u>0.0520</u>
<sup>b</sup> Edge distortion after coldwork (in.):	<u>None</u>
<sup>c</sup> Specimen growth after coldwork (in.):	<u>0.025 in 15</u>
Specimen growth after ream (in.):	<u>0.025 in 15 (no change)</u>
Specimen growth after countersink (in.):	<u>0.025 in 15 (no change)</u>

<sup>a</sup>Bow direction

↓ Direction of coldwork



(+) Indicates bow as shown in sketch  
 (-) Indicates bow in opposite direction

<sup>b</sup>Edge distortion



Value indicates amount of side bow.

<sup>c</sup>Measurements taken after each operation indicated. Some of the difference may be contributed to reamer wander and temperature variance.

PHASE I: TASK 4A-EDGE MARGIN AND HOLE SPACING DATA

SPECIMEN NUMBER: 4S DATE: 5/30/73

TEST CONDITIONS

Specimen Description

Material: <u>300 M steel</u>	Hole spacing (in.): <u>1.50</u>
Material gage (in.): <u>0.375</u>	Nominal hole size (in.): <u>0.375</u>
Size (L x W)(in.): <u>15 x 1.50</u>	Edge margin: <u>0.75 in.</u>
Number of holes: <u>9</u>	

Coldwork Information

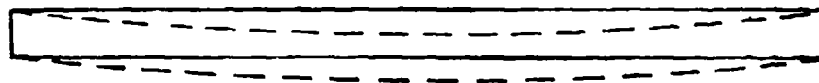
Coldwork process: Push, no sleeve  
 Mandrel taper (in./in.): 0.045  
 Mandrel diameter (in.): 0.358  
 Expansion (in.): 0.023

RESULTING DATA

Edge bulge at holes, average (in.): 0.0015  
 Edge bulge between holes, average (in.): 0.0007  
<sup>a</sup>Bow after coldwork (in.): 0.064  
<sup>a</sup>Bow after ream and countersink (in.): 0.060  
<sup>b</sup>Edge distortion after coldwork (in.): 0.005  
<sup>c</sup>Specimen growth after coldwork (in.): 0.018 in 15  
 Specimen growth after ream (in.): 0.018 in 15 (no change)  
 Specimen growth after countersink (in.): 0.018 in 15 (no change)

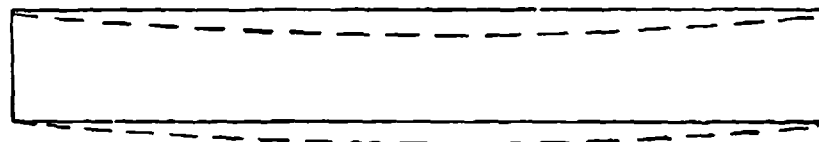
<sup>a</sup>Bow direction

↓ Direction of coldwork



(+) Indicates bow as shown in sketch  
 (-) Indicates bow in opposite direction

<sup>b</sup>Edge distortion



Value indicates amount of side bow

<sup>c</sup>Measurements taken after each operation indicated. Some of the difference may be contributed to reamer wander and temperature variance

PHASE I-TASK 4A-EDGE MARGIN AND HOLE SPACING DATA

SPECIMEN NUMBER: 7S DATE: 7/5/73

TEST CONDITIONS

Specimen Description

Material: <u>300 M steel</u>	Hole spacing (in.): <u>2.25</u>
Material gage (in.): <u>0.75</u>	Nominal hole size (in.): <u>3/4</u>
Size (L x W)(in.): <u>15 x 3</u>	Edge margin: <u>1-1/2 in.</u>
Number of holes: <u>6</u>	

Coldwork Information

Coldwork process: Push, no sleeve  
 Mandrel taper (in./in.): 0.045  
 Mandrel diameter (in.): 0.7225  
 Expansion (in.): 0.030

RESULTING DATA

Edge bulge at holes, average (in.): 0.0025  
 Edge bulge between holes, average (in.): 0.0007  
<sup>a</sup>Bow after coldwork (in.): +0.013  
<sup>a</sup>Bow after ream and countersink (in.): +0.013  
<sup>b</sup>Edge distortion after coldwork (in.): None  
<sup>c</sup>Specimen growth after coldwork (in.): 0.014 in 15  
 Specimen growth after ream (in.): No change  
 Specimen growth after countersink (in.): No change

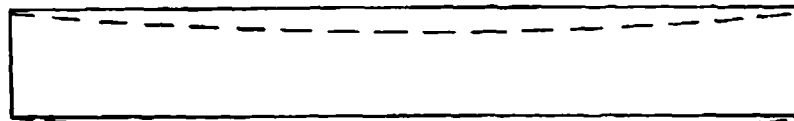
<sup>a</sup>Bow direction

↓ Direction of coldwork



(+) Indicates bow as shown in sketch  
 (-) Indicates bow in opposite direction

<sup>b</sup>Edge distortion



Value indicates amount of side bow

<sup>c</sup>Measurements taken after each operation indicated. Some of the difference may be contributed to reamer wander and temperature variance.

PHASE I--TASK 4A--EDGE MARGIN AND HOLE SPACING DATA

SPECIMEN NUMBER: 8S DATE: 7/5/73

TEST CONDITIONS

Specimen Description

Material: <u>300 M steel</u>	Hole spacing (in.): <u>3</u>
Material gage (in.): <u>0.75</u>	Nominal hole size (in.): <u>3/4</u>
Size (L x W)(in.): <u>15 x 3</u>	Edge margin: <u>1-1/2 in.</u>
Number of holes: <u>4</u>	

Coldwork Information

Coldwork process: Push, no sleeve  
 Mandrel taper (in./in.): 0.045  
 Mandrel diameter (in.): 0.7225  
 Expansion (in.): 0.030

RESULTING DATA

Edge bulge at holes, average (in.): 0.0025  
 Edge bulge between holes, average (in.): None  
<sup>a</sup>Bow after coldwork (in.): +0.010  
<sup>a</sup>Bow after ream and countersink (in.): +0.010  
<sup>b</sup>Edge distortion after coldwork (in.): None  
<sup>c</sup>Specimen growth after coldwork (in.): 0.010 in 15  
 Specimen growth after ream (in.): No change  
 Specimen growth after countersink (in.): No change

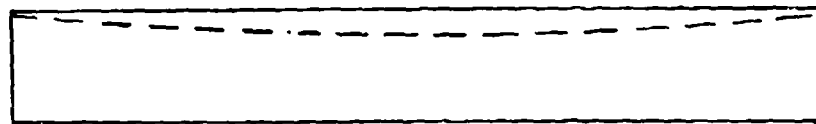
<sup>a</sup>Bow direction

↓ Direction of coldwork



(+) Indicates bow as shown in sketch  
 (-) Indicates bow in opposite direction

<sup>b</sup>Edge distortion



Value indicates amount of side bow

<sup>c</sup>Measurements taken after each operation indicated. Some of the difference may be contributed to reamer wander and temperature variance

PHASE I-TASK 4A-EDGE MARGIN AND HOLE SPACING DATA

SPECIMEN NUMBER: 9 S DATE: 7/5/73

TEST CONDITIONS

Specimen Description

Material: <u>300 M steel</u>	Hole spacing (in.): <u>2.25</u>
Material gage (in.): <u>0.75</u>	Nominal hole size (in.): <u>7/4</u>
Size (L x W)(in.): <u>15 x 2.25</u>	Edge margin: <u>1.1 J in.</u>
Numer of holes: <u>6</u>	

Coldwork Information

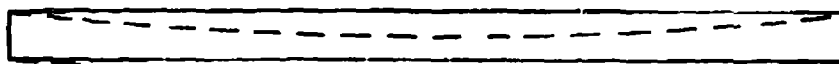
Coldwork process: Push, no sleeve  
 Mandrel taper (in./in.): 0.045  
 Mandrel diameter (in.): 0.7225  
 Expansion (in.): 0.030

RESULTING DATA

Edge bulge at holes, average (in.): 0.0035  
 Edge bulge between holes, average (in.): 0.0015  
<sup>a</sup>Bow after coldwork (in.): 0.030  
<sup>a</sup>Bow after ream and countersink (in.): 0.030  
<sup>b</sup>Edge distortion after coldwork (in.): 0.005  
<sup>c</sup>Specimen growth after coldwork (in.): 0.013 in 15  
 Specimen growth after ream (in.): No change  
 Specimen growth after countersink (in.): No change

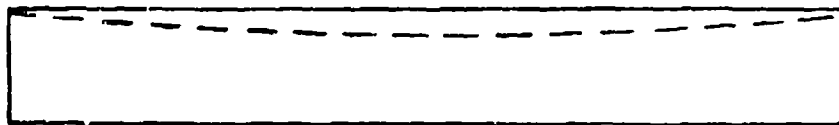
<sup>a</sup>Bow direction

↓ Direction of coldwork



(+) Indicates bow as shown in sketch  
 (-) Indicates bow in opposite direction

<sup>b</sup>Edge distortion



Value indicates amount of side bow

<sup>c</sup>Measurements taken after each operation indicated. Some of the difference may be contributed to reamer wander and temperature variance



PHASE I-TASK 4A-EDGE MARGIN AND HOLE SPACING DATA

SPECIMEN NUMBER: 10 S DATE: 7/5/73

TEST CONDITIONS

Specimen Description

Material: <u>300 M steel</u>	Hole spacing (in.): <u>3.00</u>
Material gage (in.): <u>0.75</u>	Nominal hole size (in.): <u>3/4</u>
Size (L x W)(in.): <u>15 x 2.25</u>	Edge margin: <u>1-1/8 in.</u>
Number of holes: <u>4</u>	

Coldwork Information

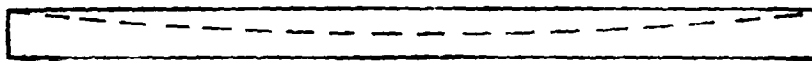
Coldwork process: Push, no sleeve  
 Mandrel taper (in./in.): 0.045  
 Mandrel diameter (in.): 0.7225  
 Expansion (in.): 0.035 & 0.046

RESULTING DATA

Edge bulge at holes, average (in.): 0.004 (.035 interf.) & .0055 (.046 interf.)  
 Edge bulge between holes, average (in.): None (both cases)  
<sup>a</sup>Bow after coldwork (in.): 0.026  
<sup>a</sup>Bow after ream and countersink (in.): 0.026  
<sup>b</sup>Edge distortion after coldwork (in.): None  
<sup>c</sup>Specimen growth after coldwork (in.): 0.011 in 15  
 Specimen growth after ream (in.): No change  
 Specimen growth after countersink (in.): No change

<sup>a</sup>Bow direction

↓ Direction of coldwork



(+) Indicates bow as shown in sketch  
 (-) Indicates bow in opposite direction


<sup>b</sup>Edge distortion



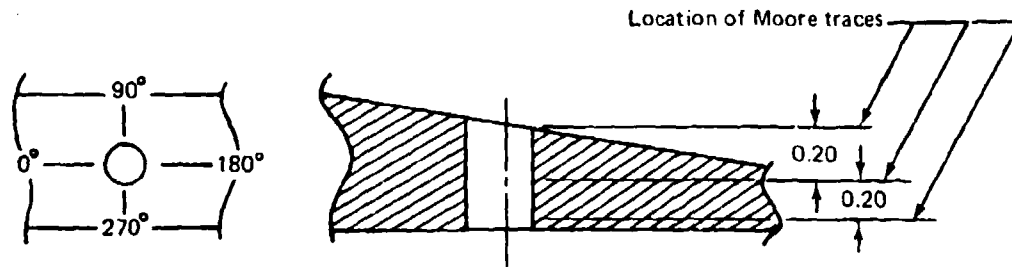
Value indicates amount of side bow

<sup>c</sup>Measurements taken after each operation indicated. Some of the difference may be contributed to reamer wander and temperature variance

PHASE I-TASK 4B-MATERIAL TAPER EFFECT

Material	Taper (deg)	Centerline shift (in.)	Direction of shift
2024-T851 (Al)	2	0.0035	Top of hole moved as illustrated in all cases 
2024-T851 (Al)	4	0.0035	
Ti-6Al-4V	2	0.002	
Ti-6Al-4V	4	0.003	

PHASE I - TASK 4B - SPECIMEN S5, 300M STEEL 2° TAPER

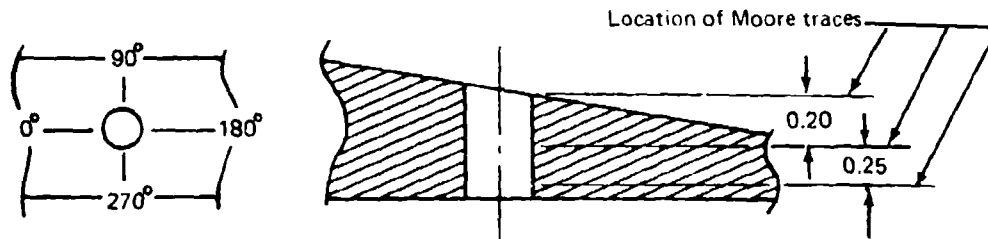


Before coldworking: Center of top of hole, 0.0025 in. toward 180° and 0.0015 in. toward 90°

After coldworking: Center of top of hole, 0.0010 in. toward 180° and 0.0025 in. toward 90°

Conclusion: Center of top of hole moved 0.0008 in. toward 180° (down slope)

SPECIMEN S6, 300M STEEL, 4° TAPER

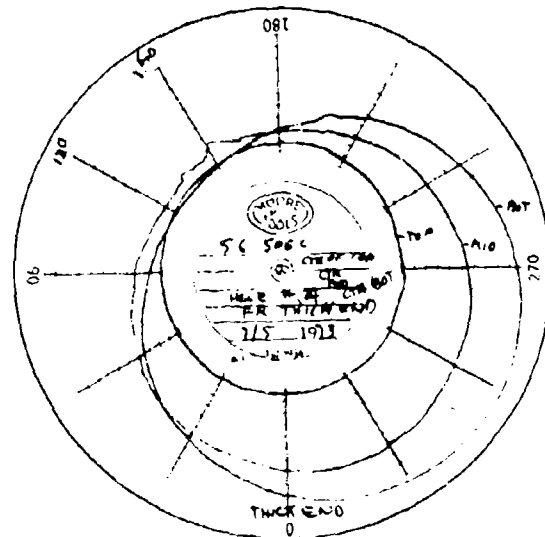
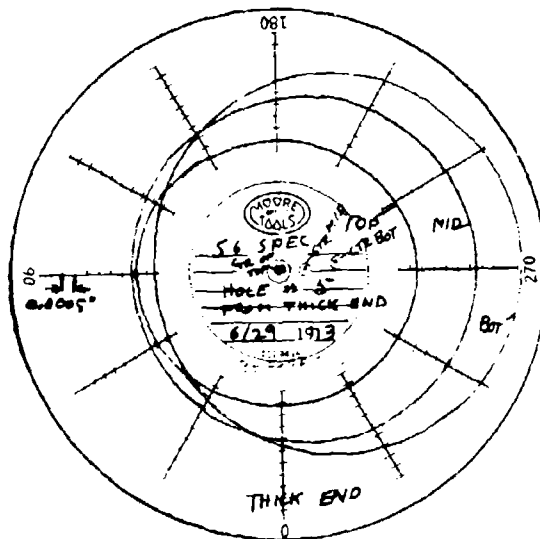
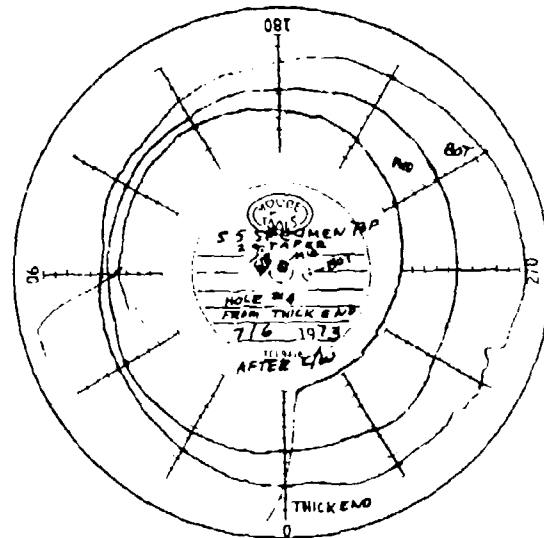
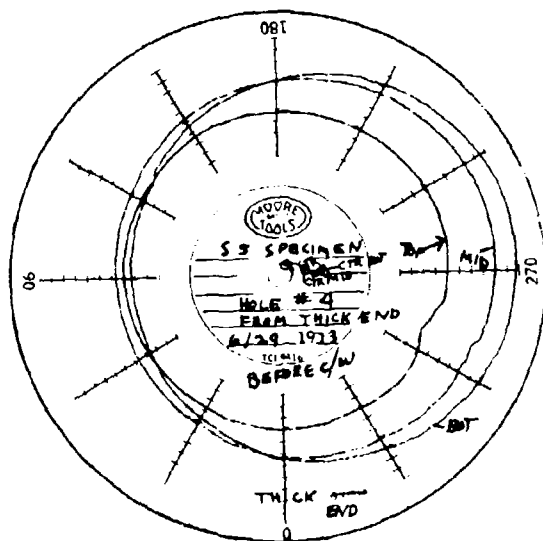


Before coldworking: Center of top of hole 0.0025 in. toward 90° from center of bottom of hole

After coldworking: Center of top of hole 0.0025 in. toward 150° from center of bottom of hole

Conclusion: Center of top of hole moved approximately 0.0017 in. toward 180° (down slope)

PHASE I - TASK 4B - MOORE TRACE DATA FOR 300M STEEL; CENTERLINE SHIFT AS A RESULT OF SURFACE TAPER



PHASE I - TASK 4C - LUBRICANT VARIATION

DATE: 1/23/73

MATERIAL: 2024-T851(A1) MANDREL TAPER (in./in.): 0.045

MATERIAL THICKNESS (in.): 0.375 COLDWORK PROCESS: Sleeve

NOMINAL HOLE SIZE (in.): 3/8

Hole no.	Maximum expansion (in.)	Sleeve lubricant	Pull force (lb)	Remarks
A1	0.0130	Fel Pro 300	945	Standard sleeve presently used in production
A2	0.0130	Fel Pro 300	1000	
A3	0.0130	Fel Pro 300	1005	
A4	0.0130	Fel Pro 300	965	
A5	0.0130	Fel Pro 300	975	
A6	0.0130	LLC 36 air dried	1500	Loud snapping (chatter) occurred throughout test; pickup on mandrel.
A7	0.0130	LLC 36 air dried	1500	
A8	0.0130	LLC 36 air dried	1535	
B1	0.0130	LLC 36 air dried	1415	
B2	0.0130	LLC 36 air dried	1405	
B3	0.0130	LLC 36 baked	1490	
B4	0.0130	LLC 36 baked	1420	
B5	0.0130	LLC36 baked	1380	
B6	0.0130	LLC 36 baked	1510	Pickup from air dried LLC 36 removed from mandrel.
B7	0.0130	LLC 36 baked	1505	
B8	0.0130	Moly Kote-G paste	1560	
C1	0.0130	Moly Kote-G paste	1470	
C2	0.0130	Moly Kote-G paste	1420	Sleeve lubed inside and mandrel lubed after insertion in plate.
C3	0.0130	Moly Kote G paste	1410	
C4	0.0130	Moly Kote-G paste	1400	

PHASE I-TASK 4C-SLEEVE LUBRICANT TESTS

(Boeing and Program Data)

Sleeve lubricant:		Average force (lb)												
Basic	+	+	+	+	+	+	+	+	+	+	+			
		Basic	Additive	Mandrel wipe	Hole diameter (in.)	Material thickness (in.)	Hole expansion	Material	0.045-in. taper	0.034-in. taper	0.030-in. taper	0.025-in. taper	0.020-in. taper	0.015-in. taper
Fel Pro 300 (properly mixed)	-	-	-	Dry	3/8	3/8	0.013	2024-T851	965		1,250			1,400
LLC 36 air dried	-	-	-	↓	↓	↓	↓	↓	1,470					
LLC 36 baked	-	-	-	↓	↓	↓	↓	↓	1,460					
Moly Kote-G paste	-	-	-	Moly Kote-G paste	↓	↓	↓	↓	1,450					
Fel Pro 300 (properly mixed)	-	-	-	Dry	3/4	1-1/8	0.025	↓	6,500		7,500		12,000	
	-	-	-	↓	↓	↓	↓	↓		8,880		9,870	10,830	15,440
	-	-	-	Ethyl alcohol	↓	↓	↓	↓		10,600		12,660	11,800	15,430
	-	-	-	Dry	↓	↓	↓	↓						21,400
	-	-	-	Docosanol alcohol	↓	↓	↓	↓						15,400
	-	-	-	Johnson 150 wax draw	↓	↓	↓	↓						17,200
	-	-	-	Ethyl alcohol	↓	↓	↓	↓						22,200
	-	-	-	Eicosanol alcohol	↓	↓	↓	↓						22,700
	-	-	-	Dry	↓	↓	↓	↓						17,500
	-	-	-	Stearyl alcohol	↓	↓	↓	↓						19,200
	-	-	-	Ethyl alcohol	↓	↓	↓	↓						17,300
	-	-	-	Cetyl alcohol (hot coat)	↓	↓	↓	↓						18,000
	-	-	-	Dry	↓	↓	↓	↓						







PHASE I—TASK 4D—SLEEVE GEOMETRY

MATERIAL: 2024 T851 (AI) MANDREL TAPER (IN./IN.): 0.045  
 DATE: 1/30/73 MAXIMUM EXPANSION (IN.): 0.019  
 MATERIAL THICKNESS (IN.): 0.75

Hole no.	Sleeve type	Retained expansion (in.)	Pull force (lb)	Remarks
1	Standard	0.0105	2280	
2	Standard	0.0110	1980	
3	30° scarf edge	0.0100	2000	(a)
4	30° scarf edge	0.0105	2030	
5	Helical wound	0.0105	2160	
6	Helical wound	0.0105	2180	
7	Helical wound	0.0115	2120	
8	Helical wound	0.0110	2125	
9	Helical wound	0.0105	1950	

<sup>a</sup> Additional tests were conducted in aluminum (2024-T851) and Ti-6Al-4V comparing removal characteristics of 30° scarf split sleeves with standard sleeves. These tests showed that there was no appreciable difference between the two. Close examination of the scarf indicated that it was not uniform.

PHASE I-TASK 4E-DIAMETER CREEP

DATE: 2/6/73

MAXIMUM EXPANSION (IN.): 0.018-0.020

NOMINAL HOLE SIZE (IN.): 3/8

MANDREL TAPER (IN./IN.): 0.045

PROCESS : REAM, COLDWORK, REAM

MATERIAL THICKNESS (IN.): 0.075

Material tested	Hole size (in.)		
	Immediately after ream	One hour after ream	24 hours after ream
2024-T851 (Al)	0.3753/0.3754	0.3752/0.3753	0.3752/0.3753
Ti-6Al-4V	0.3753/0.3754	0.3752/0.3753	0.3752/0.3753

PHASE I--TASK 4F--MANDREL FINISH VARIATION

DATE: 2/7/73

MATERIAL: 2024-T851 (AI)

MATERIAL THICKNESS (IN.): 0.75

NOMINAL HOLE SIZE (IN.): 3/8

MAXIMUM EXPANSION (IN.): 0.018-0.020

MANDREL TAPER (IN./IN.): 0.045

COLDWORK PROCESS: Sleeve

Hole no.	Mandrel finish	Force (lb)
1	None	2800
2	None	2840
3	None	2800
4	None	2600
5	Vapor blast + Fel Pro 300	3000
6	↓	2580
7		2400
8		2500
9		2480
10		2470
11		2780
12		2540

PHASE I-TASK 4F-MANDREL FINISH VARIATION

DATE: 2/7/73

MATERIAL: Ti-6Al-4V

MATERIAL THICKNESS (IN.) 0.75

NOMINAL HOLE SIZE (IN.) 3/8

MAXIMUM EXPANSION (IN.) 0.018-0.020

MANDREL TAPER (IN./IN.) 0.045

COLDWORK PROCESS: Sleeve

Hole no.	Mandrel finish	Force (lb)
1	None	3740
2	None	3860
3	None	3700
4	Vapor blast + Fel Pro 300	3560
5	↓	3470
6	↓	3600
7	↓	3680
8	↓	3650

PHASE I - TASK 5 - MULTIMATERIAL STACK PROCESS DATA

SPECIMEN NUMBER: IV TEST NUMBER: 1 DATE: 12/13/72

MATERIAL COMBINATION: 1. 2024-T851 2. 6Al-4V-Ti 3. 2024-T851 MANDREL TYPE: ST 5300-CBM-12-0-N

MATERIAL GAGE (IN.) 1. 0.250 2. 0.290 3. 0.250 MANDREL TAPER (IN./IN.): 0.045

NOMINAL HOLE SIZE (IN.) 3/8 MANDREL MAX DIA (IN.): 0.3537

SLEEVE THICKNESS (IN.): 0.010

LUBRICANT (SLEEVE): Fel Pro 300 (on sleeve)

Hole no.	Hole diameter (in.)						Pull force (lb)	Actual coldwork diameter expansion (in.)	Retained diameter expansion in aluminum (in.)	Retained diameter expansion in titanium (in.)	Remarks
	Before coldwork		After coldwork		Ti	Al					
	Ti	Al	Ti	Al							
C-7	0.3555	0.3550	0.3660	0.3675	0.3675	0.3675	0.019	0.0125	0.0105	Sleeves fairly easy to remove 3 sleeves required use of screw driver for removal--rest pulled out with pliers.	
C-8	0.3555	0.3555	0.3665	0.3675	0.3675	0.3675	0.019	0.0120	0.0110		
D-1	0.3550	0.3545	0.3660	0.3675	0.3675	0.3675	0.019	0.0130	0.0110		
D-2	0.3555	0.3545	0.3665	0.3675	0.3675	0.3675	0.019	0.0130	0.0110		
D-3	0.3555	0.3545	0.3660	0.3675	0.3675	0.3675	0.019	0.0130	0.0105		
D-4	0.3555	0.3545	0.3660	0.3680	0.3680	0.3680	0.019	0.0135	0.0105		
D-5	0.3550	0.3545	0.3660	0.3675	0.3675	0.3675	0.019	0.0130	0.0110		
D-6	0.3550	0.3545	0.3660	0.3680	0.3680	0.3680	0.019	0.0135	0.0110		
D-7	0.3550	0.3545	0.3660	0.3680	0.3680	0.3680	0.019	0.0135	0.0110		
D-8	0.3550	0.3545	0.3660	0.3675	0.3675	0.3675	0.019	0.0130	0.0110		

PHASE I - TASK 5 - MULTIMATERIAL STACK PROCESS DATA

SPECIMEN NUMBER: IV TEST NUMBER: 2 DATE: 12/13/72

MATERIAL COMBINATION: 1. 2024-T851 2. 6Al-4V-Ti 3. 2024-T851 MANDREL TYPE: ST 5300-CBM-12-O-N

MATERIAL GAGE (IN.) 1. 0.250 2. 0.290 3. 0.250 MANDREL TAPER (IN./IN.): 0.045

NOMINAL HOLE SIZE (IN.) 3/8 MANDREL MAX DIA (IN.): 0.3537

SLEEVE THICKNESS (IN.): 0.010

LUBRICANT (SLEEVE): Fel Pro 300 (on sleeve)

Hole no.	Hole diameter (in.)				Pull force (lb)	Actual coldwork diameter expansion (in.)	Retained diameter expansion in aluminum (in.)	Retained diameter expansion in titanium (in.)	Remarks
	Before coldwork		After coldwork						
	T <sub>i</sub>	A <sub>i</sub>	T <sub>f</sub>	A <sub>f</sub>					
A1	0.3595	0.3600	0.3560	0.3680	1795	0.014	0.0065	0.0080	Sleeves easy to remove with pliers - most free to slide in hole.
A2	0.3595	0.3600	0.3565	0.3680	1595	0.014	0.0070	0.0080	
A3	0.3595	0.3600	0.3565	0.3680	1495	0.014	0.0070	0.0080	
A4	0.3595	0.3600	0.3565	0.3680	1480	0.014	0.0065	0.0080	
A5	0.3595	0.3600	0.3565	0.3680	1615	0.014	0.0070	0.0080	
A6	0.3595	0.3600	0.3570	0.3680	1680	0.014	0.0075	0.0080	
A7	0.3595	0.3600	0.3560	0.3690	1650	0.014	0.0065	0.0090	
A8	0.3595	0.3600	0.3560	0.3680	1780	0.014	0.0065	0.0080	
B1	0.3595	0.3600	0.3570	0.3680	1765	0.014	0.0075	0.0080	
B2	0.3595	0.3600	0.3560	0.3685	2060	0.014	0.0065	0.0085	

PHASE I - TASK 5 - MULTIMATERIAL STACK PROCESS DATA

SPECIMEN NUMBER: IV TEST NUMBER: 3 DATE: 12/13/72

MATERIAL COMBINATION: 1. 2024-T851 2. 6Al-4V-Ti 3. 2024-T851 MANDREL TYPE: ST 5300-CBM-12-0-N

MATERIAL GAGE (IN.) 1. 0.250 2. 0.290 3. 0.250 MANDREL TAPER (IN./IN.): 0.045

NOMINAL HOLE SIZE (IN.) 3/8 MANDREL MAX DIA (IN.): 0.3537

SLEEVE THICKNESS (IN.): 0.010

LUBRICANT (SLEEVE): Fel Pro 300 (on sleeve)

Hole no.	Hole diameter (in.)				Pull force (lb)	Actual coldwork diameter expansion (in.)	Retained diameter expansion in aluminum (in.)	Retained diameter expansion in titanium (in.)	Remarks
	Before coldwork		After coldwork						
	Ti	Al	Ti	Al					
F1	0.3655	0.3655	0.3680	0.3680	1565	0.008	0.0035	0.0025	Sleeves easy to remove—free to pull out with fingers.
F2	0.3655	0.3655	0.3685	0.3695	1440	0.008	0.0040	0.0030	
F3	0.3655	0.3655	0.3685	0.3695	1350	0.008	0.0040	0.0030	
F4	0.3655	0.3655	0.3685	0.3690	1365	0.008	0.0035	0.0030	
F5	0.3655	0.3655	0.3680	0.3690	1350	0.008	0.0035	0.0025	
F6	0.3655	0.3655	0.3680	0.3690	1360	0.008	0.0035	0.0025	
G1	0.3655	0.3655	0.3680	0.3690	1350	0.008	0.0035	0.0025	
G2	0.3655	0.3655	0.3680	0.3690	1350	0.008	0.0035	0.0025	
G3	0.3655	0.3655	0.3680	0.3690	1360	0.008	0.0035	0.0025	
G4	0.3655	0.3655	0.3685	0.3695	1355	0.008	0.0040	0.0030	

PHASE I - TASK 5 - MULTIMATERIAL STACK PROCESS DATA

SPECIMEN NUMBER: 2V TEST NUMBER: 4 DATE: 12/13/72

MATERIAL COMBINATION: 1. 6Al-4V-Ti 2. 2024-T851 3. 6Al-4V-Ti MANDREL TYPE: ST 5310-CBM-12-0-N

MATERIAL GAGE (IN.): 1. 0.285 2. 1.00 3. 0.285 MANDREL TAPER (IN./IN.): 0.045

NOMINAL HOLE SIZE (IN.) 3/8 MANDREL MAX DIA (IN.): 0.3537

SLEEVE THICKNESS (IN.): 0.010

LUBRICANT (SLEEVE): Fel Pro 300

Hole no.	Hole diameter (in.)			Pull force (lb)	Actual coldwork diameter expansion (in.)	Retained diameter expansion in aluminum (in.)	Retained diameter expansion in titanium (in.)	Remarks
	Before coldwork		After coldwork					
	Ti	Al						
C7	0.3550	0.3550	0.3660	0.3685	0.019	0.0135	0.0110	1. Sleeves fairly easy to remove--4 sleeves required use of screwdriver for removal--rest pulled out with pliers. 2. Sleeve thinout accounts for much of the difference in retained expansion.
C8	0.3550	0.3550	0.3665	0.3685	0.019	0.0135	0.0115	
D1	0.3550	0.3550	0.3660	0.3680	0.019	0.0130	0.0110	
D2	0.3550	0.3550	0.3660	0.3685	0.019	0.0135	0.0110	
D3	0.3550	0.3550	0.3665	0.3680	0.019	0.0130	0.0115	
D4	0.3550	0.3550	0.3665	0.3680	0.019	0.0130	0.0115	
D5	0.3550	0.3550	0.3665	0.3685	0.019	0.0135	0.0115	
D6	0.3550	0.3550	0.3660	0.3685	0.019	0.0135	0.0110	
D7	0.3550	0.3550	0.3660	0.3685	0.019	0.0135	0.0110	
D8	0.3550	0.3550	0.3660	0.3685	0.019	0.0135	0.0110	



PHASE I-TASK 5-MULTIMATERIAL STACK PROCESS DATA

SPECIMEN NUMBER: 2V TEST NUMBER: 5 DATE: 12/13/72

MATERIAL COMBINATION: 1. 6Al-4V-Ti 2. 2024-T851 3. 6Al-4V-Ti MANDREL TYPE: ST 5300-CBM-12-0-N

MATERIAL GAGE (IN.) 1. 0.285 2. 1.00 3. 0.285 MANDREL TAPER (IN./IN.): 0.045

NOMINAL HOLE SIZE (IN.) 3/8 MANDREL MAX DIA (IN.): 0.3537

SLEEVE THICKNESS (IN.): 0.010

LUBRICANT (SLEEVE): Fel Pro 300 (on sleeve)

Hole no.	Hole diameter (in.)			Pull force (lb)	Actual coldwork diameter expansion (in.)	Retained diameter expansion in aluminum (in.)	Retained diameter expansion in titanium (in.)	Remarks	
	Before coldwork		After coldwork						
	Ti	Al	Ti						
A2	0.3605	0.3610	0.3670	0.3695	2800	0.013	0.0085	0.0065	Sleeves easy to remove—sleeve thinnout accounts for part of the difference in retained expansion.
A3	0.3605	0.3610	0.3670	0.3695	2400	0.013	0.0085	0.0065	
A4	0.3605	0.3610	0.3675	0.3695	2300	0.013	0.0085	0.0070	
A5	0.3605	0.3610	0.3670	0.3690	2220	0.013	0.0080	0.0065	
A6	0.3605	0.3610	0.3670	0.3695	2420	0.013	0.0085	0.0065	
A7	0.3605	0.3610	0.3670	0.3695	2400	0.013	0.0085	0.0065	
B1	0.3605	0.3610	0.3670	0.3695	2460	0.013	0.0085	0.0065	
B2	0.3605	0.3610	0.3670	0.3695	2440	0.013	0.0085	0.0065	
B3	0.3605	0.3610	0.3670	0.3695	2460	0.013	0.0085	0.0065	
B4	0.3605	0.3610	0.3675	0.3695	2460	0.013	0.0085	0.0070	

PHASE I-TASK 5-MULTIMATERIAL STACK PROCESS DATA

SPECIMEN NUMBER: 2V TEST NUMBER: 6 DATE: 12/13/72

MATERIAL COMBINATION: 1 6Al-4V-Ti 2 2024-T851 3 6Al-4V-Ti MANDREL TYPE: ST 5300-CBM-12-0-N

MATERIAL GAGE (IN.) 1 0.285 2 1.00 3 0.285 MANDREL TAPER (IN./IN.): 0.045

NOMINAL HOLE SIZE (IN.) 3/8 MANDREL MAX DIA (IN.): 0.3537

SLEEVE THICKNESS (IN.): 0.010

LUBRICANT (SLEEVE): Fel Pro 300 (on sleeve)

Hole no.	Hole diameter (in.)			Pull force (lb.)	Actual coldwork diameter expansion (in.)	Retained diameter expansion in aluminum (in.)	Retained diameter expansion in titanium (in.)	Remarks
	Before coldwork	After coldwork						
	Ti	Ti	Al					
F1	0.3655	0.3650	0.3695	1800	0.008	0.0040	0.0025	Sleeves easy to remove with pliers. Some pulled out with use of fingers.
F2	0.3655	0.3650	0.3695	1820	0.008	0.0040	0.0025	
F3	0.3655	0.3680	0.3695	1720	0.008	0.0035	0.0025	
F4	0.3655	0.3695	0.3695	1850	0.008	0.0035	0.0030	
F5	0.3655	0.3680	0.3695	1660	0.008	0.0040	0.0025	
G1	0.3655	0.3685	0.3695	1700	0.008	0.0035	0.0030	
G2	0.3655	0.3680	0.3695	1680	0.008	0.0040	0.0025	
G3	0.3655	0.3685	0.3695	1480	0.008	0.0040	0.0030	
G4	0.3655	0.3680	0.3695	1460	0.008	0.0035	0.0025	
G5	0.3655	0.3680	0.3695	1460	0.008	0.0035	0.0025	

PHASE I-TASK 5-MULTIMATERIAL PROCESS DATA

TEST OBJECTIVE

To determine size differential in aluminum and titanium stack after final ream operation

TEST CONDITIONS

a) Material

- 1) Test plate 1-V consists of 0.0250-in.-thick 2024-T851 plate + 0.250-in.-thick Ti-6Al-4V plate + 0.250-in.-thick 2024-T851 plate (0.75 in. total)
- 2) Test plate 2-V consists of 0.250-in.-thick Ti-6Al-4V plate + 1.00 in.-thick 2024-T851 plate + 0.250-in.-thick Ti-6Al-4V plate.

b) Sizing method

- 1) Reaming (0.3735-in. diameter) using TB1 (freon)

TEST RESULTS

a) Test plate 1-V as-reamed hole diameter in inches

2024-T851	Ti-6Al-4V	2024-T851
0.3737	0.3742	0.3742
0.3738	0.3740	0.3740

b) Test plate 2-V as-reamed hole diameter in inches

Ti-6Al-4V	2024-T851	Ti-6Al-4V
0.3741	0.3741	0.3742
0.3742	0.3742	0.3745

PHASE I-TASK 6-SIZING PARAMETERS

Aluminum (2024-T851)-3/8-in. nominal diameter hole in 3/8-in.-thick material, 0.019-in. expansion

Test plate hole no.	Maximum diameter at exit	Typical hole size requirement (in.)	Material to be removed diameter difference (in.)	Comments
D-1	0.370	} 0.3730 0.3740 0.3730	0.003 min 0.007 max	Reamed five holes with 0.373 reamer; no sign of exit not cleaning up.
D-2	0.369			
D-3	0.370			
D-4	0.370			
E8	0.370			
D8	0.369			
F2	0.371			
F3	0.369			
F4	0.367			
G-1	0.368			

Titanium (Ti-6Al-4V)-3/8-in. nominal diameter hole in 3/8-in.-thick material, 0.019-in. expansion

Test Plate VII hole no.	Maximum diameter at exit	Typical hole size requirement (in.)	Material to be removed diameter difference (in.)	Comments
A1	0.369	} 0.3730 0.3740 0.3730	0.002 min 0.005 max	Reamed five holes with 0.373 diameter reamer; all holes cleaned up
B1	0.370			
C1	0.370			
D1	0.371			
A2	0.370			
B2	0.370			
C2	0.370			
D2	0.370			
E2	0.370			
F2	0.371			
G2	0.370			

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**APPENDIX III**

**PHASE II DATA**

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A. ALUMINUM

Task 1 (base metal)

	<u>Stress (ksi)</u>	<u>Cycles</u>	
1) 2024-T851	30	370,000	
		510,000	
		468,000	
	25	810,000	
		15,576,000 NF	
		1,660,000	
	35	239,000	
		219,000	
	40	112,000	
		143,000	
	2) 7175-T736	30	8,022,000
			8,156,000
10,123,000 NF			

Task 2 (open holes)

	<u>Stress (ksi)</u>	<u>Cycles</u>	
1) <u>2024-T851</u>	30	39,000	
		46,000	
		47,000	
	a) Honed holes	30	45,000
			47,000
			37,000
		25	46,000
			52,000
			219,000
	b) Reamed only	20	11,000
			10,000
			59,000
	c) C/W and postreamed	40	14,000
			15,000
			975,000
	c) C/W and postreamed	25	366,000
			12,700,000 NF
			96,000
	c) C/W and postreamed	35	114,000

	40	35,000 38,000
2) 7175-T736		
a) Reamed only	30	45,000 56,000 69,000
b) C/W and postreamed	30	510,000 618,000 692,000

Task 3 (ZLT-filled holes)

	<u>Stress (ksi)</u>	<u>Cycles</u>
1) <u>2024-T851</u>		
a) Reamed-net-fit Hi-Loks	30	696,000 565,000 127,000 237,000 205,000
	25	404,000 684,000
	35	82,000 79,000
	40	52,000 49,000
b) C/W and postreamed-net-fit Hi-Loks	30	591,000 950,000 608,000
	25	7,779,000 NF 8,323,000 NF
	35	311,000 387,000
	40	161,000 149,000
c) Protruding-head Taperlok	30	1,236,000 947,000 6,086,000 2,662,000
	25	10,075,000 NF 1,594,000 10,164,000 NF
	35	328,000 369,000

	40	237,000
		156,000
d) 100°-flush head Taperlok	30	147,000
		264,000
		196,000
	25	612,000
		661,000
2) <u>7175-T736</u>		
a) Reamed-net-fit Hi-Loks	30	359,000
		1,007,000
		253,000
b) C/W and postreamed-net-fit Hi-Loks	30	513,000
		523,000
		293,000

Task 4 (process/application variations)

	<u>Stress (ksi)</u>	<u>Cycles</u>
1) All 2024-T851		
a) <u>Open holes</u>		
90°-sleeve split	30	382,000
		424,000
		335,000
C/W-as-drilled hole	30	261,000
		491,000
		226,000
C/W-abusively drilled hole	30	110,000
		287,000
		93,000
C/W-no postream	30	431,000
		333,000
		330,000
C/W and score one hole	30	300,000
		94,000
		393,000
C/W plus 1/64-in. postream	30	235,000
		249,000
		214,000
C/W plus 1/32-in. postream	30	283,000
		256,000
		285,000
C/W plus 1/16-in. postream	30	312,000
		372,000
		226,000



Square wire sleeve	30	167,000
		339,000
		586,000
0.060-in.-thick material	30	48,000
		49,000
		65,000
1-1/2D E/M; 5-1/4D hole spacing	30	855,000
		203,000
		325,000
2D E/M; 5-1/4 SP	30	504,000
		535,000
		253,000
2-1/2D E/M; 5-1/4 SP	30	756,000
		393,000
		254,000
2-1/2D E/M; 3D SP	30	339,000
		355,000
		380,000
2-1/2D E/M; 4D SP	30	300,000
		294,000
		272,000
b) <u>ZLT-filled holes</u> (net-fit Hi-loks unless otherwise noted)		
One hole not C/W	30	855,000
		703,000
		325,000
C/W-0.002 clearance, Hi-Lok		694,000
		366,000
		697,000
C/W-0.000 interference, Hi-Lok		120,000
		185,000
		250,000
C/W-100°-csk, after		1,247,000
		950,000
		1,186,000
C/W-100°-csk, before *		169,000
		508,000
		213,000
C/W-70°-csk, after		290,000
		315,000
		191,000
C/W--cracked, before		93,000
		515,000
		625,000

c)	<u>ZLT-15-hole coupon, filled holes</u>		
	C/W and postreamed	40	149,850 150,320 135,990
d)	<u>LLT-15-hole coupon, filled holes</u>		
	C/W and postreamed-one at time	30	265,000 264,000 288,000
	C/W and postreamed-production technique	40	153,000 146,000
		30	273,900
	C/W-no postream-production technique	40	154,600 157,200 165,500
e)	<u>HLT-filled holes</u>		
	C/W-net-fit, 0.010-in. shim	30	580,620 371,350 500,440
	C/W-0.002 clearance, 0.010-in. shim	30	281,720 291,700 355,200
	C/W-0.002 interference, 0.010-in. shim	30	924,180 655,880 900,530
	C/W-net-fit flush-head, 0.010-in. shim	30	508,360* 343,460* 557,400*
	C/W-net fit, no shim	30	294,720 386,990 399,190
	C/W-net fit, no shim, upset removed	30	429,000 674,690 990,370
	Taperlok-0.010-in. shim	30	682,310 741,500 369,400
	Taperlok-flush head, 0.010-in. shim	30	1,422,000* 517,810* 548,000*

\*Test specimen design did not produce evaluation of countersink zone, only shank zone properly evaluated

Reamed only, 0.010-in. shim	30	201,290 151,220 122,060
C/W-0.060-in. shim	30	365,020 867,530

**B. TITANIUM**

<u>Task 1 (base metal)</u>	<u>Stress (ksi)</u>	<u>Cycles</u>		
1) Ti-6Al-4V (ann)	80	4,051,000 4,200,000		
	85	591,000 1,400,000		
	95	605,000 1,071,000		
	100	188,000 463,000		
	2) Ti-6Al-4V (STA)	135	35,000	
		115	87,000 44,000	
3) Ti-6Al-4V (STOA)		115	113,000 97,000 117,000	
	4) Ti-6Al-6V-2Sn (ann)	115	69,000 53,000 117,000	
		5) Ti-6Al-6V-2Sn (STA)	115	103,000 90,000 60,000
6) Ti-6Al-6V-2Sn (STOA)			115	189,000 107,000 148,000
	<u>Task 2 (open holes)</u>		<u>Stress (ksi)</u>	<u>Cycles</u>
	1) Ti-6Al-4V (ann)	a) Honed holes	65	41,000 66,000 58,000
b) Reamed only			60	67,000 43,000

	65	41,000 39,000
	50	103,000 142,000
	55	420,000 51,000 117,000
c) C/W and postreamed	60	117,000 116,000
	50	1,576,000 6,865,000
	70	70,000 64,000
	65	88,000 104,000
2. Ti-6Al-4V (STA)		
a) Reamed only	70	26,000 30,000 36,000
b) C/W and postreamed	70	81,000 83,000 51,000
3) Ti-6Al-4V (STOA)		
a) Reamed only	70	30,000 32,000 33,000
b) C/W and postreamed	70	70 00 38,000 58,000
4) Ti-6Al-6V-2Sn (ann)		
a) Reamed only	70	51,000 35,000 28,000
b) C/W and postreamed	70	50,000 70,000 79,000
5) Ti-6Al-6V-2Sn (STA)		
a) Reamed only	70	22,000 23,000 24,000

b) C/W and postreamed	70	76,000 94,000 72,000
6) Ti-6Al-6V-2Sn (STOA)		
a) Reamed only	70	38,000 38,000 30,000
b) C/W and postreamed	70	67,000 48,000 55,000
7) Ti-6Al-4V (ann) (3/4-in.-diameter holes)		
C/W and postreamed	70	86,000 54,000 61,000

Task 3 (ZLT-filled holes)

	<u>Stress (ksi)</u>	<u>Cycles</u>
1) Ti-6Al-4V (ann)		
Reamed-net-fit Hi-Loks	70	90,000 83,000 78,000
	75	47,000 52,000
	65	109,000 92,000
	60	246,000 139,000
2) Ti-6Al-4V (STA)		
Reamed-net-fit Hi-Loks	70	65,000 74,000 82,000
3) Ti-6Al-4V (STOA)		
Reamed-net-fit Hi-Loks	70	82,000 74,000 69,000
4) Ti-6Al-6V-2Sn (ann)		
Reamed-net-fit Hi-Loks	70	53,000 43,000 56,000
5) Ti-6Al-6V-2Sn (STA)		
Reamed-net-fit Hi-Loks	70	54,000 48,000 29,000

6) Ti-6Al-6V-2Sn (STOA)		
Reamed-net-fit Hi-Loks	70	70,000 52,000 51,000
Ti-6Al-4V (ann)		
C/W and postreamed with net-fit Hi-Loks	70	1,830,000 347,000 698,000
	65	1,333,000 2,273,000
	75	203,000 199,000
	80	180,000 137,000
7) Ti-6Al-4V (STA)		
C/W and postreamed with net-fit Hi-Loks	70	509,000 468,000 545,000
9) Ti-6Al-4V (STOA)		
C/W and postreamed with net-fit Hi-Loks	70	1,580,000 616,000 146,000
10) Ti-6Al-6V-2Sn (ann)		
C/W and postreamed with net-fit Hi-loks	70	530,000 487,000 195,000
11) Ti-6Al-6V-2Sn (STA)		
C/W and postreamed with net-fit Hi-Loks	70	143,000 99,000 110,000
12) Ti-6Al-6V-2Sn (STOA)		
C/W and Postreamed with net-fit Hi-Loks	70	197,000 90,000 147,000
13) Ti-6Al-4V (ann)		
a) Protruding-head Taperloks	70	367,000 689,000 5,323,000
	75	3,086,000 10,061,000

	65	7,788,000 NF
		7,774,000 NF
	60	300,000
		7,602,000 NF
b) Flush-head Taperloks	70	1,146,000
		240,000
		370,000
	75	372,000
		99,000
	65	266,000
		563,000
	60	1,092,000
		2,602,000

Task 4 (process/application variations)

1) (all Ti-6Al-4V (ann))

a) Open holes

	<u>Stress (ksi)</u>	<u>Cycles</u>
90°-sleeve split (C/W)	70	179,000
		87,000
		79,000
C/W as-drilled hole	70	63,000
		66,000
		66,000
C/W-abusively drilled hole	70	47,000
		43,000
		54,000
C/W-no postream	70	79,000
		88,000
		82,000
C/W-score, one hole	70	85,000
		72,000
		76,000
C/W plus 1/64-in. postream	70	61,000
		64,000
		64,000
C/W plus 1/32-in. postream	70	54,000
		76,000
		67,000
C/W plus 1/16-in. postream	70	62,000
		67,000
		54,000

C/W square wire sleeve (no results, see data sheet)			
0.060-in.-thick material C/W plus postream	70	61,000 50,000 61,000	
1-1/2D E/M; 5-1/4D hole spacing C/W plus postream	70	46,000 90,000 68,000	
2D E/M; 5-1/4D hole spacing C/W plus postream	70	49,000 56,000 52,000	
2-1/2D E/M; 5-1/4D hole spacing C/W plus postream	70	67,000 63,000 62,000	
2-1/2D E/M; 3D hole spacing C/W plus postream	70	58,000 81,000 74,000	
2-1/2D E/M; 4D hole spacing C/W plus postream	70	59,000 104,000 66,000	
b) Filled holes (ZLT) -(net-fit Hi-Loks unless otherwise noted)			
One hole not C/W	70	119,000 77,000 1,286,000	
C/W-0.002-in. clearance, Hi-Lok	70	153,000 226,000 179,000	
C/W-0.002-in. interference, Hi-lok	70	4,421,000 6,836,000 824,000	
C/W-csk after	70	217,000 212,000 483,000	
C/W-csk before	70	760,000 757,000 1,064,000	
C/W-70	C/W-70°-csk after	70	555,000 570,000 435,000



	C/W-prefatigued	70	709,000
			431,000
	C/W-cracked before	70	312,000
			92,000
			782,000
c)	ZLT-15-hole coupon, filled holes		
	C/W postreamed	70	124,450
			122,210
			60,780
d)	LLT-15-hole coupon, filled holes		
	C/W and postreamed - production technique	70	40,190
			31,840
			47,330
	C/W, no postreamed - production technique	70	98,040
			187,150
			191,330
	C/W, postreamed - 2024-T851 stringer plus Ti-6Al-4V (ann) skin	40(Al) 64(Ti)	61,590 79,170 64,620
e)	HLT-filled holes		
	C/W-net-fit, 0.010 shim	70	21,280
			22,500
			17,340
	C/W-0.002-in. clearance, 0.010-in. shim	70	18,660
			20,640
			20,000
	C/W-0.002-in. interference, 0.010-in shim	70	24,140
			24,700
			26,630
	C/W-net-fit, flush head, 0.010-in. shim	70	11,580
			6,200
			11,170
	C/W-net-fit, no shim	70	30,700
			39,950
			33,630
	C/W-net-fit-no shim, upset removed	70	98,140
			36,180
			31,890
	Taperlok -protruding head, 0.010-in. shim	70	73,970
			78,490
			62,280

Taperlok - flush head, 0.010 shim	70	9,590 8,450 8,740
Reamed only - net-fit Hi-Lok	70	19,050 18,060 10,940

C. 300M STEEL (270/300 KSI)

Task 1 (base metal)

<u>Stress (ksi)</u>	<u>Cycles</u>
110	10,000,000 NF 10,000,000 NF
120	10,000,000 NF
130	591,000 177,000 2,558,000
135	364,000
140	84,000 114,000

Task 2 (open holes)

	<u>Stress (ksi)</u>	<u>Cycles</u>
a) Honed holes	105	43,000 34,000 42,000
b) Reamed only	100	113,000 400,000
	105	139,000 103,000 75,000
	110	48,000 60,000
	115	32,000 49,000
c) C/W and postreamed	100	99,000 132,000
	105	54,000 72,000 71,000
	110	41,000 62,000

	115	127,000 46,000
d) C/W and postreamed 3/4-in.-diameter holes	100	100,000 75,000 210,000
<b>Task 3 (ZLT-filled holes)</b>		
	<u>Stress (ksi)</u>	<u>Cycles</u>
a) Reamed only plus net-fit Hi-Loks	100	112,000 237,000
	105	97,000 136,000
	110	76,000 90,000 62,000
	115	40,000 51,000
b) C/W and postreamed with net-fit Hi-Loks (0.045 in./in. mandrels taper)	100	673,000 8,300,000
	105	462,000 4,203,000
	110	141,000 382,000 252,000
c) C/W and postream with net fit Hi-Loks (0.030 in./in. mandrel taper)	110	390,000 349,000 264,000
d) C/W and postream with netfit Hi-Loks (0.045 in./in. mandrel taper) (0.005 in. less interference)	110	121,000 118,000 105,000
e) C/W and postream with net fit Hi-Loks (0.015 in./in. mandrel taper)	110	287,000 364,000 76,000
<b>Task 4 (process/application variations)</b>		
	<u>Stress (ksi)</u>	<u>Cycles</u>
a) <u>Open holes</u>		
0°-sleeve process	110	93,000 280,000 178,000

90°-split sleeve process	110	163,000
		128,000
		114,000
C/W -no postream	110	428,000
		388,000
		208,000
C/W -score, one hole	110	103,000
		67,000
		110,000
C/W -as-drilled hole	110	266,000
		152,000
		252,000
C/W -abusively drilled holes	110	113,000
		150,000
		380,000
C/W plus 1/64-in. postream	110	65,000
		45,000
		59,000
C/W plus 1/32-in. postream	110	248,000
		121,000
		209,000
C/W plus 1/16-in. postream	110	58,000
		72,000
		55,000
0.060-in.-thick material	110	71,000
		12,000
		47,000
1-1/2D E/M; 5-1/4D hole spacing	110	100,000
		170,000
		177,000
2D E/M; 5-1/4D hole spacing	110	78,000
		44,000*
		56,000*
2-1/2D E/M; 5-1/4D hole spacing	110	70,000
		72,000
		182,000
2-1/2D E/M; 3D hole spacing	110	91,000
		80,000
		116,000

\*Grip failed

2-1/2D E/M; 4D hole spacing	110	120,000
		145,000
		143,000
b) <u>ZLT-filled holes</u> (net-fit Hi-Loks unless otherwise noted)		
One hole, not C/W	110	43,000
		52,000
		33,000
C/W - 0.002-in. clearance, Hi-Lok	110	711,000
		254,000
		283,000
C/W - 0.002-in. interference, Hi-Lok	110	3,282,000
		198,000
		244,000
C/W - 100°-csk after	110	9,993,000 NF
		7,760,000 NF
		1,510,000
C/W - 70°-csk after	110	935,000
		420,000
		2,547,000
C/W - 100°-csk before	110	38,000
		26,000
		36,000
C/W - prefatigued	110	343,000
		7,508,000 NF
C/W - cracked before	110	7,484,000 NF
		486,000
c) <u>HLT-filled holes</u> (Hi-Loks)		
C/W - net-fit, 0.020-in. shim	110	18,830
		17,240
		13,750
C/W - 0.002-in. clearance-fit, 0.020-in. shim	110	14,850
		21,820
		17,150
C/W - 0.002-in. interference fit, 0.020-in. shim	110	20,350
		15,040
		21,930
C/W - net fit, flush head, 0.020-in shim, side plates reduced to 0.125 in. thick	110	7,910
		8,090
		9,300

	<u>Stress</u>	<u>Cycles</u>	<u>Stress*</u>	<u>Cycles</u>
Reamed only 0.020-in. shim	110	4,220	110	4,220
	95	8,040	110	2,500
	95	9,320	110	3,000
C/W--net fit, no shim	122	7,150	110	10,000
	122	9,660	110	15,000
	122	11,770	110	20,000

\*Values converted to 110 ksi stress

PHASE II TASK 1 - BASE METAL VALUES

TEST NUMBER: II Base  
 NOMINAL EXPANSION VALUE: -

GENERAL TEST CONDITIONS

DATE: 1-15-73

1. Specimen Description

Zero load transfer  
 Configuration: Fig. 2  
 Width: 1.50"  
 Hole spacing: -  
 Edge margin: -  
 Material: 2024 T 851  
 Material gauge: 0.250"  
 Surface Treatment: Shot Peen  
 Fastener: None

3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: -  
 Sleeve orientation: -  
 CW Mandrel: .0M - -0-N  
 CW M: -  
 Major Dia.: -  
 Surface: Fel Pro 300 (on sleeve)

**NOT APPLICABLE**





2. Hole Preparation

Nominal hole size: -  
 Process: -

2024  
 Base Metal  
 30 ksi

4. Fatigue Conditions

Net stress: 30 ksi  
 Test load: 10,500 lbs  
 Load ratio: (R) = 0.1  
 Test Frequency: 5000/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophore (36 Kip)

Specimen No. R623077	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
-1									370		
-2									510		
-3									468		

NO HOLES

 Taken at Minimum (midpoint)

PHASE II TASK I - BASE METAL VALUES

TEST NUMBER: II BASE

NOMINAL EXPANSION VALUE: -

GENERAL TEST CONDITIONS

DATE: 1-15-73

1. Specimen Description

Zero load transfer.  
 Configuration: Fig 2  
 Width: 1.50"  
 Hole spacing: -  
 Edge margin: -  
 Material: 2024 T 851  
 Material gauge: 0.250"  
 Surface Treatment: Shot Peen  
 Fastener: None

3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: -  
 Sleeve orientation: -  
 CW Mandrel: 0.0M - 0-N  
 CW M: -  
 Major Dia.: -  
 Surface: Fel Pro 300 (on sleeve)

**NOT APPLICABLE**

2. Hole Preparation

Nominal hole size: -  
 Process: -

2024  
 Base Metal  
 25 ksi

4. Fatigue Conditions

Net stress: 25 ksi  
 Test load: 9,600 lbs  
 Load ratio: (R) = 0.1  
 Test Frequency: 5000/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophore (36 Kip)

Specimen No. R623077	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (inches)	Retained Diametrical Expansion (inches)	Cycles to failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW	After ream	Before CW	After CW	After Ream				
-4										810	
-5										15,576 NF	 No Failure
-10										1,660	

**NO HOLES**

1 - Taken at Minimum (midpoint)



PHASE II TASK 1 - BASE METAL VALUES

TEST NUMBER: 11 Base

NOMINAL EXPANSION VALUE: -

GENERAL TEST CONDITIONS

DATE: 1-15-73

1. Specimen Description

Zero load transfer  
 Configuration: Fig. 2  
 Width: 1.50"  
 Hole spacing: -  
 Edge margin: -  
 Material: 2024 T 851  
 Material gauge: 0.250"  
 Surface Treatment: Shot Peen  
 Fastener: None

3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: -  
 Sleeve orientation: -  
 CW Mandrel: UM- -0-N  
 CW Mandrel Major Dia.: -  
 CW Mandrel: Fel Pro 300 (on sleeve)

**NOT APPLICABLE**


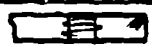

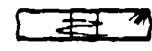
2. Hole Preparation

Nominal hole size: -  
 Process: -

2024  
 Base Metal  
 35 ksi

4. Fatigue Conditions

Net stress: 35 ksi  
 Test load: 11,750 lbs  
 Load ratio: (R) = 0.1  
 Test Frequency: 5000/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophore (36 Kip)

Specimen No. R623077	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (inches)	Retained Diametrical Expansion (inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
-6										239	
-7										219	
											

**NO HOLES**

[1] - Taken at Minimum (midpoint)

PHASE II TASK 1 - BASE METAL VALUES

TEST NUMBER: II Base

NOMINAL EXPANSION VALUE: -

GENERAL TEST CONDITIONS

DATE: 1-15-73

1. Specimen Description

Zero load transfer  
 Configuration: Fig. 2  
 Width: 1.50"  
 Hole spacing: -  
 Edge margin: -  
 Material: 2024 T 851  
 Material gauge: 0.250"  
 Surface Treatment: Shot Peen  
 Fastener: None

3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: -  
 Sleeve orientation: -  
 CW Mandrel: -0-N  
 CW M: -  
 Major Dia.: -  
 Minor Dia.: Fel Pro 300 (on sleeve)

**NOT APPLICABLE**





2. Hole Preparation

Nominal hole size: -  
 Process: -

2024  
 Base Metal  
 40 ksi

4. Fatigue Conditions

Net stress: 40 ksi  
 Test load: 12,500 lbs  
 Load ratio: (R) = 0.1  
 Test Frequency: 5000/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophore (36 Kip)

Specimen No. R623077	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
-8										112	
-9										143	
											

NO HOLES

 Taken at Minimum (midpoint)

PHASE II TASK 1 - BASE METAL VALUES

TEST NUMBER: BASE (7175 T736)

NOMINAL EXPANSION VALUE: -

GENERAL TEST CONDITIONS

DATE: 4-5-73

1. Specimen Description

Zero load transfer  
 Configuration: Fig. 2  
 Width: 1.50"  
 Hole spacing: -  
 Edge margin: -  
 Material: 7175 T736  
 Material gauge: 0.250"  
 Surface Treatment: Shot Peen  
 Fastener: None

3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: -  
 Sleeve orientation: -  
 CW Mandrel: UM - -0-N  
 CW M: -  
 Major Dia.: -  
 Surface: Fel Pro 300 (on sleeve)

**NOT APPLICABLE**

2. Hole Preparation

Nominal hole size: -  
 Process: -

7175  
Base Metal

4. Fatigue Conditions

Net stress: 30 ksi  
 Test load: 11,250 lbs  
 Load ratio: (R) 0.1  
 Test Frequency: 5000/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophore (36 Kip)

Specimen No. R623077	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diometrical Expansion (Inches)	Retained Diometrical Expansion (Inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW	After ream	Before CW	After CW	After Ream				
-1										8,022	
-2										8,156	
-3										10,123 NF	

NO HOLES

Token of Minimum (independent)

PHASE II - TASK 1 - BASE METAL VALUES

Ti-6Al-4V (annealed)  
base metal  
80 ksi

TEST IT1 SPECIMEN 623077 DATE 8/16/73

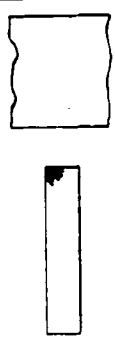
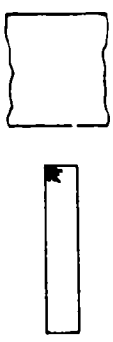
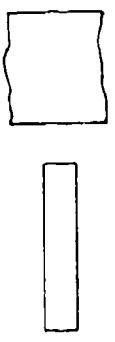
**SPECIMEN DESCRIPTION**  
 Configuration Fig. 2  
 Material Ti-6Al-4V (annealed)  
 Width (in) 1.50  
 Hole spacing -  
 Edge margin (in) -  
 Material gauge (in) 0.250  
 Surface treatment SHOULDER

**COLDWORK PROCESS**  
 Interference \_\_\_\_\_  
 Sieve type \_\_\_\_\_  
 Sleeve thickness (in) \_\_\_\_\_  
 Sleeve orientation \_\_\_\_\_  
 Mandrel material \_\_\_\_\_  
 Mandrel taper (in/in) \_\_\_\_\_  
 Mandrel max diameter (in) \_\_\_\_\_  
 Lubrication \_\_\_\_\_

**HOLE PREPARATION**  
 Nominal hole size (in) \_\_\_\_\_  
 Process \_\_\_\_\_  
 Type \_\_\_\_\_  
 Fit \_\_\_\_\_  
 Torque (in/ft) \_\_\_\_\_

**FASTENER INSTALLATION**

**FATIGUE CONDITIONS**  
 Max net stress (ksi) 80  
 Max test load (kip) 30.5  
 Load ratio (R) 0.1  
 Test frequency 4000 cpm  
 Test laboratory Materials  
 Test engineer D. Reese  
 Test machine 100 kip Vibraphore

Specimen dash no	Hole no	Hole diameter (in)			Hole finish (RHR)			Coldwork expansion (in)		Fastener size (in)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
1	1											4,051,000	 Failed at radius intersection
	2												
	3												
	4												
2	1											4,200,000	 Failed at radius intersection
	2												
	3												
	4												
	1												 Failed at radius intersection
	2												
	3												
	4												

PHASE II - TASK 1 - BASE METAL VALUES

Ti-6Al-4V (annealed)  
base metal  
85 ksi

TEST IT2 SPECIMEN 623077 DATE 8/16/73




FATIGUE CONDITIONS  
 Max net stress (ksi) 85  
 Max test load (kips) 33  
 Load ratio (R) 0.1  
 Test frequency 4000 cpm  
 Test laboratory Materials  
 Test engineer D. Reese  
 Test machine 100-kip Vibraphore

COLDWORK PROCESS  
 Interference \_\_\_\_\_  
 Sleeve type \_\_\_\_\_  
 Sleeve thickness (in) \_\_\_\_\_  
 Sleeve orientation \_\_\_\_\_  
 Mandrel material \_\_\_\_\_  
 Mandrel taper (in/in) \_\_\_\_\_  
 Mandrel max diameter (in) \_\_\_\_\_  
 Lubrication \_\_\_\_\_

HOLE PREPARATION  
 Nominal hole size (in) \_\_\_\_\_  
 Process \_\_\_\_\_

FASTENER INSTALLATION  
 Type \_\_\_\_\_  
 Fit \_\_\_\_\_  
 Torque (in-lb) \_\_\_\_\_

SPECIMEN DESCRIPTION  
 Configuration Fig. 2  
 Material Ti-6Al-4V (annealed)  
 Width (in) 1.50  
 Hole spacing \_\_\_\_\_  
 Edge margin (in) \_\_\_\_\_  
 Material gauge (in) 0.250  
 Surface treatment Shot peen

Specimen dash no	Hole no	Hole diameter (in)		Hole finish (RHR)			Coldwork expansion (in)		Fastener size (in)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
4	1										591,000	 Failed at radius intersection
	2											
	3											
	4											
5	1										1,400,000	 Failed at radius intersection
	2											
	3											
	4											
	1											 Failed at radius intersection
	2											
	3											
	4											

PHASE II - TASK 1 - BASE METAL VALUES

Ti-6Al-4V (annealed)  
base metal  
95 ksi

TEST IT3 SPECIMEN 623077 DATE 8/16/73

**SPECIMEN DESCRIPTION**  
 Configuration Fig. 2  
 Material Ti-6Al-4V (annealed)  
 Width (in.) 1.50  
 Hole spacing \_\_\_\_\_  
 Edge margin (in.) \_\_\_\_\_  
 Material gaug. (in.) 0.250  
 Surface treatment Shot peen

**COLDWORK PROCESS**  
 Interference \_\_\_\_\_  
 Sleeve type \_\_\_\_\_  
 Sleeve thickness (in.) \_\_\_\_\_  
 Sleeve orientation \_\_\_\_\_  
 Mandrel material \_\_\_\_\_  
 Mandrel taper (in./in.) \_\_\_\_\_  
 Mandrel max diameter (in.) \_\_\_\_\_  
 Lubrication \_\_\_\_\_

**HOLE PREPARATION**  
 Nominal hole size (in.) \_\_\_\_\_  
 Process \_\_\_\_\_

**FASTENER INSTALLATION**  
 Type \_\_\_\_\_  
 Fit \_\_\_\_\_  
 Torque (in. lb.) \_\_\_\_\_

**FATIGUE CONDITIONS**  
 Max net stress (ksi) 95  
 Max test load (kip) 37  
 Load ratio (R) 0.1  
 Test frequency 4000 cpm  
 Test laboratory Materials  
 Test engineer D. Reese  
 Test machine 100-kip Vibration

Specimen dash no.	Hole diameter (in.)		Hole finish (RHR)		Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
	Before coldwork	After ream	Before coldwork	After coldwork	Actual	Retention	Diameter	Fit		
-6	1								605,000	
	2									
	3									
	4									
-7	1								1,071,000	
	2									
	3									
	4									
	1									
	2									
	3									
	4									

PHASE II - TASK 1 - BASE METAL VALUES

Ti 6Al 4V (annealed),  
base metal  
100 ksi

TEST IT4 SPECIMEN 623077 DATE 8/16/73

FATIGUE CONDITIONS  
 Max net stress (ksi) 100  
 Max test load (kip) 39  
 Load ratio (R) 0.1  
 Test frequency 4000 cpm  
 Test laboratory Materials  
 Test engineer D. Reese  
 Test machine 100-kip Vibraphore

COLDWORK PROCESS  
 Interference \_\_\_\_\_  
 Sleeve type \_\_\_\_\_  
 Sleeve thickness (in.) \_\_\_\_\_  
 Sleeve orientation \_\_\_\_\_  
 Mandrel material \_\_\_\_\_  
 Mandrel taper (in/in) \_\_\_\_\_  
 Mandrel max diameter (in.) \_\_\_\_\_  
 Lubrication \_\_\_\_\_

HOLE PREPARATION  
 Nominal hole size (in.) \_\_\_\_\_  
 Process \_\_\_\_\_

FASTENER INSTALLATION  
 Type \_\_\_\_\_  
 Fit \_\_\_\_\_  
 Torque (in. lb) \_\_\_\_\_

SPECIMEN DESCRIPTION  
 Configuration Fig. 2  
 Material Ti 6Al 4V (annealed)  
 Width (in.) 1.50  
 Hole spacing \_\_\_\_\_  
 Edge margin (in.) \_\_\_\_\_  
 Material gauge (in.) 0.250  
 Surface treatment Shot peen

Specimen dash no	Hole no	Hole diameter (in.)		Hole finish (RHR)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
8	1										188,000	
	2											
	3											
	4											
9	1										463,000	
	2											
	3											
	4											
	1											Failed at radius intersection
	2											
	3											
	4											

PHASE II - TASK 1 - BASE METAL VALUES

Ti-6Al 4V (sta),  
base metal  
135 ksi

TEST ITS SPECIMEN 623077 DATE 8/16/73

<b>SPECIMEN DESCRIPTION</b>	<b>HOLE PREPARATION</b>	<b>FATIGUE CONDITIONS</b>
Configuration <u>Fig. 2</u>	Nominal hole size (in) _____	Max. net stress (ksi) <u>135</u>
Material <u>Ti-6Al 4V (sta)</u>	Process _____	Max. test load (kip) <u>45</u>
Width (in) <u>1.50</u>	Sleeve thickness (in) _____	Load ratio (R) <u>0.1</u>
Hole spacing _____	Sleeve orientation _____	Test frequency <u>4000 cpm</u>
Edge margin (in) _____	Mandrel material _____	Test laboratory <u>Materials</u>
Material gauge (in) <u>0.250</u>	<b>FASTENER INSTALLATION</b>	Test engineer <u>D. Reese</u>
Surface treatment <u>Shot peen</u>	Type _____	Test machine <u>100-kip Vibraphore</u>
	Mandrel taper (in/in) _____	
	Mandrel max. diameter (in) _____	
	Lubrication _____	
	Torque (in. lb) _____	

Specimen diag. no.	Hole no.	Hole diameter (in.)		Hole finish (RHII)		Colltwk expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before colltwk	After ream	Before colltwk	After colltwk	Actual	Retention	Diameter	Fit		
1 sta	1									35,000	
	2										
	3										
	4										
2 sta	1									87,000	
	2										
	3										
	4										
3 sta	1									44,000	Failed at radius intersection 
	2										
	3										
	4										



PHASE II - TASK 1 - BASE METAL VALUES

Ti 6Al-4V (stoa),  
base metal,  
115 ksi

TEST IT6 SPECIMEN 623077 DATE 8/16/73

<b>SPECIMEN DESCRIPTION</b>	<b>COLDWORK PROCESS</b>	<b>HOLE PREPARATION</b>	<b>FATIGUE CONDITIONS</b>
Configuration <u>Fig. 2</u>	Interference _____	Nominal hole size (in) _____	Max net stress (ksi) <u>115</u>
Material <u>Ti 6Al-4V (stoa)</u>	Sleeve type _____	Process _____	Max test load (kip) <u>43</u>
Width (in) <u>1.50</u>	Sleeve thickness (in) _____		Load ratio (R) <u>0.1</u>
Hole spacing _____	Sleeve orientation _____		Test frequency <u>4000 cpm</u>
Edge margin (in) _____	Mandrel material _____	<b>FASTENER INSTALLATION</b>	Test laboratory _____
Material gauge (in) <u>0.250</u>	Mandrel taper (in/in) _____	Type _____	Test engineer <u>D. Reese</u>
Surface treatment <u>Shot (peen)</u>	Mandrel max diameter (in) _____	Fit _____	Test machine <u>100-k ip Vibraphore</u>
	Lubrication _____	Torque (in ft) _____	

Specimen dash no	Hole no	Hole diameter (in)		Hole finish (RHR)		Coldwork expansion (in)		Fastener size (in)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	After coldwork	Actual	Retained	Diameter	Fit		
1 stoa	1									113,000	
	2										
	3										
	4										
2 stoa	1									97,000	
	2										
	3										
	4										
3 stoa	1									117,000	
	2										Failed at radius intersection
	3										
	4										

PHASE II - TASK 1 - BASE METAL VALUES

Ti-6Al-6V-2Sn (annealed),  
base metal,  
115 ksi

TEST 117 SPECIMEN 623077 DATE 9/20/73

SPECIMEN DESCRIPTION

Configuration Fig. 2  
Material Ti-6Al-6V-2Sn (annealed)  
Width (in) 1.50  
Hole spacing  
Edge margin (in)  
Material gauge (in) 0.250  
Surface treatment Shot peen

COLDWORK PROCESS

Interference  
Sleeve type  
Sleeve thickness (in)  
Sleeve orientation  
Mandrel material  
Mandrel taper (in/in)  
Mandrel max diameter (in)  
Lubrication

HOLE PREPARATION

Nominal hole size (in)  
Process  
FASTENER INSTALLATION  
Type  
Fit  
Torque (in-lb)

FATIGUE CONDITIONS

Max net stress (ksi) 115  
Max test load (kip) 44.4  
Load ratio (R) 0.1  
Test frequency 4000 cpm  
Test laboratory Materials  
Test engineer D Reese  
Test machine 100-kip Vibraphore

Specimen dash no	Hole no	Hole diameter (in)		Hole finish (RHRI)			Coldwork expansion (in)		Fastener size (in)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	After ream	After coldwork	Before coldwork	Actual	Retained	Diameter		
1-662	1										69,000	
	2											
	3											
	4											
2-662	1										53,000	
	2											
	3											
	4											
3-662	1										117,000	
	2											
	3											
	4											

PHASE II - TASK 1 - BASE METAL VALUES

Ti-6Al-6V-2Sn (sta),  
base metal,  
115 ksi

TEST ITB SPECIMEN 623077 DATE 9/20/73

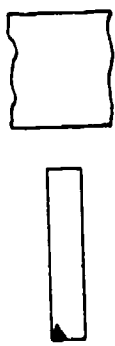


**SPECIMEN DESCRIPTION**  
 Configuration Fig. 2  
 Material Ti-6Al-6V-2Sn (sta)  
 Width (in) 1.50  
 Hole spacing \_\_\_\_\_  
 Edge margin (in) \_\_\_\_\_  
 Material gage (in) 0.250  
 Surface treatment Shot peen

**COLDWORK PROCESS**  
 Interference \_\_\_\_\_  
 Sleeve type \_\_\_\_\_  
 Sleeve thickness (in) \_\_\_\_\_  
 Sleeve orientation \_\_\_\_\_  
 Mandrel material \_\_\_\_\_  
 Mandrel taper (in/in) \_\_\_\_\_  
 Mandrel max diameter (in) \_\_\_\_\_  
 Lubrication \_\_\_\_\_

**HOLE PREPARATION**  
 Nominal hole size (in) \_\_\_\_\_  
 Process \_\_\_\_\_

**FASTENER INSTALLATION**  
 Type \_\_\_\_\_  
 Fit \_\_\_\_\_  
 Torque (in-lb) \_\_\_\_\_

**FATIGUE CONDITIONS**  
 Max net stress (ksi) 115  
 Max test load (kip) 43.2  
 Load ratio (R) 0.1  
 Test frequency 4000 cpm  
 Test laboratory Materials  
 Test engineer D. Reese  
 Test machine 100-kip Vibraphore



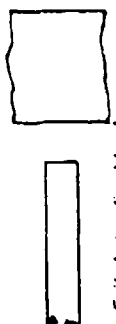
Specimen dash no	Hole no	Hole diameter (in)			Hole finish (RHR)		Coldwork expansion (in)		Fastener size (in)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	Actual	Retained	Diameter	Fit		
1. 662 sta	1										103,000	
	2									Failed at radius blend		
	3											
	4											
3. 662 sta	1										90,000	
	2									Failed at radius blend		
	3											
	4											
3. 662 sta	1										60,000	
	2									Failed at radius blend		
	3											
	4											

**PHASE II-TASK 1- BASE METAL VALUES**

Ti 6Al 6V2Sn (stoal),  
base metal,  
115 ksi

TEST IT9 SPECIMEN 623077 DATE 9/20/73


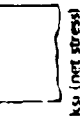

<b>SPECIMEN DESCRIPTION</b>	<b>COLDWORK PROCESS</b>	<b>HOLE PREPARATION</b>	<b>FATIGUE CONDITIONS</b>
Configuration <u>Fig. 2</u>	Interference _____	Nominal hole size (in.) _____	Max. net stress (ksi) <u>115</u>
Material <u>Ti-6Al-6V2Sn (stoal)</u>	Sleeve type _____	Process _____	Max. test load (kip) <u>44</u>
Width (in.) <u>1.50</u>	Sleeve thickness (in.) _____		Load ratio (R) <u>0.1</u>
Hole spacing _____	Sleeve orientation _____		Test frequency <u>4000 cpm</u>
Edge margin (in.) _____	Mandrel material _____	<b>FASTENER INSTALLATION</b>	Test laboratory <u>Materials</u>
Material gauge (in.) <u>0.250</u>	Mandrel taper (in./in.) _____	Type _____	Test engineer <u>D. Reese</u>
Surface treatment <u>Shot peen</u>	Mandrel max diameter (in.) _____	Fit _____	Test machine <u>100 kip Vibraphore</u>
	Lubrication _____	Torque (in. lb) _____	

Specimen dash no	Hole no	Hole diameter (in.)				Hole finish (HR)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
1-662 stoal	1												189,000	
	2													Failed at radius blend
	3													
	4													
2-662 stoal	1												102,000	
	2													Failed at radius blend
	3													
	4													
3-662 stoal	1												148,000	
	2													Failed at radius blend
	3													
	4													Failed at radius blend

PHASE II - TASK 1 - BASE METAL VALUES  
300 M Base Metal, 110 KSI

TEST ID: IA SPECIMEN: 623077 DATE: 6/11/73

SPECIMEN DESCRIPTION		HOLE PREPARATION		FATIGUE CONDITIONS	
Configuration	<u>Fig. 2</u>	Normal hole size (in.)	_____	Min net stress (ksi)	<u>110 and 135</u>
Material	<u>300 M steel (270-300 ksi)</u>	Process	_____	Max test load (kip)	<u>41.9 and 50</u>
Width (in.)	<u>1.50</u>	Shave the faces (in.)	_____	Load ratio (R)	<u>0.1</u>
Hole spacing	_____	Shave orientation	_____	Test frequency	<u>4400 cpm</u>
Edge margin (in.)	_____	Material material	<u>FASTENER INSTALLATION</u>	Test laboratory	<u>Materials</u>
Material gap (in.)	<u>0.250</u>	Manufacture taper (in/in)	Type	Test equipment	<u>D. Reeser</u>
Surface treatment	<u>Shot peen</u>	Manufacture hole diameter (in.)	Fit	Test machine	<u>100-kip Vibrashore</u>
		Lubrication	Torque (in. lb)		

Specimen tag no	Hole no	Hole diameter (in.)		Hole finish (RHRI)		Cracks expansion (in.)		Engine size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	Before coldwork	After ream	Actual	Retained	Diameter	Fit		
-1	1									364,000	 135 ksi (net stress)
	2										
	3										
	4										
-2	NO HOLES									1,000,000	No failure  110 ksi (net stress)
	4										
-3	1									1,000,000	No failure  110 ksi (net stress)
	2										
	3										
	4										

PHASE II - TASK 1 - BASE METAL VALUES

300 M Base Metal, 140 KSI

TEST 1B SPECIMEN 623017 DATE 6/11/72

SPECIMEN DESCRIPTION

Configuration Fig 2

Material 300 M steel (270-300 ksi)

Width (in) 1.50

Hole spacing \_\_\_\_\_

Edge margin (in) \_\_\_\_\_

Material gap (in) 0.250

Surface treatment Shot green

COLUMNWORK PROCESS

Interference \_\_\_\_\_

Sleeve type \_\_\_\_\_

Sleeve thickness (in) \_\_\_\_\_

Sleeve orientation \_\_\_\_\_

Material material \_\_\_\_\_

Material (inner (in)) \_\_\_\_\_

Material (max diameter (in)) \_\_\_\_\_

Lubrication \_\_\_\_\_

HOLE PREPARATION

Nominal hole size (in) \_\_\_\_\_

Process \_\_\_\_\_

FASTENER INSTALLATION

Type \_\_\_\_\_

Fit \_\_\_\_\_

Torque (in lb) \_\_\_\_\_

FATIGUE CONDITIONS

Max net stress (ksi) 140

Max test load (kip) 52

Load ratio (R) 0.1

Test frequency 4300 SPD

Test laboratory Materials

Test engineer D. Reese

Test machine 100 kip Vibrophor

Specimen dash no	Hole no	Hole diameter (in)		Hole finish (HRH)		Columnwork expansion (in)		Fastener size (in)		Cycles to failure	Origin of failure and remarks
		Before colwork	After colwork	Before colwork	After colwork	Actual	Retained	Diameter	F/I		
-4	1									84,000	
	2										
	3										
	4										
-5	NO HOLES										
	1										
	2										
	3										
-5	4									114,000	
	1										
	2										
	3										
-5	4										
	1										
	2										
	3										
-5	4										
	1										
	2										
	3										



PHASE II - TASK 1 - BASE METAL VALUES

300 M Base Metal 130 KSI

TEST ID SPECIMEN 623077 DATE 6/11/73

SPECIMEN DESCRIPTION

Fig. 2

Configuration \_\_\_\_\_  
 Material 300 M steel (270-300 KSI)  
 Width (in.) 1.50  
 Hole spacing \_\_\_\_\_  
 Edge margin (in.) \_\_\_\_\_  
 Material gap (in.) 0.250  
 Surface treatment Shot green

COLDWORK PROCESS

Interference \_\_\_\_\_  
 Sieve type \_\_\_\_\_  
 Sieve thickness (in.) \_\_\_\_\_  
 Sieve orientation \_\_\_\_\_  
 Mandrel material \_\_\_\_\_  
 Mandrel taper (in./in.) \_\_\_\_\_  
 Mandrel max diameter (in.) \_\_\_\_\_  
 Lubrication \_\_\_\_\_

HOLE PREPARATION

Nominal hole size (in.) \_\_\_\_\_  
 Process \_\_\_\_\_  
 FASTENER INSTALLATION  
 Type \_\_\_\_\_  
 Torque (in.-lb) \_\_\_\_\_

FATIGUE CONDITIONS

Max net stress (ksi) 130  
 Max test load (kip) 49.2  
 Load ratio (R) 0.1  
 Test frequency 4200 cpm  
 Test laboratory Material  
 Test engineer D. Reese  
 Test machine 100-kip Vibration

Specimen Label no	Hole no	Hole diameter (in.)			Hole finish (RHRI)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	F.A.		
-7	1											591,000	
	2												
	3												
-8	NO HOLES												
	4											177,000	
	1											2,558,000	
	2												
-9	3												
	4												



PHASE II TASK 2 - BASIC OPEN HOLE VALUES

TEST NUMBER: II A 1

NOMINAL EXPANSION VALUE: -

GENERAL TEST CONDITIONS

DATE: 1-30-73

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 2  
 Width: 1.50"  
 Hole spacing: 1.50"  
 Edge margin: 0.75"  
 Material: 2024 T 851  
 Material gauge: 0.375"  
 Surface Treatment: Shot Peen  
 Fastener: None

3. CW Process

Sleeve type: Axial  
 Sleeve thickness: 0.005"  
 Sleeve orien: 0°  
 CW Mn: 500-CBM-  
 CW: per:  
 Major Dia.: 0.375"  
 Material: Fel Pro 300 (on sleeve)

NOT APPLICABLE





2. Hole Preparation

Nominal hole size: 3/8"  
 Process: Drill, ream, Hone

2024  
 Honed Open  
 30 ksi

4. Fatigue Conditions

Net stress: 30 ksi  
 Test load: 8,500 lbs.  
 Load ratio: (R) 0.1  
 Test Frequency: 5000/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophore (36 KIP)

Specimen No. R-623078	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches) 	Cycles to Failure (Thousands)	Origin of Failure and Remarks
				After Hone			After Hone				
-1	1	-	-	.3755	-	-	25	-	-	39	
	2	-	-	.3755	-	-	25	-	-		
-2	1	-	-	.3760	-	-	25	-	-	46	
	2	-	-	.3760	-	-	25	-	-		
-3	1	-	-	.3755	-	-	20	-	-	47	
	2	-	-	.3755	-	-	20	-	-		

 Taken at Minimum (midpoint)

PHASE II TASK 2 - BASIC OPEN HOLE VALUES

TEST NUMBER: II A 2

NOMINAL EXPANSION VALUE: -

GENERAL TEST CONDITIONS

DATE: 1-30-73

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 2  
 Width: 1.50"  
 Hole spacing: 1.50"  
 Edge margin: 0.75"  
 Material: 2024 T 851  
 Material gauge: 0.375"  
 Surface Treatment: Shot Peen  
 Fastener: None

3. CW Process

Sleeve type: Axial  
 Sleeve thickness: uo  
 Sleeve orientation: uo  
 CW Method: uo-CBM- (-)-N  
 per: uo  
 Net Major Dia.: uo  
 Location: Fel Pro 300 (on sleeve)

NOT APPLICABLE -





2. Hole Preparation

Nominal hole size: 3/8"  
 Process: Drill & Ream

4. Fatigue Conditions

Net stress: 30 ksi  
 Test load: 8,500 lbs.  
 Load ratio: (R) 0.1  
 Test Frequency: 5,000/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophone (36 Kip)

2024  
 Reamed Open  
 30 ksi

Specimen No. R-623078	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (inches)	Retained Diametrical Expansion (inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
-5	1	-	-	.3760	-	-	40	-	-	45	
	2	-	-	.3760	-	-	50	-	-		
-6	1	-	-	.3765	-	-	50	-	-	47	
	2	-	-	.3765	-	-	50	-	-		
-7	1	-	-	.3760	-	-	45	-	-	37	
	2	-	-	.3760	-	-	50	-	-		

 Taken at Minimum (midpoint)

PHASE II TASK 2 - BASIC OPEN HOLE VALUES

TEST NUMBER: 2A

NOMINAL EXPANSION VALUE: -

GENERAL TEST CONDITIONS

DATE: 3-9-73

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 2  
 Width: 1.50"  
 Hole spacing: 1.50"  
 Edge margin: 0.75"  
 Material: 2024 T851  
 Material gauge: 0.250"  
 Surface Treatment: Shot Peen  
 Fastener: None

3. CW Process

Sleeve type: \_\_\_\_\_  
 Sleeve thickness: \_\_\_\_\_  
 Sleeve orifice: \_\_\_\_\_  
 CW Material: \_\_\_\_\_  
 CW Process: \_\_\_\_\_  
 Major Dia.: \_\_\_\_\_  
 Minor Dia.: \_\_\_\_\_

- NOT APPLICABLE -



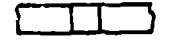
2. Hole Preparation

Nominal hole size: 3/8"  
 Process: Ream

2024  
 Reamed Open  
 20 ksi

4. Fatigue Conditions

Net stress: 20 ksi  
 Test load: 5,675 lbs  
 Load ratio: (R) = 0.1  
 Test Frequency: 5000/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophore 36 Kip)

Specimen No. R623078	Hole No.	Hole Diameter (Inches) After Ream	Fastener Diameter (Inches)	Net Fit Between Fastener and Hole	Hole Finish (RHR) After Ream	Cycles to Failure (Thousands)	Origin of Failure and Remarks
-14	1	.3760			65	59	 C/W 35 ksi (Net Stress)
	2	.3765			65		
-21	1	.3730			30	219	 C/W
	2	.3730			30		
-	1						
	2						

PHASE II TASK 2 - BASIC OPEN HOLE VALUES

TEST NUMBER: IIA 3

NOMINAL EXPANSION VALUE: -

GENERAL TEST CONDITIONS

DATE: 1-30-73

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 2  
 Width: 1.50"  
 Hole spacing: 1.50"  
 Edge margin: 0.75"  
 Material: 2024 T 851  
 Material gauge: 0.375"  
 Surface Treatment: Shot Peen  
 Fastener: None

3. CW Process

Sleeve type: Axial  
 Sleeve thickness: -  
 Sleeve ori: 0°  
 CW M: 300-CBM- -0-N  
 Super: -  
 Rel Major Dia.: -  
 Location: Fel Pro 300 (on sleeve)

NOT APPLICABLE

2. Hole Preparation

Nominal hole size: 3/8"  
 Process: Drill & Ream

4. Fatigue Conditions

Net stress: 25 ksi  
 Test load: 7000 lbs.  
 Load ratio: (R) = 0.1  
 Test Frequency: 5000/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophore (36 Kip)

2024  
Reamed Open  
25 ksi

Specimen No. R-623078	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW	After ream	Before CW	After CW	After Ream				
-8	1	-	-	.3760	-	-	60	-	-	46	
	2	-	-	.3760	-	-	55	-	-		
-9	1	-	-	.3760	-	-	45	-	-	52	
	2	-	-	.3760	-	-	55	-	-		

1 - Taken at Maximum (midpoint)



PHASE II TASK 2 - BASIC OPEN HOLE VALUES

TEST NUMBER: 11 A4 (a)

NOMINAL EXPANSION VALUE: -

GENERAL TEST CONDITIONS

DATE: 3-9-73

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 2  
 Width: 1.50"  
 Hole spacing: 1.50"  
 Edge margin: 0.75"  
 Material: 2024 T851  
 Material gauge: 0.250"  
 Surface Treatment: Shot Peen  
 Fastener: None

3. CW Process

Sleeve type: \_\_\_\_\_  
 Sleeve thickness: \_\_\_\_\_  
 Sleeve or: \_\_\_\_\_  
 CWM: \_\_\_\_\_  
 C: \_\_\_\_\_  
 Paper: \_\_\_\_\_  
 Major Dia.: \_\_\_\_\_  
 Location: \_\_\_\_\_

- NOT APPLICABLE -




2. Hole Preparation

Nominal hole size: 3/8"  
 Process: Ream

2024  
Reamed Open  
35 ksi

4. Fatigue Conditions

Net stress: 35 ksi  
 Test load: 10,000 lbs  
 Load ratio: (R) = 0.1  
 Test Frequency: 5000/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophore (36 Kip)

Specimen No. R623078	Hole No.	Hole Diameter (Inches) After Ream	Fastener Diameter (Inches)	Net Fit Between Fastener and Hole	Hole Finish (RHR) After Ream	Cycles to Failure (Thousands)	Origin of Failure and Remarks
-11A	1	.3732			25	27	
	2	.3732			-		
-12A	1	.3733			25	28	
	2	.3733			-		
-	1						
	2						

PHASE II TASK 2 - BASIC OPEN HOLE VALUES

TEST NUMBER: ILA 5

NOMINAL EXPANSION VALUE: -

GENERAL TEST CONDITIONS

DATE: 1-30-73

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 2  
 Width: 1.50"  
 Hole spacing: 1.50"  
 Edge margin: 0.75"  
 Material: 2024 T 851  
 Material gauge: 0.375"  
 Surface Treatment: Shot Peen  
 Fastener: None

3. CW Process

Sleeve type: Axial  
 Sleeve thickness: -  
 Sleeve orient: 0°  
 CW Mor: W-CBM -0-N  
 CW per: -  
 Major Dia.: -  
 Material: Fel Pro 300 (on sleeve)

- NOT APPLICABLE -

2. Hole Preparation

Nominal hole size: 3/8"  
 Process: Drill & Ream

4. Fatigue Conditions

Net stress: 40 ksi  
 Test load: 11,500 lbs.  
 Load ratio: (R) - 0.1  
 Test Frequency: 5000/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophone (36 Kip)

2024  
 Reamed Open  
 40 ksi

Specimen No. R-623078	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW	After ream	Before CW	After CW	After Ream				
-12	1	-	-	.3760	-	-	50	-	-	14	
	2	-	-	.3760	-	-	100	-	-		
-13	1	-	-	.3760	-	-	100	-	-	15	
	2	-	-	.3765	-	-	80	-	-		

Taken at Minimum (mid-point)

PHASE II TASK 2 - BASIC OPEN HOLE VALUES

TEST NUMBER: 11A6

NOMINAL EXPANSION VALUE: 0.0185-0.020

GENERAL TEST CONDITIONS

DATE: 12-19-73

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 2  
 Width: 1.50"  
 Hole spacing: 1.50"  
 Edge margin: 0.75"  
 Material: 2024 T 851  
 Material gauge: 0.250"  
 Surface Treatment: Shot Peen  
 Fastener: None

3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: 0.010"  
 Sleeve orientation: 0°  
 CW Mandrel: ST 5300-CBM-12 -0-N  
 CW Mandrel Taper: 0.045"/"  
 CW Mandrel Major Dia.: 0.354"  
 Lubrication: Fel Pro 300 (on sleeve)





2. Hole Preparation

Nominal hole size: 3/8"  
 Process: Drill, ream, CW & ream

4. Fatigue Conditions

Net stress: 25 ksi  
 Test load: 7,000 lbs.  
 Load ratio: (R) = 0.1  
 Test Frequency: 5000/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophore (36 Kip)

2024  
 C/W Open  
 25 ksi

Specimen No. R-623078	Hole No.	Hole Diameter (inches)			Hole Finish (RMR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
-15	1	.3555	.3665	.3735	35	20	30	.0185	.0110	975	 C/W
	2	.3552	.3668	.3735	-	-	-	.0188	.0116		
-16	1	.3552	.3665	.3735	35	20	30	.0188	.0113	366	 C/W
	2	.3555	.3665	.3735	-	-	-	.0185	.0110		
-22	1	.3555	.3670	.3730	40	20	30	.0185	.0115	12,700	 No Failure
	2	.3555	.3670	.3730	-	-	-	.0185	.0115		

! - Taken at Minimum (midpoint)



PHASE II TASK 2 - BASIC OPEN HOLE VALUES

TEST NUMBER: 11A7

NOMINAL EXPANSION VALUE: 0.0185-0.020

GENERAL TEST CONDITIONS

DATE: 2-9-73

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig 2  
 Width: 1.50"  
 Hole spacing: 1.50"  
 Edge margin: 0.75"  
 Material: 2024 T 851  
 Material gauge: 0.250"  
 Surface Treatment: Shot Peen  
 Fastener: None

3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: 0.010"  
 Sleeve orientation: 0°  
 CW Mandrel: ST 5300-CBM- 12 -0-N  
 CW Mandrel Taper: 0.045"/"  
 CW Mandrel Major Dia.: 0.354"  
 Lubrication: Fel Pro 300 (on sleeve)


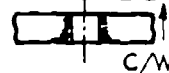
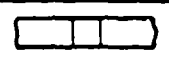
2. Hole Preparation

Nominal hole size: 3/8"  
 Process: Drill, ream, CW & ream

4. Fatigue Conditions

Net stress: 35 ksi  
 Test load: 9,900 lbs.  
 Load ratio: (R) = 0.1  
 Test Frequency: 5000/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophore (36 Kip)

2024  
 C/W Open  
 35 ksi

Specimen No. R-623078	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (inches)	Retained Diametrical Expansion (inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW $\Delta$	After ream	Before CW	After CW	After Ream				
-17	1	.3555	.3665	.3735	40	20	30	.0185	.0110	96	 C/W
	2	.3555	.3665	.3735	-	-	-	.0185	.0110		
-18	1	.3555	.3665	.3735	35	15	30	.0185	.0110	114	 C/W
	2	.3555	.3665	.3735	-	-	-	.0185	.0110		
											

PHASE II TASK 2 - BASIC OPEN HOLE VALUES

TEST NUMBER: II A 8

NOMINAL EXPANSION VALUE: 0.0181-0.020

GENERAL TEST CONDITIONS

DATE: 2-9-73

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig 2  
 Width: 1.50"  
 Hole spacing: 1.50"  
 Edge margin: 0.75"  
 Material: 2024 T 851  
 Material gauge: 0.250"  
 Surface Treatment: Shot Peen  
 Fastener: None

3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: 0.010"  
 Sleeve orientation: 0°  
 CW Mandrel: ST 5300-CBM- 12 -0-N  
 CW Mandrel Taper: 0.045"/"  
 CW Mandrel Major Dia.: 0.354"  
 Lubrication: Fel Pro 300 (on sleeve)



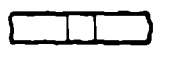
2. Hole Preparation

Nominal hole size: 3/8"  
 Process: Drill, ream, CW & ream

4. Fatigue Conditions

Net stress: 40 ksi  
 Test load: 11,400 lbs.  
 Load ratio: (R) = 0.1  
 Test Frequency: 5000/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophone (36 Kip)

2024  
 C/W Open  
 40 ksi

Specimen No. R-623078	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (inches)	Retained Diametrical Expansion (inches) $\nabla$	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW $\nabla$	After ream	Before CW	After CW	After Ream				
-19	1	.3555	.3665	.3735	40	20	30	.0185	.0110	35	 C/W
	2	.3555	.3665	.3735	-	-	-	.0185	.0110		
-20	1	.3560	.3665	.3735	40	20	30	.0180	.0105	38	 C/W
	2	.3555	.3665	.3735	-	-	-	.0185	.0110		
											

$\nabla$  Taken at Minimum (midpoint)

PHASE II TASK 2 - BASIC OPEN HOLE VALUES

TEST NUMBER: 11A9 (7175 T 736)

NOMINAL EXPANSION VALUE: \_\_\_\_\_

GENERAL TEST CONDITIONS

DATE: 4-5-73

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 2  
 Width: 1.50"  
 Hole spacing: 1.50"  
 Edge margin: 0.75"  
 Material: 7175 T 736  
 Material gauge: 0.250  
 Surface Treatment: Shot Peen  
 Fastener: None

3. CW Process

Sleeve type: Axial  
 Sleeve thickness: \_\_\_\_\_  
 Sleeve orient: 0°  
 CW Mn: JU-CBM -0-N  
 CW Major Dia.: \_\_\_\_\_  
 Material: Fel Pro 300 (on sleeve)

- NOT APPLICABLE -




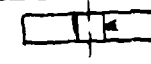
2. Hole Preparation

Nominal hole size: 3/8"  
 Process: Ream Only

4. Fatigue Conditions

Net stress: 30 ksi  
 Test load: 8,500 lbs.  
 Load ratio: (R) 0.1  
 Test Frequency: 5000/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophore (36 Kip)

7175  
Reamed Open  
30 ksi

Specimen No. R-673078	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
-1	1	-	-	.3735	-	-	35	-	-	45	
	2	-	-	.3735	-	-	-	-	-		
-2	1	-	-	.3735	-	-	40	-	-	56	
	2	-	-	.3735	-	-	-	-	-		
-3	1	-	-	.3735	-	-	35	-	-	69	
	2	-	-	.3735	-	-	-	-	-		

1 - Taken at Minimum (midpoint)

PHASE II TASK 2 - BASIC OPEN HOLE VALUES

TEST NUMBER: II A 10 (7175 T 736)

NOMINAL EXPANSION VALUE: 0.019"

GENERAL TEST CONDITIONS

DATE: 4-15-73

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 2  
 Width: 1.50"  
 Hole spacing: 1.50"  
 Edge margin: 0.75"  
 Material: 7175 T 736  
 Material gauge: 0.250  
 Surface Treatment: Shot Peen  
 Fastener: None

3. CW Process

Sleeve type: Axial Slot  
 Sleeve thickness: \_\_\_\_\_  
 Sleeve orientat: \_\_\_\_\_  
 CW Mandr: CBM -0-N  
 CW M- \_\_\_\_\_  
 C' \_\_\_\_\_ Major Dia.: \_\_\_\_\_  
 \_\_\_\_\_ Fel Pro 300 (on sleeve)

NOT APPLICABLE

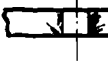
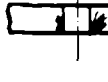

2. Hole Preparation

Nominal hole size: 3/8"  
 Process: Ream, C/W, Ream

4. Fatigue Conditions

Net stress: 30 ksi  
 Test load: 8,575 lbs.  
 Load ratio: (R) = 0.1  
 Test Frequency: 5000/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophore (36 Kip)

7175  
C/W Open  
30 ksi

Specimen No. R-623078	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW $\Delta$	After ream	Before CW	After CW	After Ream				
4	1	.3540	.3670	.3735	35	15	40	.0190	.0130	510	 C/W
	2	.3540	.3670	.3735	-	-	-	.0190	.0130		
-5	1	.3540	.3670	.3735	35	15	35	.0190	.0130	618	 C/W
	2	.3540	.3670	.3735	-	-	-	.0190	.0130		
-6	1	.3540	.3665	.3735	40	15	40	.0190	.0125	692	 C/W
	2	.3540	.3670	.3735	-	-	-	.0190	.0130		

1 - Taken at Minimum (midpoint)

PHASE II - TASK 2 - BASIC OPEN-HOLE VALUES

Ti 6Al 5V annealed,  
honed open,  
65 ksi

TEST 2T1 SPECIMEN 623078 DATE 9/14/73

SPECIMEN DESCRIPTION

Configuration Fig. 2  
Material Ti-6Al-4V (annealed)  
Width (in) 1.50  
Hole spacing (in) 1.50  
Edge margin (in) 0.75  
Material gauge (in) 0.250  
Surface treatment Shot peen

COLDWORK PROCESS

Interference \_\_\_\_\_  
Sleeve type \_\_\_\_\_  
Sleeve thickness (in.) \_\_\_\_\_  
Sleeve orientation \_\_\_\_\_  
Mandrel material \_\_\_\_\_  
Mandrel taper (in./in.) \_\_\_\_\_  
Mandrel max diameter (in.) \_\_\_\_\_  
Lubrication \_\_\_\_\_

HOLE PREPARATION

Nominal hole size (in.) 3/8  
Process Drill, ream, hone  
FASTENER INSTALLATION  
Type \_\_\_\_\_  
Fit \_\_\_\_\_  
Torque (in. lb) \_\_\_\_\_

FATIGUE CONDITIONS

Max net stress (ksi) 65  
Max test load (kip) 19  
Load ratio (R) 0.1  
Test frequency 4000 cpm  
Test laboratory Materials  
Test engineer D. Reese  
Test machine 36-kip Vibrophore

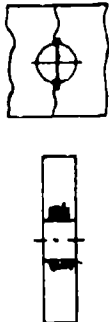
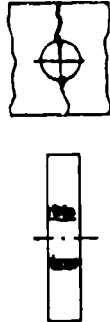
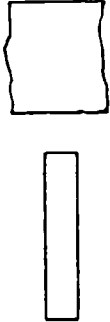
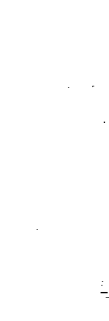

Specimen dash no	Hole no	Hole diameter (in.)			Hole finish (RHR)			Catchwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After hone	After coldwork	Before coldwork	After coldwork	Actual	Retention	Diameter	Fit			
1	1		0.3755									41,000	
	2		0.3755										
	3												
	4												
2	1		0.3755									66,000	
	2		0.3755										
	3												
	4												
3	1		0.3755									58,000	
	2		0.3755										
	3												
	4												

PHASE II - TASK 2 - BASIC OPEN-HOLE VALUES

Ti-6Al-4V,  
reamed open,  
60 ksi

TEST 212 SPECIMEN 623078 DATE 8/30/73

<b>SPECIMEN DESCRIPTION</b>	<b>COLLWORK PROCESS</b>	<b>HOLE PREPARATION</b>	<b>FATIGUE CONDITIONS</b>
Configuration <u>Fig. 2</u>	Interference _____	Nominal hole size (in) <u>0.375</u>	Max net stress (ksi) <u>60</u>
Material <u>Ti-6Al-4V (annealed)</u>	Sleeve type _____	Process <u>Ream</u>	Max test load (kip) <u>18.5</u>
Width (in) <u>1.50</u>	Sleeve thickness (in) _____		Load ratio (R) <u>0.1</u>
Hole spacing (in) <u>1.50</u>	Sleeve orientation _____		Test frequency <u>4000 cpm</u>
Edge margin (in) <u>0.75</u>	Mandrel material _____	<b>FASTENER INSTALLATION</b>	Test laboratory <u>Materials</u>
Material gauge (in) <u>0.250</u>	Mandrel taper (in/in) _____	Type _____	Test engineer <u>D. Reese</u>
Surface treatment <u>Shot peen</u>	Mandrel max diameter (in) _____	Fit _____	Test machine <u>36-kip Vibraphore</u>
	Lubrication _____	Torque (in. lb) _____	

Specimen dash no	Hole no	Hole diameter (in)		Hole finish (RHR)			Coldwork expansion (in)		Fastener size (in)		Cycles to failure	Origin of failure and remarks	
		Before coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit			
4	1		0.3755			25					67,000		
	2		0.3755										
	3												
	4												
5	1		0.3755			25					43,000		
	2		0.3755										
	3												
	4												
	1												
	2												
	3												
	4												

PHASE II - TASK 2 - BASIC OPEN-HOLE VALUES

Ti 6Al-4V,  
reamed open  
64 ksi

TEST 2T3 SPECIMEN 623078 DATE 8/30/73

**SPECIMEN DESCRIPTION** Fig. 2  
 Configuration: \_\_\_\_\_  
 Material: Ti-6Al-4V (annealed)  
 Width (in): 1.50  
 Hole spacing (in): 1.50  
 Edge margin (in): 0.75  
 Material gage (in): 0.250  
 Surface treatment: Shot peen

**COLDWORK PROCESS**  
 Interference: \_\_\_\_\_  
 Sleeve type: \_\_\_\_\_  
 Sleeve thickness (in): \_\_\_\_\_  
 Sleeve orientation: \_\_\_\_\_  
 Mandrel material: \_\_\_\_\_  
 Mandrel taper (in./in.): \_\_\_\_\_  
 Mandrel max diameter (in.): \_\_\_\_\_  
 Lubrication: \_\_\_\_\_

**FASTENER INSTALLATION**  
 Type: \_\_\_\_\_  
 Fit: \_\_\_\_\_  
 Torque (in. lb): \_\_\_\_\_

**HOLE PREPARATION**  
 Nominal hole size (in): 0.375  
 Process: Ream

**FATIGUE CONDITIONS**  
 Max net stress (ksi): 65  
 Max test load (kip): 19.2  
 Load ratio (R): 0.1  
 Test frequency: 4000 cpm  
 Test laboratory: Materials  
 Test engineer: D. Reese  
 Test machine: 36 kip Vibraphore

Specimen dash no	Hole no	Hole diameter (in)			Hole finish (RHR)		Coldwork expansion (in.)		Fastener size (in)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	Actual	Retained	Diameter	Fit		
.6	1			0.3755							41,000	
	2			0.3755								
	3											
	4											
.7	1			0.3755		25					39,000	
	2			0.3755								
	3											
	4											
	1											
	2											
	3											
	4											





PHASE II - TASK 2 - BASIC OPEN-HOLE VALUES

Ti 6Al 4V,  
reamed open,  
55 ksi

TEST 2T5 SPECIMEN 623078 DATE 8/30/73

**SPECIMEN DESCRIPTION**  
 Configuration Fig. 2  
 Material Ti 6Al 4V (annealed)  
 Width (in.) 1.50  
 Hole spacing (in.) 1.50  
 Edge margin (in.) 0.75  
 Material gauge (in.) 0.250  
 Surface treatment Shot peen

**COLDWORK PROCESS**  
 Interference \_\_\_\_\_  
 Sleeve type \_\_\_\_\_  
 Sleeve thickness (in.) \_\_\_\_\_  
 Sleeve orientation \_\_\_\_\_  
 Mandrel material \_\_\_\_\_  
 Mandrel taper (in./in.) \_\_\_\_\_  
 Mandrel max diameter (in.) \_\_\_\_\_  
 Lubrication \_\_\_\_\_

**HOLE PREPARATION**  
 Nominal hole size (in.) 0.375  
 Process Ream

**FASTENER INSTALLATION**  
 Type \_\_\_\_\_  
 Fit \_\_\_\_\_  
 Torque (in. lb) \_\_\_\_\_

**FATIGUE CONDITIONS**  
 Max net stress (ksi) 55  
 Max test load (kip) 16  
 Load ratio (R) 0.1  
 Test frequency 4000 cpm  
 Test laboratory Materials  
 Test engineer D. Reese  
 Test machine 36 kip Vibraphore

Specimen dash no	Hole no	Hole diameter (in.)			Hole finish (RHRI)			Coldwork expansion (in.)			Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit			
8	1		0.3755	0.3755			30						42,000	
	2		0.3755				-							
	3													
	4													
11	1		0.3755				25						57,000	
	2		0.3755				-							
	3													
	4													
12	1		0.3755				25						117,000	
	2		0.3755				-							
	3													
	4													



PHASE II-TASK2 - BASIC OPEN-HOLE VALUES

Ti-6Al-4V,  
C&W open,  
50 ksi

TEST 2T7 SPECIMEN 623078 DATE 8/30/73

**SPECIMEN DESCRIPTION**  
 Configuration Fig. 2  
 Material Ti-6Al-4V (annealed)  
 Width (in.) 1.50  
 Hole spacing (in.) 1.50  
 Edge margin (in.) 0.75  
 Material gage (in.) 0.250  
 Surface treatment Shot peen

**COLDWORK PROCESS**  
 Interference (in.) 0.019  
 Sleeve type Split  
 Sleeve thickness (in.) 0.010  
 Sleeve orientation 0°  
 Mandrel material AISI 9260 steel  
 Mandrel taper (in./in.) 0.045  
 Mandrel max diameter (in.) 0.353  
 Lubrication Fel Pro 300

**HOLE PREPARATION**  
 Nominal hole size (in.) 0.375  
 Process Ream, C/W, ream

**FASTENER INSTALLATION**  
 Type \_\_\_\_\_  
 Fit \_\_\_\_\_  
 Torque (in. lb) \_\_\_\_\_

**FATIGUE CONDITIONS**  
 Max net stress (ksi) 50  
 Max test load (kip) 14.4  
 Load ratio (R) 0.1  
 Test frequency 4000 cpm  
 Test laboratory Materials  
 Test engineer D. Reese  
 Test machine 36 kip Vibrashore

Specimen dash no	Hole no	Hole diameter (in)			Hole finish (RHR)			Coldwork expansion (in)		Fastener size (in)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
.15	1	0.3545	0.3635	0.3555	30	18	20	0.0185	0.0090			1,576,000	
	2	0.3545	0.3635	0.3755	-	-	-	0.0185	0.0090				
	3												
	4												
16	1	0.3545	0.3630	0.3755	25	15	25	0.0185	0.0085			6,868,000	
	2	0.3545	0.3630	0.3755	-	-	-	0.0185	0.0085				
	3												
	4												
.17	1	0.3545	0.3635	0.3755	25	12	25	0.0185	0.0090			-	
	2	0.3545	0.3635	0.3755				0.0185	0.0090				
	3												
	4												

Ti-6Al-4V,  
C/W open,  
70 ksi

**PHASE II - TASK 2 - BASIC OPENHOLE VALUES**

TEST 2T8 SPECIMEN 623078 DATE 8/30/73

**SPECIMEN DESCRIPTION**

Configuration Fig 2  
 Material Ti-6Al-4V (annealed)  
 Width (in) 1.50  
 Hole spacing (in) 1.50  
 Edge margin (in) 0.75  
 Material gauge (in) 0.250  
 Surface treatment Shot peen

**COLDWORK PROCESS**

Interference 0.019  
 Sleeve type Split  
 Sleeve thickness (in) 0.010  
 Sleeve orientation 0°  
 Mandrel material AISI 9260 steel  
 Mandrel taper (in./in) 0.045  
 Mandrel max diameter (in) 0.353  
 Lubrication Fel Pro 300

**HOLE PREPARATION**

Nominal hole size (in) 0.375  
 Process Ream, C/W, ream

**FATIGUE CONDITIONS**

Max net stress (ksi) 70  
 Max test load (kip) 20  
 Load ratio (R) 0.1  
 Test frequency 4000 cpm  
 Test laboratory Materials  
 Test engineer O. Reese  
 Test machine 100 kip Vibraphore

**FASTENER INSTALLATION**

Type \_\_\_\_\_  
 Fit \_\_\_\_\_  
 Torque (in-lb) \_\_\_\_\_

Specimen dash no	Hole no	Hole diameter (in.)		Hole finish (RRR)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter		
.18	1	0.345	0.3635	0.3755	20	10	20	0.0185	0.0090			
	2	0.3545	0.3635	0.3755	-	-	-	0.0185	0.0090			
	3											
	4											
.19	1	0.3545	0.3635	0.3755	25	12	20	0.0185	0.0090		64,000	
	2	0.3545	0.3635	0.3755	-	-	-	0.0185	0.0090			
	3											
	4											
	1											
	2											
	3											
	4											

PHASE II - TASK 2 - BASIC OPEN-HOLE VALUES

Tr-6Al-4V,  
C/W open,  
65 ksi

TEST 2T9 SPECIMEN 623078 DATE 8/30/73

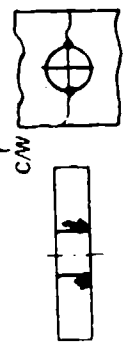
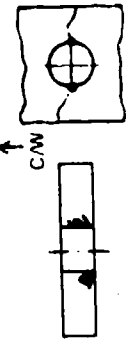
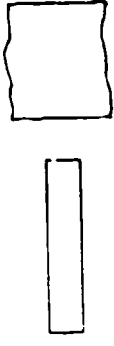
**SPECIMEN DESCRIPTION**  
 Configuration Fig. 2  
 Material Tr-6Al-4V (annealed)  
 Width (in) 1.50  
 Hole spacing (in) 1.50  
 Edge margin (in) 0.75  
 Material gauge (in) 0.250  
 Surface treatment Shot peen

**COLDWORK PROCESS**  
 Interference (in) 0.019  
 Sleeve type Split  
 Sleeve thickness (in) 0.010  
 Sleeve orientation 0  
 Mandrel material AISI 9260 steel  
 Mandrel taper (in/in) 0.045  
 Mandrel max diameter (in) 0.353  
 Lubrication Fel Pro 300

**HOLE PREPARATION**  
 Nominal hole size (in) 0.375  
 Process Ream, C/W, ream

**FASTENER INSTALLATION**  
 Type \_\_\_\_\_  
 Fit \_\_\_\_\_  
 Torque (in lb) \_\_\_\_\_

**FATIGUE CONDITIONS**  
 Max net stress (ksi) 65  
 Max test load (kip) 18.7  
 Load ratio (R) 0.1  
 Test frequency 4000 cpm  
 Test laboratory Materials  
 Test engineer D. Reese  
 Test machine 100 kip Vibraphore

Specimen dash no	Hole no	Hole diameter (in)			Hole finish (RHR)			Coldwork expansion (in)		Fastener size (in)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
20	1	0.3545	0.3640	0.3755	25	12	25	0.0185	0.0095			88,000	
	2	0.3545	0.3635	0.3755	-	-	-	0.0185	0.0090				
	3												
	4												
21	1	0.3545	0.3640	0.3755	30	15	25	0.0185	0.0095			104,000	
	2	0.3545	0.3635	0.3755	-	-	-	0.0185	0.0090				
	3												
	4												
1	1												
2	2												
3	3												
4	4												



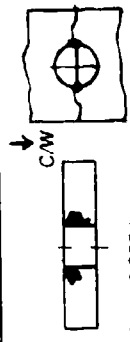


PHASE II - TASK 2 - BASIC OPEN-HOLE VALUES

Ti-6Al-4V, sta.  
C/W open,  
70 ksi

TEST 2T11 SPECIMEN 623078 DATE 9/12/73

<b>SPECIMEN DESCRIPTION</b>	<b>COLLIDWORK PROCESS</b>	<b>HOLE PREPARATION</b>	<b>FATIGUE CONDITIONS</b>
Configuration <u>Fig. 2</u>	Interference (in.) <u>0.019</u>	Nominal hole size (in.) <u>3/8</u>	Max net stress (ksi) <u>70</u>
Material <u>Ti-6Al-4V (sta)</u>	Sieve type <u>Split</u>	Process <u>Drill, ream, C/W</u>	Max test load (kip) <u>20.5</u>
Width (in.) <u>1.50</u>	Sieve thickness (in.) <u>0.010</u>		Load ratio (R) <u>0.1</u>
Hole spacing (in.) <u>1.50</u>	Sieve orientation <u>0</u>		Test frequency <u>4000 cpm</u>
Edge margin (in.) <u>0.75</u>	Mandrel material <u>AISI 9260 steel</u>	<b>FASTENER INSTALLATION</b>	Test laboratory <u>Materials</u>
Material gauge (in.) <u>0.250</u>	Mandrel taper (in./in.) <u>0.045</u>	Type <u>Fit</u>	Test engineer <u>D. Reese</u>
Surface treatment <u>Shot peen</u>	Mandrel max diameter (in.) <u>0.353</u>	Fit <u>Fit</u>	Test machine <u>100-kip Vibraphore</u>
	Lubrication <u></u>	Torque (in. lb) <u></u>	

Specimen dash no	Hole no	Hole diameter (in.)		Hole finish (RH/R)		Collidwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before collidwork	After ream	Before collidwork	After collidwork	Actual	Retained	Diameter	Fit		
4 sta	1	0.3545	0.3630	0.3740	0.3740	35	20	35	0.0085	0.0085	81,000 
	2	0.3545	0.3630	0.3740	0.3740	-	-	-	0.0085	0.0085	
	3										
	4										
5 sta	1	0.3545	0.3630	0.3740	0.3740	40	20	30	0.0185	0.0085	85,000 
	2	0.3545	0.3630	0.3740	0.3740	-	-	-	0.0185	0.0085	
	3										
	4										
6 sta	1	0.3545	0.3630	0.3740	0.3740	40	20	30	0.0185	0.0085	51,000 
	2	0.3545	0.3630	0.3740	0.3740	-	-	-	0.0185	0.0085	
	3										
	4										





PHASE II - TASK 2 - BASIC OPEN-HOLE VALUES

Ti-6Al-4V stoa.  
C/W open.  
70 ksi

TEST 2T13 SPECIMEN 623078 DATE 9/12/73

FATIGUE CONDITIONS  
 Max net stress (ksi) 70  
 Max test load (kip) 20  
 Load ratio (R) 0.1  
 Test frequency 4000 cpm  
 Test laboratory Materials  
 Test engineer D. Reese  
 Test machine 100-kip Vibraphore

SPECIMEN DESCRIPTION  
 Fig. 2  
 Configuration Ti-6Al-4V (stoa)  
 Material 1.50  
 Width (in.) 1.50  
 Hole spacing (in.) 1.50  
 Edge margin (in.) 0.75  
 Material gage (in.) 0.250  
 Surface treatment Shot peen

COLDWORK PROCESS  
 Interference (in.) 0.019  
 Sleeve type Split  
 Sleeve thickness (in.) 0.010  
 Sleeve orientation 0  
 Mandrel material AISI 9260 steel  
 Mandrel taper (in./in.) 0.045  
 Mandrel max diameter (in.) 0.353  
 Lubrication Fei Pro 300

HOLE PREPARATION  
 Nominal hole size (in.) 3/8  
 Process Drill, ream, C/W

FASTENER INSTALLATION  
 Type \_\_\_\_\_  
 Fit \_\_\_\_\_  
 Torque (in. lb) \_\_\_\_\_

Specimen depth no	Hole no	Hole diameter (in.)			Hole finish (RHHR)		Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	Actual	Retained	Diameter	Fit		
4 Stoa	1	0.3545	0.3640	0.3740	45	20	35	0.0185	0.0095		70,000	
	2	0.3540	0.3640	0.3740				0.0185	0.0095			
	3											
	4											
5 Stoa	1	0.3545	0.3640	0.3740	40	10	35	0.0185	0.0095		38,000	
	2	0.3545	0.3640	0.3740				0.0185	0.0095			
	3											
	4											
6 Stoa	1	0.3545	0.3640	0.3740	35	15	35	0.0185	0.0095		58,000	
	2	0.3545	0.3640	0.3735				0.0185	0.0095			
	3											
	4											

PHASE II - TASK 2 - BASIC OPEN-HOLE DATA

TEST 2T14 SP. SIMEN 623078 DATE 10/1/73

Ti-6Al-6V-2Sn,  
reamed open.  
70 ksi

SPECIMEN DESCRIPTION

Configuration: Fig. 2  
 Material: Ti-6Al-6V-2Sn (annealed)  
 Width (in): 1.50  
 Hole spacing (in): 1.50  
 Edge margin (in): 0.75  
 Material peak (in): 0.250  
 Surface treatment: Shot peen



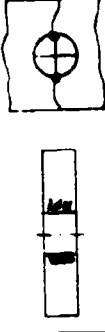
COLDWORK PROCESS  
 Interference: \_\_\_\_\_  
 Sleeve type: \_\_\_\_\_  
 Sleeve thickness (in): \_\_\_\_\_  
 Sleeve orientation: \_\_\_\_\_  
 Mandrel material: \_\_\_\_\_  
 Mandrel taper (in./in.): \_\_\_\_\_  
 Mandrel max diameter (in.): \_\_\_\_\_  
 Lubrication: \_\_\_\_\_

HOLE PREPARATION  
 Nominal hole size (in.): 0.375  
 Process: Ream

FASTENER INSTALLATION  
 Type: \_\_\_\_\_  
 Fit: \_\_\_\_\_  
 Torque (in. lb): \_\_\_\_\_

FATIGUE CONDITIONS

Max net stress (ksi): 70  
 Max test load (kip): 20.3  
 Load ratio (R): 0.1  
 Test frequency: 4000 cpm  
 Materials: \_\_\_\_\_  
 Test laboratory: D. Reese  
 Test engineer: \_\_\_\_\_  
 Test machine: 36-kip Vibraphore

Spec. det. no.	Hole no.	Hole diameter (in.)			Hole finish (RHR)			Collwork expansion (in.)		Cycles to failure	Origin of failure and remarks
		Before collwork	After collwork	After ream	Before collwork	After collwork	After ream	Actual	Retained		
1-662	1		0.3750	30						51,000	
	2		0.3750	25							
	3										
	4										
2-662	1		0.3750	15						35,000	
	2		0.3750	15							
	3										
	4										
3-662	1		0.3750	15						28,000	
	2		0.3750	15							
	3										
	4										

PHASE II TASK 2 - BASIC OPEN-HOLD DATA

T1-6Al-6V-2Sn,  
C/W open,  
70 ksi

TEST 2T15 SPECIMEN 623078 DATE 10/11/73

SPECIMEN DESCRIPTION		COLDWORK PROCESS		HOLE PREPARATION		FATIGUE CONDITIONS	
Configuration	Fig. 2	Interference (in)	0.019	Nominal hole size (in)	0.375	Max. net stress (ksi)	70
Material	T1-6Al-6V-2Sn (annealed)	Sleeve type	Split	Process	Ream: C/W, ream	Max. test load (kip)	20.3
Width (in)	1.50	Sleeve thickness (in)	0.010			Load ratio (R)	0.1
Hole spacing (in)	1.50	Sleeve orientation	0			Test frequency	4000 cpm
Edge margin (in)	0.75	Mandrel material	AISI 9260 steel	FASTENER INSTALLATION		Test laboratory	Materials
Material gap (in)	0.250	Mandrel taper (in/in)	0.045	Type		Test engineer	D. Reese
Surface treatment	Shot peen	Mandrel max diameter (in)	0.353	Fit		Test machine	36-kip Vibraphore
		Lubricant	Fel Pro 300	Torque (in. lbs)			

Specimen dash no	Hole no	Hole diameter (in)		Hole finish (RHR)		Coldwork expansion (in)		Fastener size (in)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	Before coldwork	After coldwork	Actual	Retained	Diameter	Fit		
4-662	1	0.3540	0.3620	35	20	0.0190	0.0080			50,000	
	2	0.3540	0.3620			0.0190	0.0080				
	3										
	4										
5-662	1	0.3540	0.3620	35	20	0.0190	0.0080			70,000	
	2	0.3540	0.3630			0.0190	0.0090				
	3										
6-662	1	0.3540	0.3620	35	20	0.0190	0.0080			79,000	
	2	0.3540	0.3620			0.0190	0.0080				
	3										
4											

Ti-6Al-6V-2Sn sta,  
reamed open,  
70 ksi

PHASE II - TASK 2 - BASIC OPEN-HOLE DATA

TEST: 2T16 SPECIMEN: 623078 DATE: 10/1/73

**SPECIMEN DESCRIPTION**  
 Configuration: Fig. 2  
 Material: Ti-6Al-6V-2Sn (sta)  
 Width (in.): 1.50  
 Hole spacing (in.): 1.50  
 Edge margin (in.): 0.75  
 Material gage (in.): 0.250  
 Surface treatment: Shot peen

**COLDWORK PROCESS**  
 Interference: \_\_\_\_\_  
 Sleeve type: Ream  
 Sleeve thickness (in.): \_\_\_\_\_  
 Sleeve orientation: \_\_\_\_\_  
 Mandrel material: \_\_\_\_\_  
 Mandrel taper (in./in.): \_\_\_\_\_  
 Mandrel max diameter (in.): \_\_\_\_\_  
 Lubrication: \_\_\_\_\_

**HOLE PREPARATION**  
 Nominal hole size (in.): 0.375  
 Process: Ream

**FASTENER INSTALLATION**  
 Type: \_\_\_\_\_  
 F<sub>11</sub>: \_\_\_\_\_  
 Torque (in. lb): \_\_\_\_\_

**FATIGUE CONDITIONS**  
 Max net stress (ksi): 70  
 Max test load (kip): 20  
 Load ratio (R): 0.1  
 Test frequency: 4000 cpm  
 Materials: \_\_\_\_\_  
 Test laboratory: D. Reese  
 Test engineer: \_\_\_\_\_  
 Test machine: 36-kip Vibraphore

Specimen dash no	Hole no	Hole diameter (in.)		Hole finish (RHR)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	F <sub>11</sub>		
1662 sta	1		0.3750			25					22,000	
	2		0.3750									
	3											
	4											
2662 sta	1		0.3750			15					23,000	
	2		0.3750									
	3											
	4											
3662 sta	1		0.3750			15					24,000	
	2		0.3750									
	3											
	4											

**PHASE II - TASK 2 - BASIC OPEN-HOLE DATA**

T1-6Al-6V-2Sn sta.  
C/W open.  
70 ksi

TEST: 2117 SPECIMEN: 623078 DATE: 10/11/73

**SPECIMEN DESCRIPTION**  
 Configuration: Fig. 2  
 Material: T1-6Al-6V-2Sn (sta)  
 Width (in.): 1.50  
 Hole spacing (in.): 1.50  
 Edge margin (in.): 0.75  
 Material gauge (in.): 0.250  
 Surface treatment: Shot/peen

**COLDWORK PROCESS**  
 Interference (in.): 0.019  
 Sleeve type: Split  
 Sleeve thickness (in.): 0.010  
 Sleeve orientation: 0  
 Mandrel material: ANSI 9260 steel  
 Mandrel taper (in./in.): 0.045  
 Mandrel max diameter (in.): 0.353  
 Lubrication: Fel Pro 300

**HOLE PREPARATION**  
 Nominal hole size (in.): 0.375  
 Process: Ream, C/W, ream

**FASTENER INSTALLATION**  
 Type: \_\_\_\_\_  
 Fit: \_\_\_\_\_  
 Torque (in. lb): \_\_\_\_\_

**FATIGUE CONDITIONS**  
 Max net stress (ksi): 70  
 Max test load (k ip): 20  
 Load ratio (R): 0.1  
 Test frequency: 4000 cpm  
 Test laboratory: Materials  
 Test engineer: D. Reese  
 Test machine: 36-kip Vibraphore

Specimen dash no	Hole no	Hole diameter (in.)			Hole finish (RHRI)		Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After ream	Actual	Retained	Diameter	Fit		
4-662 sta	1	0.3540	0.3625	0.3745	35	20	75	0.0190	0.0085		76,000	
	2	0.3540	0.3625	0.3745				0.0190	0.0085			
	3											
	4											
5-662 sta	1	0.3540	0.3620	0.3745	35	20	25	0.0190	0.0080		94,000	
	2	0.3540	0.3625	0.3745				0.0190	0.0085			
	3											
	4											
6-662 sta	1	0.3540	0.3625	0.3745	35	20	30	0.0190	0.0085		72,000	
	2	0.3540	0.3630	0.3745				0.0190	0.0090			
	3											
	4											

PHASE II - TASK 2 - BASIC OPEN-HOLE DATA

TEST 2T18 SPECIMEN 623078 DATE 10/1/73

Ti-6Al-6V-2Sn st0a,  
reamed open,  
70 ksi

**SPECIMEN DESCRIPTION**  
 Configuration Fig. 2  
 Material Ti-6Al-6V-2Sn (st0a)  
 Width (in.) 1.50  
 Hole spacing (in.) 1.50  
 Edge margin (in.) 0.75  
 Material gauge (in.) 0.250  
 Surface treatment Shot peen

**COLDWORK PROCESS**  
 Interference \_\_\_\_\_  
 Sleeve type \_\_\_\_\_  
 Sleeve thickness (in.) \_\_\_\_\_  
 Sleeve orientation \_\_\_\_\_  
 Mandrel material \_\_\_\_\_  
 Mandrel taper (in/in) \_\_\_\_\_  
 Mandrel max diameter (in.) \_\_\_\_\_  
 Lubrication \_\_\_\_\_

**HOLE PREPARATION**  
 Nominal hole size (in.) 0.375  
 Process Ream

**FASTENER INSTALLATION**  
 Type \_\_\_\_\_  
 Fit \_\_\_\_\_  
 Torque (in. lb) \_\_\_\_\_

**FATIGUE CONDITIONS**  
 Max net stress (ksi) 70  
 Max test load (kip) 20  
 Load ratio (R) 0.1  
 Test frequency 4000 cpm  
 Test laboratory Materials  
 Test engineer D. Reese  
 Test machine 36-kip Vibraphore

Specimen dash no	Hole no	Hole diameter (in.)			Hole finish (RHR)		Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	Actual	Retained	Diameter	Fit		
1-662 st0a	1		0.3750	15							38,000	
	2			-								
	3											
	4											
2-662 st0a	1		0.3750	15							38,000	
	2			-								
	3											
	4											
3-662 st0a	1		0.3750	15							30,000	
	2			-								
	3											
	4											

PHASE II - TASK 2 - BASIC OPEN-HOLE DATA

Ti-6Al-6V-2Sn stoa,  
C/W open,  
70 ksi

TEST 2T19 SPECIMEN 623078 DATE 10/11/73

FATIGUE CONDITIONS  
 Max net stress (ksi) 70  
 Max test load (kip) 20  
 Load ratio (R) 0.1  
 Test frequency 4000 cpm  
 Test laboratory Materials  
 Test engineer D. Reese  
 Test machine 36-kip Vibraphore

HOLE PREPARATION  
 Nominal hole size (in.) 0.375  
 Process Ream, C/W, ream

COLDWORK PROCESS

Interference (in.) 0.019  
 Sleeve type Split  
 Sleeve thickness (in.) 0.010  
 Sleeve orientation 0  
 Mandrel material AISI 9260 steel  
 Mandrel taper (in/in) 0.045  
 Mandrel max diameter (in.) 0.353  
 Lubrication Fel Pro 300  
 Torque (in. lb)

SPECIMEN DESCRIPTION

Fig. 2  
 Configuration Ti 6Al-6V-2Sn (stoa)  
 Material 1.50  
 Width (in.) 1.50  
 Hole spacing (in.) 0.75  
 Edge margin (in.) 0.250  
 Material grade (in.) Shot peen  
 Surface treatment

Specimen flush to	Hole no	Hole diameter (in.)		Hole finish (RA/R)		Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	Before coldwork	After coldwork	Actual	Required	Diameter	Fit		
4.662 stoa	1	0.3540	0.3620	35	20	0.0190	0.0080			67,000	
	2	0.3540	0.3625	-	-	0.0190	0.0085				
	3										
	4										
5.662 stoa	1	0.3540	0.3620	35	20	0.0190	0.0080			48,000	
	2	0.3540	0.3620	-	-	0.0190	0.0080				
	3										
	4										
6.662 stoa	1	0.3540	0.3625	35	20	0.0190	0.0085			55,000	
	2	0.3540	0.3625	-	-	0.0190	0.0085				
	3										
	4										

PHASE II - TASK 2 - BASIC OPEN-HOLE DATA

Ti-6Al-4V  
C/W 0.015  
3/4 in. O, 70 Ksi

TEST 2T20 SPECIMEN 623078 DATE 10/24/73

SPECIMEN DESCRIPTION		COLLWORK PROCESS		HOLE PREPARATION		FATIGUE CONDITIONS	
Configuration	Fig. 2	Interference (in.)	0.030	Nominal hole size (in.)	0.750	Max net stress (ksi)	70
Material	Ti-6Al-4V (annealed)	Sleeve type	Split	Process	Ream, C/W, ream	Max test load (k-lb)	59
Width (in.)	3.00	Sleeve thickness (in.)	0.015			Load ratio (R)	0.1
Hole spacing (in.)	3.00	Sleeve orientation	0			Test frequency	4000 cpm
Edge margin (in.)	1.50	Mandrel material	AISI 9260	FASTENER INSTALLATION		Test laboratory	Materials
Material gage (in.)	0.375	Mandrel taper (in./in.)	0.045	Type		Test engineer	D. Reese
Surface treatment	Shot peen	Mandrel max diameter (in.)	0.7140	Fit		Test machine	100-kip Vibraphore
		Coating	Fel Pro 300	Torque (in. lb)			

Specimen dash no.	Hole no.	Hole diameter (in.)			Hole finish (RHR)			Collwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before collwork	After collwork	After ream	Before collwork	After collwork	After ream	Actual	Retained	Diameter	Fit		
25	1	0.715	0.7270	0.7510	25	15	25	0.027	0.0120			86,000	
	2	0.715	0.7270	0.7515	-	-	-	0.029	0.0120				
	3												
	4												
26	1	0.715	0.7270	0.7515	30	20	30	0.029	0.0120			54,000	
	2	0.715	0.7270	0.7505	-	-	-	0.029	0.0120				
	3												
	4												
27	1	0.715	0.7265	0.7505	25	15	35	0.029	0.0115			61,000	
	2	0.715	0.7265	0.7575	-	-	-	0.029	0.0115				
	3												
	4												



PHASE II - TASK 2 - BASIC OPEN-HOLE VALUES

300 M, Honed, Open

TEST 2S1 SPECIMEN 623078 DATE 7/19/73

SPECIMEN DESCRIPTION

Configuration Fig. 2  
 Material 300 M steel (270-300 ksi)  
 Width (in) 1.50  
 Hole spacing 1.50  
 Edge margin (in) 0.75  
 Material gauge (in) 0.250  
 Surface treatment Shot peen

COLDWORK PROCESS

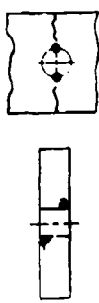
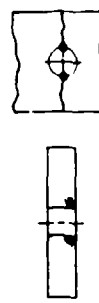
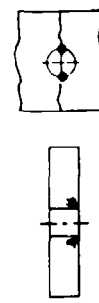
Interference \_\_\_\_\_  
 Sleeve type \_\_\_\_\_  
 Sleeve thickness (in) \_\_\_\_\_  
 Sleeve orientation \_\_\_\_\_  
 Mandrel material \_\_\_\_\_  
 Mandrel taper (in/in) \_\_\_\_\_  
 Mandrel max diameter (in) \_\_\_\_\_  
 Lubrication \_\_\_\_\_

HOLE PREPARATION

Nominal hole size (in) 3/8  
 Process Drill, ream, and hone  
 FASTENER INSTALLATION  
 Typr. \_\_\_\_\_  
 Fit \_\_\_\_\_  
 Torque (in/ft) \_\_\_\_\_

FATIGUE CONDITIONS

Max. net stress (ksi) 105  
 Max. test load (kip) 29.4  
 Load ratio (R) 0.1  
 Test frequency 4200 cpm  
 Test laboratory Materials  
 Test engineer D. Reese  
 Test machine 36-kip Vibraphore

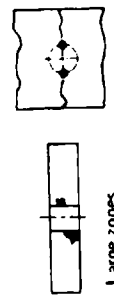
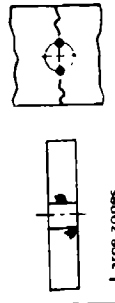
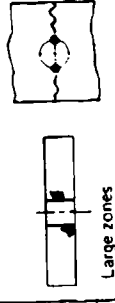





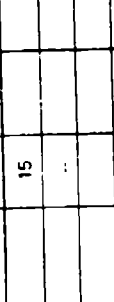
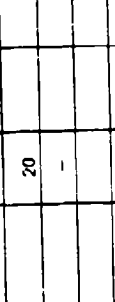
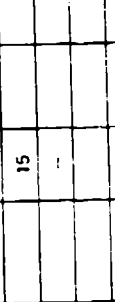

Specimen mark no.	Hole no.	Hole diameter (in)		Hole finish (RHR)		Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After ream	Before coldwork	After coldwork	Actual	Retained	Diameter	Fit		
-1	1		0.3804							43,000	
	2		0.3804								
	3										
	4										
-2	1		0.3803							54,000	
	2		0.3803								
	3										
	4										
-3	1		0.3803							42,000	
	2		0.3803								
	3										
	4										

PHASE II - TASK 2 - BASIC OPEN-HOLE VALUES

300 M, Reamed, Open, 105 KSI

TEST 2S2 SPECIMEN 623028 DATE 7/10/73



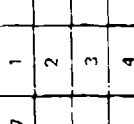

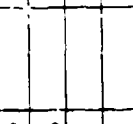

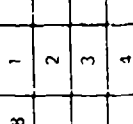

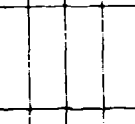

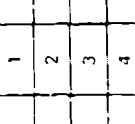
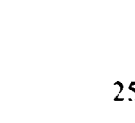
SPECIMEN DESCRIPTION		COLDWORK PROCESS		HOLE PREPARATION		FATIGUE CONDITIONS	
Configuration	Fig 2	Interference		Nominal hole size (in)	3/8	Max net stress (ksi)	105
Material	300 M steel (270-300 ksi)	Sleeve type		Process	Drill and ream	Max test load (kip)	30
Width (in)	1.50	Sleeve thickness (in)				Load ratio (R)	0.1
Hole spacing	1.50	Sleeve orientation				Test frequency	7000 gpm
Edge margin (in)	0.75	Mandrel material		FASTENER INSTALLATION		Test laboratory	Materials
Material grade (in)	0.250	Mandrel taper (in/in)		Type		Test engineer	D. Reese
Surface treatment	Shot peen	Mandrel max diameter (in)		Fit		Test machine	36 kip Vibraphore
		Lubrication		Torque (in lbf)			

Specimen dash no	Hole no	Hole diameter (in)		Hole finish (RHR)		Coldwork expansion (in)		Fastener size (in)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After ream	Before coldwork	After ream	Actual	Retained	Diameter	Fit		
-4	1		0.375		15					139,000	
	2		0.375								
	3										
	4										
-5	1		0.375		20					103,000	
	2		0.375								
	3										
	4										
-6	1		0.375		15					75,000	
	2		0.375								
	3										
	4										

PHASE II - TASK 2 - BASIC OPEN-HOLE VALUES  
300 M, Reamed, Open, 110 KSI

TEST 253 SPECIMEN 623078 DATE 7/10/73

SPECIMEN DESCRIPTION		COLDWORK PROCESS		HOLE PREPARATION		FATIGUE CONDITIONS	
Configuration	Fig. 2	Interference		Nominal hole size (in.)	3/8	Max. int. stress (ksi)	110
Material	300 M steel (270-300 ksi)	Shear type		Process	Drill and ream	Max. test load (kip)	31
Width (in.)	1.50	Sleeve thickness (in.)				Load ratio (R)	0.1
Hole spacing	1.50	Shear orientation				Test frequency	7000 cpm
Edge radius (in.)	0.75	Mandrel material		FASTENER INSTALLATION		Test laboratory	Materials
Material gauge (in.)	0.250	Mandrel taper (in/in)		Type		Test engineer	D. Reese
Surface treatment	Shot peen	Mandrel max diameter (in.)		Fit		Test machine	36-kip Vibraphore
		Lubrication		Torque (in. lb)			

Specimen dash no.	Hole no.	Hole diameter (in.)			Hole finish (HR)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After ream	After ream	Before coldwork	After coldwork	Actual	Retained	Diameter	Fit			
-7	1		0.3750	20								48,000	
	2		0.3745										
	3												
	4												
-8	1		0.3745	20								60,000	
	2		0.3745										
	3												
	4												
	1												
	2												
	3												
	4												

PHASE II - TASK 2 - BASIC OPEN-HOLE VALUES

300 M Reamed, Open, 120 KSI

TEST 2S4 SPECIMEN 623078 DATE 7/10/73

SPECIMEN DESCRIPTION

Configuration Fig. 2  
 Material 300 M steel (270-300 ksi)  
 Width (in) 1.50  
 Hole spacing 1.50  
 Edge margin (in) 0.75  
 Material gage (in) 0.250  
 Surface treatment Shot peen

COLDWORK PROCESS


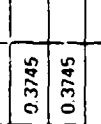
Interference \_\_\_\_\_  
 Sleeve type \_\_\_\_\_  
 Sleeve thickness (in) \_\_\_\_\_  
 Sleeve orientation \_\_\_\_\_  
 Mandrel material \_\_\_\_\_  
 Mandrel taper (in/in) \_\_\_\_\_  
 Mandrel max diameter (in) \_\_\_\_\_  
 Lubrication \_\_\_\_\_

HOLE PREPARATION

Nominal hole size (in) 3/8  
 Process Drill and ream  
 FASTENER INSTALLATION  
 Type \_\_\_\_\_  
 Fit \_\_\_\_\_  
 Torque (in lb) \_\_\_\_\_

FATIGUE CONDITIONS

Max out stress (ksi) 120  
 Max test load (kip) 37  
 Load ratio (R) 0.1  
 Test frequency 7000 cpm  
 Test laboratory Materials  
 Test engineer D. Reese  
 Test machine 36-kip Vibraphore

Specimen rough no	Hole no	Hole diameter (in)		Hole finish (HRI)		Coldwork expansion (in)		Fastener size (in)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After ream	Before coldwork	After ream	Actual	Retained	Diameter	Fit		
-9	1		0.3745		20					32,000	 Large zone - one side
	2		0.3745		-						
	3										
	4										
-10	1		0.3745		20					49,000	 Large zone - one side
	2		0.3745		-						
	3										
	4										
	1										
	2										
	3										
	4										

PHASE II - TASK 2 - BASIC OPEN-HOLE VALUES

300 M, Reamed, Open, 100 KSI

TEST: 255 SPEC MEN: 623078 DATE: 7/10/73

SPECIMEN DESCRIPTION

Configuration: Fig. 2  
 Material: 300 M steel (270-300 ksi)  
 Width (in.): 1.50  
 Hole spacing: 1.50  
 Edge margin (in.): 0.75  
 Material grade (in.): 0.250  
 Surface treatment: Shot peen

COLDWORK PREP. CS

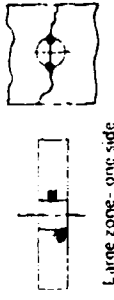
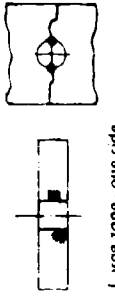
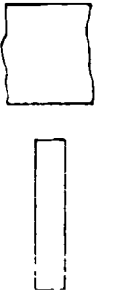





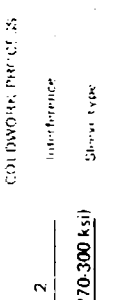
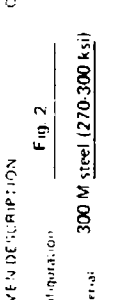
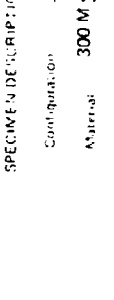

Interference: \_\_\_\_\_  
 Sleeve type: \_\_\_\_\_  
 Sleeve thickness (in.): \_\_\_\_\_  
 Sleeve manipulation: \_\_\_\_\_  
 Mandrel material: \_\_\_\_\_  
 Mandrel taper (in./in.): \_\_\_\_\_  
 Mandrel max diameter (in.): \_\_\_\_\_  
 Lubrication: \_\_\_\_\_

HOLE PREPARATION

Nominal hole size (in.): 3/8  
 Process: Drill and ream  
 FASTENER INSTALLATION  
 Type: \_\_\_\_\_  
 Fit: \_\_\_\_\_  
 Torque (in. lb): \_\_\_\_\_

FATIGUE CONDITIONS

Max. net stress (ksi): 100  
 Max. test load (kips): 28  
 Load ratio (R): 0.1  
 Test frequency: 7000 cpm  
 Test laboratory: Materials  
 Test equipment: D. Reese  
 Test machine: 36 kip Vibration

Specimen no.	Hole no.	Hole diameter (in.)			Hole finish (IR48)			Coldwork exposure (in.)			Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After ream	After finish	Before coldwork	After coldwork	After ream	Actual	Exposure	Fastener	Fit			
.11	1		0.3745				20						113,000	 Large zone - one side
	2		0.3745											 Large zone - one side
	3													 Large zone - one side
	4													
.12	1		0.3745			20							400,000	
	2		0.3745											
	3													
	4													
	1													
	2													
	3													
	4													

PHASE II - TASK 2 - BASIC OPEN-HOLE VALUES

300 M, C/W, Open, 100 KSI

TEST 256 SPECIMEN 623078 DATE 7/26/73

SPECIMEN DESCRIPTION

Configuration Fig. 2  
 Material 300 M steel (270-300 ksi)  
 Width (in) 1.50  
 Hole spacing 1.50  
 Edge radius (in) 0.75  
 Material case (in) 0.250  
 Surface treatment Shot peen

COLDWORK PROCESS

Interference (in) 0.023 / 0.024  
 Steer type Push (no sleeve)  
 Steer thickness (in) -  
 Steer orientation -  
 Mandrel material Carbide (BAC 5972)  
 Mandrel taper (in/in) 0.045  
 Mandrel max diameter (in) 0.358

HOLE PREPARATION

Nominal hole size (in) 3/8  
 Process Ream, C/W, Ream

FATIGUE CONDITIONS

Max. int. stress (ksi) 100  
 Max. test load (kip) 28.2  
 Load ratio (R) 0.1  
 Test frequency 4700 cpm  
 Test laboratory Materials  
 Test engineer D. Reese  
 Test machine 100-kip Vibraphore

Lubrication Fel Pro 300 in hole and on mandrel

Note: Spiral reamer marks in holes from withdrawal, coldworked holes more difficult to ream

Specimen Hole no.	Hole diameter (in.)			Hole finish (RH/R)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
	Before coldwork (a)	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit			
-13	1	0.3335	0.3510	0.3765	20	5	20	0.0245	0.0175		99,000	
	2	0.3335	0.3515	0.3745				0.0245	0.0180			
	3											
	4											
-14	1	0.3335	0.3510	0.3725	20	5	25	0.0245	0.0175		132,000	
	2	0.3335	0.3510	0.3740				0.0245	0.0175			
	3											
	4											
1												
2												
3												
4												

<sup>a</sup> Taken at minimum (midpoint)

<sup>b</sup> Step in hole where reamer failed, did not fail at step or stepped hole

PHASE II - TASK 2 - BASIC OPEN-HOLE VALUES

300 M. C/W. Open. 105 KSI

TEST 257 SPECIMEN 623078 DATE 7/27/72

SPECIMEN DESCRIPTION		COLDWORK PROCESS		HOLE PREPARATION		FATIGUE CONDITIONS	
Configuration	Fig 2	Interference (in.)	0.0245	Nominal hole size (in.)	3/8	Max. net stress (ksi)	105
Material	300 M steel (270-300 ksi)	Sleeve type	Push (no sleeve)	Process	Ream. C/W ream	Max test load (kips)	29.3
Width (in.)	1.50	Sleeve thickness (in.)				Load ratio (R)	0.1
Hole spacing	1.50	Sleeve orientation				Test frequency	4200 cpm
Edge margin (in.)	0.75	Mandrel material	Carbide (BAC 5972)	FASTENER INSTALLATION		Test laboratory	Materials
Material gap (in.)	0.250	Mandrel taper (in./in.)	0.045	Type		Test engineer	D. Reese
Surface treatment	Shot peen	Mandrel max. diameter (in.)	0.358	Fit		Test machine	100 k ip V. Ibraphore
		Lubrication	Fel Pro 300 in hole and on mandrel	Torque (in. ft)			

Note: Spiral reamer marks in holes from withdrawal; coldworked holes more difficult to ream.

Specimen dash no.	Hole dia. (in.)	Hole diameter (in.)				Hole finish (RH)			Coldwork expansion (in.)		Fastener size (in.)	Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork (a)	After ream	Before coldwork	After coldwork	Alter ream	Actual	Retained (a)	Diameter			
15	1	0.3335	0.3520	0.3745	15	5	20	0.0245	0.0185			54,000	
16	1	0.3335	0.3515	0.3740	20	5	20	0.0245	0.0180			72,000	
17	1	0.3335	0.3510	0.3740	20	5	20	0.0245	0.0175			71,000	

<sup>a</sup> Taken at minimum (midpoint)

PHASE II - TASK 2 - BASIC OPEN-HOLE VALUES

300 M, C/W, Open, 110 KSI

TEST 258 SPECIMEN 623078 DATE 7/27/73

SPECIMEN DESCRIPTION		COLDWORK PROCESS		HOLE PREPARATION		FATIGUE CONDITIONS	
Configuration	Fig. 2	Interference (in.)	0.0245	Nominal hole size (in.)	3/8	Max. net stress (ksi)	110
Material	300 M steel (270-300 ksi)	Sleeve type	Push (no sleeve)	Process	Ream, C/W, ream	Max. test load (kip)	31
Width (in.)	1.50	Sleeve thickness (in.)				Load ratio (R)	0.1
Min. thickness	1.50	Sleeve orientation				Test frequency	4200 cpm
Edge radius (in.)	0.75	Mandrel material	Carbide (BAC 5972)	FASTENER INSTALLATION		Test laboratory	Materials
Mandrel size (in.)	0.250	Mandrel taper (in/in)	0.045	Type		Test engineer	D. Reese
Surface treatment	Shot peen	Mandrel max diameter (in.)	0.358	F <sub>t</sub>		Test machine	100 kip Vitraphore
		Lubrication	Fel Pro 300 in hole and on mandrel	Torque (in. lb)			

Note: Spiral reamer marks in holes from withdrawal; coldworked holes more difficult to ream.

Specimen dash no.	Hole no.	Hole diameter (in.)			Hole finish (RHR)		Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork (a)	After ream	Before coldwork	After coldwork	Actual	Retained	Diameter	F <sub>t</sub>		
-18	1	0.3335	0.3515	0.3745	20	5	0.0245	0.0180			41,000	C/W Large zones 0.078 in. bow
	2	0.3335	0.3515	0.3795			0.0245	0.0180				
	3											
	4											
-19	1	0.3335	0.3505	0.3745	20	5	0.0245	0.0170			62,000	C/W 0.070 in. bow
	2	0.3335	0.3505	0.3745			0.0245	0.0170				
	3											
	4											
1												
2												
3												
4												

<sup>a</sup> Taken at minimum (midpoint)  
<sup>b</sup> Reamer failed (step in hole), did not fail in this hole



PHASE II - TASK 2 - BASIC OPEN-HOLE VALUES  
300 M, C/W, Open, 115 KSI

TEST 259 SPECIMEN 623078 DATE 7/21/73

SPECIMEN DESCRIPTION		COLDWORK PROCESS		HOLE PREPARATION		FATIGUE CONDITIONS	
Configuration	<u>Fig 2</u>	Interference (in.)	<u>0.0245</u>	Nominal hole size (in.)	<u>3/8</u>	Max net stress (ksi)	<u>115</u>
Material	<u>300 M steel (270 300 ksi)</u>	Process	<u>Push (no sleeve)</u>	Process	<u>Ream, C/W, ream</u>	Max test load (kip)	<u>.32</u>
Width (in.)	<u>1.5</u>	Sleeve thickness (in.)	<u>-</u>			Load ratio (R)	<u>0.1</u>
Hole spacing	<u>1.5</u>	Sleeve orientation	<u>-</u>			Test frequency	<u>4200 cpm</u>
Edge margin (in.)	<u>0.75</u>	Mandrel material	<u>Carbide (BAC 5972)</u>	FASTENER INSTALLATION		Test laboratory	<u>Materials</u>
Material type (in.)	<u>0.250</u>	Mandrel taper (in/in)	<u>0.045</u>	Type		Test engineer	<u>D. Reese</u>
Surface treatment	<u>Shot peen</u>	Mandrel max diameter (in.)	<u>0.358</u>	Fit		Test machine	<u>100 kip Vbraphore</u>

Lubrication Fel Pro 300 in hole and on mandrel  
 Torque (in-lb) -

Note: Spiral reamer marks in holes from withdrawal; coldworked holes more difficult to ream.

Specimen id no.	Hole diameter (in.)				Hole finish (IRHR)			Coldwork expansion (in.)		Fastener type (in.)	Cycles to failure	Origin of failure and remarks
	Before coldwork	After coldwork (a)	After ream	After ream	Before coldwork	After coldwork	After ream	Actual	Retained (a)			
-20	1	0.3335	0.3500	0.3745	15	5	20	0.0245	0.0165			
	2	0.3335	0.3500	0.3745	-	-	-	0.0245	0.0165			
	3											
-21	1	0.3335	0.3510	0.3745	20	5	20	0.0245	0.0175			
	2	0.3335	0.3510	0.3745	-	-	-	0.0245	0.0175			
	3											
	4											
	1											
	2											
	3											
	4											

a Taken at minimum (midpoint)

PHASE II - TASK 2 - BASIC OPEN-HOLE DATA

300 M.  
open, C/W,  
3/4-in. hole  
110 ksi

TEST 11S10 SPECIMEN 62380 DATE 10/15/73

<b>SPECIMEN DESCRIPTION</b>	<b>COLDWORK PROCESS</b>	<b>HOLE PREPARATION</b>	<b>FATIGUE CONDITIONS</b>
Configuration <u>Fig. 2</u>	Interference (in.) <u>0.0450-0.046</u>	Nominal hole size (in.) <u>0.750</u>	Max net stress (ksi) <u>110</u>
Material <u>300 M steel (270-300 ksi)</u>	Sleeve type <u>Push no sleeve</u>	Process <u>Ream, C/W, ream</u>	Max test load (kips) <u>53.2</u>
Width (in.) <u>3.00</u>	Sleeve thickness (in.) <u>-</u>		Load ratio (R) <u>0.1</u>
Hole spacing <u>3.00</u>	Sleeve orientation <u>-</u>		Test frequency <u>4000 cpm</u>
Edge margin (in.) <u>1.50</u>	Mandrel material <u>Carbide (BAC 5972)</u>	<b>FASTENER INSTALLATION</b>	Test laboratory <u>Materials</u>
Material gage (in.) <u>0.375</u>	Mandrel taper (in./in.) <u>0.030</u>	Type <u>-</u>	Test engineer <u>D. Reese</u>
Surface treatment <u>Shot peen</u>	Mandrel max diameter (in.) <u>0.7325</u>	Fill <u>-</u>	Test machine <u>60=80-100</u>
	Lubrication <u>Fel Pro 300</u>	Torque (in.-lb) <u>-</u>	<u>Vibraphore</u>

Specimen dash no	Hole no	Hole diameter (in.)				Hole finish (RHR)				Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	After ream	Before coldwork	After coldwork	After ream	After ream	Actual	Retained	Diameter	Fit		
-25	1	0.6875	0.7160	0.7485	0.7485	110	55	75	75	0.0450	0.0285			100,000	 Failed in grip
	2	0.6870	0.7160	0.7490	0.7490	-	-	65	65	0.0455	0.0290				
	3														
	4														
-26	1	0.6875	0.7170	0.7485	0.7485	110	55	70	70	0.0450	0.0295			75,000	 C/W
	2	0.6875	0.7170	0.7485	0.7485	-	-	-	-	0.0450	0.0295				
	3														
	4														
-27	1	0.6875	0.7165	0.7480	0.7480	110	55	70	70	0.0450	0.0240			210,000	 C/W
	2	0.6875	0.7165	0.7485	0.7485	-	-	-	-	0.0450	0.0290				
	3														
	4														

PHASE II TASK 3 BASIC FILLED HOLE VALUES

TEST NUMBER: 3A 1

NOMINAL EXPANSION VALUE: -

GENERAL TEST CONDITIONS

DATE: 2-6-73

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig 2  
 Width: 1.50"  
 Hole spacing: 1.50"  
 Edge margin: 0.75"  
 Material: 2024 T851  
 Material gauge: 0.250"  
 Surface Treatment: Shot Peen  
 Fastener: HiLok (Prot HD)

3. CW Process

Sleeve type: \_\_\_\_\_  
 Sleeve thickness: \_\_\_\_\_  
 Sleeve orie: \_\_\_\_\_  
 CW M: \_\_\_\_\_  
 CW per: \_\_\_\_\_  
 Major Dia.: \_\_\_\_\_  
 orion: \_\_\_\_\_

*NOT APPLICABLE*




2. Hole Preparation

Nominal hole size: 3/8"  
 Process: Ream, Install Fastener  
 Fastener Installation Torque: 220-240 In/lbs

2024  
 Reamed Hilok  
 30KSI

4. Fatigue Conditions

Net stress: 30 ksi  
 Test load: 8500 lbs  
 Load ratio: (R) = 0.1  
 Test Frequency: 5000/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophore (36 kip)

Specimen No. R623079	Hole No.	Hole Diameter (Inches) After Ream	Fastener Diameter (Inches)	Net Fit Between Fastener and Hole	Hole Finish (RHR) After Ream	Cycles to Failure (Thousands)	Origin of Failure and Remarks
-1	1	.3735	.3737	+.0002	45	696	
	2	.3735	.3735	NET	25		
-2	1	.3735	.3735	NET	35	565	
	2	.3735	.3735	NET	30		
-3	1	.3735	.3735	NET	30	127	
	2	.3740	.3735	-.0005	25		

PHASE II TASK 3 BASIC FILLED HOLE VALUES

TEST NUMBER: 3A 1a

NOMINAL EXPANSION VALUE: -

GENERAL TEST CONDITIONS

DATE: 2-6-73

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig 2  
 Width: 1.50"  
 Hole spacing: 1.50"  
 Edge margin: 0.75"  
 Material: 2024 T851  
 Material gauge: 0.250"  
 Surface Treatment: Shot Peen  
 Fastener: Hilok (Prot HD)

3. CW Process

Sleeve type: \_\_\_\_\_  
 Sleeve thickness: \_\_\_\_\_  
 Sleeve ID: \_\_\_\_\_  
 CW: \_\_\_\_\_  
 Taper: \_\_\_\_\_  
 Drill Major Dia.: \_\_\_\_\_  
 Lubrication: \_\_\_\_\_

- NOT APPLICABLE -



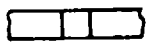
2. Hole Preparation

Nominal hole size: 3/8"  
 Process: Ream, Install Fastener  
 Fastener Installation Torque - 220/240 In/lbs

2024  
 Reamed Hilok  
 30ksi

4. Fatigue Conditions

Net stress: 30ksi  
 Test load: 8500 lts  
 Load ratio: (R) = 0.1  
 Test Frequency: 5000/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophore (36Kip)

Specimen No. R623079	Hole No.	Hole Diameter (Inches) After Ream	Fastener Diameter (Inches)	Net Fit Between Fastener and Hole	Hole Finish (RHR) After Ream	Cycles to Failure (Thousands)	Origin of Failure and Remarks
-10	1	.3735	.3735	NET	45	237	 Head
	2	.3735	.3735	NET	-		
-11	1	.3740	.3740	NET	40	205	 Head
	2	.3745	.3740	-0005	-		
-	1						
	2						

PHASE II TASK 3 BASIC FILLED HOLE VALUES

TEST NUMBER: 3A 2

NOMINAL EXPANSION VALUE: -

GENERAL TEST CONDITIONS

DATE: 2-6-73

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig 2  
 Width: 1.50"  
 Hole spacing: 1.50"  
 Edge margin: 0.75"  
 Material: 2024 T851  
 Material gauge: 0.250"  
 Surface Treatment: Shot Peen  
 Fastener: Hilok (Prot HD)

3. CW Process

Sleeve type: \_\_\_\_\_  
 Sleeve thickness: \_\_\_\_\_  
 Sleeve orle: \_\_\_\_\_  
 CW M: \_\_\_\_\_  
 Major Dia.: \_\_\_\_\_  
 Location: \_\_\_\_\_

**NOT APPLICABLE**



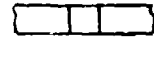
2. Hole Preparation

Nominal hole size: 3/8"  
 Process: Ream, Install Fastener  
 Fastener Installation Torque: 220-240 in/lbs

2024  
 Reamed Hilok  
 25ksi

4. Fatigue Conditions

Net stress: 25ksi  
 Test load: 7000 lbs  
 Load ratio: (R) = 0.1  
 Test Frequency: 5000/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophore (36Kip)

Specimen No. R623079	Hole No.	Hole Diameter (Inches) After Ream	Fastener Diameter (Inches)	Net Fit Between Fastener and Hole	Hole Finish (RHR) After Ream	Cycles to Failure (Thousands)	Origin of Failure and Remarks
-4	1	.3740	.3735	-.0005	25	404	
	2	.3745	.3735	-.001	20		
-5	1	.3745	.3735	-.001	15	684	
	2	.3745	.3735	-.001	15		
-	1						
	2						

PHASE II TASK 3 BASIC FILLED HOLE VALUES

TEST NUMBER: 3A 3

NOMINAL EXPANSION VALUE: -

GENERAL TEST CONDITIONS

DATE: 2-6-73

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig 2  
 Width: 1.50"  
 Hole spacing: 1.50"  
 Edge margin: 0.75"  
 Material: 2024 T851  
 Material gauge: 0.250"  
 Surface Treatment: Shot Peen  
 Fastener: Hilok (Prot HD)

3. CW Process

Sleeve type: \_\_\_\_\_  
 Sleeve thickness: \_\_\_\_\_  
 Sleeve or CW: \_\_\_\_\_  
 Paper: \_\_\_\_\_  
 Core Major Dia.: \_\_\_\_\_  
 Location: \_\_\_\_\_

**NOT APPLICABLE**




2. Hole Preparation

Nominal hole size: 3/8"  
 Process: Ream, Install Fastener  
 Fastener Installation Torque: 220-240 in/lbs

2024  
 Reamed Hilok  
 35ksi

4. Fatigue Conditions

Net stress: 35 ksi  
 Test load: 9950 lbs  
 Load ratio: (R) = 0.1  
 Test Frequency: 5000/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophore (36Kip)

Specimen No. R623079	Hole No.	Hole Diameter (Inches) After Ream	Fastener Diameter (Inches)	Net Fit Between Fastener and Hole	Hole Finish (RHR) After Ream	Cycles to Failure (Thousands)	Origin of Failure and Remarks
-6	1	.3740	.3740	NET	20	82	
	2	.3745	.3740	NET	20		
-7	1	.3745	.3735	-.001	20	79	 burnishing under head
	2	.3740	.3735	-.0005	20		
-	1						
	2						



PHASE II TASK 3 - BASIC FILLED HOLE VALUES

TEST NUMBER: 3A 5 (2024)

NOMINAL EXPANSION VALUE: 0.018" - 0.020"

GENERAL TEST CONDITIONS

DATE: 2-8-73

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 2  
 Width: 1.50"  
 Hole spacing: 1.50"  
 Edge margin: 0.75"  
 Material: 2024 T851  
 Material gauge: 0.250"  
 Surface Treatment: Shot Peen  
 Fastener: Hilok (Prot HD)

3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: 0.010"  
 Sleeve orientation: 0°  
 CW Mandrel: ST 5300-CBM-12 -O-N  
 CW Mandrel Taper: 0.045"/"  
 CW Mandrel Major Dia.: 0.3738"  
 Lubrication: Fel Pro 300 (on sleeve)

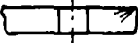


2. Hole Preparation

Nominal hole size: 3/8"  
 Process: C/W, Ream, Install Fastener  
 Fastener Installation Torque: 220-240 in/lbs

4. Fatigue Conditions

Net stress: 30 ksi  
 Test load: 8,500 lbs  
 Load ratio: (R) = 0.1  
 Test Frequency: 5000/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophore (36Kip)

2024  
 C/W Hilok  
 30ksi

Specimen No. R623079	Hole No.	Hole Diameter (Inches) After Ream	Fastener Diameter (Inches)	Net Fit Between Fastener and Hole	Hole Finish (RHR) After Ream	Cycles to Failure (Thousands)	Origin of Failure and Remarks
-12	1	.3730	.3737	.0007	20	591	 outside
	2	.3730	.3737	.0007	20		
-13	1	.3730	.3735	.0005	25	950	 outside
	2	.3730	.3737	.0007	30		
-14	1	.3730	.3736	.0006	20	608	 fretting undernut
	2	.3730	.3737	.0007	25		



PHASE II TASK 3 - BASIC FILLED HOLE VALUES

TEST NUMBER: 3A5 (7175)

NOMINAL EXPANSION VALUE: -

GENERAL TEST CONDITIONS

DATE: 4-6-73

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig 2  
 Width: 1.50"  
 Hole spacing: 1.50"  
 Edge margin: 0.75"  
 Material: 7175 T 736  
 Material gauge: 0.250"  
 Surface Treatment: Shot Peen  
 Fastener: Hilok (Prot Head)

3. CW Process None Used

Sleeve type: \_\_\_\_\_  
 Sleeve thickness: \_\_\_\_\_  
 Sleeve orien: \_\_\_\_\_  
 CW M- \_\_\_\_\_  
 CW \_\_\_\_\_  
 Major Dia.: \_\_\_\_\_  
 orien: \_\_\_\_\_

**- NOT APPLICABLE -**




2. Hole Preparation

Nominal hole size: 3/8"  
 Process: Ream, Install Fastener  
 Fastener Installation Torque: 225-250 in/lbs

7175  
 Reamed Hilok  
 30 ksi

4. Fatigue Conditions

Net stress: 30 ksi  
 Test load: 8,550 lbs  
 Load ratio: (R) = 0.1  
 Test Frequency: 5000/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophore (36 Kip)

Specimen No. R623079	Hole No.	Hole Diameter (Inches) After Ream	Fastener Diameter (Inches)	Net Fit Between Fastener and Hole	Hole Finish (RHR) After Ream	Cycles to Failure (Thousands)	Origin of Failure and Remarks
-1	1	.3735	.3735	0	35	359	 head
	2	.3735	.3735	0	-		
-2	1	.3735	.3735	0	35	1,007	 head
	2	.3735	.3735	0	-		
-3	1	.3735	.3735	0	40	253	
	2	.3735	.3735	0	-		

PHASE II TASK 3 - BASIC FILLED HOLE VALUES

TEST NUMBER: 3A 6 (2024)

NOMINAL EXPANSION VALUE: 0.018" - 0.020"

GENERAL TEST CONDITIONS

DATE: 2-8-73

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig 2  
 Width: 1.50"  
 Hole spacing: 1.50"  
 Edge margin: 0.75"  
 Material: 2024 T851  
 Material gauge: 0.250"  
 Surface Treatment: Shot Peen  
 Fastener: Hilok (Prot Head)

3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: 0.010"  
 Sleeve orientation: 0°  
 CW Mandrel: ST 5300-CBM-12-0-N  
 CW Mandrel Taper: 0.045"/"  
 CW Mandrel Major Dia.: 0.3738"  
 Lubrication: Fel Pro 300 (on sleeve)



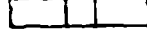
2. Hole Preparation

Nominal hole size: 3/8"  
 Process: C/W, Ream, Install Fastener  
 Fastener Installation Torque: 220-240 in/lbs

2024  
 C/W Hilok  
 25 ksi

4. Fatigue Conditions

Net stress: 25 ksi  
 Test load: 7,000 lbs  
 Load ratio: (R) = 0.1  
 Test Frequency: 5000/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophore (36 Kip)

Specimen No. R623079	Hole No.	Hole Diameter (Inches) After Ream	Fastener Diameter (Inches)	Net Fit Between Fastener and Hole	Hole Finish (RHR) After Ream	Cycles to Failure (Thousands)	Origin of Failure and Remarks
-15	1	.3730	.3736	.0006	25	7,779	 No Failure
	2	.3730	.3735	.0005	30		
-16	1	.3730	.3738	.0008	25	8,323	
	2	.3730	.3738	.0008	25		
	1						
	2						

PHASE II TASK 3 - BASIC FILLED HOLE VALUES

TEST NUMBER: 3A 6 (7175)

NOMINAL EXPANSION VALUE: .019"

GENERAL TEST CONDITIONS

DATE: 4-6-73

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 2  
 Width: 1.50"  
 Hole spacing: 1.50"  
 Edge margin: 0.75"  
 Material: 7175 T 736  
 Material gauge: 0.250"  
 Surface Treatment: Shot Peen  
 Fastener: Hilok (Prot Head)

3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: 0.010"  
 Sleeve orientation: 0°  
 CW Mandrel: ST 5300-CBM-12 -0-N  
 CW Mandrel Taper: 0.045"/"  
 CW Mandrel Major Dia.:                       
 Lubrication: Fel Pro 300 (on sleeve)

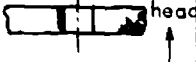

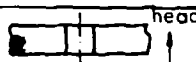
2. Hole Preparation

Nominal hole size: 3/8"  
 Process: C W, Ream, Install Fastener  
 Installation Torque - 225-250 in/lbs

4. Fatigue Conditions

Net stress: 30 ksi  
 Test load: 8,450 lbs  
 Load ratio: (R) = 0.1  
 Test Frequency: 5000/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophore (36 Kip)

7175  
 CW Hilok  
 30 ksi

Specimen No. R623079	Hole No.	Hole Diameter (Inches) After Ream	Fastener Diameter (Inches)	Net Fit Between Fastener and Hole	Hole Finish (RHR) After Ream	Cycles to Failure (Thousands)	Origin of Failure and Remarks
-4	1	.3740	.3740	0	40	513	
	2	.3740	.3740	0	-		
-5	1	.3735	.3735	0	35	523	
	2	.3735	.3735	0	-		
-6	1	.3735	.3735	0	40	293	
	2	.3735	.3735	0	-		

PHASE II TASK 3 - BASIC FILLED HOLE VALUES

TEST NUMBER: 3 A 7

NOMINAL EXPANSION VALUE: 0.018" - 0.020"

GENERAL TEST CONDITIONS

DATE: 2-8-73

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig 2  
 Width: 1.50"  
 Hole spacing: 1.50"  
 Edge margin: 0.75"  
 Material: 2024 T 851  
 Material gauge: 0.250"  
 Surface Treatment: Shot Peen  
 Fastener: Hilok (Prot. Head)

3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: 0.010"  
 Sleeve orientation: 0°  
 CW Mandrel: ST 5300-CBM-12 -0-N  
 CW Mandrel Taper: 0.045"/"  
 CW Mandrel Major Dia.: 0.3738"  
 Lubrication: Fel Pro 300 (on sleeve)





2. Hole Preparation

Nominal hole size: 3/8"  
 Process: C/W, Ream, Install Fastener  
 Fastener Installation Torque: 220-240 in./lbs

2024  
 C/W Hilok  
 35 ksi

4. Fatigue Conditions

Net stress: 35 ksi  
 Test load: 9,900 lbs  
 Load ratio: (R) = 0.1  
 Test frequency: 5000/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophore (36 Kip)

Specimen No. R623079	Hole No.	Hole Diameter (Inches) After Ream	Fastener Diameter (Inches)	Net Fit Between Fastener and Hole	Hole Finish (RHR) After Ream	Cycles to Failure (Thousands)	Origin of Failure and Remarks
-17	1	.3730	.3737	.0007	25	311	
	2	.3730	.3736	.0006	30		Nut Side
-18	1	.3730	.3738	.0008	20	387	
	2	.3730	.3738	.0008	25		Head Side
	1						
	2						

PHASE II TASK 3 - BASIC FILLED HOLE VALUES

TEST NUMBER: 3 A 8

NOMINAL EXPANSION VALUE: 0.018" - 0.020"

GENERAL TEST CONDITIONS

DATE: 2-8-73

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 2  
 Width: 1.50"  
 Hole spacing: 1.50"  
 Edge margin: 0.75"  
 Material: 2024 T 851  
 Material gauge: 0.250"  
 Surface Treatment: Shot Peen  
 Fastener: Hilok (Prot Head)

3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: 0.010"  
 Sleeve orientation: 0°  
 CW Mandrel: ST 5300-CBM-12 -0-N  
 CW Mandrel Taper: 0.045"/"  
 CW Mandrel Major Dia.: 0.3738"  
 Lubrication: Fel Pro 300 (on sleeve)



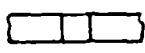
2. Hole Preparation

Nominal hole size: 3/8"  
 Process: C/W, Ream, Install Fastener  
 Fastener Installation Torque: 220-240 in./lbs

4. Fatigue Conditions

Net stress: 40 ksi  
 Test load: 11,350 lbs  
 Load ratio: (R) = 0.1  
 Test Frequency: 5000/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophore (36 Kip)

2024  
 C/W Hilok  
 40 ksi

Specimen No.	Hole No.	Hole Diameter (Inches) After Ream	Fastener Diameter (Inches)	Net Fit Between Fastener and Hole	Hole Finish (RHR) After Ream	Cycles to Failure (Thousands)	Origin of Failure and Remarks
-19	1	.3730	.3735	.0005	25	161	
	2	.3730	.3735	.0005	20		Head Side
-20	1	.3730	.3736	.0006	25	149	
	2	.3730	.3735	.0005	30		Nut Side
-	1						
	2						

PHASE II TASK 3 - BASIC FILLED HOLE VALUES

TEST NUMBER: 3 A -9 a

NOMINAL EXPANSION VALUE: -

GENERAL TEST CONDITIONS

DATE: 2-13-73

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig 2  
 Width: 1.50"  
 Hole spacing: 1.50"  
 Edge margin: 0.75"  
 Material: 2024 T851  
 Material gauge: 0.250"  
 Surface Treatment: Shot Peen  
 Fasteners: Tapertok (Prot Head)

3. CW Process

Sleeve type: \_\_\_\_\_  
 Sleeve thickness: \_\_\_\_\_  
 Sleeve ID: \_\_\_\_\_  
 CW: \_\_\_\_\_  
 Taper: \_\_\_\_\_  
 Barrel Major Dia.: \_\_\_\_\_  
 Location: \_\_\_\_\_

NOT APPLICABLE




2. Hole Preparation

Nominal hole size: 3/8"  
 Process: Ream, Install Fastener  
 Fastener Installation Torque: 220-240 in./lbs

2024  
 Prot. Head T/L  
 30 ksi

4. Fatigue Conditions

Net stress: 30 ksi  
 Test load: 8,400 lbs  
 Load ratio: (R) = 0.1  
 Test Frequency: 5000/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophore (36 Kip)

Specimen No.	Hole No.	Head Protrusion (Inches) After Ream	Fastener Diameter (Inches)	Net Fit Between Fastener and Hole	Hole Finish (RHR) After Ream	Cycles to Failure (Thousands)	Origin of Failure and Remarks
-23	1	.232	-		30	94	
	2	.228	-		-		Nut Side
-24	1	.229	-		35	6.086	
	2	.230	-		-		Head Side
-25	1	.231	-		20	2.662	
	2	.230	-		-		Head Side

PHASE II TASK 3 - BASIC FILLED HOLE VALUES

TEST NUMBER: 3A 9b

NOMINAL EXPANSION VALUE:         

GENERAL TEST CONDITIONS

DATE: 3-6-73

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 2  
 Width: 1.50"  
 Hole spacing: 1.50"  
 Edge margin: 0.75"  
 Material: 2024 T851  
 Material gauge: 0.250"  
 Surface Treatment: Shot Peen  
 Fasteners: Taperlok (Prot. Head)

3. CW Process

Sleeve type:           
 Sleeve thickness:           
 Sleeve orien:           
 CW M:           
 CW:           
 Major Dia.:           
 orien:         

- NOT APPLICABLE -




2. Hole Preparation

Nominal hole size: 3/8"  
 Process: Ream, Install Fastener  
 Fastener Installation Torque: 220-240 in-lbs

4. Fatigue Conditions

Net stress: 30 ksi  
 Test load: 9,450 lbs  
 Load ratio: (R) = 0.1  
 Test Frequency: 5000/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophone (36 Kip)

2024  
 Pro. Head T/L  
 30 ksi

Specimen No.	Hole No.	Head Protrusion (Inches) After Ream	Fastener Diameter (Inches)	Net Fit Between Fastener and Hole	Hole Finish (RHR) After Ream	Torque (in/lbs)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
-35	1	.224			55	225	1,236	
	2	.237			-	225		
-	1							
	2							
-	1							
	2							

PHASE II TASK 3 - BASIC FILLED HOLE VALUES

TEST NUMBER: 3A-10

NOMINAL EXPANSION VALUE: -

GENERAL TEST CONDITIONS

DATE: 2-13-73

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig 2  
 Width: 1.50"  
 Hole spacing: 1.50"  
 Edge margin: 0.75"  
 Material: 2024 T B51  
 Material gauge: 0.250"  
 Surface Treatment: Shot Peen  
 Fastener: Taperlok (Prot. Head)

3. CW Process

Sleeve type: \_\_\_\_\_  
 Sleeve thickness: \_\_\_\_\_  
 Sleeve orient: \_\_\_\_\_  
 CW M- \_\_\_\_\_  
 C" \_\_\_\_\_  
 Major Dia.: \_\_\_\_\_  
 Location: \_\_\_\_\_

**- NOT APPLICABLE -**

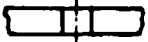


2. Hole Preparation

Nominal hole size: 3/8"  
 Process: Ream, Install Fastener  
 Fastener Installation Torque: 220-240 in/lbs

2024  
 Prot. Head T/L  
 25 ksi

4. Fatigue Conditions

Net stress: 25 ksi  
 Test load: 7,000 lbs  
 Load ratio: (R) = 0.1  
 Test Frequency: 5000/Minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophone (36 Kip)

Specimen No.	Hole No.	Head Protrusion (Inches) After Ream	Fastener Diameter (Inches)	Net Fit Between Fastener and Hole	Hole Finish (RHR) After Ream	Cycles to Failure (Thousands)	Origin of Failure and Remarks
-26	1	.230	-		30	10,075	
	2	.231			-		No Failure
-27	1	.225	-		30	1,594	
	2	.231	-		-		
-22	1	.241	-	-	45	10,164	
	2	.240	-	-	-		No Failure



PHASE II TASK 3 - BASIC FILLED HOLE VALUES

TEST NUMBER: 3A -11

NOMINAL EXPANSION VALUE: \_\_\_\_\_

GENERAL TEST CONDITIONS

DATE: 2-13-73

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig 2  
 Width: 1.50"  
 Hole spacing: 1.50"  
 Edge margin: 0.75"  
 Material: 2024 T 851  
 Material gauge: 0.250"  
 Surface Treatment: Shot Peen  
 Fastener: Taperlok (Prot. Head)

3. CW Process

Sleeve type: \_\_\_\_\_  
 Sleeve thick: \_\_\_\_\_  
 Sleeve: \_\_\_\_\_  
 CW: \_\_\_\_\_  
 Paper: \_\_\_\_\_  
 Mandrel Major Dia.: \_\_\_\_\_  
 Application: \_\_\_\_\_

**- NOT APPLICABLE -**


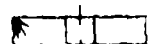
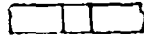
2. Hole Preparation

Nominal hole size: 3/8"  
 Process: Ream, Install Fastener  
 Fastener Installation Torque: 220-240 in./lbs

4. Fatigue Conditions

Net stress: 35 ksi  
 Test load: 9,800 lbs  
 Load ratio: (R) = 0.1  
 Test Frequency: 5000/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophore (36 Kip)

2024  
 Prot. Head T/L  
 35 ksi

Specimen No. R623079	Hole No.	Head Protrusion (Inches) After Ream	Fastener Diameter (Inches)	Net Fit Between Fastener and Hole	Hole Finish (RHR) After Ream	Cycles to Failure (Thousands)	Origin of Failure and Remarks
-28	1	.230			25	328	 Headside Failure
	2	.231			-		
-29	1	.232			30	369	 Headside Failure
	2	.230			-		
-	1						
	2						

PHASE II TASK 3 - BASIC FILLED HOLE VALUES

TEST NUMBER: 3A-12

NOMINAL EXPANSION VALUE: \_\_\_\_\_

GENERAL TEST CONDITIONS

DATE: 2-13-73

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig 2  
 Width: 1.50"  
 Hole spacing: 1.50"  
 Edge margin: 0.75"  
 Material: 2024 T 851  
 Material gauge: 0.250"  
 Surface Treatment: Shot Peen  
 Fastener: Taperlok (Prot. Head)

3. CW Process

Sleeve type: \_\_\_\_\_  
 Sleeve thick- \_\_\_\_\_  
 Sleeve c \_\_\_\_\_  
 CW \_\_\_\_\_  
 Taper: \_\_\_\_\_  
 Taper Major Dia.: \_\_\_\_\_  
 Location: \_\_\_\_\_

NOT APPLICABLE -




2. Hole Preparation

Nominal hole size: 3/8"  
 Process: Ream, Install Fastener  
 Fastener Installation Torque: 220-240 in./lbs

4. Fatigue Conditions

Net stress: 40 ksi  
 Test load: 11,250 lbs  
 Load ratio: (R) = 0.1  
 Test Frequency: 5000/minute  
 Test laboratory: Materials  
 Test engineer: D. Reese  
 Test Machine: Vibrophore (36 Kip)

2024  
 Prot. Head T/L  
 40 ksi

Specimen No. R623079	Hole No.	Head Protrusion (Inches)	Fastener Diameter (Inches)	Net Fit Between Fastener and Hole	Hole Finish (RHR) After Ream	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		After Ream					
-30	1	.234	-		25	237	
	2	.233	-		-		Headside Failure
-31	1	.232	-		30	-	
	2	.230	-		-		Spec. Overloaded No Data
-36	1	.234	-		50	156	
	2	.234	-		-		Headside Failure

PHASE II TASK 3 - BASIC FILLED HOLE VALUES

TEST NUMBER: 3A 13

NOMINAL EXPANSION VALUE: -

GENERAL TEST CONDITIONS

DATE: 2-13-73

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 2  
 Width: 1.50"  
 Hole spacing: 1.50"  
 Edge margin: 0.75"  
 Material: 2024 T 851  
 Material gauge: 0.250"  
 Surface Treatment: Shot Peen  
 Fastener: Taperlok (100° Head)

3. CW Process

Sleeve type: -  
 Sleeve thick: -  
 Sleeve: -  
 CW: -  
 Taper: -  
 and/or Major Dia.: -  
 Location: -

NOT APPLICABLE -



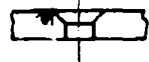
2. Hole Preparation

Nominal hole size: 3/8"  
 Process: Ream, Install Fastener  
 Fastener Installation Torque: 225-240 in/lbs

2024  
 100° Head T/L  
 30 ksi

4. Fatigue Conditions

Net stress: 30 ksi  
 Test load: 8,475 lbs  
 Load ratio: (R) = 0.1  
 Test Frequency: 5000/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophore (36 Kip)

Specimen No. R623079	Hole No.	Head Protrusion (Inches) After Ream	Fastener Diameter (Inches)	Net Fit Between Fastener and Hole	Hole Finish (RHR) After Ream	Cycles to Failure (Thousands)	Origin of Failure and Remarks
-32	1	.201	-		30	147	
	2	.190	-		-		
-33	1	.207	-		30	264	
	2	.206	-		-		
-34	1	.204	-		30	196	
	2	.202	-		-		

PHASE II TASK 3 - BASIC FILLED HOLE VALUES

TEST NUMBER: 3A 14

NOMINAL EXPANSION VALUE: -

GENERAL TEST CONDITIONS

DATE: 3-9-73

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig 2  
 Width: 1.50"  
 Hole spacing: 1.50"  
 Edge margin: 0.75"  
 Material: 2024 T 851  
 Material gauge: 0.250"  
 Surface Treatment: Shot Peen  
 Fastener: Taperlok (Flush Head)

3. CW Process

Sleeve type: \_\_\_\_\_  
 Sleeve thick: \_\_\_\_\_  
 Sleeve o: \_\_\_\_\_  
 CW A: \_\_\_\_\_  
 taper: \_\_\_\_\_  
 urel Major Dia.: \_\_\_\_\_  
 ation: \_\_\_\_\_

NOT APPLICABLE




2. Hole Preparation

Nominal hole size: 3/8"  
 Process: Ream, Install Fastener

2024  
 100° Head T/L  
 25 ksi

4. Fatigue Conditions

Net stress: 25 ksi  
 Test load: 7000 lbs  
 Load ratio: (R) = 0.1  
 Test Frequency: 5000/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophore (36 Kip)

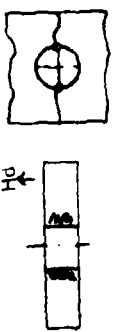
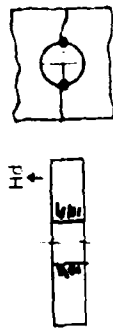
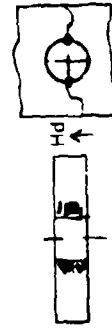
Specimen No. R623079	Hole No.	Head Protrusion (Inches) After Ream	Fastener Diameter (Inches)	Net Fit Between Fastener and Hole	Hole Finish (RHR) After Ream	Cycles to Failure (Thousands)	Origin of Failure and Remarks
-21	1	.204			45	612	
	2	.205			-		
-23	1	.206			40	661	
	2	.207			-		
-	1						
	2						

PHASE II - TASK 3 - BASIC FILLEDHOLE DATA

Ti-6Al-4V,  
reamed, Hi-Lok  
70 ksi

TEST 3T1 SPECIMEN 623078 DATE 9/19/73

<p><b>SPECIMEN DESCRIPTION</b></p> <p>Configuration <u>Fig. 2</u></p> <p>Material <u>Ti-6Al-4V (annealed)</u></p> <p>Width (in.) <u>1.50</u></p> <p>Hole spacing <u>1.50</u></p> <p>Edge margin (in.) <u>0.75</u></p> <p>Material gauge (in.) <u>0.250</u></p> <p>Surface treatment <u>Shot peen</u></p>	<p><b>COLDWORK PROCESS</b></p> <p>Interference _____</p> <p>Sleeve type _____</p> <p>Sleeve thickness (in.) _____</p> <p>Sleeve orientation _____</p> <p>Mandrel material _____</p> <p>Mandrel taper (in./in.) _____</p> <p>Mandrel max diameter (in.) _____</p> <p>Lubrication _____</p>	<p><b>HOLE PREPARATION</b></p> <p>Nominal hole size (in.) <u>0.375</u></p> <p>Process <u>Ream</u></p> <p><b>FASTENER INSTALLATION</b></p> <p>Type <u>Hi-Lok prot hd</u></p> <p>Fit (in.) <u>Net to 0.0005 clearance</u></p> <p>Torque (in./lb) <u>240 to 250</u></p>
<b>FATIGUE CONDITIONS</b>		
Max net stress (ksi) <u>70</u>	Max test load (kip) <u>20</u>	Load ratio (R) <u>0.1</u>
Test frequency <u>4000 gpm</u>	Test laboratory <u>Materials</u>	Test engineer <u>D. Reese</u>
Test machine <u>Vibraphore 36-kip</u>		

Specimen designation	Hole diameter (in.)			Hole finish (HR)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
	Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
1	1	0.3740	0.3740			40			0.3740	Net	90,000	
	2	0.3740	0.3740						0.3740	Net		
	3											
	4											
2	1	0.3750	0.3750			50			0.3745	0.0005	83,000	
	2	0.3750	0.3750						0.3745	0.0005		
	3											
	4											
3	1	0.3740	0.3740			40			0.3740	Net	78,000	
	2	0.3740	0.3740						0.3740	Net		
	3											
	4											

T-6Al-4V  
reamed Hi-Lok,  
75 ksi

**PHASE II - TASK 3 - BASIC FILLED-HOLE DATA**

TEST 312 SPECIMEN 623079 DATE 9/19/73

<b>SPECIMEN DESCRIPTION</b>	<b>HOLE PREPARATION</b>	<b>FATIGUE CONDITIONS</b>
Configuration <u>F-2</u>	Nominal hole size (in.) <u>0.375</u>	Max net stress (ksi) <u>75</u>
Material <u>T-6Al-4V (annealed)</u>	Process <u>Ream</u>	Max test load (kip) <u>22</u>
Width (in.) <u>1.50</u>	Sleeve thickness (in.) _____	Load ratio (R) <u>0.1</u>
Hole spacing (in.) <u>1.50</u>	Sleeve orientation _____	Test frequency <u>4000 cpm</u>
Edge margin (in.) <u>0.75</u>	Mandrel material _____	Test laboratory <u>Materials</u>
Material gauge (in.) <u>0.250</u>	<b>FASTENER INSTALLATION</b>	Test engineer <u>D. Reese</u>
Surface treatment <u>Shot peen</u>	Type <u>Hi-Lok prot hd</u>	Test machine <u>Vibraphore 36 kip</u>
	Fit (in.) <u>Net to 0.0005 clearance</u>	
	Torque (in lb) <u>-240 to 360</u>	

Specimen ID no.	Hole diameter (in.)			Hole finish (RHR)		Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
	Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	Actual	Retained	Diameter	Fit		
4	1		0.3740					0.3740	Net	47,000	
	2		0.3740					0.3740	Net		
	3										
	4										
5	1		0.3740					0.3740	Net	52,000	
	2		0.3740					0.3740	Net		
	3										
	4										
1											
7											
3											
4											

PHASE II - TASK 3 - BASIC FILLED-HOLE DATA

Ti-6Al-4V  
reamed, Hi-Lok  
65 ksi

TEST 3T3 SPECIMEN 623079 DATE 9/19/73

**SPECIMEN DESCRIPTION**  
 Configuration Fig. 2  
 Material Ti-6Al-4V (annealed)  
 Width (in.) 1.50  
 Hole spacing 1.50  
 Edge margin (in.) 0.75  
 Material gauge (in.) 0.250  
 Surface treatment Shot peen

**COLDWORK PROCESS**  
 Interference \_\_\_\_\_  
 Sleeve type \_\_\_\_\_  
 Sleeve thickness (in.) \_\_\_\_\_  
 Sleeve orientation \_\_\_\_\_  
 Mandrel material \_\_\_\_\_  
 Mandrel taper (in./in.) \_\_\_\_\_  
 Mandrel max diameter (in.) \_\_\_\_\_  
 Lubrication \_\_\_\_\_

**HOLE PREPARATION**  
 Nominal hole size (in.) 0.375  
 Process Ream

**FASTENER INSTALLATION**  
 Type Hi-Lok prot hd  
 Fit Net to 0.0005 clearance  
 Torque (in. lb) 240 to 250

**FATIGUE CONDITIONS**  
 Max net stress (ksi) 65  
 Max test load (kip) 19.3  
 Load ratio (R) 0.1  
 Test frequency 4000 cpm  
 Test laboratory Materials  
 Test engineer D. Reese  
 Test machine 36-kip Vibraphore

Specimen dash no	Hole no	Hole diameter (in.)			Hole finish (RHRR)		Collarwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before collarwork	After ream	0.3740	Before collarwork	After collarwork	Actual	Retained	Diameter	Fit		
6	1		0.3740						0.3740	Net	199,000	
	2		0.3740					0.3740	Net			
	3											
	4											
7	1		0.3740			45			0.3740	Net	92,000	
	2		0.3740					0.3740	Net			
	3											
	4											
	1											
	2											
	3											
	4											

PHASE II - TASK 3 - BASIC FILLED-HOLE DATA

Ti-6Al-4V,  
reamed, Hi-Lok,  
60 ksi

TEST 314 - SPECIMEN 623079 - DATE 9/19/73

**SPECIMEN DESCRIPTION**  
 Configuration Fig. 2  
 Material Ti-6Al-4V (annealed)  
 Width (in) 1.50  
 Hole spacing 1.50  
 Edge margin (in) 0.75  
 Material gage (in) 0.250  
 Surface treatment Shot peen

**COLDWORK PROCESS**  
 Interference \_\_\_\_\_  
 Sleeve type \_\_\_\_\_  
 Sleeve thickness (in) \_\_\_\_\_  
 Sleeve orientation \_\_\_\_\_  
 Mandrel material \_\_\_\_\_  
 Mandrel taper (in./in) \_\_\_\_\_  
 Mandrel max diameter (in.) \_\_\_\_\_  
 Lubrication \_\_\_\_\_

**HOLE PREPARATION**  
 Nominal hole size (in.) 0.375  
 Process Ream

**FASTENER INSTALLATION**  
 Type \_\_\_\_\_  
 Fit (in.) Hi-Lok prol hd  
 Net to 0.0005 clearance  
 Torque (in.-lb) 240 to 250

**FATIGUE CONDITIONS**  
 Max net stress (ksi) 60  
 Max test load (kip) 17.7  
 Load ratio (R) 0.1  
 Test frequency 4000 cpm  
 Test laboratory Materials  
 Test engineer D. Reese  
 Test machine 36-Vibraphore

Specimen dash no	Hole no	Hole diameter (in)		Hole finish (RHR)		Coldwork expansion (in)		Fastener size (in)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After ream	Before coldwork	After coldwork	Actual	Reamed	Diameter	Fit		
8	1		0.3740		40			0.3740	Net	246,000	
	2		0.3740		-			0.3740	Net		
	3										
	4										
9	1		0.3740		45			0.3740	Net	139,000	
	2		0.3740		-			0.3740	Net		
	3										
	4										
1											
2											
3											
4											



PHASE II - TASK 3 - BASIC FILLED-HOLE DATA

Ti-6Al-4V sta.  
reamed, Hi-Lok,  
70 ksi

TEST 3T5 SPECIMEN 623079 DATE 9/19/73

SPECIMEN DESCRIPTION		COLDWORK PROCESS		HOLE PREPARATION		FATIGUE CONDITIONS	
Configuration	<u>Fig. 2</u>	Interference	<u>0.375</u>	Nominal hole size (in)	<u>0.375</u>	Max net stress (ksi)	<u>70</u>
Material	<u>Ti-6Al-4V (sta)</u>	Sleeve type	<u>Ream</u>	Process	<u>Ream</u>	Max test load (kip)	<u>20.4</u>
Width (in)	<u>1.50</u>	Sleeve thickness (in)				Load ratio (R)	<u>0.1</u>
Hole spacing	<u>1.50</u>	Sleeve orientation				Test frequency	<u>4000 cpm</u>
Edge margin (in)	<u>0.75</u>	Mandrel material		FASTENER INSTALLATION		Test laboratory	<u>Materials</u>
Material gauge (in)	<u>0.250</u>	Mandrel taper (in/in)		Type	<u>Hi-Lok_prot hd</u>	Test engineer	<u>D. Reese</u>
Surface treatment	<u>Shot peen</u>	Mandrel max diameter (in)		Fit	<u>Net to 0.0005 clearance</u>	Test machine	<u>36 kip Vibration</u>
		Lubrication		Torque (in lb)	<u>240/250</u>		

Specimen dash no	Hole no	Hole diameter (in)		Hole finish (RHR)		Coldwork expansion (in)		Fastener size (in)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After ream	Before coldwork	After ream	Actual	Retainer	Diameter	Fit		
1 sta	1		0.3740		25			0.3740	Net	65,000	
	2		0.3740		-			0.3740	Net		
	3										
	4										
2 sta	1		0.3740		20			0.3740	Net	74,000	
	2		0.3470		-			0.3740	Net		
	3										
	4										
3 sta	1		0.3740		25			0.3740	Net	82,000	
	2		0.3740		-			0.3740	Net		
	3										
	4										



PHASE II - TASK 3 - BASIC FILLED-HOLE DATA

Ti-6Al-6V-2Sn,  
reamed Hi-Lok,  
70 ksi

TEST 317 SPECIMEN 623079 DATE 9/19/73

**SPECIMEN DESCRIPTION**  
 Configuration Fig. 2  
 Material Ti-6Al-6V-2Sn (annealed)  
 Width (in.) 1.50  
 Hole spacing 1.50  
 Edge margin (in.) 0.75  
 Material gauge (in.) 0.250  
 Surface treatment Shot peen

**COLDWORK PROCESS**  
 Interference \_\_\_\_\_  
 Sleeve type \_\_\_\_\_  
 Sleeve thickness (in.) \_\_\_\_\_  
 Sleeve orientation \_\_\_\_\_  
 Mandrel material \_\_\_\_\_  
 Mandrel taper (in./in.) \_\_\_\_\_  
 Mandrel max diameter (in.) \_\_\_\_\_  
 Lubrication \_\_\_\_\_

**HOLE PREPARATION**  
 Nominal hole size (in.) 0.375  
 Process Ream

**FASTENER INSTALLATION**  
 Type Hi-Lok pin/hd  
 Fit Net to 0.0005 clearance  
 Torque (in. lb) 240-250

**FATIGUE CONDITIONS**  
 Max net stress (ksi) 70  
 Max test load (kip) 20.2  
 Load ratio (R) 0.1  
 Test frequency 4000 cpm  
 Test laboratory Materials  
 Test engineer D. Reese  
 Test machine 36-kip Vibration

Specimen depth No.	Hole No.	Hole diameter (in.)				Hole finish (RHR)		Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	After ream	Before coldwork	After coldwork	Actual	Retained	Diameter	Fit		
1-662	1			0.3745						0.3740	0.0005	53,000	
	2			0.3745						0.3740	0.0005		
	3												
	4												
2-662	1			0.3745						0.3740	0.0005	43,000	
	2			0.3745						0.3740	0.0005		
	3												
	4												
3-662	1			0.3740						0.3740	Net	56,000	
	2			0.3740						0.3740	Net		
	3												
	4												

PHASE II - TASK 3 - BASIC FILLED-HOLE DATA

Ti-6Al-6V-2Sn sta.  
reamed, Hi-Lok,  
70 ksi

TEST 3T8 SPECIMEN 623079 DATE 9/19/73

FATIGUE CONDITION:  
Max net stress (ksi) 70  
Max test load (kip) 20.2  
Load ratio (R) 0.1  
Test frequency 4000 cpm  
Test laboratory Materials  
Test engineer D. Reese  
Test machine 36 kip Vibraphore

HOLE PREPARATION  
Nominal hole size (in.) 0.375  
Process Ream

COLDWORK PROCESS

Interference \_\_\_\_\_  
Sleeve type \_\_\_\_\_  
Sleeve thickness (in.) \_\_\_\_\_  
Sleeve orientation \_\_\_\_\_  
Mandrel material \_\_\_\_\_  
Mandrel taper (in./in.) \_\_\_\_\_  
Mandrel max diameter (in.) \_\_\_\_\_  
Lubrication \_\_\_\_\_

SPECIMEN DESCRIPTION

Fig. 2  
Material Ti-6Al-6V-2Sn (sta)  
Width (in.) 1.50  
Hole spacing 1.50  
Edge margin (in.) 0.75  
Material gauge (in.) 0.250  
Surface treatment Shot Peened

FASTENER INSTALLATION

Type \_\_\_\_\_  
Fit Hi-Lok, prot hd  
Net to 0.0005 clearance  
Torque (in. lb) 24.250

Specimen dash no	Hole no	Hole diameter (in.)		Hole finish (RHR)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
4-662	1		0.3740			30			0.3740	Net	54,000	
	2		0.3740			-			0.3740	Net		
	3											
	4											
5-662	1		0.3740			35			0.3740	Net	48,000	
	2		0.3740			-			0.3740	Net		
	3											
6-662	1		0.3750			30			0.3740	0.0010	29,000	
	2		0.3745			-			0.3740	0.0005		
	3											
	4											

PHASE II - TASK 3 - BASIC FILLED-HOLE DATA

Ti-6Al 6V 2Sn stoa, reamed, Hi-Lok, 70 ksi

TEST: 3T9 SPECIMEN: 623079 DATE: 9/19/73

FATIGUE CONDITIONS:  
 Max. test stress (ksi) 70  
 Min. test load (kip) 20  
 Load ratio (R) 0.1  
 Test frequency 4000 cpm  
 Test laboratory Materials  
 Test engineer D. Reese  
 Test machine 36 kip Vibration

HOLE PREPARATION  
 Nominal hole size (in) 0.375  
 Process Ream

FASTENER INSTALLATION  
 Type Hi-Lok, PROT hd  
 Fit Net to 0.0005 clearance  
 Torque (in lb) 240.250

SPECIMEN DESCRIPTION  
 Fig. 2  
 Ti-6Al 6V 2Sn (stoa)

Configuration  
 Interference \_\_\_\_\_  
 Sleeve type \_\_\_\_\_  
 Sleeve thickness (in) \_\_\_\_\_  
 Sleeve or cladding \_\_\_\_\_  
 Mandrel material \_\_\_\_\_  
 Mandrel taper (in/in) \_\_\_\_\_  
 Mandrel max. diameter (in) \_\_\_\_\_  
 Surface treatment: Shot peen

Specimen dash no	Hole no	Hole diameter (in)				Hole finish (HRH)		Countdown expansion (in)		Fastener size (in)		Cycles to failure	Origin of failure and remarks
		Before countdown	After countdown	After ream	After ream	Actual	Retained	Diameter	Fit				
7662 stoa	1		0.3740	25					0.3740	Net	70,000		
	2		0.3740						0.3740	Net			
	3												
	4												
8662 stoa	1		0.3740	25					0.3740	Net	52,000		
	2		0.3740						0.3740	Net			
	3												
	4												
9662 stoa	1		0.3740	30					0.3740	Net	51,000		
	2		0.3740						0.3740	Net			
	3												
	4												



PHASE II - TASK 3 - BASIC FILLED-HOLE DATA

Tr-6Al-4V,  
C/W, Hi-Lok,  
65 ksi

TEST 3T11 SPECIMEN 623079 DATE 9/20/73

SPECIMEN DESCRIPTION		COLDWORK PROCESS		HOLE PREPARATION		FATIGUE CONDITIONS	
Configuration	Fig. 2	Interference	0.019	Normal hole size (in.)	0.375	Max. net stress (ksi.)	65
Material	Tr-6Al-4V (annealed)	Slit type	Split	Process	Ream, C/W, ream	Max. test load (kip)	19
Width (in.)	1.50	Sleeve thickness (in.)	0.010			Load ratio (R)	0.1
Hole spacing	1.50	Sleeve orientation	0			Test frequency	4000 cpm
Edge margin (in.)	0.75	Mandrel material	AISI 9260 Steel	FASTENER INSTALLATION		Test laboratory	Materials
Material gap (in.)	0.250	Mandrel taper (in./in.)	0.045	Type	Hi-Lok, prot hd	Test engineer	D Reese
Surface treatment	Shot peen	Mandrel max diameter (in.)	0.353	Fit	Net to 0.0005 clearance	Test machine	36-kip Vibration
		Lubrication	Fel Pro 300	Torque (in. lb)	240-250		

Specimen dash no	Hole no	Hole diameter (in.)		Hole finish (RHR)		Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After ream	Before coldwork	After ream	Actual	Retained	Diameter	Fit		
13	1	0.3545	0.3745	30	20	0.0185	0.0090	0.3740	0.0005	1,333,000	
	2	0.3545	0.3635	-	-	0.0184	0.0090	0.3740	0.0005		
	3										
	4										
14	1	0.3545	0.3745	40	20	0.0185	0.0090	0.3740	0.0005	2,273,000	
	2	0.3545	0.3745	-	-	0.0185	0.0090	0.3740	0.0005		
	3										
	4										
1											
2											
3											
4											

PHASE II-TASK 3 - BASIC FILLED-HOLE DATA

Ti-6Al-4V,  
C/W, Hi-Lok,  
75 ksi

TEST 3T12 SPECIMEN 623079 DATE 9/20/73

SPECIMEN DESCRIPTION		COLDWORK PROCESS		HOLE PREPARATION		FATIGUE CONDITIONS	
Configuration	Fig. 2	Interferer	0.019	Nominal hole size (in.)	0.375	Max. net stress (ksi)	75
Material	Ti-6Al-4V (annealed)	Sieve type	Split	Process	Ream, C/W, ream	Max. test load (kip)	22
Width (in.)	1.50	Sleeve thickness (in.)	0.010			Load ratio (R)	0.1
Hole spacing	1.50	Sleeve orientation	0			Test frequency	5000 cpm
Edge margin (in.)	0.75	Mandrel material	AISI 9260 steel	FASTENER INSTALLATION		Test laboratory	Materials
Material grade (in.)	0.250	Mandrel taper (in./in.)	0.045	Type	Hi-Lok, prof. hd	Test engineer	D. Reese
Surface treatment	Shot peen	Mandrel max. diameter (in.)	0.353	Fit	Net to 0.0005 Clearance	Test machine	36-kip V/braphore
		Lubrication	Fel-Pro 300	Torque (in. lb)	240-250		

Specimen dash no.	Hole no.	Hole diameter (in.)		Major finish (HRH)		Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	Before coldwork	After ream	Actual	Retained	Diameter	Fit		
.15	1	0.3545	0.3635	55	20	0.0185	0.0090	0.3740	0.0005	203,000	
	2	0.3545	0.3635		-	0.0185	0.0090	0.3740	0.0005		
	3										
	4										
.16	1	0.3545	0.3635	50	20	0.0185	0.0090	0.3740	0.0005	199,000	
	2	0.3545	0.3635		-	0.0185	0.0090	0.3740	0.0005		
	3										
	4										
	1										
	2										
	3										
	4										



PHASE II - TASK 3 - BASIC FILLED-HOLE DATA

Ti-6Al-4V,  
C/W, Hi-Lok,  
80 ksi

TEST 3T13 SPECIMEN 623079 DATE 9/20/73

**FATIGUE CONDITIONS**  
 Max net stress (ksi) 80  
 Max test load (kip) 22.9  
 Load ratio (R) 0.1  
 Test frequency 4000 cpm  
 Test laboratory Materials  
 Test engineer D. Reese  
 Test machine 36-kip Vibraphore

**HOLE PREPARATION**  
 Nominal hole size (in) 0.375  
 Process Ream, C/W, ream

**FASTENER INSTALLATION**  
 Type Hi-Lok, prot hd  
 Fit Met to 0.0005 clearance  
 Torque (in. lb) 240.250

**COLDWORK PROCESS**  
 Interference 0.018  
 Process Split

**FASTENER FINISH (RHR)**  
 After ream 25  
 After coldwork 25

**SPECIMEN DESCRIPTION**  
 Fig. 2 Ti-6Al-4V (annealed)  
 Configuration Split  
 Material 0.010  
 Width (in) 0  
 Hole spacing AlSi9260 steel  
 Edge margin (in) 0.045  
 Material gauge (in) 0.353  
 Surface treatment Fel Pro 300

Specimen dash no	Hole no	Hole diameter (in)		Hole finish (RHR)		Coldwork expansion (in)		Fastener size (in)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After ream	Before coldwork	After coldwork	Actual	Retained	Diameter	F-i		
.17	1	0.3545	0.3745	50	25	0.0185	0.0090	0.3740	0.0005	180,000	
	2	0.3545	0.3745	-	-	0.0185	0.0090	0.3740	0.0005		
	3										
	4										
.18	1	0.3545	0.3745	50	25	0.0185	0.0090	0.3740	0.0005	137,000	
	2	0.3545	0.3745	-	-	0.0185	0.0090	0.3740	0.0005		
	3										
	4										
1											
2											
3											
4											

PHASE II - TASK 3 - BASIC FILLED-HOLE DATA

Ti-6Al-4V sta.  
C/W, Hi-Lok,  
70 ksi

TEST 3T14 SPECIMEN 623079 DATE 9/27/73

**SPECIMEN DESCRIPTION**  
 Configuration Fig 2  
 Material Ti-6Al-4V (sta)  
 Width (in) 1.50  
 Hole spacing 1.50  
 Edge margin (in) 0.75  
 Material grade (in) 0.250  
 Surface treatment Shot peen

**COLDWORK PROCESS**  
 Interference 0.019  
 Sleeve type Split  
 Sleeve thickness (in) 0.010  
 Sleeve orientation 0  
 Mandrel material AISI 9260 steel  
 Mandrel taper (in/in) 0.045  
 Mandrel max diameter (in) 0.353  
 Lubrication Fel Pro 300

**HOLE PREPARATION**  
 Nominal hole size (in) 0.375  
 Process Ream, C/W, ream

**FASTENER INSTALLATION**  
 Type Hi-Lok, prot hd  
 Fit Net to 0.0005 Clearance  
 Torque (in. lb) 240-250

**FATIGUE CONDITIONS**  
 Max net stress (ksi) 70  
 Max test load (kip) 20.1  
 Load ratio (R) 0.1  
 Test frequency 4000 cpm  
 Test laboratory Materials  
 Test engineer D. Reese  
 Test machine 36 kip Vibraphore

Specimen dash no	Hole no	Hole diameter (in)		Hole finish (IRHR)		Coldwork expansion (in)		Fastener size (in)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After ream	Before coldwork	After coldwork	Actual	Retained	Diameter	Fit		
7	1	0.3545	0.3745	45	20	0.0185	0.0090	0.3740	0.0005	509,000	
	2	0.3545	0.3745	-	-	0.0185	0.0090	0.3740	0.0005		
	3										
	4										
8	1	0.3545	0.3745	45	20	0.0185	0.0085	0.3740	0.0005	468,000	
	2	0.3454	0.3745	-	-	0.0185	0.0080	0.3740	0.0005		
	3										
	4										
9	1	0.3545	0.3745	50	25	0.0185	0.0090	0.3740	0.0005	545,000	
	2	0.3545	0.3745	-	-	0.0185	0.0090	0.3740	0.0005		
	3										
	4										

Ti-6Al-4V stoa.  
C/W, Hi-Lok.  
70 ksi

**BASIC FILLED-HOLE DATA**

PHASE II - TASK 3 - TEST 3T15 SPECIMEN 623079 DATE 9/27/73

FATIGUE CONDITIONS  
 Max net stress (ksi) 70  
 Max test load (kip) 19.5  
 Load ratio (R) 0.1  
 Test frequency 4000 cpm  
 Test laboratory Materials  
 Test engineer D. Reese  
 Test machine 36 kis Vibraphore

HOLE PREPARATION  
 Nominal hole size (in) 0.375  
 Process Ream, C/W, ream

COLDWORK PROCESS  
 Interference (in.) 0.019  
 Sleeve type Split  
 Sleeve thickness (in.) 0.010  
 Sleeve orientation 0°  
 Mandrel material AISI 9260 steel  
 Mandrel taper (in./in.) 0.045  
 Mandrel max diameter (in.) 0.353  
 Lubrication Fel Pro 300

SPECIMEN DESCRIPTION  
 Fig. 2  
 Configuration Ti-6Al-4V stoa  
 Material 1.50  
 Width (in.) 1.50  
 Hole spacing (in.) 0.75  
 Edge margin (in.) 0.250  
 Material grade (in.) Shot peen  
 Surface treatment

FASTENER INSTALLATION  
 Type Hi-Lok, prot hd  
 Net to 0.0005 clearance  
 Torque (in. lb) 240.250

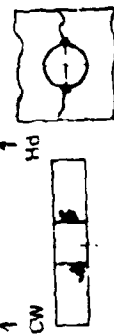
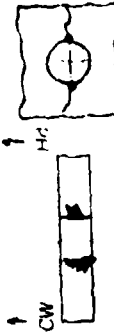
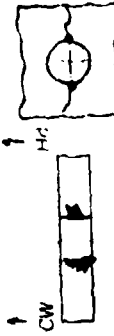
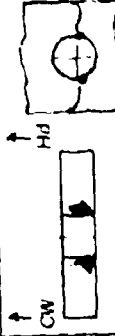
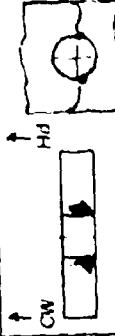

Specimen dash no	Hole no	Hole diameter (in)		Hole finish (RHR)			Coldwork expansion (in)		Fastener size (in)		Cycles to failure	Origin of failure and remarks	
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retention	Diameter			F-t
.10 stoa	1	0.3545	0.3635	0.3745	50	25	35	0.0185	0.0090	0.3740	0.0005	1,588,000	
	2	0.3545	0.363E	0.3745				0.0185	0.0090	0.3740	0.0005		
	3												
	4												
.12 stoa	1	0.3545	0.3635	0.3745	50	25	40	0.0185	0.0090	0.3740	0.0005	145,000	
	2	0.3545	0.3635	0.3745				0.0185	0.0090	0.3740	0.0005		
	3												
	4												

Ti-6Al-6V-2Sn.  
C/W Hi-Lok,  
70 ksi

**PHASE II - TASK 3 - BASIC FILLED-HOLE DATA**

TEST 3T16 SPECIMEN 623079 DATE 9/27/73

<p><b>SPECIMEN DESCRIPTION</b></p> <p>Configuration <u>Fl. 2</u></p> <p>Material <u>Ti-6Al-6V-2Sn(annealed)</u></p> <p>Width (in.) <u>1.50</u></p> <p>Hole spacing (in.) <u>1.50</u></p> <p>Edge margin (in.) <u>0.75</u></p> <p>Material gage (in.) <u>0.250</u></p> <p>Surface treatment <u>Shot peen</u></p>	<p><b>COLDWORK PROCESS</b></p> <p>Interference (in.) <u>0.019</u></p> <p>Sleeve type <u>Split</u></p> <p>Sleeve thickness (in.) <u>0.010</u></p> <p>Sleeve orientation <u>0°</u></p> <p>Mandrel material <u>AISI 9260 steel</u></p> <p>Mandrel taper (in./in.) <u>0.045</u></p> <p>Mandrel max diameter (in.) <u>0.353</u></p> <p>Lubricant <u>Fel Pro 300</u></p>	<p><b>HOLE PREPARATION</b></p> <p>Normal hole size (in.) <u>0.375</u></p> <p>Process <u>Ream, C/W, ream</u></p>	<p><b>FATIGUE CONDITIONS</b></p> <p>Max. net stress (ksi) <u>70</u></p> <p>Max. test load (kip) <u>20.6</u></p> <p>Load ratio (R) <u>0.1</u></p> <p>Test frequency <u>4000 cpm</u></p> <p>Test laboratory <u>Materials</u></p> <p>Test engineer <u>D. Reese</u></p> <p>Test machine <u>36-kip Vibraphone</u></p>
<p><b>FASTENER INSTALLATION</b></p> <p>Type <u>Hi-Lok prot hd</u></p> <p>Fit (in.) <u>Net to 0.0005 clearance</u></p> <p>Torque (in. lb) <u>240 to 250</u></p>			

Specimen dash no	Hole no	Hole diameter (in.)		Hole finish (RHR)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks	
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter			Fit
.10	1	0.3545	0.3625	0.3740	50	25	35	0.0185	0.0080	0.3740	Net	530,000	
	2	0.3545	0.3625	0.3740	-	-	-	0.0185	0.0080	0.3740	Net		
	3												
	4												
.11	1	0.3545	0.3625	0.3740	50	25	45	0.0185	0.0080	0.3740	Net	487,000	
	2	0.3545	0.3625	0.3740	-	-	-	0.0185	0.0080	0.3740	Net		
	3												
	4												
.12	1	0.3545	0.3630	0.3740	55	25	35	0.0185	0.0085	0.3740	Net	195,000	
	2	0.3550	0.3630	0.3740	-	-	-	0.0185	0.0085	0.3740	Net		
	3												
	4												

PHASE II - TASK 3 - BASIC FILLED-HOLE DATA

Tr-6Al 6V 2Sn sta.  
C/W Hi Lok,  
70 ksi

TEST 3T17 SPECIMEN 623079 DATE 9/27/73

SPECIMEN DESCRIPTION

Fig. 2  
Configuration: Tr-6Al 6V 2Sn (sta.)  
Material: 1.50  
Width (in.): 1.50  
Hole spacing: 0.75  
Edge margin (in.): 0.250  
Material prep: Shot peen  
Surface treatment: Shot peen

COLDWORK PROCESS

Interference (in.): 0.019  
Process: Split  
Sleeve type: 0.010  
Sleeve thickness (in.): 0"  
Sleeve orientation: AISI 9260 steel  
Mandrel material: 0.045  
Mandrel taper (in./in.): 0.353  
Mandrel max diameter (in.): Fel Pro 300  
Lubrication:

HOLE PREPARATION

Normal hole size (in.): 0.375  
Process: Ream, C/W, ream  
FASTENER INSTALLATION  
Type: Hi Lok, prot hd  
Fit: Net to 0.0005 clearance  
Torque (in. lb.): 240 250

FATIGUE CONDITIONS

Max net stress (ksi): 70  
Max test load (kip): 22.8  
Load ratio (R): 0-1  
Test frequency: 4000 GPM  
Test laboratory: Materials  
Test engineer: D. Reese  
Test machine: 36-kip Vibraphore

Specimen dash no	Hole no	Hole diameter (in.)		Hole finish (RHRI)		Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks	
		Before coldwork	After ream	Before coldwork	After coldwork	Actual	Retained	Diameter	Fit			
.13	1	0.3595	0.3620	0.3740	45	25	40	0.0185	0.0075	0.3740	Net	
	2	0.3545	0.3620	0.3740				0.0185	0.0075	0.3740	Net	
	3											
	4											
.14	1	0.3545	0.3620	0.3740	50	25	35	0.0185	0.0075	0.3740	Net	
	2	0.3545	0.3625	0.3740				0.0185	0.0080	0.3740	Net	
	3											
	4											
.15	1	0.3545	0.3625	0.3740	50	25	40	0.0185	0.0080	0.3740	Net	
	2	0.3545	0.3625	0.3740				0.0185	0.0080	0.3740	Net	
	3											
	4											

Ti-6Al-5V 2Sn stoa.  
C/W, Hi-Lok,  
70 ksi

**PHASE II - TASK 3 - BASIC FILLED HOLE DATA**

TEST 3T18 SPECIMEN 623079 DATE 9/20/73

<b>SPECIMEN DESCRIPTION</b>	<b>COLDWORK PROCESS</b>	<b>HOLE PREPARATION</b>	<b>FATIGUE CONDITIONS</b>
Configuration Fig. 2	Interference (in.)	Normal hole size (in.)	Max. net stress (ksi)
Ti-6Al-2Sn (stoa)	0.019	0.375	70
Material	Sleeve type	Process	Max. test load (kip)
Ti-6Al-2Sn (stoa)	Split	Ream, C/W, ream	20
Width (in.)	Sleeve thickness (in.)		Load ratio (R)
1.50	0.010		0.1
Hole spacing	Sleeve orientation		Test frequency
1.50	0°		4000/cpm
Edge margin (in.)	Mandrel material	<b>FASTENER INSTALLATION</b>	Materials
0.75	AISI 9260 steel		D. Reese
Material gage (in.)	Mandrel taper (in/in)	Type	Test equipment
0.250	0.045	Hi-Lok, prot. hd	36-kip Vibration
Surface treatment	Mandrel max diameter (in.)	Fit (in.)	
Shot peen	0.353	Net to 0.005 clearance	
	Lubrication	Torque (in. lb)	
	Fel Pro 300	240 250	

Specimen dash no	Hole no	Hole diameter (in.)				Hole finish (RHR)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	After coldwork	Actual	Ream	After ream	Actual	Ream	Diameter	Fit		
16-662 STOA	1	0.3545	0.3630	0.3735	45	20	45	0.0185	0.0085	0.3735	Net	197,000		
	2	0.3545	0.3630	0.3735	-	-	-	0.0185	0.0085	0.3735	Net			
	3													
	4													
17-662 STOA	1	0.3545	0.3630	0.3735	45	20	50	0.0185	0.0085	0.3735	Net	90,000		
	2	0.3545	0.3630	0.3735	-	-	-	0.0185	0.0085	0.3735	Net			
	3													
	4													
18-662 STOA	1	0.3545	0.3630	0.3735	50	25	45	0.0185	0.0085	0.3735	Net	147,000		
	2	0.3545	0.3630	0.3735	-	-	-	0.0185	0.0085	0.3735	Net			
	3													
	4													

PHASE II - TASK 3 - BASIC FILLED HOLE DATA

Ti 6Al 4V  
prot hd, Taper Lok,  
70 ksi

TEST 3119 SPECIMEN 623079 DATE 10.19.73

SPECIMEN DESCRIPTION		COLL WORK PROCESS		HOLE PREPARATION		FATIGUE CONDITIONS	
Configuration	Fig. 2	Interference		Nominal hole size (in)	0.375	Min. net stress (ksi)	70
Material	Ti 6Al 4V (annealed)	Sleeve type		Process	Ream	Max. test load (kip)	20
Width (in)	1.50	Sleeve thickness (in)				Load ratio (R)	0.1
Hole spacing	1.50	Sleeve orientation				Test frequency	4000 cpm
Edge margin (in)	0.75	Mandrel material		FASTENER INSTALLATION			
Material outer (in)	0.250	Mandrel taper (in/in)		Type	Taper Lok, prot hd	Test laboratory	Materials
Surface treatment	Shot peen	Mandrel max diameter (in)		Fit (in)	Boresit class F (0.187 0.289)	Test engineer	D. Reese
		Lubrication		Torque (in lb)	240.250	Test machine	36 kip Vibratory

Specimen dash no.	Hole no.	Hole diameter (in)			Hole finish (RH/R)			Fastener expansion (in)			Fastener size (in)		Cycles to failure	Origin of failure and remarks
		Before collwork	After ream	After collwork	Before collwork	After collwork	Actual	Retained	Diameter	Fit				
19	1		0.240			20				Class F		367,000		
	2		0.240							Class F				
	3													
	4													
20	1		0.240			25				Class F		689,000		
	2		0.240							Class F				
	3													
	4													
21	1		0.230			15				Class F		5,323,000		
	2		0.230							Class F				
	3													
	4													

Ti-6Al-4V  
prot hd, Taper Lok,  
75 ksi

PHASE II - TASK 3 - BASIC FILLED-HOLE DATA

TEST 3120 SPECIMEN 623079 DATE 10/18/73

**FATIGUE CONDITIONS**  
 Max test stress (ksi) 75  
 Max test load (kip) 21.5  
 Load ratio (R) 0.1  
 Test frequency 4000 cpm  
 Test laboratory Materials  
 Test engineer D. Reese  
 Test machine 36-kip Vibraphore

**HOLE PREPARATION**  
 Nominal hole size (in.) 0.375  
 Process Ream

**COUPLER PROCESS**  
 Interference \_\_\_\_\_  
 Sleeve type \_\_\_\_\_  
 Sleeve thickness (in.) \_\_\_\_\_  
 Sleeve orientation \_\_\_\_\_  
 Mandrel material \_\_\_\_\_  
 Mandrel taper (in./in.) \_\_\_\_\_  
 Mandrel max diameter (in.) \_\_\_\_\_  
 Lubrication \_\_\_\_\_

**FASTENER INSTALLATION**  
 Type Taper Lok, prot hd  
 $F_t$  (in.) Boeing Class F (0.187-0.289)  
 Torque (in. lbs) 240.250

**SPECIMEN DESCRIPTION**  
 Configuration Fig. 2  
 Material Ti-6Al-4V (annealed)  
 Width (in.) 1.50  
 Hole spacing 1.50  
 Edge margin (in.) 0.75  
 Material gauge (in.) 0.250  
 Surface treatment Shot peen

Specimen tag no	Hole no	Hole diameter (in.)				Hole finish (RHR)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After ream	After coldwork	After ream	Actual	Retained	Diameter	F-t					
-22	1		0.230		20				Class F		3,086,000			
	2		0.230		-				Class F					
	3													
	4													
-23	1		0.230		15				Class F		10,061,000			
	2		0.230		-				Class F					
	3													
	4													
	1													
	2													
	3													
	4													



PHASE II - TASK 3 - BASIC FILLED-HOLE DATA

Ti-6Al-4V,  
prot hd, Taper Lok,  
65 ksi

TEST 3T21 SPECIMEN 623079 DATE 10/18/73

SPECIMEN DESCRIPTION

Configuration Fig. 2  
Material Ti-6Al-4V (annealed)  
Width (in) 1.50  
Hole spacing 1.50  
Edge margin (in) 0.75  
Material gauge (in) 0.250  
Surface treatment Shot peen

COLDWORK PROCESS

Interference \_\_\_\_\_  
Sleeve type \_\_\_\_\_  
Sleeve thickness (in) \_\_\_\_\_  
Sleeve orientation \_\_\_\_\_  
Mandrel material \_\_\_\_\_  
Mandrel taper (in/in) \_\_\_\_\_  
Mandrel max diameter (in) \_\_\_\_\_  
Lubrication \_\_\_\_\_

SOLE PREPARATION

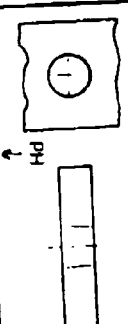
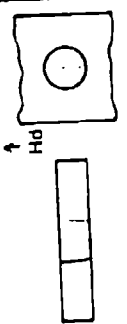
Nominal hole size (in) 0.375  
Process Ream

FASTENER INSTALLATION

Type Taper Lok prot hd  
Fit (in.) Boeing class F (0.187-0.283)  
Torque (in lb) 240-250

FATIGUE CONDITIONS

Max net stress (ksi) 65  
Max test load (kip) 19  
Load ratio (R) 0.1  
Test frequency 4000 cpm  
Test laboratory Materials  
Test engineer D. Reese  
Test machine 36-kip Vibraphore

Specimen dish no	Hole no	Hole diameter (in)			Hole finish (RHRI)			Coldwork expansion (in)		Fastener size (in)		Cycles to failure	Origin of failure and remarks
		Before coltwork	After coltwork	After ream	Before coltwork	After coltwork	After ream	Actual	Retained	Diameter	Fit		
-24	1		0.230	0.230			15			Class F	Class F	7,788,000	 Hd
	2		0.240							Class F	Class F		No failure
	3												
	4												
-25	1		0.230				10			Class F	Class F	7,774,000	 Hd
	2		0.235							Class F	Class F		No failure
	3												
	4												
	1												
	2												
	3												
	4												

PHASE II - TASK 3 - BASIC FILLED-HOLE DATA

Ti-6Al-4V.  
 prot hd, Taper Lok  
 60 ksi

TEST 3T22 SPECIMEN 623079 DATE 10/18/73

SPECIMEN DESCRIPTION

Configuration Fig 2  
 Material Ti-6Al-4V (annealed)  
 Width (in) 1.50  
 Hole spacing 1.50  
 Edge margin (in) 0.75  
 Material gage (in) 0.250  
 Surface treatment Shot peen

COLDWORK PROCESS

Interference \_\_\_\_\_  
 Sleeve type \_\_\_\_\_  
 Sleeve thickness (in) \_\_\_\_\_  
 Sleeve orientation \_\_\_\_\_  
 Mandrel material \_\_\_\_\_  
 Mandrel taper (in./in) \_\_\_\_\_  
 Mandrel max diameter (in) \_\_\_\_\_  
 Lubrication \_\_\_\_\_

HOLE PREPARATION

Nominal hole size (in) 0.375  
 Process Ream

FASTENER INSTALLATION

Type \_\_\_\_\_  
 Fit (in.) Boeing class F (0.187-0.289)  
 Torque (in. lb) 240-250  
 Taper Lok prot hd \_\_\_\_\_  
 Test laboratory \_\_\_\_\_  
 Test engineer D. Reese  
 Test machine 36-kip Vibraphore

FATIGUE CONDITIONS

Max net stress (ksi) 60  
 Max test load (kip) 17.5  
 Load ratio (R) 0.1  
 Test frequency 4000 cpm  
 Materials \_\_\_\_\_  
 Test laboratory \_\_\_\_\_  
 Test engineer D. Reese  
 Test machine 36-kip Vibraphore

Specimen dash no	Hole no	Hole diameter (in)				Hole finish (RHR)			Coldwork expansion (in)		Fastener size (in)		Cycles to failure	Origin of failure and remarks				
		Before coldwork	After coldwork	After ream	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit						
.26	1		0.230		15						Class F	Class F	300,000					
	2		0.188		-						Class F	Class F			7,602,000			
	3																No failure	
	4																	
.27	1		0.230		15						Class F	Class F	7,602,000					
	2		0.230		-						Class F	Class F			No failure			
	3																	
	4																	
	1																	
	2																	
	3																	
	4																	

PHASE II - TASK 3 - BASIC FILLED-HOLE DATA

Ti-6Al-4V,  
flush hd, Taper Lock  
70 ksi

TEST 3123 SPECIMEN 623079 DATE 10/18/73

<b>SPECIMEN DESCRIPTION</b>	<b>COLDWORK PROCESS</b>	<b>HOLE PREPARATION</b>	<b>FATIGUE CONDITIONS</b>
Configuration <u>Fig. 2</u>	Interference _____	Nominal hole size (in.) <u>0.375</u>	Max net stress (ksi) <u>70</u>
Material <u>Ti-6Al-4V (annealed)</u>	Sleeve type _____	Process <u>Ream</u>	Max test load (kip) <u>20</u>
Width (in.) <u>1.50</u>	Sleeve thickness (in.) _____		Load ratio (R) <u>0.1</u>
Hole spacing <u>1.50</u>	Sleeve orientation _____		Test frequency <u>4000 cpm</u>
Edge margin (in.) <u>0.075</u>	Mandrel material _____	<b>FASTENER INSTALLATION</b>	Test laboratory _____
Material gage (in.) <u>0.250</u>	Mandrel taper (in/in) _____	Type _____	Test engineer <u>D. Reese</u>
Surface treatment <u>Shot peen</u>	Mandrel max diameter (in.) _____	Fit (in.) <u>Boeing class F (0.187-0.289)</u>	Test machine <u>36 kip Vibraphore</u>
	Lubrication _____	Torque (in. lb) _____	
		<u>Taper Lok, flush hd</u>	

Specimen dash no	Hole no	Hole diameter (in.)				Hole finish (IRHR)			Coldwork expansion (in.)			Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	After coldwork	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit			
28	1		0.206					20				Class F	Class F	1,146,000	
	2		0.201					-				Class F	Class F		
	3														
	4														
29	1		0.201					20				Class F	Class F	240,000	
	2		0.202					-				Class F	Class F		
	3														
	4														
30	1		0.200					25				Class F	Class F	370,000	
	2		0.217					-				Class F	Class F		
	3														
	4														

PHASE II-TASK 3- BASIC FILLED-HOLE DATA

Ti-6Al-4V,  
flush hd, Taper Lok,  
75 ksi

TEST 3T24 SPECIMEN 623079 DATE 10-19-73

<b>SPECIMEN DESCRIPTION</b>	<b>COLDWORK PROCESS</b>	<b>HOLE PREPARATION</b>	<b>FATIGUE CONDITIONS</b>
Configuration <u>Fig. 2</u>	Interference _____	Nominal hole size (in) <u>0.375</u>	Max net stress (ksi) <u>75</u>
Material <u>Ti-6Al-4V (annealed)</u>	Sleeve type _____	Process <u>Ream</u>	Max test load (kip) <u>21.5</u>
Width (in) <u>1.50</u>	Sleeve thickness (in) _____		Load ratio (R) <u>0.1</u>
Hole spacing <u>1.50</u>	Sleeve orientation _____		Test frequency <u>4000 gpm</u>
Edge margin (in) <u>0.75</u>	Mandrel material _____	<b>FASTENER INSTALLATION</b>	Test laboratory <u>Materials</u>
Material gauge (in) <u>0.250</u>	Mandrel taper (in/in) _____	Type _____	Test engineer <u>D. Reese</u>
Surface treatment <u>Shot peen</u>	Mandrel max diameter (in) _____	Fit _____	Test machine <u>36-kip Vibraphore</u>
	Lubrication _____	Torque (in-lb) <u>240-250</u>	

Specimen dash no	Hole no	Hole diameter (in)		Hole finish (RHRI)		Coldwork expansion (in)		Fastener size (in)		Cycles to failure	Origin of failure and remarks	
		Before coldwork	After coldwork	Before coldwork	After ream	Actual	Retained	Diameter	Fit			
31	1	0.202			20			Class F		372,000		
	2	0.208			-			Class F				
	3											
	4											
32	1	0.1920			20			Class F		99,000		
	2	0.1930			-			Class F				
	3											
	4											
1												
2												
3												
4												

PHASE II - TASK 3 - BASIC FILLED-HOLE DATA

T1-6AI-4V,  
 flush hd, Taper Lok,  
 65 ksi

TEST 3T25 SPECIMEN 623079 DATE 10/19/73

<b>SPECIMEN DESCRIPTION</b>	<b>COLDWORK PROCESS</b>	<b>HOLE PREPARATION</b>	<b>FATIGUE CONDITIONS</b>
Configuration <u>Fig. 2</u>	Interference _____	Nominal hole size (in) <u>0.375</u>	Max net stress (ksi) <u>65</u>
Material <u>T1-6AI-4V (annealed)</u>	Sleeve type _____	Process <u>Ream</u>	Max test load (kip) <u>19</u>
Width (in) <u>1.50</u>	Sleeve thickness (in) _____		Load ratio (R) <u>0.1</u>
Hole spacing <u>1.50</u>	Sleeve orientation _____		Test frequency <u>4000.com</u>
Edge margin (in) <u>0.75</u>	Mandrel material _____	<b>FASTENER INSTALLATION</b>	Test laboratory <u>Materials</u>
Material gauge (in) <u>0.250</u>	Mandrel taper (in/in) _____	Type _____	Test engineer <u>D. Reese</u>
Surface treatment <u>Shot peen</u>	Mandrel max diameter (in) _____	Fit _____	Test machine <u>36 kip Vibrashore</u>
	Lubrication _____	Torque (in lb) <u>240-250</u>	

Specimen dash no	Hole no	Hole diameter (in.)			Hole finish (RHR)		Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	Actual	Retainer	Diameter	Fit		
33	1		0.214	20			Class F			266,000		
	2		0.206	-			Class F					
	3											
	4											
34	1		0.197	25			Class F			563,000		
	2		0.198	-			Class F					
	3											
	4											
	1											
	2											
	3											
	4											

PHASE II - TASK 3 - BASIC FILLED-HOLE VALUES

Ti-6Al-4V,  
flush hd, Taper Lok,  
60 ksi

TEST 3126 SPECIMEN 623079 DATE 10/19/73

**SPECIMEN DESCRIPTION**  
 Configuration Fig. 2  
 Material Ti-6Al-4V (annealed)  
 Width (in) 1.50  
 Hole spacing 1.50  
 Edge margin (in) 0.75  
 Material gauge (in) 0.250  
 Surface treatment Shot peen

**COLDWORK PROCESS**  
 Interference \_\_\_\_\_  
 Sleeve type \_\_\_\_\_  
 Sleeve thickness (in) \_\_\_\_\_  
 Sleeve orientation \_\_\_\_\_  
 Mandrel material \_\_\_\_\_  
 Mandrel taper (in/in) \_\_\_\_\_  
 Mandrel max diameter (in) \_\_\_\_\_  
 Lubrication \_\_\_\_\_

**HOLE PREPARATION**  
 Nominal hole size (in) 0.375  
 Process Ream

**FASTENER INSTALLATION**  
 Type Taper Lok, flush hd  
 Fit Boeing Class F (0.187-0.289)  
 Torque (in lbf) 240-250

**FATIGUE CONDITIONS**  
 Max net stress (ksi) 60  
 Max test load (kip) 17.5  
 Load ratio (R) 0.1  
 Test frequency 4000 cpm  
 Test laboratory Materials  
 Test engineer D. Reese  
 Test machine 36 kip Vibraphore

Specimen dash no	Hole no	Hole diameter (in)		Hole finish (RHRI)		Collwork expansion (in)		Fastener slip (in)		Cycles to failure	Origin of failure and remarks
		Before collwork	After collwork	Before collwork	After collwork	Actual	Retained	Diameter	Fit		
35	1		0.215		20			Class F		1,092,000	
	2		0.202		-			Class F			
	3										
	4										
36	1		0.204		20			Class F		2,602,000	
	2		0.204		-			Class F			
	3										
	4										
	1										
	2										
	3										
	4										

PHASE II - TASK 3 - BASIC FILLED-HOLE VALUES  
300 M, Ream, Filled, 100 KSI

TEST 3S1 SPECIMEN 623079 DATE 8/14/73

FATIGUE CONDITIONS  
 Max net stress (ksi) 100  
 Max test load (kip) 28.1  
 Load ratio (R) 0.1  
 Test frequency 4200.com  
 Test laboratory Materials  
 Test engineer D. Reese  
 Test machine 100 kip Vibrashore

HOLE PREPARATION  
 Nominal hole size (in) 3/8  
 Process Ream, install fastener

COLL WORK PROCESS  
 Interference \_\_\_\_\_  
 Sleeve type \_\_\_\_\_  
 Sleeve thickness (in) \_\_\_\_\_  
 Sleeve orientation \_\_\_\_\_  
 Mandrel material \_\_\_\_\_  
 Mandrel taper (in/in) \_\_\_\_\_  
 Mandrel max diameter (in) \_\_\_\_\_  
 Lubrication \_\_\_\_\_

SPECIMEN DESCRIPTION  
 Fig. 2  
 Configuration 300 M steel (270-300 ksi)  
 Material 300 M steel (270-300 ksi)  
 Width (in) 1.50  
 Hole spacing 1.50  
 Hole margin (in) 0.75  
 Material gauge (in) 0.250  
 Surface treatment Shot peen

FASTENER INSTALLATION  
 Type Hi-Lok, prot hd (steel)  
 F<sub>ii</sub> (in.) 0.0005-0.0010 clearance  
 Torque (in-lb) 240

Specimen dash no	Hole no	Hole diameter (in.)			Hole finish (RHR)			Coldwork expansion (in.)		Fastener sup (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After ream	After coldwork	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	F <sub>ii</sub>		
-1	1		0.3745			10				0.3735	+0.001	112,000	
	2		0.3745			-				0.3735	+0.001		
	3												
	4												
-2	1		0.3745			10				0.3740	+0.0005	237,000	
	2		0.3745			-				0.3740	+0.0005		
	3												
	4												
1													
2													
3													
4													





PHASE II - TASK 3 - BASIC FILLED-HOLE VALUES

300 M, Ream, Filled, 110 KSI

TEST: 353 SPECIMEN 623079 DATE 8/14/73

SPECIMEN DESCRIPTION

Fig 2  
 Configuration: 300 M steel (270-300 ksi)  
 Material: 300 M steel (270-300 ksi)  
 Width (in): 1.50  
 Hole spacing: 1.50  
 Edge margin (in): 0.75  
 Material grade (in): 0.250  
 Surface treatment: Shot peen

COLDWORK PROCESS

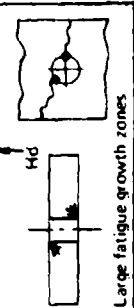
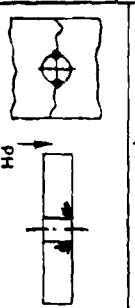
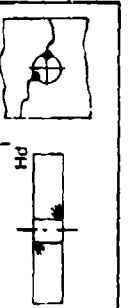
Interference: \_\_\_\_\_  
 Sleeve type: \_\_\_\_\_  
 Sleeve thickness (in): \_\_\_\_\_  
 Sleeve orientation: \_\_\_\_\_  
 Mandrel material: \_\_\_\_\_  
 Mandrel taper (in/in): \_\_\_\_\_  
 Mandrel max diameter (in): \_\_\_\_\_  
 Lubrication: \_\_\_\_\_

HOLE PREPARATION

Nominal hole size (in): 3/8  
 Process: Ream, install fastener  
 FASTENER INSTALLATION  
 Type: Hi-Lok, prot hd (steel)  
 Fit (in): 0.0005-0.0010 clearance  
 Torque (in lb): 240

FATIGUE CONDITIONS

Max out stress (ksi): 110  
 Max test load (kip): 31  
 Load ratio (R): 0.1  
 Test frequency: 4200 cpm  
 Test laboratory: Materials  
 Test engineer: D. Reese  
 Test machine: 100 kip Vibration

Specimen dash no	Hole no	Hole diameter (in)		Hole finish (RHS)		Coldwork expansion (in)		Fastener size (in)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After ream	Before coldwork	After coldwork	Actual	Retained	Diameter	E:		
-5	1		0.3745		10			0.3740	+0.0005	76,000	
	2		0.3745					0.3740	+0.0005		
	3										
	4										
-6	1		0.3745		10			0.3735	+0.0010	90,000	
	2		0.3745					0.3735	+0.0010		
	3										
	4										
-7	1		0.3745		10			0.3740	+0.0005	62,000	
	2		0.3745					0.3740	+0.0005		
	3										
	4										

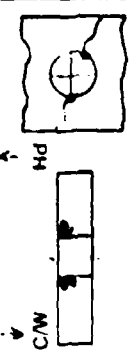
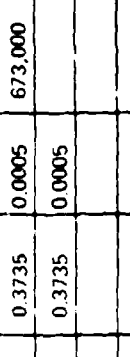
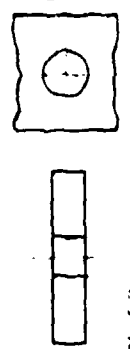
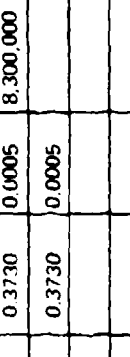
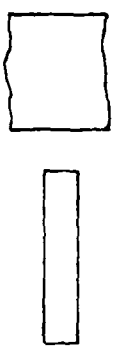
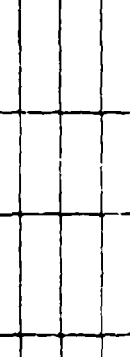


PHASE II - TASK 3 - BASIC FILLED-HOLE VALUES

300 M  
C/W, net fit Hi-Lok,  
100 ksi

TEST 3S5 SPECIMEN 623079 DATE 8/27/73

<b>SPECIMEN DESCRIPTION</b>	<b>COLDWORK PROCESS</b>	<b>HOLE PREPARATION</b>	<b>FATIGUE CONDITIONS</b>
Configuration	Interference (in.) 0.023	Nominal hole size (in.) 0.375	Max net stress (ksi) 100
Material 300 M steel (270-300 ksi)	Sleeve type Push, no sleeve	Process Ream, C/W, ream	Max test load (kip) 28
Width (in.) 1.50	Sleeve thickness (in.)		Load ratio (R) 0.1
Hole spacing (in.) 1.50	Sleeve orientation		Test frequency 4000 cpm
Edge margin (in.) 0.75	Mandrel material Carbide (BAC 5972)	<b>FASTENER INSTALLATION</b>	Test laboratory Materials
Material gage (in.) 0.250	Mandrel taper (in/in) 0.045	Type Hi-Lok prot hd	Test engineer D. Reese
Surface treatment Shot peen	Mandrel max diameter (in.) 0.358	Fit (in.) Net to 0.0005 clearance	Test machine 100-kip Vibraphore
	Lubrication Fel Pro 300	Torque (in. lb) 240-250	

Specimen dash no	Hole no	Hole diameter (in.)		Hole finish (RHR)		Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After ream	Before coldwork	After coldwork	Actual	Retained	Diameter	Fit		
.10	1	-	0.3740	-	-	-	-	0.3735	0.0005	673,000	
	2	-	0.3740	-	-	-	-	0.3735	0.0005		
	3	-		-	-	-	-				
	4	-			-	-	-				
.11	1	-	0.3735	-	-	-	-	0.3730	0.0005	8,300,000	
	2	-	0.3735	-	-	-	-	0.3730	0.0005		
	3	-		-	-	-	-				
	4	-			-	-	-				
1										No failure	
2											
3											
4											

PHASE II - TASK 3 - BASIC FILLED-HOLE VALUES

300 M  
C/W, net fit, Hi Lok.  
105 ksi

TEST 3S6 SPECIMEN 623079 DATE 8/27/73

<b>SPECIMEN DESCRIPTION</b>	<b>COLDWORK PROCESS</b>	<b>HOLE PREPARATION</b>	<b>FATIGUE CONDITIONS</b>
Configuration _____	Interference (in.) <u>0.0235</u>	Nominal hole size (in.) <u>0.375</u>	Max net stress (ksi) <u>105</u>
Material <u>300 M steel (270-300 ksi)</u>	Sleeve type <u>Push, no sleeve</u>	Process <u>Ream, C/W, ream</u>	Max test load (kip) <u>29</u>
Width (in.) <u>1.50</u>	Sleeve thickness (in.) _____		Load ratio (R) <u>0.1</u>
Hole spacing (in.) <u>1.50</u>	Sleeve orientation _____		Test frequency <u>4000 cpm</u>
Edge margin (in.) <u>0.75</u>	Mandrel material <u>Carbide (BAC 5972)</u>	<b>FASTENER INSTALLATION</b>	Test laboratory _____
Material grade (in.) <u>0.250</u>	Mandrel taper (in/in) <u>0.045</u>	Type _____	Test engineer <u>O. Reese</u>
Surface treatment <u>Shot peen</u>	Mandrel max diameter (in.) <u>0.358</u>	Fit (in.) <u>Net to 0.0005 clearance</u>	Test machine <u>100 kip Vibraphore</u>
	Lubrication <u>Fel Pro 300</u>	Torque (in. lb) <u>240-250</u>	

Specimen dash no	Hole no	Hole diameter (in)			Hole finish (RHR)		Coldwork expansion (in)		Fastener size (in)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	Actual	Retained	Diameter	Fit		
.12	1	-	0.3735	30	-	-	-	0.3735	Net	462,000		
	2	-	0.3735	-	-	-	-	0.3735	Net			
	3	-	-	-	-	-	-	-	-			
	4	-	-	-	-	-	-	-	-	-		
.13	1	-	0.3735	25	-	-	-	0.3735	Net	4,203,000		
	2	-	0.3735	-	-	-	-	0.3735	Net			
	3	-	-	-	-	-	-	-	-			
	4	-	-	-	-	-	-	-	-			
1												
2												
3												
4												

**PHASE II - TASK 3 - BASIC FILLED-HOLE VALUES**  
**300 M, C/W, Filled, 110 KSI, 0.045 Taper, 0.023-0.0245 Interference**

TEST 357 SPECIMEN 623079 DATE 8/17/73

**FATIGUE CONDITIONS**  
 Max. net stress (ksi) 110  
 Max. inst. load (kip) 31  
 Load ratio (R) 0.1  
 Test frequency 4700 cpm  
 Test laboratory Materials  
 Test engineer D. Reese  
 Test machine 100 kip Vibration

**MOLE PREPARATION**  
 Nominal hole size (in.) 0.378  
 Process C/W, ream, install fastener

**COLDWORK PROCESS**

Interference (in.) 0.0230/0.0245  
 Push (no sleeve)                       
 Sleeve type                       
 Sleeve thickness (in.)                       
 Sleeve orientation                       
 Mandrel material Carbide (BAC 5972)  
 Mandrel taper (in/in) 0.045  
 Mandrel max. diameter (in.) 0.358  
 Lubrication Fel-Pro in hole and on mandrel

**SPECIMEN DESCRIPTION**

Configuration Fig 2  
 Material 300 M steel (270-300 ksi)  
 Width (in.) 1.50  
 Hole spacing 1.50  
 Edge margin (in.) 0.75  
 Material gap (in.) 0.250  
 Surface treatment Shot peen

**FASTENER INSTALLATION**

Type Hi-Lok, prot hd (steel)  
 Fit (in.) Net to 0.0005 clearance  
 Torque (in. lb) 240

Specimen dash no.	Hole diameter (in.)				Hole finish (RHH)			Conduces expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
	Before collars	After ream	After collars	After ream	Before rollwork	After rollwork	After ream	Actual	Retained	Diameter	Fit		
-14	1		0.3740	10				0.0245		0.3735	0.0005	141,000	
	2		0.3740	-				0.0245		0.3735	0.0005		
	3												
	4												
-15	1		0.3745	15				0.0230		0.3740	0.0005	362,000	
	2		0.3745	-				0.0230		0.3740	0.0005		
	3												
	4												
-16	1		0.3740	15				0.0230		0.3740	Net	252,000	
	2		0.3745	-				0.0230		0.3740	0.0005		
	3												
	4												

PHASE II - TASK 3 - BASIC FILLED-HOLE VALUES

300 M  
C/W, net fit, Hi-Lok  
115 ksi

TEST 358 SPECIMEN 623079 DATE 8/27/73

**SPECIMEN DESCRIPTION:**  
 Configuration \_\_\_\_\_  
 Material 300 M steel (270-300 ksi)  
 Width (in.) 1.50  
 Hole spacing (in.) 1.50  
 Edge margin (in.) 0.75  
 Material gage (in.) 0.250  
 Surface treatment Shot peen

**COLDWORK PROCESS:**  
 Interference (in.) 0.0235  
 Sleeve type Push, no sleeve  
 Sleeve thickness (in.) \_\_\_\_\_  
 Sleeve orientation \_\_\_\_\_  
 Mandrel material Carbide (BAC 2972)  
 Mandrel taper (in./in.) 0.045  
 Mandrel max diameter (in.) 0.358  
 Lubrication Fel Pro 300

**HOLE PREPARATION:**  
 Nominal hole size (in.) 0.375  
 Process Ream, C/W, ream

**FASTENER INSTALLATION:**  
 Type \_\_\_\_\_  
 Fit (in.) \_\_\_\_\_  
 Torque (in. lb) 240-250

**FATIGUE CONDITIONS:**  
 Max net stress (ksi) 115  
 Max test load (kip) 32  
 Load ratio (R) 0.1  
 Test frequency 4000 cpm  
 Test laboratory Materials  
 Test engineer D. Reese  
 Test machine 100-kip Vibraphore

Specimen dash no.	Hole no.	Hole diameter (in.)			Hole finish (RHR)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
.17	1	-	0.3735	30	-	-	-	-	-	0.3735	Net	305,000	
	2	-	0.3740	-	-	-	-	-	-	0.3740	Net		
	3	-	-	-	-	-	-	-	-	-	-		
	4	-	-	-	-	-	-	-	-	-	-		
.18	1	-	0.3735	20	-	-	-	-	-	0.3735	Net	96,000	
	2	-	0.3735	-	-	-	-	-	-	0.3735	Net		
	3	-	-	-	-	-	-	-	-	-	-		
	4	-	-	-	-	-	-	-	-	-	-		
1	1	-	-	-	-	-	-	-	-	-			
2	2	-	-	-	-	-	-	-	-	-			
3	3	-	-	-	-	-	-	-	-	-			
4	4	-	-	-	-	-	-	-	-	-			

**PHASE II - TASK 3 - BASIC FILLED-HOLE VALUES**  
**300 M, C/W, Filled, 110 KSI, 0.030 Taper, 0.0245 Interference**

TEST: 3S9 SPECIMEN: 623079 DATE: 8/16/73

**SPECIMEN DESCRIPTION**  
 Configuration: Fig. 2  
 Material: 300 M steel (270-300 ksi)  
 Width (in.): 1.50  
 Hole spacing: 1.50  
 Edge margin (in.): 0.75  
 Material gauge (in.): 0.250  
 Surface treatment: Shot peen

**COILWORK PROCESS**  
 Interference: 0.0245  
 Sleeve type: Push (no sleeve)  
 Sleeve thickness (in.):             
 Sleeve orientation:             
 Mandrel material: Carbide (BAC 5972)  
 Mandrel taper (in/in): 0.030  
 Mandrel max diameter (in.): C-358  
 Lubrication: Fel Pro .000 in hole and on mandrel

**HOLE PREPARATION**  
 Nominal hole size (in.): 3/8  
 Process: C/W, ream, install fastener

**FASTENER INSTALLATION**  
 Type: Hi-Lok, prot hd (steel)  
 Fit (in.): 0.0005, 0.0010 clearance  
 Torque (in lb): 240

**FATIGUE CONDITIONS**  
 Max. net stress (ksi): 110  
 Max. net load (kip): 31.4  
 Load ratio (R): 0.1  
 Test frequency: 4200 cpm  
 Test laboratory: Materials  
 Test engineer: D. Reese  
 Test machine: 100 kip Vibration

Specimen dash no.	Specimen no.	Hole diameter (in.)			Hole finish (RH)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks	
		Before coldwork	After ream	After coldwork	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit			
-19	1		0.3740				10	0.0245		0.3730	0.0010	390,000		
	2		0.3740					0.0245		0.3735	0.0005			
	3													
	4													
-20	1		0.3740			10	0.0245			0.3730	0.0010	349,000		
	2		0.3740				0.0245			0.3735	0.0005			
	3													
	4													
-21	1		0.3740			10	0.0245			0.3735	0.0005	264,000		
	2		0.3740				0.0245			0.3735	0.0005			
	3													
	4													

**PHASE II - TASK 3 - BASIC FILLED-HOLE VALUES**  
**300 M, C/W, Filled, 110 KSI, 0.045 Taper, 0.020 Interference**

TEST 3S10 SPECIMEN 623079 DATE 8/16/73

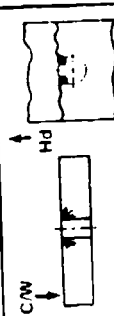

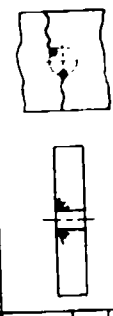
**SPECIMEN DESCRIPTION**  
 Configuration Fig. 2  
 Material 300 M steel (270-300 ksi)  
 Width (in.) 1.50  
 Hole spacing 1.50  
 Edge margin (in.) 0.75  
 Material age (in.) 0.250  
 Surface treatment Shot peen

**COLLWORK PROCESS**  
 Interference (in.) 0.0195  
 Sleeve type Push (no sleeve)  
 Sleeve thickness (in.)             
 Sleeve orientation             
 Mandrel material Carbide (BAG-5972)  
 Mandrel taper (in/in) 0.045  
 Mandrel max diameter (in) 0.3580  
 Lubrication Fel Pro 300 on sleeve

**HOLE PREPARATION**  
 Nominal hole size (in.) 3/8  
 Process C/W, ream, install fastener

**FASTENER INSTALLATION**  
 Type Hi-Lok, prol hd (steel)  
 Fit Net  
 Torque (in lb) 240

**FATIGUE CONDITIONS**  
 Max net stress (ksi) 110  
 Max test load (kip) 31  
 Load ratio (R) 0.1  
 Test speed (rpm) 4200  
 Test laboratory Materials  
 Test engineer D. Reese  
 Test machine 100-kip Vibration

Specimen dash no	Hole no	Hole diameter (in)			Hair finish (RH)		Collwork expansion (in)		Fastener size (in)		Cycles to failure	Origin of failure and remarks
		Before collwork	After ream	After collwork	Before collwork	After collwork	Actual	Retained	Diameter	Fit		
-22	1		0.3740			15	0.0195		0.3740	Net	121,000	
	2		0.3740			-	0.0195		0.3740	Net		
	3											
	4											
-23	1		0.3740			15	0.0195		0.3740	Net	118,000	
	2		0.3740			-	0.0195		0.3740	Net		
	3											
-24	1		0.3740			15	0.0195		0.3740	Net	105,000	
	2		0.3740			-	0.0195		0.3740	Net		
	3											
	4											



PHASE II - TASK 3 - BASIC FILLED-HOLE VALUES

300 M  
C/W, net fit, Hi-Lok,  
(0.015 taper mandrel),  
110 ksi

TEST 3S11 SPECIMEN 623079 DATE 8/27/73

<b>SPECIMEN DESCRIPTION</b>	<b>COLLIDWORK PROCESS</b>	<b>HOLE PREPARATION</b>	<b>FATIGUE CONDITIONS</b>
Configuration <u>Fig 2</u>	Interference (in.) <u>0.023</u>	Nominal hole size (in.) <u>0.375</u>	Max net stress (ksi) <u>110</u>
Material <u>300 M steel (270-300 ksi)</u>	Sleeve type <u>Push, no sleeve</u>	Process <u>Ream, C/W, ream</u>	Max test load (kip) <u>31</u>
Width (in.) <u>1.50</u>	Sleeve thickness (in.) _____		Load ratio (R) <u>0.1</u>
Hole spacing (in.) <u>1.50</u>	Sleeve orientation _____		Test frequency <u>4000 cpm</u>
Edge margin (in.) <u>0.75</u>	Mandrel material <u>Carbide-BAC-5972</u>	<b>FASTENER INSTALLATION</b>	Test laboratory <u>Materials</u>
Material gage (in.) <u>0.250</u>	Mandrel taper (in/in) <u>0.015</u>	Type <u>Hi-Lok, prct hd</u>	Test engineer <u>D. Reese</u>
Surface treatment <u>Shot peen</u>	Mandrel max diameter (in.) <u>0.358</u>	Fit (in.) <u>Net to 0.0005 clearance</u>	Test machine <u>100-kip Vibraphore</u>
	Lubrication <u>Fel Pro 300</u>	Torque (in. lb) <u>240-250</u>	

Specimen dash no	Hole no	Hole diameter (in.)				Hole finish (RHR)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream		Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
-25	1	-	0.3735	25	-	-	-	-	-	0.3730	0.0005	287,000		
	2	-	0.3735	-	-	-	-	-	-	0.3730	0.0005			
	3	-	-	-	-	-	-	-	-	-	-			
	4	-	-	-	-	-	-	-	-	-	-			
-26	1	-	0.3735	25	-	-	-	-	-	0.3735	Net	364,000		
	2	-	0.3735	-	-	-	-	-	-	0.3735	Net			
	3	-	-	-	-	-	-	-	-	-	-			
	4	-	-	-	-	-	-	-	-	-	-			
-27	1	-	0.3740	20	-	-	-	-	-	0.3740	Net	76,000		
	2	-	0.3740	-	-	-	-	-	-	0.3740	Net			
	3	-	-	-	-	-	-	-	-	-	-			
	4	-	-	-	-	-	-	-	-	-	-			

PHASE II TASK 4 - APPLICATION AND PROCESS PARAMETERS

TEST NUMBER: 4 A 1

NOMINAL EXPANSION VALUE: .019"

GENERAL TEST CONDITIONS

DATE: 3-27-73

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig 2  
 Width: 1.50"  
 Hole spacing: 1.50"  
 Edge margin: 0.75"  
 Material: 2024 T 851  
 Material gauge: 0.250"  
 Surface Treatment: Shor Peen  
 Fastener: None

3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: 0.010"  
 Sleeve orientation: 90°  
 CW Mandrel: SI 5300-CBA-12  
 CW Mandrel Taper: 0.045"/"  
 CW Mandrel Major Dia.: .3730"  
 Lubrication: Fel Pro 300 (on sleeve)

2. Hole Preparation

Nominal hole size: 3/8"  
 Process: ream, CW & ream

4. Fatigue Conditions

Net stress: 30 ksi  
 Test load: 8,500 lbs.  
 Load ratio: (R) 0.1  
 Test Frequency: 5000/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophore (36 KIP)



Specimen No. R62308(i)	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (inches)	Retained Diametrical Expansion (inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW	After ream	Before CW	After CW	After Ream				
-21	1	.3540	.3665	.3735	60	30	40	.0190	.0125	382	Sleeve Split C/W
	2	.3545	.3665	.3735	60	30	-	.0185	.0120		
-22	1	.3545	.3665	.3735	50	20	45	.0185	.0120	424	Sleeve Split C/W
	2	.3545	.3670	.3735	55	-	-	.0185	.0125		
-23	1	.3540	.3665	.3735	60	30	35	.0190	.0125	335	Sleeve Split C/W
	2	.3540	.3665	.3735	55	20	-	.0190	.0125		

Taken at Minimum (midpoint)

PHASE II TASK 4 - APPLICATION AND PROCESS PARAMETERS

TEST NUMBER: 4 A 2

NOMINAL EXPANSION VALUE: .0195"

GENERAL TEST CONDITIONS

DATE: 4-17-73

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig 2  
 Width: 1.50"  
 Hole spacing: 1.50"  
 Edge margin: 0.75"  
 Material: 2024 T 851  
 Material gauge: 0.250"  
 Surface Treatment: Shot Peen  
 Fastener: None

3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: 0.010"  
 Sleeve orientation: 0°  
 CW Mandrel: ST 5300-CBM-12 -0-N  
 CW Mandrel Taper: .045"/"  
 CW Mandrel Major Dia.: .353"  
 Lubrication: Fel Pro 300 (on sleeve)





2. Hole Preparation

Nominal hole size: 3/8"  
 Process: \* Drill CW & ream  
 \* Drill with Precision Drill

4. Fatigue Conditions

Net stress: 30 ksi  
 Test load: 8,590 lbs.  
 Load ratio: (R) = 0.1  
 Test Frequency: 5000/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophore (36 KIP)

Coldworked Good Drilled Hole  
 Open

Specimen No. R623080	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
-6	1	.3545	.3665	.3730	45	20	30	.0185	.0120	261	 C/W
	2	.3545	.3665	.3730	-	-	-	.0185	.0120		
-7	1	.3545	.3665	.3730	45	20	35	.0185	.0120	491	 C/W
	2	.3545	.3665	.3730	-	-	-	.0185	.0120		
-8	1	.3545	.3665	.3730	50	25	40	.0185	.0120	226	 C/W
	2	.3545	.3665	.3730	-	-	-	.0185	.0120		

[ ] > Taken at Minimum (only cut)

PHASE II TASK 4 - APPLICATION AND PROCESS PARAMETERS

TEST NUMBER: 4 A 3

NOMINAL EXPANSION VALUE: 0.0185"

GENERAL TEST CONDITIONS

DATE: 4-19-73

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 2  
 Width: 1.50"  
 Hole spacing: 1.50"  
 Edge margin: 0.75"  
 Material: 2024 T 851  
 Material gauge: 0.250"  
 Surface Treatment: Shot Peen  
 Fastener: None

3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: 0.010"  
 Sleeve orientation: 0°  
 CW Mandrel: ST 5300-CBM-12 -0-N  
 CW Mandrel Taper: 0.045"/"  
 CW Mandrel Major Dia.: .353"  
 Lubrication: Fel Pro 300 (on sleeve)




2. Hole Preparation

Nominal hole size: 3/8"  
 Process: \*Drill, CW & ream  
 \* Abusively Drilled

4. Fatigue Conditions

Net stress: 30 ksi  
 Test load: 8,550 lbs.  
 Load ratio: (R) = 0.1  
 Test Frequency: 5000/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophore (36 KIP)

Coldworked Abusively Drilled  
Open

Specimen No. R623080	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (inches)	Retained Diametrical Expansion (inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW △	After CW △	After ream	Before CW △	After CW △	After Ream				
-9	1	.3545	.3670	.3730	120	45	30	.0185	.0125	110	 C/W
	2	.3545	.3670	.3730	-	-	-	.0185	.0125		
-10	1	.3545	.3670	.3730	125	40	35	.0185	.0125	287	 C/W
	2	.3545	.3670	.3730	-	-	-	.0185	.0125		
-11	1	.3545	.3670	.3730	145	35	30	.0185	.0125	93	 C/W
	2	.3545	.3670	.3730	-	-	-	.0185	.0125		

△ Taken at Minimum (midpoint)    △ Hole Bell Mouthed    △ Spiral Gauge In Hole

PHASE II TASK 4 - APPLICATION AND PROCESS PARAMETERS

TEST NUMBER: 4 A 4

NOMINAL EXPANSION VALUE: 0.019"

GENERAL TEST CONDITIONS

DATE: 3-27-73

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig 2  
 Width: 1.50"  
 Hole spacing: 1.50"  
 Edge margin: 0.75"  
 Material: 2024 T 851  
 Material gauge: 0.250"  
 Surface Treatment: Shot Peen  
 Fastener: None

3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: 0.010"  
 Sleeve orientation: 0°  
 CW Mandrel: ST 5300-CBM- 12 -0-N  
 CW Mandrel Taper: 0.045"/"  
 CW Mandrel Major Dia.: .3730"  
 Lubrication: Fel Pro 300 (on sleeve)





2. Hole Preparation

Nominal hole size: 3/8"  
 Process: ream, CW

4. Fatigue Conditions

Net stress: 30 ksi +  
 Test load: 8,580 lbs.  
 Load ratio: (R) = 0.1  
 Test Frequency: 5000/m inute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophore (36 KIP)

No Postream  
 Open Hole

Specimen No. R623080	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
-24	1	.3545	.3665	-	35	15	-	.0185	.0120	431	
	2	.3545	.3665	-	-	-	-	.0185	.0120		
-25	1	.3545	.3665	-	30	15	-	.0185	.0120	333	
	2	.3545	.3665	-	-	-	-	.0185	.0120		
-26	1	.3540	.3665	-	35	20	-	.0190	.0125	330	
	2	.3540	.3665	-	-	-	-	.0190	.0125		

[1] - Taken at Maximum (rupture)

PHASE II TASK 4 - APPLICATION AND PROCESS PARAMETERS

TEST NUMBER: 4 A 5

NOMINAL EXPANSION VALUE: 0.019"

GENERAL TEST CONDITIONS

DATE: 3-28-73

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig 2  
 Width: 1.50"  
 Hole spacing: 1.50"  
 Edge margin: 0.75"  
 Material: 2024 T 851  
 Material gauge: 0.250"  
 Surface Treatment: Shot Peen  
 Fastener: None

3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: 0.010"  
 Sleeve orientation: 0°  
 CW Mandrel: ST 5300-CBM-12 -0-N  
 CW Mandrel Taper: 0.045"/"  
 CW Mandrel Major Dia.: .3530"  
 Lubrication: Fel Pro 300 (on sleeve)

2. Hole Preparation





Nominal hole size: 3/8"  
 Process: Ream, C/W, Ream & Score \*  
 \* 90° to  $\phi$

4. Fatigue Conditions

Net stress: 30 ksi +  
 Test load: 8,500 lbs.  
 Load ratio: (R) = 0.1  
 Test Frequency: 5000/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophore (36 KIP)

Postscore One Hole  
Open

Black fretting products from reaming in all holes and fatigue fracture

Specimen No. R623080	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
-27	1	.3540	.3665	.3730	40	25	45	.0190	.0125	300	 Failure in Unscored Hole C/W
	2	.3545	.3665	.3730	-	-	-	.0185	.0120		
-28	1	.3545	.3665	.3730	35	15	50	.0185	.0120	∞	 Failure in Unscored Hole C/W
	2	.3545	.3665	.3730	-	-	-	.0185	.0120		
-29	1	.3545	.3665	.3730	40	20	45	.0185	.0120	393	 Failure in Unscored Hole C/W
	2	.3545	.3665	.3730	-	-	-	.0185	.0120		

1 - Taken at Minimum (midpoint)

PHASE II TASK 4 - APPLICATION AND PROCESS PARAMETERS

TEST NUMBER: 4 A 6

NOMINAL EXPANSION VALUE. 0.019"

GENERAL TEST CONDITIONS

DATE: 3-28-73

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 2  
 Width: 1.50"  
 Hole spacing: 1.50"  
 Edge margin: 0.75"  
 Material: 2024 T 851  
 Material gauge: 0.250"  
 Surface Treatment: Shot Peen  
 Fastener: None

3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: 0.010"  
 Sleeve orientation: 0°  
 CW Mandrel: ST 5300-CBM- 12 -0-N  
 CW Mandrel Taper: 0.045"/"  
 CW Mandrel Major Dia.: 3530"  
 Lubrication: Fel Pro 300 (on sleeve)





2. Hole Preparation

Nominal hole size: 3/8"  
 Process: Ream, C/W & Ream (full 1/64")

Full 1/64" Postream  
Open Hole

4. Fatigue Conditions

Net stress: 30 ksi  
 Test load: 8,450 lbs.  
 Load ratio: (R) = 0.1  
 Test Frequency: 5000/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophone (36 KIP)

Specimen No. R623080	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
-30	1	.3545	.3665	.3895	35	15	-	.0185	.0120	235	 C/W
	2	.3545	.3665	.3895	-	-	-	.0185	.0120		
-31	1	.3545	.3665	.3895	40	20	35	.0185	.0120	249	 C/W
	2	.3545	.3665	.3895	-	-	-	.0185	.0120		
-32	1	.3545	.3665	.3895	45	20	30	.0185	.0120	214	 C/W
	2	.3545	.3665	.3895	-	-	-	.0185	.0120		

 Taken at Minimum (midpoint)

PHASE II TASK 4 - APPLICATION AND PROCESS PARAMETERS

TEST NUMBER: 4 A 7  
 NOMINAL EXPANSION VALUE: 0.019"

GENERAL TEST CONDITIONS

DATE: 3-28-73

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 2  
 Width: 1.50"  
 Hole spacing: 1.50"  
 Edge margin: 0.75"  
 Material: 2024 T 851  
 Material gauge: 0.250"  
 Surface Treatment: Shot Peen  
 Fastener: None

3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: 0.010"  
 Sleeve orientation: 0°  
 CW Mandrel: ST 5300-CBM-12 -G-N  
 CW Mandrel Taper: 0.045"/"  
 CW Mandrel Major Dia.: .3530"  
 Lubrication: Fel Pro 300 (on sleeve)


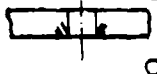


2. Hole Preparation

Nominal hole size: 3/8"  
 Process: Ream, C/W, Ream 1/32 os

1/32" Postream  
Open Hole

4. Fatigue Conditions

Net stress: 30 ksi  
 Test load: 8,270 lbs.  
 Load ratio: (R) 0.1  
 Test Frequency: 5000/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophore (36 KIP)

Specimen No. R623080	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
-33	1	.3545	.3665	.4075	50	20	55	.0185	.0120	283	 ↑ C/W
	2	.3545	.3665	.4075	-	-	-	.0185	.0120		
-34	1	.3545	.3665	.4075	45	20	45	.0185	.0120	256	 ↑ C/W
	2	.3545	.3665	.4075	-	-	-	.0185	.0120		
-35	1	.3545	.3665	.4075	35	15	40	.0185	.0120	285	 ↑ C/W
	2	.3545	.3665	.4075	-	-	-	.0185	.0120		

 Taken at Minimum (midpoint)



PHASE II TASK 4 - APPLICATION AND PROCESS PARAMETERS

TEST NUMBER: 4 A B

NOMINAL EXPANSION VALUE: 0.019"

GENERAL TEST CONDITIONS

DATE: 3-28-73

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig 2  
 Width: 1.50"  
 Hole spacing: 1.50"  
 Edge margin: 0.75"  
 Material: 2024 T 851  
 Material gauge: 0.250"  
 Surface Treatment: Shot Peen  
 Fastener: None

3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: 0.010"  
 Sleeve orientation: 0°  
 CW Mandrel: ST 5300-CBM- 12 -0-N  
 CW Mandrel Taper: 0.045"/"  
 CW Mandrel Major Dia.: .3730"  
 Lubrication: Fel Pro 300 (on sleeve)



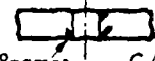

2. Hole Preparation


Nominal hole size: 3/8" + 1/16"  
 Process: Ream, C/W, Ream 1/16 os

4. Fatigue Conditions

Net stress: 30 ksi  
 Test load: 8,000 lbs.  
 Load ratio: (R) C, 1  
 Test Frequency: 5000/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophore (36 KIP)

1/16" Postream  
Open Hole

Specimen No. R623080	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
36	1	.3545	.3665	.4375	30	15	25	.0185	.0120	312	 Reamer C/W Chatter
	2	.3545	.3665	.4375	-	-	-	.0185	.0120		
37	1	.3545	.3665	.4375	35	15	25	.0185	.0120	372	 Reamer C/W Chatter
	2	.3545	.3665	.4375	-	-	-	.0185	.0120		
38	1	.3545	.3665	.4375	30	15	30	.0185	.0120	226	 Reamer C/W Chatter
	2	.3545	.3665	.4375	-	-	-	.0185	.0120		

 Taken at Minimum (midpoint)

PHASE II TASK 4 - APPLICATION AND PROCESS PARAMETERS

TEST NUMBER: 4 A 9

NOMINAL EXPANSION VALUE: 0.019"

GENERAL TEST CONDITIONS

DATE: 3-29-73

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig 2  
 Width: 1.50"  
 Hole spacing: 1.50"  
 Edge margin: 0.75"  
 Material: 2024 T 851  
 Material gauge: 0.250"  
 Surface Treatment: Shot Peen  
 Fastener: None

3. CW Process

Sleeve type: Square Wire  
 Sleeve thickness: 0.018"  
 Sleeve orientation: 0°  
 CW Mandrel: ST 5300-CBM- -0-N  
 CW Mandrel Taper: 0.045"/"  
 CW Mandrel Major Dia.: .3530"  
 Lubrication: Fel Pro 300 (on sleeve)

2. Hole Preparation



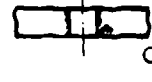

Nominal hole size: 3/8"  
 Process: \_\_\_\_\_

4. Fatigue Conditions

Net stress: 30 ksi  
 Test load: 9,400 lbs.  
 Load ratio: (R) = 0.1  
 Test Frequency: 5000/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophone (36 KIP)

Sq. Wire Sleeve  
Open Hole

\*Trouble encountered with wire sleeve  
 C/W one hole twice - Gauge In Test  
 Section + Mark In Hole

Specimen No. R623080	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (inches)	Retained Diametrical Expansion (inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
12	1	.3690	.3800	.3895	35	-	40	.0200	.0110	167	 ↑ C/W
	2	.3690	.3800	.3895	-	-	-	.0200	.0110		
13	1	.3690	.3800	.3895	30	-	30	.0200	.0110	339	 ↑ C/W
	2	.3690	.3800	.3895	-	-	-	.0200	.0110		
14	1	.3690	.3805	.3895	35	-	40	.0200	.0115	586	 ↑ C/W
	2	.3690	.3800	.3895	-	-	-	.0200	.0110		

1. Refer to Appendix (unp. and)

PHASE II TASK 4 - APPLICATION AND PROCESS PARAMETERS

TEST NUMBER: 481

NOMINAL EXPANSION VALUE: 0.019"

GENERAL TEST CONDITIONS

DATE: 3-27-73

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig 2  
 Width: 1.50"  
 Hole spacing: 1.50"  
 Edge margin: 0.75"  
 Material: 2024 T851  
 Material gauge: 0.060"  
 Surface Treatment: Shot Peen  
 Fastener: None

2. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: 0.010"  
 Sleeve orientation: 0°  
 CW Mandrel: ST 5300-CBM-12 -0-N  
 CW Mandrel Taper: 0.045"/"  
 CW Mandrel Major Dia.: .3730"  
 Lubrication: Fel Pro 300 (on sleeve)


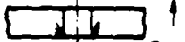

3. Hole Preparation

Nominal hole size: 3/8"  
 Process: Drill, ream, CW & ream

4. Fatigue Conditions

Net stress: 30 ksi  
 Test load: 2,150 lbs.  
 Load ratio: (R) = 0.1  
 Test Frequency: 3500/minute  
 Test Laboratory: Materials  
 Test Engineer: D Reese  
 Test Machine: Vibrophore (36 Kip)

.060 Gage  
Open Hole

Specimen No. R623080	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches) $\nabla$	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW $\nabla$	After ream	Before CW	After CW	After Ream				
-1	1	.3540	.3665	.3735	40	20	30	.0190	.0125	48	 CW
	2	.3540	.3665	.3735	-	-	-	.0190	.0125		
-2	1	.3540	.3665	.3735	40	20	25	.0190	.0125	49	 CW
	2	.3540	.3665	.3735	-	-	-	.0190	.0125		
-3	1	.3540	.3665	.3735	40	20	30	.0190	.0125	65	 CW
	2	.3540	.3665	.3735	-	-	-	.0190	.0125		

$\nabla$  Taken at Minimum (midpoint)

PHASE II TASK 4 - APPLICATION AND PROCESS DEVELOPMENT

TEST NUMBER: 4 C 1

NOMINAL EXPANSION VALUE: 0.019 (One Hole)

GENERAL TEST CONDITIONS

DATE: 3-30-73

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig 2  
 Width: 1.50"  
 Hole spacing: 1.50"  
 Edge margin: 0.75"  
 Material: 2024 T851  
 Material gauge: 0.250"  
 Surface Treatment: Shot Peen  
 Fastener: Prot Hd. HI-Lol

3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: 0.010"  
 Sleeve orientation: 0°  
 CW Mandrel: ST 5300-CBM-12 (0.1N)  
 CW Mandrel Taper: 0.045"/"  
 CW Mandrel Major Dia: .3530  
 Lubrication: Fel Pro 300 (on sleeve)





2. Hole Preparation


Nominal hole size: 3/8"  
 Process: 1. Ream C/W, Ream & Install Fastener  
2. Ream and Install Fastener  
 Fastener Instl. Torque: 225-250 in/lbs  
 Fastener Diameter: .3735

4. Fatigue Conditions

Net stress: 30 ksi  
 Test load: 8,550/lbs  
 Load ratio: (R) 0.1  
 Test Frequency: 5000/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophore (36 Kip)

One Hole Not C/W Filled Holes

Specimen No. R623080	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (inches)	Retained Diametrical Expansion (inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
-57	1	.3545	.3665	.3735	40	20	25	.0185	.0125	855	 failure at non-coldworked hole
	2	-	-	.3735	-	-	-	-	-		
-58	1	.3540	.3660	.3735	30	15	30	.0190	.0120	703	 failure through coldworked hole
	2	-	-	.3735	-	-	-	-	-		
-59	1	.3540	.3665	.3735	35	15	30	.0190	.0125	375	 failure at non-coldworked hole
	2	-	-	.3735	-	-	-	-	-		

 Taken at Minimum (midpoint)

PHASE II TASK 4 - APPLICATION AND PROCESS PARAMETERS

TEST NUMBER: 4 C 2

NOMINAL EXPANSION VALUE: 0.019"

GENERAL TEST CONDITIONS

DATE: 3-30-73

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 2  
 Width: 1.50"  
 Hole spacing: 1.50"  
 Edge margin: 0.75"  
 Material: 2024 T851  
 Material gauge: 0.250"  
 Surface Treatment: Shot Peen  
 Fastener: Prot. Hd. Hi-Lok  
(.002 Clearance Fit)

3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: 0.010"  
 Sleeve orientation: 0°  
 CW Mandrel: ST 5300-CBM-12 -0-N  
 CW Mandrel Taper: 0.045"/"  
 CW Mandrel Major Dia.: .3530  
 Lubrication: Fel Pro 300 (on sleeve)

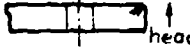


2. Hole Preparation

Nominal hole size: 3/8"  
 Process: Ream, CW & ream  
 Fastener Torque: 225/250 in/lbs  
 Fastener Diameter: .3735

4. Fatigue Conditions

Net stress: 30 ksi  
 Test load: 8.550 lbs.  
 Load ratio: (R) = 0.1  
 Test Frequency: 5000/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophore (36 Kip)

**.002" CL. Hi-Lok  
Hole C/W**

Specimen No. R623080	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (inches)	Retained Diametrical Expansion (inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW	After ream	Before CW	After CW	After Ream				
-42	1	.3540	.3665	.3755	35	15	30	.0190	.0125	694	
	2	.3540	.3665	.3755	-	-	-	.0190	.0125		
-43	1	.3540	.3665	.3755	30	15	25	.0190	.0125	366	
	2	.3540	.3665	.3755	-	-	-	.0190	.0125		
-44	1	.3540	.3665	.3755	30	15	30	.0190	.0125	697	
	2	.3540	.3665	.3755	-	-	-	.0190	.0125		

 Taken at Minimum (midpoint)

PHASE II TASK 4 - APPLICATION AND PROCESS PARAMETERS

TEST NUMBER: 4 C 3

NOMINAL EXPANSION VALUE: 0.019"

GENERAL TEST CONDITIONS

DATE: 4-16-73

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig 2  
 Width: 1.50"  
 Hole spacing: 1.50"  
 Edge margin: 0.75"  
 Material: 2024 T851  
 Material gauge: 0.250"  
 Surface Treatment: Shot Peen  
 Fastener: HI-Lok (.002" interference)

3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: 0.010"  
 Sleeve orientation: 0°  
 CW Mandrel: ST 5300-CBM-T2 -0-N  
 CW Mandrel Taper: 0.045"/"  
 CW Mandrel Major Dia.: .353"  
 Lubrication: Fel Pro 300 (on sleeve)



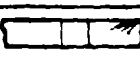
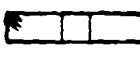
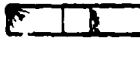
2. Hole Preparation

Nominal hole size: 3/8"  
 Process: ream, CW & ream  
 Fastener Diameter: .3535  
 Fastener Inst'l Torque: 225/250 In/lb.

4. Fatigue Conditions

Net stress: 30 ksi  
 Test load: 8,630 lbs.  
 Load ratio: (R) 0.1  
 Test Frequency: 5000/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophore (36 Kip)

C/W .002  
Interference HI-Lok

Specimen No. K623080	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (inches)	Retained Diametrical Expansion (inches) 	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
-45	1	.3540	.3665	.3710	35	15	30	.0190	.0125	120	 head ↑
	2	.3540	.3665	.3710	-	-	-	.0190	.0125		
-46	1	.3540	.3665	.3710	40	20	25	.0190	.0125	185	 head ↑
	2	.3540	.3665	.3710	-	-	-	.0190	.0125		
-47	1	.3540	.3665	.3710	30	15	30	.0190	.0125	258	 head ↑
	2	.3540	.3665	.3710	-	-	-	.0190	.0125		

 Taken at Minimum (midpoint)

PHASE II TASK 4 - APPLICATION AND PROCESS PARAMETERS

TEST NUMBER: 4 C 4  
 NOMINAL EXPANSION VALUE: 0.019"

GENERAL TEST CONDITIONS

DATE: 4-2-73

1. Specimen Description

Zero load transfer, 2 hole, CSK  
 Configuration: Fig 2  
 Width: 1.50"  
 Hole spacing: 1.50"  
 Edge margin: 0.75"  
 Material: 2024 T851  
 Material gauge: 0.250"  
 Surface Treatment: Shot Peen  
 Fastener: Hi-Lok 100 Hd., Net Fit

Sleeve type: Axial Split  
 Sleeve thickness: 0.010"  
 Sleeve orientation: 0°  
 CW Mandrel: ST 5300-CBM-12 -0-N  
 CW Mandrel Taper: 0.045"/"  
 CW Mandrel Major Dia.: .353  
 Lubrication: Fel Pro 300 (on sleeve)


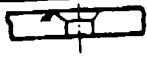


2. Hole Preparation

Nominal hole size: 3/8"  
 Process: Ream, C/W, Ream & CSK  
 Fastener Diameter: .3538-.3540  
 Fastener Inst'l Torque: 225/250 in/lbs

100° CSK after C/W  
 Net Fit Hi-Lok

4. Fatigue Conditions

Net stress: 30 ksi  
 Test load: 8,600 lbs.  
 Load ratio: (R) = 0.1  
 Test Frequency: 5,000  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophore (36 Kip)

Specimen No. R623080	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (inches)	Retained Diametrical Expansion (inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
-48	1	.3540	.3665	.3735	35	15	30	.0190	.0125	1,247	
	2	.3540	.3665	.3735	-	-	-	.0190	.0125		
-49	1	.3540	.3665	.3735	40	20	45	.0190	.0125	950	
	2	.3540	.3665	.3735	-	-	-	.0190	.0125		
-50	1	.3540	.3665	.3540	40	20	35	.0190	.0125	1,186	
	2	.3540	.3665	.3540	-	-	-	.0190	.0125		

 Taken at Minimum (midpoint)

PHASE II TASK 4 - APPLICATION AND PRODUCTION PERMITS

TEST NUMBER: 4 C 5

NOMINAL EXPANSION VALUE: 0.019"

GENERAL TEST CONDITIONS

DATE: 4-2-73

1. Specimen Description

Zero load transfer, 2 hole, CSK  
 Configuration: Fig 2  
 Width: 1.50"  
 Hole spacing: 1.50"  
 Edge margin: 0.75"  
 Material: 2024 T851  
 Material gauge: 0.250"  
 Surface Treatment: Shot Peen  
 Fastener: Hi-Lok 100° HD, Net Fit

3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: 0.010"  
 Sleeve orientation: 0°  
 CW Mandrel: ST 5300-CBM- 12 -0-N  
 CW Mandrel Taper: 0.045"/"  
 CW Mandrel Major Dia.: .353"  
 Lubrication: Fel Pro 300 (on sleeve)


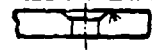
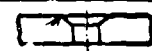

2. Hole Preparation

Nominal hole size: 3/8"  
 Process: Ream, CSK, C/W, Ream  
 Fastener Diameter: .3740  
 Fastener Inst'l Torque: 225/250 in/lbs

4. Fatigue Conditions

Net stress: 301 ksi  
 Test load: 8,550 lbs.  
 Load ratio: (R) = 0.1  
 Test Frequency: 5000/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophore (36 Kip)

100° CSK Before C/W  
 Net Fit HI-Lok

Specimen No. R623080	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
-51	1	.3540	.3665	.3740	25	15	40	.0190	.0125	169	
	2	.3540	.3665	.3740	-	-	-	.0190	.0125		
-52	1	.3540	.3665	.3740	30	15	40	.0190	.0125	508	
	2	.3540	.3665	.3740	-	-	-	.0190	.0125		
-53	1	.3540	.3665	.3740	30	15	45	.0190	.0125	213	
	2	.3540	.3665	.3740	-	-	-	.0190	.0125		

 Taken at Minimum (midpoint)



PHASE II TASK 4 - APPLICATION AND PROCESS PARAMETERS

TEST NUMBER: 4C 6

NOMINAL EXPANSION VALUE: .0185

GENERAL TEST CONDITIONS

DATE: 4-16-73

1. Specimen Description

Zero load transfer, 2 hole  
 Configuration: Fig. 2  
 Width: 1.50"  
 Hole spacing: 1.50"  
 Edge margin: 0.75"  
 Material: 2024 T851  
 Material gauge: 0.250"  
 Surface Treatment: Shot Peen  
 Fastener: HI-Lok with 70° head

3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: 0.010"  
 Sleeve orientation: 0°  
 CW Mandrel: ST 5300-CBM- 12 -0-N  
 CW Mandrel Taper: 0.045"/"  
 CW Mandrel Major Dia.: .3530  
 Lubrication: Fel Pro 300 (on sleeve)





2. Hole Preparation

Nominal hole size: 3/8"  
 Process: Drill, ream, CW & ream, CSK  
 Fastener Diameter: .3800"  
 Fastener Inst'l Torque: 225/250"/in.lb.  
 Fastener Fit: Net

4. Fatigue Conditions

Net stress: 30 ksi  
 Test load: 8,550 lbs.  
 Load ratio: (R) = 0.1  
 Test Frequency: 5,000/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophore (36 Kip)

70° CSK after C/W  
 Net Fit HI-Lok

Specimen No. 2623080	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (inches)	Retained Diametrical Expansion (inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
-54	1	.3545	.3665	.3800	40	20	35	.0185	.0120	290	
	2	.3545	.3665	.3800	-	-	-	.0185	.0120		
-55	1	.3545	.3665	.3800	35	15	40	.0185	.0120	315	
	2	.3545	.3665	.3800	-	-	-	.0185	.0120		
-56	1	.3545	.3665	.3800	40	20	35	.0185	.0120	191	
	2	.3545	.3665	.3800	-	-	-	.0185	.0120		

 Taken at Minimum (midpoint)

PHASE II TASK 4 - APPLICATION AND PROCESS PARAMETERS

TEST NUMBER: 4 C 7

NOMINAL EXPANSION VALUE: 0.019

GENERAL TEST CONDITIONS

DATE: 4-25-73

1. Specimen Description

Zero load transfer, 2 hole, no CSK  
 Configuration: Fig. 2  
 Width: 1.50"  
 Hole spacing: 1.50"  
 Edge margin: 0.75"  
 Material: 2024 T851  
 Material gauge: 0.250"  
 Surface Treatment: Shot Peen  
 Fastener: Prot. Hd. Nut Fit HI-Lok

3. CW Process

Sleeve type: Axial Split  
 Sleeve thickness: 0.010"  
 Sleeve orientation: 0°  
 CW Mandrel: ST 5300-CBM-12 -0-N  
 CW Mandrel Taper: 0.045"/"  
 CW Mandrel Major Dia.: .3530  
 Lubrication: Fel Pro 300 (on sleeve)



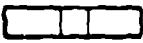

2. Hole Preparation

Nominal hole size: 3/8"  
 Process: 1. Ream.  
 2. Install under-size fastener

4. Fatigue Conditions

Net stress: 30 ksi  
 Test load: 8,750 lbs.  
 Load ratio: (R) = 0.1  
 Test Frequency: 5000/minute  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophone (36 Kip)

Reamed only with Hi-Lok  
 Test at 30 ksi

Specimen No. R623080	Hole No.	Hole Diameter (Inches)			Hole Finish (RHR)			Actual CW Diametrical Expansion (Inches)	Retained Diametrical Expansion (Inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW 	After ream	Before CW	After CW	After Ream				
-15	1	-	-	.3430	-	-	-	-	172		
	2	-	-	.3430	-	-	-	-			
-16	1	-	-	.3430	-	-	-	-	200		
	2	-	-	.3430	-	-	-	-			
-17	1	-	-	.3430	-	-	-	-	222		
	2	-	-	.3430	-	-	-	-			

 Taken at Minimum (midpoint) Test engineer did not stop at 80,000 cycles

PHASE II TASK 4 - APPLICATION AND PROCESS PARAMETERS

TEST NUMBER: 4 C 8

NOMINAL EXPANSION VALUE: 0.019"

Precracked and C/W  
net-fit Hi-Lok  
30 ksi

GENERAL TEST CONDITIONS:

DATE: 4-3-73

1. Specimen Description

Zero load transfer, 2 holes, no CSA  
Configuration: Fig. 2  
Width: 1.50"  
Hole spacing: 1.50"  
Edge margin: 0.75"  
Material: 2024 T851  
Material gauge: 0.250"  
Surface Treatment: Shot Peen  
Fastener: Net fit - Hi-Lok

3. C/W Process

Sleeve type: Avial 111  
Sleeve thickness: 0.010"  
Sleeve orientation: 0°  
C/W Mandrel: ST 5000-CBM-12 -0-N  
C/W Mandrel Taper: 0.045"/"  
C/W Mandrel Major Dia.: .353"  
Lubrication: Fel-Pro 300 (on sleeve)

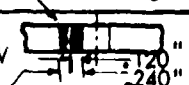


2. Hole Preparation

Nominal hole size: 3/8"  
Process: 1. Pilot Drill  
2. Notch (fatigue crack to length to give .030" crack length at pre C/W ream dia. (at 30 ksi)  
3. Ream  
4. C/W  
5. Ream  
6. Install net fit HI-Lok


4. Fatigue Conditions

Net stress: 30 ksi  
Test load: 8,650 lbs.  
Load ratio: (R) 0.1  
Test Frequency: 5000/minute  
Test Laboratory: Materials  
Test Engineer: D. Reese  
Test Machine: Vibrophore (36 Kip)

.030 ± .005" crack after C/W ream  
.3540 diameter

Specimen No. R623080	Hole No.	Hole Diameter (inches)			Hole Finish (RHR)			Actual CW Diometrical Expansion (Inches)	Retained Diometrical Expansion (Inches)	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW	After ream	Before CW	After CW	After Ream				
-18	1	.3540	.3670	.3735	40	20	45	.0190	.0130	30 to crack 93 after C/W	 Orig. crack after C/W and postream
	2	.3540	.3670	.3735	-	-	-	.0190	.0130	123 total	
-19	1	.3540	.3670	.3735	40	20	50	.0190	.0130	32 to crack 515 aft CW	 failure origin Orig. crack at hole .021 aft. C/W & postream
	2	.3540	.3670	.3735	-	-	-	.0190	.0130	547 total	
-20	1	.3540	.3670	.3735	35	15	55	.0190	.0130	18 to crack 607 aft. CW	 failure origin Orig. crack .021 after C/W & postream
	2	.3540	.3670	.3735	-	-	-	.0190	.0130	625 total	

 Taken at Minimum (midpoint)  
Pilot Hole Dia. = .3155"

 -18 (30,000 cycles - .050 crack) -19 & -20  
.050" crack (gives .030" at .354" diameter)

PHASE II TASK 4 - APPLICATION AND PROCESS PARAMETERS

TEST NUMBER 4 D 1 (Edge Margin) (Open Holes)  
 NOMINAL EXPANSION VALUE: 0.019 Inch

GENERAL TEST CONDITIONS

DATE: \_\_\_\_\_

1. Specimen Description

Edge Margin - 4 Hole, No CSK  
 Configuration: Fig. 7a  
 Width: 3.124  
 Hole spacing: 1.50" x 2.00"  
 Edge Margin: .562  
 Material: 2024-T851  
 Material Gage: 0.025 Inch  
 Surface Treatment: Shot Peen  
 Fastener: None

3. CW Process

Sleeve Type: Split  
 Sleeve orientation: 0°




2. Hole Preparation

Nominal Hole Size: 3/8 Inch  
 Process: Ream, Coldwork, Ream

4. Fatigue Conditions

Net Stress: 30 ksi  
 Test Load: 18,115 lbs  
 Load Ratio: R= 0.1  
 Test Frequency: 5000/Min.  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophore (36 KIP)

1-1/2D E/M  
 C/W open hole  
 30 ksi

Specimen No. R623080	Hole No.	Hole Diameter (Inches)			Hole Finish (RHR) Final Ream	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW	After Ream			
-89	1	.3540	.3665	.3735	35	359	 CW
	2	.3542	.3665	.3735	-		
	3	.3542	.3665	.3735	35		
	4	.3544	.3665	.3735	-		
-90	1	.3545	.3665	.3735	40	215	 CW
	2	.3545	.3666	.3735	-		
	3	.3545	.3666	.3735	45		
	4	.3545	.3668	.3735	-		
-91	1	.3545	.3666	.3735	40	183	 CW
	2	.3544	.3666	.3735	-		
	3	.3544	.3664	.3735	35		
	4	.3545	.3667	.3735	-		

PHASE II TASK 4 - APPLICATION AND PROCESS PARAMETERS

TEST NUMBER 4 D 2 (Edge Margin) (Open Holes)  
 NOMINAL EXPANSION VALUE: 0.019 Inch

GENERAL TEST CONDITIONS

DATE: \_\_\_\_\_

1. Specimen Description

Edge Margin - 4 Hole, No CSK  
 Configuration: Fig 7b  
 Width: 3.50"  
 Hole spacing: 1.50" x 2.00"  
 Edge Margin: .750"  
 Material: 2024-1851  
 Material Gage: 0.025 Inch  
 Surface Treatment: Shot Peen  
 Fastener: None

3. CW Process

Sleeve Type: Split  
 Sleeve orientation: 0°




2. Hole Preparation

Nominal Hole Size: 3/8 Inch  
 Process: Ream, Coldwork, Ream

4. Fatigue Conditions

Net Stress: 30 ksi  
 Test Load: 20,860 lbs  
 Load Ratio: R= 0.1  
 Test Frequency: 5000/Min.  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophore (36 KIP)

2D E/M  
 C/W open hole  
 30 ksi

Specimen No. R623080	Hole No.	Hole Diameter (Inches)			Hole Finish (RHR) Final Ream	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW	After Ream			
-93	1	.3540	.3667	.3735	35	504	
	2	.3542	.3666	.3735	-		
	3	.3544	.3666	.3735	-		
	4	.3543	.3665	.3735	35		
-94	1	.3544	.3667	.3735	35	535	
	2	.3535	.3667	.3735	-		
	3	.3542	.3668	.3735	40		
	4	.3542	.3667	.3735	35		
-95	1	.3543	.3667	.3735	40	253	
	2	.3542	.3668	.3735	35		
	3	.3544	.3667	.3735	40		
	4	.3543	.3667	.3735	35		

PHASE II TASK 4 - APPLICATION AND PROCESS PARAMETERS

TEST NUMBER 4 D 3 (Edge Margin) (Open Holes)  
 NOMINAL EXPANSION VALUE: 0.019 Inch

GENERAL TEST CONDITIONS

DATE: \_\_\_\_\_

1. Specimen Description

Edge Margin - 4 Hole, No CSK  
 Configuration: Fig. 7C  
 Width: 3.874  
 Hole spacing: 1.50" x 2.00"  
 Edge Margin: .937  
 Material: 2024-T851  
 Material Gage: 0.025 Inch  
 Surface Treatment: Shot Peen  
 Fastener: None

3. CW Process

Sleeve Type: Split  
 Sleeve orientation: 0°

2. Hole Preparation

Nominal Hole Size: 3/8 Inch  
 Process: Ream, Coldwork, Ream

4. Fatigue Conditions

Net Stress: 30 ksi  
 Test Load: 23,725 lbs  
 Load Ratio: R=0.1  
 Test Frequency: 5000/Min.  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophore (36 KIP)

2:1:2D E/M  
 C/W open hole  
 30 ksi

Specimen No. R623080	Hole No.	Hole Diameter (Inches)			Hole Finish (RHR) Final Ream	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW	After Ream			
-97	1	.3542	.3670	.3735	40	756	
	2	.3542	.3673	.3735	-		
	3	.3542	.3670	.3735	-		
	4	.3542	.3670	.3730	35		
-98	1	.3543	.3669	.3735	35	393	
	2	.3545	.3669	.3735	-		
	3	.3542	.3669	.3735	-		
	4	.3543	.3673	.3735	35		
-99	1	.3544	.3673	.3735	40	254	
	2	.3543	.3670	.3740	35		
	3	.3544	.3672	.3735	35		
	4	.3544	.3672	.3735	35		

PHASE II TASK 4 - APPLICATION AND PROCESS PARAMETERS

TEST NUMBER 4 D 4 (Edge Margin) (Open Holes)  
 NOMINAL EXPANSION VALUE: 0.019 Inch

GENERAL TEST CONDITIONS

DATE: \_\_\_\_\_

1. Specimen Description

Edge Margin - 4 Hole, No CSK  
 Configuration: Fig 7d  
 Width: 2.994  
 Hole spacing: 1.50" x 1.12"  
 Edge Margin: .9.37  
 Material: 2024-T851  
 Material Gage: 0.025 Inch  
 Surface Treatment: Shot Peen  
 Fastener: None

3. CW Process

Sleeve Type: Split  
 Sleeve orientation: 0°


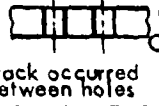

2. Hole Preparation

Nominal Hole Size: 3/8 Inch  
 Process: Ream, Coldwork, Ream

4. Fatigue Conditions

Net Stress: 30 ksi  
 Test Load: 17,330 lbs  
 Load Ratio: R=0.1  
 Test Frequency: 5000/Min.  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophore (36 KIP)

3D hole spacing  
 C-W open hole  
 30 ksi

Specimen No. R623080	Hole No.	Hole Diameter (Inches)			Hole Finish (RHR) Final Ream	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW	After Ream			
-101	1	.3545	.3665	.3535	35		
	2	.3544	.3665	.3535	-		
	3	.3544	.3665	.3535	-		
	4	.3544	.3665	.3535	35		
-102	1	.3543	.3665	.3535	35		
	2	.3540	.3665	.3535	40		
	3	.3542	.3665	.3535	40		
	4	.3542	.3665	.3535	35		
-103	1	.3540	.3666	.3535	40		
	2	.3542	.3665	.3535	-		
	3	.3542	.3665	.3535	-		
	4	.3539	.3665	.3535	40		

PHASE II TASK 4 - APPLICATION AND PROCESS PARAMETERS

TEST NUMBER 4 D 5 (Edge Margin) (Open Holes)  
 NOMINAL EXPANSION VALUE: 0.019 Inch

GENERAL TEST CONDITIONS

DATE: \_\_\_\_\_

1. Specimen Description

Edge Margin - 4 Hole, No CSK  
 Configurations: Fig. 7c  
 Width: 3.374  
 Hole spacing: 1.50" x 1.50"  
 Edge Margin: .937  
 Material: 2024-T851  
 Material Gage: 0.025 Inch  
 Surface Treatment: Shot Peen  
 Fastener: None

3. CW Process

Sleeve Type: Split  
 Sleeve orientation: 0°




2. Hole Preparation

Nominal Hole Size: 3/8 Inch  
 Process: Ream, Coldwork, Ream

4. Fatigue Conditions

Net Stress: 30 ksi  
 Test Load: 19,900 lbs  
 Load Ratio: R = 0.1  
 Test Frequency: 5000/Min.  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Vibrophone (36 KIP)

4D hole spacing  
 CW open hole  
 30 ksi

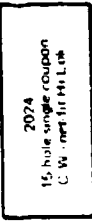
Specimen No. R623080	Hole No.	Hole Diameter (Inches)			Hole Finish (RHR) Final Ream	Cycles to Failure (Thousands)	Origin of Failure and Remarks
		Before CW	After CW	After Ream			
-105	1	.3543	.3665	.3735	40	300	 CW
	2	.3543	.3666	.3735	-		
	3	.3542	.3666	.3735	40		
	4	.3542	.3666	.3735	-		
-106	1	.3544	.3670	.3735	40	294	 CW
	2	.3543	.3670	.3735	-		
	3	.3543	.3670	.3735	35		
	4	.3543	.3670	.3735	40		
-107	1	.3543	.3670	.3735	35	272	 CW
	2	.3542	.3670	.3735	40		
	3	.3543	.3670	.3735	40		
	4	.3543	.3670	.3735	35		



PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

2024, 15-Hole, Single, C/W, Filled

TEST E1 SPECIMEN 623080 DATE 5/9/73



SPECIMEN DESCRIPTION

Configuration F-g 9  
 Material 2024-T851  
 Width (in) 1.00  
 Hole spacing 1.00  
 Edge margin (in) 0.50  
 Material grade (in) 0.250  
 Surface treatment Shot peen

COLDWORK PROCESS

Interference (in) 0.014/0.015  
 Sleeve type Split  
 Sleeve thickness (in) 0.008  
 Sleeve orientation 0°  
 Mandrel material H 11 steel  
 Mandrel taper (in/in) 0.015  
 Mandrel max diameter (in) 0.2300  
 Lubricator Fel Pro

HOLE PREPARATION

Minimal hole size (in) 1/4  
 Process Ream, C/W, ream  
 FASTENER INSTALLATION  
 Type Hi Lok, 1/4 in. prot hd  
 Fit Nut  
 Torque (in lb) 80 (stringer only)

FATIGUE CONDITIONS

Max test stress (ksi) 40  
 Max test load (lbf) 7500  
 Load ratio (R) 0.1  
 Test frequency 600 cpm  
 Test laboratory Materials  
 Test engineer D Reese  
 Test machine Riehle Los

Specimen dash no	Hole no (a)	Hole diameter (in)		Hole finish (RHR)		Conductor expansion (in)		Fastener expansion		Cycles to failure	Origin of failure and remarks
		Before coldwork	After ream	Before coldwork	After ream	A 1.01	H 1.01	Diameter	F 1		
83	1	0.2310	0.2485		20	0.015				149,850	
	2										
	3										
	4										
84	1	0.2310	0.2485		25	0.015				150,320	
	2										
	3										
	4										
85	1	0.2310	0.2485		20	0.015				135,990	
	2										
	3										
	4										

a Typical hole measurement

PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

2024, 15-Hole, Dual, C/W, Filled, One At Time

TEST: F1 SPECIMEN: 623080 DATE: 5/9/73

2024  
15 hole dual coupon  
C/W and filled one  
at time (net-fit)

SPECIMEN DESCRIPTION

Configuration: Fig. 8  
Material: 2024-T851  
Width (in.): Skin-2.50; stringer-1.00  
Hole spacing: 1.00  
Edge margin (in.): Skin-1.25; stringer-0.50  
Mandrel material: H-11 steel  
Mandrel taper (in./in.): 0.015  
Surface treatment: Shot peen  
Mandrel max diameter (in.): 0.2300  
Lubrication: Fel P-0

COLDWORK PROCESS

Interference (in.): 0.014/0.015  
Sleeve type: Split  
Sleeve thickness (in.): 0.008  
Sleeve orientation: 0°  
Mandrel max diameter (in.): 0.2300  
Lubrication: Fel P-0

HOLE PREPARATION

Nominal hole size (in.): 1/4  
Process: Ream, C/W, ream

FASTENER INSTALLATION

Type: Hi-Lok, 1/4-in. prot hd  
Fit: Net

Torque (in. lb): 80 (fasteners installed one at a time)

FATIGUE CONDITIONS

Max net stress (ksi): 30  
Max test load (top): 22.7  
Load ratio (R): 0.1  
Test frequency: 600 cpm  
Test laboratory: Materials  
Test engineer: D. Reese  
Test machine: Riehle-Loos

Specimen ID	Hole No. (a)	Hole diameter (in.)			Hole finish (RHR)		Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Sub- component	After coldwork	After ream	Before coldwork	After coldwork	Actual	Retained	Diameter	Fit		
-86	1	0.2310	0.2485	0.2485		15	0.015				265,000	C/W Hd Hole 4
	2											Fretting evident on surfaces Hd Hole 8
	3											Fretting on surface C/W Hd Hole 3
	4											Fretting on surface C/W Hd Hole 3
-87	1	0.2310	0.2485	0.2485		20	0.015				264,000	Fretting on surface C/W Hd Hole 3
	2											Fretting on surface C/W Hd Hole 3
	3											Fretting on surface C/W Hd Hole 3
	4											Fretting on surface C/W Hd Hole 3
-88	1	0.2310	0.2485	0.2485		15	0.015				288,000	Fretting on surface C/W Hd Hole 3
	2											Fretting on surface C/W Hd Hole 3
	3											Fretting on surface C/W Hd Hole 3
	4											Fretting on surface C/W Hd Hole 3

a Typical hole measurement

**PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS**  
**2024, 15-Hole, Dual, C/W, Filled, Production Technique**

2024  
 15-hole dual coupon  
 C/W and filled,  
 production technique

TEST: F2 SPECIMEN: 623080 DATE: 5/9/73

<b>SPECIMEN DESCRIPTION</b>	<b>COLDWORK PROCESS</b>	<b>HOLE PREPARATION</b>	<b>FATIGUE CONDITIONS</b>
Configuration: <u>Fig B</u>	Interference (in.): <u>0.014/0.015</u>	Nominal hole size (in.): <u>1/4</u>	89, 90-40
Material: <u>2024-T851</u>	Sleeve type: <u>Split</u>	Process: <u>Ream, C/W, ream</u>	Max net stress (ksi): <u>91.30</u>
Width (in.): <u>Skin-2.50, stringer-1.00</u>	Sleeve thickness (in.): <u>0.008</u>		Gross-26.1
hole spacing: <u>1.00</u>	Sleeve orientation: <u>0°</u>		Max test load (kips): <u>Mar-22.6</u>
Edge margin (in.): <u>Skin-1.25; stringer-0.50</u>	Mandrel material: <u>H-11 steel</u>		Load ratio (R): <u>0.1</u>
Material gauge (in.): <u>0.250</u>	Mandrel taper (in./in.): <u>0.015</u>	<b>FASTENER INSTALLATION</b>	Test frequency: <u>600 cpm</u>
Surface treatment: <u>Shot peen</u>	Mandrel max diameter (in.): <u>0.2300</u>	Type: <u>Hi-Lok 1/4-in. prot hd</u>	Test laboratory: <u>Materials</u>
	Lubrication: <u>Fel Pro</u>	Fit: (in.): <u>0.0015</u>	Test engineer: <u>D. Reese</u>
		Torque (in.-lb): <u>80 (middle; two end fasteners installed first, then the rest)</u>	Test machine: <u>Riehle-Lox</u>

Specimen dash no	Hole no (a)	Hole diameter (in.)		Hole finish (RHRI)		Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After ream	Before coldwork	After ream	Actual	Retained	Diameter	Fit		
-89	1	0.2310	0.2485		15	0.015		(b)		153,000	C/W Stringer-hole 3 Hd
	2										Fretting on surfaces Skin-Hole 2 Hd
	3										C/W Hole 5 Hd
	4										Fretting on surfaces Hole 4 Hd
-90	1	0.2310	0.2485		25	0.015		(b)		146,000	C/W Stringer-hole 3 Hd
	2										Fretting on surfaces Skin-Hole 2 Hd
	3										C/W Hole 5 Hd
	4										Fretting on surfaces Hole 4 Hd
-91	1	0.2310	0.2485		25	0.015		(c)		273,900	C/W Stringer-hole 3 Hd
	2										Fretting on surfaces Skin-Hole 2 Hd
	3										C/W Hole 5 Hd
	4										Fretting on surfaces Hole 4 Hd

a Typical hole measurement      b Gross stress      c Net stress

PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

2024, 15-Hole, Dual, C/W, Filled, No Postream

2024  
15 hole dual coupon  
C/W - filled,  
no postream

TEST: F3 SPECIMEN: 623080 DATE: 6/22/73

**SPECIMEN DESCRIPTION**  
 Configuration: Fig. 8  
 Material: 2024-T851  
 Width (in.): Skin-2.50; stringer-1.00  
 Hole spacing: 1.00  
 Edge margin (in.): Skin-1.25; stringer-0.50  
 Material gauge (in.): 0.250  
 Surface treatment: Shot peen

**COLDWORK PROCESS**  
 Interference (in.): 0.014/0.015  
 Sleeve type: Split  
 Sleeve thickness (in.): 0.008  
 Sleeve orientation: 0  
 Mandrel material: H-11 steel  
 Mandrel taper (in./in.): 0.015  
 Mandrel max diameter (in.): 0.2380  
 Lubrication: Fel Pro

**HOLE PREPARATION**  
 Nominal hole size (in.): 1/4  
 Process: Ream, C/W

**FASTENER INSTALLATION**  
 Type: Hi-Lok 1/4-in. prof hd  
 Fit: Net  
 Torque (in.-lb): 80

**FATIGUE CONDITIONS**  
 Max net stress (ksi): 40  
 Max test load (kip): 26.5  
 Load ratio (R): 0.1  
 Test frequency: 600 cpm  
 Test laboratory: Materials  
 Test engineer: D. Reese  
 Test machine: Richke-Los

Specimen cash no	Hole no (a)	Hole diameter (in.)		Hole finish (RHR)			Coldwork expansion (in.)		Fastener size (in.)		Cyc. to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter		
-76	1	0.2390	0.2495			20					154,600	C/W Stringer-hole 3 Hd
	2											Fretting both sides Skin-hole 2
	3											C/W Stringer-hole 9 Hd
	4											Fretting both sides Skin-hole 10 Hole 11
b-78	1	0.2390	0.2495			20					165,500	C/W Stringer-hole 9 Hd
	2											Fretting both sides Skin-hole 10 Hole 11
	3											C/W Stringer-hole 9 Hd
	4											Fretting both sides

<sup>a</sup>Typical hole measurement

<sup>b</sup>Hole spacing 1.3/8 in. versus 1 in. on -76 and -77

PHASE II TASK 4 - APPLICATION AND EFFECT OF PARAMETERS

TEST NUMBER: 4 G 1

GENERAL TEST CONDITIONS

DATE: 4-24-73

1. Specimen Description

High Load Transfer: Fig. 10  
 Material: 2024-T851  
 Material Gauge: 0.250"  
 Surface Treatment: Shot Peen  
 Fastener: Hi-Lok, Prot. Head

3. Fastener Installation:

Fastener Fit: Net  
 Installation Torque: 225/250 In/lbs.


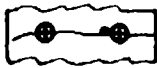

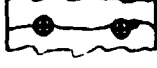
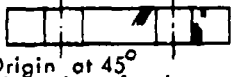

2. Hole Preparation

Nominal Hole Size: 3/8"  
 Process: Ream, C/W, Ream  
 CW Process: Sleeve  
 CW Interference: 0.0185"

4. Fatigue Conditions

Net Stress: 30 ksi  
 Test Load: 16,800 lbs  
 Load Ratio: R = 0.1  
 Test Frequency: 600 CPM  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Riehle-Los

C/W Net Fit P.H. HiLok  
.010" Shim

Specimen No. R623080	Typical Hole Diameter Before CW (Inches)	Typical Final Hole Diameter (Inches)	Cycles to Failure	Origin of Failure and Remarks	↑ LOAD
-109	.3545	.3730	580,620	 No Surface Fretting	
-110	.3545	.3730	371,350	 Origin at 45° to $\bar{C}$ No surface fretting	
-111	.3545	.3735	500,440	 Origin at 45° No surface fretting	

PHASE II TASK 4 - APPLICATION AND PROCESS PARAMETERS

TEST NUMBER: 4 G 2

GENERAL TEST CONDITIONS

DATE: 4-24-73

1. Specimen Description

High Load Transfer: Fig 10  
 Material: 2024 T851  
 Material Gauge: 0.250"  
 Surface Treatment: Shot Peen  
 Fastener: Hi-Lok - Prot. Head

3. Fastener Installation:

Fastener Flt: .002" clearance  
 Installation Torque: 225/250 in/lbs


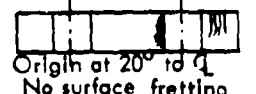
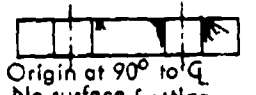
2. Hole Preparation

Nominal Hole Size: 3/8"  
 Process: Ream, C/W, ream  
 CW Process: Sleeve  
 CW Interference: 0.0185"

4. Fatigue Conditions

Net Stress: 30 ksi  
 Test Load: 16,800 lbs.  
 Load Ratio: R = 0.1  
 Test Frequency: 600 CPM  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Riehle-Los

C/W .002 CL. HiLok  
 Prot. Head .010 Shim

Specimen No. R623080	Typical Hole Diameter Before CW (Inches)	Typical Final Hole Diameter (Inches)	Cycles to Failure	Origin of Failure and Remarks
-112	.3545	.3755	281,720	 Origin at 45° to Q No surface fretting
-113	.3545	.3755	291,700	 Origin at 20° to Q No surface fretting
-114	.3545	.3755	355,200	 Origin at 90° to Q No surface fretting

▷ Some secondary cracks at 45° away from hole on load side.



PHASE II TASK 4 - APPLICATION AND PROCESS PARAMETERS

TEST NUMBER: 4 G 3

GENERAL TEST CONDITIONS

DATE: 4-23-73

1. Specimen Description

High Load Transfer: Fig. 10  
 Material: 2024 T 851  
 Material Gauge: 0.250"  
 Surface Treatment: Shot Peen  
 Fastener: HI-Lok, Prot. Head

3. Fastener Installation:

Fastener Fit: .002" Int.  
 Installation Torque: 225/250 in/lbs

2. Hole Preparation

Nominal Hole Size: 3/8"  
 Process: Ream, C/W, Ream  
 CW Process: Sleeve  
 CW Interference: 0.0185"

4. Fatigue Conditions

Net Stress: 30 ksi  
 Test Load: 16,800 lbs.  
 Load Ratio: R = 0.1  
 Test Frequency: 600 CPM  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Riehle-Los

C/W Interference Fit HI Lok  
 Prot. Head .010" Shim

Specimen No. R623080	Typical Hole Diameter Before CW (Inches)	Typical Final Hole Diameter (Inches)	Cycles to Failure	Origin of Failure and Remarks	
-115	.3545	.3715	924, 180	ORIGIN AT 0° FROM G. NO SURFACE FRETTING	
-116	.3545	.3715	655, 880	SOME 90° SHANK FRETTING ORIGIN 0° FROM G. NO SURFACE FRETTING	
-117	.3545	.3715	900, 530	45° SHANK FRETTING MAIN ORIGIN 0° FROM G. NO SURFACE FRETTING	

↑  
LOAD

PHASE II TASK 4 - APPLICATION AND PROCESS PARAMETERS

TEST NUMBER: 4 G 4

GENERAL TEST CONDITIONS

DATE: 4-26-73

1. Specimen Description

High Load Transfer: Fig 10  
 Material: 2024 T 851  
 Material Gauge: 0.250  
 Surface Treatment: Shot Peen  
 Fastener: HI-Lok, Flush Head

3. Fastener Installation:

Fastener Fit: Net  
 Installation Torque: 225/250 in/lbs

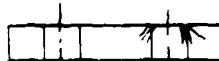


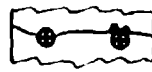
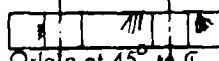

2. Hole Preparation

Nominal Hole Size: 3/8"  
 Process: Ream, C/W, Ream, CSK  
 CW Process: Sleeve  
 CW Interference: 0.019"

4. Fatigue Conditions

Net Stress: 30 ksi  
 Test Load: 16,800 lbs.  
 Load Ratio: R = 0.1  
 Test Frequency: 600 CPM  
 Test Laboratory: Materials  
 Test Engineer: D. Rees  
 Test Machine: Riehle-Lox

C/W Net Fit HI-Lok  
 Flush Head .010" Shim

Specimen No. R623080	Typical Hole Diameter Before CW (Inches)	Typical Final Hole Diameter (Inches)	Cycles to Failure	Origin of Failure and Remarks	LOAD
-118	.3545	.3732	508, 360	 Origin at 0° to $\epsilon$ No surface fretting	
-119	.3545	.3732	343, 460	 Origin at 45° to $\epsilon$ No surface fretting	
-120	.3545	.3732	557, 400	 Origin at 45° to $\epsilon$ No surface fretting	



PHASE II TASK 4 - APPLICATION AND PROCESS PARAMETERS

TEST NUMBER: 405

GENERAL TEST CONDITIONS

DATE: 4-26-73

1. Specimen Description

High Load Transfer: Fig. 10  
 Material: 2024 T 851  
 Material Gauge: 0.250"  
 Surface Treatment: Shot Peen  
 Fastener: Hi-Lok (Prot. Head)

3. Fastener Installation:

Fastener Fit: Net fit  
 Installation Torque: 225/250 in/lbs  
NO SHIM

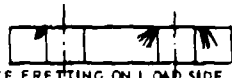


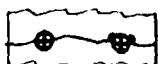
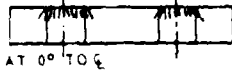
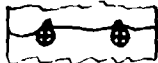
2. Hole Preparation

Nominal Hole Size: 3/8"  
 Process: Ream, C/W & Ream  
 CW Process: Sleeve  
 CW Interference: 0.0185

4. Fatigue Conditions

Net Stress: 30 ksi  
 Test Load: 16,800 lbs.  
 Load Ratio: R=0.1  
 Test Frequency: 600 CPM  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Riehle-Loe

C/W Net Fit HiLok  
Prot. Head - No Shim

Specimen No. R623080	Typical Hole Diameter Before CW (Inches)	Typical Final Hole Diameter (Inches)	Cycles to Failure	Origin of Failure and Remarks	↑ LOAD
-121	.3545	.3735	294, 720	 SURFACE FRETTING ON LOAD SIDE ORIGINS AT 45° TO C	
-123	.3545	.3735	386, 990	 SERIOUS SURFACE FRETTING ON LOAD SIDE ORIGIN AT 45° TO C SERIOUS SECONDARY CRACKS IN FRETTING	
-123	.3545	.3735	399, 190	 ORIGIN AT 0° TO C SURFACE FRETTING ON LOAD SIDE	

NOTE: Surface fretting only occurs on load side at first row of holes.

PHASE II TASK 4 - APPLICATION AND PROCESS PARAMETERS

TEST NUMBER: 4 G 6

GENERAL TEST CONDITIONS

DATE: 4-27-73

1. Specimen Description

High Load Transfer: Fig. 10  
 Material: 2024 T 851  
 Material Gauge: 0.250  
 Surface Treatment: Shot Peen  
 Fastener: HI-Lok (Prot. Head)

3. Fastener Installation:

Fastener Fit: Net  
 Installation Torque: 225/250 in/lbs

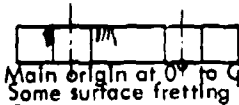
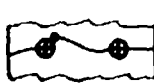
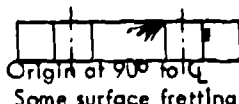

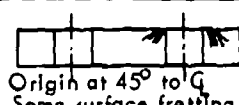
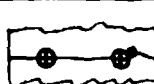
2. Hole Preparation

Nominal Hole Size: 3/8"  
 Process: Ream. C/W, Ream  
 CW Process: Sleeve  
 CW Interference: 0.0185"

4. Fatigue Conditions

Net Stress: 30 ksi  
 Test Load: 16,800 lbs.  
 Load Ratio: R = 0.1  
 Test Frequency: 600 CPM  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Riehle-Los

C/W Net Fit HI-Lok  
 Prot. Head No Shim  
 Upset Removed &  
 Primed

Specimen No. R623080	Typical Hole Diameter Before CW (Inches)	Typical Final Hole Diameter (Inches)	Cycles to Failure	Origin of Failure and Remarks	LOAD
-124	.3545	.3735	429,000	 <p>Main origin at 0° to G Some surface fretting</p>	
-125	.3545	.3735	674,690	 <p>Origin at 90° to G Some surface fretting</p>	
-126	.3545	.3735	990,370	 <p>Origin at 45° to G Some surface fretting</p>	

PHASE II TASK 4 - APPLICATION AND PROCESS PARAMETERS

TEST NUMBER: 4 G 7

GENERAL TEST CONDITIONS

DATE: 4-27-73

1. Specimen Description

High Load Transfer: Fig. 10  
 Material: 2024 T 851  
 Material Gauge: 0.250  
 Surface Treatment: Shot Peen  
 Fastener: Taper-Lok (Prot. Head)

3. Fastener Installation:

Fastener Fit: Net  
 Installation Torque: 225/250 in/lbs.

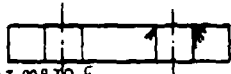

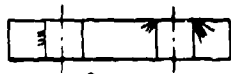

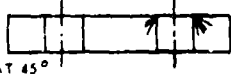

2. Hole Preparation

Nominal Hole Size: 3/8"  
 Process: Ream only

4. Fatigue Conditions

Net Stress: 30 ksi  
 Test Load: 16,800 lbs.  
 Load Ratio: R = 0.1  
 Test Frequency: 600 CPM  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Riehle-Loe

T/L Prot. Head .010 Shim

Specimen No. R623080	Typical Hole Diameter Before CW (Inches)	Typical Head Protrusion (Inches)	Cycles to Failure	Origin of Failure and Remarks	LOAD
-127	-	.230/.250	682,310	 ORIGIN AT 90° TO $\epsilon$ NO SURFACE FRETTING	
-128	-	.230/.250	741,500	 MAIN ORIGIN AT 45° FRETTING IN FAILED HOLE AT SIDES NO SURFACE FRETTING	
-129	-	.230/.250	369,400	 ORIGIN AT 45° FRETTING IN FAILED HOLE AT SIDES NO SURFACE FRETTING	

PHASE II TASK 4 - APPLICATION AND PROCESS PARAMETERS

TEST NUMBER: 4 G 8

GENERAL TEST CONDITIONS

DATE: 4-25-73

1. Specimen Description

High Load Transfer: Fig. 10  
 Material: 2024 T 851  
 Material Gauge: 0.250  
 Surface Treatment: Shot Peen  
 Fastener: Taper-Lok, 100° head

3. Fastener Installation:

Fastener Fit: \_\_\_\_\_  
 Installation Torque: 225/250 in/lbs.

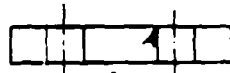

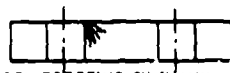

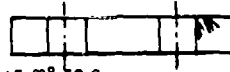

2. Hole Preparation

Nominal Hole Size: 3/8"  
 Process: Ream

4. Fatigue Conditions

Net Stress: 30 ksi  
 Test Load: 16,800 lbs.  
 Load Ratio: R = 0.1  
 Test Frequency: 600 CPM  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Riehle-Los

T/L Flush Head .010" Shim

Specimen No. R623080	Typical Hole Diameter Before CW (Inches)	Typical Head Protrusion (Inches)	Cycles to Failure	Origin of Failure and Remarks	LOAD
-130	-	.230/.250	1,422,370	 ORIGIN AT 45° TO Q NO SURFACE FRETTING	
-131	-	.230/.250	517,810	 CORKSCREW FRETTING ON SHANK ORIGIN ON 0° TO Q, NO SURFACE FRETTING	
-132	-	.230/.250	548,000	 ORIGIN AT 90° TO Q SOME SHANK FRETTING NO SURFACE FRETTING	

PHASE II TASK 4 - APPLICATION AND PROCESS PARAMETERS

TEST NUMBER: 4 G 9

GENERAL TEST CONDITIONS

DATE: 5-3-73

1. Specimen Description

High Load Transfer: Fig. 10  
 Material: 2024 T 851  
 Material Gauge: 0.250  
 Surface Treatment: Shot Peen  
 Fastener: Hi-Lok (Prot. Head)

3. Fastener Installation:

Fastener Fit: Net  
 Installation Torque: 225/250 In/lbs.

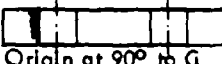


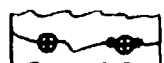


2. Hole Preparation

Nominal Hole Size: 3/8"  
 Process: Drill and ream

4. Fatigue Conditions

Net Stress: 30 ksi  
 Test Load: 16,800 lbs.  
 Load Ratio: R = 0.1  
 Test Frequency: 600 CPM  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Riehle-Los

Reamed Net Fit HiLok  
 Prot. Head .010" Shim

Specimen No. R623080	Typical Hole Diameter Before CW (Inches)	Typical Final Hole Diameter (Inches)	Cycles to Failure	Origin of Failure and Remarks	LOAD
-133	-	.3735	201,290	 Origin at 90° to Q No surface fretting	
-134	-	.3735	151,220	 Origin at 90° to Q No surface fretting	
-135	-	.3735	122,060	 Origin at 90° to Q No surface fretting	

PHASE II TASK 4 - APPLICATION AND PROCESS PARAMETERS

TEST NUMBER: 4 G 10

GENERAL TEST CONDITIONS

DATE: 5-7-73

1. Specimen Description

High Load Transfer: Fig 10  
 Material: 2024 T 851  
 Material Gauge: 0.250  
 Surface Treatment: Shot Peen  
 Fastener: Hi-Lok (Prot. Head)

3. Fastener Installation:

Fastener Fit: Net  
 Installation Torque: 225/250 in/lbs.  
.060 sand blasted Micarta

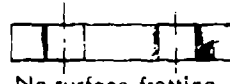

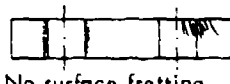
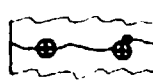
2. Hole Preparation

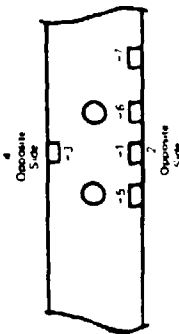
Nominal Hole Size: 3/8"  
 Process: C/W, ream  
 C/W Process: Sleeve  
 C/W Interference: 0.0185"

4. Fatigue Conditions

Net Stress: 30 ksi  
 Test Load: 16,800 lbs.  
 Load Ratio: R = 0.1  
 Test Frequency: 600 CPM  
 Test Laboratory: Materials  
 Test Engineer: D. Reese  
 Test Machine: Riehle-Los

C/W Net Fit HiLok  
 Prot. Head .060" Shim

Specimen No. R623080	Typical Hole Diameter Before CW (Inches)	Typical Final Hole Diameter (Inches)	Cycles to Failure	Origin of Failure and Remarks	LOAD
					↑
-136	.3545	.3735	365,020	 No surface fretting	
-137	.3545	.3735	867,530	 No surface fretting	



STRAIN GAGE READINGS AND CALCULATED STRESSES - ALUMINUM

Gage	Reamed only (net area = 0.428)							Cathodized (net area = 0.428)							Reamed after cathodizing (net area = 0.410)							With bolts installed																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																
	1/8	3/16	1/4	5/16	3/8	7/16	1/2	0	3/16	1/4	5/16	3/8	7/16	1/2	0	3/16	1/4	5/16	3/8	7/16	1/2	0	3/16	1/4	5/16	3/8	7/16	1/2	0	3/16	1/4	5/16	3/8	7/16	1/2	0																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																		
1	1.210	1.964	2.414	2.864	3.314	3.764	4.214	0	1.913	2.437	2.961	3.485	4.009	4.533	5.057	5.581	6.105	6.629	7.153	7.677	8.201	8.725	9.249	9.773	10.297	10.821	11.345	11.869	12.393	12.917	13.441	13.965	14.489	15.013	15.537	16.061	16.585	17.109	17.633	18.157	18.681	19.205	19.729	20.253	20.777	21.301	21.825	22.349	22.873	23.397	23.921	24.445	24.969	25.493	26.017	26.541	27.065	27.589	28.113	28.637	29.161	29.685	30.209	30.733	31.257	31.781	32.305	32.829	33.353	33.877	34.401	34.925	35.449	35.973	36.497	37.021	37.545	38.069	38.593	39.117	39.641	40.165	40.689	41.213	41.737	42.261	42.785	43.309	43.833	44.357	44.881	45.405	45.929	46.453	46.977	47.501	48.025	48.549	49.073	49.597	50.121	50.645	51.169	51.693	52.217	52.741	53.265	53.789	54.313	54.837	55.361	55.885	56.409	56.933	57.457	57.981	58.505	59.029	59.553	60.077	60.601	61.125	61.649	62.173	62.697	63.221	63.745	64.269	64.793	65.317	65.841	66.365	66.889	67.413	67.937	68.461	68.985	69.509	70.033	70.557	71.081	71.605	72.129	72.653	73.177	73.701	74.225	74.749	75.273	75.797	76.321	76.845	77.369	77.893	78.417	78.941	79.465	79.989	80.513	81.037	81.561	82.085	82.609	83.133	83.657	84.181	84.705	85.229	85.753	86.277	86.801	87.325	87.849	88.373	88.897	89.421	89.945	90.469	90.993	91.517	92.041	92.565	93.089	93.613	94.137	94.661	95.185	95.709	96.233	96.757	97.281	97.805	98.329	98.853	99.377	99.901	100.425	100.949	101.473	101.997	102.521	103.045	103.569	104.093	104.617	105.141	105.665	106.189	106.713	107.237	107.761	108.285	108.809	109.333	109.857	110.381	110.905	111.429	111.953	112.477	112.999	113.523	114.047	114.571	115.095	115.619	116.143	116.667	117.191	117.715	118.239	118.763	119.287	119.811	120.335	120.859	121.383	121.907	122.431	122.955	123.479	124.003	124.527	125.051	125.575	126.099	126.623	127.147	127.671	128.195	128.719	129.243	129.767	130.291	130.815	131.339	131.863	132.387	132.911	133.435	133.959	134.483	135.007	135.531	136.055	136.579	137.103	137.627	138.151	138.675	139.199	139.723	140.247	140.771	141.295	141.819	142.343	142.867	143.391	143.915	144.439	144.963	145.487	146.011	146.535	147.059	147.583	148.107	148.631	149.155	149.679	150.203	150.727	151.251	151.775	152.299	152.823	153.347	153.871	154.395	154.919	155.443	155.967	156.491	157.015	157.539	158.063	158.587	159.111	159.635	160.159	160.683	161.207	161.731	162.255	162.779	163.303	163.827	164.351	164.875	165.399	165.923	166.447	166.971	167.495	168.019	168.543	169.067	169.591	170.115	170.639	171.163	171.687	172.211	172.735	173.259	173.783	174.307	174.831	175.355	175.879	176.403	176.927	177.451	177.975	178.499	179.023	179.547	180.071	180.595	181.119	181.643	182.167	182.691	183.215	183.739	184.263	184.787	185.311	185.835	186.359	186.883	187.407	187.931	188.455	188.979	189.503	190.027	190.551	191.075	191.599	192.123	192.647	193.171	193.695	194.219	194.743	195.267	195.791	196.315	196.839	197.363	197.887	198.411	198.935	199.459	200.000	200.524	201.048	201.572	202.096	202.620	203.144	203.668	204.192	204.716	205.240	205.764	206.288	206.812	207.336	207.860	208.384	208.908	209.432	209.956	210.480	211.004	211.528	212.052	212.576	213.100	213.624	214.148	214.672	215.196	215.720	216.244	216.768	217.292	217.816	218.340	218.864	219.388	219.912	220.436	220.960	221.484	222.008	222.532	223.056	223.580	224.104	224.628	225.152	225.676	226.200	226.724	227.248	227.772	228.296	228.820	229.344	229.868	230.392	230.916	231.440	231.964	232.488	233.012	233.536	234.060	234.584	235.108	235.632	236.156	236.680	237.204	237.728	238.252	238.776	239.300	239.824	240.348	240.872	241.396	241.920	242.444	242.968	243.492	244.016	244.540	245.064	245.588	246.112	246.636	247.160	247.684	248.208	248.732	249.256	249.780	250.304	250.828	251.352	251.876	252.400	252.924	253.448	253.972	254.496	255.020	255.544	256.068	256.592	257.116	257.640	258.164	258.688	259.212	259.736	260.260	260.784	261.308	261.832	262.356	262.880	263.404	263.928	264.452	264.976	265.500	266.024	266.548	267.072	267.596	268.120	268.644	269.168	269.692	270.216	270.740	271.264	271.788	272.312	272.836	273.360	273.884	274.408	274.932	275.456	275.980	276.504	277.028	277.552	278.076	278.600	279.124	279.648	280.172	280.696	281.220	281.744	282.268	282.792	283.316	283.840	284.364	284.888	285.412	285.936	286.460	286.984	287.508	288.032	288.556	289.080	289.604	290.128	290.652	291.176	291.700	292.224	292.748	293.272	293.796	294.320	294.844	295.368	295.892	296.416	296.940	297.464	297.988	298.512	299.036	299.560	300.084	300.608	301.132	301.656	302.180	302.704	303.228	303.752	304.276	304.800	305.324	305.848	306.372	306.896	307.420	307.944	308.468	308.992	309.516	310.040	310.564	311.088	311.612	312.136	312.660	313.184	313.708	314.232	314.756	315.280	315.804	316.328	316.852	317.376	317.900	318.424	318.948	319.472	320.000	320.524	321.048	321.572	322.096	322.620	323.144	323.668	324.192	324.716	325.240	325.764	326.288	326.812	327.336	327.860	328.384	328.908	329.432	329.956	330.480	331.004	331.528	332.052	332.576	333.100	333.624	334.148	334.672	335.196	335.720	336.244	336.768	337.292	337.816	338.340	338.864	339.388	339.912	340.436	340.960	341.484	342.008	342.532	343.056	343.580	344.104	344.628	345.152	345.676	346.200	346.724	347.248	347.772	348.296	348.820	349.344	349.868	350.392	350.916	351.440	351.964	352.488	353.012	353.536	354.060	354.584	355.108	355.632	356.156	356.680	357.204	357.728	358.252	358.776	359.300	359.824	360.348	360.872	361.396	361.920	362.444	362.968	363.492	364.016	364.540	365.064	365.588	366.112	366.636	367.160	367.684	368.208	368.732	369.256	369.780	370.304	370.828	371.352	371.876	372.400	372.924	373.448	373.972	374.496	375.020	375.544	376.068	376.592	377.116	377.640	378.164	378.688	379.212	379.736	380.260	380.784	381.308	381.832	382.356	382.880	383.404	383.928	384.452	384.976	385.500	386.024	386.548	387.072	387.596	388.120	388.644	389.168	389.692	390.216	390.740	391.264	391.788	392.312	392.836	393.360	393.884	394.408	394.932	395.456	395.980	396.504	397.028	397.552	398.076	398.600	399.124	399.648	400.172	400.696	401.220	401.744	402.268	402.792	403.316	403.840	404.364	404.888	405.412	405.936	406.460	406.984	407.508	408.032	408.556	409.080	409.604	410.128	410.652	411.176	411.700	412.224	412.748	413.272	413.796	414.320	414.844	415.368	415.892	416.416	416.940	417.464	417.988	418.512	419.036	419.560	420.084	420.608	421.132	421.656	422.180	422.704	423.228	423.752	424.276	424.800	425.324	425.848	426.372	426.896	427.420	427.944	428.468	428.992	429.516	430.040	430.564	431.088	431.612	432.136	432.660	433.184	433.708	434.232	434.756	435.280	435.804	436.328	436.852	437.376	437.900	438.424	438.948	439.472	440.000	440.524	441.048	441.572	442.096	442.620	443.144	443.668	444.192	444.716	445.240	445.764	446.288	446.812	447.336	447.860	448.384	448.908	449.432	449.956	450.480	451.004	451.528	452.052	452.576	453.100	453.624	454.148	454.672	455.196	455.720	456.244	456.768	457.292	457.816	458.340	458.864	459.388	459.912	460.436	460.960	461.484	462.008	462.532	463.056	463.580	464.104	464.628	465.152	465.676	466.200	466.724	467.248	467.772	468.296	468.820	469.344	469.868	470.392	470.916	471.440	471.964	472.488	473.012	473.536	474.060	474.584	475.108	475.632	476.156	476.680	477.204	477.728	47

PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

Ti-6Al-4V,  
90 split, open,  
70 ksi

TEST 4A1 SPECIMEN 623080 DATE 10/3/73

**SPECIMEN DESCRIPTION**  
 Configuration Fig. 2  
 Material Ti-6Al-4V (annealed)  
 Width (in.) 1.50  
 Hole spacing 1.50  
 Edge margin (in.) 0.75  
 Material gauge (in.) 0.250  
 Surface treatment Shot peen

**COLDWORK PROCESS**  
 Interference 0.019  
 Sleeve type Split  
 Sleeve thickness (in.) 0.010  
 Sleeve orientation 89  
 Mandrel material AISI 9260 steel  
 Mandrel taper (in/in) 0.045  
 Mandrel max diameter (in.) 0.353  
 Lubrication Fel Pro 300

**HOLE PREPARATION**  
 Nominal hole size (in.) 0.375  
 Process Ream, C/W, ream

**FASTENER INSTALLATION**  
 Type \_\_\_\_\_  
 Fit \_\_\_\_\_  
 Torque (in. lb) \_\_\_\_\_

**FATIGUE CONDITIONS**  
 Max net stress (ksi) 70  
 Max test load (kip) 20.8  
 Load ratio (R) 0.1  
 Test frequency 4000 cpm  
 Test laboratory Materials  
 Test engineer D. Reese  
 Test machine 36 kip Vibraphore

Specimen dash no	Hole no	Hole diameter (in.)		Hole finish (RHR)		Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After ream	Before coldwork	After ream	Actual	Retained	Diameter	Fit		
1	1	0.3550	0.3640	30	25	0.0180	0.0090	0.0180	0.0090	179,000	
	2	0.3550	0.3640	-	-	0.0180	0.0090	-	-		
2	1	0.3550	0.3640	35	25	0.0180	0.0090	0.0180	0.0090	87,000	
	2	0.3550	0.3640	-	-	0.0180	0.0090	-	-		
3	1	0.3550	0.3640	30	25	0.0180	0.0090	0.0180	0.0090	79,000	
	2	0.3550	0.3640	-	-	0.0180	0.0090	-	-		
4	1	0.3550	0.3640	30	25	0.0180	0.0090	0.0180	0.0090	79,000	
	2	0.3550	0.3640	-	-	0.0180	0.0090	-	-		
3	1	0.3550	0.3640	30	25	0.0180	0.0090	0.0180	0.0090	79,000	
	2	0.3550	0.3640	-	-	0.0180	0.0090	-	-		
4	1	0.3550	0.3640	30	25	0.0180	0.0090	0.0180	0.0090	79,000	
	2	0.3550	0.3640	-	-	0.0180	0.0090	-	-		



PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

Ti-6Al-4V,  
C/W, drilled hole,  
70 ksi

TEST: 4A2 (T) SPECIMEN: 623080 DATE: 10/16/73

<b>SPECIMEN DESCRIPTION</b>	<b>COLDWORK PROCESS</b>	<b>HOLE PREPARATION</b>	<b>FATIGUE CONDITIONS</b>
Configuration: Fig. 2	Interference (in.): 0.019	Nominal hole size (in.): 0.375	Max net stress (ksi): 70
Material: Ti-6Al-4V (annealed)	Sleeve type: Split	Process: Drill (good), C/W, ream	Max test load (kip): 20.5
Width (in.): 1.50	Sleeve thickness (in.): 0.010		Load ratio (R): 0.1
Hole spacing (in.): 1.50	Sleeve orientation: 0°		Test frequency: 4000 cpm
Edge margin (in.): 0.75	Mandrel material: AISI 9260 steel	<b>FASTENER INSTALLATION</b>	Test laboratory: Materials
Material gauge (in.): 0.250	Mandrel taper (in./in.): 0.045	Type: _____	Test engineer: D. Reese
Surface treatment: Shot peen	Mandrel max diameter (in.): 0.353	Fit: _____	Test machine: 36-kip Vibrator
	Lubrication: Fel Pro 300	Torque (in. lb): _____	

Specimen dash no	Hole no	Hole diameter (in.)		Hole finish (RHR)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
4	1	0.3550	0.3750	55	30	30	0.0180	0.0100			63,000	
	2	0.3550	0.3750	-	-	-	-	0.0100				
	3											
	4											
5	1	0.3550	0.3750	55	30	30	0.0180	0.0100			66,000	
	2	0.3555	0.3750	-	-	-	-	0.0095				
	3											
	4											
6	1	0.3550	0.3750	55	30	30	0.0180	0.0100			66,000	
	2	0.3550	0.3750	-	-	-	-	0.0100				
	3											
	4											

PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

Ti-6Al-6V,  
C/W, abusively drilled hole,  
70 ksi

TEST 4A3 (T) SPECIMEN 623080 DATE 10/16/73

FATIGUE CONDITIONS  
 Max net stress (ksi): 70  
 Max test load (kip): 20.5  
 Load ratio (R): 0.1  
 Test frequency: 4000 gpm  
 Test laboratory: Materials  
 Test engineer: D. Reese  
 Test machine: 36-kip Vibraphore

HOLE PREPARATION  
 Nominal hole size (in): 0.375  
 Process: Drill (abusively) C/W, ream

COLDWORK PROCESS  
 Interference (in.): 0.019  
 Sleeve type: Split  
 Sleeve thickness (in): 0.010  
 Sleeve orientation: 0°  
 Mandrel material: AISI 9260 steel  
 Mandrel taper (in/in): 0.045  
 Mandrel max diameter (in): 0.353  
 Lubrication: Fel Pro 300

FASTENER INSTALLATION  
 Type: \_\_\_\_\_  
 Fit: \_\_\_\_\_  
 Torque (in lb): \_\_\_\_\_

SPECIMEN DESCRIPTION

Fig. 2  
 Configuration: Ti-6Al-4V (annealed)  
 Material: Ti-6Al-4V (annealed)  
 Width (in): 1.50  
 Hole spacing (in.): 1.50  
 Edge margin (in.): 0.75  
 Material gauge (in.): 0.250  
 Surface treatment: Shot peen

Specimen dash no	Hole no	Hole diameter (in)		Hole finish (RHR)			Coldwork expansion (in)		Fastener size (in)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	F-it		
7	1	0.3565	0.3655	65	40	30	0.0165	0.0090			47,000	
	2	0.3570	0.3660				0.0160	0.0090				
	3											
	4											
8	1	0.3570	0.3655	65	45	30	0.0160	0.0085			43,000	
	2	0.3570	0.3655	70			0.0160	0.0085				
	3											
	4											
9	1	0.3580	0.3660	75	45	30	0.0150	0.0080			54,000	
	2	0.3590	0.3660				0.0140	0.0070				
	3											
	4											

PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

T<sub>1</sub>-6A1-4V,  
C/W open,  
no postream,  
70 ksi

TEST 4A4 SPECIMEN 623080 DATE 10/3/73

SPECIMEN DESCRIPTION		COLDWORK PROCESS		HOLE PREPARATION		FATIGUE CONDITIONS	
Configuration	Fig. 2	Interference (in.)	0.019	Nominal hole size (in.)	0.375	Max net stress (ksi)	70
Material	T <sub>1</sub> -6A1-4V (annealed)	Sleeve type	Split	Process	Ream, C/W	Max test load (kip)	20.5
Width (in.)	1.50	Sleeve thickness (in.)	0.010			Load ratio (R)	0.1
Hole spacing (in.)	1.50	Sleeve orientation	0°			Test frequency	4000 cpm
Edge margin (in.)	0.75	Mandrel material	AISI 9260 steel	FASTENER INSTALLATION		Test laboratory	Materials
Material gage (in.)	0.250	Mandrel taper (in/in)	0.045	Type		Test engineer	D. Reese
Surface treatment	Shot peen	Mandrel max diameter (in.)	0.353	Fit		Test machine	36-kip Vibraphore
		Lubrication	Fel Pro 300	Torque (in. lb)			

Specimen dash no	Hole no	Hole diameter (in.)		Hole finish (RHRI)		Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After ream	Before coldwork	After coldwork	Actual	Retained	Diameter	Fit		
10	1	0.3540	0.3745	35	20	0.0190	0.0090			79,000	
	2	0.3540	0.3745	-	-	0.0190	0.0090				
	3										
	4										
11	1	0.3540	0.3745	35	20	0.0190	0.0090			88,000	
	2	0.3540	0.3745	-	-	0.0190	0.0090				
	3										
	4										
12	1	0.3540	0.3745	35	20	0.0190	0.0090			82,000	
	2	0.3540	0.3745	-	-	0.0190	0.0090				
	3										
	4										

PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

Ti-6Al-4V,  
C/W open,  
scored,  
70 ksi

TEST 4A5 SPECIMEN 623080 DATE 10/3/73

SPECIMEN DESCRIPTION		COLL WORK PROCESSES		HOLE PREPARATION		FATIGUE CONDITIONS	
Configuration	Fig. 2	Interference (in.)	0.019	Nominal hole size (in.)	0.375	Max net stress (ksi)	70
Material	Ti-6Al-4V (annealed)	Sleeve type	Split	Process	Ream, C/W, ream score, one hole	Max test load (kip)	20.4
Width	1.50	Sleeve thickness (in.)	0.010			Load ratio (R)	0.1
Hole spacing (in.)	1.50	Sleeve orientation	0°			Test frequency	4000 cpm
Edge margin (in.)	0.75	Mandrel material	AISI 9260 steel	FASTENER INSTALLATION		Test laboratory	Materials
Material type (in.)	0.250	Mandrel taper (in./in.)	0.045	Type		Test engineer	D. Reese
Surface treatment	Shot peen	Mandrel max diameter (in.)	0.353	Fit		Test machine	36-kip vibraphore
		Lubrication	Fel Pro 300	Torque (in. lb)			

Specimen dash no	Hole no	Hole diameter (in.)			Hole finish (RHRI)		Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After ream	After coldwork	Before coldwork	After ream	Actual	Retained	Diameter	Fit		
13	1	0.3540	0.3630	0.3745	35	20	35	0.0190	0.0090		85,000	
	2	0.3540	0.3630	0.3745				0.0190	0.0090			
	3											
	4											
14	1	0.3540	0.3635	0.3745	35	20	35	0.0190	0.0095		72,000	
	2	0.3540	0.3635	0.3745				0.0190	0.0095			
	3											
	4											
15	1	0.3540	0.3630	0.3745	35	20	35	0.0190	0.0090		76,000	
	2	0.3540	0.3630	0.3745				0.0190	0.0090			
	3											
	4											

PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

T1-6A1-4V,  
open, 1/64 postream,  
70 ksi

TEST 4A6 SPECIMEN 623080 DATE 10/12/73

**SPECIMEN DESCRIPTION**  
 Configuration Fig. 2  
 Material T1-6A1-4V (annealed)  
 Width (in.) 1.50  
 Hole spacing (in.) 1.50  
 Edge margin (in.) 0.75  
 Material gauge (in.) 0.250  
 Surface treatment Shot peen

**COLDWORK PROCESS**  
 Interference (in.) 0.019  
 Sleeve type Split  
 Sleeve thickness (in.) 0.010  
 Sleeve orientation 0°  
 Mandrel material AISI 9260 steel  
 Mandrel taper (in./in.) 0.045  
 Mandrel max diameter (in.) 0.353  
 Lubrication Fel Pro 300

**HOLE PREPARATION**  
 Nominal hole size (in.) 0.375  
 Process Ream, C/W, ream, 1/64-oversize

**FASTENER INSTALLATION**  
 Type \_\_\_\_\_  
 Fit \_\_\_\_\_  
 Torque (in. lb) \_\_\_\_\_

**FATIGUE CONDITIONS**  
 Max net stress (ksi) 70  
 Max test load (kip) 20.2  
 Load ratio (R) 0.1  
 Test frequency 4000 cpm  
 Test laboratory Materials  
 Test engineer D. Reese  
 Test machine 36-kip Vibraphore

Specimen tag no.	Hole diameter (in.)				Hole finish (RHR)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
	Before coldwork	After coldwork	After ream	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
.16	1	0.3540	0.3635	0.3900	35	20	40	0.019	0.0095			61,000	
	2	0.3540	0.3635	0.3900				0.019	0.0095				
	3												
	4												
.17	1	0.3540	0.3630	0.3900	35	20	45	0.019	0.0090			64,000	
	2	0.3540	0.3630	0.3900				0.019	0.0090				
	3												
	4												
.18	1	0.3540	0.3635	0.3900	35	15	45	0.019	0.0095			64,000	
	2	0.3540	0.3635	0.3900				0.019	0.0095				
	3												
	4												

PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

Ti-6Al-4V,  
open, 1/32-postream,  
70 ksi

TEST 4A7 SPECIMEN 623080 DATE 10/12/73

**SPECIMEN DESCRIPTION**  
 Configuration Fig. 2  
 Material Ti-6Al-4V (annealed)  
 Width (in.) 1.50  
 Hole spacing (in.) 1.50  
 Edge margin (in.) 0.75  
 Material gage (in.) 0.250  
 Surface treatment Shot peen

**COLDWORK PROCESS**  
 Interference (in.) 0.019  
 Sleeve type Split  
 Sleeve thickness (in.) 0.010  
 Sleeve orientation 0°  
 Mandrel material AISI 9760 steel  
 Mandrel taper (in./in.) 0.045  
 Mandrel max diameter (in.) 0.353  
 Lubrication Fel Pro 300

**HOLE PREPARATION**  
 Nominal hole size (in.) 0.375  
 Process Ream, C/W, ream, 1/32 oversize

**FASTENER INSTALLATION**  
 Type \_\_\_\_\_  
 Fit \_\_\_\_\_  
 Torque (in. lb) \_\_\_\_\_

**FATIGUE CONDITIONS**  
 Max net stress (ksi) 70  
 Max test load (kip) 20  
 Load ratio (R) 0.1  
 Test frequency 4000 cpm  
 Test laboratory Materials  
 Test engineer D. Reese  
 Test machine 36 kip Vibraphore

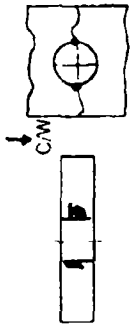
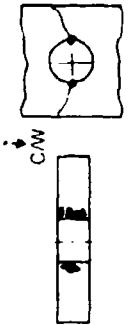
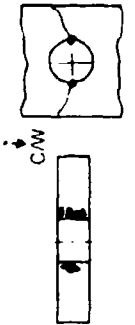
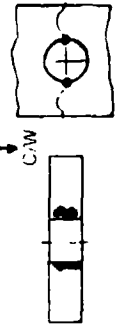
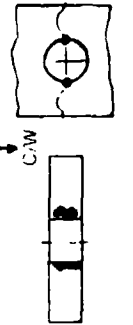

Specimen depth no.	Hole diameter (in.)			Hole finish (RH/RL)		Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
	Before coldwork	After ream	After coldwork	Before coldwork	After ream	Actual	Retained	Diameter	Fit		
19	1	0.3540	0.3630	0.4065	20	30	0.019	0.0090		54,000	
	2	0.3540	0.3630	0.4065	-	-	0.019	0.0090			
	3										
	4										
20	1	0.3540	0.3630	0.4065	15	30	0.019	0.0090		76,000	
	2	0.3540	0.3630	0.4065	-	-	0.019	0.0090			
	3										
	4										
21	1	0.3540	0.3635	0.4065	15	30	0.019	0.0095		67,000	
	2	0.3540	0.3635	0.4065	-	-	0.019	0.0095			
	3										
	4										

PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

Ti 6Al4V,  
open, 1/16-postream,  
70 ksi

TEST 4A8 SPECIMEN 623080 DATE 10/12/73

SPECIMEN DESCRIPTION		COLDWORK PROCESS		HOLE PREPARATION		FATIGUE CONDITIONS	
Configuration	Fig. 2	Interference (in.)	0.019	Nominal hole size (in.)	0.375	Max net stress (ksi)	70
Material	Ti 6Al4V (annealed)	Sleeve type	Split	Process	Ream, C/W, ream	Max rest load (kip)	19.4
Width (in.)	1.50	Sleeve thickness (in.)	0.010		1/16 oversize	Load ratio (R)	0.1
Hole spacing (in.)	1.50	Sleeve orientation	0°			Test frequency	4000 cpm
Edge margin (in.)	0.75	Mandrel material	AISI 9260 steel	FASTENER INSTALLATION		Test laboratory	Materials
Material gage (in.)	0.250	Mandrel taper (in./in.)	0.045	Type		Test engineer	D. Reese
Surface treatment	Shot peen	Mandrel max diameter (in.)	0.353	Fit		Test machine	36-kip Vibraphore
		Lubrication	Fel Pro 300	Torque (in. lb)			

Specimen dash no.	Hole no.	Hole diameter (in.)			Hole finish (RHR)		Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	Actual	Retained	Diameter	F-1		
22	1	0.3540	0.3630	0.4380	35	25	45	0.019	0.0090		62,000	
	2	0.3540	0.3630	0.4380	-	-	-	0.019	0.0090			
	3											
	4											
23	1	0.3540	0.3630	0.4380	35	20	45	0.019	0.0090		67,000	
	2	0.3540	0.3630	0.4380	-	-	-	0.019	0.0090			
	3											
	4											
24	1	0.3540	0.3630	0.4380	35	20	45	0.019	0.0090		54,000	
	2	0.3540	0.3630	0.4380	-	-	-	0.019	0.0090			
	3											
	4											

PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

Ti-6Al 4V  
square wire sleeve,  
70 ksi

TEST 4A9 SPECIMEN 623080 DATE 10/12/73

SPECIMEN DESCRIPTION		COLDWORK PROCESS		HOLE PREPARATION		FATIGUE CONDITIONS	
Configuration	Fig. 2	Interference (in.)	0.019	Nominal hole size (in.)	0.375	Max net stress (ksi)	70
Material	Ti 6Al 4V (annealed)	Sleeve type	Square wire	Process	Ream, C/W, ream	Max test load (lb)	Not tested
Width (in.)	1.50	Sleeve thickness (in.)	0.018			Load ratio (R)	0.1
Hole spacing (in.)	1.50	Sleeve orientation	-			Test frequency	Not tested
Edge margin (in.)	0.75	Mandrel material	AISI 9260 steel	FASTENER INSTALLATION		Test laboratory	Not tested
Material grade (in.)	0.250	Mandrel taper (in/in)	0.045	Type		Test engineer	Not tested
Surface treatment	Shot peen	Mandrel max diameter (in.)	0.353	Fit		Test machine	Not tested
		Lubrication	Fel-Pro 300	Torque (in lb)			

Specimen dash no	Hole no	Hole diameter (in.)		Hole finish (RHRI)		Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	Before coldwork	After coldwork	Actual	Retained	Diameter	Fit		
25	1	0.3715		30							Coldwork specimen
	2	0.3715									
	3										
	4										
26	1	0.3715		30							Square wire sleeve tripled in coldwork specimen
	2	0.3715									
	3										
	4										
27	1	0.3715		35							Not completed
	2	0.3715									
	3										
	4										



Ti-6Al-4V,  
0.060-in. gage mtI  
70 ksi

PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

TEST 481 SPECIMEN 623080 DATE 10/3/73

**SPECIMEN DESCRIPTION**  
 Configuration Fig. 2  
 Material Ti-6Al-4V (annealed)  
 Width (in.) 1.50  
 Hole spacing (in.) 1.50  
 Edge margin (in.) 0.75  
 Material gage (in.) 0.060  
 Surface treatment Shot peen

**COI DWORK PROCESS**  
 Interference (in.) 0.019  
 Sleeve type Split  
 Sleeve thickness (in.) 0.010  
 Sleeve orientation 0°  
 Mandrel material AISI 9260 steel  
 Mandrel taper (in./in.) 0.045  
 Mandrel max diameter (in.) 0.353  
 Lubrication Fel Pro 300

**HOLE PREPARATION**  
 Nominal hole size (in.) 0.375  
 Process Ream, C/W, ream

**FASTENER INSTALLATION**  
 Type \_\_\_\_\_  
 Fit \_\_\_\_\_  
 Torque (in.-lb) \_\_\_\_\_

**FATIGUE CONDITIONS**  
 Max net stress (ksi) 70  
 Max test load (kip) 4.9  
 Load ratio (R) 0.1  
 Test frequency 4000 cpm  
 Test laboratory Materials  
 Test engineer D. Reese  
 Test machine 36-kip Vibraphore

Specimen tag no.	Hole no.	Hole diameter (in.)		Hole finish (RHR)		Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After ream	Before coldwork	After coldwork	Actual	Reamnet	Diameter	Fit		
28	1	0.3545	0.3745	25	15	25	0.0185	0.0080		61,000	
	2	0.3545	0.3745				0.0185	0.0080			
	3										
	4										
29	1	0.3545	0.3745	25	10	25	0.0185	0.0080		50,000	
	2	0.3545	0.3745				0.0185	0.0080			
	3										
	4										
30	1	0.3545	0.3745	25	15	25	0.0185	0.0085		61,000	
	2	0.3545	0.3745				0.0185	0.0085			
	3										
	4										

Ti-6Al-4V  
one hole, C/W,  
70 ksi

PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

TEST 4C1 SPECIMEN 623080 DATE 10/4/73

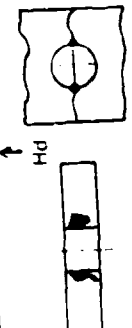
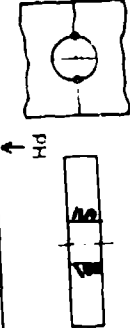
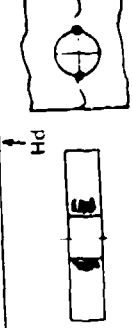
FATIGUE CONDITIONS  
 Max net stress (ksi) 70  
 Max test load (kip) 20.5  
 Load ratio (R) 0.1  
 Test frequency 4000 cpm  
 Test laboratory Materials  
 Test engineer D. Reese  
 Test machine 36 Vibraphore

HOLE PREPARATION  
 Nominal hole size (in) 0.375  
 Process Ream one hole,  
ream, C/W, ream one hole

FASTENER INSTALLATION  
 Type Hi-Lok, pilot hd  
 Fit Net to 0.0005 clearance  
 Torque (in-lb) 240.250

COLDWORK PROCESS  
 Interference (in.) 0.019  
 Sleeve type Split  
 Sleeve thickness (in) 0.010  
 Sleeve orientation 0°  
 Mandrel material AISI 9260 steel  
 Mandrel taper (in/in) 0.045  
 Mandrel max diameter (in) 0.353  
 Lubrication Fel Pro 300

SPECIMEN DESCRIPTION  
 Configuration Fig. 2  
 Material Ti-6Al-4V (annealed)  
 Width (in) 1.50  
 Hole spacing (in.) 1.50  
 Edge margin (in) 0.75  
 Material gauge (in) 0.250  
 Surface treatment Shot peen

Specimen dash no	Hole no	Hole diameter (in)				Hole finish (RHRI)			Coldwork expansion (in)		Fastener size (in)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After margin	After ream	After coldwork	Before coldwork	After coldwork	Actual	Retained	Diameter	Fit			
31	1	0.3540	0.3635	0.3745	35	20	30	0.0190	0.0095	0.3740	0.3740	119,000	 Failed in reamed hole	
	2	-	-	0.3745	-	-	-	-	-	0.3740	0.0005	-		
	3	-	-	-	-	-	-	-	-	-	-	-		
	4	-	-	-	-	-	-	-	-	-	-	-		
32	1	0.3540	0.3635	0.3745	35	20	25	0.0190	0.0095	0.3740	0.0005	77,000	 Failed in reamed hole	
	2	-	-	0.3745	-	-	-	-	-	0.3740	0.0005	-		
	3	-	-	-	-	-	-	-	-	-	-	-		
	4	-	-	-	-	-	-	-	-	-	-	-		
33	1	0.3540	0.3635	0.3745	35	20	25	0.0190	0.0095	0.3740	0.0005	1,286,000	 Failed in reamed hole	
	2	-	-	0.3745	-	-	-	-	-	0.3740	0.0005	-		
	3	-	-	-	-	-	-	-	-	-	-	-		
	4	-	-	-	-	-	-	-	-	-	-	-		

T1-6A1-4V,  
 C/W, 0.002 clearance Hi-Lok,  
 70 ksi

**PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS**

TEST 4C2 SPECIMEN 623080 DATE 10/15/73

<b>SPECIMEN DESCRIPTION</b> Configuration <u>Fig. 2</u> Material <u>T1-6A1-4V (annealed)</u> Width (in.) <u>1.50</u> Hole spacing (in.) <u>1.50</u> Edge margin (in.) <u>0.075</u> Material gauge (in.) <u>0.250</u> Surface treatment <u>Shot peen</u>	<b>COLDWORK PROCESS</b> Interference (in.) <u>0.019</u> Sleeve type <u>Split</u> Sleeve thickness (in.) <u>0.010</u> Sleeve orientation <u>0°</u> Mandrel material <u>AISI 9260 steel</u> Mandrel taper (in./in.) <u>0.045</u> Mandrel max diameter (in.) <u>0.353</u> Lubrication <u>Fel Pro 300</u>	<b>HOLE PREPARATION</b> Nominal hole size (in.) <u>0.375</u> Process <u>Ream, C/W, ream</u> <b>FASTENER INSTALLATION</b> Type <u>Hi-Lok, prot hd</u> F <sub>1</sub> (in.) <u>0.002 clearance</u> Torque (in. lb) <u>240-250</u>
<b>FATIGUE CONDITIONS</b>		
Max net stress (ksi)	<u>70</u>	
Max test load (kip)	<u>20.5</u>	
Load ratio (R)	<u>0.1</u>	
Test frequency	<u>4000 cpm</u>	
Test laboratory	<u>Materials</u>	
Test engineer	<u>D. Reese</u>	
Test machine	<u>36 Vibrephore</u>	

Specimen dash no	Hole no	Hole diameter (in.)		Hole finish (RHRI)		Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After ream	Before coldwork	After coldwork	Actual	Retained	Diameter	Fit		
34	1	0.3540	0.3755	35	15	0.0190	0.0110	0.3735	0.002	153,000	
	2	0.3540	0.3755	-	-	-	0.0110	0.3735	0.002		
	3										
	4										
35	1	0.3560	0.3755	35	15	0.0190	0.0105	0.3735	0.002	226,000	
	2	0.3560	0.3755				0.0105	0.3735	0.002		
	3										
	4										
36	1	0.3560	0.3755	35	15	0.0190	0.100	0.3735	0.002	179,000	
	2	0.3560	0.3755				0.0095	0.3735	0.002		
	3										
	4										

PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

Ti-6Al-4V  
C/W, 0.002 interference, Hi-Lok  
70 ksi

TEST 4C3 SPECIMEN 623080 DATE 10/15/73

SPECIMEN DESCRIPTION

Fig. 2  
Configuration Ti-6Al-4V (annealed)  
Material Ti-6Al-4V (annealed)  
Width (in.) 1.50  
Hole spacing (in.) 1.50  
Edge margin (in.) 0.75  
Material grade (in.) 0.250  
Surface treatment Shot peen

COLDWORK PROCESS

Interference (in.) 0.019  
Sleeve type Split  
Sleeve thickness (in.) 0.010  
Sleeve orientation 0°  
Mandrel material AISI 9260 steel  
Mandrel taper (in./in.) 0.045  
Mandrel max diameter (in.) 0.353  
Lubrication Fel Pro 300

HOLE PREPARATION

Normal hole size (in.) 0.375  
Process Ream, C/W, ream  
FASTENER INSTALLATION  
Type Hi-Lok prot hd  
Fit (in.) 0.002 interference  
Torque (in. lb) 240-250

FATIGUE CONDITIONS

Max net stress (ksi) 70  
Max test load (kip) 20.2  
Load ratio (R) 0.1  
Test frequency 4000 cpm  
Test laboratory Materials  
Test engineer D. Reese  
Test machine 36 Vitraphore

Specimen dash no	Hole no	Hole diameter (in.)		Hole finish (IRHR)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
37	1	0.3540	0.3715	35	15	30	0.0190	0.0110	0.3735	0.002	4,421,000	
	2	0.3540	0.3715	-	-	-	0.0190	0.0100	0.3735	0.002		
	3											
	4											
38	1	0.3540	0.3715	35	15	30	0.0190	0.0100	0.3735	0.002	6,836,000	
	2	0.3540	0.3715	-	-	-	0.0190	0.0100		0.002		
	3											
	4											
39	1	0.3540	0.3715	35	15	40	0.0190	0.0100	0.3735	0.002	824,000	
	2	0.3540	0.3715	-	-	-	0.0190	0.0110		0.002		
	3											
	4											

PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

Ti 6Al-4V  
100° csk after C/W  
70 ksi

TEST 4C4 SPECIMEN 623080 DATE 10/17/73

**SPECIMEN DESCRIPTION**  
 Configuration Fig. 2  
 Material Ti 6Al-4V (annealed)  
 Width (in.) 1.50  
 Hole spacing (in.) 1.50  
 Edge margin (in.) 0.75  
 Material gage (in.) 0.250  
 Surface treatment Shot peen

**COLDWORK PROCESS**  
 Interference (in.) 0.019  
 Sleeve type split  
 Sleeve thickness (in.) 0.010  
 Sleeve orientation 0°  
 Mandrel material AISI 9260 steel  
 Mandrel taper (in./in.) 0.045  
 Mandrel max diameter (in.) 0.353  
 Lubrication Fel Pro 300

**HOLE PREPARATION**  
 Nominal hole size (in.) 0.375  
 Process C/W, ream, csk

**FASTENER INSTALLATION**  
 Type Hi-Lok 100-hd  
 Fit (in.) Net to 0.0005 clearance  
 Torque (in. lb) 240-250

**FATIGUE CONDITIONS**  
 Max net stress (ksi) 70  
 Max test load (kip) 20.5  
 Load ratio (R) 0.1  
 Test frequency 4000 cpm  
 Test laboratory Materials  
 Test engineer D. Reese  
 Test machine 36-kip Vibraphore

Specimen dash no.	Hole no.	Hole diameter (in.)		Hole finish (Ra/Rz)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
40	1	0.3545	0.3630	35	20	30	0.0185	0.0085	0.3745	0.0005	217,000	
	2	0.3545	0.3630	-	-	-	0.0185	0.0085	0.3745	0.0005		
	3											
	4											
41	1	0.3545	0.3630	35	20	30	0.0185	0.0085	0.3745	0.0005	212,000	
	2	0.3545	0.3630	-	-	-	0.0185	0.0085	0.3745	0.0005		
	3											
	4											
42	1	0.3545	0.3620	35	20	30	0.0185	0.0075	0.3745	0.0005	483,000	
	2	0.3545	0.3620	-	-	-	0.0185	0.0075	0.3745	0.0005		
	3											
	4											

PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

TEST 4C5 SPECIMEN 623080 DATE 10/17/73

Ti-6Al-4V,  
100° csk before C/W,  
70 ksi

SPECIMEN DESCRIPTION

Configuration Fig. 2  
 Material Ti-6Al-4V (annealed)  
 Width (in.) 1.50  
 Hole spacing (in.) 1.50  
 Edge margin (in.) 0.75  
 Material gauge (in.) 0.250  
 Surface treatment Shot peen

COLDWORK PROCESS

Interference (in.) 0.019  
 Sieve type Split  
 Sieve thickness (in.) 0.010  
 Sieve orientation 0°  
 Mandrel material AISI 9260 steel  
 Mandrel taper (in./in.) 0.045  
 Mandrel max diameter (in.) 0.353  
 Lubrication Fel Pro 300

HOLE PREPARATION

Nominal hole size (in.) 0.375  
 Process Csk, C/W, ream

FATIGUE CONDITIONS

Max net stress (ksi) 70  
 Max test load (kip) 20.1  
 Load ratio (R) 0.1  
 Test frequency 4000 cpm  
 Test laboratory Materials  
 Test engineer D. Reese  
 Test machine 36-kip Vibraphore

FASTENER INSTALLATION

Type Hi-Lok flush hd  
 Fit (in.) Net to 0.0005 clearance  
 Torque (in. lb) 240-250

Specimen dash no	Hole no	Hole diameter (in.)		Hole finish (RHR)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks	
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter			Fit
43	1	0.3550	0.3635	0.3745	30	10	20	0.0180	0.0085	0.3740	0.0005	760,000	
	2	0.3545	0.3635	0.3745	-	-	-	0.0185	0.0090	0.3740	0.0005		
	3												
	4												
44	1	0.3545	0.3635	0.3745	30	10	20	0.0185	0.0090	0.3740	0.0005	757,000	
	2	0.3545	0.3635	0.3745	-	-	-	0.0185	0.0090	0.3740	0.0005		
	3												
	4												
45	1	0.3545	0.3635	0.3745	30	10	20	0.0185	0.0090	0.3740	0.0005	1,064,000	
	2	0.3545	0.3635	0.3745	-	-	-	0.0185	0.0090	0.3740	0.0005		
	3												
	4												

PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

Ti 6Al-4V,  
70° csk after C/W,  
70 ksi

TEST 4C6 SPECIMEN G23080 DATE 10/17/73

**SPECIMEN DESCRIPTION**  
 Configuration Fig. 2  
 Material Ti 6Al 4V (annealed)  
 Width (in.) 1.50  
 Hole spacing (in.) 1.50  
 Edge margin (in.) 0.75  
 Material gauge (in.) 0.250  
 Surface treatment Shot peen

**COLDWORK PROCESS**  
 Interference (in.) 0.019  
 Sleeve type Split  
 Sleeve thickness (in.) 0.010  
 Sleeve or entation 0°  
 Mandrel material AISI 9260 steel  
 Mandrel taper (in./in.) 0.045  
 Mandrel max diameter (in.) 0.353  
 Lubrication Fel Pro 300

**HOLE PREPARATION**  
 Nominal hole size (in.) 0.375  
 Process C/W, ream, csk

**FASTENER INSTALLATION**  
 Type Boeing radius lead-in bolt, 70° hd  
 Fit Net to 0.001 interference  
 Torque (in. lb) 240.250

**FATIGUE CONDITIONS**  
 Max net stress (ksi) 70  
 Max test load (kip) 20.5  
 Load ratio (R) 0.1  
 Test frequency 4000 cpm  
 Test laboratory Materials  
 Test engineer D. Reese  
 Test machine 36-kip Vibraphone

Specimen ID	Hole no	Hole diameter (in.)		Hole finish (RHR)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter		
46	1	0.3545	0.3620	0.3790	35	20	30	0.0185	0.0075	0.3800	0.001	
	2	0.3545	0.3620	0.3790	-	-	-	0.0185	0.0075	0.3800	0.001	
	3											
	4											
47	1	0.3545	0.3625	0.3790	35	20	30	0.0185	0.0080	0.3800	0.001	
	2	0.3545	0.3620	0.3790	-	-	-	0.0185	0.0080	0.3800	0.001	
	3											
	4											
48	1	0.3545	0.3620	0.3790	35	20	30	0.0185	0.0075	0.3800	0.001	
	2	0.3545	0.3620	0.3790	-	-	-	0.0185	0.0075	0.3800	0.001	
	3											
	4											

Ti-6Al-4V,  
prefatigue,  
C/W, net-fit Hi-Lok,  
70 ksi

**PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS**

TEST: 4C7(T) SPECIMEN: 623080 DATE: 11/16/73

**FATIGUE CONDITIONS**  
 Max net stress (ksi) 70  
 Max test load (kip) 20  
 Load ratio (R) 0.1  
 Test frequency 4000 cpm  
 Test laboratory Materials  
 Test engineer D. Reese  
 Test machine 36-kip Vibraphore

**HOLE PREPARATION**  
 Nominal hole size (in.) 0.375  
 Process Ream undersize, install fastener, fatigue 80,000 cycles ream, C/W, ream

**COLDWORK PROCESS**  
 Instrument (in.) 0.019  
 Sleeve type Split  
 Sleeve thickness (in.) 0.010  
 Sleeve orientation 0°  
 Mandrel material AISI 9260 steel  
 Mandrel taper (in./in.) 0.045  
 Mandrel max diameter (in.) 0.353  
 Lubrication Fel Pro 300

**FASTENER INSTALLATION**  
 Type Hi-Lok, prot hd  
 Fit (in.) Net to 0.0005 clearance  
 Torque (in. lb) 240-250

**SPECIMEN DESCRIPTION**  
 Fig. 2  
 Material Ti-6Al-4V (annealed)  
 Width (in.) 1.50  
 Hole spacing (in.) 1.50  
 Edge margin (in.) 0.75  
 Material gauge (in.) 0.250  
 Surface treatment SHOT PEEN

Specimen ID	Hole diameter (in.)				Hole finish (HRH)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
	Before coldwork	After coldwork	After ream	After collwork	Before collwork	After collwork	After ream	Actual	Retained	Diameter	Fit		
49	1												
	2												
	3												
	4												
50	1	0.3540	0.3735	30	15	25	25	0.0190	0.0095	0.3735	Net	708,000	
	2	0.3540	0.3735	-	-	-	-	0.0190	0.0095	0.3735	Net		
	3												
	4												
51	1	0.3540	0.3735	30	15	25	25	0.0190	0.0095	0.3735	Net	431,000	
	2	0.3540	0.3735					0.0190	0.0095	0.3735	Net		
	3												
	4												

49, 50, 51: initial cycling



PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

Ti-6Al-4V,  
precracked,  
C/W, net-fit Hi-Lok,  
70 ksi

TEST 4C8 (T) SPECIMEN 623080 DATE 11/16/73

SPECIMEN DESCRIPTION		COLDWORK PROCESS		HOLE PREPARATION		FATIGUE CONDITIONS	
Configuration	Fig. 2	Interference (in.)	0.019	Nominal hole size (in.)	0.375	Max net stress (ksi)	70
Material	Ti-6Al-4V (annealed)	Sieve type	Split	Process	Ream undersize, notch, fatigue rack, ream, C/W, ream	Max test load (kip)	20
Width (in.)	1.50	Sieve thickness (in.)	0.010	Sieve orientation	0°	Load ratio (R)	0.1
Hole spacing (in.)	1.50	Sieve orientation	0°	FASTENER INSTALLATION		Test frequency	4000 cpm
Edge margin (in.)	0.75	Mandrel material	AISI 9260 steel	Type	Hi-Lok prot hd	Test laboratory	Materials
Material gauge (in.)	0.250	Mandrel taper (in./in.)	0.045	Fit (in.)	Net to 0.0005 clearance	Test engineer	D. Reese
Surface treatment	Shot peen	Mandrel max diameter (in.)	0.353	Torque (in. lb)	240-250	Test machine	36-kip Vibraphore
		Lubrication	F-1 Pro 300				

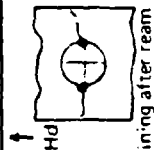
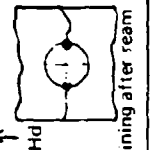
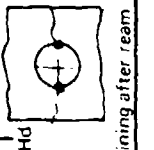
Specimen dash no	Hole no (a)	Hole diameter (in.)		Hole finish (HRH)		Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks	
		Before coldwork	After coldwork	Before coldwork	After ream	Actual	Retained	Diameter	Fit			
52	1	0.3540	0.3635	30	15	25	0.0095	0.0190	0.3735	Net	312,000	 Failed at hole no. 1. 0.020-in crack remaining after ream
	2	0.3540	0.3635	-	-	-	0.0095	0.0190	0.3735	Net		
	3											
	4											
53	1	0.3540	0.3635	30	15	25	0.0095	0.0190	0.3735	Net	92,000	 Failed at hole no. 1, 0.030-in crack remaining after ream
	2	0.3540	0.3635	-	-	-	0.0095	0.0190	0.3735	Net		
	3											
	4											
54	1	0.3540	0.3635	30	15	25	0.0095	0.0190	0.3735	Net	782,000	 Failed at hole no. 2. 0.010-in crack remaining after ream
	2	0.3540	0.3635	-	-	-	0.0095	0.0190	0.3735	Net		
	3											
	4											

Fig. 1. Hole crack.

PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

Ti 6Al4V  
1 1/2 D edge margin,  
open, C/W,  
70 ksi

TEST 4D1(I) SPECIMEN 623080 DATE 10/22/73

**SPECIMEN DESCRIPTION**  
 Configuration Fig. 7A  
 Material Ti 6Al 4V (annealed)  
 Width (in) 3.125  
 Hole spacing (in) 3.50 x 2  
 Edge margin (in) 0.562  
 Spigot radius (in) 0.250  
 Surface treatment Shot peen

**COLDWORK PROCESS**  
 Interference (in) 0.019  
 Sleeve type Split  
 Sleeve thickness (in) 0.010  
 Sleeve orientation 0°  
 Mandrel material ALISI 9260 steel  
 Mandrel taper (in/in) 0.045  
 Mandrel max diameter (in) 0.3530  
 Lubrication Fel Pro 300

**HOLE PREPARATION**  
 Nominal hole size (in) 0.375  
 Process Ream, C/W, ream

**FATIGUE CONDITIONS**  
 Max net stress (ksi) 70  
 Max test load (kip) 41.6  
 Load ratio (R) 0.1  
 Test frequency 4000 cpm  
 Test laboratory Materials  
 Test engineer D. Reese  
 Test machine 100 kip Vibraphore

**FASTENER INSTALLATION**  
 Type \_\_\_\_\_  
 Fit \_\_\_\_\_  
 Torque (in. lb) \_\_\_\_\_

Specimen ID	Hole diameter (in)		Hole depth (HHR)		Coldwork expansion (in)		Fastener size (in)		Cycles to failure	Origin of failure (a) and remarks
	Before coldwork	After ream	Before coldwork	After coldwork	Actual	Retained	Diameter	Fit		
85	1	0.3530	0.3745	15	40	0.0180	0.0095		46,000	
	2	0.3530	0.3745	-	-	0.0180	0.0095			
	3	0.3550	0.3745	25	15	0.0180	0.0095			
	4	0.3550	0.3745	-	-	0.0180	0.0095			
86	1	0.3550	0.3745	15	40	0.0180	0.0095		90,000	
	2	0.3550	0.3745	-	-	0.0180	0.0095			
	3	0.3550	0.3745	25	15	0.0180	0.0095			
	4	0.3550	0.3745	-	-	0.0180	0.0095			
87	1	0.3550	0.3745	15	35	0.0180	0.0095		68,000	
	2	0.3550	0.3745	-	-	0.0180	0.0095			
	3	0.3550	0.3745	30	15	0.0180	0.0095			
	4	0.3550	0.3745	-	-	0.0180	0.0095			




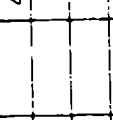
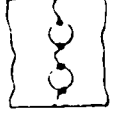


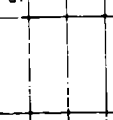
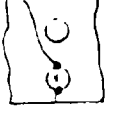
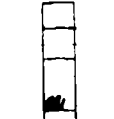

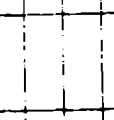
Failure diagrams are not to scale.

PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

Ti-6Al-4V,  
2 D edge margin,  
open, C/W,  
70 ksi

TEST: 4D2 (T) SPECIMEN: 623080 DATE: 10/19/73

SPECIMEN DESCRIPTION		COLDWORK PROCESS		HOLE PREPARATION		FATIGUE CONDITIONS	
Fig. 7B		Interference (in.)		Nominal hole size (in.)		Max net stress (ksi)	
Configuration		0.019	0.375				70
Material	Ti-6Al-4V (annealed)	Split	Ream, C/W, ream				41.5
Width (in.)	3.50	0.010					0.1
Hole spacing (in.)	3.50 x 2.00	0°					4000 cpm
Edge margin (in.)	0.750	AISI 9260 steel	FASTENER INSTALLATION				Materials
Material grade (in.)	0.250	Mandrel material	Type				D. Reese
Surface treatment	Shot peen	Mandrel taper (in/in)	Fit				100 kip Vibraphore
		Mandrel max diameter (in.)	Torque (in lb)				
		0.353	Fel Pro 300				
		Lubrication					

Specimen ID	Hole diameter (in.)				Hole finish (RHR)		Coldwork expansion (in.)		Fatiguer size (in.)		Cycles to failure	Origin of failure and remarks
	End face	Start	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
89	1	0.3550	0.3645	0.3745	35	15	3C	0.0180	0.0085		49,000	
	2	0.3550	0.3645	0.3745	-	-	-	0.0180	0.0085			
	3	0.3550	0.3645	0.3745	30	15	3S	0.0180	0.0085			
	4	0.3550	0.3645	0.3745	-	-	-	0.0180	0.0085			
90	1	0.3550	0.3640	0.3745	30	15	2S	0.0180	0.0090		56,000	
	2	0.3550	0.3640	0.3745	-	-	-	0.0180	0.0090			
	3	0.3550	0.3640	0.3745	35	15	30	0.0180	0.0090			
	4	0.3550	0.3640	0.3745	-	-	-	0.0185	0.0090			
91	1	0.3545	0.3640	0.3745	30	12	2S	0.0185	0.0095		52,000	
	2	0.3545	0.3640	0.3745	-	-	-	0.0185	0.0095			
	3	0.3545	0.3640	0.3745	25	10	30	0.0185	0.0095			
	4	0.3545	0.3640	0.3745	-	-	-	0.0185	0.0095			

PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

TEST 4D3 (T) SPECIMEN 623080 DATE 10/22/73

Ti-6Al-4V,  
2 1/2-D edge margin,  
open, C/W  
70 ksi

**SPECIMEN DESCRIPTION**  
 Configuration Fig. 7C  
 Material Ti-6Al-4V (annealed)  
 Width (in.) 3.875  
 Hole spacing (in.) 3.50 x 2.00  
 Edge margin (in.) 0.937  
 Material gage (in.) 0.250  
 Surface treatment Shot peen

**COLDWORK PROCESS**  
 Interference (in.) 0.019  
 Sleeve type Split  
 Sleeve thickness (in.) 0.010  
 Sleeve orientation 0°  
 Mandrel material AISI 9260 steel  
 Mandrel taper (in./in.) 0.045  
 Mandrel max diameter (in.) 0.353  
 Lubrication Fel Pro 300

**HOLE PREPARATION**  
 Nominal hole size (in.) 0.375  
 Process Ream, C/W, ream

**FASTENER INSTALLATION**  
 Type \_\_\_\_\_  
 Fit \_\_\_\_\_  
 Torque (in.-lb.) \_\_\_\_\_

**FATIGUE CONDITIONS**  
 Max net stress (ksi) 70  
 Max test load (k-ips) 41.5  
 Load ratio (R) 0.1  
 Test frequency 4000 cpm  
 Test laboratory Materials  
 Test engineer D. Reese  
 Test machine 100-kip Vibraphore

Specimen dash no	Hole no	Hole diameter (in.)			Hole finish (RHR)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
93	1	0.3550	0.3645	0.3745	30	15	40	0.0180	0.0095			67,000	
	2	0.3550	0.3645	0.3745	-	-	-	0.0180	0.0095				
	3	0.3550	0.3640	0.3745	35	15	35	0.0180	0.0090				
	4	0.3550	0.3640	0.3745	-	-	-	0.0180	0.0090				
94	1	0.3550	0.3645	0.3745	30	15	40	0.0180	0.0095			63,000	
	2	0.3550	0.3640	0.3745	-	-	-	0.0180	0.0090				
	3	0.3550	0.3645	0.3745	25	10	30	0.0180	0.0095				
	4	0.3550	0.3640	0.3745	-	-	-	0.0180	0.0090				
95	1	0.3550	0.3640	0.3745	30	15	40	0.0180	0.0090			62,000	
	2	0.3550	0.3645	0.3745	-	-	-	0.0180	0.0090				
	3	0.3550	0.3645	0.3745	30	15	40	0.0180	0.0095				
	4	0.3550	0.3640	0.3745	-	-	-	0.0180	0.0090				

PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

Ti-6Al-4V,  
2 1/2 D edge margin,  
open, C/W,  
70 ksi

TEST: 4D4(T) SPECIMEN: 623080 DATE: 10/23/73

SPECIMEN DESCRIPTION		COLDWORK PROCESS		HOLE PREPARATION		FATIGUE CONDITIONS	
Configuration	Fig. 7D	Interference (in.)	0.019	Nominal hole size (in.)	0.375	Max net stress (ksi)	Z0
Material	Ti-6Al-4V (annealed)	Sleeve type	Split	Process	Ream, C/W, ream	Max test load (kip)	41.5
Width (in.)	2.995	Sleeve thickness (in.)	0.010			Load ratio (R)	0.1
Hole spacing (in.)	1.125 x 1.50	Sleeve orientation	AISI 9260 steel			Test frequency	4000 cpm
Edge margin (in.)	0.4375	Mandrel material	0.045	FASTENER INSTALLATION		Test laboratory	Materials
Material gap (in.)	0.250	Mandrel taper (in./in.)	0.045	Type		Test engineer	D. Reese
Surface treatment	Shot peen	Mandrel max diameter (in.)	0.353	Fit		Test machine	100-kip Vibraphore
		Lubrication	Fel Pro 300	Torque (in. lb)			

Specimen day no.	Hole diameter (in.)				Hole finish (RHR)		Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
	Before coldwork	After coldwork	After ream	After ream	Before coldwork	After coldwork	Actual	Retained	Diameter	Fit		
97	1	0.3545	0.3640	0.3745	40	20	0.0185	0.0095			50,000	
	2	0.3545	0.3640	0.3745	-	-	0.0185	0.0095				
	3	0.3545	0.3640	0.3745	35	15	0.0185	0.0095				
	4	0.3545	0.3640	0.3745	-	-	0.0185	0.0095				
98	1	0.3545	0.3640	0.3750	30	15	0.0185	0.0095			81,000	
	2	0.3545	0.3640	0.3750	-	-	0.0185	0.0095				
	3	0.3545	0.3640	0.3750	35	15	0.0185	0.0095				
	4	0.3545	0.3640	0.3750	-	-	0.0185	0.0095				
100	1	0.3545	0.3640	0.3750	35	15	0.0185	0.0095			74,000	
	2	0.3545	0.3640	0.3750	-	-	0.0185	0.0095				
	3	0.3545	0.3640	0.3750	35	15	0.0185	0.0095				
	4	0.3545	0.3640	0.3750	-	-	0.0185	0.0095				

\*98 has 1.125 x 3.50 spacing

PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

Ti-6Al-4V,  
2 1/2" D edge margin,  
open, C/W,  
70 ksi

TEST 4D5 (T) SPECIMEN 623080 DATE 10/22/13

**SPECIMEN DESCRIPTION**  
 Configuration Fig. 7E  
 Material Ti-6Al-4V (annealed)  
 Width (in.) 3.375  
 Hole spacing (in.) 1.50 x 3.50  
 Edge margin (in.) 0.9375  
 Material grade (in.) 0.250  
 Surface treatment Shot Peen

**COLLWORK PROCESS**  
 Interference (in.) 0.019  
 Sleeve type Split  
 Sleeve thickness (in.) 0.010  
 Sleeve orientation 0°  
 Mandrel material AISI 9260 steel  
 Mandrel taper (in./in.) 0.045  
 Mandrel max diameter (in.) 0.353  
 Lubrication Fel Pro 300

**HOLE PREPARATION**  
 Nominal hole size (in.) 0.375  
 Process Ream, C/W, ream

**FASTENER INSTALLATION**  
 Type \_\_\_\_\_  
 Fit \_\_\_\_\_  
 Torque (in. lb) \_\_\_\_\_

**FATIGUE CONDITIONS**  
 Max net stress (ksi) 70  
 Max test load (kip) 41.5  
 Load ratio (R) 0.1  
 Test frequency 4000 cpm  
 Test laboratory Materials  
 Test engineer D. Reese  
 Test machine 100 kip Vibraphore

Specimen ID	Hole no.	Hole diameter (in.)			Hole finish (RRR)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before collwork	After collwork	After ream	Before collwork	After collwork	After ream	Actual	Returned fit	Diameter	Fit		
101	1	0.3545	0.3745	0.3745	30	15	35	0.0185	0.010L			59,000	
	2	0.3550	0.3640	0.3745				0.0180	0.0090				
	3	0.3550	0.3540	0.3745	30	15	40	0.0180	0.0090				
	4	0.3550	0.3645	0.3745				0.0180	0.0090				
102	1	0.3545	0.3640	0.3745	25	10	30	0.0185	0.0085			104,000	
	2	0.3545	0.3640	0.3740				0.0185	0.0095				
	3	0.3545	0.3640	0.3745	30	15	35	0.0185	0.0095				
	4	0.3545	0.3640	0.3745				0.0185	0.0095				
103	1	0.3545	0.3640	0.3745	30	15	40	0.0185	0.0095			66,000	
	2	0.3545	0.3640	0.3745				0.0185	0.0095				
	3	0.3545	0.3640	0.3745	35	15	35	0.0185	0.0095				
	4	0.3545	0.3640	0.3745				0.0185	0.0095				

PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

Ti-6Al-4V,  
15 hole, single,  
C/W, net fit Hi-Lok,  
70 ksi

TEST: 4E1 SPECIMEN: 623080 DATE: 11/18/73

SPECIMEN DESCRIPTION		COLDWORK PROCESS		HOLE PREPARATION		FATIGUE CONDITIONS	
Configuration	Fig. 9	Interference (in.)	0.14/0.15	Nominal hole size (in.)	0.250	Max net stress (ksi)	70
Material	Ti-6Al-4V	Sleeve type	Split	Process	Ream, C/W, ream	Max test load (kip)	12
Width (in.)	1.00	Sleeve thickness (in.)	0.008			Load ratio (R)	0.1
Hole spacing (in.)	1.00	Sleeve orientation	0°			Test frequency	600 cpm
E-jog margin (in.)	0.50	Mandrel material	H-11 steel	FASTENER INSTALLATION		Test laboratory	Materials
Material gauge (in.)	0.250	Mandrel taper (in./in.)	0.015	Type	Hi-Lok, prot hd	Test engineer	D. Reese
Surface treatment	Shot peen	Mandrel max diameter (in.)	0.230	F <sub>r</sub> (in.)	Net to 0.0005 clearance	Test machine	60- to 80- kip Riehle Los
		Lubrication	Fel Pro 300	Torque (in. lb)	80		

Specimen dash no.	Hole no.	Hole diameter (in.)			Hole finish (RH/R)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	F <sub>r</sub>		
1	1	0.2315	0.2375	0.2485	25	15	20	0.0145	0.0060	0.2485	Net	124,950	
	2	0.2315	0.2375	0.2485	-	-	-	0.0145	0.0060	0.2485	Net		
	3	0.2315	0.2375	0.2485	25	10	25	0.0145	0.0060	0.2485	Net		
	4	0.2315	0.2375	0.2485	-	-	-	0.0145	0.0060	0.2485	Net		
2	1	0.2315	0.2375	0.2490	20	10	20	0.0145	0.0060	0.2485	0.0005	122,210	
	2	0.2315	0.2375	0.2490	-	-	-	0.0145	0.0060	0.2485	0.0005		
	3	0.2315	0.2375	0.2490	25	10	25	0.0145	0.0060	0.2485	0.0005		
	4	0.2315	0.2375	0.2490	-	-	-	0.0145	0.0060	0.2485	0.0005		
3	1	0.2315	0.2375	0.2490	-	-	-	0.0145	0.0060	0.2485	0.0005	60,780	
	2	0.2315	0.2375	0.2490	20	10	-	0.0145	0.0060	0.2485	0.0005		
	3	0.2315	0.2375	0.2490	-	-	-	0.0145	0.0060	0.2485	0.0005		
	4	0.2315	0.2375	0.2490	25	15	-	0.0145	0.0060	0.2485	0.0005		

PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

Ti-6Al-4V,  
15-hole, dual,  
C/W, prot hd Hi-Lok,  
70 ksi

TEST 4F1 SPECIMEN 620380 DATE 11/21/73

FATIGUE CONDITIONS  
 Max net stress (ksi) 70  
 Max test load (kip) 51.8  
 Load ratio (R) 0.1  
 Test frequency 600 cpm  
 Test laboratory Materials  
 Test engineer D. Reese  
 Test machine 60- to 80-kip  
Riehle-Los

HOLE PREPARATION  
 Nominal hole size (in) 0.250  
 Process Ream, C/W, ream

FASTENER INSTALLATION  
 Type Hi-Lok, prot hd  
 Fit (in.) Net to 0.0005 clearance  
 Torque (in lb) 80

COLDWORK PROCESS  
 Interference (in) 0.014/0.015  
 Sieve type Split  
 Sieve thickness (in) 0.008  
 Sieve orientation 0°  
 Mandrel material H-II steel  
 Mandrel taper (in/in) 0.015  
 Mandrel max diameter (in) 0.2305  
 Lubrication Fel Pro 300

SPECIMEN DESCRIPTION  
 Fig. 8  
 Configuration Ti-6Al-4V (annealed)  
 Material Ti-6Al-4V, stringer, 1.0  
 Width (in) Skin, 2.50, stringer, 1.0  
 Hole spacing 1.00  
 Edge margin (in) Skin, 1.25, stringer, 0.50  
 Material gauge (in) 0.250  
 Surface treatment Shot peen

Specimen dash no.	Hole no.	Hole diameter (in.)		Hole finish (RHR)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	F-I		
4	1	0.2325	0.2395	25	15	20	0.014	0.0070	0.2495	Net	40,190	
	2	0.2325	0.2395	-	-	-	0.014	0.0070	0.2495	Net		
	3	0.1325	0.2395	25	15	20	0.014	0.0070	0.2495	Net		
	4	0.2325	0.2395	-	-	-	0.014	0.0070	0.2495	Net		
	1	0.2325	0.2395	25	15	20	0.014	0.0070	0.2495	Net	39,840	
	2	0.2325	0.2395	-	-	-	0.014	0.0070	0.2495	Net		
	3	0.2325	0.2395	25	15	20	0.014	0.0070	0.2495	Net		
	4	0.2325	0.2395	-	-	-	0.014	0.0070	0.2495	Net		
	1	0.2325	0.2395	25	15	20	0.014	0.0070	0.2495	Net	47,330	
	2	0.2325	0.2395	-	-	-	0.014	0.0070	0.2495	Net		
	3	0.2325	0.2395	25	15	20	0.014	0.0070	0.2495	Net		



**PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS**

Ti-6Al-4V,  
15-hole, dual,  
prot hd, Hi-Lok  
C/W, no postream,  
70 ksi

TEST 4F2 SPECIMEN 623080 DATE 11/21/73

<b>SPECIMEN DESCRIPTION</b>		<b>COLLIDWORK PROCESS</b>		<b>HOLE PREPARATION</b>		<b>FATIGUE CONDITIONS</b>	
Configuration	Fig 8	Interference (in.)	0.014-0.015	Nominal hole size (in.)	0.250	Max net stress (ksi)	70
Material	Ti-6Al-4V (annealed)	Sleeve type	Split	Process	Ream, C/W	Max test load (kip)	50.5
Width (in.)	Skin, 2.50, stringer, 1.00	Sleeve thickness (in.)	0.008			Load ratio (R)	0.1
Hole spacing	1.00	Sleeve orientation	0°			Test frequency	600 cpm
Edge margin (in.)	Skin, 1.25, stringer, 0.50	Mandrel material	H-11 steel	<b>FASTENER INSTALLATION</b>			
Material gage (in.)	0.250	Mandrel taper (in./in.)	0.015	Type	Hi-Lok, prot hd	Test laboratory	Materials
Surface treatment	Shot peen	Mandrel max diameter (in.)	0.242	Fit (in.)	Net to 0.0005 clearance	Test engineer	D. Reese
		Lubrication	-Fat-Res-300	Torque (in. lb)	80	Test machine	60- to 80-kip Riehle-Los

Specimen dash no	Hole no	Hole diameter (in.)		Hole finish (RHRI)		Collidwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before collidwork	After collidwork	Before collidwork	After collidwork	Actual	Retained	Diameter	Fit		
7	1	0.2430	0.2500	20	10	0.0180	0.0070	0.2495	0.0005	98,040	Failed at eighth fastener - stringer C/W Hd
	2	0.2430	0.2500	20	10	0.0180	0.0070	0.2495	0.0005		
	3	0.2430	0.2500	20	15	0.0180	0.0070	0.2495	0.0005		
	4	0.2430	0.2500	20	15	0.0180	0.0070	0.2495	0.0005		
8	1	0.2430	0.2500	20	10	0.0180	0.0070	0.2495	0.0005	187,150	Failed at ninth fastener - skin C/W Hd
	2	0.2430	0.2500			0.0180	0.0070	0.2495	0.0005		
	3	0.2430	0.2500	20	10	0.0180	0.0070	0.2495	0.0005		
	4	0.2430	0.2500			0.0180	0.0070	0.2495	0.0005		
9	1	0.2470	0.2500	20	10	0.0180	0.0070	0.2495	0.0005	191,330	Failed at eighth fastener C/W Hd
	2	0.2430	0.2500			0.0180	0.0070	0.2495	0.0005		
	3	0.2430	0.2500	20	10	0.0180	0.0070	0.2495	0.0005		
	4	0.2430	0.2500			0.0150	0.0070	0.2495	0.0005		

Skin, T1-6Al-4V  
Stringer, 2024-T851,  
15-hole, dual,  
C/W, prot hd, Hi-Lok.

**PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS**

TEST 4F3 SPECIMEN 623080 DATE 11/12/73

**FATIGUE CONDITIONS**  
64-T1-6Al-4V  
48-2024-T851  
Max net stress (ksi) 44.3  
Max test load (kip) 0.1  
Load ratio (R) 600 cpm  
Test frequency Materials  
Test laboratory D. Reese  
Test engineer 60 to 80-kip  
Test machine Richie-Los

**HOLE PREPARATION**  
Nominal hole size (in.) 0.250  
Ream, C/W, ream  
Process  
Sieve type Split  
Sieve thickness (in.) 0.008  
Sieve orientation 0°  
Mandrel material H II steel  
Mandrel taper (in./in.) 0.015  
Mandrel max diameter (in.) 0.2305  
Lubrication Fel Pro 300

**COLDWORK PROCESS**  
Interferer (in.) 0.014-0.015  
Sieve type Split  
Sieve thickness (in.) 0.008  
Sieve orientation 0°  
Mandrel material H II steel  
Mandrel taper (in./in.) 0.015  
Mandrel max diameter (in.) 0.2305  
Lubrication Fel Pro 300

**FASTENER INSTALLATION**  
Type: Hi-Lok, prot hd  
Fit (in.) Net to 0.0005 clearance  
Torque (in. lb) 80

**SPECIMEN DESCRIPTION**  
Fig. 8  
Configuration Skin, T1-6Al-4V (annealed)  
Material Stringer, 2024-T851  
Width (in.) Skin, 2.50 stringer, 1.0  
Hole spacing 1.00  
Edge margin (in.) Skin, 1.25, stringer, 0.50  
Material gauge (in.) 0.250  
Surface treatment Shot Peen

Specimen dash no.	Hole no.	Hole diameter (in.)		Hole finish (RRR)		Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks		
		Before coldwork	After ream	Before coldwork	After coldwork	Actual	Retained	Diameter	Fit				
10	1	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net	61,590	
11	2	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
12	3	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
13	4	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
14	5	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
15	6	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
16	7	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
17	8	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
18	9	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
19	10	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
20	11	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
21	12	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
22	13	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
23	14	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
24	15	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
25	16	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
26	17	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
27	18	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
28	19	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
29	20	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
30	21	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
31	22	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
32	23	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
33	24	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
34	25	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
35	26	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
36	27	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
37	28	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
38	29	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
39	30	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
40	31	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
41	32	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
42	33	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
43	34	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
44	35	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
45	36	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
46	37	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
47	38	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
48	39	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
49	40	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
50	41	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
51	42	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
52	43	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
53	44	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
54	45	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
55	46	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
56	47	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
57	48	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
58	49	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
59	50	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
60	51	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
61	52	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
62	53	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
63	54	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
64	55	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
65	56	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
66	57	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
67	58	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
68	59	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
69	60	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
70	61	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
71	62	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
72	63	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
73	64	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
74	65	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
75	66	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
76	67	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
77	68	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
78	69	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
79	70	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
80	71	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
81	72	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
82	73	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
83	74	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
84	75	0.2325	0.2400	0.2495	25	15	20	0.014	0.0075	0.2495	Net		
85	76	0.2325	0.2400	0.2495									

**PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS**

Ti-6Al-4V,  
high load transfer,  
C/W, net fit Hi-Lok,  
0.010 micarta,  
40 ksi

TEST: 4G1 SPECIMEN 623080 DATE 10/9/73

SPECIMEN DESCRIPTION		COLDWORK PROCESS		HOLE PREPARATION		FATIGUE CONDITIONS	
Configuration	Fig. 10	Interference (in.)	0.019	Nominal hole size (in.)	0.375	Max net stress (ksi)	70
Material	Ti-6Al-4V (annealed)	Sleeve type	Split	Process	Ream, C/W, ream	Max test load (kip)	37
Width (in.)	3	Sleeve thickness (in.)	0.010			Load ratio (R)	0.1
Hole spacing (in.)	1.50	Sleeve orientation	0°			Test frequency	600 cpm
Edge margin (in.)	0.75	Mandrel material	AISI 9260 steel	FASTENER INSTALLATION		Test laboratory	Materials
Material edge (in.)	0.250	Mandrel taper (in./in.)	0.045	Type	Hi-Lok, prot hd	Test engineer	D. Reese
Surface treatment	Shot peen	Mandrel max diameter (in.)	0.353	Fit (in.)	Net to 0.0005 clearance	Test machine	60- to 80-kip Riehle-Los
		Lubrication	Fel Pro 300	Torque (in. lb)	240		

Specimen dash no	Hole no	Hole diameter (in.)		Hole finish (IRHR)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks	
		Before coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit			
1	1	0.3545	0.3635	0.3740	45	20	55	0.0185	0.0090	0.3740	Net	21,280	
	2	0.3545	0.3635	0.3740	-	-	-	0.0185	0.0090	0.3740	Net		
	3	0.3545	0.3635	0.3740	-	-	60	0.0185	0.0090	0.3740	Net		
	4	0.3545	0.3635	0.3740	-	-	-	0.0185	0.0090	0.3740	Net		
2	1	0.3545	0.3635	0.3740	45	20	60	0.0185	0.0090	0.3740	Net	22,500	
	2	0.3545	0.3635	0.3740	-	-	-	0.0185	0.0090	0.3740	Net		
	3	0.3545	0.3635	0.3740	60	-	-	0.0185	0.0090	0.3740	Net		
	4	0.3545	0.3635	0.3740	-	-	-	0.0185	0.0090	0.3740	Net		
3	1	0.3545	0.3635	0.3740	50	20	50	0.0185	0.0090	0.3740	Net	17,340	
	2	0.3545	0.3635	0.3740	-	-	-	0.0185	0.0090	0.3740	Net		
	3	0.3545	0.3635	0.3740	-	-	55	0.0185	0.0090	0.3740	Net		
	4	0.3545	0.3635	0.3740	-	-	-	0.0185	0.0090	0.3740	Net		

PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

Ti 6Al-4V,  
high load transfer,  
C/W, 0.002 clearance Hi-Lok,  
0.010 micarta,  
70 ksi

TEST 4G2 SPECIMEN 623080 DATE 10/9/73

SPECIMEN DESCRIPTION		COLDWORK PROCESS		HOLE PREPARATION		FATIGUE CONDITIONS	
Configuration	Fig. 10	Interference (in.)	0.019-0.020	Nominal hole size (in.)	0.375	Max net stress (ksi)	70
Material	Ti-6Al-4V (annealed)	Sleeve type	Split	Process	Ream, C/W, ream	Max test load (kip)	36.3
Width (in.)	3.00	Sleeve thickness (in.)	0.010			Load ratio (R)	0.1
Hole spacing (in.)	1.50	Sleeve orientation	0°			Test frequency	600 cpm
Edge margin (in.)	0.75	Mandrel material	AISI 9260 steel	FASTENER INSTALLATION		Test laboratory	Materials
Material gage (in.)	0.250	Mandrel taper (in./in.)	0.045	Type	Hi-Lok, prot hd	Test engineer	D. Reese
Surface treatment	Shot peen	Mandrel max diameter (in.)	0.353	Fit (in.)	0.001-0.002 in. clearance	Test machine	60 to 80 kip Riehle-LoS
		Lubrication	Fel-Pro 300	Torque (in. lb)	240		

Specimen dash no.	Hole no.	Hole diameter (in.)			Hole finish (RHR)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
4	1	0.3545	0.3635	0.3760	65	25	60	0.0185	0.0090	0.3740	0.002	18,660	C/W Hd
	2	0.3545	0.3635	0.3760	-	-	-	0.0185	0.0090	0.3740	0.002		
	3	0.3545	0.3635	0.3760	70	-	-	0.0185	0.0090	0.3740	0.002		
	4	0.3545	0.3635	0.3760	-	-	65	0.0158	0.0090	0.3740	0.002		
5	1	0.3545	0.3630	0.3760	60	20	60	0.0185	0.0090	0.3740	0.002	20,640	C/W Hd
	2	0.3545	0.3630	0.3760	-	-	-	0.0185	0.0090	0.3740	0.002		
	3	0.3545	0.3630	0.3760	65	-	65	0.0185	0.0090	0.3740	0.002		
	4	0.3545	0.3630	0.3760	-	-	-	0.0185	0.0090	0.3740	0.002		
6	1	0.3545	0.3635	0.3760	55	20	70	0.0185	0.0090	0.3740	0.002	20,000	C/W Hd
	2	0.3545	0.3635	0.3760	-	-	-	0.0185	0.0090	0.3740	0.002		
	3	0.3545	0.3635	0.3760	-	-	-	0.0185	0.0090	0.3740	0.002		
	4	0.3545	0.3635	0.3760	-	-	-	0.0185	0.0090	0.3740	0.002		

PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

Ti-6Al-4V,  
high load transfer,  
C/W, 0.002 interference Hi-Lok,  
0.010 micarta,  
70 ksi

TEST 4G3 SPECIMEN 623080 DATE 10/10/73

SPECIMEN DESCRIPTION		COLDWORK PROCESS		MOLE PREPARATION		FATIGUE CONDITIONS	
Configuration	Fig. 10	Interference (in.)	0.019-0.020	Nominal hole size (in.)	0.375	Max net stress (ksi)	70
Material	Ti-6Al-4V (annealed)	Sleeve type	Split	Process	Ream, C/W, ream	Max test load (kip)	37.5
Width (in.)	3.00	Sleeve thickness (in.)	0.010			Load ratio (R)	0.1
Hole spacing (in.)	1.50	Sleeve orientation	0°			Test frequency	600 cpm
Edge margin (in.)	0.75	Mandrel material	AISI 9260 steel	FASTENER INSTALLATION		Test laboratory	Materials
Material gauge (in.)	0.250	Mandrel taper (in./in.)	0.045	Type	Hi-Lok, prot hd	Test engineer	D. Reese
Surface treatment	Shot peen	Mandrel max diameter (in.)	0.353	Fit (in.)	0.001-0.002 interference	Test machine	60- to 80-kip Riehle-Los
		Lubrication	Fel Pro 300	Torque (in. lb)	240-250		

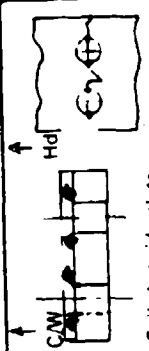
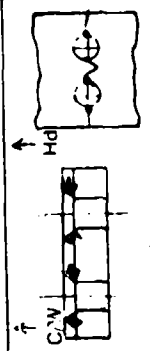
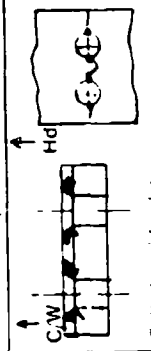
Specimen dash no	Hole no	Hole diameter (in.)		Hole finish (RHR)		Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After ream	Before coldwork	After coldwork	Actual	Retained	Diameter	Fit		
7	1	0.3545	0.3730	60	20	0.0185	0.0090	0.3740	0.001	24,140	
	2	0.3545	0.3730	-	-	0.0185	0.0090	0.3740	0.001		
	3	0.3545	0.3730	-	-	0.0185	0.0090	0.3740	0.001		
	4	0.3545	0.3730	-	-	0.0185	0.0090	0.3740	0.001		
8	1	0.3545	0.3730	60	20	0.0185	0.0085	0.3740	0.001	24,700	
	2	0.3545	0.3730	-	-	0.0185	0.0085	0.3740	0.001		
	3	0.3545	0.3730	-	-	0.0185	0.0090	0.3740	0.001		
	4	0.3545	0.3730	-	-	0.0185	0.0090	0.3740	0.001		
9	1	0.3550	0.3730	70	20	0.0180	0.0085	0.3740	0.001	26,630	
	2	0.3550	0.3730	-	-	0.0180	0.0085	0.3740	0.001		
	3	0.3550	0.3730	-	-	0.0180	0.0085	0.3740	0.001		
	4	0.3545	0.3730	-	-	0.0185	0.0090	0.3740	0.001		

PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

Ti-6Al-4V  
high load transfer,  
C/W, flush hd Hi-Lok,  
0.010 micarta,  
70 ksi

TEST 404 SPECIMEN 623080 DATE 10/30/73

SPECIMEN DESCRIPTION		COLDWORK PROCESS		HOLE PREPARATION		FATIGUE CONDITIONS	
Configuration	Fig. 10	Interference (in.)	0.019-0.020	Nominal hole size (in.)	0.375	Max net stress (ksi)	70
Material	Ti-6Al-4V (annealed)	Sleeve type	Split	Process	Ream, C/W, ream, csk	Max test load (kip)	37.3
Width (in.)	3.00	Sleeve thickness (in.)	0.010			Load ratio (R)	0.1
Hole spacing (in.)	1.50	Sleeve orientation	0°			Test frequency	600 cpm
Edge margin (in.)	0.75	Mandrel material	AISI 9260 steel	FASTENER INSTALLATION		Test laboratory	Materials
Material gauge (in.)	0.250	Mandrel taper (in./in.)	0.045	Type	Hi-Lok (flush hd)	Test engineer	D. Reese
Surface treatment	Shot peen	Mandrel max diameter (in.)	0.553	Fit (in.)	Net to 0.0005 clearance	Test machine	60- to 80 kip Riehle-Los
		Lubrication	Fel Pro 300	Torque (in. lb)	240-250		

Specimen dash no	Hole no	Hole diameter (in.)			Hole finish (RHR)		Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks	
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	Actual	Retained	Diameter	Fit			
-10	1	0.3550	0.3645	0.3740	25	15	20	0.0180	0.0095	0.3735	0.0005	11,580	
	2	0.3550	0.3645	0.3740	-	-	-	0.0180	0.0095	0.3735	0.0005		
	3	0.3550	0.3645	0.3740	30	15	20	0.0180	0.0095	0.3735	0.0005		
	4	0.3550	0.3645	0.3740	-	-	-	0.0180	0.0095	0.3735	0.0005		Failed at side plate
-11	1	0.3545	0.3645	0.3740	30	15	20	0.0185	0.0100	0.3730	0.0010	6,200	
	2	0.3545	0.3650	0.3740	-	-	-	0.0185	0.0105	0.3730	0.0010		
	3	0.3545	0.3650	0.3740	25	15	20	0.0185	0.0105	0.3730	0.0110		
	4	0.3545	0.3645	0.3740	-	-	-	0.0185	0.0100	0.3735	0.0005		Failed at side plate
-12	1	0.3550	0.3645	0.3740	30	15	20	0.0180	0.0095	0.3735	0.0005	11,170	
	2	0.3550	0.3650	0.3740	-	-	-	0.0180	0.0100	0.3735	0.0005		
	3	0.3550	0.3650	0.3740	25	15	20	0.0180	0.0100	0.3735	0.0005		
	4	0.3550	0.3645	0.3740	-	-	-	0.0180	0.0095	0.3735	0.0005		Failed at side plate

PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

Ti-6Al-4V  
high load transfer,  
C/W, net fit Hi-Lok,  
No micarta

TEST 4G5 - SPECIMEN 623080 DATE 10/30/73

SPECIMEN DESCRIPTION		COLDWORK PROCESS		HOLE PREPARATION		FATIGUE CONDITIONS	
Configuration	Fig. 10	Interference (in.)	0.019	Nominal hole size (in.)	0.375	Max net stress (ksi)	70
Material	Ti-6Al-4V (annealed)	Sleeve type	Split	Process	0.010	Max test load (kip)	37.3
Width (in.)	3.00	Sleeve thickness (in.)	0.010			Load ratio (R)	0.1
Hole spacing (in.)	1.50	Sleeve orientation	0°			Test frequency	600 cpm
Edge margin (in.)	0.75	Mandrel material	AISI 9260 steel	FASTENER INSTALLATION		Test laboratory	Materials
Material gauge (in.)	0.250	Mandrel taper (in./in.)	0.045	Type	Hi-Lok, prot hd	Test engineer	D. Reese
Surface treatment	Shot peen	Mandrel max diameter (in.)	0.353	F <sub>it</sub> (in.)	Net to 0.0005 clearance	Test machine	60- to 80-kip Riehle-Los
		Lubrication	Fel Pro 300	Torque (in-lb)	240-250		

Specimen dash no.	Hole no.	Hole diameter (in.)		Hole finish (RHR)		Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks		
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	Actual	Retained	Diameter			F <sub>it</sub>	
.13	1	0.3550	0.3650	0.3740	20	15	25	0.0180	0.0100	0.3735	0.0005	30,700	
	2	0.3550	0.3650	0.3740	-	-	-	0.0180	0.0100	0.3735	0.0005		
	3	0.3550	0.3650	0.3740	25	15	25	0.0180	0.0100	0.3735	0.0005		
	4	0.3550	0.3650	0.3740	-	-	-	0.0180	0.0100	0.3735	0.0005		
.14	1	0.3550	0.3650	0.3740	25	15	25	0.0180	0.0110	0.3735	0.0005	39,950	
	2	0.3550	0.3645	0.3740	-	-	-	0.0180	0.0095	0.3740	Net		
	3	0.3550	0.3645	0.3740	30	10	25	0.0180	0.0095	0.3740	Net		
	4	0.3550	0.3645	0.3740	-	-	-	0.0180	0.0095	0.3735	Net		
.15	1	0.3550	0.3650	0.3740	30	15	25	0.0180	0.0100	0.3735	0.0005	33,630	
	2	0.3550	0.3650	0.3740	-	-	-	0.0180	0.0100	0.3735	0.0005		
	3	0.3550	0.3650	0.3740	25	10	25	0.0180	0.0100	0.3735	0.0005		
	4	0.3550	0.3650	0.3740	-	-	-	0.0180	0.0100	0.3735	0.0005		

**PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS**

Ti-6Al-4V,  
high load transfer,  
C/W, net fit Hi-Lok,  
upset removed,  
70 ksi

TEST 4G6 SPECIMEN 623080 DATE 11/1/73

SPECIMEN DESCRIPTION		COLDWORK PROCESS		HOLE PREPARATION		FATIGUE CONDITIONS	
Configuration	<u>Fig 10</u>	Interference (in.)	<u>0.019</u>	Nominal hole size (in.)	<u>0.375</u>	Max net stress (ksi)	<u>70</u>
Material	<u>Ti-6Al-4V (annealed)</u>	Sleeve type	<u>Split</u>	Process	<u>Ream, C/W, ream</u>	Max test load (kip)	<u>37.3</u>
Width (in.)	<u>3.00</u>	Sleeve thickness (in.)	<u>0.010</u>			Load ratio (R)	<u>0.1</u>
Hole spacing (in.)	<u>1.50</u>	Sleeve orientation	<u>0°</u>			Test frequency	<u>600 cpm</u>
Edge margin (in.)	<u>0.75</u>	Mandrel material	<u>AISI 9260 steel</u>	FASTENER INSTALLATION		Test laboratory	<u>Materials</u>
Material gage (in.)	<u>0.250</u>	Mandrel taper (in./in.)	<u>0.045</u>	Type	<u>Hi-Lok, prot hd</u>	Test engineer	<u>D. Reese</u>
Surface treatment	<u>Shot peen</u>	Mandrel max diameter (in.)	<u>0.353</u>	Fir (in.)	<u>Net to 0.0005 clearance</u>	Test machine	<u>60- to 80-kip Riehle-Los</u>
		Lubrication	<u>Fel Pro 300</u>	Torque (in. lb)	<u>240-250</u>		

Specimen dash no	Hole no	Hole diameter (in.)			Hole finish (RHR)		Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks	
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	Actual	Retained	Diameter	Fit			
.16	1	0.3550	0.3645	0.3740	25	15	20	0.0180	0.0950	0.3740	Net	98,140	
	2	0.3550	0.3645	0.3740	-	-	-	0.0180	0.0950	0.3740	Net		
	3	0.3550	0.3645	0.3740	25	15	20	0.0180	0.0950	0.3740	Net		
	4	0.3550	0.3645	0.3740	-	-	-	0.0180	0.0950	0.3740	Net		
.17	1	0.3550	0.3645	0.3740	25	15	20	0.0180	0.0950	0.3740	Net	36,180	
	2	0.3550	0.3645	0.3740	-	-	-	0.0180	0.0950	0.3740	Net		
	3	0.3550	0.3645	0.3740	20	15	20	0.0180	0.0950	0.3740	Net		
	4	0.3550	0.3645	0.3740	-	-	-	0.0180	0.0950	0.3740	Net		
.18	1	0.3550	0.3650	0.3740	30	15	20	0.0180	0.0950	0.3740	Net	31,890	
	2	0.3550	0.3650	0.3740	-	-	-	0.0180	0.0950	0.3740	Net		
	3	0.3550	0.3650	0.3740	25	15	20	0.0180	0.0950	0.3740	Net		
	4	0.3550	0.3650	0.3740	-	-	-	0.0180	0.0950	0.3740	Net		



PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

Ti-6Al-4V,  
Taper Lok,  
0.010 in. micaarta,  
70 ksi

TEST 4G7 SPECIMEN 623080 DATE 11/1/73

SPECIMEN DESCRIPTION		COLLIDWORK PROCESS		HOLE PREPARATION		FATIGUE CONDITIONS	
Configuration	Fig. 10	Interference		Nominal hole size (in.)	0.375	Max net stress (ksi)	70
Material	Ti-6Al-4V (annealed)	Sleeve type		Process	Ream	Max test load (kip)	37
Width (in.)	3.00	Sleeve thickness (in.)				Load ratio (R)	0.1
Hole spacing (in.)	1.50	Sleeve orientation				Test frequency	600 cpm
Edge margin (in.)	0.75	Mandrel material		FASTENER INSTALLATION		Test laboratory	Materials
Material gage (in.)	0.250	Mandrel taper (in/in.)		Type	Taper lok, prot hd	Test engineer	D. Reese
Surface treatment	Shot peen	Mandrel max diameter (in.)		F <sub>1</sub> (in.)	Boeing class F (0.187-0.289)	Test machine	Materials
		Lubrication		Torque (in. lb)	240 250		Riehle-Los

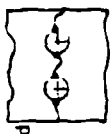

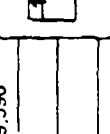
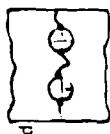
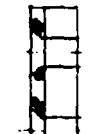
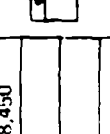
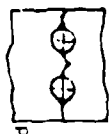
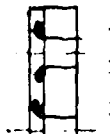
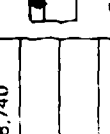
Specimen class no	Hole no	Fastener protrusion (in.)		Hole finish (IRHR)		Collidwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before collidwork	After ream	Before collidwork	After collidwork	Actual	Retained	Diameter	F-11		
-19	1		0.2800		20				Class F	73,970	
	2		0.2800		-				Class F		
	3		0.2800		25				Class F		
	4		0.2800		-				Class F		
-20	1		0.2800		24				Class F	78,990	
	2		0.2800		-				Class F		
	3		0.2800		20				Class F		
	4		0.2800		20				Class F		
-21	1		0.2800		20				Class F	62,280	
	2		0.2800		-				Class F		
	3		0.2800		20				Class F		
	4		0.2800		-				Class F		

PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

Ti-6Al-4V,  
Taper Lok, push hd,  
0.010-in. micarta,  
70 ksi

TEST 4G8 SPECIMEN 623060 DATE 10/31/73

SPECIMEN DESCRIPTION		COLDWORK PROCESS		HOLE PREPARATION		FATIGUE CONDITIONS	
Configuration	Fig. 10	Interference		Nominal hole size (in.)	0.375	Max net stress (ksi)	70
Material	Ti-6Al-4V (annealed)	Sleeve type		Process	Ream	Max test load (kip)	37
Width (in.)	3.00	Sleeve thickness (in.)				Load ratio (R)	0.1
Hole spacing (in.)	1.50	Sleeve orientation				Test frequency	600 cpm
Edge margin (in.)	0.75	Mandrel material		FASTENER INSTALLATION		Test laboratory	Materials
Material gauge (in.)	0.125 side plate 0.250 center	Mandrel taper (in./in.)		Type	Taper Lok flush hd	Test engineer	D. Reese
Surface treatment	Shot peen	Mandrel max diameter (in.)		Fit (in.)	Boeing class F (0.187-0.289)	Test machine	60 to 80 kip Riehle-Los
		Lubrication		Torque (in. lb)	240-250		

Specimen dash no	Hole no	Fastener protrusion (in.)		Hole finish (RHR)		Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After ream	Before coldwork	After coldwork	Actual	Retained	Diameter	Fit		
22	1		0.280						Class F	9,590	
	2		0.280						Class F		
	3		0.280						Class F		
	4		0.280								Failed in side plate
23	1		0.280						Class F	8,450	
	2		0.280						Class F		
	3		0.280						Class F		
	4		0.280								Failed in side plate
24	1		0.280						Class F	8,740	
	2		0.280						Class F		
	3		0.280						Class F		
	4		0.280								Failed in side plate

PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

Ti-6Al-4V  
ream only, net fit, Hi-Lok,  
0.010 in. micarta,  
70 ksi

TEST 4G9 SPECIMEN 6230880 DATE 10/10/73

<b>SPECIMEN DESCRIPTION</b>	<b>COLDWORK PROCESS</b>	<b>SOLE PREPARATION</b>	<b>FATIGUE CONDITIONS</b>
Confirmation <u>Fig. 10</u>	Interference _____	Nominal hole size (in.) <u>0.375</u>	Max net stress (ksi) <u>70</u>
Material <u>Ti-6Al-4V (annealed)</u>	Sleeve type _____	Process <u>Ream</u>	Max test load (kip) <u>37</u>
Width (in.) <u>3.00</u>	Sleeve thickness (in.) _____		Load ratio (R) <u>0.1</u>
Hole spacing (in.) <u>1.50</u>	Sleeve orientation _____		Test frequency <u>600 cpm</u>
Edge margin (in.) <u>0.75</u>	Mandrel material _____	<b>FASTENER INSTALLATION</b>	Test laboratory <u>Materials</u>
Material gage (in.) <u>0.250</u>	Mandrel taper (in/in) _____	Type <u>Hi-Lok, prot hd</u>	Test engineer <u>D. Reese</u>
Surface treatment <u>Shot peen</u>	Mandrel max diameter (in.) _____	Fit (in.) <u>Net to 0.001 clearance</u>	Test machine <u>60- to 80-kip Richie-Los</u>
	Lubricator _____	Torque (in. lb) <u>240</u>	

Specimen dash no	Hole no	Hole diameter (in.)		Hole finish (RHRI)		Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After ream	Before coldwork	After coldwork	Actual	Retained	Diameter	Fit		
25	1		0.3750					0.3740	0.001	19,050	
	2		0.3750					0.3740	0.001		
	3		0.3750					0.3740	0.001		
	4		0.3750					0.3740	0.001		
26	1		0.3750					0.3740	0.001	18,060	
	2		0.3750		50			0.3740	0.001		
	3		0.3750					0.3740	0.001		
	4		0.3750					0.3740	0.001		
27	1		0.3750					0.3740	0.001	10,940	
	2		0.3750		40			0.3740	0.001		
	3		0.3750					0.3740	0.001		
	4		0.3750					0.3740	0.001		



PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

300 M,  
C/W, net fit, Hi Lok,  
sleeve process,  
110 ksi

TEST 4A1 SPECIMEN 623080 DATE 11/13/73

SPECIMEN DESCRIPTION		COLDWORK PROCESS		HOLE PREPARATION		FATIGUE CONDITIONS	
Configuration	Fig. 2	Interference (in.)	0.018	Nominal hole size (in.)	0.375	Max net stress (ksi)	110
Material	300 M steel (220-300 ksi)	Sleeve type	Split	Process	Ream, C/W, ream	Max test load (kip)	31.3
Width (in.)	1.50	Sleeve thickness (in.)	0.010			Load ratio (R)	0.1
Hole spacing (in.)	1.50	Sleeve orientation	0°			Test frequency	4000 cpm
Edge margin (in.)	0.75	Mandrel material	AISI 9260	FASTENER INSTALLATION		Test laboratory	Materials
Material gage (in.)	0.250	Mandrel taper (in/in)	0.045	Type	Hi-Lok, prof hd	Test engineer	D. Reese
Surface treatment	Shot peen	Mandrel max diameter (in.)	0.3525	Fit (in.)	Net to 0.0005 clearance	Test machine	100-kip Vibraphore
		Lubrication	Fel Pro 300	Torque (in. lb)	240-250		

<sup>a</sup>Sleeve thinout was 0.002 in.

<sup>b</sup>Mandrel size reduced to 0.3513 after two holes; stabilized at 0.3510 after three holes

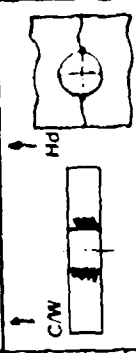
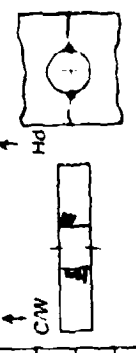
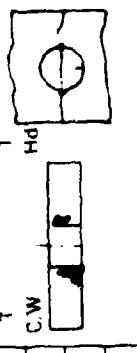
Specimen dash no.	Hole no.	Hole diameter (in.)				Hole finish (RHIT)		Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	After ream	Before coldwork	After coldwork	Actual	Retained	Diameter	Fit		
21	1	0.3550	0.3600	0.3740	20	10	15	0.0123	0.0050	0.3740	Net	93,000	
	2	0.3550	0.3600	0.3740	-	-	-	0.0123	0.0050	0.3740	Net		
	3												
	4												
22	1	0.3550	0.3595	0.3745	20	10	20	0.0120	0.0045	0.3740	0.0005	280,000	
	2	0.3550	0.3595	0.3745				0.0120	0.0045	0.3740	0.0005		
	3												
	4												
23	1	0.3550	0.3595	0.3745	20	10	15	0.0120	0.0045	0.3740	Net	178,000	
	2	0.3550	0.3595	0.3745				0.0120	0.0045	0.3740	Net		
	3												
	4												

PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

300 M,  
C/W net fit Hi-Lok,  
sleeve process,  
110 ksi

TEST 4A2 SPECIMEN 623080 DATE 11/13/73

SPECIMEN DESCRIPTION		COLDWORK PROCESS		HOLE PREPARATION		FATIGUE CONDITIONS	
Configuration	Fig. 2	Interference (in.)	0.018	Nominal hole size (in.)	0.375	Max net stress (ksi)	110
Material	300 M steel (270-300 ksi)	Sleeve type	Split	Process	Ream, C/W, ream	Max test load (kip)	31.3
Width (in.)	1.50	Sleeve thickness (in.)	0.010			Load ratio (R)	0.1
Hole spacing (in.)	1.50	Sleeve orientation	90°			Test frequency	4000 cpm
Edge margin (in.)	0.75	Mandrel material	AISI 9260	FASTENER INSTALLATION		Test laboratory	Materials
Material gauge (in.)	0.250	Mandrel taper (in./in.)	0.045	Type	Hi-Lok, prot hd	Test engineer	D. Reese
Surface treatment	Shot peen	Max. max diameter (in.)	0.3510	Fit (in.)	Net to 0.0005 clearance	Test machine	100-kip Vibraphore
		Lubrication	Fel Pro 300	Torque (in.-lb)	240 250		

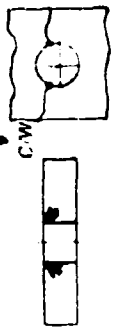
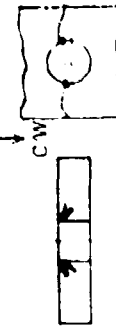
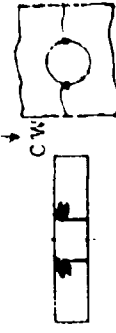
Specimen dash no	Hole no	Hole diameter (in.)		Hole finish (RMR)		Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks	
		Before coldwork	After coldwork	Alter ream	Before coldwork	After coldwork	Actual	Retained	Diameter			Fit
24	1	0.3550	0.3595	0.3740	20	10	0.0120	0.0045	0.3740	Net	103,000	
	2	0.3550	0.3595	0.3740	-	-	0.0120	0.0045	0.3740	Net		
	3											
	4											
25	1	0.3550	0.3600	0.3740	20	10	0.0120	0.0050	0.3740	Net	128,000	
	2	0.3550	0.3600	0.3740	-	-	0.0120	0.0050	0.3740	Net		
	3											
	4											
25	1	0.3545	0.3595	0.3740	25	15	0.0125	0.0050	0.3740	Net	114,000	
	2	0.3545	0.3595	0.3740	-	-	0.0125	0.0050	0.3740	Net		
	3											
	4											

PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

300 M,  
C/W only, open,  
110 ksi

TEST 4A3 SPECIMEN 623080 DATE 9/7/73

<b>SPECIMEN DESCRIPTION</b>	<b>COLDWORK PROCESS</b>	<b>HOLE PREPARATION</b>	<b>FATIGUE CONDITIONS</b>
Configuration <u>Fig. 2</u>	Interference (in.) <u>0.073</u>	Nominal hole size (in.) <u>3/8</u>	Max. net stress (ksi) <u>110</u>
Material <u>300 M steel (270-300 ksi)</u>	Sleeve type <u>Push, no sleeve</u>	Process <u>Ream, C/W</u>	Max. test load (kip) <u>0.1</u>
Width (in.) <u>1.50</u>	Sleeve thickness (in.) <u>-</u>		Load ratio (R) <u>4000 cpm</u>
Hole spacing (in.) <u>1.50</u>	Sleeve orientation <u>-</u>		Test frequency <u>Materials</u>
Edge margin (in.) <u>0.75</u>	Mandrel material <u>Carbide (BAC 5972)</u>	<b>FASTENER INSTALLATION</b>	Test laboratory <u>D. Reese</u>
Material gauge (in.) <u>0.250</u>	Mandrel taper (in./in.) <u>0.030</u>	Type <u>-</u>	Test engineer <u>M</u>
Surface treatment <u>Shot peen</u>	Mandrel max. diameter (in.) <u>0.353</u>	Fit <u>-</u>	Test machine <u>100-kip vibraphore</u>
	Lubrication <u>Fel Pro 300</u>	Torque (in. lb) <u>-</u>	

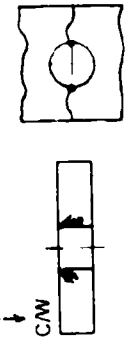
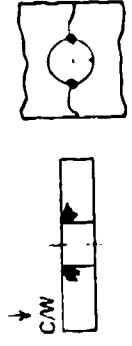
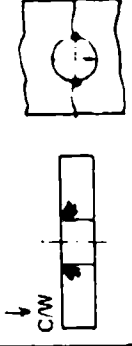
Specimen dash no.	Hole no.	Hole diameter (in.)		Hole finish (RHR)		Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After ream	Before coldwork	After ream	Actual	Retained	Diameter	Fit		
-27	1	0.3350	0.3505	20	10	0.023	0.0155			428,000	
	2	0.3350	0.3505	-	-	0.023	0.0155				
	3										
	4										
-28	1	0.3350	0.3505	25	15	0.023	0.0155			788,000	
	2	0.3350	0.3505	-	-	0.023	0.0155				
	3										
	4										
-29	1	0.3350	0.3505	20	10	0.023	0.0155			208,000	
	2	0.3350	0.3505	-	-	0.023	0.0155				
	3										
	4										

**PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS**

300 M,  
open, C/W,  
scored  
110 ksi

TEST 4A4 SPECIMEN 623080 DATE 5/7/73

<p><b>SPECIMEN DESCRIPTION</b></p> <p>Configuration <u>Fig. 2</u></p> <p>Material <u>300 M (270-300 ksi)</u></p> <p>Width (in.) <u>1.50</u></p> <p>Hole spacing (in.) <u>1.50</u></p> <p>Edge margin (in.) <u>0.75</u></p> <p>Material gage (in.) <u>0.250</u></p> <p>Surface treatment <u>Shot peen</u></p>	<p><b>COLDWORK PROCESS</b></p> <p>Interference (in.) <u>0.023</u></p> <p>Sleeve type <u>Push, no sleeve</u></p> <p>Sleeve thickness (in.) <u>-</u></p> <p>Sleeve orientation <u>-</u></p> <p>Mandrel material <u>Carbide (BAC 5972)</u></p> <p>Mandrel taper (in./in.) <u>0.030</u></p> <p>Mandrel max diameter (in.) <u>0.358</u></p> <p>Lubrication <u>Fel Pro 300</u></p>	<p><b>HOLE PREPARATION</b></p> <p>Nominal hole size (in.) <u>3/8</u></p> <p>Process <u>Ream, C/W, ream score</u></p> <p>Push, no sleeve <u>-</u></p> <p>FASTENER INSTALLATION</p> <p>Type <u>-</u></p> <p>Fit <u>-</u></p> <p>Torque (in.-lb) <u>-</u></p>	<p><b>FATIGUE CONDITIONS</b></p> <p>Max net stress (ksi) <u>110</u></p> <p>Max test load (kip) <u>31.2</u></p> <p>Load ratio (R) <u>0.1</u></p> <p>Test frequency <u>4000 cpm</u></p> <p>Test laboratory <u>Materials</u></p> <p>Test engineer <u>D. Reese</u></p> <p>Test machine <u>100-kip Vibraphore</u></p>
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Specimen dash no	Hole no	Hole diameter (in.)			Hole finish (RHR)		Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	Actual	Retained	Diameter	Fit		
-30	1	0.3350	0.3495	0.3735	25	15	20	0.023	0.0145		103,000	
	2	0.3350	0.3500	0.3735	-	-	20	0.023	0.0150			
	3											
	4											
-31	1	0.3350	0.3500	0.3740	25	10	75	0.023	0.0150		67,000	
	2	0.3350	0.3500	0.3745	-	-	25	0.023	0.0150			
	3											
	4											
-32	1	0.3350	0.3495	0.3735	25	15	20	0.023	0.0145		110,000	
	2	0.3350	0.3495	0.3735	-	-	20	0.023	0.0145			
	3											
	4											





**PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS**

300 M.  
abusive drill,  
open, C/W  
110 ksi

TEST 4A6 SPECIMEN 623080 DATE 10/11/73

**FATIGUE CONDITIONS**  
 Max net stress (ksi) 110  
 Max test load (kip) 31.2  
 Load ratio (R) 0.1  
 Test frequency 400 cpm  
 Test laboratory Materials  
 Test engineer D. Reese  
 Test machine 100-kip vibraphore

**HOLE PREPARATION**  
 Nominal hole size (in) 3/8  
 Drill, C/W, ream  
 Process  
**FASTENER INSTALLATION**  
 Type  
 Fit  
 Torque (in. lb)

**COLDWORK PROCESS**  
 Interference 0.023  
 Push, no sleeve  
 Sleeve thickness (in.)  
 Sleeve orientation  
 Mandrel material Carbide (BAC 5972)  
 Mandrel taper (in./in.) 0.030  
 Mandrel max diameter (in.) 0.357  
 Lubrication Fel Pro 300

**SPECIMEN DESCRIPTION**  
 Fig. 2  
 Configuration 300 M steel (270-300 ksi)  
 Material 300 M steel (270-300 ksi)  
 Width (in.) 1.50  
 Hole spacing 1.50  
 Edge margin (in.) 0.75  
 Material grade (in.) 0.250  
 Surface treatment Shot peen

Specimen dash no	Hole no	Hole diameter (in.)		Hole finish (RHR)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
.9	1	0.3350	0.03485	0.3730	60	10	20	0.022	0.0135		113,000	
	2	0.3350	0.03490	0.3730	-	-	-	0.022	0.0140			
	3											
	4											
.10	1	0.3370	0.3490	0.3735	50	15	15	0.020	0.0120		150,000	
	2	0.3360	0.3490	0.3735	-	-	-	0.021	0.0125			
	3											
	4											
.11	1	0.3400	0.3495	0.3730	60	10	20	0.017	0.0095		380,000	
	2	0.3350	0.3495	0.3735	-	-	-	0.022	0.00145			
	3											
	4											



PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

300 M,  
1/32-postream,  
110 ksi

TEST 4AB SPECIMEN 623080 DATE 10/11/73

SPECIMEN DESCRIPTION		COLDWORK PROCESS		HOLE PREPARATION		FATIGUE CONDITIONS	
Configuration	Fig. 2	Interference	0.023	Nominal hole size (in.)	3/8	Max net stress (ksi)	110
Material	300 M steel (270-300 ksi)	Sleeve type	Push no sleeve	Process	Ream, C/W, ream (13/32)	Max test load (kip)	30.3
Width (in.)	1.50	Sleeve thickness (in.)	-			Load rate (R)	0.1
Hole spacing	1.50	Sleeve orientation	-			Test frequency	4000 cpm
Edge margin (in.)	0.75	Mandrel material	Carbide (BAC 5972)	FASTENER INSTALLATION		Test laboratory	Materials
Material gage (in.)	0.250	Mandrel taper (in./in.)	0.030	Type		Test engineer	D. Reese
Surface treatment	Shot peen	Mandrel max diameter (in.)	0.358	Fit		Test machine	100-kip Vibraphore
		Lubrication	Fel Pro 300	Torque (in. lb)			

Specimen dash no	Hole no	Hole diameter (in.)				Hole finish (RHR)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
36	1	0.3345	0.3490	0.4055	0.4055	30	15	20	0.0235	0.0145			248,000	
	2	0.3345	0.3490	0.4055	0.4055	-	-	20	0.0235	0.0145				
	3													
	4													
37	1	0.3345	0.3490	0.4055	0.4055	20	10	20	0.0235	0.0145			121,000	
	2	0.3345	0.3490	0.4055	0.4055	-	-	20	0.0235	0.0145				
	3													
	4													
38	1	0.3345	0.3490	0.4055	0.4055	25	12	20	0.0235	0.0145			209,000	
	2	0.3345	0.3490	0.4055	0.4055	-	-	-	0.0235	0.0145				
	3													
	4													

PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

300 M  
1/16 postream,  
100 ksi

TEST 4A9 SPECIMEN 623080 DATE 10/12/73

SPECIMEN DESCRIPTION		COLDWORK PROCESS		HOLE PREPARATION		FATIGUE CONDITIONS	
Configuration	Fig. 2	Interference	0.023	Nominal hole size (in.)	3/8	Max net stress (ksi)	110
Material	300 M (270-300 Ksi)	Sleeve type	Push, no sleeve	Process	Ream, C.W. ream (7/16)	Max test load (kip)	29.6
Width (in.)	1.50	Sleeve thickness (in.)	-			Load ratio (R)	0.1
Hole spacing	1.50	Sleeve orientation	-			Test frequency	4000 cpm
Edge margin (in.)	0.75	Mandrel material	Carbide (BAC 5972)	FASTENER INSTALLATION		Test laboratory	Materials
Material gauge (in.)	0.250	Mandrel taper (in./in.)	0.030	Type		Test engineer	D. Reese
Surface treatment	Shot peen	Mandrel max diameter (in.)	0.358	Fit		Test machine	100-kip Vibraphore
		Lubrication	Fel Pro 300	Torque (in. lb)			

Specimen dash no	Hole no	Hole diameter (in.)				Hole finish (RHR)		Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	After ream coldwork	Before coldwork	After coldwork	Actual	Retained	Diameter	Fit		
39	1	0.3345	0.3490	0.4365	25	12	25	0.0235	0.0145			58,000	
	2	0.3345	0.3490	0.4365	-	-	-	0.0235	0.0145				
	3												
	4												
40	1	0.3345	0.3490	0.4370	30	15	30	0.0235	0.0145			77,000	
	2	0.3345	0.3490	0.4370	-	-	-	0.0235	0.0145				
	3												
	4												
41	1	0.3345	0.3490	0.4370	30	15	25	0.0235	0.0145			55,000	
	2	0.3345	0.3490	0.4370	-	-	-	0.0235	0.0145				
	3												
	4												

PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

300 M,  
0.060-in. gage mtl  
110 ksi

TEST 481 SPECIMEN 623080 DATE 9/24/73

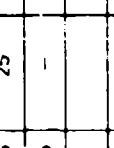
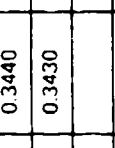
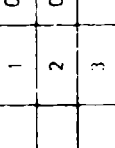
**SPECIMEN DESCRIPTION**  
 Configuration Fig. 2  
 Material 300 M steel (270-300 ksi)  
 Width (in.) 1.50  
 Hole spacing 1.50  
 Edge margin (in.) 0.76  
 Material gage (in.) 0.060  
 Surface treatment Shot peen

**COLDWORK PROCESS**  
 Interference 0.023  
 Sleeve type Push, no sleeve  
 Sleeve thickness (in.) -  
 Sleeve orientation -  
 Mandrel material Carbide (BAC 5972)  
 Mandrel taper (in./in.) 0.030  
 Mandrel max diameter (in.) 0.358  
 Lubrication Fel Pro 300

**HOLE PREPARATION**  
 Nominal hole size (in.) 3/8  
 Process Ream, C/W, ream

**FASTENER INSTALLATION**  
 Type -  
 Fit -  
 Torque (in. lb) -

**FATIGUE CONDITIONS**  
 Max net stress (ksi) 110  
 Max test load (kip) 3.6  
 Load ratio (R) 0.1  
 Test frequency 4000 rpm  
 Test laboratory Materials  
 Test engineer D. Reese  
 Test machine 36 kip Vibraphore

Specimen dash no	Hole no	Hole diameter (in.)			Hole finish (RHR)		Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	Actual	Retained	Diameter	Fit		
1	1	0.3345	0.3405	0.3735	25	12	15	0.0235	0.0060		71,000	
	2	0.3345	0.3440	0.3735	-	-	-	0.0235	0.0095			
	3											
	4											
2	1	0.3345	0.3440	0.3740	25	15	20	0.0235	0.0095		12,000	
	2	0.3395	0.3430	0.3740				0.0235	0.0085			
	3											
	4											
3	1	0.3345	0.3460	0.3735	20	10	15	0.0235	0.0115		47,000	
	2	0.3345	0.3470	0.3735	-	-	-	0.0235	0.0125			
	3											
	4											

PHASE I - TASK 4 - APPLICATION AND PROCESS PARAMETERS

300 M.  
1 hole, not C/W,  
filled,  
110 ksi

TEST 4CI SPECIMEN 623080 DATE 9/10/73

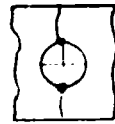
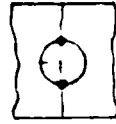
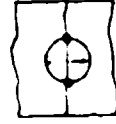
**SPECIMEN DESCRIPTION**  
 Configuration: Fig. 2  
 Material: 300 M steel (270-300 ksi)  
 Width (in): 1.50  
 Hole spacing: 1.50  
 Edge margin (in): 0.75  
 Material gauge (in): 0.250  
 Surface treatment: Shot peen

**COLDWORK PROCESS**  
 Interference: 0.023  
 Sleeve type: Push, no sleeve  
 Sleeve thickness (in): -  
 Sleeve orientation: -  
 Mandrel material: Carbide (BAC 5972)  
 Mandrel taper (in./in.): 0.030  
 Mandrel max diameter (in.): 0.358  
 Lubrication: Fel Pro 300

**HOLE PREPARATION**  
 Nominal hole size (in): 3/8  
 Process: Hole 1, ream  
 Hole 2, ream, C/W 1 ream

**FASTENER INSTALLATION**  
 Type: Hi-Lok prot hd  
 Fit: Net to 0.0005 clearance  
 Torque (in. lb): 240/250

**FATIGUE CONDITIONS**  
 Max net stress (ksi): 110  
 Max test load (kip): 30.6  
 Load ratio (R): 0.1  
 Test frequency: 400 cpm  
 Test laboratory: Materials  
 Test engineer: D. Reese  
 Test machine: 100-kip vibraphore

Specimen dash no	Hole no	Hole diameter (in)			Hole finish (RH/R)		Coldwork expansion (in)		Fastener size (in)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	Actual	Retained	Diameter	Fit		
42	1	-	-	0.3740	-	-	-	-	0.3735	0.0008	43,000	 Failed in reamed hole
	2	0.3345	0.3490	0.3740	25	15	0.0235	0.0145	0.3735	0.0005		
	3											
	4											
43	1	-	-	0.3740	-	-	-	-	0.3735	0.0005	52,000	 Failed in reamed hole
	2	0.3350	0.3490	0.3740	25	12	0.0230	0.0140	0.3735	0.0005		
	3											
	4											
44	1	-	-	0.3740	-	-	-	-	0.3740	NET	33,000	 Failed in reamed hole
	2	0.3350	0.3490	0.3740	30	15	0.0230	0.0140	0.3740	NET		
	3											
	4											

PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

300 M,  
0.002 clearance Hi-Lok,  
110 ksi

TEST 4C2 SPECIMEN 623080 DATE 9/24/73

<b>SPECIMEN DESCRIPTION</b>	<b>COLDWORK PROCESS</b>	<b>HOLE PREPARATION</b>	<b>FATIGUE CONDITIONS</b>
Configuration <u>Fig. 2</u>	Interference <u>0.023</u>	Nominal hole size (in) <u>0.375</u>	Max net stress (ksi) <u>110</u>
Material <u>300 M steel (270-300 ksi)</u>	Sleeve type <u>Push, no sleeve</u>	Process <u>Ream, C/W ream</u>	Max test load (kip) <u>31.3</u>
Width (in) <u>1.50</u>	Sleeve thickness (in.) _____		Load ratio (R) <u>0.1</u>
Hole spacing <u>1.50</u>	Sleeve orientation _____		Test frequency <u>4000 gpm</u>
Edge margin (in) <u>0.75</u>	Mandrel material <u>Carbide (BAC 5972)</u>	<b>FASTENER INSTALLATION</b>	Test laboratory <u>Materials</u>
Material gage (in.) <u>0.250</u>	Mandrel taper (in/in) <u>0.030</u>	Type <u>Hi-Lok, prot hd</u>	Test engineer <u>D. Reese</u>
Surface treatment <u>Shot peen</u>	Mandrel max diameter (in.) <u>0.358</u>	Fit <u>0.002 clearance</u>	Test machine <u>100-kip Vibraphore</u>
	Lubrication <u>EsL Pro 300</u>	Torque (in lb) <u>240-250</u>	

Specimen dash no	Hole no	Hole diameter (in)		Hole finish (RHR)		Coldwork expansion (in)		Fastener size (in)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	Before coldwork	After coldwork	Actual	Retained	Diameter	Fit		
-48	1	0.3335	0.3500	25	10	0.0245	0.0165	0.3735	0.002	711,000	
	2	0.3335	0.3500	-	-	0.0245	0.0165	0.3735	0.002		
	3										
	4										
-49	1	0.3335	0.3505	30	15	0.0245	0.0170	0.3735	0.002	254,000	
	2	0.3335	0.3490	-	-	0.0245	0.0155	0.3753	0.002		
	3										
	4										
-50	1	0.3335	0.3490	28	10	0.0245	0.0155	0.3735	0.002	283,000	
	2	0.3335	0.3490	-	-	0.0245	0.0155	0.3735	0.002		
	3										
	4										





PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

300 M  
100° csk after C/W,  
110 ksi

TEST 4C4 SPECIMEN 623080 DATE 9/28/73

<b>SPECIMEN DESCRIPTION</b>	<b>COLDWORK PROCESS</b>	<b>HOLE PREPARATION</b>	<b>FATIGUE CONDITIONS</b>
Configuration <u>Fig. 2</u>	Interference (in.) <u>0.023</u>	Nominal hole size (in.) <u>0.375</u>	Max net stress (ksi) <u>110</u>
Material <u>300 M steel (270-300 ksi)</u>	Sleeve type <u>Push, no sleeve</u>	Process	Ream, C/W, ream csk <u>31</u>
Width (in.) <u>1.50</u>	Sleeve thickness (in.)		Load ratio (R) <u>0.1</u>
Hole spacing (in.) <u>1.50</u>	Sleeve orientation		Test frequency <u>4000 gpm</u>
Edge margin (in.) <u>0.75</u>	Mandrel material <u>Carbide (BAC 5972)</u>	<b>FASTENER INSTALLATION</b>	Test laboratory <u>Materials</u>
Material gauge (in.) <u>0.250</u>	Mandrel taper (in/in) <u>0.030</u>	Type <u>Hi-Lok (100° hd)</u>	Test engineer <u>D. Reese</u>
Surface treatment <u>Shot peen</u>	Mandrel max diameter (in.) <u>0.357</u>	Fit (in.) <u>Net to 0.0005 interference</u>	Test machine <u>100-kip Vitrashore</u>
	Lubrication <u>Fel Pro 300</u>	Torque (in lb) <u>240-250</u>	

Specimen dash no	Hole no	Hole diameter (in.)				Hole finish (RHR)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	After coldwork	Before coldwork	After coldwork	After ream	Actual	Retention	Diameter	Fit		
51	1	0.3340	0.3480	0.3735	25	10	20	0.0230	0.0140	0.3740	0.0005	9,993,000		
	2	0.3340	0.3480					0.0230	0.0140	0.3740	0.0005			
	3													
	4													
52	1	0.3335	0.3480	0.3735				0.0235	0.0145	0.3740	0.0005	7,760,000		
	2	0.3340	0.3500	0.3740	40	20	20	0.0230	0.0150	0.3740	Net			
	3													
	4													
53	1	0.3340	0.3490	0.3735	25	12	20	0.0230	0.0150	0.3740	0.0005	1,510,000		
	2	0.3340	0.3490	0.3735				0.0230	0.0150	0.3740	0.0005			
	3													
	4													



PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

300 M.  
100° csk before C/W.  
110 ksi

TEST 4C6 SPECIMEN 6230880 DATE 9/24/73

**SPECIMEN DESCRIPTION**  
 Configuration Fig. 2  
 Material 300 M steel (270-300 ksi)  
 Width (in.) 1.50  
 Hole spacing (in.) 1.50  
 Edge margin (in.) 0.75  
 Material gage (in.) 0.250  
 Surface treatment Shot peen

**COLDWORK PROCESS**  
 Interference (in.) 0.023  
 Sleeve type Push, no sleeve  
 Sleeve thickness (in.) \_\_\_\_\_  
 Sleeve orientation \_\_\_\_\_  
 Mandrel material Carbide (BAC 5972)  
 Mandrel taper (in/in) 0.030  
 Mandrel max diameter (in) 0.357  
 Lubrication Fel Pro 300

**MOLE PREPARATION**  
 Nominal hole size (in) 3/8  
 Process Ream, csk, C/W, ream, install fastener

**FASTENER INSTALLATION**  
 Type Hi-Lok (100° hd)  
 F<sub>t</sub> (in.) Net to 0.0005 clearance  
 Torque (in lb) 240 250

**FATIGUE CONDITIONS**  
 Max net stress (ksi) 110  
 Max test load (kip) 30.5  
 Load ratio (R) 0.1  
 Test frequency 4000 cpm  
 Test laboratory Materials  
 Test engineer D. Reese  
 Test machine 100 kip Vibraphore

Specimen dash no	Hole no	Hole diameter (in)				Hole finish (RHR)			Coldwork expansion (in)		Fastener size (in)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	F-t		
12	1	0.3335	0.3495	0.3740	25	10	25	0.0235	0.0155	0.3740	Net	38,000		
	2	0.3335	0.3505	0.3740	-	-	-	0.0235	0.0170	0.3740	Net			
	3													
	4													
13	1	0.3335	0.3500	0.3740	25	10	20	0.0235	0.0165	0.3740	Net	26,000		
	2	0.3345	0.3500	0.3740	-	-	-	0.0235	0.0165	0.3740	Net			
	3													
	4													
14	1	0.3335	0.3515	0.3740	25	10	35	0.0235	0.0180	0.3740	Net	36,000		
	2	0.3335	0.3515	0.3735	-	-	-	0.0235	0.0180	0.3735	Net			
	3													
	4													

PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

TEST 4C7(S) SPECIMEN 623080 DATE 10/16/73

300 M.  
pretiaqued,  
80,000 cycles,  
110 ksi

**SPECIMEN DESCRIPTION**  
 Configurator Fig. 2  
 Material 300 M steel (270-300 ksi)  
 Width (in.) 1.50  
 Hole spacing (in.) 1.50  
 Edge margin (in.) 0.75  
 Material gauge (in.) 0.250  
 Surface treatment Shot peen

**COLDWORK PROCESS**  
 Interference (in.) 0.023  
 Sleeve type Push, no sleeve  
 Sleeve thickness (in.) -  
 Sleeve orientation -  
 Mandrel material Carbide (BAC 5972)  
 Mandrel taper (in./in.) 0.030  
 Mandrel max diameter (in.) 0.357  
 Lubrication Fel Pro 300

**MOLE PREPARATION**  
 Nominal hole size (in.) 3/8  
 Process Ream undersize, fatigue (80,000 cycles) C/W, ream

**FASTENER INSTALLATION**  
 Type Hi-Lok prot hd  
 Fr. (in.) Net to 0.0005 clearance  
 Torque (in. lb) 240 250

**FATIGUE CONDITIONS**  
 Max net stress (ksi) 110  
 Max rest load (kip) 32.6  
 Load ratio (R) 0.1  
 Test frequency 4000 cpm  
 Test laboratory Materials  
 Test engineer D. Reese  
 Test machine 100-kip Vibration

Specimen dash no	Hole no	Hole diameter (in.)				Hole finish (RHR)			Coldwork repairs on (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coltwork	After coltwork	After ream	After coltwork	Before coltwork	After coltwork	After ream	Actual	Retained	Diameter	Fr.		
15	1	0.3330	0.3490	0.3735	20	10	20	0.024	0.0160	0.3735	Net	343,000		
	2	0.3330	0.3490	0.3735	-	10	-	0.024	0.0155	0.3735	Net			
	3													
	4													
17	1	0.3330	0.3490	0.3735	20	10	25	0.024	0.0160	0.3735	Net	7,508,000		
	2	0.3330	0.3490	0.3735	-	-	-	0.024	0.0160	0.3735	Net			
	3													
	4												No failure	

<sup>1</sup>Specimen failed prior to reaching 80,000 cycles in initial fatigue cycling prior to C/W

**PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS**

300 M,  
 1/2-D edge margin,  
 110 ksi

TEST 4D1(S) SPECIMEN 623080 DATE 10/23/73

<b>SPECIMEN DESCRIPTION</b> Fig. 7A Configuration <u>300 M steel (270-300 ksi)</u> Material <u>3.125</u> Width (in.) <u>150 x 2.00</u> Hole spacing (in.) <u>0.562</u> Edge margin (in.) <u>0.250</u> Material grade (in.) <u>Shot peen</u> Surface treatment	<b>COLDWORK PROCESS</b> Interference (in.) <u>0.023</u> Sleeve type <u>Push, no sleeve</u> Sleeve thickness (in.) <u>-</u> Sleeve orientation <u>-</u> Mandrel material <u>Carbide (BAC 5972)</u> Mandrel taper (in./in.) <u>0.030</u> Mandrel max diameter (in.) <u>0.357</u> Lubrication <u>Fel Pro 300</u>	<b>HOLE PREPARATION</b> Nominal hole size (in.) <u>0.375</u> Process <u>Ream, C.W. ream</u> <b>FASTENER INSTALLATION</b> Type _____ Fit _____ Torque (in. lb) _____
<b>FATIGUE CONDITIONS</b> Max net stress (ksi) <u>110</u> Max test load (kip) <u>65.4</u> Load ratio (R) <u>0.1</u> Test frequency <u>4000 cpm</u> Test laboratory <u>Materials</u> Test engineer <u>D. Reese</u> Test machine <u>100-kip Vibraphore</u>		

Specimen dash no	Hole no	Hole diameter (in.)			Hole finish (RH/R)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
60	1	0.3345	0.3485	0.3735	25	10	15	0.0225	0.0140			100,000	
	2	0.3345	0.3485	0.3735	-	-	-	0.0225	0.0140				
	3	0.3345	0.3485	0.3735	-	-	-	0.0225	0.0140				
	4	0.3345	0.3485	0.3735	-	-	-	0.0225	0.0140				
61	1	0.3345	0.3480	0.3735	25	10	10	0.0225	0.0135			170,000	
	2	0.3345	0.3480	0.3735	-	-	-	0.0225	0.0135				
	3	0.3345	0.3480	0.3735	-	-	-	0.0225	0.0135				
	4	0.3345	0.3480	0.3735	-	-	-	0.0225	0.0135				
63	1	0.3340	0.3490	0.3735	30	10	15	0.0230	0.0150			177,000	
	2	0.3340	0.3490	0.3735	-	-	-	0.0230	0.0150				
	3	0.3340	0.3490	0.3735	-	-	-	0.0230	0.0150				
	4	0.3340	0.3490	0.3735	-	-	-	0.0230	0.0150				

PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

300 M,  
2-D edge margin,  
110 ksi

TEST 402 (S) SPECIMEN 623080 DATE 10/22/73

SPECIMEN DESCRIPTION

Configuration Fig. 7B  
 Material 300 M steel (270 300 Ksi)  
 Width (in.) 3.50  
 Hole spacing (in.) 150 x 2.00  
 Edge margin (in.) 0.750  
 Material geom (in.) 0.250  
 Surface treatment Shot peen

COLDWORK PROC


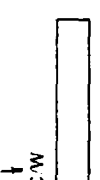
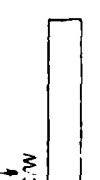
Interference (in.) 0.023-0.024  
 Sleeve type Push, no sleeve  
 Sleeve thickness (in.) -  
 Sleeve orientation -  
 Mandrel material Carbide (BAC 5972)  
 Mandrel taper (in/in) 0.030  
 Mandrel max diameter (in.) 0.357  
 Lubrication Fel Pro 300

HOLE PREPARATION

Nominal hole size (in.) 0.375  
 Process Ream, C/W, ream  
 FASTENER INSTALLATION  
 Type \_\_\_\_\_  
 Fit \_\_\_\_\_  
 Torque (in. lb) \_\_\_\_\_

FATIGUE CONDITIONS

Max net stress (ksi) 110  
 Max test load (kip) 75.7  
 Load ratio (R) 0.1  
 Test frequency 4000 cpm  
 Test laboratory Materials  
 Test engineer D. Reese  
 Test machine 100-kip Vibraphore

Specimen dash no	Hole diameter (in.)		Hole finish (RHR)		Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
	Before coldwork	After ream	Before coldwork	After coldwork	Actual	Retained	Diameter	Fit		
65	1	0.3335	0.3485	0.3735	25	10	0.0235	0.0150	78,000	 C/W
	2	0.3335	0.3485	0.3735	-	-	0.0235	0.0155		
	3	0.3335	0.3485	0.3735	20	30	0.0235	0.0150		
	4	0.3335	0.3485	0.3735	-	-	0.0235	0.0150		
66	1	0.3335	0.3490	0.3735	30	15	0.0235	0.0155	44,000	 C/W
	2	0.3335	0.3490	0.3735	-	-	0.0235	0.0155		
	3	0.3335	0.3485	0.3735	25	10	0.0235	0.0150		
	4	0.3335	0.3485	0.3735	-	-	0.0235	0.0150		
67	1	0.3340	0.3485	0.3730	30	15	0.0230	0.0145	56,000	 C/W
	2	0.3340	0.3490	0.3730	-	-	0.0230	0.0145		
	3	0.3340	0.3485	0.3730	25	10	0.0230	0.0145		
	4	0.3340	0.3485	0.3730	-	-	0.0230	0.0145		

PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

300 M,  
2 1/2 D edge margin,  
110 ksi

TEST 4D3 (S) SPECIMEN 623080 DATE 10/23/73

**SPECIMEN DESCRIPTION**  
 Configuration Fig. 7C  
 Material 300 M steel (270-300 ksi)  
 Width (in.) 3.875  
 Hole spacing (in.) 1.50 x 2.00  
 Edge margin (in.) 0.937  
 Material grade (in.) 0.250  
 Surface treatment Shot peen

**COLDWORK PROCESS**  
 Interference (in.) 0.023-0.024  
 Sleeve type Push, no sleeve  
 Sleeve thickness (in.) -  
 Sleeve orientation -  
 Mandrel material Carbide (BAC 5972)  
 Mandrel taper (in./in.) 0.030  
 Mandrel max diameter (in.) 0.357  
 Lubrication Fel Pro 300

**HOLE PREPARATION**  
 Nominal hole size (in.) 0.375  
 Process Ream, C/W, ream

**FASTENER INSTALLATION**  
 Type -  
 Fit -  
 Torque (in. lb) -

**FATIGUE CONDITIONS**  
 Max net stress (ksi) 110  
 Max test load (kip) .86  
 Load ratio (R) 0.1  
 Test frequency 4000 cpm  
 Test laboratory Materials  
 Test engineer D. Reese  
 Test machine 100-kip Vibraphore

Specimen dash no	Hole no	Hole diameter (in.)		Hole finish (RHR)		Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	Actual	Retained	Diameter		
.68	1	0.3340	0.3485	0.3735	25	10	20	0.023	0.0145	70,000	
	2	0.3340	0.3485	0.3735	-	-	-	0.023	0.0145		
	3	0.3340	0.3485	0.3735	-	-	-	0.023	0.0145		
	4	0.3340	0.3485	0.3735	-	-	-	0.023	0.0145		
.69	1	0.3340	0.3485	0.3735	30	10	15	0.023	0.0145	72,000	
	2	0.3340	0.3485	0.3735	-	-	-	0.023	0.0145		
	3	0.3340	0.3485	0.3735	-	-	-	0.023	0.0145		
	4	0.3340	0.3485	0.3735	-	-	-	0.023	0.0145		
.71	1	0.3340	0.3485	0.3740	30	10	20	0.023	0.0145	182,000	
	2	0.3340	0.3485	0.3740	-	-	-	0.023	0.0145		
	3	0.3340	0.3485	0.3740	-	-	-	0.023	0.0145		
	4	0.3340	0.3485	0.3740	-	-	-	0.023	0.0145		



PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

300 M,  
2½-D edge margin,  
110 ksi

TEST 4D4(S) SPECIMEN 623080 DATE 10/23/73

<b>SPECIMEN DESCRIPTION</b>	<b>COLDWORK PROCESS</b>	<b>HOLE PREPARATION</b>	<b>FATIGUE CONDITIONS</b>
Configuration <u>Fig. 7D</u>	Interference (in.) <u>0.023-0.024</u>	Nominal hole size (in.) <u>0.375</u>	Max net stress (ksi) <u>110</u>
Material <u>300 M steel (270-300 ksi)</u>	Sleeve type <u>Push, no sleeve</u>	Process <u>Ream, C/W, ream</u>	Max test load (kip) <u>61.8</u>
Width (in.) <u>2.995</u>	Sleeve thickness (in.) <u>-</u>		Load ratio (R) <u>0.1</u>
Hole spacing (in.) <u>1.125 x 1.50</u>	Sleeve orientation <u>-</u>		Test frequency <u>4000 cpm</u>
Edge margin (in.) <u>0.9375</u>	Mandrel material <u>Carbide (BAC 5972)</u>	<b>FASTENER INSTALLATION</b>	Test laboratory <u>Materials</u>
Material gage (in.) <u>0.250</u>	Mandrel taper (in./in.) <u>0.030</u>	Type <u>-</u>	Test engineer <u>D. Reese</u>
Surface treatment <u>Shot peen</u>	Mandrel max diameter (in.) <u>0.357</u>	Fit <u>-</u>	Test machine <u>100-kip Vibraphore</u>
	Lubrication <u>Fel Pro 300</u>	Torque (in. lb) <u>-</u>	

Specimen dash no	Hole no	Hole diameter (in.)			Hole finish (RHR)			Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
72	1	0.3335	0.3485	0.3740	25	10	20	0.0235	0.0150			91,000	
	2	0.3335	0.3485	0.3740	-	-	-	0.0235	0.0150				
	3	0.3335	0.3485	0.3740	-	-	-	0.0235	0.0150				
	4	0.3335	0.3485	0.3740	-	-	-	0.0235	0.0150				
73	1	0.3335	0.3485	0.3745	25	10	25	0.0235	0.0150			80,000	
	2	0.3335	0.3485	0.3740	-	-	-	0.0235	0.0150				
	3	0.3335	0.3485	0.3735	-	-	-	0.0235	0.0150				
	4	0.3335	0.3485	0.3735	-	-	-	0.0235	0.0150				
74	1	0.3340	0.3485	0.3735	25	10	20	0.0230	0.0145			116,000	
	2	0.3340	0.3485	0.3735	-	-	-	0.0230	0.0145				
	3	0.3340	0.3485	0.3735	-	-	-	0.0230	0.0145				
	4	0.3340	0.3485	0.3735	-	-	-	0.0230	0.0145				

PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

300 M.  
2 1/2-D edge margin,  
110 ksi

TEST 4D5 (S) SPECIMEN 623080 DATE 10/23/73

**SPECIMEN DESCRIPTION**  
 Configuration Fig. 7E  
 Material 300 M steel (270-300 ksi)  
 Width (in.) 3.375  
 Hole spacing (in.) 150 x 1.50  
 Edge margin (in.) 0.9375  
 Material gage (in.) 0.250  
 Surface treatment Shot peen

**COLDWORK PROCESS**  
 Interference (in.) 0.023-0.024  
 Sleeve type Push, no sleeve  
 Sleeve thickness (in.) -  
 Sleeve orientation -  
 Mandrel material Carbide (BAC 5972)  
 Mandrel taper (in/in) 0.030  
 Mandrel max diameter (in) 0.357  
 Lubrication Fel Pro 300

**FASTENER INSTALLATION**  
 Type -  
 Fit -  
 Torque (in. lb) -

**HOLE PREPARATION**  
 Nominal hole size (in) 0.375  
 Process Ream, C/W, ream

**FATIGUE CONDITIONS**  
 Max net stress (ksi) 110  
 Max test load (kip) 72.2  
 Load ratio (R) 0.1  
 Test frequency 4000 cpm  
 Test laboratory Materials  
 Test engineer D. Reese  
 Test machine 100-kip Vibraphore

Specimen dash no	Hole diameter (in)			Hole finish (IRHR)			Coldwork expansion (in)			Fastener size (in)		Cycles to failure	Origin of failure and remarks
	Before col-work	After col-work	After ream	Before col-work	After col-work	After ream	Actual	Retained	Diameter	Fit			
76	1	0.3335	0.3485	0.3735	45	20	25	0.0235	0.0150			120,000	
	2	0.3335	0.3485	0.3735	-	-	-	0.0235	0.0150				
	3	0.3340	0.3485	0.3735	-	-	-	0.0230	0.0145				
	4	0.3340	0.3485	0.3735	-	-	-	0.0230	0.0145				
77	1	0.3340	0.3500	0.3730	50	25	20	0.0230	0.0160			145,000	
	2	0.3340	0.3485	0.3730	-	-	-	0.0230	0.0145				
	3	0.3340	0.3485	0.3730	-	-	-	0.0230	0.0145				
	4	0.3340	0.3490	0.3730	-	-	-	0.0230	0.0150				
78	1	0.3335	0.3485	0.3730	40	15	15	0.0235	0.0150			143,000	
	2	0.3335	0.3485	0.3735	-	-	-	0.0235	0.0150				
	3	0.3340	0.3485	0.3730	-	-	-	0.0230	0.0145				
	4	0.3340	0.3485	0.3730	-	-	-	0.0230	0.0145				

PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

300 M.  
high load transfer,  
CW, net fit Hi-Lok  
0.020 micarta,  
110 ksi

TEST 4E1 SPECIMEN 623080 DATE 11/17/73

**SPECIMEN DESCRIPTION**  
 Configuration Fig. 10  
 Material 300 M (270-300 ksi)  
 Width (in) 3.00  
 Hole spacing 1.50  
 Edge margin (in) 0.75  
 Material gage (in) 0.250  
 Surface treatment Shot Peened  
 Shim Thickness 0.020

**COLDWORK PROCESS**  
 Interference (in) 0.023  
 Sleeve type Push, no sleeve  
 Sleeve thickness (in) -  
 Sleeve orientation -  
 Mandrel material Carbide (BAC 5792)  
 Mandrel taper (in/in) 0.030  
 Mandrel max diameter (in) 0.357  
 Lubrication Fel Pro 300

**HOLE PREPARATION**  
 Nominal hole size (in) 0.375  
 Process Ream, CW, ream  
 Push, no sleeve -  
 Type Hi-Lok, prot hd  
 Fit (in) Net to 0.005 interference  
 Torque (in lbf) 240-250

**FATIGUE CONDITIONS**  
 Max net stress (ksi) 110  
 Max test load (kip) 62  
 Load ratio (R) 0.1  
 Test frequency 600 cpm  
 Test laboratory Materials  
 Test engineer D. Reese  
 Test machine 180 to 240 kip  
Riehle-Loe

Specimen dash no	Hole no	Hole diameter (in)		Hole finish (RHR)			Coldwork expansion (in)		Fastener size (in)		Cycles to failure	Origin of failure and remarks	
		Before coldwork	After coldwork	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit			
1	1	0.3335	0.3485	0.3730	0.3730	25	10	20	0.0235	0.0150	0.3735	0.0005	 CW Hd Fasteners failed; side plate broke
	2	0.3335	0.3485	0.3730	0.3730	-	-	-	0.0235	0.0150	0.3735	0.0005	
	3	0.3335	0.3485	0.3730	0.3730	20	10	20	0.0235	0.0150	0.3730	Net	
	4	0.3335	0.3485	0.3730	0.3730	-	-	-	0.0235	0.0150	0.3730	Net	
2	1	0.3335	0.3485	0.3730	0.3730	20	10	20	0.0235	0.0150	0.3735	0.0005	 CW Hd Fasteners failed; side plate broke
	2	0.3335	0.3485	0.3730	0.3730	-	-	-	0.0235	0.0150	0.3735	0.0005	
	3	0.3335	0.3485	0.3735	0.3735	25	10	20	0.0235	0.0150	0.3735	Net	
	4	0.3335	0.3485	0.3735	0.3735	-	-	-	0.0235	0.0150	0.3735	Net	
3	1	0.3335	0.3485	0.3730	0.3730	20	10	20	0.0235	0.0150	0.3735	0.0005	 CW Hd Fasteners failed; side plate broke
	2	0.3335	0.3490	0.3730	0.3730	-	-	-	0.0235	0.0155	0.3735	0.0005	
	3	0.3335	0.3490	0.3730	0.3730	20	10	20	0.0235	0.0155	0.3730	Net	
	4	0.0335	0.3490	0.3730	0.3730	-	-	-	0.0235	0.0155	0.3730	Net	

**PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS**

300 M  
high load transfer,  
C/W, 0.0002 clearance Hi-Lok,  
0.020 micarta,  
110 ksi

TEST 4E2 SPECIMEN 623080 DATE 11/17/73

**SPECIMEN DESCRIPTION**  
 Fig. 10  
 Configuration 300 M (270 300 ksi)  
 Material 300 M (270 300 ksi)  
 Width (in.) 3.00  
 Hole spacing (in.) 1.50  
 Edge margin (in.) 0.750  
 Material grade (in.) 0.250  
 Surface treatment: Shot peen  
 Shim thickness (in.) 0.020

**COLDWORK PROCESS**  
 Interference (in.) 0.023  
 Sleeve type Push, no sleeve  
 Sleeve thickness (in.)  
 Sleeve orientation  
 Mandrel material Carbide (BAC 579)  
 Mandrel taper (in/in) 0.030  
 Mandrel max diameter (in) 0.3570  
 Lubrication Fel Pro 300

**HOLE PREPARATION**  
 Nominal hole size (in) 0.375  
 Process  
 Type Hi Lok, prot hd  
 F-11 0.002 0.0003 clearance  
 Torque (in lb) 240-250

**FATIGUE CONDITIONS**  
 Max net stress (ksi) 110  
 Max test load (kip) 61  
 Load ratio (R) 0.1  
 Test frequency 600 cpm  
 Test laboratory Materials  
 Test engineers D. Reese  
 Test machine 180 to 240 - kip  
 Riehle-Los

Specimen dash no.	Hole no.	Hole diameter (in.)		Hole finish (RH/R)			Collwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks	
		Before collwork	After collwork	Before collwork	After collwork	After ream	Actual	Retained	Diameter	F-11			
4	1	0.3335	0.3485	0.3765	25	10	75	0.0235	0.0150	0.3735	0.3735	14 850	
	2	0.3335	0.3485	0.3765	-	-	-	0.0235	0.0150	0.3735	0.3735		
	3	0.3335	0.3485	0.3765	25	10	30	0.0235	0.0150	0.3735	0.0030		
	4	0.3335	0.3485	0.3765	-	-	-	0.0235	0.0150	0.3735	0.0030		
5	1	0.3335	0.3485	0.3760	25	10	-	0.0235	0.0150	0.3735	0.0025	21 820	
	2	0.3335	0.3485	0.3760	-	-	-	0.0235	0.0150	0.3735	0.0025		
	3	0.3335	0.3485	0.3755	25	10	-	0.0235	0.0150	0.3735	0.0020		
	4	0.3335	0.3485	0.3760	-	-	-	0.0235	0.0150	0.3735	0.0025		
6	1	0.3335	0.3485	0.3755	25	10	25	0.0235	0.0150	0.3730	0.0025	17 150	
	2	0.3335	0.3485	0.3755	-	-	-	0.0235	0.0150	0.3730	0.0025		
	3	0.3335	0.3485	0.3750	25	10	30	0.0235	0.0150	0.3730	0.0020		
	4	0.3335	0.3485	0.3750	-	-	-	0.0235	0.0150	0.3730	0.0020		

PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

300 M  
high load transfer,  
C.W. 0.002 interference, Hi-Lok  
0.020 micarta  
110 ksi

TEST 4E3 SPECIMEN 623080 DATE 11/18/73

SPECIMEN DESCRIPTION

Configuration: Fig. 10  
Material: 300 M (270-300 ksi)  
Width (in.): 3.00  
Hole spacing (in.): 1.50  
Edge margin (in.): 0.75  
Material gage (in.): 0.250  
Surface treatment: Shot peen  
Shim thickness (in.): 0.020

COLDWORK PROCESS

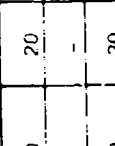
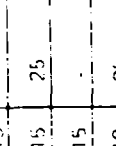
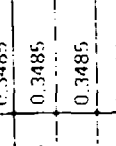
Interference (in.): 0.023  
Sleeve type: Push, no sleeve  
Sleeve thickness (in.):  
Sleeve orientation:  
Mandrel material: Carbide (BAC 5792)†  
Mandrel taper (in/in): 0.030  
Mandrel max diameter (in.): 0.357  
Lubrication: Fet Pro 300

FATIGUE CONDITIONS

Max int stress (ksi): 110  
Max test load (kip): 61  
Load ratio (R): 0.1  
Test frequency: 600 cpm  
Test laboratory: Materials  
Test engineer: D. Reese  
Test machine: 180.240 kip  
Riehle-Los

HOLE PREPARATION

Nominal hole size (in.): 0.0325  
Process: Ream, C/W, ream  
Type: Hi-Lok, prot hd  
Fit (in.): 0.002 0.003 interference  
Torque (in lb): 240-250

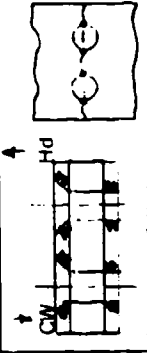
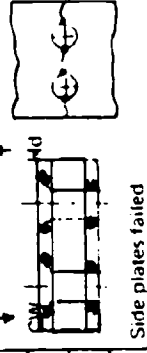
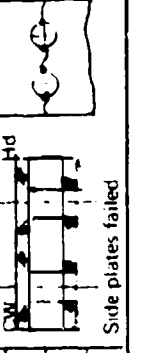
Specimen dash no	Hole no	Hole diameter (in.)		Hole finish (RHRI)		Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks
		Before coldwork	After coldwork	Before coldwork	After coldwork	Actual	Retention	Diameter	Fit		
7	1	0.3335	0.3485	25	10	0.0235	0.0150	0.3735	0.002	20,350	
	2	0.3335	0.3485	-	-	0.0235	0.0150	0.3735	0.002		
	3	0.3335	0.3485	25	10	0.0235	0.0150	0.3735	0.002		
	4	0.3335	0.3485	-	-	0.0235	0.0150	0.3735	0.002		
8	1	0.3335	0.3485	25	10	0.0235	0.0150	0.3735	0.002	15,040	
	2	0.3335	0.3485	-	-	0.0235	0.0150	0.3735	0.002		
	3	0.3335	0.3485	25	10	0.0235	0.0150	0.3735	0.0025		
	4	0.3335	0.3485	-	-	0.0235	0.0150	0.3735	0.0025		
9	1	0.3335	0.3485	25	10	0.0235	0.0150	0.3735	0.0025	21,930	
	2	0.3335	0.3485	-	-	0.0235	0.0150	0.3735	0.0025		
	3	0.3335	0.3485	25	10	0.0235	0.0150	0.3735	0.0025		
	4	0.3335	0.3485	-	-	0.0235	0.0150	0.3735	0.0025		

PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS

300 M  
high load transfer,  
C/W, flush hd, Hi-Lok  
0.020 micarta,  
110 ksi

TEST 4E4 SPECIMEN 623080 DATE 11/18/73

<b>SPECIMEN DESCRIPTION</b>	<b>COLDWORK PROCESS</b>	<b>HOLE PREPARATION</b>	<b>FATIGUE CONDITIONS</b>
Configuration <u>Fig. 10</u>	Interference (in.) <u>0.023</u>	Nominal hole size (in.) <u>0.375</u>	Max net stress (ksi) <u>110</u>
Material <u>300 M (270-300 ksi)</u>	Sleeve type <u>push, no sleeve</u>	Process <u>ream, C/W, ream, csk</u>	Max test load (kip) <u>62</u>
Width (in.) <u>3.00</u>	Sleeve thickness (in.) <u>-</u>		Load ratio (R) <u>0.1</u>
Hole spacing <u>1.50</u>	Sleeve orientation <u>-</u>		Test frequency <u>600 cpm</u>
Edge margin (in.) <u>0.750</u>	Mandrel material <u>Carbide (BAC 5792)</u>	<b>FASTENER INSTALLATION</b>	Test laboratory <u>Materials</u>
Material gauge (in.) <u>0.125 side plates, 0.250 center</u>	Mandrel taper (in./in.) <u>0.030</u>	Type <u>Hi-Lok 1000 hd</u>	Test engineer <u>D. Biese</u>
Surface treatment <u>Shot peen</u>	Mandrel max diameter (in.) <u>0.357</u>	F.i.t. (in.) <u>Net to 0.0005 interference</u>	Test machine <u>180 to 240 kip Riehle-Loe</u>
Shim thickness (in.) <u>0.020</u>	Lubrication <u>FelPro 300</u>	Torque (in. lb) <u>240-250</u>	

Specimen dash no	Hole no	Hole diameter (in.)		Hole finish (RHRR)		Coldwork expansion (in.)		Fastener size (in.)		Cycles to failure	Origin of failure and remarks	
		Before coldwork	After ream	Before coldwork	After coldwork	Actual	Retained	Diameter	F.i.t			
-10	1	0.335	0.3485	0.3735	25	10	0.0235	0.0150	0.3735	Net	7,910	
	2	0.3335	0.3485	0.3735	-	-	0.0235	0.0150	0.3735	Net		
	3	0.0335	0.3485	0.3735	25	10	0.0235	0.0150	0.3735	Net		
	4	0.3335	0.3485	0.3735	-	-	0.0235	0.0150	0.3735	Net		
-11	1	0.3335	0.3485	0.3730	25	10	0.0235	0.0150	0.3735	0.0005	8,090	
	2	0.3335	0.3485	0.3730	-	-	0.0235	0.0150	0.3730	Net		
	3	0.3335	0.3485	0.3730	25	10	0.0235	0.0150	0.3735	0.0005		
	4	0.3335	0.3485	0.3730	-	-	0.0235	0.0150	0.3735	0.0005		
12	1	0.3335	0.3485	0.3735	30	15	0.0235	0.0150	0.3735	Net	9,300	
	2	0.3335	0.3485	0.3730	-	-	0.0235	0.0150	0.3735	0.0005		
	3	0.3335	0.3485	0.3730	30	15	0.0235	0.0150	0.3735	0.0005		
	4	0.3335	0.3485	0.3730	-	-	0.0235	0.0150	0.3735	0.0005		

**PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS**

300 M  
high load transfer,  
reamed, net fit, Hi-Lok,  
0.020 micarta,  
110 ksi

TEST: 4E5 SPECIMEN 623080 DATE 11/12/73

<b>SPECIMEN DESCRIPTION</b>	<b>COLDWORK PROCESS</b>	<b>HOLE PREPARATION</b>	<b>FATIGUE CONDITIONS</b>
Configuration <b>Fig. 10</b>	Interference _____	Nominal hole size (in.) <u>0.375</u>	Max net stress (ksi) <u>110 and 95</u>
Material <u>300 M (270-300 ksi)</u>	Sleeve type _____	Process <u>Ream</u>	Max test load (kip) <u>54 (95), 62 (110)</u>
Width (in.) <u>3.00</u>	Sleeve thickness (in.) _____		Load ratio (R) <u>0.1</u>
Hole spacing <u>1.50</u>	Sleeve orientation _____		Test frequency <u>600 cpm</u>
Edge margin (in.) <u>0.75</u>	Mandrel material _____	<b>FASTENER INSTALLATION</b>	Test laboratory <u>Materials</u>
Material gauge (in.) <u>0.250</u>	Mandrel taper (in./in.) _____	Type <u>Hi-Lok, prot hd</u>	Test engineer <u>D. Reese</u>
Surface treatment <u>Shot peen</u>	Mandrel max diameter (in.) _____	Fit (in.) <u>Net to 0.0005 clearance</u>	Test machine <u>180- to 240- kip</u>
Shim Thickness (in.) <u>0.020</u>	Lubrication _____	Torque (in. lb) <u>240-260</u>	<u>Riehle-Lo</u>

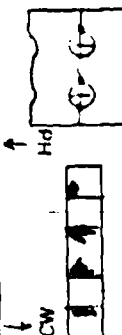

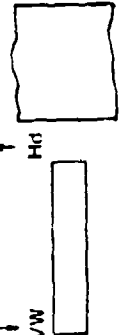
Specimen dash no	Hole no	Hole diameter (in.)		Hole finish (RHR)			Coldwork expansion (in.)		Fastener size (in.)		Cycles in failure	Origin of failure and remarks
		Before coldwork	After ream	Before coldwork	After coldwork	After ream	Actual	Retained	Diameter	Fit		
13	1	0.3735				25			0.3735	Net	4,220	
	2	0.3735				-			0.3735	Net		
	3	0.3735				25			0.3735	Net		
	4	0.3735				-			0.3735	Net		
14	1	0.3735				25			0.3735	Net	8,040	
	2	0.3735				-			0.3735	Net		
	3	0.3735				25			0.3735	Net		
	4	0.3735				-			0.3735	Net		
15	1	0.3735				25			0.3735	Net	9,320	
	2	0.3735				-			0.3735	Net		
	3	0.3735				25			0.3735	Net		
	4	0.3735				-			0.3735	Net		

**PHASE II - TASK 4 - APPLICATION AND PROCESS PARAMETERS**

300 M  
C/W, net fit Hf-Lok,  
no micaarta,  
110 ksi

TEST 4E6 SPECIMEN 623080 DATE 11/15/73

<b>SPECIMEN DESCRIPTION</b>	<b>Fig. 10</b>	<b>HOLE PREPARATION</b>	<b>FATIGUE CONDITIONS</b>
Configuration	300 M (270-300 ksi)	Interference (in.)	Max net stress (ksi) <u>122</u>
Material	300 M	Push no sleeve	Max test load (kip) <u>72.5</u>
Width (in.)	3.00	Sleeve type	Load ratio (R) <u>0.1</u>
Hole spacing (in.)	1.50	Sleeve thickness (in.)	Test frequency <u>600 cpm</u>
Edge margin (in.)	0.75	Sleeve orientation	Test laboratory <u>Materials</u>
Material gauge (in.)	0.250	Manufact material	Test engineer <u>D. Reese</u>
Surface treatment	Shot peen	Carbide (BAC 5792) fastener installation	Test machine <u>180- to 240- kip Richie-Lo</u>
		Mandrel taper (in/in)	
		Mandrel max diameter (in)	
		Fit (in.)	
		Type	
		Hi Lok, prot hd	
		Net to 0.0005 clearance	
		Torque (in lb)	
		Fel Pro 300	
		240-250	

Specimen flash no	Hole diameter (in)			Hole finish (RHRI)			Collwork expansion (in)		Fastener size (in)		Cycles to failure	Origin of failure and remarks
	Enter collwork	After ream	After collwork	Before collwork	After collwork	After ream	Actual	Retained	Diameter	Fit		
.16	1	0.3335	0.3485	0.3735	20	10	20	0.0235	0.0150	0.3735	Net	
	2	0.3335	0.3485	0.3735	25	10	20	0.0235	0.0150	0.3735	Net	
	3	0.3335	0.3485	0.3735	25	10	20	0.0235	0.0150	0.3735	Net	
	4	0.3335	0.3485	0.3735	25	10	20	0.0235	0.0150	0.3735	Net	
.17	1	0.3335	0.3485	0.3735	20	10	20	0.0235	0.0150	0.3730	Net	
	2	0.3335	0.3485	0.3730	20	10	20	0.0235	0.0150	0.3730	Net	
	3	0.3335	0.3485	0.3730	20	10	20	0.0235	0.0150	0.3730	Net	
	4	0.3335	0.3485	0.3730	20	10	20	0.0235	0.0150	0.3730	Net	
.18	1	0.3340	0.3485	0.3740	30	10	20	0.0230	0.0145	0.3740	Net	
	2	0.3340	0.3485	0.3735	35	10	20	0.0230	0.0145	0.3735	Net	
	3	0.3335	0.3485	0.3735	35	10	20	0.0235	0.0150	0.3735	Net	
	4	0.3335	0.3485	0.3735	35	10	20	0.0235	0.0150	0.3735	Net	





## COST STUDY

### Elemental Flow Times

### Normal man-minutes

	<u>AL</u>	<u>Ti</u>	<u>SH</u>
Positioning - Hand drill		0.03	
Hand reamer		0.02	
Winslow drill		0.08	
Quackenbush drill		0.16	
Taperlok reamer		0.06	
Torque tool		0.05	
Drilling - Hand drill	0.32	-	-
Winslow drill, regular hole (6000)	0.18	-	-
Winslow drill, Boeing PT bolt hole (HS-2)	0.10		
Winslow drill, Taperlok hole	0.19		
Quackenbush drill	-	0.62	3.1
Reaming - Manual, straight hole	0.04	-	-
Manual, tapered hole	0.16	-	-
Quackenbush, straight hole	-	0.84	0.84
Quackenbush, tapered hole	-	0.334	1.05
Pin ream, tapered hole	0.15	0.20	0.20
Bolts/nuts - Insert	0.06	0.06	0.06
Drive Boeing PT bolt	0.086	-	-
Drive Taperlok	0.08	0.12	0.15
Inspect protrusion (Taperlok)	0.08	0.08	0.08
Place nut	0.43	0.43	0.43
Torque nut, regular	0.05	0.05	0.05
Torque nut, HiLok	0.07	0.07	0.07
Primer/sealant	0.025	-	-
Inspection - Inspect regular hole	0.02	0.02	0.10
Inspect PT hole	0.04	0.04	0.04
Inspect tapered hole	0.12	0.36	0.40
Inspect flushness	0.03	0.03	0.03
Inspect C/W hole	0.04	0.04	0.04
Coldworking - Place sleeve	0.065	0.065	-
Insert and pull	0.050	0.050	-
Remove sleeve	0.02	0.02	-
Lubricate and bake	-	-	0.10
Push or squeeze mandrel	-	-	0.16

Process Times and Costs (at \$10.50/hr)

Normal man-minutes

1) <u>Taperlok--protruding head</u>		<u>Aluminum</u>	<u>Titanium</u>	<u>Steel</u>
		Prorated setup and sample plates	0.236	0.69
Position drill	0.08	0.16	0.16	
Drill straight hole	--	0.62	3.10	
Drill/csk tapered hole	0.19	--	--	
Position reamer	--	0.16	0.16	
Ream taper	--	0.334	0.105	
Inspect hole	0.12	0.36	0.40	
10% pin ream	0.015	--	--	
100% pin ream	--	0.20	0.20	
Insert bolt	0.06	0.06	0.06	
Inspect protrusion	0.08	0.08	0.08	
Drive bolt	0.08	0.12	0.15	
Install nut	0.43	0.43	0.43	
Torque nut	0.05	0.05	0.05	
Inspect flushness	0.03	0.03	0.03	
14% PF&D*	<u>0.192</u>	<u>0.468</u>	<u>0.80</u>	
Total normal man-minutes		1.563	4.210	6.545
Labor cost		\$0.274	\$0.735	\$1.14
Cutter cost/hole--drill		0.03	0.015	0.135
Cutter cost/hole--Taperlok reamer		--	0.11	0.84
Total installation cost		<u>\$0.304</u>	<u>\$0.86</u>	<u>\$2.115</u>
Steel Taperlok pin	\$0.54			
Titanium Taperlok pin	0.97			
Steel nut	0.07			
Titanium seal nut	0.43			
<u>Total costs/installation</u>		<u>Aluminum</u>	<u>Titanium</u>	<u>Steel</u>
Steel Taperlok and steel nut		\$0.91	\$1.47	\$2.73
Steel Taperlok and seal nut		1.27	1.83	3.09
Titanium Taperlok and steel nut		1.34	1.90	3.16
Titanium Taperlok and seal nut		1.70	2.36	3.52

\*Personal fatigue and delay

2) Coldworked holes with titanium Hi-Loks--protruding head

	<u>Normal man-minutes</u>		
	<u>Aluminum</u>	<u>Titanium</u>	<u>Steel</u>
Prorated setup	0.110	0.110	0.25
Position drill	-0.08	0.16	0.16
Drill straight hole	0.10	0.62	3.10
Inspect hole--sample	-0.01	0.01	0.01
Place sleeve on mandrel	0.065	0.065	
Insert and pull	0.050	0.050	
Remove sleeves	0.020	0.020	-
Drylube hole	-	-	0.10
Place aligner on mandrel	-	-	0.02
Insert mandrel	-	-	0.03
Position part on yoke and push	-	-	0.16
Inspect hole	0.02	0.02	0.02
Position reamer	-	0.16	0.16
Postream	0.04	0.84	0.84
Insert bolt	0.06	0.06	0.06
Place nut	0.43	0.43	0.43
Torque nut	0.07	0.07	0.07
14% PF&D	<u>0.147</u>	<u>0.376</u>	<u>0.76</u>
Total normal man-minutes	1.202	2.991	6.17
Labor cost	\$0.21	\$0.523	\$1.08
Cutter cost/hole--drill	-	0.015	0.135
Cutter cost/hole--ream	-	0.021	0.21
C/W sleeve cost	0.14	0.14	-
Mandrel cost	-	-	0.30
Total installation cost	<u>\$0.35</u>	<u>\$0.699</u>	<u>\$1.725</u>
Titanium Hi-Lok pin	0.31		
Aluminum collar	0.05		
Aluminum seal nut	0.14		
<u>Total costs/installation</u>	<u>Aluminum</u>	<u>Titanium</u>	<u>Steel</u>
C/W holes with titanium Hi-Lok plus aluminum collar	\$0.71	\$1.06	\$2.09
C/W holes with titanium Hi-Lok plus aluminum seal nut	0.80	1.15	2.18

3) Coldworked holes with steel lockbolts and 10% steel Hi-Loks

	<u>Normal man-minutes</u>		
	<u>Aluminum</u>	<u>Titanium</u>	<u>Steel</u>
Prorated setup	0.110	0.110	0.25
Position drill	0.08	0.16	0.16
Drill straight hole	0.10	0.62	3.10
Inspect hole--sample	0.01	0.01	0.01
Place sleeve on mandrel	0.065	0.065	-
Insert and pull	0.050	0.05	-
Remove sleeves	0.02	0.02	-
Drylube hole	-	-	0.10
Place aligner on mandrel	-	-	0.02
Insert mandrel	-	-	0.03
Position part as yoke and push	-	-	0.16
Inspect hole	0.02	0.02	0.02
Position reamer	0.01	0.16	0.16
Postream	0.04	0.84	0.84
Insert lockbolt--90%	0.054	0.054	0.054
Place collar--90%	0.02	0.02	0.02
Pull lockbolt and swage collar--90%	0.07	0.07	0.07
Insert Hi-Lok--10%	0.006	0.006	0.006
Place nut--10%	0.043	0.043	0.043
Torque nut--10%	0.007	0.007	0.007
14% PF&D	<u>0.099</u>	<u>0.315</u>	<u>0.705</u>
<b>Total normal man-minutes</b>	<b>0.804</b>	<b>2.570</b>	<b>5.755</b>
<b>Labor cost</b>	<b>\$0.14</b>	<b>\$0.45</b>	<b>\$1.01</b>
Cutter cost--drill	-	0.015	0.135
Cutter cost--reamer	-	0.021	0.21
C/W sleeve cost	0.14	0.14	-
Mandrel cost	-	-	0.30
<b>Total installation cost</b>	<b>\$0.28</b>	<b>\$0.626</b>	<b>\$1.655</b>
Steel lockbolt pin	\$0.09		
Aluminum seal collar	0.03		
Steel Hi-Lok pin	0.17		
Aluminum seal nut	0.14		
<b>Total installed costs</b>	<b><u>Aluminum</u></b>	<b><u>Titanium</u></b>	<b><u>Steel</u></b>
C/W noles with 90% steel lockbolts, 10% steel Hi-Loks	\$0.42	\$0.77	\$1.80

4) Interference-fit straight-shank bolt

	<u>Normal man-minutes</u>		
	<u>Aluminum</u>	<u>Titanium</u>	<u>Steel</u>
Prorated setup and sample plates	0.19	0.36	--
Position drill	0.08	0.16	--
Drill straight hole	0.10	0.62	--
Position reamer	--	0.16	--
Ream	--	0.84	--
Inspect sample	0.04	0.04	--
Insert bolt	0.06	0.06	--
Drive bolt	0.08	0.12	--
Place nut	0.43	0.43	--
Torque nut	0.07	0.07	--
14% PF&D	<u>0.147</u>	<u>0.40</u>	--
Total normal man-minutes	1.197	3.26	--
Labor cost	\$0.21	\$0.57	
Cutter cost/hole—drill	--	0.015	
Cutter cost/hole—reamer	--	0.021	
Total installation cost	<u>\$0.21</u>	<u>\$0.606</u>	
Interference-fit titanium pin	0.34		
Aluminum collar	0.05		
Aluminum seal nut	0.14		
<u>Total costs/installation</u>	<u>Aluminum</u>	<u>Titanium</u>	<u>Steel</u>
Interference-fit titanium pin with aluminum collar	\$0.60	\$1.00	--
Above with aluminum seal nut	0.69	1.09	

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13. ABSTRACT In this 21-month program, optimized process parameters for sleeve coldworking of fastener holes have been developed, and the effects of process and application parameters on structural performance have been defined for selected aluminum, titanium, and high-strength steel alloys. The sleeve coldworking process for fastener holes is a process that uses a tapered mandrel in conjunction with a disposable, prelubricated sleeve to compressively prestress a significant size zone around each hole which offsets the stress concentration of the hole itself. The sleeve method allows higher degrees of prestressing than possible with other methods and offers potential for significant improvements in fatigue performance. In addition, it does not require precision controls germane to other fatigue-rated hole preparation/fastener installation systems. This technical report covers the results of this 21-month program. In addition to definition of optimized methods and the effects of process and application variations upon structural performance, the results include performance and economics comparisons for the process with other fatigue-rated hole preparation/fastener systems.		

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