Bendix

Aerospace Systems Division

R. BRADFORD
BOYD BOLTS

NO.	REV. NO.
ATM718	

PAGE 1 OF 14

ALSEP FASTENER STUDIES

DATE 6 December '67

This unscheduled ATM has been written to summarize and document all the design and testing effort conducted on the ALSEP fastener to date.

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Manfred Katz

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Thomas Fenske

1.0 SUMMARY

The Calfax Live Lock fastener was selected for the original design since it met all the requirements set forth for the ALSEP fastener.

After the astronaut review of the original hardware it was stated that the total time for deployment was excessive. Bendix was directed to design a fastener, or fastening system, which would reduce the time required for unfastening.

Bendix reviewed many fastening schemes and selected promising candidates for further study and test. All fastening methods, other than the screw type, failed because the release force exceeded the capability of the astronaut while maintaining minimum structural integrity parameters.

The current recommendation is to use a Boydbolt, a 75° turn-to-release fastener, using a combination experiment handling and tie down release tool for unfastening. This recommendation meets the basic astronaut requirements, and satisfies all the structural specifications.

2.0 FASTENER REQUIREMENTS

The fastener requirements were established twice; once for the original ALSEP fastener and once for the directed modified fastener. Sections 2.1 and 2.2 outline these specific requirements.

2.1 Original Fastener Requirements

Bendix established the original fastener requirements from structural, human factors, and system engineering inputs. The original fastener criteria were as follows:

1) Physical properties high enough to satisfy the LM environmental loads; static and dynamic. (900 lbs. minimum tensile strength).

2) Capable of being quickly released with little effort, i.e., 17 inch-lbs on a 1 1/2" diameter handle.

3) Quantity of fasteners minimized.

4) No "hang-up" after initial release or unfastening.

5) Cold welding eliminated.

6) Simple and convenient astronaut release tool interface.

7) Commonality throughout the ALSEP system.

8) No pyrotechnic devices are permitted.

9) Minimum weight.

10) Use materials which are non-magnetic.

From these requirements the Calfax Live Lock fastener was selected for the original ALSEP design (see Section 3.0).

2.2 Modified Fastener Requirements

After the crew had an opportunity to evaluate the Calfax Live Lock on a crew engineering mock-up, a number of objections were submitted. These objections resulted in a revised set of requirements with direction from MSC to replace the Calfax Live Lock fastener. The specific objectives were as follows:

1) Reduce the time and effort required to deploy ALSEP. The suggested method of approach was to reduce the quantity of fasteners and to develop a non-twist type fastener.

2) Positive indication that the release mechanism has been actuated.

3) The possibility of re-engagement or "hang-up" after unfastening must be eliminated.

4) The impact on the present ALSEP design will be held to a minimum. (1/4 inch limit for the fastener diameter).

Section 4.0 covers the study and testing conducted to satisfy these requirements.

3.0 CALFAX LIVE LOCK

The Calfax Live Lock fastener (see Figures 1, 2, 3) was selected for the original design after extensive investigation. This investigation took the form of contacting specific fastener companies and agencies throughout the country.

The specific features of the Calfax Live Lock fastener which satisfy the requirements listed in Section 2.1 are as follows:

1) Mechanical Properties for Calfax Live Lock, 1/4 diameter

   Rated tension --- 900 lbs.
   Ultimate tension load --- 1200 lbs.
   Rated shear load --- 1730 lbs.
   Ultimate shear load --- 3000 lbs.
   Sheet separation --- not to exceed .015 inch at rated tensile load
   Locking torque --- 30 inch-lbs.

2) 3/4 to 1 turn to release fastener.

3) Incorporation of a retaining ring washer to prevent remote possibility of the stud tending to refasten .

4) Solid film lubricant (Electrofilm 2306) to prevent cold welding and provide a reliable lubrication system.

5) A total quantity of 19 fasteners were required to provide adequate tie down for the sunshield (this was proven minimum per test TR 2267, reference No. 13)

6) Dynamic integrity verified by Lockheed Missiles and Space Company's Test Report No. A5184-2, Litton Data Systems Test MJO 2907-12 and meets the requirements specified in MIL-F-22978A (references 1, 2, 3, 4)

3.1 Fasteners Research

Table 1 presents the fastener companies and the specific type fastener which were considered for the original ALSEP design.

Table 1

Fastener Sources Researched

Company	Person Contacted	Type of Fastener
Grumman Aircraft Bethpage, Long Island	Robert Caughlin Jack LaRussa	General quick release and specifically Calfax's Live Lock
Standard Pressed Steel Santa Ana, California	J. Owens	Milson structural panel fastener
"APIC" Apollo Parts Information Center, Huntsville, Ala.	Glen Lindsey Earl Pugh J. Rizzardi	General quick release astronaut approved fasteners. Fastener test reports
Simmons Fasteners Albany, New York	William C. Kraft	Lock stud, Link lock
Camloc Fastener Corp. Paramus, New Jersey	J. Frederic Dreher	1/4 turn fasteners, Stressed panel fastener
Cinch Monadnock City of Industry, Calif.	Applications Engineer	Airlock (1/4 turn)
Deutsch Fastener Corp. Los Angeles, Calif. Dayton, Ohio	E. O. Baumgarten Dick Lowry	Quarter loc stud, Zip loc, Turn-loc, Press-loc fastener
South Co. Fasteners		Lion 1/4 turn
Dzus Fasteners West Islip, New York		Universal Fastener, Standard 1/4 turn, Panel Fastener
Spiron, Inc.		High strength quick release
Timber-Top, Inc. Freeport, New York	John M. Sadler	Mini-synclamps quick release
Calfax, Inc. Torance, Calif.	Frank Cosenza	Live lock, Boydbolt,

3.2 Evaluation Tests - Calfax Live Lock

To prove the design integrity of the Calfax Live Lock fastener a number of tests were conducted by Bendix to expose any problems which might exist. The first three tests were pre Proto #1.

1) Calfax Fastener Vibration Test

Test Requirements - Memo 9712-190 (Reference No. 5)
Test Report - TR 1980 (Reference No. 7)
Date Conducted - 12/19/66

Summary - The dummy Passive Seismic experiment (20 lbs.) was subjected to the existing qualification dynamic levels. The four Calfax Live Lock fasteners tested passed with no unfastening or unacceptable release torques.

2) Calfax Fastener Thermal Vacuum Test

Test Requirements - Memo 9712-190 (Reference No. 5)
Test Report - TR 1942 (Reference No. 6)
Date Conducted - 1/3/67

Summary - one mounted fastener was subjected to 1.0×10^{-8} torr and 300°F for a period of 48 hours and 120 hours. No cold welding occured and all release torques were under 18 in-lbs.

3) Calfax Fastener - Cold Environment

Test Requirements - Memo 9712-190 (Reference No. 5)
Test Report - TR 2076 (Reference No. 8)
Date Conducted - 2/1/67

Summary - One mounted fastener was subjected to low temperatures and its release torque recorded. Temperatures of -60°F can be experienced by the fastener and still be released with less than 16 in-lbs. torque.

4) Proto #1 Test

Test Requirements - Memo 9712-181 (Reference No. 9)
Memo 9712-332 (Reference No. 10)
Memo 9712-385 (Reference No. 11)

Test Report - TR 2152
Date Conducted - 5/19/67

The first time the Calfax Live-Lock fastener was tested in the ALSEP system was the Proto #1 structure for Compartment #1.

The test article consisted of the primary structure, thermal plate, sunshield, dummy experiments and dummy electronic modules. The Calfax Live-Lock fastener was used to retain all experiments and sunshield tie downs. The vibration environment was to the ATR-16 levels. These levels were more severe than the levels previously used (i.e., sinusoidal inputs at 50 cps required 6.0 g's for ATR-16 and previously required 3.5 g's).

Loosening of the Calfax Live-Lock fastener occured on the experiments and sunshield during the sine sweep only. At no time did a fastener release completely, however, an improvement in the locking feature had to be made. All efforts in connection with the unloosening problem on the Calfax Live-Lock were terminated when MSC directed Bendix to study and implement a non-twist type fastener to replace the Calfax Live-Lock.

4.0 CALFAX REPLACEMENT STUDY

To satisfy the requirements set forth in Section 2.2, an investigation into non-twist type fasteners was conducted. Table 2 presents the non-twist fasteners which were considered for the Calfax Live-Lock replacement.

In addition to the sources in the fastener industry, Bendix Aerospace investigated designs of various fastening methods listed in Table 3.

A common criteria of all the fastening systems was a 330 lbs. minimum pretension. This minimum requirement was established by testing on the Proto #1 model of Compartment #1 (see Section 5.1). Along with this pretension requirement there are astronaut constraints which limit the release force capability as follows:

1) Maximum downward force - 20 lbs.

2) Maximum upward force - 5 lbs. (ALSEP lifts off lunar surface)

3) Maximum sideward force - 4 lbs. (assume $\mu = .4$)

After preliminary investigation of the non-twist type fasteners, both general industry and Bendix designs, the Tensol Lock (push-to-release, see Figure 5) was selected as the basic design to develop and test further.

Figure 4 compares the preload vs. release force required for each individual fastener evaluated in the study.

Although the Tensol Lock fasteners are not commonly made in the 1/4" diameter size, preliminary tests run by Norco, Inc. (manufacturer of Tensol Lock) and their engineering judgement indicated that the Tensol Lock would operate satisfactorily in the 1/4" size.

In addition to the non-twist type fastener a Boydbolt (twist type) was considered as a fastening back up method. The Boydbolt (see Figure 6) which basically is a fast lead screw with a pip pin locking feature looks very promising on paper in addition to the limited testing conducted on it. The basic or standard design has been modified to reflect certain features which satisfy the present ALSEP design criteria and is called a Boydbolt-special (see Figure 7).

The specific features of the Boydbolt-special are as follows:

1) 75^{o} twist to release

2) Ball lock locking feature which provides a positive mechanical constraint against dynamic unloosening.

3) Locking spline in the unfastened position to prevent possible refastening.

4) A spring incorporated into the fastener head to assist fastener extraction and insure positive release.

5) Dead ending the threads such that a positive stop is provided when 75^{o} has been turned.

6) A preloading nut to provide the necessary tension required and also allow slight variations in grip lengths.

7) Multisided socket head on the tie down release tool engagement interface.

8) Stepped down bolt shank to ensure that the balls in the locking mechanism do not protrude beyond the 1/4 inch shank.

The special version of the Boydbolt is in the development stage at this time, therefore evaluation testing on the specific flight design has not been done.

Table 2

Non Twist Type

Company	Person Contacted	Type of Fastener
Avdel, Inc. Burbank, Calif.	Duran	Ball-lok pins
Adjustable Bushing Corp. North Hollywood, Calif.	Ken Pitzer	Expando grip
Space Lok, Inc. Burbank, Calif.	R. Maddox	Quick release pip-pins, Test results in tension
Norco Georgetown, Conn.	Heath McDowell Ray Metz	Tensol lock, Stud lock, Cuplex Interlock

Table 3

Bendix Investigated Designs

1) Manual break-away bolts

2) Keyhole or elongated slide mechanisms

3) Pneumatic system

4) Ganged slide latch

5) Ganged push-pull mechanisms

6) Split nut on shouldered bolt

5.0 EVALUATION TESTS - CALFAX REPLACEMENTS

The objectives to be accomplished through testing were as follows:

1) Establish the minimum pretension and the minimum number of fasteners required to tie down the sunshield to the primary structure.

2) Evaluate the performance (dynamic and static) of the prototype Tensol-Lock fasteners, 1/4" diameter, supplied by Norco, Inc.

3) Evaluate the dynamic performance of the Boydbolt fastener supplied by Tridair Industries.

Three separate tests were conducted to achieve these objectives, namely, the ALSEP Compartment #1 Fastener Vibration Test, Dynamic Load-Tensol Lock and Boydbolt test, and Static Load-Tensol Lock test.

5.1 ALSEP Compartment #1 Fastener Vibration Test

Test Requirements - Memo 9712-455 (Reference 13)
Test Report - TR 2267 and Memo 9712-566 (Reference 14, 15)
Date Conducted - 9/13/67

Summary - ALSEP Proto #1 model of Compartment #1 was subjected to a series of qualification level (LTA-3) sine vibration tests.

The quantity (19 to 11) and preload (0 to 500 lbs.) of the sunshield fasteners were varied with each test and the resulting deflection and g load recorded.

A 330 lbs. pretension combined with the original quantity of sunshield fasteners (19) is the minimum recommended configuration. All other combinations resulted in excessive sunshield deflections.

5.2 Dynamic Load - Tensol Lock and Boydbolt Test

Test Requirements - Memo 9712-521 (Reference 16)
Date Conducted - 10/6/67

3) The Tensol Lock fastener tested did not show repeatibility in performance. Sometime the fasteners would work as desired, while at other times the release force would be extremely high. The main cause of its erratic performance is mainly due to the smallness in size (1/4" diameter). The 1/4" diameter Tensol Pin design is borderline and should not be considered further.

4) The Boydbolt successfully passed the LTA-3 DR qualification levels on the LSM Proto #1 structure. The fastener satisfies the ALSEP design criteria and is adaptable into a 75° turn to release version.

This design is recommended as the basic fastening method for ALSEP.

5) As a future fastening method the area of pyrotechnics should be reconsidered. These devices lend themselves to the ALSEP design because of the high quantity of fasteners needed.

7.0 REFERENCES

Ref. No.	Date	Identification No.	Title of Document
1	September '66	Report MJO 2907-12	Litton Data Systems Calfax Panel Fasteners
2	September '66	Report A 5184-2	Lockheed's Qualification Tests of "Calfax Type" High Strength Rotary Panel Fasteners
3	September '66	Report 1415138	General Specifications for Panel Fasteners, Rotary, Quick Operating, High Strength
4	September '66	MIL-F-22978A	MIL SPEC. Fastener, Rotary, Quick Operating, High Strength
5	October '66	Memo 9712-190	Test Requirements - Calfax Fastener

Ref. No.	Date	Identification No.	Title of Document
6	January '67	TR 1942	Test Report - Calfax Thermal Vacuum Evaluation
7	February '67	Report TR 1980	Test Report - Calfax Vibration Evaluation
8	April '67	Report TR 2076	Test Report - Calfax Cold Environment Evaluation
9	October '66	Memo 9712-181	Test Requirements - Dynamic Test of ALSEP Compartment 1 Structural Assembly
10	March '67	Memo 9712-332	TestRequirements - Dynamic Test of ALSEP Compartment 1 Structural Assembly
11	May '67	Memo 9712-385	Test Requirements - ALSEP Proto #1 Compartment #1 Vibration Test
12	June '67	Report TR 2152	Test Report - ALSEP Compartment #1, Proto No. 1
13	August '67	Memo 9712-455	Test Requirement - ALSEP Compartment #1, Fastener Vibration Test
14	October '67	Report TR 2267	Test Report - ALSEP Compartment #1, (Prototype 1) Fasteners
15	October '67	Report 9712-556	Test Report - ALSEP Compartment #1 Fastener Vibration Test Results
16	October '67	Memo 9712-521	Test Requirements - Calfax Fastener Replacement
17	October '67	Report TR 2260	Test Report - Static Load Calfax Fastener Replacements

DATE	LTR	CHANGE
[illegible]	1	CA18018 (LW) [illegible] ADDED WGT.
[illegible]	B	NOTE 1: CA1800 7 (WAS CA1807) ADDED .025 [illegible]

CA18018

B

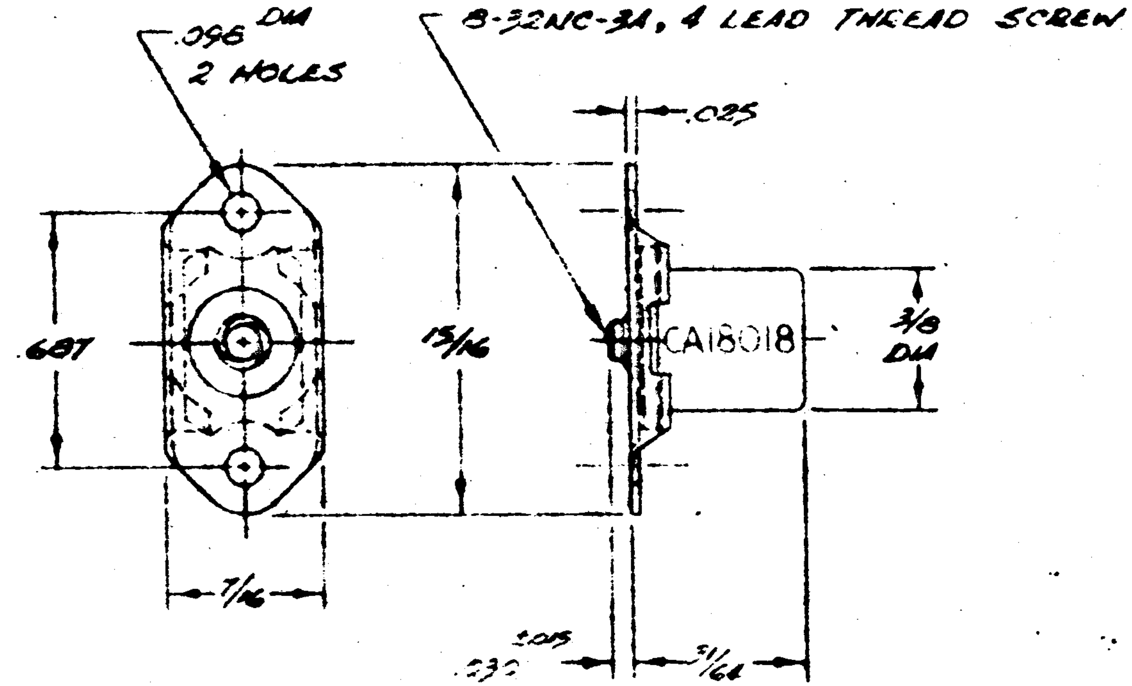


FIG. 1

NOTES:
1. TO BE USED WITH CA1800 7 STUD NUT & CA1825 RETAINING RING
2. RECEPTACLE TOTAL FLOAT: .025 MIN
3. SCREW & RATCHETING COMPONENTS DRY FILM LUBED WITH ELECTROFILM #2306 FOR HIGH VACUUM APPLICATIONS
4. SPRING PRESSURE ON RATCHET PLATES 4.5 LBS MIN

MATERIAL OR NAME	SPECIFICATION
SCREW — A-286 CRES	AMS 5735
HOUSING — 18-8 TYPE 300 SERIES CRES	MIL-S-7720

UNLESS OTHERWISE SPECIFIED

TOLERANCE ON DIM
DECIMALS .XX ± .010, .XXX ± .005
FRACTIONS ± 1/64
ANGLES ± 1°

FINISH: CRES COMPONENTS PASSIVATED PER MIL-S-5002

HEAT TREAT: SCREW: 140,000 PSI MIN

.0127 LBS/EA

SCALE: 2:1

DRAWN BY: [illegible] 11-1-66
ENGINEERING:
APPROVED: [illegible] 11-1-66

RECEPTACLE ASSY
LIVE LOCK ● 3/4 TURN

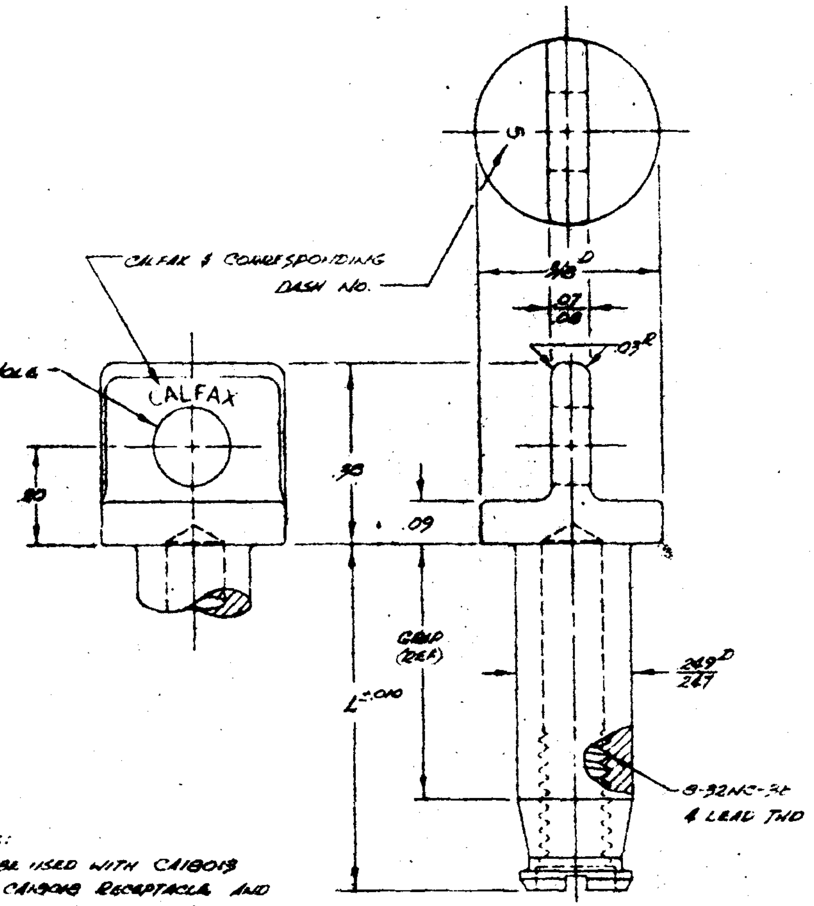
CA18018

calfax, inc.
A MEMBER OF THE TRIDENT GROUP
TWX 910-325-6204
Phone 213-772-6311
2900 Compton Blvd. Redondo Beach 90278, California

	LTR	CHANGE
	B	ADDED -6 THRU -60
	C	REVISED NOTES; [illegible] ADDED SHT 2 / .156 HOLE

CA18007—
SHT 1 OF 2

C



DASH NO	L	GRIP RANGE MIN	GRIP RANGE MAX	WT LBS/100
[illegible]	.312	.094	.125	.695
[illegible]	.343	.126	.156	.737
[illegible]	.375	.157	.187	.779
[illegible]	.406	.188	.218	.821
[illegible]	.437	.219	.250	.862
[illegible]	.468	.251	.281	.903
[illegible]	.500	.282	.312	.945
[illegible]	.531	.313	.343	1.013
[illegible]	.562	.344	.375	1.037
[illegible]	.593	.376	.406	1.061
[illegible]	.625	.407	.437	1.085
[illegible]	.656	.438	.468	1.109
[illegible]	.687	.469	.500	1.133
[illegible]	.715	.501	.531	1.157
[illegible]	.750	.532	.562	1.161
[illegible]	.781	.563	.593	1.205
[illegible]	.812	.594	.625	1.229
[illegible]	.843	.626	.656	1.253
[illegible]	.975	.657	.687	1.277
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[illegible]	.937	.719	.750	1.325
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[illegible]	1.125	.907	.937	1.470
[illegible]	1.156	.938	.968	1.496
[illegible]	1.187	.969	1.000	1.524
[illegible]	1.218	1.001	1.031	1.545
[illegible]	1.250	1.032	1.062	1.567
[illegible]	1.281	1.063	1.093	1.591
[illegible]	1.312	1.094	1.125	1.619
[illegible]	1.343	1.126	1.156	1.641
[illegible]	1.375	1.157	1.187	1.667
[illegible]	1.406	1.188	1.218	1.712
[illegible]	1.437	1.219	1.250	1.757
[illegible]	1.468	1.251	1.281	1.783
[illegible]	1.500	1.282	1.312	1.809

DASH NO	L	GRIP RANGE MIN	GRIP RANGE MAX	WT #/100
40	1.531	1.313	1.343	1.895
41	1.562	1.344	1.375	1.561
42	1.593	1.376	1.406	.867
43	1.625	1.407	1.437	1.913
44	1.656	1.438	1.468	1.949
45	1.687	1.469	1.500	1.969
46	1.718	1.501	1.531	1.991
47	1.750	1.532	1.562	2.017
48	1.781	1.563	1.593	2.043
49	1.812	1.594	1.625	2.069
50	1.843	1.626	1.656	2.095
51	1.875	1.657	1.687	2.12
52	.906	1.688	1.718	2.147
53	1.937	1.719	1.750	2.173
54	1.968	1.75	1.781	2.199
55	2.000	1.782	1.812	2.225
56	2.031	1.813	1.843	2.251
57	2.062	1.844	1.875	2.276
58	2.093	1.876	1.906	2.300
59	2.125	1.907	1.937	2.326
60	2.156	1.938	1.968	2.352

FIG. 2

NOTES:
1. TO BE USED WITH CA18013 OR CA18018 RECEPTACLE AND CA18025 RETAINING RING
2. TURNS REQUIRED TO TIGHTEN OR REMOVE STUD NUT:
   3/4 AT MAX GRIP
   1 AT MIN GRIP
3. WEIGHTS SHOWN ARE CLOSE APPROXIMATIONS ONLY
4. SEE SHT 2 FOR FASTENER MECHANICAL PROPERTIES AND INSTALLATION PROCEDURES

UNLESS OTHERWISE SPECIFIED		
TOLERANCE ON DIM: DECIMALS: .XX ± .010, .XXX ± .005; FRACTIONS: ± 1/64; ANGLES: ± 1°	FINISH: DRY FILM LUBE WITH ELECTROFILM #2396	HEAT TREAT: ~
		SCALE: 2:1

MATERIAL OR NAME	SPECIFICATION
18-8 TYPE 300 SERIES CRES	MIL S-7720

DRAWN BY / ENGINEERING / APPROVED

STUD NUT—3/4 TURN —SPADE HEAD—

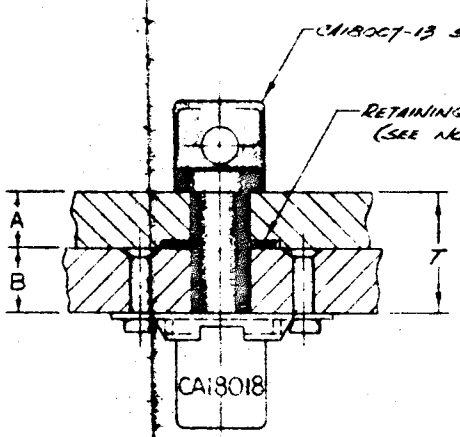
calfax, Inc.
A MEMBER OF THE [illegible] GROUP
2800 Compton Blvd., Redondo Beach 90278, California

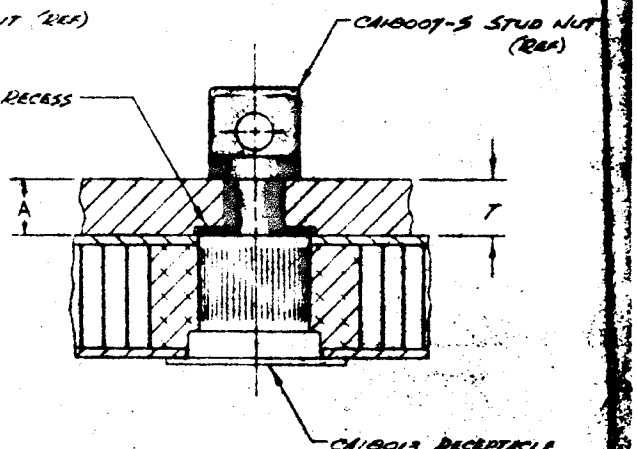
CA18007—
SHT 1 OF 2

DATE	LTR	CHANGE

CA18007—
SHT 2 OF 2

FASTENER MECHANICAL PROPERTIES	
LOCKING TORQUE	30 INCH-LBS (MAX)
UNLOCKING TORQUE	35 INCH-LBS (MAX)
TORQUE OUT	50 INCH-LBS (MIN)
ULTIMATE SHEAR LOAD	2000 LBS (MIN)
RATED SHEAR LOAD	1730 LBS (MIN)
ULTIMATE TENSILE LOAD	1200 LBS (MIN)
RATED TENSILE LOAD	900 LBS (MIN)
SHEAT SEPARATION (TEST CONDITION)	NOT TO EXCEED 0.015 INCH AT RATED TENSILE LOAD
SHEAT PULL-UP	1/32 INCH (MIN)
STUD PUSH-OUT	75 LBS (MIN)
RECEPTACLE PUSH-OUT	75 LBS (MIN)





NOTES:
1. RETAINING RING RECESS FOR CA1825 RETAINING RING: C'BORE .500 +.015 -.000 DIA x .030 +.005 -.000 DEEP

2. STUD NUT HOLE SIZES:
   A) FOR PANEL A: .250 +.005 -.000 DIA
   B) FOR PANEL B: .250 +.005 -.000 DIA (MAY BE INCREASED UP TO .295 DIA TO CORRECT FOR MISALIGNMENT OF MATING STUDS & RECEPTACLES)

HOW TO SELECT PROPER STUD NUT DASH NO.

1. FIND "T" (COMBINED THICKNESS OF PANELS "A" & "B")
   EXAMPLE: IF "A" = .250 AND "B" = .240, "T" = .490
2. IF "T" = .490, SELECT (-13) FROM SHEET 1, SINCE .490 FALLS BETWEEN .465 AND .500 (SEE GRIP RANGE COLUMN)

HOW TO SELECT PROPER STUD NUT DASH NO.

1. FIND "T" (THICKNESS OF PANEL "A" IN ABOVE CASE)
2. IF "T" = .240, SELECT (-5) FROM SHEET 1, SINCE .240 FALLS BETWEEN .219 AND .250 (SEE GRIP RANGE COLUMN)

FIG. 3

UNLESS OTHERWISE SPECIFIED		MATERIAL OR NAME	SPECIFICATION
TOLERANCE ON DIM. DECIMALS XX ± .010, XXX ± .005; FRACTIONS ± 1/64; ANGLES ± 1°	FINISH / HEAT TREAT / WEIGHT / SCALE 2/1	DRAWN BY / ENGINEERING / APPROVED	11-29-84

INSTALLATION PROCEDURES

CA18007—
SHT 2 OF 2

calfax, INC. A MEMBER OF THE TRIDENT GROUP

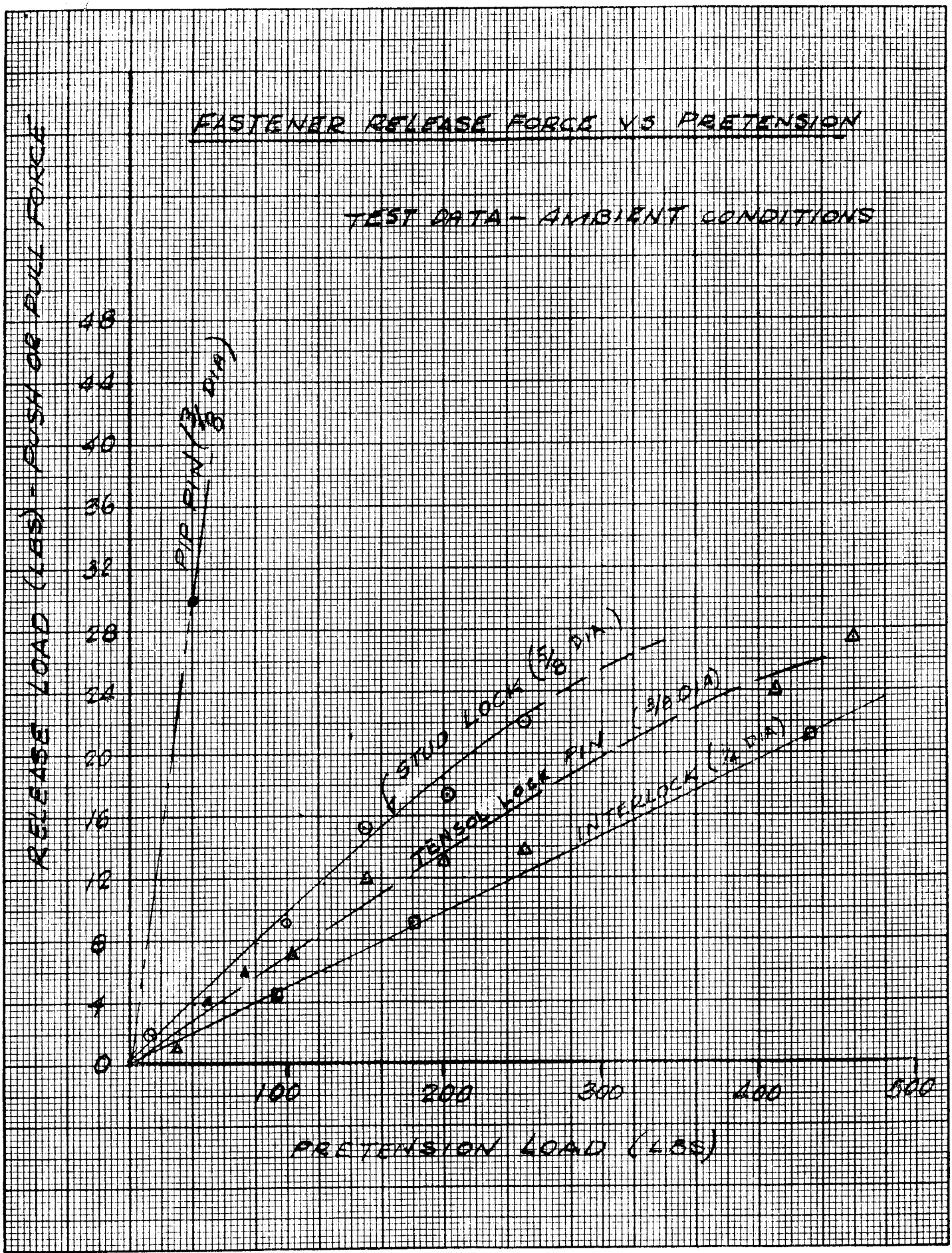


FIG. 4

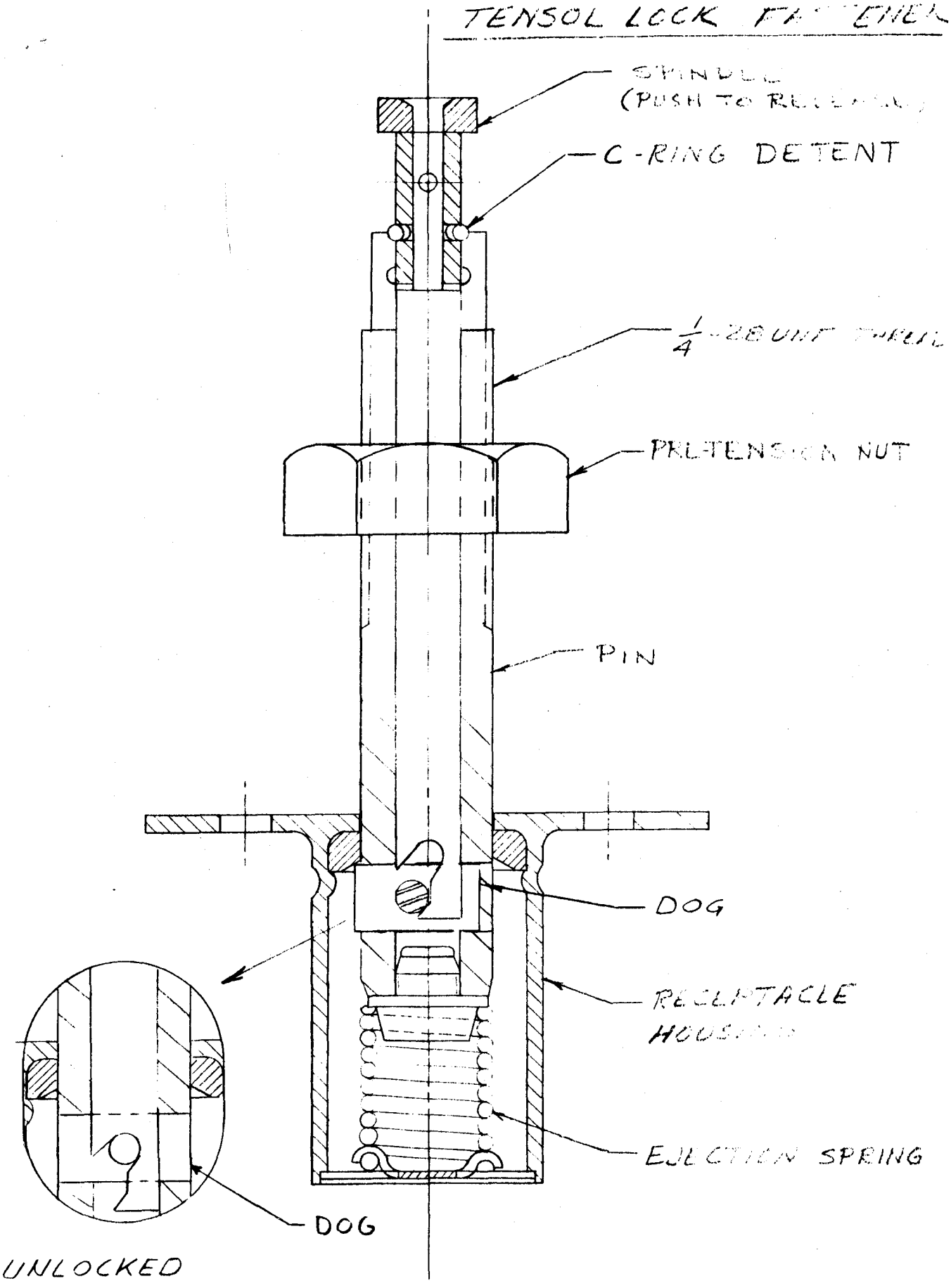

TENSOL LOCK FASTENER
SPINDLE
(PUSH TO RELEASE)
C-RING DETENT
1/4-28 UNF THREAD
PRE-TENSION NUT
PIN
DOG
RECEPTACLE
HOUSING
EJECTION SPRING
DOG
UNLOCKED
CONFIGURATION

FIG. 5

BOYDBOLT FASTENER

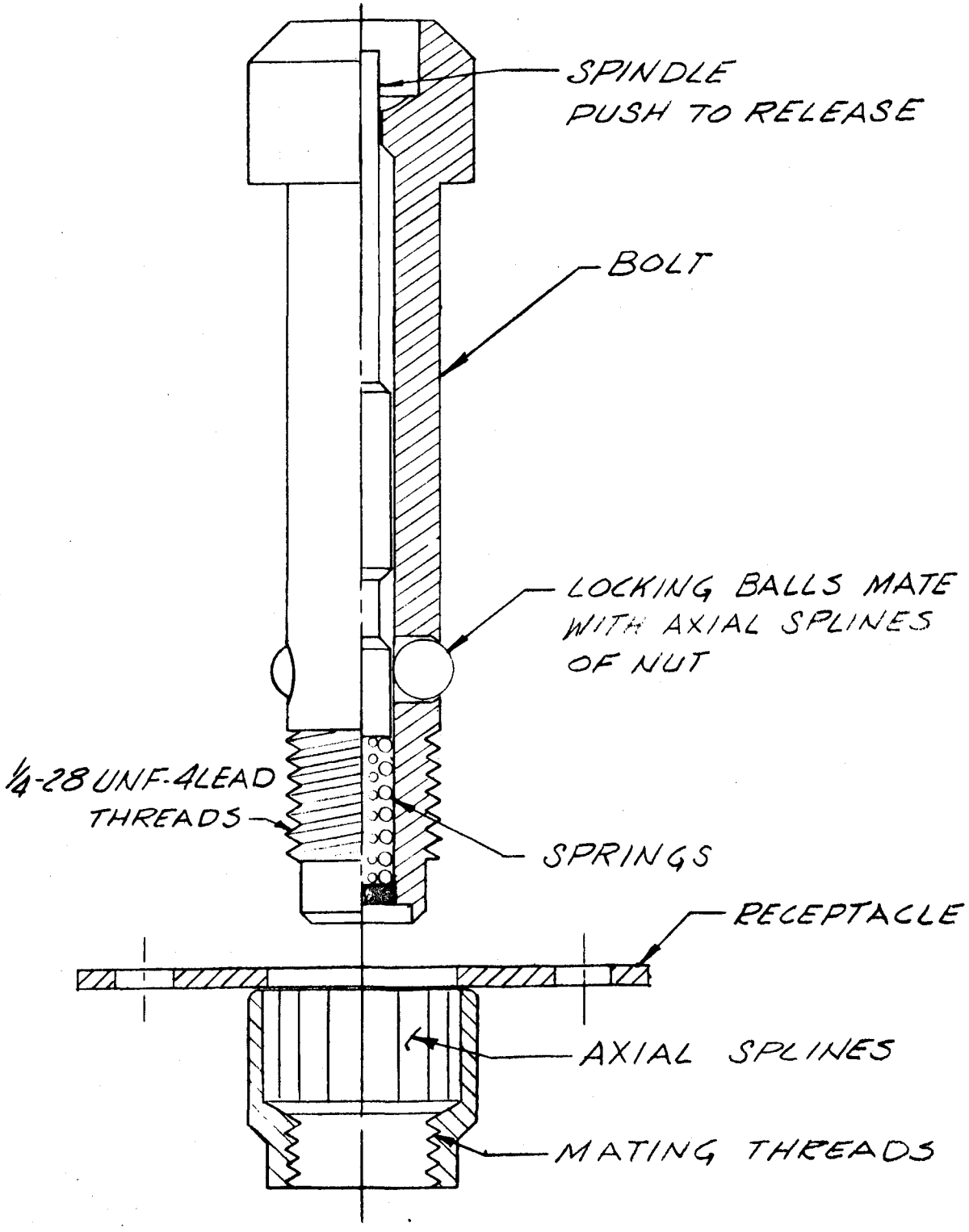
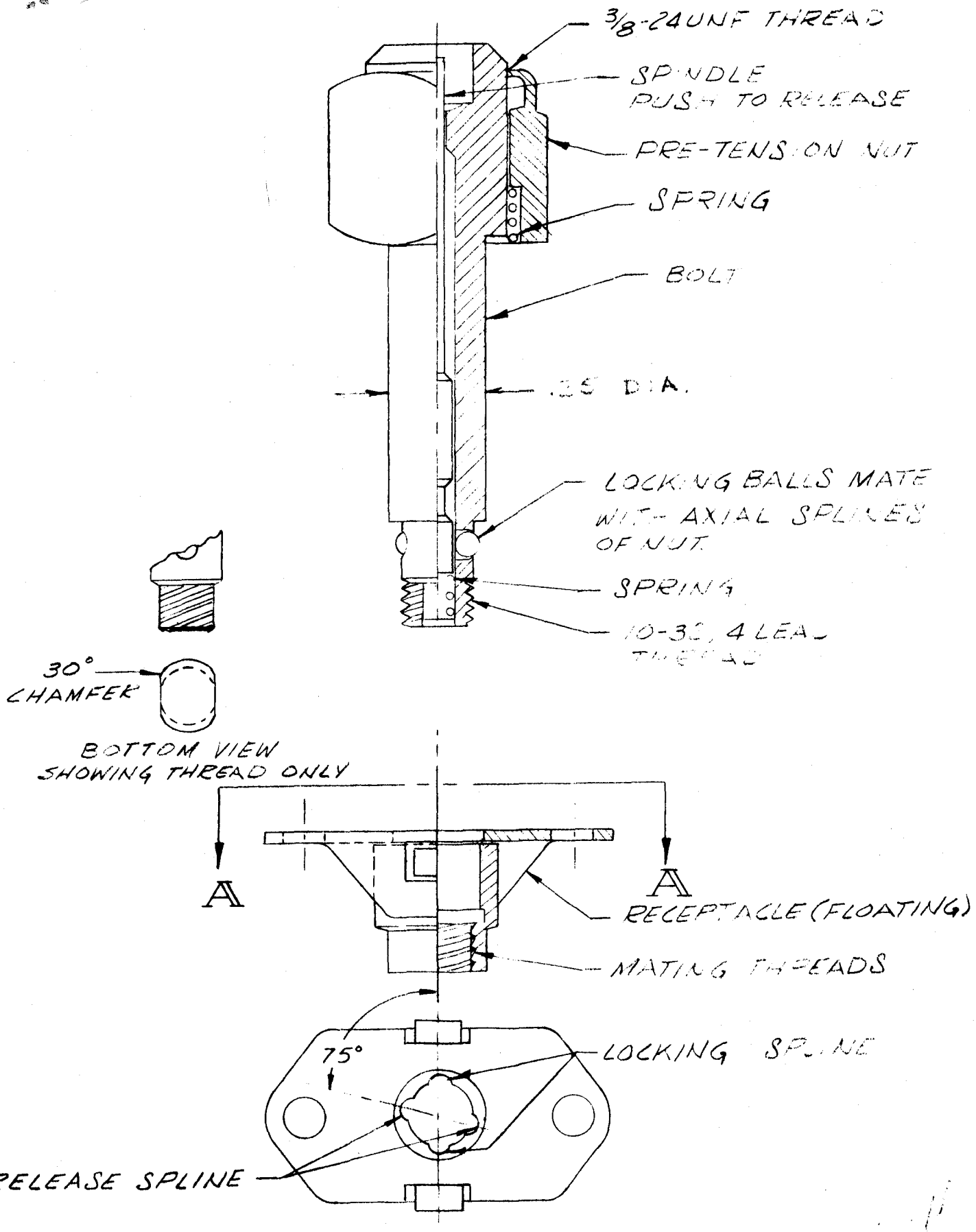


FIG. 6

BOYD BOLT - SPECIAL



SECTION AA

FIG. 7