NAVAL AIR DEVELOPMENT CENTER

Johnsville, Warminster, Pennsylvania

REPORT NO. NADC-MA-6704 26 JUL 1967

SECURING FASTENERS AND OTHER ASSEMBLING DEVICES;
REVIEW AND EVALUATION OF PRESENT PRACTICES,
DESIGN, USAGE LIMITATIONS, AND ENGINEERING DOCUMENTATION;
ESTABLISHMENT OF

AIRTASK A34 530 004/200 1/F012 07 02
WORK UNIT #07

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DEPARTMENT OF THE NAVY
NAVAL AIR DEVELOPMENT CENTER
JOHNSVILLE
WARMINSTER, PA. 18974

MAEM
90210
2 Aug 1967

From: Commanding Officer, Naval Air Development Center, Johnsville, Warminster, Pa. 18974
To: Commander, Naval Air Systems Command (AIR 530323)

Subj: AIRTASK A34 530 004/200 1/F012 07 02, WU #07 Securing Fasteners and Other Assembling Devices; Review and Evaluation of Present Practices, Design and Usage Limitations and Engineering Documentation; establishment of

Ref: (a) BUWEPS ltr NWSA/RAAE-333/632:GDN of 11 Aug 1965

Encl: (1) Six copies of Report No. MADC-MA-6704 of 26 Jul 1967

1. By reference (a) the Bureau of Naval Weapons requested an investigation of devices for and methods of securing fasteners and locking assemblies be initiated. Devices to be investigated included lock wire, lock washers, cotter pins, adhesive compounds, and self-locking elements.

2. This investigation has been completed and the results are included in enclosure (1).

3. This area of the work is completed. The work unit will remain open to accomplish other work thereunder.

E. R. LAMSON
By direction

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DATE 26 JUL 1967

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SECURING FASTENERS AND OTHER ASSEMBLING DEVICES;
REVIEW AND EVALUATION OF PRESENT PRACTICES,
DESIGN, USAGE LIMITATIONS, AND ENGINEERING DOCUMENTATION;
ESTABLISHMENT OF

A. Object

To review and evaluate fastener-safety devices and methods and the applicable engineering documentation; and to investigate the relative reliability of such methods and devices.

B. Details

1. Test and Test Specimens

(a) The Weidemann Baldwin Universal Fatigue Testing Machine, Model SF-10-U, was selected for evaluating the fastener-safety devices under investigation. This machine (see Plate 1) produces a sinusoidal vibratory force, with a constant frequency of 1800 cycles per minute. The amplitude applied to the test specimen is variable. The fixture used for testing is shown in Plates 2 and 3. This fixture is designed to accommodate bolts of ½ inch diameter. Plate 3 shows lockwire installed for testing, and the method used to mark nuts and bolt-ends so that any displacement of the nut on the bolt would be revealed.

(b) The fastener-safety devices tested are shown in Plate 4. They include the following devices, all of which except for item 8, were obtained from local Navy supply:

(1) Bolt, self-locking, with non-metallic insert conforming to type A of reference (a). (Tested against freely-spinning, plain, hexagonal nut, standard height.)

(2) Cotter pins, corrosion-resistant, conforming to type C of reference (b) and dash number 158 of reference (c). (Tested against freely-spinning, castellated nuts (cres).)

(3) Nut self-locking, hexagon, non-metallic insert, low height. (Tested against plain, cadmium-plated bolts.)

(4) Nut, self-locking, hexagon, reduced height, short beam. (Tested against plain, cadmium-plated bolts.)

(5) Washers, lock, flat, external tooth, conforming to dash number 33 of reference (d). (Tested against freely-spinning, plain, hexagonal nut, reduced height.)

(6) Washers, lock-spring, helical. (Tested against freely-spinning, plain, hexagonal nut, reduced height.)

(7) Washers, lock, flat, internal tooth. (Tested against freely-spinning, plain hexagonal nut, reduced height.)

(8) Washers, lock, flat, internal tooth. (Specimens having a uniform tooth angle. Provided for test by manufacturer)

(9) Wire, lock, CRES, nominal diameter 0.020 inch. (Tested against freely-spinning, castellated nuts (cres).)

(c) Test specimens were subjected to the fixed frequency of 1800 cycles per minute with an amplitude of 0.450 ± 0.015 inches. Testing continued until the nut was observed to have rotated 30 degrees or more, considered as failing for the purpose of this report, or until one million cycles had been completed without failure. This procedure is intended as an accelerated vibration test, comparing the relative reliability of fastener-safety devices, and affording means of determining approximate life expectancies. Test results are presented in Table 1 and Plate 5, with the fastener-safety devices arranged in order according to greatest average number of cycles to failure.

2. Reports From Industry

(a) The Aerospace Industries Association of America, Inc. was requested to circularize its membership on the question of current

usage and reliability in the field of fastener-safety devices. Responses were received from seven airframe manufacturers. Thirteen categories of fastener-safety devices are reported in use by these manufacturers. Replies are summarized in Table 2.

(b) Analysis of Table 2 reveals the following series of industrial preferences in fastener-safety devices used in aircraft.

Device	Number of Responding Manufacturers Using Each Device
Nuts, self-locking (includes non-metallic inserts and all-metal nuts)	7
Bolts, self-locking	6
Lockwire	6
Washers, Lock (Toothed, Tab, Split, etc.)	6
Adhesive compounds	5
Cotter pins	4
Rod-end locks	4
Clevis pins	3
Threaded inserts	2
Turnbuckle clip-lock assemblies	2

Keys, staking, and peening were reported in use by only one manufacturer respectively.

3. Technical Literature

(a) A survey of the technical literature covering the past five years located two relevant reports (references (e) and (f)). Reference (e) indicated the need for coloring cotter pins black (if corrosion-resistant), and olive-drab (if cadmium-plated) to enhance visibility in night inspections under red light. Uncolored cotter pins, missing from their installations, had gone unnoticed, resulting in a number of aircraft accidents. Tests indicated that when colored as described above, this objection to the use of cotter pins was eliminated. Reference (e) recommends revision of the applicable military standards to provide such coloring. It is to be noted that, of the nine fastener-safety devices tested as specified in paragraph B.1.c., cotter pins rated highest in average number of cycles to failure (see Table 1).

(b) Reference (f) is concerned with a comparison of fastener techniques and locking devices used on military electronic equipment. Six basic categories of fasteners and locking devices are compared for effective locking action in reference (f). These include lock screws, self-locking nuts, sheet metal nuts, non-metallic fasteners (such as nylon screws with steel cores and nylon nuts and screws), threaded inserts, and self-tapping screws. Specimens of each of the six categories were subjected to tensile, torque, shock, and vibration tests. Comparison of the results reported in reference (f) for self-locking nuts and threaded inserts (included in Table 2 and paragraph B.2.b. herein) indicates no significant difference in performance.

(c) In Section V, Overall Conclusions of reference (f), it is stated that any categorized generalization concerning threaded fastener capabilities is unrealistic, and that test results indicate that such factors as size, material, finish, special features and method of application can greatly influence the in-use capability of fasteners. Identical fasteners, it is stated, when used under different circumstances will display varying in-use capabilities.

C. Discussion

1. Two of the responding airframe manufacturers indicate that they have no information on the reliability of the devices they are using, and one manufacturer points out that the relative reliability of these methods and devices is dependent on the specific installation and service environment, and that any generalization of relative reliability is largely meaningless (see "Comments" in Table 2). This is in agreement with the conclusions of reference (f).

2. Table 1 and Plate 5 illustrate the superiority of cotter pins over the other eight fastener-safety devices when tested as specified in paragraph B.1.c. In addition, in accordance with Table 1 of reference (g) cotter pins may be used at temperatures up to 800°F when made of corrosion resistant steel, whereas devices using non-metallic inserts as self-locking elements are limited to 250°F. It is assumed that if the recommendations of reference (e) relating to the coloring of cotter pins are included in the specified military standards the use of these fastener-safety devices would be extended.

D. Conclusions

1. Based on the investigation conducted, as reported in Sections B and C and Tables 1 and 2 of this report, it is concluded that:

(a) Any classification of fastener-safety devices based on relative reliability is unrealistic since these devices are greatly influenced by such factors as size, material, finish and special features, and display variable in-use capabilities when used under differing circumstances or service environments.

(b) Cotter pins show a significant superiority to most of the other devices tested as specified in paragraph B.1.c.

E. Recommendations

It is recommended that:

1. Reference (g) be revised as follows: Change title to read: "Cotter Pinning and Lock Wiring, General Practices for" since the present title of reference (g) gives no indication that it includes general instructions for the selection and application of cotter pins.

2. The revisions recommended by reference (e) be accomplished in order to extend the service use of cotter pins.

Prepared by:

A. M. PHILLIPS
Project Engineer

Approved by:

R. J. CARROLL, Head
Mechanical Systems Branch

REFERENCES

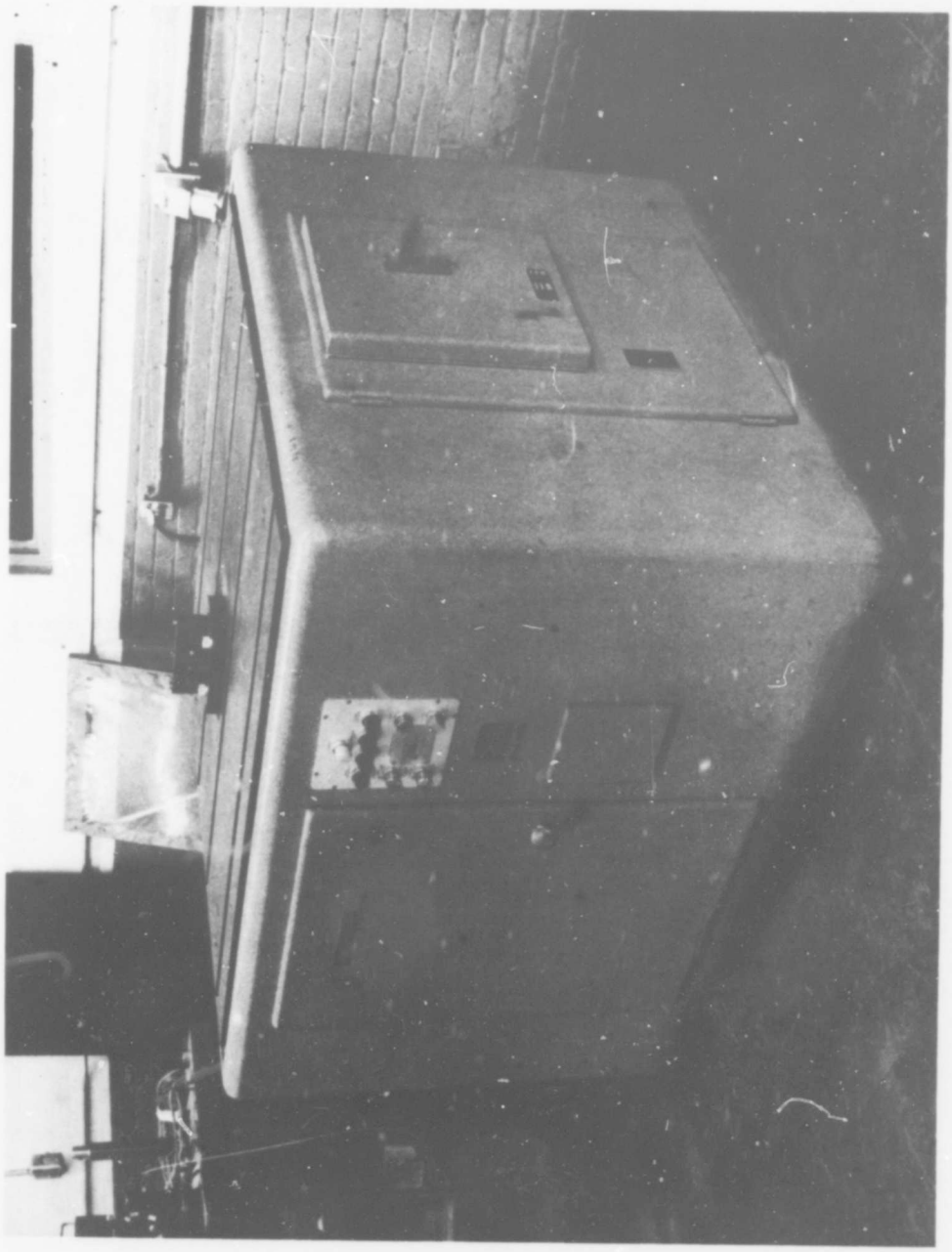
(a) Military Specification MIL-F-18240 Fastener, Externally Threaded, 250°F, Self-Locking Element for, of 5 December 1961
(b) Specification FF-P-386b Pins, Cotter (Split) of 21 March 1951
(c) Military Standard MS24665, Pins, Cotter of 20 April 1961
(d) Military Standard MS 35335, Washer, Lock, Flat - External Tooth of 5 December 1963
(e) Naval Air Engineering Center Report No. NAEC AML 2333, Pins, Cotter; Coloring of, dated 15 December 1965
(f) IIT Research Institute Technology Center Report No. 4, Investigation of Fasteners and Fastening Techniques, Final Progress Report, 15 May 1964 to 14 September 1965
(g) Military Standard MS 33540, Safety Wiring, General Practices for, of 17 March 1959

PLATES

1 - Weidemann Baldwin Universal Fatigue Testing Machine, Model SF-10-U with test fixture mounted on oscillator. Photo No. 381847
2 - Test fixture and specimens partly assembled. Photo No.381846
3 - Test fixture and specimens assembled. Photo No.381848
4 - Fastener-safety devices tested. Photo No. 383294
5 - Bar graph. Fastener-safety devices in order according to greatest average number of cycles to failure.

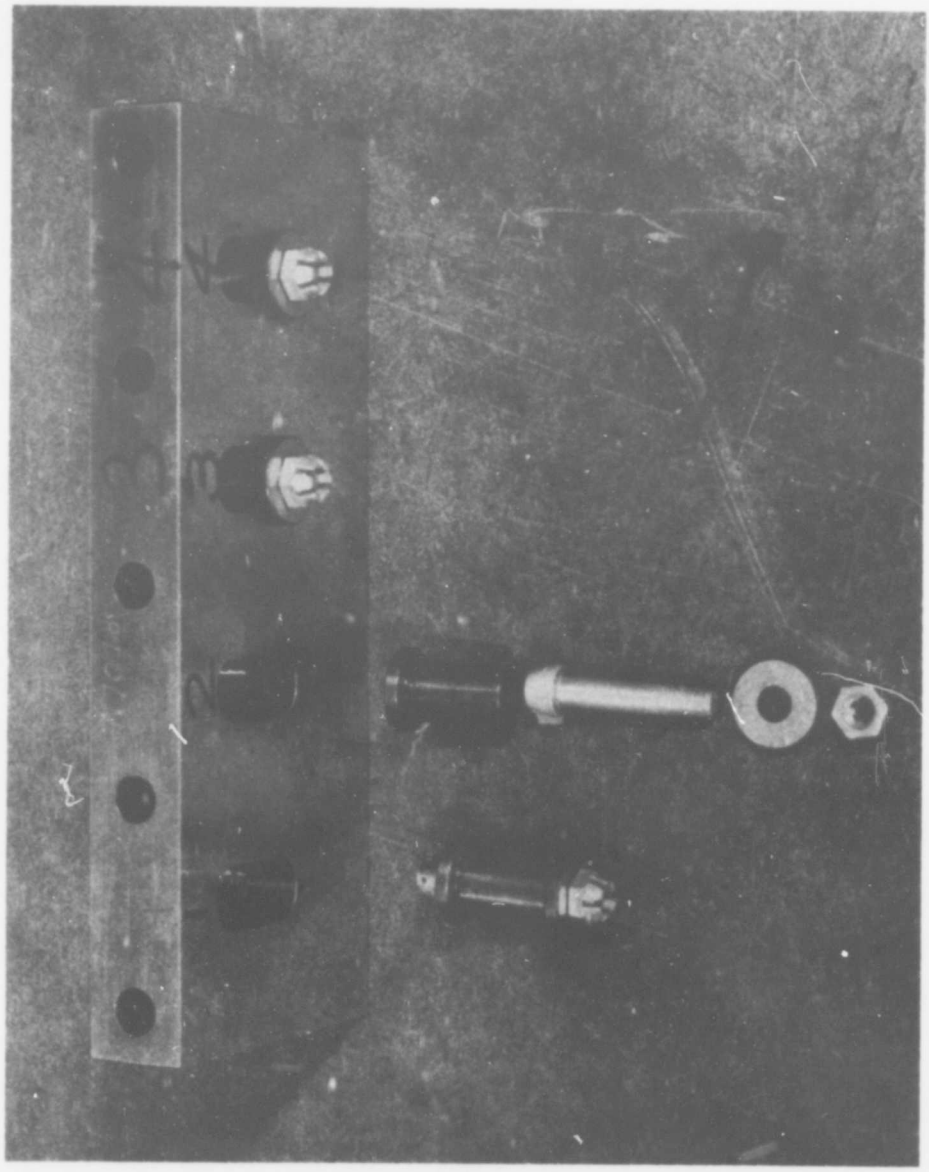
TABLES

1 - Test Results- Fastener-Safety Devices
2 - Fastener-Safety Devices Used by Airframe Manufacturers



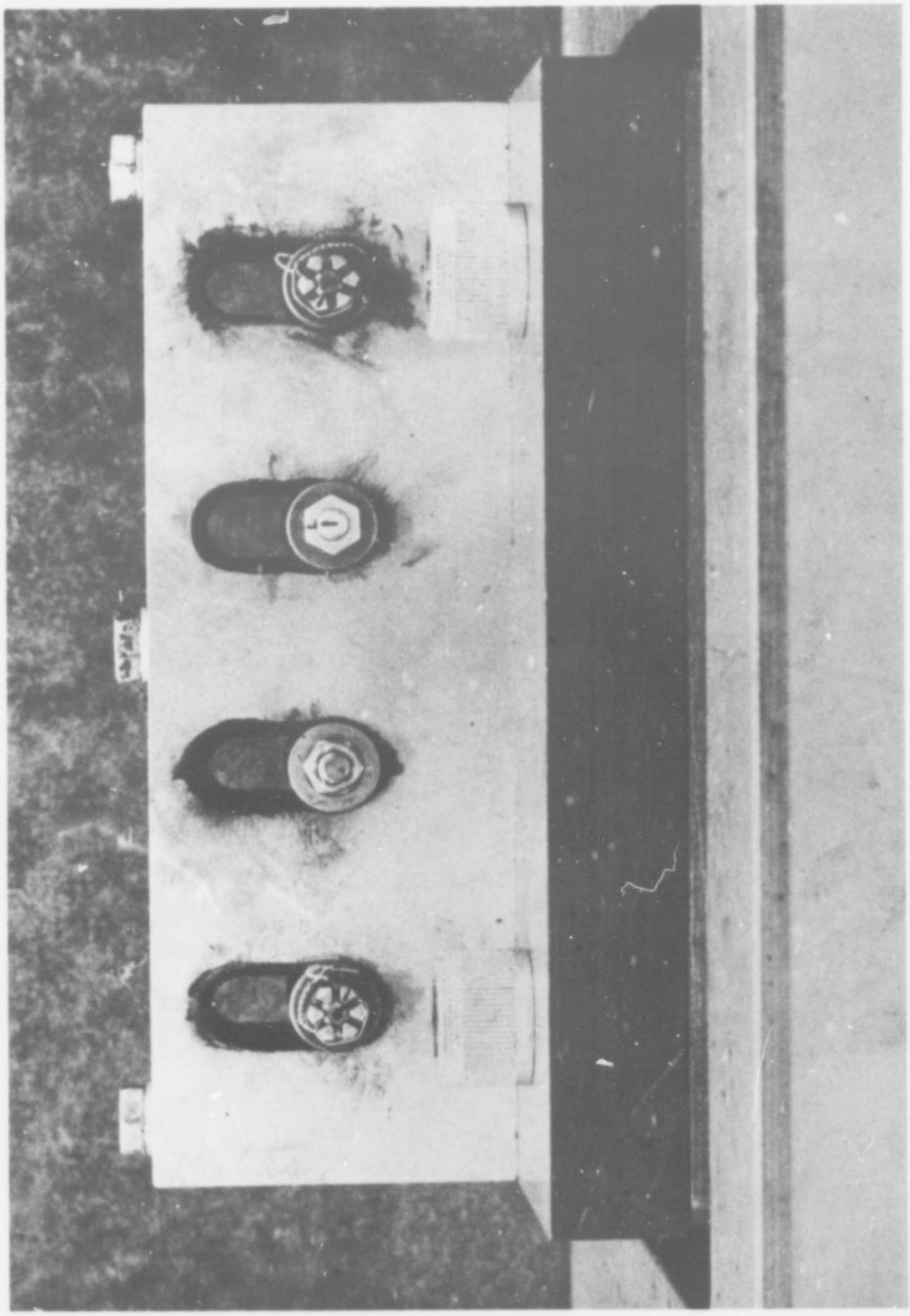
Weidmann Baldwin Universal Fatigue Testing Machine, Model SF-10-U,
With Test Fixture Mounted on Oscillator

Plate 1



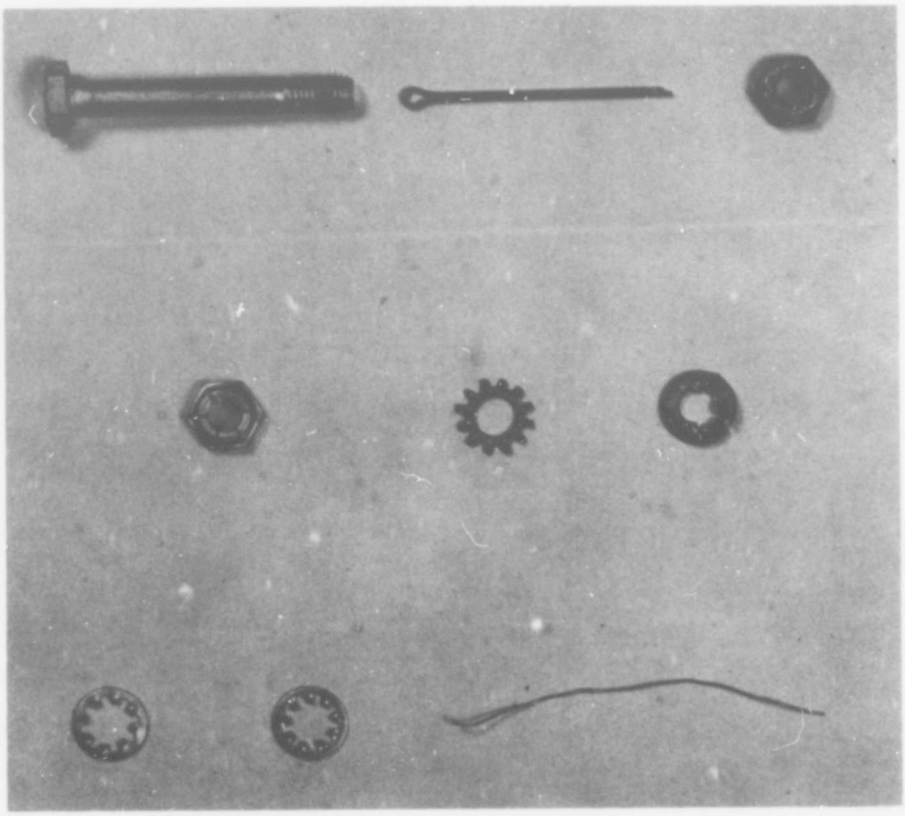
Test Fixture and Specimens Partly Assembled

Plate 2



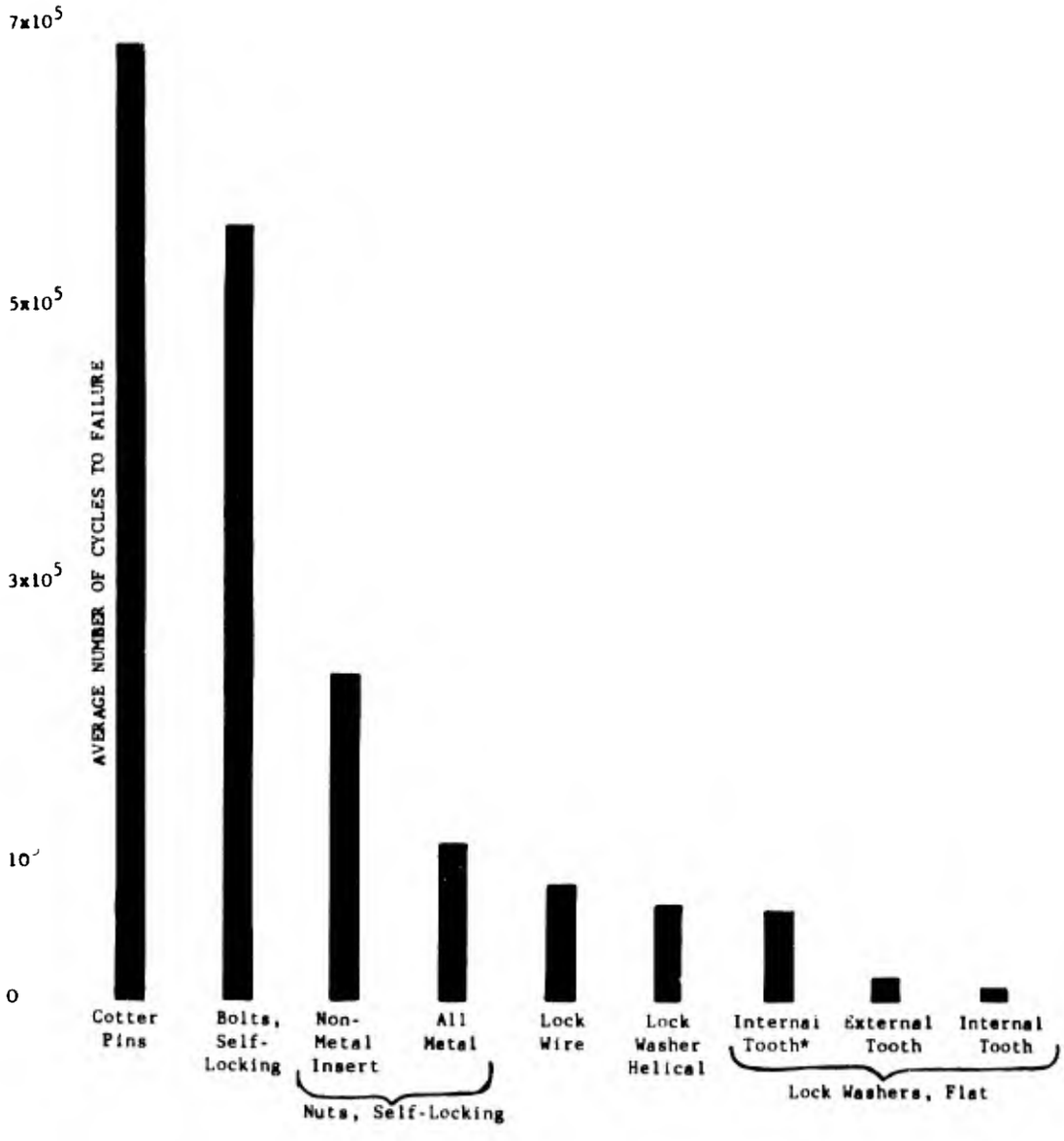
Test Fixture and Specimens Partly Assembled

Plate 3



Fastener-Safety Devices Tested

Plate 4



*Provided by manufacturer

BAR GRAPH. FASTENER-SAFETY DEVICES IN ORDER ACCORDING TO GREATEST AVERAGE NUMBER OF CYCLES TO FAILURE

PLATE 5

TEST RESULTS - FASTENER SAFETY DEVICES

DEVICES TESTED 1/	NUMBER TESTED	NUMBER FAILING	CYCLES TO FAILURE			COMPLETED ONE MILLION CYCLES
			AVERAGE TO NEAREST HUNDRED	EXTREMES LOW	EXTREMES HIGH	
Cotter Pin, CRES	7	5	686,800	200,000	990,000	2
Bolt, self-locking, non-metallic insert	5	4	558,000	200,000	893,000	1
Nut, self-locking, hexagon, non-metallic insert	7	4	233,000	233,000	233,000	3
Nut, self-locking, hexagon reduced height, short beam	12	12	111,600	7,000	372,000	0
Lockwire, CRES, 0.020 inch dia.	5	5	82,000	28,000	134,000	0
Washer, lock-spring, helical 2/	12	9	68,800	5,000	240,000	1
Washer, lock, flat, internal tooth (Provided for test by manufacturer.)	16	14	62,200	12,000	178,000	2
Washer, lock, flat, external tooth	8	8	15,400	5,000	44,000	0
Washer, lock, flat, internal tooth	8	8	8,500	4,000	17,000	0

1/ See paragraph B.1.b. and Plate 4.

2/ Bolts failed on two specimens; one after 122,000 cycles, the other after 240,000 cycles.

TABLE 1

FASTENER-SAFETY DEVICES USED BY AIRFRAME MANUFACTURERS

MANUFACTURER	DEVICES	COMMENTS
A.	Non-metallic inserts Nuts, deformed-thread Lockwire Adhesive compounds Threaded inserts Keys Nuts, non-metallic inserts Clevis pins Rod-end locks	"The space program design group prefers deformed thread nuts." "We have no reliability information for these items."
B.	Cotter pins Bolts, non-metallic inserts Nuts, self-locking Lockwire Adhesive compounds Washers, Lock, Split and Tab Washers, Lock Washers, Key Clevis pins Rod-end locks	"Use of cotter pins is limited to ground equipment."
C.	Nuts and bolts, self locking (76.8%) Cotter pins (9.6%) Lockwire (6.8%) Washers, Lock (5.5%) Adhesives (1.9%)	"We do not have factual information regarding relative reliability of these fastening means."
D.	Lockwire Washers, Lock Washers, Key Cotter pins Adhesives Nuts, self-locking Bolts, self-locking Clevis pins Rod-end locks Turnbuckle, Clip-lock	"Relative reliability of these devices is somewhat meaningless as it is dependent on applicability in the particular installation and service environment." "Only limited use made of adhesives . . . tests show they have unpredictable retention capabilities."
E.	Lockwire Washers, Tab Nuts and Bolts, self-locking Turnbuckle, Clip-lock	"Do not use adhesive compounds as locking device."
F.	Nuts, self-locking, all metal Threaded inserts Washers, Lock, Split Washers, Lock, Toothed	"For general purpose all-metal, self-locking nuts are preferred." "Lockwire and cotter pins are generally avoided."
G.	Nuts and Bolts, self-locking Cotter pins Lockwire Washers, Lock Adhesive compounds Staking Peening Rod-end locks	"Nuts with nylon inserts are superior to the all-metal self-locking nut; however, nylon material limits nut application to 250°F max."

TABLE 2

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4. DESCRIPTIVE NOTES (Type of report and inclusive dates)
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5. AUTHOR(S) (Last name, first name, initial)
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13. ABSTRACT
→ The purpose of the work was
To review and evaluate fastener-safety devices and methods and the applicable engineering documentation; and to investigate the relative reliability of such methods and devices.

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14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Fasteners Assembling Devices Usage Limitations Engineering Documentations						

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