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Comparative Strength Tests of Tension Bolts with UNF and BSF Threads

(Revised Version of Technical Note No. Structures 212)

by

R. F. Mousley, F. Clifton and D. Le Brocq

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COMPARATIVE STRENGTH TESTS OF TENSION BOLTS WITH UNF AND BSF THREADS

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SUMMARY

Results are given of comparative tests in tension of bolts with Unified Fine (UNF) and British Standard Fine (BSF) threads. Separate tests were made with ordinary nuts, with thin nuts, and with a pair of locknuts. The tests were made early in 1956.

The UNF bolts were found on the average to be as strong in tension as the BSF bolts, or slightly stronger.

In general, with a single nut, failure occurred in the thread of the UNF bolts but in the core of the BSF bolts.

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1 INTRODUCTION

The use of the Unified screw thread to BS Specification No.1580* is now prescribed for Service aircraft, and tests have been made at the request of the J.A.C. Materials Sub-Committee to compare the tension strength of bolt/nut combinations having Unified threads with similar combinations having British Standard Fine threads. The aircraft standard bolts with Unified threads were found on the average to be not weaker than the corresponding British Standard Fine thread bolts.

It should be remarked that the tests were made early in 1956 before the results of work by the Mechanical Engineer Research Laboratory had been published[1].

2 TESTS AND TEST RESULTS

The tests were made in direct tension on high-tensile steel British Standard Fine threaded (BSF) bolts supplied to BS Specification A.25** (A.27 nuts) and Unified Fine Threaded (UNF) aircraft bolts supplied to BS Specification A.102 (A.103 nuts). Two diameters of bolt, $\frac{1}{4}$" and $\frac{1}{2}$" were tested, with ordinary nuts alone, thin nuts alone and with both types of nut lightly locked together. The $\frac{1}{2}$" diameter bolts had rolled threads and the $\frac{1}{4}$" diameter bolts had cut threads. The results of the tests are given in Table 5 and plotted on Fig.1.

In addition to these tension tests, tests on the bolt shanks in double shear between hardened steel plates were made, to serve as controls for the strength of the bolt material. The results are given in Table 6. These shear control tests were made in preference to tension control tests as they gave a consistent basis for material control and could be made directly on the bolt shank without the need for machining of specimens.

Mean values and coefficients of variation of the bolt tension failing loads are given in Table 1, and the corresponding bolt shank tension stresses and the mean control shear stresses in Table 2. The bolts and nuts for each set of tests were taken at random from single batches obtained from one source of supply.

3 ANALYSIS OF RESULTS

Fig.1 and Table 4(a) give a comparison of the tensile failing loads of the bolt/nut combinations, and show the difference in strength due to all causes, including differences in material strength. Tables 3 and 4(b) give a comparison of the strengths of the two types of thread, based on a "thread strength efficiency" which is the failing strength of the nut/bolt combination expressed in terms of the ultimate strength of the unthreaded shank. This shank ultimate strength has been estimated from the control shear test results, by using a shear-tension relationship[2] to convert the mean control ultimate shear stresses into ultimate tension stresses. Ultimate loads for the bolt shanks in tension are then obtained by multiplying these stresses by the cross-sectional area of the unthreaded part of the shank.

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* This specification defines the thread form.

** A summary of information on the specifications mentioned in this Note is given in Appendix 1.

4 CONCLUSIONS

The bolt/nut combinations with Unified threads to the aircraft Specification A.102 are on the average not less strong in tension than the corresponding BSF bolts to aircraft Specification A.25, except for the $\frac{1}{2}$" diameter bolt with single locknut, where the UNF bolts are slightly weaker than the BSF. It is to be noted that in general, with a single nut, failure occurred in the thread of the UNF bolts, but in the core of the BSF bolts.

LIST OF SYMBOLS

t_1	tons/sq in.	0.1% proof stress in tension
f_t	tons/sq in.	Ultimate stress in tension
n		Number of test results in a group
$\bar{x}$		Mean value from group of test results
v		Coefficient of variation for group of test results

$$v = \frac{1}{\bar{x}}\sqrt{\frac{\Sigma(x - \bar{x})^2}{n-1}}$$

LIST OF REFERENCES

Ref. No.	Author	Title, etc.
1	Field, J.E.	Tightening and tensile tests on joints. The Engineer, 2nd and 9th May, 1958.
2	Ripley, E.L. Beard, A.J.	Shear strength of pins in steel, and aluminium magnesium and copper alloys. R.A.E. Technical Note No. Structures 120. July, 1953.

APPENDIX 1

SUMMARY OF INFORMATION ON THE SPECIFICATIONS MENTIONED IN THIS NOTE

These abbreviated notes are intended only for general guidance and to identify the particular bolts and nuts used. For precise data and detailed information, reference should be made to the full specification.

Specification	Description
B.S.S. A 25	High tensile steel hexagon-headed bolts for aircraft with British Standard Fine threads as defined by B.S.84. Material: 55 ton alloy steel, hardened, tempered, cold worked and cadmium plated.
B.S.S. A 27	Medium tensile steel hexagon nuts for aircraft with British Standard Fine thread as defined by B.S.84. Material: 45 ton carbon steel, hardened, tempered, cold worked and cadmium plated.
B.S.S. A 102	Aircraft bolts with Unified hexagon head and Unified fine thread as defined by B.S.1580. Material: 55 ton carbon or alloy steel, hardened, tempered and cadmium plated.
B.S.S. A 103	Aircraft Unified hexagon nuts with Unified fine thread as defined by B.S.1580. Material: 45 ton carbon steel, hardened, tempered, cold worked and cadmium plated.
B.S.84	Form of BSF thread. (See Fig.2).
B.S.1580	Form of Unified thread. (See Fig.2).

TABLE 1

Mean failing loads and coefficients of variation

Bolt diameter (ins.)	Bolt designation		Failing load (tons)			
			Bolt shank in double shear	Tension		
				Single locknut	Single ordinary nut	Ordinary nut with locknut
¼	B.S.F. B.S.A25 bolts with B.S.A27 nuts	$\bar{x}$	3.48	1.47	2.14	2.27
		v%	7.0	7.0	3.0	2.7
		n	10	10	10	10
	U.N.F. B.S.A102 bolts with B.S.A103 nuts	$\bar{x}$	3.67	1.71	2.40	2.46
		v%	1.2	4.0	2.6	2.0
		n	10	10	10	21
½	B.S.F. B.S.A25 bolts with B.S.A27 nuts	$\bar{x}$	15.11	7.43	9.85	10.38
		v%	1.5	5.1	4.1	3.3
		n	10	10	10	10
	U.N.F. B.S.A102 bolts with B.S.A103 nuts	$\bar{x}$	16.0	6.95	10.29	11.72
		v%	1.3	5.0	2.4	1.9
		n	10	10	10	10

TABLE 2

Mean failing stresses

Bolt designation	Bolt diameter (ins.)	Mean ultimate shear stress in control tests tons/sq in.	Derived ultimate tensile control stress tons/sq in.	Mean tension stress in bolt shank* at nut - bolt failure		
				Single locknut	Single nut	Nut with locknut
B.S.F. B.S. A25 bolts B.S. A27 nuts	¼	35.4	53.6	29.93	43.58	46.23
	½	38.5	60.4	37.84	50.17	52.88
U.N.F. B.S. A102 bolts B.S. A103 nuts	¼	37.4	57.1	34.82	48.86	50.09
	½	40.7	63.4	35.40	52.42	59.70

* Unthreaded part of shank.

TABLE 3

Thread strength efficiencies

Bolt designation	Bolt diameter (ins.)	Percentage thread strength efficiency+		
		Single locknut	Single nut	Nut with locknut
B.S.F. B.S. A25 bolts with B.S. A27 nuts	$\frac{1}{4}$	56	[81]	[86]*
	$\frac{1}{2}$	63	[83]	[87]
U.N.F. B.S. A102 bolts with B.S. A103 nuts	$\frac{1}{4}$	61	84	[88]
	$\frac{1}{2}$	56	83	[94]

* Boxed values refer to tests in which the majority of failures were at the thread root.

\+ The percentage thread strength efficiency is taken to be:-

$$\frac{\text{Tension stress in shank at nut/bolt failure}}{\text{Derived ultimate control tension strength of shank}} \times 100$$

TABLE 4

Comparison of tension strength of Unified thread bolt-nut combination and British Standard Fine bolt-nut combinations

Values of the ratio: $\frac{\text{Tension strength of Unified thread A102 - A103 bolts}}{\text{Tension strength of B.S. A25 - A27 bolts}}$

$\frac{1}{4}$" diameter			$\frac{1}{2}$" diameter		
Locknut alone	Ordinary nut alone	Ordinary nut with locknut	Locknut alone	Ordinary nut alone	Ordinary nut with locknut
(a) Assessed on mean test load					
1.16	1.12	1.08	0.94	1.04	1.13
(b) Assessed on thread strength efficiency					
1.09	1.03	1.02	0.89	1.00	1.08

TABLE 5

Tension failing loads for bolt - nut combinations

½" Bolts with nuts and locknuts				¼" Bolts with nuts and locknuts			
Specimen identification	Thread form	Ultimate load (tons)	Mode of failure	Specimen identification	Thread form	Ultimate load (tons)	Mode of failure
1	B S.F.	10.14	T	1	B S F	2.26	T
2	Bolt B.S. A25	10.70	T	2	Bolt B.S. A25	2.29	T
3	Nut B.S. A27	10.52	T	3	Nut B S. A27	2.25	T
4		10.60	T	4		2.26	T
5		10.50	T	5		2.37	T
6		10.58	T	6		2.18	T
7		10.40	T	7		2.33	T
8		9.90	T	8		2.29	T
9		9.73	T	9		2.33	T
10		10.73	T	10		2.18	T
1	U.N.F.			F 31	U.N.F.	2.46	T
	Bolt B.S. A102	11.74	T	F 32	Bolt B.S.A102	2.45	T
2	Nut A103	11.70	T	F 33	Nut A103	2.54	T
3		11.80	T	F 34		2.55	T
4		11.15	T	F 35		2.42	T
5		11.81	T	F 36		2.49	T
6		11.89	T	F 37		2.55	T
7		11.89	T	F 38		2.47	T
8		11.88	T	F 39		2.46	T
9		11.78	T	F 40		2.45	T
10		11.59	T	F 41		2.45	T
				F 42		2.42	T
				F 43		2.41	T
				F 44		2.46	T
				F 45		2.52	T
				F 46		2.46	T
				F 47		2.38	T
				F 48		2.41	T
				F 49		2.48	T
				F 50		2.50	T
				F 51		2.38	T

Key to mode of failure

T Tension failure at root of thread.

TABLE 5 (Continued)

Tension failing loads for bolt - nut combinations

½" Bolts with single nuts				¼" Bolts with single nuts			
Specimen identification	Thread form	Ultimate load (tons)	Mode of failure	Specimen identification	Thread form	Ultimate load (tons)	Mode of failure
1	B.S.F.	10.47	T	1	B.S.F.	2.04	B
2	Bolt B.S. A25	9.69	T	2	Bolt B.S. A25	2.24	T
3	Nut B.S. A27	10.00	T	3	Nut B.S. A27	2.14	T
4		9.23	T	4		2.19	B
5		9.86	T	5		2.08	T
6		10.30	B	6		2.18	B
7		9.68	T	7		2.12	T
8		9.32	T	8		2.16	T
9		9.73	T	9		2.19	T
10		10.20	T	10		2.06	T
1	U.N.F.	9.83	B	F 21	U.N.F.	2.52	B
2	Bolt B.S. A102	10.36	B	F 22	Bolt B.S. A102	2.43	B
3	Nut A103	10.39	B	F 23	Nut A 103	2.37	B
4		10.26	B	F 24		2.34	B
5		10.21	B	F 25		2.44	B
6		10.20	B	F 26		2.41	B
7		10.10	B	F 27		2.40	B
8		10.25	B	F 28		2.35	B
9		10.60	B	F 29		2.31	B
10		10.73	B	F 30		2.46	B

Key to mode of failure

T Tension failure at root of thread.

B Both threads stripped.

TABLE 5 (Continued)

Tension failing loads for bolt - nut combinations

$\frac{1}{2}$" Bolts with locknuts alone				$\frac{1}{4}$" Bolts with locknuts alone			
Specimen identification	Thread form	Ultimate load (tons)	Mode of failure	Specimen identification	Thread form	Ultimate load (tons)	Mode of failure
1	B.S.F.	7.10	B	1	B.S.F.	1.30	B
2	Bolt B.S. A25	7.65	B	2	Bolt B.S. A25	1.39	B
3	Nut B.S. A27	7.82	B	3	Nut B.S. A27	1.57	B
4		6.90	B	4		1.54	B
5		7.77	B	5		1.45	B
6		7.98	B	6		1.63	B
7		7.09	B	7		1.10	B
8		7.15	B	8		1.45	B
9		7.63	B	9		1.40	B
10		7.18	B	10		1.57	B
1	U.N.F.			F 11	U.N.F.	1.83	B
	Bolt B.S. A102	6.90	B	F 12	Bolt B.S. A102	1.66	B
2	Nut A103	7.30	B	F 13	Nut A103	1.66	B
3		6.95	B	F 14		1.76	B
4		6.25	B	F 15		1.69	B
5		6.67	B	F 16		1.71	B
6		6.70	B	F 17		1.58	B
7		6.96	B	F 18		1.76	B
8		7.43	B	F 12		1.69	B
9		7.13	B	F 20		1.73	B
10		7.25	B				

Key to mode of failure

B Both threads stripped

TABLE 6

Failing loads of bolt shanks in double shear*

½" Bolts			¾" Bolts		
Specimen identification	Thread form	Ultimate load (tons)	Specimen identification	Thread form	Ultimate load (tons)
G 1	B.S.F.	14.83	D 1	B.S.F.	3.30
G 2	B.S.A25	14.89	D 2	B.S.A25	3.81
G 3		15.28	D 3		3.14
G 4		15.17	D 4		3.55
G 5		14.90	D 5		3.79
G 6		15.45	D 6		3.66
G 7		15.04	D 7		3.14
G 8		15.34	D 8		3.35
G 9		15.27	D 9		3.60
G 10		14.90	D 10		3.43
1	U.N.F.	16.25		U.N.F.	
2	B.S.A102	15.93	F 1	B.S.A102	3.61
3		16.08	F 2		3.72
4		15.91	F 3		3.70
5		16.31	F 4		3.66
6		15.70	F 5		3.60
7		16.11	F 6		3.70
8		15.99	F 7		3.68
9		15.66	F 8		3.68
10		16.10	F 9		3.69
			F 10		3.67

* The shear values are for a ratio of bolt dia: shear plate thickness of 0.67 for the ½" bolts and 0.5 for the ¾" bolts, except for the ½" B.S.F. A25 bolts, for which the ratio was 1.4.

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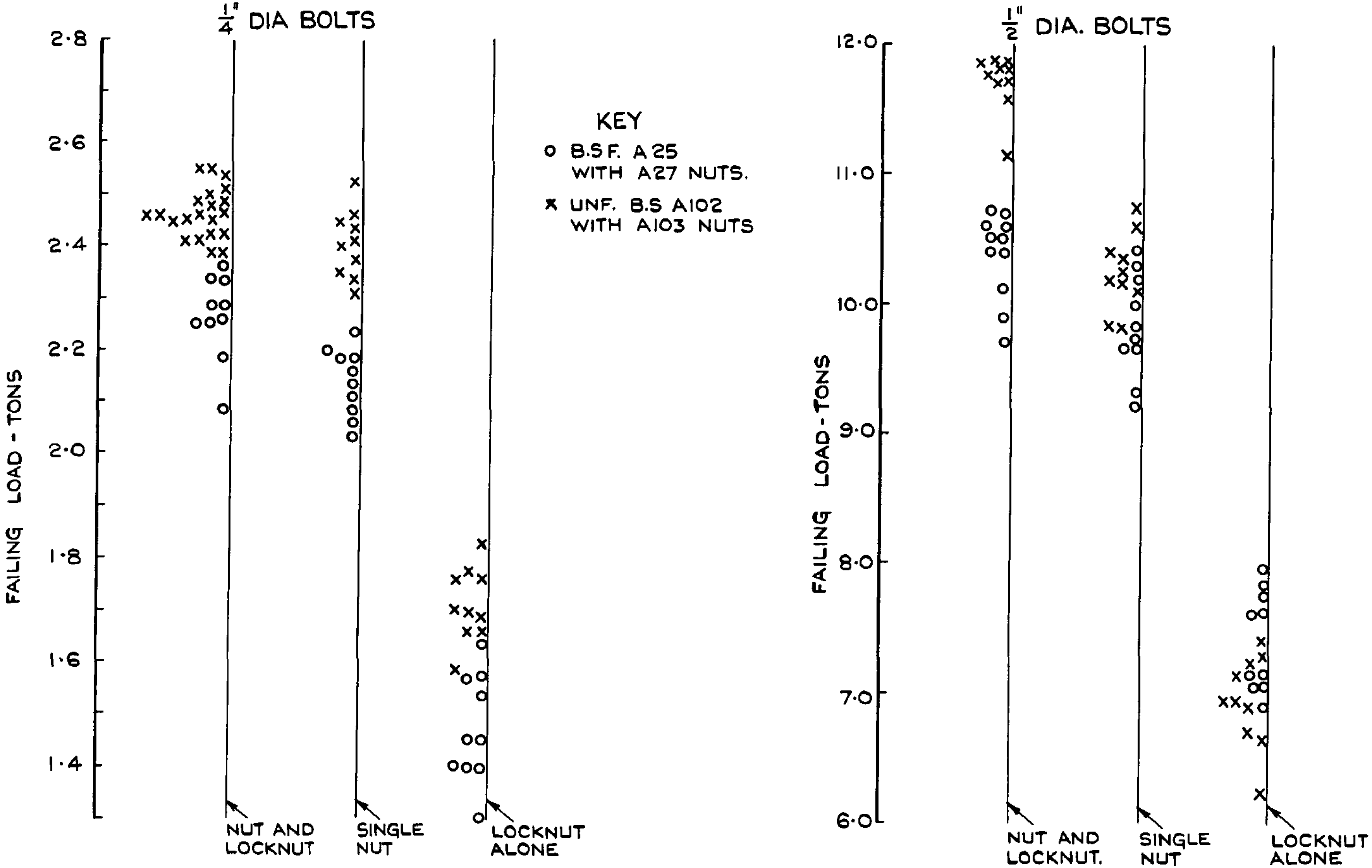
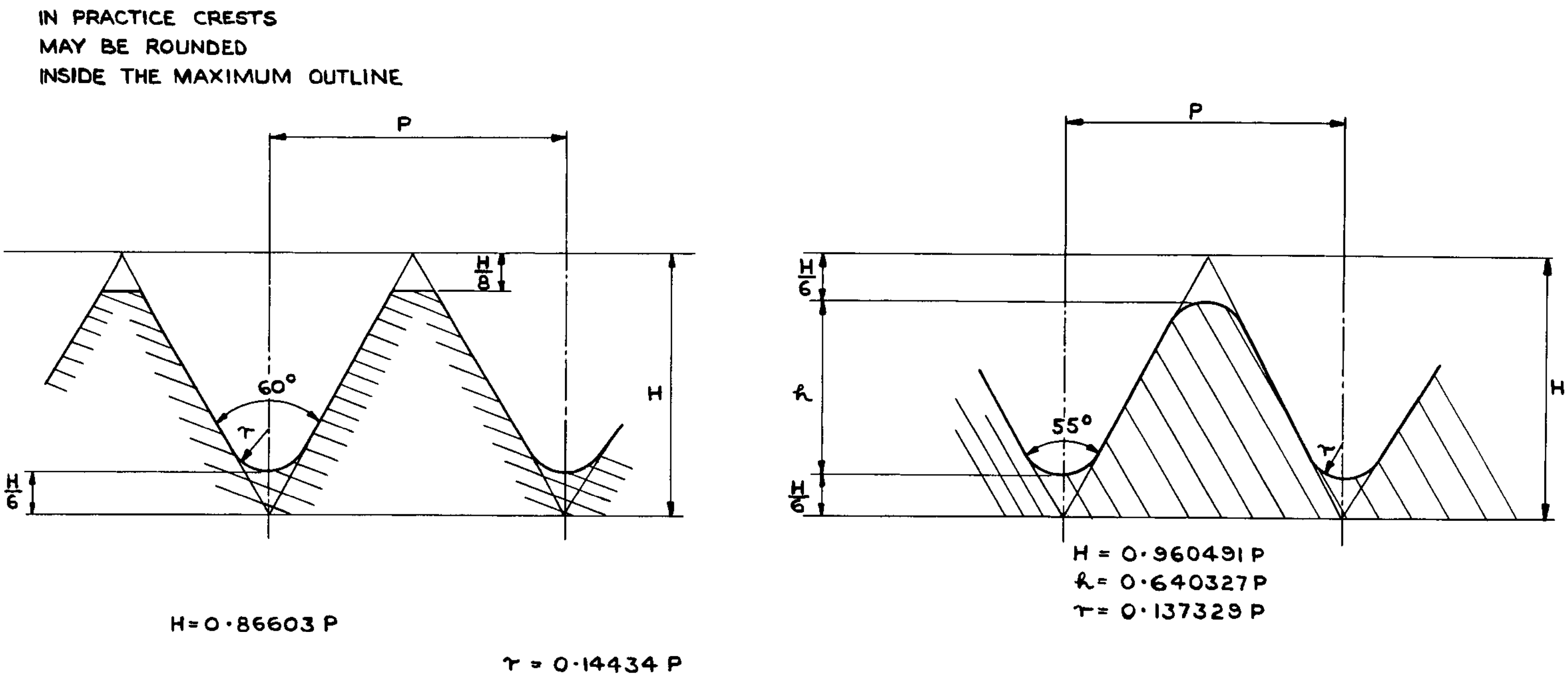


FIG. 1. TENSION TEST RESULTS.



UNIFIED BOLT THREAD DESIGN FORM – B.S. 1580
(MAXIMUM METAL CONDITION)

B.S.F. BASIC THREAD FORM – B.S. 84.

FIG. 2. THREAD FORMS.

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