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BDX-613-825

RECOMMENDED SCREW TORQUES
FOR 0.6, 0.8, AND 1.0 UNIFIED
NATIONAL MINIATURE THREADS

PDO 6984735, Topical Report

C. W. Elder, Project Leader

Internal Distribution July 1973
Revised September 1973

Prepared for the
United States Atomic Energy Commission
Under Contract Number AT(29-1)-613 USAEC

**Kansas City
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Project Leader:
C. W. Elder
Department 822

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Topical Report

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RECOMMENDED SCREW TORQUES FOR 0.6, 0.8, AND 1.0 UNIFIED NATIONAL MINIATURE THREADS

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Prepared by C. W. Elder, D/822, under PDO 6984735

Maximum torques for 0.6, 0.8, and 1.0 Unified National Miniature (UNM) screw threads have been established. During the study (which included investigations of the effects of lubrication, material, length of thread engagement, and screw head style) an Analysis of Variance found that only screw size significantly affected failure torque values. It was found that screws could be torqued to the recommended value, removed, and reinstalled with the same torque without galling or thread damage.

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SUMMARY

Suitable torque values were developed for 0.6, 0.8, and 1.0 Unified National Miniature (UNM) screws commonly used in miniature electromechanical devices. The possible effects on the torque value of lubrication, material, length of thread engagement, and screw head style were also studied. Since no torque recommendations for miniature series screws was ever found that could be applied to miniature device assembly, the torque values for assembly application were established by direct experimentation.

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DISCUSSION

SCOPE AND PURPOSE

The purpose of this activity was to develop suitable torque values for 0.6, 0.8, and 1.0 Unified National Miniature (UNM) screws commonly used in miniature electromechanical devices. The effects on torque value of silver plate lubrication, material combination, length of thread engagement, and screw head style were studied.

PRIOR WORK

Torque-tension relationships in threaded connections have been studied to find how much torque must be applied to a specific screw in a given material to yield the desired tension in the joint. In general, as much as 90 percent of the forces required to tighten a screw merely overcome the friction in the threads and under the screw head. Frictional forces are difficult to predict in these areas because of such variables as thread dimensions and finish, actual contact area under the head, and the presence of any oils on the thread. Therefore, any mathematical relationships between torque and tension can only be approximations at best. For this reason, experimentation is probably the most accurate method of establishing desired torque values for any given threaded joint configuration.

ACTIVITY

The experiment was established in the two-level factorial design form. The variables studied were head style (pan head or fillister); length of thread engagement (two diameters or $2/3$ diameter); lubrication (standard or silver-plated screw); and tap drill size (oversize or standard--oversize on two diameters deep holes only (Figures 1 and 2).

The oversize tap drill was tested because of the better yield obtainable by tapping into an oversize hole, resulting in less tap breakage. It was desired to learn if the partial threads obtained had any significant effect on joint strength.

All screws were made from 303 SE stainless steel. The five materials most commonly found in miniature mechanisms were selected for the internal threads:

- Annealed 302 stainless steel;
- T6510 7075 aluminum;

1.0 UNM, 302 STAINLESS (50X)

0.6 UNM, 7075 T-6 ALUMINUM (50X)

0.8 UNM, 7075 T-6 ALUMINUM (50X)

0.6 UNM, 302 STAINLESS (50X)

Figure 1. Thread Samples Made With Standard Tap Drill

1.0 UNM, BERYLLIUM COPPER (40X)

0.8 UNM, 302 STAINLESS (50X)

0.6 UNM, 17-4PH STAINLESS (50X)

1.0 UNM, 7075 T-6 ALUMINUM (40X)

Figure 2. Thread Samples Made With Oversize Tap Drill

- H-900 17-4 PH stainless steel;
- Beryllium copper; and
- Hyperco 50 armature steel.

A Sturtevant Model TTF-1/4 Torque Testing Fixture and a Sturtevant 0 to 16 inch-ounce (113 mN-m) flat beam torque wrench were used for the tests. Special adapters held the small screwdriver blades used to install the screws (Figure 3). Each screw was threaded into the sample plate and tightened until failure occurred. The maximum torque reading was then recorded (Appendix A).

Figure 3. Torque Testing Experimental Fixture Showing Torque Adapter (Figure 4) and Block (Figure 5)

Figure 4. Torque Adapter

Figure 5. Block Used to Space Screw During Testing (See Table 1) To Compensate for Lack of Thread Relief Under Screw Head

Table 1. Block Measurements

Block Identification Number	"A" Diameter (Inch) $\pm 0.002^*$	Material
A1, A2	0.025-0.027	Annealed 303 Se Stainless Steel
B1, B2	0.033-0.035	Annealed 303 Se Stainless Steel
C1, C2	0.040-0.042	Annealed 303 Se Stainless Steel
D1, D2	0.025-0.027	7075 T-6 Aluminum
E1, E2	0.033-0.035	7075 T-6 Aluminum
F1, F2	0.040-0.042	7075 T-6 Aluminum
G1, G2	0.025-0.027	17-4 PH Stainless Steel (H-900 Condition)
H1, H2	0.033-0.035	17-4 PH Stainless Steel (H-900 Condition)
I1, I2	0.040-0.042	17-4 PH Stainless Steel (H-900 Condition)
J1, J2	0.025-0.027	Beryllium Copper
K1, K2	0.033-0.035	Beryllium Copper
L1, L2	0.040-0.042	Beryllium Copper
M1, M2	0.025-0.027	Hyperco 50
N1, N2	0.033-0.035	Hyperco 50
Q1, Q2	0.040-0.042	Hyperco 50
*0.001 Inch = 0.0254 mm		

An analysis of variance (Appendix B) by Statistical Quality Control Department revealed that only the screw size significantly affected the failure torque reading. Consequently, other test variables were ignored in further testing and calculations. The average torque value was obtained for each material and size combination, and the recommended maximum torque value was established as approximately half the average reading. This maximum torque value was adjusted slightly higher or lower according to the distribution of values about the average of the minimum and maximum readings (Tables 2 and 3).

Table 2. Recommended Maximum Torque Values for UNM Series 303 Se Stainless Steel Screws

Internal Thread Material	Torque Values for UNM Screw Sizes (Inch-Ounce) (mN-m)		
	0.6 UNM	0.8 UNM	1.0 UNM
303 SE Stainless Steel	1.5 (10)	4.0 (28)	6.0 (42)
7075 T-6 Aluminum	2.0 (14)	5.0 (35)	8.0 (56)
17-4 PH Stainless Steel (H 900)	2.0 (14)	4.0 (28)	6.0 (42)
Beryllium Copper	2.0 (14)	5.0 (35)	7.0 (49)
Hyperco 50 Armature Steel	2.0 (14)	4.0 (28)	7.0 (49)

Table 3. Test Readings

Screw Material	UNM Screw Sizes	Torque Readings (Inch-Ounce) (mN-m)		
		Maximum	Minimum	Average
Annealed 303 SE Stainless Steel	0.6	8.0 (56)	2.0 (14)	3.54 (25)
	0.8	10.0 (70)	6.0 (42)	8.17 (57)
	1.0	16.0 (113)	7.0 (49)	12.66 (89)
7075 T-6 Aluminum	0.6	7.0 (49)	3.0 (21)	4.50 (31)
	0.8	15.0 (105)	8.0 (56)	10.29 (72)
	1.0	19.0 (134)	10.0 (70)	15.2 (107)
17-4 PH Stainless Steel (H-900)	0.6	5.0 (35)	3.0 (21)	3.87 (27)
	0.8	9.0 (63)	6.0 (42)	7.70 (54)
	1.0	16.0 (113)	9.0 (63)	11.21 (79)
Beryllium Copper	0.6	5.0 (35)	3.0 (21)	3.70 (26)
	0.8	14.0 (98)	7.0 (49)	9.42 (66)
	1.0	17.0 (120)	12.0 (84)	13.37 (94)
Hyperco 50	0.6	5.0 (35)	3.0 (21)	4.0 (28)
	0.8	10.0 (70)	6.0 (42)	7.95 (56)
	1.0	15.0 (105)	10.0 (70)	12.46 (88)

Since only screw size had a significant effect, a plot was made using screw root diameter versus recommended torque value. The plot included the three UNM sizes studied, plus values for UNF screws (dry torque) through 8-36 screws drawn from available references (Table 4). The Statistical Quality Control Department provided a curve fit quadratic equation that related torque

Table 4. Recommended Maximum Torque Values
for Dry UNF and UNM Series Screws
With Steel Internal Threads

Screw Size	Threads/ Inch	Dry Torque (Inch-Ounce) (mN-m)
0.6 UNM	169	2 (14)
0.8 UNM	127	4 (28)
1.0 UNM	102	6 (42)
0	80	16 (113)
2	64	36 (251)
3	56	56 (395)
4	48	76 (536)
5	44	110 (776)
6	40	140 (988)
8	36	290 (2047)

to screw root diameter; the curve matched the original plot very closely (Figure 6), supporting the conclusion that screw size was the primary controlling variable.

The 302 steel-in-steel joints (Figure 7) were then tested to determine whether the new torque values would promote galling after repeated installation and removal of the screws. Two samples were installed and removed four times for each size and steel-in-steel combination except 0.6 UNM screws in 303 Se plate. (The 302 stainless steel plate and 303 Se stainless steel

screws had an interference problem not associated with the test.) All were successfully installed with no apparent damage to either part.

Figure 6. Plot of Screw Root Diameter Versus Recommended Torque Value Compared to Quadratic Equation Curve

Figure 7. Steel-in-Steel Samples Tested for Galling and Stripping
(See Table 5)

ACCOMPLISHMENTS

The maximum recommended torque values for different screw sizes and material combinations were established.

Only screw size was found to significantly affect failure torque values.

After being torqued to the recommended value, the screws were removed, reinstalled, and retorqued without galling or thread damage.

Direct experimentation was found to be the most reliable method of determining the proper torque for a particular application.

Table 5. Tap Drill and Thread Measurements

Sample Identification Number	X ₂ 0.002 (Inch)*	"A" Tap Drill Size (Inch)*	"B" Thread Size (UNM)	Material
A1	0.042	0.0193-0.0198	0.8	Annealed 303 SE
A2	0.042**	0.0198-0.0204	0.6	Annealed 303 SE
A3	0.020	0.0187-0.0198	0.6	Annealed 303 SE
B1	0.060	0.0256-0.0263	0.8	Annealed 303 SE
B2	0.060**	0.0263-0.0270	0.8	Annealed 303 SE
B3	0.020	0.0248-0.0263	0.8	Annealed 303 SE
C1	0.080	0.0319-0.0327	1.0	Annealed 303 SE
C2	0.080**	0.0327-0.0337	1.0	Annealed 303 SE
C3	0.080	0.0309-0.0327	1.0	Annealed 303 SE
D1	0.042	0.0193-0.0198	0.6	7075 T6510 Aluminum
D2	0.042**	0.0198-0.0204	0.6	7075 T6510 Aluminum
D3	0.020	0.0187-0.0198	0.6	7075 T6510 Aluminum
E1	0.060	0.0256-0.0263	0.8	7075 T6510 Aluminum
E2	0.060**	0.0263-0.0270	0.8	7075 T6510 Aluminum
E3	0.020	0.0248-0.0263	0.8	7075 T6510 Aluminum
F1	0.080	0.0319-0.0327	1.0	7075 T6510 Aluminum
F2	0.080**	0.0327-0.0337	1.0	7075 T6510 Aluminum
F3	0.030	0.0309-0.0327	1.0	7075 T6510 Aluminum
G1	0.042	0.0193-0.0198	0.6	17-4 PH Stainless (H-900)
G2	0.042**	0.0198-0.0204	0.6	17-4 PH Stainless (H-900)
G3	0.020	0.0187-0.0198	0.6	17-4 PH Stainless (H-900)
H1	0.060	0.0256-0.0263	0.8	17-4 PH Stainless (H-900)
H2	0.060**	0.0263-0.0270	0.8	17-4 PH Stainless (H-900)
H3	0.020	0.0248-0.0263	0.8	17-4 PH Stainless (H-900)
I1	0.080	0.0319-0.0327	1.0	17-4 PH Stainless (H-900)
I2	0.080**	0.0327-0.0337	1.0	17-4 PH Stainless (H-900)
I3	0.030	0.0309-0.0327	1.0	17-4 PH Stainless (H-900)
J1	0.042	0.0193-0.0198	0.6	Beryllium Copper
J2	0.042**	0.0198-0.0204	0.6	Beryllium Copper
J3	0.020	0.0187-0.0198	0.6	Beryllium Copper
K1	0.060	0.0256-0.0263	0.8	Beryllium Copper
K2	0.060**	0.0263-0.0270	0.8	Beryllium Copper
K3	0.020	0.0248-0.0263	0.8	Beryllium Copper
L1	0.080	0.0319-0.0327	1.0	Beryllium Copper
L2	0.080**	0.0327-0.0337	1.0	Beryllium Copper
L3	0.030	0.0309-0.0327	1.0	Beryllium Copper
M1	0.042	0.0193-0.0198	0.6	Hyperco 50
M2	0.042**	0.0198-0.0204	0.6	Hyperco 50
M3	0.020	0.0187-0.0198	0.6	Hyperco 50
N1	0.060	0.0256-0.0263	0.8	Hyperco 50
N2	0.060**	0.0263-0.0270	0.8	Hyperco 50
N3	0.020	0.0248-0.0263	0.8	Hyperco 50
Q1	0.080	0.0319-0.0327	1.0	Hyperco 50
Q2	0.080**	0.0327-0.0337	1.0	Hyperco 50
Q3	0.030	0.0309-0.0327	1.0	Hyperco 50

*1 Inch = 25.4 mm
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Appendix A

SCREW TORQUE TEST TABLES

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Table A-1. Screw Torque Test Results for 0.6 UNM Screws in Combination With 302 Stainless Steel Plate Material 0.036 and 0.021 Inch (0.91 and 0.53 mm) Thick

Test Number	Pan (P) or Fillister (F) Screw Head	Two Diameter (2) or 2/3 Diameter (2/3) Length of Engagement	Silver Plate Lubrication or Dry	Standard or Oversize Tap Drill	Maximum Torque (Inch-Ounce)**	Remarks
1A	F	2/3	Silver Plate	Standard	4*	Did Not Seat Against Head; Broke Before Head Bottomed Out
1B	F	2/3	Silver Plate	Standard	2*	
2A	P	2/3	Silver Plate	Standard	4*	
2B	P	2/3	Silver Plate	Standard	5*	
3A	F	2	Silver Plate	Standard	3*	Broke; Head Did Not Seat
3B	F	2	Silver Plate	Standard	3*	
4A	P	2	Silver Plate	Standard	4*	
4B	P	2	Silver Plate	Standard	3*	
5A	F	2/3	Dry	Standard	4*	Did Not Seat Against Head
5B	F	2/3	Dry	Standard	3*	
6A	P	2/3	Dry	Standard	3*	
6B	P	2/3	Dry	Standard	3*	
7A	F	2	Dry	Standard	4*	
7B	F	2	Dry	Standard	3*	
8A	P	2	Dry	Standard	3*	
8B	P	2	Dry	Standard	3*	
9A	F	2	Silver Plate	Oversize	3*	
9B	F	2	Silver Plate	Oversize	3*	
10A	P	2	Silver Plate	Oversize	4*	
10B	P	2	Silver Plate	Oversize	4*	
11A	F	2	Dry	Oversize	3*	Did Not Seat Against Head
11B	F	2	Dry	Oversize	3*	
12A	P	2	Dry	Oversize	3*	
12B	P	2	Dry	Oversize	3*	

*Screw broke
**Inch-Ounce = 7.061 mN-m

Table A-2. Screw Torque Test Results for 0.8 UNM Screws in Combination With 302 Stainless Steel Plate Material 0.061 and 0.021 Inch (1.54 and 0.53 mm) Thick

Test Number	Pan (P) or Fillister (F) Screw Head	Two Diameter (2) or 2/3 Diameter (2/3) Length of Engagement	Silver Plate Lubrication or Dry	Standard or Oversize Tap Drill	Maximum Torque (Inch-Ounce)***	Remarks
1A	F	2/3	Silver Plate	Standard	6*	Broken on Removing
1B	F	2/3	Silver Plate	Standard	6**	
2A	P	2/3	Silver Plate	Standard	8**	
2B	P	2/3	Silver Plate	Standard	10*	
3A	F	2	Silver Plate	Standard	6*	
3B	F	2	Silver Plate	Standard	9*	
4A	P	2	Silver Plate	Standard	10*	
4B	P	2	Silver Plate	Standard	10*	
5A	F	2/3	Dry	Standard	8**	
5B	F	2/3	Dry	Standard	7**	
6A	P	2/3	Dry	Standard	10*	
6B	P	2/3	Dry	Standard	9*	
7A	F	2	Dry	Standard	6*	
7B	F	2	Dry	Standard	8*	
8A	P	2	Dry	Standard	9*	
8B	P	2	Dry	Standard	9*	
9A	F	2	Silver Plate	Oversize	7*	
9B	F	2	Silver Plate	Oversize	8*	
10A	P	2	Silver Plate	Oversize	8*	
10B	P	2	Silver Plate	Oversize	8*	
11A	F	2	Dry	Oversize	7*	
11B	F	2	Dry	Oversize	8*	
12A	P	2	Dry	Oversize	9*	
12B	P	2	Dry	Oversize	10*	
*Screw Broke **Threads Stripped on Screw ***Inch-Ounce = 7.061 mN-m						

Table A-3. Screw Torque Test Results for 1.0 UNM Screws in Combination With 302 Stainless Steel Plate Material 0.082 and 0.032 Inch (2.08 and 0.81 mm) Thick

Test Number	Pan (P) or Fillister (F) Screw Head	Two Diameter (2) or 2/3 Diameter (2/3) Length of Engagement	Silver Plate Lubrication or Dry	Standard or Oversize Tap Drill	Maximum Torque (Inch-Ounce)***
1A	F	2/3	Silver Plate	Standard	18*
1B	F	2/3	Silver Plate	Standard	7*
2A	P	2/3	Silver Plate	Standard	13**
2B	P	2/3	Silver Plate	Standard	15*
3A	F	2	Silver Plate	Standard	11*
3B	F	2	Silver Plate	Standard	12*
4A	P	2	Silver Plate	Standard	13*
4B	P	2	Silver Plate	Standard	14*
5A	F	2/3	Dry	Standard	10*
5B	F	2/3	Dry	Standard	12*
6A	P	2/3	Dry	Standard	12*
6B	P	2/3	Dry	Standard	10*
7A	F	2	Dry	Standard	11*
7B	F	2	Dry	Standard	13*
8A	P	2	Dry	Standard	12*
8B	P	2	Dry	Standard	13*
9A	F	2	Silver Plate	Oversize	13*
9B	F	2	Silver Plate	Oversize	14*
10A	P	2	Silver Plate	Oversize	14*
10B	P	2	Silver Plate	Oversize	16*
11A	F	2	Dry	Oversize	14*
11B	F	2	Dry	Oversize	12*
12A	P	2	Dry	Oversize	12*
12B	P	2	Dry	Oversize	13*
*Screw Failure **Thread Failure ***Inch-Ounce = 7.061 mN-m					

Table A-4. Screw Torque Test Results for 0.6 UNM Screws in Combination With 7075 T-6 Aluminum Plate Material 0.043, 0.041, and 0.023 Inch (1.08, 1.04, and 0.58 mm) Thick

Test Number	Pan (P) or Fillister (F) Screw Head	Two Diameter (2) or 2/3 Diameter (2/3) Length of Engagement	Silver Plate Lubrication or Dry	Standard or Oversize Tap Drill	Maximum Torque (Inch-Ounce)***
1A	F	2/3	Silver Plate	Standard	4*
1B	F	2/3	Silver Plate	Standard	3*
3A	P	2/3	Silver Plate	Standard	4*
2B	P	2/3	Silver Plate	Standard	5*
3A	F	2	Silver Plate	Standard	4*
3B	F	2	Silver Plate	Standard	3**
4A	P	2	Silver Plate	Standard	5*
4B	P	2	Silver Plate	Standard	7*
5A	F	2/3	Dry	Standard	5*
5B	F	2/3	Dry	Standard	4*
6A	P	2/3	Dry	Standard	4*
6B	P	2/3	Dry	Standard	5*
7A	F	2	Dry	Standard	4*
7B	F	2	Dry	Standard	4*
8A	P	2	Dry	Standard	5*
8B	P	2	Dry	Standard	5*
9A	F	2	Silver Plate	Oversize	4*
9B	F	2	Silver Plate	Oversize	4*
10A	P	2	Silver Plate	Oversize	5*
10B	P	2	Silver Plate	Oversize	7*
11A	F	2	Dry	Oversize	4*
11B	F	2	Dry	Oversize	4*
12A	P	2	Dry	Oversize	4*
12B	P	2	Dry	Oversize	5*
*Screw Broke **Threads Stripped ***Inch-Ounce = 7.061 mN-m					

Table A-5. Screw Torque Test Results for 0.8 UNM Screws in Combination With 7075 T-6 Aluminum Plate Material 0.064, 0.063, and 0.022 Inch (1.62, 1.61, and 0.55 mm) Thick

Test Number	Pan (P) or Fillister (F) Screw Head	Two Diameter (2) or 2/3 Diameter (2/3) Length of Engagement	Silver Plate Lubrication or Dry	Standard or Oversize Tap Drill	Maximum Torque (Inch-Ounce)***
1A	F	2/3	Silver Plate	Standard	8*
1B	F	2/3	Silver Plate	Standard	8*
2A	P	2/3	Silver Plate	Standard	10**
2B	P	2/3	Silver Plate	Standard	12*
3A	F	2	Silver Plate	Standard	8*
3B	F	2	Silver Plate	Standard	10*
4A	P	2	Silver Plate	Standard	12*
4B	P	2	Silver Plate	Standard	13*
5A	F	2/3	Dry	Standard	9*
5B	F	2/3	Dry	Standard	8*
6A	P	2/3	Dry	Standard	10*
6B	P	2/3	Dry	Standard	11*
7A	F	2	Dry	Standard	9*
7B	F	2	Dry	Standard	9*
8A	P	2	Dry	Standard	12*
8B	P	2	Dry	Standard	12*
9A	F	2	Silver Plate	Oversize	9*
9B	F	2	Silver Plate	Oversize	9*
10A	P	2	Silver Plate	Oversize	15*
10B	P	2	Silver Plate	Oversize	15*
11A	F	2	Dry	Oversize	8*
11B	F	2	Dry	Oversize	8*
12A	P	2	Dry	Oversize	11*
12B	P	2	Dry	Oversize	11*
*Screw Broke **Thread Stripped ***Inch-Ounce = 7.061 mN-m					

Table A-6. Screw Torque Test Results for 1.0 UNM Screws in Combination With 7075 T-6 Aluminum Plate Material 0.082 and 0.032 Inch (2.08 and 0.81 mm) Thick

Test Number	Pan (P) or Fillister (F) Screw Head	Two Diameter (2) or 2/3 Diameter (2/3) Length of Engagement	Silver Plate Lubrication or Dry	Standard or Oversize Tap Drill	Maximum Torque (Inch-Ounce)***	Remarks
1A	F	2/3	Silver Plate	Standard	10*	Plate and Screw Failed
1B	F	2/3	Silver Plate	Standard	13*	
2A	P	2/3	Silver Plate	Standard	17*	
2B	P	2/3	Silver Plate	Standard	17**	
3A	F	2	Silver Plate	Standard	16*	
3B	F	2	Silver Plate	Standard	17*	
4A	P	2	Silver Plate	Standard	10*	
4B	P	2	Silver Plate	Standard	19*	
5A	F	2/3	Dry	Standard	13*	
5B	F	2/3	Dry	Standard	13*	
6A	P	2/3	Dry	Standard	12*	
6B	P	2/3	Dry	Standard	15*	
7A	F	2	Dry	Standard	13*	
7B	F	2	Dry	Standard	12*	
8A	P	2	Dry	Standard	14*	
8B	P	2	Dry	Standard	17*	
9A	F	2	Silver Plate	Oversize	15*	
9B	F	2	Silver Plate	Oversize	16*	
10A	P	2	Silver Plate	Oversize	18*	
10B	P	2	Silver Plate	Oversize	19*	
11A	F	2	Dry	Oversize	13*	
11B	F	2	Dry	Oversize	13*	
12A	P	2	Dry	Oversize	17*	
12B	P	2	Dry	Oversize	17*	
*Screw Failure **Thread Failure ***Inch-Ounce = 7.061 mN-m						

Table A-7. Screw Torque Test Results for 0.6 UNM Screws in Combination With 17-4 PH Stainless Steel (H-900 Condition) Plate Material 0.044, 0.042, and 0.019 Inch (1.11, 1.06, and 0.48 mm) Thick

Test Number	Pan (P) or Fillister (F) Screw Head	Two Diameter (2) or 2/3 Diameter (2/3) Length of Engagement	Silver Plate Lubrication or Dry	Standard or Oversize Tap Drill	Maximum Torque (Inch-Ounce)***
1A	F	2/3	Silver Plate	Standard	4*
1B	F	2/3	Silver Plate	Standard	3*
2A	P	2/3	Silver Plate	Standard	4**
2B	P	2/3	Silver Plate	Standard	4**
3A	F	2	Silver Plate	Standard	3*
3B	F	2	Silver Plate	Standard	3*
4A	P	2	Silver Plate	Standard	4*
4B	P	2	Silver Plate	Standard	4*
5A	F	2/3	Dry	Standard	3*
5B	F	2/3	Dry	Standard	3*
6A	P	2/3	Dry	Standard	4**
6B	P	2/3	Dry	Standard	4*
7A	F	2	Dry	Standard	3*
7B	F	2	Dry	Standard	3*
8A	P	2	Dry	Standard	4*
8B	P	2	Dry	Standard	4*
9A	F	2	Silver Plate	Oversize	4*
9B	F	2	Silver Plate	Oversize	4*
10A	P	2	Silver Plate	Oversize	5*
10B	P	2	Silver Plate	Oversize	5*
11A	F	2	Dry	Oversize	4*
11B	F	2	Dry	Oversize	4*
12A	P	2	Dry	Oversize	5*
12B	P	2	Dry	Oversize	5*
*Screw Broke **Threads Stripped ***Inch-Ounce = 7.061 mN-m					

Table A-8. Screw Torque Test Results for 0.8 UNM Screws in Combination With 17-4 PH Stainless Steel (H-900 Condition) Plate Material 0.062, 0.060, and 0.022 Inch (1.60, 1.52, and 0.55 mm) Thick

Test Number	Pan (P) or Fillister (F) Screw Head	Two Diameter (2) or 2/3 Diameter (2/3) Length of Engagement	Silver Plate Lubrication or Dry	Standard or Oversize Tap Drill	Maximum Torque (Inch-Ounce)***
1A	F	2/3	Silver Plate	Standard	6**
1B	F	2/3	Silver Plate	Standard	7**
2A	P	2/3	Silver Plate	Standard	8**
2B	P	2/3	Silver Plate	Standard	9**
3A	F	2	Silver Plate	Standard	6*
3B	F	2	Silver Plate	Standard	6*
4A	F	2	Silver Plate	Standard	9*
4B	P	2	Silver Plate	Standard	8*
5A	F	2/3	Dry	Standard	8*
5B	F	2/3	Dry	Standard	8*
6A	P	2/3	Dry	Standard	8*
6B	P	2/3	Dry	Standard	9*
7A	F	2	Dry	Standard	7*
7B	F	2	Dry	Standard	7*
8A	P	2	Dry	Standard	8*
8B	P	2	Dry	Standard	8*
9A	F	2	Silver Plate	Oversize	7*
9B	F	2	Silver Plate	Oversize	7*
10A	P	2	Silver Plate	Oversize	8*
10B	P	2	Silver Plate	Oversize	9*
11A	F	2	Dry	Oversize	7*
11B	F	2	Dry	Oversize	7*
12A	P	2	Dry	Oversize	9*
12B	P	2	Dry	Oversize	9*
*Screw Broke **Threads Stripped ***Inch-Ounce = 7.061 mN-m					

Table A-9. Screw Torque Test Results for 1.0 UNM Screws in Combination With 17-4 PH Stainless Steel (H-900 Condition) Plate Material 0.081, 0.079, and 0.032 Inch (2.05, 2.00, and 0.81 mm) Thick

Test Number	Pan (P) or Fillister (F) Screw Head	Two Diameter (2) or 2/3 Diameter (2/3) Length of Engagement	Silver Plate Lubrication or Dry	Standard or Oversize Tap Drill	Maximum Torque (Inch-Ounce)***
1A	F	2/3	Silver Plate	Standard	10*
1B	F	2/3	Silver Plate	Standard	10*
2A	P	2/3	Silver Plate	Standard	16**
2B	P	2/3	Silver Plate	Standard	10**
3A	F	2	Silver Plate	Standard	13*
3B	F	2	Silver Plate	Standard	12*
4A	P	2	Silver Plate	Standard	13*
4B	P	2	Silver Plate	Standard	11*
5A	F	2/3	Dry	Standard	12*
5B	F	2/3	Dry	Standard	10*
6A	P	2/3	Dry	Standard	13*
6B	P	2/3	Dry	Standard	13*
7A	F	2	Dry	Standard	10
7B	F	2	Dry	Standard	11*
8A	P	2	Dry	Standard	11*
8B	P	2	Dry	Standard	12*
9A	F	2	Silver Plate	Oversize	10*
9B	F	2	Silver Plate	Oversize	9*
10A	P	2	Silver Plate	Oversize	10*
10B	P	2	Silver Plate	Oversize	9*
11A	F	2	Dry	Oversize	10*
11B	F	2	Dry	Oversize	10*
12A	P	2	Dry	Oversize	12*
12B	P	2	Dry	Oversize	12*
*Screw Failure **Thread Failure ***Inch-Ounce = 7.061 mN-m					

Table A-10. Screw Torque Test Results for 0.6 UNM Screws in Combination With Beryllium Copper Plate Material 0.044, 0.041, and 0.023 Inch (1.11, 1.04, and 0.58 mm) Thick

Test Number	Pan (P) or Fillister (F) Screw Head	Two Diameter (2) or 2/3 Diameter (2/3) Length of Engagement	Silver Plate Lubrication or Dry	Standard or Oversize Tap Drill	Maximum Torque (Inch-Ounce)**
1A	F	2/3	Silver Plate	Standard	4*
1B	F	3/3	Silver Plate	Standard	4*
2A	P	2/3	Silver Plate	Standard	4*
2B	P	2/3	Silver Plate	Standard	4*
3A	F	2	Silver Plate	Standard	3*
3B	F	2	Silver Plate	Standard	3*
4A	P	2	Silver Plate	Standard	4*
4B	P	2	Silver Plate	Standard	4*
5A	F	2/3	Dry	Standard	4*
5B	F	2/3	Dry	Standard	4*
6A	P	2/3	Dry	Standard	4*
6B	P	2/3	Dry	Standard	5*
7A	F	2	Dry	Standard	3*
7B	F	2	Dry	Standard	3*
8A	P	2	Dry	Standard	4*
8B	P	2	Dry	Standard	4*
9A	F	2	Silver Plate	Oversize	3*
9B	F	2	Silver Plate	Oversize	3*
10A	P	2	Silver Plate	Oversize	4*
10B	P	2	Silver Plate	Oversize	4*
11A	F	3	Dry	Oversize	3*
11B	F	2	Dry	Oversize	4*
12A	P	2	Dry	Oversize	4*
12B	P	2	Dry	Oversize	3*
*Screw Failure **Inch-Ounce = 7.061 mN-m					

Table A-11. Screw Torque Test Results for 0.8 UNM Screws in Combination With Beryllium Copper Plate Material 0.063, 0.062, and 0.020 Inch (1.61, 1.60, and 0.50 mm) Thick

Test Number	Pan (P) or Fillister (F) Screw Head	Two Diameter (2) or 2/3 Diameter (2/3) Length of Engagement	Silver Plate Lubrication or Dry	Standard or Oversize Tap Drill	Maximum Torque (Inch-Ounce)**
1A	F	2/3	Silver Plate	Standard	7*
1B	F	2/3	Silver Plate	Standard	8*
2A	P	2/3	Silver Plate	Standard	9*
2B	P	2/3	Silver Plate	Standard	10*
3A	F	2	Silver Plate	Standard	8*
3B	F	2	Silver Plate	Standard	8*
4A	P	2	Silver Plate	Standard	12*
4B	P	2	Silver Plate	Standard	14*
5A	F	2/3	Dry	Standard	7*
5B	F	2/3	Dry	Standard	7*
6A	P	2/3	Dry	Standard	10*
6B	P	2/3	Dry	Standard	10*
7A	F	2	Dry	Standard	8*
7B	F	2	Dry	Standard	7*
8A	P	2	Dry	Standard	10*
8B	P	2	Dry	Standard	12*
9A	F	2	Silver Plate	Oversize	9*
9B	F	2	Silver Plate	Oversize	8*
10A	P	2	Silver Plate	Oversize	11*
10B	P	2	Silver Plate	Oversize	14*
11A	F	2	Dry	Oversize	8*
11B	F	2	Dry	Oversize	7*
12A	P	2	Dry	Oversize	10*
12B	P	2	Dry	Oversize	12*
*Screw Failure **Inch-Ounce = 7.061 mN-m					

Table A-12. Screw Torque Test Results for 1.0 UNM Screws in Combination With Beryllium Copper Plate Material 0.082 and 0.032 Inch (2.08 and 0.81 mm) Thick

Test Number	Pan (P) or Fillister (F) Screw Head	Two Diameter (2) or 2/3 Diameter (2/3) Length of Engagement	Silver Plate Lubrication or Dry	Standard or Oversize Tap Drill	Maximum Torque (Inch-Ounce)**
1A	F	2/3	Silver Plate	Standard	12*
1B	F	2/3	Silver Plate	Standard	12*
2A	P	2/3	Silver Plate	Standard	15*
2B	P	2/3	Silver Plate	Standard	14*
3A	F	2	Silver Plate	Standard	12*
3B	F	2	Silver Plate	Standard	12*
4A	P	2	Silver Plate	Standard	14*
4B	P	2	Silver Plate	Standard	14*
5A	F	2/3	Dry	Standard	15*
5B	F	2/3	Dry	Standard	12*
6A	P	2/3	Dry	Standard	13*
6B	P	2/3	Dry	Standard	15*
7A	F	2	Dry	Standard	13*
7B	F	2	Dry	Standard	13*
8A	P	2	Dry	Standard	14*
8B	P	2	Dry	Standard	17*
9A	F	2	Silver Plate	Oversize	13
9B	F	2	Silver Plate	Oversize	12*
10A	P	2	Silver Plate	Oversize	13*
10B	P	2	Silver Plate	Oversize	14*
11A	F	2	Dry	Oversize	12*
11B	F	2	Dry	Oversize	13*
12A	P	2	Dry	Oversize	13
12B	P	2	Dry	Oversize	14*
*Screw Failure **Inch-Ounce = 7.061 mN-m					

Table A-13. Screw Torque Test Results for 0.6 UNM Screws in Combination With Hyperco 50 Armature Steel Plate Material 0.043, 0.041, and 0.020 Inch (1.08, 1.04, and 0.50 mm) Thick

Test Number	Pan (P) or Fillister (F) Screw Head	Two Diameter (2) or 2/3 Diameter (2/3) Length of Engagement	Silver Plate Lubrication or Dry	Standard or Oversize Tap Drill	Maximum Torque (Inch-Ounce)**
1A	F	2/3	Silver Plate	Standard	4*
1B	F	2/3	Silver Plate	Standard	4*
2A	P	2/3	Silver Plate	Standard	5*
2B	P	2/3	Silver Plate	Standard	5*
3A	F	2	Silver Plate	Standard	4*
3B	F	2	Silver Plate	Standard	4*
4A	P	2	Silver Plate	Standard	4*
4B	P	2	Silver Plate	Standard	4*
5A	F	2/3	Dry	Standard	5*
5B	F	2/3	Dry	Standard	4*
6A	P	2/3	Dry	Standard	4*
6B	P	2/3	Dry	Standard	4*
7A	F	2	Dry	Standard	4*
7B	F	2	Dry	Standard	4*
8A	P	2	Dry	Standard	4*
8B	P	2	Dry	Standard	3*
9A	F	2	Silver Plate	Oversize	3*
9B	F	2	Silver Plate	Oversize	3*
10A	P	2	Silver Plate	Oversize	4*
10B	P	2	Silver Plate	Oversize	4*
11A	F	2	Dry	Oversize	4*
11B	F	2	Dry	Oversize	4*
12A	P	2	Dry	Oversize	4*
12B	P	2	Dry	Oversize	4*
*Screw Failure **Inch-Ounce = 7.061 mN-m					

Table A-14. Screw Torque Test Results for 0.8 UNM Screws in Combination With Hyperco 50 Armature Steel Plate Material 0.060 and 0.020 Inch (1.52 and 0.50 mm) Thick

Test Number	Pan (P) or Fillister (F) Screw Head	Two Diameter (2) or 2/3 Diameter (2/3) Length of Engagement	Silver Plate Lubrication or Dry	Standard or Oversize Tap Drill	Maximum Torque (Inch-Ounce)***
1A	F	2/3	Silver Plate	Standard	7**
1R	F	3/3	Silver Plate	Standard	7**
2A	P	2/3	Silver Plate	Standard	0*
2B	P	2/3	Silver Plate	Standard	9*
3A	F	2	Silver Plate	Standard	7*
3B	F	2	Silver Plate	Standard	8*
4A	P	2	Silver Plate	Standard	9*
4B	P	2	Silver Plate	Standard	8*
5A	F	2/3	Dry	Standard	8*
5B	F	2/3	Dry	Standard	8*
6A	P	2/3	Dry	Standard	10*
6B	P	2/3	Dry	Standard	9*
7A	F	2	Dry	Standard	8*
7B	F	2	Dry	Standard	6*
8A	P	2	Dry	Standard	8*
8B	P	2	Dry	Standard	8*
9A	F	2	Silver Plate	Oversize	7*
9B	F	2	Silver Plate	Oversize	7*
10A	P	2	Silver Plate	Oversize	8*
10B	P	2	Silver Plate	Oversize	9*
11A	F	2	Dry	Oversize	6*
11B	F	2	Dry	Oversize	6*
12A	P	2	Dry	Oversize	8*
12R	P	2	Dry	Oversize	9*
*Screw Failure **Thread Failure ***Inch-Ounce = 7.061 mN-m					

Table A-15. Screw Torque Test Results for 1.0 UNM Screws in Combination With Hyperco 50 Armature Steel Plate Material 0.081 and 0.031 Inch (2.05 and 0.78 mm) Thick

Test Number	Pan (P) or Fillister (F) Screw Head	Two Diameter (2) or 2/3 Diameter (2/3) Length of Engagement	Silver Plate Lubrication or Dry	Standard or Oversize Tap Drill	Maximum Torque (Inch-Ounce)***
1A	F	2/3	Silver Plate	Standard	13*
1B	F	2/3	Silver Plate	Standard	13*
2A	P	2/3	Silver Plate	Standard	13**
2B	P	2/3	Silver Plate	Standard	14**
3A	F	2	Silver Plate	Standard	12*
3B	F	2	Silver Plate	Standard	11*
4A	P	2	Silver Plate	Standard	13*
4B	P	2	Silver Plate	Standard	13*
5A	F	2/3	Dry	Standard	12*
5B	F	2/3	Dry	Standard	10*
6A	P	2/3	Dry	Standard	14*
6B	P	2/3	Dry	Standard	14*
7A	F	2	Dry	Standard	11*
7B	F	2	Dry	Standard	12*
8A	P	2	Dry	Standard	14*
8B	P	2	Dry	Standard	14*
9A	F	2	Silver Plate	Oversize	11*
9B	F	2	Silver Plate	Oversize	11*
10A	P	2	Silver Plate	Oversize	13*
10B	P	2	Silver Plate	Oversize	12*
11A	F	2	Dry	Oversize	12*
11B	F	2	Dry	Oversize	11*
12A	P	2	Dry	Oversize	13*
12B	P	2	Dry	Oversize	12*
*Screw Failure **Thread Failure ***Inch-Ounce = 7.061 mN-m					

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Appendix B

**STATISTICAL QUALITY CONTROL
DEPARTMENT ANALYSIS OF VARIANCE**

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Internal
Memorandum

Kansas City
Division

Date September 21, 1972 Letter No.

Kansas City, Missouri

To C. W. Elder, D/822

From B. J. Neal, D/416

Subject SCREW TORQUES FOR 0.60, 0.80 and 1.0 UNM THREADS

A study was initiated to develop suitable torque values for application to 0.6, 0.8, and 1.0 UNM screws used in miniature electromechanical mechanisms. As a part of this investigation, an experiment was run to provide test data for the following:

- 1) Determine the effects of lubrication, material, length of thread engagement, screw size, and screw head style on torque values;
- 2) Check the agreement of observed torque values and torque values predicted by the mathematical model defining the relationship between applied torque and internal stress in screws; and
- 3) Provide the maximum, minimum, and average "torque-to-failure" value for a given screw size, material and type of tap drill.

The five factors and their respective levels used in the experiment are listed below.

A. Factor A--Type of Material of Internal Thread

- 1) 303Se Stainless condition A
- 2) 7075-T6510 Aluminum
- 3) 17-4 PH condition H-900 stainless steel
- 4) Beryllium copper
- 5) Hipercro 50

B. Factor B--Screw Size

- 1) 0.6 UNM
- 2) 0.8 UNM
- 3) 1.0 UNM

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C. Factor C--Lubrication (Screw)

- 1) Dry
- 2) Silver plated

D. Factor D--Length of Thread Engagement

- 1) 2 x diameter
- 2) $2/3$ x diameter

E. Factor E--Screw Head Style

- 1) pan head
- 2) fillister

For each combination of factors two torque readings were recorded.

Conclusions:

- 1) Screw size was the only factor to have a significant effect on the torque value.
- 2) The screw size x head configuration interaction may be significant, but a test statistic was not available from this data. If this interaction is of interest, it should be studied again in a smaller experiment which provides an exact test statistic.
- 3) The mathematical model showed significant lack of fit indicating the model is not suitable for prediction.

A five-factor analysis of variance was run on the test data (Table R-1). The equation given below was evaluated for each combination used in the experiment. A test statistic was calculated to determine if the torque values predicted by the model were significantly different from the observed values. This was the prediction equation:

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$$T = \left(\frac{\delta_{\max} d_{mi}^2}{2} \left[1 + \left\{ 1 + \left(\frac{8 (p/w) (d_p/2)}{d_{mi}} \right)^2 \right\}^{1/2} \right]^{-1} \right) \times$$

$$\left(\mu_H (0.707) \left\{ \frac{D_H^2}{4} + \frac{D_{ma}^2}{4} \right\}^{1/2} + (p/w) \frac{(d_p)}{2} \right)$$

where

$\delta_{\max}$ = Maximum Principle Stress,

d_{mi} = Minor Diameter of Screw,

p/w = Input-Output Factor for Power Screw,

d_p = Pitch Diameter of Screw,

μ_H = Coefficient of Friction Between Screw Head and Plate,

D_H = Diameter of Screw Head, and

D_{ma} = Major Diameter of Internally Threaded Member.

Table B-2 shows the maximum, minimum and average readings for each combination of material, screw size and tap drill.

B. J. Neal

B. J. Neal
Statistical Quality Control

BJN:tac

B. Roberts, D/416/C. Latimer/File

Table B-1. Analysis of Variance

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-Ratio***
A	4	131.9583	32.9896	4.13
B	2	3304.6083	1652.3042	223.59*
C	1	2.2042	2.2042	0.47
D	1	1.2042	1.2042	0.12
E	1	155.2042	155.2042	8.06
AB	8	33.5167	4.1896	1.96
AC	4	6.2750	1.5688	1.03
AD	4	20.6917	5.1729	26.14
AE	4	11.8583	2.9646	1.41
BC	2	5.6583	2.8292	1.48
BD	2	7.3083	3.6542	6.18
BE	2	27.0083	13.5042	**
CD	1	3.0375	3.0375	**
CE	1	4.0042	4.0042	**
DE	1	0.1042	0.1042	**
ABC	8	22.0500	2.7563	1.34
ABD	8	11.4833	1.4354	0.70
ABE	8	11.1167	1.3896	0.95
ACD	4	3.2750	0.8188	0.40
ACE	4	4.8083	1.2021	1.37
ADE	4	6.1250	1.5313	1.74
BCD	2	2.4250	1.2125	0.59
BCE	2	0.2583	0.1292	0.55
BDE	2	0.8083	0.4042	0.18
CDE	1	0.7042	0.7042	0.40
ABCD	8	16.4500	2.0563	1.43
ABCE	8	9.1167	1.1396	1.37
ABDE	8	9.1500	1.1438	1.38
ACDE	4	2.2750	0.5688	0.68
BCDE	2	4.0583	2.0292	2.44
ABCDE	8	6.6500	0.8313	0.59
RES	120	172.5000	1.4375	

*Significant effect

**No test statistic available

***A statistical test to determine if a test parameter(s) has a significant effect on the test results

Table B-2. Maximum, Minimum, and Average Readings (Inch-Ounces)

Material and Drill Type	Screw Size (UNM)								
	0.6			0.8			1.0		
	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.
303 Se Stainless Standard	8.0	2.0	3.69	10.0	6.0	8.19	15.0	7.0	12.25
Over Sized	4.0	3.0	3.25	10.0	7.0	8.13	16.0	12.0	13.5
7075 T6510 Aluminum Standard	7.0	3.0	4.44	13.0	8.0	10.06	19.0	10.0	14.81
Over Sized	7.0	4.0	4.62	15.0	8.0	10.75	19.0	13.0	16.00
17-4 PH H-900 Stainless Standard	4.0	3.0	3.56	9.0	6.0	7.62	16.0	10.0	11.69
Over Sized	5.0	4.0	4.50	9.0	7.0	7.88	12.0	9.0	10.25
Beryllium Copper Standard	5.0	3.0	3.81	14.0	7.0	9.19	17.0	12.0	13.56
Over Sized	4.0	3.0	3.50	14.0	7.0	9.88	14.0	12.0	13.0
Hiperco 50 Standard	5.0	3.0	4.13	10.0	6.0	8.06	15.0	10.0	12.75
Over Sized	4.0	3.0	3.75	9.0	6.0	7.75	13.0	11.0	11.88
*Inch-Ounce = 7.061 mN-m									