Report No. 6-RD-65

AD 664366

ESTABLISHMENT OF STANDARDIZATION DATA
FOR MONEL AND K-MONEL FASTENERS

Conducted for:
Department of the Navy
Bureau of Ships

Contract No. NObs-90493

22 April 1965

VALUE
ENGINEERING COMPANY
2316 Jefferson Davis Highway - Alexandria, Va. - 548-8300

IN REPLY REFER TO:

August 23, 1965

Chief, Bureau of Ships
Department of the Navy
Washington, D. C. 20360

Attention: Code 634

Reference: Contract No. NObs-90493

Gentlemen:

This letter report is a supplement to Standardization Task Report, Task
No. 1 (dated 22 April 1965) and Standardization Task Report, Task No. 2
(dated 26 April 1965), both reports titled Establishment of Standardization
Data for Monel and K-Monel Fasteners.   This letter report is to confirm
discussions held with Mr. Forrest Nagley, Code 634B, on 17 August 1965.
Subjects covered in this report are:

    (1) Correlation of theoretical and observed minimum
           length of engagement for monel and K-monel studs.

    (2) Effect of thread cutting and rolling and interference
           fit engagement on the grain size and hardness of
           monel and K-monel studs.

(1) Correlation of theoretical and observed length of engagement -

      The adequacy of existing theoretical equations to predict the length
of engagement necessary to result in breakage of the stud before shearing
of the threads was studied.   Results of the calculations were compared to
the experimental values.   If the calculated values are equal to or greater
than the experimental values, the equations are valid and may be used to
predict lengths of engagement that will develop the full strength of the stud.

Equations used to calculate length of engagement were those shown in Handbook H28, Part I, pages 5 and 6.* Values for the various factors in the equations are shown in Tables I, III and IV. Values are shown for sizes 1/2, 7/8 and 1-1/8 inch class 2A studs engaged in class 3B holes. Also shown are values for 1-1/8 inch class 5 stud engaged in a class 5 hole. Shown below is a sample computation of length of engagement for a 1-1/8 inch K-monel class 2A stud engaged in a class 3B tapped hole in cast monel material.

*1960 reprint

SAMPLE COMPUTATION

Step A

Solve for AS_s/L_e and AS_n/L_e where

$$AS_s = 3.1416 n L_e K_n \max \left[(1/2n) + 0.57735(E_s \min - K_n \max) \right] \qquad (1)$$

and

$$AS_n = 3.1416 n L_e D_s \min \left[(1/2n) + 0.57735(D_s \min - E_n \max) \right] \qquad (2)$$

where AS_s = Thread shear area of the external thread, sq. in.
AS_n = Thread shear area of the internal thread, sq. in.
n = Number of threads per inch
L_e = Length of engagement, in.
$K_n \max$ = Maximum minor diameter of internal thread, in.
$E_s \min$ = Minimum pitch diameter of external thread, in.
$D_s \min$ = Minimum major diameter of external thread, in.
$E_n \max$ = Maximum pitch diameter of internal thread, in.

From Table I, $AS_s/L_e = 1.9936$
$AS_n/L_e = 2.6789$

Step B

Solve for $AS_s/AS_n = 1.9936/2.6789 = 0.7441$

Step C

Determine L_e where
$$L_e = 2A_s/3.1416 n K_n \max \left[(1/2n) + 0.57735(E_s \min - K_n \max) \right] \qquad (3)$$

where A_s = tensile stress area, sq. in., and is shown in Handbook H28, Table III.3.
$L_e = 0.7654$ (see Table I)

Step D

Solve for J

$$J = \frac{AS_s \times \text{Tensile Strength of external thread}}{AS_n \times \text{Tensile Strength of internal thread}} \qquad (4)$$

Values of $(T.S.)_{external}/(T.S.)_{internal}$ for the materials tested are shown in Table III. The tensile strengths of stud monel and K-monel stud material used are tabulated in Table II.

$$J = 0.7441 \times 1.9323 = 1.438$$

Step E

Determine Q, the minimum length of engagement.

If J is less than 1, $Q = L_e$

If J is greater than 1, $Q = J \times L_e$

Since for this sample computation J is greater than 1,

$$Q = J \times L_e = 1.438 \times 0.7654 = 1.10 \text{ inches}$$

The experimental value for the 1-1/8 K-monel stud engaged in cast monel was 1.07 inches.

$$* \qquad * \qquad *$$

The calculated engagement values for all the combinations tested are shown in Table V. The experimental values are shown in Table VI.

The minimum lengths of engagement, Q, for class 5 interference fit threads were calculated as in the Sample Calculation and are shown in Table VIII (see also Tables IA, II, III and VII for values used to calculate Q). Experimental values for 1/2 inch class 5 interference fit threads are shown in Table IX. In all cases, the experimental values were equal to or lower than the calculated values thus indicating the validity of the equations.

TABLE I - Values from Equations 1-4 for 2A/3B Fit

Size (UNC)	1/2	7/8	1-1/8
n	13	9	7
$D_s \min$ (class 2A)	0.4876	0.8592	1.1064
$E_s \min$ (class 2A)	0.4435	0.7946	1.0228
$E_n \max$ (class 3B)	0.4548	0.8089	1.0393
$K_n \max$ (class 3B)	0.4284	0.9875	0.9875
A_s	0.1419	0.462	0.763
$1/2n$	0.0384	0.0556	0.0714
$3.1416 n K_n \max$	17.496	21.717	21.716
$E_s \min - K_n \max$	0.0151	0.0265	0.0353
$0.57735 (E_s \min - K_n \max)$	0.0087	0.0153	0.0204
$12n \div 0.57735 (E_s \min - K_n \max)$	0.0471	0.0709	0.0918
$3.1416 n K_n \max \left[1/2n + 0.57735 (E_s \min - K_n \max) \right] = \dfrac{AS_s}{L_e}$	0.8241	1.540	1.9936
$3.1416 n D_s \min$	19.914	24.293	24.331
$D_s \min - E_n \max$	0.0328	0.0503	0.0671
$0.57735 (D_s \min - E_n \max)$	0.0189	0.0290	0.0387
$1/2n + 0.57735 (D_s \min - E_n \max)$	0.0573	0.0846	0.1101
$3.1416 n D_s \min \left[1/2n + 0.57735 (D_s \min - E_n \max) \right] = \dfrac{AS_n}{L_e}$	1.1411	2.0552	2.6789
$2A_s$	0.2838	0.924	1.526
$L_e = 2A_s / 3.1416 n K_n \max \left[1/2n + 0.57735 (E_s \min - K_n \max) \right]$	0.3443	0.6000	0.7054
$AS_s / AS_n = (AS_s/L_e)/(AS_n L_e)$	0.7221	0.7493	0.7441

Size	i/2	7/8	1-1/8
n	13	9	7
$D_s$min (class 5)	0.4846	0.8502	1.0952
$E_s$min (class 5)	0.4547	0.8095	1.0406
$E_n$max (class 5)	0.4537	0.8077	1.0381
$K_n$max (class 5)	0.440	0.789	1.015
A_s	0.1419	0.462	0.763
$1/2n$	0.0384	0.0556	0.0714
$3.1416nK_n$max	17.9700	22.3088	22.3211
$E_s$min-$K_n$max	0.0147	0.0205	0.0256
$0.57735(E_s$min-$K_n$max$)$	0.0085	0.0118	0.0148
$12n + 0.57735(E_s$min-$K_n$max$)$	0.0469	0.0674	0.0862
$3.1416nK_n$max$\left[1/2n + 0.57735(E_s\text{min-}K_n\text{max})\right] = \dfrac{AS_s}{L_e}$	0.8428	1.5036	1.9241
$3.1416nD_s$min	19.7915	24.0389	24.0848
$D_s$min-$E_n$max	0.0309	0.0425	0.0559
$0.57735(D_s$min-$E_n$max$)$	0.0178	0.0245	0.0323
$1/2n + 0.57735(D_s$min-$E_n$max$)$	0.0562	0.0801	0.1037
$3.1416nD_s$min$\left[1/2n + 0.57735(D_s\text{min-}E_n\text{max})\right] = \dfrac{AS_n}{L_e}$	1.1123	1.9255	2.4976
$2A_s$	0.2838	0.924	1.526
$L_e = 2A_s/3.1416nK_n$max$\left[1/2n + 0.57735(E_s\text{min-}K_n\text{max})\right]$	0.3367	0.6145	0.7930
$AS_s/AS_n = (AS_s/L_e)/(AS_nL_e)$	0.7577	0.7808	0.7703

TABLE II - Tensile Strength of Stud Material

Stud Material	STUD TENSILE STRENGTH, psi		
	1/2 inch	7/8 inch	1-1/8 inch
Monel	106,500	95,500	90,500
K-monel	178,700	163,000	156,500

TABLE III - Ratio of External to Internal Material
Tensile Strengths

Size	Stud Material	$(T.S.)_{external} / (T.S.)_{internal}$			
		INTERNAL MATERIAL (Tensile Strength, psi)			
		Monel (78,400)	HTS (72,000)	HY80 (107,000)	HY80 Cast (113,000)
1/2	Monel	-	1.4791	0.9953	-
	K-monel	2.2793	2.4819	1.6700	1.5814
7/8	Monel	-	1.3263	0.8925	-
	K-monel	2.0790	2.2638	1.5233	1.4424
1-1/8	Monel	-	1.2569	0.8457	-
	K-monel	1.9323	2.1041	1.4158	1.3407

TABLE IV - J Values (Equation 4) for 2A/3B Fit

Size	Stud Material	J			
		Monel	HTS	HY80	HY80 Cast
1/2	Monel	-	1.068	0.719	-
	K-monel	1.646	1.792	1.206	1.142
7/8	Monel	-	0.994	0.669	-
	K-monel	1.558	1.696	1.141	1.081
1-1/8	Monel	-	0.935	0.629	-
	K-monel	1.438	1.566	1.053	0.998

TABLE V - Calculated Length of Engagement for 2A/3B Fit

Size (inches)	Stud Material	Minimum Length of Engagement, Q(inches)			
		Internal Thread Material			
		Monel	HTS Plate	HY80 Plate	HY80 Cast
1/2	Monel	-	0.37	0.34	-
	K-monel	0.57	0.62	0.42	0.39
7/8	Monel	-	0.60	0.60	-
	K-monel	0.93	1.02	0.68	0.65
1-1/8	Monel	-	0.77	0.77	-
	K-monel	1.10	1.20	0.81	0.77

TABLE VI - Experimental Length of Engagement for 2A/3B Fit

Size (inches)	Stud Material	Minimum Length of Engagement (inches)			
		Internal Thread Material			
		Monel	HTS Plate	HY80 Plate	HY80 Cast
1/2	Monel	-	0.31	0.31	-
	K-monel	0.38	0.45	0.34	0.42
7/8	Monel	-	0.56	0.50	-
	K-monel	0.94	0.72	0.56	0.56
1-1/8	Monel	-	0.71	0.64	-
	K-monel	1.07	1.00	0.79	0.86

TABLE VII - J Values (Equation 4) for Class 5 Interference Fit

Size	Stud Material	J			
		Monel	HTS	HY80	HY80 Cast
1/2	Monel	-	1.121	0.754	-
	K-monel	1.727	1.881.	1.265	1.198
7/8	Monel	-	1.036	0.697	-
	K-monel	1.623	1.768	1.189	1.126
1-1/8	Monel	-	0.968	0.651	-
	K-monel	1.488	1.621	1.091	1.033

TABLE VIII - Calculated Length of Engagement for Class 5
Interference Fit

Size (inches)	Stud Material	Minimum Length of Engagement, Q (inches)			
		Internal Thread Material			
		Monel	HTS Plate	HY80 Plate	HY80 Cast
1/2	Monel	-	0.38	0.34	-
	K-monel	0.58	0.63	0.43	0.40
7/8	Monel	-	0.64	0.61	-
	K-monel	1.00	1.09	0.73	0.69
1-1/8	Monel	-	0.79	0.79	-
	K-monel	1.17	1.29	0.87	0.82

TABLE IX - Experimental Length of Engagement for Class 5
Interference Fit

Size (inches)	Stud Material	Minimum Length of Engagement, (inches)			
		Internal Thread Material			
		Monel	HTS Plate	HY80 Plate	HY80 Cast
1/2	Monel	-	0.31	0.31	-
	K-monel	0.58	0.50	0.35	0.35

TABLE X - Comparison of Calculated and Experimental
Length of Engagement for 2A/3B Fit

Size (inch)	Stud Material	Internal Thread Material	Minimum Length of Engagement (inches)	
			Calculated	Experimental
1/2	Monel	HTS plate	0.37	0.31
1/2	Monel	HY80 plate	0.34	0.31
1/2	K-monel	Monel cast	0.57	0.38
1/2	K-monel	HTS plate	0.62	0.45
1/2	K-monel	HY80 plate	0.42	0.34
1/2	K-monel	HY80 cast	0.39	0.42
7/8	Monel	HTS plate	0.60	0.56
7/8	Monel	HY80 plate	0.60	0.50
7/8	K-monel	Monel cast	0.93	0.94
7/8	K-monel	HTS plate	1.02	0.72
7/8	K-monel	HY80 plate	0.68	0.56
7/8	K-monel	HY80 cast	0.65	0.56
1-1/8	Monel	HTS plate	0.77	0.71
1-1/8	Monel	HY80 plate	0.77	0.64
1-1/8	K-monel	Monel cast	1.11	1.07
1-1/8	K-monel	HTS plate	1.20	1.00
1-1/8	K-monel	HY80 plate	0.81	0.79
1-1/8	K-monel	HY80 cast	0.77	0.86

TABLE XI - Comparison of Calculated and Experimental
Length of Engagement for Class 5 Interference Fit

Size (inch)	Stud Material	Internal Thread Material	Minimum Length of Engagement (inches)	
			Calculated	Experimental
1/2	Monel	HTS plate	0.38	0.31
1/2	Monel	HY80 plate	0.34	0.31
1/2	K-monel	Monel cast	0.58	0.58
1/2	K-monel	HTS plate	0.63	0.50
1/2	K-monel	HY80 plate	0.43	0.35
1/2	K-monel	HY80 cast	0.40	0.35

Conclusion

A comparison of calculated and experimental lengths of engagement for the 2A/3B fit and the class 5 interference fit is presented in Tables X and XI respectively.

The factor 2 in the numerator of Equation 3 means that it is assumed that the area in shear must be twice the tensile stress area to develop the full strength of the stud. For steel and brass, this factor varies from 1.7 to 2.0. Taking the factor as 2 provides a small safety factor against thread stripping. The ratio of tensile strength to shear strength for age hardened K-monel, for instance, could be as low as 1.7 (see INCO Technical Bulletin T-9, 1963, Table 7). This would explain why several of the calculated lengths of engagement were greater than the experimental value since the factor 2 used is, in some cases, greater than the actual tensile to shear strength ratio.

Based on a comparison of calculated and experimental values of length of engagement and in order to assure stud breaking before thread stripping for any stud tapped hole material combination, it os recommended that the following be used when employing the formulas in Handbook H28.

a. The maximum expected tensile strength of the stud material. For the studs used in the testing program the tensile strengths to be used are 180,000 psi for K-monel studs and 110,000 for the monel studs.

b. The minimum specified tensile strength of the tapped hole material. The minimum specified tensile strength for cast monel is 65,000 psi. There is no specified minimum tensile strength for HY80 plate and casting and Grade H1 steel plate. It is recommended that a value of 105,000 psi be used for the HY80 steel plate and casting and 70,000 psi be used for the Grade HT steel; unless lower values have been observed and reported to the Bureau of Ships.

c. Results of tests conducted in Task No. 3 indicated a tolerance range for the diameter corresponding to the equivalent stress area, D_{esa}. The maximum value, $D_{esa}max$, was found to equal $E_s min-0.010$ inch where $E_s min$ equals the minimum pitch diameter of the UNC class 2A thread.

Stress area computed on this basis are, in some cases, greater than shown in Handbook H28 Table III.3, for the UNC thread series. Therfore, $D_{esa}max$ values should be used in determining A_s when computations are aimed at reliable minimum thread engagement with extreme tensile strength values for stud and body materials.

(2) Effect of thread cutting and rolling and interference fit engagement on Monel and K-monel studs. -

An attempt was made to determine the effect of thread cutting and rolling and interference fit engagement on the grain size and hardness of monel and K-monel studs.

Figures 1 through 8 are photomicrographs of the cross-sections of monel and K-monel studs with cut and rolled thread, before and after engagement.

Thread cutting had no effect on the structure of the monel and K-monel studs (see Figures 1 and 5). There was no difference in hardness between the center and thread area of the monel and K-monel studs (see Table XII and Figure 9).

Thread rolling resulted in a reduction of the size of the grains in the thread area (see Figures 3, and 7 and 8). There was a definite increase in hardness in the thread area of the rolled monel stud (298 DPN in the thread area as compared to 206-221 DPN in the center of the sample). The rolled K-monel stud showed no difference in hardness between the center of the sample and thread area. This is most likely due to the fact that the working caused by the thread rolling was not sufficient to increase the hardness.

The studs shown in Figures 1 through 8 have class 4 interference fit threads. Several studs were engaged in tapped holes having class 5 threads to determine the effect of interference fit engagement. These studs (Figures 2, 4 and 6) exhibited distortion of the thread area and deformation of the grains. There was also a definite increase in hardness in the thread area of these studs (see Table XII).
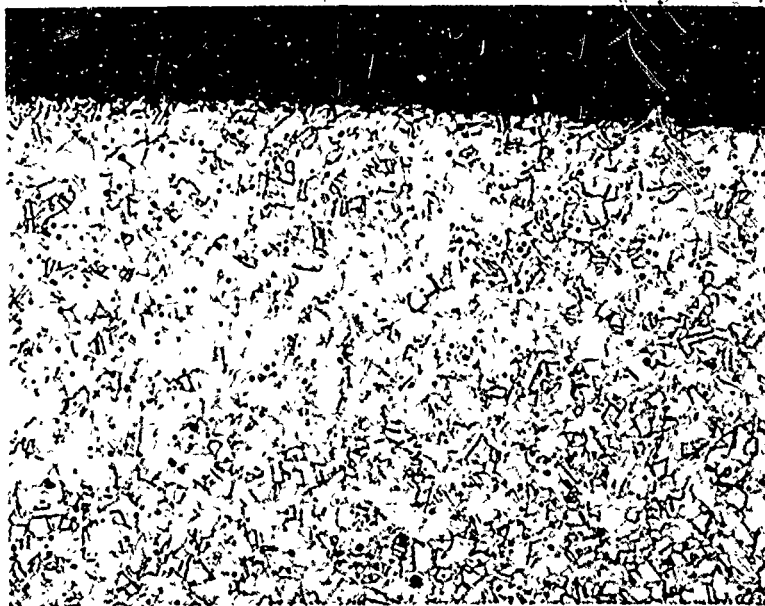

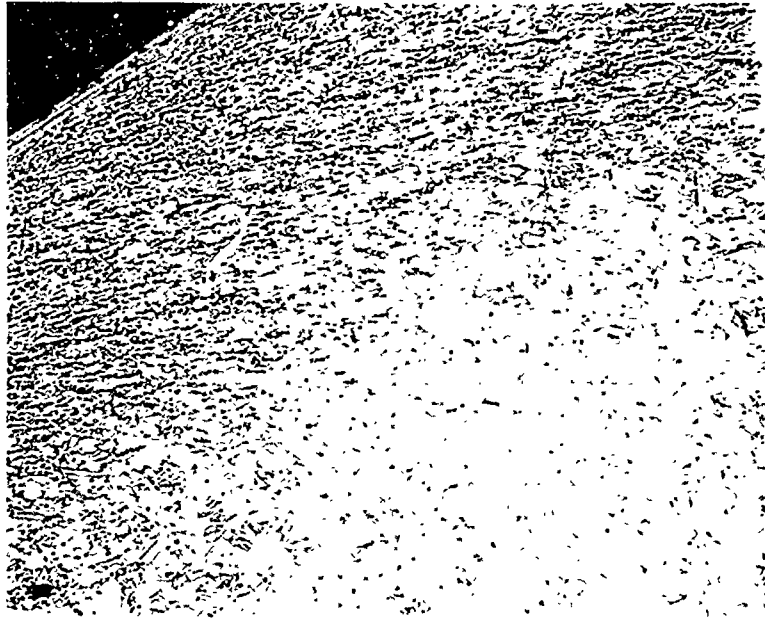Figure 1 - Monel Stud with Cut Threads Before Engagement

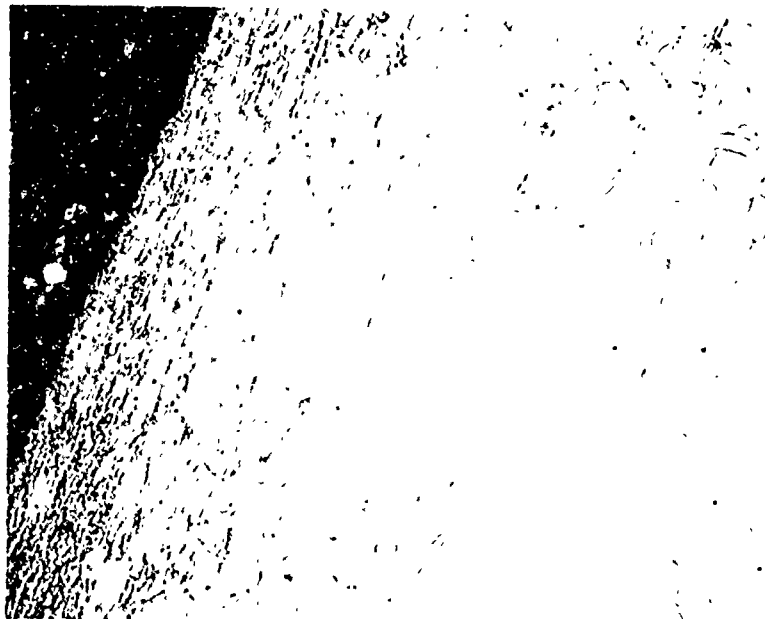Figure 2 - Monel Stud with Cut Threads After Engagement

Figure 3 - Monel Stud with Rolled Threads Before Engagement

Figure 4 - Monel Stud with Rolled Threads After Engagement

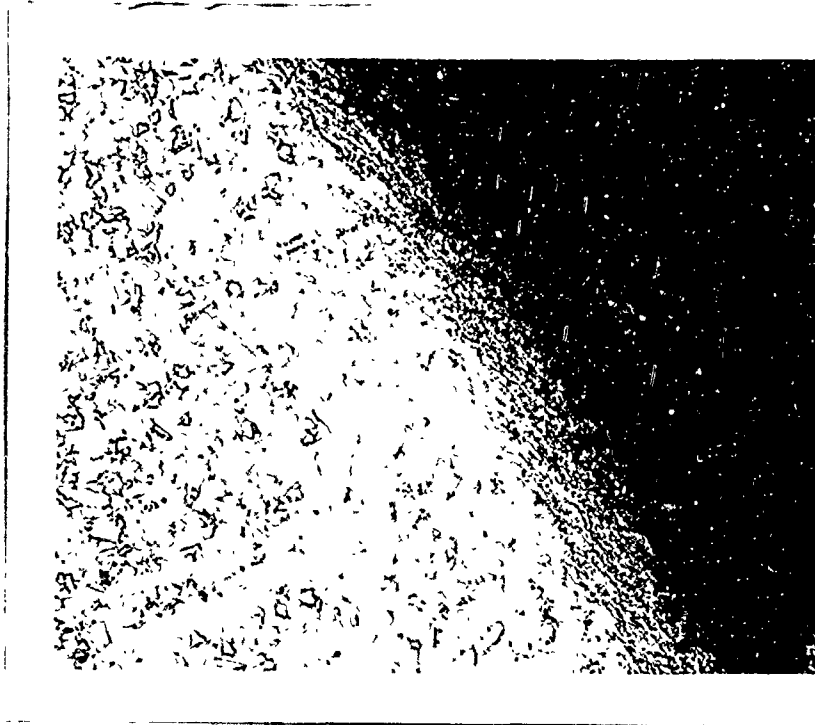Figure 5 - K-Monel Stud with Cut Threads Before Engagement

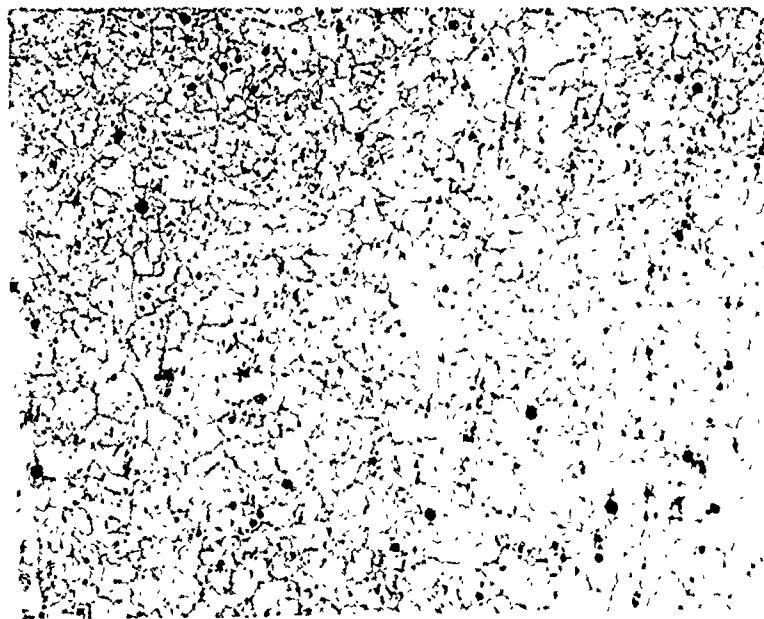Figure 6 - K-Monel Studs with Cut Threads After Engagement

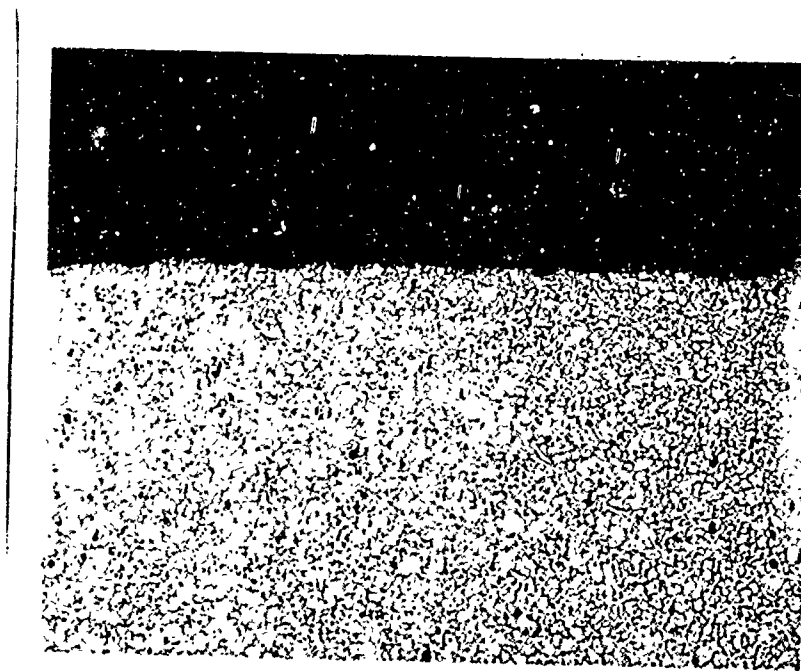Figure 7 - K-Monel Studs with Rolled Threads Before Engagement
(center)

Figure 8 - K-Monel Studs with Rolled Threads Before Engagement
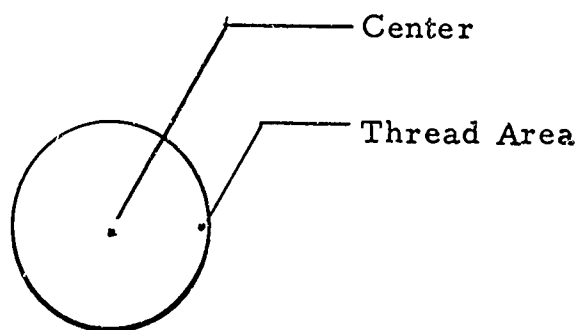(thread area)

Center

Thread Area

Figure 9 - Sketch of Cross-Section of a stud showing
locations of Microhardness Readings

TABLE XII - Microhardness Readings

Figure No.	Stud Material (thread)	Condition	Hardness (center)		Hardness (thread)	
			DPN	Rockwell	DPN	Rockwell
1	Monel (cut)	Before engagement	208-220	93-96 B	205-222	93-96 B
2	Monel (cut)	After engagement	131	73 B	245	99.5 B
3	Monel (rolled)	Before engagement	206-221	93-96 B	298	29 C
4	Monel (rolled)	After engagement	208-235	93-98 B	322-335	33-34 C
5	K-monel (cut)	Before engagement	322	33 C	322	33 C
6	K-monel (cut)	After engagement	383	39 C	421	43 C
7 & 8	K-monel (rolled)	Before engagement	280-322	27-33 C	296-322	29-33 C

Very truly yours,

VALUE ENGINEERING COMPANY

Elliot Goodman

Elliot Goodman
Project Engineer

EG:bl

STANDARDIZATION TASK REPORT
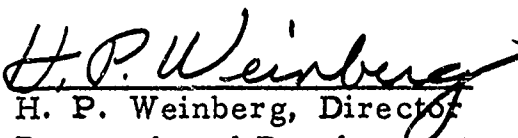TASK NO. 1

ESTABLISHMENT OF STANDARDIZATION DATA
FOR MONEL AND K-MONEL FASTENERS

Conducted for:
Department of the Navy
Bureau of Ships

Contract No. NObs-90493

22 April 1965

Conducted by: E. Goodman
T.. Hogland
J. Miller

Approved by: *H. P. Weinberg*
H. P. Weinberg, Director
Research and Development

VALUE ENGINEERING COMPANY
2316 Jefferson Davis Highway
Alexandria, Virginia

I PURPOSE

Purpose: \The purpose of the testing performed in this task is to determine
the minimum length of engagement of studs necessary so that there will be no
plastic deformation, in shear, of the internal threads when the stud is loaded to
its breaking point. Data must be applicable to the following material combinations.

a. K-Monel studs in Monel castings

b. K-Monel studs in high tensile steel (HTS) plate

c. K-Monel studs in HY80 steel plate

d. K-Monel studs in HY80 steel casting

e. Monel studs in high tensile steel (HTS) plate

f. Monel studs in HY80 steel plate

When failure of a thread assembly occurs it is desirable that breaking of
the stud occurs rather than the stripping of the external or internal threads. In
other words, the length of thread engagement should be sufficient to develop the
full strength of the stud.\

II MATERIALS TESTED

A. Requirements:-

1. K-Monel Studs - K-monel studs used in the performance of this
task must conform to Military Standard MS18116 and the applicable requirements
of specifications QQ-N-286 and MIL-B-857.

2. Monel Studs - Monel studs used in the performance of this task
must conform to the applicable requirements of QQ-N-281 and MIL-B-857,
except that the studs must have the following mechanical properties:

Tensile strength - 80,000 psi, minimum

Yield strength - 40,000 psi, minimum (0.2 percent offset)

Elongation in 2 inches - 20 percent, minimum

3. Plate Materials - Plate materials must conform to the following specifications.

Material	Specification
High Tensile Steel Plate (HTS)	MIL-S-16113 Grade HT
HY80 Steel Plate	MIL-S-16216
Cast HY80 Steel	MIL-S-23008
Cast Monel	QQ-N-288

4. Porosity - All cast materials must be subjected to radiographic examination to ascertain freedom from porosity.

B. Actual Chemical and Mechanical Properties:-

Tables I and II are a compilation of the required and actual chemical composition and mechanical properties, respectively, of the studs and materials used for tests performed in this task.

All cast materials were subjected to radiographic examination. The cast HY80 was found to be free from porosity. Several plates of cast monel had an area of porosity which was marked so that no holes were drilled and tapped in these areas.

Table I Chemical Composition

Material	Item	C	Si	Mn	Cr	Ni	Cu	Fe	Cb	Mo	S	Al	Ti	V	P
Monel Studs	Required	0.3 max	.5 max	2.0 max	-	63-67	Bal.	2.5 max	-	-	.024 max	.5 max	-	-	-
	1/2 in.	.14	.10	.93	-	64.21	33.03	1.56	-	-	.010	-	-	-	-
	7/8 in.	.15	.19	.90	-	64.80	33.14	.79	-	-	.005	-	-	-	-
	1-1/8 in.	.15	.10	1.13	-	64.12	33.84	.63	-	-	.005	-	-	-	-
K-Monel Studs	Required	.25 max	1.0 max	1.5 max	-	63-70	Bal.	2.0 max	-	-	.010 max	2.0-4.0	.25-1.00	-	-
	1/2 in.	.16	.10	.55	-	64.80	30.46	.60	-	-	.005	2.79	.51	-	-
	7/8 in.	.16	.10	.55	-	64.80	30.46	.60	-	-	.005	2.79	.51	-	-
	1-1/8 in.	.23	.11	.53	-	65.75	29.66	.56	-	-	.005	2.70	.43	-	-
Monel Casting	Required	.35 max	2.0 max	1.5 max	-	62-68	26-33	2.5 max	-	-	-	-	-	-	-
	Actual	.24	1.97	.96	-	63.2	31.01	1.22	1.40	-	-	-	-	-	-
HY80 Steel Casting	Required	.2 max	.50 max	.55-.75	1.35-1.65	2.50-3.25	.2 max	-	-	.30-.60	.015 max	-	.02 max	.03 max	.020 max
	Actual	.18	.28	.62	1.60	3.10	.15	-	-	.49	.006	-	.004	.01	.005

Table II Mechanical Properties

Material	Item	Tensile Strength (psi)	Yield Strength (psi)	Elongation in 2" (%)
Monel Studs	Required	80,000 min.	40,000 min.	20.0 min.
	1/2" Studs	106,500	102,000	23.0
	7/8" Studs	95,500	83,000	30.0
	1-1/8" Studs	90,500	77,000	31.0
K-Monel Studs	Required	130,000 min.	90,000 min.	20.0 min.
	1/2 Studs	178,700	148,200	20.3
	7/8 Studs	163,000	119,100	23.4
	1-1/8 Studs	151,500	107,200	24.2
Monel Casting	Required	65,000 min.	32,500 min.	25 min.
	Actual	78,400	39,900	45.0
HY80 Steel Casting	Required	For information only	80,000-95,000	20.0 min.
	Actual	113,000	92,000	22.5

III THREAD GAGING

The thread major diameter, minor diameter, pitch diameter, included angle and thread lead of each stud and bolt used in this program were measured at three points along the thread. An average of the three results for each dimension was used. The major diameter was measured on a Pratt & Whitney Super Micrometer. Tri-roll gages were used to measure the pitch diameter to an accuracy of 0.0001 inch. The included angle, minor diameter and lead were measured on a J & L Comparator to an accuracy of 0.0001 inch.

The pitch diameter and minor diameter of the internal holes were measured with a Bryant P-21 Thread Gage.

All monel and K-monel studs had UNC class 2A cut threads and all tapped holes had UNC class 3B cut threads in accordance with Handbook H28, Screw-

Thread Standards for Federal Services.

IV TEST PROCEDURE

A. Measurement of Length of Engagement:-

Thread lead is the distance a threaded part moves axially, with respect to a fixed mating part, in one complete rotation. This presents a relatively easy method of determining length of engagement. The lead of each stud used in this program was measured. The length of engagement was determined, therefore, by turning the stud to a point where actual engagement began and then counting the number of turns of the stud.

B. Procedure:-

Studs were engaged at different lengths of engagement in tapped holes of the four plate and cast materials and the studs loaded axially to their breaking point or until stripping of the external or internal threads occurred. A sketch of the test set-up is shown in Figure 1. A photograph of the set-up is shown in Figure 2. Rate of loading was 0.060 in./min.

V RESULTS

Results of the pull tests for various lengths of engagement and for different combinations of stud and plate materials are shown in Table III. A summary of the minimum length of engagement data is shown in Table IV. The minimum length of engagement was taken as that engagement below which thread stripping occurred when the stud was loaded axially.
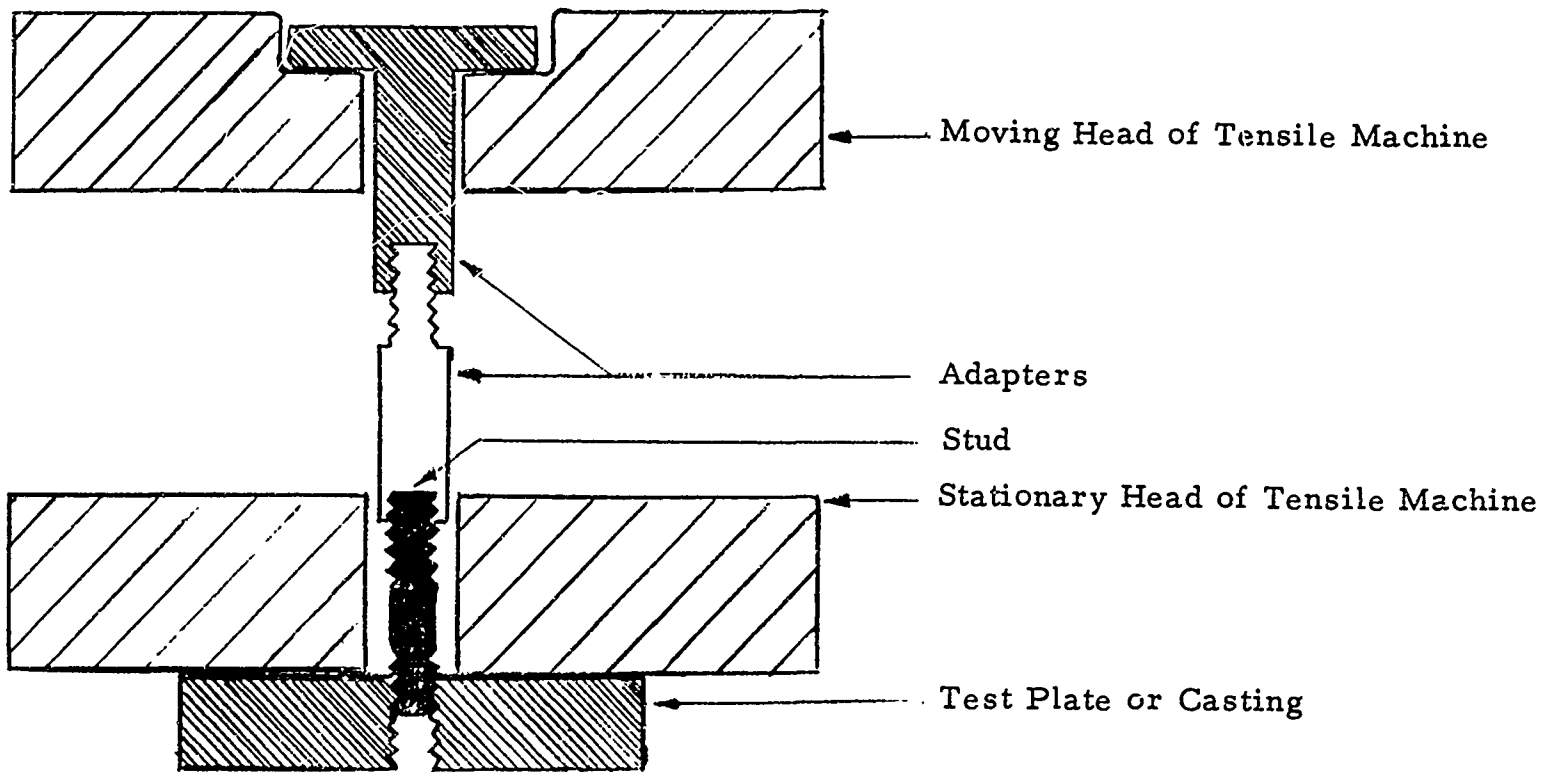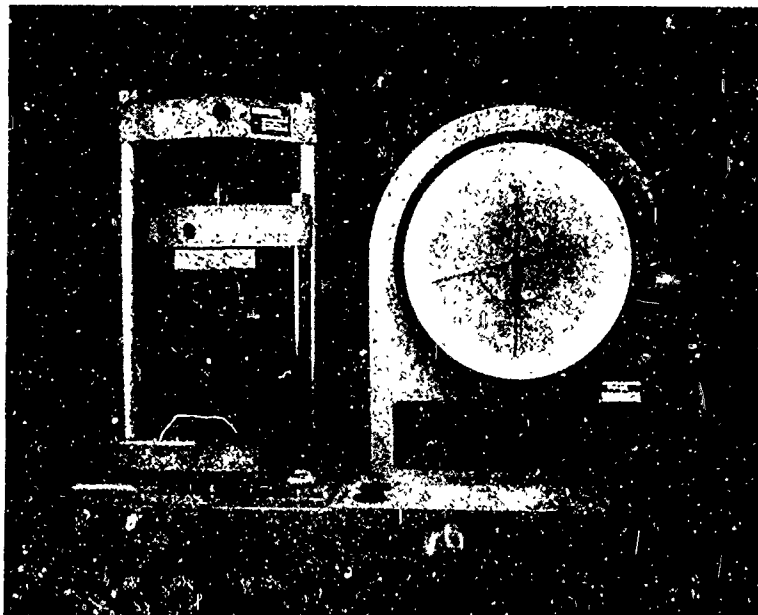
Figure 1 - Sketch of Test Set-Up

Moving Head of Tensile Machine

Adapters

Stud

Stationary Head of Tensile Machine

Test Plate or Casting

Figure 2 - Determination of Minimum Length of
Engagement

Table III Length of Engagement

Stud Material	Plate Material	Size (inch)	Length of Engagement (inches)	Ultimate Load (lbs)	Type of Failure
Monel	HY80	1/2	0.27	14,500	SB
			0.31	15,750	SB*
			0.27	14,650	TS
	HTS	1/2	0.31	16,475	SB*
			0.23	11,275	TS
			0.27	14,925	TS
K-Monel	HY80	1/2	0.34	25,400	SB
			0.34	25,525	SB
	HY80(cast)	1/2	0.34	18,900	TS
			0.46	25,400	SB
			0.42	25,375	SB*
	Monel	1/2	0.46	25,350	SB
			0.38	25,700	SB*
			0.34	24,000	TS
			0.38	26,050	SB*
	HTS	1/2	0.34	21,500	TS
			0.38	23,000	TS
			0.45	27,500	SB*
Monel	HTS	7/8	0.50	43,600	TS
			0.56	48,850	SB*
	HY80		0.44	43,950	TS
			0.50	44,650	SB*
K-Monel	HY80	7/8	0.56	73,000	SB*
			0.44	62,200	TS
			0.50	62,200	TS
	HY80(cast)	7/8	0.78	71,500	SB
			0.67	71,400	SB
			0.56	70,600	SB*
			0.44	69,100	TS
	Monel	7/8	0.56	50,000	TS
			0.67	57,400	TS
			0.78	66,500	TS
			0.89	69,800	TS
			1.00	70,600	SB
			0.94	70,600	SB*
			0.89	69,800	SB

Table III(cont'd)

Stud Material	Plate Material	Size (inch)	Length of Engagement (inches)	Ultimate Load (lbs)	Type of Failure
	HTS	7/8	0.56	58,100	TS
			0.78	71,400	SB
			0.67	68,900	TS
			0.72	70,100	SB*
Monel	HTS	1-1/8	0.71	70,200	SB*
			0.43	47,400	TS
			0.57	63,200	TS
			0.64	70,500	TS
	HY80	1-1/8	0.71	70,800	SB
			0.57	72,000	TS
			0.64	69,800	SB*
K-Monel	HY80	1-1/8	0.71	105,200	TS
			0.86	113,000	SB
			0.79	112,000	SB*
	HY80(cast)	1-1/8	0.71	106,200	TS
			0.86	112,000	SB*
			0.79	107,300	TS
	Monel	1-1/8	0.71	87,000	TS
			1.00	110,000	TS
			1.14	112,300	SB
			1.07	112,300	SB*
	HTS	1-1/8	0.71	92,700	TS
			1.00	112,300	SB*
			0.86	105,200	TS
			0.92	109,900	TS

SB - Stud Broke
TS - Thread Stripping occurred
* - Minimum Length of Engagement

Table IV Minimum Length of Engagement

| Stud Material | Size (inches) | Minimum Length of Engagement (inches) | | | |
| | | Internal Thread Material | | | |
		Monel Casting	High Tensile Steel Plate	HY80 Steel Plate	HY80 Steel Casting
Monel	1/2	-	0.31	0.31	-
K-Monel	1/2	0.38	0.45	0.34	0.42
Monel	7/8	-	0.56	0.50	-
K-Monel	7/8	0.94	0.72	0.56	0.56
Monel	1-1/8	-	0.71	0.64	-
K-Monel	1-1/8	1.07	1.00	0.79	0.86

In practically all cases where there was stripping of the stud threads, the diameter measured across the stripped threads fell between the minor and pitch diameters which corresponds to the equivalent diameter result of Task 3. It must be pointed out, however, that the diameter of the stripped stud is also dependent on the depth of thread engagement and not solely on the material into which the stud is engaged. In general, however, it was found that the harder the mating material the smaller the stripped diameter of the stud. One difficulty encountered in measuring the stripped diameter of the studs was that instead of being completely stripped, in many cases the threads folded over as the stud was being pulled out of the hole.