ESTABLISHMENT OF STANDARDIZATION DATA FOR MONEL AND K-MONEL FASTENERS

Conducted for:
Department of the Navy
Bureau of Ships

Contract No. NObs-90493

6 April 1965

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

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Task II

Purpose: The purpose of testing performed in this task is (1) to determine thread distortion caused by various amounts of thread interference, (2) to evaluate changes in material as a result of thread interference, length of engagement, and axial stud loading to its breaking point, and (3) to produce comparative data on break-away torque and prevailing back-out torque of the stud, and corresponding torques for backing off self locking nuts.

The following thread forms and fits are to be investigated.

	Stud Thread Class	Engaged in Tapped Hole Thread Class
1.	5 cut	5
2.	5 rolled	5
3.	3A cut	3B
4.	3A rolled	3B
5.	2A cut	3B
6.	2A rolled	3B
7.	5 cut	3B
8.	5 rolled	3B
9.	5 cut 1/	3B

1/ Using sealant in accordance with MIL-S-22473.

Each of these nine fits must be tested using K-monel studs engaged in Monel casting, HTS plate, HY80 plate, and HY80 casting and Monel studs engaged in HTS and HY80 plates.

Thread Dimensions

Handbook H28 (1957); Part III (pages 48-52), provides dimensions for external and internal interference fit (class 5) threads. These dimensions and pitch diameter limits were based on the externally threaded members being steel ASTM A-325 (SAE grade 5) or better. In the absence of any other dimensional data, these dimensions in Handbook H28 were used when class 5 threads were required for the monel and K-monel studs used in this program. NC5 HF threads were used for monel and K-monel studs engaged in tapped holes in HTS, HY80 plate and HY80 casting. NC5 ONF threads were used for K-monel studs engaged in tapped holes in monel castings. NC5 IF threads were used for tapped holes in HTS, HY80 plate and HY80 casting and NC5 INF threads were used for tapped holes in monel castings.

Testing: Studs were engaged to the minimum length of engagement as determined in Task I. With the stud engaged, a self-locking nut, in accordance with MS17828, was installed until a length of two thread pitches extended beyond the locking device of the nut. The break-away and back-out torques for removing the nut were determined without any axial load on the nut. Self-locking nuts from both Elastic Stop Nut Corporation (ESNA) and Greer Stop Nut Company were used in order to compare torque data for nuts supplied by different sources. The average torques for 1/2 and 7/8 inch nuts are shown in Table I. Torque values for the 1/2 inch nuts are an average of the values presented in Table II of Monthly Status Report No. 8, dated 8 March 1965, and additional tests run to get a more representative average torque value. The nut end of the studs had UNC 2A threads.

Table I. Break-away and Back-out Torques for Self-Locking Nuts

Size (inch)	Torque	ESNA	GREER
1/2	Break-away	118 in.-lb.	98 in.-lb.
	Back-out	76 in.-lb.	67 in.-lb.
7/8	Break-away	27 ft.-lb.	31 ft.-lb.
	Back-out	19 ft.-lb.	21 ft.-lb.

The break-away and back-out torques for removing the studs were, subsequently, determined. Results for 1/2 and 7/8 inch studs are shown in Table II. The test set-up for determining these torques is shown in Figure 2 of the SUPPLEMENT to Monthly Status Report No. 8 dated 29 March 1965.

Table II. Break-away and Back-out Torques of Studs

Size: 1/2 inch Plate Material: HY80

Stud Material	Cut or Rolled	Class 3B 1/	Interference	Class 5 1/	Interference
K-monel	Cut	60-40 2/ ft-lb	0.0060 inch	38-20 ft-lb	0.0051
	Cut	70-40 in-lb	.0011	30-25 ft-lb	.0036
	Rolled	120-90 ft-lb	.0047	38-25 ft-lb	.0054
	Rolled	45-32 ft-lb	.0016	30-23 ft-lb	.0022
Monel	Cut	60-45 ft-lb	.0070	30-20 ft-lb	.0071
	Cut	170-110 in-lb	.0017	29-19 ft-lb	.0038
	Rolled	60-45 ft-lb	.0054	45-30 ft-lb	.0053
	Rolled	45-30 ft-lb	.0008	20-12 ft-lb	.0024

Size: 1/2 inch Plate Material: HTS

Stud Material	Cut or Rolled	Class 3B 1/	Interference	Class 5 1/	Interference
K-monel	Cut	170-120 in-lb	0.0038	30-20 ft-lb	0.0049
	Cut	200-70 in-lb	.0028	30-20 ft-lb	.0043
	Rolled	30-20 ft-lb	.0019	55-40 ft-lb	.0049
	Rolled	25-15 ft-lb	.0001	35-20 ft-lb	.0044
Monel	Cut	60-35 in-lb	.0026	20-12 ft-lb	.0072
	Cut	25-15 in-lb	.0014	18-13 ft-lb	.0052
	Rolled	240-160 in-lb	.0022	35-22 ft-lb	.0052
	Rolled	60-50 in-lb	.0027	30-18 ft-lb	.0039

Table II (cont'd)

Size: 1/2 inch Plate Material: Cast HY80

Stud Material	Cut or Rolled	Class 3B	Interference	Class 5	Interference
K-monel	Cut	80-60 ft-lb	0.0045	25-15 ft-lb	0.0058
	Cut	33-25 ft-lb	.0037	60-50 ft-lb	.0003
	Rolled	82-60 ft-lb	.0042	38-35 ft-lb	.0048
	Rolled	20-18 ft-lb	.0028	30-26 ft-lb	.0026

Size: 1/2 inch Plate Material: Cast Monel

Stud Material	Cut or Rolled	Class 3B	Interference	Class 5	Interference
K-monel	Cut	250-100 in-lb	0.0072	60-50 ft-lb	0.0038
	Cut	50-35 ft-lb	.0015	45-35 ft-lb	.0023
	Rolled	70-45 ft-lb	.0064	110-80 ft-lb	.0052
	Rolled	45-30 ft-lb	.0031	55-35 ft-lb	.0034

Size: 7/8 inch Plate Material: HY80

Stud Material	Cut or Rolled	Class 3B (ft-lb)	Interference	Class 5 (ft-lb)	Interference
K-monel	Cut	380-320	0.0053	180-110	0.0085
	Cut	250-150	.0028	200-130	.0035
	Rolled	400-280	.0035	220-140	.0054
	Rolled	215-170	.0022	190-140	.0027
Monel	Cut	200-200	.0067	110-85	.0085
	Cut	50-35	.0029	65-25	.0008
	Rolled	170-140	.0079	210-190	.0062
	Rolled	150-100	.0018	80-65	.0016

Size: 7/8 inch Plate Material: HTS

Stud Material	Cut or Rolled	Class 3B (ft-lb)	Interference	Class 5 (ft-lb)	Interference
K-monel	Cut	260-180	0.0069	150-100	0.0069
	Cut	250-180	.0041		
	Rolled	260-190	.0058	300-240	.0052
	Rolled	230-180	.0017	210-160	.0025
Monel	Cut	110-60	.0045	160-130	.0074
	Cut	115-60	.0022	110-70	.0049
	Rolled	110-90	.0056	80-40	.0036
	Rolled	65-50	.0002	65-50	.0032

Table II (cont'd)

Size: 7/8 inch Plate Material: Cast HY80

Stud Material	Cut or Rolled	Class 3B (ft-lb)	Interference	Class 5 (ft-lb)	Interference
K-monel	Cut	300-240	0.0073	150-140	0.0068
	Cut			130-100	.0052
	Rolled	180-140	.0061	200-170	.0053
	Rolled	285-210	.0028	150-100	.0027

1/ Internal Thread Class.
2/ Break-away-Back-off torques.

Several studs were reengaged to determine to what extent the break-away and back-out torques were reduced as a result of the first engagement. These data are tabulated in Table III.

Table III. Break-away and Back-out Torques after Reapplication.

Size (inch)	Stud Material	Stud-Cut or Rolled	Internal Thread Material	Internal Thread Class	Torques after First Application (ft-lb)	Torques after Reapplication
1/2	K-monel	Cut	HTS	5	30-20	60-30 in-lb
			HY80	5	38-20	200-50 in-lb
			Cast HY80	5	25-15	20-10 ft-lb
			Monel	5	60-50	200-130 in-lb
		Rolled	HTS	5	55-40	100-50 in-lb
			HY80	5	38-25	130-40 in-lb
			Cast HY80	5	38-35	26-20 ft-lb
	Monel	Cut	HTS	3	60-35	40-15 ft-lb
			HY80	5	30-20	180-50 in-lb
		Rolled	HTS	5	35-22	180-90 in-lb
			HY80	5	45-30	22-15 in-lb
7/8	K-monel	Cut	HTS	5	150-100	100-60 ft-lb
			HY80	5	180-110	40-25 ft-lb
			Cast HY80	5	150-140	80-40 in-lb
		Rolled	HTS	5	300-240	90-60 ft-lb
			HY80	5	220-140	30-25 ft-lb
	Monel	Cut	HY80	5	110-85	40-35 ft-lb
		Rolled	HTS	5	80-40	70-40 ft-lb

In general, the deformation of the external and internal threads occurring during the first application resulted in the break-away and back-out torques of the studs after the second application to be lower than the corresponding torques of the nuts.

These studs were reengaged and axially loaded to their breaking point. The object of this load test was to determine whether the thread distortion occurring during engagement weakened them to a point where they would strip when the stud was loaded axially. In all the load tests performed, the stud broke without any stripping of the external or internal threads. All load tests were performed with the studs engaged to the minimum length of engagement determined from testing performed in Task I (See Monthly Status Report No. 8).

Figures 1 through 4 show the deformation which occurred when monel and K-monel studs with cut and rolled, class 5 threads were engaged in class 5 tapped holes in HY80 plate. During driving, plastic flow occurs which results in an increase of the stud major diameter. Typical increases in major diameter resulting from interference fit is shown in Table IV.

<u>General Comments</u>:

Based on the test data it is recommended that class 5 studs not be engaged in class 3B tapped holes. The larger minor diameter of the 3B holes as compared to that of class 5 resulted, in many cases, in excessive driving torques and, in some cases, in seizing and galling of the threads.

In testing K-monel studs in tapped holes in cast monel, NC5 ONF threads were used for the studs and NC5 INF threads were used for the holes. Although not too much difficulty was experienced with the 1/2 inch studs, engaging 7/8 inch

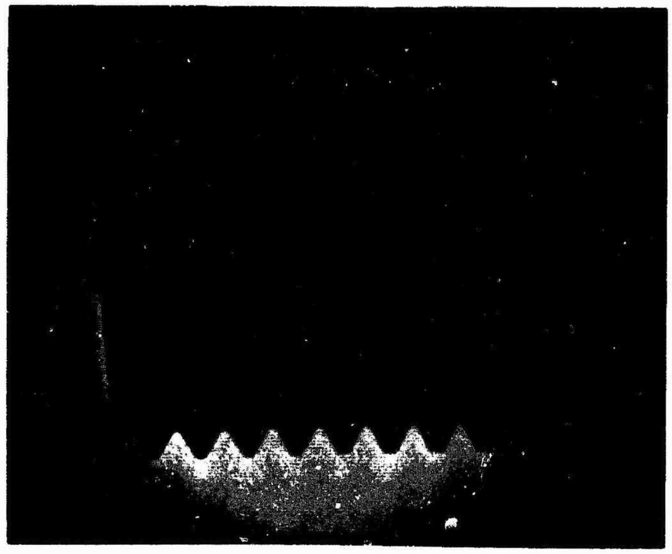


FIGURE 1: Deformation of a 7/8 inch K-Monel Stud with Cut, Class 5 Threads after Engagement in a Class 5 Tapped Hole in HY80 Plate.

FIGURE 2: Deformation of a 7/8 inch Monel Stud with Cut, Class 5 Threads after Engagement in a Class 5 Tapped Hole in HY80 Plate.

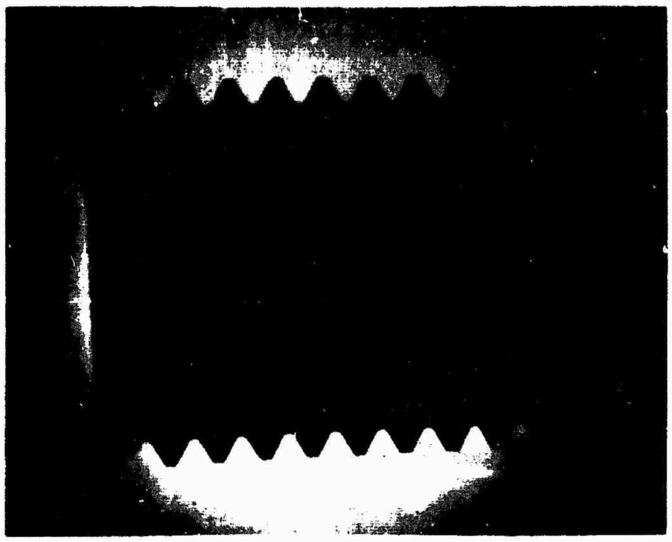


FIGURE 3: Deformation of a 7/8 inch K-Monel Stud with Rolled, Class 5 Threads after Engagement in a Class 5 Tapped Hole in HY80 Plate.

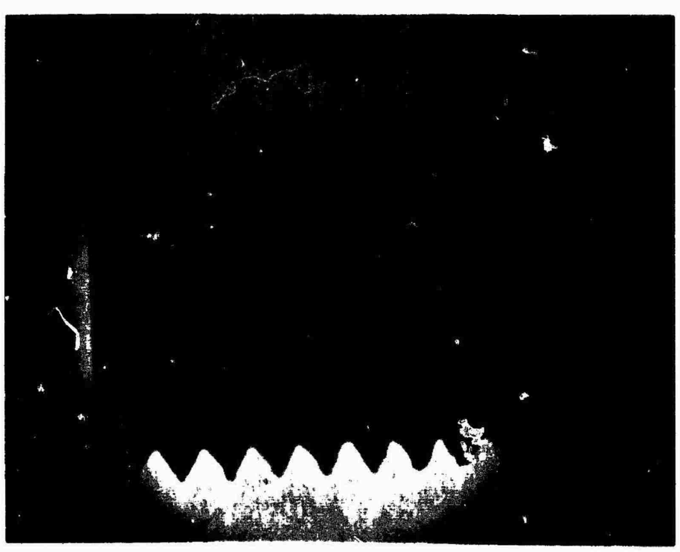


FIGURE 4: Deformation of a 7/8 inch Monel Stud with Rolled, Class 5 Threads after Engagement in a Class 5 Tapped Hole in HY80 Plate.

Table IV. Increase in Stud Major Diameter as a Result of Interference Fit

Size (inch)	Stud Material	Stud-Cut or Rolled	HTS Major Diameter Change (inch)	HTS Pitch Diameter Interference (inch)	HY80 MDC (inch)	HY80 PDI (inch)	Cast HY80 MDC (inch)	Cast HY80 PDI (inch)	Monel MDC (inch)	Monel PDI (inch)
1/2	K-monel	Cut	0.0031	0.0049	0.0029	0.0060	0.0040	0.0058	0.0071	0.0023
		Cut	.0020	.0028	.0012	.0011	.0010	.0037	.0052	.0015
		Rolled	.0017	.0044	.0097	.0022	.0017	.0048	.0054	.0064
		Rolled	.0056	.0019	.0012	.0016	.0059	.0026	.0084	.0052
	Monel	Cut	.0036	.0052	.0083	.0038				
		Cut	.0016	.0014	.0021	.0017				
		Rolled	.0001	.0039	.0043	.0008				
		Rolled	.0012	.0027						
7/8	K-monel	Cut	.0082	.0069	.0076	.0085	.0119	.0068		
		Cut	.0035	.0041	.0092	.0028	.0060	.0052		
		Rolled	.0081	.0052	.0060	.0054	.0044	.0061	.0130	.0023
		Rolled	.0007	.0009	.0031	.0027	.0119	.0027		
	Monel	Cut	.0210	.0074	.0224	.0085				
		Cut	.0144	.0045						
		Rolled	.0035	.0056	.0127	.0018				
		Rolled	.0029	.0036	.0105	.0016				

NC5 ONF studs in NC5 INF holes caused seizing and galling, in the majority of tests conducted. In many cases, balling of the seized metal was so great that it resulted in torsional failure of the stud when attempting to back it out. The use of NC5 HF studs in the NC5 INF tapped holes in the cast monel greatly reduced the frequency of seizing and galling.

Task IV

Purpose: The purpose of this task is to obtain data on which to base thread dimensions for 8UN interference-fit threads. The major diameter, minor diameter, and pitch diameter for external and internal threads for sizes 1 to 2 inches are to be determined. These dimensions are to be determined for monel and K-monel studs and tapped holes in HTS, HY80, cast HY80 and cast monel.

Work Performed: All the necessary studs and plates with tapped holes to perform this task have been received. All studs and holes have been measured.

Task V

Purpose: The purpose of this task is to standardize a method for assuring proper bolt tension. Prestressing experiments are to include three of the methods described in Handbook H28, Part III, pages 52-53, namely, the micrometer, torque measurement, and angular turn of the nut methods. Both through bolting and set-stud bolting assemblies are to be investigated. The effect of different t.:cknesses of the material being clamped on the three methods of determining preload are to be investigated.

Test Equipment: To accurately relate angular turn of the nut, applied torque, and bolt elongation to actual bolt tension, a bolt-tension calibrator must be used. A Skidmore-Wilhelm Torque Tension Tester was used in this program to measure induced bolt tension (Figure 5). A schematic drawing of this apparatus is shown in Figure 6. The bolt to be tested is put through the shoulder (see Figure 6) and then through the cover and the nut engaged. The initial length of the bolt is measured and then the nut tightened to a predetermined torque. The torque, angular turn of the nut, and elongation are recorded and the nut tightened to the next level. In set-stud bolting the shoulder is threaded and the setting end of the stud engaged into it. The nut end of the stud is put through the cover and the nut engaged.

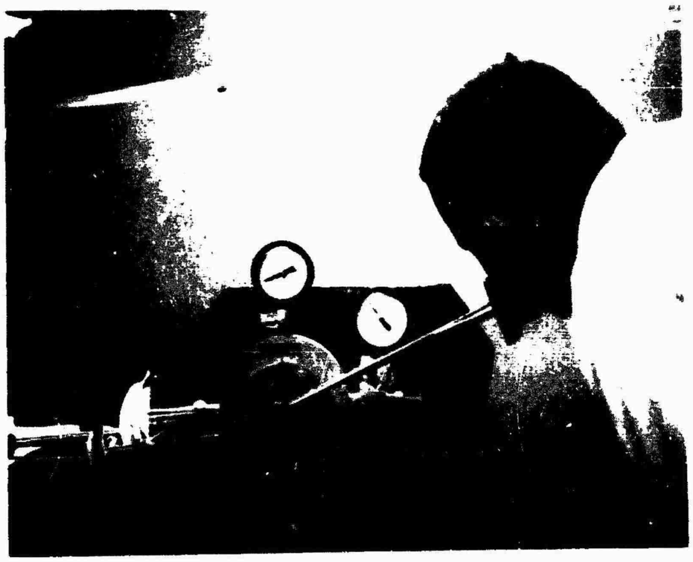


FIGURE 5: Skidmore-Wilhelm Torque Tension Tester

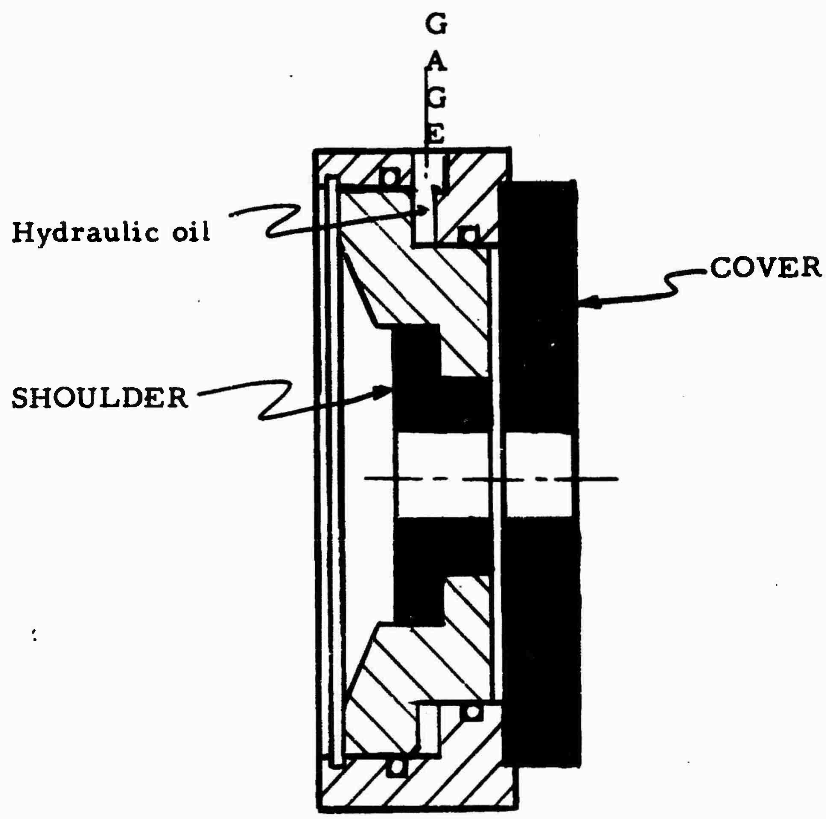


FIGURE 6: Skidmore-Wilhelm Torque Tension Tester

Testing:

The following are the test parameters used in this prestress task.

1. Bolt and Stud Materials

   a. Monel

   b. K-monel

2. Shoulder and Cover Materials (see Figure 6).

   a. High Tensile Steel (HTS)

   b. HY80

   c. Cast HY80

   d. Cast Monel

   e. Valve Bronze

3. Shoulder and Cover Thicknesses

The following are thicknesses of materials being clamped. For through bolting the total thickness is the sum of the shoulder and cover thickness.

a. For through bolting:

(1) Shoulder - 2 inches   Cover - 1-1/8 inches

and (2) Shoulder - 9/16 inch   Cover - 9/16 inch

b. For set-stud bolting:

(1) 9/16 inch

(2) 1-1/8 inches

(3) 2 inches

For set-stud bolting the setting end of the stud was engaged in the shoulder and the above three cover thicknesses tested.

4. Nut

Self-locking nuts in accordance with MS 17828 were used throughout this task.

5. Washer

No washer was used in these prestress tests.

6. Plating

Bolts, studs and nuts were not plated.

7. Lubrication

Nuts: Nuts were used as received from the manufacturer.

Bolts and studs: Bolts and studs were vapor degreased in trichloroethylene and lubricated with "3-in-1" SAE 20 oil.

8. Torqued Member:

The nut was torqued in all of the prestress tests.

9. Nut Seating to Begin Angular Turn:

The original plan was to begin measuring angular turn of the nut at 100 inch-pounds torque or 10 percent of the ultimate torque rating shown on MS 17828, whichever is smaller. The torque at which to begin angular turn, however, must be greater than the torque to engage the nut on the bolt at no preload. Since the torque needed to turn 1/2 inch self-locking nuts on the bolt at no preload varied between about 85 to 100 inch-pounds, angular turn of the nut for 1/2 inch nuts was begun at 120 inch-pounds.

Shown in Figures 1 through 20 are the results of prestress tests performed on 1/2 inch monel and K-monel bolts and studs. Prestress vs. Angular Turn of the Nut data are plotted in Figures 1 through 6 for set-stud bolting and in Figures 13 through 16 for through-bolting. Prestress vs. Applied Torque data are plotted in Figures 7 through 12 for set-stud bolting and 17 through 20 for through-bolting. The data from which these curves were plotted will be tabulated in the next report. Prestress vs. Elongation data will also be included in the next monthly report.

A discussion of the merits of each of the three methods of controlling prestress will be included in the next report at which time prestress tests for the 7/8 and 1-1/8 inch bolts and studs will be completed.

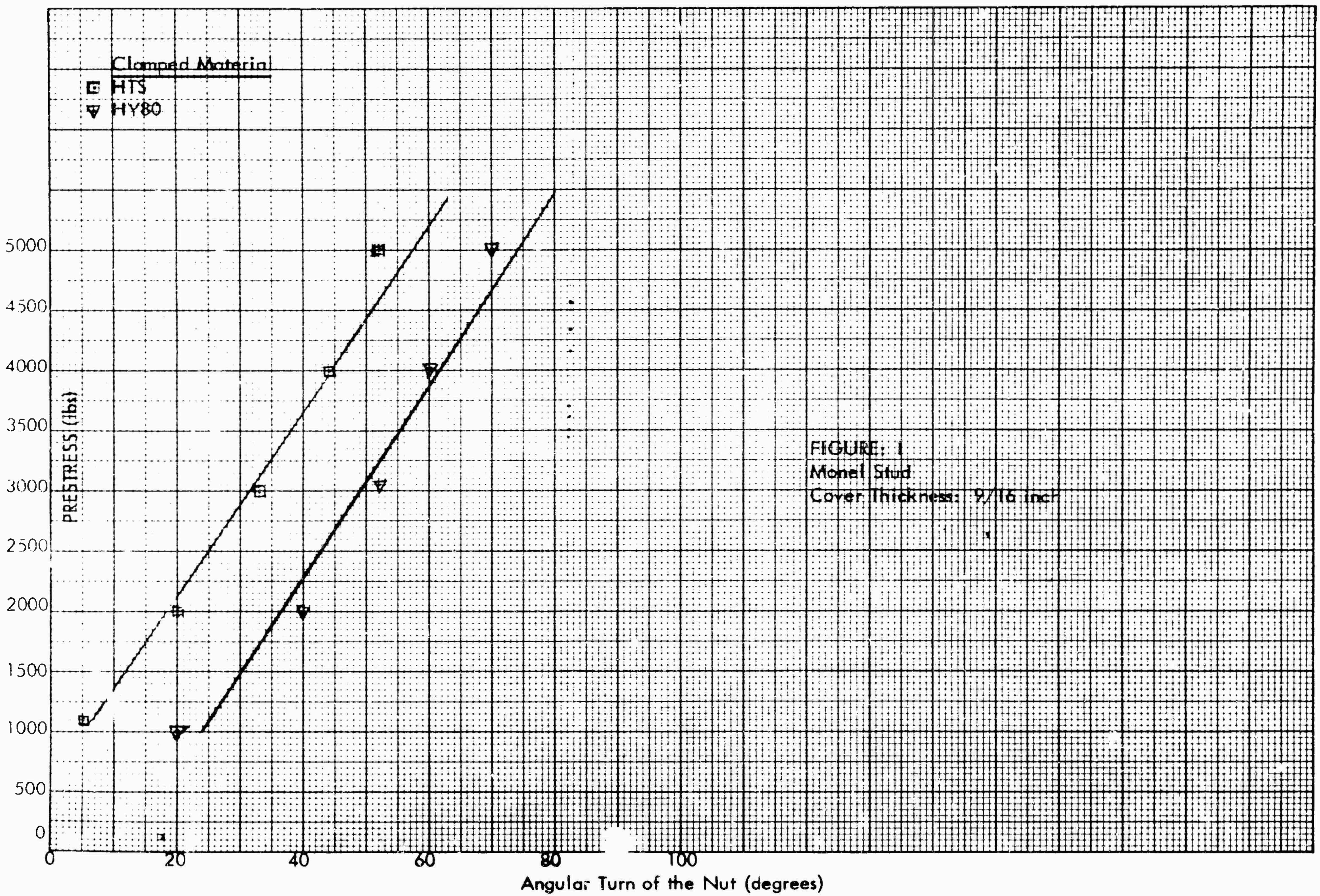
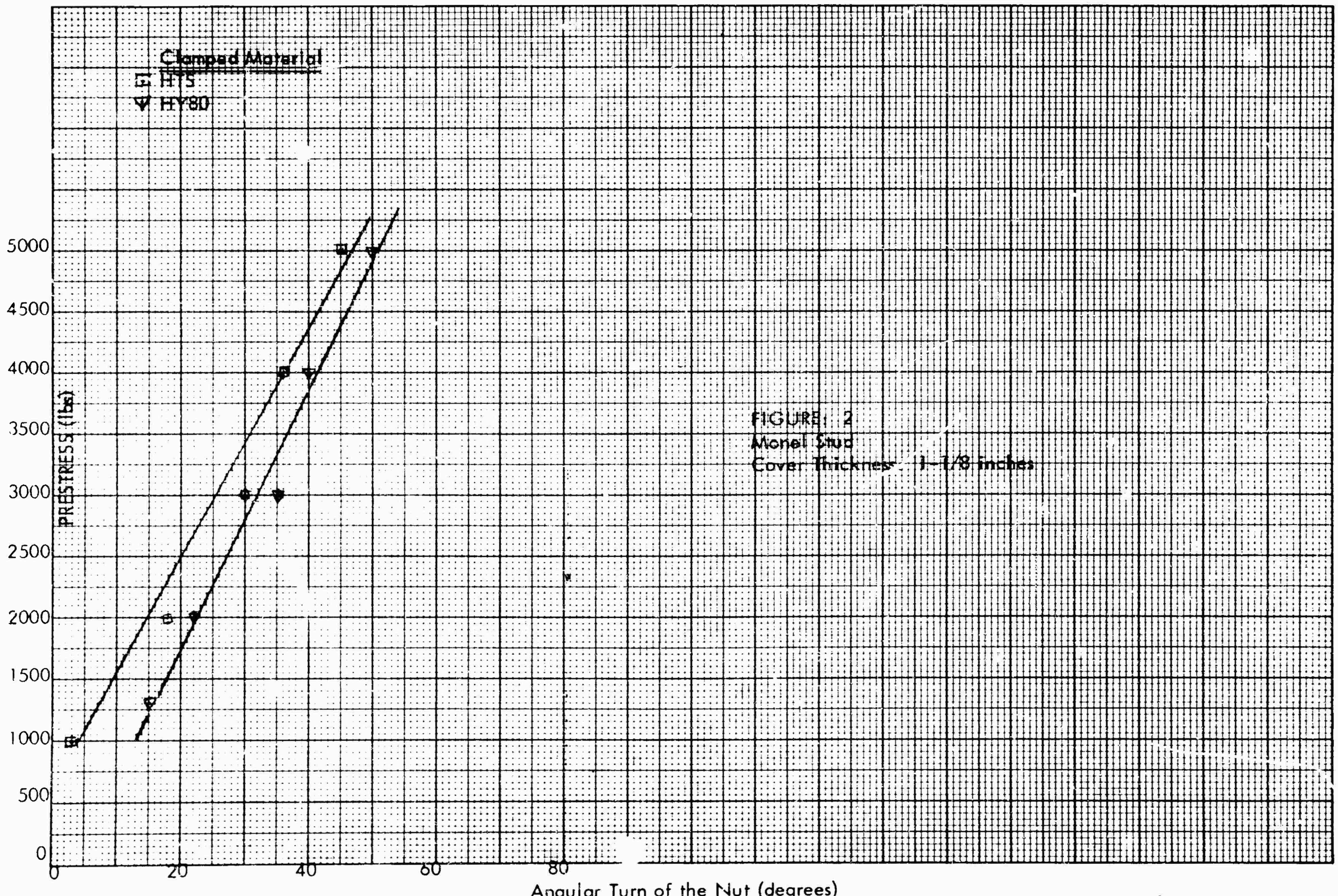


FIGURE: 1
Monel Stud
Cover Thickness: 9/16 inch



Clamped Material
HTS
HY80
PRESTRESS (lbs)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
20
40
60
80
Angular Turn of the Nut (degrees)
FIGURE 2
Monel Stud
Cover Thickness 1-1/8 inches

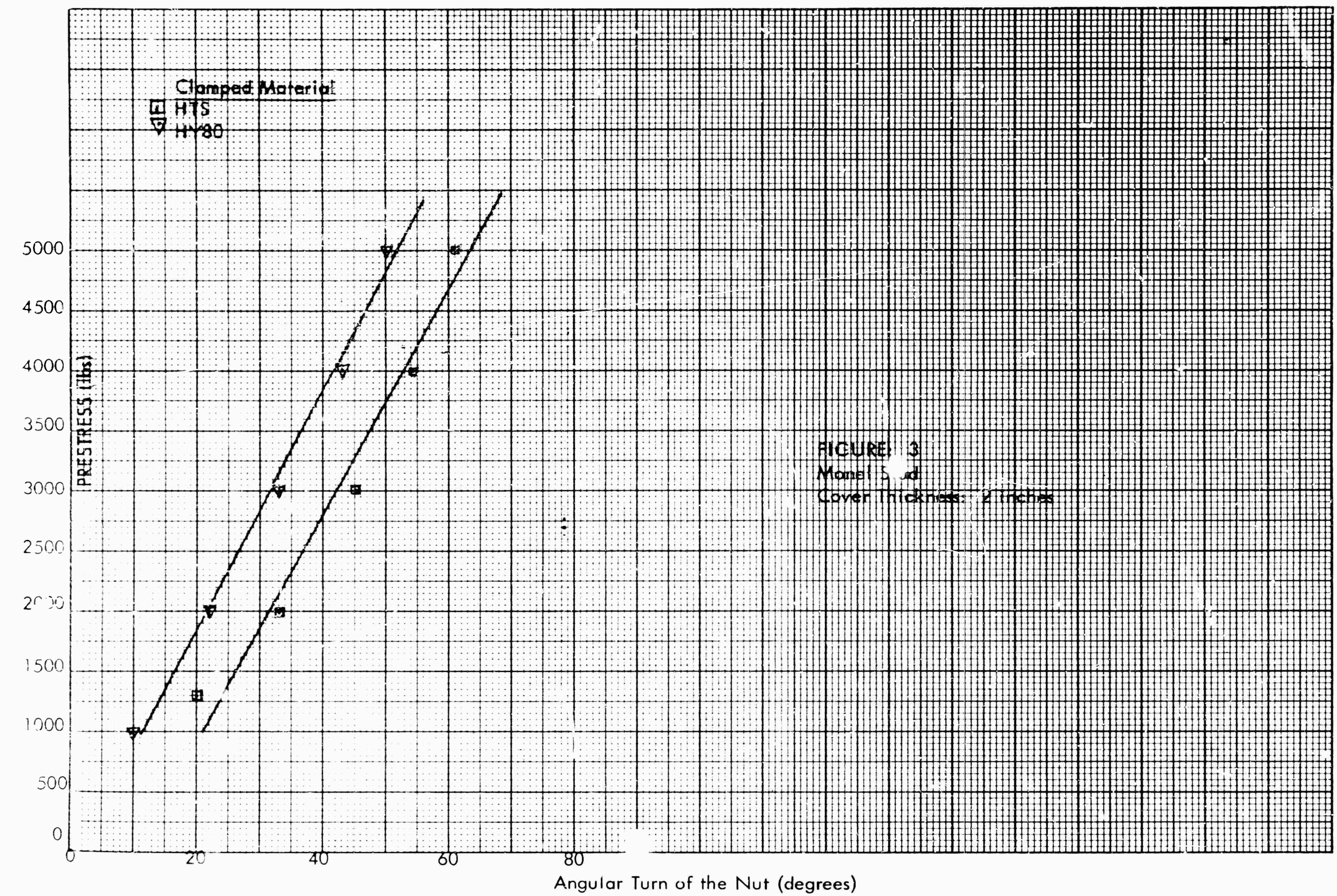


FIGURE 3
Monel Stud
Cover Thickness: 2 Inches

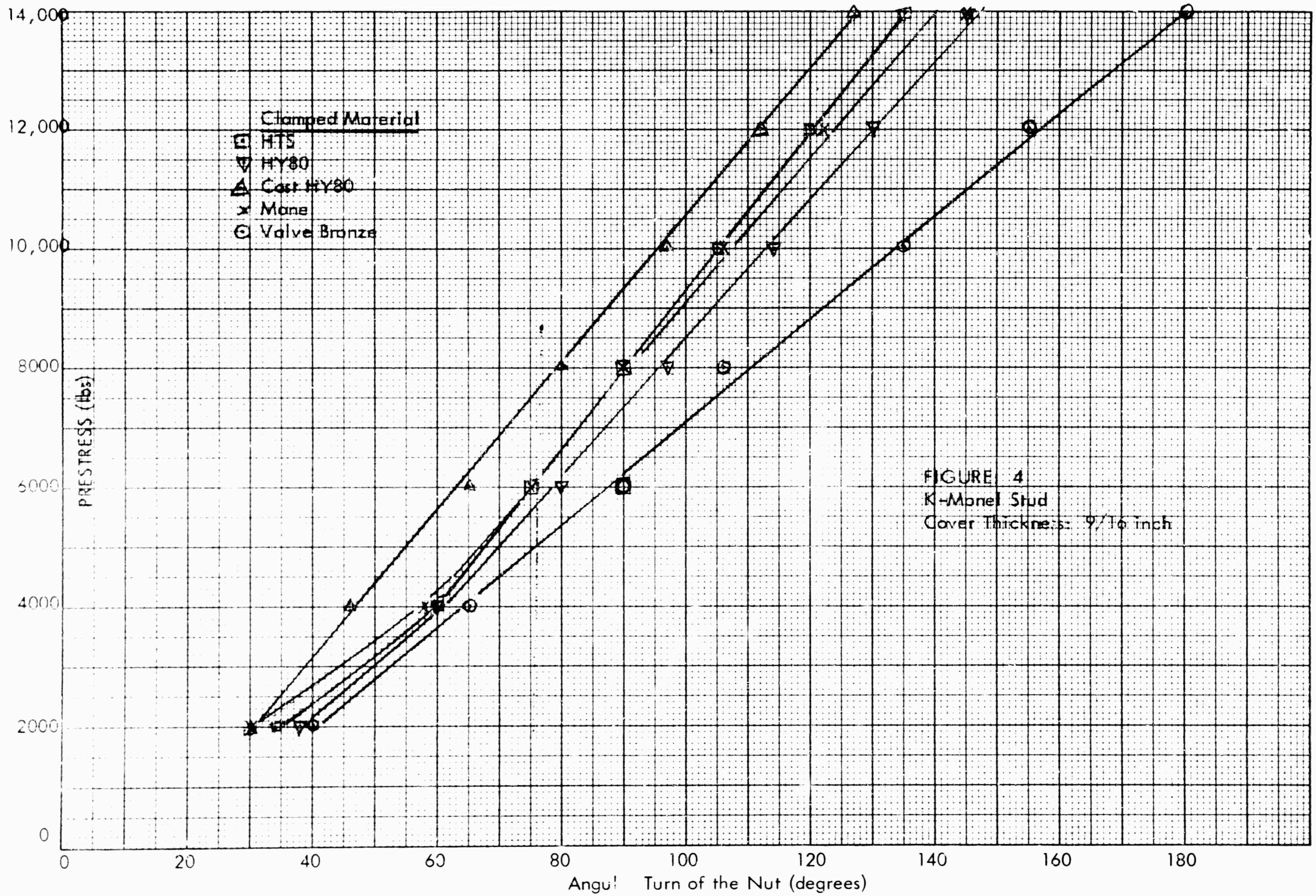


FIGURE 4
K-Monel Stud
Cover Thickness: 9/16 inch

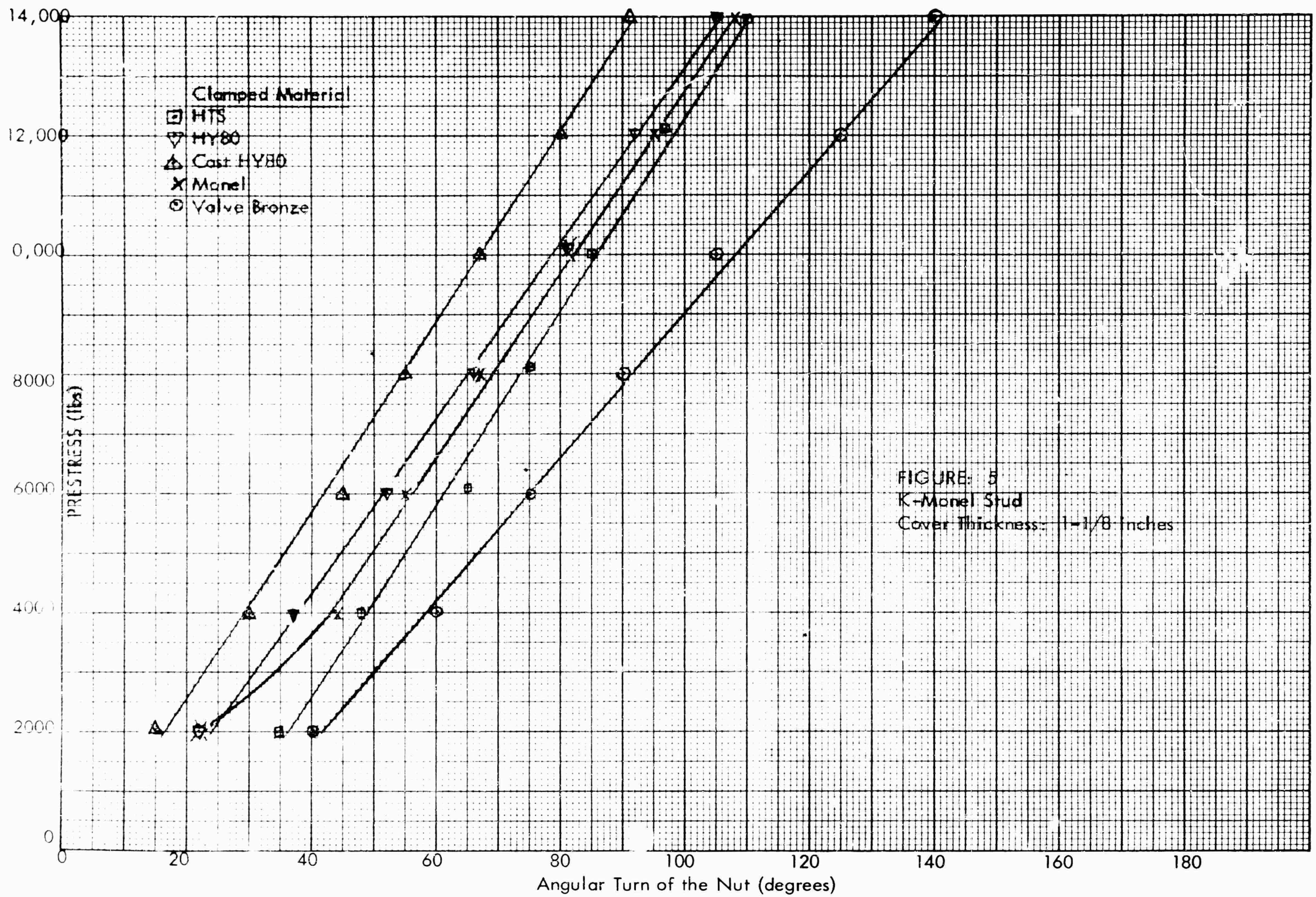


FIGURE: 5
K-Monel Stud
Cover Thickness: 1-1/8 inches

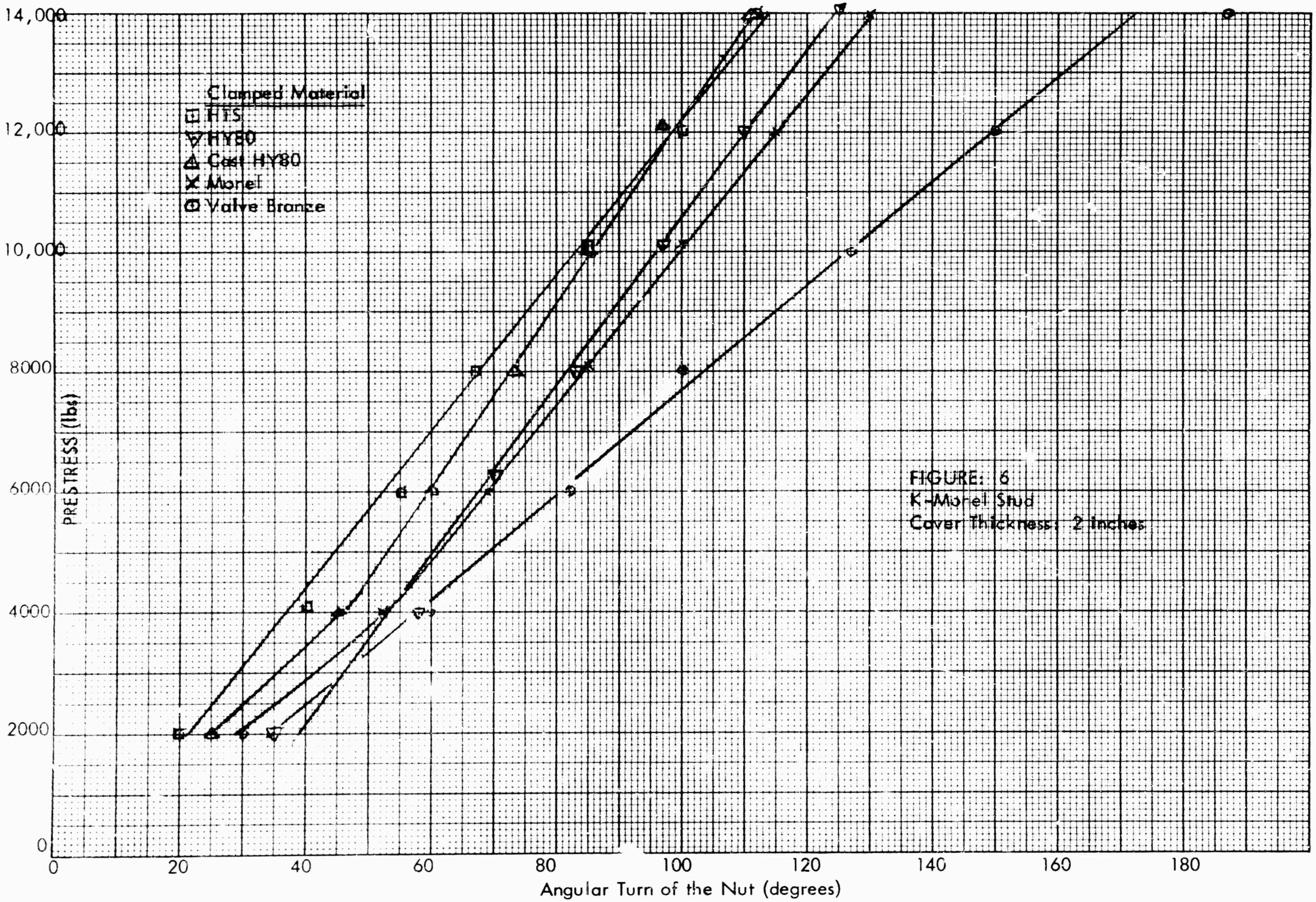


FIGURE: 6
K-Monel Stud
Cover Thickness: 2 Inches

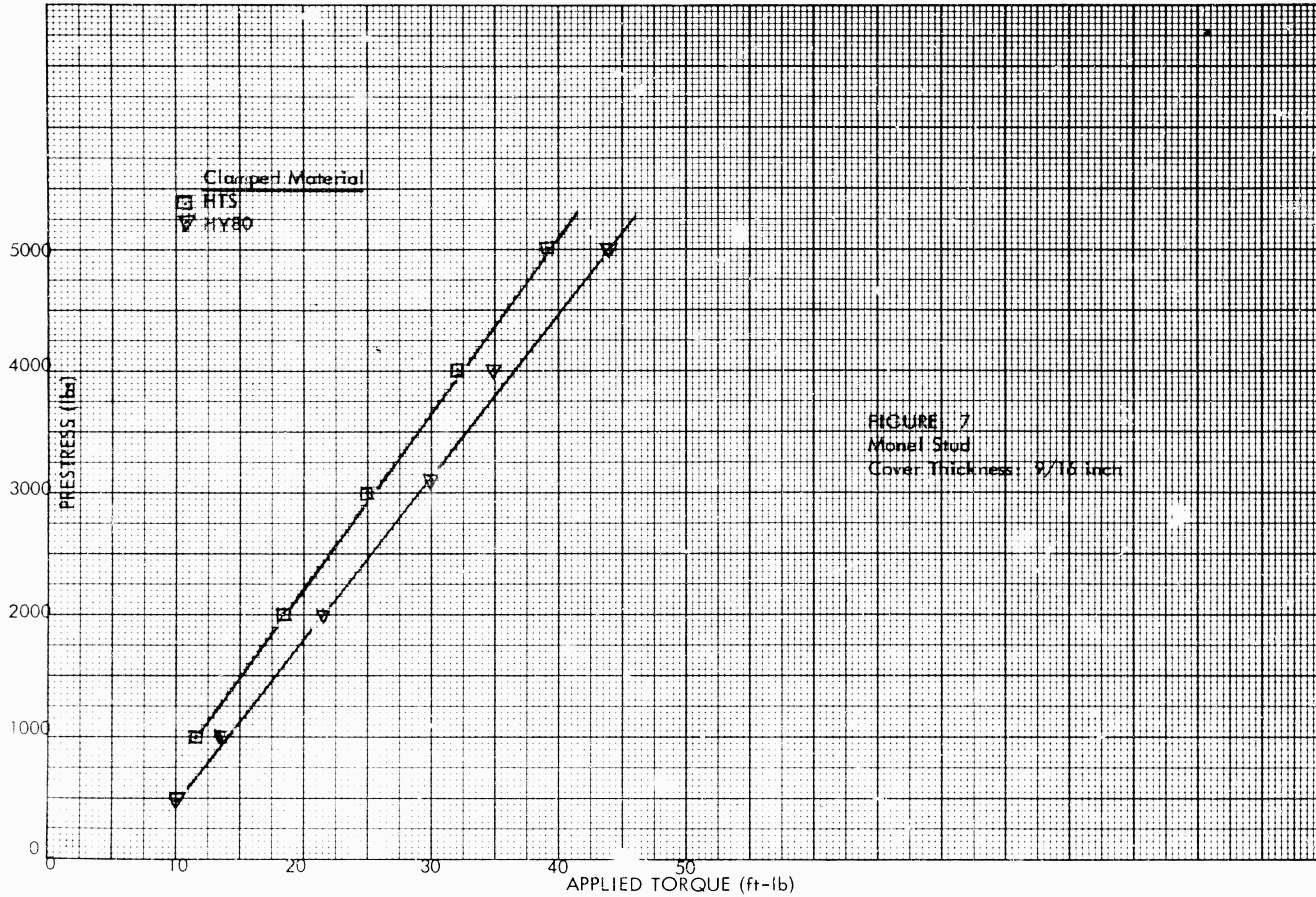


FIGURE 7
Monel Stud
Cover Thickness: 9/16 inch

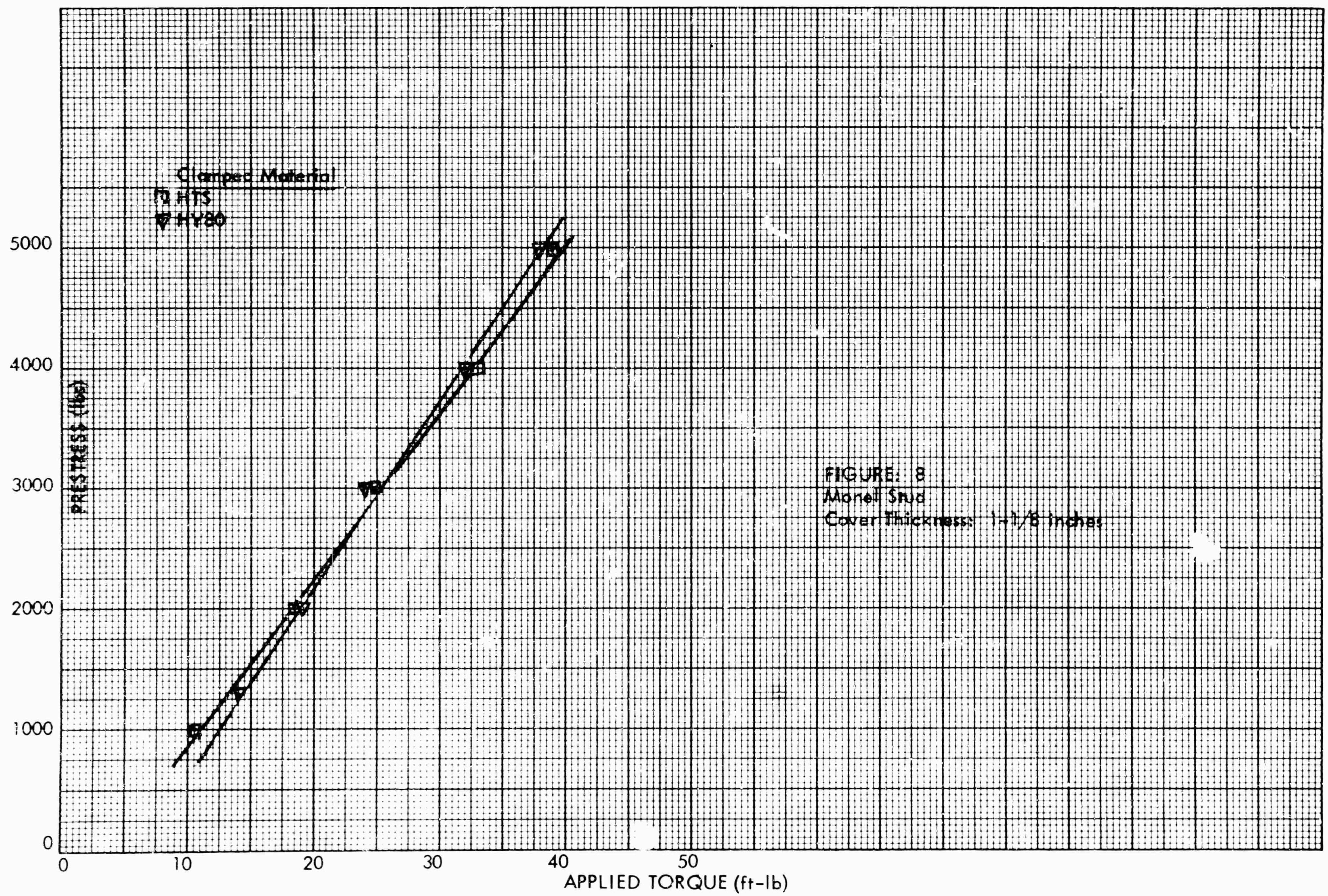


FIGURE: 8
Monell Stud
Cover Thickness: 1-1/8 inches

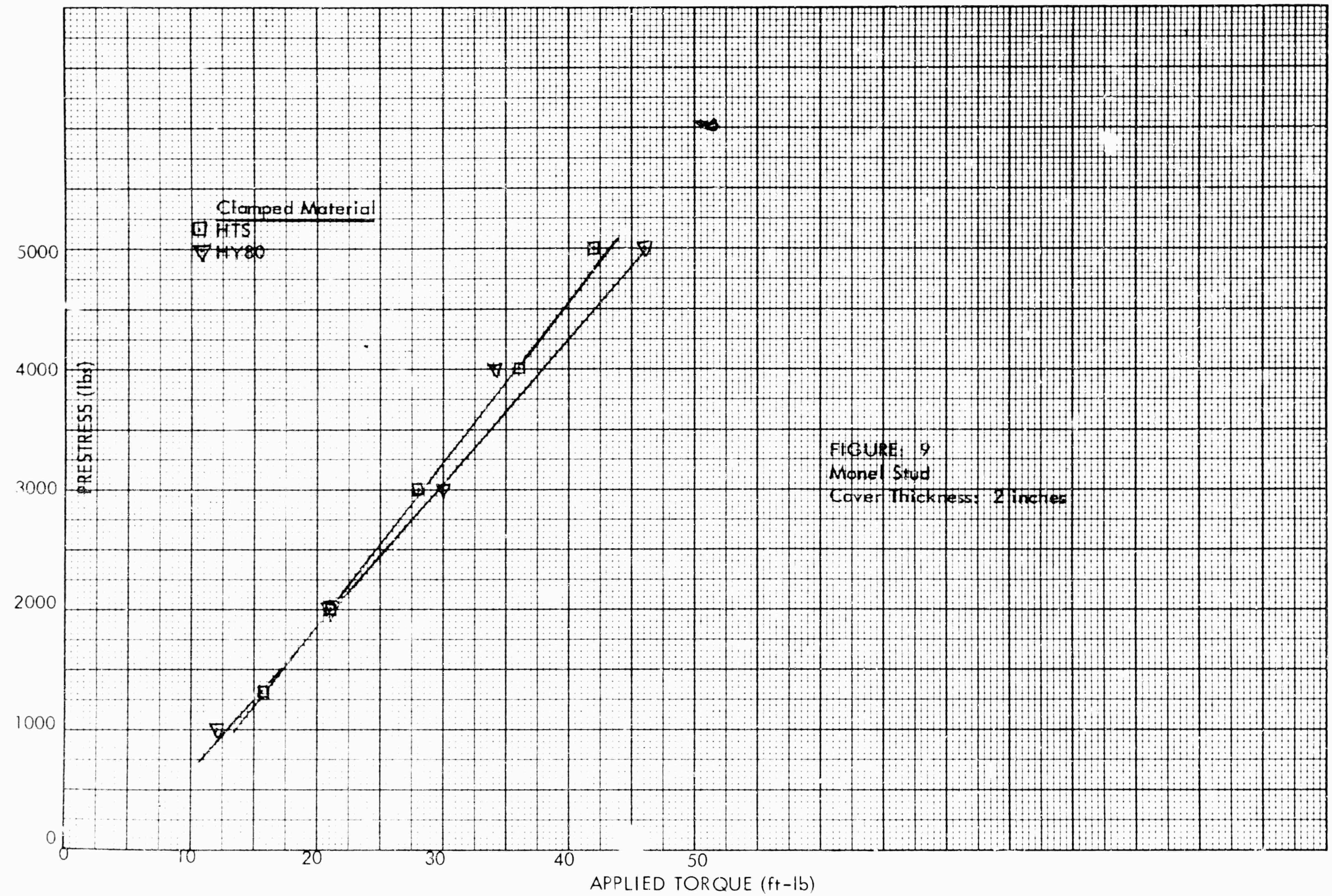


FIGURE: 9
Monel Stud
Cover Thickness: 2 inches

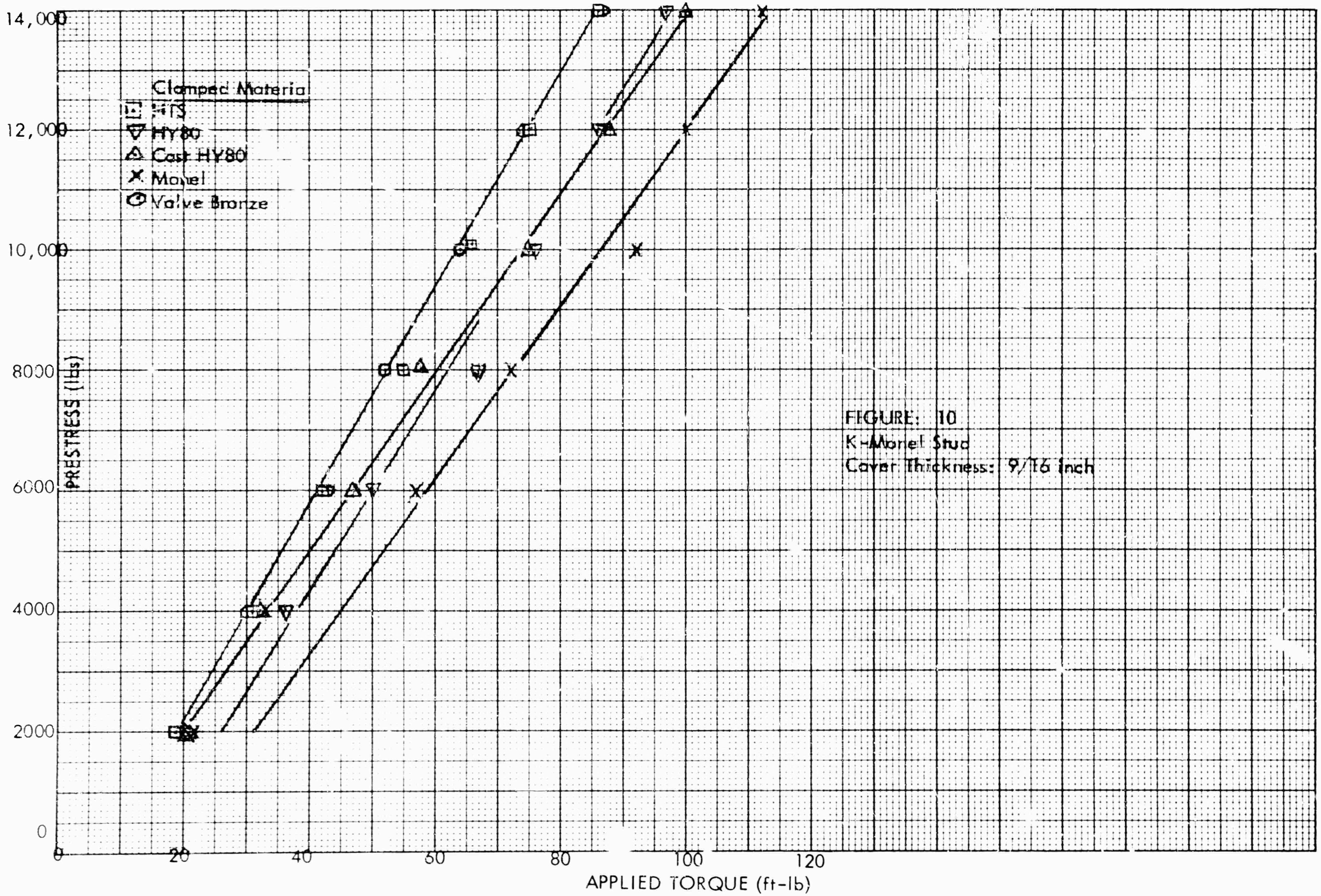


FIGURE: 10
K-Monel Stud
Cover Thickness: 9/16 inch

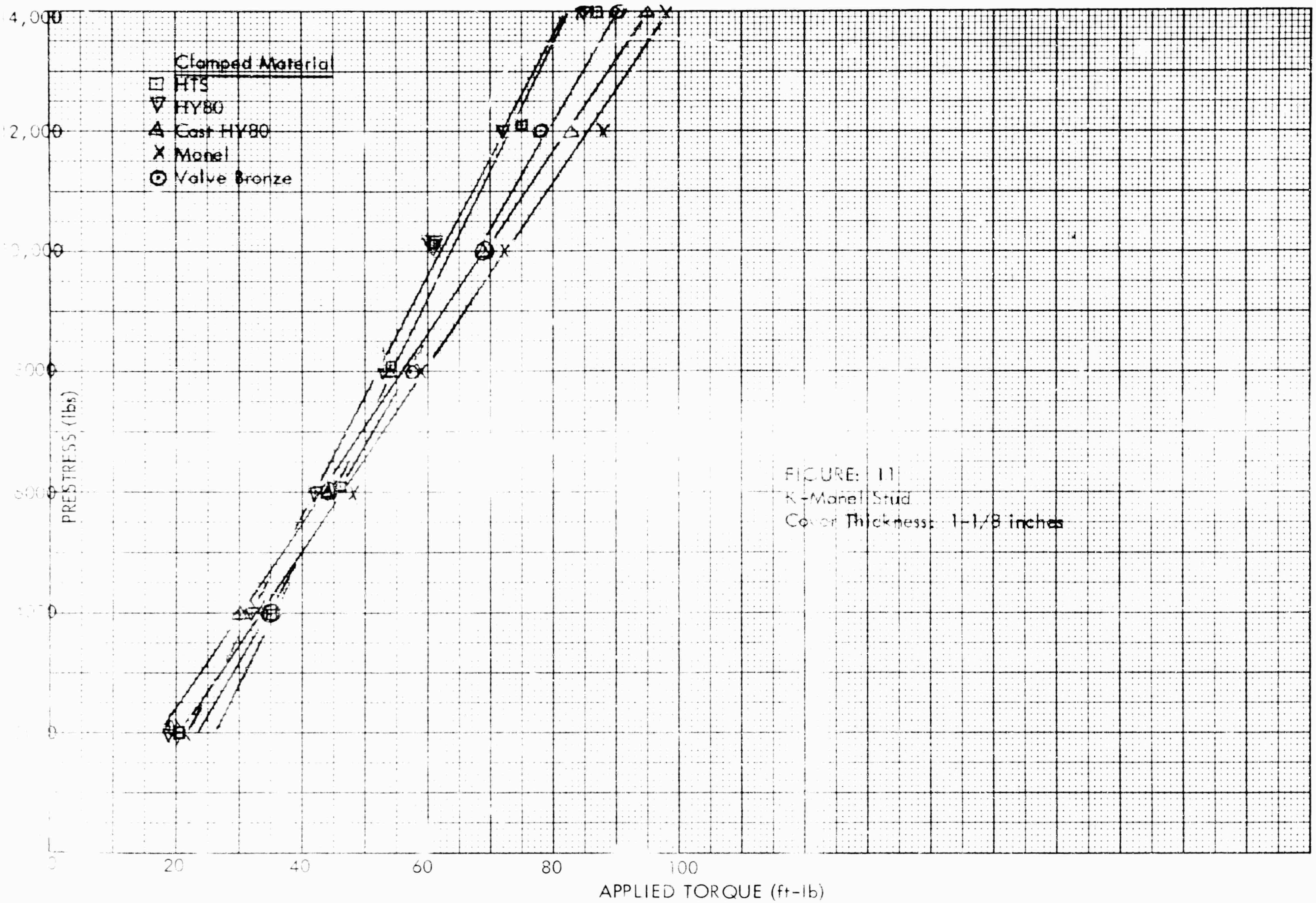
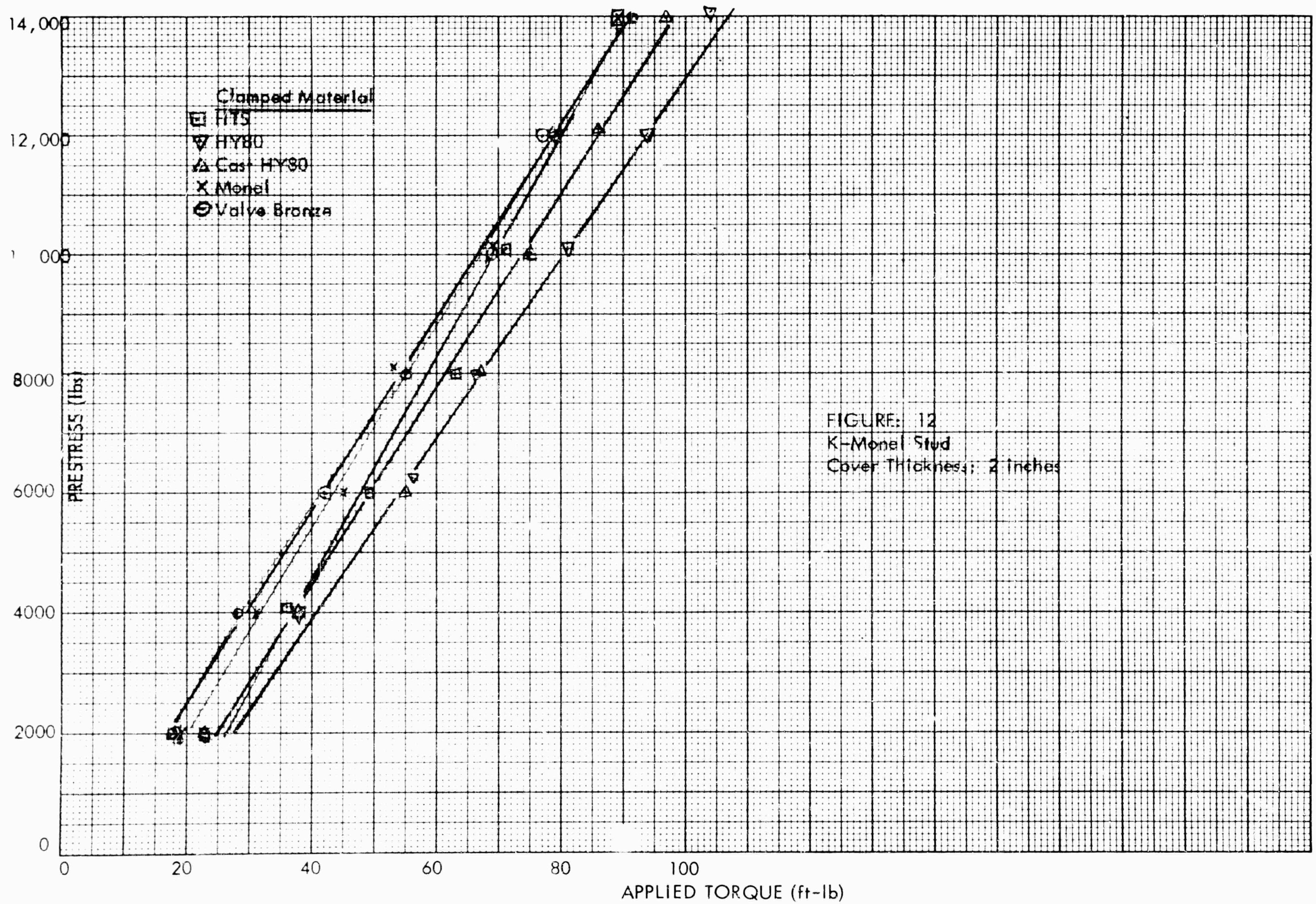


FIGURE: 11
K-Monel Stud
Cover Thickness: 1-1/8 inches



14,000
12,000
000
8000
6000
4000
2000
0
PRESTRESS (lbs)
0
20
40
60
80
100
APPLIED TORQUE (ft-lb)
Clamped Material
HTS
HY80
Cast HY80
Monel
Valve Bronze
FIGURE: 12
K-Monel Stud
Cover Thickness: 2 Inches

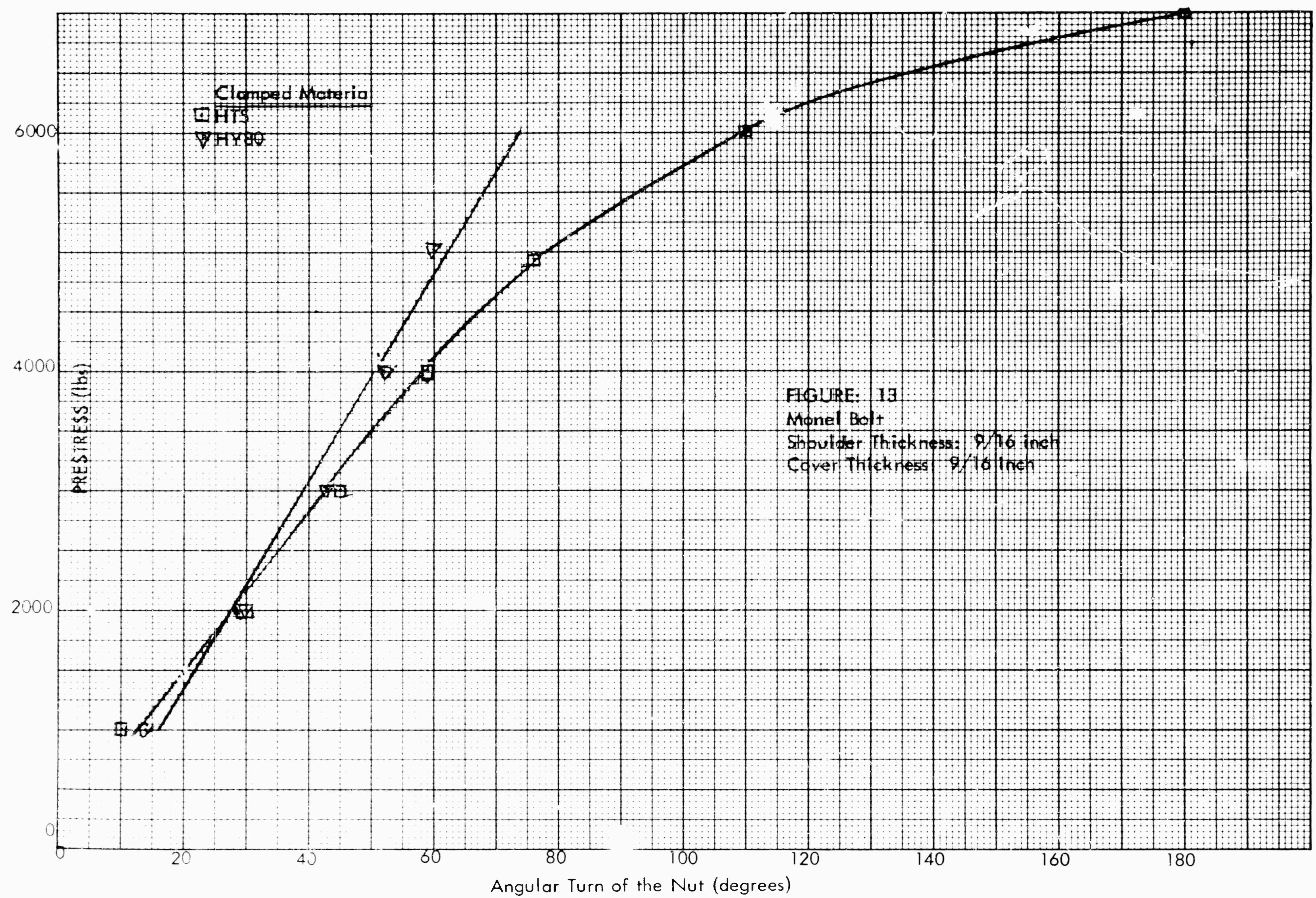
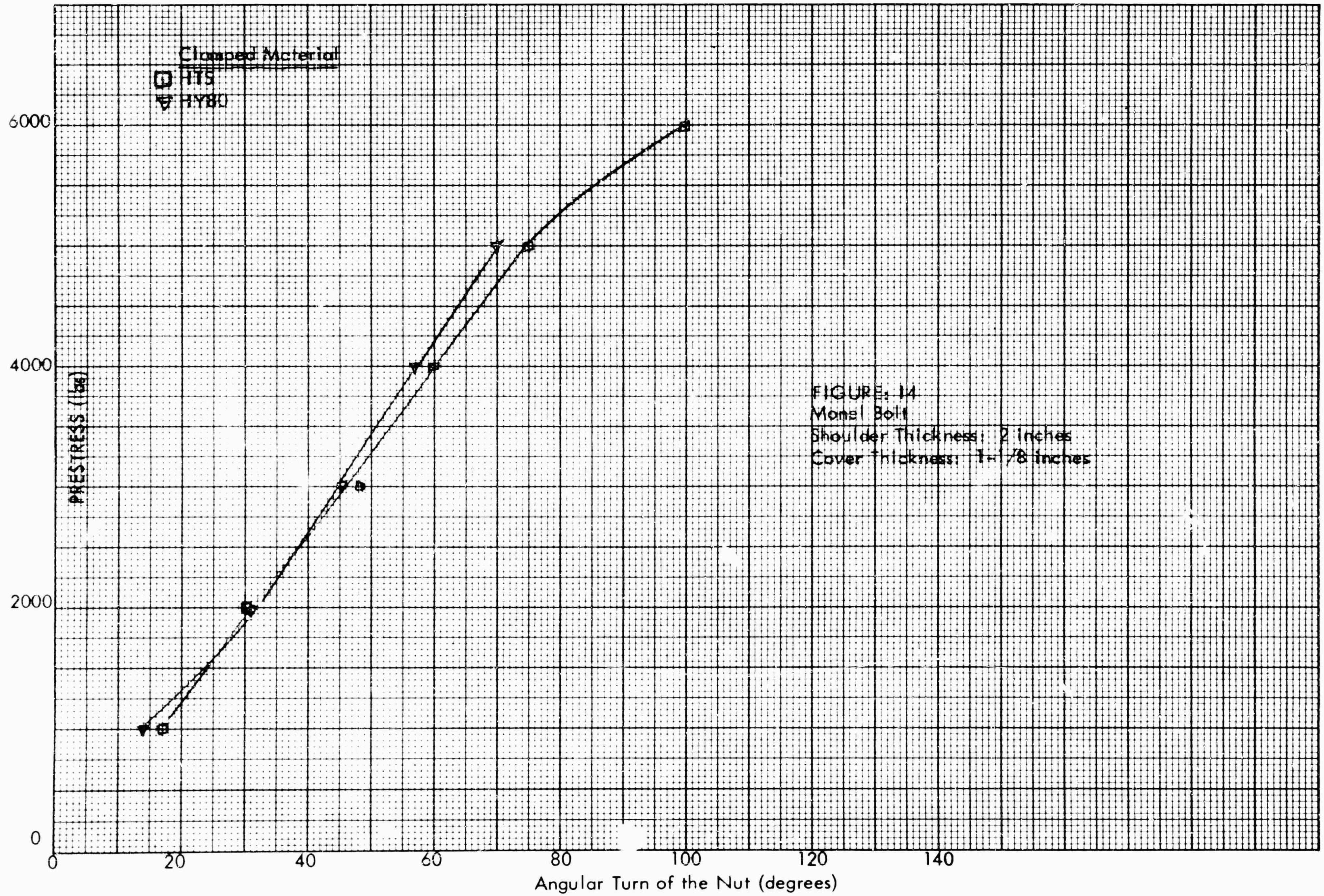


FIGURE: 13
Monel Bolt
Shoulder Thickness: 9/16 inch
Cover Thickness 9/16 inch


Clasped Material
HTS
HY80
6000
4000
2000
0
PRESTRESS (lbs)
0
20
40
60
80
100
120
140
Angular Turn of the Nut (degrees)
FIGURE: 14
Monel Bolt
Shoulder Thickness: 2 inches
Cover Thickness: 1-1/8 inches

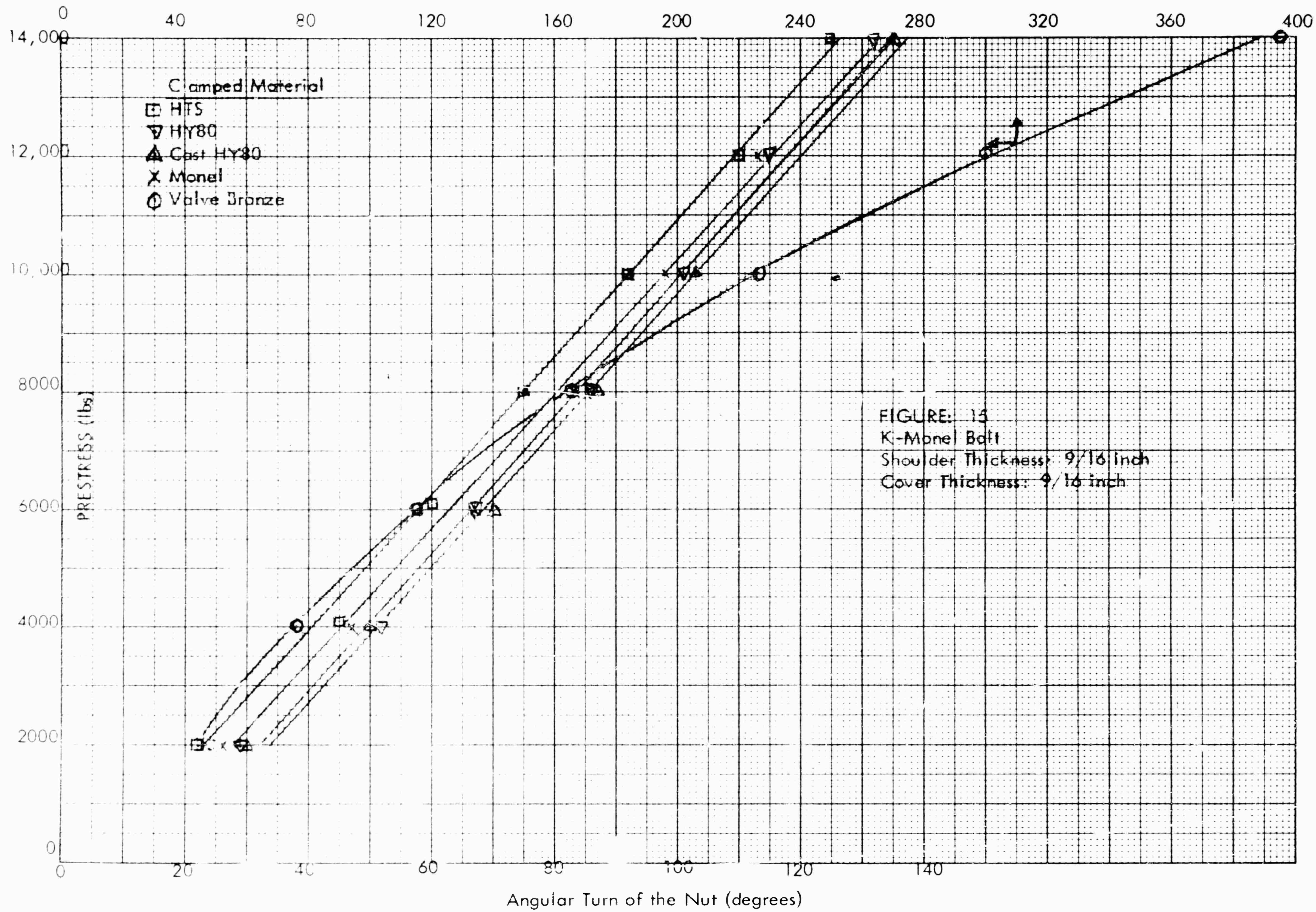


FIGURE: 15
K-Monel Bolt
Shoulder Thickness: 9/16 inch
Cover Thickness: 9/16 inch

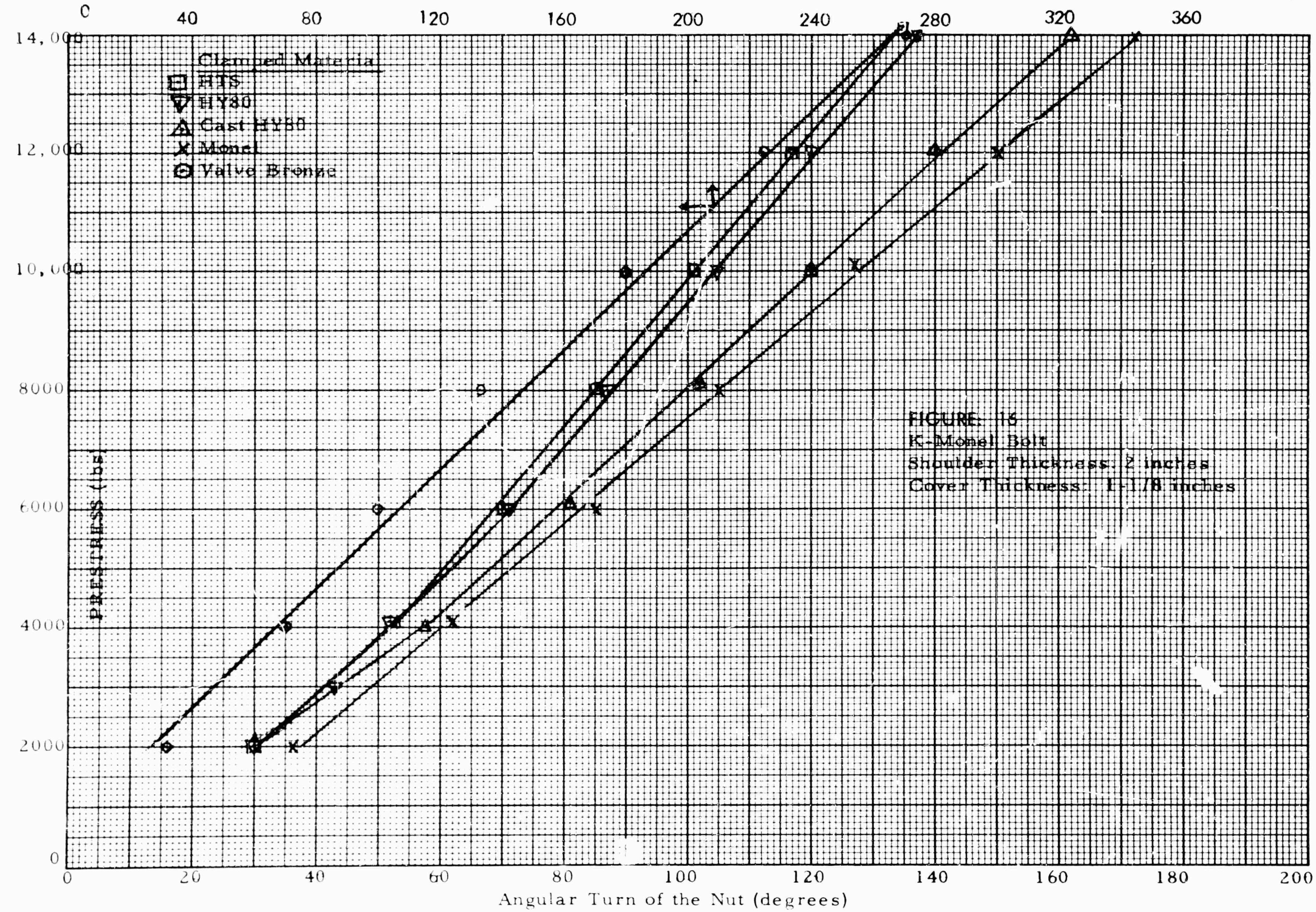


FIGURE 16
K-Monel Bolt
Shoulder Thickness: 2 inches
Cover Thickness: 1-1/8 inches

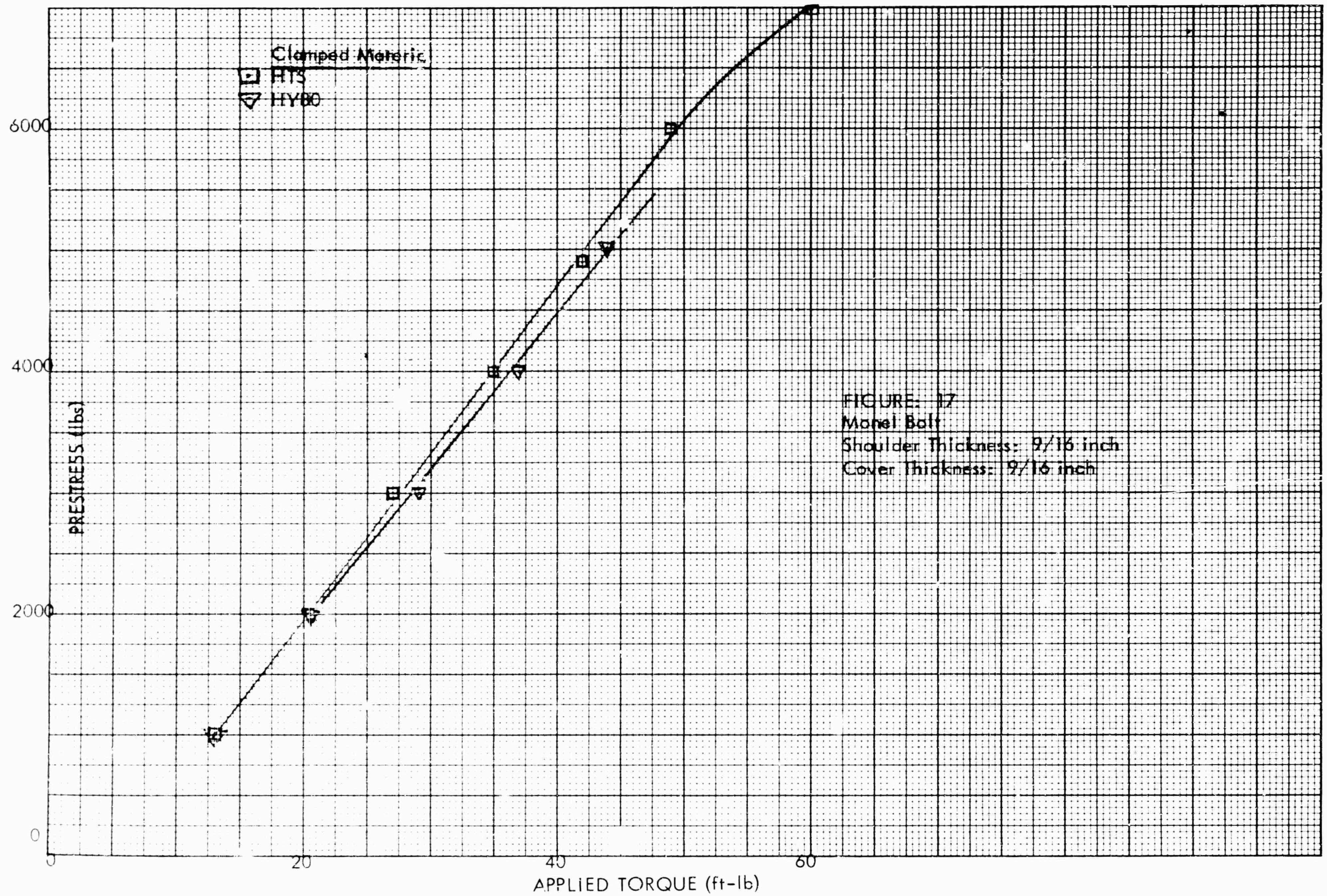


FIGURE: 17
Monel Bolt
Shoulder Thickness: 9/16 inch
Cover Thickness: 9/16 inch

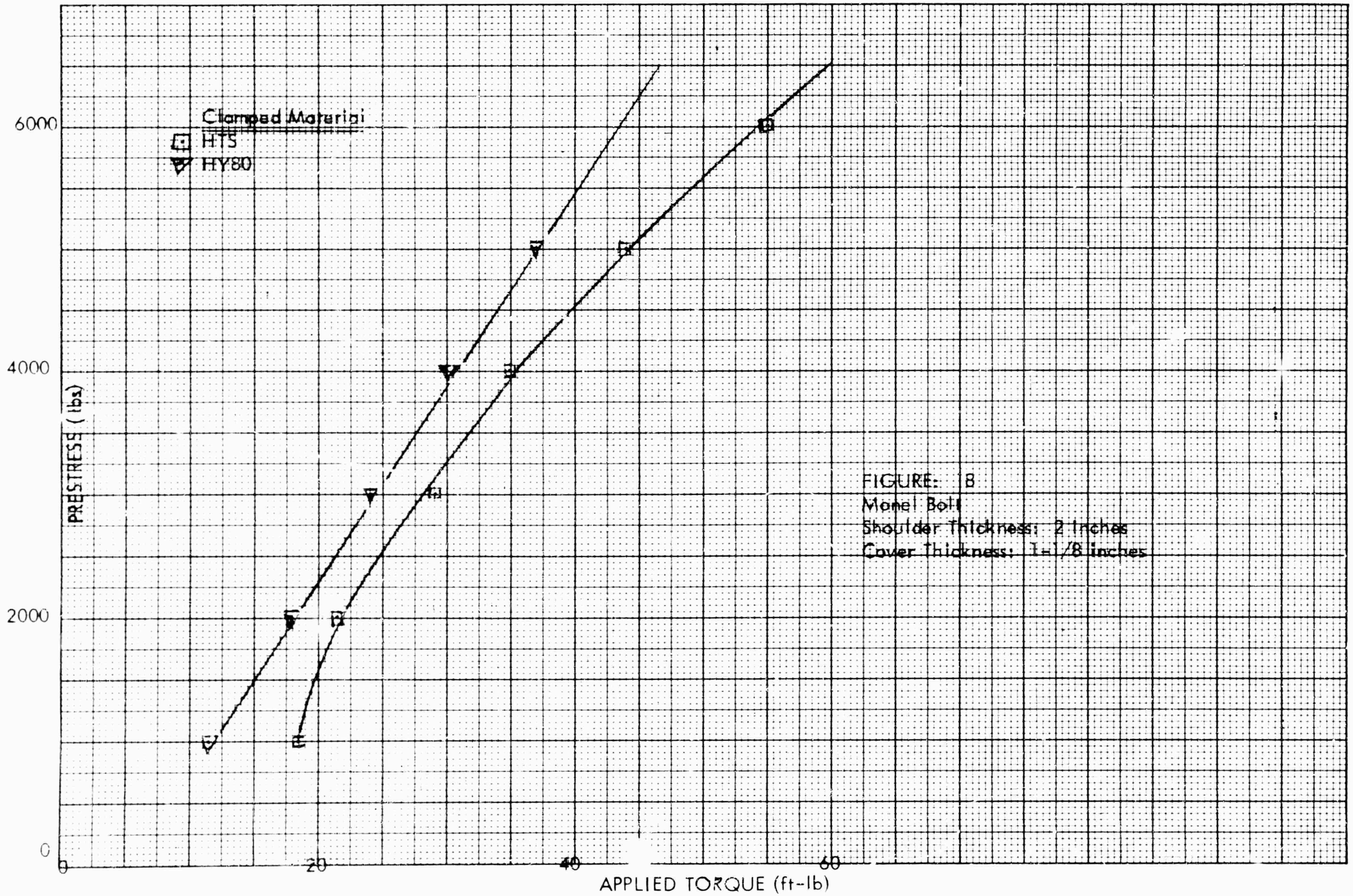


FIGURE: 18
Monel Bolt
Shoulder Thickness: 2 Inches
Cover Thickness: 1-1/8 Inches

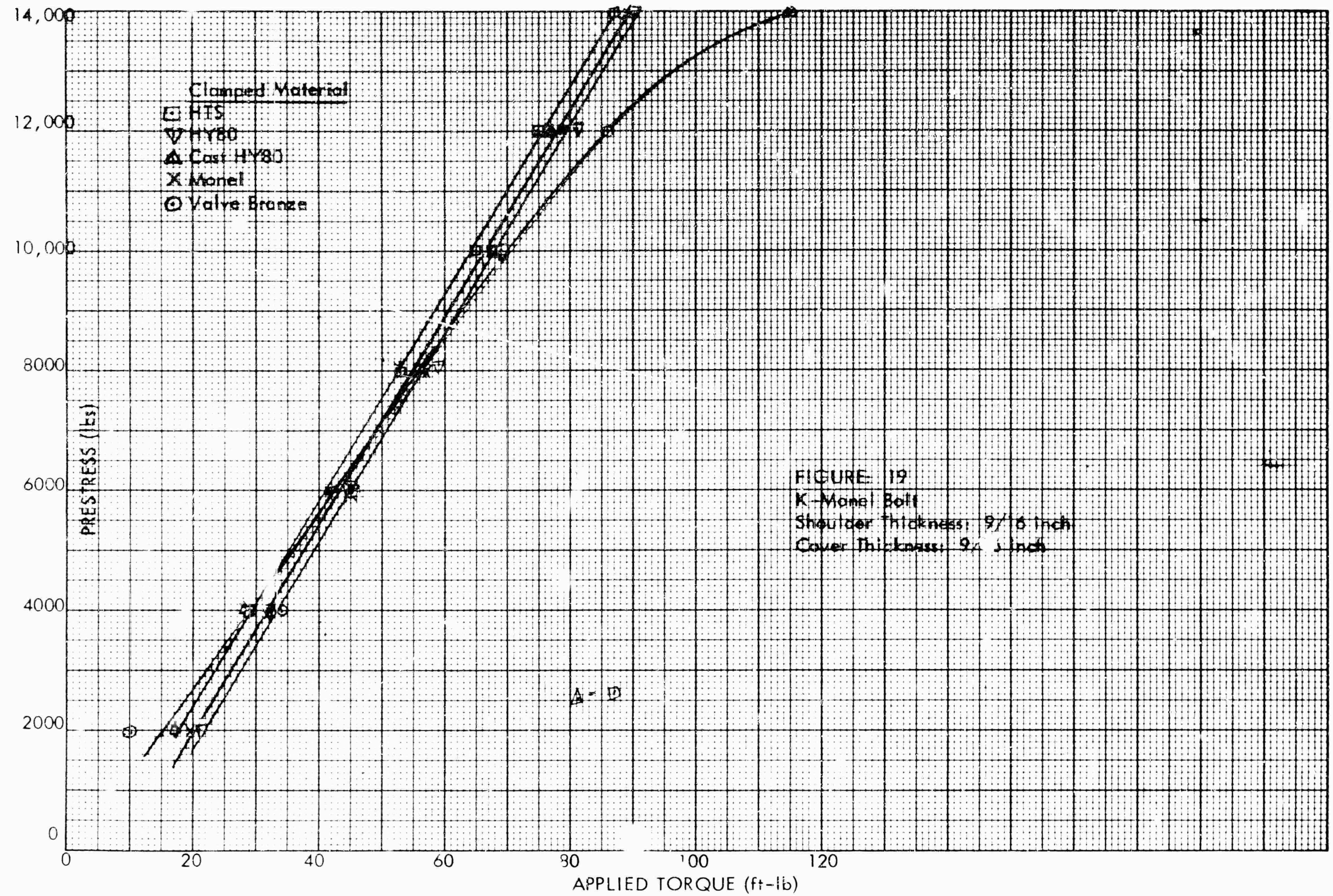


FIGURE 19
K-Monel Bolt
Shoulder Thickness: 9/16 Inch
Cover Thickness: 9/ 6 Inch

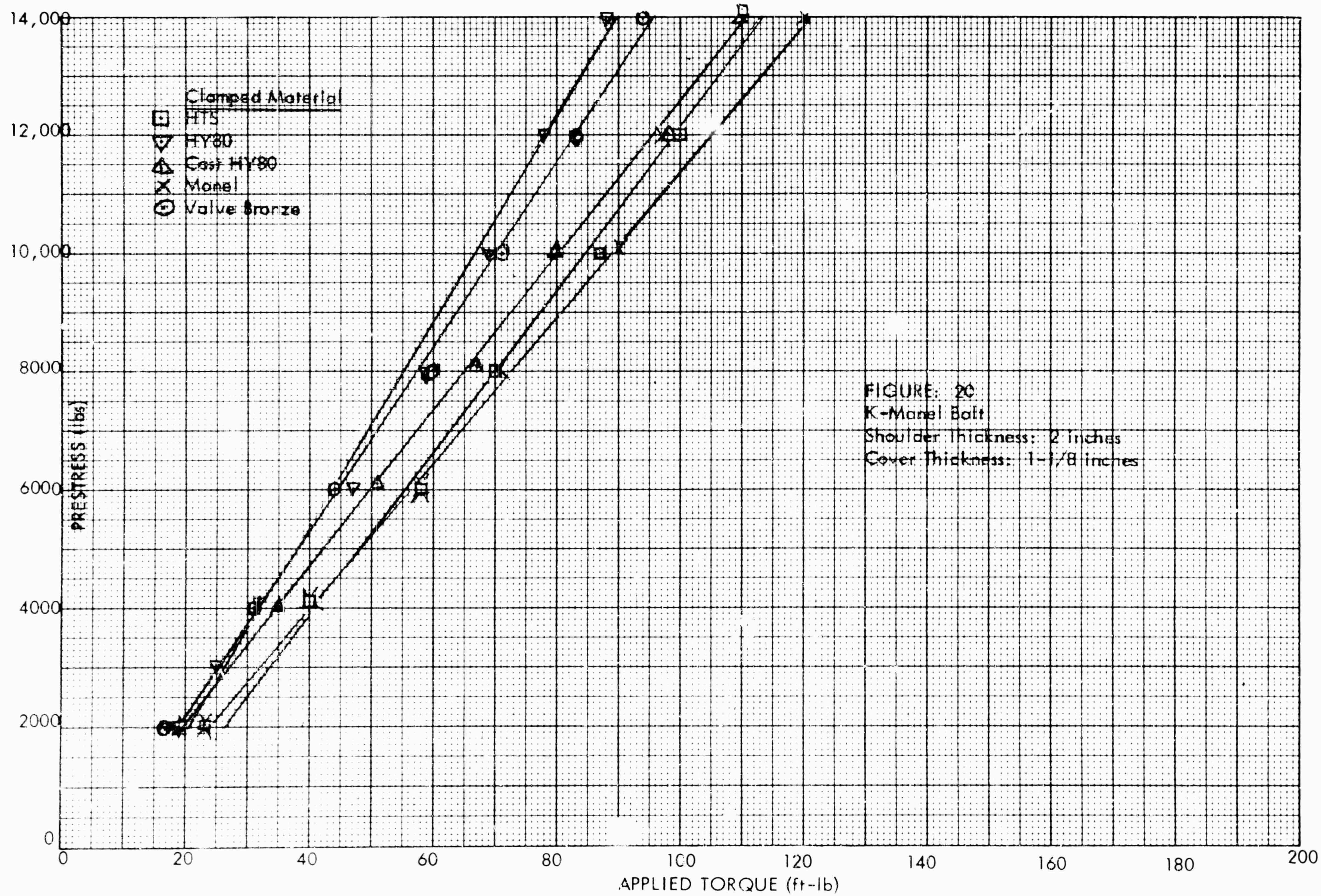


FIGURE: 20
K-Monel Bolt
Shoulder Thickness: 2 inches
Cover Thickness: 1-1/8 inches