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TCG-NNT-1

Case No. 532.00
Ref. Symbol: 1611
Project No. ET-1314
Completed 1/18/54

TO: DISTRIBUTION

Re: Temperature tests of Ball Nut Lead Screws

PROGRAM 1212018 CATEGORY 01 05 0 ORG. 0001 DATE 5 4 6 3

Object of Test

This series of tests was performed as a preliminary study of the performance characteristics of the ball nut lead screw. This type lead screw is incorporated in the MC-342 IFI and the MC-172 IFI. Of special interest was an evaluation of several different wipers, designed to serve as an ice remover for the lead screws. These wipers were considered important since it was realized that any excess of moisture in the ball race or in the ball return tube could cause serious difficulty if a freezing condition were to exist. In this event, the balls could freeze, disallowing all ball movement and hence increasing the friction of the nut on the screw by a high factor. It was hoped that an effective wiper-ball nut combination would be found during the course of these tests.

Authorization for Test

This test was requested by Division 1332 in a Work Order Authorization dated March 4, 1953. Mr. H. Tebbon was the consultant.

Part I-Procedure and Results

The MC-172 was used as the vehicle for the initial ball nut tests. Some general information was desired on the ball nut lead screw operation at the usual environmental temperature conditions. For these tests, the ball nut was fitted with Teflon wipers, one at each end of the nut. The Teflon was designed to assume a close wiping tolerance at approximately -90°F. The difference in the thermal coefficients of expansion of the Teflon wiper and the steel lead screw makes this design necessary. That is, the Teflon would contract more than the steel, hence would bind on the steel if the Teflon was not properly designed. It was hoped that the low friction value—generally observed with the use of Teflon—could be used to advantage as a lead screw wiper. To obtain some indication of the effect of loading the screw, and also to better isolate the cause of any failure that might occur, the unit was operated with and without heelplate at each temperature condition. Typical current and time for these operations, which consisted of three insertions and three retractions, would include:

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ACCOUNTABILITY CARD
FILE No. ~~[illegible]~~ H-5
~~[illegible]~~ alphabetically

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With heelplate			Without heelplate	
Temperature (°F)	Insertion time (sec)	Current (amp)	Insertion time (sec)	Current (amp)
+165	5	3-1/4	5	3-1/2
+ 75	5	3-1/4	5	3-3/4
- 65	8.1	8	11.5	12.5
- 90	12	18	10	16

To determine the ability of the wipers to remove ice from the screw, a thin layer of ice was allowed to form on the surface of the screw at both -65 and -90°F before the unit was operated. The first few tests appeared quite successful as the nut was observed scraping the screw clean of the ice that had formed. Time and current values for the runs also looked reasonable, 15 seconds for insertion and a steady state current of approximately 14-15 amperes. Further tests with the added weight of the heelplate caused wear of the Teflon and eventual failure of the wipers to keep the balls within the nut relatively free of moisture. After about a half-dozen such trial runs, the unit became badly jammed at a -90°F and remained jammed after the temperature was raised to -65°F. It was thus realized that wipers fabricated from Teflon might not prove efficient. It was decided to test other plastic wipers manufactured from other low friction materials to compare with stainless steel wipers and so to determine finally if these plastics should be further considered for use with the lead screw.

Part II-Procedure and Results

The jig shown in Fig. 1 was used for this part of the test. The various wipers were fitted to the ball nut as shown in Fig. 1. The motor, an EB400 IFI motor, could drive the screw and move the nut along the full length of the lead screw and, hence, provide a wear test for the different wipers. A recording ammeter (Brush d-c amplifier and pen meter measuring the voltage drop across a shunt) was used to monitor motor current. The torque required to rotate the screw was measured by a torque wrench on the end of the lead screw as shown in Fig. 1. Two torque wrenches were made especially for this measurement, one 9-inch (used to approximately 600 ounce-inches) and one 5-inch wrench (used to approximately 50 ounce-inches capacity). These wrenches utilized strain gages that had been positioned on the wrench at a point of maximum bending. A Brown Model BL-320 universal analyzer and a magnetic direct inking oscillograph were used for torque wrench calibration (accomplished by static loading) and all test measurements. All measurements were made from the end of the lead screw by making one complete revolution of

the lead screw with the torque wrench. A graph depicting wrench strain was automatically scribed during this revolution. The average value of this curve was determined and compared with original calibration data.

Test measurements were made with the entire jig stabilized at the following temperatures: +165° F, +70°F, +30°F, -10°F, -90°F. At the two latter temperatures, ice was allowed to form over the length of the lead screw surface and an additional set of measurements were made. The measurements taken following each wiper installation are listed below. The order of listing was, in general, the order of actual testing. Measurement Nos. 2 through 7 were made at each temperature condition, except where noted. Number 1 was made immediately following each wiper installation, and No. 8 was made just before wiper disassembly, following all the temperature tests.

Test Measurements

1. The torque required to rotate the screw through the nut. The IFI motor was detached from the jig for this measurement, which was taken at room temperature only, immediately after wiper installation.

2. The steady state current required to operate the unit. An operation consisted of running the nut the length of the screw three times in each direction.

3. The torque required to turn the screw when the IFI Motor clutch was held in the energized position.

4. The same measurement as in No. 3 was made, after the unit had been cycled a minimum of 25 cycles.

5. After ice had been allowed to form (at -10, -65, -90°F), the unit was operated, the current recorded, and the scraping ability of the wiper observed.

6. Ice was allowed to reform at temperature conditions listed in 5, and the torque measurement No. 3 was taken again.

7. A measurement of the torque required to rotate the screw with the motor removed from the jig.

8. The final measurement was made for each wiper at room temperature following all the temperature work. Measurement No. 3 was repeated.

A total of 16 different wipers were tested according to the above general scheme. These wipers were made from various plastics and were designed to

assure a close wiping tolerance at certain temperatures. This is a consideration, since the coefficient of thermal expansion for such plastics runs up to a factor of 10 times that of the steel lead screw. A list of the wipers and the temperature at which they were designed to assume this close tolerance would include:

1. Nylon FM 10001 designed for -30°F
2. Nylon FM 10001 designed for -10°F
3. Nylon FM 10001 designed for -90°F
4. 303 stainless steel
5. Nylatron G designed for -30°F
6. Nylatron G designed for -10°F
7. Nylatron G designed for -90°F
8. Nylatron GS designed for -30°F
9. Nylatron GS designed for -10°F
10. Nylatron GS designed for -90°F
11. Laminated Fiberglas designed for +30°F
12. Laminated Fiberglas designed for -10°F
13. Laminated Fiberglas designed for -90°F
14. Teflon designed for -30°F
15. Teflon designed for -10°F
16. Teflon designed for -90°F
17. No wiper

Results

The torque values, inounce-inches, that were obtained from measurement No. 7 are plotted in Fig. 22 (It was this measurement No. 7 that gave best indication of the effect of the use of the different wipers at the given temperature conditions). This measurement was taken after the motor was removed from the jig, hence represents the torque required to move the nut

on the screw. The torque required to turn the lead screw in its bearings was checked at intervals and found to be too small to use as a corrective factor. As would be expected, the lowest readings appear for the cases when no wiper was used. Teflon gave fairly low torque values as would be expected, but all the Teflon samples failed to operate at the extreme temperature of -90°F. The wipers became chipped and caused the entire unit to become jammed, as in the case of the MS-172. The stainless steel wiper gave fairly low readings going to a high of only 38 ounce-inches at -90°F.

Table I lists a composite summary of data obtained from measurements listed above as items 2, 5, and 6. Item 3 is not separately mentioned since the difference in readings would be no greater than 10 percent of the value listed as item 4. The table is considered self explanatory and will not be further detailed. To obtain a list of wipers that still appear worthy of lead nut association, we accept the results tabulated for stainless steel (two such tests with stainless steel were performed with agreement within 15 percent) as a criterion. That is to say, we need not further consider the utilization of any wiper that appears to have a greater torque requirement than stainless steel, since this is the main reason plastics were being investigated for such use, i.e. to make use of the low friction coefficients generally associated with these materials. Those wipers giving, in general, lower order torque and current readings would include:

No. 3 Nylon designed for -90°F

No. 6 Nylatron G designed for -10°F

No. 10 Nylatron GS designed for -90°F

No. 11 Laminated Fiberglas designed for -30°F

No. 12 Laminated Fiberglas designed for -10°F

No. 13 Laminated Fiberglas designed for -90°F

To further narrow this list down, we may compare these attributes with the results shown in Fig. 2, where the same wipers were tested to measurement No. 7. We note that only Nos. 6 and 13 appear about as good as stainless steel. The difference is small and does not stand out as a deciding factor.

As a final attempt at analysis, we may look at the data obtained from the measurements described above in items 1 and 8 (Table II). In general we see indication that the plastics have been worn down during the series of tests and no longer present the tolerances originally specified. The other extreme appears in the form of much higher torque values following all tests

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indicating binding caused by wiper damage. There are five notable exceptions to these two extremes just mentioned. That is to say, five of the wipers remained fully intact and retained a good tolerance and fit throughout the series of tests. These we identify from Table II as wipers Nos. 4, 6, 10, 12, and 13. The first of these is the stainless steel. We note that wiper Nos. 6 and 13 have been shown to be satisfactory from the analysis of all other data. Hence, we find these two materials showing up best. They are Nylatron G and laminated Fiberglas. A final choice might be readily made by noting that two of the Nylatron G series failed under -90°F test. This then (at least as a result of this data) leaves the Fiberglas series as the superior material for such use. Again, however, there is no startling evidence contained in any of the data that would have Fiberglas used in place of stainless steel. Since stainless steel wipers present no difficulties in retaining the tolerances at all temperatures, they are to be preferred.

In passing, it should be worth noting that the ball nut used in this test traveled the full length of the lead screw approximately 10,000 times. The lead screw and nut showed little visible evidence of their extended use.

Test Conducted by R. S. HOOPER-1611-4

Original Signed By
B. R. DAUBERT

RSH:1611-4:bb

Approved by B. R. DAUBERT-1611-1

Enc. Tables I and II, Figs. 1 and 2

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TABLE I

Current and Torque Values Obtained in Wiper Ball Nut Tests

Wiper no.	+165°F Current (amps)	+165°F Torque (ounce-inches)	+70°F Current (amps)	+70°F Torque (ounce-inches)	[illegible]°F Current (amps)	[illegible]°F Torque (ounce-inches)	-10°F Current (amps)	-10°F Torque (ounce-inches)	-90°F Current (amps)	-90°F Torque (ounce-inches)
1	7	60	7.1	60	7	50	9	110	11	540
							9.5*	145*	12.5*	610*
2	7	52	7	52	7	42	8	86	10	560
							9*	137*	11.5*	580*
3	6.7	60	7	55	8	80	8	140	8.7	170
							9*	210*	10*	200*
4	7	100	7.5	110	8.5	110	9.5	140	10.3	232
							10.5 *	165*	11*	256*
5	6.2	72	7	67	7.2	85	9	200	25.5	253
							24*	170*	47**	426*
6	7	51	7	50	8	90	7.8	68	9.5	190
							9*	150*	9.5*	212*
7	6.3	50	7	49	7.3	62	7.3	70	13.5	340
							16.3*	223*	45**	558*
8	6.8	68	7.7	95	7.5	58	7.5	64	10.5	223
							25*	110*	25*	320*
9	6.8	55	7.5	85	8	62	9.3	181	10	362
							20*	130*	25*	408*
10	7	58	7.4	64	8	72	7.3	77	9	224
							14*	40*	13.5*	298*
11	7.2	54	8.5	72	8	85	8.5	85	9.2	213
							9.3*	150*	18*	256*
12	7	81	8	138	8.5	107	7.8	102	9.5	138
							9.5*	106*	10*	234*
13	6.3	64	7	60	7.5	69	8	94	10	191
							10*	127*	10*	324*

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TABLE I (cont.)

Current and Torque Values Obtained in Wiper Ball Nut Tests

Wiper No.	+165°F Current (amps)	+165°F Torque (ounce-inches)	+70°F Current (amps)	+70°F Torque (ounce-inches)	+30°F Current (amps)	+30°F Torque (ounce-inches)	-20°F Current (amps)	-20°F Torque (ounce-inches)	-90°F Current (amps)	-90°F Torque (ounce-inches)
14	7	64	7.5	77	8	94	9.5 15*	106 136*	13 45**	212 250**
15	7	64	7	73	8	94	8.5 25**	90 139**	no test	
16	7	64	7.3	81	7.5	85	8 25**	106 115**	no test	
17	7	43	6.7	45	7	57	7.7 11*	66 80*	9.3 11*	225 250*

* Denotes values obtained during ice removal tests

** Denotes cases where the unit became jammed; further tests were discontinued

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Table II

Comparison Between Torque Values Before and After Measurement

Wiper No.	Torque before all tests (ounce-inches)	Torque after all tests (ounce-inches)
1	no recording made	no recording made
2	no recording made	no recording made
3	12.3	0.33
4	1.0	1.0
5	2.5	8.0*
6	1.5	1.2
7	.8	98.0*
8	1.9	wiper destroyed
9	1.2	wiper destroyed
10	1.8	5.9
11	21.3	1.3
12	1.4	0.5
13	1.3	2.8
14	7.2	1.6
15	9.0	38.0*
16	2.0	2.4*
17	1.1	7.8

* Indicates that the wiper had been noticeably chipped or cracked in the course of the testing

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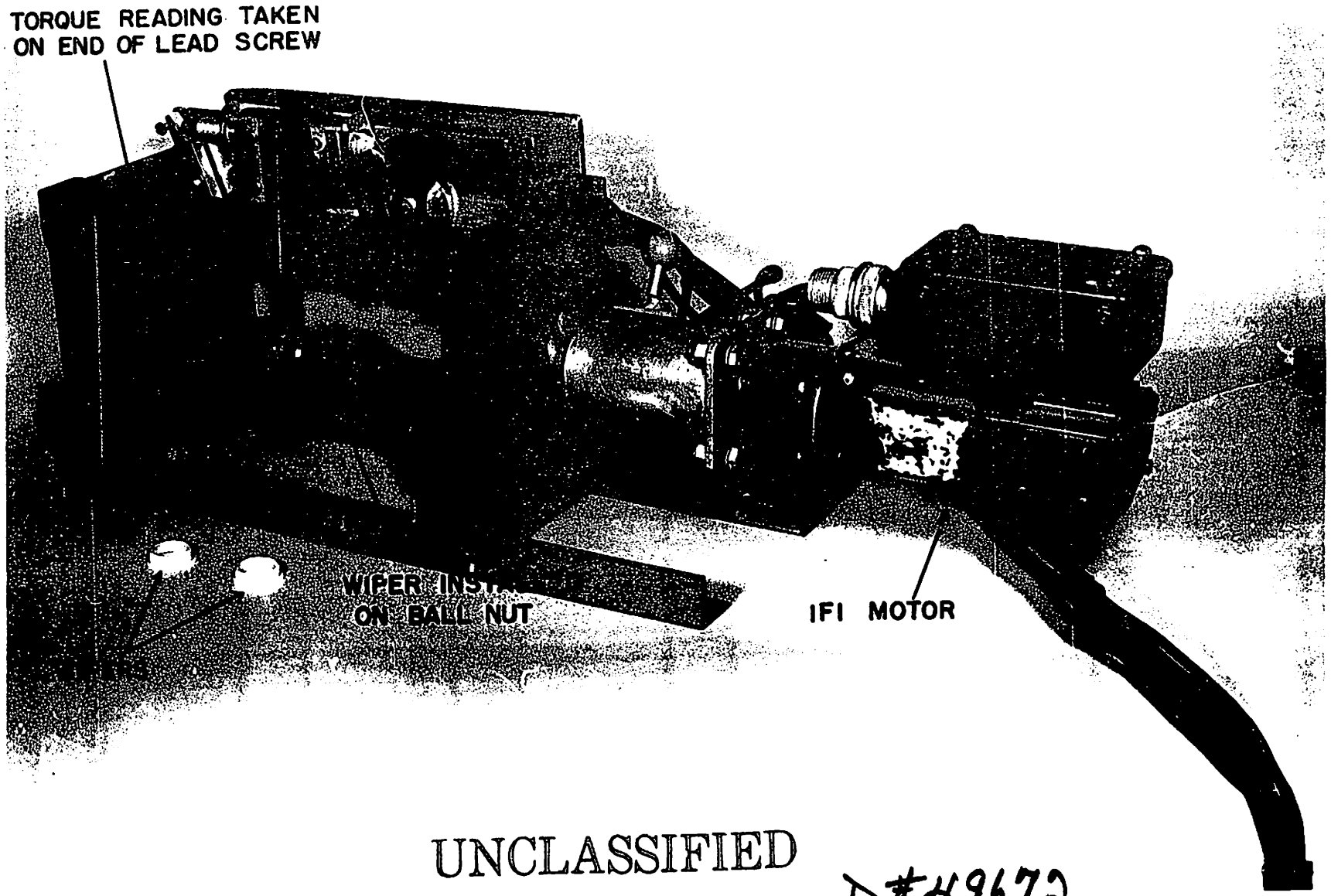

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FIG. 1 - JIG FOR THE BALL NUT LEAD SCREW TESTS

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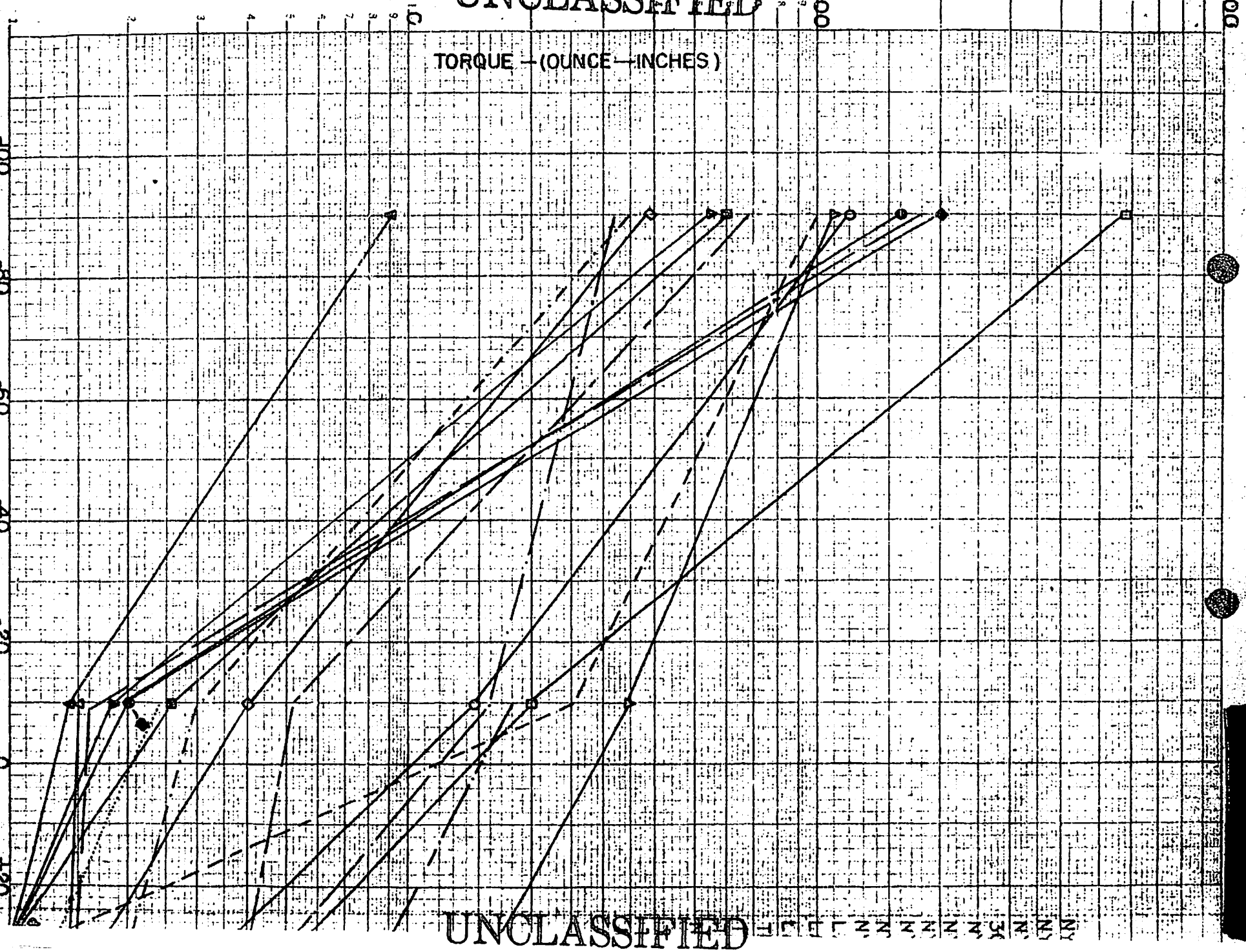

FIG. 2 — TORQUE VALUES RECORDED

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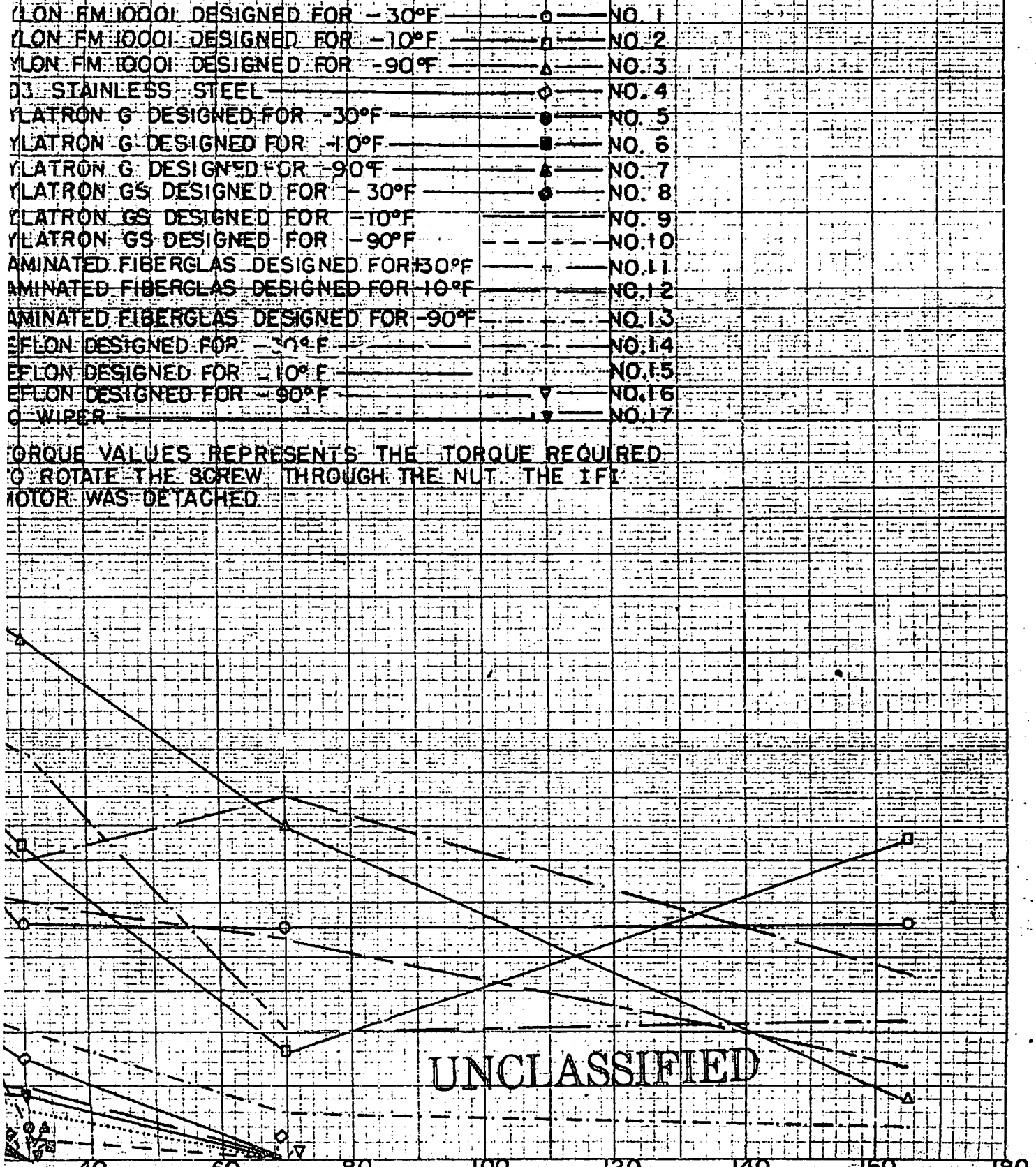

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