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SM-2 CLUTCH TESTING

By

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ABSTRACT

The criteria and methods for test evaluation of electro-magnetic clutch characteristics are discussed. An evaluation of the relative merits of two commercial clutches, both of the multiple disc friction type, is presented with test results. One of these clutches, the Stearns Model GS-506, was incorporated in the clutch assembly design for the SM-2 Reactor Program. The other clutch, the Maxitorq series 8000, size 23, was an optional selection for this purpose. Neither had been tested by usage and selection was on the basis of manufacturer's information. The testing performed gives only a sampling of the numerous commercial electro-magnetic clutches available.

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1.0 SUMMARY

The comparative testing of one Stearns and one Maxitorq clutch yielded the following results:

	Stearns			Maxitorq	Stearns (Re-Test)
	.032 air gap	.016 air gap	.024" air gap		
Rated Torque (lb.-ft.)	90	90	90	75	90
Breakaway Torque (lb.-ft.	42.5	130.0	85.0	140 (a)	60.0 (b)
Slippage Torque (lb.-ft.)	38.0	----	----	133 (a)	58.0 (b)
Average release time (sec.)	----	----	0.030	0.015	0.026
Rated Voltage	24	24	24	24	24
Inductance - dis-engaged (mh)	----	----	108.0	49.0	108.0

NOTES: (a) Readings taken at 20 volts. At the rated 24 volts, torque exceeded this value and could not be determined without anchoring test stand.

(b) Taken with air gap reduced to 0.024" and rated 24 volts to clutch. Circuit the same as that used for Maxitorq test.

The geometry of the test stand and wiring has inherent weaknesses. These consist of switch time (lag or lead), release time readout of the selsyn, frictional resistance of the pulley cable and voltage feedback from the clutch voltage recording galvanometer circuit. The errors induced by these imperfections are, however, the same for the testing of both clutches, therefore, yielding a good comparison. The resulting cumulative errors are included in measured times. Calculations indicate that these errors result in release times 0.005 seconds higher than the theoretical possible under ideal testing.

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2.0 INTRODUCTION

An important feature of reactor control design is the ability to shutdown rapidly in an emergency. The maximum permissible time for this operation is normally less than one second if extensive damage to the reactor is to be avoided. To obtain minimum scram time with a mechanically driven control system, the clutch release time must be the minimum obtainable consistent with reliable performance.

As part of the SM-2 program under Contract AT(30-3)-326 with the Atomic Energy Commission, Task 11 was set up for Control Rod Drive Development. A natural sub-task of this development was the investigation of clutches. Although time had not permitted testing of the Stearns clutch picked for the SM-2 rod drive prior to incorporation in the design, it was necessary that the clutch was proven satisfactory before start of production of the prototype drive. A task sub-division, Task 11-5, was set up for this purpose. It was planned that the selected clutch and one or two others of approximately the same size and with similar characteristics would be tested at the same time. This would provide valuable background for future design. A second clutch, the Maxitorq Model No. 23, was used for comparison testing.

This report covers the procedures, testing, results and conclusions of these tests. Both clutches were operated at 24 volts, although they had been ordered as 90 volt clutches. The instrumentation group recommended the reduction to 24 volt coils to better adapt the clutches to the transistorized circuit of the reactor. The reduction in voltage also reduced the amplitude of the peak inverse voltage upon de-energizing of the clutch. Special coils were installed by the manufacturers to fit Alco requirements.

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3.0 GENERAL TEST PROCEDURES

The purpose of this testing was to determine the torque, release time and inductance for the two clutches. Following is the description of the methods employed in obtaining the values for these characteristics.

3.1 Break-away Torque

These readings were taken with the clutch mounted on the test rig as shown in Fig. 1. With the drive motor turned off, the voltage to the clutch was slowly increased until the clutch engaged. Torque readings were then taken at even voltages from the first even voltage above engagement up to the 24 volts for which the clutch is rated. The reading taken was that at which the clutch discs failed to hold, or rotational slippage began (static break-away).

3.2 Slippage Torque

This torque is the value at which the discs slip past each other with the clutch engaged. The readings were taken with the motor driving and the clutch coil energized, but the driven shaft held with a torque wrench. As with the break-away torque readings, slippage was measured at even increments of voltage above engagement value.

3.3 Release Time

A 27 lb. weight was attached to the pulley with 1/16" diameter flexible wire rope. This weight operating on a three inch radius pulley gives a constant torque of 81 lb.-in. This was earlier calculated to be approximately the torque exerted by the control rod and accelerating springs, less the hydraulic lift force and frictional drag. With the drive motor operating, the clutch is energized and the weight is lifted gradually to about the level of the stand. The Visicorder is then turned on, the clutch released and the Visicorder turned off. Clutch characteristics were determined by analysis of the tapes.

3.4 Inductance

This was measured on a standard inductance bridge with the clutch in a dismounted position and the coil de-energized.

Figure 1 - Test Facilities

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4.0 STEARNS CLUTCH TEST

The clutch was arranged for testing on the test rig, Drawing R9-50-1060 (Fig. 2) and instrumented as shown in Fig. 1. The final circuit used in testing is shown in Fig. 3.

Prior to making drop tests, the break-away torque and slippage torque were determined for varying voltages. Below ten volts, the clutch failed to engage. With a magnetic air gap of 0.032", as specified by manufacturer, and with full wave rectified voltage to the clutch coil, the break-away and slippage torques were measured with a torque wrench applied directly to the end of the shaft on which the pulley was mounted. First readings (Appendix, Table 1A) revealed torque of less than half of the rated ninety lb.-ft. value. Breakaway and slippage torque are shown graphically in Fig. 4. Since a slight increase in torque appeared to occur with additional slippage, the clutch was run in by slipping it a total of 90 revolutions, taking readings after every thirty revolutions (Appendix, Table 1B). Plotted results are shown in Fig. 5. This slipping failed to bring the clutch to rated torque, so the air gap was narrowed at the recommendation of the manufacturer. At half the rated air gap (0.016"), the clutch exceeded rated torque (Appendix, Table 2A). The air gap was adjusted to three-quarters of rated value and torque was found to be approximately rated value (Appendix, Table 2B). This setting of 0.024" air gap was used for running the drop tests. The plot of torque vs. voltage with the three different air gaps is shown in Fig. 6.

Early simulated scram testing of the clutch was done with two galvanometer pickups on a Visicorder. One galvanometer was across the clutch coil and picked up voltage decay. The other galvanometer was connected with the selsyn and picked up the start of motion when the clutch released. For early Stearns testing, 60 cycle current was fed to the selsyn. The point of release was difficult to determine accurately with 60 cycle input. On later traces the input to the selsyn was changed to 400 cycles.

The results of 100 drops with the stearns clutch indicated an average release time (clutch voltage decay to start of motion) of 0.0314 sec. (Appendix, Table 3). A third galvanometer was added after this test to determine switch release time. Various circuit arrangements were tried, taking one to three tape recorded drops of each revision, until the circuitry shown in Fig. 3 was evolved. With this improved circuit, a series of ten drops was made with visicorder traces of every other drop. The average release time was found to be 0.0296 sec. (Appendix, Table 3).

Following testing for torque and release time, the clutch was removed and coil inductance measurements were made.

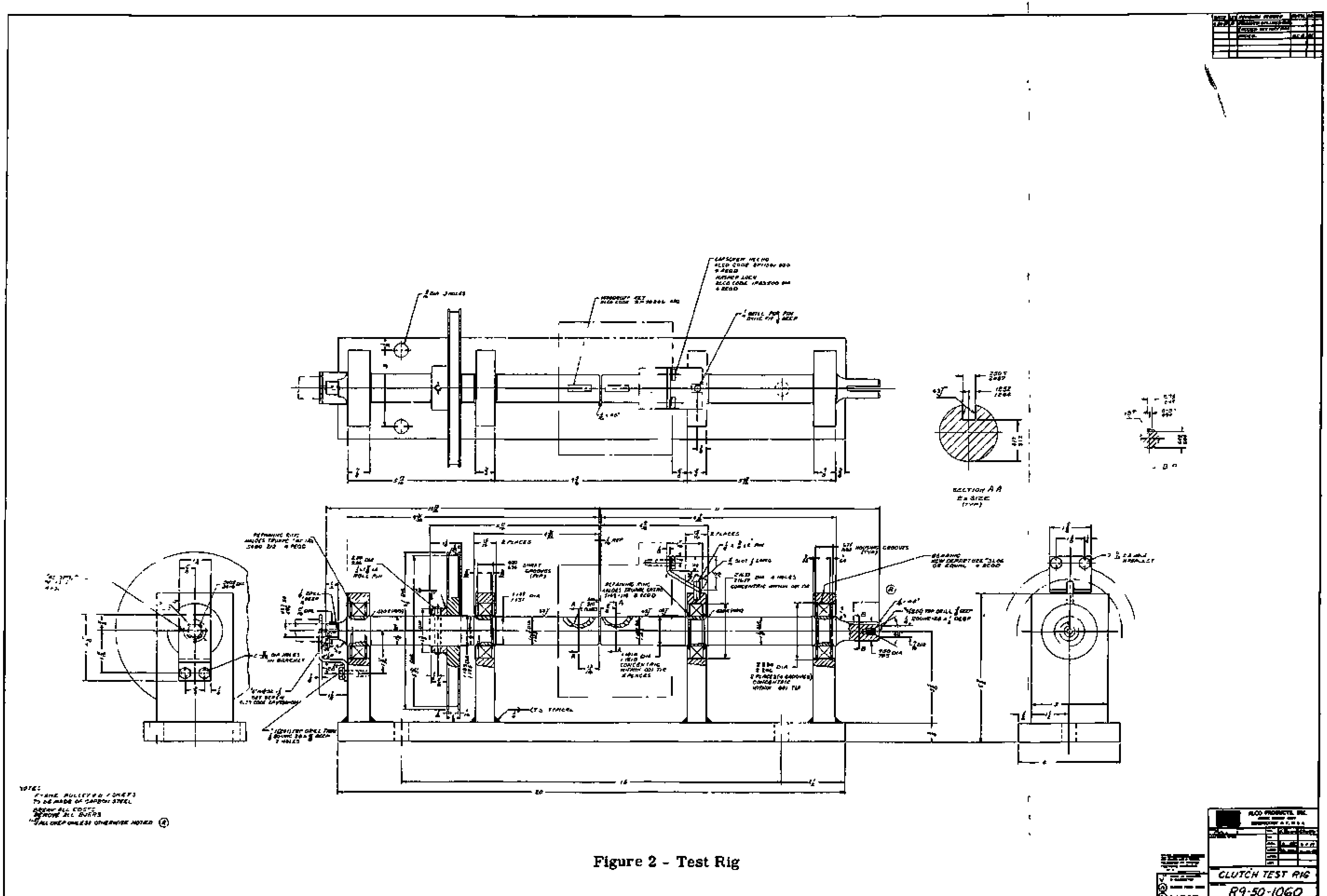

Figure 2 - Test Rig

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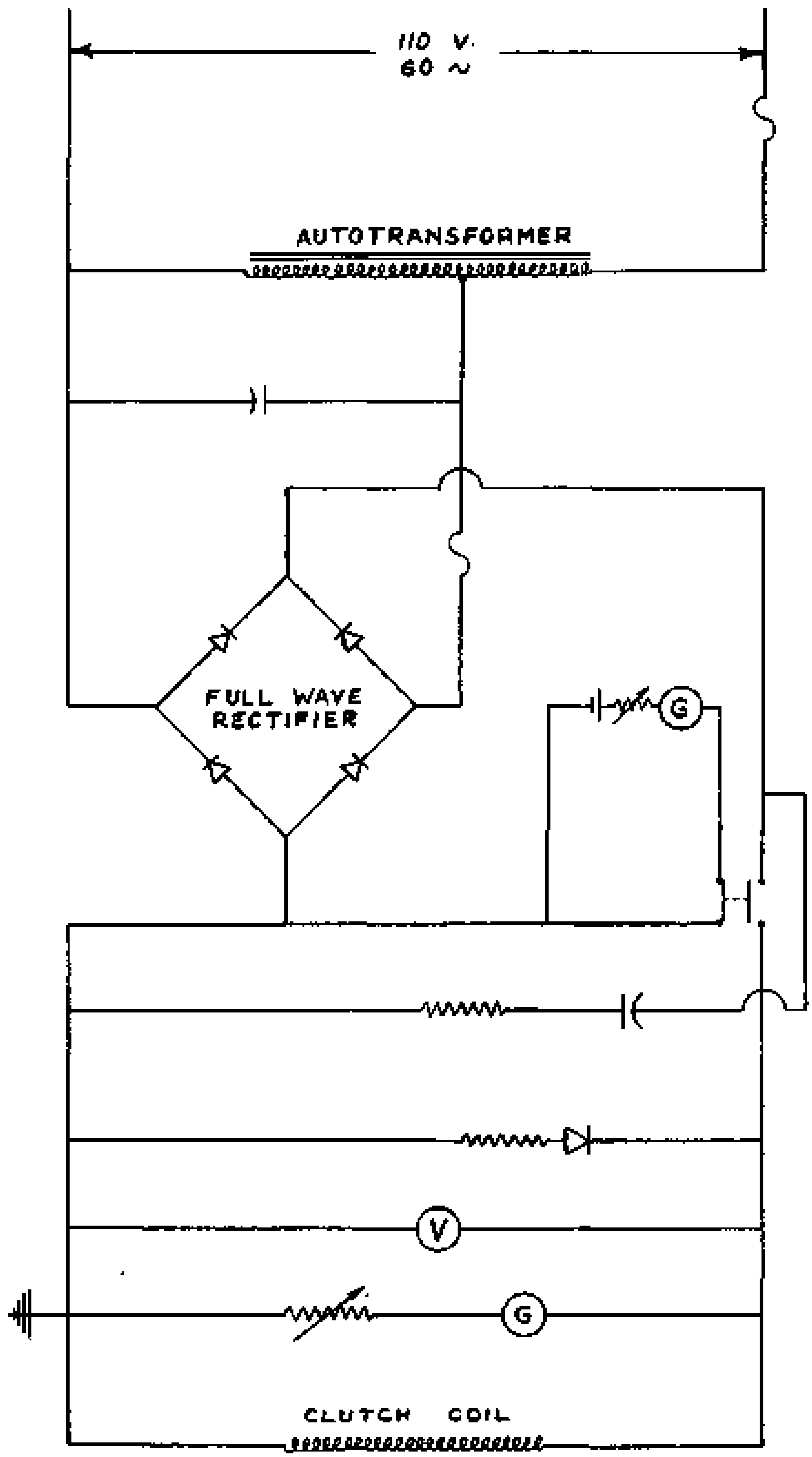

Figure 3 - Stearns Clutch Test Electrical Schematic

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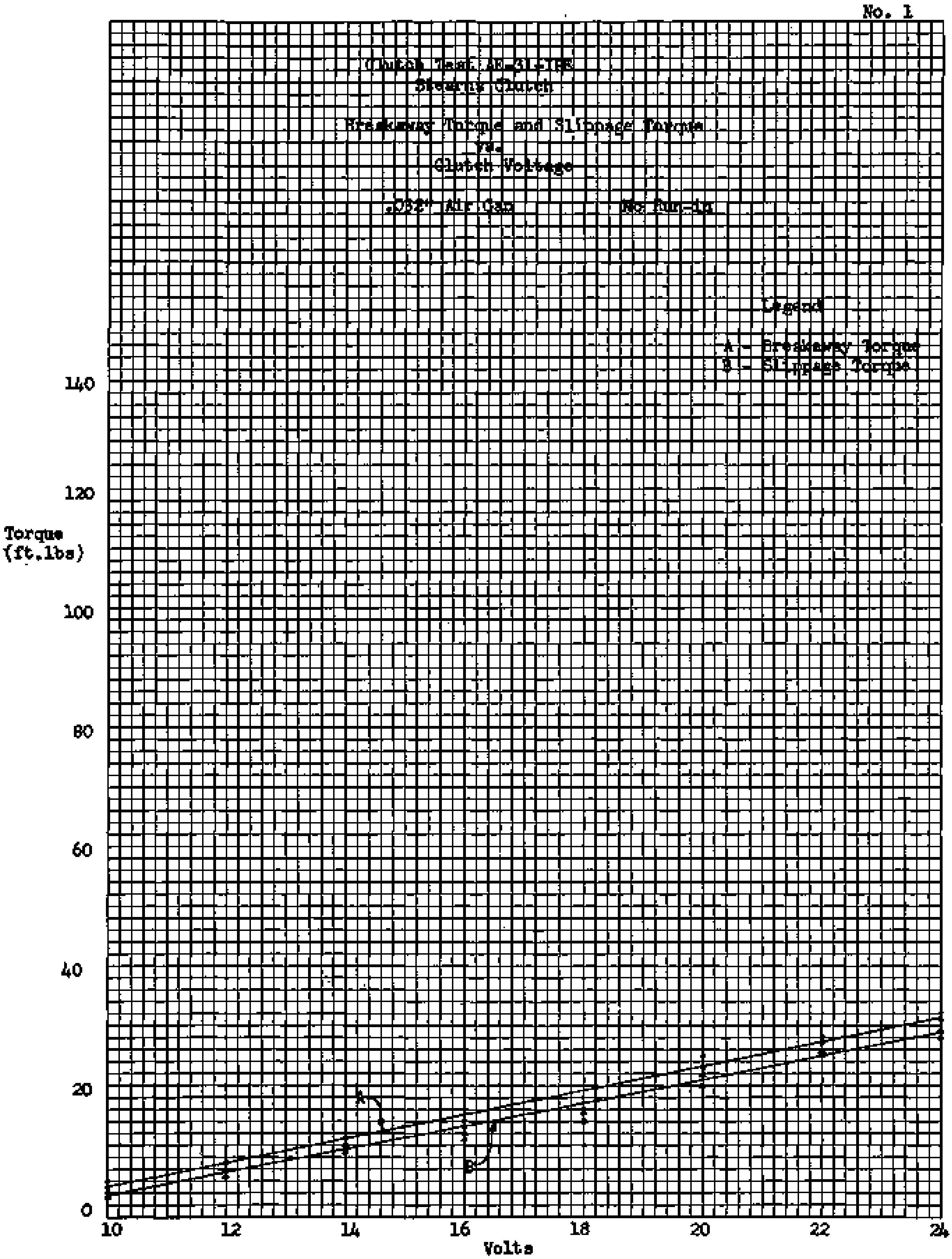

Figure 4 - Stearns Clutch - Torque vs. Voltage

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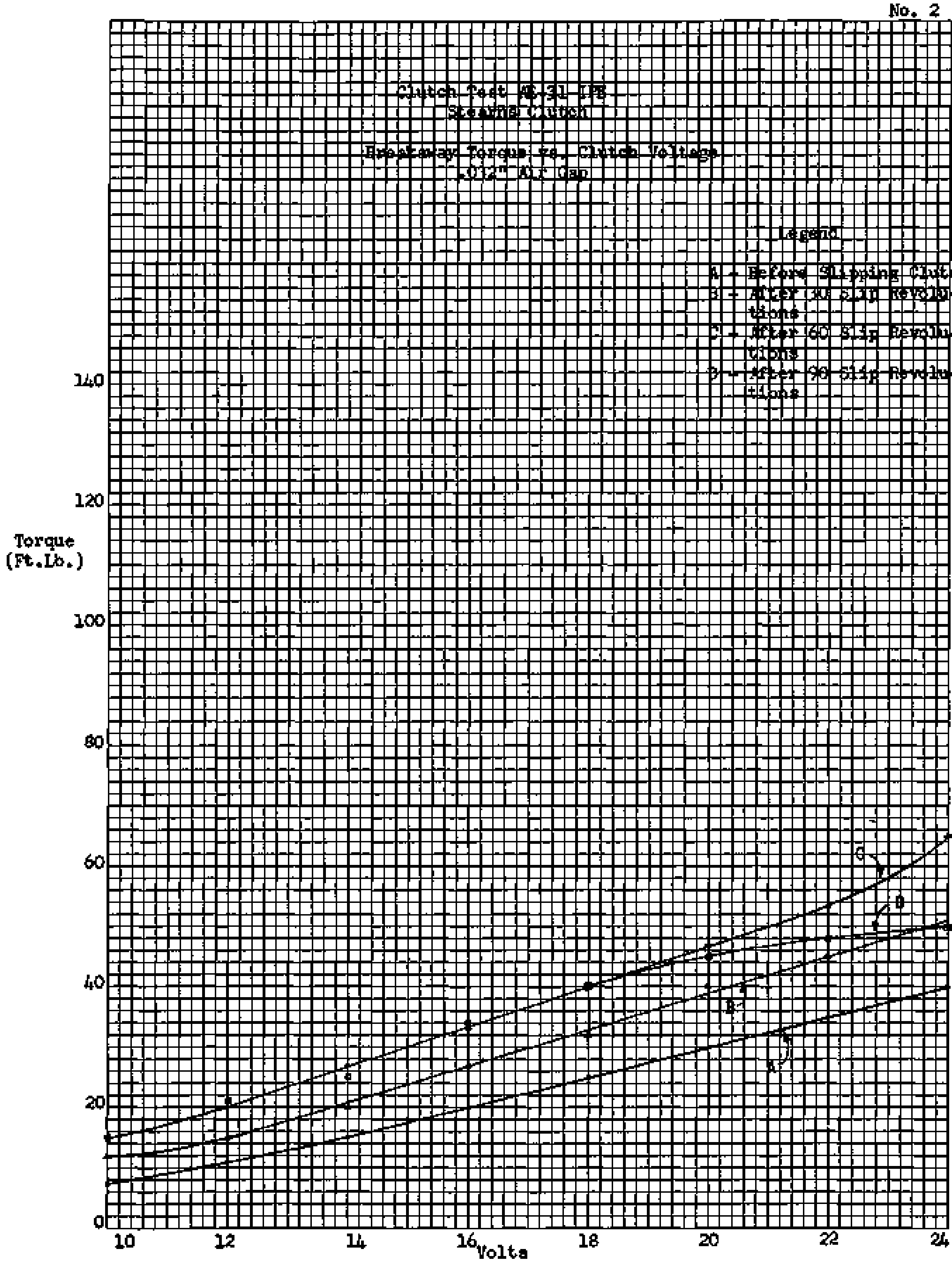

Figure 5 - Stearns Clutch - Torque vs. Voltage

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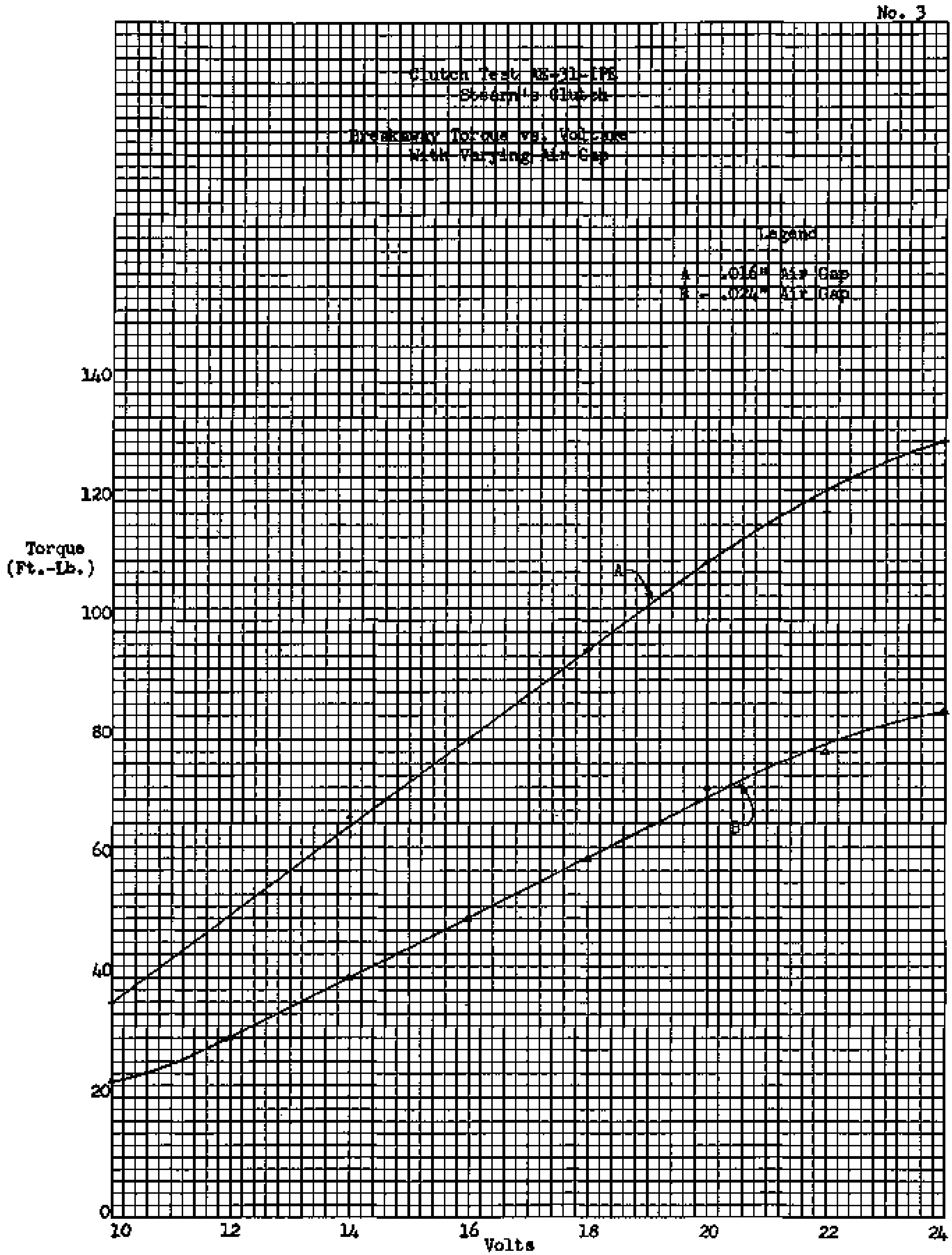

Figure 6 - Stearns Clutch - Torque vs. Voltage

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5.0 MAXITORQ CLUTCH TEST

The clutch was arranged for testing on the test rig as modified to drawing AED-441 (Fig. 7). The circuit for this test was as shown im Fig. 8. The difference between this circuit and that used for the previous Stearns clutch test is the addition of a filter in this test to smooth out the rectified current. Both lines connecting the rectifier to the clutch coil were disengaged simultaneously.

A torque wrench was applied to the end of the shaft on which the pulley was mounted. The voltage to the clutch coil was increased until the clutch engaged. Breakaway torque and slippage torque readings were then taken at two volt increments. Above 20 volts to the clutch, the torque was in excess of what could be read without anchoring the table. These results are shown graphically in Fig. 9 (Appendix, Table 4). The torque capacity of the clutch at 20 volts was 140 lb.-ft., almost double the rated 75 lb.-ft. value. It was not considered necessary to go to added expense and delay to positively determine torque at rated voltage, since it was known that this was in excess of the value at 20 volts.

The clutch was given a series of 100 simulated scrams, taking visicorder traces of every tenth scram. Study of these traces revealed an average release time for the clutch of 0.0149 seconds. (Appendix, Table 4).

The clutch was then removed from the test rig and coil inductance measurements were made. The de-energized clutch coil inductance value was found to be 49.0 mh.

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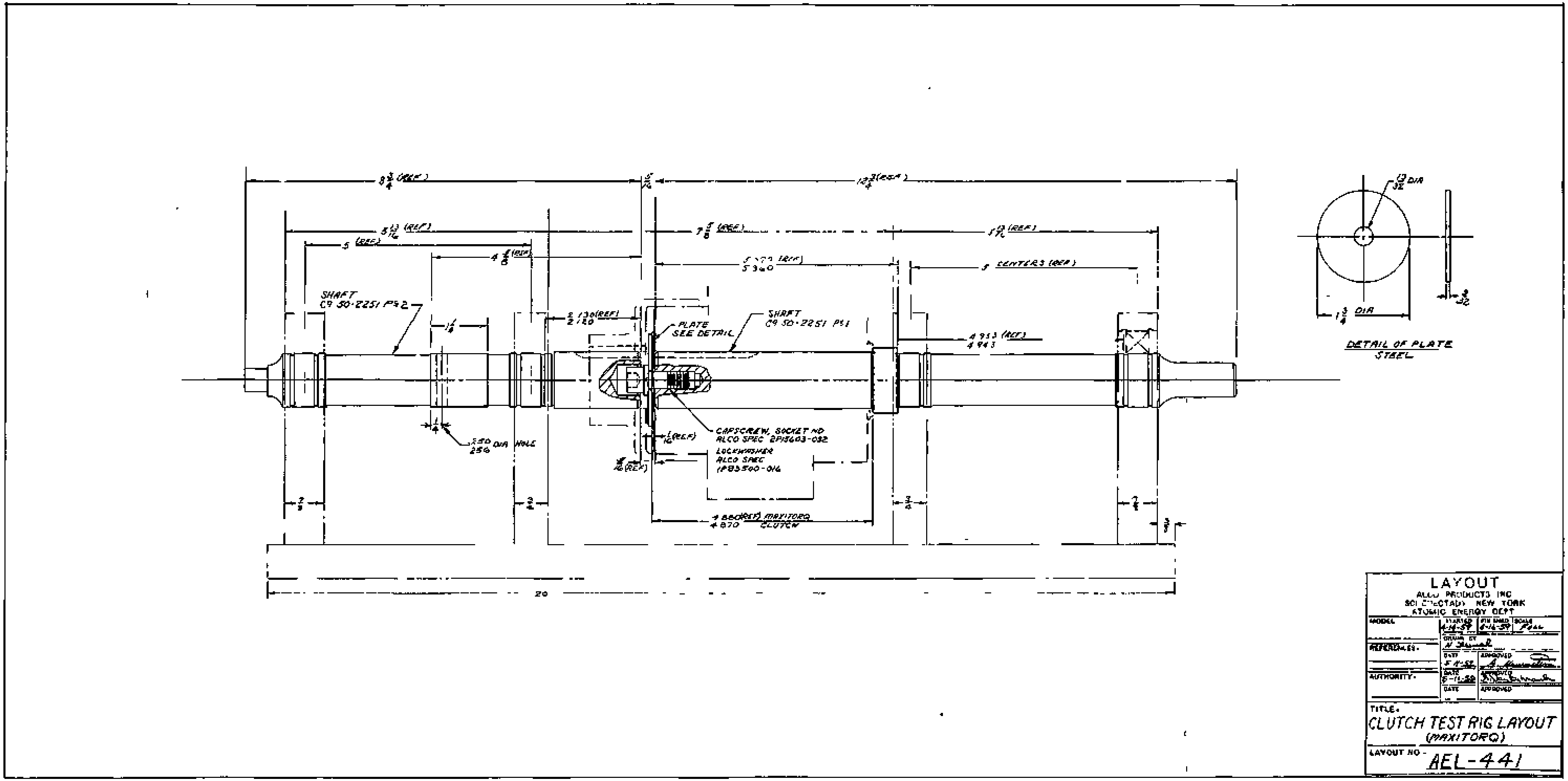

Figure 7 - Maxitorq Test Rig

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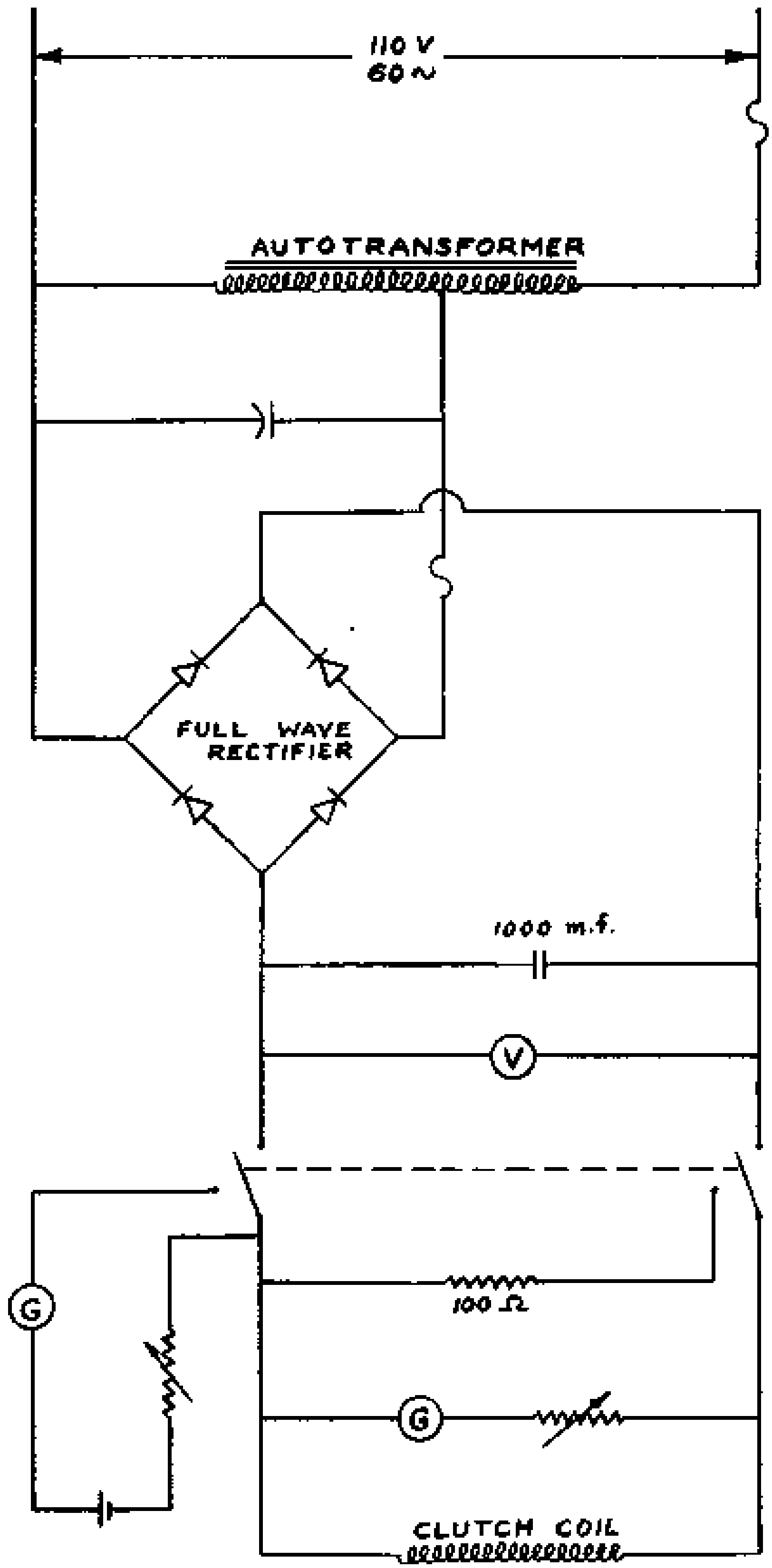

Figure 8 - Maxitorq Clutch Test Electrical Schematic

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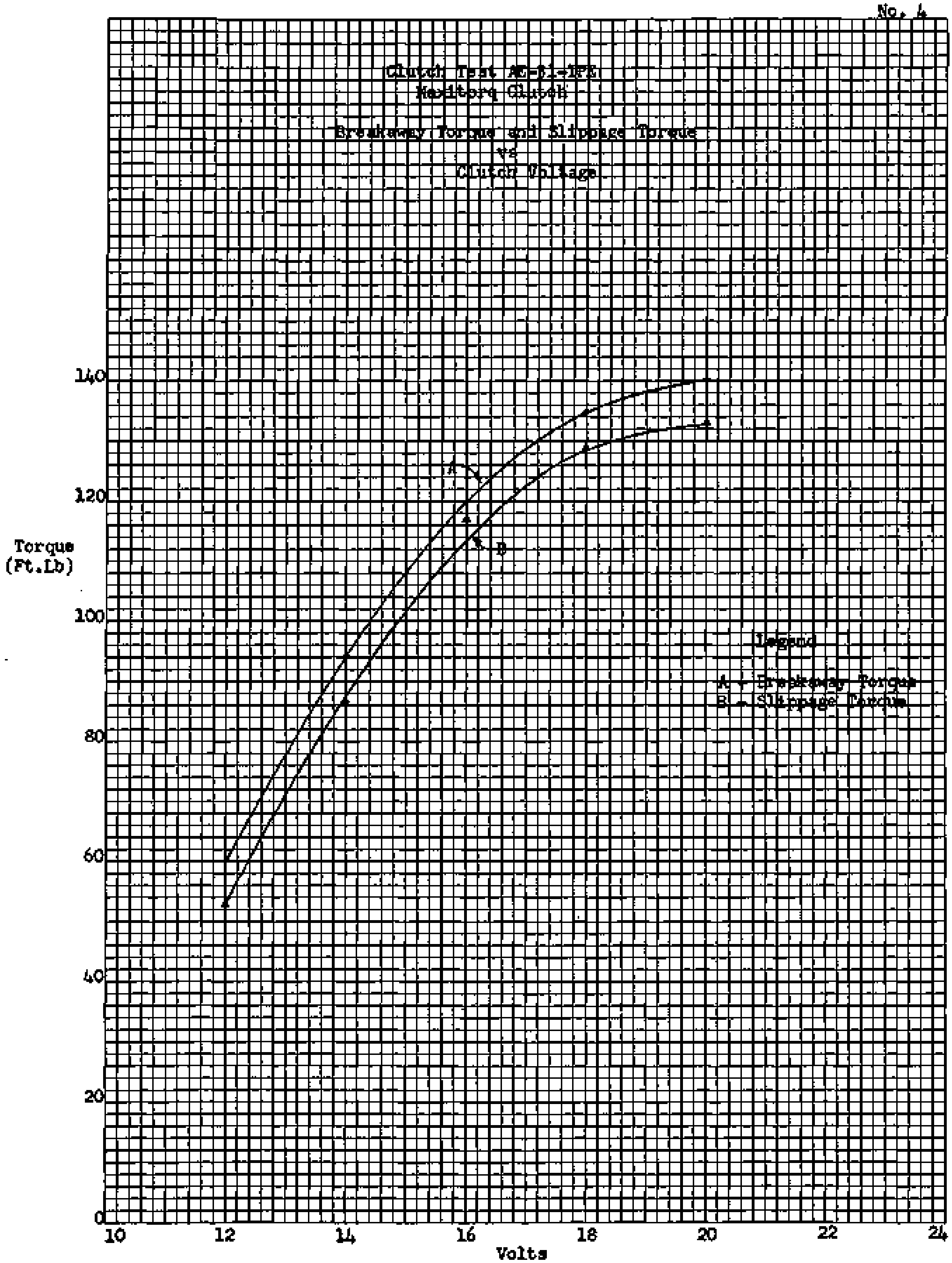

Figure 9 - Maxitorq Clutch - Torque vs. Voltage

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6.0 RE-TEST OF STEARNS CLUTCH

It was felt that the revised circuit, as used for the Maxitorq clutch testing, would be an improvement over the circuit formerly used for testing the Stearns clutch. The Stearns clutch was, therefore, remounted on the rig to test torque and release time with this circuit.

The breakaway torque, as shown in Fig. 10, was found to be considerably lower than that of the earlier test (Fig. 6 - 0.024" air gap). This was probably due to a decrease in flux. On the earlier testing, the voltmeter indicated the same voltage, but the peak full-wave unfiltered rectified value was actually greater than the peak voltage with the filter inserted in the circuit. For this reason, when reading the clutch voltages on a r.m.s. voltmeter, the flux would be greater in the case of the unfiltered voltage due to this higher peak voltage. During the period that the Stearns clutch was not mounted on the rig, the relative position of the discs probably changed. This change could cause a poorer contact between the discs and yield a lower frictional force and result in less torque. Drop time in this testing was better than that of the first test, averaging 0.0263 seconds per release. (Appendix, Table 5)

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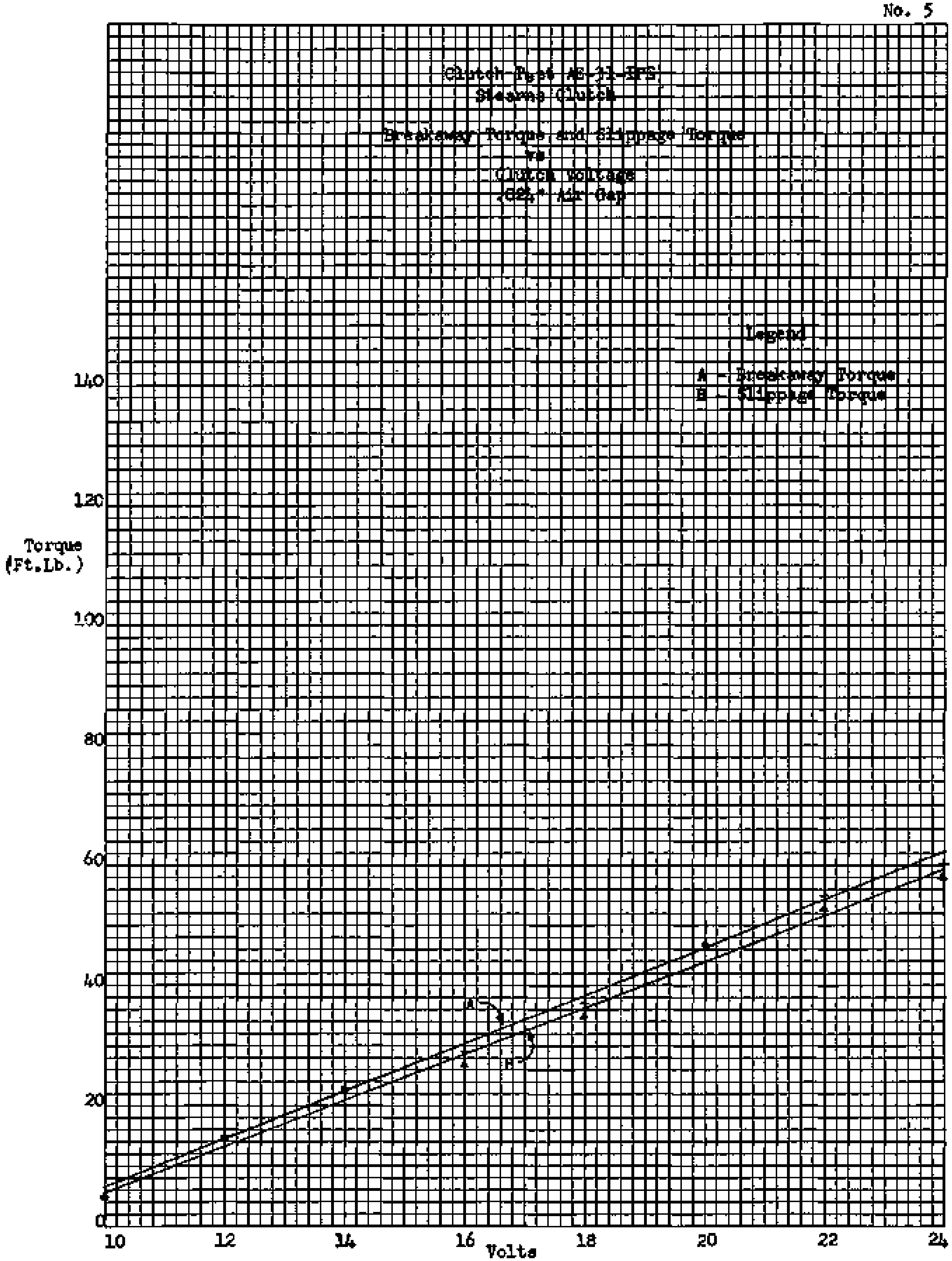

Figure 10 - Stearns Clutch - Torque vs. Voltage

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7.0 CONCLUSIONS

The testing of the two clutches under the same conditions shows significant differences. Although both clutches have an average release time acceptable for drive application, the faster release time of the Maxitorq clutch is a definite advantage.

Either clutch will transmit adequate torque to assure positive drive of the control rod. In the case of minor malfunctions, the higher torque of the Maxitorq clutch might prove advantageous. The Maxitorq clutch also has the advantage of not requiring air gap adjustment. The air gap of this clutch is set by the machining tolerances for mounting.

The mounting of either clutch in a control rod drive assembly can be readily arranged. The Stearns clutch has already been adapted to the SM-2 control rod drive.

Both of the clutches tested lack the ability to give a positive lock such as is obtained with a tooth-type clutch, and both have relatively high drop-out voltage. Independent testing of a tooth-type clutch has indicated a drop-out voltage of slightly more than 10% of rated as compared with slightly less than 50% of rated voltage for both the Stearns and Maxitorq clutches.

It is recommended that further testing of clutches be conducted to determine an optimum clutch for control rod drive application. Since the testing of these two clutches, information on several new models has been received. Of these new models, the tooth type clutches appear to be potentially superior to the two friction type clutches already satisfactorily tested. The experience obtained from these tests has indicated areas in which the test arrangement could be refined to obtain a higher degree of accuracy.

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8.0 APPENDIX

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TABLE 1

STEARNS CLUTCH - TORQUE TESTING

A. Breakaway and Slippage Torque vs. Clutch Voltage
Air gap between magnet and plunger body 0.032".

	Torque (lb.-ft.) Run #1		Torque (lb.-ft.) Run #2	
Voltage	Breakaway	Slippage	Breakaway	Slippage
10	5.0	4.5	6.0	3.6
12	9.0	8.0	9.0	7.0
14	12.0	11.0	13.0	12.0
16	15.0	13.0	16.0	14.0
18	18.0	16.0	18.0	17.5
20	25.0	22.0	27.0	24.0
22	29.0	27.0	30.0	27.5
24	33.0	30.0	34.0	31.0
26	37.0	33.0	37.5	35.0
28	42.5	38.0	42.5	38.0

B. Breakaway Torque vs. Clutch Voltage Effects of slip revolutions - .032" air gap

	Torque (lb.-ft.) after slip revolutions			
Voltage	0 Rev.	30 Rev.	60 Rev.	90 Rev.
10	7.5	12	15	15
12	11	15	20	21
14	15	20	27	25
16	20	27	33	34
18	25	32	40	40
20	30	40	47	45
22	35	45	53	48
24	40	50	65	50

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TABLE 2

STEARNS CLUTCH - TORQUE TESTING

A. Breakaway Torque vs. Voltage with 0.016 Air Gap

Voltage	Breakaway Torque (lb.-ft.)
10	36
12	50
14	67
16	80
18	95
20	110
22	118
24	130

B. Breakaway Torque vs. Voltage with 0.024" Air Gap

Voltage	Breakaway Torque (lb.-ft.)
10	23
12	30
14	40
16	50
18	60
20	72
22	78
24	85

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TABLE 3

STEARNS CLUTCH - RELEASE TIME TESTING

Testing done with an air gap of 0.024" and clutch coil voltage of 24 volts and a torque of 81 lb.-in. applied to the clutch.

Run #	Drop #	Release Time (Sec.)	Chart Speed (in/sec.)
1	1	.035	10
2	10	.035	10
3	20	.035	50
4	30	.035	10
5	40	.037	10
6	50	.030	50
7	51	.033	10
8	52	.028	10
9	53	.025	10
10	60	.028	10
11	70	.027	10
12	80	.030	10
13	90	.032	10
14	100	.030	50

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TABLE 4

MAXITORQ CLUTCH - TORQUE AND RELEASE TIME TESTING

A. Breakaway and slippage torque vs. clutch coil voltage

Voltage	Breakaway Torque (lb.-ft.)	Slippage Torque (lb.-ft.
10	0	0
12	60	53
14	94	87
16	120	117
18	135	129
20	140	133

B. Release Time Determination

Clutch voltage - 24 volts; chart speed - 10 in./sec.

Trace No.	No. of Cycles	Release Time (Sec.)
1	10	.018
2	20	.012
3	30	.017
4	40	---
5	50	.012
6	60	.015
7	70	.015
8	80	.015
9	90	.015
10	100	.015

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TABLE 5

STEARNS CLUTCH RE-TEST - TORQUE AND RELEASE TIME TESTING WITH MODIFIED CIRCUIT

A. Breakaway and slippage torque vs. voltage - air gap 0.024".

Clutch Voltage	Breakaway Torque (lb.-ft.)	Slippage Torque (lb.-ft.)
10	5	5
12	15	15
14	23	23
16	29	27
18	37	35
20	50	47
22	55	53
24	60	58

B. Release Time Determination

Clutch Voltage - 24 volts, air gap -.024", Chart Speed - 10"/sec.

Run No.	Release Time (sec.)
1	.028
2	.026
3	.025

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