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T. R. Trout

15 May 1969

SUN 143-120

Solventless /Extruded/ Powder /N-5/-Ballistics

MODIFICATION OF 2.75" FFAR STABILIZING ROD TO ELIMINATE ERRATIC PRESSURE AND THRUST EXCURSIONS WHEN STATIC TESTED AT +165°F.

15 May 1969
Date

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Author

21 May 1969
Date

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Approved

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SUNFLOWER ARMY AMMUNITION PLANT

TECHNICAL DEPARTMENT INVESTIGATION REPORT

T. R. Trout SUN 143-120 15 May 1969

Solventless /Extruded/ Powder /N-5/ - Ballistics

MODIFICATION OF 2.75" FFAR STABILIZING ROD TO ELIMINATE ERRATIC PRESSURE AND THRUST EXCURSIONS WHEN STATIC TESTED AT +165°F.

Digest

Through experimental work, a modification of the stabilizing rod in the 2.75" FFAR was developed which would eliminate the occurrence of erratic pressure and thrust excursions (NOTS Pips) in the static testing of grains at +165°F. This modification involved changing the diameter and length of the potassium sulfate on the stabilizing rod. The change from 0.3 to 0.5 inch diameter and from 12.0 to 6.0 inches length completely eliminated the occurrence of NOTS Pips when grains were tested at 180°F. An Engineering Change Proposal will be initiated recommending these changes to Drawings 9209320 and 456159 BuOrd.

INTRODUCTION

Erratic pressure and thrust excursions (NOTS Pips) occur between the saddle and late maximum pressure on the pressure-time traces from static tests of 2.75-inch FFAR rocket motors at +165°F. (see Figure 1). As may be seen from the referenced figure, the pressure fluctuations are very irregular and are considered to be the result of resonant burning, a phenomenon related to grain geometry and propellant burning rate characteristics. During the current operation, SAAP has produced approximately 550 MK 43 propellant grain lots, 14 of which have failed the requirements of C-MIL-P-18811 (NOrd) because of NOTS Pips.

During development of the 2.75-inch FFAR, it was found that a rod inserted in the grain perforation would significantly reduce the frequency of occurrence and magnitude of NOTS Pips. The present "stabilizing rod" consists of a 0.156" diameter steel rod 27" long on which is a section of salt (potassium sulfate with ethyl cellulose as a plastic binder) which is extruded to 0.30" diameter cut into the 12" lengths and glued to the steel rod. During the past few months, SAAP has designed and tested several stabilizing rod configurations with the objective of further reducing the frequency of occurrence and magnitude of NOTS Pips. The occurrence of these irregular pressure excursions is unpredictable and the corrective action taken when plagued with this problem is to condition all ballistic samples for from 7 to 10 days at 110°F. When forced to this corrective action, the production schedule at SAAP is jeopardized as no grain lots manufactured after the 20th of a month may be ballistically tested in that month. There is also the cost of operating conditioning facilities for which there is no other use and the additional handling when conditioning is necessary. This report covers the work done through which a method has been found of alleviating NOTS Pips at +165°F.

DISCUSSION

From 8 March 1968 to 19 December 1968, 384 motors, which included different stabilizing rod configurations, were static tested at temperatures ranging from -65°F. to +180°F. The results of these tests are summarized in Table I. Most of the rod configurations are shown in photographs 1 through 6.

To obtain the best possible comparison between stabilizing rods, the majority of test motors were conditioned at +180°F. With a given motor configuration, higher temperatures (above +165°F.) produce more and larger NOTS Pips.

Of the stabilizing rod configurations tested, two showed the most promise of decreasing the frequency of occurrence and magnitude of NOTS Pips. The triple rod, made by welding three full length 0.156-inch rods 120° to each other (see photograph 6), completely eliminated NOTS Pips (see Table I). However, the effect of this configuration on ballistic variables and the inherent difficulty in manufacturing such a rod led to a design differing from the present stabilizing rod only in the length and diameter of salt.

Small quantities of stabilizing rods with 1/2 and 3/8-inch diameter salt in 12 and 24-inch lengths were ordered from Plymouth Plastics, Sheboygan, Wisconsin. Additional rod configurations were made by removing varied amounts of salt. Tests conducted on 3 October 1968 (see Table I) showed that large diameter salt rods in 12 and 24-inch lengths eliminated NOTS Pips but increased Early Maximum Pressure as much as 750 psig. The volume of salt contained on these rods was better than three times that contained on a standard rod (see Table II) which accounts for the abnormally high Early Maximum Pressure. To more nearly duplicate the volume of salt on the standard rod, a set of test rods were made with 0.5-inch diameter salt in 3.5, 4.25, 5.0, and 6.0-inch lengths (see Table I). Tests conducted on 23 November 1968 showed that the increase from 3.5 to 6.0-inch salt lengths progressively decreased the occurrence of NOTS Pips from 50 to 0 percent (see Figures 3 through 22). With the sample size of 12, this difference is significant at the 95% confidence level.

Sixty grains representative of Lot SUN 7133 were loaded with 0.5 by 6.0-inch salt rods (see photograph 7) and static tested on 7 December 1968 in conjunction with a control sample with standard rods from the same lot. Ballistic results at the four test temperatures plus the results of Students "t" tests are included in Table III. The 60 psig increase in Early Maximum Pressure was found statistically significant in this study but no change in the MK 43 grain geometry of grains produced at SAAP would be necessary to compensate for this increase. Were it necessary to decrease the Early Maximum Pressure by an equivalent amount, this could be accomplished by reduction of grain length increasing the port area or changing the N-5 formulation. The change in saddle pressure at +165°F. although statistically significant would be beneficial as it would mean achievement of a more "neutral" curve. The burning time, saddle pressure, and formula time at -65°F. would in no way affect ballistic quality as these requirements are not acceptance criteria in the static testing of the MK 43 grain (see Table III).

The 6.0-inch salt rods contain 1.7 times more salt than standard stabilizing rods (see Table II). On 19 December 1968, five motors containing 6.0-inch salt rods were partial burned at +165°F. to determine how much salt remained on the rods at any given time during motor operation. Five motors containing standard rods were also partial burned at +165°F. with the shortest burn time obtained being 0.85 seconds (the rod from this motor had all salt burned off). The results, plotted on Figure 2, show that salt remains on the 6.0-inch rod for more than 1.3 seconds whereas salt on the standard rod is burned off within 0.85 seconds. It is clearly evident that the retention of the salt on the rod effectively eliminates the occurrence of erratic pressure and thrust excursions at high temperatures.

CONCLUSIONS

The frequency of occurrence and magnitude of NOTS Pips would be greatly reduced if the present stabilizing rod were redesigned by increasing the volume and diameter of salt contained on the rod. Test results indicated that a 0.5 by 6.0-inch cylinder of salt located at the forward end of the rod effectively achieves this result.

RECOMMENDATIONS

Submit an Engineering Change Proposal to alter the present stabilizing rod by (1) increasing salt diameter from 0.3 to 0.5 inches, and (2) decreasing the salt length from 12.0 to 6.0 inches.

TABLE I

SUMMARY, STABILIZING ROD STUDY

DATE	STABILIZING ROD CONFIGURATION	PHOTOGRAPH NUMBER	FIRING TEMPERATURE	SAMPLE SIZE	NUMBER OF HOTS PIPS	REMARKS
March 5	Standard with attached metal Fins	1	+70° F.	1	--	Increased EMP 500 psig.
June 17	Standard	2A	+165° F.	5	0	--
	No Rod	--	+165° F.	5	5	High magnitude pips
	Standard, no salt	3A	+165° F.	5	2	Low magnitude pips
June 19	Standard	2A	+165° F.	2	0	--
	Cruciform Cross-Section	2B	+165° F.	2	0	--
	"I" Cross-Section	2C	+165° F.	2	0	--
June 26	Standard	4A	+165° F.	5	0	--
	Kinked rod with salt	4B	+165° F.	5	0	--
	Kinked rod without salt	4C	+165° F.	5	1	--
July 3	Standard	2A	+180° F.	3	3	--
	1/4" by 5" steel rod attached to nozzle	5A	+180° F.	3	3	One high pressure motor failure. Two pips exceeding 2500 psig
	1/4" by 11" steel rod attached to nozzle	5B	+180° F.	3	3	High magnitude pips
	1/4" by 17" steel rod attached to nozzle	5C	+180° F.	3	3	High magnitude pips
July 30	Standard	2A	+180° F.	3	2	--
	Standard with one extra 5/16" by 12" salt section attached	--	+180° F.	2	0	--
	Standard with two extra 5/16" by 12" salt section attached	--	+180° F.	3	0	--
Aug. 8	Standard	2A	+165° F.	1	1	--
	Standard without salt	3A	+165° F.	1	0	--
	1/2 Length Double, without salt	3B	+165° F.	1	0	--
	1/3 Length Triple, without salt	3C	+165° F.	1	0	--
	Standard	2A	+180° F.	1	1	--
	Standard, without salt	3A	+180° F.	1	1	--
	1/2 Length Double, without salt	3B	+180° F.	1	0	--
	1/3 Length Triple, without salt	3C	+180° F.	1	0	--
Aug. 14	Standard	2A	+180° F.	8	7	--
	Full Length Triple	6	+180° F.	8	0	EMP 110 psig higher than Standard. Formula Time 0.015 seconds longer than Standard.
Sept. 4	Standard	2A	-65° F.	8	--	--
	Full Length Triple	6	-65° F.	8	--	Formula Time 0.073 seconds shorter than Standard, high ITI, low PT.

TABLE I (Continued)

Oct. 3	Standard	2A	+130° F.	8	--	--
	Full Length Triple	6	+130° F.	8	--	Formula Time 0.015 seconds shorter than Standard
	Standard	2A	-10° F.	8	--	--
	Full Length Triple	6	-10° F.	8	--	Formula Time same as Standard
	Standard	2A	+180° F.	5	4	--
	½" by 12" salt	--	+180° F.	5	0	EMP 350 psig higher than Standard.
	½" by 24" salt	--	+180° F.	5	0	EMP 750 psig higher than Standard.
	3/8" by 24" salt	--	+180° F.	5	0	EMP 650 psig higher than Standard.
Oct. 8	Standard	2A	+180° F.	1	1	--
	½" by 4½" salt at forward end of rod	7A	+180° F.	5	1	--
	½" by 4½" salt at mid point of rod	--	+180° F.	5	1	--
Oct. 11	Standard	2A	+180° F.	9	7	--
	½" by 4½" salt at forward end	7A	+180° F.	7	2	--
	Full Length Triple - using 0.090 inch steel rods	6	+180° F.	2	0	--
Oct. 18	Standard	2A	+165° F.	2	0	Partial burned (interrupted in NOTS Pip region)
	Full Length Triple	6	+165° F.	1	0	Partial burned (interrupted in NOTS Pip region)
	½" by 4½" salt at forward end	7A	+165° F.	2	0	Partial burned (interrupted in NOTS Pip region)
Nov. 23	Standard	2A	+180° F.	12	6	--
	½" by 3½" salt at forward end	--	+180° F.	12	1	--
	½" by 4½" salt at forward end	7A	+180° F.	12	1	--
	½" by 5" salt at forward end	--	+180° F.	12	1	--
	½" by 6" salt at forward end	--	+180° F.	12	0	--
Dec. 7	Standard	2A	+165° F.	15	0	SUN 7133
	Standard	2A	+130° F.	15	--	SUN 7133
	Standard	2A	-10° F.	15	--	SUN 7133
	Standard	2A	-65° F.	15	--	SUN 7133
	½" by 6" salt at forward end		+165° F.	15	0	See TABLE III for comparison of ballistic variables with SUN 7133
	½" by 6" salt at forward end		+130° F.	15	--	--
	½" by 6" salt at forward end		-10° F.	15	--	--
	½" by 6" salt at forward end		-65° F.	15	--	--
Dec. 19	Standard	2A	+165° F.	5	--	Partial burned, See Figure 2
	½" by 6" salt at forward end	--	+165° F.	5	--	Partial burned, See Figure 2
	Standard	2A	+180° F.	5	0	Partial burned (interrupted in NOTS Pip region)
	½" by 6" salt at forward end	2A	+180° F.	5	0	Partial burned (interrupted in NOTS Pip region)

TABLE II

STABILIZING ROD STUDY - SALT VOLUME

SALT CONFIGURATION DIAMETER (IN.)	LENGTH (IN.)	VOLUME OF SALT (CU. IN.)	VOLUME RATIO OF TEST SALT TO STANDARD SALT
5/16	12.0	0.620*	--
1/2	3.5	0.620	1.0
1/2	4.25	0.752	1.2
1/2	5.0	0.886	1.4
1/2	6.0	1.063	1.7
1/2	12.0	2.126	3.4
1/2	24.0	4.252	6.9
3/8	24.0	2.203	3.6

* - Standard Rod

TABLE III

EFFECTS OF 0.5 BY 6.0 INCH SALT ROD ON BALLISTIC PERFORMANCE

	+165°F.		+130°F.		-10°F.		-65°F.	
	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S
EARLY MAX. PRESSURE (PSIG)								
Reqmts. of C-MIL-P-18811	2400 max		1950 max		1600 max		1600 max	
Standard Rod	1994.7*	70.1	1678.6	48.3	1252.7	19.4	1188.0	36.3
6 Inch Salt Rod	2057.3	60.4	1692.0	88.7	1242.7	25.8	1172.0	25.7
LATE MAX. PRESSURE (PSIG)								
Reqmts. of C-MIL-P-18811	1900 max		1650 max		1600 max		1600 max	
Standard Rod	1476.7	24.1	1412.1	23.3	1448.7	15.1	1467.3	26.6
6 Inch Salt Rod	1481.3	18.8	1411.3	15.1	1439.3	19.4	1455.3	29.7
PRESSURE-TIME INTEGRAL ($LB-SEC/IN^2$)								
Reqmts. of C-MIL-P-18811			No Specification Limits					
Standard Rod	1859.8	7.0	1853.9	8.2	1830.2	5.5	1813.9	6.3
6 Inch Salt Rod	1858.6	8.0	1854.9	5.6	1825.6	6.8	1816.9	7.3
BURNING TIME (SEC)								
Reqmts. of C-MIL-P-18811	1.6 max		1.7 max		1.7 max		2.15 max	
Standard Rod	1.494	.017	1.597	.033	1.527	.013	1.782**	.033
6 Inch Salt Rod	1.493	.020	1.577	.023	1.531	.026	1.666	.030
FORMULA TIME (SEC)								
Reqmts. of C-MIL-P-18811	No Specification		1.924 max 1.804 min		1.904 max 1.804 min		No Specification	
Standard Rod	1.830	.00811	1.875	.015	1.857	.006	1.973	0.0143
6 Inch Salt Rod	1.831	.00923	1.868	.010	1.861	.012	2.123**	0.0133
SADDLE PRESSURE (PSIG)								
Reqmts. of C-MIL-P-18811	900 min		800 min		800 min		600 min	
Standard Rod	1024.7**	34.0	958.9	43.8	1062.0	20.8	819.3**	30.6
6 Inch Salt Rod	1059.3	24.3	973.3	36.6	1052.0	31.2	884.0	43.1

* Means significantly different at 95% confidence level (Students "t" Test)
** Means significantly different at 99% confidence level (Students "t" Test)

FIGURE 1

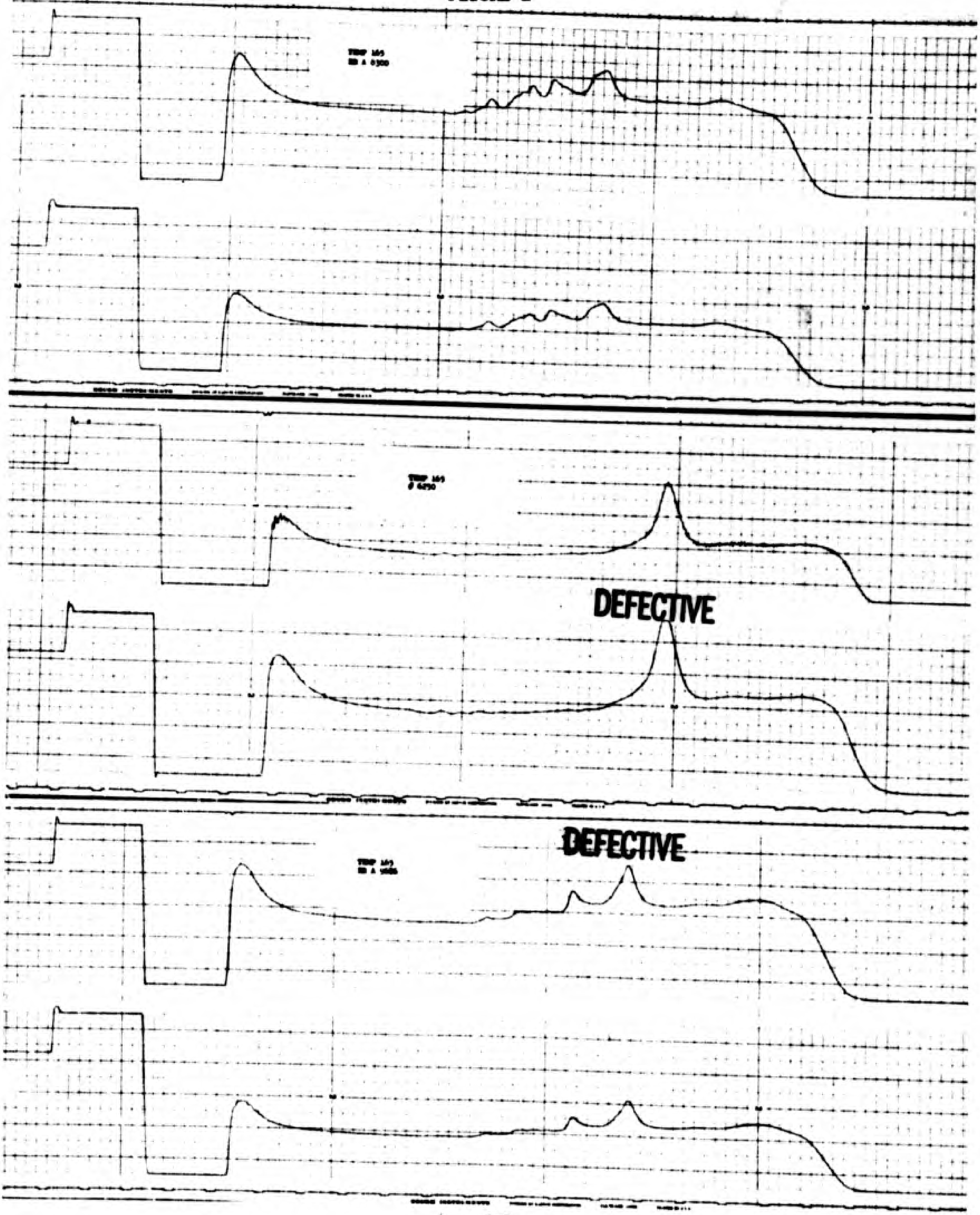


FIGURE 2

Burn Time Versus Salt Volume

+165°F Test Temperature

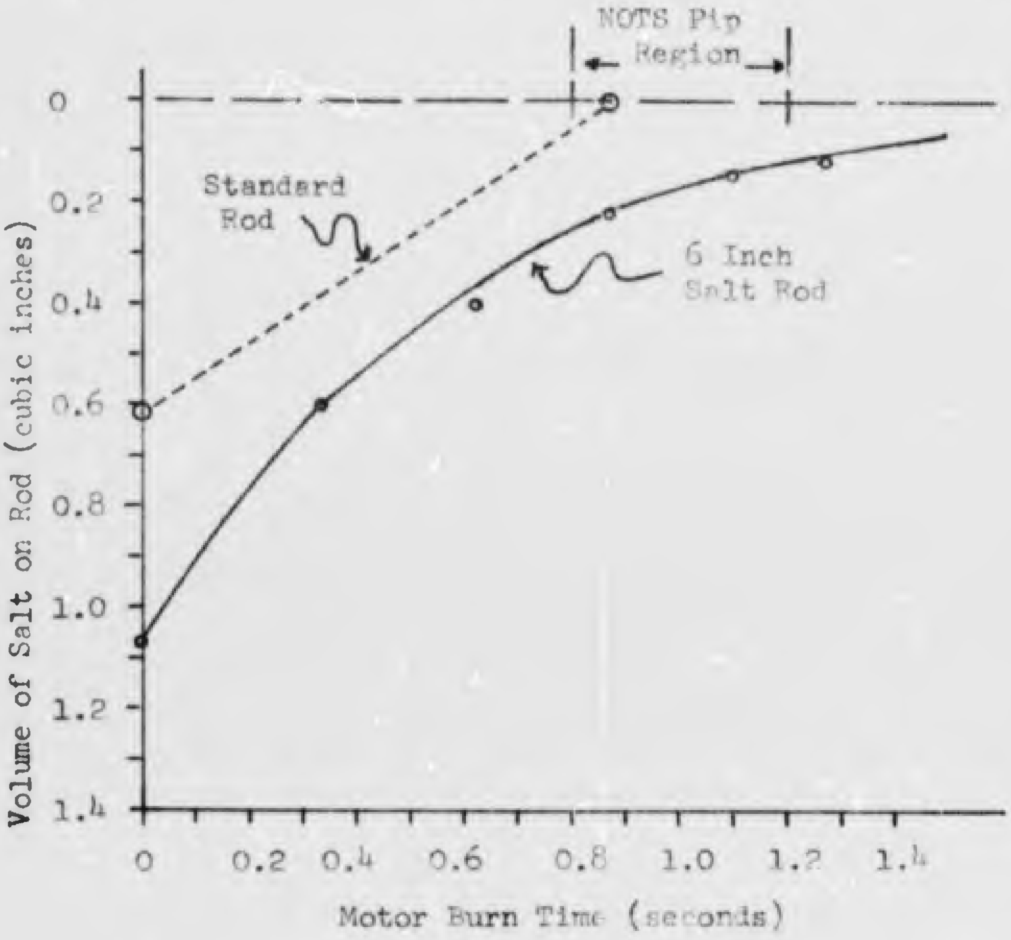
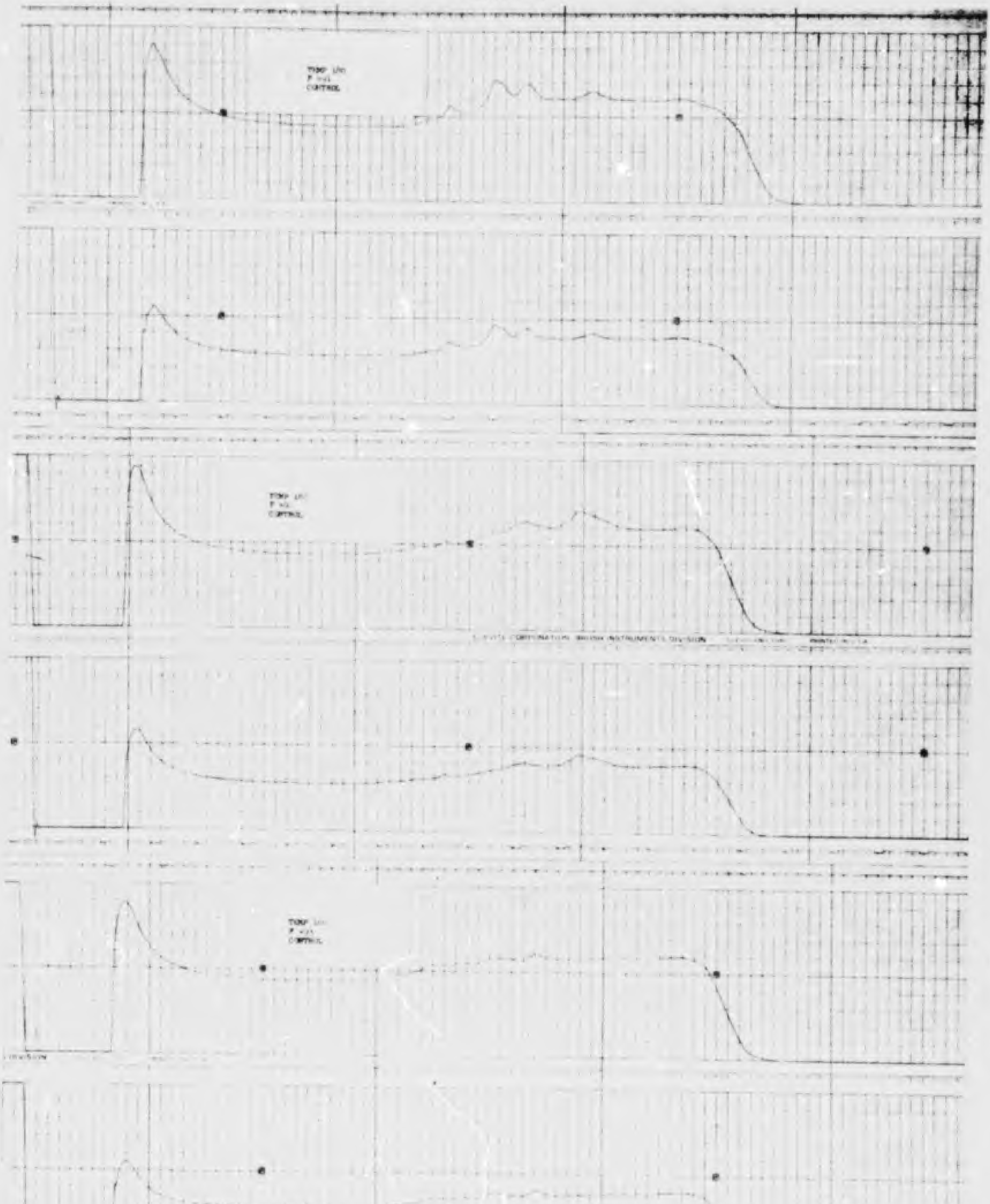


FIGURE 3



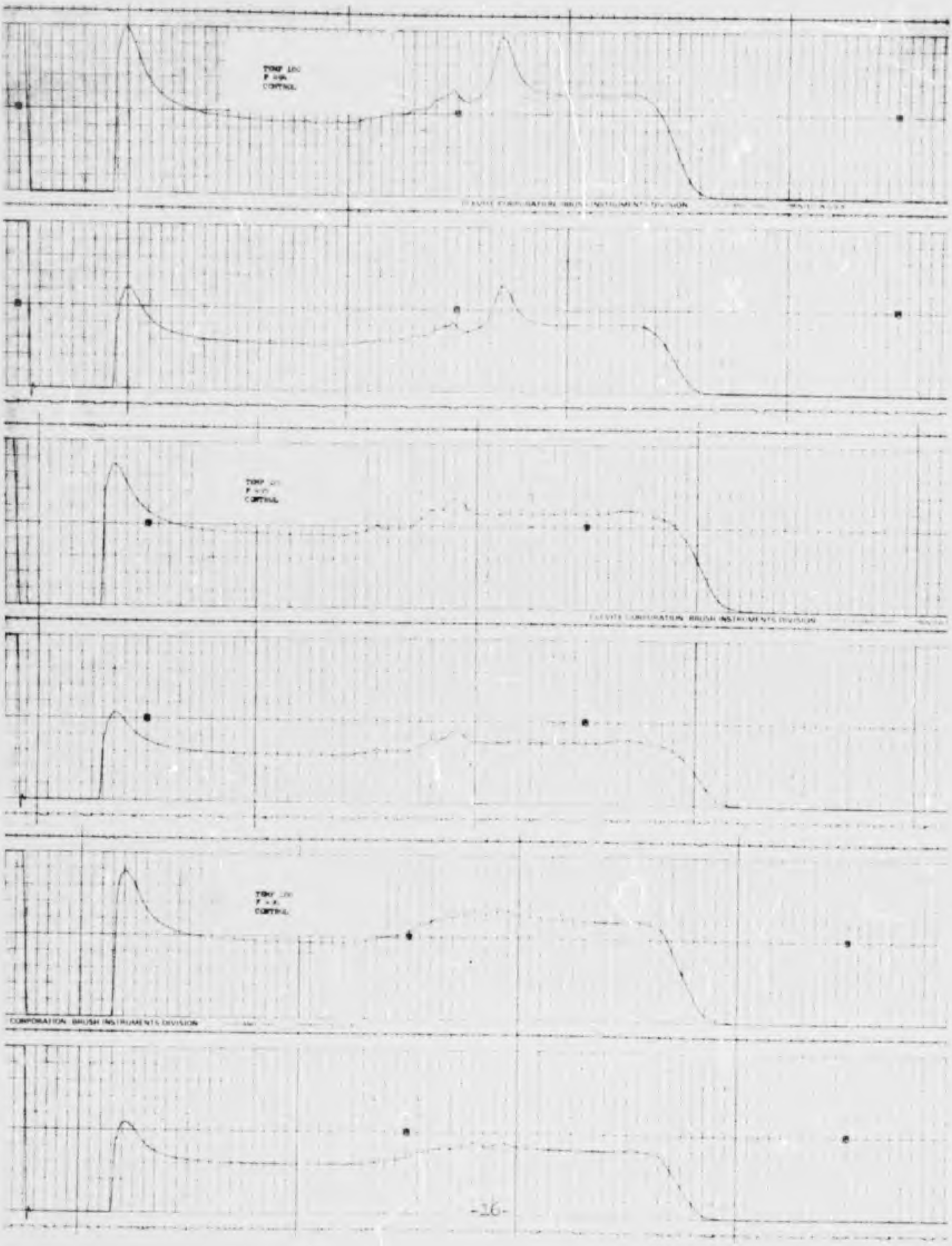
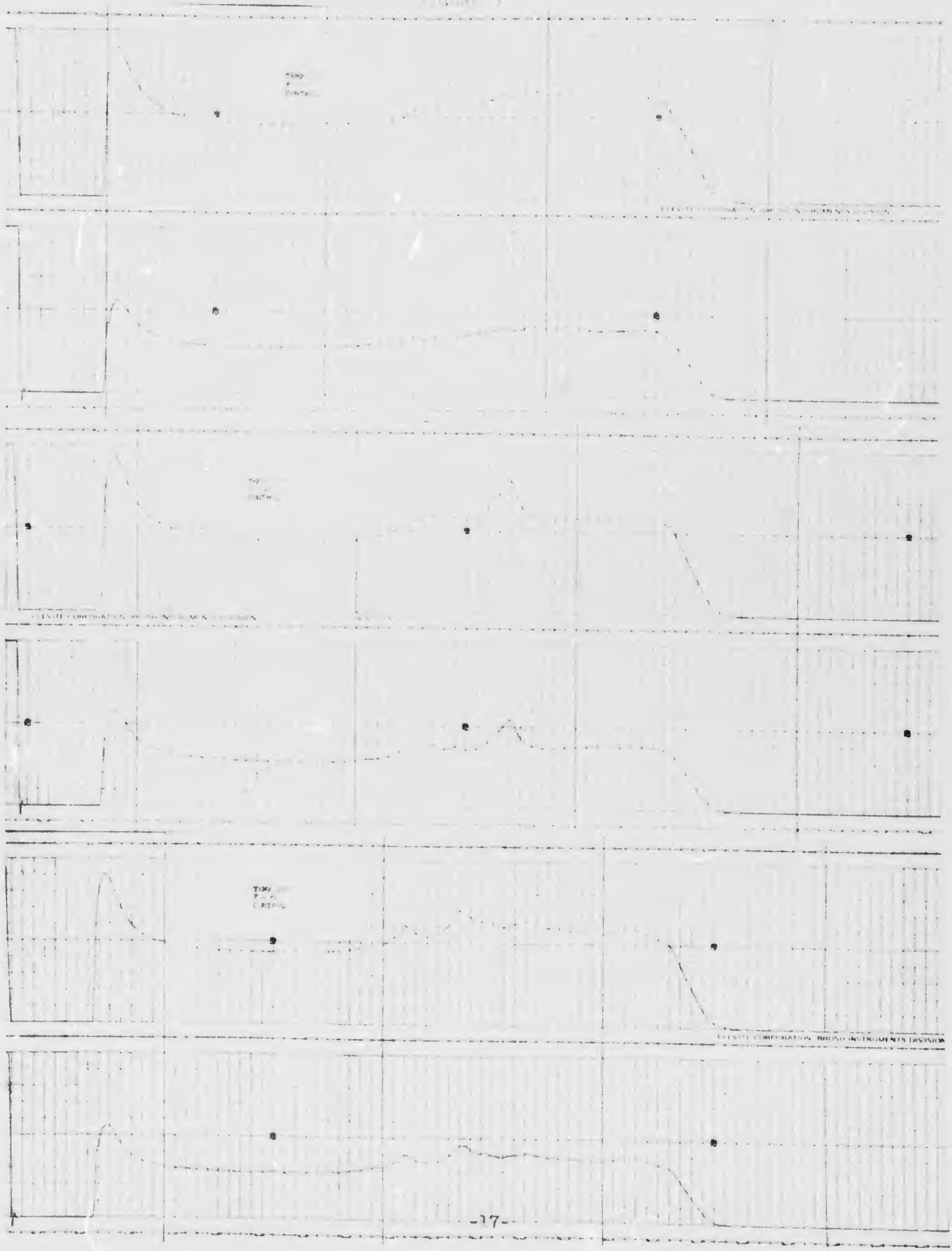

CLEVITE CORPORATION BRUSH INSTRUMENTS DIVISION
CORPORATION BRUSH INSTRUMENTS DIVISION

FIGURE 5



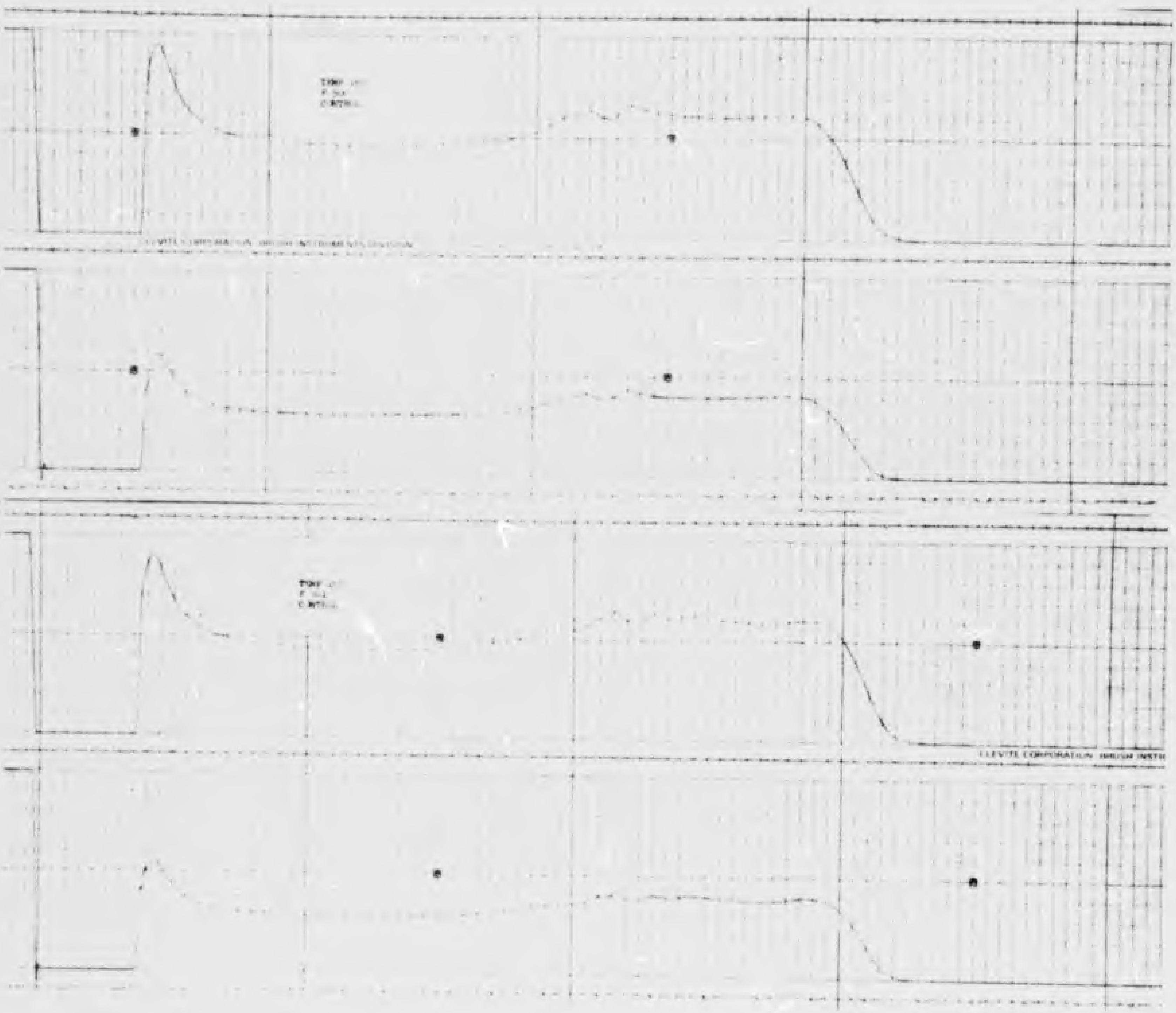

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FIGURE

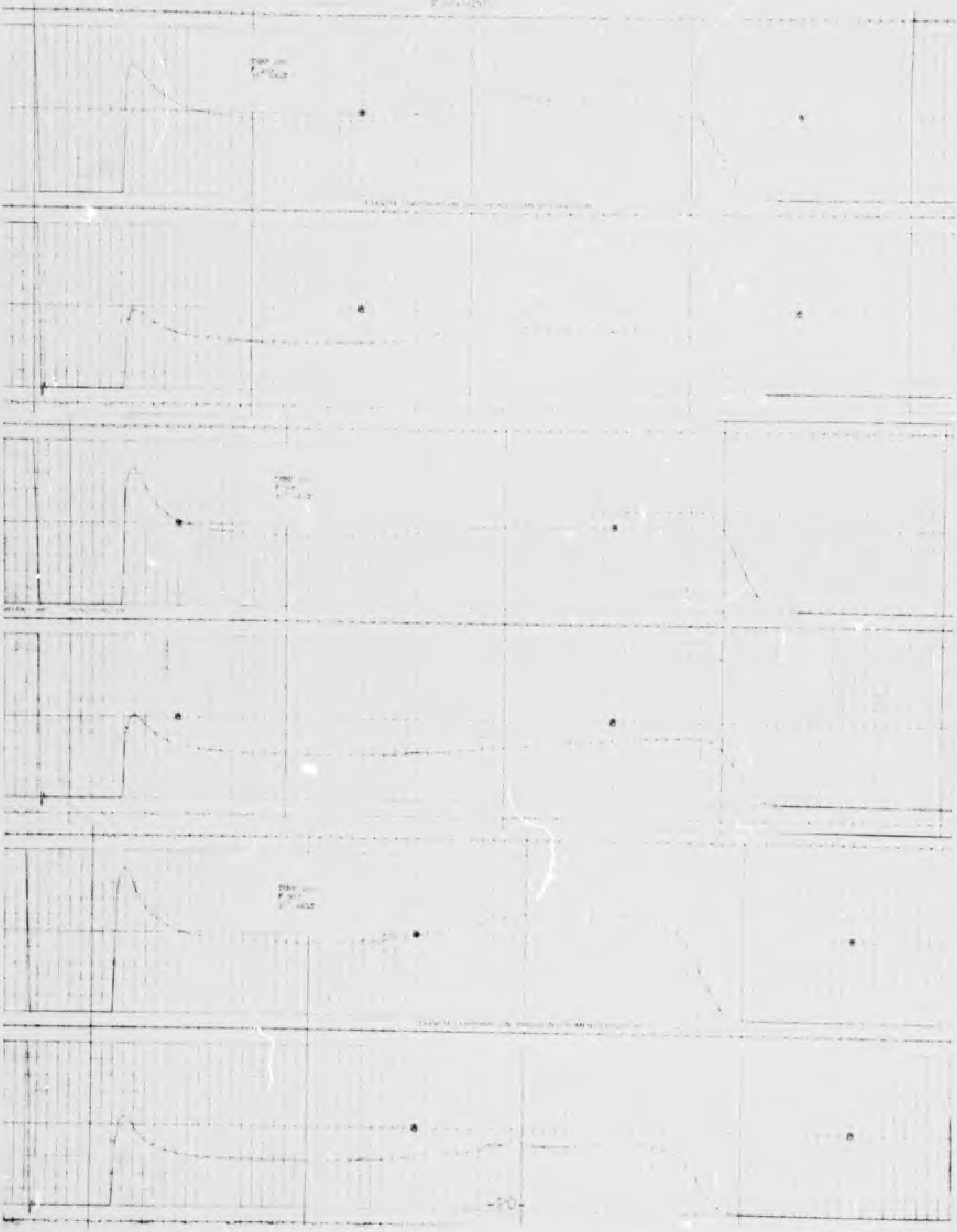


FIGURE 9

FIGURE 10

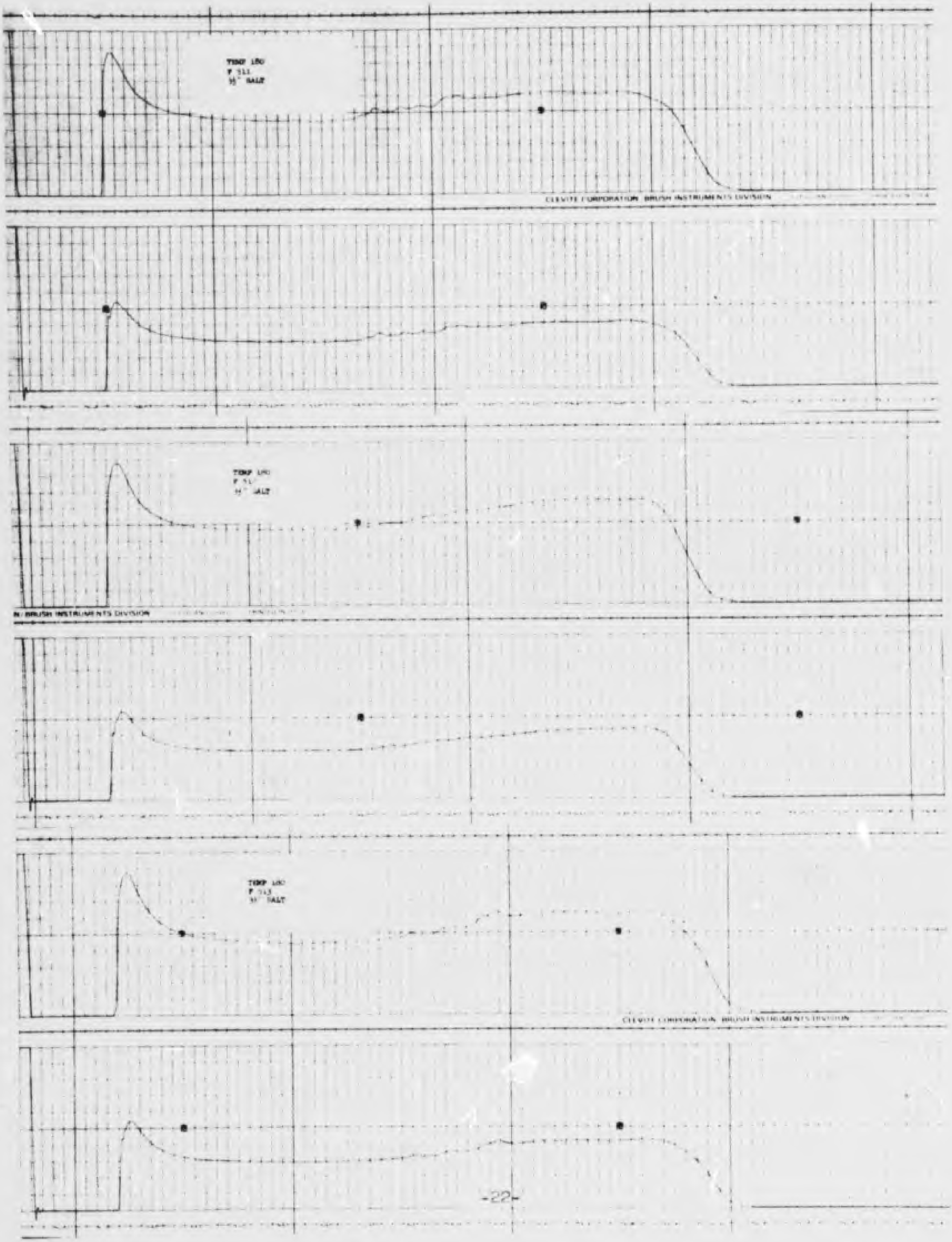


FIGURE 11

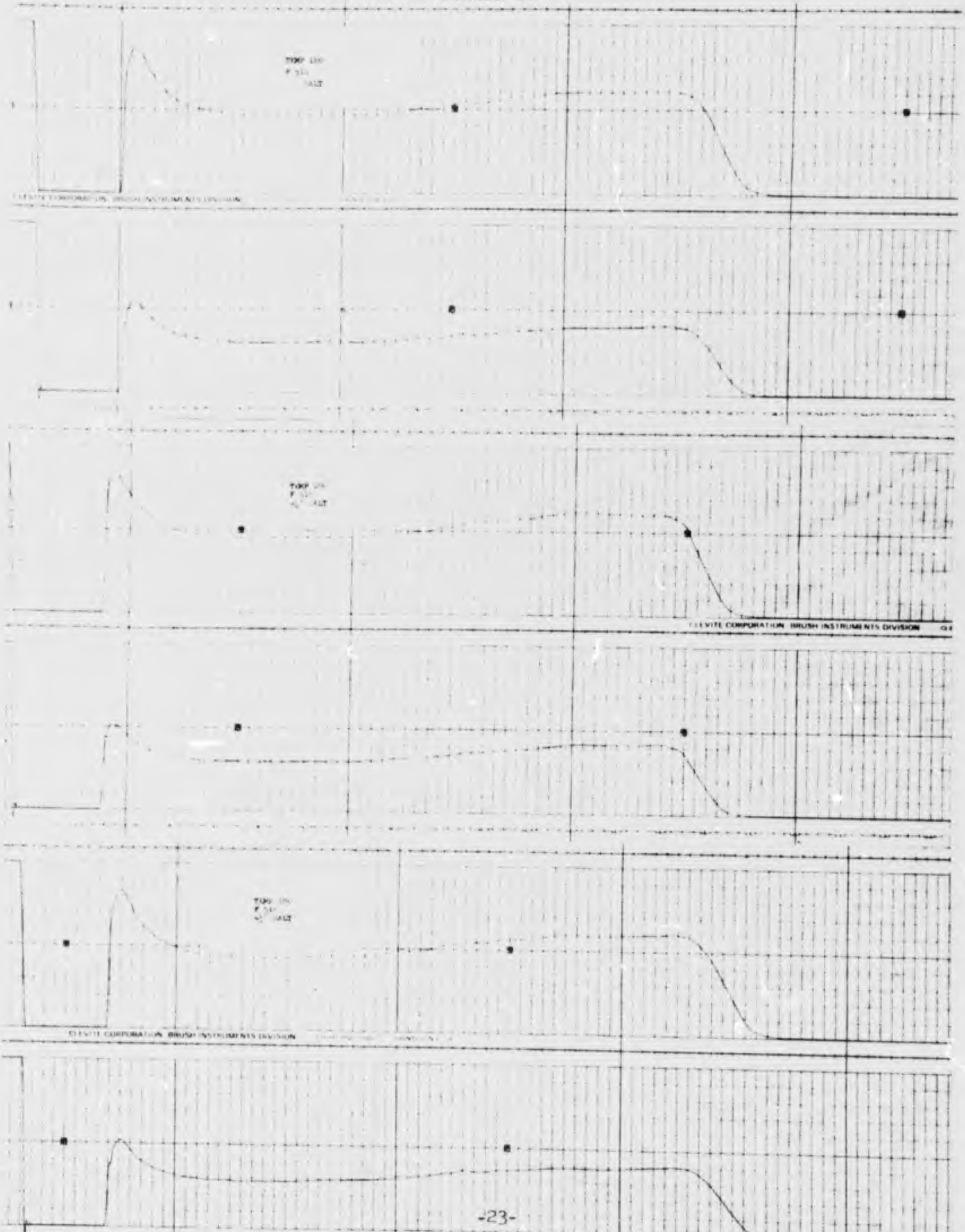
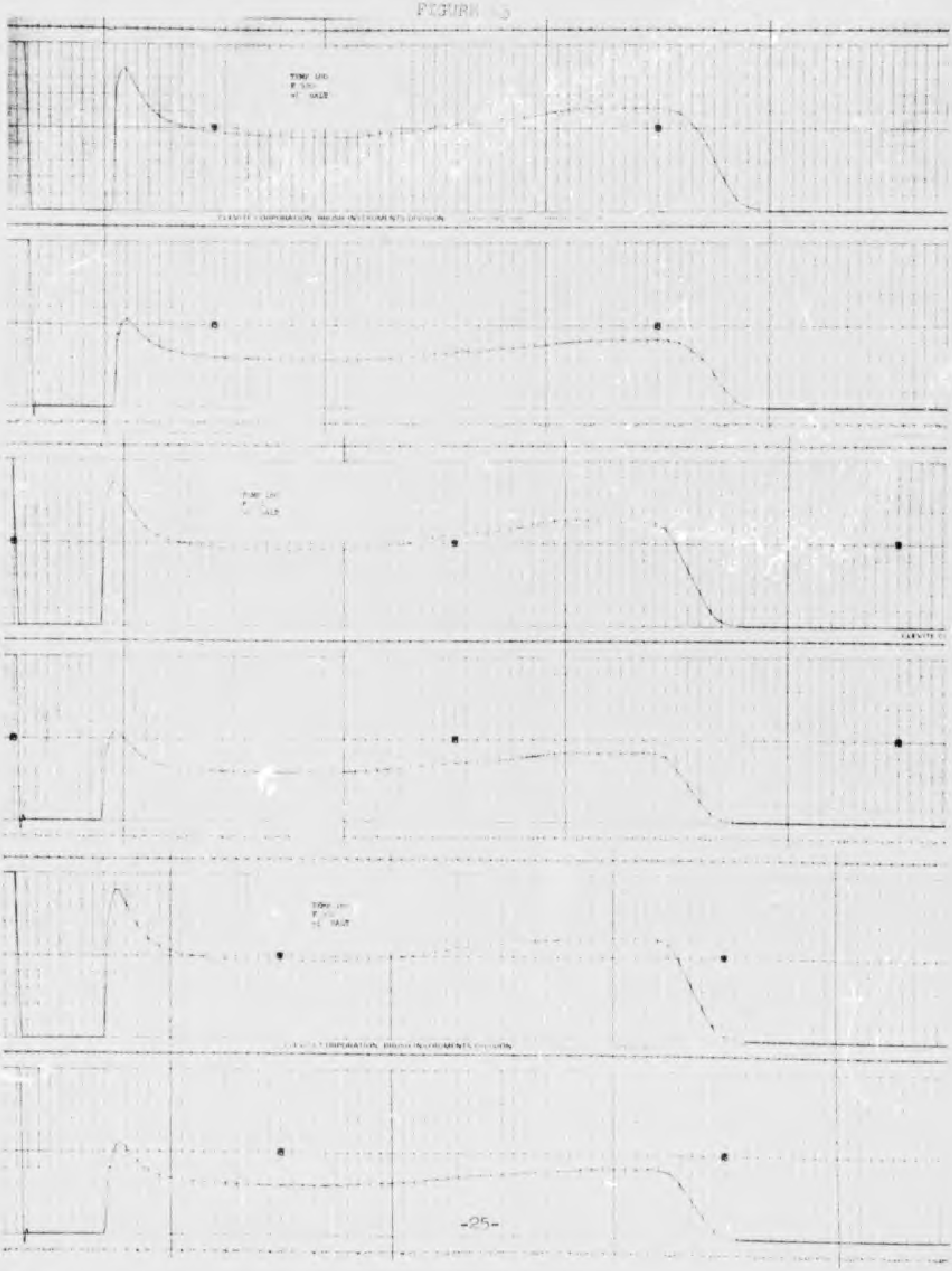


FIGURE 5



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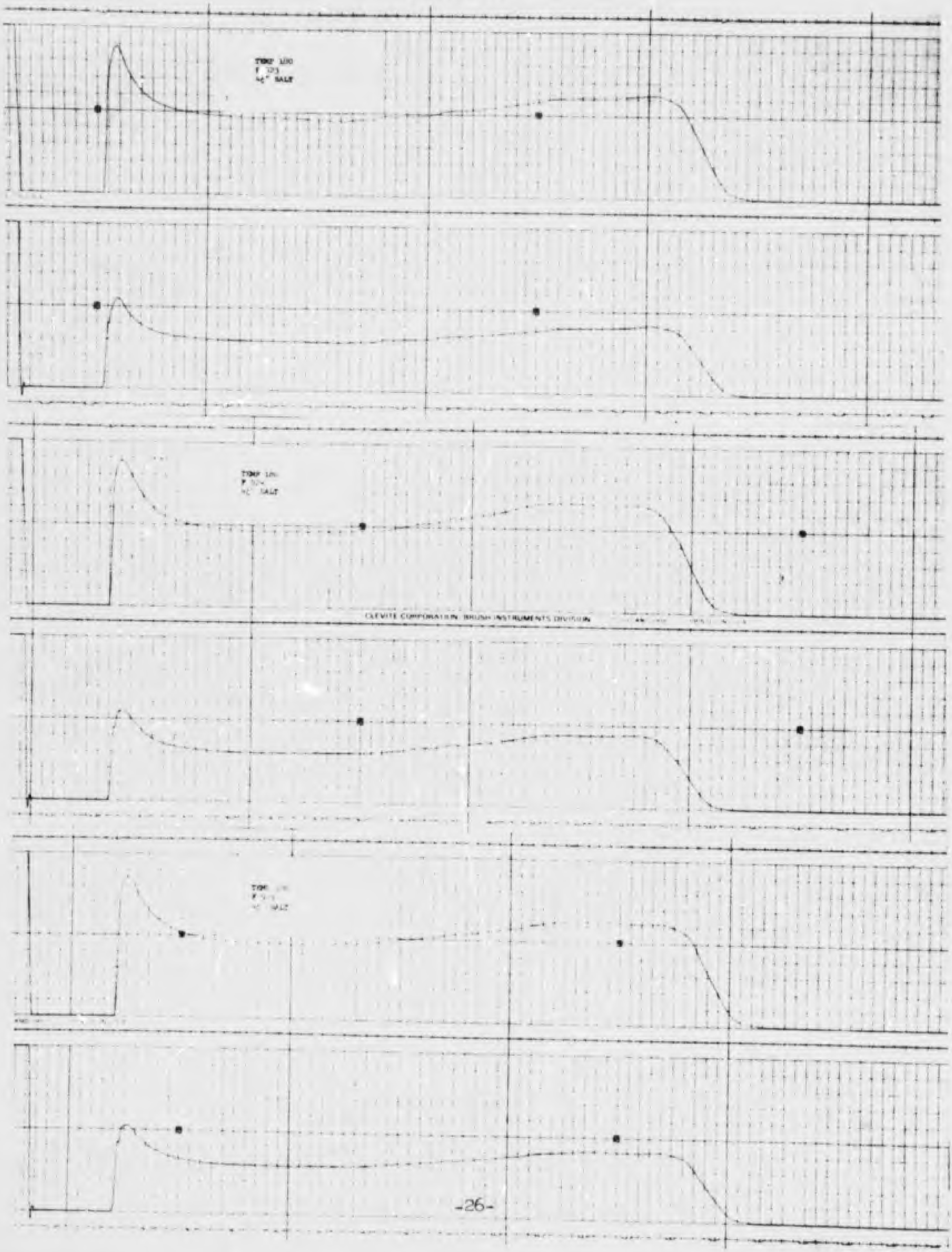

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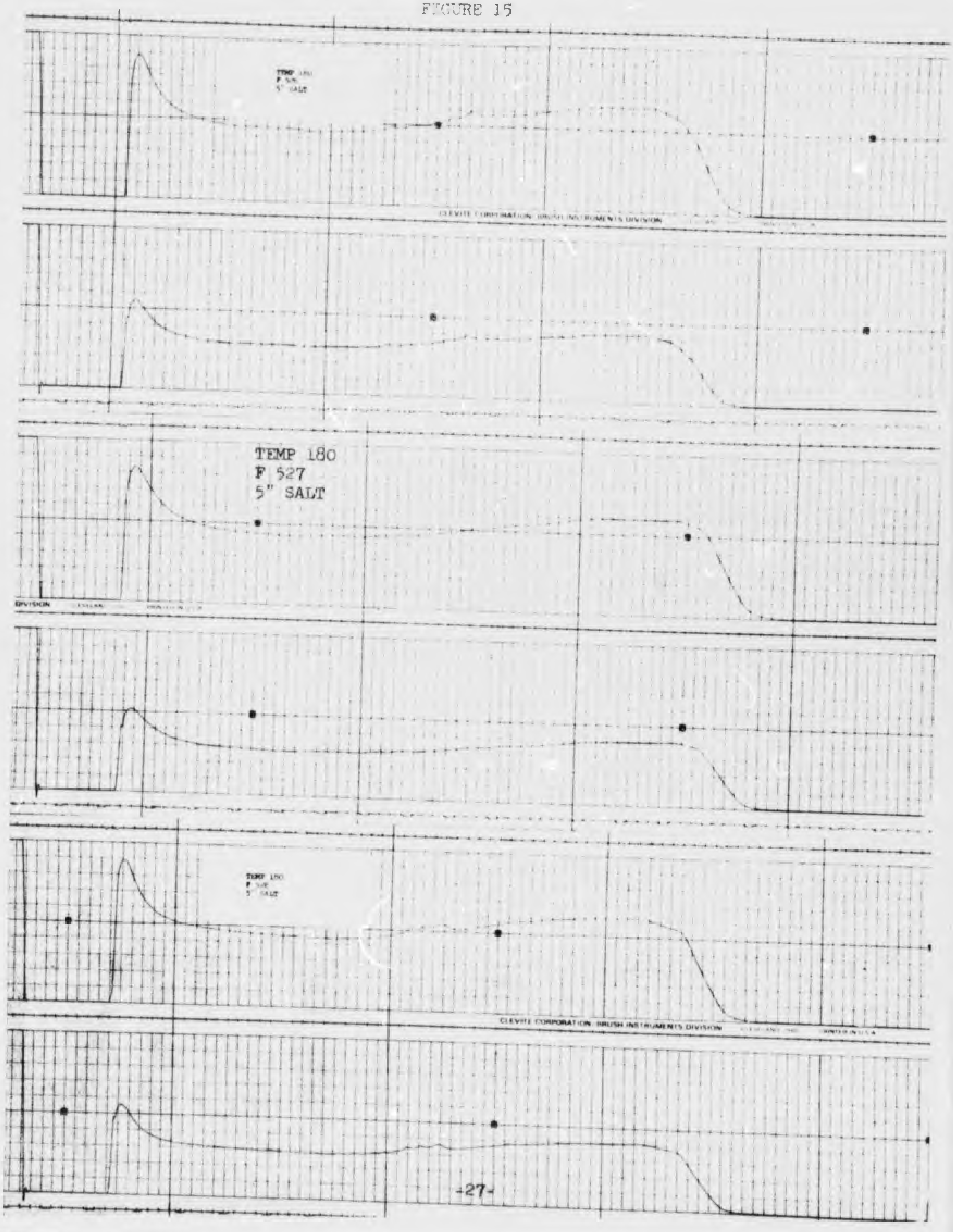

TEMP 180
F 527
5" SALT
CLEVITE CORPORATION BRUSH INSTRUMENTS DIVISION

FIGURE 16

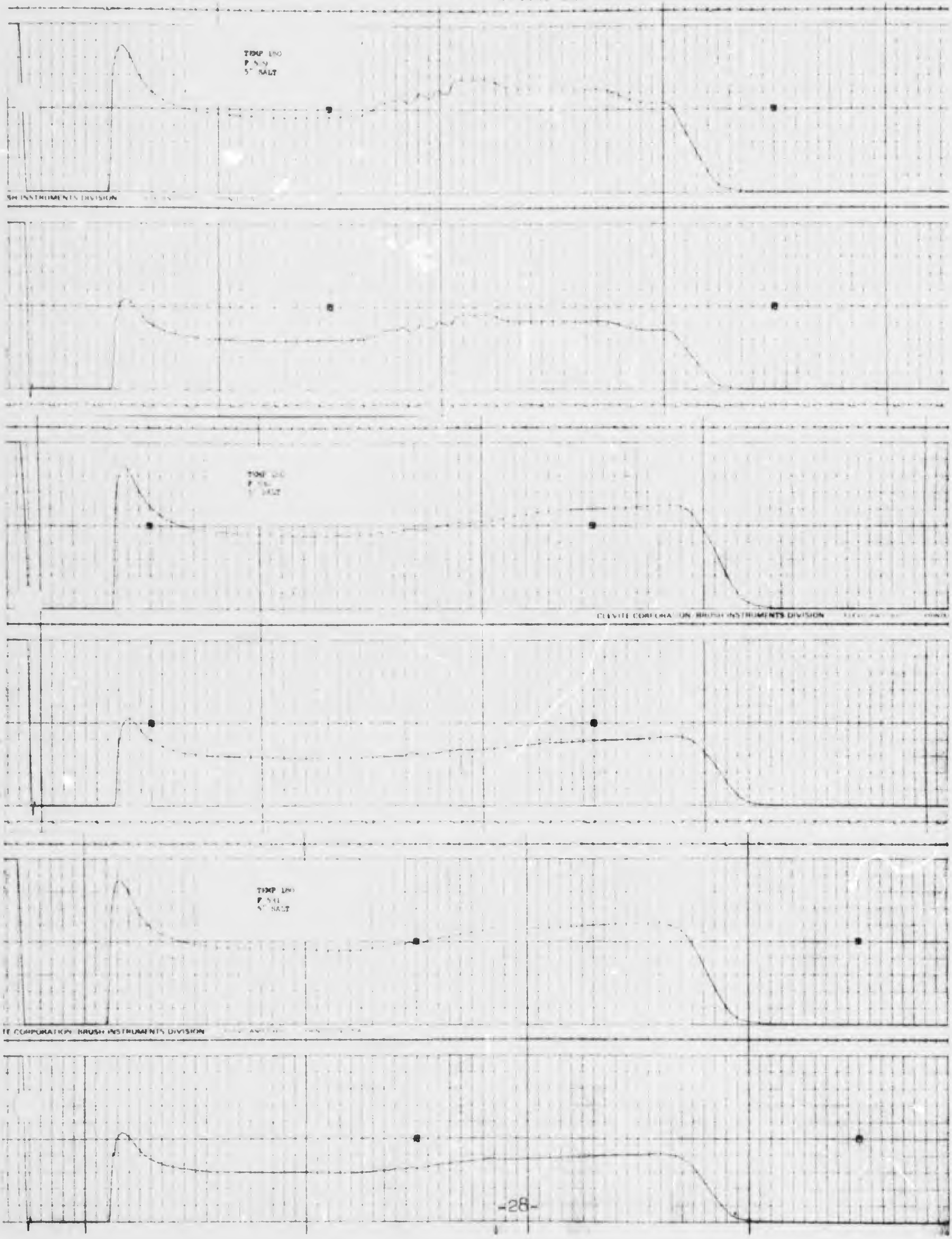

TEMP
5" SALT
CLEVITE CORPORATION BRUSH INSTRUMENTS DIVISION

FIGURE 17

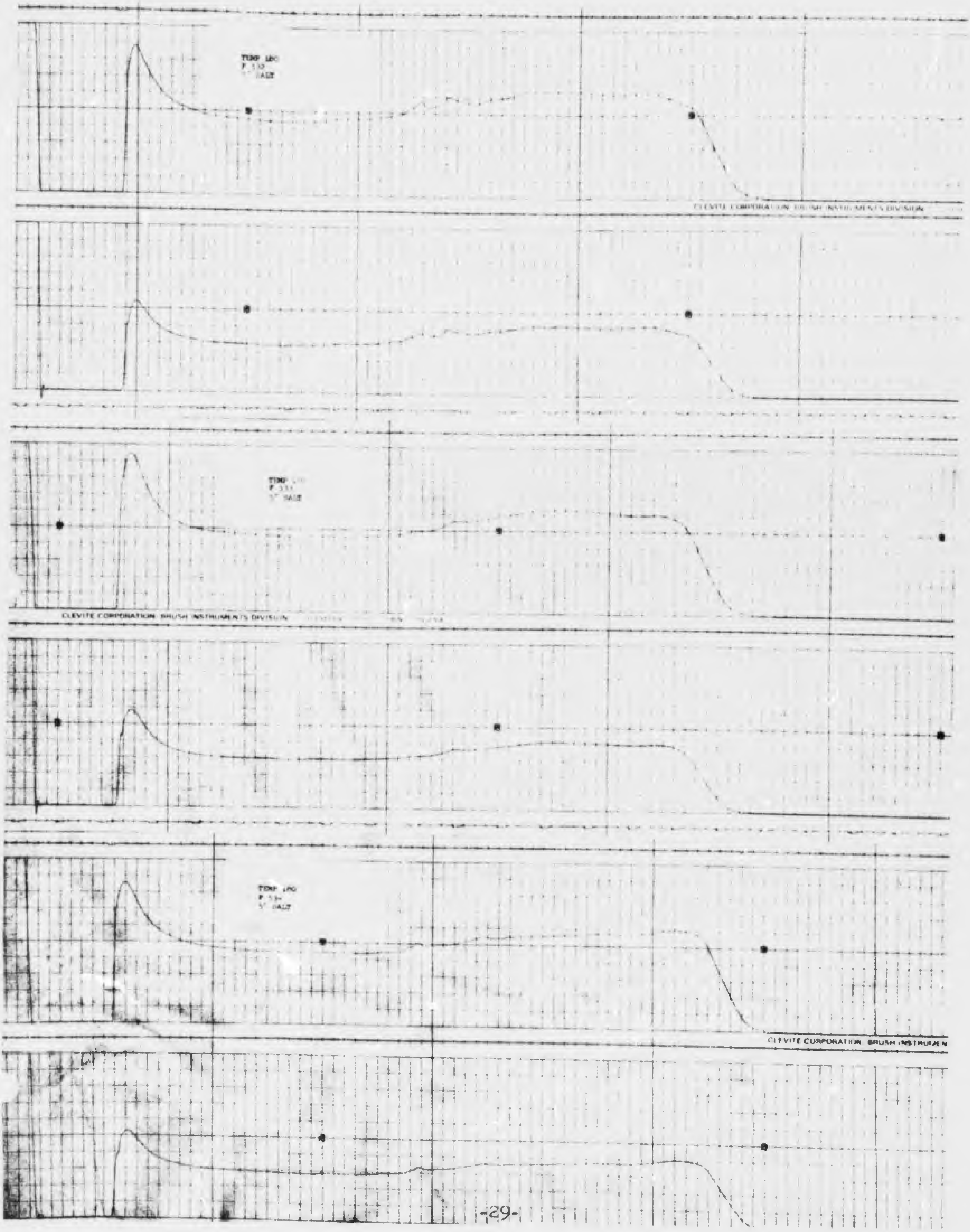


FIGURE 18

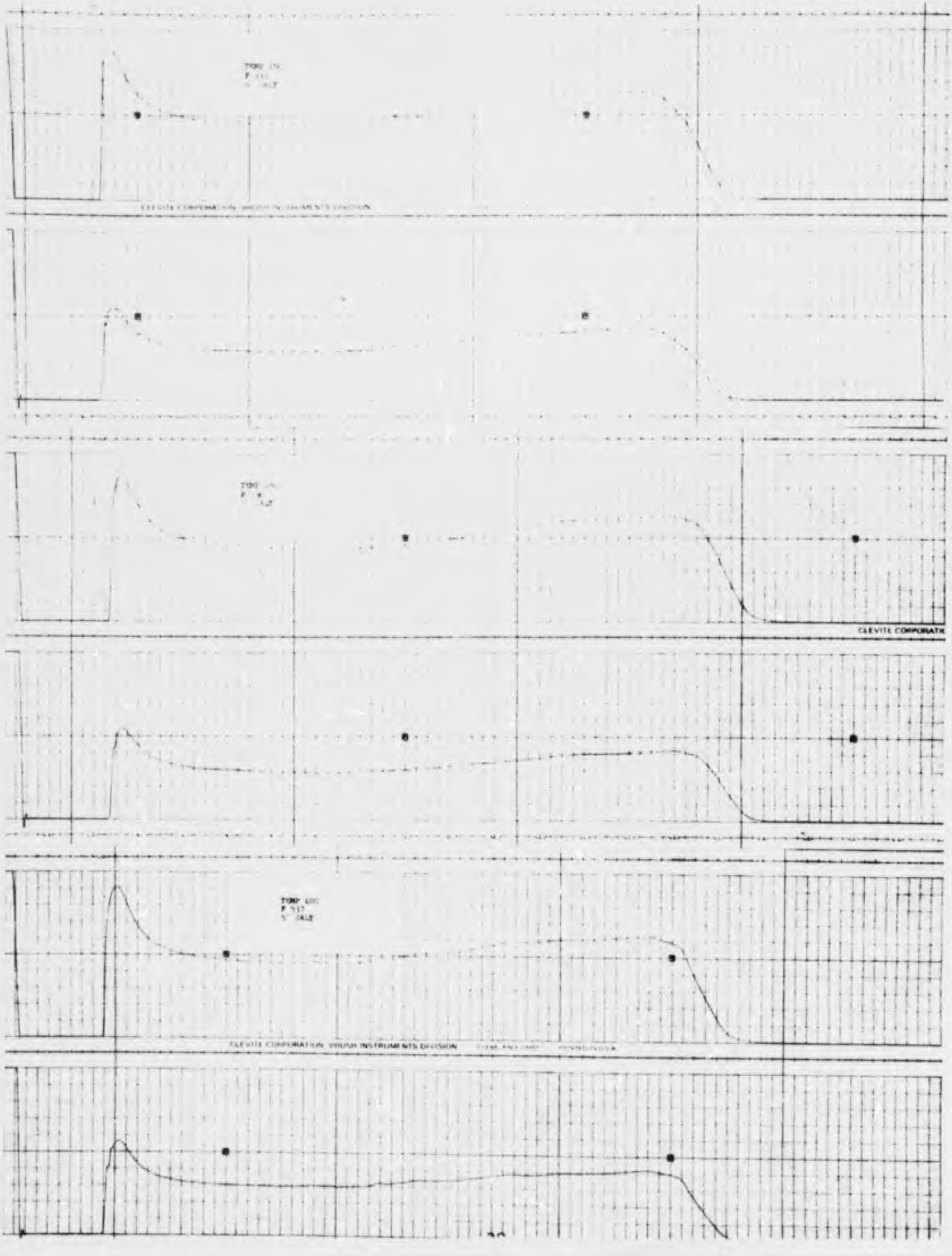
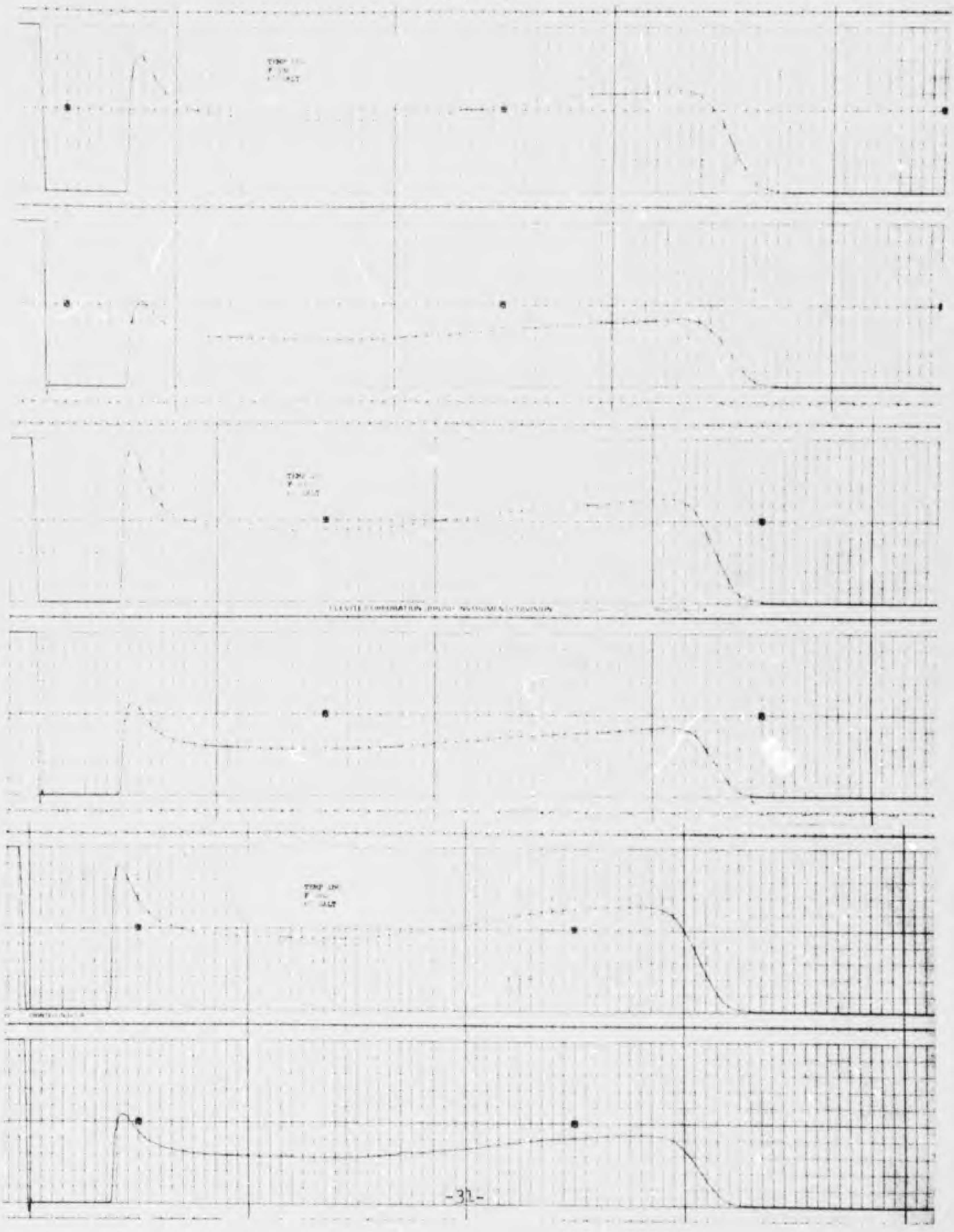


FIGURE 19



FIGURE

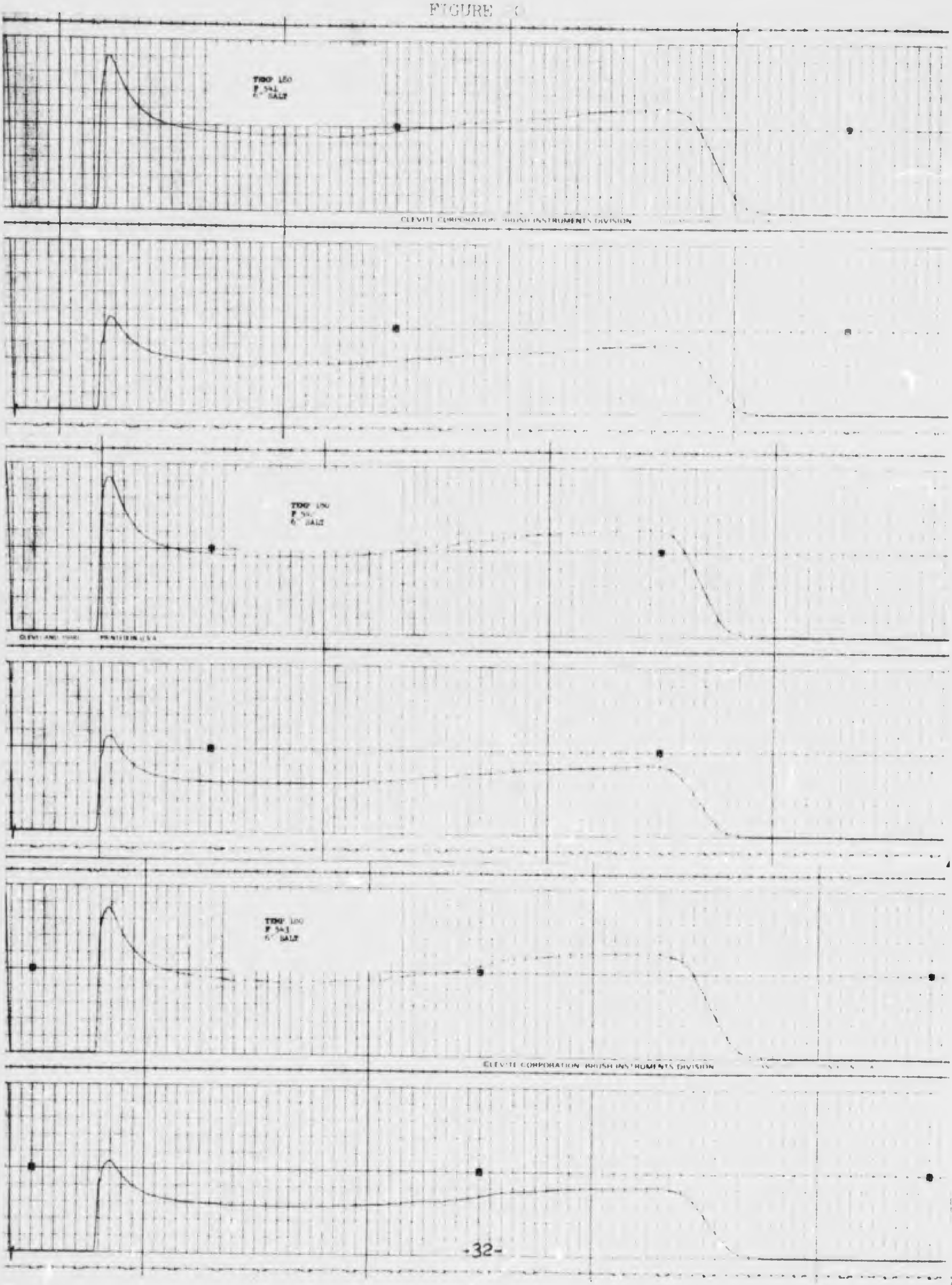
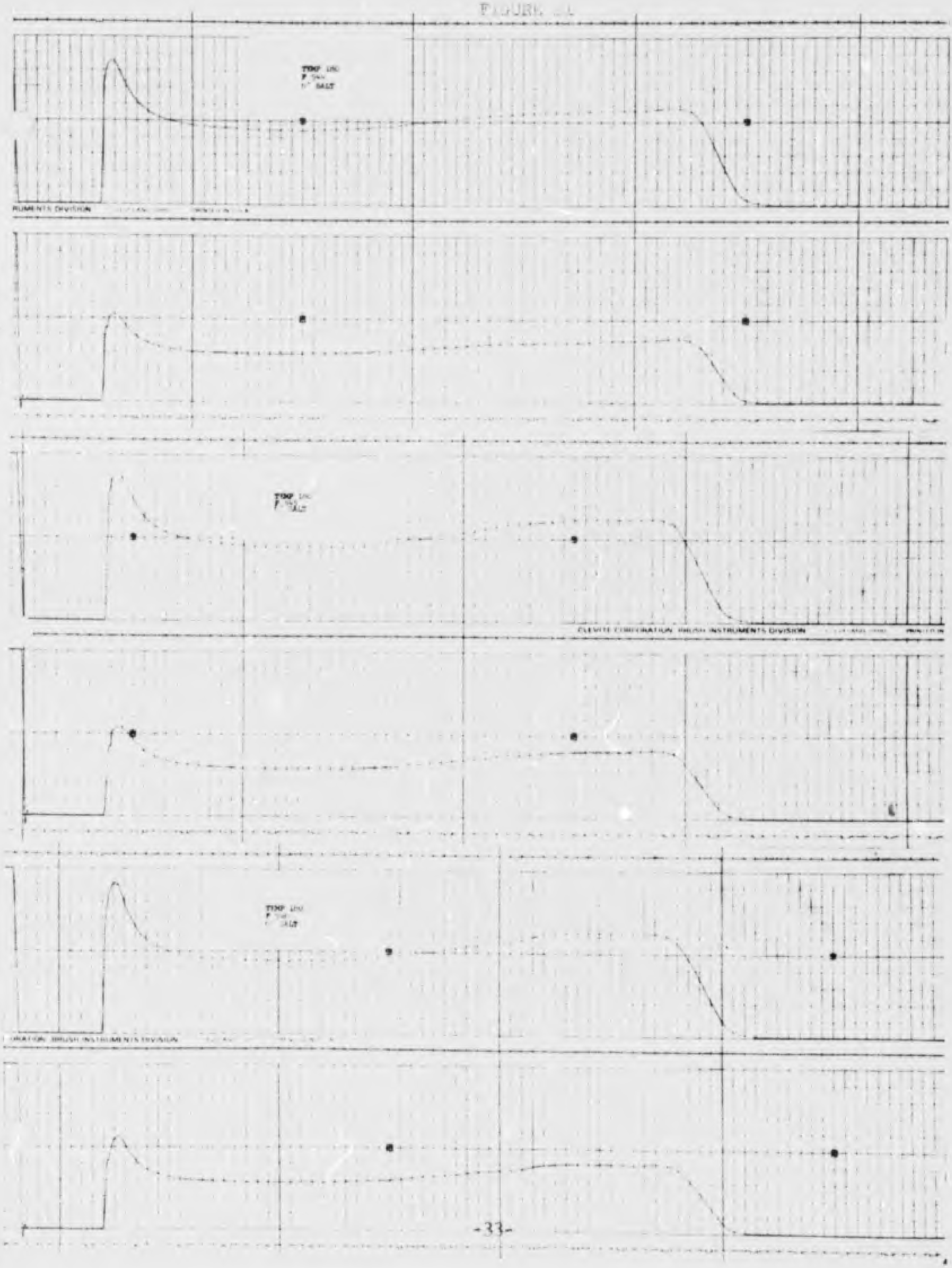
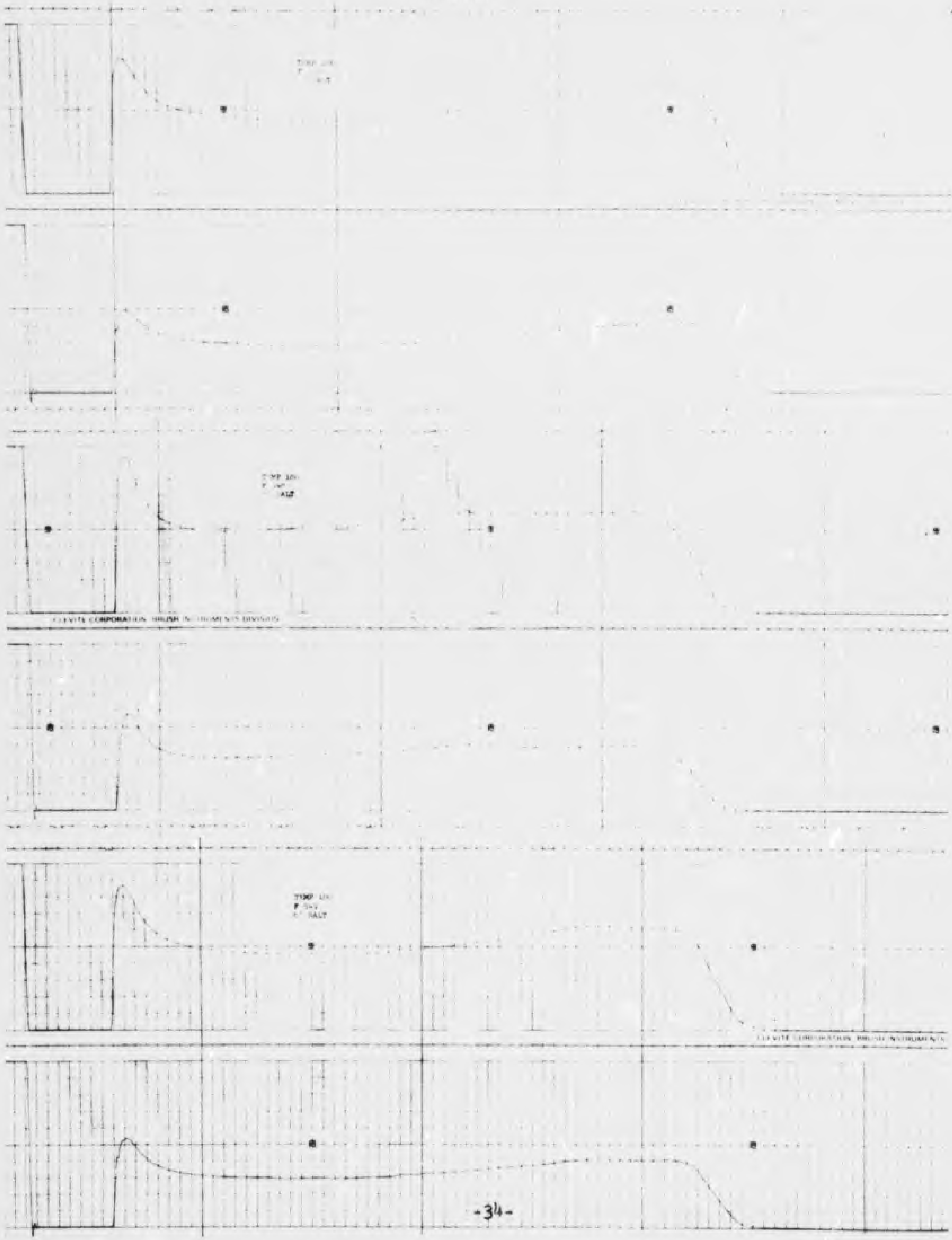
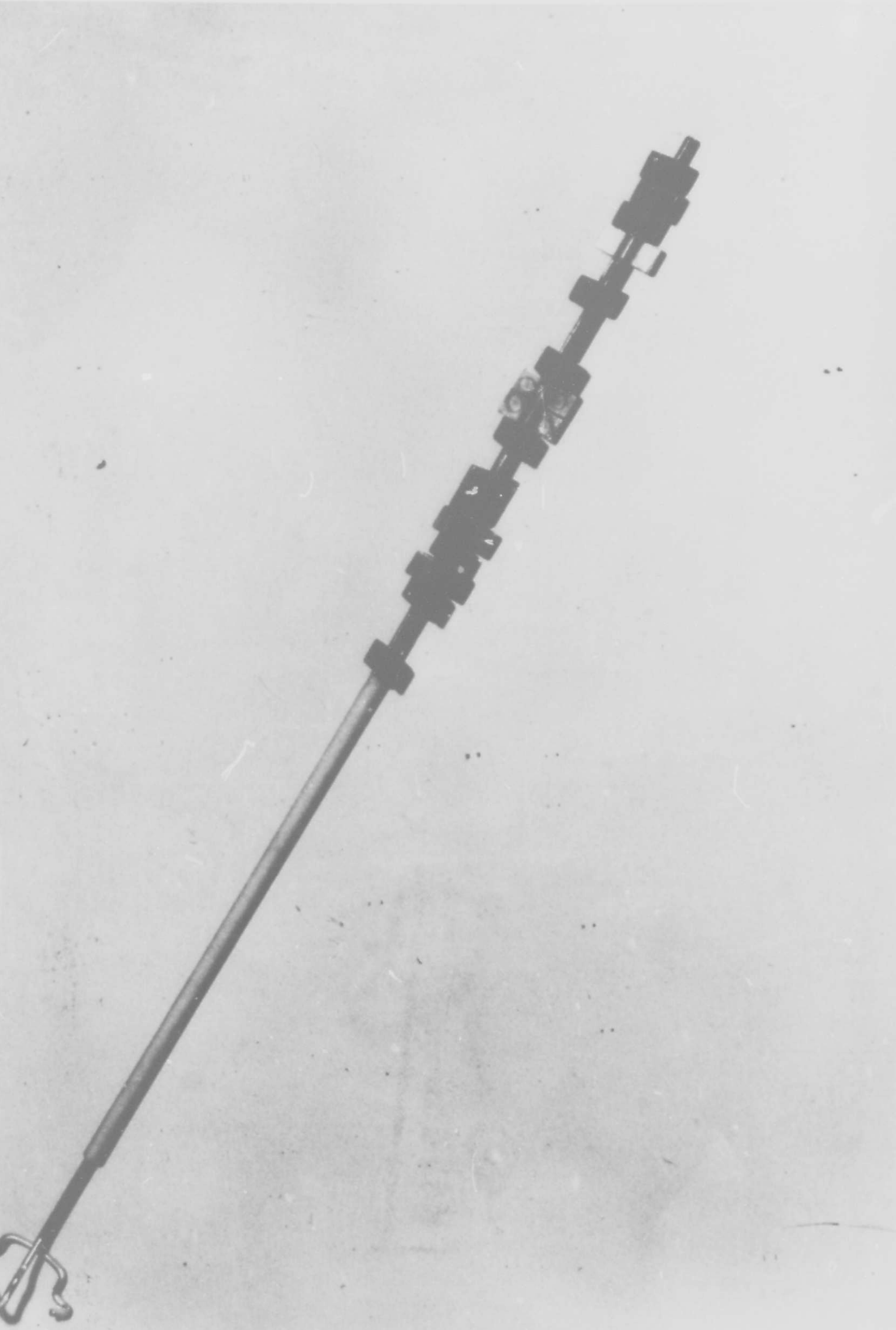

CLEVITE CORPORATION BRUSH INSTRUMENTS DIVISION
CLEVITE CORPORATION BRUSH INSTRUMENTS DIVISION

FIGURE 11



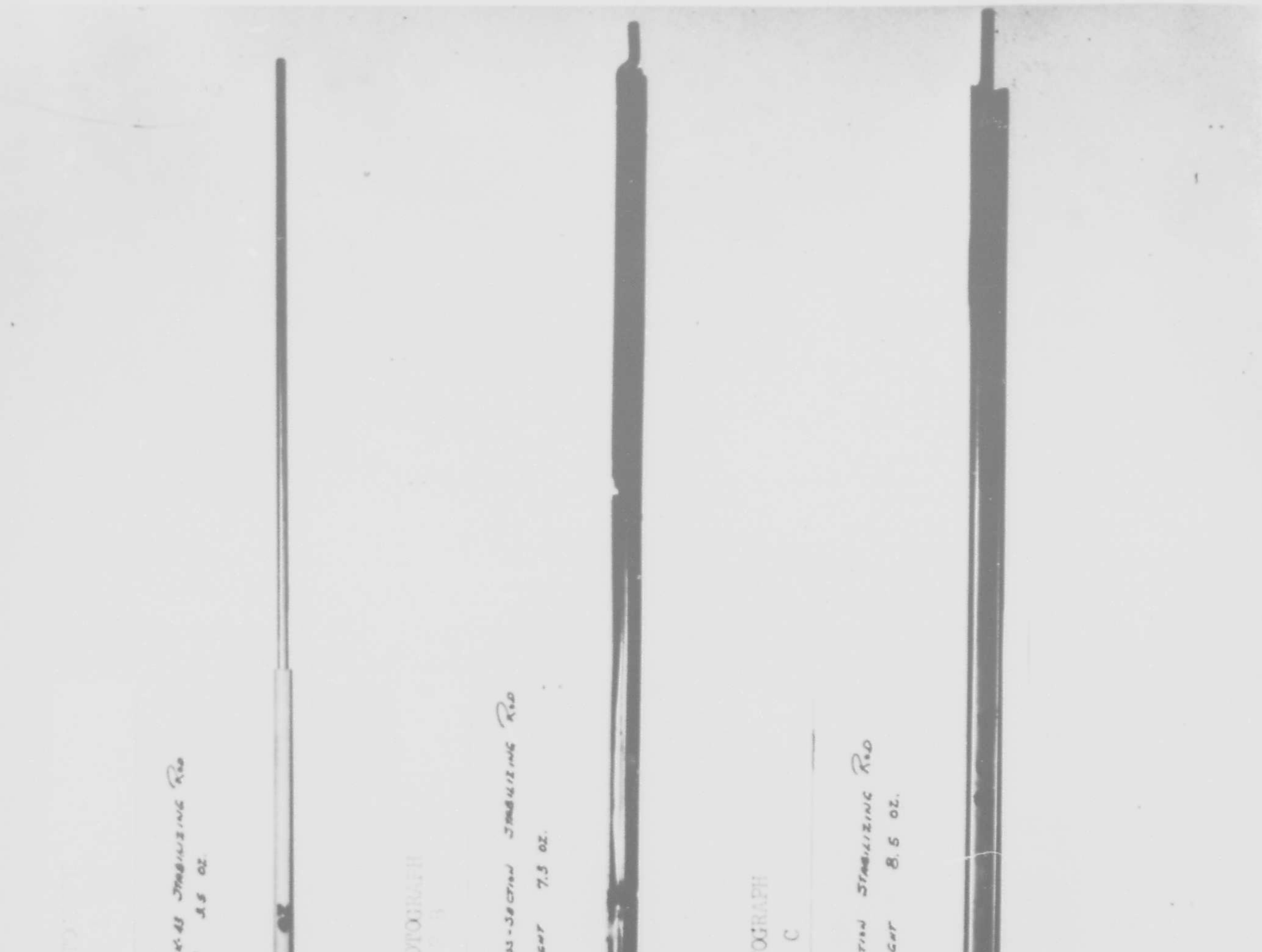
FIGURE





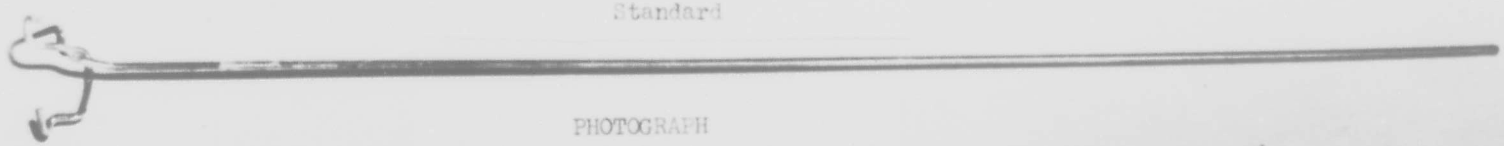
PHOTOGRAPH I

Standard rod with attached metal fins


STANDARD MK-43 STABILIZING ROD
WEIGHT 3.5 OZ.
PHOTOGRAPH
CRUCIFORM CROSS-SECTION STABILIZING ROD
WEIGHT 7.5 OZ.
PHOTOGRAPH
2 C
"L" CROSS-SECTION STABILIZING ROD
WEIGHT 8.5 OZ.

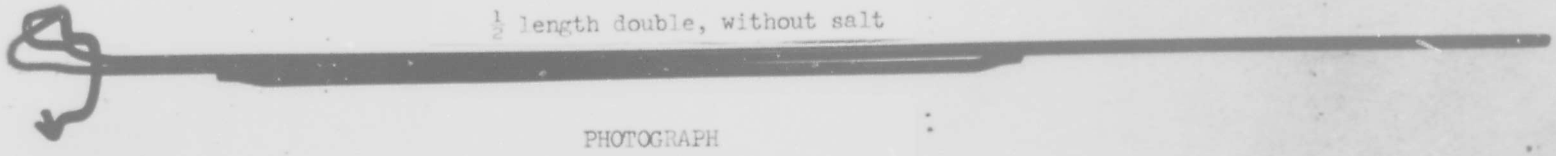
PHOTOGRAPH
3 A

Standard



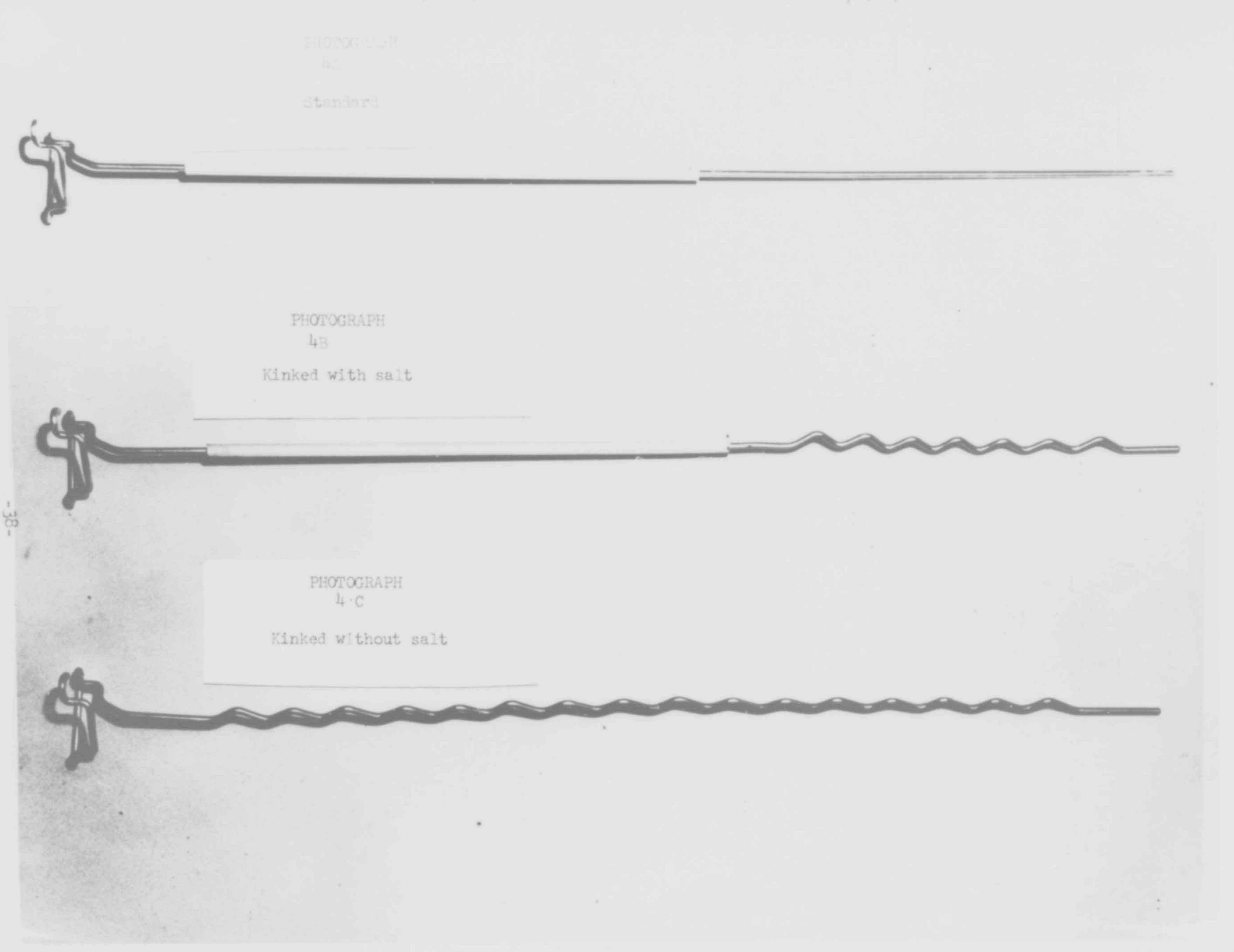
PHOTOGRAPH
3 B

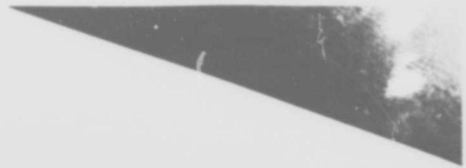
½ length double, without salt

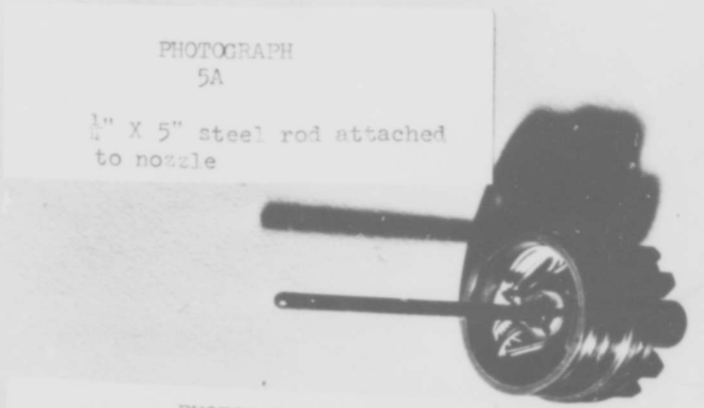


PHOTOGRAPH
3 C

½ length triple, without salt

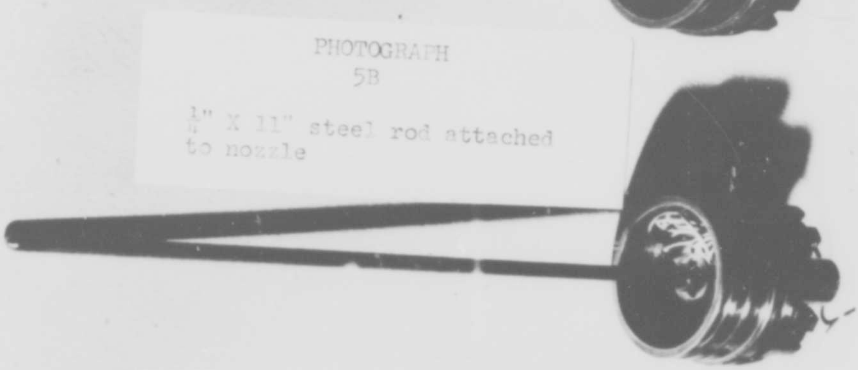

PHOTOGRAPH
4A
Standard
PHOTOGRAPH
4B
Kinked with salt
PHOTOGRAPH
4·C
Kinked without salt





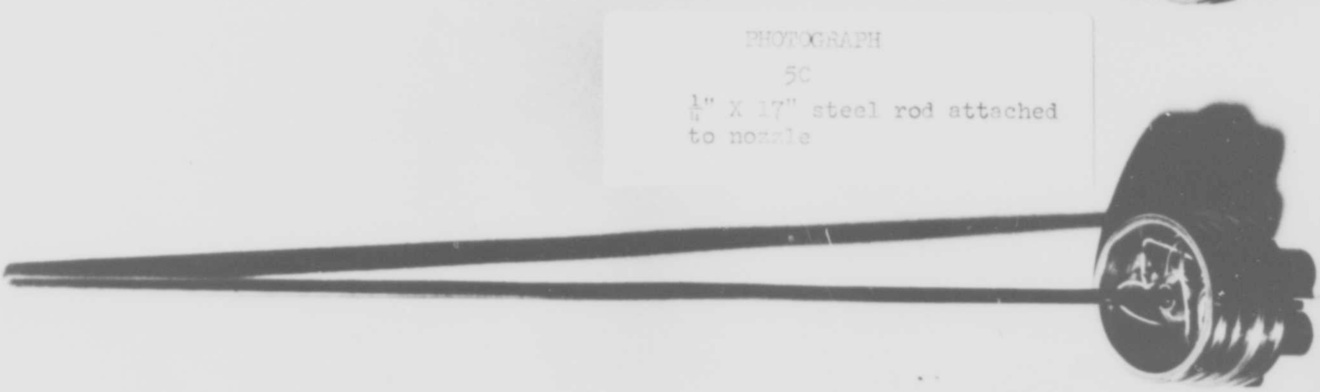
PHOTOGRAPH
5A

$\frac{1}{4}$" X 5" steel rod attached to nozzle



PHOTOGRAPH
5B

$\frac{1}{4}$" X 11" steel rod attached to nozzle



PHOTOGRAPH
5C

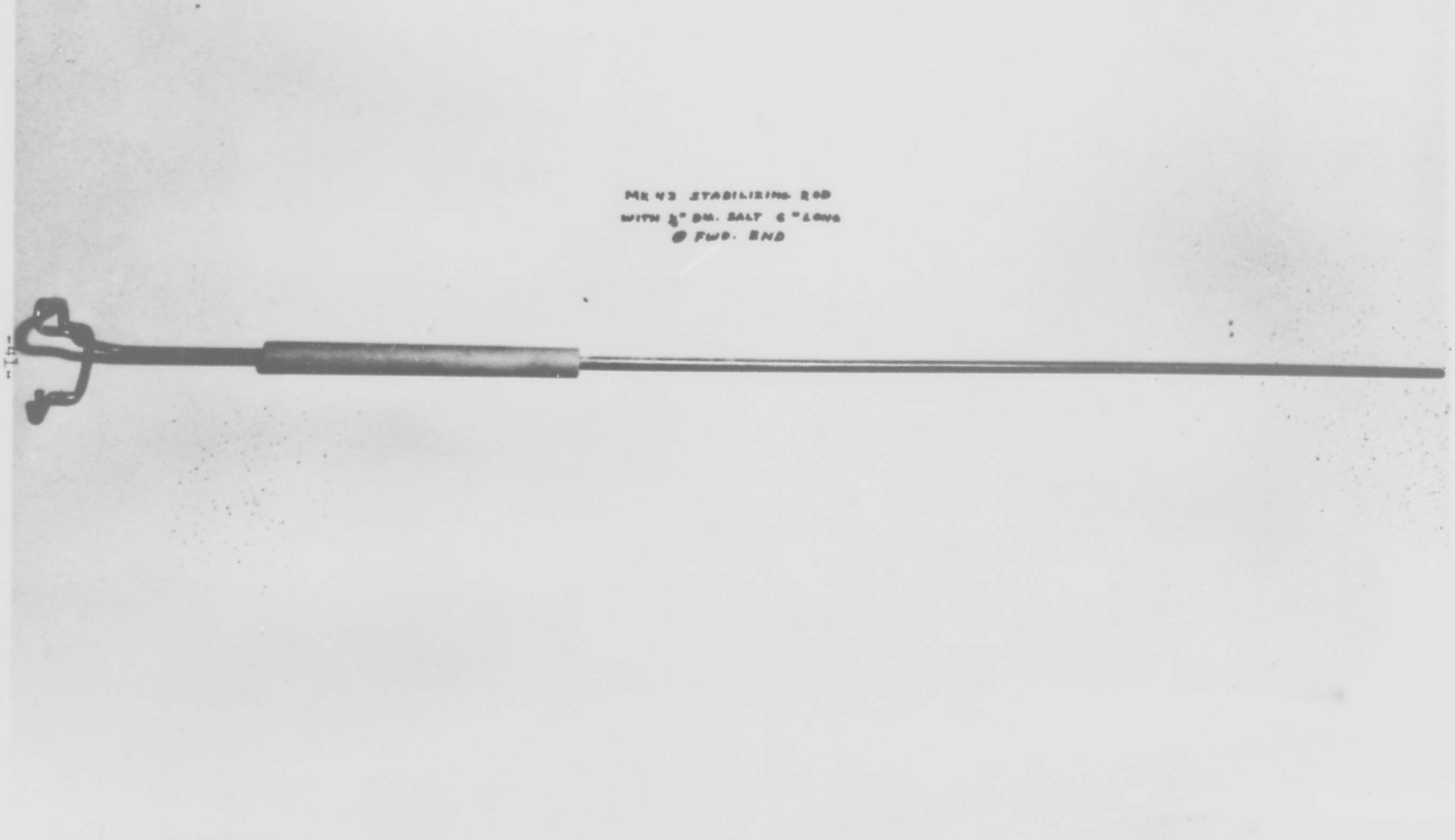
$\frac{1}{4}$" X 17" steel rod attached to nozzle

PHOTOGRAPH 6

Full Length Triple

PHOTOGRAPH 7

With salt 0.5 inch diameter
and 6.0 inches long



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MODIFICATION OF 2.75" FFAR STABILIZING ROD TO ELIMINATE ERRATIC PRESSURE AND THRUST EXCURSIONS WHEN STATIC TESTED AT +165°F.

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13. ABSTRACT

Through experimental work, a modification of the stabilizing rod in the 2.75" FFAR was developed which would eliminate the occurrence of erratic pressure and thrust excursions (NOTS Pips) in the static testing of grains at +165°F. This modification involved changing the diameter and length of the potassium sulfate on the stabilizing rod. The change from 0.3 to 0.5 inch diameter and from 12.0 to 6.0 inches length completely eliminated the occurrence of NOTS Pips when grains were tested at 180°F. An Engineering Change Proposal will be initiated recommending these changes to Drawings 9209320 and 458159 BuOrd.

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Stabilizing rod						

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