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TECHNICAL NOTE TN-1150

EXPERIMENTAL STUDY OF THE FLOW CHARACTERISTICS IN THE GAS TUBE OF THE M16A1 RIFLE

30-38

by

MARTIN HORCHLER

April 1970

DEPARTMENT OF THE ARMY
FRANKFORD ARSENAL
Philadelphia, Pa. 19137

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EXPERIMENTAL STUDY OF THE FLOW CHARACTERISTICS IN THE GAS TUBE OF THE M16A1 RIFLE

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FRANKFORD ARSENAL
Philadelphia, Pa. 19137

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ABSTRACT

Tests were conducted to measure and determine the configuration of pressure and temperature pulses in the gas tube of the M16A1 rifle. Tests involved both IMR-8208M and WC-846 propellants. The peak pressures ranged from 1000 psi to 6100 psi and the peak temperatures from 210°F to 500°F, depending on the propellant used and the location of the measuring device. Results are tabulated and actual test records are included.

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INTRODUCTION

A unique feature, and sometimes a controversial one, of the M16A1 rifle is its unconventional means of driving the bolt. This is accomplished by using a tube to transfer gas from the gas port to the bolt cavity. Since the gas tube has a tendency to accumulate residue, which is virtually impossible to remove because of its inaccessibility, it is often blamed for being the cause of malfunctions occurring with the M16 Rifle. Also, the gas transmission tube is often identified as the cause of the large variation in cyclic rates, characteristic of the M16. These are some of the reasons for the keen interest in the investigations being performed on this simple item. Also, some information was requested for a non-steady flow analysis being undertaken for simulation purposes.

The following is a summary of the experimental work done on the M16A1 gas tube at Frankford Arsenal. Four individual tests were performed. Each involved both IMR-8208M and WC-846 propellant. The purpose of the experiment was to obtain pressure and temperature information at various locations on the gas tube.

PROCEDURE

The gas tube of the M16A1 rifle is a drawn stainless steel tube, 15.17 inches long with an outer diameter of 0.180 inch and an inner diameter of approximately 0.120 inch (see Fig. 1). The forward end of the tube is plugged while the other end is open. The open end mates with a key on the bolt carrier. The plugged end contains a lateral hole in the wall which aligns with a corresponding hole in the sight bracket. This hole, in turn, aligns with the one in the barrel, called the port. Thus as the bullet passes the port, a portion of the propellant gases is diverted to the bolt carrier assembly.

The gas tube was modified (see Fig. 2) to permit the measurement of pressure and temperature. Four tests were performed as shown in Figs. 3 to 6 and outlined below:

Test I - Pressure gages were mounted at Stations 2 and 6 and Records Nos. 1 to 10 were taken. Next the key was removed and Records Nos. 41 to 44 were taken.

Test II - Pressure gages were mounted at Stations 7 and 8, and Records Nos. 11 to 20 were taken.

Test III - Pressure and temperature gages were mounted at Station Nos. 1 and 5 and Records Nos. 21 to 30 were taken. Then a 19-round burst of automatic fire was recorded, as described in Fig. 7.

Test IV - Temperature gages were mounted at Stations Nos. 2 to 5 and Records Nos. 31 to 40 were taken.

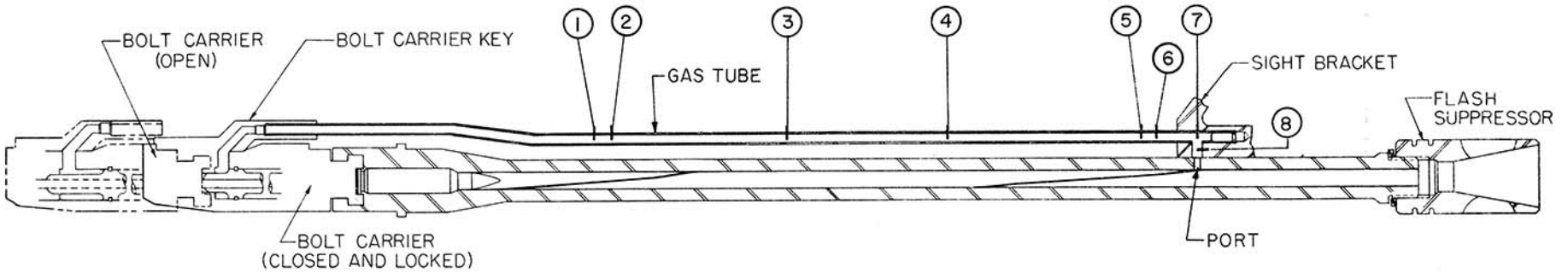


Fig. 1. Gas System, M16A1 Rifle, Showing Station Positions

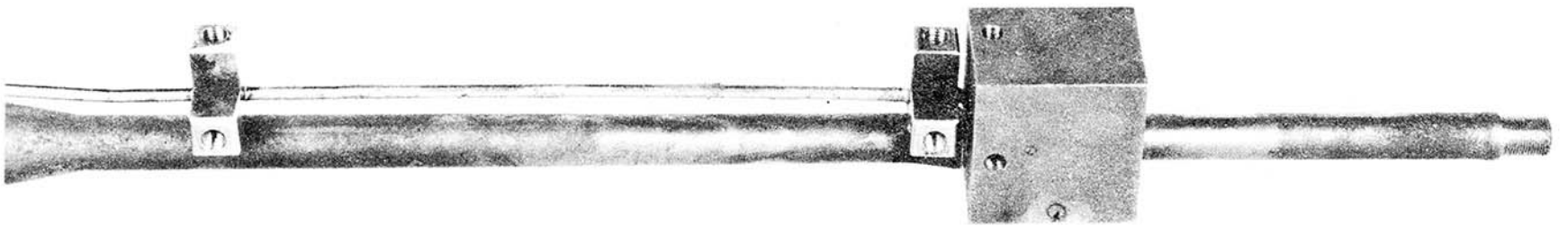
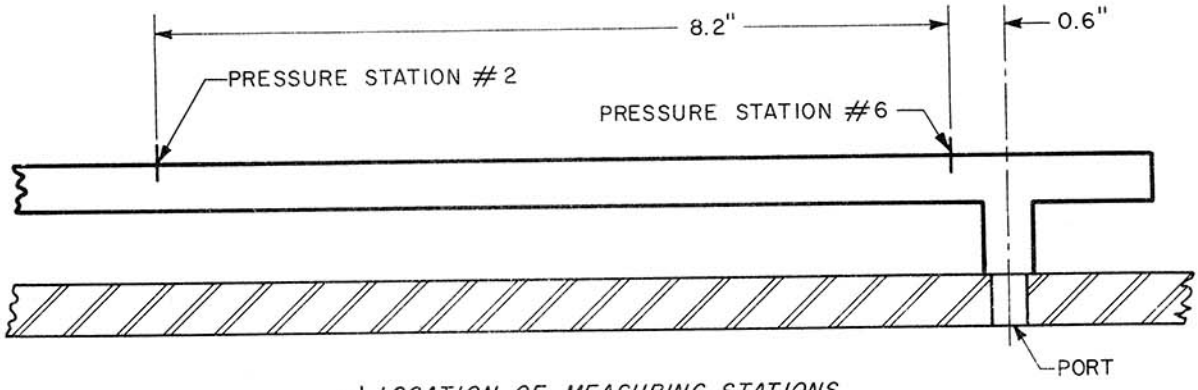
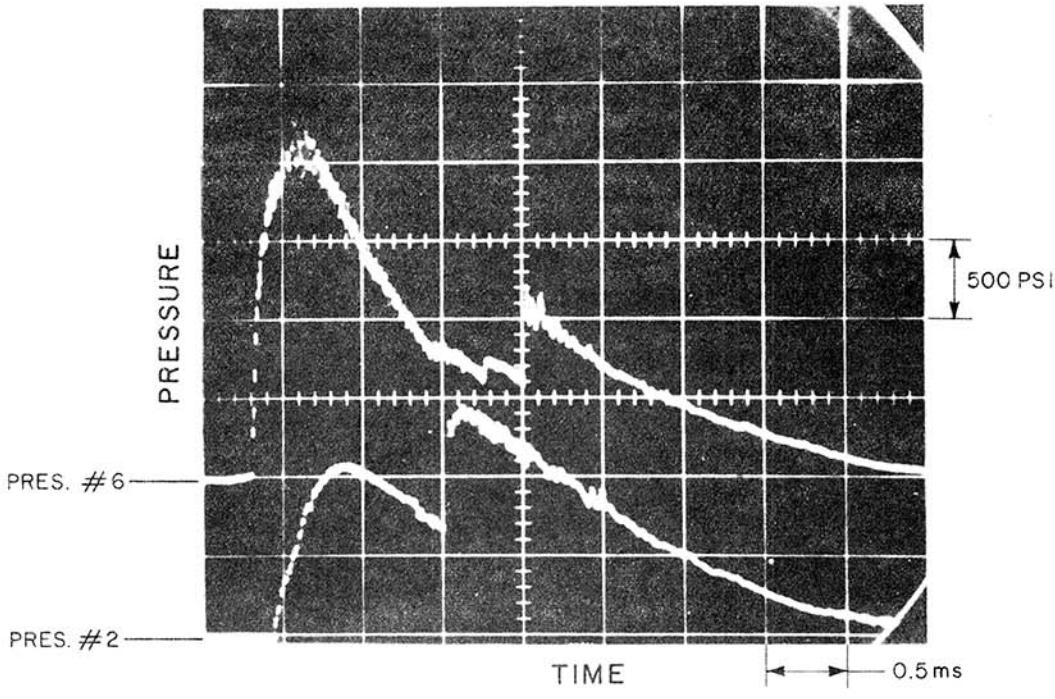


Fig. 2. Modifications to Gas Tube of M16A1 Rifle to Permit Pressure and Temperature Measurement



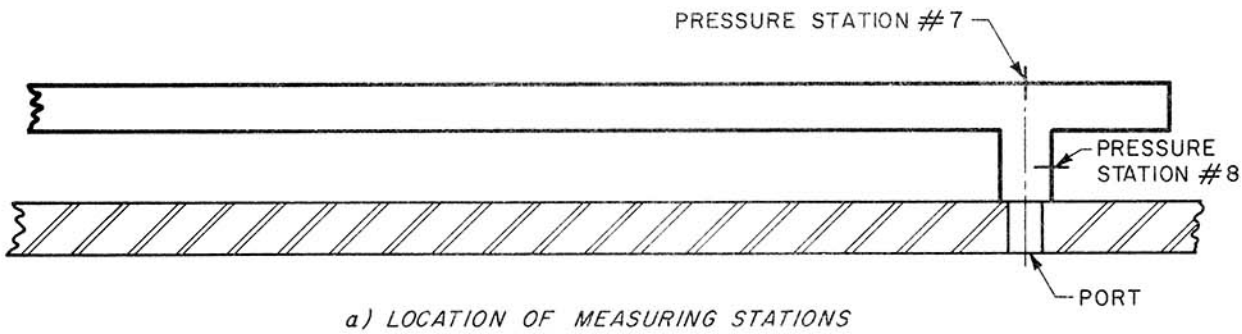
a) LOCATION OF MEASURING STATIONS



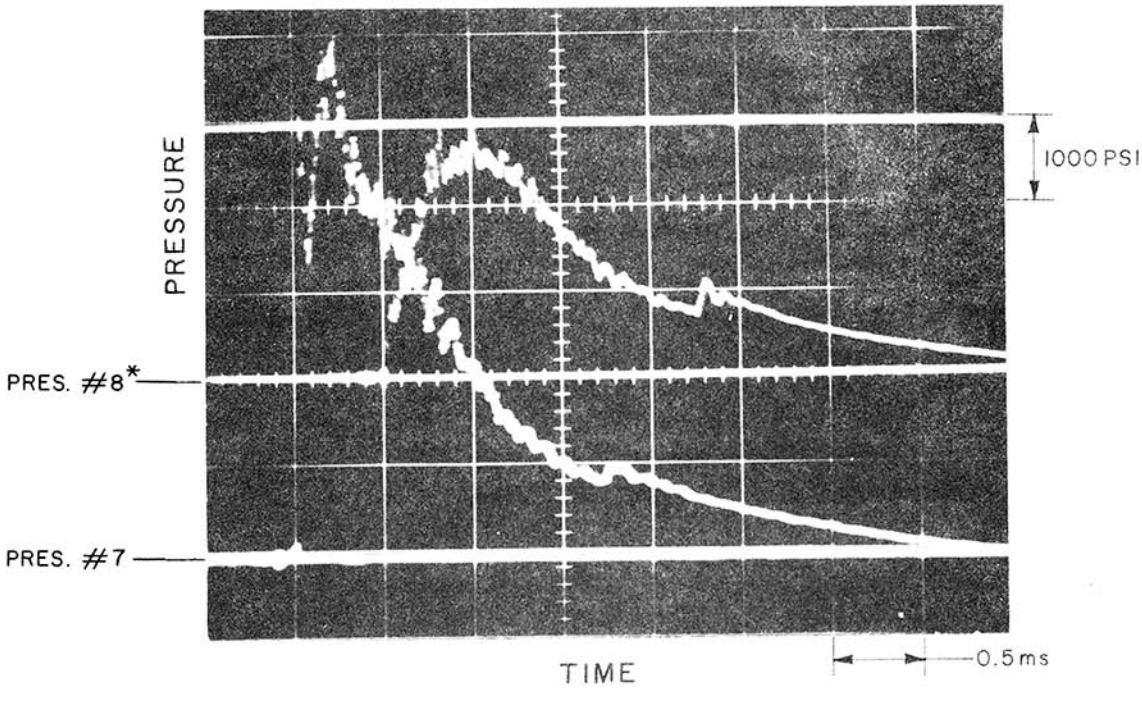
b) TYPICAL TRACES AND CALIBRATIONS

(Records Nos. 1 to 10 and 41 to 44 in Appendix A)

Fig. 3. Gas Tube Pressure Measurements for Test I



a) LOCATION OF MEASURING STATIONS

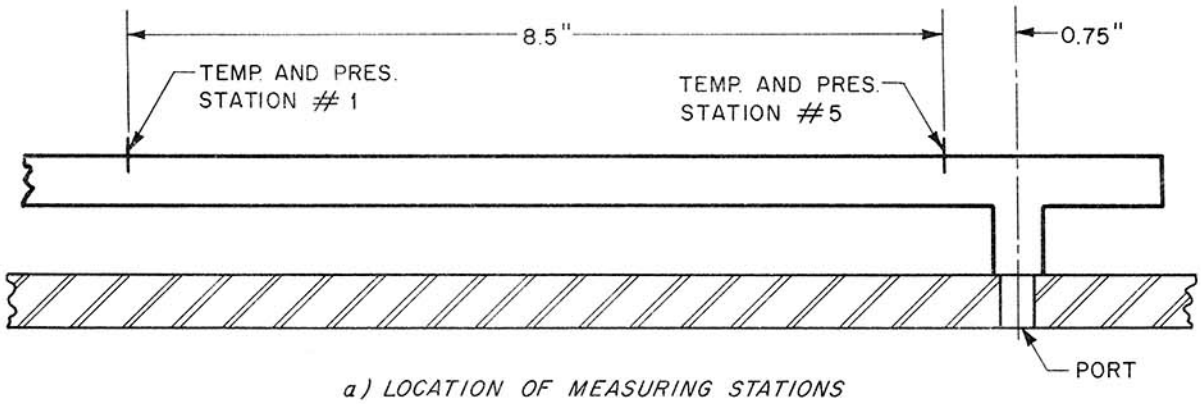


b) TYPICAL TRACES AND CALIBRATIONS

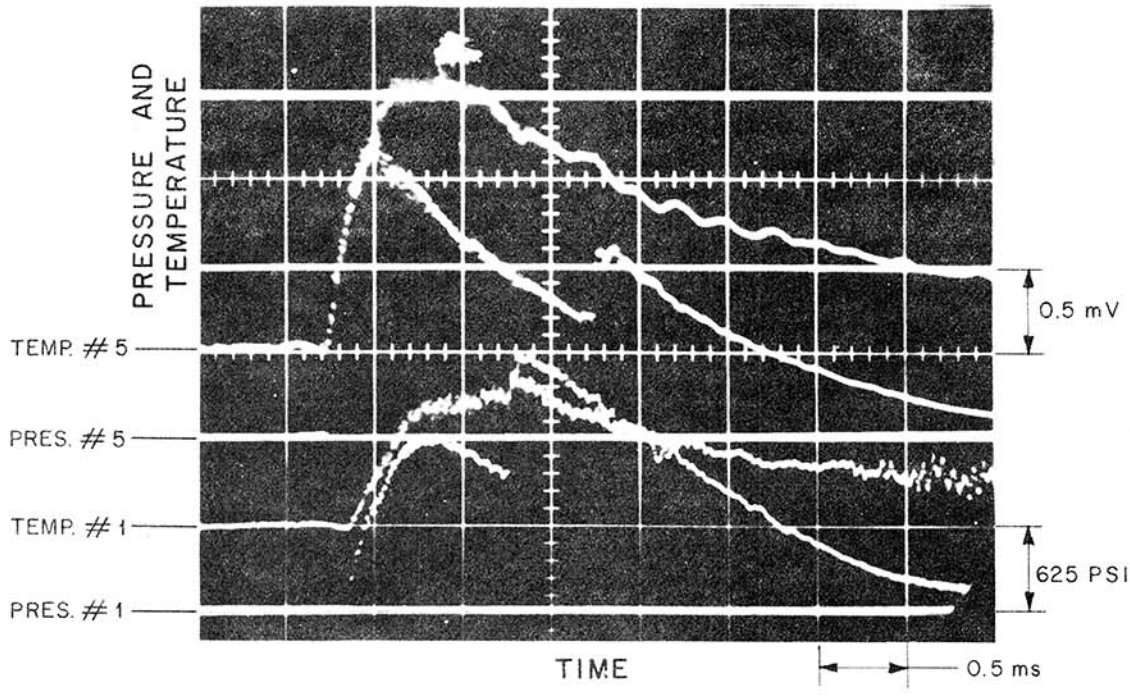
*Time is moved one division to the right.

(Records Nos. 11 to 20 in Appendix A)

Fig. 4. Gas Tube Pressure Measurements for Test 11



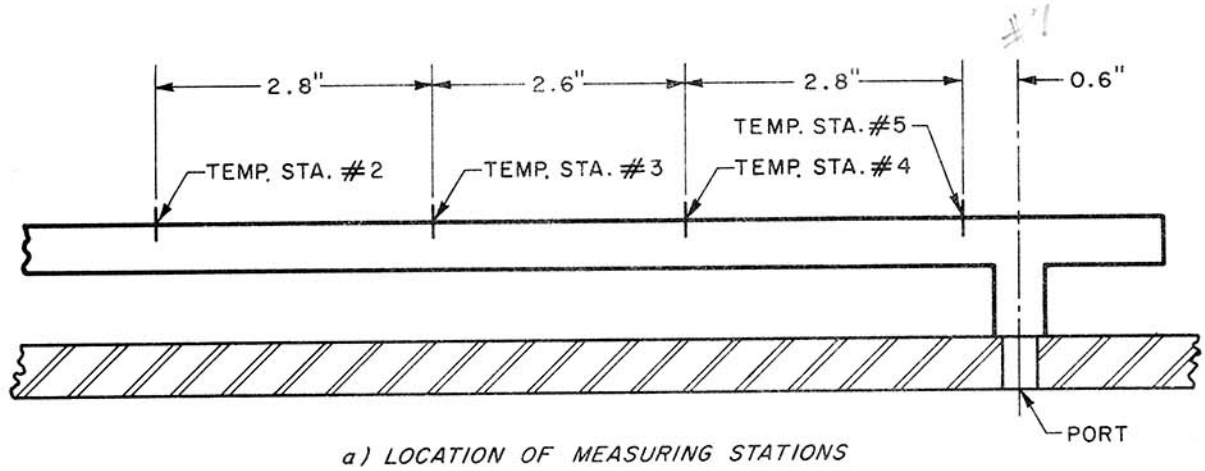
a) LOCATION OF MEASURING STATIONS



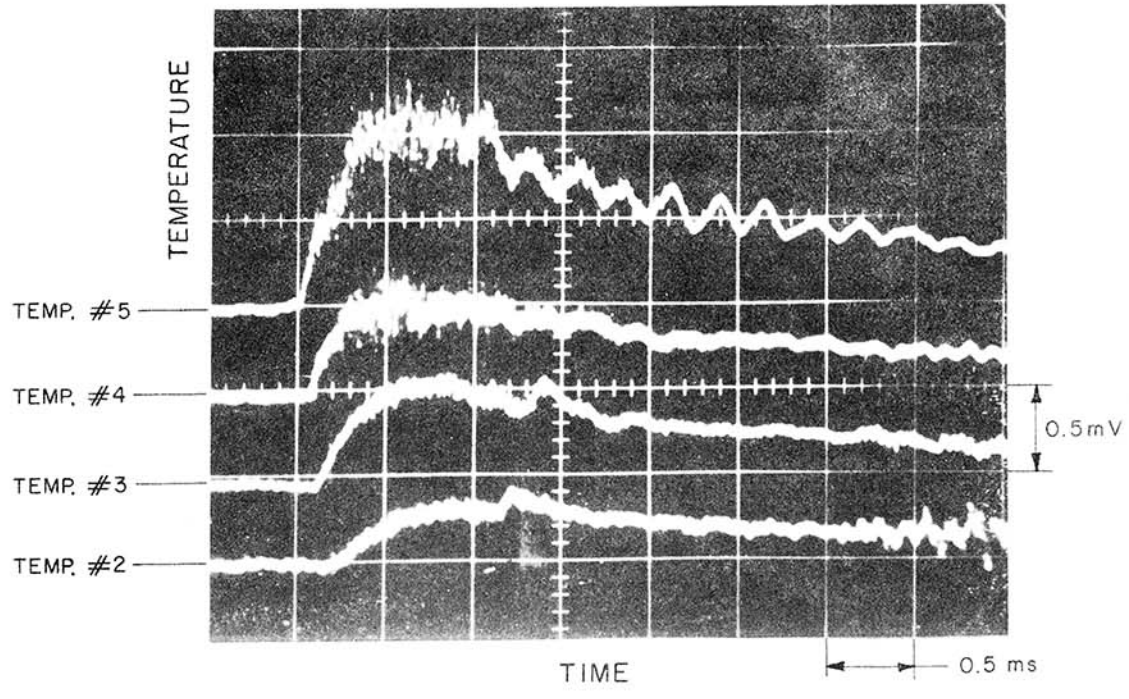
b) TYPICAL TRACES AND CALIBRATIONS

Fig. 7 and Records Nos. 21 to 30 in Appendix A)

Fig. 5. Gas Tube Pressure and Temperature Measurements for Test III



a) LOCATION OF MEASURING STATIONS



b) TYPICAL TRACES AND CALIBRATIONS

(Records Nos. 31 to 40 in Appendix A)

Fig. 6. Gas Tube Temperature Measurements for Test IV

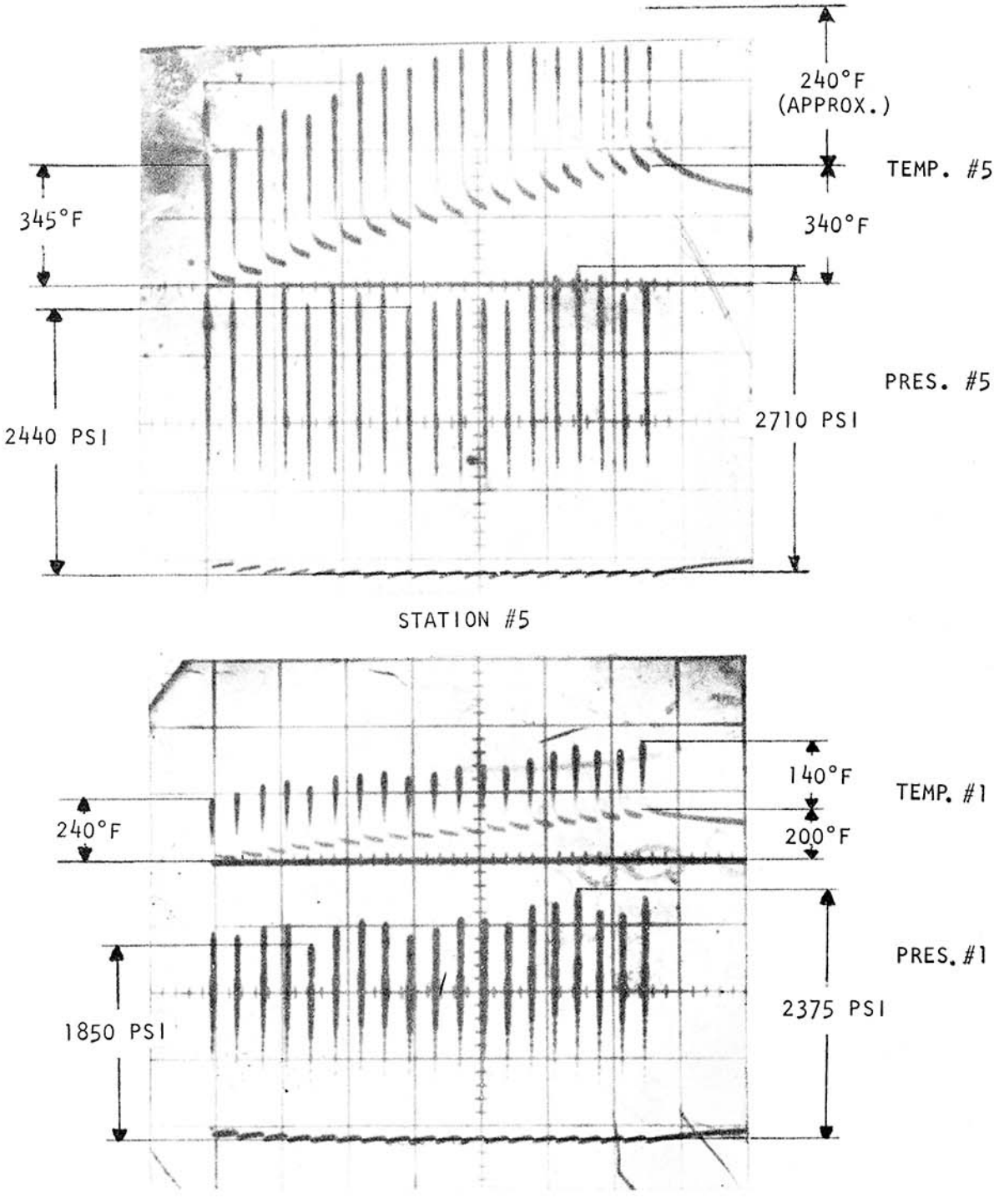


Fig. 7. Nineteen-Round Automatic Fire

Pressure was measured with a Kistler 601H pressure transducer and temperature with tungsten/tungsten-27% rhenium thermocouples. Both pressure and temperature records were read on an oscilloscope. Pressure was read directly while temperature was obtained from the millivolt reading by means of the calibration chart shown in Appendix A. Typical traces are shown on the configuration figures.

After modifying the rifle, tests were fired with two lots of ammunition:

(1) TW18048 with IMR-8208M propellant and tracer ammunition

(2) LC12304 with WC-846 propellant and ball ammunition.

RESULTS

A large number of records was generated. Variations were found to be so slight that only five records were selected at random. These, as a fair representation of the parameters, are included in this report.

Peak pressure was found to be 6100 psi (at Station 7, Test II) and peak temperature, 490°F (at Station 5, Test III). Individual readings for each test as well as the average for the five tests at each condition are tabulated in Tables 1 to 4. A typical oscillogram for each test is shown in Figures 3, 4, 5 and 6. These figures identify the traces and list the calibrations for each test. The individual test records are contained in Appendix A.

For pressure tests, both peak pressure and reflected pressure were measured as well as the time to reach these values. For temperature tests, maximum temperature and time to reach this value were measured. The temperature readings are somewhat doubtful because they only read the temperature of the part of the gas that is close to the wall. However, the response time of the thermocouples was fast (10 microseconds), so that the reading gives a good estimate of the velocity of the disturbance. The velocity of the pressure pulse was found to be approximately 4783 fps. The velocity of the reflected pulse was found to be approximately 1350 fps.

CONCLUSIONS AND RECOMMENDATIONS

1. The test results indicate the configuration of the pressure pulse proceeding along the gas tube of the M16A1 rifle.

2. The gas of the IMR propellant is slightly cooler and generates slightly less pressure in the gas tube than that of the WC propellant.

3. A temperature gage should be mounted at Station No. 7 to obtain a more realistic temperature of the gas.

Table 1. Pressure Readings for Test I

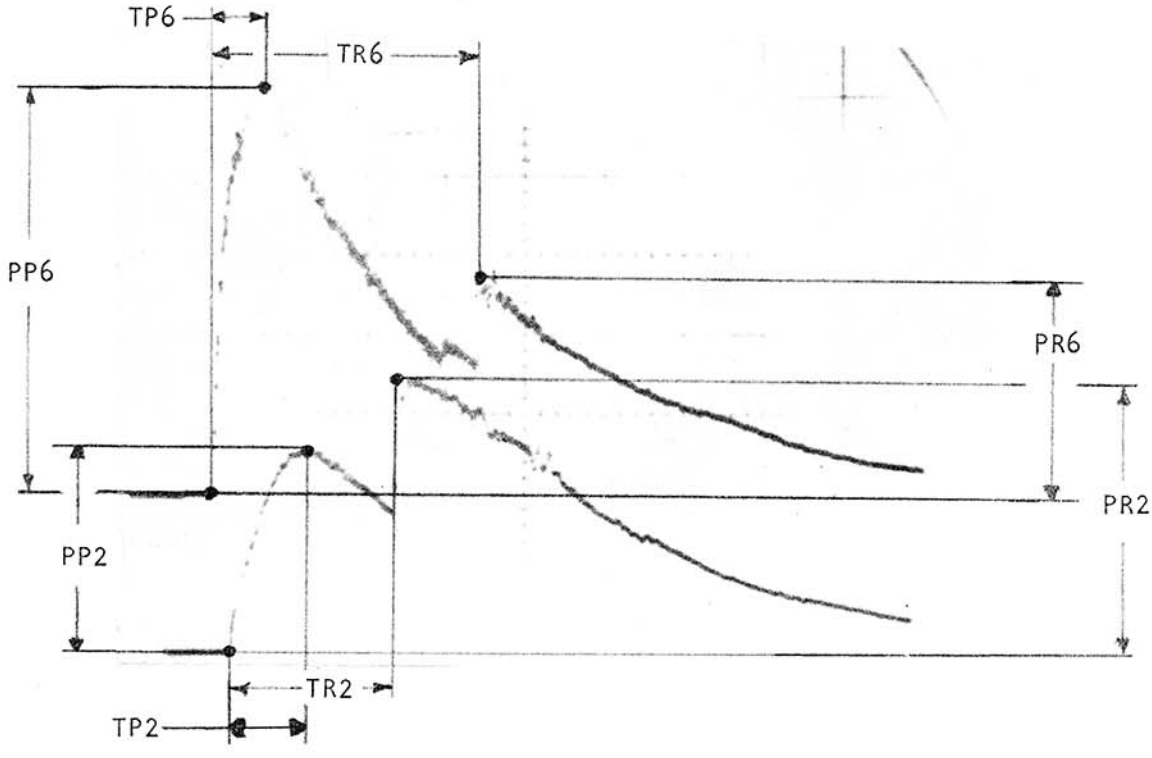


Table 1(a). Readings

Rd	PP2 (1000 psi)	TP2 (msec)	PR2 (1000 psi)	TR2 (msec)
	STATION 2 WC-846			
(1)	1.40	.50	1.80	1.10
(3)	1.40	.50	1.80	1.10
(5)	1.40	.45	1.80	1.10
(7)	1.35	.45	1.80	1.10
(9)	1.30	.50	1.70	1.10
Avg.	1.35	.48	1.80	1.10
	PP6	TP6	PR6	TR6
	STATION 6 WC-846			
(1)	2.60	.30	1.40	1.65
(3)	2.75	.30	1.45	1.65
(5)	2.60	.35	1.40	1.65
(7)	2.60	.35	1.40	1.65
(9)	2.55	.30	1.30	1.70
Avg.	2.65	.32	1.40	1.66

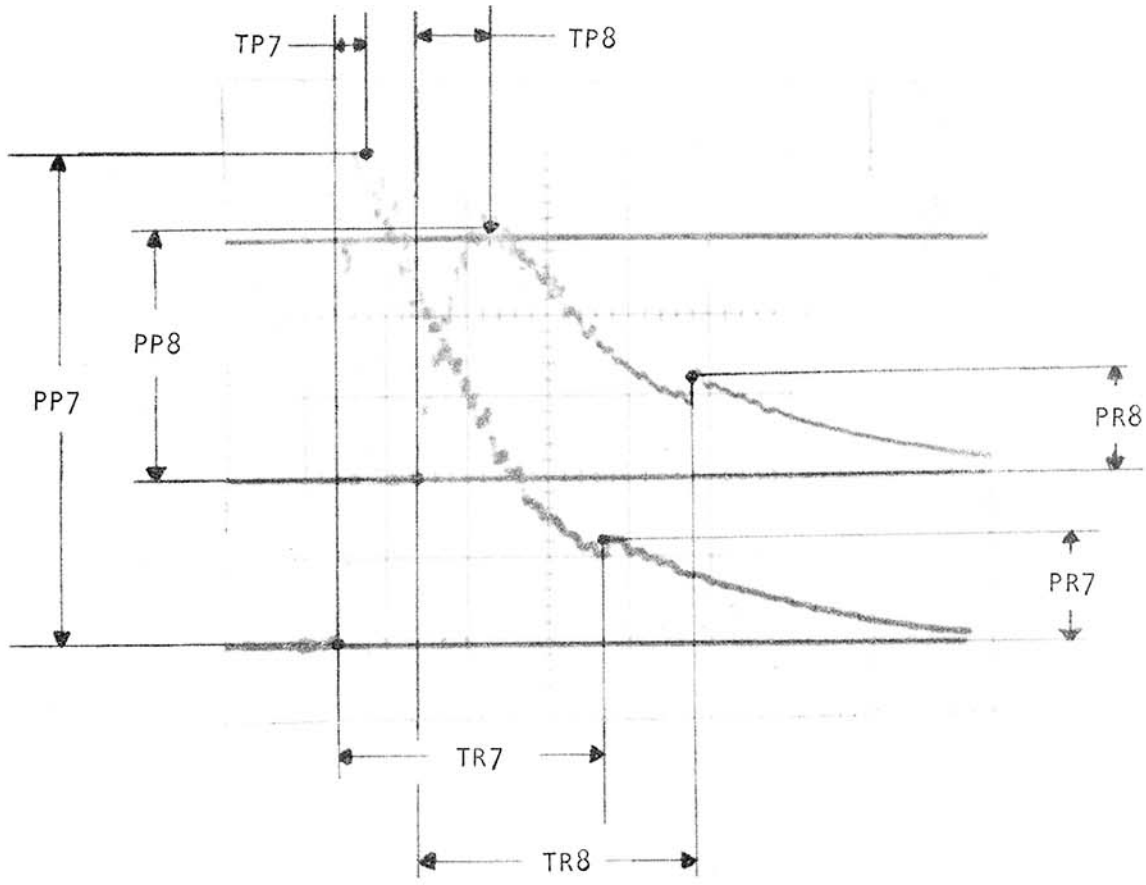
Rd	PP2 (1000 psi)	TP2 (msec)	PR2 (1000 psi)	TR2 (msec)
	STATION 2 IMR-8408M			
(2)	1.15	.40	1.45	1.15
(4)	1.10	.45	1.45	1.20
(6)	1.10	.45	1.45	1.20
(8)	1.10	.50	1.45	1.20
(10)	1.05	.50	1.40	1.20
	1.10	.46	1.45	1.19
	PP6	TP6	PR6	TR6
	STATION 6 IMR-8208M			
(2)	2.20	.30	1.10	1.70
(4)	2.10	.30	1.10	1.70
(6)	2.20	.30	1.15	1.70
(8)	2.10	.30	1.10	1.70
(10)	2.15	.30	1.10	1.70
	2.15	.30	1.10	1.70

Table 1(b). Readings With Bolt Carrier Key Removed

	PP2	TP2	PP6	TP6
	STATION 2 WC-846			
(41)	1.25	.45	2.35	.30
(43)	1.35	.50	2.50	.30

	PP2	TP2	PP6	TP6
	STATION 2 IMR-8408M			
(42)	1.05	.45	2.10	.30
(44)	1.05	.45	2.10	.30

Table 2. Pressure Readings for Test 11



Rd	PP7 (1000 psi)	TP7 (msec)	PR7 (1000 psi)	TR7 (msec)	Rd	PP7 (1000 psi)	TP7 (msec)	PR7 (1000 psi)	TR7 (msec)
		STATION 7 WC-846					STATION 7 IMR-8408M		
(11)	6.2	.25	1.3	1.75	(12)	5.7	.20	1.0	1.75
(13)	6.2	.25	1.3	1.70	(14)	5.7	.20	1.0	1.75
(15)	6.1	.25	1.2	1.70	(16)	5.6	.25	1.0	1.75
(17)	6.1	.25	1.3	1.70	(18)	5.7	.25	1.0	1.80
(19)	6.1	.25	1.3	1.70	(20)	5.6	.25	1.0	1.75
Avg.	6.1	.25	1.3	1.71		5.6	.23	1.0	1.76
	PP8	TP8	PR8	TR8		PP8	TP8	PR8	TR8
		STATION 8 WC-846					STATION 8 IMR-8408M		
(11)	3.2	.50	1.3	1.75	(12)	2.6	.40	1.1	1.80
(13)	3.2	.45	1.3	1.75	(14)	2.6	.40	1.0	1.80
(15)	3.2	.45	1.2	1.75	(16)	2.6	.40	1.1	1.80
(17)	3.2	.45	1.3	1.75	(18)	2.7	.50	1.0	1.80
(19)	3.2	.50	1.2	1.75	(20)	2.7	.50	1.0	1.80
Avg.	3.2	.47	1.3	1.75		2.6	.45	1.0	1.80

Table 3. Pressure and Temperature Readings for Test III

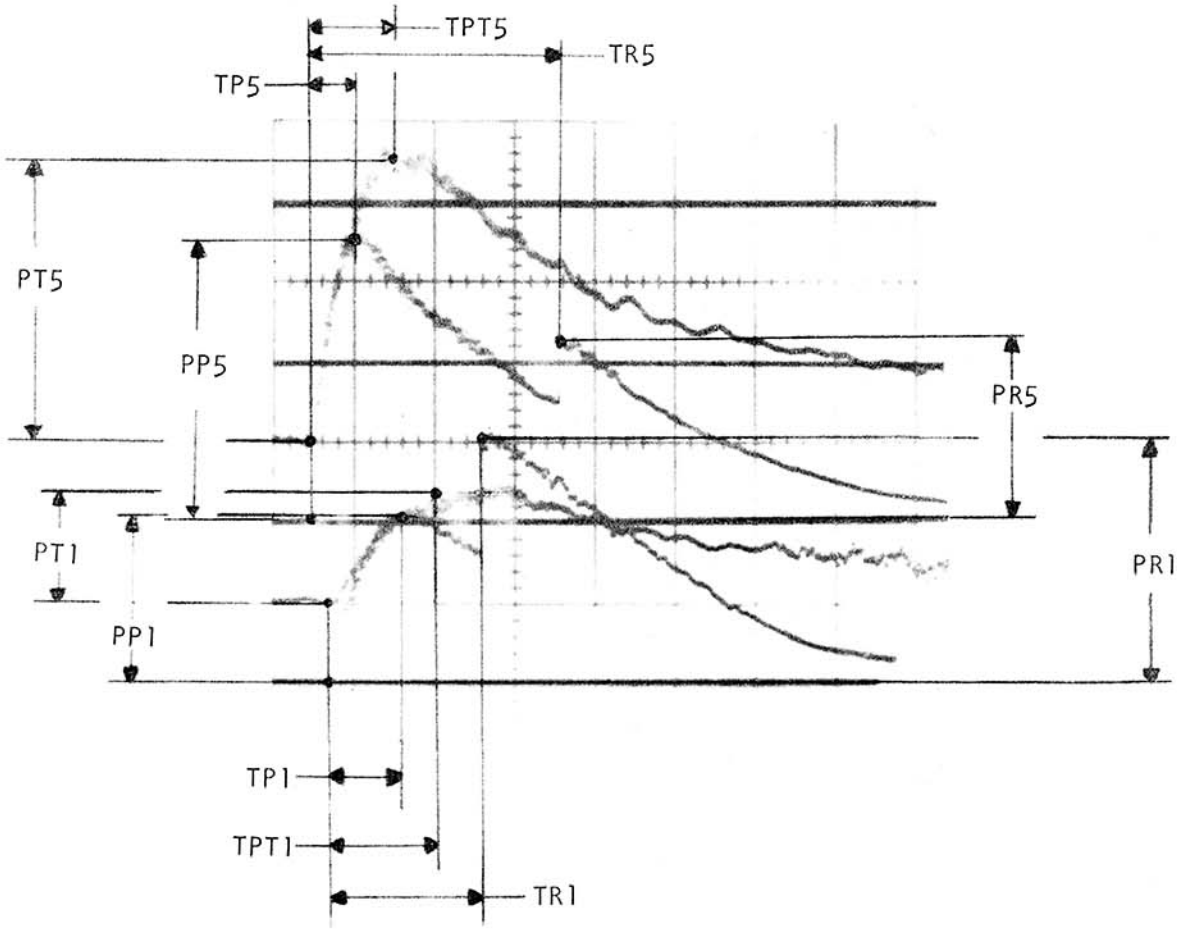


Table 3. Pressure and Temperature Readings for Test III (Continued)

Rd	PP1 (1000 psi)	TP1 (msec)	PR1 (1000 psi)	TR1 (msec)
	STATION 1 WC-846			
(21)	1.25	.45	1.80	.95
(23)	1.25	.40	1.90	.95
(25)	1.25	.40	1.90	1.00
(27)	1.25	.40	1.90	.90
(29)	1.25	.45	1.80	.95
Avg.	1.25	.42	1.85	.95
	PP5	TP5	PR5	TR5
	STATION 5 WC-846			
(21)	2.05	.30	1.30	1.65
(23)	2.10	.30	1.40	1.65
(25)	2.10	.30	1.35	1.65
(27)	2.10	.30	1.40	1.60
(29)	2.09	.30	1.30	1.65
Avg.	2.10	.30	1.35	1.64

Rd	PP1 (1000 psi)	TP1 (msec)	PR1 (1000 psi)	TP1 (msec)
	STATION 1 IMR-8208M			
(22)	1.05	.40	1.50	1.15
(24)	1.05	.40	1.50	1.05
(26)	1.05	.40	1.45	1.05
(28)	1.05	.40	1.50	1.00
(30)	1.05	.40	1.50	1.05
	1.05	.40	1.50	1.04
	PP5	TP5	PR5	TR5
	STATION 5 IMR-8408M			
(22)	1.75	.30	1.00	1.65
(24)	1.75	.30	1.05	1.70
(26)	1.75	.30	1.05	1.70
(28)	1.80	.30	1.10	1.70
(30)	1.80	.30	1.10	1.65
	1.75	.30	1.05	1.68

Rd	PT1 (°F)	TPT1 (msec)
	STATION 1 WC-846	
(21)	305	.70
(23)	320	.80
(25)	330	.60
(27)	330	.70
(29)	305	.90
Avg.	320	.75
	PT5	TPT5
	STATION 5 WC-846	
(21)	490	.60
(23)	490	.60
(25)	490	.55
(27)	480	.60
(29)	500	.55
Avg.	490	.60

Rd	PT1 (°F)	TPT1 (msec)
	STATION 1 IMR-8208M	
(22)	305	.75
(24)	305	.80
(26)	280	.80
(28)	280	.80
(30)	290	.80
	290	.80
	PT5	TPT5
	STATION 5 IMR-8208M	
(22)	410	.60
(24)	420	.55
(26)	390	.50
(28)	390	.50
(30)	390	.60
	400	.55

Table 4. Temperature Readings for Test IV

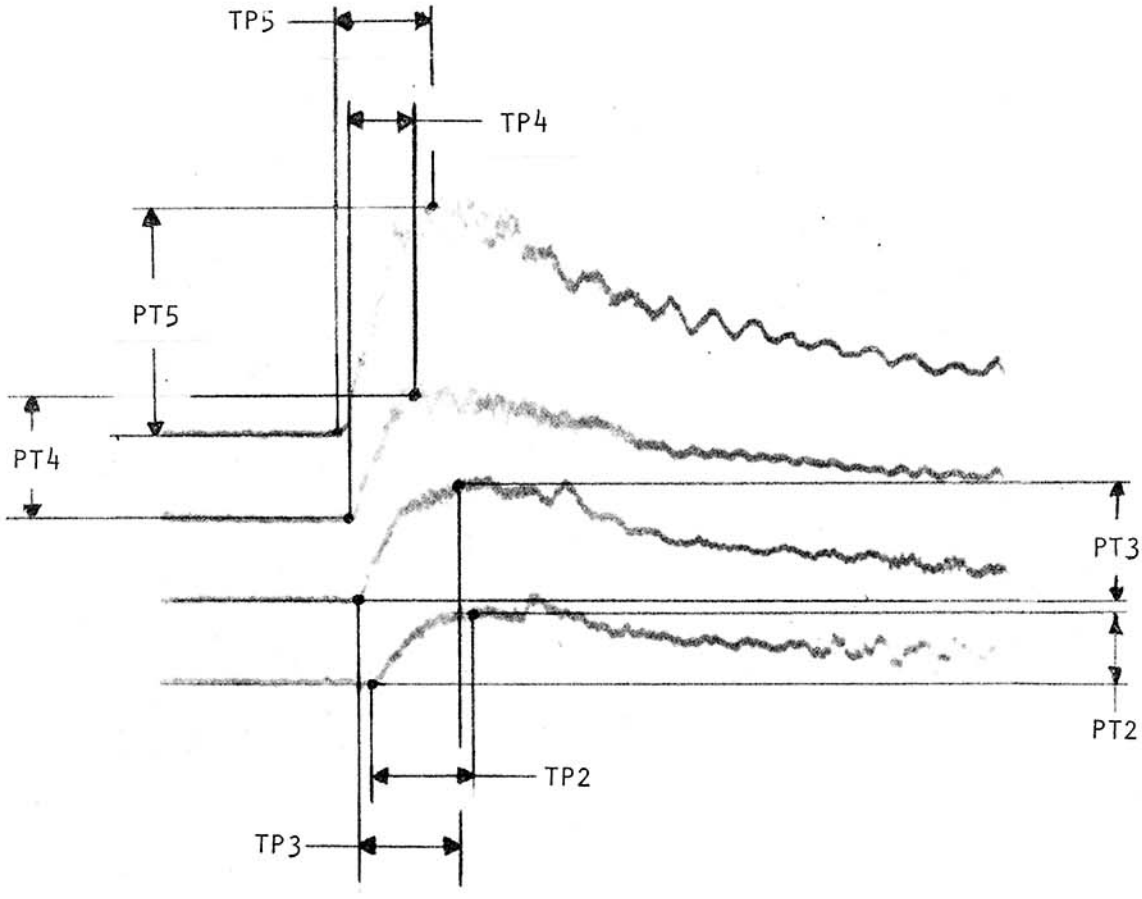


Table 4. Temperature Readings for Test IV (Continued)

Rd	PT2 (°F)	TPT2 (msec)	Rd	PT2 (°F)	TPT2 (msec)
	STATION 2 WC-846			STATION 2 IMR-8208M	
(31)	270	.70	(32)	220	.70
(33)	225	.65	(34)	210	.70
(35)	225	.75	(36)	220	.70
(37)	270	.70	(38)	225	.70
(39)	230	.70	(40)	225	.70
Avg.	230	.70		220	.70
	PT3	TP3		PT3	TP3
	STATION 3 WC-846			STATION 3 IMR-8208M	
(31)	310	.70	(32)	280	.75
(33)	320	.75	(34)	240	.75
(35)	310	.70	(36)	240	.75
(37)	310	.75	(38)	240	.75
(39)	320	.70	(40)	260	.75
Avg.	310	.72		250	.75
	PT4	TP4		PT4	TP4
	STATION 4 WC-846			STATION 4 IMR-8208M	
(31)	320	.30	(32)	280	.35
(33)	320	.35	(34)	240	.30
(35)	330	.30	(36)	240	.30
(37)	330	.35	(38)	240	.30
(39)	320	.35	(40)	260	.35
Avg.	320	.33		250	.32
	PT5	TP5		PT5	TP5
	STATION 5 WC-846			STATION 5 IMR-8208M	
(31)	470	.40	(32)	430	.35
(33)	455	.45	(34)	395	.35
(35)	460	.45	(36)	395	.40
(37)	455	.40	(38)	420	.35
(39)	455	.40	(40)	420	.35
Avg.	460	.42		410	.36

APPENDIX A

TEMPERATURE CALIBRATION CHART AND INDIVIDUAL TEST RECORDS

Temperature-Millivolt Equivalents for Tungsten/Tungsten-26% Rhenium Thermocouples—°F

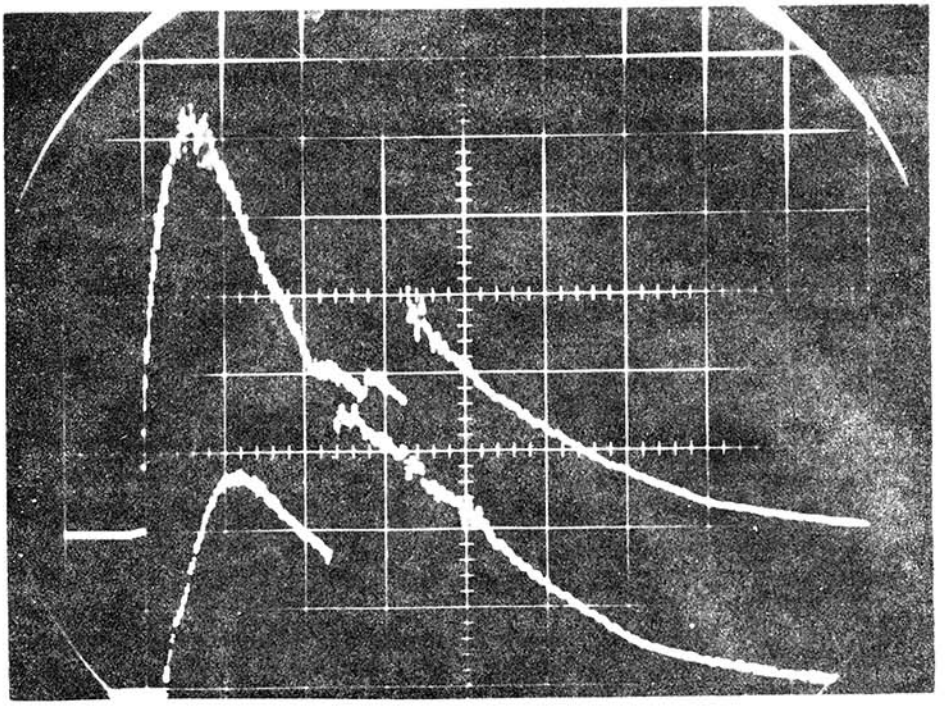
(–A) ADOPTED SEPTEMBER 11, 1961 — REFERENCE JUNCTION AT 32°F.

Degrees F	0°	100°	200°	300°	400°	500°	600°	700°	800°	900°	1000°	Degrees F
0°	—	.103	.320	.673	1.064	1.573	2.212	2.927	3.716	4.565	5.470	0°
20°	—	.136	.384	.750	1.148	1.692	2.350	3.079	3.881	4.741	5.660	20°
40°	.012	.173	.452	.828	1.246	1.816	2.492	3.235	4.049	4.919	5.851	40°
60°	.042	.215	.522	.906	1.349	1.944	2.635	3.393	4.219	5.100	6.043	60°
80°	.072	.264	.597	.985	1.458	2.076	2.779	3.553	4.391	5.283	6.236	80°
100°	.103	.320	.673	1.064	1.573	2.212	2.927	3.716	4.565	5.470	6.430	100°

Degrees F	1100°	1200°	1300°	1400°	1500°	1600°	1700°	1800°	1900°	2000°		Degrees F
0°	6.430	7.436	8.481	9.576	10.702	11.837	12.984	14.149	15.339	16.549		0°
20°	6.626	7.641	8.696	9.800	10.928	12.065	13.215	14.385	15.580	16.791		20°
40°	6.826	7.848	8.913	10.025	11.155	12.294	13.447	14.622	15.822	17.033		40°
60°	7.028	8.057	9.132	10.250	11.382	12.523	13.680	14.860	16.064	17.274		60°
80°	7.232	8.268	9.353	10.476	11.609	12.753	13.914	15.099	16.307	17.515		80°
100°	7.436	8.481	9.576	10.702	11.837	12.984	14.149	15.339	16.549	17.755		100°

Degrees F	2100°	2200°	2300°	2400°	2500°	2600°	2700°	2800°	2900°	3000°		Degrees F
0°	17.755	18.940	20.113	21.280	22.424	23.529	24.587	25.616	26.636	27.646		0°
20°	17.994	19.175	20.347	21.512	22.649	23.744	24.794	25.821	26.839	27.847		20°
40°	18.232	19.410	20.581	21.742	22.872	23.957	25.000	26.026	27.041	28.048		40°
60°	18.469	19.645	20.814	21.970	23.093	24.169	25.206	26.230	27.243	28.249		60°
80°	18.705	19.879	21.047	22.198	23.312	24.379	25.411	26.433	27.445	28.449		80°
100°	18.940	20.113	21.280	22.424	23.529	24.587	25.616	26.636	27.646	28.649		100°

Degrees F	3100°	3200°	3300°	3400°	3500°	3600°	3700°	3800°	3900°	4000°	4100°	Degrees F
0°	28.649	29.640	30.627	31.606	32.575	33.531	34.477	35.412	36.338	37.209	37.926	0°
20°	28.848	29.838	30.824	31.801	32.767	33.721	34.665	35.598	36.520	37.369	38.040	20°
40°	29.047	30.036	31.020	31.995	32.959	33.911	34.852	35.784	36.699	37.523	38.151	40°
60°	29.245	30.233	31.216	32.189	33.150	34.100	35.039	35.969	36.874	37.669	38.260	60°
80°	29.443	30.430	31.411	32.382	33.341	34.289	35.226	36.154	37.044	37.804	38.368	80°
100°	29.640	30.627	31.606	32.575	33.531	34.477	35.412	36.338	37.209	37.926	38.474	100°



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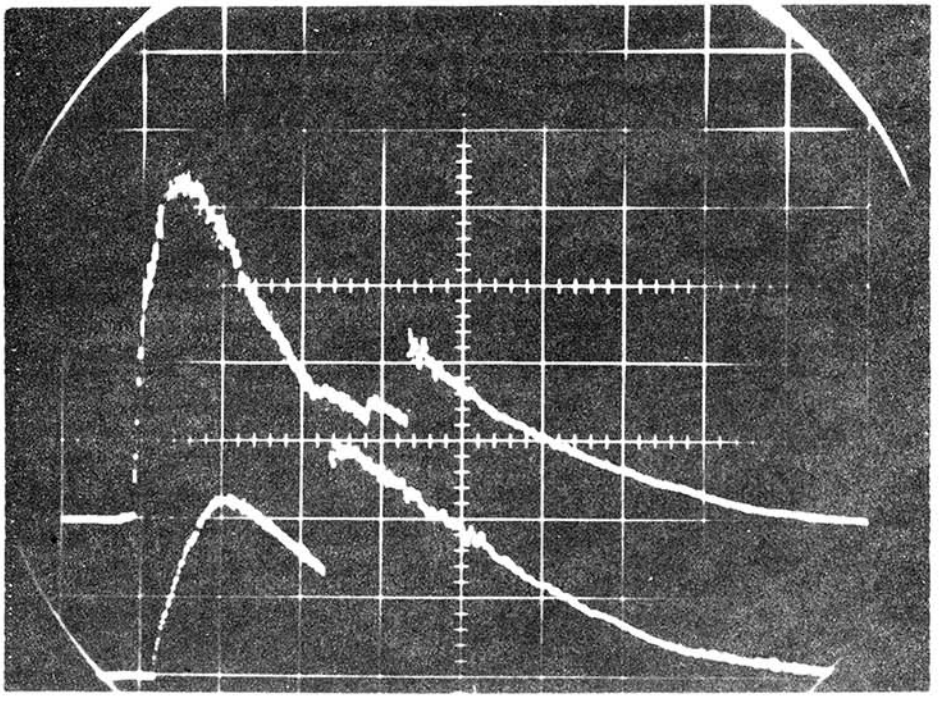

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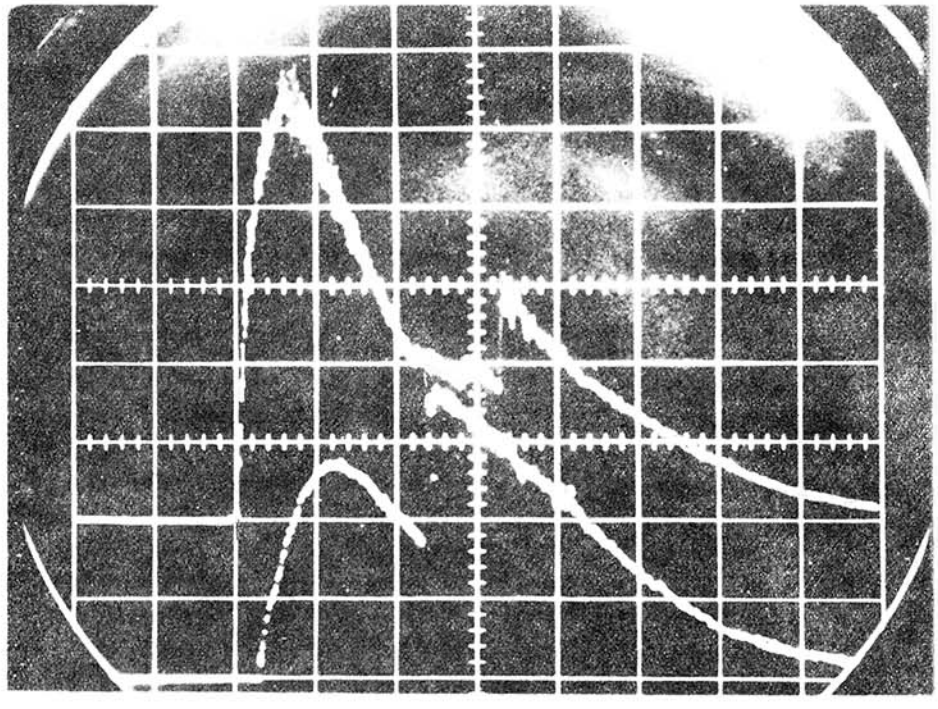

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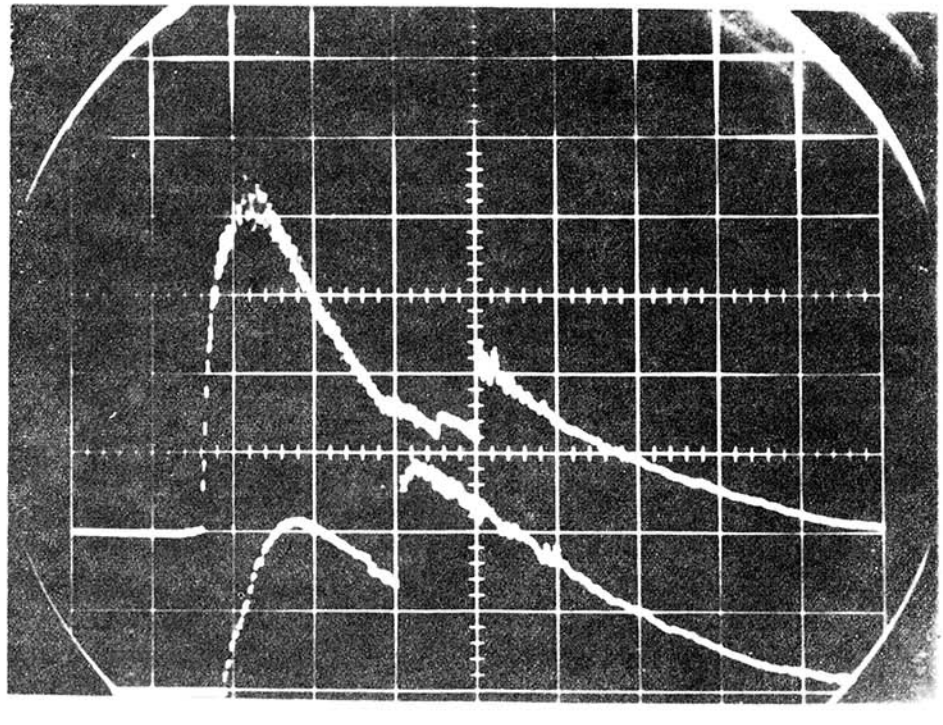

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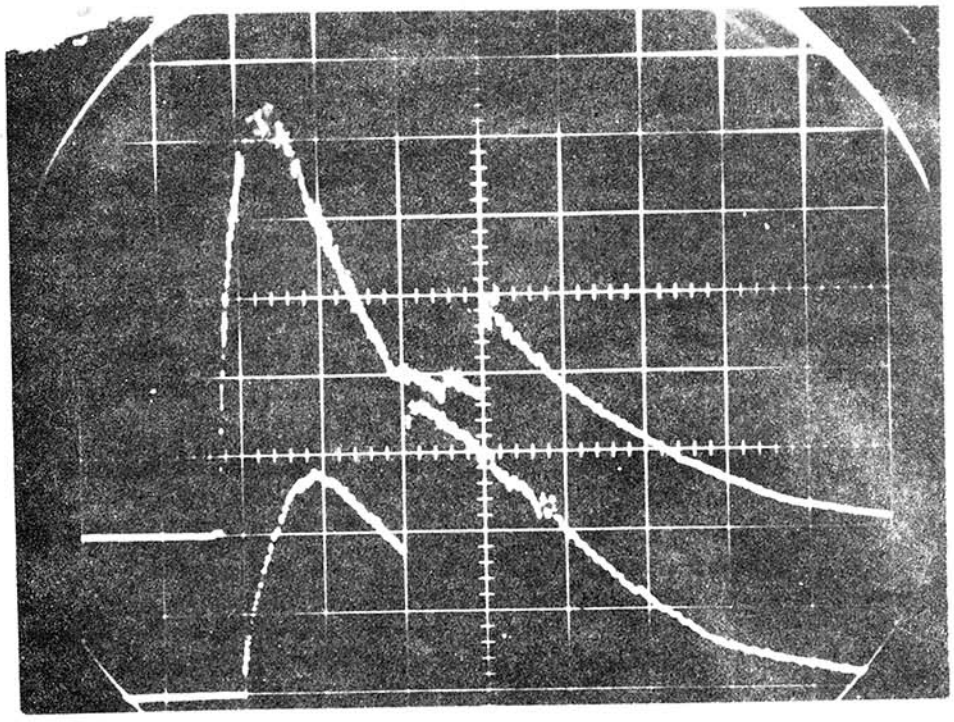

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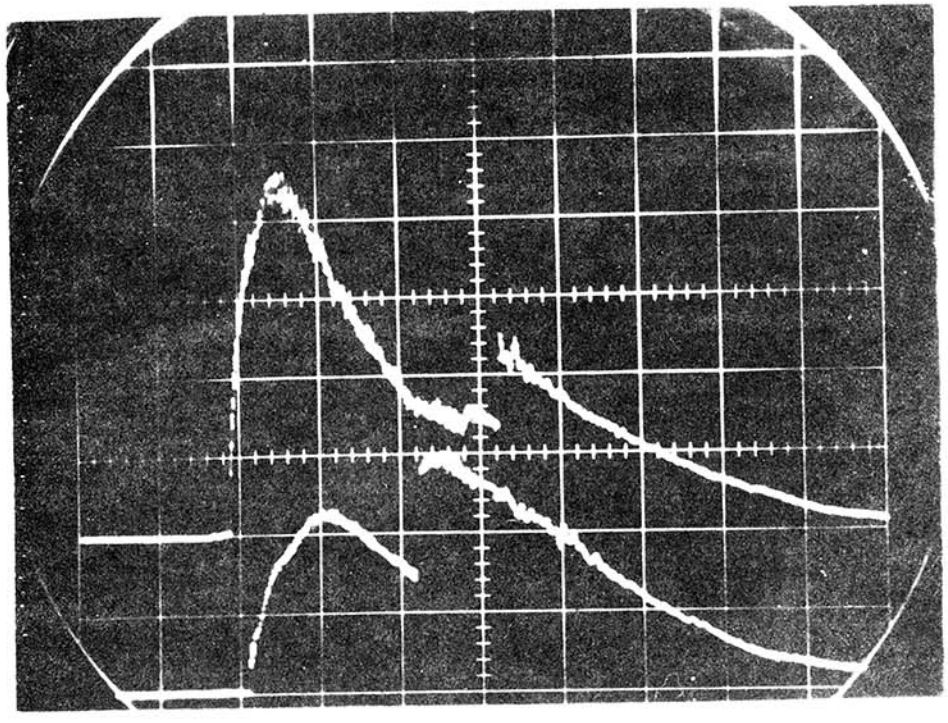

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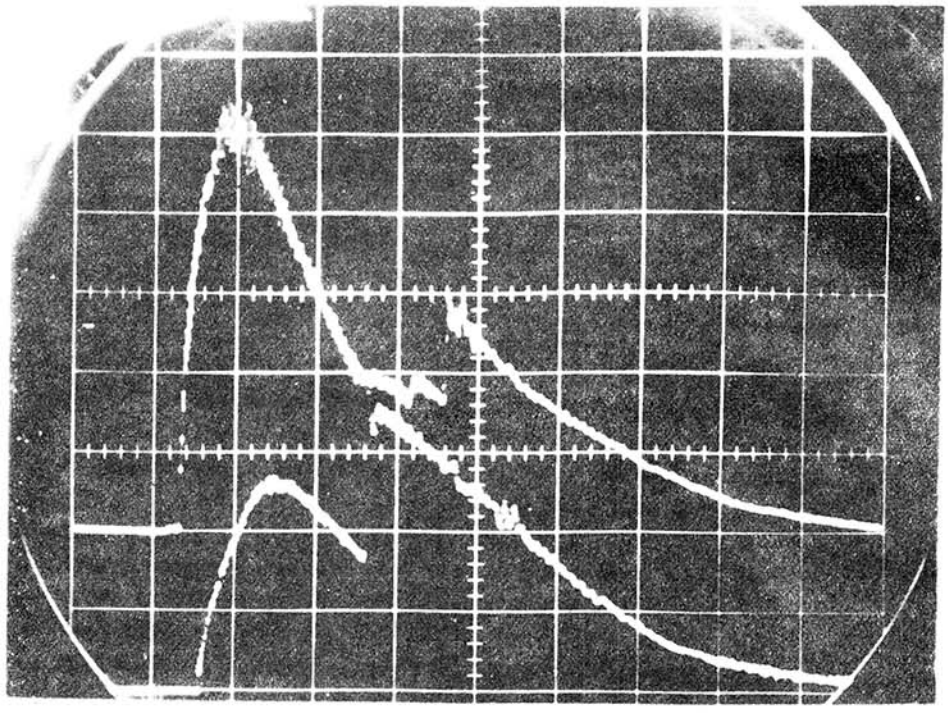

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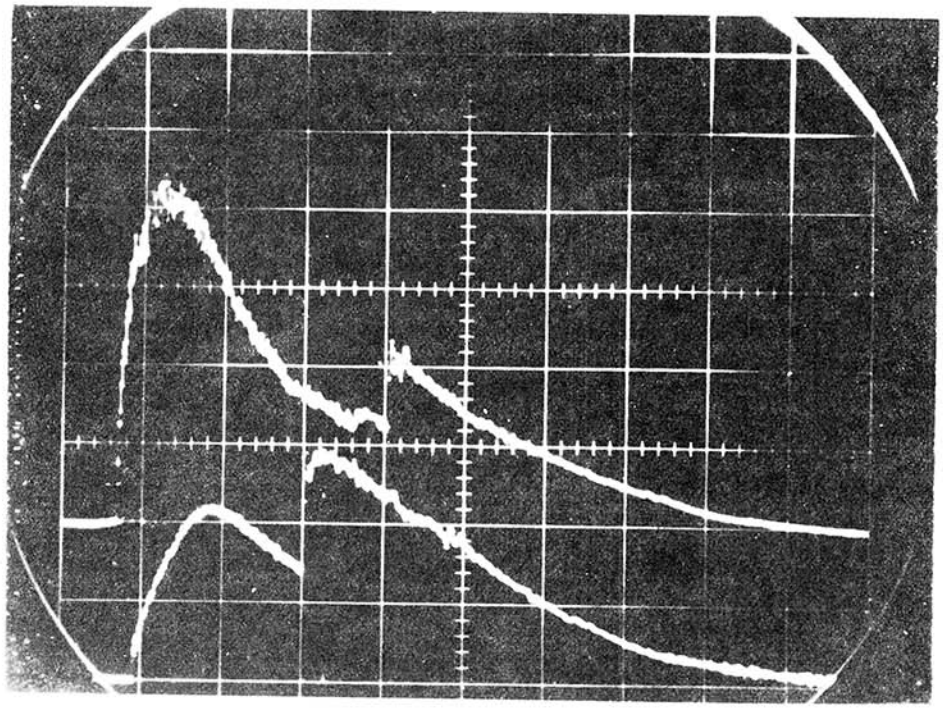

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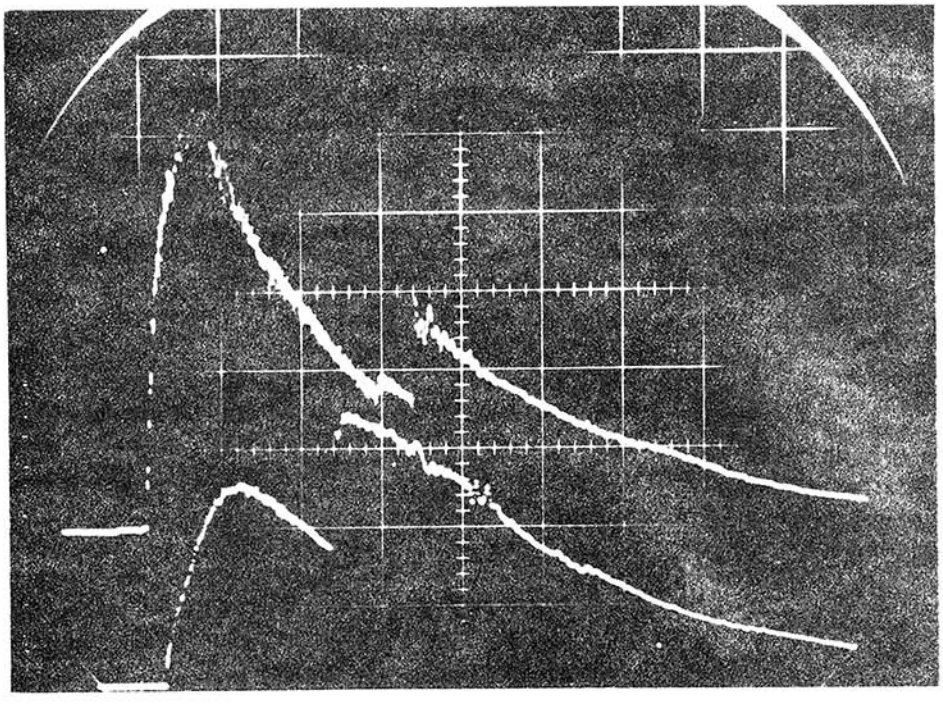

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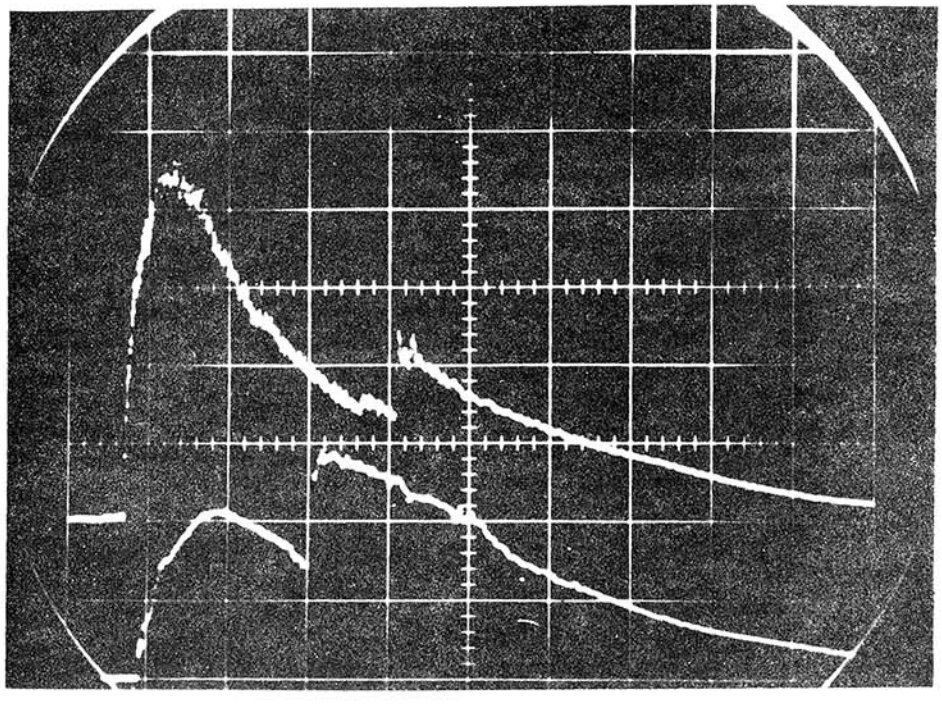

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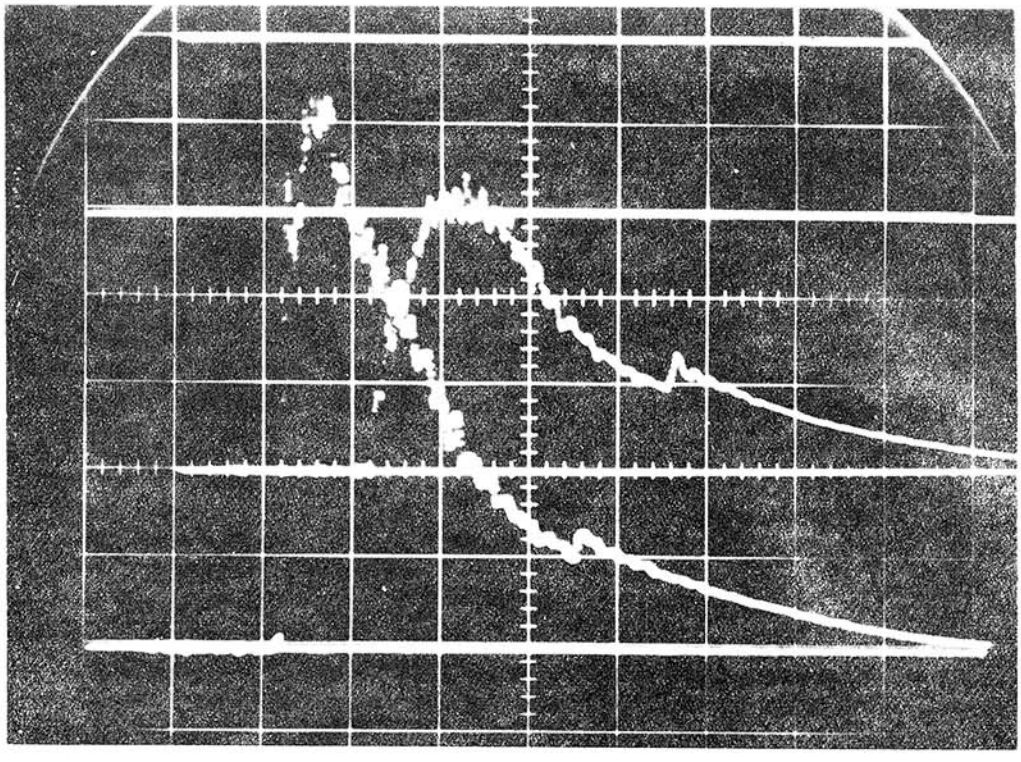

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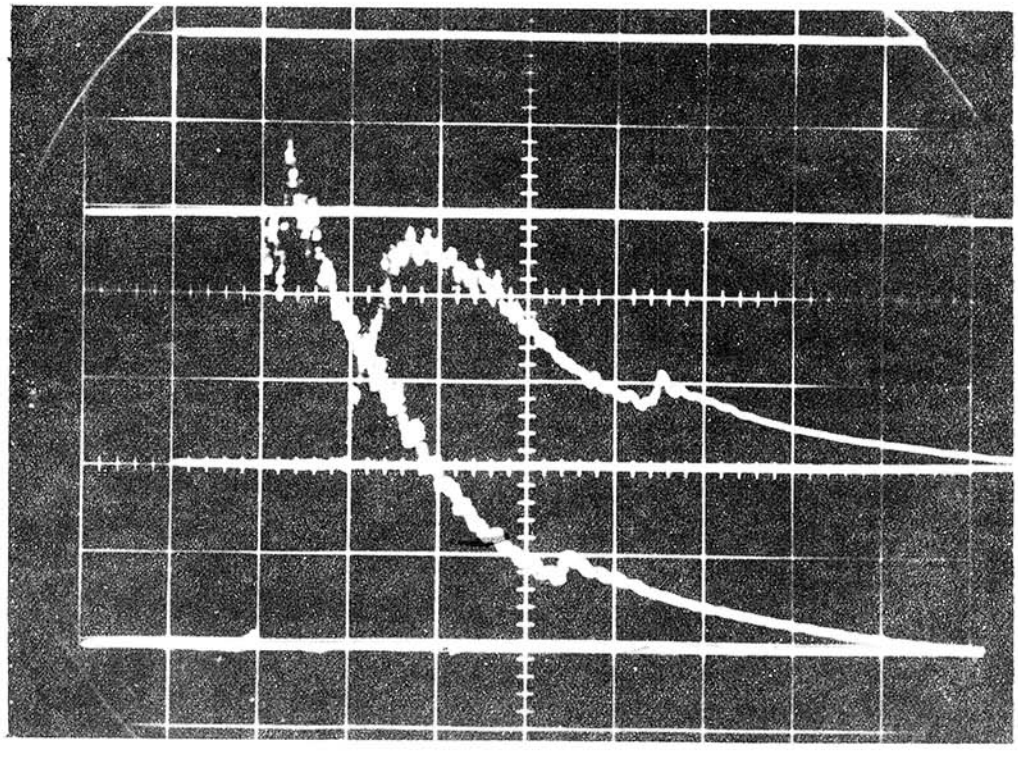

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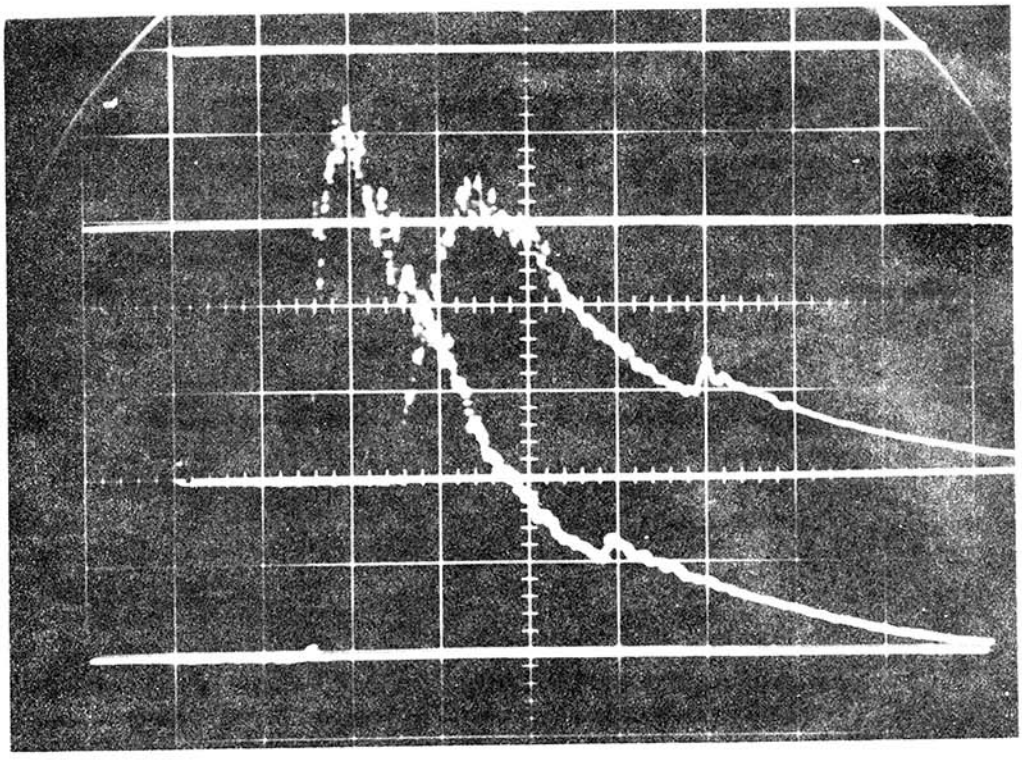

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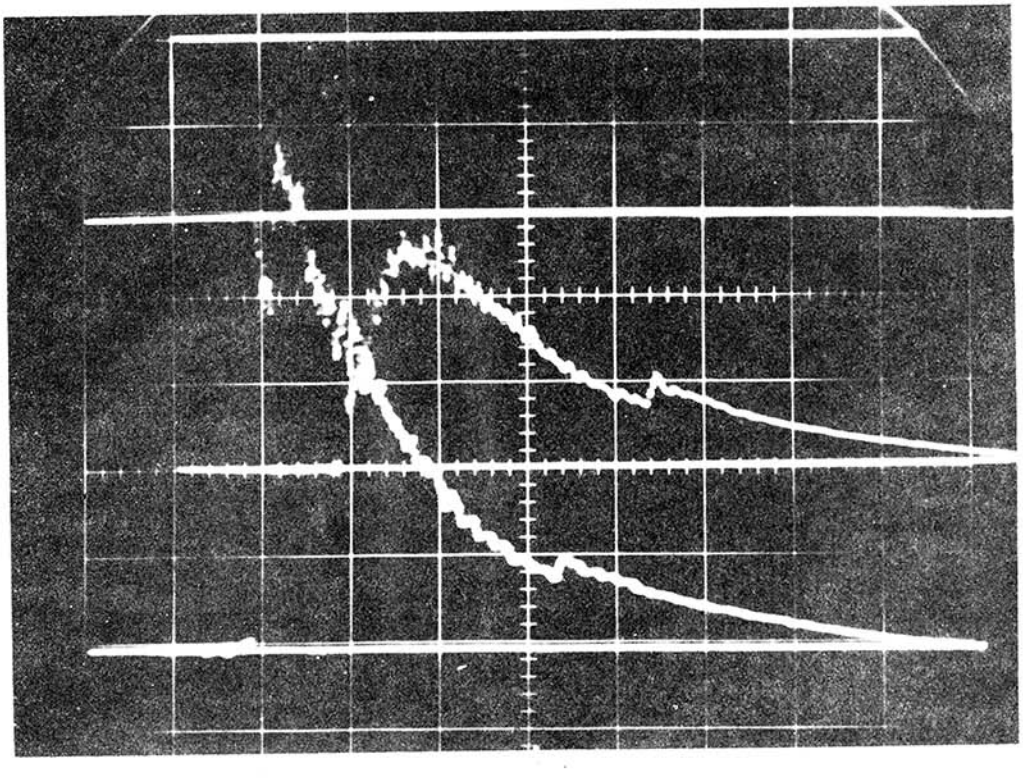

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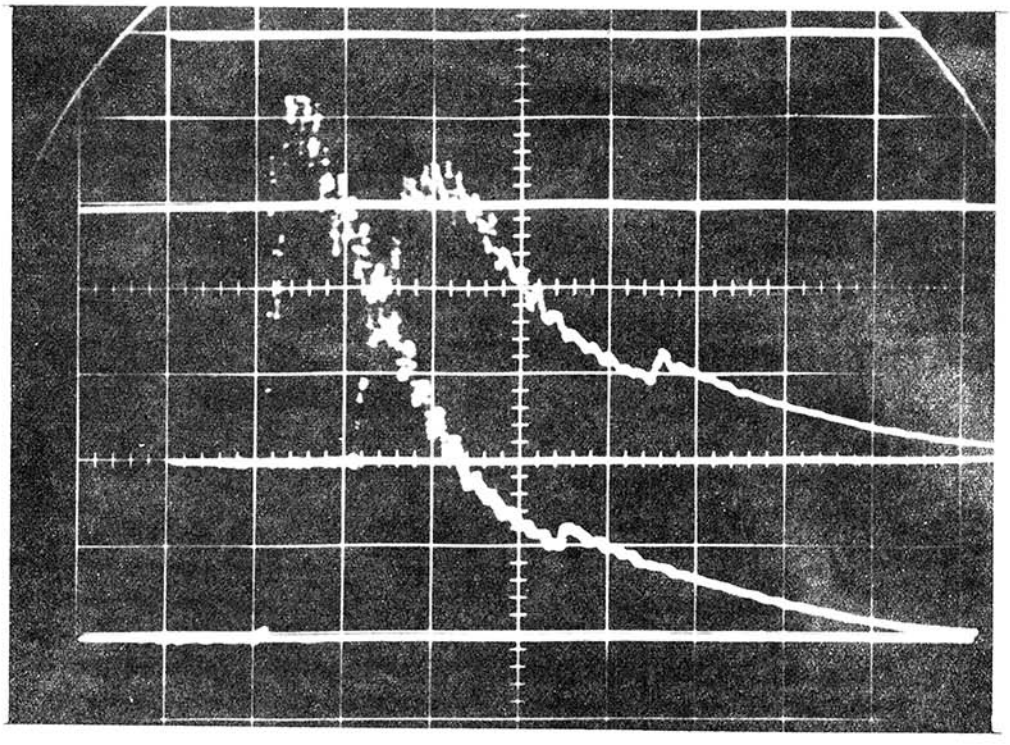

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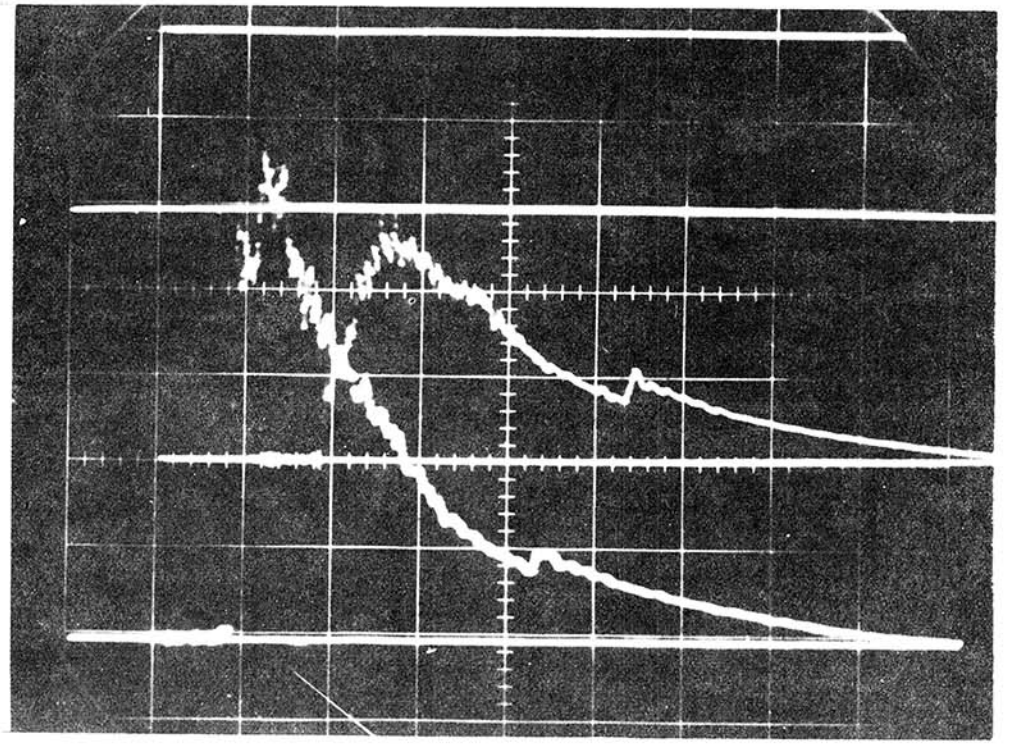

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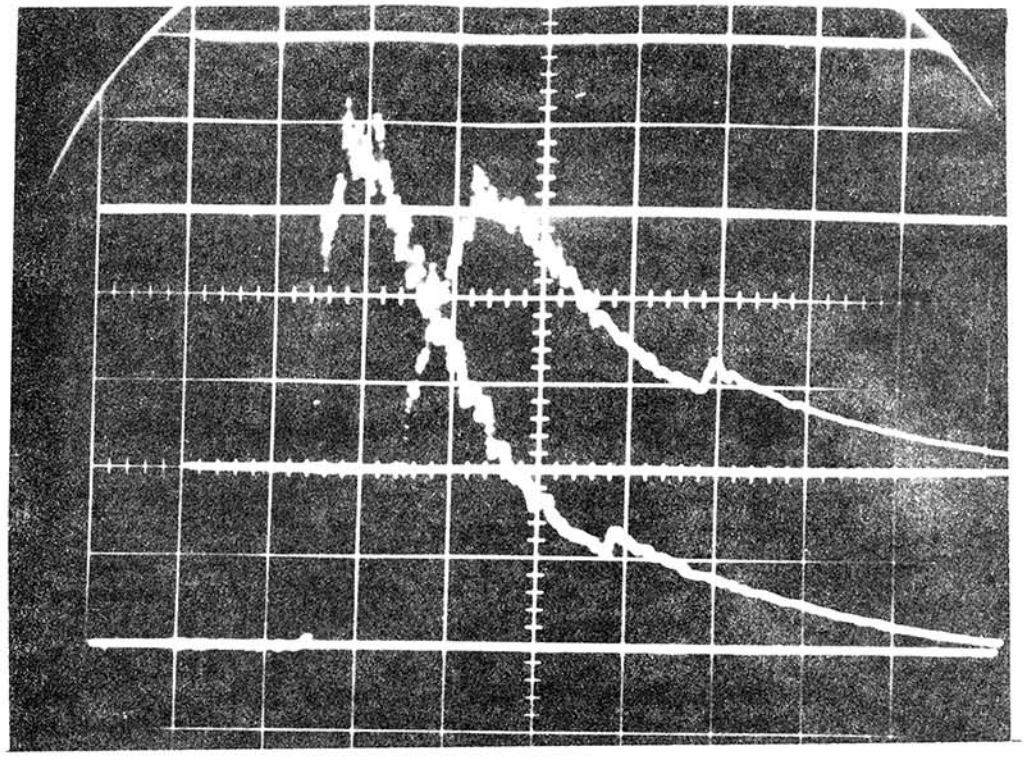

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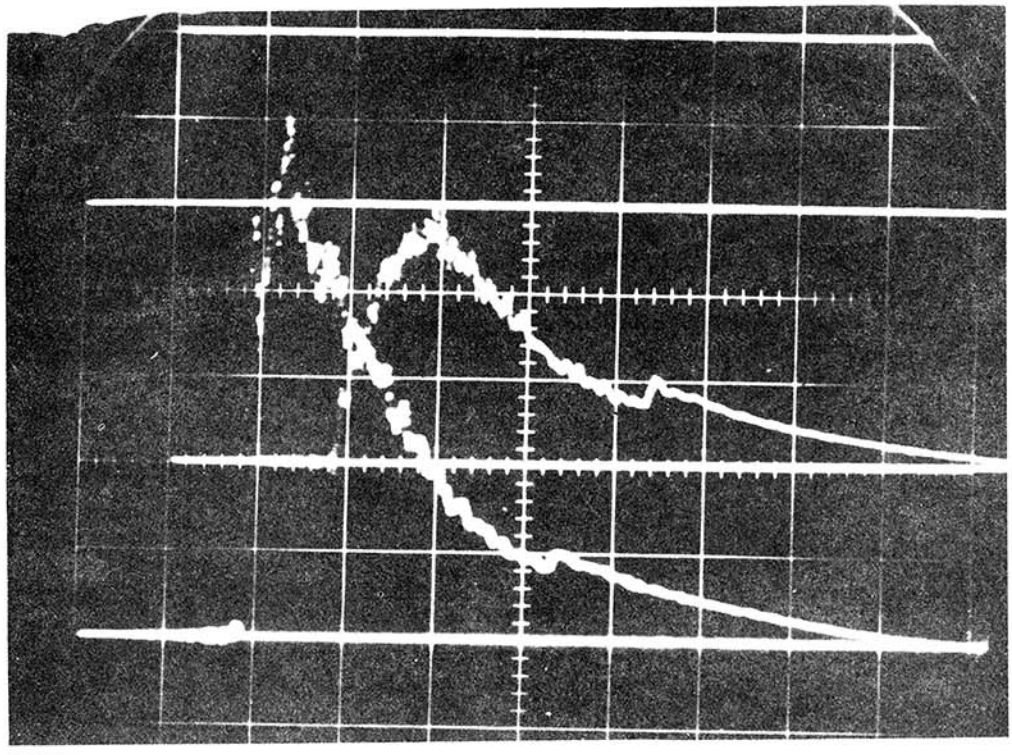

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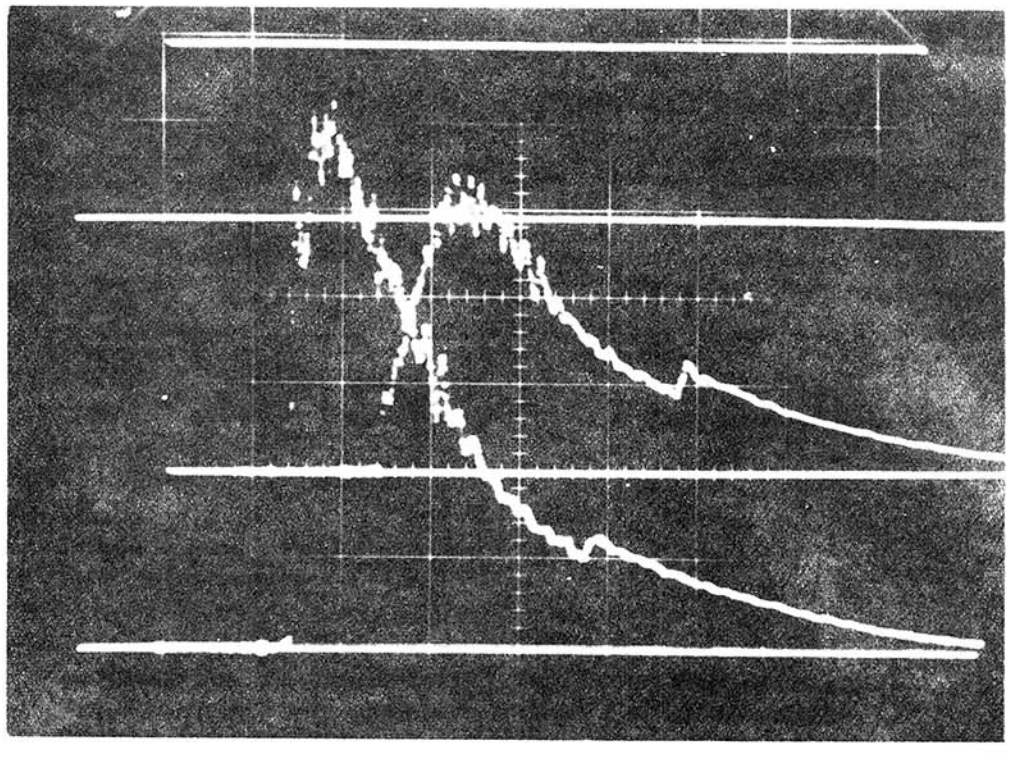

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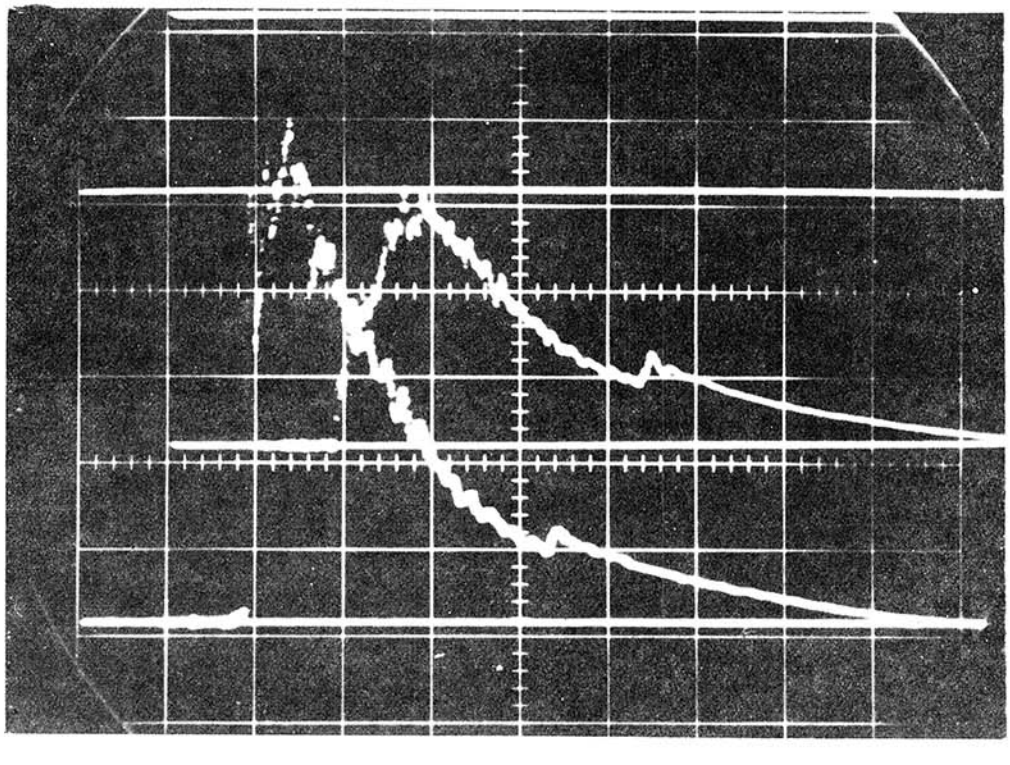

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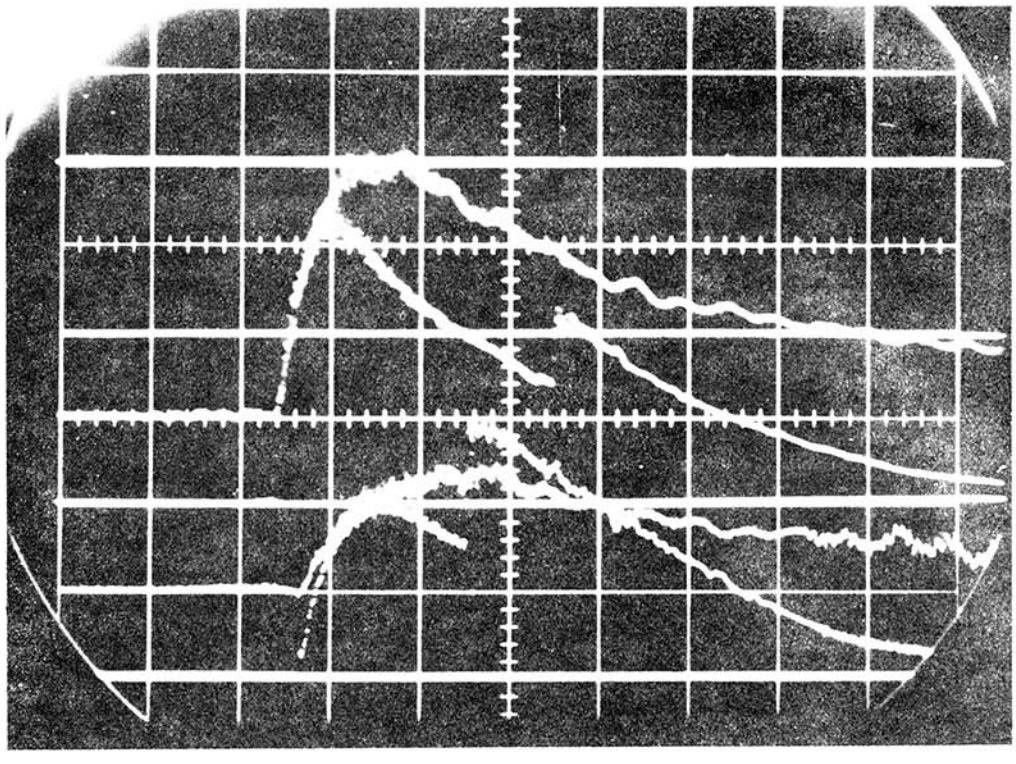

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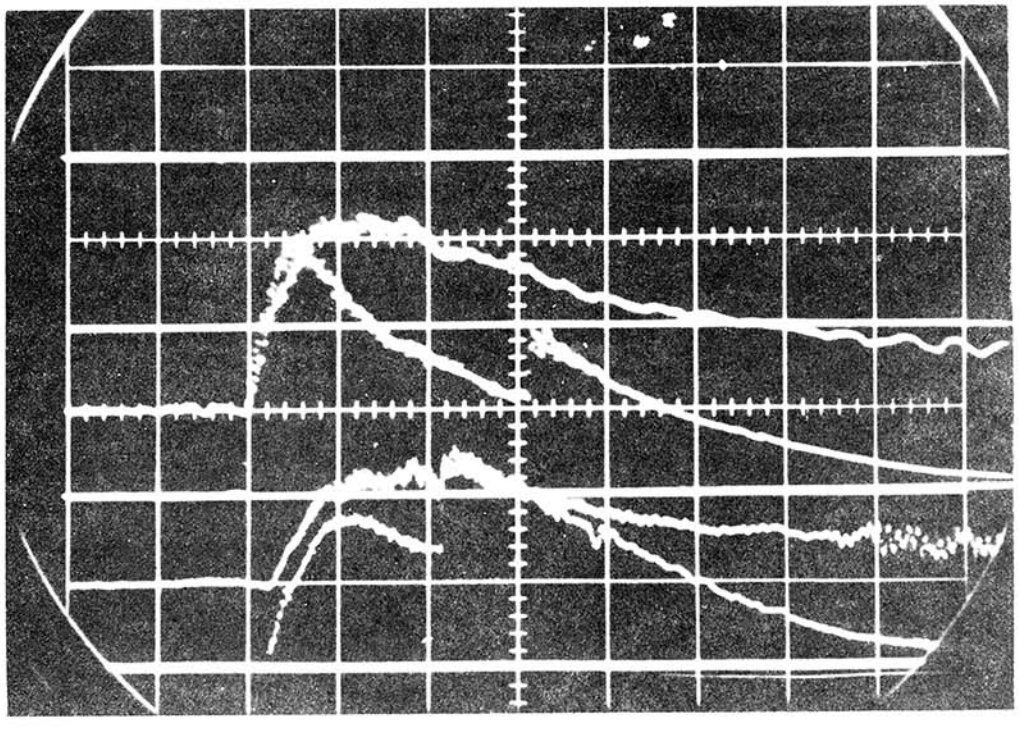

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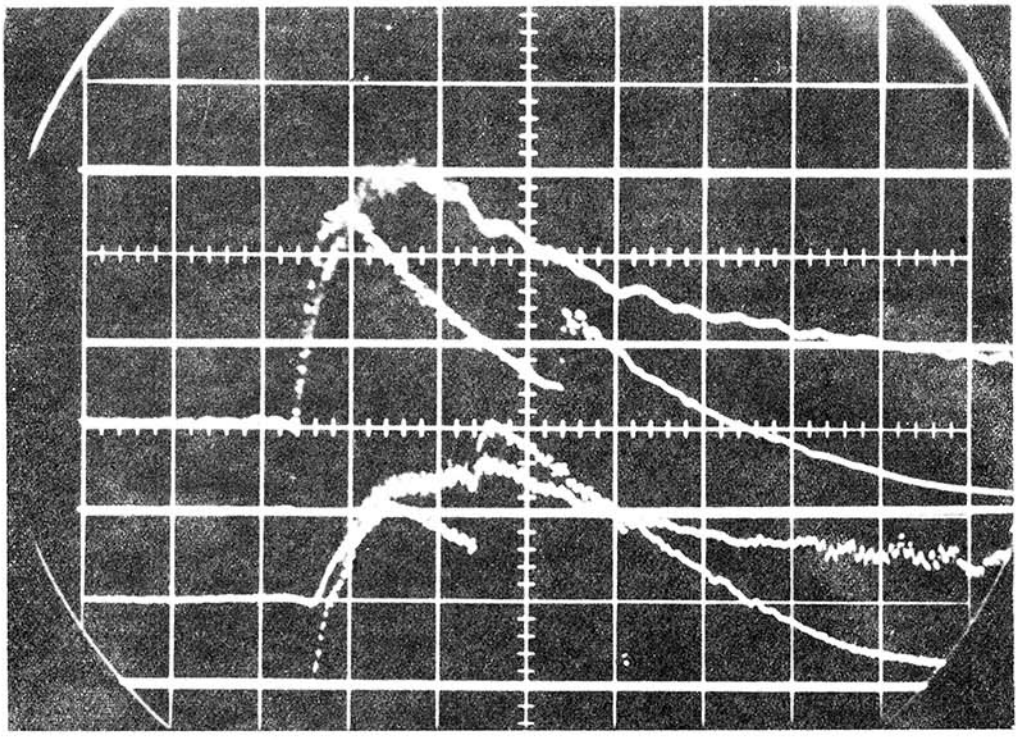

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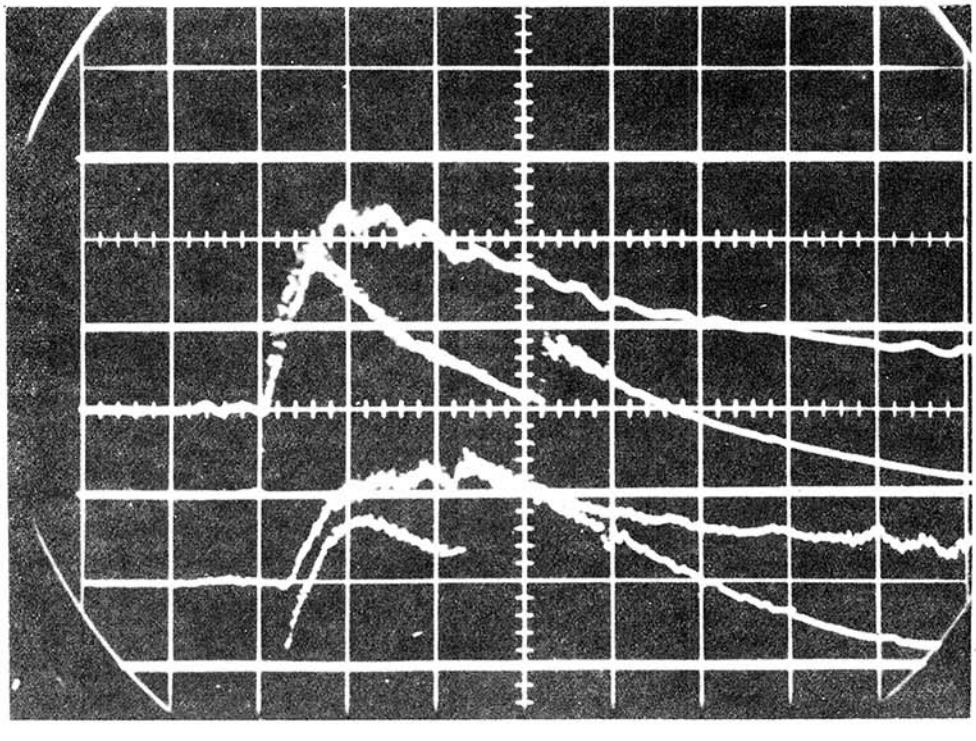

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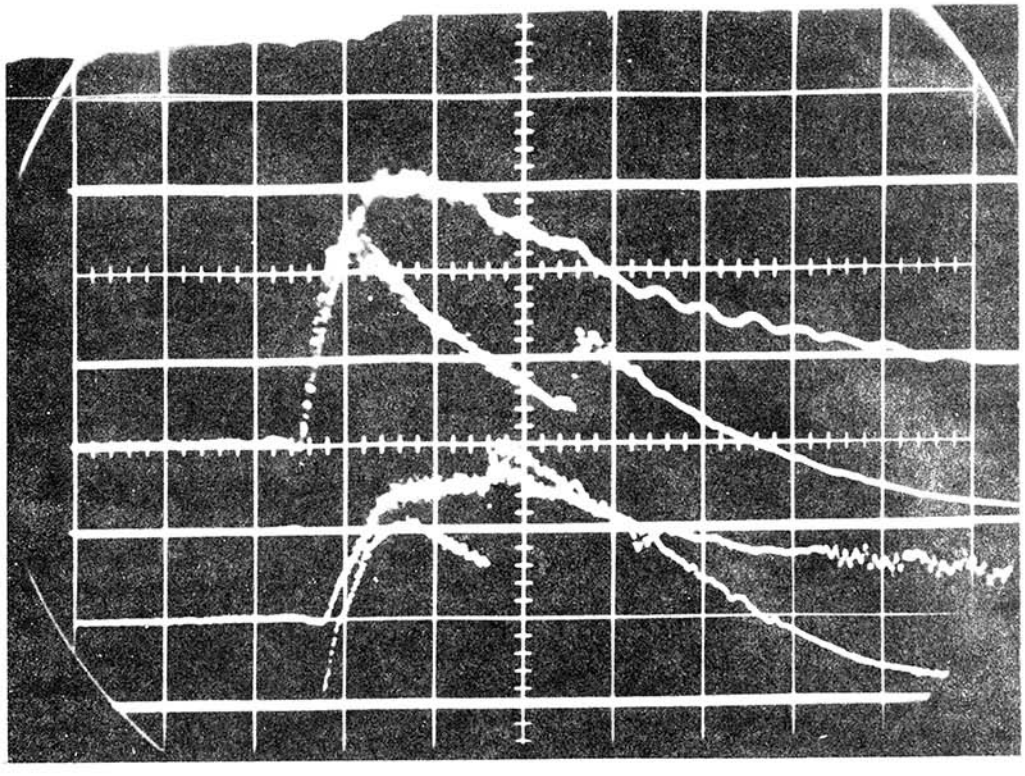

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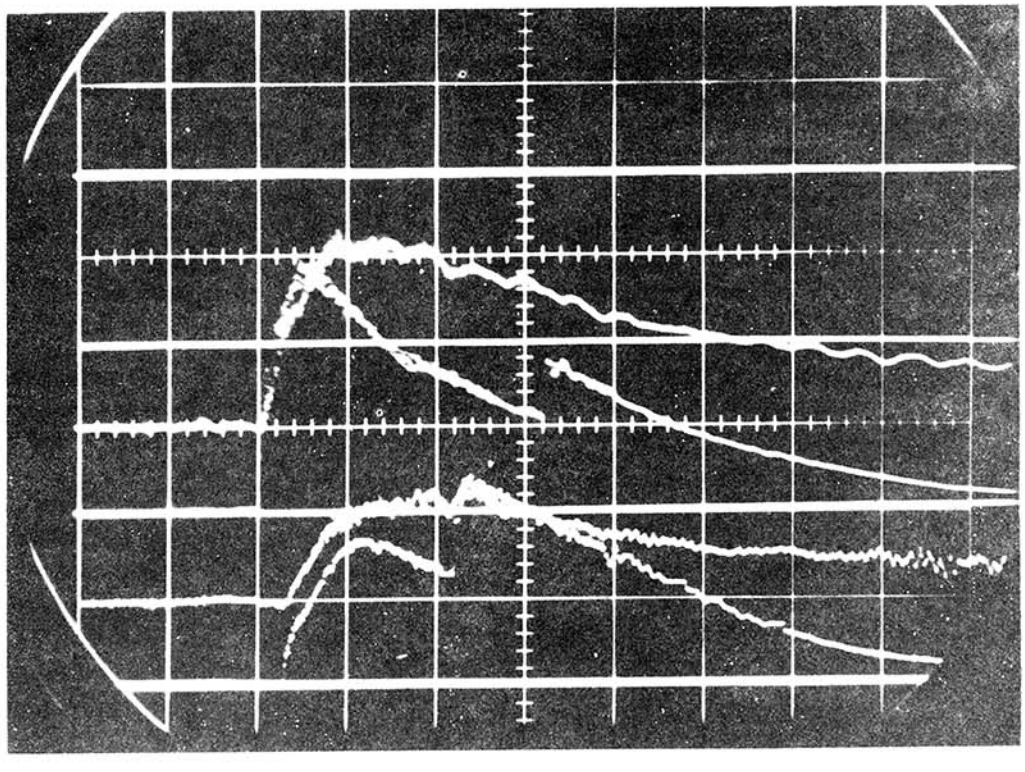

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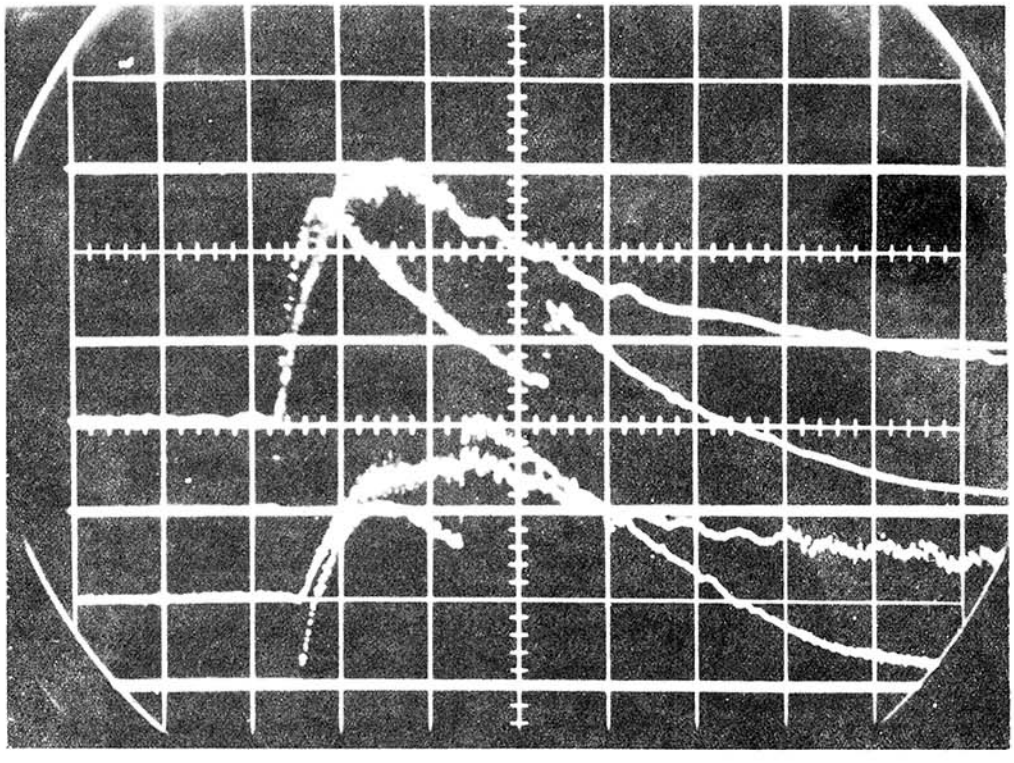

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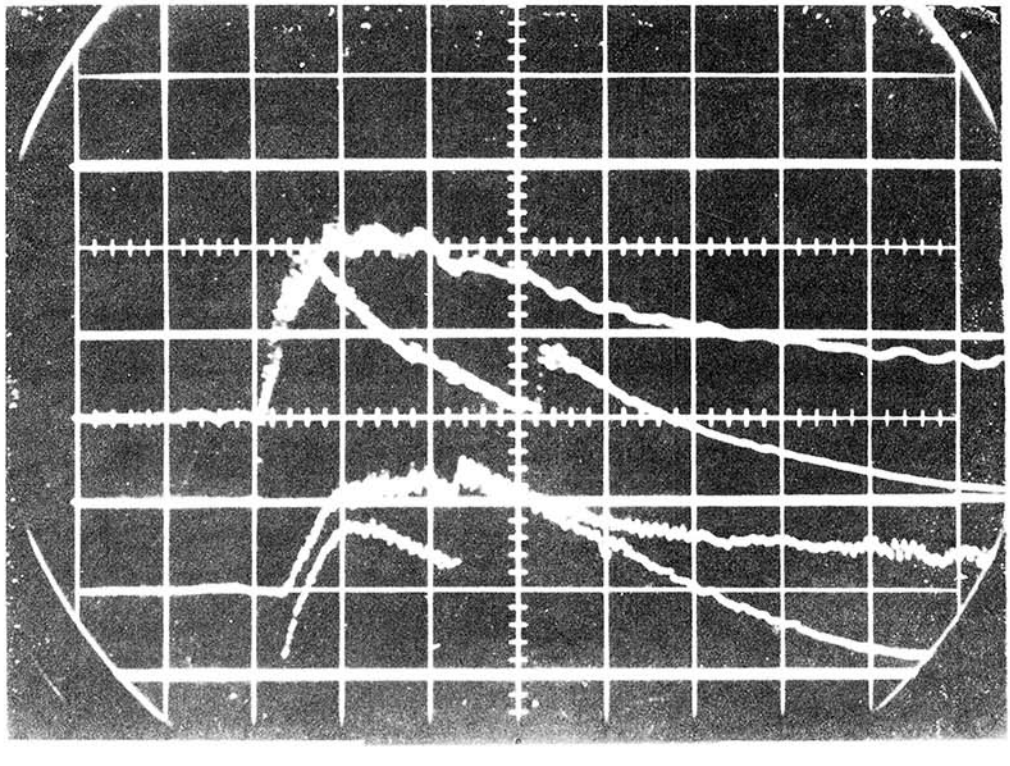

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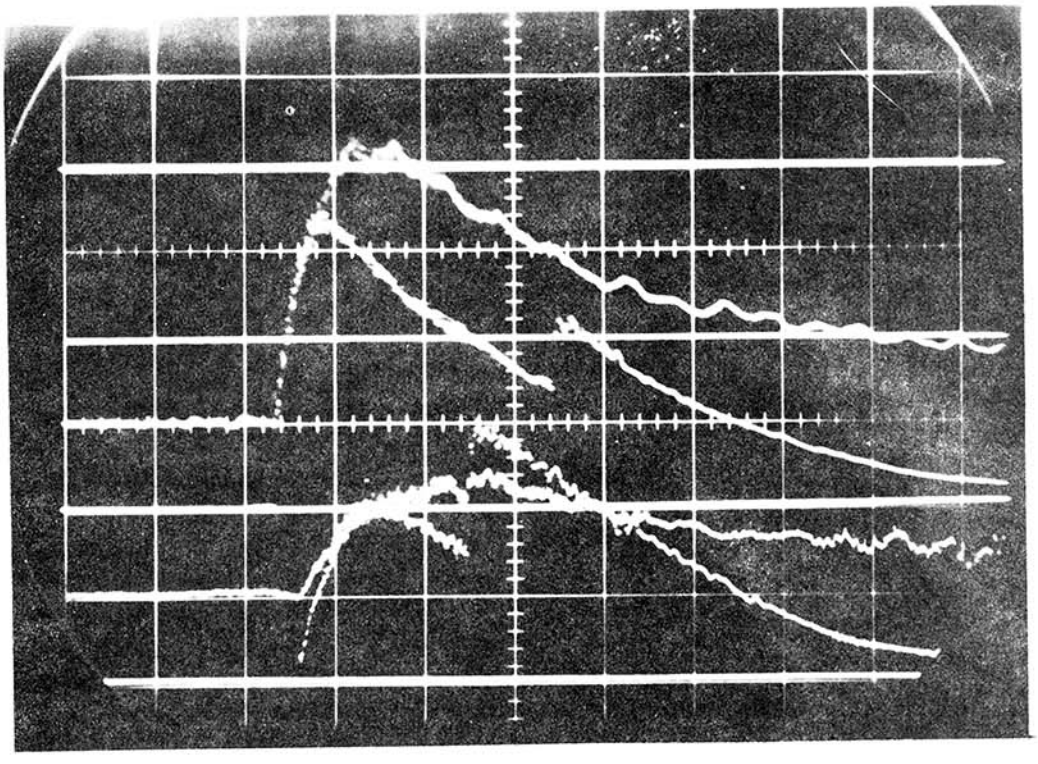

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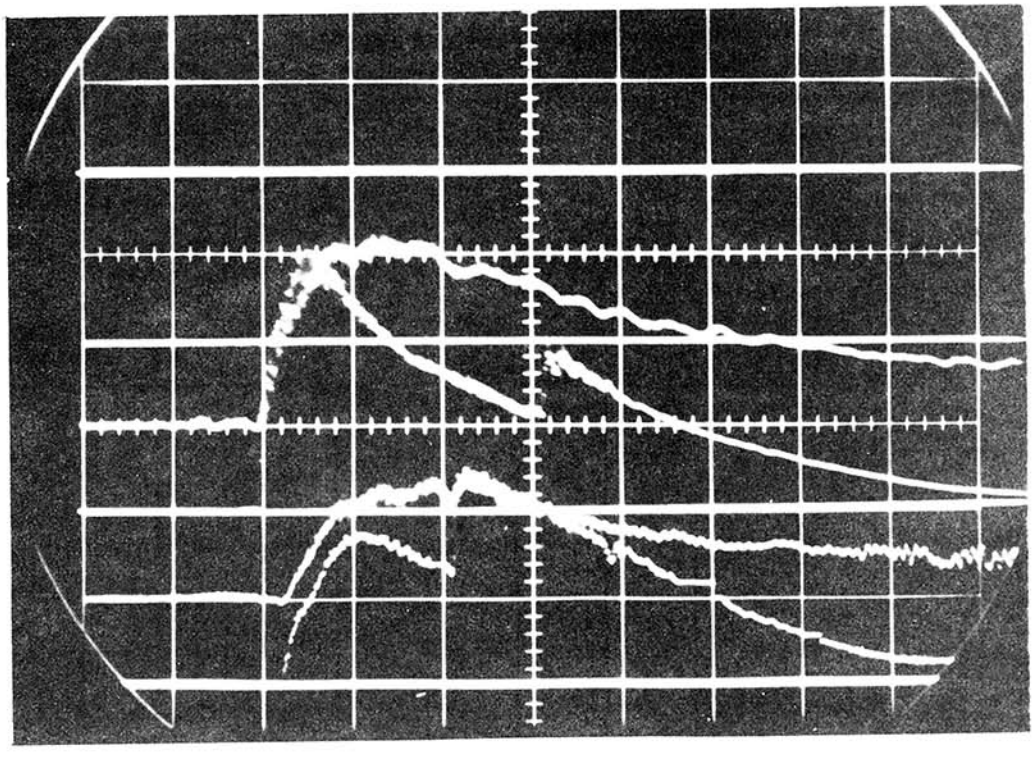

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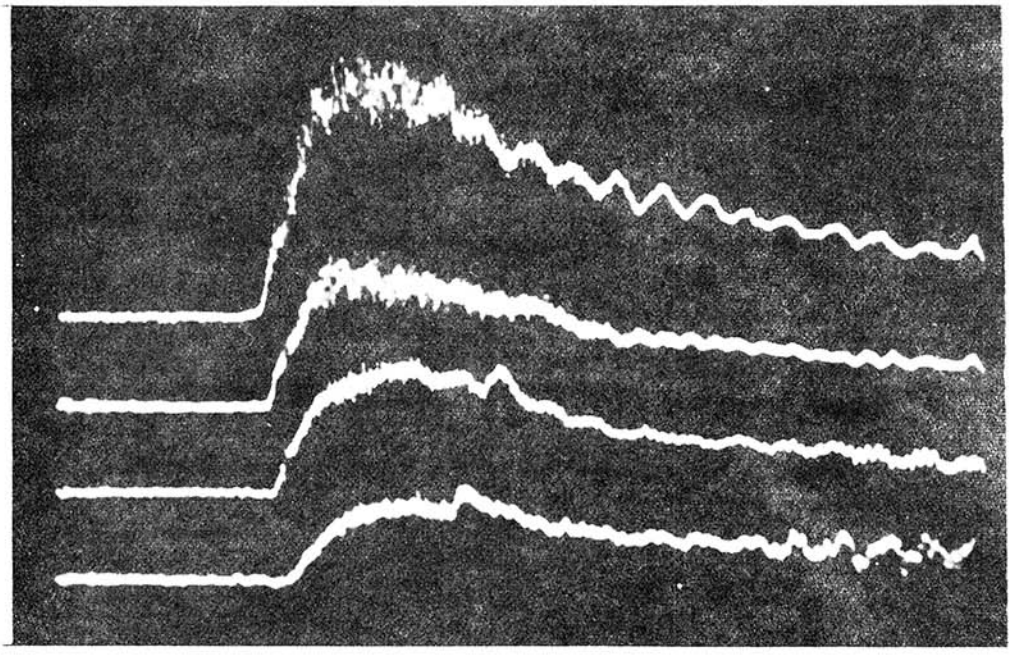

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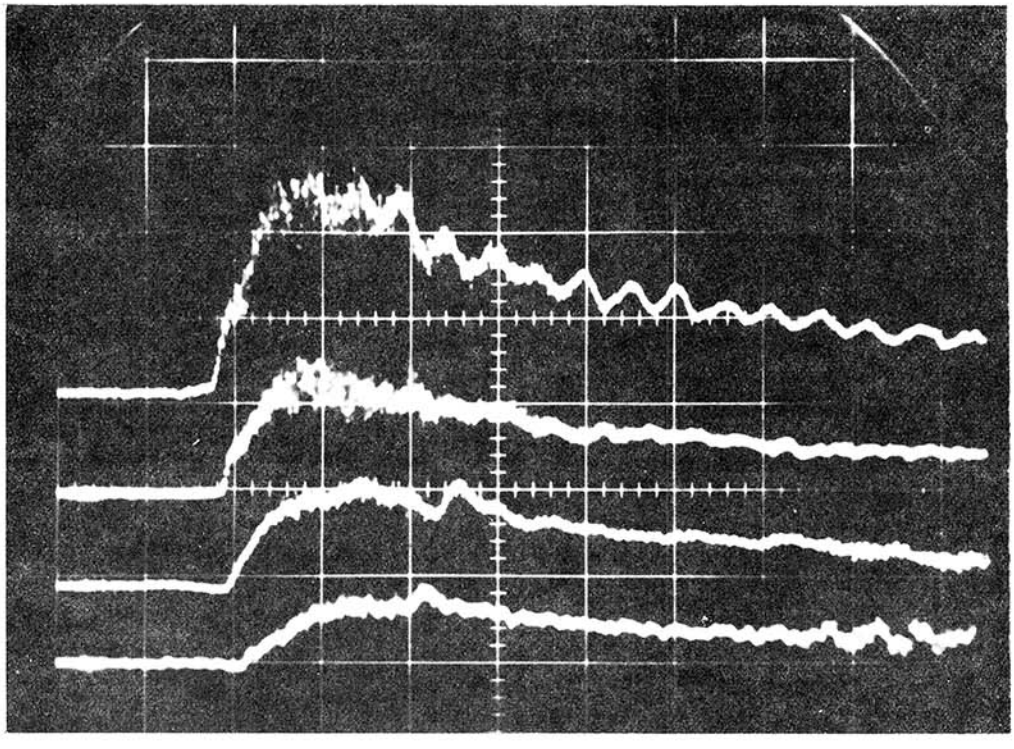

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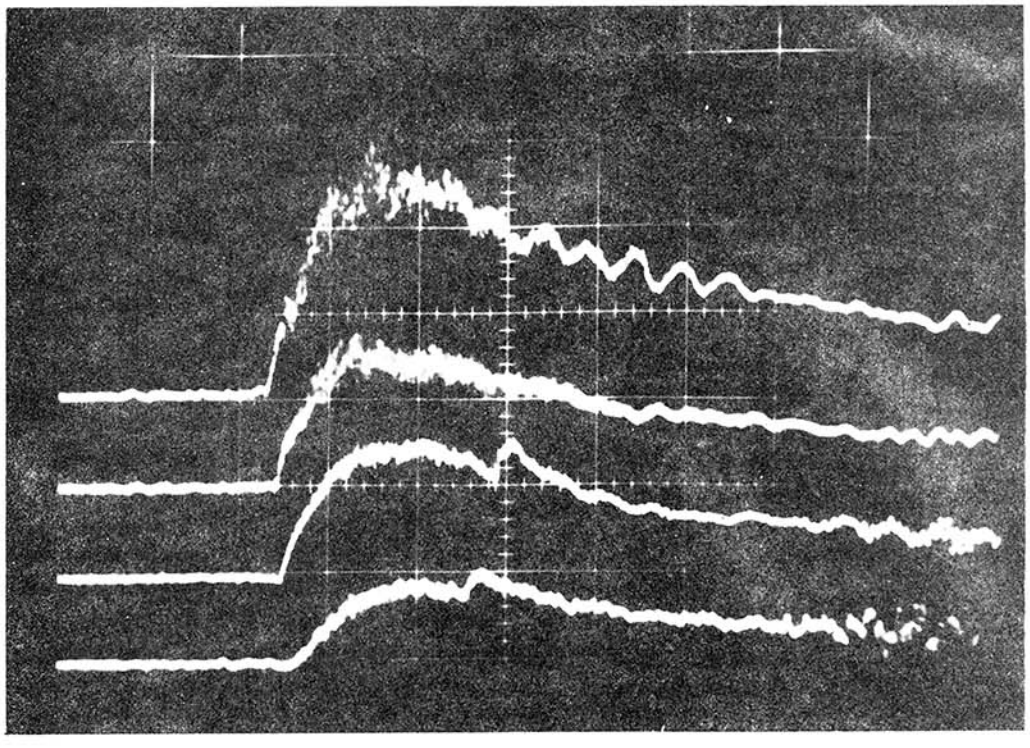

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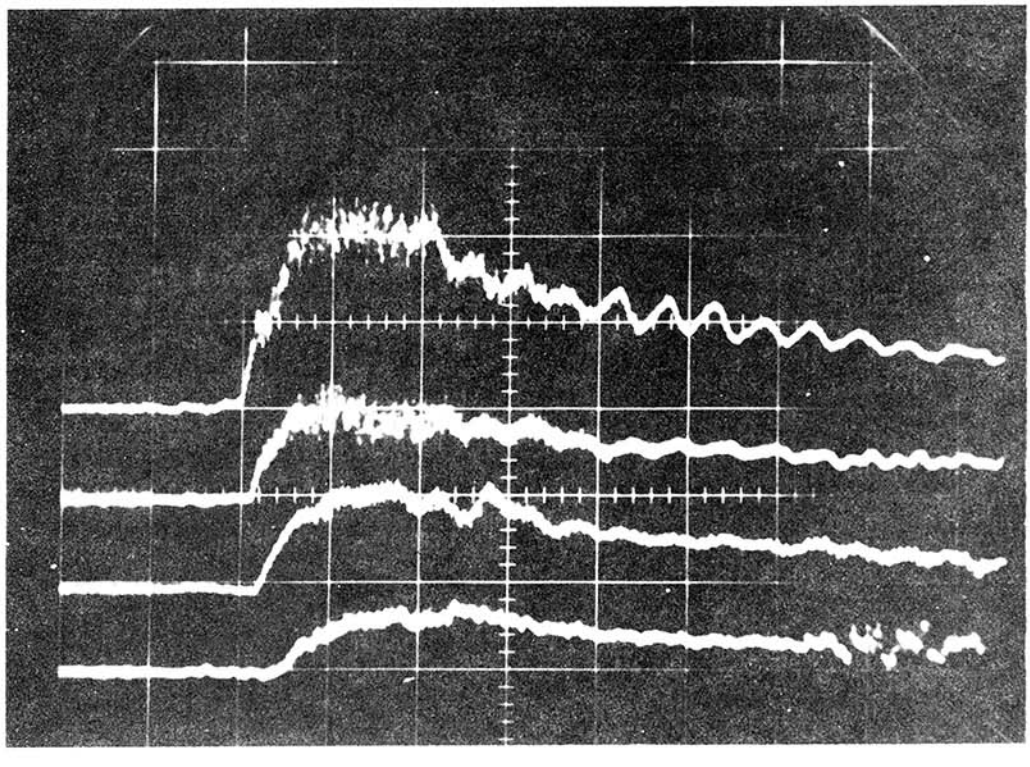

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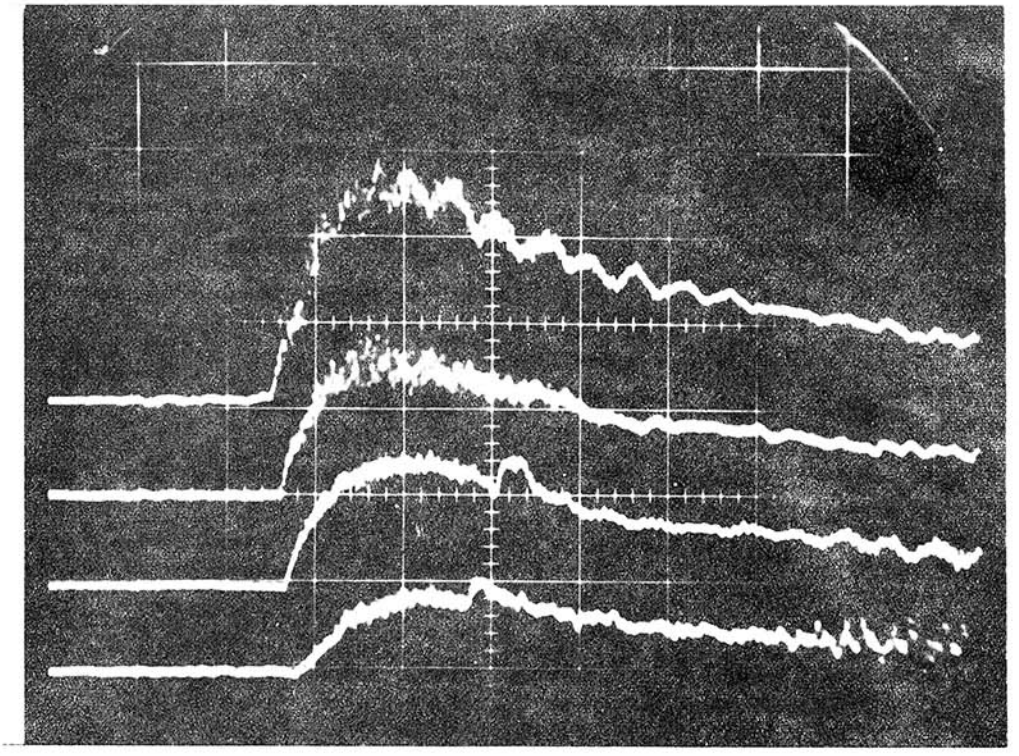

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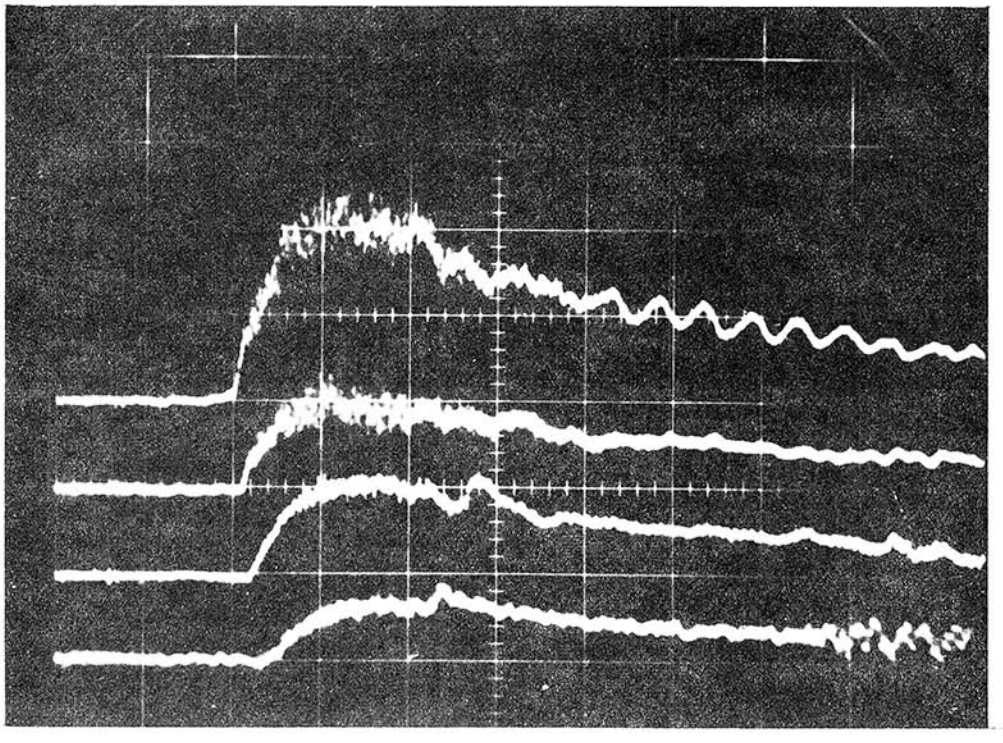

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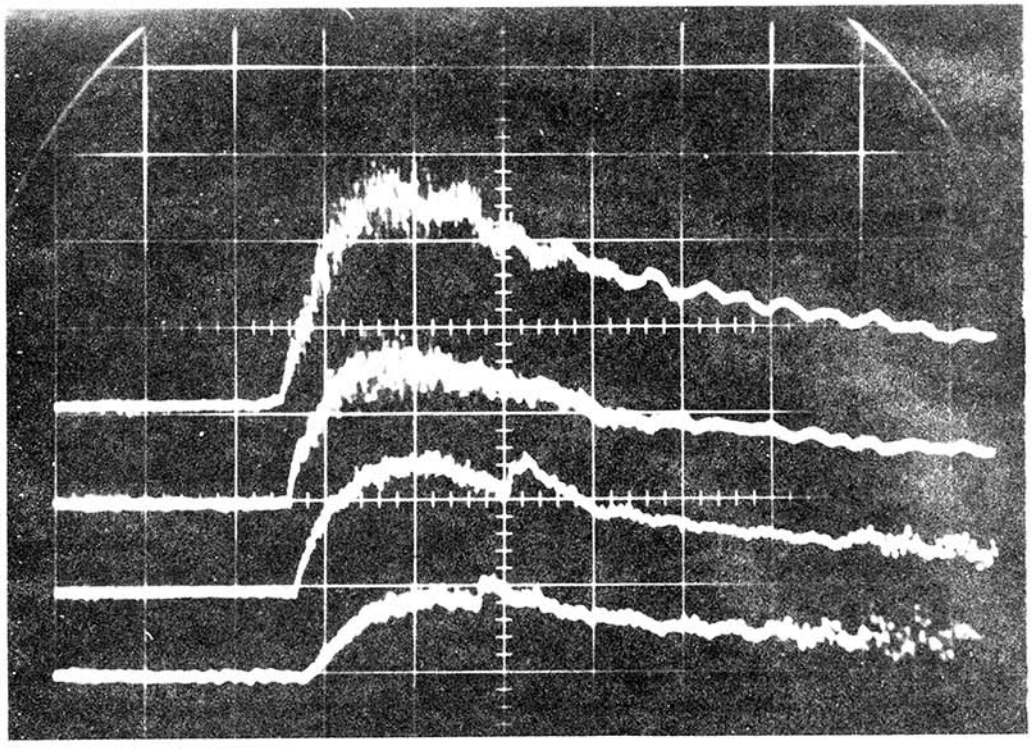

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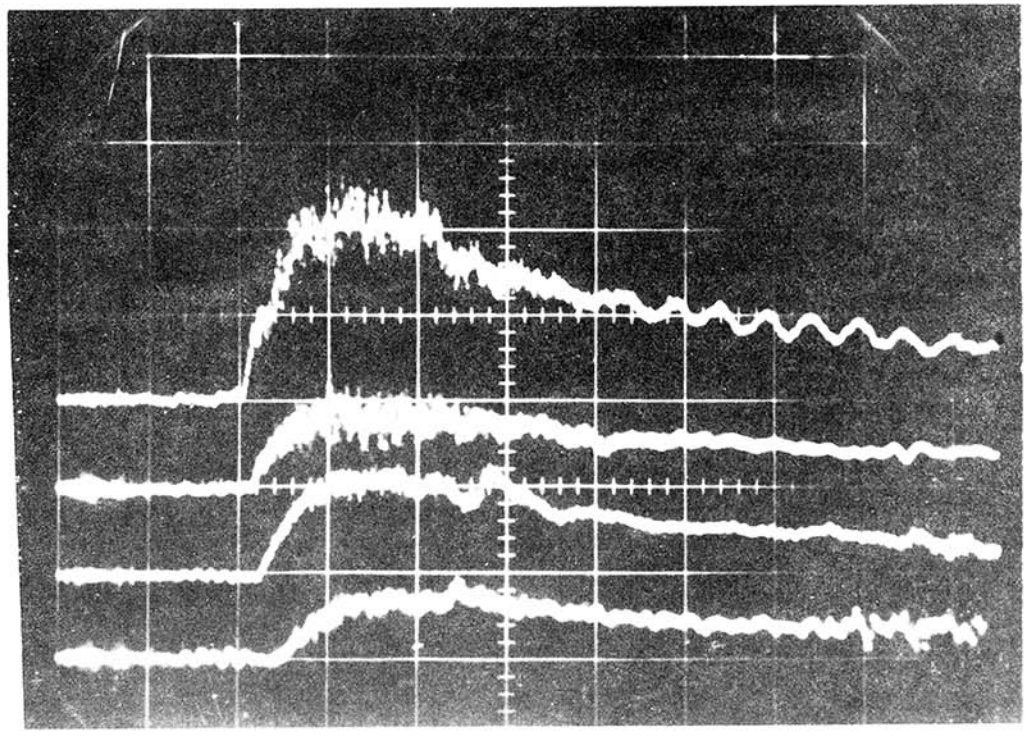

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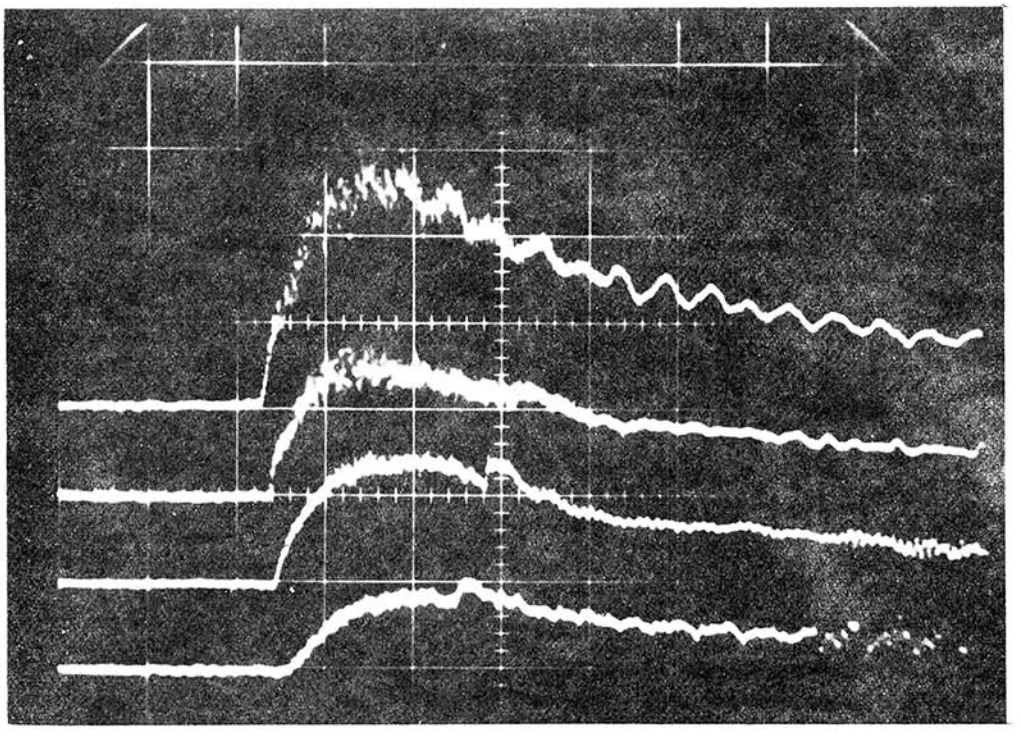

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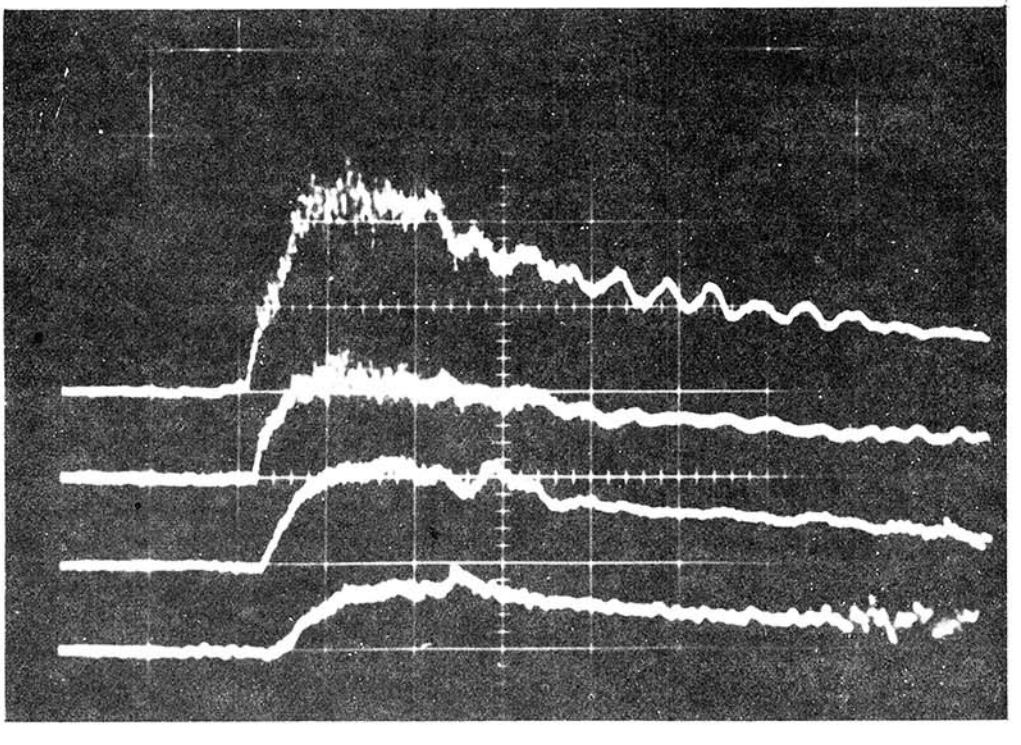

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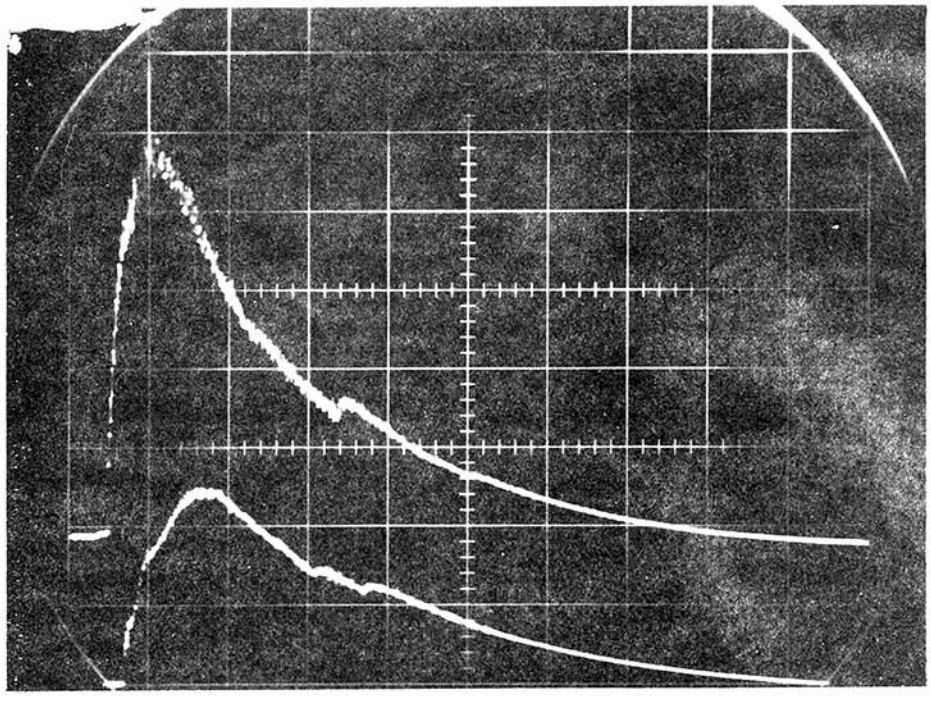

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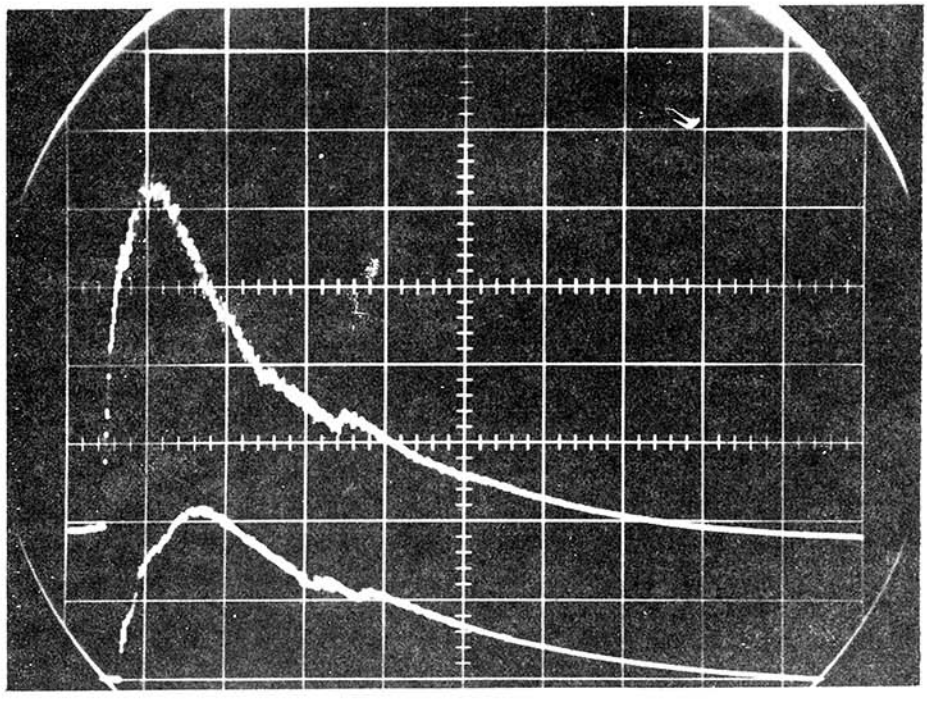

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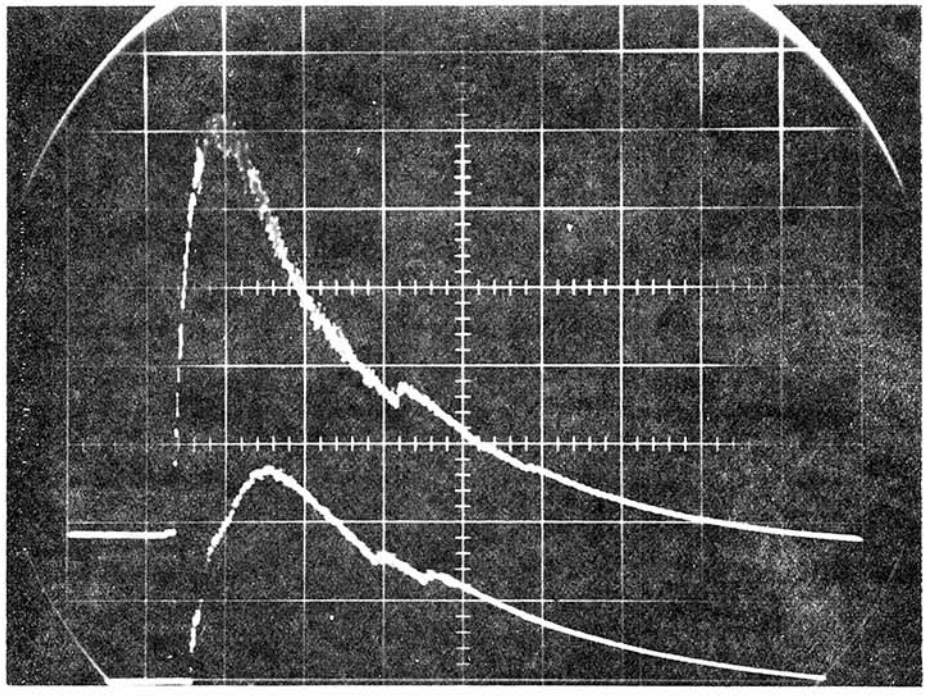

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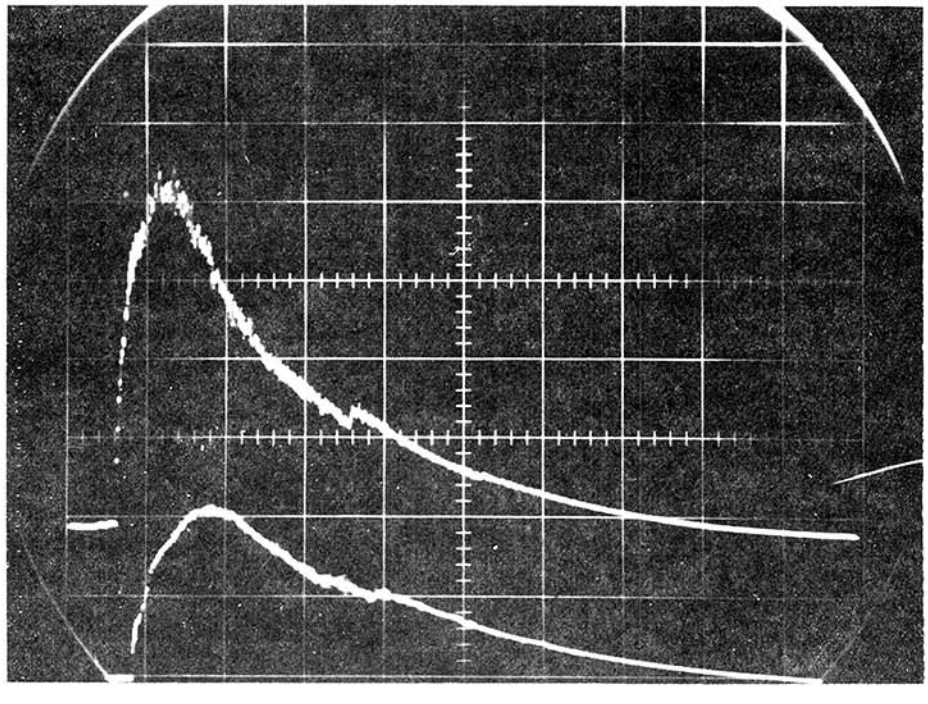

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U.S. Army Munitions Command

13. ABSTRACT

Tests were conducted to measure and determine the configuration of pressure and temperature pulses in the gas tube of the M16A1 rifle. Tests involved both IMR-8208M and WC-846 propellants. The peak pressures ranged from 1000 psi to 6100 psi and the peak temperatures from 210°F to 500°F, depending on the propellant used and the location of the measuring device. Results are tabulated and actual test records are included.

DD FORM 1 NOV 68 1473 REPLACES DD FORM 1473, 1 JAN 64, WHICH IS OBSOLETE FOR ARMY USE.

UNCLASSIFIED

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Small Arms						
M16A1 Rifle						
Pressure						
Temperature						
Gas Tube						
Flow Characteristics						