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This ATM is written in response to an MSC request to document an analysis of grenade thrust beyond the launch tube. At the technical review meeting on March 23, 1967 at Space Ordnance System, the problem of grenade thrust beyond the launch tube was discussed. It was decided that SOS would furnish rocket motor thrust versus time data to BxA. Subsequently, BxA would analyize the data to determine the effects of any thrust beyond the tube on system performance.

SUMMARY

The results of this analysis, using SOS thrust data, indicates that the thrust beyond the tube does not significantly effect the system performance. In the worst case, the grenade could be thrust off direction approximately 12', the range would be decreased .005%, and the velocity would be increased .69%. However the error in velocity measurement would be trivial.

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C. Bryer

Approved by J. McDowell
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ANALYSIS OF GRENADE THRUST BEYOND LAUNCH TUBE

The purpose for imposing the requirement that the rocket motors of the Active Seismic grenades complete thrusting prior to leaving the launch tubes is to minimize errors in ranging and velocity measurements. The range is determined by knowing the direction of flight and calculating the range on the basis of a free flight ballistic trajectory. Significant thrusting outside the launch tubes could affect the direction of flight and introduce errors of unknown magnitude and direction as well as increase the velocity of the grenade such that the assumption that the velocity is constant between range start and stop no longer remains true.

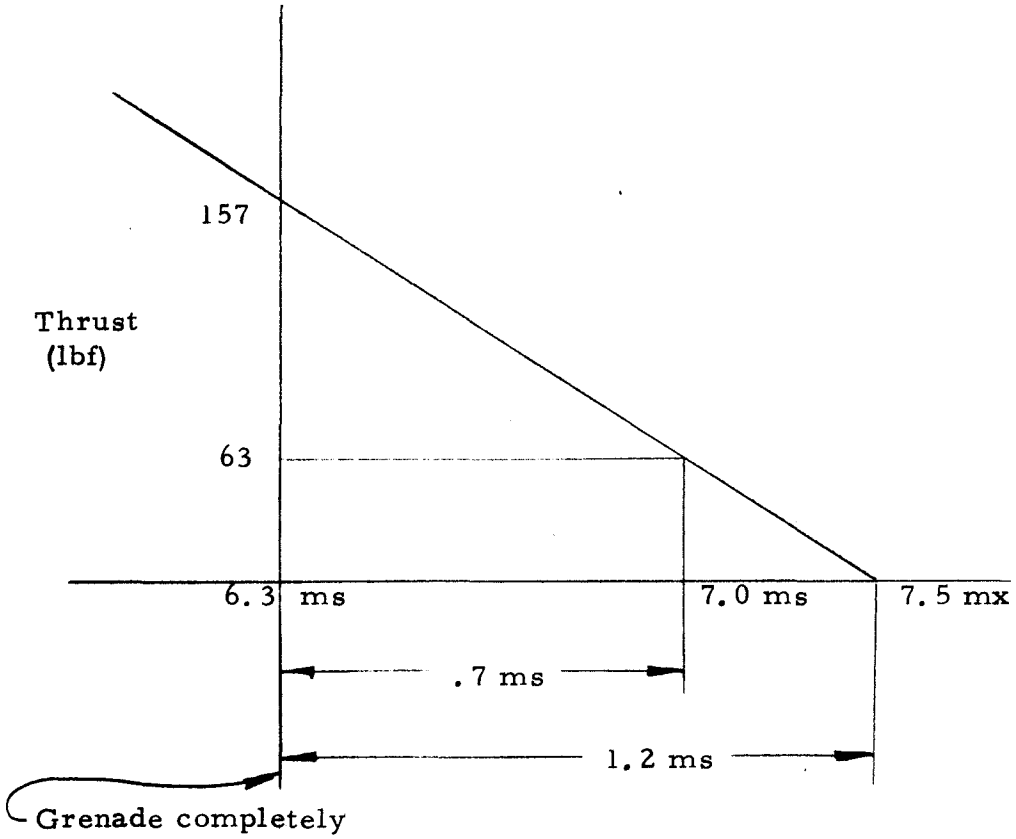
Since the velocity of the grenade is directly proportional to the total impulse delivered to each grenade, the attached SOS data sheets were examined to determine what portion of the total impulse is delivered after the grenade leaves the launch tube. The effect is detrimental only if this impulse is in a direction other than that of grenade flight or if the velocity changes such that it cannot be measured meaningfully by the range line. Examination of the data available indicates that in the majority of cases there is no significant out of tube thrust. The worst case of those available is the -1 rocket motor designed for the 5000 foot range. Following is an analysis of the effects of thrusting after the grenade leaves the launch tube.

The data indicates that the stoke duration is 6.3 m sec min and 7.0 m sec max. This is the time limit from the initial rocket motor ignition until the grenade completely leaves the launch tube. The thrust curve (page 5) yields the following data.

(1) At 6.3 millisecond after ignition the thrust is approx. 157#.

(2) At 7.0 milliseconds of ignition the thrust is approx. 63#.

(3) Assuming the thrust decreases linearly during this portion of the curve, the following diagram can be obtained.



The area under the above thrust time curve is the impulse delivered outside the launch tube when the stroke duration is at the 6.3 m sec minimum

$$\text{Area} = \text{Impulse} = 1/2\ BH$$

$$= 1/2\ (1.2 \times 10^{-3})\ (157)$$

$$= .094 \text{ lb sec}$$

The total impulse to the -1 grenade in order that its nominal velocity of 164 ft/sec be attained is as follows:

$$I = mv$$

$$= \frac{2.68}{32.2} \times 164 = 13.6 \text{ lb sec}$$

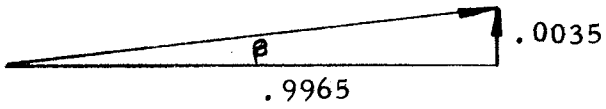
Therefore, the amount of impulse outside the launch tube is

$$\left(\frac{.094}{13.6} \times 100\right)\% = .69\% \text{ of the total impulse required.}$$

Using the engineering approximation that in worst case 50% of this out of tube thrust is delivered at right angles to the direction of grenade flight, .35% of the total impulse is delivered perpendicular to grenade flight. This yields the following velocity vector diagram

$$\tan \beta = \frac{.0035}{.9965} = .0035$$

$$\beta = 0^\circ\ 12'$$



If these forces act in a horizontal plane tending to cause the grenade to move right or left of its original flight line, the change would only be on the order of 0° 12'. If these forces act in a vertical plane, tending to change the pitch angle of the grenade, they would affect the range in the following manner:

$$\text{Range} = \frac{V^2}{g} \sin 2\theta$$

Based on the nominal launch angle of 45° with a possible variation of $\pm\ 0^\circ$ 12',

$$2\theta = \begin{matrix} 90^\circ 24' \text{ max.} \\ 89^\circ 36' \text{ min.} \end{matrix}$$

This yields a change in range of .005% in these worst case conditions.

The velocity is proportional to the impulse also. Since the impulse beyond the launch tube is only .69% of the total, the velocity error can be no greater. More important, the velocity is assumed constant for approximately 15 ms; the time for the grenade to travel 25 ft. Since the increase in velocity occurs within 1.2 ms of the time it leaves the grenade launch tube, the assumption that the velocity is constant would still be true within the velocity measurement accuracy expected.

From the data available, only one of eight exhibited out of tube thrusting and based on the above calculations the magnitude of errors is neglible in the worst case. No data is available for the -2 (3000 ft range) motor however if the thrusting beyond the tube is no greater than that from the available data, the errors will be negligible and may be ignored. Data for the -2 motor will be obtained during the SOS design verification tests to verify this.

SPACE ORDNANCE SYSTEMS, INC.
EL SEGUNDO, CALIFORNIA

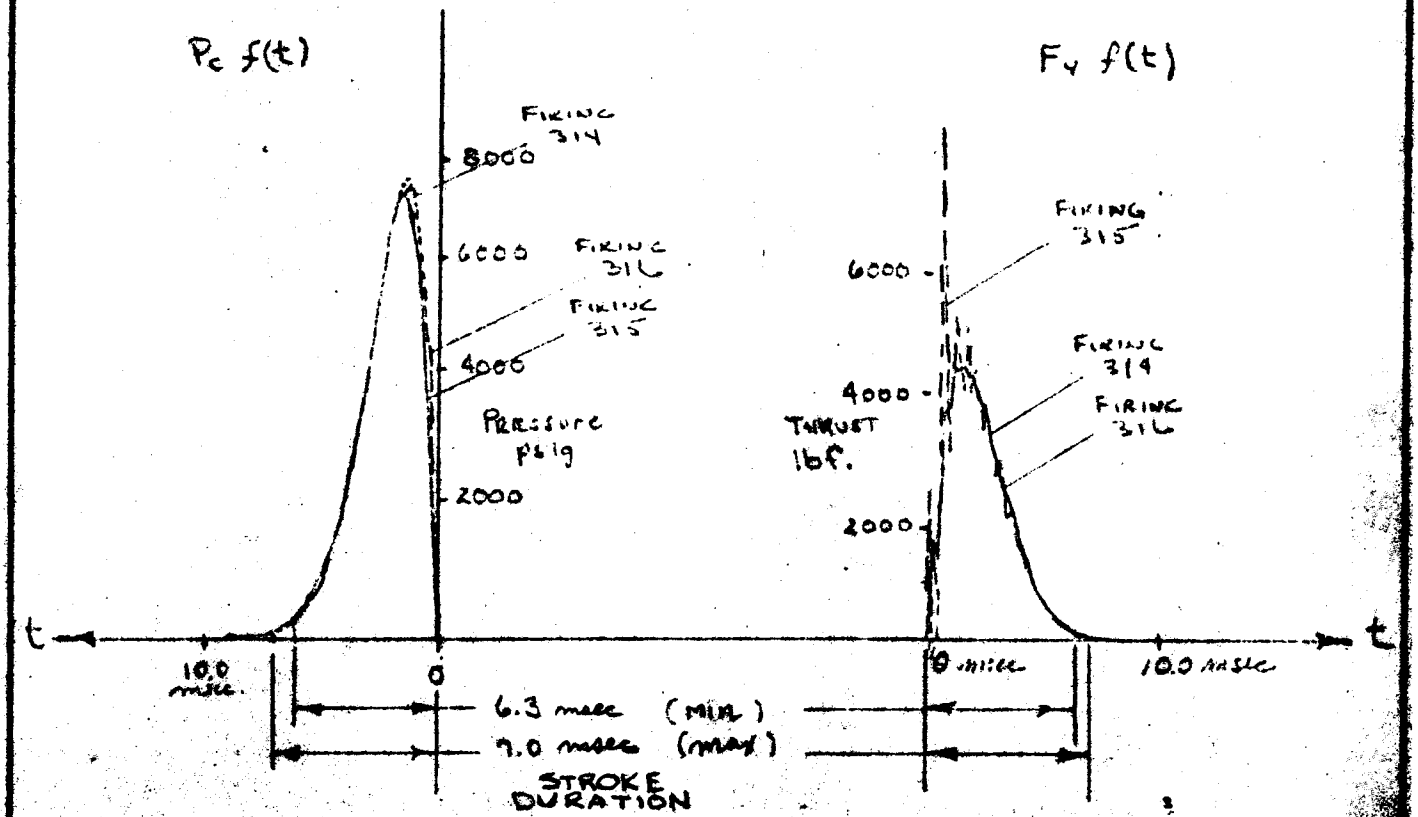
SOS

PREPARED BY: Kelly
CHECKED BY:

ENGINEERING ANALYSIS

PAGE 5 OF 17
PROJECT NO. 8051
DATE

SUBJECT: GRENADE STROKE DURATION Vs. ROCKET MTR DURATION -/MTR



(4 PIECES OF DATA)

Note: ALL P_c TRACES ARE FOR +180 °F STATIC TESTS

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EL SEGUNDO, CALIFORNIA

SOS

PREPARED BY: Reilly	ENGINEERING ANALYSIS	PAGE 6 OF 17
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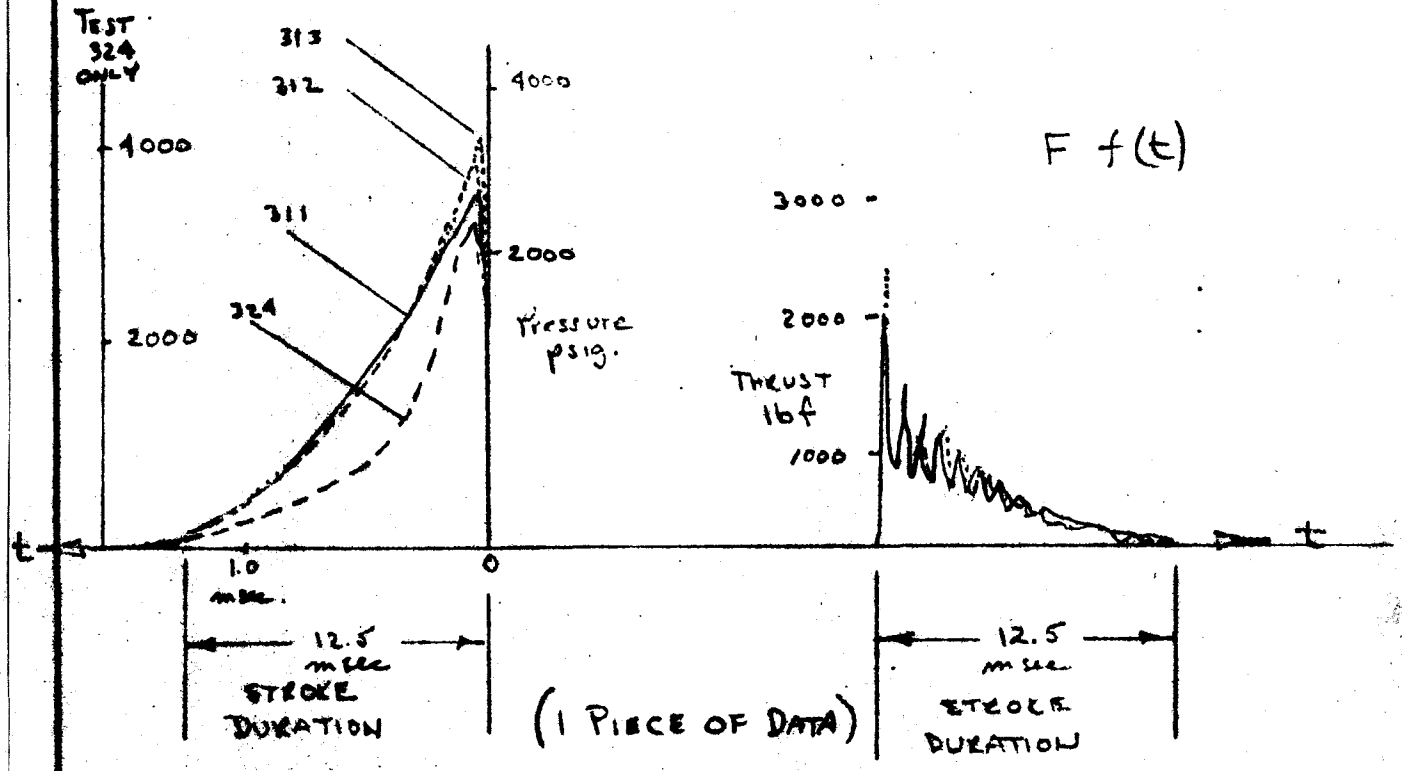
	SUBJECT: GRANADE STROKE DURATION VS. ROCKET MTR DURATION -3 MTR.	DATE 9 May 67

$P_c f(t)$



NOTE: STATIC TESTS 311, 312 & 313 ARE +180°F TESTS
STATIC TEST 324 AT -30°F.

SPACE ORDNANCE SYSTEMS, INC.

EL SEGUNDO, CALIFORNIA

PREPARED BY: Reed

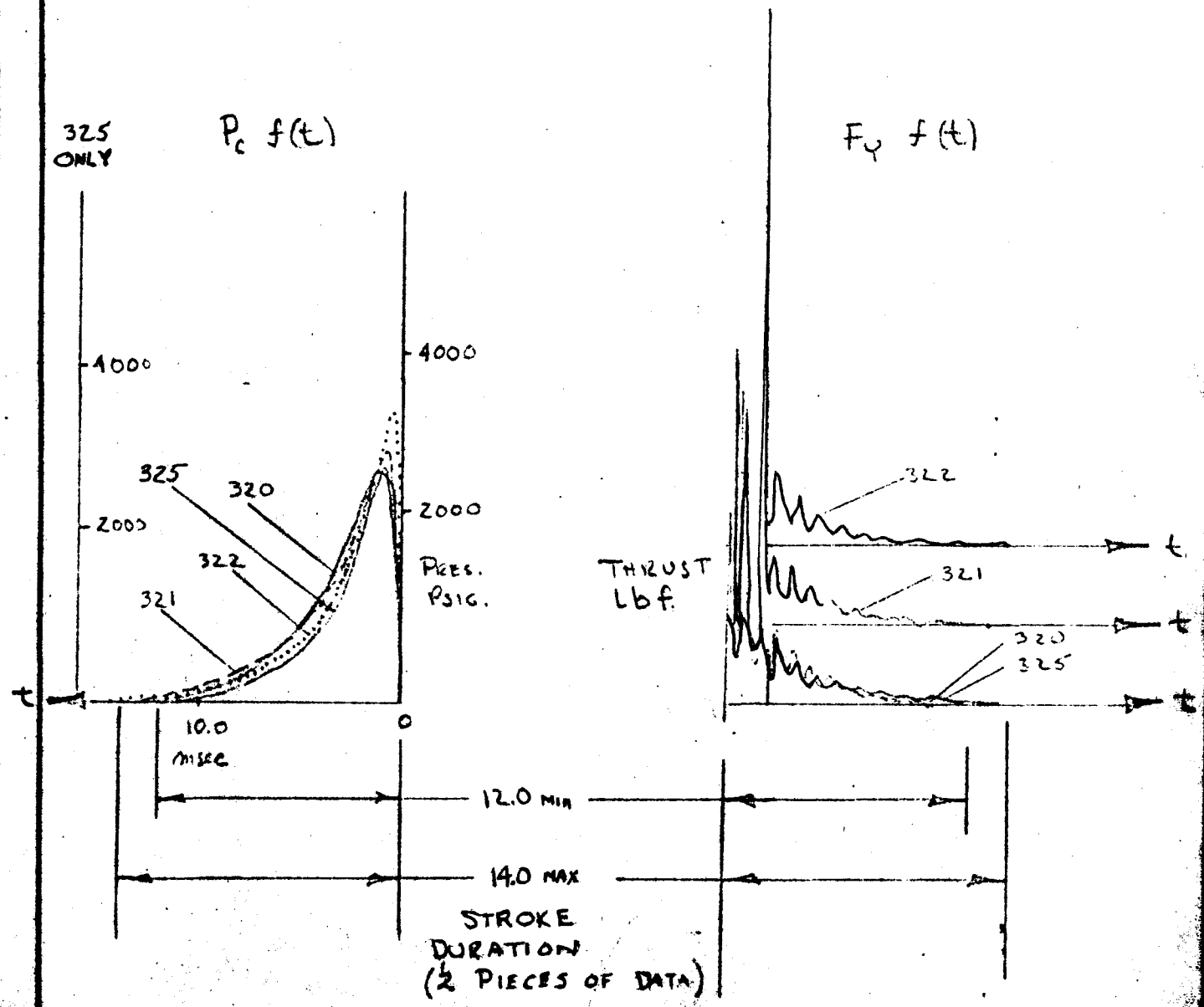
CHECKED BY:

ENGINEERING ANALYSIS

PROJECT NO. 8051

DATE 9 May 1967

SUBJECT: GRENADE STROKE DURATION VS. ROCKET MTR DURATION -9 MTR



NOTE: TESTS 321, 322 & 323 @ +180°F.

TEST 325 @ -30°F.

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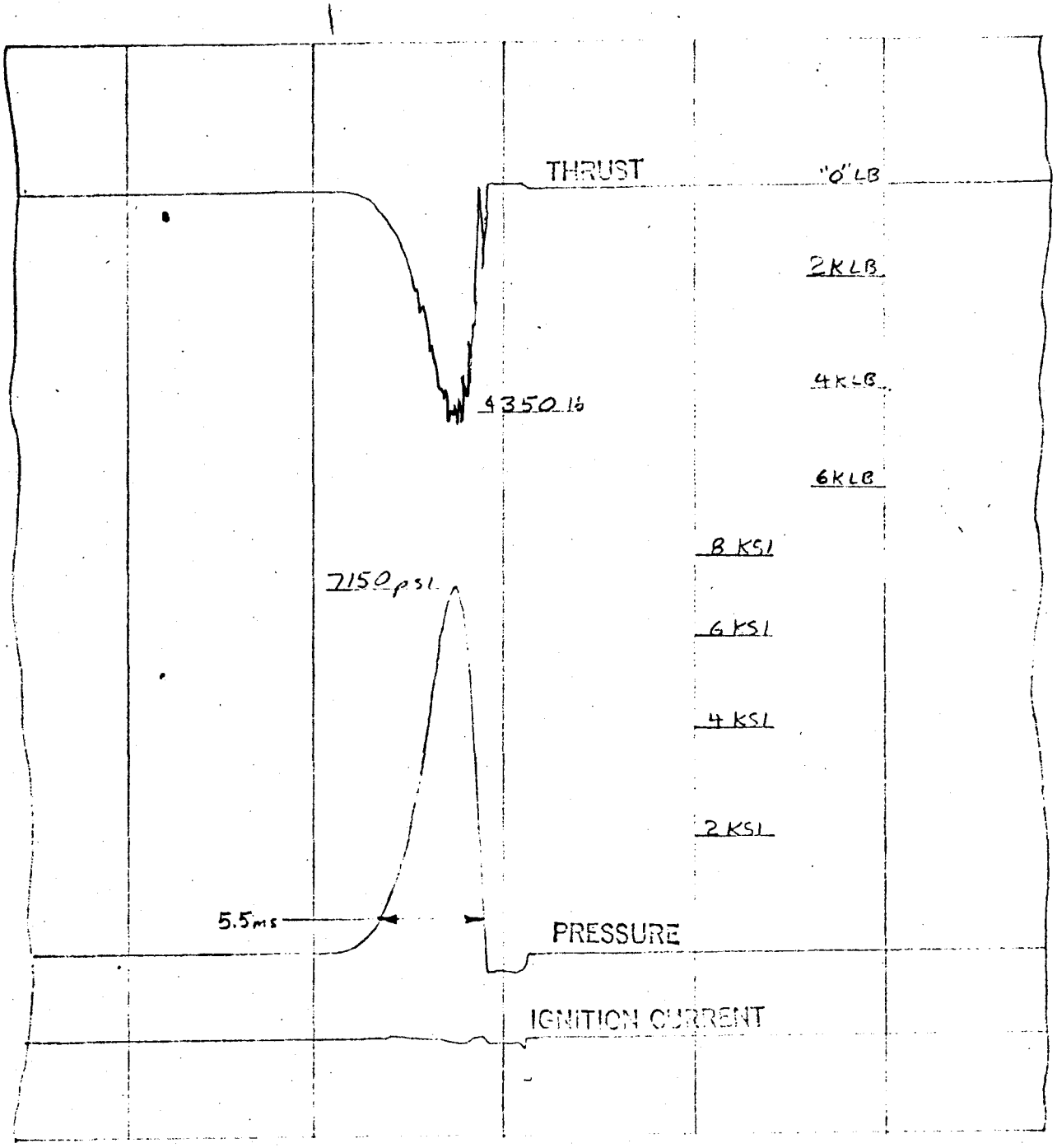
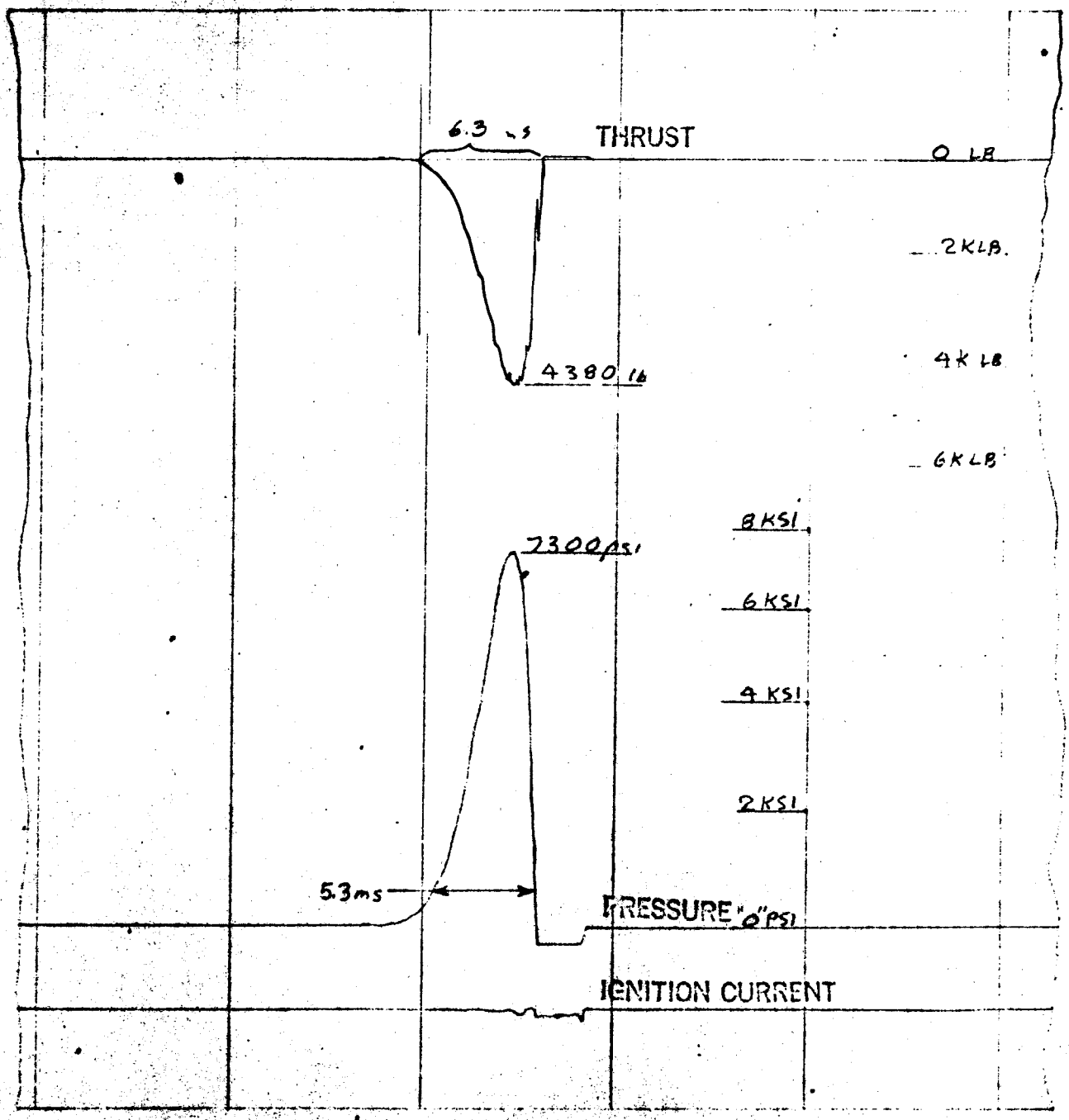


-1 ROCKET MOTOR
FIRING NO. 314
2-24-67
11.6 LB-SEC IMPULSE
+180°F



-1 ROCKET MOTOR
FIRING NO. 316
2-24-67
11.2 LB-SEC IMPULSE
+180°F

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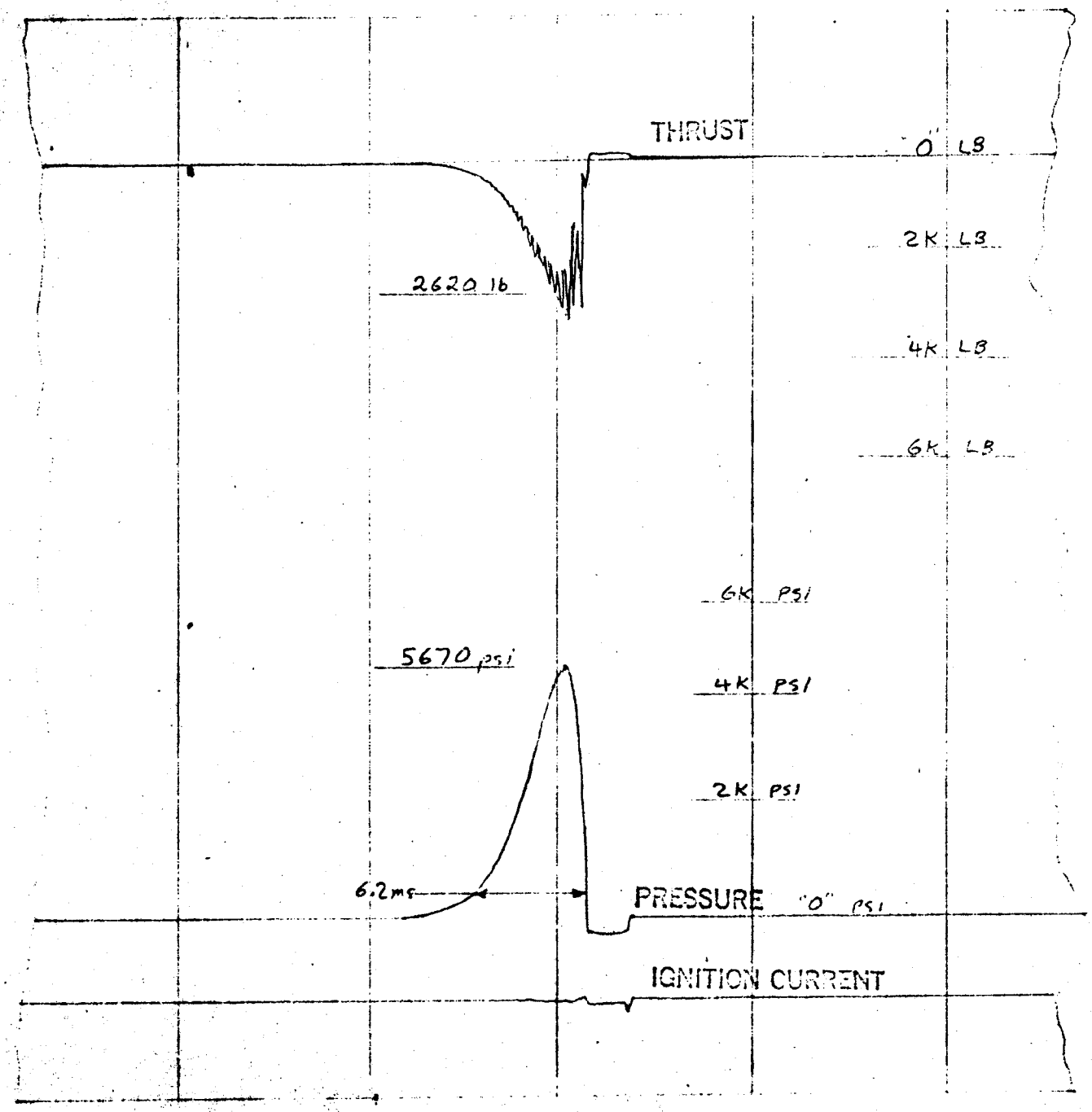
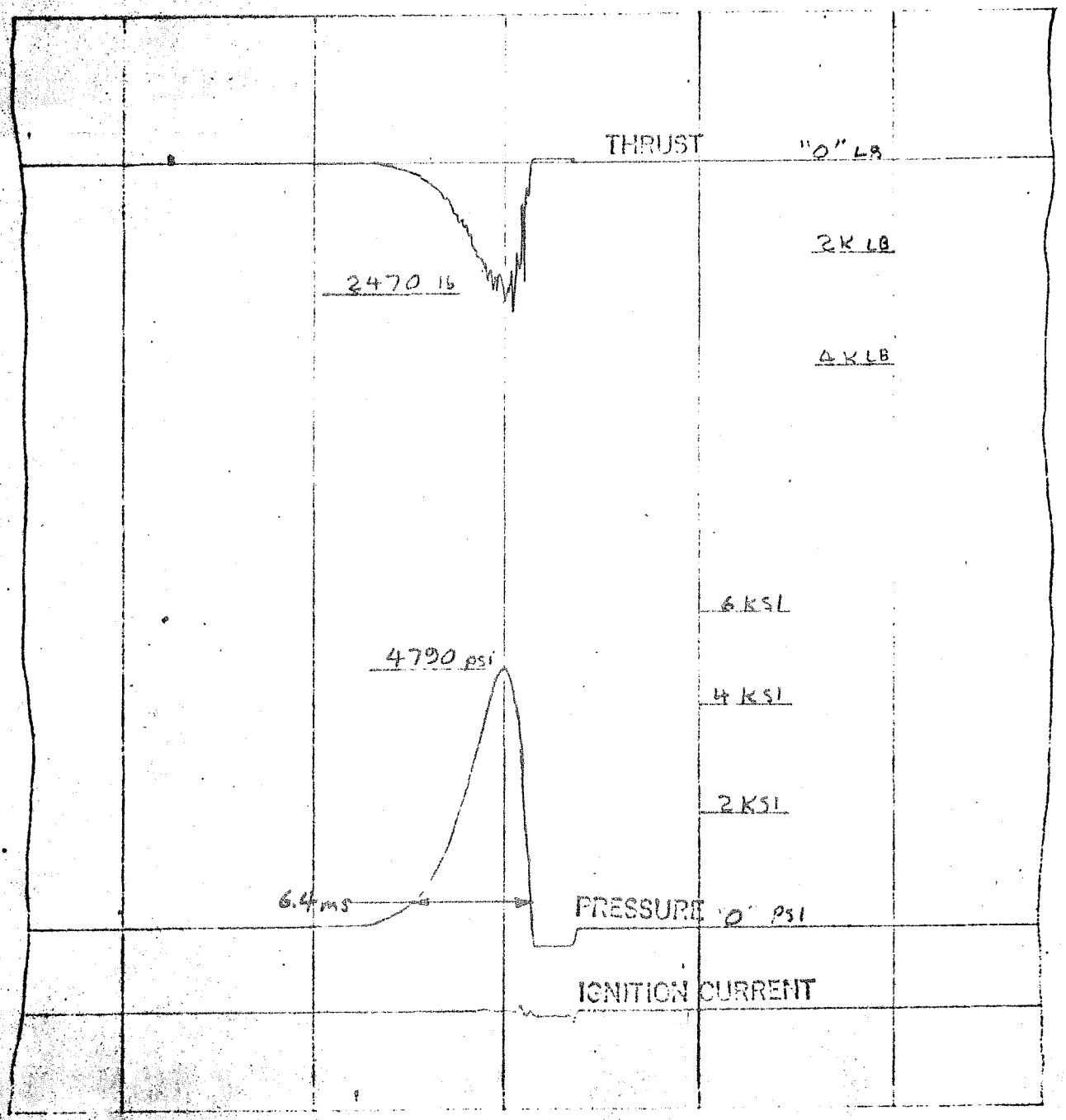
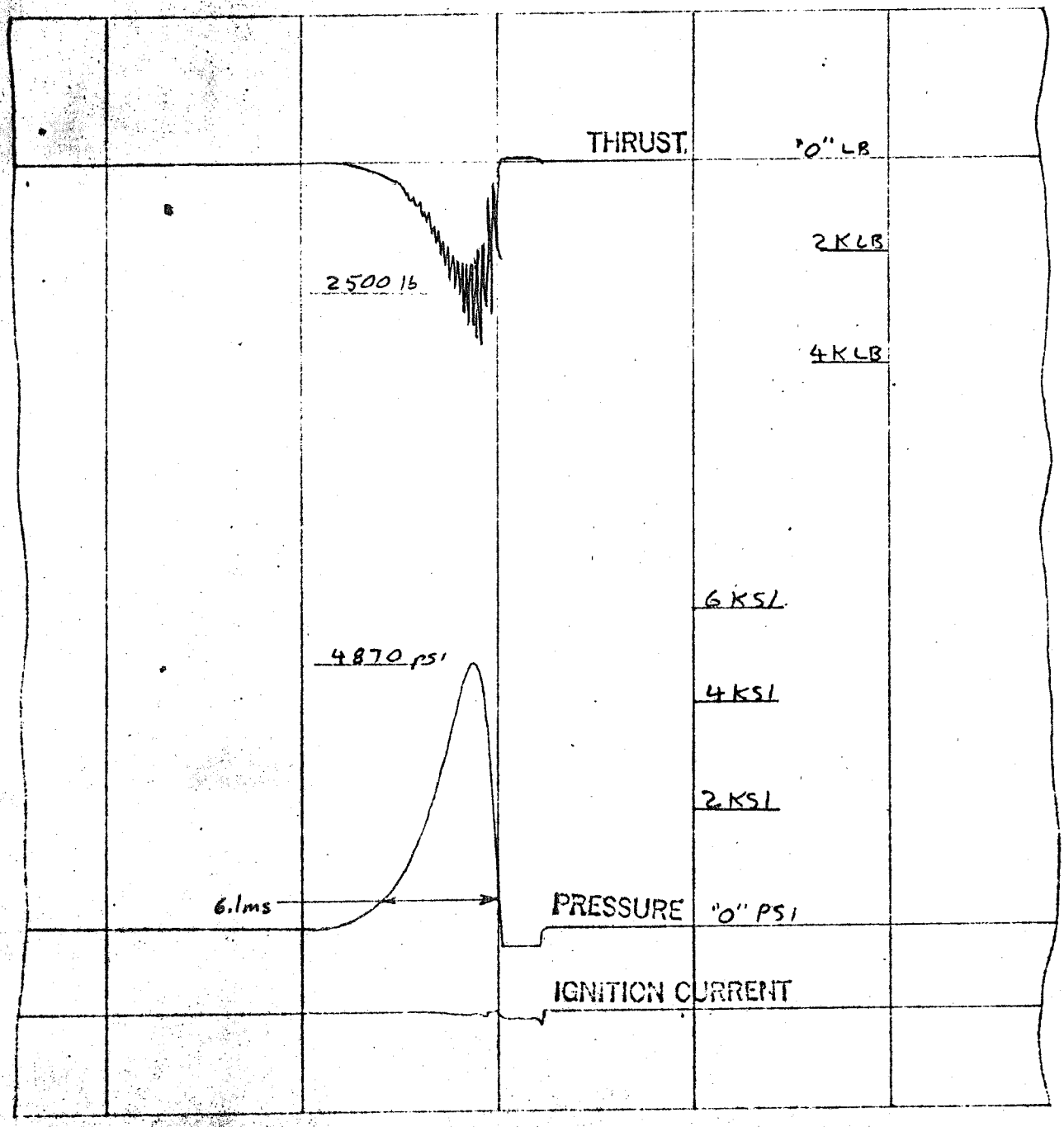


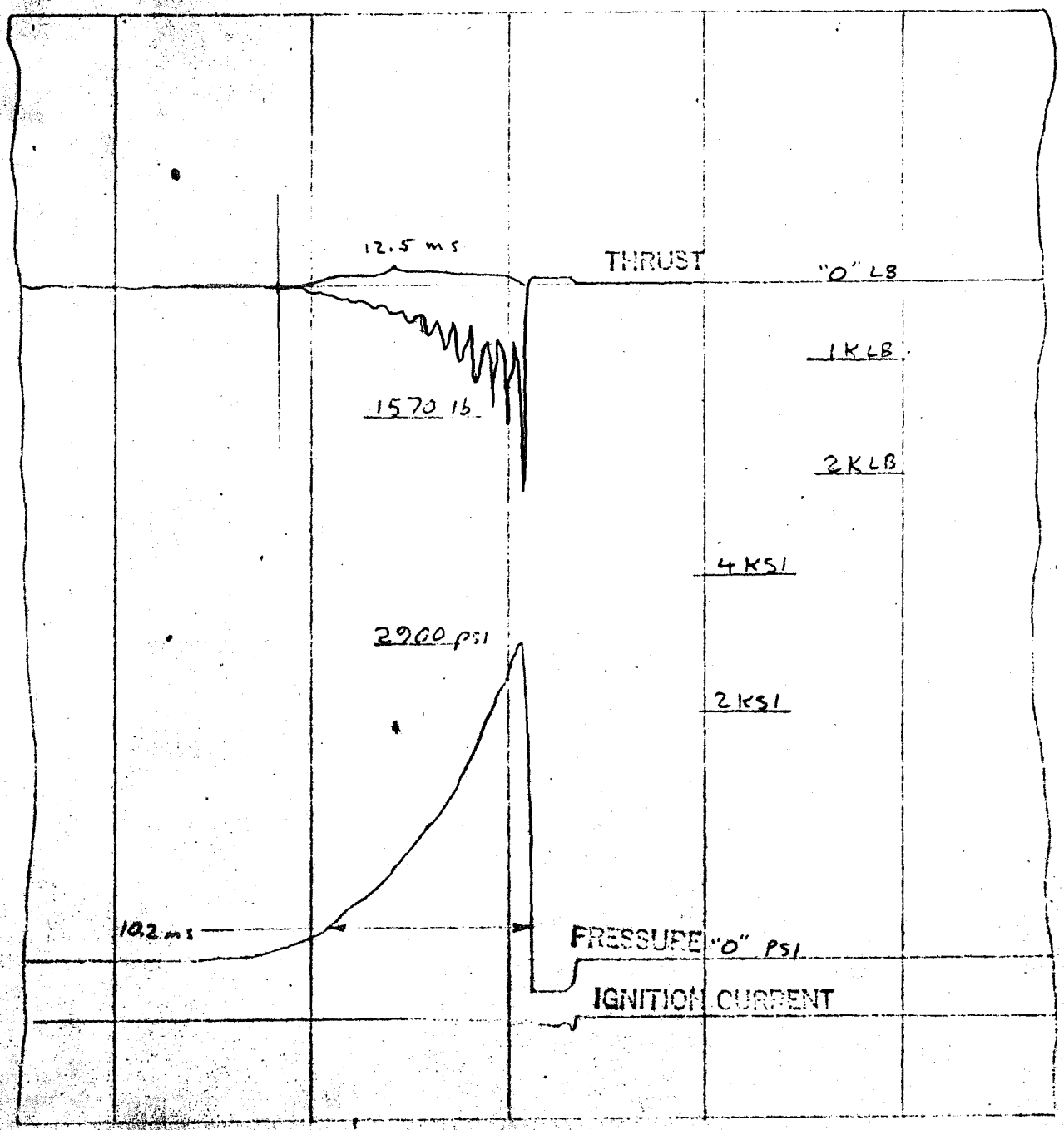
-2 ROCKET MOTOR
FIRING NO. 317
1-24-67
6.4 LB·SEC IMPULSE
+180 °F



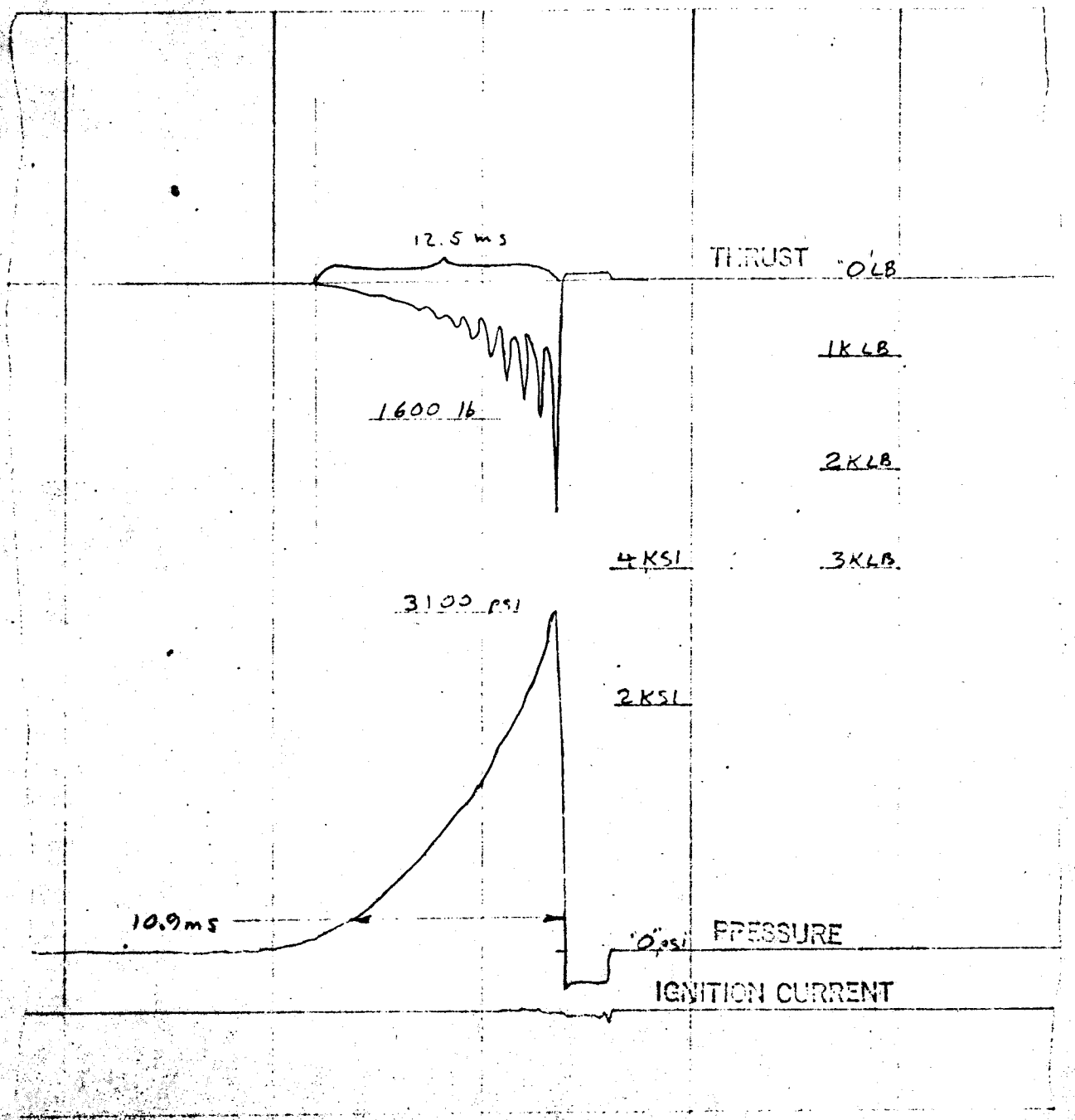
-2 ROCKET MOTOR
FIRING No 319
2-24-67
6.4 LB·SEC IMPULSE
+180 °F



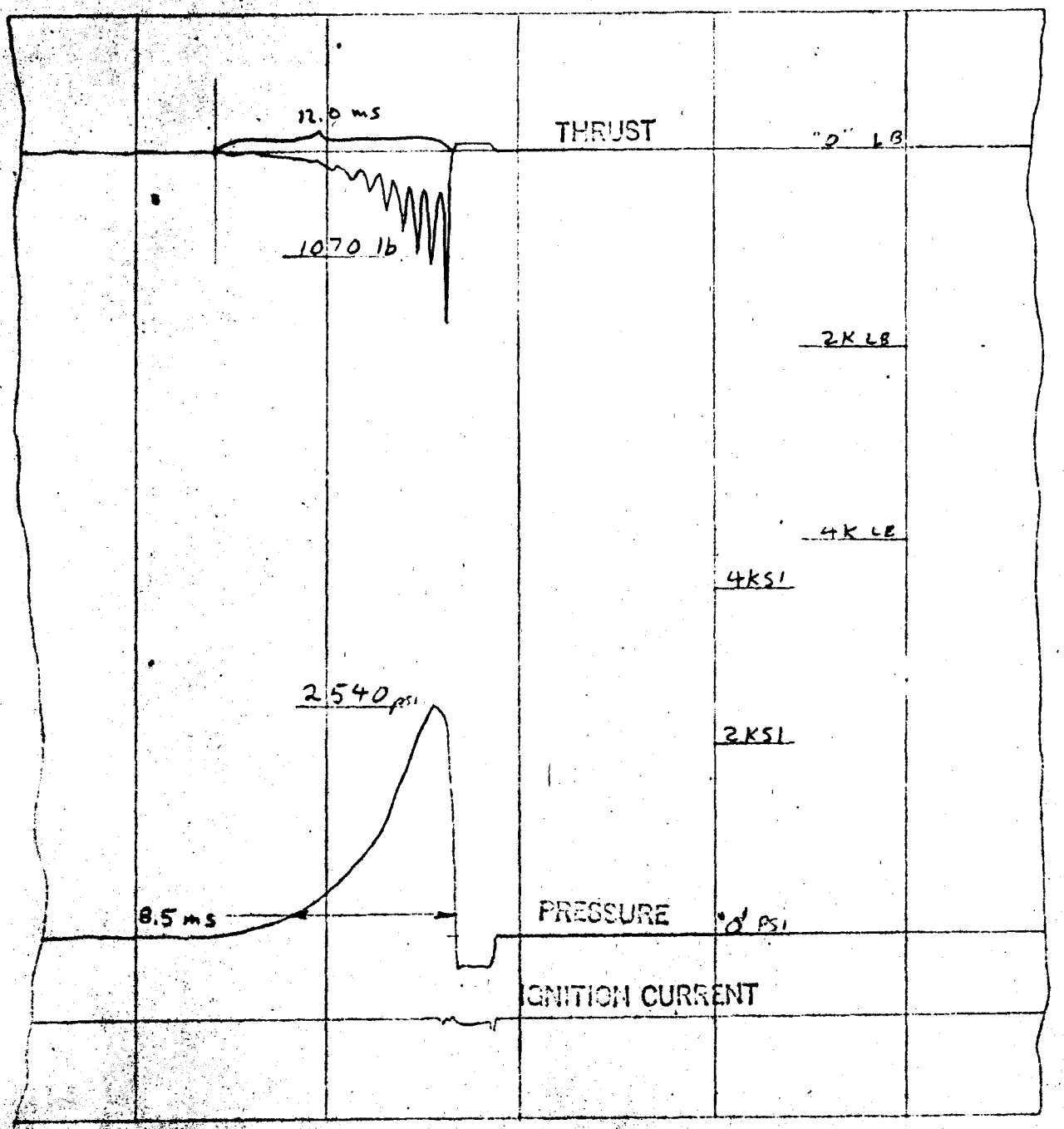
-2 ROCKET MOTOR
FIRING NO 318
2-24-67
6.4 LB·SEC IMPULSE
+180 °F



-3 ROCKET MOTOR
FIRING NO 312
2-24-67
3.6 LB·SEC IMPULSE
+180°F



-3 ROCKET MOTOR
FIRING NO. 313
1-24-67
3.6 LB·SEC IMPULSE
+180 °F



-4 ROCKET MOTOR
FIRING NO 320
1-24-67
+180°F

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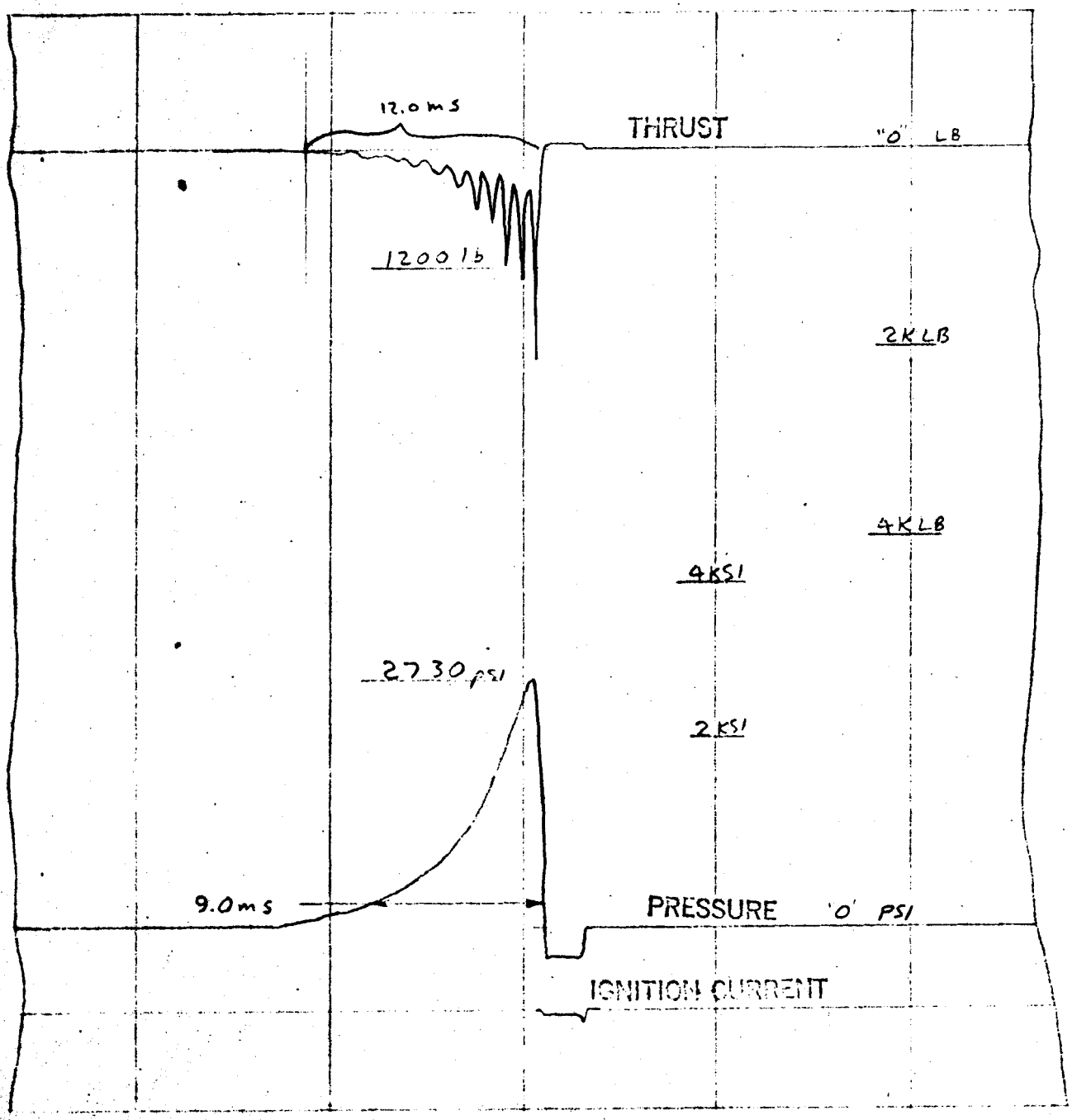
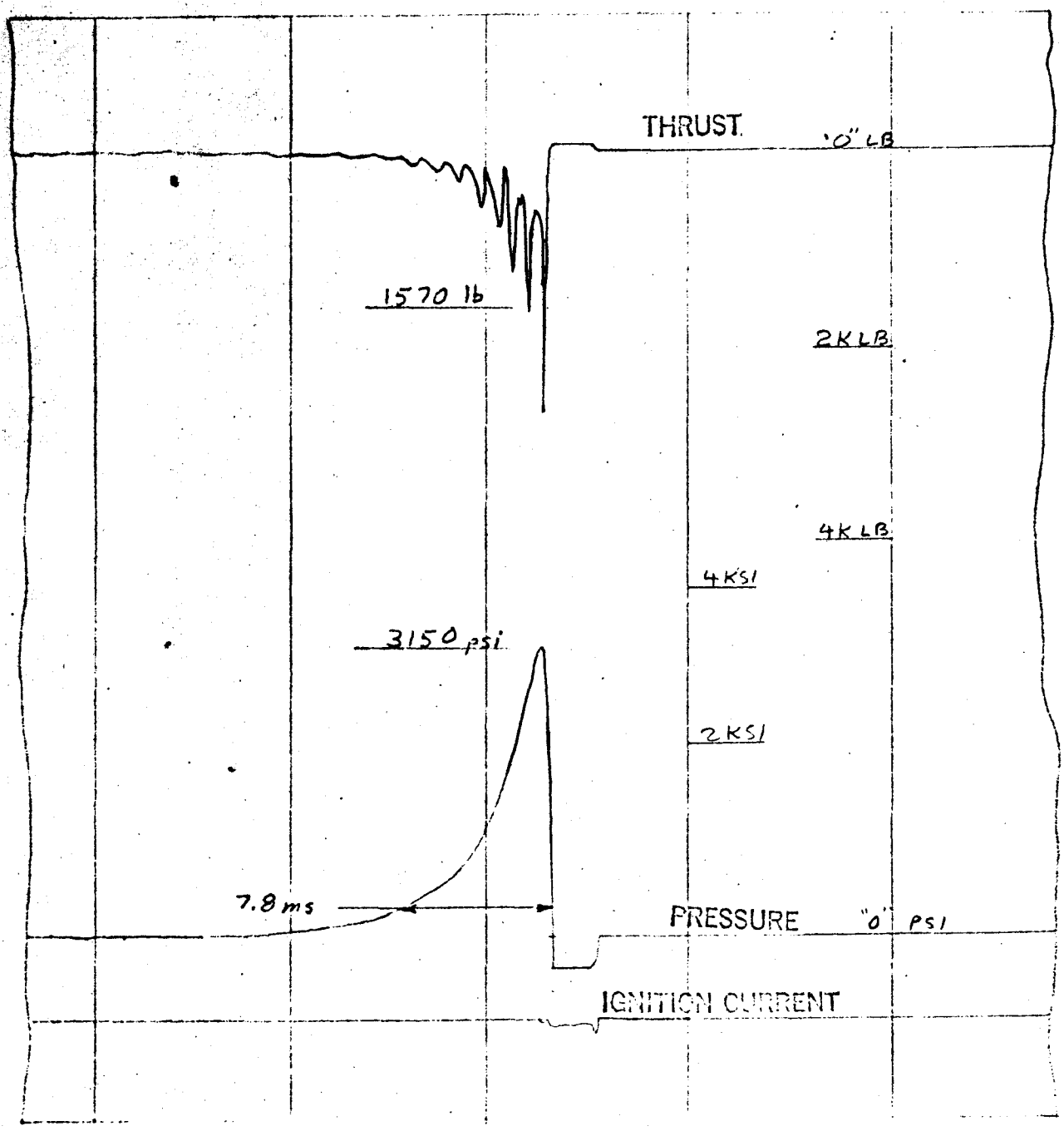


-4 ROCKET MOTOR
FIRING NO 321
1-24-67
2.06 LB-SEC IMPULSE
+180 °F



-4 ROCKET MOTOR
FIRING NO 322
2-24-67
2.05 LB·SEC IMPULSE
+180 °F