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RESEARCH MEMORANDUM

for the

Ordnance Corps, Department of the Army

PERFORMANCE OF AIR-LAUNCHED T-40 ROCKET MOTORS WITH TWO TYPES OF IGNITER

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PERFORMANCE OF AIR-LAUNCHED T-40 ROCKET MOTORS WITH TWO TYPES OF IGNITER

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SUMMARY

Air-launched firings of eight T-40 rockets have been made. Satisfactory operation was observed for six of the eight rounds, which were fired at altitudes of 29,000 to 35,000 feet and which varied from 8 to 24 months in age. Of the six rounds, five were equipped with metal powder - oxidant type igniters and the sixth had a black-powder type igniter. Two rounds equipped with black-powder type igniters did not fire. The rocket temperatures at firing ranged from 90° to 100° F.

A maximum total impulse of 23,600 pound-seconds was observed for one of the rounds. The average total impulse for four of the rounds mounted in cone-cylinder test vehicles was 22,870 pound-seconds.

Maximum velocities of over 5000 feet per second were obtained with two of these rockets while carrying pay loads of approximately 70 pounds.

INTRODUCTION

During the past several years the Lewis laboratory of the NACA has been using solid-propellant rockets for boosting air-launched research vehicles. One of the type rockets used is the T40-6KS3000 unit of which eight have been fired. Inasmuch as these were the first T-40 firings at altitude and under conditions of high acceleration, the performance is of interest for comparison with sea-level static firings. The igniter performance under altitude conditions is of particular interest. At the request of the Commanding General, Redstone Arsenal, Ordnance Corps, Huntsville, Alabama, the results of these eight rocket firings are reported herein.

APPARATUS AND PROCEDURE

The T-40 rockets described herein were used to propel research vehicles launched from a carrier plane at high altitude. A photograph of the launching airplane with one of the vehicles mounted under the center-wing section is shown in figure 1. The rockets were heated by an electric blanket while being carried aloft. Types of vehicles in which the rockets have been mounted are illustrated in figure 2. Rockets 1, 2, and 3 were mounted in vehicles of the type shown in figure 2(a); rocket 5 was mounted as shown in figure 2(b); and rockets 4, 6, 7, and 8 were mounted in vehicles illustrated in figure 2(c). Detailed descriptions of these vehicles are given in references 1, 2, and 3 and pertinent information on each of the eight firings is given in table I. The rocket igniters were fired by $4\frac{1}{2}$- to $5\frac{1}{2}$-second-delay squibs that were energized through a 3-foot-long static line as the models fell from the launching plane. The igniters were of the bayonet type and were screwed into scribed plastic throat closures (fig. 3). Rockets 1, 2, and 3 were equipped with black-powder type igniters (50 gm A-1 black powder) while the remaining 5 units had metal powder - oxidant type igniters. Each of the models carried sufficient telemeter instrumentation to allow calculation of rocket thrust. Briefly, rocket thrust was calculated from acceleration, weight, and drag data. Rocket thrust is equal to the quantity (instantaneous mass of the vehicle times the acceleration exclusive of gravity) plus total drag of the vehicle. In calculating model weight during rocket operation, the rocket propellant was assumed to be expended at a rate proportional to the rocket thrust rather than at a constant rate, and 103 pounds of propellant were assumed to be burned.

Drag data in general were obtained from pressure measurements on the bodies, boundary-layer surveys, and deceleration measurement during coasting flight (see refs. 1, 2, and 3 for drag data).

Taking possible errors in weight, acceleration, and drag into account, it is estimated that rocket thrust values given herein are accurate within ± 3 percent or ± 100 pounds, whichever is greater.

RESULTS AND DISCUSSION

As mentioned earlier, the first three rockets fired had black-powder igniters and the last five had metal powder - oxidant type igniters. The first round, with black-powder igniter, failed to fire; and while it was definitely established that the firing circuit was energized properly as the model left the launcher, no positive indication of squib or igniter firing was obtained. The precise reason for malfunction could not be determined. The second round with black-powder type igniter fired satisfactorily. On the third round, however, the igniter was definitely

observed to fire, but the main rocket charge did not ignite. Igniter firing was confirmed by a visible flash and by an acceleration pulse on the telemeter record. As a result of this igniter failure, metal powder - oxidant type igniters were used for the remainder of the firings and no further trouble was encountered. Rounds 6 and 8, however, did not ignite until about 0.12 and 0.04 second, respectively, after the first indication of squib firing. As noted in table I, rounds 1 and 3, which failed to fire, were 4 and 11 months old, respectively, while the other rounds ranged from 8 to 24 months of age at firing. Round 2, which fired satisfactorily with the black-powder igniter, was 8 months old. Rocket temperatures at firing varied from 90° to 100° F, while the altitude at ignition varied from 35,000 to 29,000 feet. The thrust-time history for rounds 2, 4, 5, 6, 7, and 8 are presented in figure 4. Rounds 4, 6, and 8 had quite high thrust peaks during ignition, ranging from 6600 pounds for round 4 to over 7000 pounds for round 8. No acceleration data were obtained during the first 3 seconds of round 7 firing; so no evaluation of the ignition characteristics for this round is possible.

Figure 5 presents tracings of the telemetered acceleration during the ignition cycle for the 3 rounds with high thrust peaks. The time and acceleration scales are different for each of the models inasmuch as the curves are direct tracings from the recording oscillograph charts. During the ignition cycle, the vehicle velocity is low and the drag is negligible so that rocket thrust is very nearly equal to acceleration times launching weight. The previously mentioned ignition delay for rounds 6 and 8 is indicated by the accelerometer pulsations just before thrust build-up. None of the other rounds displayed this characteristic. The peak acceleration encountered with round 8 was beyond the calibrated range of the accelerometer (35G). Integration of the thrust-time curves (fig. 4) for the six rockets that fired gives total impulse values of 20,410 to 23,600 pound-seconds. Rounds 2 and 5, which had the rockets internally mounted in a ram-jet combustion chamber, showed lower total impulse than the other four rounds which were mounted in the cone-cylinder vehicles. These two ram-jet mounted rockets discharged into a high-pressure region of secondary flow, which probably explains the lower total impulse. The cone-cylinder mounted rockets, on the other hand, discharged into a blunt base region with pressures equal to or lower than atmospheric pressure. The altitude range covered by rounds 4, 6, and 8 corresponds to ambient pressures of approximately 3.5 to 4.8 pounds per square inch absolute, while round 7, which was fired at a lower altitude, encountered ambient pressures from 4.6 to 8.3 pounds per square inch absolute. The following values are obtained if the observed total impulse for these four cone-cylinder vehicles is corrected to sea level by the expression: change in thrust due to change in atmospheric pressure = $(14.7 - p) \times$ nozzle-discharge area:

Round	Observed total impulse, lb-sec	Average ambient pressure, lb/sq in. abs	Total impulse corrected to sea-level pressure, lb-sec	Variation from average, percent
4	23,600	4.2	22,220	3.1
6	22,350	4.2	20,970	-2.7
7	22,200	6.5	21,120	-2.0
8	23,340	3.7	21,930	1.7
Average:	22,870		21,560	±2.4

The average observed total impulse of 22,870 pound-seconds is equal to an average specific impulse of 222, assuming 103 pounds of propellant burned. The average and maximum corrected values of 21,560 and 22,220 pound-seconds, respectively, agree very well with a static firing from the same batch (H-574) at Redstone Arsenal on July 16, 1951 (unpublished data), which gave a total impulse of 22,250 pound-seconds. The average variation of ±2.4 percent is no greater than that previously reported for fresh units static tested (refs. 4 and 5). Thus, a storage period of up to 24 months and maximum flight accelerations of over 35 g's had no apparent effect on total impulse. However, in the flight tests, a more pronounced thrust peak before "tail-off" was apparent. The time to 50 percent average thrust ranged from 5.75 to 6.02 seconds, which again agrees satisfactorily with ground static firings at similar temperatures. The valley in the thrust curve of unit 5 during the first second of operation may indicate a momentary partial ignition for this unit.

It is of interest to note (table I) that burn-out velocities of over 5000 feet per second were obtained with two of these air-launched rockets while carrying pay loads of approximately 70 pounds (table I).

SUMMARY OF RESULTS

The firings of eight air-launched T-40 rockets with propellant temperatures from 90° to 100° F gave the following results:

1. Satisfactory operation was observed for six T-40 rockets which were fired at altitudes from 29,000 to 35,000 feet and which varied in age from 8 to 24 months. Of these six units, five were equipped with metal-powder - oxidant type igniters and the sixth had a black-powder type igniter.

2. Two units equipped with black-powder type igniters did not fire, although igniter firing was observed for one of the two.

3. Maximum accelerations of over 35 g's were sustained without loss in rocket performance.

4. A maximum total impulse of 23,600 pound-seconds was observed for one of the rounds. The average total impulse for four of the rounds mounted in cone-cylinder test vehicles was 22,870 pound-seconds. This average value is equal to a specific impulse of 222, based on the assumption that 103 pounds of propellant were burned.

5. Burn-out velocities of over 5000 feet per second were obtained with two of these rockets while carrying pay loads of approximately 70 pounds.

Lewis Flight Propulsion Laboratory
National Advisory Committee for Aeronautics
Cleveland, Ohio, October 13, 1954

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2. Jones, Merle L., Rabb, Leonard, and Simpkinson, Scott H.: Drag Data for 16-Inch-Diameter Ram-Jet Engine with Double-Cone Inlet in Free Flight at Mach Numbers from 0.7 to 1.8. NACA RM E54H02, 1954.

3. Messing, Wesley E., Rabb, Leonard, and Disher, John H.: Preliminary Drag and Heat-Transfer Data Obtained from Air-Launched Cone-Cylinder Test Vehicle over Mach Number Range from 1.5 to 5.18. NACA RM E53I04, 1953.

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5. Goodloe, John H.: Final Report - Loading of T-40 Rocket Motors. Rep. No. 22-54, Redstone Div., Thiokol Chemical Corp., May 1954. (Supplemental Agreement Nos. 26 and 34, ORD Contract No. DA-01-021-ORD-76, ORD Proj. TU2-2018.)

TABLE I. - PERTINENT DATA FOR AIR-LAUNCHED T-40 ROCKET FIRINGS

	Round							
	1	2	3	4	5	6	7	8
Rocket temperature, °F	100	90	95	97	95	93	90	90
Date rocket loaded	9/15/51	7/5/51	9/25/51	7/5/51	7/5/51	8/52	8/8/52	8/52
Date rocket fired	1/30/52	3/21/52	8/26/52	3/17/53	6/3/53	10/20/53	5/26/54	8/24/54
Age at firing, months	4	8	11	20	23	14	21	24
Thiokol lot number	H-637	H-574	H-637	H-574	H-574	H-1066	H-1066	H-1066
Altitude of firing	35,000	35,000	35,000	35,000	35,000	35,000	29,000	35,000
Altitude at burn-out	------	32,000	------	28,000	31,000	28,000	15,000	32,000
Total impulse, lb-sec	------	21,410	------	23,600	20,410	22,350	[a]22,200	23,340
Time to 50-percent average thrust, sec	------	6.02	------	5.80	5.75	6.00	5.97	5.88
Weight of model, lb	760	711	733	202	449	204	202	207
Velocity at burn-out, ft/sec	------	1520	------	5110	1860	4675	4728	5080
Maximum acceleration, g	------	6.9	------	32.6	10.4	34.2	[a]>27.3	>35
Launching velocity, ft/sec	525	525	525	550	525	550	550	550

[a]During first 3 seconds of burning for unit 7, impulse was calculated from velocity change and drag, no acceleration measurements being available.

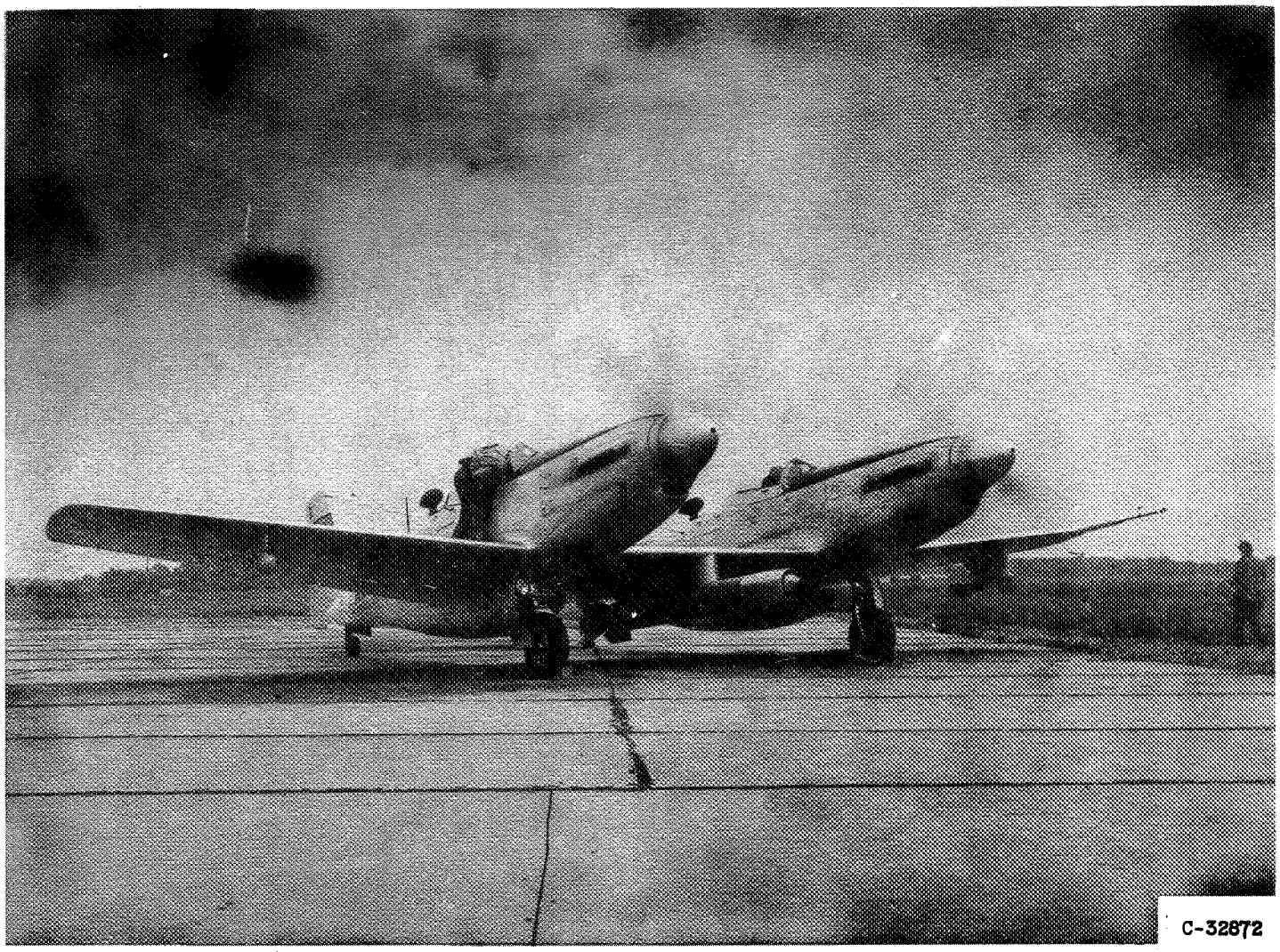
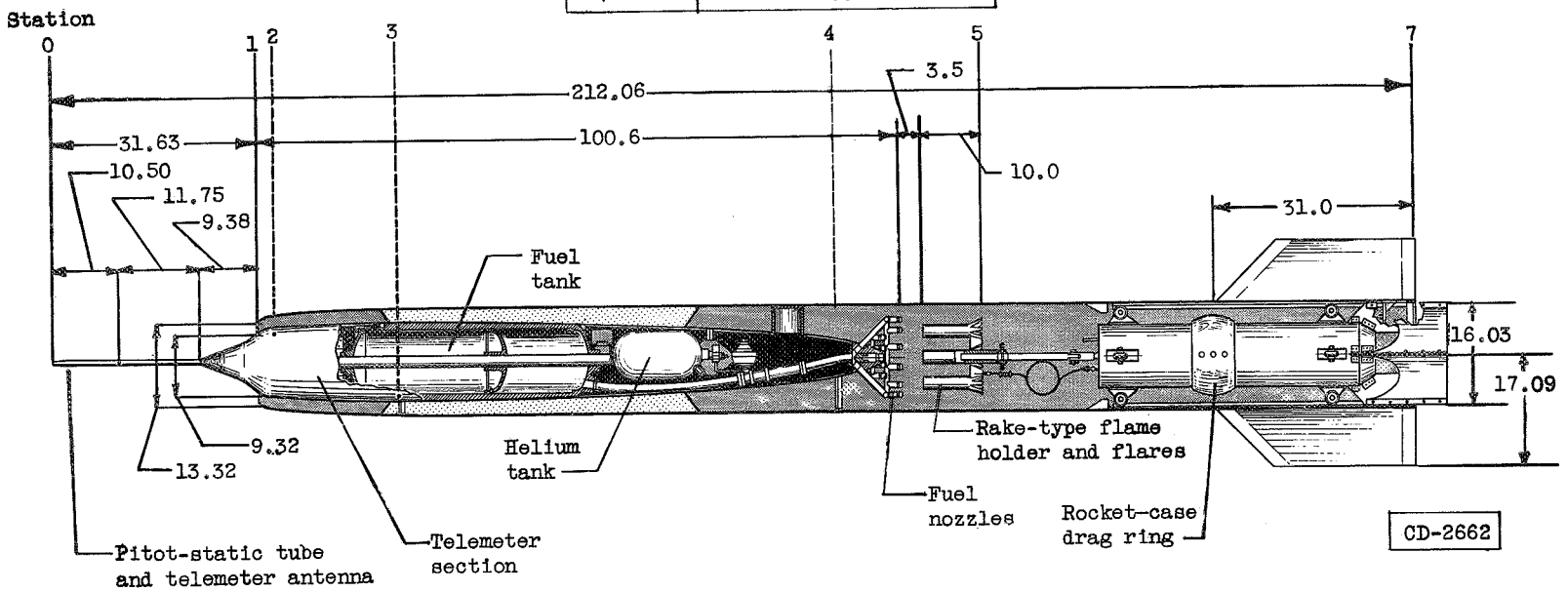


Figure 1. - Full-scale model mounted beneath center-wing panel of F-82 airplane.

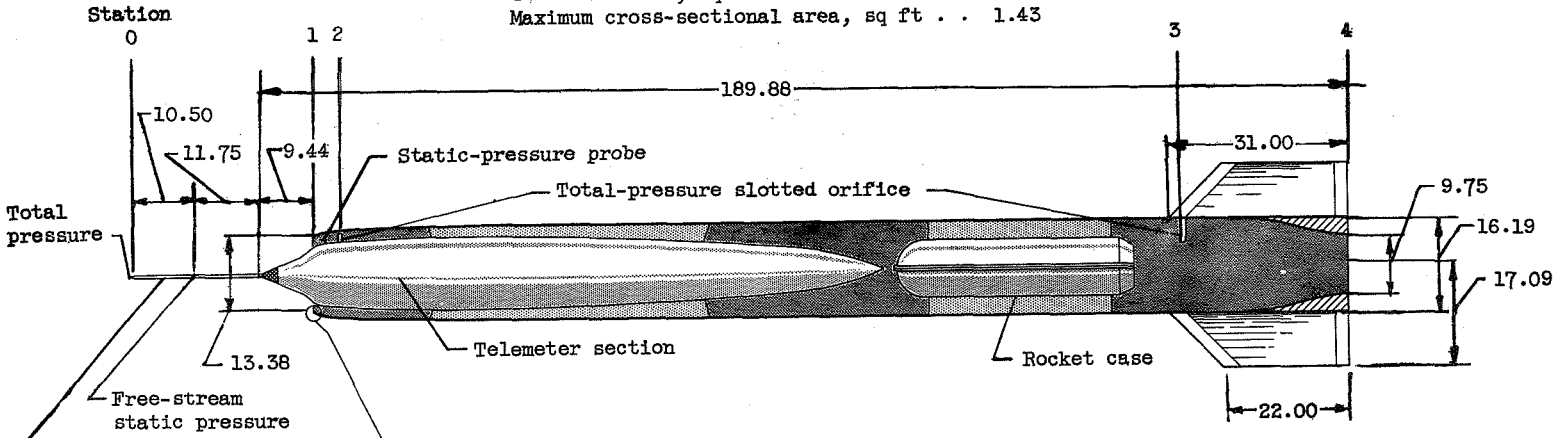
Station	Distance from pitot-static tip
1	31.63
2	34.25
3	58.38
4	122.50
5	145.81
7	212.06



(a) Ram-jet engine with internally mounted booster; configuration for rounds 1, 2, and 3.

Figure 2. - Air-launched test vehicles with T-40 rocket. (All dimensions are in inches.)

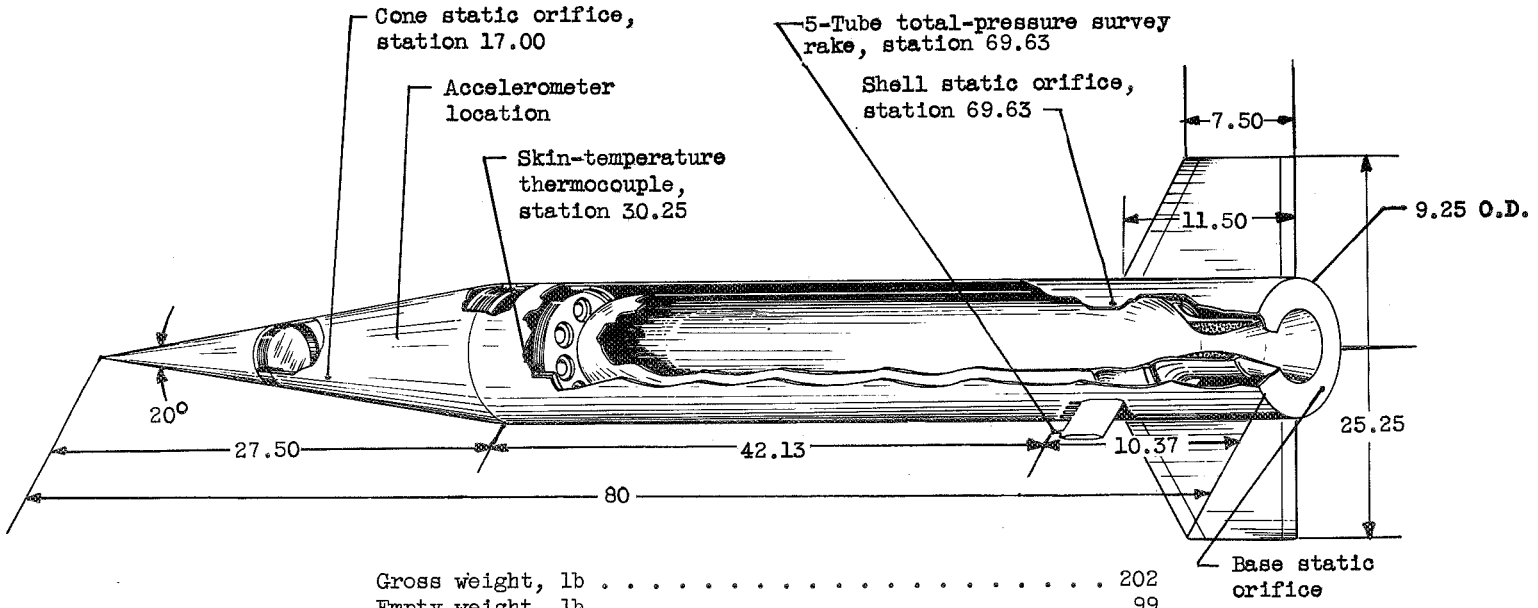
Gross weight, lb 449
Gross weight minus rocket fuel, lb 347
Inlet flow area, sq ft 0.517
Capture area, sq ft 0.976
Exit flow area, sq ft 0.518
Maximum cross-sectional area, sq ft . . 1.43



Distance from apex of cone	Centerbody outside radius	Shell inner radius
10.00	4.65	6.84
11.00	5.14	7.12
12.00	5.38	7.20
20.00	5.88	7.67
30.00	6.05	7.92
40.00	5.98	8.00
48.00	5.80	8.00
51.00	5.75	8.00
60.55	5.49	8.00
70.00	5.12	8.00
80.00	4.66	8.00

(b) Nonburning ram-jet drag model with internally mounted rocket; configuration for round 5.

Figure 2. - Continued. Air-launched test vehicles with T-40 rocket. (All dimensions are in inches).



Gross weight, lb	202
Empty weight, lb	99
Launching altitude, ft	35,000
Design Mach number at 30,000 ft	5.0
Rocket engine	JATO 6-KS-3000 T-40
Center of gravity at gross weight	station 48
Center of gravity at burn-out	station 43.5
Total base area, sq ft	0.467
Annular base area, sq ft	0.331

CD-3097

(c) Cone cylinder; configuration for rounds 4, 6, 7, and 8.

Figure 2. - Concluded. Air-launched test vehicles with T-40 rocket. (All dimensions are in inches.)

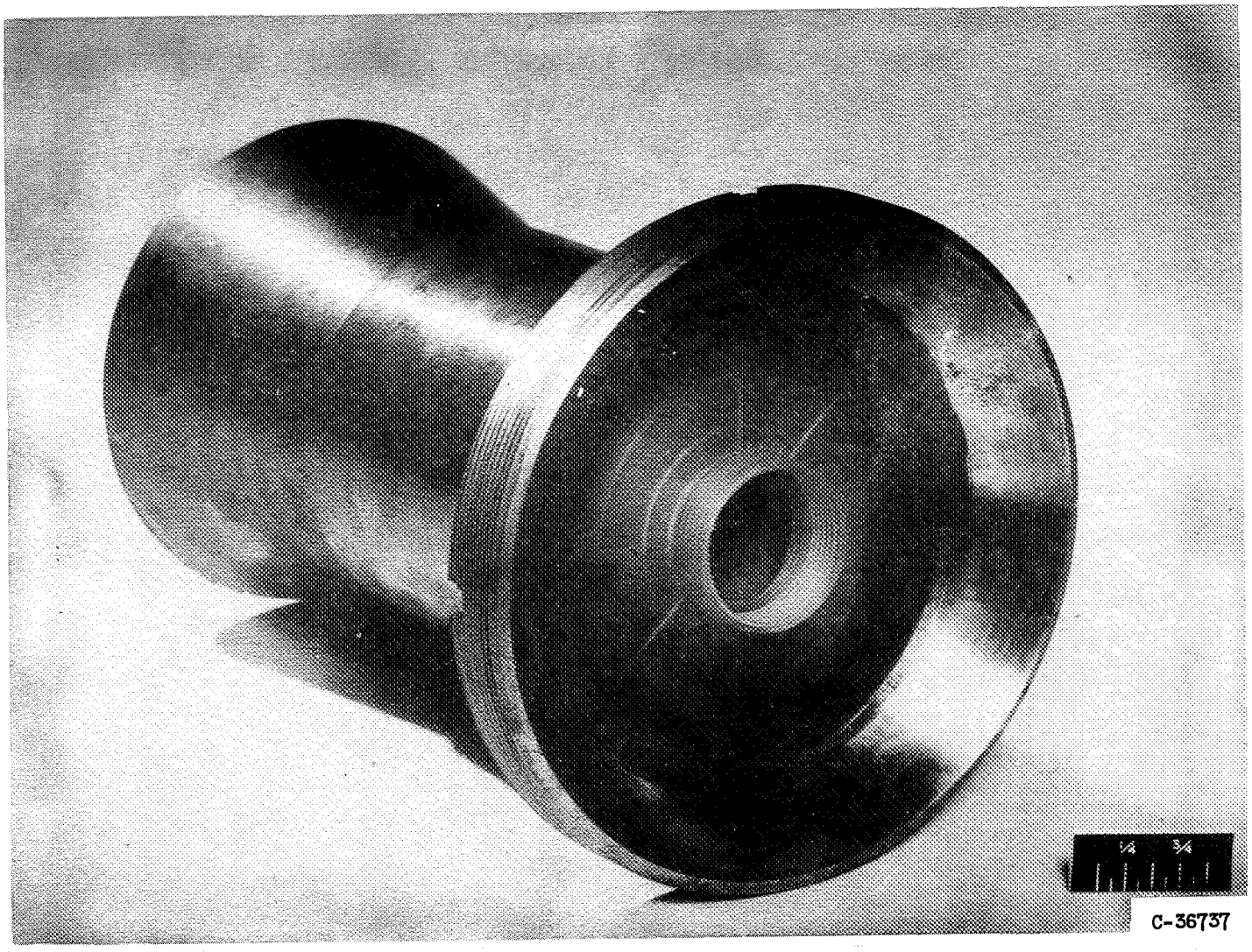
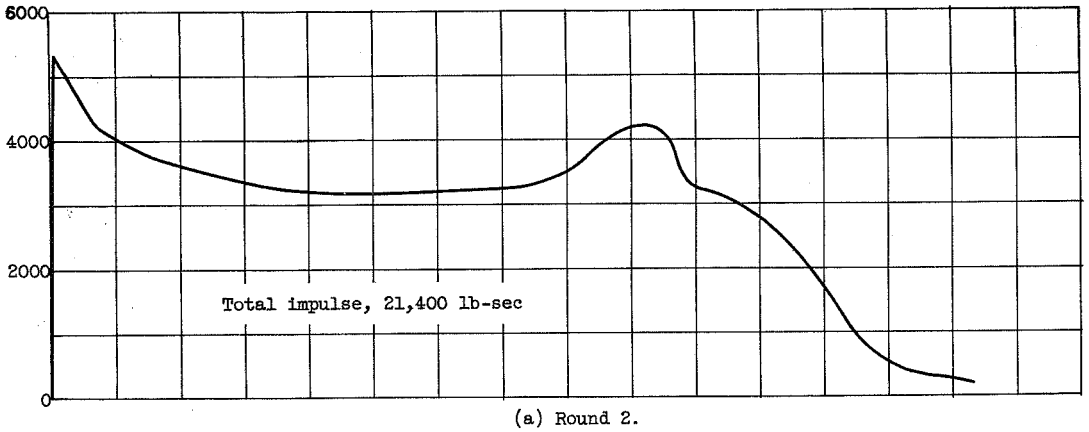
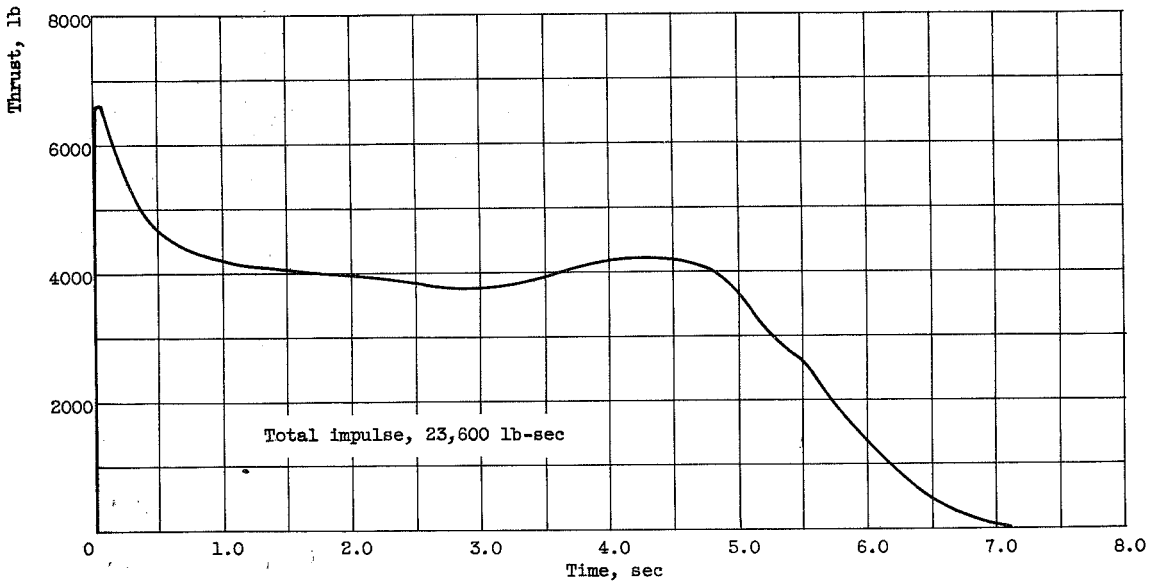


Figure 3. - Nozzle closure and igniter mount for air-launched T-40 rocket firings.

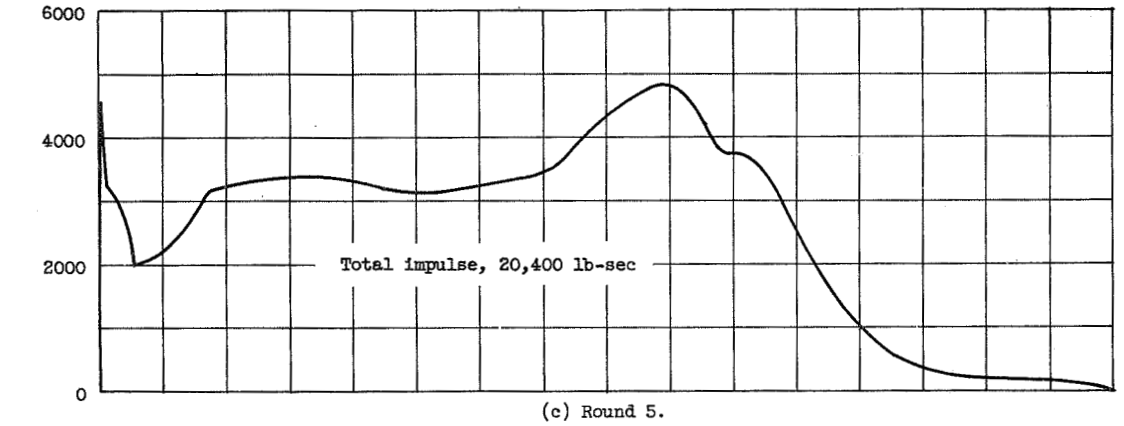


(a) Round 2.

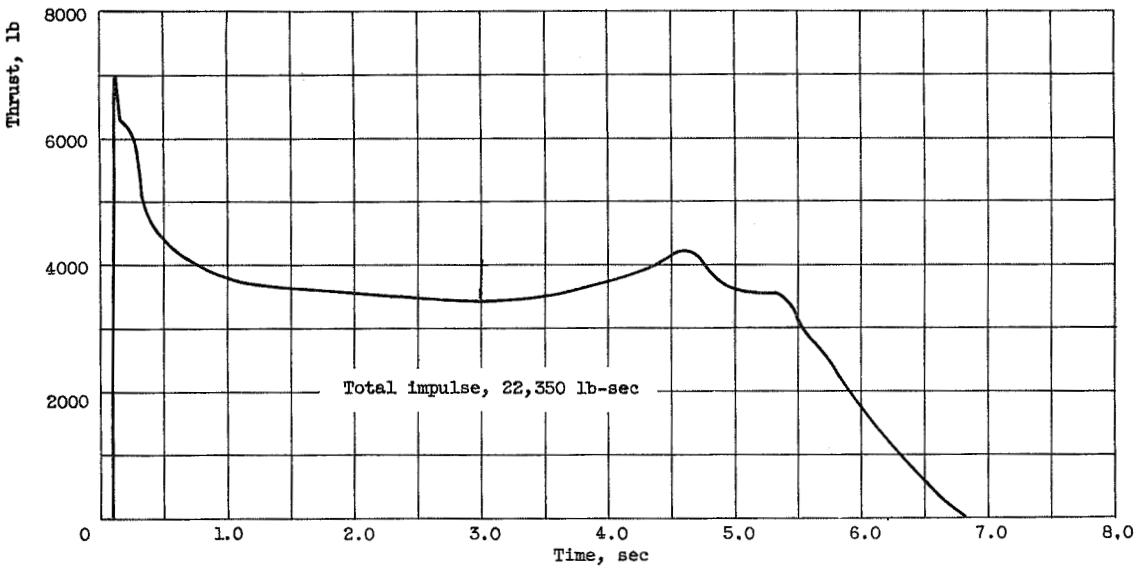


(b) Round 4.

Figure 4. - Thrust-time curves for air-launched T-40 rockets.

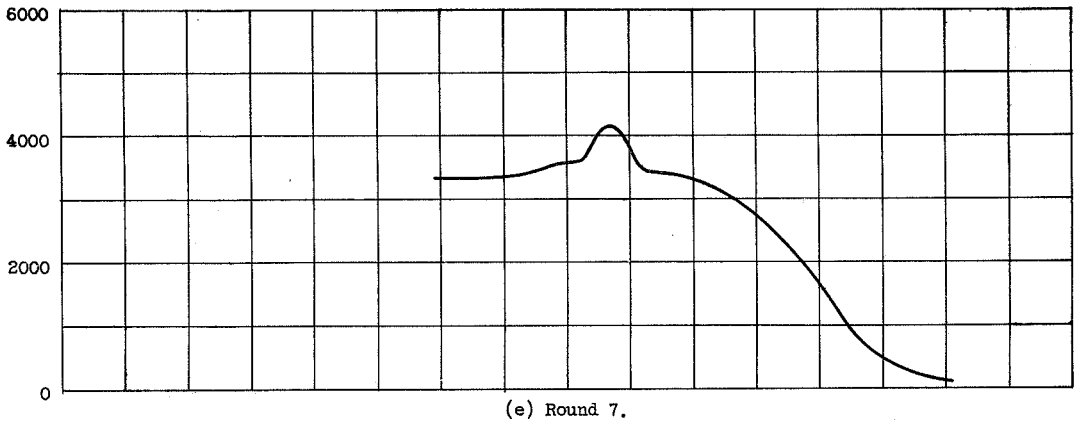


(c) Round 5.

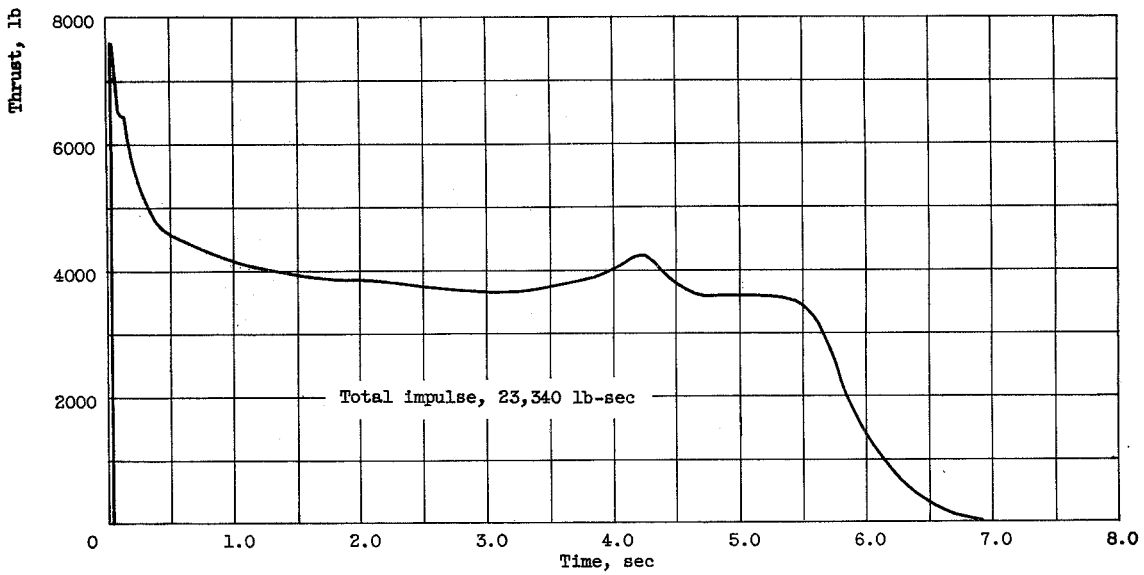


(d) Round 6.

Figure 4. - Continued. Thrust-time curves for air-launched T-40 rockets.



(e) Round 7.



(f) Round 8

Figure 4. - Concluded. Thrust-time curves for air-launched T-40 rockets.

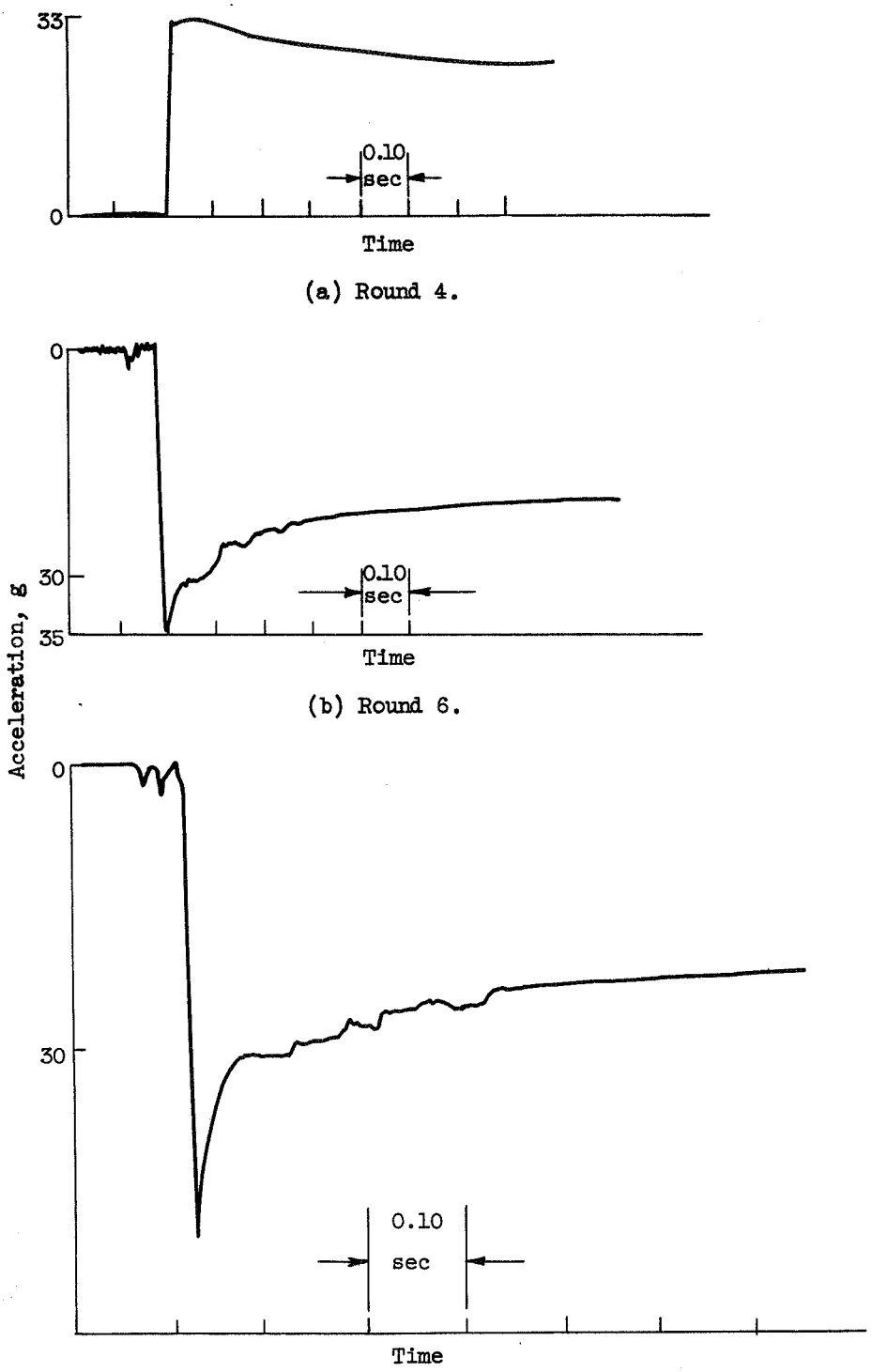


Figure 5. - Acceleration traces during ignition of rounds 4, 6, and 8.

PERFORMANCE OF AIR-LAUNCHED T-40 ROCKET MOTORS WITH TWO TYPES OF IGNITER

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PERFORMANCE OF AIR-LAUNCHED T-40 ROCKET MOTORS WITH TWO TYPES OF IGNITER

Abstract

Air-launched firings of eight T-40 rockets have been made. An average total impulse of 22,870 pound-seconds was observed for four of the rounds mounted in cone-cylinder vehicles. Maximum velocities of over 5000 feet per second were observed for two of the rounds with approximately 70-pound pay loads.