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TEST OF IMPROVED IGNITOR FOR FIRST-STAGE SEPARATION ROCKETS FOR THE ATLAS-CENTAUR LAUNCH VEHICLE

by Richard W. Heath, Henry Synor, and Ralph F. Schmiedlin

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ABSTRACT

During the course of the Atlas-Centaur separation tests, conducted at the Lewis Research Center, anomalies were discovered in the performance of the igniters that fire the Atlas retarding rockets. A new igniter was developed and tested to assess its marginality. The test results indicated that the new igniter possessed a sufficient margin of performance for flight operations.

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SUMMARY

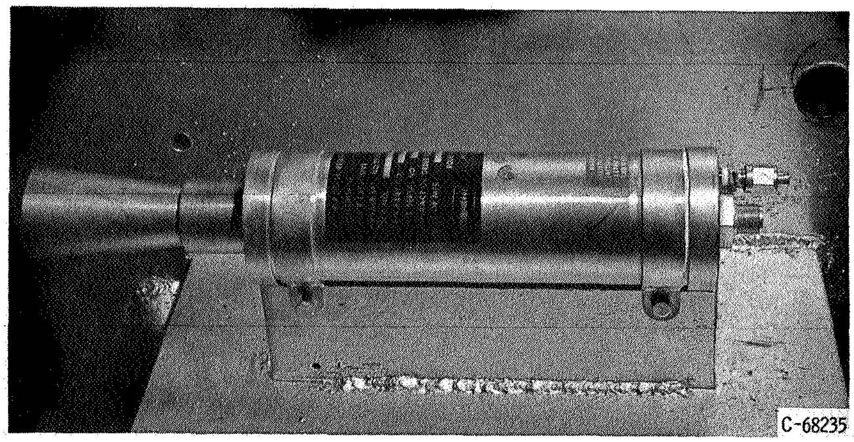
During the course of the Atlas-Centaur separation tests, conducted at the Lewis Research Center, anomalies were discovered in the performance of the igniters that fire the Atlas retarding rockets. A new igniter was developed and tested to assess its marginality. The test results indicated that the new igniter possessed a sufficient margin of performance for flight operations.

INTRODUCTION

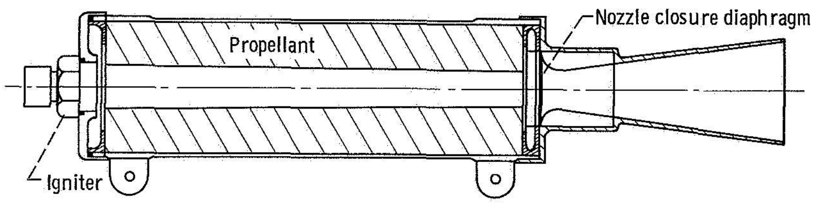
Early tests of the Atlas-Centaur staging systems (ref. 1) resulted in several failures of the Atlas retrorockets to ignite. Review of the igniter configuration and the test data indicated that the existing igniter burned too rapidly and did not direct its flame onto the rocket grain. A new igniter was provided by the rocket vendor to correct the deficiencies, and a test series was devised in which parameters which might affect rocket ignition were altered. The results of this evaluation are reported herein.

APPARATUS AND PROCEDURE

The rocket test series was conducted in the Lewis Space Power Chamber which can attain a moderate vacuum equivalent to a 100 000-foot (30 480-m) altitude. This condition can be maintained throughout small rocket firings because of the large internal tank volume (approximately 607 000 cu ft (17 200 cu m)). The tests utilized a rocket (manufactured by Rocket Power, Inc. (P/N 2547-16)) that has a nominal total impulse of 500 pound-seconds (2200 N-sec) in combination with various igniter and nozzle closure configurations. The rocket was constructed with two removable end caps; one contained



(a) Overall view.



(b) Cross section.

Figure 1. - Test rocket (P/N 2547-16, Rocket Power, Inc.).

the igniter and the other was integral with the nozzle (fig. 1). For testing, each rocket was instrumented with a fast-response strain-gage pressure transducer fitted to the end cap that contained the igniter. An 1100-0 aluminum closure diaphragm was secured across the nozzle inlet with sealant. The thickness of the closure was varied to observe its effect on ignition transients. The rocket contained 2.1 pounds (0.95 kg) of polysulfide ammonium perchlorate propellant cast with a uniform area star cross section.

The igniters were also designed and manufactured by Rocket Power, Inc. and were of an extended burn configuration. They utilized an initiator, fired electrically, to ignite the sustainer charge. The initiator was chosen to conform to Eastern Test Range requirements (ref. 2); it would sustain a 1.0-ampere current or a 1.0-watt power dissipation for 5 minutes without firing and was "sure-fire" at 5.0 amperes. The sustainer consisted of 1.75 grams of 12 to 16 mesh boron potassium nitrate granules for rapid ignition by the initiator, and 15 boron potassium nitrate pellets (weighing 0.31 g each) to continue burning after the granules were consumed. Detailed information relating to the design and development of the igniter is contained in reference 3.

The sustainer burned for approximately 10 milliseconds and was exhausted through angled ports in the igniter case onto the surface of the grain. A cross-sectional view of the igniter is shown in figure 2. The proportions of granules and pellets in some of the igniters were changed to determine their effects on the ignition process.

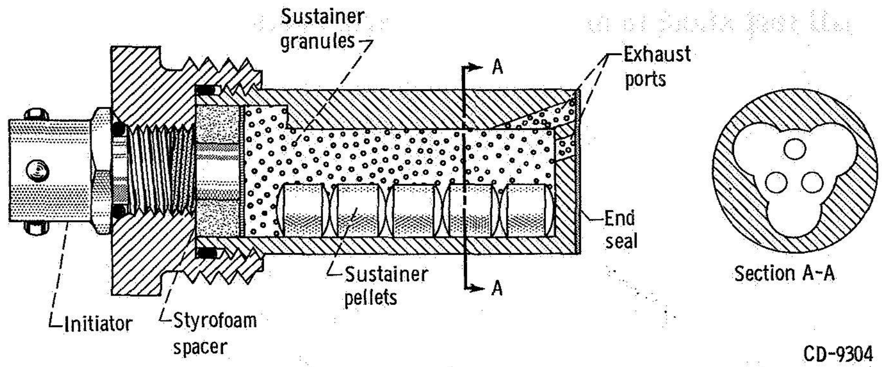


Figure 2. - Extended burn igniter. (Courtesy of Rocket Power, Inc. now Talley Ind., Inc.).

Figure 3. - Atlas model erected in Space Power Chamber.

Several tests were conducted with rockets modified from their standard configuration by varying the thickness of the closure diaphragms, or by removing the diaphragm entirely.

The test conducted with each rocket-igniter configuration consisted of firing the rocket at room temperature and at the altitude chamber pressure of 8 millimeters of mercury (1060 N/m^2) with a 30-volt direct-current power supply and measuring the rocket chamber pressure-rise history. Some of the data were obtained in conjunction with Atlas-Centaur separation tests. In these tests, eight rockets were mounted, as shown in figure 3, around the periphery of a full-scale Atlas model suspended with its longitudinal axis horizontal. Additional data were obtained from individual rockets mounted on a small test stand in one of the adjoining sections of the test chamber.

RESULTS AND DISCUSSION

In order to establish a reference case to which the results of modifications could be compared, eight igniters were fired in the unmodified condition in rockets using the as-supplied nozzle closure of 0.010-inch (0.25-mm) thickness. It was observed that the rocket being tested consistently ignited and produced pressure traces represented by that shown in figure 4. The firings produced wide bands of pressures that averaged approximately 875 psia (603 N/cm^2 abs) at the transient peak and 525 psia (362 N/cm^2 abs) at the transient minimum, or base of the "saddle." In no instance did the saddle pressure drop below 400 psia (276 N/m^2 abs), but it was noted that the peak pressures of some rockets fell below the saddles of others because of the wide ranges of pressures produced.

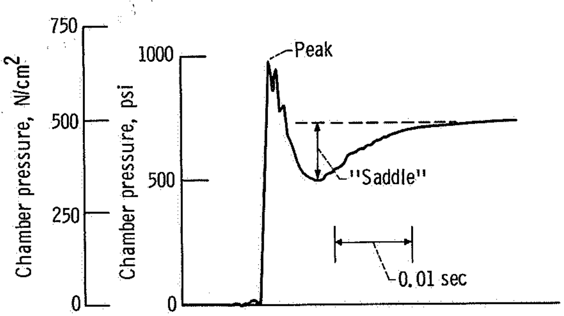


Figure 4. - Retrorocket ignition transient obtained by using standard components.

The presence of a "saddle" during the "postpeak" period indicates that the supply of hot gases from the igniter is exhausting from the rocket prior to complete grain ignition. It is felt that, in general, the more distinct the saddle becomes, the more nearly the igniter has approached burning out, or its heat has been more nearly exhausted, before the rocket has fired. While a saddle may not produce rocket failures, its presence may indicate a marginality which could lead to failures in unusual circumstances.

After the determination of a reference performance, modifications were made to the igniter and the rocket nozzle closure to evaluate their individual effects on ignition.

Effect of Igniter Granules

In order to evaluate the effects of the igniter granules, four rockets were fired with the granules removed, but with the standard number of pellets (15) in the igniter. A distinct change in the transient characteristics was noted in that the peak pressure dropped to an average of 600 psia (413 N/cm^2 abs) and a more pronounced saddle resulted with a decreased saddle base pressure of 275 psia (189 N/cm^2 abs). To make up in part for the 1.75 grams of granules removed in these tests, three pellets (0.93 g total) were added in four igniters. This modification resulted in a further attenuation of the peak to approximately 450 psia (310 N/cm^2 abs), and the saddle base pressure rose slightly to an average of 300 psia (206 N/cm^2 abs). A typical pressure trace is shown in figure 5.

Comparison of the standard ignition transient (fig. 4) with the ignition transient observed when the igniter granules were removed (fig. 5) shows that the granules accomplish their function by causing a more rapid initial combustion of the pellets. The absence of any failures to fire the rocket indicated a sufficient margin and gave confidence in the standard loading.

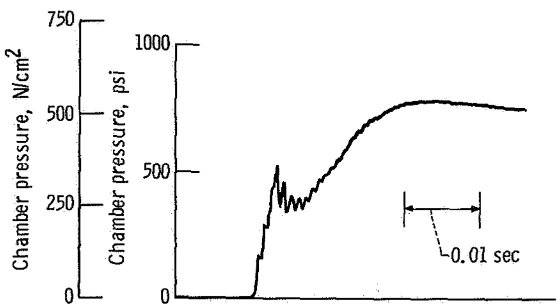


Figure 5. - Retrorocket ignition transient obtained without granules.

Effect of Nozzle Closure Thickness

An investigation was made of the effect of varying the thickness of the nozzle closure, or its elimination entirely. A number of rockets were fired with the closure removed, or with annealed aluminum diaphragms varying in thickness from 0.010 (standard) to 0.040 inch (0.25 to 1.02 mm).

Three rockets were fired with their nozzle closures removed. The removal of the nozzle closures exposed the rocket combustion chamber to vacuum prior to ignition. It was observed that no significant pressure differences were obtained when compared with those observed with the standard 0.010-inch (0.25-mm) closure. These results indicated

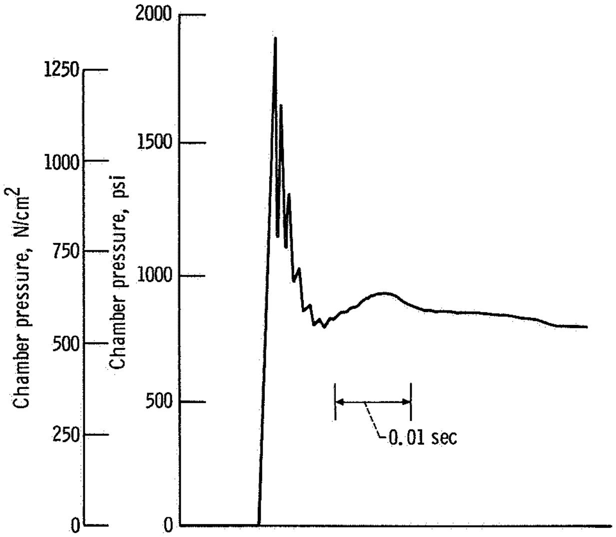


Figure 6. - Retrorocket ignition transient obtained by using 0.022-inch (0.56-mm) closure.

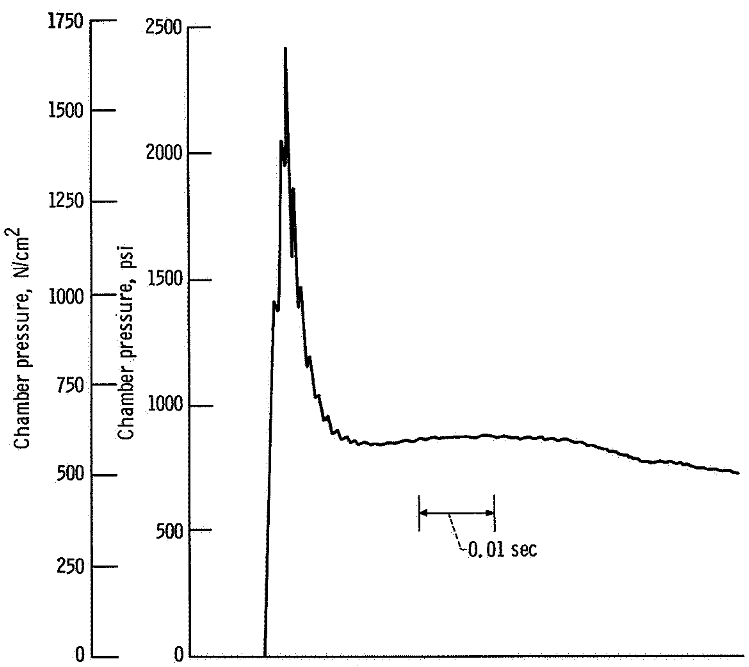


Figure 7. - Retrorocket ignition transient obtained by using 0.032-inch (0.81-mm) closure.

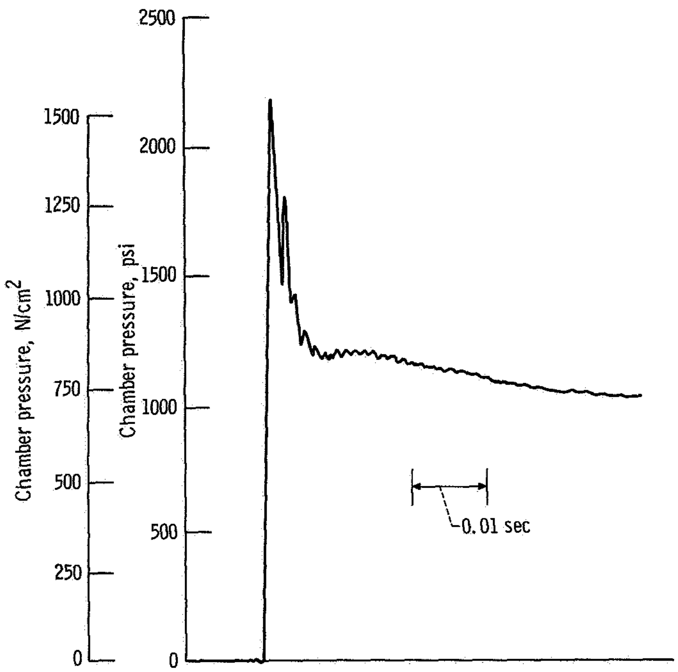


Figure 8. - Rocket ignition transient pressures obtained by using 0.040-inch (1.02-mm) closure.

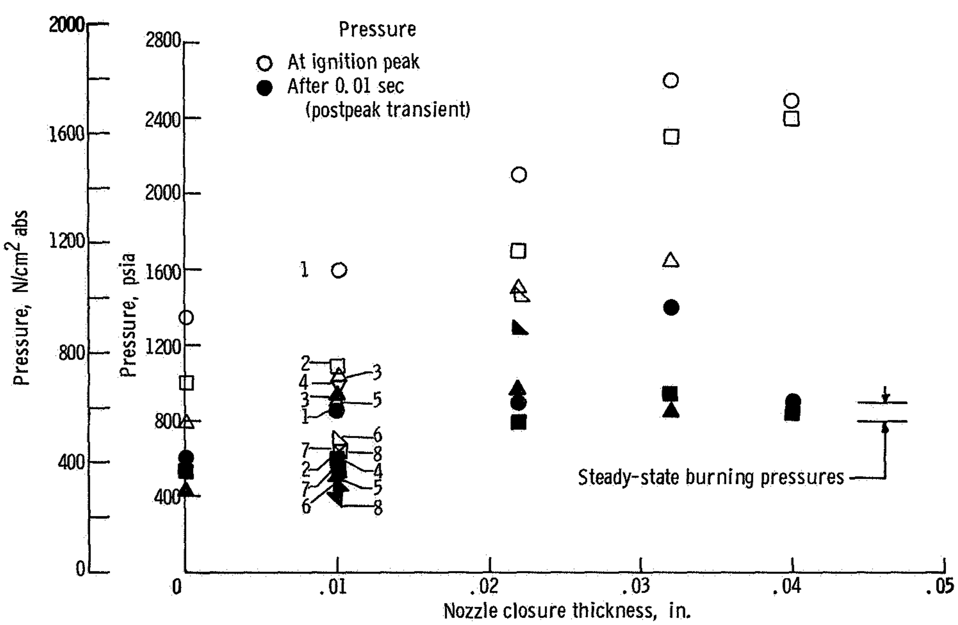


Figure 9. - Retrorocket ignition transient pressures as nozzle closure thickness is varied. (Corresponding symbols relate pressures from same rocket.)

that, in the limited number of samples tested, the standard closure did not aid the ignition process appreciably but merely served to block the entrance of contaminants during ground handling.

The diaphragm thickness was increased in three steps above the standard and the transients were compared with the "standard" shown in figure 4. The use of a 0.022-inch (0.56-mm) closure produced pressures typified by figure 6. The peak pressure was increased to an average of 1550 psia (1070 N/cm^2 abs) and the saddle pressure to approximately 825 psia (568 N/cm^2 abs) from the standard of 875 psia and 525 psia (603 and 362 N/cm^2 abs), respectively. A 0.032-inch (0.81-mm) diaphragm raised the peak pressure to an average of 2175 psia (1498 N/cm^2 abs) and eliminated the saddle; a typical trace is shown in figure 7. A 0.040-inch (1.02-mm) closure was used twice and was observed to raise peak pressures to about 2450 psia (1680 N/cm^2 abs); a typical trace is shown in figure 8. This peak pressure represents 70 percent of the rocket case hydrotest pressure; thicker closures were not used to avoid the possibility of shell rupture.

Transient pressures observed with the various closures are compared in figure 9. The "postpeak transients" noted in figure 9 represent the previously mentioned saddle, if one exists, and provide a comparison of conditions before and after the saddles are eliminated. Increasing the nozzle closure thickness beyond the standard 0.010 inch (0.25 mm) removed the tendency for the peak pressures of some motors to fall below the saddles of others. A consistent upward trend of the peaks is observed, and the saddles were eliminated when a closure thickness of 0.032 inch (0.81 mm) or greater was used.

The absence of any ignition failures resulting from the alteration of closure thickness indicated that operation of the system would not be sensitive to variances that might occur in manufacture or the installation of the closures, and sufficient margin exists in the system design.

CONCLUSIONS

The extended burn igniter, which burns for an appreciable length of time (10 msec) and directs its flame onto the grain surface, corrected the ignition deficiencies noted during earlier firings of the Atlas-Centaur retarding rocket. The igniter used in this series of tests consistently fired the test rockets. As mentioned previously, earlier tests of the same rocket, using an extremely fast burning igniter whose flame did not impinge directly on the grain, produced an unacceptable failure rate. Additional information relating to the earlier failures is contained in reference 4.

Utilization of propellant granules in the sustainer charge of the igniter aided the ignition process by providing a supply of hot gases to the main propellant grain very rapidly and increasing the overall heat input to the grain.

A wide variation in nozzle closure thicknesses caused no ignition failures, indicating the presence of a satisfactory margin in the design of the system.

Lewis Research Center,
National Aeronautics and Space Administration,
Cleveland, Ohio, March 11, 1968,
491-05-00-01-22.

REFERENCES

1. Heath, Richard W.; Synor, Henry; Schmiedlin, Ralph F.; and Povolny, John H.: Investigation of Atlas Solid Fuel Retarding Rocket During Atlas-Centaur Separation Tests. NASA TM X-1119, 1965.

2. Range Safety Division: Pre-Launch Safety Procedures. Vol. 1 of General Range Safety Plan. Rep. AFMTCH 80-2 Air Force Missile Test Center, Patrick AFB, Florida, Oct. 1, 1963.

3. Peterson, Norman L.: Development and Qualification Test Report for the P/N 2547-69 Igniter Assembly. Doc. No. 7965, Rocket Power, Inc., Oct. 26, 1964.

4. Peterson, Norman L.: Ignition Failure Investigation of the RP1 P/N 2547-11 Retard Rocket Motor (GD/A P/N 27-04300-1). Doc. No. 7964, Rocket Power, Inc., Oct. 20, 1964.

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