Conclusions

The purpose of the calculations presented is to use existing flight data as a guide for the analytical model development program. Even though the primary aim of the POLAR program is to examine the possibility of substantial negative potentials occurring on large objects in polar orbit, the application of the code to the equatorial, nonsevere charging regime serves to examine the validity of the physical and comptuatioanl models. The results of these calculations showed a remarkably close correlation between theory and experiment. Nowhere was there as much as an order of magnitude disagreement in currents, or a factor of three in potentials. What was shown, instead, was reasonable agreement between theory and experiment. Much of the uncertainty could be traced to coarse geometrical modeling of the satellite and the straight line treatment of ion trajectories. Work is presently under way to include a more accurate representation of ion dynamics in the POLAR code. This work will be particulary important for more negative surface potentials than examined here, but will apply as well to the low Earth orbit near-wake problem.

Acknowledgments

This work supported by Air Force Geophysics Laboratory, Hanscom Air Force Base, Mass., under Contract F19628-82-C-0081.

References

[1] Parks, D.E. and Katz, I., "Mechanisms That Limit Potentials on Ionospheric Satellites," *Journal of Geophysical Research,* Vol. 88, A-11, Nov. 1983, pp. 9155-9162.

[2] Samir, U., Gordon, R., Brace, L., and Theis, R., "The Near-Wake Structure of the Atmosphere Explorer C (AE-C) Satellite: A Parametric Investigation," *Journal of Geophysical Reserach,* Vol. 84, A2, Feb. 1979, pp. 513-525.

[3] Laframboise, J.G. and Parker, L.W., "Probe Design for Orbit-Limited Current Collection," *Physics of Fluids,* Vol. 16, May 1973, pp. 629-636.

[4] Katz, I., Cassidy, J.J., Mandell, M.J., Schnuelle, G.W., Steen, P.G., and Roche, J.C., "The Capabilities of the NASA Charging Analyzer Program," *Spacecraft Charging Technology-1978,* NASA CP-2071, AFGL-TR-79-0082, 1979, p. 101.

[5] Cooke, D.L., Katz, I., Mandell, M.J., Parks, D.E., and Rubin, A.G., "Three-Dimensional Calculations of Barrier Formation in Satellite Wakes," presented at AGU Fall Meeting, San Francisco, Calif., Dec. 1982.

Design of a Minimum Acceleration Mortar Charge

G.R. Simpers* and K.P. Hall†
Naval Ordnance Station, Indian Head, Maryland

Introduction

LIGHTWEIGHT mortars are often used to deploy a variety of technical payloads. As a propulsion system they are generally inexpensive, reliable, and well suited to these types of payloads. The propulsive charge is commonly made up of flaked propellant with a large surface area per unit volume to minimize both the amount of propellant required and the effect of temperature on muzzle velocity. This approach results in high levels of acceleration of the payload. Some technical payloads are unable to withstand excessive acceleration levels. The "soft mortar charge" described in this Note minimizes the acceleration of the payload.

The key difference in the approach described is the use of uninhibited artillery propellant as the propulsive charge. This makes possible wide flexibility in the propulsion system design because artillery propellant grains are available in a variety of sizes.

Technical Approach

The goal of the mortar propulsion system described is the achievement of a certain muzzle velocity for a given payload and launcher system while limiting the maximum acceleration to between 300 and 500*g*. A conventional mortar propulsion unit previously used to launch a similar payload imparted an acceleration of 1200*g*. This level of maximum acceleration was too high for a new payload.

The mortar charge described is based on a "hi-lo" mortar concept. The propellant is burned in a high-pressure chamber and vented through nozzles into the closed breech volume behind the round. If the nozzles are properly sized, the ratio of chamber pressure to breech pressure can be kept high enough to ensure sonic flow in the nozzles. The pressure-time history in the propellant chamber is thereby divorced from the dynamics of the round in the launch tube.

The configuration of the mortar pressure chamber is shown in Fig. 1. Ignition is by means of the induction coil at the rear of the unit, which fires a squib into B/KNO_3 igniter pellets held in a hard case in the center of the chamber. Artillery propellant grains loosely surround the igniter in random array. The muzzle velocity achieved depends on the amount of propellant loaded, the surface area history of the individual grains, the nozzle area chosen, and the propellant characteristics.

The muzzle velocity of a mortar-launched round is established by the mission requirements of the payload. In order to achieve this velocity with minimum acceleration levels, the round should be accelerated at a constant rate throughout its travel down the launch tube. The ideal case of a constant acceleration means that the propellant grain must have a progressive surface area history. This is achieved in the present design by the use of uninhibited seven-perforation artillery grains. These grains are readily available in a number of granulations and propellant types. Our design used grains of M-30 propellant approximately 0.8 in. long.

The initial selection of web thickness for the propellant grain was made based on the desire to have the propellant burn out near the end of the launch tube. The geometry of an available grain with characteristics close to those desired was input into a computer program (SORN). This program calculates the internal ballistics of the propellant in the high-pressure chamber and the motion of the round when subjected to these forces.

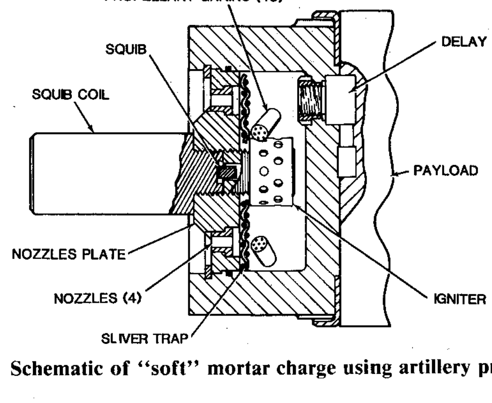

Fig. 1 Schematic of "soft" mortar charge using artillery propellant grains.

Presented as Paper 82-1147 at the AIAA/SAE/ASME 18th Joint Propulsion Conference, Cleveland, Ohio, June 21-23, 1982; received June 25, 1983; revision received Aug. 11, 1983. This paper is declared a work of the U.S. Government and therefore is in the public domain.

*Engineer. Member AIAA.

†Engineer. Associate Fellow AIAA.

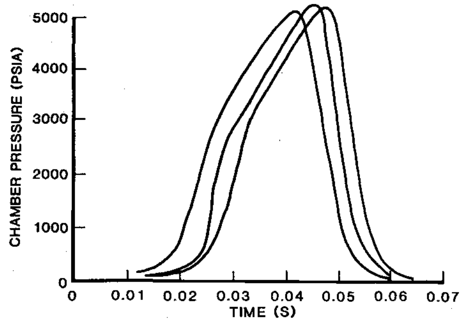

Fig. 2 Test firings at 70°F (21°C).

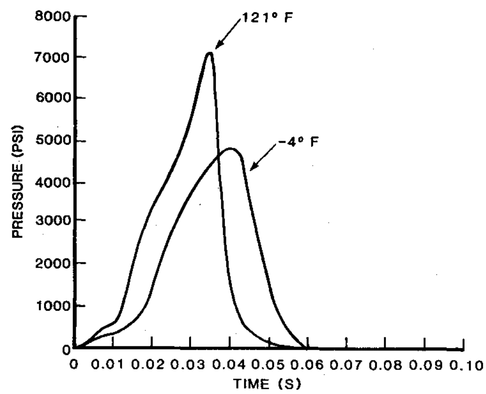

Fig. 3 Test firings at temperature extremes.

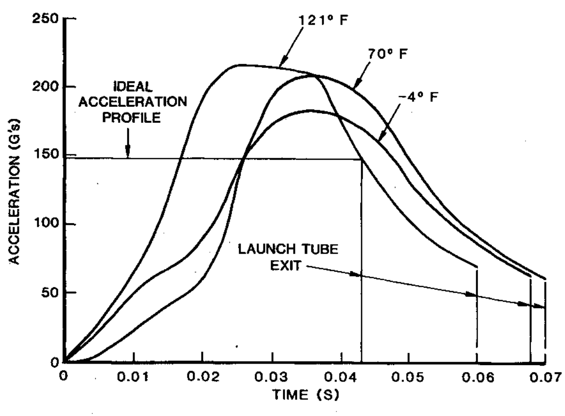

Fig. 4 Comparison of acceleration levels for different test temperatures.

Data and Results

Static tests were conducted to prove the propellant grain geometry and charge weight. Pressure-time records from three test firings at ambient temperature are compared in Fig. 2. The effect of temperature on the pressure-time history is illustrated in Fig. 3.

The pressure-time history that was measured during the static firings was used to predict the acceleration levels that would be expected for the round. An ideal acceleration would be constant at 148g for the 0.043 s required to clear the launch tube. Typical results achieved by three of the test firings compared with the ideal, are shown in Fig. 4. One test result is shown for each of the temperatures tested. The acceleration levels vs time predicted from the static tests are noticeably rounded, without the extreme acceleration peaks observed with the older propulsion system.

The final proof of the soft mortar concept was provided by a series of flight tests of dummy payloads, which took place 90 days after the first static firing. The test data collected from nine flights, using three different propellant charge weights, are summarized in Table 1. It should be noted that the highest acceleration (at 121°F using the high loading) was only 334g, well below the goal of 500g maximum. All flights met the muzzle velocity requirement.

Table 1 Flight test results

Test	Charge size	Temperature, °F	Muzzle velocity, ft/s	Peak bore pressure, psi	Acceleration, g
4	Medium	70	218	600	209
5	Medium	70	242	860	299
6	Medium	70	225	–	–
7	Low	70	204	720	251
8	High	70	244	860	299
9	Low	−4	201	500	174
10	High	−4	209	600	209
11	Low	121	226	760	265
12	High	121	257	960	334

Conclusions

A unique approach to the design of a mortar propulsion unit to minimize the acceleration of the payload was developed. The method used uninhibited grains of artillery propellant as the main propulsive charge. The approach offers the designer a great amount of flexibility in the charge design. Advantages of this design include reduced deck loads and a lower pressure in the launch tube.

This design has been adapted for use in the launching of two different technical payloads from the original launcher. In addition, new propulsion system designs have been successfully made using this concept. The use of artillery grains as the propellant source can also be applied to a variety of applications, such as payload separation or gas generator design. A smaller version is in use as a charge to expel payload contents from an outer casing for payload deployment.

Acknowledgments

Stephen Mitchell of the Naval Ordnance Station (NAVORDSTA), Indian Head, Maryland, contributed the concept of using uninhibited artillery grains for the propellant. Will Rogers of NAVORDSTA made significant contributions to the design of the igniter. Gene Elsufon and Carl Zovko of the Naval Surface Weapons Center (NSWC), White Oak, Maryland, provided the computer prediction program and actively participated in the test program. NSWC personnel designed much of the hardware and assembled the flight test data. All hands contributed greatly to the results achieved.