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AN IMPROVED AIR-CAVITY EXPLOSIVE CHARGE FOR ACCELERATING STEEL AND NICKEL PELLETS

by

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ABSTRACT

An air-cavity high explosive charge which accelerates a steel projectile of mass 5.7 grams to a velocity of 4.3 km per second, or a nickel projectile of mass 6.0 grams to 4.0 km per second, is described. Reproducibility of projectile mass obtained with this design represents a considerable improvement over earlier designs for these velocities.

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INTRODUCTION

For several years the NASA Langley Research Center has been actively engaged in a research program to investigate the entry of simulated meteoroids into the upper atmosphere. The purpose of the program is to measure the observable optical and radar properties of artificial meteors under the same conditions that similar observations have been made of natural meteors. These measured properties together with predetermined precise information on the mass, material, shape, and size of the artificial meteoroid, permit the calculation of luminous and ionization efficiencies for materials believed to exist in natural meteors.

To meet the need for an artificial meteoroid, the Ballistic Research Laboratories (BRL) undertook the development of an explosive device to accelerate a solid projectile from the NASA Trailblazer rocket system. The design requirements for the artificial meteoroid fall into two categories: (1) those placed upon the projectile itself, in order to make observations feasible and also comparable to natural meteoroids, and (2) those geometrical requirements dictated by the rocket delivery system. The requirements on the projectile are that its mass should be greater than 2 grams, to ensure sufficient luminosity for observation at the expected entry velocity, and that its velocity should be greater than 3.5 km per second, which, when added to the 10 km per second supplied by the rocket itself, would place the projectile above the threshold entry velocity for natural meteoroids. In addition, the material should be predominately iron or nickel, and the shape should be reasonably chunky. The rocket delivery system requires the explosive package to have a mass less than 1.5 kg, a diameter less than 7.5 cm and a length less than 17.3 cm.

To meet these requirements for an artificial meteoroid, BRL developed and tested an explosive device which accelerates a 5.7 gram steel projectile to a velocity of 4.3 km per second, and a 6.0 gram nickel projectile to 4 km per second. In succeeding sections of this report the charge design is described, the procedures for measuring the mass and velocity of the projectile are delineated, and detailed results are presented.

CHARGE DESIGN

The explosive device developed to accelerate an artificial meteoroid is a modification of the BRL air-cavity charges reported earlier.* The adopted charge design is shown in detail in Figure 1. While the variation of design parameters which resulted in the final design will not be described meticulously, some elaboration of design parameter considerations is given below.

The charge is a right circular cylinder of 50/50 Pentolite. The charge diameter was fixed at 7.493 cm (2.950 in.), essentially the maximum diameter that available space permitted. While space for a charge with a length of 17.3 cm was available, it was desirable to use a shorter length, if consistent with the requirements on the pellet. Charge lengths from 17.3 cm down to 12.1 cm were investigated. Over this range in lengths, no significant variation in projectile velocity was observed; however, some degradation of projectile integrity resulted from charges with lengths less than that adopted: 14.681 cm (5.780 in.).

Earlier BRL air-cavity charge designs used disc-shaped pellets, plane on both faces, with the pellet diameter the same as that of the cavity into which it fitted. The cavities were right circular cylinders, with plane bases. When these designs were used to accelerate pellets to velocities greater than 4 km per second, from sixty to eighty percent of the original pellet mass was lost during the acceleration process, depending on the particular design used. The mass lost by the pellet was principally due to irregular fracture around the periphery, but loss also resulted from a hole thru the center of the disc, the point

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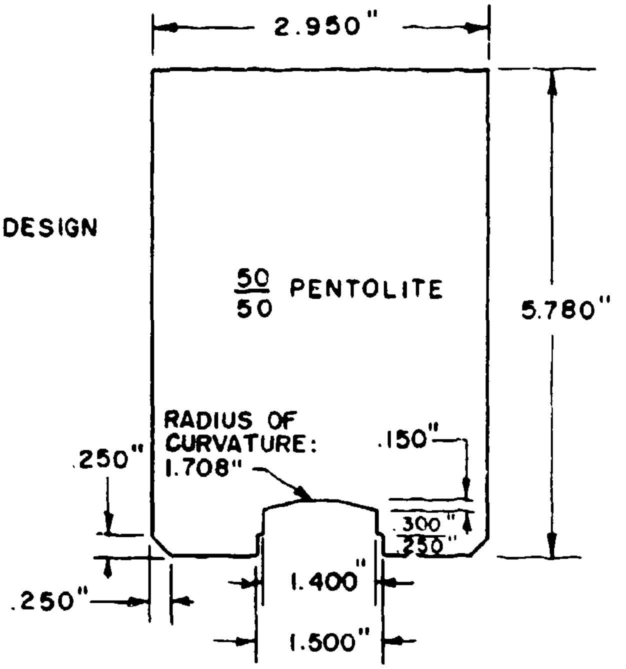
* *Kineke, John H., Jr. and Holloway, Lee S. Macro-Pellet Projection with an Air-Cavity High Explosive Charge for Impact Studies. Ballistic Research Laboratories Report No. 1264, April 1960.*

A

CHARGE DESIGN
41



B

PELLET DESIGN
E-115

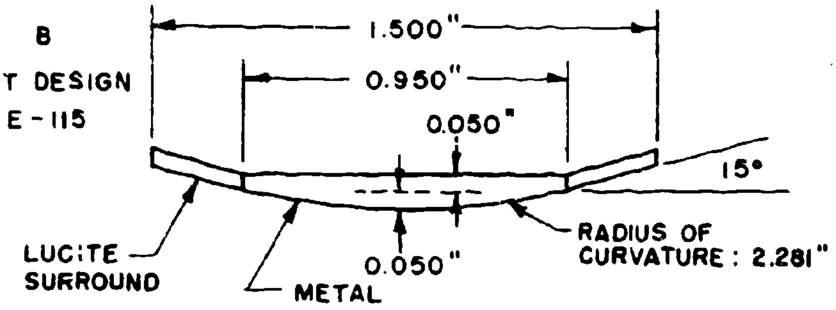


FIGURE 1. AIR CAVITY EXPLOSIVE CHARGE DESIGN FOR ACCELERATING STEEL AND NICKEL PELLETS

subject to the most intense stress. Despite the somewhat unreproducible nature of the mass loss processes, the probable error of the final pellet mass was of the order of two to five percent.

While the earlier designs are satisfactory for impact experiments, it is desirable to provide smaller uncertainty in pellet mass for simulated meteoroid experiments. These considerations led to the cavity and pellet-surround configurations shown in Figure 1. The deviations from the simpler designs are aimed at improving the integrity of the pellets by lessening damage to both the edge and center, thus reducing the uncertainty in the mass of the pellet after it has been accelerated to its final velocity. While the ranges of the cavity and pellet-surround parameters which were varied in developmental experiments are mentioned here, no detailed results will be presented.

Three modifications were made to the cavity in the charge. A recess was introduced in the cavity to accept the pellet-surround combination. With the dimensions of the recess and the cavity diameter fixed, the cylindrical wall of the cavity was varied in depth from 0.5 cm to 1.3 cm. The radius of curvature of the cavity base was also varied, from 4 cm to 12.5 cm, after it had been determined that satisfactory pellet integrity could not be achieved with a plane cavity base.

To inhibit fracture around its edge the pellet was mounted in a surround; this permitted the pellet diameter to be less than that of the cavity. The surround, of polymethyl methacrylate (Lucite) was in the form of a truncated cone to induce radial dispersion of the surround material after the acceleration process. With the surround angle and outside diameter fixed, three pellet parameters were varied in order to maximize pellet integrity. Pellet diameter was varied between 1.9 and 2.5 cm. Two thicknesses of the cylindrical portion of the disc were used: 0.127 cm and 0.178 cm. The outer face of the pellet, instead of being plane, was made a spherical segment, the radius of curvature of which was varied between 1.9 and 6.4 cm.

The adopted dimensions, shown in Figure 1, represent compromises of pellet velocity, mass, and integrity. In general, increased overall cavity depth and decreased overall pellet thickness lead to increased pellet velocity, with an attendant sacrifice of mass and integrity. The chosen values of cavity base curvature, pellet curvature, and pellet diameter represent an optimization of pellet integrity within the investigated range of these parameters.

In all of the designs tested, the charge was initiated by a booster charge of tetryl centered by means of a Lucite ring with the same outside diameter as the charge. The booster diameter was 2.515 cm and thickness 2.154 cm. In one face of the booster, a centered cylindrical cavity 0.714 cm diameter, 1.270 cm deep was drilled to accept an electric detonator.

VELOCITY DETERMINATION

Pellet velocity was determined by measurements of pellet position in successive pre-timed 0.1 μsec flash radiographs made at positions about 10 cm apart on the pellet trajectory. The experimental arrangement for these observations is depicted in Figure 2. Radiographs of steel and nickel pellets in flight are shown in Figure 3.

MASS DETERMINATION

Terminal pellet mass, the mass after the pellet had been accelerated to its final velocity, was determined by recovering pellets in a composite of low density materials. The experimental arrangement is shown in Figure 4. The validity of this procedure has been demonstrated earlier by Kineke and Holloway.

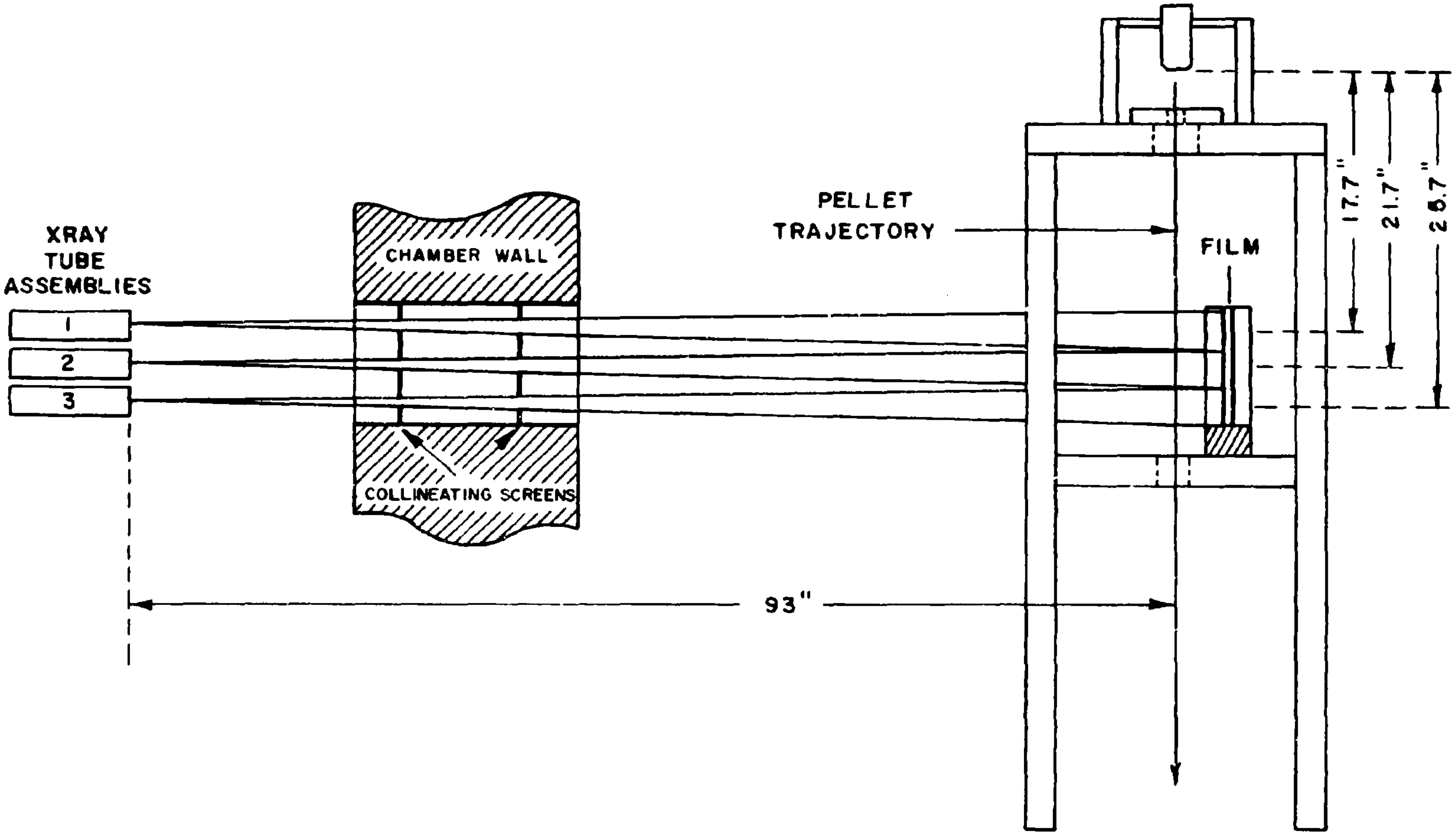
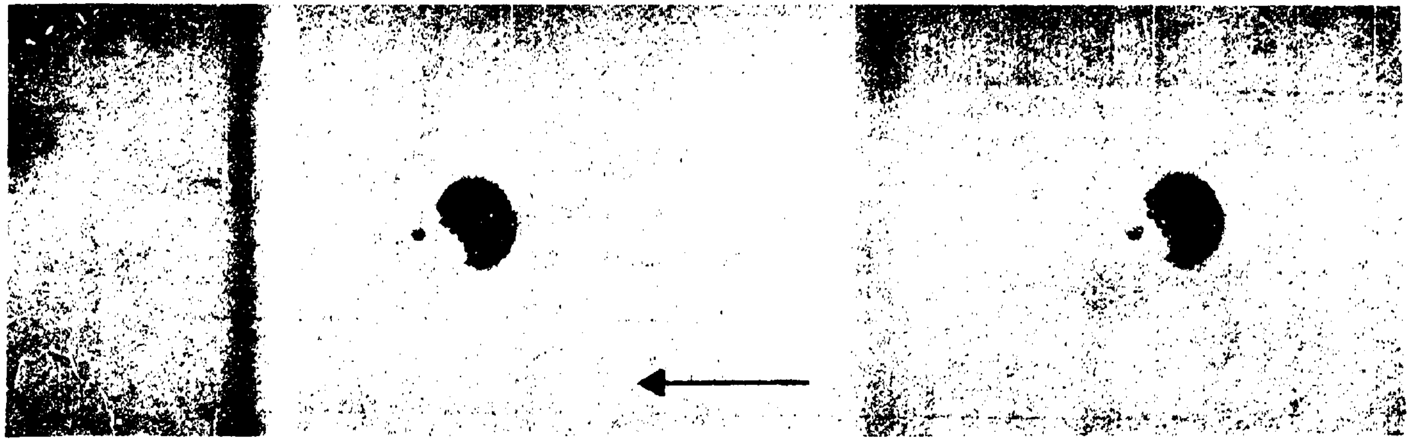


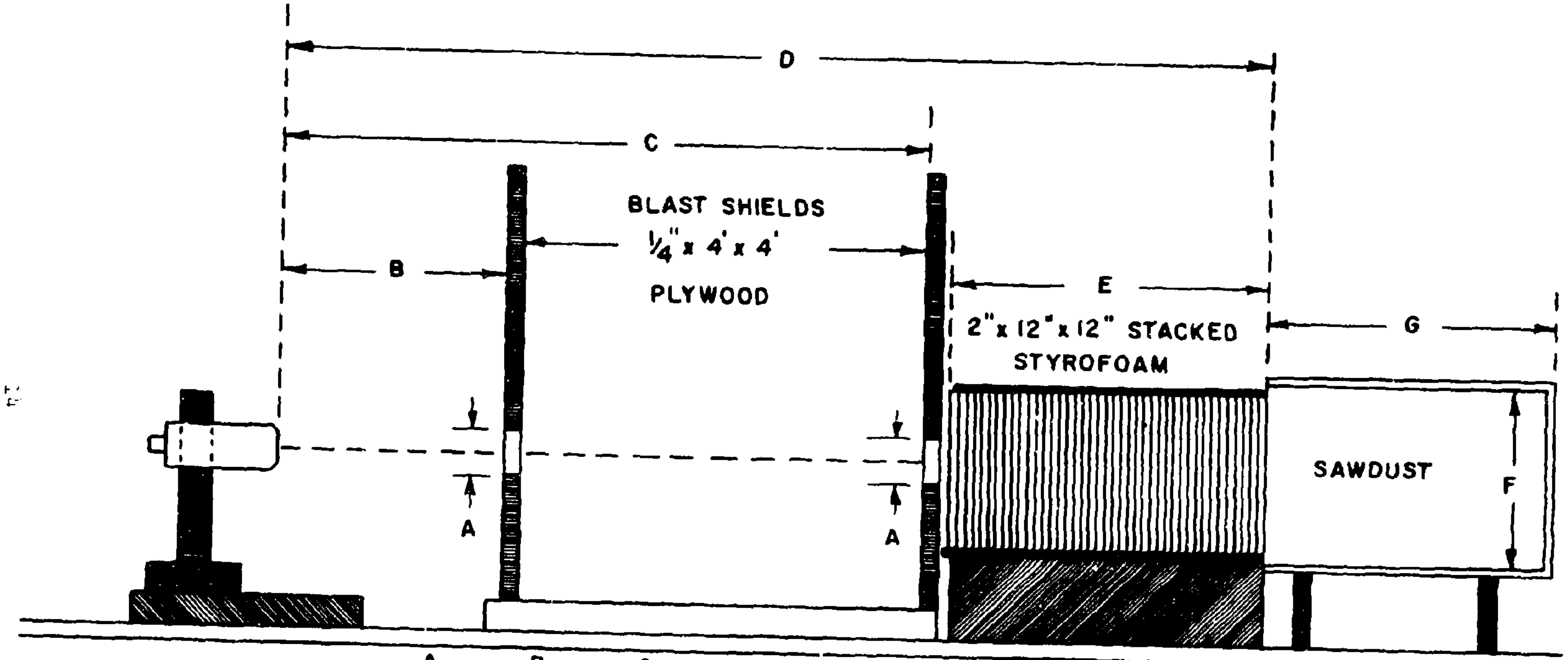
FIGURE 2. MULTIPLE FLASH X-RAY SETUP

A. STEEL PELLET AT 4.31 KM/SEC



B. NICKEL PELLET AT 3.97 KM/SEC

FIGURE 3. DOUBLE FLASH RADIOGRAPH OF PELLETS IN FLIGHT



	A	B	C	D	E	F	G
E-115 1020 STEEL	3.0"	85.0"	133.0"	241.25"	108.0"	14.25"	31.0"
E-115 "A" NICKEL	3.0"	101.0"	149.0"	281.25"	132.0"	14.25"	31.0"

FIGURE 4. PELLET RECOVERY SETUP

RESULTS

Pertinent experimental results are tabulated in Table I. Ten observations were made for both the recovered mass m_p and velocity v_p, for each design, and from these the mean, standard deviation σ, and percentage of probable error PE were calculated. The original pellet mass is tabulated as m_o.

TABLE I

Pellet Material	Steel (1020)	Nickel (A)
Pellet Density	7.86 gm/cm^3	8.885 gm/cm^3
m_o	6.956 gm	7.906 gm
m_p	5.656 gm	5.994 gm
$\sigma(m_p)$	0.051 gm	0.048 gm
$PE(m_p)$	0.61%	0.54%
v_p	4.30 km/sec	3.96 km/sec
$\sigma(v_p)$	0.09 km/sec	0.05 km/sec
$PE(v_p)$	1.41%	0.85%

The terminal masses of the pellets are some 81 and 76 percent of the original mass, for steel and nickel respectively. The degree of reproducibility of the mass, as indicated by the probable error, is almost an order of magnitude better than that achieved with earlier designs.

After the charge accelerates the projectiles to their maximum velocity, the projectiles in flight (Figure 3) are approximately hemispheres. The diameter of the hemispheres is about 75 percent of the original diameter of the pellets. Some mass is lost, due to fracture around the periphery. This material, in the form of small particles, can be seen preceding the pellet in flight, at about the same velocity as the pellet. Because of the small size of the particles, none greater than 0.1 gram, they do not contribute to observed luminosity in the upper atmosphere.

CONCLUSIONS

The air-cavity high explosive charge developed by the BRL will accelerate a steel projectile of terminal mass 5.7 grams to a velocity of 4.3 km per second, or a nickel projectile of terminal mass 6.0 grams to 4.0 km per second. While earlier charge designs featured simpler geometry for both cavity and pellet, the more complicated design which has been developed in this investigation is justified by the improved integrity of the pellet and the enhanced reproducibility of mass and velocity that have resulted.

JOHN H. KINEKE, JR.   CARROLL E. WEST, JR.

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