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SUMMARY

Capacitor sensors have been tested and evaluated, in various configurations, under hypervelocity-impact conditions which simulate, as nearly as possible with present laboratory facilities, the impacts of meteoroids in space. Light-gas guns, explosive devices, electrostatic accelerators, and exploding-wire guns have been used.

Three types of signals have been observed during hypervelocity perforations. The first is characterized by a complete discharge of the sensor within a few microseconds. The second is characterized by the rapid discharge of a substantial portion of the applied voltage. The third is characterized by the loss of less than about 10 percent of the applied voltage with the discharge time in excess of 10 μsec. During the test program most of the perforations resulted in small signals or no signals. The applied voltage was the only parameter observed which had a pronounced effect on the sensor operation.

Completely charged capacitor sensors were not permanently shorted when perforated by small single hypervelocity projectiles; however, some uncharged and partially charged sensors were permanently shorted when perforated.

INTRODUCTION

The perforation of a spacecraft by a meteoroid could result in catastrophic damage to items such as the cabin, radiator, or fuel tanks. For this reason, it is important to establish the meteoroid environment in order that future spacecraft may be properly designed. The information needed by spacecraft designers is the probability that a material of given thickness with a certain area and exposure time will be perforated by a meteoroid. The most direct means of obtaining this information is to place a sheet of material in space and observe the number of perforations. By using materials of different thicknesses the number of perforations per unit area per unit time can be found as a function of material thickness. With this information the spacecraft designer can provide proper protection against meteoroids. Capacitor-type meteoroid penetration detectors have been used to evaluate the meteoroid hazard on the Micrometeoroid Paraglider and Pegasus I, II, and III.

Tests to establish the feasibility of the capacitor-type penetration sensor and to indicate the parameters that affect the sensor operation were initiated at the NASA Langley Research Center (LRC) in 1959. Tests have also been conducted at Ballistics Research Laboratories (BRL), Space Technology Laboratories, Inc. (STL),* and North American Aviation, Inc. (NAA). This report describes the capacitor sensor and its possible modes of operation, and documents the most realistic impact tests that have been conducted by LRC personnel.

SYMBOLS

V	instantaneous voltage, volts
V_A	applied voltage, volts
V_D	peak discharge voltage, volts
R	circuit resistance, ohms
C	sensor capacitance, farads
T	constant, seconds
t	time, seconds
t_1	time at which the sensor begins to recharge, seconds
P	the probability that x large signals will result from N perforations
x	the number of large signals which will result from N perforations
N	the number of perforations
p	the probability of obtaining a large sensor signal from a single perforation
$\bar{p}$	estimate of p, x/N
σ	standard deviation

*Presently TRW Systems.

DESCRIPTION OF THE CAPACITOR-TYPE SENSOR AND DISCUSSION OF ITS OPERATION

The basic capacitor penetration sensor is shown in figure 1. Fundamentally, it consists of a parallel-plate capacitor with an electrical circuit capable of detecting a voltage change across the capacitor. The simple detection circuit shown in figure 1 consists of a battery and load resistor in series with the capacitor, and an oscilloscope to detect the voltage change across the load resistor. When a particle perforates the parallel-plate capacitor, it produces a conduction path between the capacitor plates and allows the charged capacitor to discharge partially. Perforation of the capacitor can thus be determined by monitoring the voltage across the load resistor.

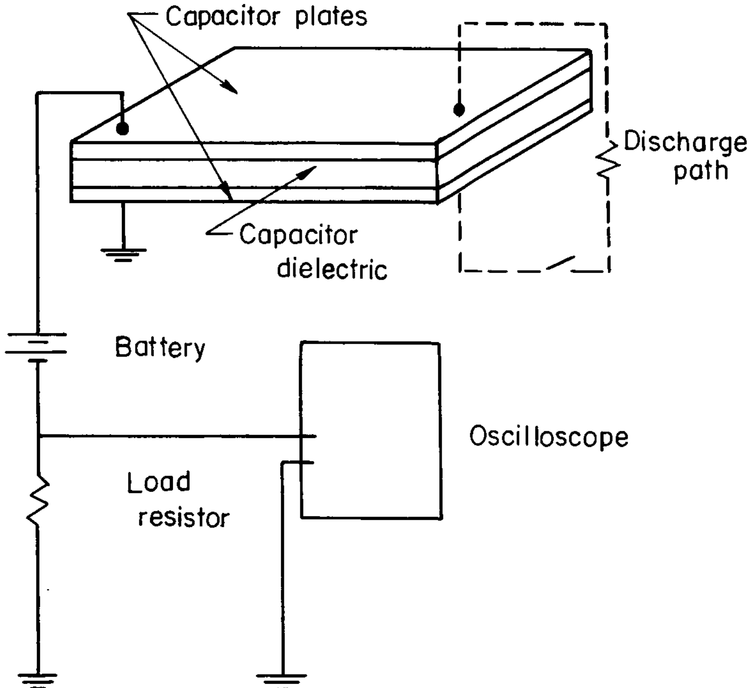


Figure 1.- Schematic diagram of capacitor and signal detection circuit.

Tests have indicated that radiation can cause the capacitor penetration sensor to produce signals that might be interpreted as meteoroid penetrations. The amount of radiation needed to produce a sensor signal, however, is not well known, nor is the degree to which the space environment is simulated by the radiation tests that have been conducted. These tests are discussed in references 1, 2, and 3. The hypervelocity-impact tests described in this report were not conducted in a radiation environment. Although the exact mechanism of the sensor discharge is not known, there are several mechanisms which either separately or combined could cause the sensor to discharge at the time of perforation. Among these are electromechanical breakdown of the dielectric, the formation of a plasma, and mechanical shorting (ref. 2).

Electromechanical breakdown may result from compression of the dielectric by the shock wave. The applied voltage sets up an electric field between the capacitor plates. As the shock wave compresses the dielectric, the electric field, which is inversely proportional to the dielectric thickness, may become great enough to cause breakdown and allow current to flow between the plates.

The formation of a plasma is possible because of the large amounts of thermal energy imparted to the sensor and projectile by the impact-induced shock wave. This plasma could provide a conduction path in a crater between the two capacitor plates.

Mechanical shorting between the two plates is possible as a result of material flow during the perforation process. As the capacitor plate material flows with the shock wave, the plate material could be drawn across the dielectric, thus allowing the capacitor to discharge. The current flowing through such a mechanical short could then produce heating sufficient to burn it out, leaving no permanent short.

The discharge path, regardless of the mechanism forming it, can be visualized as a shorting switch with some resistance placed across the capacitor as shown by the dashed portion of the circuit in figure 1. The state of the capacitor penetration sensor before impact is represented in figure 1 with the switch open. The sensor is charged to the battery potential and the only current flow is that of dielectric leakage.

When the sensor is perforated by a hypervelocity projectile the conduction path which is formed between the capacitor plates can be visualized by closing the switch in figure 1, thus allowing the capacitor discharge. It should be pointed out that the resistance of the conduction path is not constant. When the conduction path decays the capacitor begins to recharge. This may be visualized by reopening the switch in figure 1.

Two transient signals can be observed across the load resistor, one resulting from the capacitor discharge and one resulting from the capacitor recharge. A representation of a typical sensor signal is shown in figure 2. The voltage across the load resistor has been observed to vary according to the following equation:

$$V = V_D\left(1 - e^{-t/T}\right)$$

The voltage across the load during recharge is given by:

$$V = V_D e^{-\left(t-t_1\right)/RC}$$

When the sensor is substantially recharged it is ready to detect another perforation.

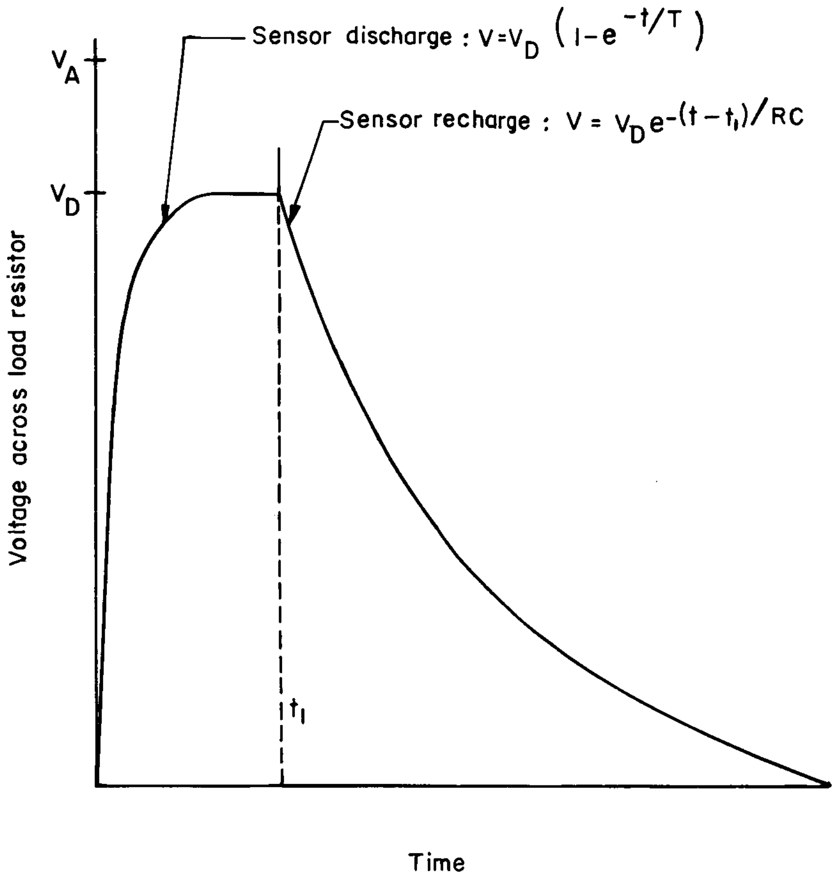


Figure 2.- A representation of a complete sensor signal.

SENSOR TEST CONFIGURATIONS

Two basic types of capacitor penetration sensors have been tested. These are designated as type A and type B.

The type A sensor has capacitor plates that are very thin compared with the dielectric thickness. The dielectric is, therefore, the primary material to be penetrated. Thus, for all practical considerations, the penetration flux to be measured by the sensor is the number of particles that can penetrate the dielectric. The type A sensor can be used as a single capacitor or in a sandwich of many capacitors. By using several capacitors, a more precise determination of the penetrating ability of the impacting particle can be made. As the particle penetrates each capacitor a signal will be produced, and thus the depth of penetration will be indicated.

The type B sensor consists of a capacitor with one plate that is very thick compared with the combined thickness of the dielectric and the other plate. Thus, the thick capacitor plate is the primary material to be penetrated, and the resulting data represent penetrations of structural metals.

During the course of this investigation, type A sensors with single capacitors and type B sensors with several variations in cross section were fabricated for laboratory testing. For convenience the test sensors usually had areas of 79 to 93 cm^2; however, sensors with areas up to 4.6 m^2 have been tested.

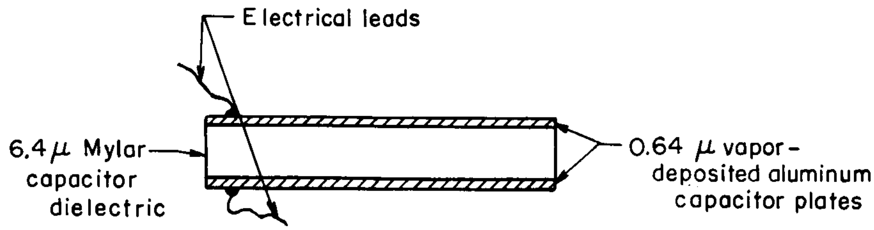


Figure 3.- Type A capacitor sensor.

The type A sensors, shown in figure 3, consisted of 6.4-μ Mylar dielectrics with vapor-deposited aluminum capacitor plates averaging 0.6 μ thick. The surface resistance of the vacuum-deposited plates when measured between two points 1 foot apart was approximately 2 ohms.

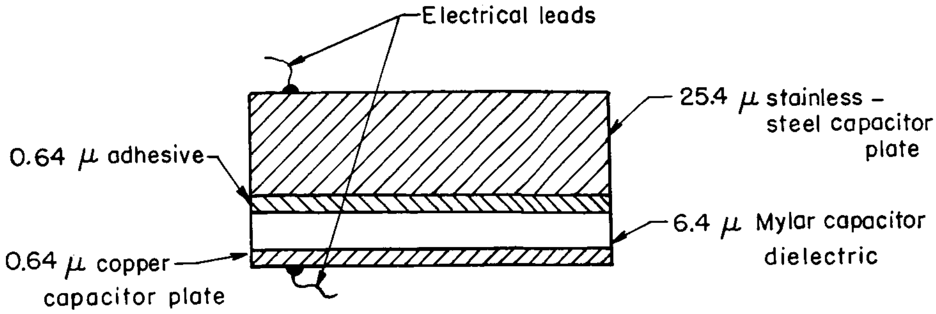
Five modifications of the type B sensors have been tested; they are designated herein as types B-1, B-2, B-3, B-4, and B-5.

The type B-1 sensors, shown in figure 4(a), consisted of 25.4-μ-thick stainless-steel sheet laminated to a 6.4-μ-thick Mylar dielectric with 0.6 μ of adhesive. The other capacitor plate consisted of 0.6 μ of copper, vapor deposited on the Mylar dielectric.

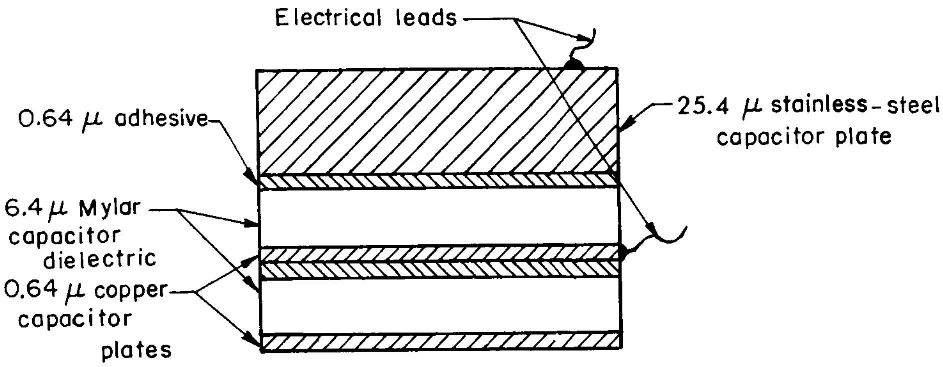
The type B-2 sensors, shown in figure 4(b), consisted of a type B-1 sensor with an additional sheet of copper-coated Mylar laminated to the copper plate of the B-1 sensor. This additional sheet had no use in these tests.

The type B-3 sensors, shown in figure 4(c), consisted of a 38-μ aluminum capacitor plate laminated, with 0.6 μ of adhesive, to a dielectric which was composed of three layers of Mylar with a total thickness of 12.7 μ. The other capacitor plate consisted of 0.6 μ of vapor-deposited copper. During some of the tests a 2.54-cm foam backup structure was laminated to the copper surface with about 50 μ of adhesive.

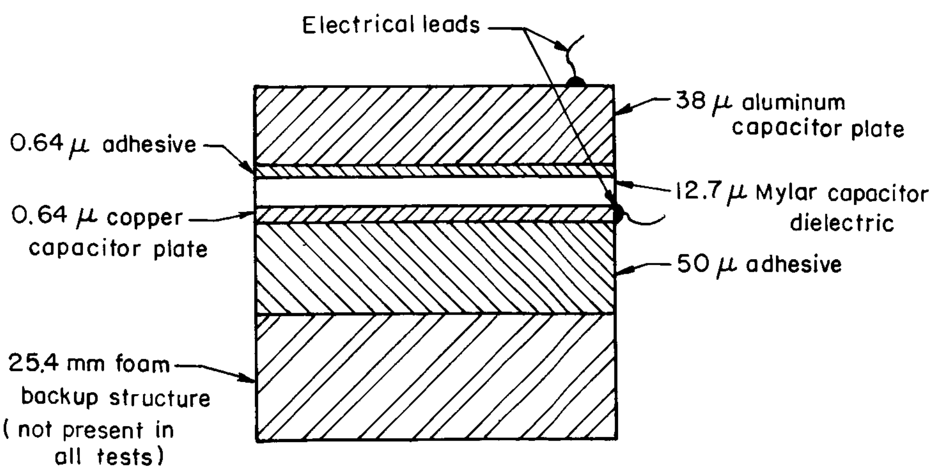
The type B-4 sensors, shown in figure 4(d), were identical to the type B-3 sensors except that the aluminum target plate was 0.2 mm thick. The type B-5 sensors, shown in figure 4(e), were also identical to the B-3 type except the target plate was 0.4 mm thick. Sensors B-4 and B-5 had 6 mm of foam laminated to the rear plate in all tests.



(a) Type B-1 capacitor sensor.

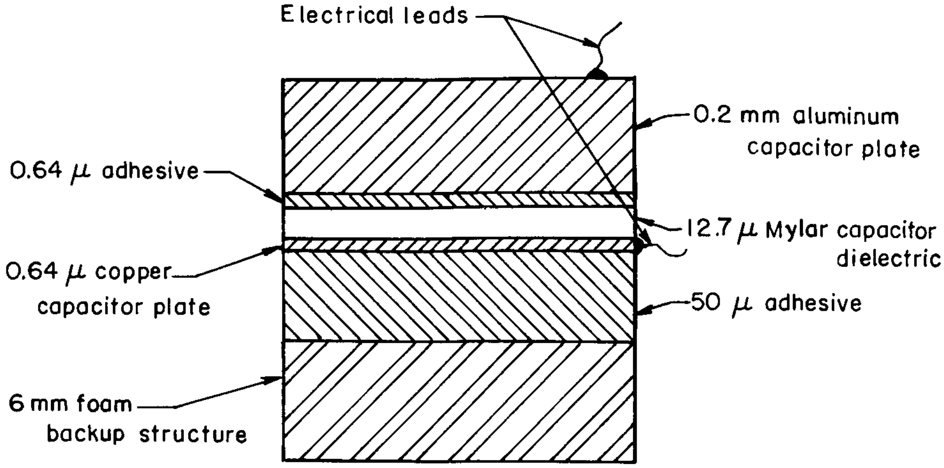


(b) Type B-2 capacitor sensor.

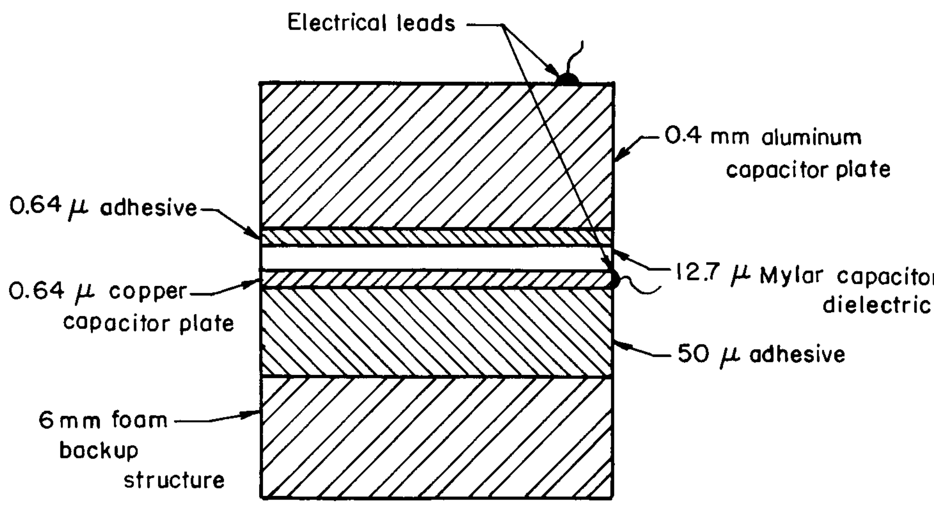


(c) Type B-3 capacitor sensor.

Figure 4.- Type B capacitor sensors.



(d) Type B-4 capacitor sensor.



(e) Type B-5 capacitor sensor.

Figure 4.- Concluded.

SIGNAL DETECTION CIRCUITS

Three signal circuits were used during the sensor testing. The first, the circuit shown in figure 1, is simply a battery, a 100-kilohm load resistor, and an oscilloscope. The second circuit, shown in figure 5, is basically the same; however, it allows the magnitude and polarity of the applied voltage to be changed. Also, there are provisions for connecting a microammeter and a capacitance bridge to the circuit. The third circuit, used in the tests of B-3 sensors, is shown in figure 6. This circuit simulated a flight-type detection system. Some elements shown in figure 6 were not used in all the tests of the B-3 sensors. Tests in which the isolation circuits and load sensors of this circuit were used are noted in the tabulated data.

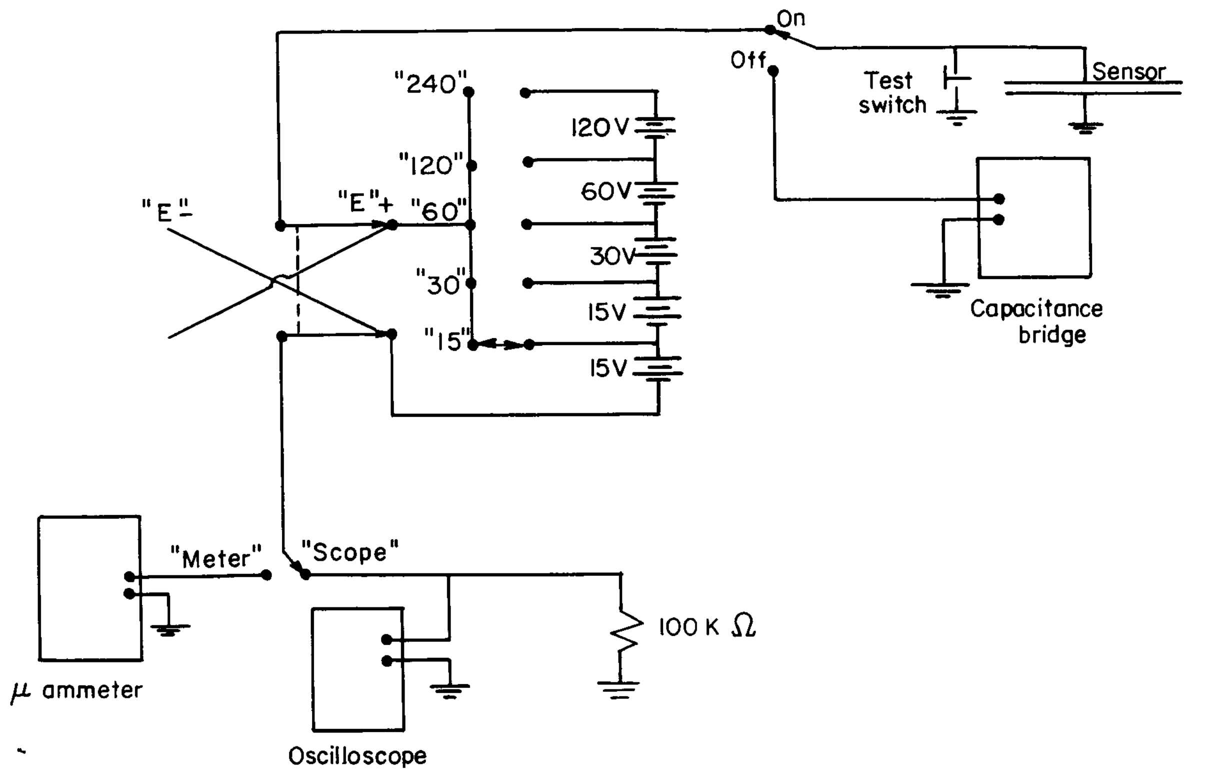


Figure 5.- Signal detection circuit used in most of the tests at North American Aviation, Inc.

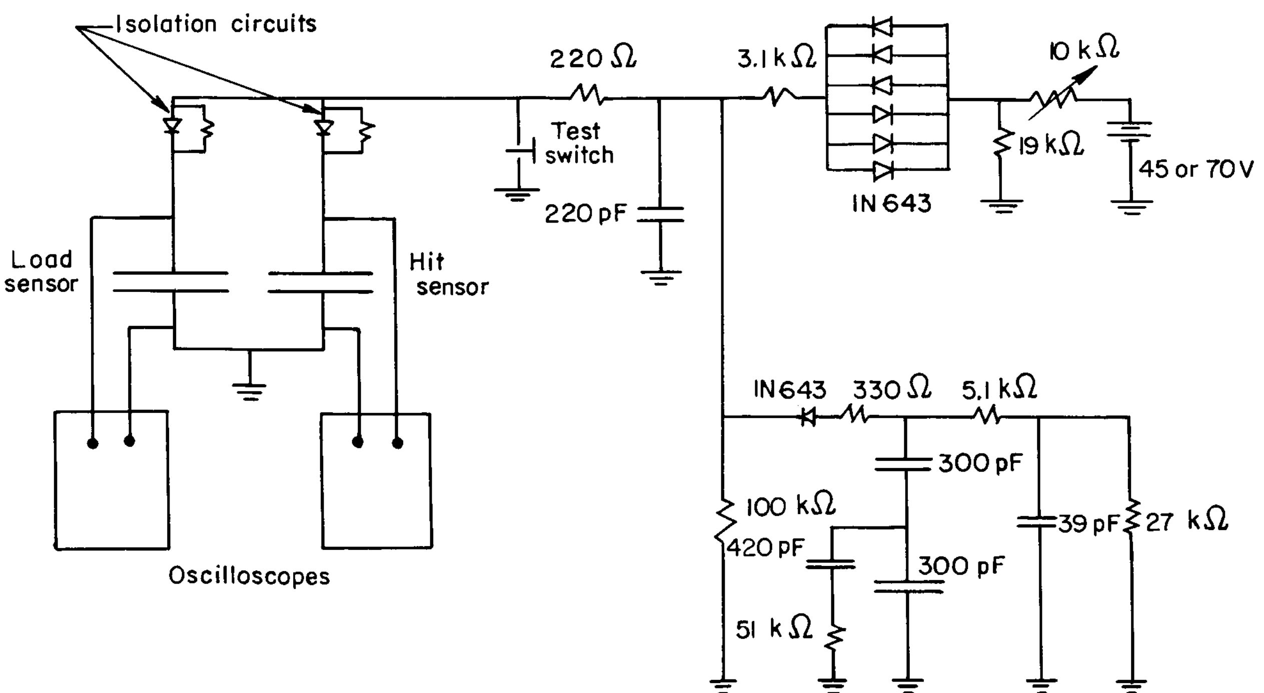


Figure 6.- Signal detection circuit used during the tests of the B-3 sensors.

TEST FACILITIES

Impact tests of capacitor sensors have been performed at the NASA Langley Research Center (LRC), Ballistic Research Laboratories (BRL), Space Technology Laboratories, Inc. (STL), and North American Aviation, Inc. (NAA). In general, the LRC, BRL, and STL facilities are not very well suited for realistic impact testing of the specific sensors investigated. Early in the program, however, these facilities were the only ones available for tests.

Most of the LRC tests utilized powder guns and light-gas guns. The projectiles accelerated were aluminum, copper, glass, magnesium, nylon, and steel spheres ranging from 1.6 to 5.6 mm in diameter and cylinders with diameters of 5.6 mm and lengths of 2.8 to 5.6 mm. Impact velocities up to 4.6 km/sec were obtained with these guns, and in all tests these projectiles possessed a great deal more penetrating potential than required to perforate the sensors. Also, the projectiles were much larger than the meteoroids that are likely to be encountered by these sensors in a flight experiment. These facts, coupled with the low impact velocities, made the tests an unrealistic simulation of meteoroid impacts in space. These tests were also complicated by small particles associated with the gun blast which were capable of perforating the sensors and affecting the observed sensor signals. The test chambers used with the LRC powder guns and light-gas guns permitted the testing of capacitor sensors under pressures of 66.7 N/m^2 (65.8×10^{-5} atm). These facilities are described in more detail in reference 4.

Tests were also conducted at LRC with explosive charges in evacuated test chambers. The charges used were composition B, pentolite, and tetryl explosives formed into cylinders 1.9 cm in diameter and 7.6 cm long. The particles to be accelerated were placed on the face of the charge. The accelerated particles consisted of a cluster of either irregularly shaped silicon particles varying in size from 50 to 150 μ or steel spheres varying in diameter from 12 to 127 μ. In most of the tests the particles broke up during acceleration; however, in some instances the steel spheres remained intact. The mass and velocity of any particular particle which was accelerated could not be determined, but a maximum velocity was determined by measuring the time between the detonation of the charge and the first impact on the sensor. Measured velocities were only 3 km/sec or less.

Tests were also conducted in the BRL shaped-charge test facility described in reference 5. The BRL charges had cylindrical cavities lined with cast iron. The collapse of the liner produced a small compact cluster of particles which varied in size from 1 to 100 μ and traveled at a uniform velocity of about 11 km/sec. Because all the particles traveled at essentially the same velocity, the signals received from the sensors tested at BRL resulted from the impacts of many particles rather than the impact of a single particle.

The STL 2-million-volt electrostatic particle accelerator described in reference 6 was used to accelerate iron spheres ranging from 0.4 to 3 μ in diameter for sensor impact testing. The smaller particles were accelerated to velocities of about 11 km/sec and the larger particles were accelerated to velocities of 1.8 km/sec. The test sensors were mounted in an evacuated test chamber and were impacted by a large number of spheres. Microscopic examination of a few randomly selected craters on the surface of the sensors left considerable doubt as to whether the sensors were completely perforated in most cases.

The most reliable test conditions were achieved with the NAA Mark IV exploding-wire gun and most of the test data presented herein are from that facility. The projectiles were glass spheres 38 to 71 μ in diameter, and they were accelerated to velocities ranging from 3.9 to 19.1 km/sec. During a single firing 1 to 20 particles (typically 4 or 5), with different diameters and velocities, are allowed to impact the target.

An indication of the diameter of the projectile is obtained as it passes through an in-flight projectile monitor. The transparent spherical projectile refracts a portion of a high-intensity collimated light beam onto a parabolic mirror that is focused on a photomultiplier. The magnitude of the photomultiplier signal is calibrated by dropping precisely measured spheres through the light beam. If a sphere is fragmented or roughened during acceleration, the amount of light refracted may be different from that of a transparent sphere, and thus may indicate an incorrect diameter.

The projectile velocity is determined from a simple time-distance relationship. The time interval begins when the projectile passes the projectile monitor and ends at the time of impact. The time of impact is established by observing the impact flash with a photomultiplier. The velocity is calculated from the time interval and the known distance from the projectile monitor to the target. During some of the tests a photomultiplier tube was placed behind the sensor also, to observe the rear flash and to indicate when the sensor was perforated. A more detailed description of the NAA facility can be found in reference 7. In all tests conducted at NAA the pressure was below 2 N/m^2 at the target.

TEST DATA

The data from the NAA impact tests are presented in tables 1 to 48. Tabulations of the LRC, BRL, and STL data are not presented because of the unrealistic test conditions; however, some comments and general observations on these tests are presented.

The tabulated data are arranged according to sensor type, size, applied voltage, backing, and added capacitance. In the tests of the B-3 sensors the use of load sensors and isolation circuits is also noted. The tabulated data consist of sensor capacitance, the indicated projectile diameter, impact velocity, the indication of perforation, and the sensor response. The load-sensor response and number of holes counted in the sensor are tabulated for some tests of the B-3 sensors.

As was mentioned in the previous section, the magnitude of the projectile-monitor signal was calibrated to indicate the projectile diameter. However, during many tests the in-flight signals were outside the calibrated region, and no projectile diameters could be associated with these signals because the integrity and surface conditions of the projectile were not known.

The sensor signals were observed with as many as five oscilloscope beams, to provide a broad range of signal sensitivity and time resolution. During most of the NAA tests a deflection of 0.01 volt could be observed in the potential across the sensor. Most tests also had one oscilloscope, triggered by the sensor signal, with a fast sweep speed (1 μsec/cm) to allow observations of the discharge portion of the sensor signal. Frequently the fast-sweep oscilloscope was triggered, not by the sensor signal, but by electromagnetic noise associated with discharging the Mark IV capacitor bank. In these tests the information concerning the discharge portion of the sensor signal was lost. However, some information concerning the discharge could be obtained from the slow-sweep oscilloscopes (100 μsec/cm) if the discharge time was above 5 μsec.

DISCUSSION OF RESULTS

Validity of Test Data

The impact tests of the capacitor sensor described herein were conducted to prove the feasibility of using the sensor to detect perforations by meteoroids. Thus, the validity of the test data depends upon the degree to which meteoroid impacts are simulated. Unfortunately, as already mentioned, several of the test facilities that were available do not simulate meteoroid impacts very well.

The LRC powder gun and light-gas gun accelerate projectiles which are orders of magnitude larger than the sensor thickness and much larger than the meteoroids that are likely to be encountered by these sensors in a flight experiment. It has been observed that the perforation of the sensor by the large projectiles often results in catastrophic damage, such as tearing of the sensor near the edges of the holes. It has also been observed in such cases that the sensor generally discharges completely.

The LRC and BRL explosive facilities both accelerate many projectiles that perforate the sensor within a very short time compared with the time constant of the sensor signal-detection circuit, and these perforations cannot be individually resolved. It has been observed during the NAA tests that if two particles perforate the sensor within a short time, the second perforation may discharge the sensor more completely than the first (for example, see fig. 7). This observation indicates that the sensor would probably be completely discharged when perforated by the cluster of particles from the explosive facilities.

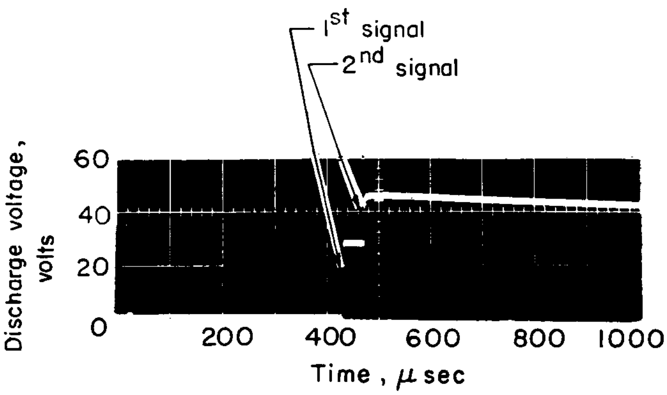


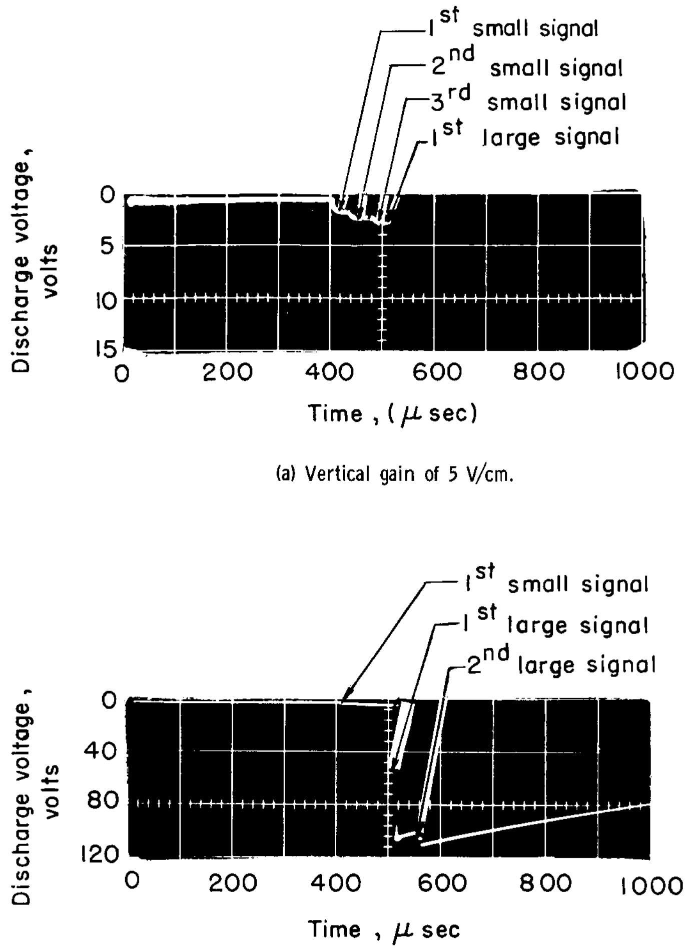
Figure 7.- Sensor signals showing multiple discharges.

Most of the sensors tested at STL did not produce signals when impacted by the 0.4-μ- to 3-μ-diameter spheres. As was mentioned previously, there is considerable doubt whether the sensors were perforated. Thus this facility was not suitable for the tests of the sensors used in this investigation.

The NAA facility accelerates projectiles which are nearly the same size as the sensor thickness, and although many projectiles are accelerated, each particle impact can be resolved. Since the number of meteoroids in space decreases as size increases, there is a low probability of encountering a meteoroid that is very large compared with the sensor thickness or of encountering more than one meteoroid within a short time. Thus the LRC and BRL test facilities do not simulate meteoroid impacts as well as the NAA facility. The data from tests in other facilities will be used only to establish the sensor performance in cases where there are no NAA data to show certain trends.

In order to determine the effects of single impacts in the NAA tests in which more than one signal was received from the sensor, only those signals which are not appreciably affected by previous signals are used. In other words, only the first small signal and the first large signal are considered. If the first signal is large, no other signals are used.

For example, figure 8 shows the sensor voltage for a test in which the sensor was impacted by more than one particle and produced both small and large signals. The test number is 2-11-64-2, and the data are presented in table 8. The sensor, initially charged to 120 volts, was impacted by five projectiles that produced three small signals and two large signals. The only signals that are considered representative of single impacts are the first small signal (in this case, 1.25 volts) and the first large signal (in this case, 102 volts).



(a) Vertical gain of 5 V/cm.

(b) Vertical gain of 40 V/cm.

Figure 8.- Illustration of both small and large signals during the same test. The data are presented in table 8, test 2-11-64-2. (Only the first small signal and the first large signal are considered representative of single impacts.)

General Types of Sensor Signals

Three types of signals have been observed during the impact tests of the capacitor sensors. One type of signal, shown in figure 9, is characterized by a complete discharge of the capacitor within a few microseconds. The second type of signal, shown in figure 10, is characterized by the loss of a large percentage of the capacitor voltage within a few microseconds. The third type of signal, shown in figure 11, is characterized by the loss of less than about 10 percent of the capacitor voltage and generally has a discharge time in excess of 10 μsec.

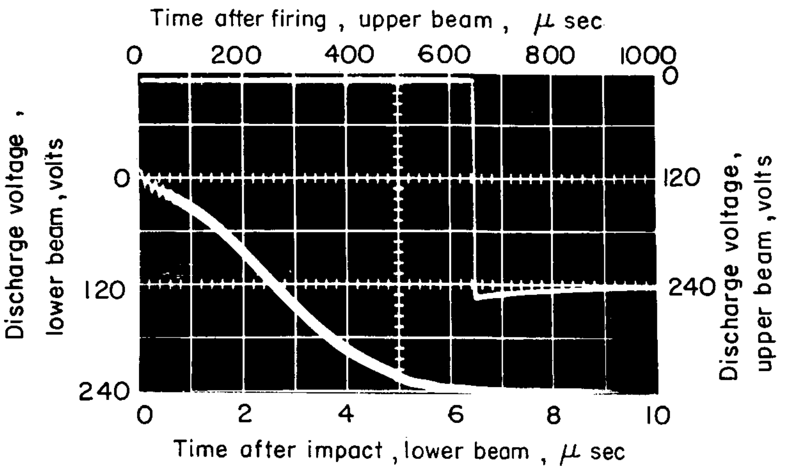


Figure 9.- A complete sensor discharge. The data are presented in table 32, test 2-13-64-2.

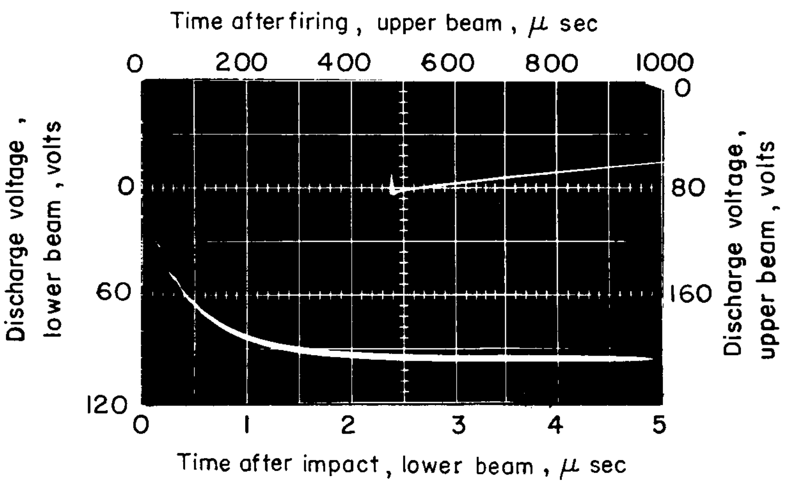


Figure 10.- An incomplete sensor discharge. The data are presented in table 37, test 1-17-64-2.

Signals indicating complete discharge of the sensor are usually observed when the sensor is perforated by a cluster of particles or by a particle that is very large compared with the sensor thickness. Signals indicating incomplete discharges, small discharges, and no discharge, are usually observed when the sensor is impacted or perforated by single small particles.

A few signals with discharge levels above 10 percent have occurred when the rear-flash photometer did not indicate a perforation; however, these signals are generally observed only when the sensor is perforated. Visual examination of the sensors indicated that they had been perforated, although the time of perforation could not be correlated with the sensor signal without a rear-flash signal.

Signals with amplitudes less than 10 percent of the applied voltage may be observed when the sensor is both partially penetrated and completely perforated, as can be seen from the data for type A, B-4, and B-5 sensors (tables 1, 47, and 48). The type A sensors were definitely perforated, but microscopic examination of the B-4 and B-5 sensors revealed that they were not perforated. In fact, a large percentage of the perforations produced small signals or no signals.

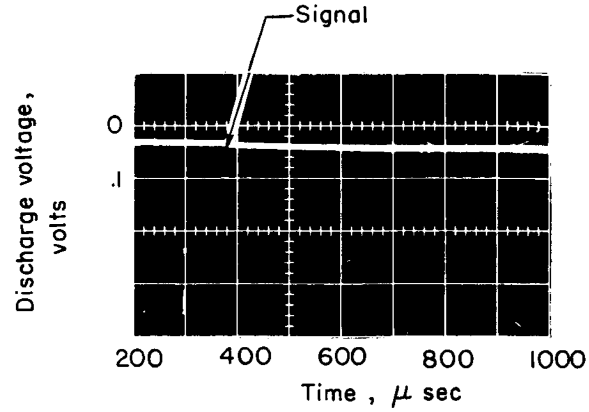


Figure 11.- A small sensor signal. The data are presented in table 37, test 2-14-64-8.

Permanent Shorting

One of the principal features of the capacitor is that it is usually not permanently shorted after a penetration, and thus more than one perforation can be detected. However, in a few cases, sensors that had been partially discharged by a previous perforation were immediately permanently shorted when perforated by small single projectiles.

During the tests described herein, no permanent shorts resulted from perforations of completely charged sensors by small single hypervelocity projectiles.

Six tests were conducted on type B-3 sensors with no applied voltage. The tests resulted in at least one perforation of each sensor. All but one sensor remained permanently shorted after the tests, and none of the shorts could be removed by later applying 70 volts across the capacitor plates.

Several sensors tested at NAA were permanently shorted after the test by impacts on the sensors of large, low-velocity pieces of the insulation used to contain the exploding wire in the NAA accelerometer. These shorts are not noted in the tabulated data.

The few permanent shorts that were noted might have been caused in several possible ways. One possibility is that projectile fragments were embedded in the dielectric and formed a permanent conduction path between the capacitor plates. This is probably not a severe problem since most meteoroids are believed to be stony and thus nonconductive, and since examinations of hypervelocity craters in metal targets generally show little or no projectile material in the crater.

A permanent short could also be produced if the metal capacitor plates came into physical contact, as a result of either tearing or material flow, to form a solid conduction path. The short would be removed only if the discharge current flowing through the short produced enough heating to burn away the contact and thus clear the sensor.

Effects of Sensor Parameters

The specific mechanism that causes the sensor to discharge has not been identified. However, during the tests several of the sensor parameters that were varied did affect the sensor signals. A discussion of the effects of these parameters on the sensor operation is presented in the following paragraphs.

Applied voltage.- The effect of applied voltage was examined at LRC with type A sensors. The projectiles, which were nylon cylinders 2.5 mm long and 5.6 mm in diameter, were launched to velocities of approximately 2.3 km/sec. Sensors charged to potentials of 2.5, 6.0, 13.5, and 64.0 volts were observed to discharge nearly completely when perforated. After the capacitors recharged, no additional voltage drops were observed (such drops would indicate arcing through the hole in the Mylar dielectric). Sensors charged to potentials in excess of 100 volts were also perforated. Again, when the Mylar dielectric was penetrated peak voltage drops approximately equal to the capacitor voltage were observed. After the penetrated capacitor recharged, however, in some cases arcing continued through the hole in the dielectric. Such arcing could give a false indication of additional sensor penetrations.

Figure 12 is a log-log plot of the normalized discharge voltage as a function of the applied voltage from the NAA tests of B-1 sensors. In order to facilitiate comparison, signals from both positively and negatively charged sensors are plotted on the same graph but identified as to polarity. The brackets indicate the actual spread of the data points. The data are taken from tables 2 to 10. It can be seen that the data fall into two regions: one near the complete discharge and the other below about 10 percent of the applied voltage. As the applied voltage is increased, the larger signals become a greater percentage of the applied voltage. The large signals from the tests with negative voltages fall within the same regions as the tests with positive voltages. The figure also indicates that the magnitude of the smaller signals decreases as the applied voltage increases.

The results shown in figure 12 are typical of all tests conducted at the NAA facility; however, the discharge levels of the B-3 sensors are somewhat lower than those shown in figure 12.

The effect of applied voltage on the larger signals shown in figure 12 may be due to the electrical field. If this is so, the same effect should be obtained by varying the dielectric thickness and maintaining constant voltage.

The data from all tests of the type B-1 sensors in which the rear-flash photometer was used have been examined to determine the effect of applied voltage on the sensor reliability. The sensor reliability, designated as p, is defined as the probability that a

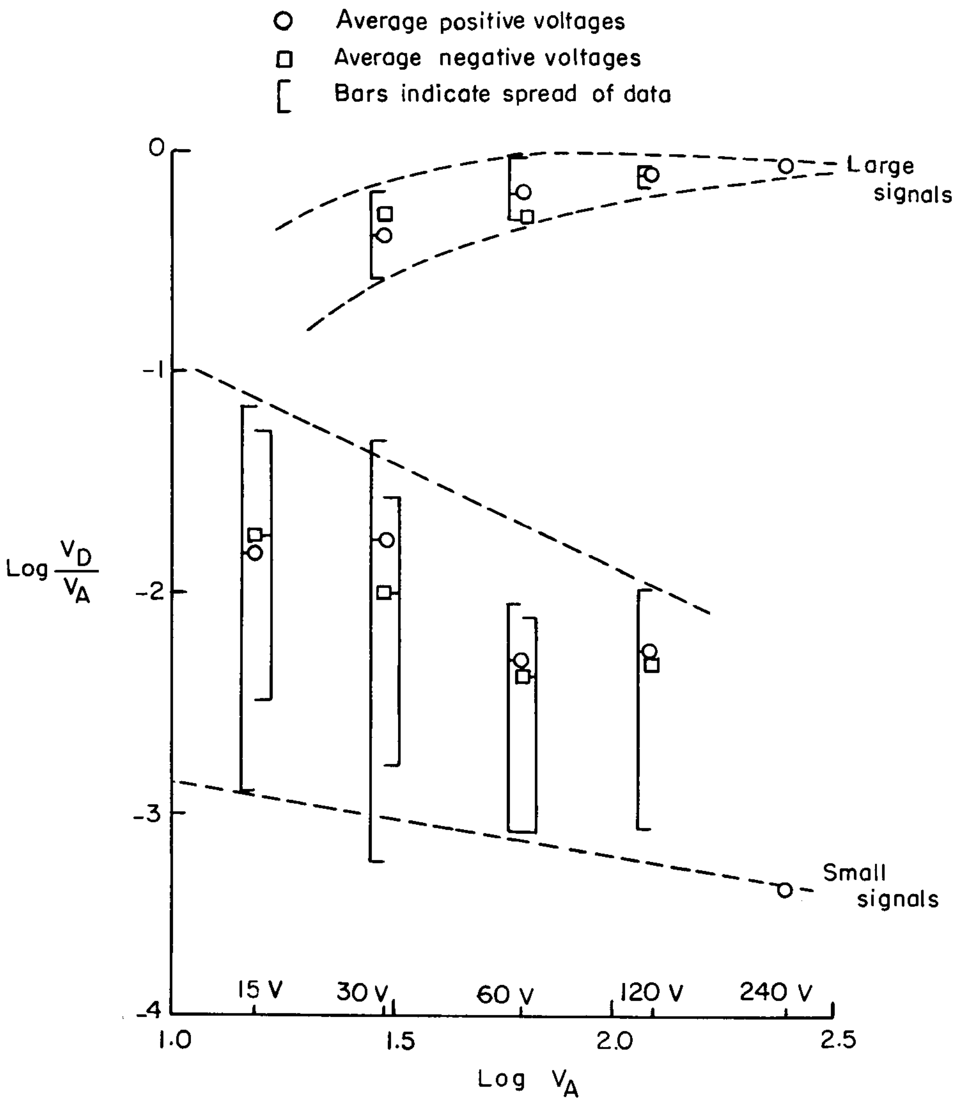


Figure 12.- Normalized discharge voltage as a function of applied voltage.

single perforation will produce a sensor signal. As already mentioned, no signals or perforations which occurred after the first large signal are considered in the analysis.

Because there are only two possible results of a perforation, either a large signal or not a large signal, the probability that x large signals will result from N perforations is given by the binomial distribution (see, e.g., ref. 8):

$$P(x) = \frac{N!}{(N - x)!x!} p^x(1 - p)^{N-x}$$

An estimate of p is $\bar{p} = \frac{x}{N}$. It can be shown (ref. 8) that $\bar{p}$ is distributed with a mean of p and a standard deviation σ of $\sqrt{\frac{p(1 - p)}{N}}$. Thus, the 2σ interval for $\bar{p}$ is given by

$$\left[p - 2\sqrt{\frac{p(1 - p)}{N}}\right] < p < \left[p + 2\sqrt{\frac{p(1 - p)}{N}}\right]$$

It can be shown that

$$\left[\frac{(N\bar{p} + 2) - 2\sqrt{1 + N\bar{p} - N\bar{p}^2}}{N + 4}\right] < p < \left[\frac{(N\bar{p} + 2) + 2\sqrt{1 + N\bar{p} - N\bar{p}^2}}{N + 4}\right]$$

and, since $\bar{p} = \frac{x}{N}$,

$$\left[\frac{(x + 2) - 2\sqrt{1 + x - \frac{x^2}{N}}}{N + 4}\right] < p < \left[\frac{(x + 2) + 2\sqrt{1 + x - \frac{x^2}{N}}}{N + 4}\right]$$

Figure 13 shows $\bar{p}$ and the 2σ interval for each applied voltage used during the tests. The confidence that p is within the limits indicated is at least 95 percent.

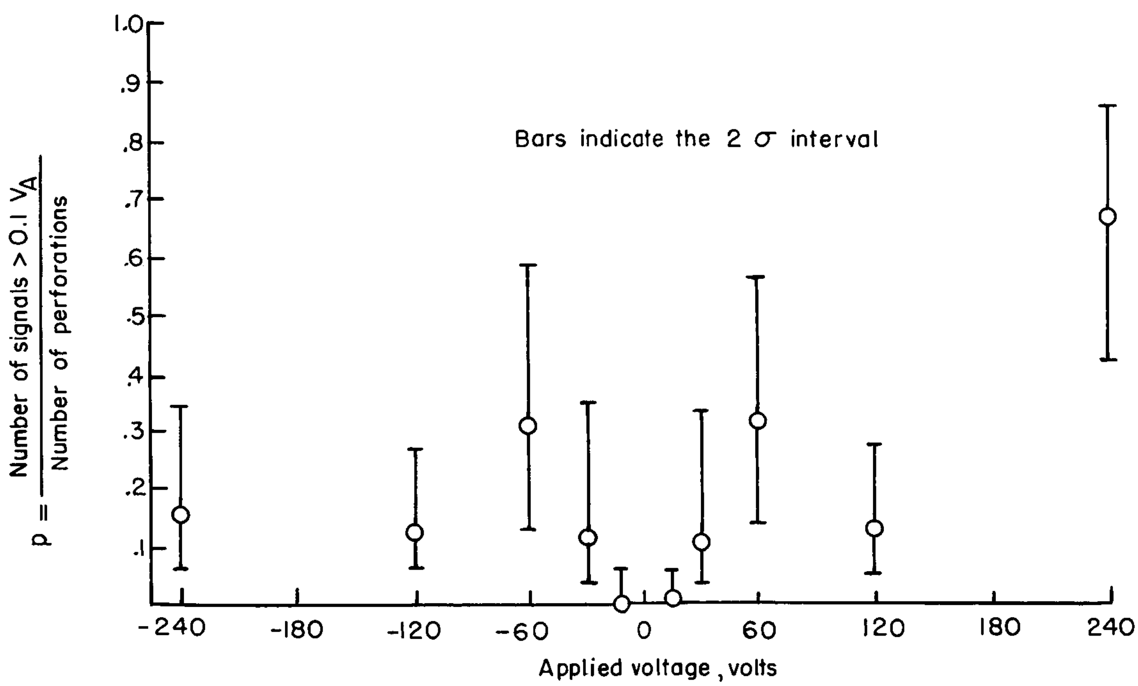


Figure 13.- Signal reliability as a function of applied voltage for all tests of B-1 sensors in which the rear-flash photometer was used.

It can be seen that the points are nearly symmetrical about zero applied voltage. The reliability of the sensor is near zero when the voltage is ±15, increases until the voltage becomes ±60, and then dips at ±120. The only unsymmetrical points are at 240 volts, where reliability is high, and at -240 volts, where the reliability is about the same as at ±120 volts.

Backing.- The sensors reported in tables 11 to 14 had 4 mm of foam tape on the rear capacitor plate. The foam had no pronounced effect on the sensor signal. The tests in which foam backing was used had somewhat higher reliability factors than the tests conducted on sensors without foam backing, but since more than three perforations from any of the tables were considered, this observation could be subject to doubt.

Sensor size.- In applications of the capacitor sensor for space experiments, it is desirable to have sensors with extremely large surface areas. Several tests were conducted to establish whether the surface area would affect the sensor performance.

The test sensors generally had areas of 79 to 93 cm^2, but tests were also conducted on sensors as large as 4.6 m^2. Additional tests were conducted to determine whether large areas could be simulated by adding capacitance in parallel with the sensor.

A type A sensor having an area of 4.6 m^2 was tested at LRC. The projectile was a nylon cylinder 5.6 mm in diameter and 2.8 mm long, and the impact velocity was 3 km/sec. At the instant of impact the sensor completely discharged, and it then recharged with no permanent short. The recharging time was considerably longer than that of the smaller sensors, as was expected; in fact, the recharging time was exactly as calculated on the basis of the circuit resistance and capacitance.

Sensors with dimensions of 8.9 by 8.9 cm, 20.3 by 20.3 cm, and 20.3 by 305 cm were tested at NAA to study the effect of area. Tests were also conducted on 8.9- by 8.9-cm sensors with added capacitance to determine the possibility of simulating large areas by maintaining a constant sensor capacitance.

Figure 14 shows the discharge voltages as a function of the total capacitance for the data presented in tables 8, 9, 18, 19, 22, 23, 31, and 33. The applied voltages were ±120 volts, and both positive and negative voltages are shown in the figure. The figure indicates that the capacitance has no pronounced effect on the larger signals, but the magnitude of the small discharges decreases as the capacitance increases. However, the range of magnitudes of the small signals is still very large.

Effects of Impact Parameters

Projectile size.- Unfortunately, neither LRC nor NAA, the only facilities that could accelerate single projectiles, had the capability of accelerating a wide range of projectile sizes at a constant velocity. Thus, the effects of projectile size on the sensor operation

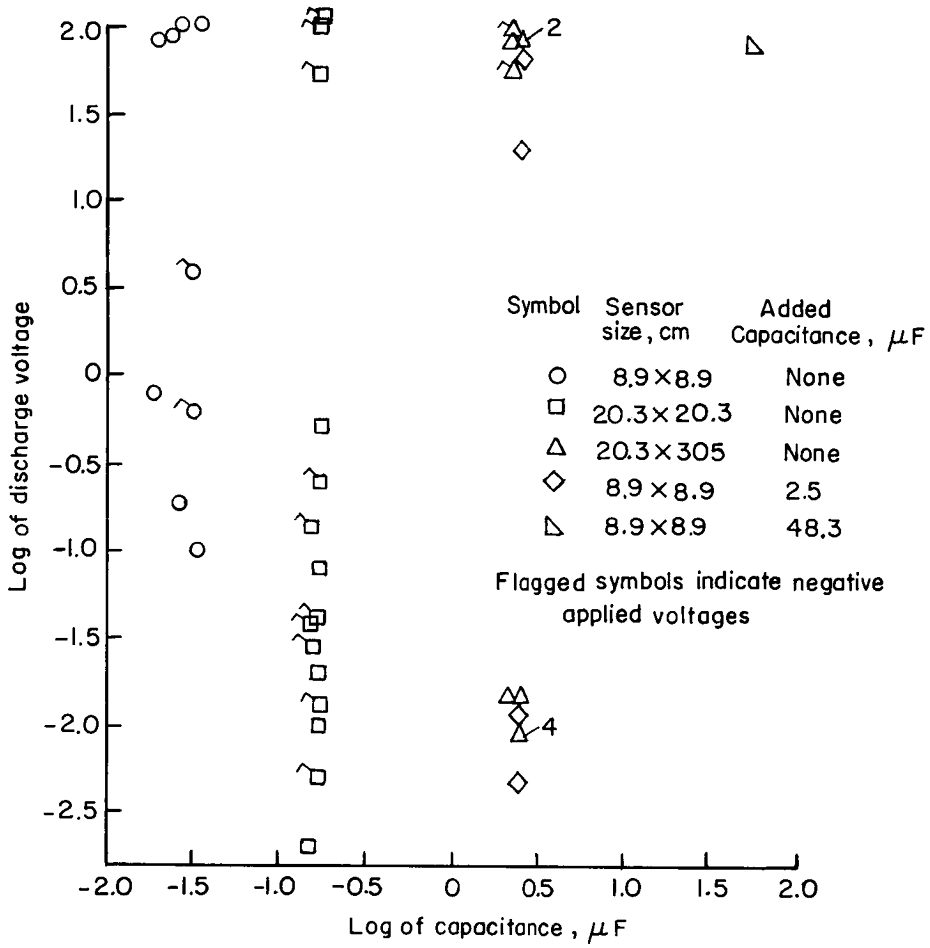


Figure 14.- Discharge voltage as a function of capacitance. Data taken from tables 8, 9, 18, 19, 22, 23, 31, and 33.

could not be studied in detail. It should be noted, however, that the very large projectiles of the LRC facility generally discharged the sensor completely, while the small projectiles of the NAA facility did not.

Projectile material.- Since the composition of meteoroids in space is unknown, it is desirable to know whether the material of the penetrating particle has an effect on the sensor operation. Type A sensors have been penetrated by aluminum, copper, lead, magnesium, nylon, steel, and glass projectiles with velocities in excess of 2.1 km/sec at LRC. In these tests all discharges were complete and, consequently, there was no observable difference between the signals generated by the different projectile materials even though the ionization potentials of the materials varied greatly.

Since the NAA facility accelerates only glass projectiles, no effect of projectile material could be established from these tests.

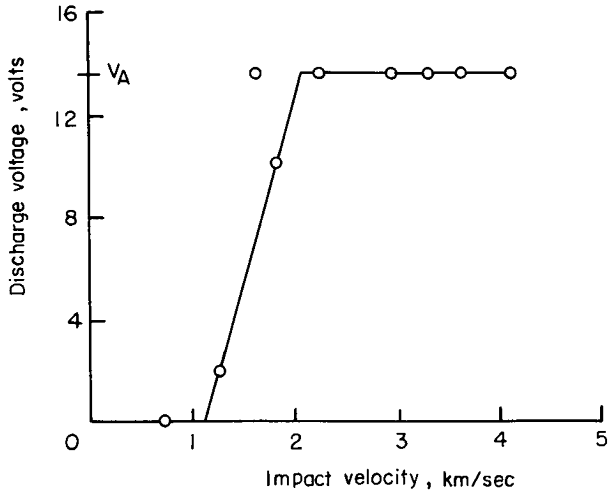


Figure 15.- Discharge voltage as a function of impact velocity from the LRC tests of type A sensors. V_A = 13.5 volts. The projectiles were cylinders 5.6 mm in diameter and 2.8 mm long.

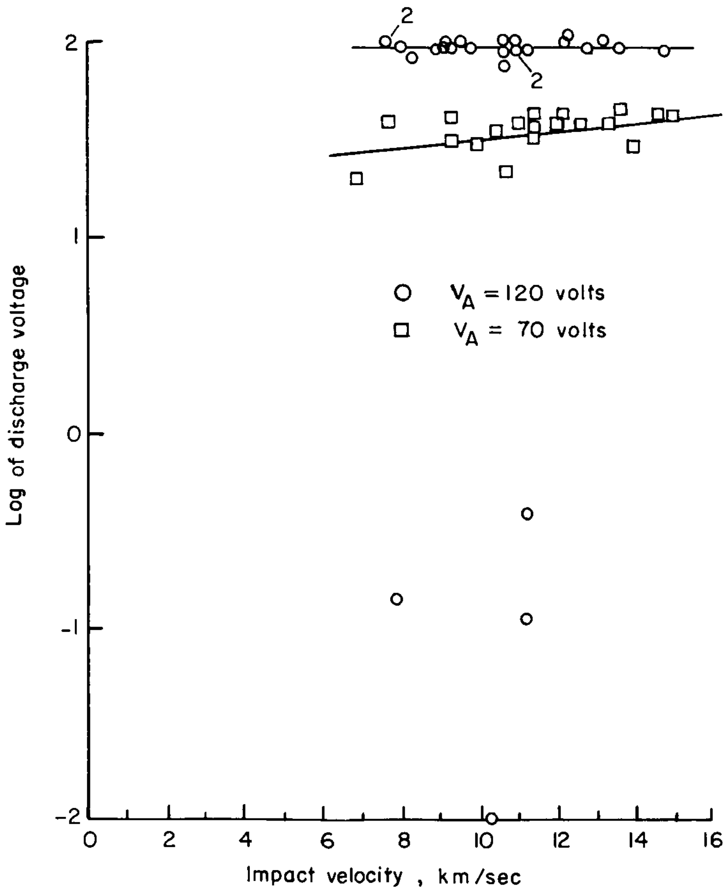


Figure 16.- Discharge voltage as a function of impact velocity. Data taken from tables 37 and 45.

Velocity.- One effect of impact velocity was noted in tests conducted on type A sensors with the LRC powder gun and light-gas gun. The projectiles, 5.6-mm-diameter nylon cylinders 2.8 mm long, impacted the sensors at velocities varying from 0.7 to 4.1 km/sec. The results of the nylon-cylinder impacts are presented in figure 15 in a plot of the peak voltage drop across the load resistor as a function of impact velocity. The sensors were completely discharged when penetrated by projectiles impacting at velocities greater than 2.1 km/sec, as indicated by the 13.5-volt drop across the load resistor.

Little effect of the impact velocity was noted in the NAA tests, which had a range of velocities from 3.9 to 19.1 km/sec. Figure 16 shows the discharge voltage as a function of the impact velocity for the B-2 sensors of table 37 and the B-3 sensors of table 45. The figure shows that the larger signals from the B-2 sensors do not vary appreciably with impact velocity, but the larger signals from the B-3 sensors have a slight tendency to increase as the impact velocity increases. The small signals in figure 16 are too few to permit a correlation with impact velocity.

SUMMARY OF RESULTS

Impact tests have been conducted on a capacitor sensor to investigate the feasibility of the sensor for detecting meteoroid penetrations and to determine the parameters that affect the sensor operation. Several configurations of the capacitor sensor have been tested at the NASA Langley Research Center, Ballistic Research Laboratories, Space Technology Laboratories, Inc., and North American Aviation, Inc. The most realistic simulation of meteoroid impacts was obtained with the NAA facility, and for this reason more confidence is placed in the data from NAA than in the data from the other facilities.

The tests probably have not indicated all the parameters that affect the sensor operation. The specific mechanism of sensor discharge has not been identified.

The results of the tests are as follows:

1. Three types of signals resulted from perforations during the test program: (a) a complete discharge of the capacitor within a few microseconds of impact, (b) a discharge of a large percentage of the applied voltage within a few microseconds, and (c) a discharge of less than about 10 percent of the applied voltage, generally with discharge times greater than 10 μsec.

2. A large percentage of the perforations resulted in small signals or no signals.

3. No permanent shorts resulted from perforations of completely charged sensors by small single hypervelocity projectiles; however, some uncharged and partially charged sensors became shorted when perforated.

4. As the applied voltage increased, the amplitude of the large signals increased and the amplitude of the small signals decreased.

5. The ratio of the number of large signals to the number of perforations varied with applied voltage and was most reliable at +120 volts.

6. It has been shown that for certain impact conditions there is an impact velocity threshold below which no sensor signal will be produced.

7. The impact velocity, when above the threshold, appeared to have little effect on the magnitude of larger sensor signals over the range tested.

8. Due to limitations of the test facilities, the effect of projectile size on the sensor operation could not be studied in detail. However, the large projectiles from the LRC facility generally discharged the sensor completely, while the small projectiles from the NAA facility did not.

9. The large projectiles, regardless of the material, generally produced complete discharge of the sensor.

10. The sensor response did not appear to be affected by the sensor area. Also, large sensor areas apparently could be simulated by adding capacitance in parallel to the sensor.

Langley Research Center,
National Aeronautics and Space Administration,
Langley Station, Hampton, Va., July 10, 1967,
124-09-14-02-23.

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TABLE 1.- DATA FROM NAA IMPACT TESTS

Sensor type: A

Sensor size: 10.2 × 15.2 cm

Applied voltage: -110 V

Backing: None

Added capacitance: None

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Perforation	Discharge voltage, V	Discharge time, μsec
5682	0.1210	46	10.3	Yes	(b)	---
		(a)	10.1	Yes	(b)	---
		49.5	9.5	Yes	0.07	20
		(a)	9.3	Yes	(b)	---
		(a)	9.0	Yes	0.11	20
		(a)	8.4	Yes	0.20	10
		47	5.9	Yes	(b)	---
		(a)	5.7	Yes	(b)	---
5683	0.1102	56	10.1	Yes	70	2
		(a)	8.0	Yes	(b)	---
		(a)	7.5	Yes	(b)	---
		(a)	[c]6.5	Yes	(b)	---
5684	0.1037	(a)	[c]8.2	Yes	(b)	---
5685	0.1025	50	8.1	Yes	(b)	---
		50	7.7	Yes	0.01	<5
5686	0.1172	(a)	10.1	Yes	0.010	<5
		(a)	7.8	Yes	0.065	500
		(a)	7.7	Yes	(b)	---
5687	0.1163	(a)	[c]10.0	Yes	0.02	600
		56	[c]7.7	Yes	(b)	---
		(a)	[c]6.9	Yes	(b)	---

[a]The in-flight signal indicating diameter was outside the calibrated region.

[b]Below theshold of detection.

[c]Impact flash not observed; velocity calculated from rear flash.

TABLE 2.- DATA FROM NAA IMPACT TESTS

Sensor type: B-1
Sensor size: 8.9 × 8.9 cm
Applied voltage: +15 V
Backing: None
Added capacitance: None

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Perforation	Discharge voltage, V	Discharge time, μsec
[a]4642	0.0302	52	12.6	No	(b)	----
		53	12.0	Yes	0.1	270
[a]4644	0.0300	(c)	13.9	No	0.3	300
[a]4645	0.0301	(c)	12.4	No	(b)	----
[a]4646	0.0302	(c)	13.3	No	(b)	----
		(c)	12.6	No	0.05	10
		(c)	12.2	Yes	0.1	20
		(c)	11.8	Yes	(b)	----
		(c)	11.5	No	0.45	550
		(c)	9.8	Yes	(b)	----
[a]4647	0.0299	44	12.6	No	(b)	----
		(c)	11.5	Yes	0.05	350
		45	9.0	No	(b)	----
[a]5132	0.0287	(c)	16.8	Yes	0.2	<5
[a]5171	0.0278	(c)	12.4	No	0.05	200
[a]5172	0.0289	(c)	11.7	Yes	0.45	600
		(c)	6.9	No	(b)	----
[a]5173	0.0287	(c)	11.5	Yes	0.9	240
		(c)	11.1	Yes	(b)	----
		53	10.6	Yes	(b)	----
		(c)	10.0	Yes	(b)	----
		49.5	6.3	No	1.0	1850

See footnotes at end of table, p. 28.

TABLE 2.- DATA FROM NAA IMPACT TESTS – Concluded

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Perforation	Discharge voltage, V	Discharge time, μsec
[a]5304	0.0290	(c)	7.2	No	(b)	---
		47	6.9	Yes	0.02	315
		(c)	6.4	Yes	(b)	---
		(c)	5.0	No	(b)	---
		47	5.9	No	(b)	---

[a]The vertical gain of the oscilloscope was calibrated with a battery.

[b]Below threshold of detection.

[c]The in-flight signal indicating diameter was outside the calibrated region.

TABLE 3.- DATA FROM NAA IMPACT TESTS

Sensor type: B-1

Sensor size: 8.9 × 8.9 cm

Applied voltage: -15 V

Backing: None

Added capacitance: None

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Perforation	Discharge voltage, V	Discharge time, μsec
[a]4637	0.0298	(b)	12.4	No	(c)	----
		(b)	11.8	No	(c)	----
		(b)	10.2	Yes	0.25	25
		(b)	9.6	No	0.55	150
		(b)	7.1	No	(c)	----
[a]4638	0.0303	52	14.4	No	(c)	----
		50	13.3	Yes	(c)	----
		(b)	13.0	Yes	0.80	90
		50	7.8	No	(c)	----
		54	6.3	No	(c)	----
[a]4639	0.0309	(b)	8.3	No	(c)	----
[a]4641	0.0289	(b)	13.4	Yes	0.05	Fast
		52	13.3	Yes	(c)	----
		52	12.4	Yes	(c)	----
		54	12.0	Yes	(c)	----
		49	9.8	Yes	(c)	----
[a]5161	0.0286	50.5	7.5	Yes	0.05	100
		53	6.2	No	0.10	200
[a]5163	0.0281	(b)	13.3	Yes	0.15	100
		46	7.2	No	0.30	1450
		51.5	6.5	No	(c)	----
[a]5164	0.0274	(b)	12.4	Yes	(c)	----
		(b)	11.7	Yes	(c)	----
		(b)	10.3	Yes	(c)	----
		(b)	9.8	Yes	(c)	----

See footnotes at end of table, p. 30.

TABLE 3.- DATA FROM NAA IMPACT TESTS – Concluded

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Perforation	Discharge voltage, V	Discharge time, μsec
[a]5165	0.0292	(b)	13.4	Yes	0.5	5700
		(b)	12.4	No	(c)	----
		53	10.4	No	(c)	----
		51.5	10.2	Yes	(c)	----
		(b)	9.8	Yes	(c)	----
		46	8.2	No	(c)	----
		(b)	6.9	No	(c)	----
		(b)	6.8	No	(c)	----
[a]5166	0.0296	46	5.9	No	0.05	100

[a]The vertical gain of the oscilloscope was calibrated with a battery.
[b]The in-flight signal indicating diameter was outside the calibrated region.
[c]Below threshold of detection.

TABLE 4.- DATA FROM NAA IMPACT TESTS

Sensor type: B-1
Sensor size: 8.0 × 8.9 cm
Applied voltage: +30 V
Backing: None
Added capacitance: None

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Perforation	Discharge voltage, V	Discharge time, μsec
[a]2-10-64-2	0.029	(b)	8.9	(c)	0.04	30
		(b)	8.7	(c)	(d)	---
		48	8.1	(c)	(d)	---
		(b)	8.0	(c)	0.11	20
		(b)	[e]7.6	(c)	13	<5
		(b)	[e]7.2	(c)	14	<5
		(b)	[e]7.1	(c)	15	<5
[a]2-10-64-3	0.030	48	14.1	(c)	0.6	<5
		(b)	12.7	(c)	1.2	10
		64	10.9	(c)	1.2	10
[a]2-12-64-5	0.0225	(b)	14.1	(c)	0.02	10
		(b)	13.9	(c)	(d)	---
		51	13.2	(c)	8.0	<5
		(b)	12.1	(c)	(d)	---
		38	11.2	(c)	8.0	<5
		(b)	10.9	(c)	(d)	---
		61	10.6	(c)	(d)	---
		46	9.4	(c)	(d)	---
		51	6.6	(c)	(d)	---
2-12-64-6	0.0339	43	10.6	(c)	20	<5
		(b)	8.0	(c)	30	<5
		41	7.3	(c)	Short	---
		(b)	7.1	(c)	Short	---
		61	6.3	(c)	Short	---
		(b)	5.8	(c)	Short	---

See footnotes at end of table, p. 33.

TABLE 4.- DATA FROM NAA IMPACT TESTS – Continued

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Perforation	Discharge voltage, V	Discharge time, μsec
4650	0.0286	(b)	12.6	No	(d)	---
		54	11.2	Yes	0.3	40
		48	10.1	Yes	0.9	145
		(b)	7.9	No	(d)	---
		44	7.4	Yes	1.35	350
4651	0.0302	45	14.9	Yes	0.15	230
		(b)	11.5	No	(d)	---
4652	0.0317	(b)	13.0	Yes	0.15	55
		(b)	12.9	Yes	0.55	180
		(b)	10.2	Yes	(d)	---
		49	9.9	No	(d)	---
		(b)	8.8	No	(d)	---
		(b)	7.9	Yes	(d)	---
		(b)	7.4	No	0.75	350
		52	6.4	No	(d)	---
4653	0.0290	44	9.2	No	0.05	50
		44	8.2	Yes	0.10	160
		(b)	6.1	No	0.2	100
5156	0.0244	(b)	12.6	No	0.1	20
		(b)	12.2	Yes	(d)	---
		(b)	11.7	Yes	12	<5
		53	11.5	Yes	(d)	---
		(b)	11.2	Yes	(d)	---
		53	10.4	Yes	(d)	---
		(b)	9.9	Yes	(d)	---
		46	8.2	No	(d)	---
5157	0.0284	53	11.5	Yes	1.45	800
		(b)	9.6	Yes	(d)	---
		(b)	9.3	Yes	(d)	---
		(b)	7.4	No	(d)	---

See footnotes at end of table, p. 33.

TABLE 4.- DATA FROM NAA IMPACT TESTS – Concluded

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Perforation	Discharge voltage, V	Discharge time, μsec
5158	0.0278	53	11.5	Yes	0.6	70
		53	10.9	Yes	(d)	--
		(b)	10.6	Yes	(d)	--
		46	9.6	Yes	8	<5
		46	9.2	Yes	(d)	--
		51.5	8.4	Yes	(d)	--
		(b)	6.6	No	(d)	--
		(b)	6.3	Yes	10	<5
		(b)	5.5	No	(d)	--

[a]No rear flash.

[b]The in-flight signal indicating diameter was outside the calibrated region.

[c]Not measured because instrumentation was not in operation.

[d]Below threshold of detection.

[e]Impact flash not observed; velocity calculated from sensor signal.

TABLE 5.- DATA FROM NAA IMPACT TESTS

Sensor type: B-1
Sensor size: 8.9 × 8.9 cm
Applied voltage: -30 V
Backing: None
Added capacitance: None

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Perforation	Discharge voltage, V	Discharge time, μsec
4654	0.0289	(a)	13.0	Yes	0.8	290
		(a)	12.8	Yes	(b)	---
		54	8.8	No	(b)	---
		(a)	8.5	No	(b)	---
4655	0.0304	(a)	12.8	Yes	0.4	60
		(a)	10.4	No	0.7	610
4656	0.0304	(a)	11.9	Yes	0.05	10
		(a)	11.5	Yes	0.25	100
		(a)	7.6	Yes	0.30	50
		(a)	6.0	No	15	<5
					15	[c]<5
4657	0.0289	(a)	15.0	Yes	(b)	---
		(a)	14.4	Yes	(b)	---
		44	11.5	Yes	(b)	---
		44	10.6	Yes	(b)	---
		44	10.2	Yes	(b)	---
		52	7.4	No	(b)	---
		54	7.2	No	(b)	---
4658	0.0290	(a)	9.5	No	(b)	---
		(a)	7.9	Yes	15	<5
5159	0.0284	(a)	12.4	Yes	0.1	100
		46	9.2	No	(b)	---
		(a)	6.7	No	0.2	800
		(a)	6.6	No	(b)	---
		(a)	5.6	No	(b)	---

See footnotes at end of table, p. 35.

TABLE 5.- DATA FROM NAA IMPACT TESTS – Concluded

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Perforation	Discharge voltage, V	Discharge time, μsec
5160	0.0290	(a)	13.9	Yes	0.30	100
		(a)	8.6	No	(b)	---
		47.5	7.1	Yes	0.35	100
		(a)	6.6	No	(b)	---
		47	6.4	Yes	(b)	---
5174	0.0282	47.5	9.2	Yes	0.15	300

[a]The in-flight signal indicating diameter was outside the calibration region.

[b]Below threshold of detection.

[c]Sensor arced 5 μsec after discharge.

TABLE 6.- DATA FROM NAA IMPACT TESTS

Sensor type: B-1

Sensor size: 8.9 × 8.9 cm

Applied voltage: +60 V

Backing: None

Added capacitance: None

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Perforation	Discharge voltage, V	Discharge time, μsec
[a]2-13-64-7	0.0192	51	9.9	(b)	0.2	10
		48	8.7	(b)	(c)	--------
		43	8.4	(b)	0.4	10
		(d)	[e]7.6	(b)	(c)	--------
4557	0.0306	53	8.8	Yes	0.4	400
		49	7.1	No	(c)	--------
		50	6.4	No	(c)	--------
		(d)	4.9	No	(c)	--------
[f]4559	0.0296	(d)	12.6	No	(c)	--------
		(d)	11.8	No	0.05	20
		45	11.0	No	54	4
		(d)	10.1	No	(c)	--------
		51	9.7	No	(c)	--------
		(d)	9.5	No	(c)	--------
		44	8.8	Yes	60	<5
		49	7.4	No	Short	--------
		49	6.9	No	Short	--------
		51	6.4	No	Short	--------
5060	0.0299	(d)	12.6	Yes	0.2	600
5146	0.0297	(d)	8.7	No	(c)	--------
		(d)	7.6	No	0.05	Uncertain
		(d)	6.7	No	0.05	Uncertain
5145	0.0308	(d)	17.2	Yes	30	20
		(d)	13.3	No	(c)	--------

See footnotes at end of table, p. 37.

TABLE 6.- DATA FROM NAA IMPACT TESTS – Concluded

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Perforation	Discharge voltage, V	Discharge time, μsec
5155	0.0297	53	9.7	No	(c)	----
		(d)	8.7	Yes	(c)	----
		(d)	8.4	Yes	32	30
		(d)	7.4	Yes	(c)	----
		(d)	7.2	Yes	(c)	----
		(d)	6.6	Yes	(c)	----
5234	0.0314	60	13.9	Yes	0.5	1100
		(d)	11.2	Yes	(c)	----
5235	0.0314	(d)	13.7	Yes	0.30	80
		(d)	10.7	No	0.75	900
5237	0.0314	(d)	11.2	Yes	0.55	800
5238	0.0314	(d)	11.7	Yes	0.45	65
		(d)	9.9	Yes	0.85	90
		(d)	8.2	Yes	(c)	----
		(d)	8.1	Yes	1.4	90
		(d)	[e]6.9	Yes	36	<5

[a]No rear flash.

[b]Not measured because instrumentation was not in operation.

[c]Below threshold of detection.

[d]The in-flight signal indicating diameter was outside the calibrated region.

[e]Impact flash not observed; velocity calculated from sensor signal.

[f]Shorted on impact.

TABLE 7.- DATA FROM NAA IMPACT TESTS

Sensor type: B-1

Sensor size: 8.9 × 8.9 cm

Applied voltage: -60 V

Backing: None

Added capacitance: None

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Perforation	Discharge voltage, V	Discharge time, μsec
4563	0.0308	51	7.1	No	0.05	250
4566	0.0303	54	10.3	No	0.3	50
		52	7.9	No	0.8	135
		(a)	6.3	No	1.0	30
		52	5.2	No	1.2	225
5147	0.0293	(a)	11.5	Yes	0.3	500
		53	9.8	No	(b)	---
5150	0.0285	53	10.0	Yes	(b)	---
5152	0.02723	56	9.4	No	0.15	300
		(a)	8.3	No	(b)	---
		46	8.2	No	(b)	---
5153	0.0281	46	10.0	No	0.35	50
		47.5	9.8	Yes	(b)	---
		(a)	8.8	Yes	28	40
5154	0.0308	(a)	9.2	No	0.1	90
		(a)	7.6	Yes	0.3	70
		(a)	6.7	No	30	40
5175	0.0283	(a)	8.4	Yes	0.45	100

[a]The in-flight signal indicating diameter was outside the calibrated region.

[b]Below threshold of detection.

TABLE 8.- DATA FROM NAA IMPACT TESTS

Sensor type: B-1
Sensor size: 8.9 × 8.9 cm
Applied voltage: +120 V
Backing: None
Added capacitance: None

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Perforation	Discharge voltage, V	Discharge time, μsec
[a]2-10-64-1	0.0186	(b)	10.9	(c)	0.8	10
		(b)	9.6	(c)	0.8	5
		(b)	9.1	(c)	(d)	---
		(b)	8.9	(c)	82	<5
		(b)	8.3	(c)	(d)	---
		(b)	7.7	(c)	(d)	---
		43	7.6	(c)	(d)	---
		43	7.5	(c)	(d)	---
		(b)	6.8	(c)	96	<5
		53	6.6	(c)	(d)	---
		(b)	[e]6.2	(c)	96	<5
		(b)	[e]5.5	(c)	96	<5
[a]2-11-64-1	0.0250	(b)	10.3	(c)	0.4	140
		66	9.8	(c)	(d)	---
[a]2-11-64-2	0.0194	71	9.6	(c)	1.25	10
		(b)	8.9	(c)	1.50	10
		(b)	8.0	(c)	2.00	10
		(b)	7.5	(c)	102	1.5
		(b)	6.9	(c)	108	<5

See footnote at end of table, p. 40.

TABLE 8.- DATA FROM NAA IMPACT TESTS – Concluded

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Perforation	Discharge voltage, V	Discharge time, μsec
[a]2-12-64-3A	0.0327	(b)	[e]14.1	(c)	0.10	5
		(b)	[e]12.7	(c)	0.15	10
		63	11.4	(c)	(d)	---
		(b)	11.2	(c)	(d)	---
		(b)	10.5	(c)	0.3	10
		43	10.0	(c)	0.4	15
		61	9.8	(c)	(d)	---
		48	8.9	(c)	100	0.5
		69	7.5	(c)	(d)	---
		41	6.9	(c)	(d)	---
		43	6.7	(c)	(d)	---
		63	6.3	(c)	(d)	---
		51	6.2	(c)	(d)	---
[a]2-12-64-4	0.0225	63	11.2	(c)	90	0.5
		(b)	9.5	(c)	110	<5
		38	9.0	(c)	(d)	---
		(b)	8.2	(c)	110	<5
		(b)	7.5	(c)	(d)	---
		(b)	5.8	(c)	(d)	---
		(b)	4.2	(c)	100	<5

[a]No rear flash.

[b]The in-flight signal indicating diameter was outside the calibrated region.

[c]Not measured because instrumentation was not in operation.

[d]Below threshold of detection.

[e]Impact flash not observed; velocity calculated from sensor signal.

TABLE 9.- DATA FROM NAA IMPACT TESTS

Sensor type: B-1

Sensor size: 8.9 × 8.9 cm

Applied voltage: -120 V

Backing: None

Added capacitance: None

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Perforation	Discharge voltage, V	Discharge time, μsec
[a]4567	0.0299	(b)	6.1	No	0.60	160
4568	0.0303	(b)	10.2	Yes	4	<5
		(b)	8.2	Yes	(c)	---
		(b)	8.1	No	(c)	---
		(b)	7.9	Yes	(c)	---
		(b)	6.7	No	(c)	---
		(b)	6.4	Yes	(c)	---
		(b)	6.2	No	(c)	---
		(b)	5.8	No	(c)	---

[a]The vertical gain of the oscilloscope was calibrated with a battery.

[b]The in-flight signal indicating diameter was outside the calibrated region.

[c]Below threshold of detection.

TABLE 10.- DATA FROM NAA IMPACT TESTS

Sensor type: B-1
Sensor size: 8.9 × 8.9 cm
Applied voltage: +240 V
Backing: None
Added capacitance: None

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Perforation	Discharge voltage, V	Discharge time, μsec
[a]2-12-64-2	0.0327	(b)	14.7	(c)	(d)	--
		(b)	13.2	(c)	200	<5
		(b)	11.4	(c)	(d)	--
		56	10.7	(c)	(d)	--
		(b)	9.4	(c)	(d)	--
		63	8.7	(c)	200	<5
		51	7.7	(c)	(d)	--
		(b)	6.2	(c)	(d)	--
[a]2-12-64-9	0.0322	61	13.2	(c)	0.1	5
		66	10.7	(c)	0.2	5
		(b)	9.4	(c)	0.9	10
		41	7.5	(c)	(d)	--
		(b)	7.1	(c)	(d)	--
[a]2-12-64-10	0.0235	51	11.9	(c)	210	<5
		(b)	[e]10.6	(c)	225	<5
		(b)	[e]10.3	(c)	230	<5
		(b)	9.7	(c)	(d)	--
		(b)	7.2	(c)	(d)	--
		(b)	5.6	(c)	(d)	--

[a]No rear flash.
[b]The in-flight signal indicating diameter was outside the calibrated region.
[c]Not measured because instrumentation was not in operation.
[d]Below threshold of detection.
[e]Impact flash not observed, velocity calculated from sensor signal.

TABLE 11.- DATA FROM NAA IMPACT TESTS

Sensor type: B-1

Sensor size: 8.9 × 8.9 cm

Applied voltage: +15 V

Backing: Foam tape

Added capacitance: None

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Perforation	Discharge voltage, V	Discharge time, μsec
[a]5307	0.0307	(b)	13.0	Yes	13.7	<5
		(b)	10.9	No	(c)	--
		(b)	10.6	No	(c)	--
		52	10.3	Yes	(c)	--
		50	9.8	No	(c)	--
		(b)	9.0	No	(c)	--
		(b)	8.8	No	(c)	--
		(b)	8.2	No	(c)	--
		(b)	8.0	No	(c)	--
		54	7.7	No	(c)	--
		(b)	7.6	No	(c)	--

[a]The vertical gain of the oscilloscope was calibrated with a battery.

[b]The in-flight signal indicating diameter was outside the calibrated region.

[c]Below threshold of detection.

TABLE 12.- DATA FROM NAA IMPACT TESTS

Sensor type: B-1
Sensor size: 8.9 × 8.9 cm
Applied voltage: +60 V
Backing: Foam tape
Added capacitance: None

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Perforation	Discharge voltage, V	Discharge time, μsec
5062	0.0286	(a)	12.6	Yes	0.8	10
		(a)	12.2	Yes	16	20

[a]The in-flight signal indicating diameter was outside the calibrated region.

TABLE 13.- DATA FROM NAA IMPACT TESTS

Sensor type: B-1
Sensor size: 8.9 × 8.9 cm
Applied voltage: -60 V
Backing: Foam tape
Added capacitance: None

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Perforation	Discharge voltage, V	Discharge time, μsec
4560	0.0287	(a)	10.6	Yes	(b)	--
		49	9.8	Yes	(b)	--
4562	0.0243	51	12.6	Yes	41	3
		(a)	4.6	Yes	35	<5
4564	0.0304	(a)	9.5	Yes	38	<5
		49	6.4	No	(b)	--
		49	5.1	No	(b)	--

[a]The in-flight signal indicating diameter was outside the calibrated region.
[b]Below threshold of detection.

TABLE 14.- DATA FROM NAA IMPACT TESTS

Sensor type: B-1

Sensor size: 8.9 × 8.9 cm

Applied voltage: +240 V

Backing: Foam tape

Added capacitance: None

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Perforation	Discharge voltage, V	Discharge time, μsec
[a]5308	0.0286	(b)	13.0	Yes	220	<5
		(b)	10.6	No	(c)	--
		(b)	9.8	No	(c)	--
		(b)	9.4	No	(c)	--
		(b)	8.8	No	(c)	--
		53	8.0	Yes	(c)	--
		(b)	7.0	No	(c)	--
		(b)	6.6	No	(c)	--
		(b)	6.5	No	(c)	--
[a]5309	0.0290	47.5	9.2	Yes	120	<5
		(b)	8.8	No	(c)	--
		(b)	8.7	No	120	<5
		(b)	8.2	Yes	(c)	--
		(b)	7.9	Yes	(c)	--
		(b)	7.7	No	(c)	--
		(b)	7.6	No	(c)	--
		(b)	6.8	No	(c)	--
		(b)	6.5	No	(c)	--
		(b)	5.6	No	(c)	--
[a]5310	0.0297	46	11.2	Yes	200	<5
		50.5	10.7	Yes	200	<5
		(b)	6.8	No	(c)	--

[a]The sensor signal was attenuated by a factor of 10 so that it could be displayed on the oscilloscope.

[b]The in-flight signal indicating diameter was outside the calibrated region.

[c]Below threshold of detection.

TABLE 15.- DATA FROM NAA IMPACT TESTS

Sensor type: B-1

Sensor size: 20.3 × 20.3 cm

Applied voltage: +15 V

Backing: None

Added capacitance: None

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Perforation	Discharge voltage, V	Discharge time, μsec
[a]4766	0.1672	(b)	12.2	Yes	(c)	---
		(b)	11.9	Yes	(c)	---
		(b)	11.5	Yes	(c)	---
		(b)	8.9	Yes	(c)	---
		(b)	7.8	No	(c)	---
		(b)	7.6	No	(c)	---
		(b)	7.2	No	(c)	---
		(b)	5.0	No	(c)	---
5326	0.1707	53	7.6	No	(c)	---
		(b)	7.5	No	(c)	---
		(b)	5.8	Yes	(c)	---
5555	0.1613	(b)	13.7	Yes	0.11	30
		(b)	12.4	Yes	0.13	<5
		(b)	11.8	No	(c)	---
		(b)	11.4	No	(c)	---
		(b)	11.2	No	0.20	<5
		(b)	10.0	No	(c)	---
		51.5	9.5	Yes	(c)	---
		(b)	8.2	No	(c)	---
		(b)	8.0	Yes	(c)	---
		(b)	6.6	No	(c)	---
5560	0.1586	(b)	8.8	No	(c)	---
		(b)	8.2	Yes	0.04	400
		(b)	4.6	No	(c)	---

See footnotes at end of table, p. 49.

TABLE 15.- DATA FROM NAA IMPACT TESTS – Continued

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Perforation	Discharge voltage, V	Discharge time, μsec
5561	0.1585	(b)	13.3	No	0.02	100
		(b)	9.4	No	(c)	----
		(b)	7.5	Yes	(c)	----
		53	7.2	No	0.12	450
		(b)	6.8	No	(c)	----
		54.5	6.7	No	(c)	----
		47	6.6	No	(c)	----
		(b)	6.1	No	(c)	----
		(b)	5.8	No	(c)	----
		(b)	5.2	No	(c)	----
5562	0.1585	(b)	12.4	Yes	0.11	250
		(b)	11.5	Yes	(c)	----
		(b)	10.9	Yes	(c)	----
		54	7.4	Yes	(c)	----
		(b)	6.9	Yes	0.45	<5
		(b)	5.7	No	(c)	----
		(b)	5.1	No	(c)	----
5563	0.1618	(b)	13.5	Yes	0.04	285
		(b)	10.5	No	(c)	----
		50.5	7.8	Yes	(c)	----
		(b)	6.9	Yes	0.6	<5

See footnotes at end of table, p. 49.

TABLE 15.- DATA FROM NAA IMPACT TESTS – Concluded

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Perforation	Discharge voltage, V	Discharge time, μsec
5565	0.1617	(b)	13.7	No	(c)	----
		(b)	12.6	No	(c)	----
		49.5	12.0	Yes	0.10	200
		(b)	9.2	No	(c)	----
		(b)	7.9	No	(c)	----
		(b)	7.4	No	(c)	----
		(b)	7.3	Yes	0.2	300
		49.5	6.5	No	(c)	----
		(b)	6.4	No	(c)	----
		54	5.5	No	(c)	----
		55.5	4.5	No	(c)	----
		(b)	4.2	Yes	0.3	Fast
		(b)	4.1	No	(c)	----
5566	0.1611	(b)	13.9	Yes	0.06	30
		(b)	12.6	Yes	0.09	30
		(b)	11.8	Yes	(c)	----
		54	11.5	Yes	0.30	400
		(b)	10.0	No	(c)	----
		(b)	9.2	No	(c)	----
		(b)	7.1	No	(c)	----
		(b)	6.5	No	(c)	----

[a]In-flight photometer malfunction. The vertical gain of the oscilloscope was calibrated with a battery.

[b]The in-flight signal indicating diameter was outside the calibrated region.

[c]Below threshold of detection.

TABLE 16.- DATA FROM NAA IMPACT TESTS

Sensor type: B-1
Sensor size: 20.3 × 20.3 cm
Applied voltage: -15 V
Backing: None
Added capacitance: None

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Perforation	Discharge voltage, V	Discharge time, μsec
[a]4757	0.1537	(b)	9.0	No	0.009	575
[a]4758	0.1547	(b)	14.4	Yes	0.5	170
		(b)	12.2	No	(c)	--------
		49	11.4	No	(c)	--------
		(b)	10.7	No	(c)	--------
		(b)	[d]9.0	No	0.7	<5
[a]4759	0.1609	(b)	8.2	No	0.006	500
[a]4760	0.1622	(b)	13.9	Yes	0.05	Uncertain
		(b)	12.0	Yes	(c)	--------
		(b)	11.9	No	(c)	--------
		(b)	9.6	No	(c)	--------
		(b)	8.7	No	(c)	--------
		(b)	7.1	No	(c)	--------
		(b)	6.6	No	(c)	--------
		(b)	5.2	No	(c)	--------
[a]4761	0.1606	(b)	15.0	Yes	0.03	10
		(b)	13.3	Yes	0.05	10
		(b)	11.7	Yes	0.10	10
		(b)	8.2	No	(c)	--------

See footnotes at end of table, p. 51.

TABLE 16.- DATA FROM NAA IMPACT TESTS – Concluded

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Perforation	Discharge voltage, V	Discharge time, μsec
[a,e]4762	0.1532	52	11.9	No	(c)	---
		(b)	10.3	Yes	(c)	---
		(b)	9.8	Yes	(c)	---
		(b)	9.6	Yes	(c)	---
		(b)	9.1	Yes	(c)	---
		(b)	9.0	Yes	(c)	---
		(b)	8.6	Yes	(c)	---
		(b)	8.5	No	(c)	---
		(b)	8.2	No	(c)	---
		(b)	5.7	No	(c)	---
		(b)	5.5	No	(c)	---
[a]4763	0.1579	(b)	13.5	Yes	0.05	10
		(b)	12.2	No	0.20	50
		(b)	8.5	No	(c)	---
		(b)	6.6	No	(c)	---
[a]5243	0.1581	(b)	12.6	Yes	0.10	50
5323	0.1674	(b)	11.4	Yes	(c)	---
		52	11.2	Yes	0.07	100
5550	0.1607	(b)	10.0	No	(c)	---
		(b)	9.8	No	(c)	---
		(b)	8.3	Yes	0.01	50
		(b)	7.8	No	(c)	---
		(b)	6.7	Yes	0.03	150
		50.5	6.0	No	(c)	---
		56	5.4	No	0.05	250
5551	0.1617	56	10.3	Yes	0.02	50
		(b)	7.1	No	0.05	400

[a]The vertical gain of the oscilloscope was calibrated with a battery.
[b]The in-flight signal indicating diameter was outside the calibrated region.
[c]Below threshold of detection.
[d]Impact flash not observed; velocity calculated from sensor signal.
[e]In-flight photometer malfunction. Sensor signal very ragged.

TABLE 17.- DATA FROM NAA IMPACT TESTS

Sensor type: B-1

Sensor size: 20.3 × 20.3 cm

Applied voltage: -60 V

Backing: None

Added capacitance: None

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Perforation	Discharge voltage, V	Discharge time, μsec
[a]4569	0.1638	(b)	11.5	Yes	(c)	---
		(b)	10.9	Yes	(c)	---
		(b)	10.3	Yes	(c)	---
		(b)	7.9	Yes	(c)	---
[a]4570	0.1627	48	9.2	Yes	28	1.0
		48	8.5	Yes	44	<5
		48	7.1	Yes	(d)	---
		48	6.9	No	(d)	---

[a]The vertical gain of the oscilloscope was calibrated with a battery.

[b]The in-flight signal indicating diameter was outside the calibrated region.

[c]Oscilloscope malfunction.

[d]Below threshold of detection.

TABLE 18.- DATA FROM NAA IMPACT TESTS

Sensor type: B-1

Sensor size: 20.3×20.3 cm

Applied voltage: +120 V

Backing: None

Added capacitance: None

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Perforation	Discharge voltage, V	Discharge time, μsec
[a]4576	0.1523	(b)	13.0	No	0.002	10
		45	8.9	Yes	0.1	80
		52	6.0	No	(c)	---
[a]4577	0.1613	53	9.4	No	(c)	---
		44	7.5	No	(c)	---
		47	5.0	No	(c)	---
[d]5318	0.1710	(b)	12.0	Yes	(c)	---
		(b)	11.5	No	(c)	---
		56	9.8	No	(c)	---
		(b)	9.5	No	(c)	---
		(b)	9.0	No	(c)	---
		47.5	7.2	No	(c)	---
		(b)	7.1	No	(c)	---
		50.5	7.0	No	(c)	---
[d]5319	0.1655	54.5	10.5	Yes	(c)	---
		49.5	7.4	Yes	(c)	---
		(b)	7.2	Yes	(c)	---
[d]5320	0.1660	(b)	7.7	Yes	0.08	475
		(b)	7.0	Yes	(c)	---
		(b)	6.4	No	(c)	---
		(b)	6.2	No	(c)	---
[d]5321	0.1682	56	9.2	No	(c)	---
		56	8.8	No	0.01	200

See footnotes at end of table, p. 54.

TABLE 18.- DATA FROM NAA IMPACT TESTS – Concluded

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Perforation	Discharge voltage, V	Discharge time, μsec
[d]5544	0.1627	(b)	13.4	No	0.02	50
		(b)	13.0	Yes	0.06	80
		(b)	9.3	Yes	0.09	30
		(b)	8.8	No	(c)	---
		(b)	8.7	Yes	0.17	535
[d]5545	0.1580	(b)	10.9	Yes	0.5	100
		(b)	10.0	Yes	(c)	---
		(b)	9.8	Yes	(c)	---
		(b)	9.4	No	(c)	---
		(b)	9.2	No	(c)	---
		47.5	9.0	No	(c)	---
		56	8.5	Yes	(c)	---
		(b)	7.8	No	(c)	---
		46	7.4	No	(c)	---
		(b)	5.6	No	(c)	---
		51.5	5.1	No	(c)	---

[a]The vertical gain of the oscilloscope was calibrated with a battery.

[b]The in-flight signal indicating diameter was outside the calibrated region.

[c]Below threshold of detection.

[d]The sensor signal was attenuated by a factor of 10 so that it could be displayed on the oscilloscope.

TABLE 19.- DATA FROM NAA IMPACT TESTS

Sensor type: B-1

Sensor size: 20.3 × 20.3 cm

Applied voltage: -120 V

Backing: None

Added capacitance: None

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Perforation	Discharge voltage, V	Discharge time, μsec
[a]4571	0.1576	(b)	[c]12.8	Yes	0.25	40
		52	[c]11.1	Yes	0.6	600
[a]5239	0.1581	(b)	8.4	Yes	104	1.3
[a]5240	0.1582	(b)	12.4	Yes	112	<5
[d]5316	0.1688	(b)	8.2	No	(e)	----
		(b)	7.2	Yes	0.013	----
[d]5317	0.1592	(b)	11.2	Yes	0.005	10
		(b)	10.9	No	0.01	30
		(b)	10.0	Yes	(e)	----
		(b)	9.5	Yes	0.013	5
		(b)	6.7	Yes	0.015	5
		53	6.2	No	0.020	5
[d]5546	0.1544	(b)	14.4	No	0.03	60
		(b)	9.4	Yes	0.065	65
		(b)	8.0	Yes	0.5	300
		(b)	6.0	No	(e)	----
[d]5547	0.1598	(b)	12.6	Yes	0.04	60
		(b)	11.2	No	(e)	----
		(b)	9.7	No	0.08	420
		(b)	9.0	No	(e)	----
		49.5	6.8	No	(e)	----
		(b)	5.1	No	0.09	30
		(b)	4.9	Yes	55	<5
		(b)	4.6	Yes	60	<5
		(b)	4.0	Yes	65	<5

See footnotes at end of table, p. 56.

TABLE 19.- DATA FROM NAA IMPACT TESTS – Concluded

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Perforation	Discharge voltage, V	Discharge time, μsec
[d]5548	0.1524	(b)	11.1	Yes	0.14	165
		(b)	8.2	No	(e)	---
		(b)	7.6	No	0.17	65
		(b)	7.5	No	(e)	---
		(b)	7.3	No	(e)	---
		(b)	6.8	Yes	0.2	---
		54	6.2	No	(e)	---
		(b)	6.1	No	(e)	---
		(b)	5.9	No	(e)	---
		(b)	5.8	Yes	(e)	---
		(b)	5.6	Yes	(e)	---
		(b)	5.3	No	(e)	---
		(b)	5.2	No	(e)	---
		(b)	5.0	No	(e)	---
[d]5549	0.1537	47	7.5	Yes	0.04	400

[a]The vertical gain of the oscilloscope was calibrated with a battery.

[b]The in-flight signal indicating diameter was outside the calibrated region.

[c]Impact flash not observed; velocity calculated from perforation flash.

[d]The sensor signal was attenuated by a factor of 10 so that it could be displayed on the oscilloscope.

[e]Below threshold of detection.

TABLE 20.- DATA FROM NAA IMPACT TESTS

Sensor type: B-1
Sensor size: 20.3 × 305 cm
Applied voltage: +15 V
Backing: None
Added capacitance: None

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Perforation	Discharge voltage, V	Discharge time, μsec	Position (a)
5403	2.060	(b)	15.5	Yes	0.01	>5	2
		(b)	12.6	Yes	(c)	---	
5407	2.050	55.5	13.0	No	(c)	---	6
		(b)	12.0	Yes	(c)	---	
5408	2.045	(b)	10.7	No	(c)	---	7
		(b)	8.4	Yes	(c)	---	
5409	2.045	(b)	7.5	Yes	(c)	---	8
		(b)	7.3	Yes	(c)	---	
		(b)	6.7	No	(c)	---	
5413	2.045	(b)	15.2	No	(c)	---	12
		(b)	13.9	No	(c)	---	
		(b)	13.0	Yes	(c)	---	
		(b)	9.2	No	(c)	---	
		(b)	8.6	No	(c)	---	
		(b)	8.0	No	(c)	---	
5414	2.291	(b)	10.6	Yes	0.01	20	1
		(b)	5.7	No	(c)	---	
5417	2.283	(b)	9.7	No	(c)	---	4
		(b)	9.5	Yes	(c)	---	
		(b)	8.2	Yes	0.005	100	
		(b)	7.9	Yes	(c)	---	
		(b)	7.5	Yes	(c)	---	
		53	7.3	Yes	(c)	---	
		47.5	7.2	No	(c)	---	
		(b)	7.1	No	(c)	---	
		(b)	6.0	No	(c)	---	
		(b)	4.8	No	(c)	---	

See footnotes at end of table, p. 59.

TABLE 20.- DATA FROM NAA IMPACT TESTS – Continued

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Perforation	Discharge voltage, V	Discharge time, μsec	Position (a)
5418	2.280	(b)	11.2	No	(c)	----	5
		(b)	11.0	Yes	(c)	----	
5419	2.279	(b)	9.0	No	(c)	----	6
		(b)	8.8	No	(c)	----	
		(b)	8.4	Yes	(c)	----	
		(b)	7.6	Yes	(c)	----	
		46	7.2	No	(c)	----	
		(b)	6.6	No	(c)	----	
		(b)	5.4	No	(c)	----	
5420	2.279	(b)	12.6	No	(c)	----	7
		(b)	10.9	No	(c)	----	
		(b)	10.6	Yes	(c)	----	
		(b)	9.4	Yes	0.013	170	
		(b)	7.8	No	(c)	----	
5422	2.242	56	9.2	Yes	(c)	----	9
		(b)	9.1	Yes	(c)	----	
5423	2.243	46	7.8	Yes	(c)	----	10
		(b)	7.0	No	(c)	----	
		46	6.5	Yes	(c)	----	
		51	6.2	No	(c)	----	
		(b)	6.0	Yes	(c)	----	
		(b)	5.8	Yes	(c)	----	
		(b)	5.1	No	(c)	----	
		(b)	4.7	No	(c)	----	
5424	2.243	(b)	8.9	Yes	(c)	----	11
5427	2.242	(b)	9.5	Yes	(c)	----	14
		(b)	8.2	Yes	(c)	----	
		(b)	5.1	No	(c)	----	
5429	2.172	(b)	11.7	Yes	0.1	Fast	1
		(b)	10.1	Yes	(c)	----	
		(b)	9.1	Yes	(c)	----	
		(b)	8.9	Yes	(c)	----	

See footnotes at end of table, p. 59.

TABLE 20.- DATA FROM NAA IMPACT TEST – Concluded

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Perforation	Discharge voltage, V	Discharge time, μsec	Position (a)
5433	2.143	(b)	13.3	Yes	(c)	---	5
		(b)	11.7	Yes	(c)	---	
		(b)	11.6	No	(c)	---	
		(b)	9.5	No	(c)	---	
5435	2.143	(b)	10.5	Yes	(c)	---	7
		(b)	8.6	Yes	(c)	---	
		(b)	7.6	Yes	(c)	---	
		(b)	7.4	Yes	(c)	---	

[a]Identification of the impact area along the 305-cm side of the sensor.

[b]The in-flight signal indicating diameter was outside the calibrated region.

[c]Below threshold of detection.

TABLE 21.- DATA FROM NAA IMPACT TESTS

Sensor type: B-1
Sensor size: 20.3 × 305 cm
Applied voltage: -15 V
Backing: None
Added capacitance: None

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Perforation	Discharge voltage, V	Discharge time, μsec	Position (a)
5438	2.197	(b)	11.5	Yes	(c)	--	1
		(b)	8.7	No	(c)	--	
		49.5	6.4	No	(c)	--	
		(b)	6.0	No	(c)	--	
5439	2.184	(b)	6.4	Yes	(c)	--	1
5440	2.182	(b)	16.8	No	(c)	--	2
		(b)	15.2	Yes	(c)	--	
		(b)	9.5	No	(c)	--	
		(b)	7.2	Yes	(c)	--	
5441	2.177	(b)	13.0	No	(c)	--	3
		(b)	9.4	Yes	(c)	--	
		(b)	5.6	No	(c)	--	
		(b)	4.7	No	(c)	--	
5442	2.168	(b)	9.6	Yes	0.05	<5	4
		(b)	[d]9.5	Yes	.30	<5	
		(b)	[d]9.3	Yes	.31	<5	
		(b)	[d]8.8	Yes	.32	<5	
		(b)	[d]8.4	Yes	.50	<5	
		(b)	7.6	No	(c)	--	
		(b)	6.4	No	(c)	--	
		(b)	4.9	No	(c)	--	
		(b)	4.6	No	(c)	--	

See footnotes at end of table, p. 61.

TABLE 21.- DATA FROM NAA IMPACT TESTS – Concluded

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Perforation	Discharge voltage, V	Discharge time, μsec	Position (a)
5444	2.038	(b)	9.7	Yes	(c)	--	1
		50.5	9.0	No	(c)	--	
		(b)	8.6	No	(c)	--	
		(b)	7.9	No	(c)	--	
		(b)	7.4	No	(c)	--	
5446	2.002	(b)	9.5	Yes	(c)	--	3
		47.5	8.4	Yes	(c)	--	
		(b)	7.4	No	(c)	--	
		46	7.1	No	(c)	--	
		(b)	6.1	No	(c)	--	

[a]Identification of the impact area along the 305-cm side of the sensor.

[b]The in-flight signal indicating diameter was outside the calibrated region.

[c]Below threshold of detection.

[d]Impact flash not observed; velocity calculated from rear flash.

TABLE 22.- DATA FROM NAA IMPACT TESTS

Sensor type: B-1

Sensor size: 20.3 × 305 cm

Applied voltage: +120 V

Backing: None

Added capacitance: None

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Perforation	Discharge voltage, V	Discharge time, μsec	Position (a)
[b]5381	2.19	(c)	12.6	Yes	0.015	50	1
[b]5382	2.19	(c)	13.0	Yes	(d)	---	2
		(c)	12.6	Yes	0.010	80	
		(c)	10.7	No	.017	100	
		(c)	5.1	No	(d)	---	
[b]5383	2.187	(c)	9.8	No	(d)	---	1
		(c)	9.4	No	(d)	---	
		(c)	8.8	No	(d)	---	
		(c)	8.4	No	(d)	---	
[b]5384	2.185	(c)	11.2	Yes	0.01	80	2
		(c)	9.6	No	(d)	---	
		50.5	9.5	No	(d)	---	
		(c)	8.1	No	(d)	---	
		(c)	7.8	Yes	.02	80	
		50.5	7.7	Yes	(d)	---	
		(c)	7.6	No	(d)	---	
		(c)	7.5	No	(d)	---	
		(c)	7.4	No	(d)	---	
		(c)	7.3	No	(d)	---	
		53	4.7	No	(d)	---	
[b]5385	2.182	(c)	9.2	Yes	(d)	---	3
		54.5	9.1	Yes	(d)	---	
		(c)	8.9	No	(d)	---	
		(c)	8.8	No	85	<5	
		(c)	7.8	No	(d)	---	

See footnotes at end of table, p. 63.

TABLE 22.- DATA FROM NAA IMPACT TESTS – Concluded

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Perforation	Discharge voltage, V	Discharge time, μsec	Position (a)
[b]5386	2.179	(c)	11.8	Yes	0.01	100	4
[b]5388	2.127	(c)	11.2	Yes	(d)	---	6
		(c)	10.9	Yes	0.015	60	
		(c)	[e]10.6	Yes	(d)	---	
		(c)	9.4	Yes	83	<5	
		46	[e]9.2	Yes	(d)	---	
		56	8.0	No	(d)	---	
[b]5392	2.380	(c)	8.1	No	(d)	---	3
		54	7.9	Yes	(d)	---	
[b]5397	2.36	(c)	11.4	Yes	0.01	60	8
		(c)	9.2	No	(d)	---	
		(c)	8.8	No	(d)	---	
		(c)	8.2	No	(d)	---	
		(c)	7.3	Yes	0.02	150	
		(c)	7.0	Yes	(d)	---	
		(c)	4.3	No	(d)	---	
[b]5400	2.355	(c)	11.2	Yes	80	<5	11
		(c)	10.1	Yes	(d)	---	
		(c)	9.3	Yes	(d)	---	
		(c)	8.4	Yes	(d)	---	
		(c)	8.5	No	(d)	---	
		(c)	6.6	No	(d)	---	

[a]Identification of the impact area along the 305-cm side of the sensor.

[b]The sensor signal was attenuated by a factor of 10 so that it could be displayed on the oscilloscope.

[c]The in-flight signal indicating diameter was outside the calibrated region.

[d]Below threshold of detection.

[e]Impact flash not observed; velocity calculated from rear flash.

TABLE 23.- DATA FROM NAA IMPACT TESTS

Sensor type: B-1
Sensor size: 20.3 × 305 cm
Applied voltage: -120 V
Backing: None
Added capacitance: None

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Perforation	Discharge voltage, V	Discharge time, μsec	Position (a)
[b]5261	2.240	(c)	13.0	Yes	(d)	---	
		(c)	11.9	Yes	(d)	---	
		(c)	11.2	Yes	(d)	---	
		(c)	10.9	Yes	(d)	---	
		49.5	10.7	Yes	(d)	---	
		(c)	10.5	Yes	(d)	---	
		49	10.3	Yes	(d)	---	
		53	10.1	Yes	(d)	---	
		(c)	9.8	Yes	(d)	---	
[b]5448	2.004	(c)	8.9	Yes	(d)	---	2
		46	8.7	No	(d)	---	
		(c)	8.5	No	(d)	---	
		(c)	8.1	Yes	(d)	---	
		(c)	6.9	No	(d)	---	
		(c)	6.7	Yes	(d)	---	
		(c)	6.6	No	90	6	
		51	6.0	No	(d)	---	
		(c)	4.8	No	(d)	---	
[b]5451	1.976	(c)	11.2	Yes	(d)	---	5
		(c)	11.1	Yes	(d)	---	
		(c)	10.2	Yes	(d)	---	
		(c)	9.3	Yes	(d)	---	
		(c)	9.2	Yes	(d)	---	
		(c)	8.9	Yes	60	5	
		(c)	6.6	No	(d)	---	
		(c)	5.6	No	(d)	---	

See footnotes at end of table, p. 65.

TABLE 23.- DATA FROM NAA IMPACT TESTS – Concluded

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Perforation	Discharge voltage, V	Discharge time, μsec	Position (a)
[b]5452	2.158	(c)	6.6	Yes	(d)	---	2
		47.5	6.4	No	(d)	---	
		(c)	5.9	No	(d)	---	
		(c)	5.6	No	(d)	---	
		(c)	5.2	No	(d)	---	
		(c)	5.0	No	(d)	---	

[a]Identification of the impact area along the 305-cm side of the sensor.

[b]The sensor signal was attenuated by a factor of 10 so that it could be displayed on the oscilloscope.

[c]The in-flight signal indicating diameter was outside the calibrated region.

[d]Below threshold of detection.

TABLE 24.- DATA FROM NAA IMPACT TESTS

Sensor type: B-1

Sensor size: 20.3×305 cm

Applied voltage: +240 V

Backing: None

Added capacitance: None

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Perforation	Discharge voltage, V	Discharge time, μsec	Position (a)
[b]5369	2.288	47	7.6	Yes	(c)	---	
[b]5375	2.285	(d)	10.6	Yes	200	<5	1
[b]5378	2.279	(d)	10.3	Yes	190	6	4
		(d)	10.1	Yes	(c)	---	
		(d)	8.8	Yes	(c)	---	
		(d)	8.2	No	(c)	---	
[b]5379	2.279	46	11.8	No	(c)	---	5
		(d)	9.2	Yes	190	5	
[b]5380	2.277	(d)	11.8	Yes	0.01	50	6
		54	10.1	Yes	200	5	
		(d)	10.0	No	(c)	---	
		(d)	7.8	No	(c)	---	
		(d)	7.0	No	(c)	---	
		52	6.5	No	(c)	---	
[b]5539	1.884	46	11.5	Yes	0.02	60	1
		(d)	8.7	Yes	0.03	50	
		(d)	8.1	Yes	0.04	450	
		(d)	6.7	No	(c)	---	

[a]Identification of the impact area along the 305-cm side of the sensor.

[b]The sensor signal was attenuated by a factor of 10 so that it could be displayed on the oscilloscope.

[c]Below threshold of detection.

[d]The in-flight signal indicating diameter was outside the calibrated region.

TABLE 25.- DATA FROM NAA IMPACT TESTS

Sensor type: B-1

Sensor size: 20.3 × 305 cm

Applied voltage: -240 V

Backing: None

Added capacitance: None

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Perforation	Discharge voltage, V	Discharge time, μsec	Position (a)
[b]5258	2.576	(c)	11.8	Yes	(d)	--	
		(c)	11.2	Yes	(d)	--	
		(c)	10.6	No	(d)	--	
		(c)	10.2	No	(d)	--	
[b]5259	2.573	(c)	8.6	Yes	(d)	--	
		(c)	6.6	Yes	180	6	
[b]5260	2.128	(c)	12.7	No	(d)	--	
		(c)	12.2	Yes	140	5	
		(c)	11.5	Yes	(d)	--	
		46	10.9	Yes	(d)	--	
		(c)	9.4	No	(d)	--	
		(c)	9.2	Yes	(d)	--	
[b]5454	2.158	(c)	6.8	Yes	(d)	--	2
		47.5	6.4	No	(d)	--	
		(c)	5.9	No	(d)	--	
		(c)	5.5	No	(d)	--	
		(c)	5.2	No	(d)	--	
		(c)	5.0	No	(d)	--	

See footnotes at end of table, p. 69.

TABLE 25.- DATA FROM NAA IMPACT TESTS – Continued

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Perforation	Discharge voltage, V	Discharge time, μsec	Position (a)
[b]5455	2.109	(c)	11.5	Yes	(d)	--	1
		(c)	11.2	Yes	(d)	--	
		(c)	11.1	Yes	(d)	--	
		52	10.1	Yes	(d)	--	
		(c)	9.2	Yes	(d)	--	
		(c)	8.7	Yes	(d)	--	
		(c)	8.0	Yes	(d)	--	
		46	7.0	No	(d)	--	
		(c)	5.5	No	(d)	--	
		47.5	5.2	No	(d)	--	
		(c)	5.0	Yes	65	5	
		(c)	4.9	Yes	(d)	--	
[b]5456	2.109	(c)	13.6	Yes	(d)	--	2
		(c)	10.9	Yes	(d)	--	
		(c)	9.1	Yes	(d)	--	
		(c)	7.8	No	(d)	--	
[b]5459	2.385	(c)	11.2	No	(d)	--	3
		(c)	10.6	Yes	(d)	--	
		(c)	6.9	Yes	(d)	--	
[b]5460	2.393	(c)	12.4	Yes	(d)	--	4
		(c)	9.6	Yes	(d)	--	
		(c)	9.0	No	(d)	--	
		(c)	7.3	No	(d)	--	
		(c)	7.0	Yes	(d)	--	
		(c)	6.2	Yes	70	<5	
		(c)	5.1	No	(d)	--	
		(c)	4.7	No	(d)	--	

See footnotes at end of table, p. 69.

TABLE 25.- DATA FROM NAA IMPACT TESTS – Concluded

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Perforation	Discharge voltage, V	Discharge time, μsec	Position (a)
[b]5461	2.393	(c)	12.6	No	(d)	---	5
		(c)	11.5	Yes	(d)	---	
		(c)	11.4	Yes	(d)	---	
		(c)	10.6	No	(d)	---	
		(c)	9.6	No	(d)	---	
		(c)	8.2	No	(d)	---	
		(c)	7.7	No	(d)	---	
		(c)	7.4	No	(d)	---	
[b]5537	2.387	(c)	11.2	Yes	(d)	---	9
		56	9.8	No	(d)	---	

[a]Identification of the impact area along the 305-cm side of the sensor.

[b]The sensor signal was attenuated by a factor of 10 so that it could be displayed on the oscilloscope.

[c]The in-flight signal indicating diameter was outside the calibrated region.

[d]Below threshold of detection.

TABLE 26.- DATA FROM NAA IMPACT TESTS

Sensor type: B-1

Sensor size: 8.9 × 8.9 cm

Applied voltage: +15 V

Backing: None

Added capacitance: 0.13 μF

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Perforation	Discharge voltage, V	Discharge time, μsec
[a]4784	0.1594	(b)	11.6	No	(c)	--
		48	8.9	Yes	(c)	--
		49	8.1	No	(c)	--
[a]4785	0.1605	(b)	11.5	No	(c)	--
		(b)	10.9	Yes	(c)	--
		49	9.6	Yes	(c)	--
		54	9.1	No	(c)	--
		(b)	7.8	No	0.1	<5
		(b)	6.4	No	0.1	<5
		(b)	5.2	No	(c)	--
[a]4787	0.1608	54	10.3	No	(c)	--
		(b)	10.0	Yes	(c)	--
		(b)	9.5	No	(c)	--
		45	8.8	No	(c)	--
		(b)	8.7	No	(c)	--
		(b)	8.6	Yes	(c)	--
		47	8.2	Yes	(c)	--
		(b)	8.1	Yes	(c)	--
		52	7.4	Yes	(c)	--
		52	[d]7.2	Yes	(c)	--
		(b)	7.1	No	(c)	--
		(b)	6.6	No	(c)	--
		(b)	6.4	No	(c)	--
		(b)	5.7	No	(c)	--
		53	5.2	No	(c)	--
		(b)	5.1	No	(c)	--

See footnotes at end of table, p. 72.

TABLE 26.- DATA FROM NAA IMPACT TESTS – Continued

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Perforation	Discharge voltage, V	Discharge time, μsec
[a]4789	0.1606	(b)	11.9	Yes	0.05	<5
		(b)	9.1	No	0.15	<5
		(b)	7.7	No	(c)	----
		50	6.4	No	(c)	----
		(b)	6.3	No	(c)	----
		(b)	6.2	No	(c)	----
		(b)	5.2	No	(c)	----
[a]4790	0.1699	(b)	14.7	Yes	0.1	Ring
		(b)	13.6	Yes	(c)	----
		(b)	13.0	Yes	0.3	110
		(b)	12.8	Yes	(c)	----
		(b)	12.6	No	(c)	----
		53	12.0	No	(c)	----
		47	11.6	No	(c)	----
		(b)	11.2	No	(c)	----
		(b)	9.6	No	0.5	400
		(b)	9.3	No	(c)	----
		(b)	9.0	No	(c)	----
		(b)	8.8	No	(c)	----
		(b)	8.4	No	(c)	----
		48	6.6	No	(c)	----

See footnotes at end of table, p. 72.

TABLE 26.- DATA FROM NAA IMPACT TESTS – Concluded

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Perforation	Discharge voltage, V	Discharge time, μsec
[a]5170	0.1600	(b)	12.6	No	0.3	2600
		(b)	12.2	Yes	(c)	----
		(b)	11.1	No	(c)	----
		(b)	10.9	No	(c)	----
		(b)	10.6	No	(c)	----
		46	9.6	No	(c)	----
		(b)	8.0	Yes	(c)	----
		(b)	7.7	Yes	(c)	----
		(b)	7.5	No	(c)	----
		(b)	6.3	Yes	(c)	----
		(b)	5.1	No	(c)	----

[a]The vertical gain of the oscilloscope was calibrated with a battery.

[b]The in-flight signal indicating diameter was outside the calibrated region.

[c]Below threshold of detection.

[d]Impact flash not observed; velocity calculated from rear flash.

TABLE 27.- DATA FROM NAA IMPACT TESTS

Sensor type: B-1
Sensor size: 8.9 × 8.9 cm
Applied voltage: -15 V
Backing: None
Added capacitance: 0.13 μF

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Perforation	Discharge voltage, V	Discharge time, μsec
[a]4791	0.1597	(b)	14.9	No	0.1	200
		(b)	14.4	Yes	(c)	----
		(b)	12.6	Yes	(c)	----
		(b)	11.2	Yes	(c)	----
		(b)	8.5	Yes	(c)	----
[a]4792	0.1593	(b)	11.1	No	(c)	----
		(b)	7.3	Yes	(c)	----
[a]4794	0.1596	(b)	10.1	Yes	0.05	100
[a]5168	0.1591	56	10.9	Yes	0.05	Ring
		54	9.6	Yes	(c)	----
		(b)	8.1	Yes	(c)	----
		(b)	[d]7.3	Yes	0.3	180
		(b)	[d]7.2	Yes	(c)	----

[a]The vertical gain of the oscilloscope was calibrated with a battery.
[b]The in-flight signal indicating diameter was outside the calibrated region.
[c]Below threshold of detection.
[d]Impact flash not observed; velocity calculated from rear flash.

TABLE 28.- DATA FROM NAA IMPACT TESTS

Sensor type: B-1

Sensor size: 8.9 × 8.9 cm

Applied voltage: +240 V

Backing: None

Added capacitance: 0.13 μF

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Perforation	Discharge voltage, V	Discharge time, μsec
[a]5312	0.1608	(b)	12.0	Yes	[c]275	<5
		47.5	10.1	Yes	(d)	--
		56.0	9.6	Yes	(d)	--
		(b)	9.5	Yes	(d)	--
		54	7.6	Yes	(d)	--
		(b)	6.5	No	(d)	--
[a]5541	0.1603	(b)	8.2	No	0.005	20
		49	6.5	No	0.02	35
		46	6.2	Yes	120	<5
[a]5543	0.1615	54.5	10.9	No	0.013	35
		55.5	10.0	Yes	[e]200	<5
		(b)	6.4	No	(d)	--
		(b)	6.3	No	(d)	--
		(b)	5.9	No	(d)	--
		(b)	5.2	No	(d)	--
		(b)	5.1	No	(d)	--
		46	4.8	No	(d)	--
		(b)	4.0	No	(d)	--

[a]The sensor signal was attenuated by a factor of 10 so that it could be displayed on the oscilloscope.

[b]The in-flight signal indicating diameter was outside the calibrated region.

[c]Discharge greater than applied voltage due to overshoot.

[d]Below threshold of detection.

[e]Overshoot on sensor signal.

TABLE 29.- DATA FROM NAA IMPACT TESTS

Sensor type: B-1

Sensor size: 8.9 × 8.9 cm

Applied voltage: +240 V

Backing: None

Added capacitance: 0.3 μF

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Perforation	Discharge voltage, V	Discharge time, μsec
[a]2-13-64-3	0.318	43	12.1	(b)	(c)	--
		(d)	11.9	(b)	0.45	40
		(d)	[e]10.9	(b)	0.50	20
		38	9.3	(b)	(c)	--
		43	7.9	(b)	(c)	--
		38	6.6	(b)	(c)	--

[a]No rear flash.

[b]Not measured because instrumentation was not in operation.

[c]Below threshold of detection.

[d]The in-flight signal indicating diameter was outside the calibrated region.

[e]Impact flash not observed; velocity calculated from sensor signal.

TABLE 30.- DATA FROM NAA IMPACT TESTS

Sensor type: B-1

Sensor size: 8.9 × 8.9 cm

Applied voltage: +15 V

Backing: None

Added capacitance: 2.3 μF

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Perforation	Discharge voltage, V	Discharge time, μsec
5328	2.6165	56	10.6	Yes	(a)	---
		49.5	9.8	No	(a)	---
		(b)	8.1	No	(a)	---
		46	7.4	No	(a)	---
		(b)	7.2	No	(a)	---
		(b)	5.3	No	(a)	---
5331	2.3310	(b)	12.2	Yes	(a)	---
5332	2.3314	55.5	10.5	Yes	(a)	---
		(b)	10.1	Yes	(a)	---
5335	2.3319	(b)	11.9	Yes	0.15	530
		(b)	6.9	No	(a)	---
5337	2.3321	(b)	13.9	Yes	(a)	---

[a]Below threshold of detection.

[b]The in-flight signal indicating diameter was outside the calibrated region.

TABLE 31.- DATA FROM NAA IMPACT TESTS

Sensor type: B-1

Sensor size: 8.9 × 8.9 cm

Applied voltage: +120 V

Backing: None

Added capacitance: -2.3 μF

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Perforation	Discharge voltage, V	Discharge time, μsec
[a]5341	2.3309	(b)	10.9	No	(c)	---
		(b)	6.8	Yes	(c)	---
[a]5348	2.3308	(b)	12.0	No	(c)	---
		49.5	10.1	Yes	0.01	100
		(b)	7.5	No	(c)	---
[a]5363	2.3301	(b)	13.7	Yes	95	10
		(b)	13.3	Yes	(c)	---
		(b)	12.6	Yes	(c)	---
		(b)	10.2	Yes	(c)	---
		(b)	9.7	Yes	(c)	---
		53	8.2	No	(c)	---
		(b)	[d]7.2	Yes	(c)	---
		(b)	6.5	No	(c)	---
[a]5364	2.3311	(b)	10.4	No	0.005	100
		(b)	5.5	No	(c)	---
		(b)	5.1	No	(c)	---

See footnotes at end of table, p. 78.

TABLE 31.- DATA FROM NAA IMPACT TESTS – Concluded

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Perforation	Discharge voltage, V	Discharge time, μsec
[a]5365	2.3311	(b)	15.5	Yes	(c)	--
		(b)	13.5	Yes	(c)	--
		(b)	13.0	Yes	(c)	--
		(b)	11.5	Yes	90	20
		(b)	[d]11.2	Yes	(c)	--
		(b)	10.5	No	(c)	--
		(b)	8.6	No	(c)	--
		47.5	7.5	Yes	(c)	--
		(b)	6.8	No	(c)	--
		(b)	5.6	No	(c)	--
		54	4.6	No	(c)	--

[a]The sensor signal was attenuated by a factor of 10 so that it could be displayed on the oscilloscope.

[b]The in-flight signal indicating diameter was outside the calibrated region.

[c]Below threshold of detection.

[d]Impact flash not observed; velocity calculated from rear flash.

TABLE 32.- DATA FROM NAA IMPACT TESTS

Sensor type: B-1

Sensor size: 8.9 × 8.9 cm

Applied voltage: +240 V

Backing: None

Added capacitance: 2.9 μF

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Perforation	Discharge voltage, V	Discharge time, μsec
[a]2-13-64-2	2.92	(b)	9.5	(c)	(d)	--
		46	7.9	(c)	(d)	--
		(b)	6.6	(c)	(d)	--
		(b)	6.5	(c)	(d)	--
		(b)	6.0	(c)	240	<5

[a]No rear flash.

[b]The in-flight signal indicating diameter was outside the calibrated region.

[c]Not measured because instrumentation was not in operation.

[d]Below threshold of detection.

TABLE 33.- DATA FROM NAA IMPACT TESTS

Sensor type: B-1

Sensor size: 8.9 × 8.9 cm

Applied voltage: +120 V

Backing: None

Added capacitance: 48 μF

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Perforation	Discharge voltage, V	Discharge time, μsec
[a]2-11-64-8	48.3	38	13.4	(b)	(c)	---
		41	12.7	(b)	(c)	---
		41	11.7	(b)	(c)	---
		38	7.9	(b)	[d]88	100

[a]No rear flash.

[b]Not measured because instrumentation was not in operation.

[c]Below threshold of detection.

[d]Sensor signal very ragged.

TABLE 34.- DATA FROM NAA IMPACT TESTS

Sensor type: B-2

Sensor size: 8.9 × 8.9 cm

Applied voltage: +15 V

Backing: None

Added capacitance: None

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Perforation	Discharge voltage, V	Discharge time, μsec
[a,b]11-19-63-2	0.0315	(c)	5.1	(c)	1.5	<5
		(c)	[d]5.0	(c)	2.75	<5
		(c)	[d]4.9	(c)	3.25	<5
		(c)	[d]4.8	(c)	3.30	<5
		(c)	[d]4.7	(c)	3.50	<5
		(c)	[d]4.68	(c)	3.85	<5
		(c)	[d]4.40	(c)	3.85	<5
[a,b]11-19-63-3	0.0315	(c)	9.1	(c)	0.010	--
		(c)	7.1	(c)	0.015	--
[a,b]11-19-63-4	0.0315	(c)	10.5	(c)	(e)	--
		(c)	9.1	(c)	1.75	<5
		(c)	[d]9.0	(c)	1.50	<5
		(c)	[d]8.7	(c)	4.00	<5
		(c)	[d]8.5	(c)	4.50	<5
		(c)	[d]7.7	(c)	4.50	<5
		(c)	[d]4.0	(c)	4.50	<5
[a,b]11-19-63-5	0.0311	(c)	11.4	(c)	0.01	10
		(c)	6.7	(c)	(e)	--
[a,b]11-19-63-6	0.062	(c)	19.1	(c)	(e)	--
		(c)	16.6	(c)	(e)	--
		(c)	16.2	(c)	(e)	--
		(c)	15.9	(c)	(e)	--
		(c)	14.4	(c)	14.5	<5
		(c)	13.6	(c)	(e)	--
		(c)	13.2	(c)	(e)	--
		(c)	12.7	(c)	(e)	--
		(c)	9.5	(c)	(e)	--

See footnotes at end of table, p. 83.

TABLE 34.- DATA FROM NAA IMPACT TESTS – Continued

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Perforation	Discharge voltage, V	Discharge time, μsec
[a,b]11-19-63-7	0.062	(c)	15.9	(c)	1.25	<5
		(c)	14.4	(c)	2.50	<5
		(c)	13.2	(c)	(e)	---
		(c)	9.5	(c)	(e)	---
		(c)	8.6	(c)	(e)	---
		(c)	8.0	(c)	(e)	---
		(c)	7.1	(c)	2.75	<5
		(c)	6.6	(c)	3.00	<5
		(c)	6.5	(c)	(e)	---
		(c)	6.3	(c)	(e)	---
		(c)	5.2	(c)	(e)	---
11-20-63-2	0.0321	(c)	16.3	(c)	0.1	150
		(c)	10.0	(c)	(e)	---
		(c)	7.2	(c)	(e)	---
[b]1-14-64-1	0.0321	(c)	6.6	(c)	0.04	30
		52	6.3	(c)	1.00	<5
		(f)	[d]5.8	(c)	3.20	<5
		(f)	[d]5.7	(c)	4.00	<5
		(f)	[d]5.4	(c)	4.60	<5
		(f)	[d]5.3	(c)	5.00	<5
		(f)	4.0	(c)	5.00	<5
[b]1-15-64-1	0.0305	48	9.3	(c)	3.0	<5
		(f)	[d]8.3	(c)	3.0	<5
		48	7.2	(c)	3.0	<5
		(f)	[d]5.7	(c)	3.0	<5
		(f)	[d]5.2	(c)	3.0	<5

See footnotes at end of table, p. 83.

TABLE 34.- DATA FROM NAA IMPACT TESTS – Concluded

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Perforation	Discharge voltage, V	Discharge time, μsec
[b]1-15-64-2	0.0305	53	8.5	(c)	3.2	<5
		(f)	[d]7.8	(c)	3.2	<5
		(f)	[d]7.4	(c)	3.2	<5
		(f)	[d]6.0	(c)	3.0	<5
		(f)	[d]5.7	(c)	(e)	--
		(f)	[d]5.5	(c)	3.0	<5
		(f)	[d]5.0	(c)	3.0	<5

[a]In-flight photometer not in operation.

[b]No rear flash.

[c]Not measured because instrumentation was not in operation.

[d]Impact flash not observed; velocity calculated from sensor signal.

[e]Below threshold of detection.

[f]The in-flight signal indicating diameter was outside the calibrated region.

TABLE 35.- DATA FROM NAA IMPACT TESTS

Sensor type: B-2

Sensor size: 8.9 × 8.9 cm

Applied voltage: +30 V

Backing: None

Added capacitance: None

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Perforation	Discharge voltage, V	Discharge time, μsec
[a,b]11-20-63-4	0.0321	(c)	14.7	(c)	11.5	<5
		(c)	12.7	(c)	(d)	--
		(c)	7.0	(c)	11.5	<5
		(c)	6.8	(c)	15.0	<5
		(c)	[e]6.5	(c)	15.0	<5
[a,b]11-20-63-5	0.0321	(c)	13.6	(c)	(d)	--
		(c)	11.7	(c)	0.4	<5
		(c)	11.2	(c)	6.5	<5
		(c)	10.6	(c)	(d)	--
		(c)	8.7	(c)	(d)	--
		(c)	7.5	(c)	(d)	--
		(c)	[e]6.8	(c)	8.0	--
		(c)	6.6	(c)	12.0	<5
		(c)	[e]6.4	(c)	16.0	<5
		(c)	6.2	(c)	(d)	--
		(c)	[e]6.0	(c)	19.0	<5
		(c)	5.9	(c)	(d)	--
		(c)	[e]5.2	(c)	16.0	<5
		(c)	[e]5.0	(c)	15.0	<5
		(c)	[e]4.7	(c)	14.0	<5

See footnotes at end of table, p. 85.

TABLE 35.- DATA FROM NAA IMPACT TESTS – Concluded

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Perforation	Discharge voltage, V	Discharge time, μsec
[b]1-14-64-4	0.0305	(c)	10.6	(c)	0.04	20
		(c)	7.1	(c)	(d)	--
		(c)	7.0	(c)	(d)	--
		(c)	[e]6.8	(c)	10.0	<5
		(c)	6.6	(c)	10.0	<5
		(c)	[e]6.4	(c)	11.0	<5
		(c)	[e]6.3	(c)	12.0	<5
[b]1-15-64-4	0.0320	41	9.8	(c)	10	<5
		(f)	6.6	(c)	(d)	--
		(f)	5.5	(c)	(d)	--
		38	5.4	(c)	(d)	--

[a]In-flight photometer not in operation.
[b]No rear flash.
[c]Not measured because instrumentation was not in operation.
[d]Below threshold of detection.
[e]No impact flash observed; velocity calculated from sensor signal.
[f]The in-flight signal indicating diameter was outside the calibrated region.

TABLE 36.- DATA FROM NAA IMPACT TESTS

Sensor type: B-2

Sensor size: 8.9 × 8.9 cm

Applied voltage: +60 V

Backing: None

Added capacitance: None

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Perforation	Discharge voltage, V	Discharge time, μsec
a,b11-20-63-6	0.0321	(c)	14.4	(c)	(d)	--
		(c)	e13.1	(c)	40	<5
		(c)	12.7	(c)	48	<5
		(c)	11.9	(c)	(d)	--
		(c)	11.5	(c)	54	<5
		(c)	11.2	(c)	(d)	--
		(c)	10.9	(c)	(d)	--
		(c)	10.5	(c)	52	<5
		(c)	10.0	(c)	56	<5
		(c)	9.5	(c)	(d)	--
		(c)	9.1	(c)	(d)	--
		(c)	8.9	(c)	(d)	--
		(c)	8.8	(c)	(d)	--
		(c)	8.5	(c)	(d)	--
		(c)	8.0	(c)	60	<5
		(c)	7.5	(c)	60	<5
		(c)	7.0	(c)	(d)	--
		(c)	6.6	(c)	(d)	--
		(c)	6.4	(c)	(d)	--
		(c)	6.1	(c)	(d)	--
		(c)	5.7	(c)	(d)	--
		(c)	5.2	(c)	(d)	--
a,b11-20-63-7	0.0321	(c)	6.0	(c)	(d)	--

See footnotes at end of table, p. 87.

TABLE 36.- DATA FROM NAA IMPACT TESTS – Concluded

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Perforation	Discharge voltage, V	Discharge time, μsec
11-20-63-8	0.0321	(c)	11.2	(c)	24	<5
		(c)	9.0	(c)	(d)	--
		(c)	[e]8.6	(c)	37	<5
		(c)	8.2	(c)	(d)	--
		(c)	[e]5.9	(c)	40	<5
		(c)	[e]5.8	(c)	40	<5
		(c)	5.0	(c)	(d)	--
[b]1-15-64-9	0.031	(c)	13.2	(c)	38	<5
		61	10.6	(c)	Short	<5
		(c)	10.0	(c)	Short	--
		63	9.3	(c)	Short	--
		(c)	6.1	(c)	Short	--
[b]1-16-64-1	0.031	(c)	19.1	(c)	0.8	10
		(c)	17.4	(c)	(d)	--
		(c)	17.0	(c)	(d)	--
		63	12.7	(c)	36	<5
		(c)	11.9	(c)	(d)	--
		66	11.7	(c)	(d)	--
		43	9.8	(c)	(d)	--
		(c)	7.3	(c)	(d)	--
		56	7.0	(c)	36	<5
		56	6.8	(c)	(d)	--

[a]In-flight photometer not in operation.

[b]No rear flash.

[c]Not measured because instrumentation was not in operation.

[d]Below threshold of detection.

[e]No impact flash; velocity calculated from sensor signal.

TABLE 37.- DATA FROM NAA IMPACT TESTS

Sensor type: B-2
Sensor size: 8.9×8.9 cm
Applied voltage: +120 V
Backing: None
Added capacitance: None

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Perforation	Discharge voltage, V	Discharge time, μsec
[a]1-15-64-5	0.032	(b)	12.3	(c)	104	<5
		(b)	10.9	(c)	104	<5
		42	[d]10.6	(c)	104	<5
		(b)	[d]9.8	(c)	104	<5
		(b)	[d]9.3	(c)	104	<5
		(b)	[d]9.1	(c)	104	<5
		(b)	[d]8.1	(c)	Short	<5
		(b)	7.8	(c)	Short	--
		47	7.2	(c)	Short	--
[a]1-15-64-8	0.0305	47	10.6	(c)	72	<5
		62	10.3	(c)	(e)	--
		47	9.8	(c)	(e)	--
		42	8.5	(c)	76	<5
		(b)	[d]8.0	(c)	76	<5
		(b)	[d]6.3	(c)	76	<5
		(b)	6.1	(c)	(e)	--
[a]1-16-64-4	0.0315	(b)	10.6	(c)	86	2
		(b)	[d]10.3	(c)	90	<5
		(b)	10.0	(c)	94	<5
		52	9.8	(c)	(e)	--
		47	8.3	(c)	100	<5

See footnotes at end of table, p. 93.

TABLE 37.- DATA FROM NAA IMPACT TESTS – Continued

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Perforation	Discharge voltage, V	Discharge time, μsec
[a]1-16-64-5	0.0315	(b)	13.1	(c)	(e)	--
		47	10.9	(c)	88	2
		(b)	9.3	(c)	104	<5
		(b)	8.9	(c)	(e)	--
		63	8.7	(c)	104	<5
		(b)	8.3	(c)	104	<5
		56	[d]8.0	(c)	104	<5
		(b)	7.5	(c)	103	<5
		58	6.9	(c)	103	<5
		42	6.1	(c)	100	<5
		(b)	[d]5.2	(c)	100	<5
		(b)	[d]4.7	(c)	100	<5
		(b)	3.9	(c)	92	<5
[a]1-16-64-6	0.0315	52	10.9	(c)	88	2
		(b)	6.8	(c)	(e)	--
		(b)	6.3	(c)	(e)	--
		(b)	5.1	(c)	(e)	--
		(b)	5.8	(c)	96	<5
		63	5.6	(c)	(e)	--
		52	5.4	(c)	(e)	--
		(b)	4.8	(c)	96	<5
[a]1-16-64-7	0.0315	(b)	11.2	(c)	88	2
		(b)	9.3	(c)	96	<5
		65	7.2	(c)	(e)	--
		56	7.1	(c)	(e)	--
		66	6.2	(c)	(e)	--
[a]1-16-64-8	0.0315	(b)	14.7	(c)	88	2
		(b)	14.1	(c)	(e)	--
		(b)	12.3	(c)	(e)	--
		42	9.1	(c)	(e)	--
		(b)	[d]8.3	(c)	80	<5
		62	8.1	(c)	90	<5

See footnotes at end of table, p. 93.

TABLE 37.- DATA FROM NAA IMPACT TESTS – Continued

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Perforation	Discharge voltage, V	Discharge time, μsec
[a]1-16-64-10	0.0315	47	11.6	(c)	(e)	--
		62	8.3	(c)	84	2
[a]1-17-64-1	0.0315	(b)	13.6	(c)	88	2.5
		(b)	13.1	(c)	(e)	--
		(b)	[d]9.5	(c)	96	<5
		47	9.3	(c)	100	<5
		52	9.1	(c)	(e)	--
		65	8.0	(c)	100	<5
		(b)	6.8	(c)	96	<5
		58	5.5	(c)	(e)	--
[a]1-17-64-2	0.0315	47	8.0	(c)	92	2.5
[a]1-17-64-3	0.0315	(b)	[d]13.2	(c)	96	2.5
		(b)	12.7	(c)	(e)	--
		47	12.3	(c)	104	<5
		55	11.2	(c)	104	<5
		47	10.3	(c)	104	<5
		(b)	9.5	(c)	(e)	--
		(b)	7.6	(c)	100	<5
		42	[d]7.1	(c)	100	<5
		(b)	[d]7.0	(c)	100	<5
		47	6.9	(c)	100	<5
		(b)	6.1	(c)	108	<5
		55	[d]5.9	(c)	108	<5
		(b)	[d]5.0	(c)	104	<5
		(b)	[d]4.8	(c)	104	<5

See footnotes at end of table, p. 93.

TABLE 37.- DATA FROM NAA IMPACT TESTS – Continued

Test	Capacitance, μF	Projectile, diameter, μ	Velocity, km/sec	Perforation	Discharge voltage, V	Discharge time, μsec
[a]1-17-64-4	0.0315	(b)	12.7	(c)	88	2
		71	11.2	(c)	96	<5
		58	10.9	(c)	(e)	---
		56	9.5	(c)	(e)	---
		(b)	[d]8.5	(c)	96	<5
		(b)	8.3	(c)	98	<5
		56	8.1	(c)	(e)	---
		71	8.0	(c)	(e)	---
		71	7.4	(c)	(e)	---
		(b)	[d]4.2	(c)	84	<5
		(b)	[d]3.9	(c)	84	<5
[a]1-17-64-5	0.0315	42	9.3	(c)	92	2.5
		(b)	8.1	(c)	100	<5
[a]1-17-64-6	0.0315	42	12.3	(c)	96	2.5
[a]2-14-64-1	0.0015	(b)	11.2	(c)	0.8	10
		(b)	9.5	(c)	1.2	10
		51	9.1	(c)	90	<5
		38	8.3	(c)	108	<5
		71	7.5	(c)	(e)	---
		56	7.2	(c)	(e)	---
		71	6.8	(c)	(e)	---
		53	6.5	(c)	(e)	---
		(b)	6.4	(c)	(e)	---
		48	6.1	(c)	(e)	---

See footnotes at end of table, p. 93.

TABLE 37.- DATA FROM NAA IMPACT TESTS – Continued

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Perforation	Discharge voltage, V	Discharge time, μsec
[a]2-14-64-3	0.0310	(b)	11.2	(c)	0.4	5
		53	10.9	(c)	96	1
[a]2-14-64-5	0.0310	41	9.5	(c)	96	1
		41	9.1	(c)	(e)	--
		58	8.7	(c)	(e)	--
		(b)	[d]8.3	(c)	102	<5
		38	7.5	(c)	108	<5
		(b)	[d]7.3	(c)	110	<5
		(b)	[d]7.2	(c)	112	<5
		(b)	6.9	(c)	(e)	--
		(b)	[d]6.5	(c)	112	<5
		(b)	[d]5.4	(c)	108	<5
		(b)	[d]4.8	(c)	108	<5
		(b)	[d]4.7	(c)	108	<5
		(b)	[d]4.6	(c)	108	<5
		(b)	[d]4.0	(c)	108	<5
[a]2-14-64-6B	0.031	(b)	10.6	(c)	96	1
		(b)	9.5	(c)	102	<5
		(b)	7.3	(c)	105	<5
		(b)	[d]6.7	(c)	105	<5
		(b)	[d]6.2	(c)	105	<5
[a]2-14-64-7	0.031	(b)	8.9	(c)	90	1
		61	6.8	(c)	(e)	--
		(b)	6.4	(c)	(e)	--
[a]2-14-64-8	0.031	53	10.3	(c)	0.01	10
		38	5.5	(c)	(e)	--

See footnotes at end of table, p. 93.

TABLE 37.- DATA FROM NAA IMPACT TESTS – Concluded

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Perforation	Discharge voltage, V	Discharge time, μsec
[a]2-14-64-9	0.031	(b)	7.6	(c)	96	1
		(b)	6.9	(c)	108	<5
		(b)	[d]6.3	(c)	108	<5
		(b)	[d]6.0	(c)	108	<5
		(b)	[d]5.9	(c)	108	<5
		(b)	5.0	(c)	102	<5
[a,f]2-14-64-10	0.031	(b)	7.9	(c)	0.14	130
		(b)	7.1	(c)	(e)	---
		(b)	6.0	(c)	90	1
		(b)	5.4	(c)	(e)	---
		(b)	5.2	(c)	(e)	---
[a]2-14-64-11	0.031	61	9.1	(c)	96	1
		43	8.3	(c)	(e)	---
		46	7.2	(c)	(e)	---
		53	6.8	(c)	96	<5
		46	6.6	(c)	(e)	---
		(b)	5.6	(c)	(e)	---

[a]No rear flash.

[b]The in-flight signal indicating diameter was outside the calibrated region.

[c]Not measured because instrumentation was not in operation.

[d]Impact flash not observed; velocity calculated from sensor signal.

[e]Below threshold of detection.

[f]The in-flight photometer went off scale after the first particle.

TABLE 38.- DATA FROM NAA IMPACT TESTS

Sensor type: B-2
Sensor size: 8.9 × 8.9 cm
Applied voltage: +240 V
Backing: None
Added capacitance: None

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Perforation	Discharge voltage, V	Discharge time, μsec
[a]1-16-64-2	0.0315	(b)	10.0	(c)	200	<5
		47	8.7	(c)	220	<5
		52	6.7	(c)	(d)	---
		56	6.6	(c)	(d)	---
		56	5.8	(c)	(d)	---
		(b)	5.5	(c)	(d)	---
		(b)	5.4	(c)	190	<5
[a]1-16-64-3	0.0315	(b)	9.1	(c)	(d)	---
		(b)	8.3	(c)	(d)	---
		56	7.4	(c)	170	2.0

[a]No rear flash.

[b]The in-flight signal indicating diameter was outside the calibrated region.

[c]Not measured because instrumentation was not in operation.

[d]Below threshold of detection.

TABLE 39.- DATA FROM NAA IMPACT TESTS

Sensor type: B-2

Sensor size: 8.9 × 8.9 cm

Applied voltage: +120 V

Backing: None

Added capacitance: 2.9 μF

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Perforation	Discharge voltage, V	Discharge time, μsec
[a]2-14-64-6A	2.92	61	14.7	(b)	(c)	--
		(d)	13.6	(b)	(c)	--
		(d)	12.7	(b)	90	<5

[a]No rear flash. Impact-flash photometer went off scale after sensor signal.

[b]Not measured because instrumentation was not in operation.

[c]Below threshold of detection.

[d]The in-flight signal indicating diameter was outside the calibrated region.

TABLE 40.- DATA FROM NAA IMPACT TESTS

Sensor type: B-2
Sensor size: 8.9×8.9 cm
Applied voltage: +120 V
Backing: None
Added capacitance: 48 μF

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Perforation	Discharge voltage, V	Discharge time, μsec
[a]2-14-64-2	48.3	38	13.1	(b)	69	60

[a]No rear flash. Impact-flash photometer went off scale after sensor signal; the sensor signal was ragged.

[b]Not measured because instrumentation was not in operation.

TABLE 41.- DATA FROM NAA IMPACT TESTS

Sensor type: B-2
Sensor size: 50.8 × 102 cm
Applied voltage: 42 to 46 V
Backing: None
Load sensor: No
Isolation circuit: No

Test	Applied voltage, V	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Perforation	Discharge voltage, V	Discharge time, μsec
4176	46	1.025	(a)	14.4	No	(b)	---
			(a)	12.4	Yes	(b)	---
			(a)	11.5	No	(b)	---
			(a)	11.2	No	(b)	---
			(a)	10.6	No	(b)	---
			53	10.3	Yes	32	<5
			50	9.1	No	(b)	---
			(a)	8.7	No	(b)	---
			52	7.6	No	(b)	---
			(a)	5.9	No	(b)	---
4178	46	1.025	(a)	15.2	Yes	32	<5
4305	42	1.10	(a)	12.2	Yes	0.02	<5
			(a)	11.2	No	(b)	---
			(a)	10.8	No	(b)	---
			(a)	9.4	No	(b)	---
			(a)	9.1	No	(b)	---
			50	6.9	No	(b)	---
4306	42	1.10	(a)	9.4	Yes	0.005	10
			(a)	8.7	No	0.010	100
			54	5.8	Yes	0.015	10
4308	42	1.10	(a)	13.4	Yes	0.005	10
			(a)	10.3	No	0.010	100
			(a)	9.4	No	(b)	---

[a]The in-flight signal indicating diameter was outside the calibrated region.
[b]Below threshold of detection.

TABLE 42.- DATA FROM NAA IMPACT TESTS

Sensor type: B-3
Sensor size: 50.8 × 102 cm
Applied voltage: 42 V
Backing: Foam tape
Load sensor: No
Isolation circuit: Yes

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Discharge voltage, V	Discharge time, μsec	Holes in sensor
4309	(a)	(b)	12.2	4	<5	3
		(b)	11.2	2	<5	
		(b)	9.8	(c)	--	
		(b)	8.1	(c)	--	
4311	(a)	(b)	7.6	(c)	--	2
		(b)	6.6	(c)	--	

[a]Not measured because instrumentation was not in operation.
[b]The in-flight signal indicating diameter was outside the calibrated region.
[c]Below threshold of detection.

TABLE 43.- DATA FROM NAA IMPACT TESTS

Sensor type: B-3
Sensor size: 50.8 × 102 cm
Applied voltage: 42.5 to 45 V
Backing: 2.54-cm foam
Load sensor: No
Isolation circuit: Yes

Test	Applied voltage, V	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Discharge voltage, V	Discharge time, μsec	Holes in sensor
4267	45	1.15	53	13.2	16	<5	1
4271	44	1.05	(a)	11.8	3	<5	1
			(a)	4.9	(b)	<5	
4272	44	1.16	52	12.9	14	<5	3
			(a)	12.5	22	<5	
			50	9.7	(b)	--	
			(a)	5.9	(b)	--	
4273	44	1.25	(a)	7.1	2	<5	1
4274	44	1.07	(a)	12.5	(b)	--	2
			(a)	10.8	6	<5	
			(a)	7.3	(b)	--	
			55	5.7	(b)	--	
4276	42.5	1.10	(a)	13.2	16	<5	4
			(a)	8.4	22	<5	
			54	7.7	28	<5	
			(a)	7.6	30	<5	
4278	42.5	1.10	(a)	9.1	0.01	<5	2

[a]The in-flight signal indicating diameter was outside the calibrated region.
[b]Below threshold of detection.

TABLE 44.- DATA FROM NAA IMPACT TESTS

Sensor type: B-3
Sensor size: 50.8 × 102 cm
Applied voltage: 42.0 V
Backing: 2.54-cm foam
Load sensor: Yes
Isolation circuit: Yes

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Hit-sensor discharge, V	Hit-sensor discharge time, μsec	Load-sensor discharge, V	Load-sensor discharge time, μsec	Holes in sensor
4280	0.095	(a)	10.7	14	<5	6	1200	2
		(a)	10.6	(b)	---	(b)	----	
4282	1.056	(a)	12.2	18	<5	10	1100	3
		(a)	11.2	18	<5	(b)	----	
		(a)	10.6	20	<5	(b)	----	
		(a)	8.5	20	<5	(b)	----	
		(a)	7.8	(b)	---	(b)	----	
		(a)	5.8	(b)	---	(b)	----	
4285	1.050	53	11.8	20	1.0	8	1200	2
			11.5	22	<5	(b)	----	
4286	1.050	(a)	7.1	8	1.0	(b)	----	3
		(a)	5.8	24	<5	10	1300	
		50	5.6	(b)	---	(b)	----	
		48	5.1	22	<5	(b)	----	
4287	1.060	(a)	11.8	14	0.5	6	1200	1
		(a)	6.4	(b)	---	(b)	----	
		(a)	6.1	(b)	---	(b)	----	
		47	4.9	(b)	---	(b)	----	
		(a)	4.7	(b)	---	(b)	----	
4289	1.27	(a)	10.6	16	0.5	(b)	----	2
		(a)	10.0	20	<5	6	1100	
		53	7.9	(b)	---	(b)	----	
		(a)	4.4	(b)	---	(b)	----	
4291	1.19	(a)	14.0	16	0.8	8	1200	1
		50	11.8	20	<5	(b)	----	
		(a)	8.5	(b)	---	(b)	----	
		47	7.9	(b)	---	(b)	----	
4292	1.25	(a)	7.0	2	<5	2	1200	1
4293	1.24	(a)	6.9	2	<5	(b)	----	1

See footnotes at end of table, p. 101.

TABLE 44.- DATA FROM NAA IMPACT TESTS – Concluded

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Hit-sensor discharge, V	Hit-sensor discharge time, μsec	Load-sensor discharge, V	Load-sensor discharge time, μsec	Holes in sensor
4294	1.25	48	6.8	(b)	---	(b)	----	1
4295	1.25	(a)	10.6	16	0.8	6	1100	1
		(a)	6.3	(b)	---	(b)	----	
		(a)	5.4	(b)	---	(b)	----	
4296	1.25	(a)	8.7	4	<5	1	1000	2
		47	4.7	(b)	---	(b)	----	
4297	1.25	54	11.5	6	0.5	8	1300	2
		(a)	11.2	(b)	---	(b)	----	
		(a)	10.3	18	<5	(b)	----	
		47	5.1	(b)	---	(b)	----	
		(a)	4.7	(b)	---	(b)	----	
4298	1.25	48	11.5	20	0.4	10	1100	4
		(a)	11.0	22	<5	(b)	----	
		(a)	7.6	(b)	---	(b)	----	
		(a)	7.3	(b)	---	(b)	----	
		54	6.7	(b)	---	(b)	----	
4301	1.25	(a)	11.8	(b)	---	(b)	----	1
		(a)	11.3	(b)	---	(b)	----	
		48	8.5	6	1.0	(b)	----	
4302	1.10	(a)	15.5	16	<5	(b)	----	1
		(a)	10.0	(b)	---	(b)	----	
4304	1.10	(a)	12.2	10	0.5	(b)	----	8
		(a)	10.6	(b)	---	(b)	----	
		45	9.1	12	<5	(b)	----	
		(a)	8.4	(b)	---	(b)	----	
		(a)	8.1	(b)	---	(b)	----	
		(a)	7.6	(b)	---	(b)	----	
		(a)	7.0	(b)	---	(b)	----	
		45	6.7	(b)	---	(b)	----	

[a]The in-flight signal indicating diameter was outside the calibrated range.

[b]Below threshold of detection.

TABLE 45.- DATA FROM NAA IMPACT TESTS

Sensor type: B-3
Sensor size: 50.8 × 102 cm
Applied voltage: 70 V
Backing: 2.54-cm foam
Load sensor: Yes
Isolation circuit: Yes

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Hit-sensor discharge, V	Hit-sensor discharge time, μsec	Load-sensor discharge, V	Load-sensor discharge time, μsec	Holes in sensor
4438	1.126	46	8.7	(a)	---	(a)	----	3
		(b)	6.3	(a)	---	(a)	----	
4439	1.121	45	9.2	36	0.3	(a)	----	2
		(b)	8.7	50	<5	(a)	----	
4441	1.124	(b)	5.7	(a)	---	(a)	----	4
4442	1.124	(b)	14.6	(a)	---	(a)	----	4
4443	1.126	(b)	13.2	34	<5	22	1800	6
		46	12.5	40	<5	(a)	----	
		(b)	12.4	44	<5	(a)	----	
		46	13.3	46	<5	(a)	----	
		(b)	10.5	46	<5	(a)	----	
		46	10.0	(a)	---	(a)	----	
		(b)	9.1	50	<5	(a)	----	
4444	1.126	49	11.8	34	<5	20	1800	7
		(b)	10.1	(a)	---	(a)	----	
		46	8.4	44	<5	(a)	----	
		46	6.5	40	<5	(a)	----	
		(b)	5.1	40	<5	(a)	----	
4446	1.267	(b)	9.2	28	0.4	22	1700	14
		46	8.5	(a)	---	(a)	----	
		(b)	8.1	(a)	---	(a)	----	
		(b)	7.9	(a)	---	(a)	----	
		(b)	7.8	42	<5	(a)	----	
		(b)	7.1	52	<5	(a)	----	
		(b)	7.0	(a)	---	(a)	----	
		(b)	6.2	(a)	---	(a)	----	
		(b)	5.5	(a)	---	(a)	----	
		(b)	5.3	(a)	---	(a)	----	
		(b)	5.1	(a)	---	(a)	----	
		(b)	4.4	(a)	---	(a)	----	

See footnotes at end of table, p. 105.

TABLE 45.- DATA FROM NAA IMPACT TESTS – Continued

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Hit-sensor discharge, V	Hit-sensor discharge time, μsec	Load-sensor discharge, V	Load-sensor discharge time, μsec	Holes in sensor
4447	1.268	52	10.8	34	0.4	21	1700	6
		(b)	7.6	42	<5	(a)	----	
		46	7.0	48	<5	(a)	----	
4449	1.259	49	12.0	36	0.3	27	2000	6
		46	11.8	52	<5	(a)	----	
		(b)	11.7	(a)	----	(a)	----	
		49	10.3	(a)	----	(a)	----	
		(b)	9.1	51	<5	(a)	----	
		44	8.8	56	<5	(a)	----	
		(b)	8.5	(a)	----	(a)	----	
		(b)	6.5	(a)	----	(a)	----	
		44	6.3	(a)	----	(a)	----	
		46	5.9	(a)	----	(a)	----	
		47	5.7	(a)	----	(a)	----	
		(b)	5.6	(a)	----	(a)	----	
		44	4.8	(a)	----	(a)	----	
4450	1.249	(b)	10.6	20	0.5	8	1600	4
		51	7.3	(a)	----	(a)	----	
		52	4.4	(a)	----	(a)	----	
4451	1.246	45	8.9	(a)	----	(a)	----	5
		(b)	8.3	(a)	----	(a)	----	
4452	1.249	44	13.4	40	0.25	24	1700	8
		46	11.8	54	<5	(a)	----	
		44	10.0	56	<5	(a)	----	
		(b)	9.8	56	<5	(a)	----	
		44	8.9	(a)	----	(a)	----	
		46	8.4	(a)	----	(a)	----	
		(b)	7.5	(a)	----	(a)	----	
		44	7.0	(a)	----	(a)	----	
		(b)	6.8	(a)	----	(a)	----	
		(b)	6.5	(a)	----	(a)	----	
		46	5.7	(a)	----	(a)	----	
		44	5.3	(a)	----	(a)	----	

See footnotes at end of table, p. 105.

TABLE 45.- DATA FROM NAA IMPACT TESTS – Continued

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Hit-sensor discharge, V	Hit-sensor discharge time, μsec	Load-sensor discharge, V	Load-sensor discharge time, μsec	Holes in sensor
4453	1.253	(b)	17.5	(a)	----	(a)	----	1
		(b)	15.5	(a)	----	(a)	----	
		44	11.2	32	0.25	11	1700	
		52	10.3	(a)	----	(a)	----	
		46	9.4	(a)	----	(a)	----	
		(b)	5.4	(a)	----	(a)	----	
		46	5.1	(a)	----	(a)	----	
4456	1.252	(b)	14.4	36	<5	13	1600	2
4458	1.251	(b)	14.9	36	0.25	18	1700	5
		52	12.9	46	<5	(a)	----	
		(b)	11.3	(a)	(a)	(a)	----	
		(b)	10.6	(a)	(a)	(a)	----	
		52	10.0	(a)	(a)	(a)	----	
		51	8.7	(a)	(a)	(a)	----	
		51	7.0	(a)	(a)	(a)	----	
		46	5.3	(a)	(a)	(a)	----	
4459	1.251	(b)	10.3	32	<5	12	1600	2
4460	1.249	(b)	9.1	(a)	(a)	(a)	----	1
		(b)	4.7	(a)	(a)	(a)	----	
4461	1.259	49	9.8	30	0.4	12	1700	7
4462	1.251	(b)	16.1	(a)	(a)	(a)	----	5
		(b)	15.5	(a)	(a)	(a)	----	
		(b)	8.5	(a)	----	(a)	----	
		(b)	7.8	(a)	----	(a)	----	
		(b)	6.6	(a)	----	(a)	----	
		(b)	5.8	(a)	----	(a)	----	
		44	5.2	(a)	----	(a)	----	
4463	1.251	46	13.9	26	<5	9	1700	2
		44	8.5	(a)	----	(a)	----	

See footnotes at end of table, p. 105.

TABLE 45.- DATA FROM NAA IMPACT TESTS - Concluded

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Hit-sensor discharge, V	Hit-sensor discharge time, μsec	Load-sensor discharge, V	Load-sensor discharge time, μsec	Holes in sensor
4464	1.252	(b)	12.4	36	0.45	22	1600	7
		52	11.3	40	<5	(a)	----	
		46	10.8	46	<5	(a)	----	
		(b)	8.2	54	<5	(a)	----	
		51	7.9	(a)	----	(a)	----	
		(b)	7.8	(a)	----	(a)	----	
		(b)	7.7	(a)	----	(a)	----	
		(b)	7.0	(a)	----	(a)	----	
		(b)	6.7	(a)	----	(a)	----	
		46	6.1	(a)	----	(a)	----	
		(b)	5.2	(a)	----	(a)	----	
4465	1.257	46	7.1	(a)	----	(a)	----	3
		(b)	6.8	18	0.25	6	1600	
4466	1.260	(b)	11.2	28	0.25	15.0	1600	3
		(b)	8.9	36	<5	(a)	----	
4468	1.250	(b)	8.5	(a)	----	(a)	----	4
		(b)	7.6	(a)	----	(a)	----	
		(b)	7.5	(a)	----	(a)	----	
		53	7.1	(a)	----	(a)	----	
		(b)	6.9	(a)	----	(a)	----	
		(b)	6.6	(a)	----	(a)	----	
4471	1.241	(b)	7.6	34	0.4	18	1450	6
		(b)	5.1	(a)	----	(a)	----	
		(b)	4.8	34	<5	(a)	----	
		(b)	4.7	36	<5	(a)	----	
		(b)	4.6	38	<5	(a)	----	
		(b)	4.5	38	<5	(a)	----	
4472	1.245	46	11.3	36	0.8	(a)	----	5
		(b)	10.0	50	<5	(a)	----	
		49	9.1	(a)	----	(a)	----	
		(b)	8.5	(a)	----	(a)	----	
		(b)	7.9	(a)	----	(a)	----	
		44	6.2	(a)	----	(a)	----	
		51	6.1	(a)	----	(a)	----	
		44	5.7	(a)	----	(a)	----	

[a]Below threshold of detection.

[b]The in-flight signal indicating diameter was outside the calibrated region.

TABLE 46.- DATA FROM NAA IMPACT TESTS

Sensor type: B-3
Sensor size: 50.8×102 cm
Applied voltage: Zero
Backing: 2.54-cm foam
Load sensor: Yes
Isolation circuit: Yes

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Holes in sensor	Permanent short after test
4440	1.16	44	10.8	18	Yes
		54	10.6		
		52	8.1		
		(a)	8.0		
4473	1.245	(a)	12.9	8	Yes
		(a)	7.1		
		(a)	6.1		
		(a)	5.8		
		44	4.7		
[b]4478	1.128	--	---	6	Yes
[b,c]4479	1.120	--	---	1	Yes
4480	1.126	46	12.9	2	Yes
		52	11.8		
4481	1.190	53	11.8	1	No
		52	8.1		

[a]The in-flight signal indicating diameter was outside the calibrated region.
[b]In-flight photometer not in operation.
[c]No impact flashes were observed.

TABLE 47.- DATA FROM NAA IMPACT TESTS

Sensor type: B-4

Sensor size: 8.9 × 8.9 cm

Applied voltage: -120 V

Backing: 4-mm foam

Added capacitance: None

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Perforation	Discharge voltage, V	Discharge time, μsec
[a]2-11-64-4	0.023	(b)	15.6	(c)	0.075	5
		(b)	12.1	(c)	0.150	80
		61	8.7	(c)	(d)	---
		(b)	8.4	(c)	(d)	---
		51	7.5	(c)	(d)	---
		(b)	7.1	(c)	(d)	---
		43	6.4	(c)	(d)	---
[a]2-11-64-5	0.0225	58	13.6	(c)	(d)	---
		66	11.9	(c)	0.2	100
		(b)	7.8	(c)	(d)	---
		48	6.9	(c)	(d)	---

[a]No rear flash.

[b]The in-flight signal indicating diameter was outside the calibration region.

[c]Microscopic examination of the craters indicated that there were no perforations.

[d]Below threshold of detection.

TABLE 48.- DATA FROM NAA IMPACT TESTS

Sensor type: B-5
Sensor size: 8.9 × 8.9 cm
Applied voltage: -120 V
Backing: 4-mm foam
Added capacitance: None

Test	Capacitance, μF	Projectile diameter, μ	Velocity, km/sec	Perforation	Discharge voltage, V	Discharge time, μsec
[a]2-11-64-6	0.00198	43	11.4	(b)	1.8	<5
		51	8.6	(b)	(c)	---
[a]2-11-64-7	0.0235	53	12.1	(b)	0.04	10
		69	11.6	(b)	(c)	---
		(d)	11.2	(b)	0.09	5
		(d)	8.0	(b)	0.1	140
		43	7.6	(b)	0.5	50
		(d)	6.6	(b)	(c)	---
		43	4.7	(b)	(c)	---

[a]No rear flash.
[b]Microscopic examination of the craters indicated that there were no perforations.
[c]Below threshold of detection.
[d]The in-flight signal indicating diameter was outside the calibrated region.

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