956058

RECEIVED 9950-705

MAY 3 - 1982

PATENTS AND
TU OFFICE

FINAL TECHNICAL REPORT
GIT/EES Project No. A–2971

DEVELOPMENT OF A FLASH, BANG, and SMOKE SIMULATION OF A SHELLBURST

By

F. R. Williamson, J. F. Kinney, T. V. Wallace

AUG 1982
RECEIVED
NASA STI FACILITY
ACCESS DEPT.

Prepared for

CALIFORNIA INSTITUTE OF TECHNOLOGY
JET PROPULSION LABORATORY
4800 OAK GROVE DRIVE
PASADENA, CALIFORNIA 91103

Under

Task Order No. RD–182/136

Subcontract under

NASA Contract NAS7–100

January 1982

GEORGIA INSTITUTE OF TECHNOLOGY
A Unit of the University System of Georgia
Engineering Experiment Station
Atlanta, Georgia 30332

GT EES

1982

(NASA-CR-169251) DEVELOPMENT OF A FLASH, BANG, AND SMOKE SIMULATION OF A SHELL BURST Final Technical Report (Georgia Inst. of Tech.) 165 p HC A08/MF A01 CSCL 12B
N82-31053
Unclas
G3/66 28602

GIT/EES Project No. A-2971 January 1982

Final Technical Report

DEVELOPMENT OF A FLASH, BANG, AND SMOKE SIMULATION OF A SHELLBURST

By

F. R. Williamson, J. F. Kinney
T. V. Wallace

Prepared for
California Institute of Technology
Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, California 91103

Under
Task Order No. RD-182/136
A Subcontract under
NASA Contract NAS7-100

This work was performed for the Jet Propulsion Laboratory, California Institute of Technology sponsored by the National Aeronautics and Space Administration under Contract NAS7-100.

Submitted by
Georgia Institute of Technology
Engineering Experiment Station
Atlanta, Georgia 30332

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE (*When Data Entered*)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS
BEFORE COMPLETING FORM

1. REPORT NUMBER

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (*and Subtitle*)
DEVELOPMENT OF A FLASH, BANG, AND SMOKE SIMULATION OF A SHELLBURST

5. TYPE OF REPORT & PERIOD COVERED
Final

6. PERFORMING ORG. REPORT NUMBER
GIT/EES Project No. A-2971

7. AUTHOR(*s*)
F. R. Williamson, J. F. Kinney,
T. V. Wallace

8. CONTRACT OR GRANT NUMBER(*s*)
Task Order No. RD-182/136
A Subcontract Under
NASA Contract NAS7-100

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Georgia Institute of Technology
Engineering Experiment Station
Atlanta, Georgia 30332

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS

11. CONTROLLING OFFICE NAME AND ADDRESS
California Institute of Technology
Jet Propulsion Laboratory, 4800 Oak Grove Drive
Pasadena, California 91103

12. REPORT DATE
January 1982

13. NUMBER OF PAGES
163

14. MONITORING AGENCY NAME & ADDRESS (*if different from Controlling Office*)

15. SECURITY CLASS. (*of this report*)
UNCLASSIFIED

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (*of this Report*)

17. DISTRIBUTION STATEMENT (*of the abstract entered in Block 20, if different from Report*)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (*Continue on reverse side if necessary and identify by block number*)
Indirect fire simulation
Indirect fire cue
Flash-bang-smoke cue
Shellburst cue
Firing device
Battlefield simulation

20. ABSTRACT (*Continue on reverse side if necessary and identify by block number*)
A large number of experiments (cue test firings) were performed in the definition of the cue concepts and packaging configurations. A total of 344 of these experiments were recorded with instrumentation photography to allow a quantitative analysis of the smoke cloud to be made as a function of time. These analyses were predominantly made using a short range test site at the Georgia Tech Research Facility in Cobb County, Georgia. Supplementary long-range visibility tests were conducted to insure the required 3 kilometer visibility of the smoke signature. Finally, representative cueing devices

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE (*When Data Entered*)

20. cont.

meeting the visibility goals were delivered to the Jet Propulsion Laboratory for demonstration and testing before a representative user group from the U.S. Army.

This development effort has identified two basic cueing concepts for meeting the goals set forth for visibility and safety. The first involved pyrotechnic cue compounds that generated the smoke through a burning process. The second generic approach generated a smoke cue through the deployment of an inert powder or dust. The flash requirement was met by the use of a simple flashbulb providing a visibility in normal daylight to a range of 2.5 kilometers and having no hazards of flash burns to personnel or danger of starting grass fires. The goal of this investigation was to allow a cue payload to be defined on the basis of the signature size requirements that are to be met. Data on smoke signature size as a function of cue material weight are presented. The cue concepts considered here are potentially usable in a projectile delivery system, but are not limited to that single application.

TABLE OF CONTENTS

TABLE OF CONTENTS (cont.)

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (cont.)

LIST OF ILLUSTRATIONS (cont.)

LIST OF TABLES

SECTION 1

INTRODUCTION

1.1 SCOPE

This report describes a systematic investigation into various concepts for generating flash/bang/smoke cues that are suitable for use in a simulated battlefield scenario to indicate the impact of indirect fire or as a cue for mines. This development effort was conducted under Contract No. 956058 for the Jet Propulsion Laboratory in support of their investigations into simulation methods for area effects weapons for the U.S. Army Program Manager Training Devices.

The needs for more realistic and cost-effective training techniques are becoming increasingly important in times of decreasing resources and increasing weapon complexity. Modern technology has advanced the effectiveness of training techniques for military personnel in the simulated battlefield scenario, but the area of indirect fire cueing or simulation remains to be developed into an effective training tool. Indirect fire weapons include mortar and artillery that use a relatively high angle of fire and can not be simulated by laser pairing techniques used for small arms fire.

1.2 BACKGROUND

Indirect fire is a very effective method for suppressing troop activity on the battlefield, but the current training practices do not include a realistic simulation or cue of these weapon types. Frequently the effects of this weapon category are introduced into the training scenario by a referee or observer throwing a smoke grenade at the desired impact point. While this method can place a flash, bang, and smoke cue at the point where the indirect fire was directed, it lacks the realism and surprise that is necessary for effective suppression.

Any device used for the training of personnel must regard the safety of the players. Typically an indirect fire weapon may contain several pounds of high explosives that may be d charged upon impact with the ground or at some prescribed distance above the ground. In no way can a true simulation of this effect be considered safe to personnel in the immediate area. For this reason, the terminology of a cue is used instead of simulation for the effects of the explosion of the projectile. The level of these flash, bang, and smoke cue signatures must be balanced between the safety considerations of the players, realism, surprise, and the requirements for long range visibility.

A unique method for deploying indirect fire cues was proposed by the Georgia Tech Engineering Experiment Station in 1977. This indirect fire cueing concept delivers a flash/bang/smoke cue via a lightweight projectile launched from a pneumatic cannon. The feasibility of this concept was demonstrated under a research and development program for the U.S. Army Combat Development Experimentation Command (USACDEC) under Contract No. DAAG08-78-C-0191. This research effort developed a cueing projectile and launch device that was capable of launching a flash, bang, and smoke cue to ranges in excess of 200 meters. The impact energy of the projectile was similar to that experienced in sports like tennis or softball and posed minimal threat to training personnel in the area of blunt trauma. The Flash/Bang/Smoke cue developed for the projectile had a high degree of personnel and range safety. The cue was developed around a flashbulb technology that triggered on impact and released a cloud of inert smoke material.

The experience gained by Georgia Tech personnel in the development of this remote launched cueing concept served well in the investigations reported in this technical report. Additional experience in this area was obtained under a previous investigation for USACDEC (Contract No. N00014-75-C-0320) that involved methods for generating FBS cues for ground emplaced simulators.

1.3 PROBLEM DESCRIPTION

The cue development effort described in this report addresses the specific need for defining the flash, bang, and smoke cue characteristics of candidate cueing technologies. The experiments and analyses performed with candidate cueing concepts were directed toward the definition of cue signature size as a function of cue payload. The range and personnel hazards of each cueing concept were observed to define the safe operating limits of each system approach. The goal of this investigation is to allow a cue payload to be defined on the basis of the various signature size requirements that are to be met. Guidelines for the selection of the cueing concept will depend upon the application (i.e., ground burst versus air burst).

The cue concepts considered for this study are potentially usable in a projectile delivery system, but are not limited to that single application. The cue package configurations are not optimized for enclosure in a projectile, but are considered to be adaptable to this end use. The design data obtained from this analysis are applicable over a significant range of applications in the training area of interest.

A series of Flash, Bang, and Smoke cueing goals was set forth (see Table 1) as a guide for this study. The philosophy of this investigation recognized that all three cue signatures may not be present in all of the cueing concepts. A similar argument holds that all three cue signatures may not be required for all applications. Therefore, the design of a specific cue device may be considered to be a combination of one or more cueing concepts that have been tailored to meet specific signature requirements. This approach allows the individual signatures to be measured and considered independently.

A large number of experiments (cue test firings) were performed in the definition of the cue concepts and packaging configurations. A total of 344 of these experiments were recorded with instrumentation photography to allow a quantitative analysis of the smoke cloud to be made as a function of time. These analyses were predominantly made using a short range test site at the Georgia Tech Research Facility in Cobb County, Georgia. Supplementary long-range visibility tests were conducted at Lake Sidney Lanier, Georgia, to insure the required visibility of the flash and smoke signatures as set forth in the statement of goals in Table 1. Finally, representative cueing devices meeting those goals were delivered to JPL for demonstration and testing before a representative user group from the U.S. Army.

1.4 SUMMARY OF CONCLUSIONS

The cue tests demonstrated that the smoke and flash visibility are fairly easy to meet if no limitations of personnel or range safety are considered. Two generic approaches were used for the generation of smoke cues. The first involved pyrotechnic cue compounds that generated the smoke through a burning process. The second generic approach generated a smoke cue through the deployment of an inert powder or dust.

TABLE 1. GOALS FOR FLASH, BAND, SMOKE CUES

The Flash, Bang, Smoke task shall meet the following goals:

Flash Visibility:

Normal Daylight: Visible at 200 meters when looking at the expected burst point.

Hazy Day: Draw attention at 200 meters through approximately 30° peripheral vision.

Smoke Color:

Airburst Simulation: Off-white to light gray

Groundburst Simulation: Dark gray

Smoke Cloud Size; Adequate to be easily visible at 3 km

Smoke Cloud Persistence: 3 seconds minimum under conditions of winds less than 10 MPH

Personnel Safety:

Meet applicable Surgeon General requirements

Will not cause third degree burns when exposed skin is within 20 cm of the simulated shellburst

Range Safety: Will not start fires when burst in grassy areas

---

A standard flash powder proved to be a very efficient cue concept of the first generic category, but has safety limitations due to the fireball at the time of ignition and the relatively high acoustic signature. Some of these hazards can be tolerated if the application is restricted to a minimum distance from personnel (as might be the case of an air burst).

A commercially available preparation of potassium bicarbonate (sold under the trade name of Purple-K) is normally used as the powder in dry chemical fire extinguishers. This material demonstrated cloud signatures that were adequate for the long range visibility requirements and offered a greater degree of man safety. While not as an efficient payload as the flash powder, the increased man safety was sufficient to allow a device of this design to be hand held while being activated. The smoke and the flash cue signature were previously demonstrated as being visible for a distance of 2.5 kilometers in normal daylight to the unaided eye.

Different cueing signature levels were demonstrated that followed the predicted design information. This design data was developed for each cue concept on a normalized basis. Smoke cue payloads can be adjusted for different signature requirements (such as smoke cloud volume or area).

The acoustic signature generally presents a problem of reducing the level to a point where exposure to personnel does not mandate the use of hearing protection devices (such as earplugs). Cueing concepts that do not develop the acoustic cue as a primary function of the cue combustion must frequently be aided by the rupture of the container or a diaphragm. This approach was used in the design of some of the cue units tested.

The flash requirement was easily met by the use of a simple photographic flashbulb. This device contains the burning process in a glass enclosd oxygen atmosphere to develop a very bright flash that is easily visible for a distance of 2.5 kilometers in normal daylight with the unaided eye. The contained flash does not have the hazards of flash burns to personnel nor the hazard of starting a grass fire. Conventional combustion of the flash powder cues also provides a satisfactory flash signature, but the hazard of the fireball must be considered in the final application of this technology.

This development effort has identified two basic cueing concepts for meeting the basic goals set forth in Table 1. The flash powder cue concept is a very efficent material, but has associated hazards in the fireball. The inert powder cue concept when associated with the flashbulb flash signature generator is a less efficient cue payload, but has demonstrated the ability to meet the cueing goals for long range smoke and flash visibility while providing a high degree of man and range safety.

SECTION 2

TECHNICAL DISCUSSION

2.1 OVERVIEW

The objective of the investigation described in this report was to develop a flash, bang, and smoke (FBS) cueing simulation for a remote-launch indirect-fire cueing system that meets the goals listed in Table 1. The effort focused on the chemical and related technology required to develop state-of-the-art simulation of FBS cues, and the definition of the technology that will provide the maximum effect per unit volume. Although FBS cues expected to be used in a small simulated projectile were the primary consideration in determining the cue configuration, the program was conducted in a manner that will allow the results to be applied to simulation of a variety of weapons such as simulated artillery shells or mines.

This program was based on the premise that effective training can be accomplished using cues (man/environment - safe levels of the real influences) in place of the full scale levels of the real influences of flash, bang, and smoke (FBS), each of which may be hazardous and even lethal. Once the minimum cue magnitude of each cue influence is known, the individual cues can be combined to provide satisfactory FBS cues for specific applications. The technical aspects considered in developing the individual flash, bang, and smoke cues are discussed in the following paragraphs.

2.2 FLASH CUE TECHNICAL CONSIDERATIONS

Flash cues are generated by high temperature particles that radiate in the visible and infrared bands of the electromagnetic spectrum. The primary performance parameters considered in developing the flash cue were:

1. The flash intensity will not damage the eye.
2. The flash intensity will not be sufficient to ignite dry grasses in a desert-like environment.
3. The flash intensity will not cause third-degree burns to exposed flesh within 20 cm of a simulated shell burst.
4. The flash will be visible at two hundred meters when looking directly at the expected burst point.

5. On a hazy day, the flash will draw attention to the burst point through approximately 30 degrees of peripheral vision.

Methods considered for generating the flash cue included photoflash bulbs, photoflash powder, a powder mixture, and a British FBS unit. In general, the contained combustion of zirconium wire or foil in an enclosed oxygen atmosphere such as in a photoflash bulb is not of sufficient intensity to damage the eye, cause flash burns nearby, or ignite dry grass. The flashbulb contains the products of the reaction. But if these products were free as in an uncontained reaction, they could easily burn the flesh and readily ignite grass on contact. The 5500 degree Kelvin color temperature associated with the AG1 flashbulb appears to be a safe level of temperature for the contained reaction. Table 2 lists the characteristics of several flashbulbs that were considered as candidates for the flash cue matrix.

TABLE 2. FLASHBULB CHARACTERISTICS

Flashbulb Type	Total Lummen-seconds	Peak Lummens	Diameter Millimeters	(Inches)
AG1B	5300	250 K	11.9	(15/32)
AG1	7200	450 K	11.9	(15/32)
M3B	10 K	550 K	21.4	(27/32)
M3	16 K	1000 K	21.4	(27/32)
P25	21 K	1600 K	38.1	(1 1/2)
Type 2	70 K	4200 K	60.3	(2 3/8)
Type 3	110 K	6000 K	73.0	(2 7/8)

Two pyrotechnic powder mixtures were considered. One powder mixture was a combination of phosphorus and potassium perchlorate with whiting (finely ground calcium carbonate) as a diluent; in some configurations, a conventional small arms propellant was used to expell the burning flash powder from the flash cue container. This powder had proven to be very effective during previous FBS cue research for USACDEC. The other pyrotechnic powder mixture considered was photoflash powder. The photoflash powder mixtures considered for generating the flash cue are listed in Table 3.

TABLE 3. PHOTOFLASH POWDER MIXTURES TESTED

Weight of Propellant (gm)	Shotgun Shell Size (gauge)	Weight of Photoflash Powder (gm)
0.5	12	0.5
0.5	12	1.0
0.5	12	2.0
1.0	12	0.5
1.0	12	1.0
1.0	12	2.0
2.0	12	0.5
2.0	12	1.0
2.0	12	2.0
1.0	8	1.0
1.0	16	1.0

The pyrotechnic mixtures considered for generating the flash cue may be represented by the following equations:

$$4Mg + KClO_4 \rightarrow 4MgO + KCl \qquad (1)$$

$$8Al + 3KClO_4 \rightarrow 4Al_2O_3 + 3KCl \qquad (2)$$

$$\begin{gathered}1.49Al + 0.15BaNO_3 + 0.22KClO_4 \rightarrow \\ 0.39Al_2O_3 + 0.15BaO + 0.22KCl + 0.69Al + 0.075N_2\end{gathered} \qquad (3)$$

The flash powder using aluminum flake or very fine particulate (10 to 15 micron diameter) and represented by Equation (2) appears to be the most effective flash producer. This powder burns extremely fast, and consequently is conducive to producing a significant bang. The aluminum oxide and potassium chloride products in this reaction are extremely finely divided and produce an excellent white cloud. Reactions represented by Equations (1) and (3) also produce excellent flash, are fast burning and produce a good cloud signature. But the aluminum mixture of Equation (2) appears to be the more reliable, readily ignitable mix.

A British FBS unit, a commercial device that was tested in the previous USACDEC investigation, was considered only as a reference because the cue levels are much larger than the cue levels specified in the requirements for this study. The safety hazards of this device are far beyond the acceptable limits of the applications considered in this investigation.

2.3 BANG CUE TECHNICAL CONSIDERATIONS

The bang cue is in general (pyrotechnically) caused by the rapid release of a quantity of compressed gasses. This rapid release can be that associated with a plug leaving the end of a shotgun shell or the rupture of a diaphragm or casing caused by excessive gas pressure. The only limitation on the magnitude of the bang is the safety limitation imposed by the U. S. Army Surgeon General (Technical Bulletin TB MED251) concerned with noise and the conservation of hearing. This restriction limits the peak impulse source pressure level to 140 dB (re 0.0002 dynes per square centimeter) at the ear. The use of sound protective devices could alleviate the requirement, but the bang impulse is, and will remain, a severe restriction for a ground type burst which may land within one foot of a person's head. For airburst applications, the bang cue could be limited to occur 10 to 20 meters or more away from the ear--significantly reducing the magnitude of the impulse at the ear and, thus, reducing the severity of the problem. The requirement for airburst does increase the complexity of the cue by requiring a timing device. The generic bang cue configurations considered included: (1) shotgun shell with wads - M6X propellant, 0.5 gm, (2) impact primer, (3) electrical primer, (4) shotgun shell (12 gauge) with a powder mixture of phosphorus and potassium chlorate with whiting, and (5) British FBS unit.

The shotgun shell with wads is discussed further below. The impact and electrical primers were slightly different, but they did not provide a significantly different bang signal. The mixture of phosphorus and potassium perchlorate with whiting and the British FBS unit were briefly described in the flash cue discussions in Paragraph 2.2.

Configurations considered for the bang cueing concept using the expulsion of the wad from the tube of a shotgun shell are listed in Table 4. Note that the number of wads used affects the degree of confinement of the propellant. More confinement results in a higher gas pressure at the time of release and, generally, a faster release rate that produces a louder bang.

TABLE 4. WAD EXPULSION BANG CUE CONFIGURATIONS

Propellant Weight (gm)	Shotgun Shell Size (gauge)	Number of Wads
0.5	12	1
1.0	12	1
2.0	12	1
1.0	8	1
1.0	16	1
1.0	12	2
1.0	8	2
1.0	16	2
1.0	12	3

The other configuration mentioned above involves using the heat from a photoflash bulb to ignite a priming black powder charge that in turn ignites a propellant in a sealed tube. The rupture of the tube produces the bang. The two main variables in controlling the bang from this type of unit are the quantity of propellant and the thickness of the tube wall, as measured by the number of layers of kraft paper used in the tube. The tubes can be constructed on a simple jig that allows the thickness to be controlled by the number of layers of kraft paper used in the fabrication process. The flashbulb-tube configurations considered for generating the bang cue are listed in Table 5.

TABLE 5. FLASHBULB-TUBE BANG CUE CONFIGURATIONS

Propellant Weight (gms)	Wall Thickness (layers of paper)
0.2	3
0.4	3
0.8	3
0.2	5
0.4	5
0.8	5
0.2	7
0.4	7
0.8	7

2.4 SMOKE CUE TECHNICAL CONSIDERATIONS

Smoke, as applied to signalling and cueing, is an assembly of small particles (0.01 to 10 microns diameter) of liquid or solid material dispersed in the atmosphere. Particles of this size have settling velocities on the order of 0.01 to 2 centimeters per second and, hence, should have sufficient "staying" capability. The primary criteria considered in developing the smoke cue can be summarized as follows:

1. Air burst - white
   Ground burst - gray
2. Three second persistence for wind velocities less than 10 mph
3. Cloud size large enough to be seen by the naked eye at a distance of 3 kilometers
4. Assumed to be non-toxic to man or environment.

The smoke visibility requirements for cueing a player of nearby indirect fire are minimal to the smoke generator concepts tested. The limiting requirement of smoke cue is the long range visibility requirements where a forward observer is required to visually detect the cue from a distance of 2 to 3 kilometers. A list (see Table 6) of known resolution references was assembled as a benchmark for determining the required cloud size needed in the demonstration rounds to meet the long range smoke visibility specifications. The majority of the items in this list are the bull's eye size of known targets extrapolated to a 3 kilometer range. From these values, an estimation of a 5 meter by 2 meter cloud size was made for this requirement. This size estimation may be converted to an area threshold value by using the diamond area model illustrated in Figure 1. A value of 5 square meters (54 square feet) was selected as being the required minimum cloud size for the 3 kilometer visibility requirements.

Table 7 outlines the different generic smoke cue configurations evaluated. Note that black powder is listed primarily to provide a baseline for a simple smoke cue. The manner in which black powder burns is dependent upon its confinement. Some of the black powder loads evaluated for use as the smoke cue are listed in Table 8.

For a relatively light confinement, the reaction representing combustion of 100 grams of black powder is:

$$\begin{gathered} K_{0.737}N_{0.736}C_{1.191}H_{0.218}O_{2.23}S_{0.316} + \\ 0.193CO + 0.507CO_2 + 0.0588H_2 + 0.05H_2O + 0.26K_2CO_3 + 0.368N_2 \\ 0.0485K_2SO_4 + 0.06K_2S + 0.207S + 0.231C_s \end{gathered} \tag{4}$$

The reaction is rapid, of the order of 3.2 millimeters (1/8 inch) per second, and develops 1.18 gmols gaseous products (and 0.807 gmols solid products).

TABLE 6. VISUAL RESOLUTION BENCHMARKS

	Reference Size at 3 km
o Eye Resolution	
- Point sources approximately 1 minute apart	0.87 meters
- (Rule-of-thumb) 0.1 mm apart at 25 cm from eye	1.20 meters
o 500 Yard Rifle Target	
- Bull's-eye size 40.6 cm diameter	2.70 meters
o 300 Yard Rifle Target	
- Bull's-eye size 30.5 cm diameter	3.30 meters
o 200 Yard Rifle Target	
- Bull's-eye size 30.5 cm diameter	4.90 meters

<u>Estimation of Required Cloud Size</u>

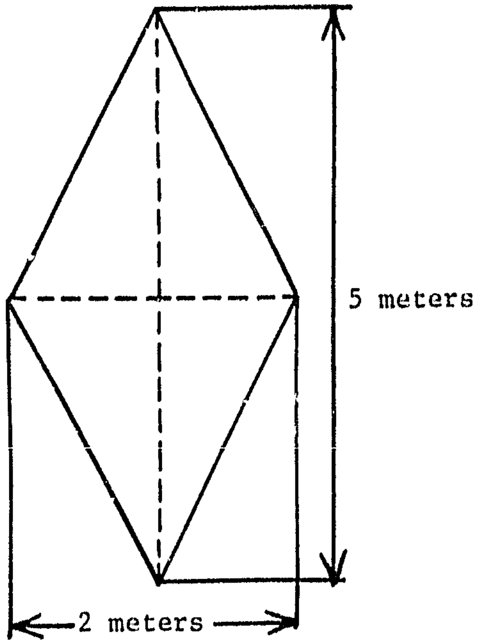
(for three kilometers visibility)

5 meters

by

2 meters

(diameter, width, or height)



Cloud Area = 2 * (Area of Triangle)
= $2 * (\frac{1}{2} * B * H)$
= $2 * (\frac{1}{2} * 2.0 * 2.5)$
= $2.0 * 2.5$
Cloud Area = $5\ m^2$
Cloud Area = $53.8\ ft^2$

Since cloud area is an easy number for comparing smoke cue size, then a cloud area of 5 square meters or 54 square feet is proposed as being the tentative threshold estimate for 3 kilometer visibility.

Figure 1. Assumed diamond shaped cloud with proposed maximum dimensions.

TABLE 7. SMOKE CUE CONFIGURATIONS

1. Black powder (FFFFg) in a shotgun shell with 1 wad
2. Black powder (FFFFg) with carbon as a diluent to intensify the cloud (loaded in a shotgun shell with 1 wad)
3. Inert powder expelled from a shotgun shell by a propellant (no wad or sabot used)
4. Inert powder expelled from a shotgun shell by a propellant (sabot used to separate the inert powder from the propellant - to give a better height to diameter ratio in the resultant cloud)
5. Anthracene and potassium chlorate (used as smoke cue and propellant)
6. Anthracene and potassium chlorate with an inert powder (anthracene and potassium chlorate used as propellant)
7. British FBS unit
8. Phosphorus and potassium perchlorate with whiting as a diluent (same charge as FBS cues)

TABLE 8. BLACK POWDER (FFFFg) SMOKE CUE LOADS

Powder Weight (gm)	Shotgun Shell Size (gauge)	Number of Wads	Diluent
1	12	1	
2	12	1	
4	12	1	
2	8	1	
2	16	1	
2	12	1	2 gm carbon black (mixed with propellant)
2	12	2	" " "
2	12	3	" " "

The relatively large amount of sulfur in the products produces an undesirable gas - smelling somewhat of rotten eggs. The 0.807 gmols solid products create the smoke associated with black powder. Approximately 560 cal/gm of heat is released in this combustion reaction; this heat coupled with its ease of ignition, contributes to the use of this reaction as a booster, igniter, and heat source.

For comparison purposes, the smokeless propellant used is typical of a double base (nitrocellulose/nitroglycerine) commercial propellant and its burning reaction is approximated by Equation (5) (for 100 grams material).

$$C_{2.137}H_{3.0086}O_{3.498}N_{1.089} +$$
$$0.2098CO + 0.99CO_2 + 1.3078H_2O + 0.1965H_2 + 0.937C_s + 0.5445N_2 \qquad (5)$$

producing 2.7 gmols of gaseous products (estimated average molecular weight 32.8) and releasing 1740 cal/gm. Note that the solid particulate material in the combustion products subsequently burns with atmospheric oxygen. These materials require somewhat more energy to initiate combustion than does black powder.

The inert smoke concept has high potential for producing a man-safe smoke cue (see Figure 4). Inert materials such as finely ground calcium carbonate, sodium bicarbonate and potassium bicarbonate were the primary inert powders evaluated. Most were expelled with a smokeless propellant so that the effect of the inert material could be quantified. Table 9 outlines the inert powder smoke cue configurations evaluated. In general, the use of a sabot with an inert powder produced a shorter and wider cloud than that produced without a sabot, probably because of the likelihood of channeling when no sabot was used.

2.5 CUE DEPLOYMENT CONCEPTS

The experiments summarized in the preceding tables can be grouped into three basic packaging configurations: bulk burning of pyrotechnic materials, surface burning of pyrotechnic materials, and inert materials. The configuration for bulk burning of pyrotechnic mixtures is shown diagramatically in Figure 2. In this conventional cue design, the cue material is contained in a confined case with the ignition device. A diaphragm used to seal the tube not only aids the combustion process but also allows the cue to produce an

TABLE 9. INERT POWDER SMOKE CUE CONFIGURATIONS

Propellant Weight (gm)	Shotgun Shell Size (gauge)	Number Of Wads	Description
0.5	12	1	3 gm inert powder with sabot
1.0	12	1	3 gm inert powder with sabot
2.0	12	1	3 gm inert powder with sabot
1.0	12	1	6 gm inert powder with sabot
1.0	12	1	6 gm inert powder without sabot
1.0	8	1	3 gm inert powder with sabot
1.0	12	2	3 gm inert powder with sabot
1.0	12	2	3 gm inert powder without sabot

TABLE 10. ANTHRACENE/POTASSIUM CHLORATE SMOKE CUE CONFIGURATIONS

Propellant Weight (gm)	Anthracene Potassium Chlorate (gm)	Number Of Wads
0.5	3	1
1.0	3	1
0.5	6	1
0.5	3	2
1.0	3	2
0.5	6	2

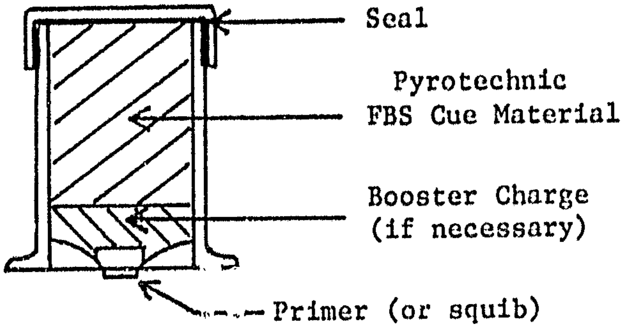


Figure 2. Diagram of pyrotechnic bulk burning cue container.

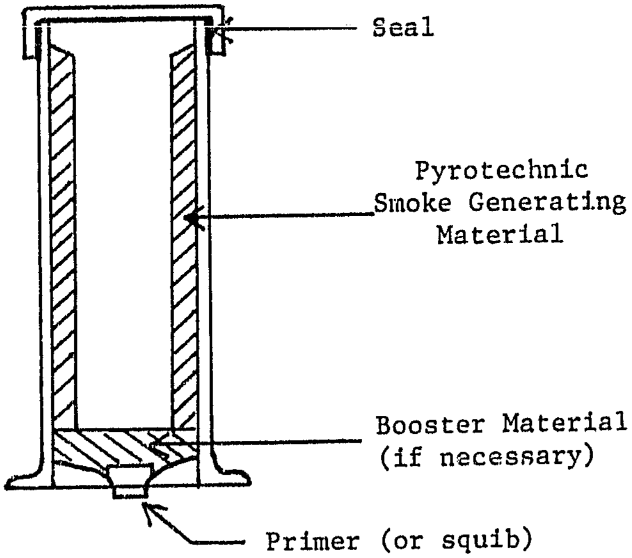


Figure 3. Diagram of cylindrical burning pyrotechnic smoke cue generator.

acoustic signature as the container or diaphragm ruptures. This cue deployment concept may produce a fireball and the discharge of burning particles if combustion is not complete at the time of rupture. The magnitudes of the flash cue and the acoustic signature are dependent upon the weight of the pyrotechnic cue material used, the degree of the confinement provided by the container, the burning rate of the cue material, and the total amount of energy released by the cue material. This deployment concept appears to present burn hazards to personnel (both exposed skin and clothes) at close ranges, fire hazards to dry grass, and high acoustic levels.

The packaging for surface burning of pyrotechnic material is based on the use of a container design utilizing a cylindrical burning configuration (see Figure 3). For this design, the cue generating material was typically placed around the inside of the container tube. The material was ignited by a small booster charge at the center and allowed to burn from the center outward while the smoke material was released from the open end. This cueing approach can be combined with flash and bang generators to meet the desired FBS performance. The cueing effectiveness of surface burning depends upon the burning rate of the smoke generating compound. Fast burning materials ejected burning powder particles. This cue deployment approach offers some degree of player and grass fire safety over the bulk burning technique discussed above.

The third cue deployment method developed was for the inert powder smoke cue materials. The inert powders were investigated to determine their cueing effectiveness as well as their potential for providing improved safety for personnel and reducing the probability of range fires. The simplest method of ejecting the cloud material appears to be to use a small propellant charge. In the interest of man-safety, this charge should be no greater than necessary to eject the cue material. The diagram in Figure 4 presents the basic concept for this cue deployment design. A fast bulk burning propellant charge is used so that all of the combustion occurs within the tube. This cue technique can be complemented by an auxiliary flash cue to provide a complete FBS device. The acoustic cue can be incorporated in the design by using a rupture diaphragm to seal the end of the tube. The peak acoustic level can be controlled by the amount and type of propellant and the thickness of the diaphragm. In the demonstration units developed for the inert powder cues, the propellant was adjusted to give a good cloud; the thickness of the rupture

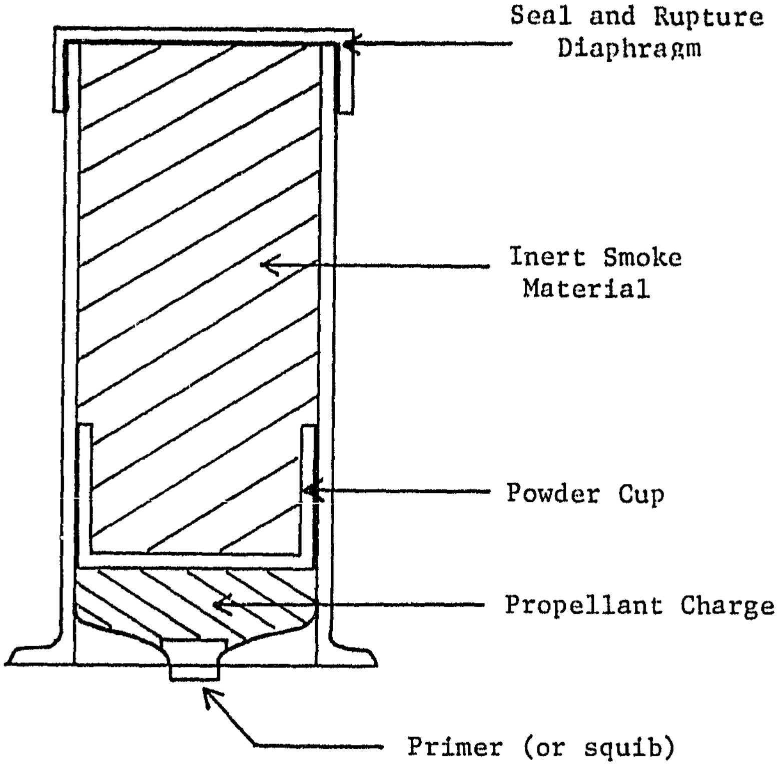


Figure 4. Diagram of inert powder Bang/Smoke cue container.

diaphragm was then adjusted (by varying the number of layers of paper used) to give a good bang cue.

An anthracene and potassium chlorate mixture was also evaluated for possible use as a smoke cue generator. This mixture can be used by itself as a smoke generator, or it can be used as a propellant. Table 10 defines the configurations evaluated for this powder mixture. The propellant for these experiments was M6X.

The combustion reaction of anthracene with potassium chlorate may be written as (depending on the ratio of the components to each other)

$$11KClO_3 + C_{14}H_{10} \rightarrow 11KCl + 5H_2O + 14CO_2 \quad (6)$$

$$5KClO_3 + 3C_{14}H_{10} \rightarrow 5KCl + 15H_2O + 42C_S \quad (7)$$

The reaction indicated by Equation (6) produces primarily gaseous products (little black smoke) and is somewhat hard to start. The reaction indicated by Equation (7) produces much better smoke and carbon particulate, and is easier to start, but burns relatively slowly. Therefore, equal parts by weight of 30 percent of black powder was added to anthracene and potassium chlorate to provide a good gray cloud, rapid burning, and easy ignition.

The phosphorous mixture referred to previously is defined in Appendix C and may be approximately represented by the reaction

$$\begin{gathered} 0.674P + 0.209CaCO_3 + 0.475KClO_4 \rightarrow \\ 0.337P_2O_5 + 0.108O_2 + 0.475KCl + 0.209CaO + 0.209CO_2 \quad (8) \end{gathered}$$

although the P_2O_5 product shown is probably a mixture of P_2O_3 and P_2O_5. This mixture liberates more than 1000 cal/gm on burning and produces a very good smoke cloud from the 1 gmol of very finely divided solid products for each 1.35 gmol of reactant. Combustion is very rapid, producing an excellent report as it splits a 12 or 8 gauge shotgun shell casing.

The concept of using a standard flashbulb with black powder attached* to the surface for an igniter is unique. The flashbulb is not overly sensitive

---

*This is accomplished by dipping the standard AG-1 flashbulb in acetone for 10 to 15 seconds - then rolling in black powder (FFFg or FFFFg), and then hanging the unit free to dry.

to static or radio-frequency (RF) energy, but can be ignited by approximately 300 milliamperes (AC or DC) from a nominal 3 volt source. This provides a nominal current level for ignition, a high enough no-fire current to be safe, and yet provides reliable ignition to the pyrotechnic mixture. The combination of an AG-1 flashbulb and the black powder attached to the surface of the bulb proved to be a reliable igniter at temperatures as low as 5 degrees Fahrenheit (the lowest limit tested).

SECTION 3

INSTRUMENTATION AND DATA REDUCTION

3.1 OVERVIEW

A main goal of this development effort was to quantify the cueing signatures of different cueing concepts. The test program described in this report recorded the signature effects of a large number of FBS cue events. Documentation of these tests included recordings of the flash phase of the cue, measurements of the peak acoustic level of the bang signature, and measurements of the smoke cloud size as a function of time. This section of the report describes the unique instrumentation and data reduction facilities developed and assembled for this research effort.

3.2 SHORT RANGE TEST INSTRUMENTATION

The majority of the experiments for evaluating FBS cue techniques were conducted at short ranges (less than 100 meters) at the Georgia Tech Research Facility in Cobb County, Georgia. The purpose of these short range tests was to gather data on a large number of cue designs in a cost effective and routine manner for the data reduction. Instrumentation cameras were used as the primary method for recording the flash and smoke signatures of the individual cue devices. The basic instrumentation is shown in Figure 5 and briefly described below.

Master Timing Control Unit. The FBS cue devices were initiated by a master timing control unit that synchronized the operation of all instrumentation used for recording the test device cue signatures.

Instrumentation Cameras. Separate 35-mm Flight Research Mod IV instrumentation cameras (capable of remote control operation) were used for recording the flash and smoke cue signatures. The cameras function in either a single frame mode or operate in a continuous (cine) filming mode as selected by an electrical command. This ability to change the recording mode electronically was used to great advantage for evaluating the smoke cue cloud characteristics.

The Mod IV camera uses a single frame 35-mm movie format. This camera is driven by a solenoid operated clutch connected to an electric motor through a

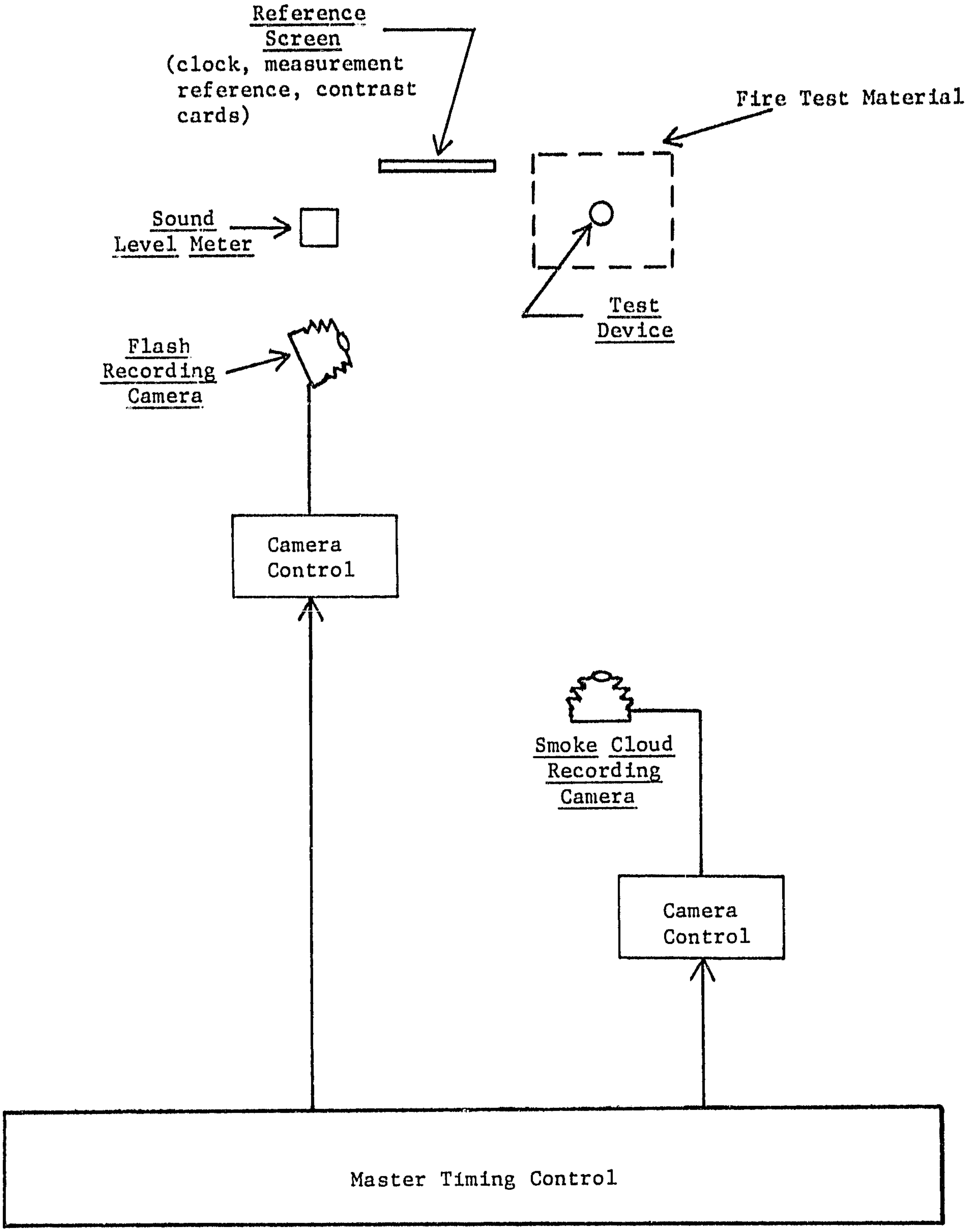


Figure 5. Block diagram of basic instrumentation for FBS investigations.

gear train. The gear ratio and motor speed determine the maximum cine rate of the camera. Single frames at rates less than the cine rate are recorded by activating the solenoid clutch with a pulse having a duration less than the time between two frames at the cine rate.

The smoke cloud recording camera had a cine rate of 10 frames per second with an effective shutter speed of approximately 1/500 second. The camera was started in the cine mode by the master timing control unit for a period of 0.8 to 1.5 seconds. Approximately 0.5 seconds after this camera was started at the 10 frames per second rate, the cue device being tested was activated (see the timing diagram in Figure 6). This ensured that the initial deployment of the smoke cue was recorded with high time resolution. After the cine period was over, the master timing control unit switched the camera mode to a pulsed operation of one frame per second for a period of approximately 10 seconds to record the relatively slow dispersion phase of the smoke cloud. This dual photographic rate gave a film strip format of each event; the high speed frames were identified by marking them with a data light in the camera. The picture frame containing the first cue activity was used as the time t = 0 for the data analysis.

The Mod IV camera uses a rotating disk shutter, and the high shutter speed (narrow slit in the disk) for the smoke cloud recordings prevented a complete photographic frame from being exposed at the same instant. Since the total frame was not exposed during the open shutter pulse from the camera, the open shutter pulse could not be used to trigger the cue device.

A second Mod IV camera was used to record the flash of the test cue device. This camera used a shutter speed of 1/10 second and a cine rate of 5 frames per second. This combination provided an open shutter over the entire frame and allowed the open shutter pulse to be used to activate the device under test. This shutter and cine filming rate allowed the short duration flash event to be simultaneously recorded over the entire exposed frame. The master timing control unit initiated the flash recording camera and, consequently, activated the test device approximately 0.5 seconds after the start of the smoke recording camera. Figure 7 illustrates a typical flash event as recorded by this camera.

Reference Background Stand. A reference background was included in the field of view of the smoke recording camera to provide a standard background

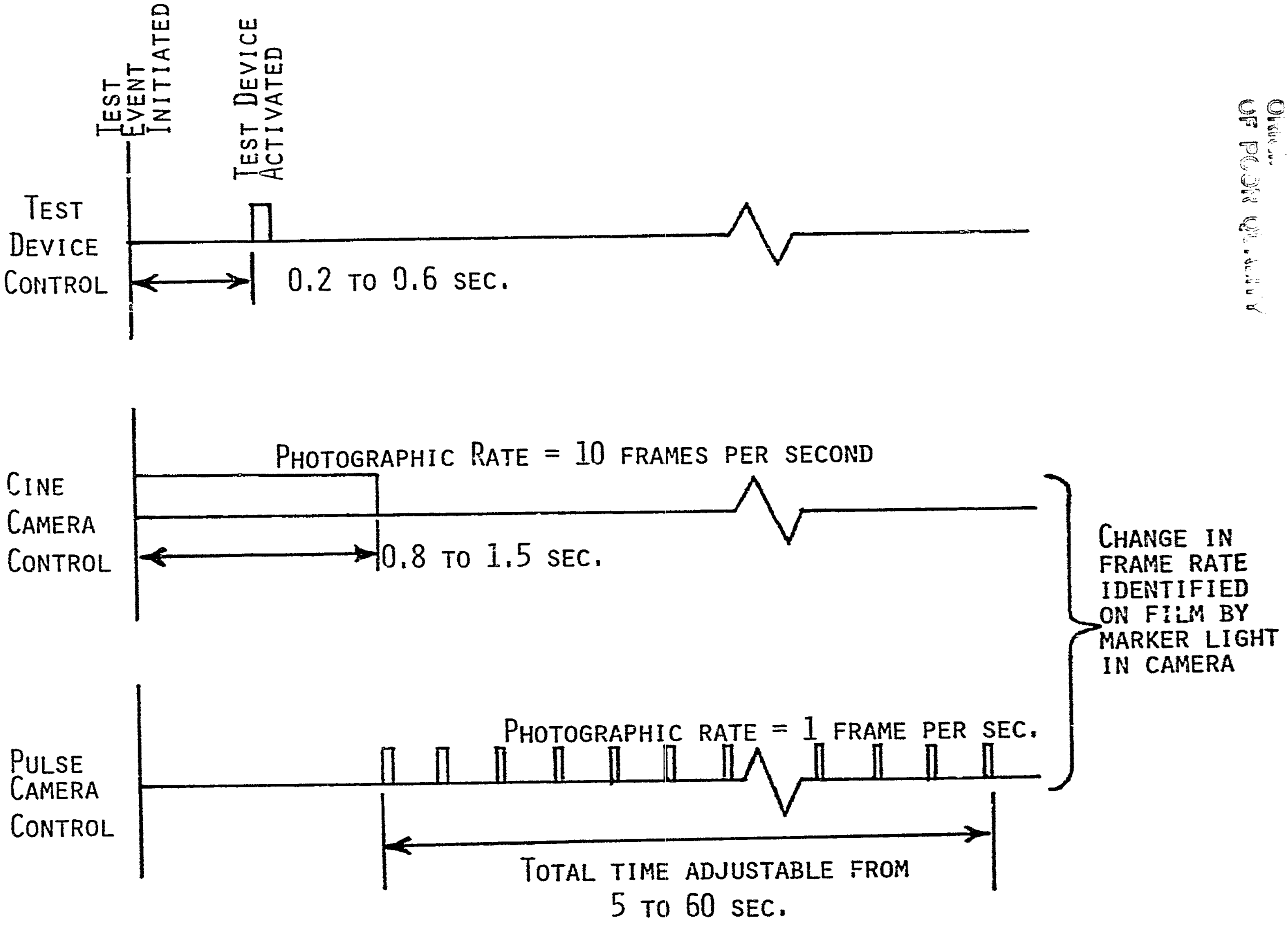


Figure 6. Photographic instrumentation event timing chart.

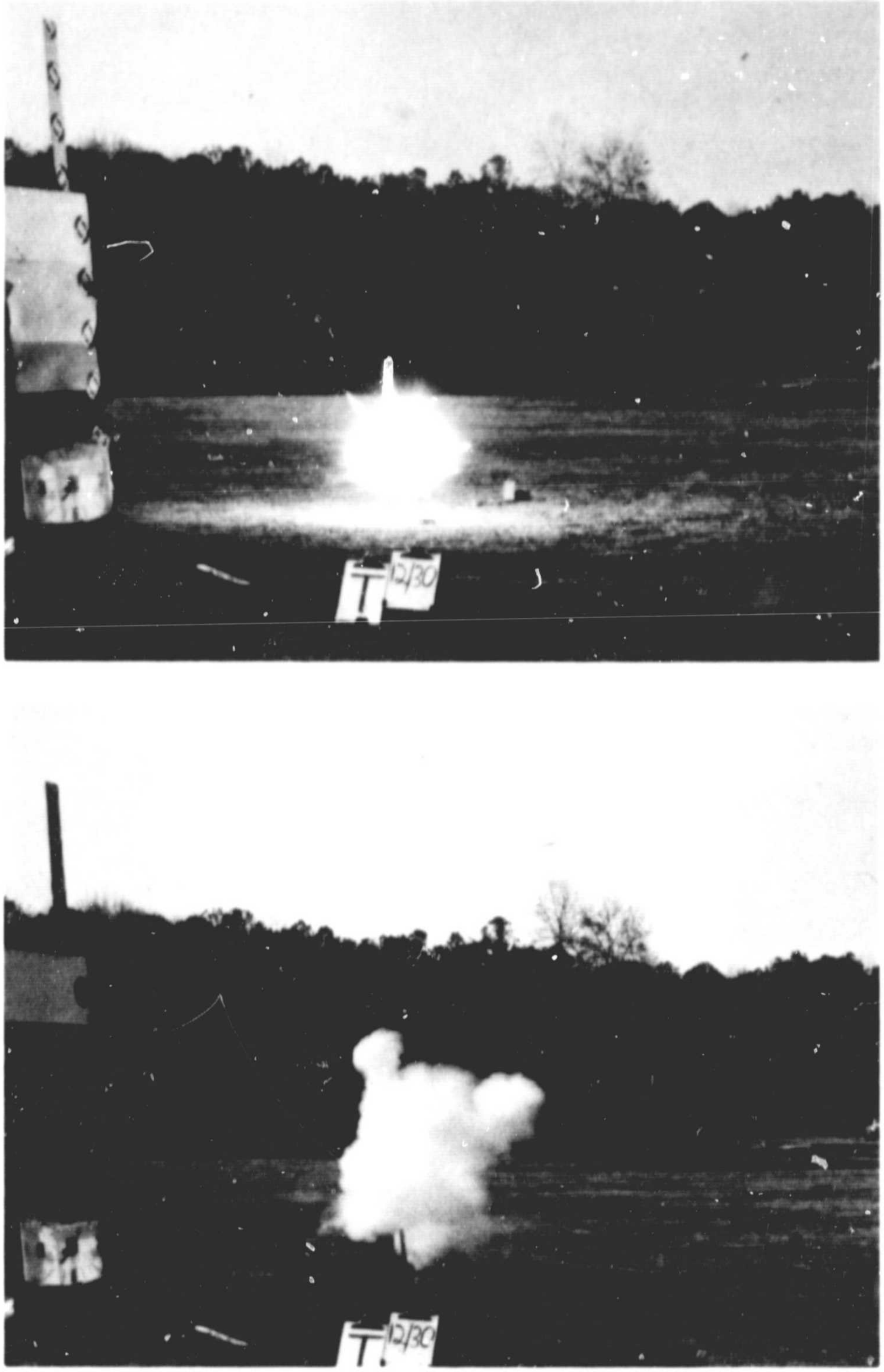


Figure 7. Example of open burning FBS cue with fireball - 12/30/T
Top: t = 0, Bottom: t = 200 ms - 16 gm Flash Powder

for size and contrast. Four different contrast cards were placed on this unit (see Figure 8) to provide a subjective reference in each test recording. Reference markers attached to the side of this screen provided a 3.05 meter (10 foot) reference distance that was used to calibrate the data processing program. A clock was also included to give a reference time of each test run.

Test ID. The test runs were identified by photographing a test ID number in the foreground of each camera. The test ID number was coded for the month, day, and cue test run number for that day. For example, the fifth cue device fired on October 5 would be given the identification number 10-5-E. This nomenclature was used in all of the test records given in this report.

Cue Ignition. Two methods of activating the test cues were used during the experiments described in this report. Since many of the tests were to quantify the signatures of various amounts and types of cue compounds, standard shotgun shells were used for holding the FBS cue material. The majority of these tests were initiated via standard primer caps. The fixture shown in Figure 9 was used to trigger the cap for 16 gauge, 12 gauge, and 8 gauge shells. The test cue was fired when electrical power was applied to a solenoid that pulled a sear from a spring loaded firing pin.

The alternate method of discharging test cue devices was to use a squib or flashbulb igniter device. These units were triggered from a six volt battery through a relay. Cue test units having this type of igniter were held in a simple manner such as being fastened to a stake.

Acoustic Measurements. Acoustic impulse levels of the bang signature were monitored by a General Radio Model 1981 sound level meter designed to capture the peak level of sound filtered through a standard A-weighted frequency spectrum. The values recorded are in the data logs in Appendix B of this report.

The acoustic measurements recorded in this report were made at a reference distance from the cue device as specified with the tabulated data. This distance was changed occasionally during the course of the experiments to accommodate drastically different levels in the expected bang signature. The reference measurement distance was also modified during the course of the experiments to compensate for a saturation characteristic discovered in the audio metering system. The graph in Figure 10 illustrates this effect that occurs at levels above 113 dBA. The data in this graph were obtained by

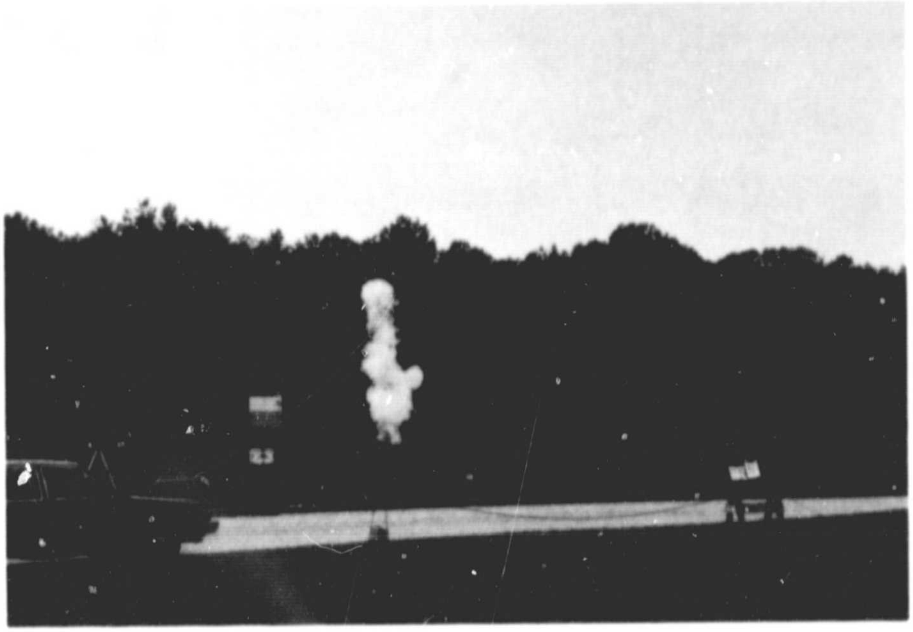


Figure 8. Flash/Bang/Smoke short-range cue test setup.

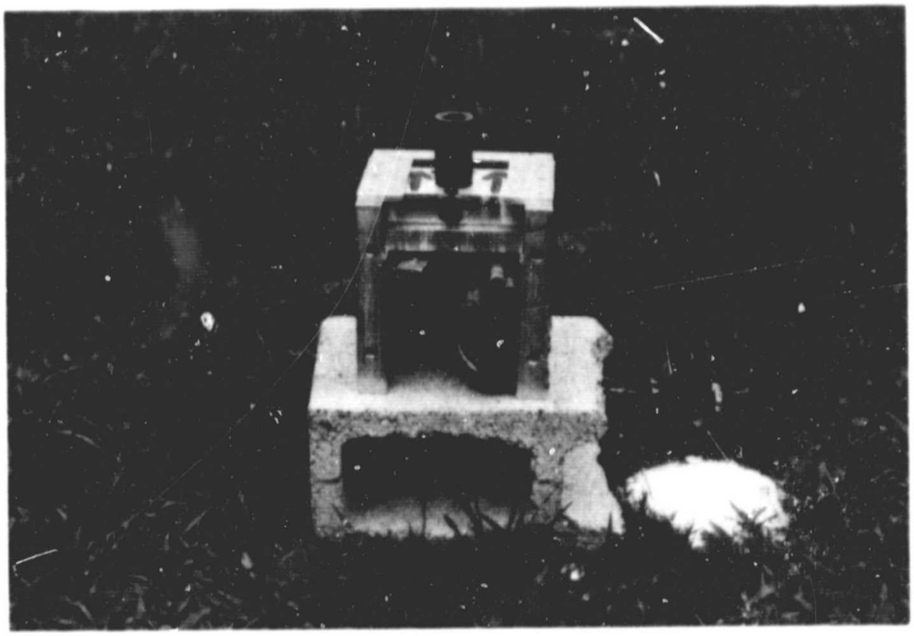


Figure 9. Shotgun shell cue testing device for impact primers.

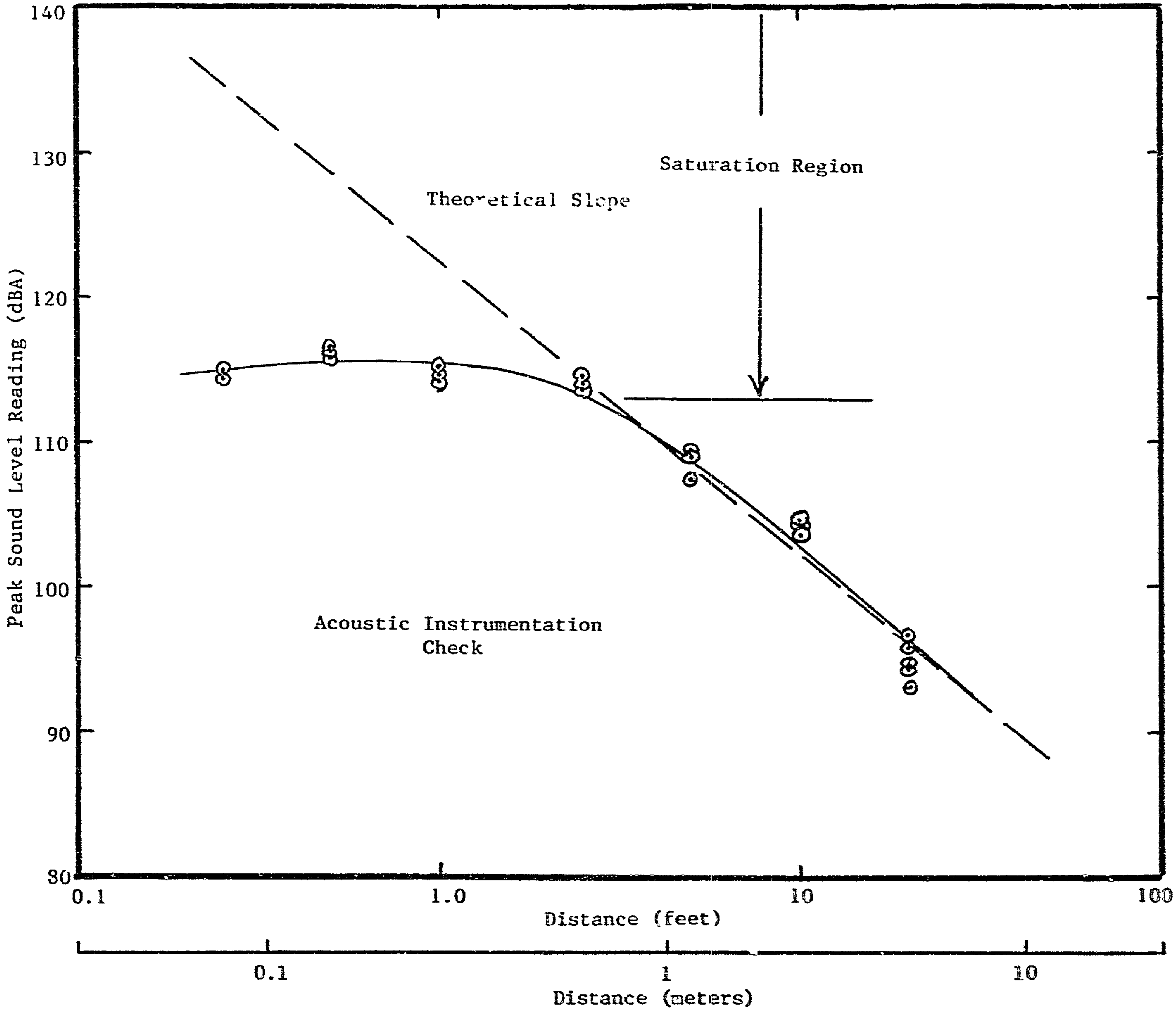


Figure 10. Linearity curve for sound level meter.

firing 22 caliber blanks at fixed distances from the sound level meter and recording the acoustic impulse level. The dashed line represents the theoretical slope as a function of distance from the sound level meter. The individual shots at each measurement distance produced good groupings.

The experimental data in Figure 10 clearly indicate that the measurement data for levels above 113 dB are not accurate, even though they are still within the design range of the meter. After this analysis identified the saturation effects within the acoustic instrumentation, the measurement distance was adjusted in an attempt to keep the expected readings within the linear range. This was not always successful, and acoustic readings in the saturation region of the meter were obtained for some of the cue tests. Therefore, values above about 113 dBA for the bang signature as recorded in the data logs (Appendix B) merely represent lower limits for the actual signature.

Fire Test Fixture. The requirement that the cue shall not start grass fires was monitored in a large number of test firings with the cue placed above the fire test fixture shown in Figure 11. The fire test fixture consisted of a four by four foot section of plywood with a surface made of dry hay affixed with staples.

3.3 LONG RANGE TEST INSTRUMENTATION

The requirement for smoke cloud visibility at ranges of 3 kilometers required that a different test location be established. Visibility over ranges of this extent in the local area is difficult due to the heavy stands of timber. This factor limited the selection of test sites to three basic scenarios: (1) locate an open field the appropriate distance from an accessible mountain top, (2) get permission to operate along side of an airport runway of suitable length, or (3) operate across the open water of a lake.

The latter scenario proved to be the easiest to meet and the long range smoke cloud visibility tests were conducted at Lake Sidney Lanier, Georgia, with the permission of the U. S. Army Corps of Engineers. The selection of the test site and the observation site was made with a criteria of a separation distance between 2 and 3 kilometers. Since the Corps of Engineers only controls a few sites along the shore of the lake, the separation distance of exactly 3 kilometers could not be easily met with the test and observation

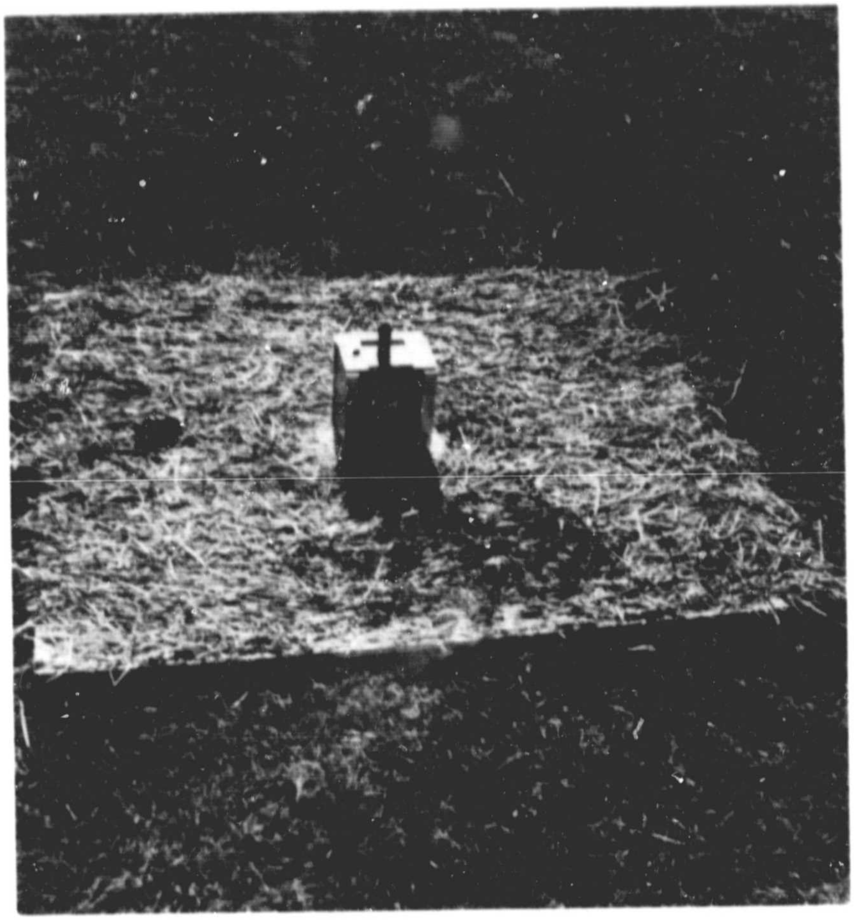


Figure 11. Cue testing device on fire test board.

sites being on publicly owned land under control of the Corps of Engineers. Figure 12 shows the location of the test site and observation site on a map of the Lake Lanier area near the dam. The separation distance was approximately 2.5 kilometers. Two field experiments were conducted at these facilities prior to the delivery and testing of the demonstration cueing units to JPL.

The basic instrumentation was reconfigured for the long range smoke visibility tests. The basic limitations were imposed by the absence of convenient power at either site. Battery power sources were assembled for the cue test firing location to operate the Mod IV camera formally used for the flash event recording. This camera was used for both the flash and smoke cloud recording during the long range tests. The time format was modified to allow this camera to operate in the cine mode and record 5 frames per second for the duration of the test run. Figures 13a and 13b illustrate the test set up at the cue firing site. The instrumentation included the test stand and the sound level meter.

The observation site was instrumented with a 16-mm movie camera with a telephoto lens and a 35-mm still camera with a telephoto lens. The site was connected to the firing site by radio and the movie camera was started at a film rate of 18 frames per second approximately 3 seconds before the cue was activated. The still camera was operated approximately 2.5 seconds after the cue was operated. Firing times were taken from a countdown given over the radio. The observations of the personnel were also recorded as part of the tests. Figure 14 illustrates the observation site.

The primary data from the long range smoke visibility tests were the photographic recordings made at the observation site. The telephoto lens was used to maximize the image size on the film. Figure 15 defines the relationships for both cameras based on the focal lengths of the lens used on the two cameras. These equations define the scale factors for the two cameras so that absolute measurements can be obtained from the film. The derivations in Figures 16 and 17 develop the viewing requirements for both the still pictures and the movies to restore the angular perspective that existed to the unaided eye at the observation site. Figure 18 illustrates an example of the still camera recordings. The scale factor was developed from the equations presented in Figures 16 and 17.

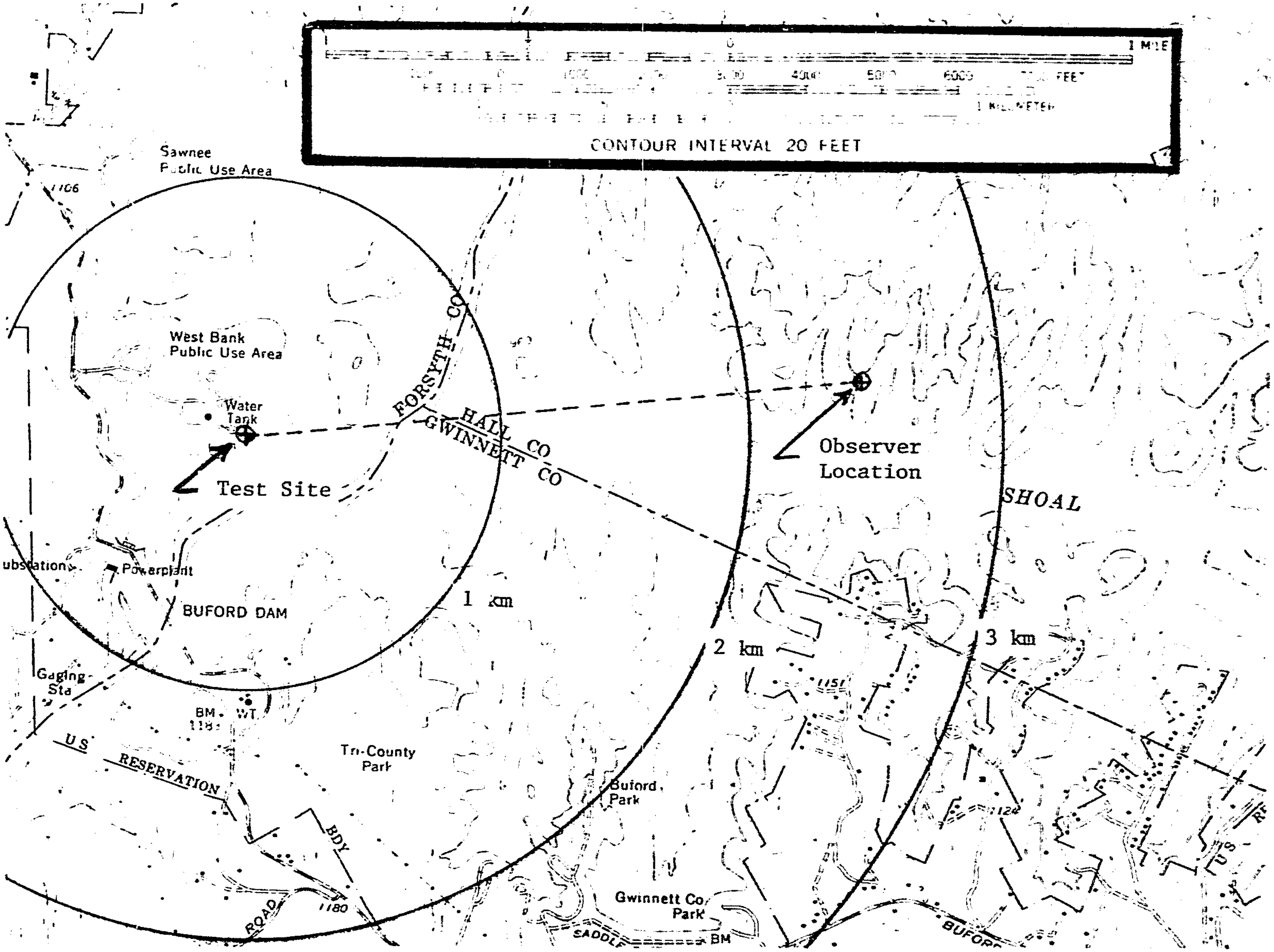


Figure 12. Long range smoke visibility test site; Lake Lanier, Georgia.

ORIGINAL PAGE
BLACK AND WHITE PHOTOGRAPH

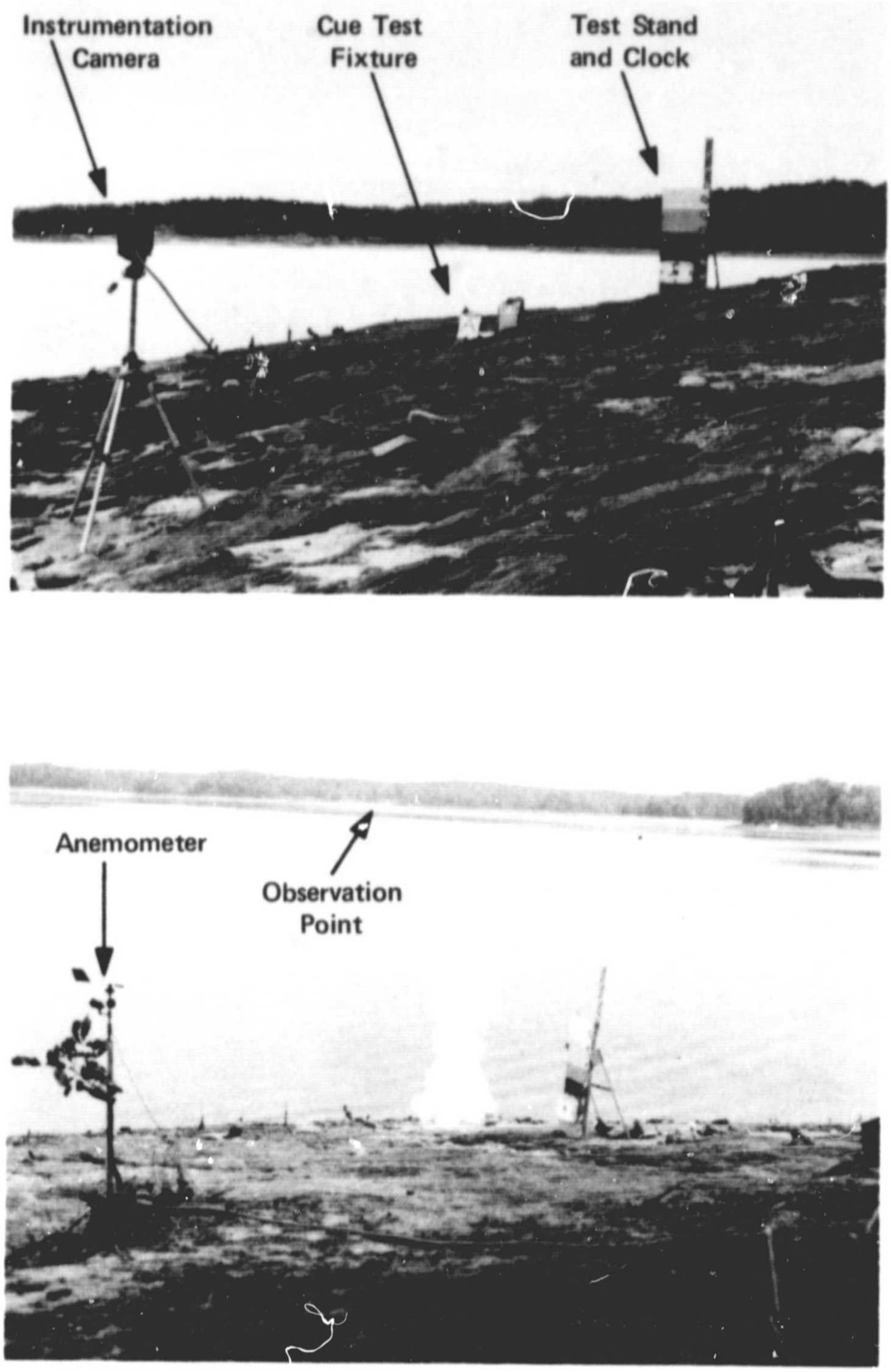
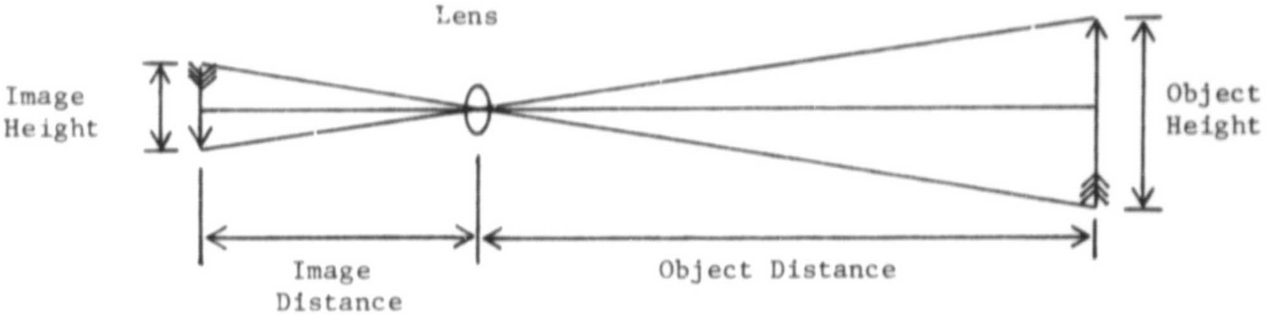


Figure 13. Cue test site for long range smoke visibility tests.
(a) Top - Instrumentation layout
(b) Bottom - View of observation range

ORIGINAL PAGE
BLACK AND WHITE PHOTOGRAPH

Figure 14. Observation site for long range smoke visibility tests.



$$\frac{\text{Object Height}}{\text{Object Distance}} = \frac{\text{Image Height}}{\text{Image Distance}}$$

For the <u>16-mm Movie Camera</u>

Image Distance = Focal Length = 120 mm

Image Height = Frame Height = 7.6 mm

Let Object Height = Vertical Field of View

$$= \frac{(\text{Image Height})(\text{Object Distance})}{(\text{Image Distance})}$$

$$= \frac{(0.0076 \text{ m})(2500 \text{ m})}{(0.120 \text{ m})}$$

Vertical Field of View = 158.3 meters

For the <u>35-mm Still Camera</u>

Image Distance = Focal Length = 300 mm

Image Width = Horizontal Width = 34 mm

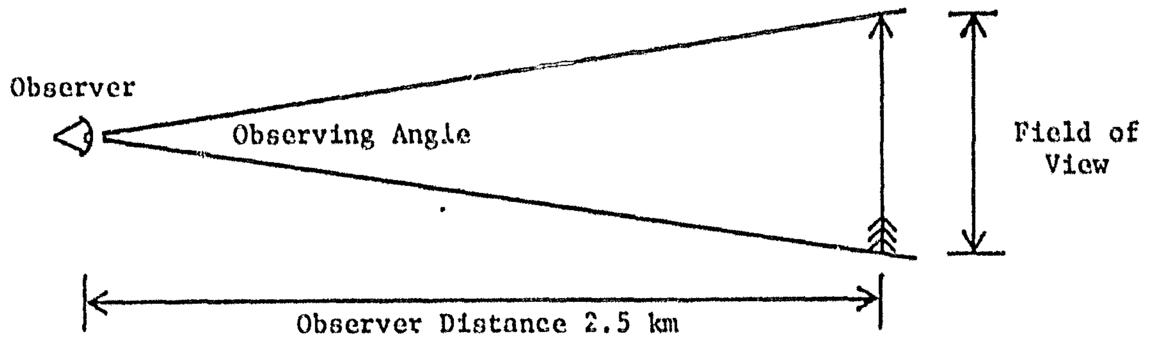
Let Object Width = Horizontal Field of View

$$= \frac{(\text{Image Width})(\text{Object Distance})}{(\text{Image Distance})}$$

$$= \frac{(0.034 \text{ m})(2500 \text{ m})}{(0.300 \text{ m})}$$

Horizontal Field of View = 283.3 meters

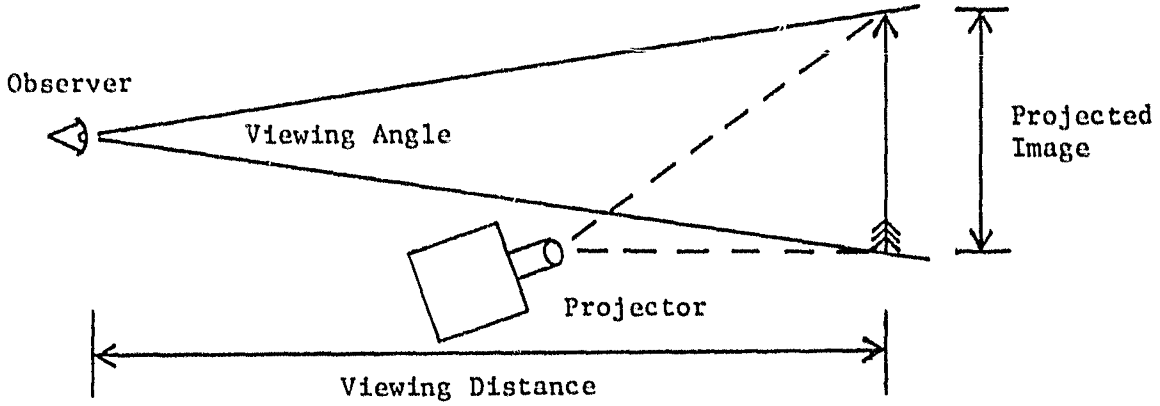
Figure 15. Derivation of camera scale factors for long range visibility tests.



$$\text{Observing Angle} = \frac{\text{Field of View}}{\text{Observer Distance}}$$

For the <u>16-mm Movie Films</u>

$$\text{Observing Angle} = \frac{158.3\ \text{m}}{2500\ \text{m}} = 0.0633\ \text{radians}$$



$$\text{Viewing Angle} = \frac{\text{Projected Image Size}}{\text{Viewing Distance}}$$

For Original Observer Viewing Angle and a 0.305 meter Image

$$\text{Viewing Distance} = \frac{\text{Projected Image Size}}{\text{Viewing Angle}}$$

$$= \frac{0.305\ \text{meters}}{0.0633\ \text{radians}}$$

$$\text{Viewing Distance} = 4.8\ \text{meters} \quad \left\{ \begin{array}{c} \text{Original Perspective} \\ \text{and} \\ 0.305\ \text{meters} \\ \text{Vertical Image} \end{array} \right.$$

Figure 16. Derivation of formulas for viewing scale factors for long range visibility tests.

For the <u>35-mm Still Camera</u>

$$\text{Observing Angle} = \frac{\text{Field of View}}{\text{Observer Distance}}$$

$$= \frac{283.3\ \text{m (horizontal)}}{2500\ \text{m}}$$

$$= 0.1133\ \text{radians}$$

$$\text{Viewing Distance} = \frac{\text{Image Size}}{\text{Viewing Angle}}$$

For Figure 18

If Image Width = 0.23 meters

$$\text{Correct Viewing Distance} = \frac{0.23\ \text{meters}}{0.1133\ \text{radians}}$$

$$= 2.1\ \text{meters}$$

For Projected Slides

If Image Width = 0.61 meters

$$\text{Correct Viewing Distance} = \frac{0.61\ \text{meters}}{0.1133\ \text{radians}}$$

$$= 5.4\ \text{meters}$$

Figure 17. Viewing scale factors for long range visibility test pictures.

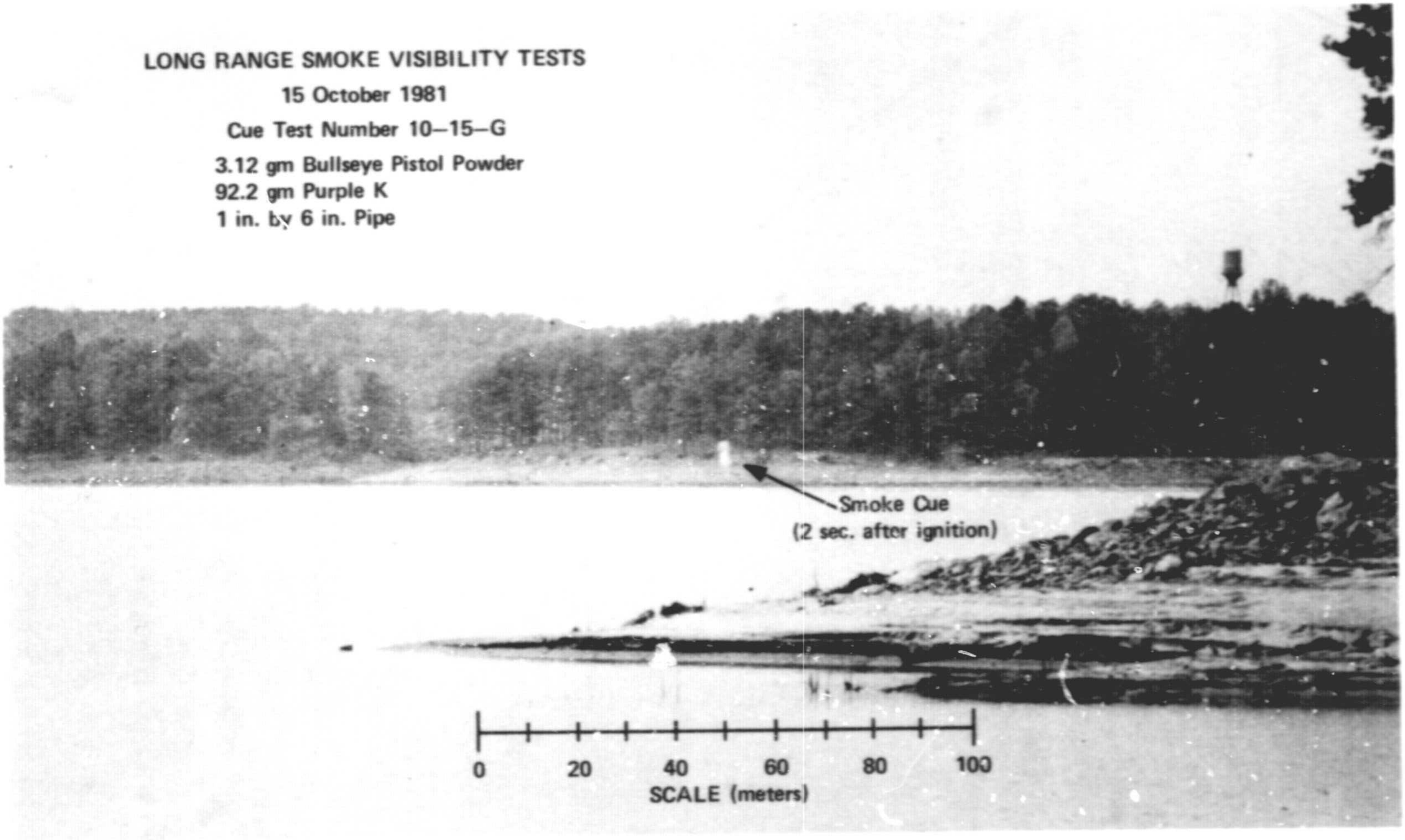


Figure 18. Still camera recording of long range visibility tests. (Correct perspective for 2.1 meter viewing distance)

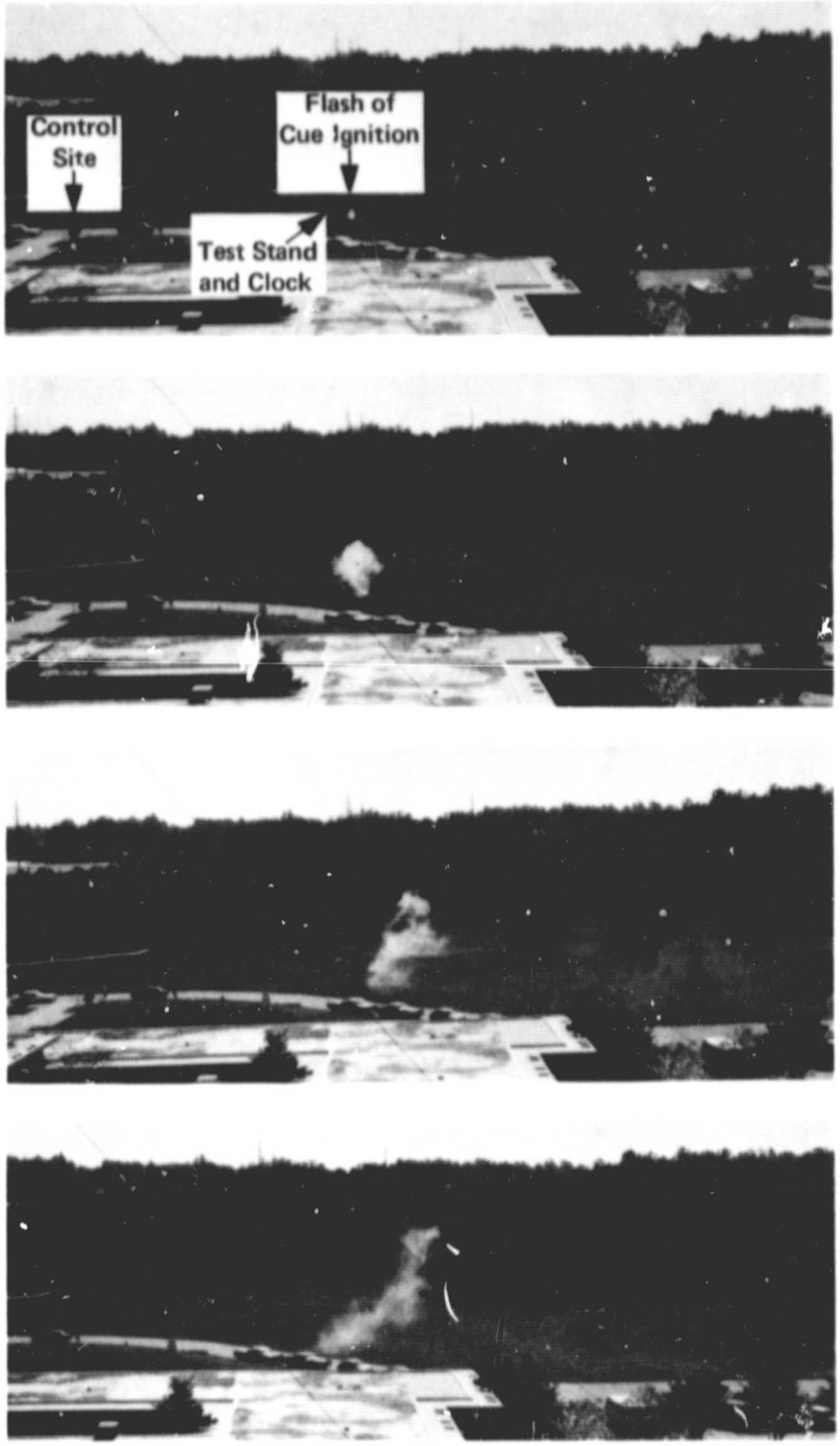
3.4 SHORT RANGE TEST DATA REDUCTION

The primary analysis of the short range cue tests was to evaluate the area and the volume of the smoke cloud as a function of time. The relative size of the smoke cloud is a function of the time after ignition, the surface wind velocity, the amount of particulate material in the cue, the force with which the cue is ejected, and the net temperature of the gasses in the cloud. A principle goal of the measurements and data reduction was to quantify the effective signature as a function of the amount of cueing material used. The photographic recordings of each cue test provide the medium for measuring the smoke cloud area and volume. Figure 19 presents an overview of the test area during a 15 second period of a cue test. This view was made from a tower approximately 200 meters from the cue device.

The philosophy of the smoke cloud data reduction was to project the photographically recorded images onto a computer display screen and use the computer to reduce the data. The TV monitor display has a movable cursor programmed so that the cloud may be outlined when the picture image is superimposed over the computer display screen. The combining process was accomplished by building a simple fixture shown in the block diagram in Figure 20. Inside the box, the film strip recording of the cue test was projected upon a ground glass rear projection screen. A half-silvered mirror was used to present a combined view of the TV monitor and the projected picture to the operator at the viewing port. Care was taken to eliminate error due to parallax.

An Apple II Plus computer was used for the data reduction program. The standard game paddle inputs allowed the cursor to be positioned on the TV monitor with a resolution of 279 by 179 pixels. Typical scale factors used for the majority of test measurements produced a resolution of approximately 3.4 centimeters per pixel which was sufficient for the accuracies desired in the final data. This method provided a very cost effective method of digitizing the cloud pictures.

Smoke clouds produced by the cues usually have very irregular shapes. In general, it may be assumed that the cue cloud will be in an elongated shape originating at the cue test device. For the purpose of this analysis, it was assumed that the cloud may be represented by a group of thin cylindrical discs as shown in Figure 21. The locations of these discs were assumed to be moved by the wind so that each disc may be offset from the adjacent ones.



Time After Ignition

0 sec.

5 sec.

10 sec.

15 sec.

Figure 19. Cloud deployment sequence on short range test area.

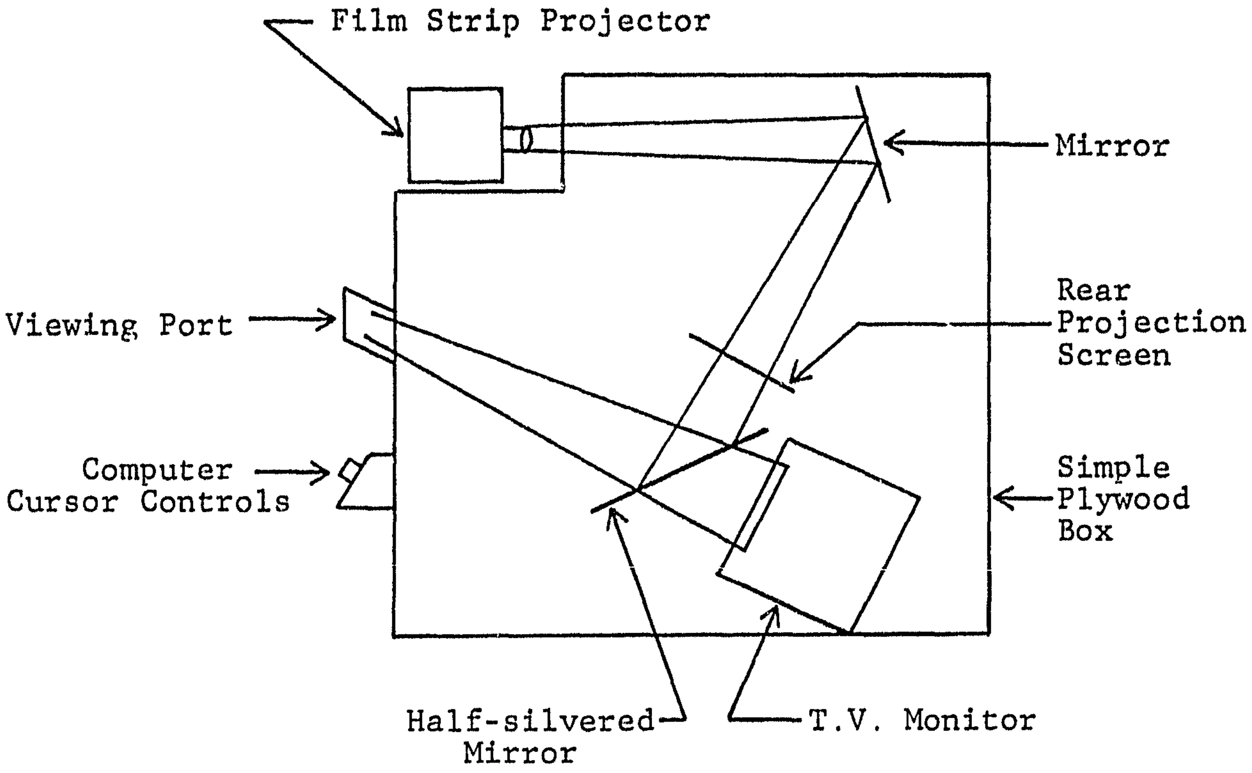
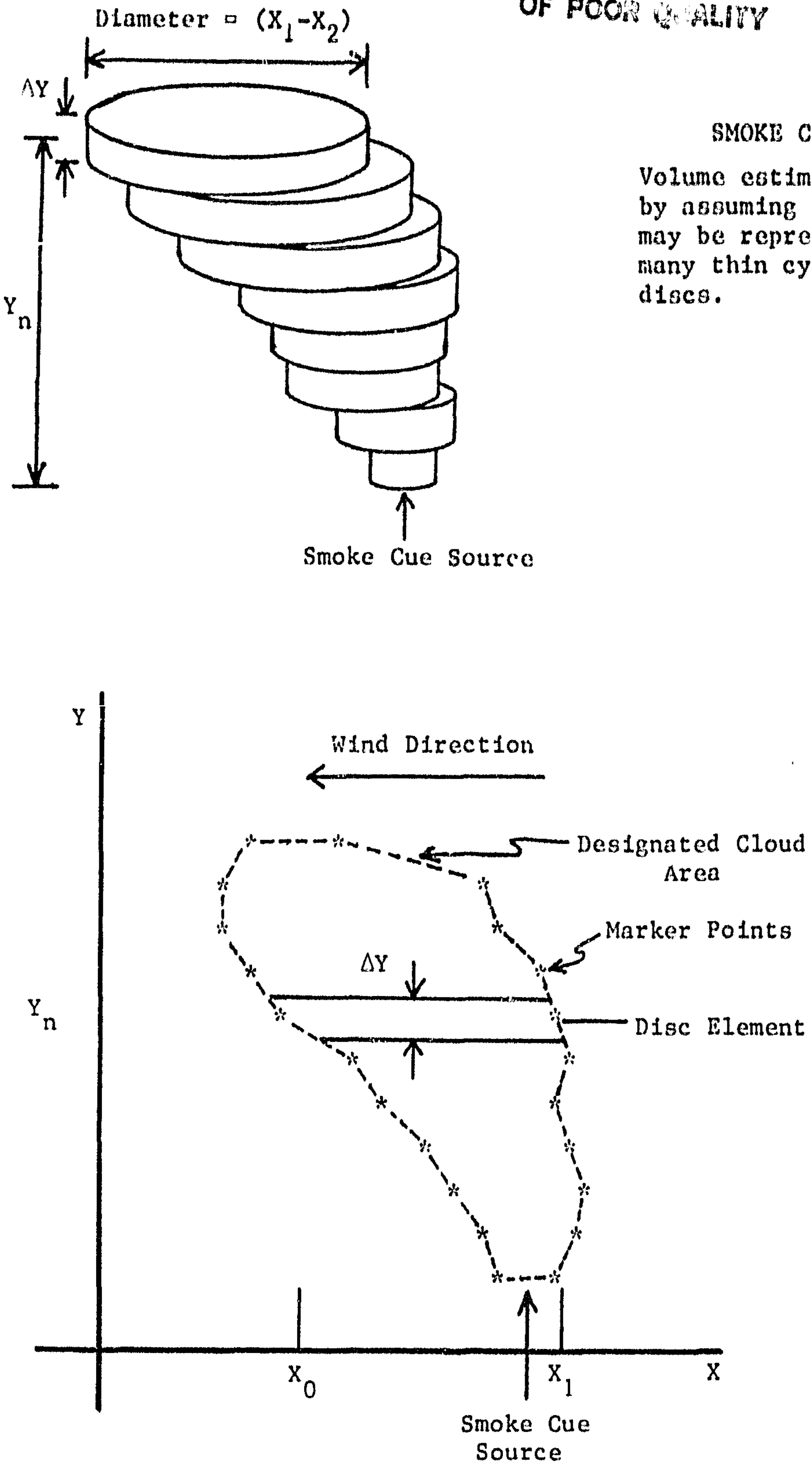


Figure 20. Fixture for data reduction of smoke cloud photographic recordings.



SMOKE CLOUD

Volume estimated by assuming the cloud may be represented by many thin cylindrical discs.

Figure 21. Smoke cloud data reduction model.

The cloud was viewed by the operator and the apparent boundaries were marked at fixed vertical levels (representing the center height of the assumed cylindrical discs). The smoke cloud data reduction program allowed for up to two separate discs to be designated at a given height since many clouds may be double humped. The outlining process was done from the top of the cloud to the bottom; the test cue was designated as a reference point. Two other reference markers that were a known distance apart were also designated once during each test run to provide a reference calibration for the computer, so that the computer could be used to evaluate the cloud measurements in absolute units.

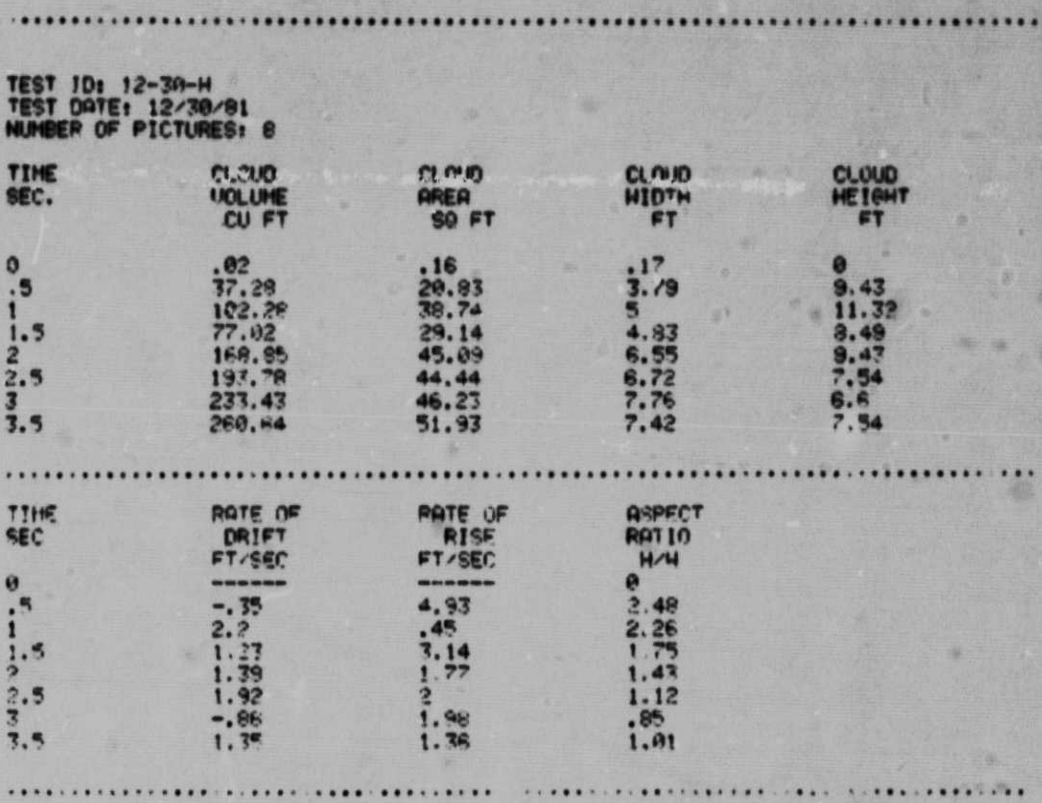
The cloud data reduction program computed the cloud area, the X and Y centroid location relative to the cue test device, the cloud volume, the rate of change of the volume and the area, and the rate of drift of the cloud centroid. The film strip record was entered into the computer by designating the cloud edges of each picture in turn in the record sequence. The data were summarized in a printout sheet for each run as shown in Figures 22 and 23. This tabulated data as a function of time was combined with other cue runs to obtain an average result of a number of tests of the same cue material.

The combining of data from several runs allowed some of the random variables to be averaged out. The source of these random disturbances was attributed to the resolution of the digitizing process, operator errors in defining the edges of the cloud, the non-circular cross section of the smoke cloud disc elements, and effects of the wind. Since the main goal was to quantify the signature effects of each cue concept so that the signature size can be scaled for different requirements, the data were normalized according to the weight of the cueing material used.

The basic smoke cue may be divided into different phases as shown in the graphs in Figures 24 and 25. The deployment phase for the gradual burn cue concept is much slower than that for an explosive release design. The explosive release may be divided into the deployment phase, the expansion phase (where wind and turbulence effects predominate), and the dispersion phase (where the cloud thins to the point that it becomes undefined). The gradual burn release characteristics apply to cue concepts where the smoke generating material is burned relatively slowly in the container in a manner such as the cylindrical burning configuration (Figure 3). This smoke profile

```
TEST ID: 12-30-HTEST DATE: 12/30/81             EVENT TIME: 0
CLOUD VOLUME = .02 CU FT
CLOUD AREA = .16 SQ FT
CLOUD WIDTH = .17 FT
CLOUD HEIGHT = 0 FT
CLOUD CENTROID: X = -.27 FT
                Y = .47 FT

TEST ID: 12-30-HTEST DATE: 12/30/81             EVENT TIME: .5
CLOUD VOLUME = 37.28 CU FT
CLOUD AREA = 20.83 SQ FT
CLOUD WIDTH = 3.79 FT
CLOUD HEIGHT = 9.43 FT
CLOUD CENTROID: X = -.61 FT
                Y = 5.41 FT

TEST ID: 12-30-HTEST DATE: 12/30/81             EVENT TIME: 1
CLOUD VOLUME = 102.28 CU FT
CLOUD AREA = 38.74 SQ FT
CLOUD WIDTH = 5 FT
CLOUD HEIGHT = 11.32 FT
CLOUD CENTROID: X = 1.59 FT
                Y = 5.87 FT

TEST ID: 12-30-HTEST DATE: 12/30/81             EVENT TIME: 1.5
CLOUD VOLUME = 77.02 CU FT
CLOUD AREA = 29.14 SQ FT
CLOUD WIDTH = 4.83 FT
CLOUD HEIGHT = 8.49 FT
CLOUD CENTROID: X = 2.82 FT
                Y = 9.01 FT

TEST ID: 12-30-HTEST DATE: 12/30/81             EVENT TIME: 2
CLOUD VOLUME = 168.85 CU FT
CLOUD AREA = 45.09 SQ FT
CLOUD WIDTH = 6.55 FT
CLOUD HEIGHT = 9.43 FT
CLOUD CENTROID: X = 4.21 FT
                Y = 10.79 FT

TEST ID: 12-30-HTEST DATE: 12/30/81             EVENT TIME: 2.5
CLOUD VOLUME = 193.78 CU FT
CLOUD AREA = 44.44 SQ FT
CLOUD WIDTH = 6.72 FT
CLOUD HEIGHT = 7.54 FT
CLOUD CENTROID: X = 6.14 FT
                Y = 12.79 FT

TEST ID: 12-30-HTEST DATE: 12/30/81             EVENT TIME: 3
CLOUD VOLUME = 233.43 CU FT
CLOUD AREA = 46.23 SQ FT
CLOUD WIDTH = 7.76 FT
CLOUD HEIGHT = 6.6 FT
CLOUD CENTROID: X = 5.29 FT
                Y = 14.77 FT

TEST ID: 12-30-HTEST DATE: 12/30/81             EVENT TIME: 3.5
CLOUD VOLUME = 260.64 CU FT
CLOUD AREA = 51.93 SQ FT
CLOUD WIDTH = 7.42 FT
CLOUD HEIGHT = 7.54 FT
CLOUD CENTROID: X = 6.64 FT
                Y = 16.13 FT
```

Figure 22. Sample computer print-out of smoke cloud data reduction program.



```
......................................................................

TEST ID: 12-30-H
TEST DATE: 12/30/81
NUMBER OF PICTURES: 8

TIME           CLOUD          CLOUD          CLOUD          CLOUD
SEC.           VOLUME         AREA           WIDTH          HEIGHT
                CU FT          SQ FT           FT             FT

0              .02            .16            .17            0
.5             37.28          20.83          3.79           9.43
1              102.28         38.74          5              11.32
1.5            77.02          29.14          4.83           8.49
2              168.85         45.09          6.55           9.47
2.5            193.78         44.44          6.72           7.54
3              233.43         46.23          7.76           6.6
3.5            260.84         51.93          7.42           7.54

......................................................................

TIME           RATE OF        RATE OF        ASPECT
SEC             DRIFT           RISE         RATIO
               FT/SEC         FT/SEC          H/W
0              ------         ------         0
.5             -.35           4.93           2.48
1              2.2            .45            2.26
1.5            1.27           3.14           1.75
2              1.39           1.77           1.43
2.5            1.92           2              1.12
3              -.86           1.98           .85
3.5            1.35           1.36           1.01

......................................................................
```

Figure 23. Computer summary of smoke cloud data reduction run.

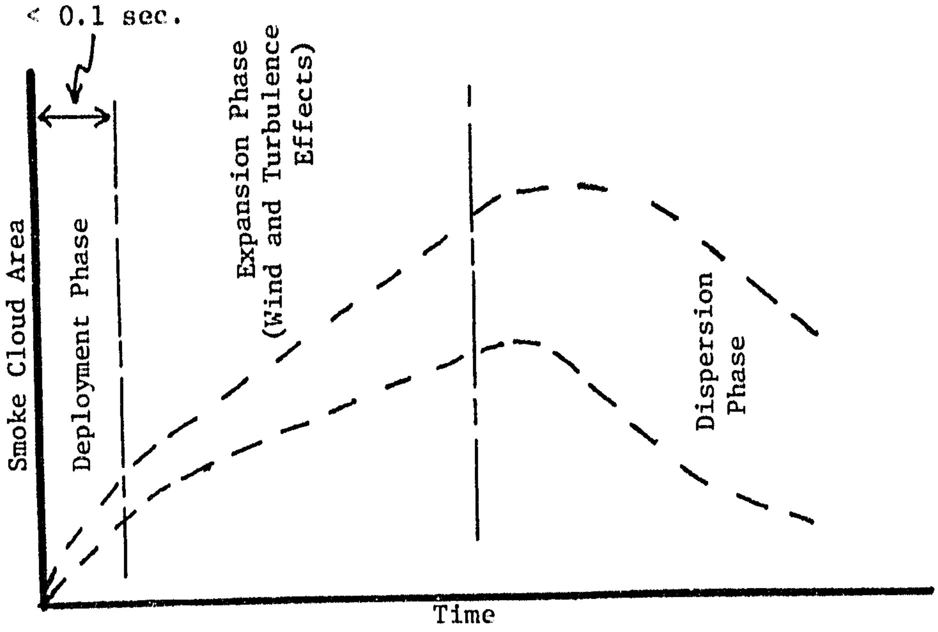


Figure 24. Explosive release characteristics.

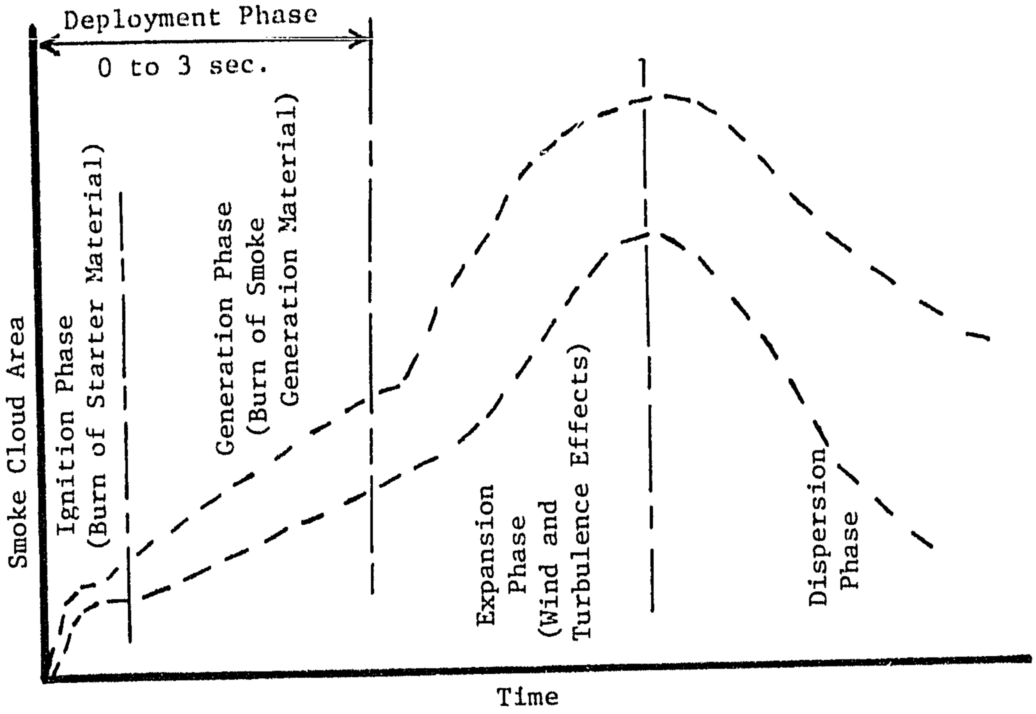


Figure 25. Gradual burn release characteristics.

has an ignition phase due to the burn of the starter material, a gradual expansion of the cloud during the generation phase and the expansion and dispersion phases seen in the previous example.

The normalization process combined the results of all test measurements of each cue firing having the same design and material. The model used for normalization assumed that the cloud volume was proportional to the weight of the cue generating material. This assumption led to the normalization of the data based on the cloud volume, since cloud area would vary nonlinearly with cue weight. Since cloud area was the measure that was directly related to the smoke cloud visibility, a method of relating the normalized data to cloud area was defined. For this transformation, the smoke cloud was assumed to be spherical in shape. The volume of the spherical cloud was defined as

$$V = \frac{4}{3} \pi R^3 \tag{9}$$

and the apparent area was defined as

$$A = \pi R^2 \tag{10}$$

If these expressions are solved for the common term, the radius (R), and equated, the relationship

$$A = 1.209V^{2/3} \tag{11}$$

can be used to obtain normalized area data directly from the normalized cloud volume data.

The normalized cloud volume was found by dividing the absolute cloud volume by the weight of the cue material. Since many values of volume were obtained as a function of time for each cue test, a tabulation was made as a function of time for all cloud pictures computed by the data reduction program (for a given smoke cloud generating material). After the normalized cloud volume was measured and tabulated for each test of the same cue concept, the normalized volumes were averaged for each time slot. A best fit straight line was calculated by the least square method for these data points to define the normalized smoke cloud volume as a function of time (see the example in Figure 26).

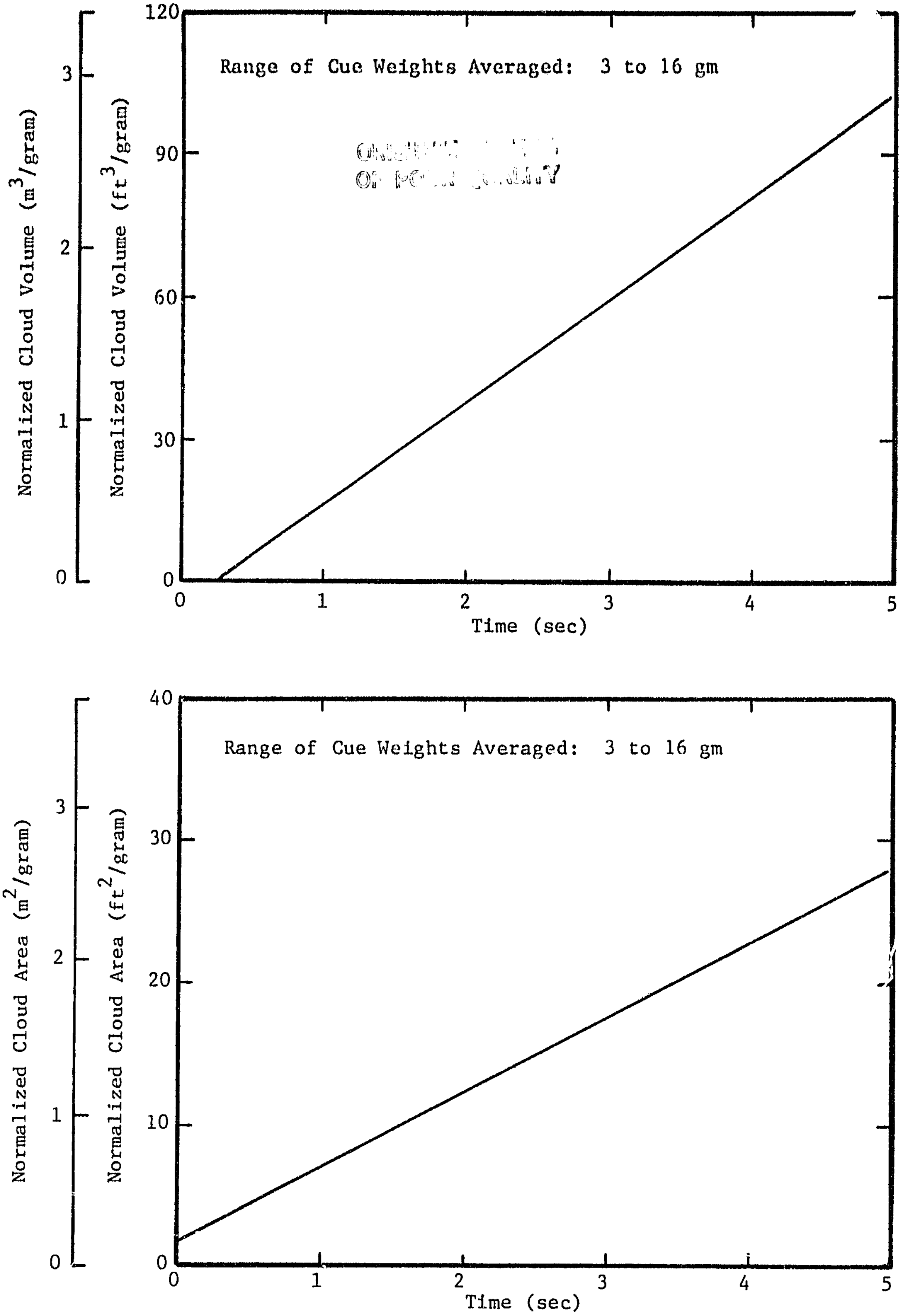


Figure 26. Normalized smoke cloud data for standard flash powder.

A similar graph for the normalized cloud area is shown in the bottom graph of Figure 26. These data were assembled in an identical manner to the volume computations described above. The area data entered into the averages was obtained from the normalized volume data through the relationship expressed in Equation (11). The best fit straight line is displayed as an area versus time plot in Figure 26.

These normalized data were developed to enable the definition of cues that cover a range of sizes in areas or volumes. The data can be extended to cues of different signature sizes by multiplying the results by the weight of smoke generating material included in the cue. Figure 27 compares measured cloud volume and area data (solid lines) for two cue weights with the signature effects predicted from the normalized curves. The measured data in these examples are considered to be in reasonable agreement with the predicted results.

3.5 LONG RANGE TEST DATA REDUCTION

Analysis of smoke cloud data obtained during the long range visibility tests differed from that described for the short range tests. The data reduction for the Mod IV camera at the cue test site was identical to the data reduction of smoke cloud data used during the short range tests. However, the long range cloud measurements were recorded with a much smaller image despite the use of a telephoto lens. A different analysis model was defined to allow the smoke cloud to be measured as a function of time from the 16-mm film. The cloud image was projected onto a screen, and the height and width of the smoke cloud were measured at 0.5 second intervals in absolute units. The first frame with detectable activity was termed the time t = 0. The cloud area was taken from the formula developed in Figure 28. Although this approximation is not as accurate as the computer analysis developed for the short range tests, it is adequate for the measurement requirements of this analysis. Figure 29 illustrates a comparison example of the cloud area measurements from the Mod IV camera and the results from the 16-mm camera located 2.5 kilometers away. The differences are attributed to the different algorithm for determining cloud area, the different angle from which the pictures were taken, and the different visibility conditions introduced by the atmosphere.

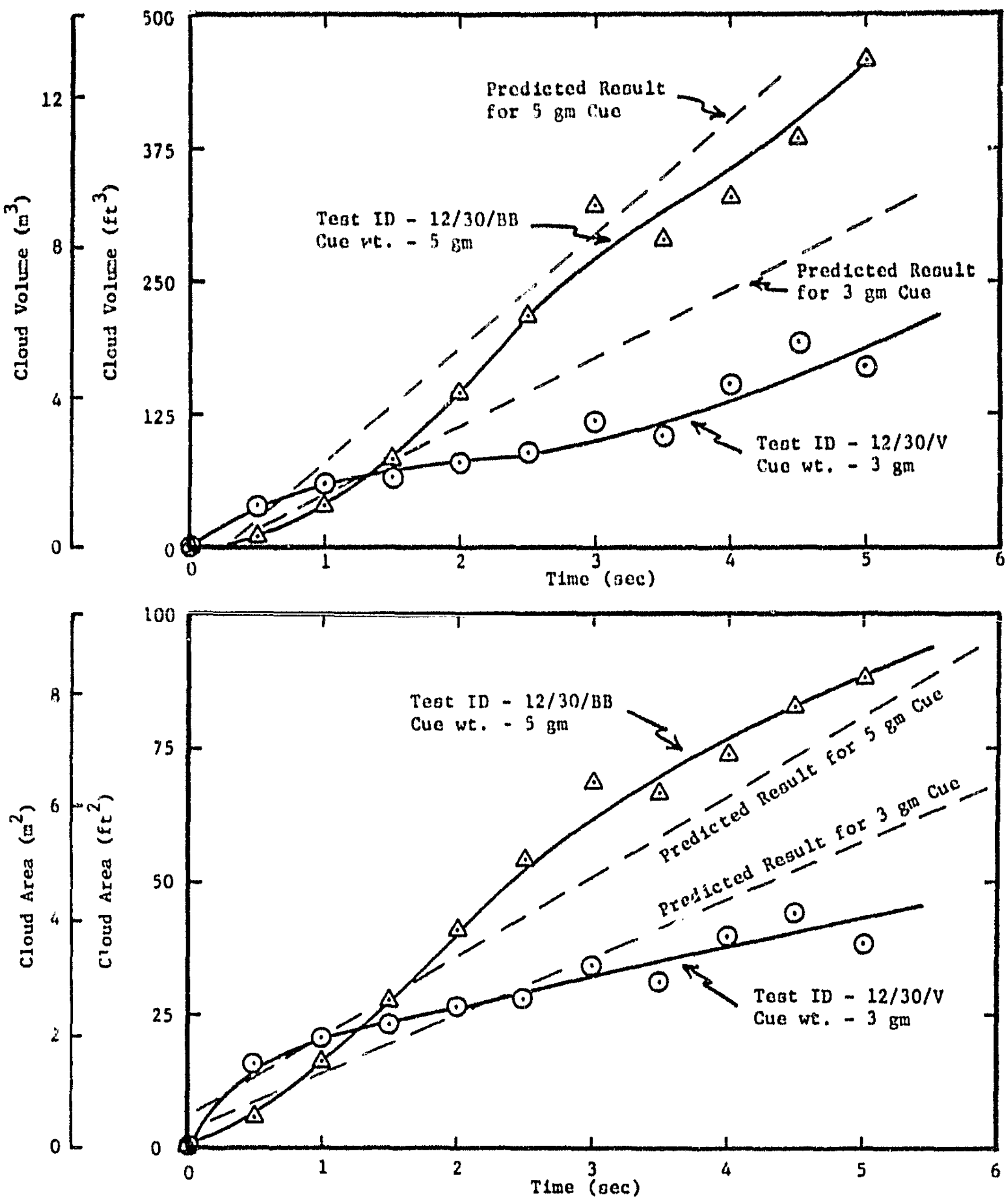
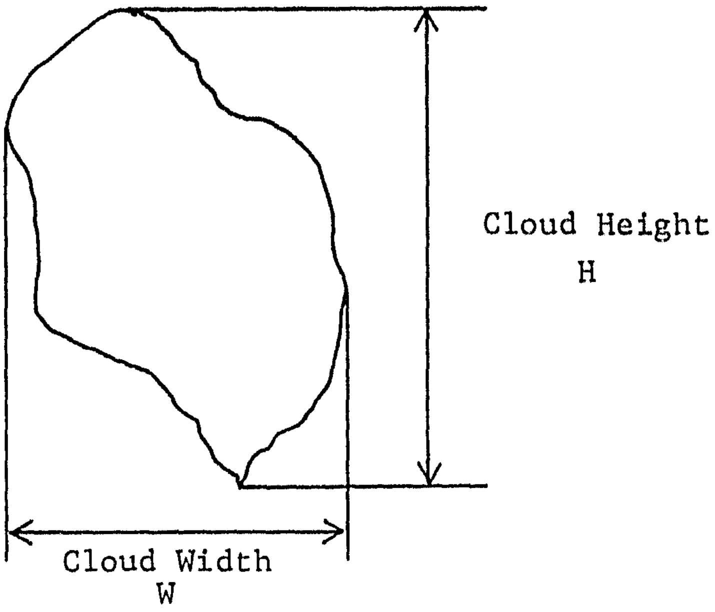


Figure 27. Examples of smoke cloud data reduction for different weights of cue material (standard flash powder).

Cloud Measurements



Cloud Area Model

Area = $\frac{1}{2}$ W H

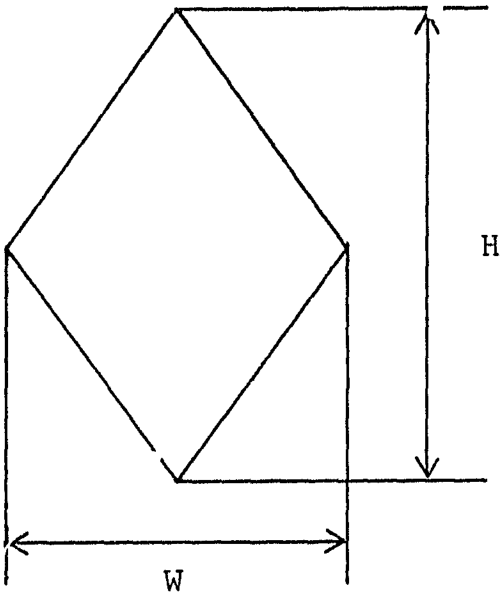


Figure 28. Model for long range smoke visibility test measurements.

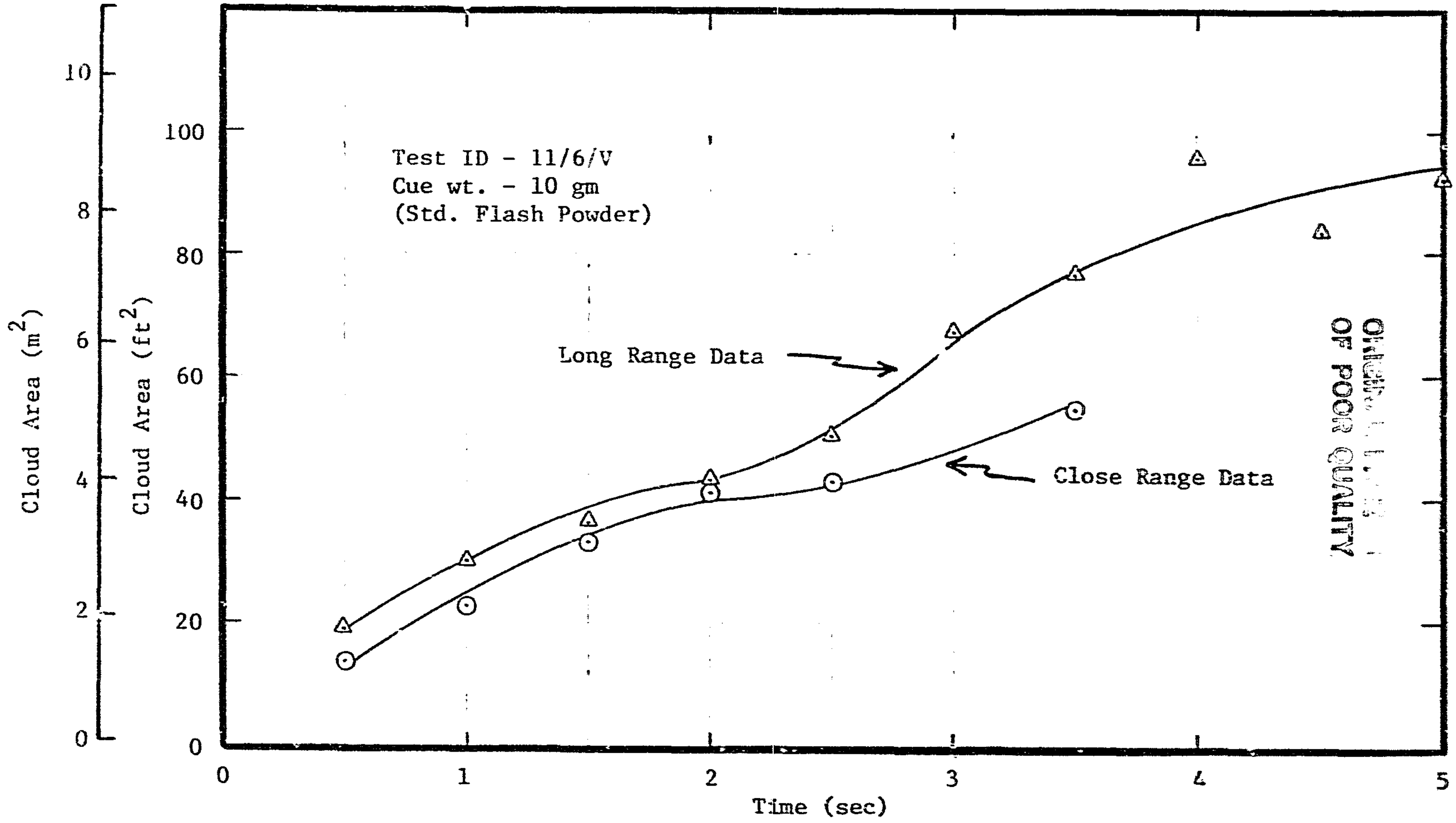


Figure 29. Comparison example of long range and short range smoke cloud measurements.

SECTION 4

EXPERIMENTAL EVALUATION

4.1 OVERVIEW

The purpose of this investigation was to test and evaluate a number of cue designs to determine a concept or concepts that appear to meet the signature level requirements set forth in Table 1 while retaining a high degree of man-safety. The testing program outlined previously defines a large test matrix for evaluating a number of cueing approaches at several levels of intensity. The analysis presented in this section represents data from both the short range test program conducted at the Georgia Tech Research Facility in Cobb County and the Long Range Visibility Tests conducted at Lake Lanier, Georgia. The data logs for all test shots discussed in this report are included in Appendix B.

The test activities of this project are summarized below to indicate the number and types of materials included in the investigation. A large number of experiments were performed for this effort of which a total of 344 were photographically recorded for data analysis. The types of experiments involved are given in Tables 11 through 13.

4.2 FLASH CUE EXPERIMENTAL EVALUATION

A series of experiments was conducted early in the program to determine if the flashbulb cue concept would be adequate for the short range flash cue requirements. Early experiments using both the AG1 bulb and the magic cube demonstrated that the flashbulb was easily visible at 200 meters when looking in the direction of the expected flash. The long range tests performed at Lake Lanier further demonstrated that the flash cue was visibile to ranges of 2.5 kilometers under clear daylight conditions.

The early flash experiments also demonstrated that the flash would draw attention at peripheral vision angles of 30 degrees at distances of 200 meters. The requirement for the peripheral vision as specified in Table 1 is for a hazy day; this requirement was interpreted in the early test in the photographic sense as a day with overcast sky so that the contrast lighting was low. Haze between the viewer and the flash cue might also be interpreted

TABLE 11. TYPES OF EXPERIMENTS DOCUMENTED

Cue Container	Number Documented
8 Gauge	63
12 Gauge	203
16 Gauge	16
No. 5 Flashbulb	5
M-3 Flashbulb	3
AG-1 Flashbulb	29
Flashcube	6
76.2 mm by 25.4 mm (3 in. by 1 in.) dia. pipe	1
152.4 mm by 25.4 mm (6 in. by 1 in.) dia. pipe	14
304.8 mm by 25.4 mm (12 in. by 1 in.) dia. pipe	4
Total Number of Experiments	344

TABLE 12. INERT SMOKE POWDERS TESTED

Powders Tested	Range of Cue Weights Tested	Number of Tests
Purple K	6 to 130 gm	68
$NaHCO_3$	3.8 to 14 gm	10
$CaCO_3$	7.2 to 83 gm	32
Plaster of Paris	6.3 to 9.5 gm	4
Acacia	5.5 to 7.7 gm	6
$KHCO_3$	12 to 25 gm	17
Coal Dust/$CaCO_3$	10 to 20 gm	4
Coal Dust	5.6 to 24 gm	17
Carbon Black	1.76 to 1.83	2
Carbon Black/ 4F Black Powder	3 to 4 gm	7
Carbon Black/$CaCO_3$	5.6 to 7.7 gm	2
Tinted $CaCO_3$	6.5 to 9 gm	7

TABLE 13. PROPELLANTS TESTED

Bullseye Pistol Powder
4-F Black Powder
4-F Black Powder/Coal Dust
2-F Black Powder
2-F Black Powder/Coal Dust
Black Powder/Anthracene/$KCLO_3$
Al/Anthracene/HC
Phosphorus Mix
Low Temperature Smoke Material
British Simulator
Flash Powder

to mean smog or fog; these conditions seldom exist in the vicinity of the Georgia Tech facilities.

The extreme intensity of the light from a flashbulb, when falling directly on the retina, seems to override normal background lighting conditions. The short flash has the ability to attract the attention of the observer. The flash intensity in all of the short range tests was not sufficient to be detected by the human observer as a change in the light level on surrounding objects. Detection of the flash cue was by direct vision of the cue device.

4.3 BANG CUE EXPERIMENTAL EVALUATION

Bang cueing techniques were evaluated using the acoustic instrumentation described in Section 3. The primary bang cue parameter measured was the peak acoustic level of the bang signature in dB relative to 0.0002 dynes per square centimeter. The sound level meter measured and held the peak level which was recorded in the data logs (along with the reference measurement distance) for each test firing.

A nonlinearity was discovered in the meter readings during the course of the experiments. This nonlinearity is documented in the result of a set of experiments described in Figure 10. This plot shows that the acoustic level readings above 113 dB are inaccurate. All readings below this value are considered accurate. Values above 113 dB can be considered only as above this threshold value.

The measurements of each cue test shot were entered into the data logs included in Appendix B. A representative number of readings are shown in the graph in Figure 30 along with the sound levels from four common impulse noise sources. The slope of the dashed lines through each source follows the fall-off of the sound intensity with distance from the source. The sound levels were transitory in nature, and the spread in the dB levels for each source caused a clustering of the data points. The measurements above the 113 dB level are not to be considered accurate and probably represent a much higher level.

After the nonlinearity in the sound level meter was noticed, the reference measurement distance for the remainder of the cue tests was changed to 9.75 meters (32 feet). This distance was still not adequate to enable

ORIGINAL PAGE IS
OF POOR QUALITY

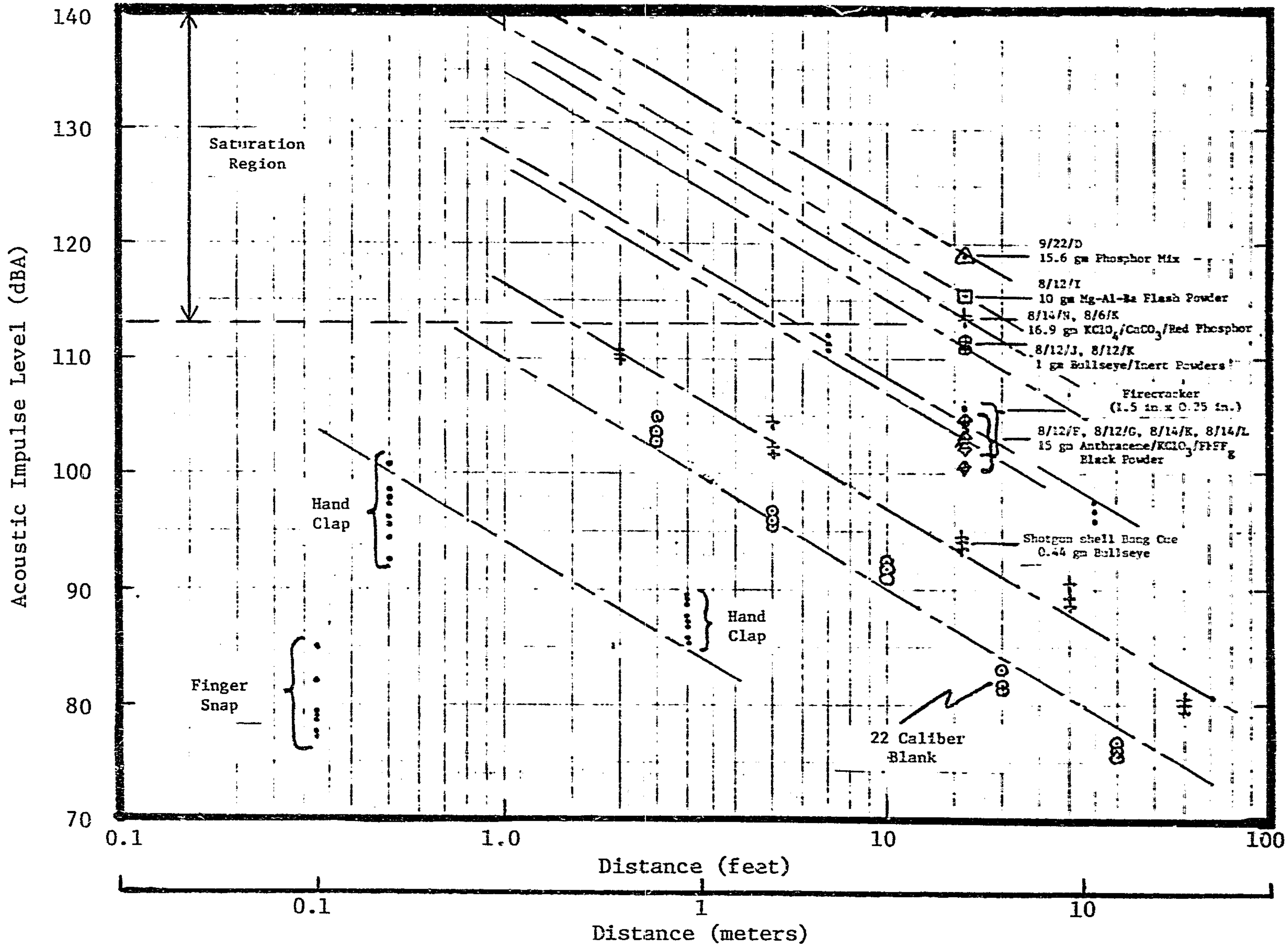


Figure 30. Representative acoustical measurements.

accurate acoustic measurements for the higher level bang cues provided by the pyrotechnic cue generators. Further movement of the sound level meter from the test site was not always practical due to the ambient background noise and the somewhat unpredictable level for a cue-to-cue test basis.

The small firecracker gives a common reference to an impulse noise that would extrapolate to the 140 dB limit at a distance of approximately 15 cm (0.5 feet) from the ear.

4.4 SMOKE CUE EXPERIMENTAL EVALUATION

A large number of data points or curves for each test cue was derived from the smoke cloud data recordings. These data for each test run include many effects that are hard to interpret due to variable wind conditions, different weights of cue generating material, etc. The data reduction technique allowed the characteristics of a given smoke generating material to be averaged over a number of test firings of different weights. The averaging method provided normalized data that are useful in designing cue signatures meeting different cloud visibility and cloud size requirements. These normalized curves can be used to establish the cue payload for a given cloud size requirement.

Figure 31 illustrates a number of curves taken from the smoke cloud data reduction showing the cloud area as a function of time.

Figure 32 illustrates the normalized results for all data using Purple-K smoke material. This curve represents the averaged results of 29 cue tests using inert powder weights of 6 grams to 130 grams. The propellant charges were adjusted to be roughly proportional to the weight of inert powder. The best fit straight line matches the averaged cloud volume data points with a correlation factor of 0.995. Due to the very wide range of cue material weights used, the averaging process produced slightly different curves when a subset of the data covering the range of 6 to 30 grams was analyzed. These data (presented in Figure 33) are more relevant to the range of smoke cues delivered as demonstration units. The normalized data in these graphs represent the average of 9 test shots.

A comparison of cloud volumes and area for three weights of the Purple-K material is shown in Figure 34. The continuous curve represents the measured results as determined from the photographic test recordings. The dashed lines

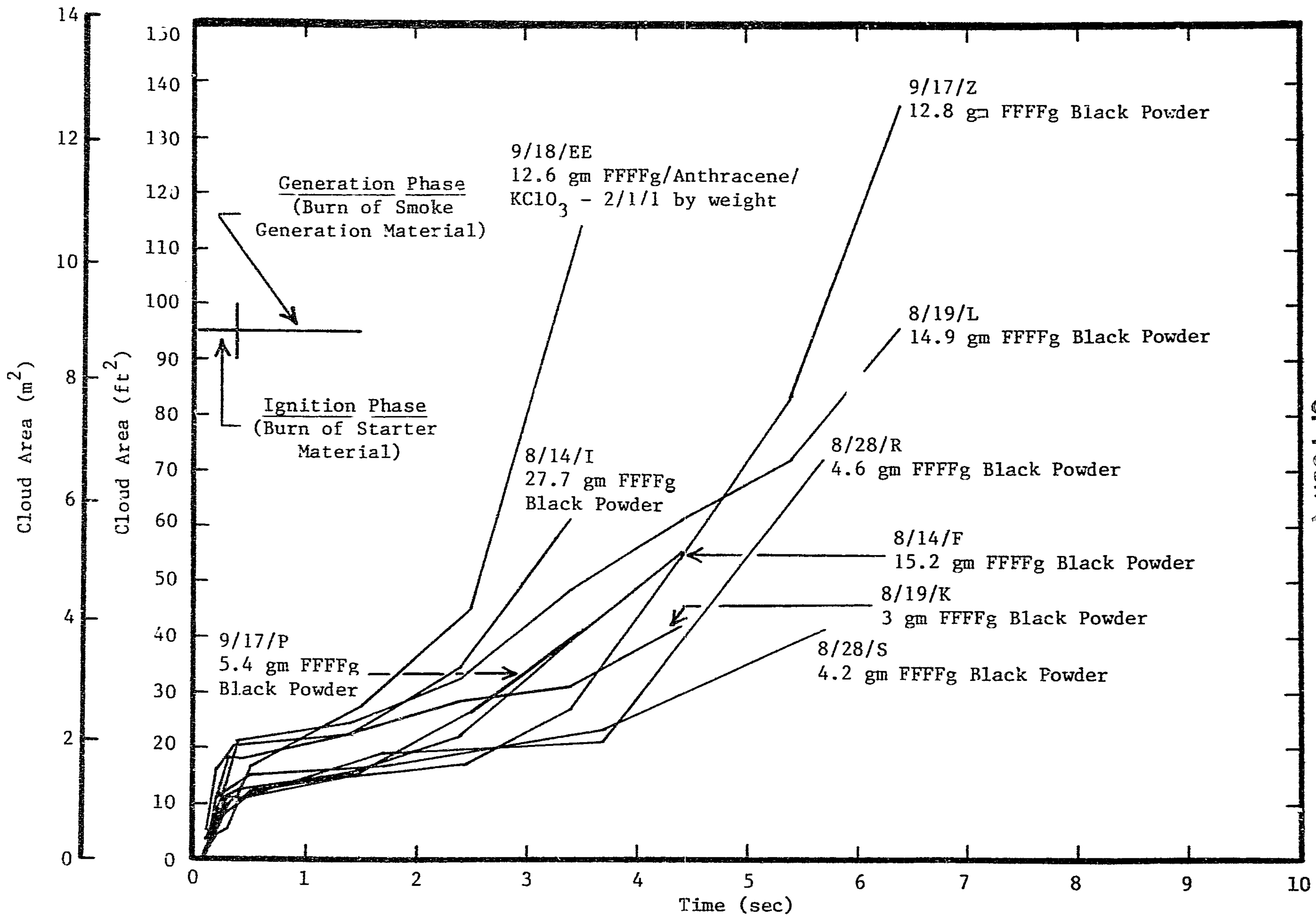


Figure 31. Graph of smoke cloud area for cue designs using cylindrical burning configuration.

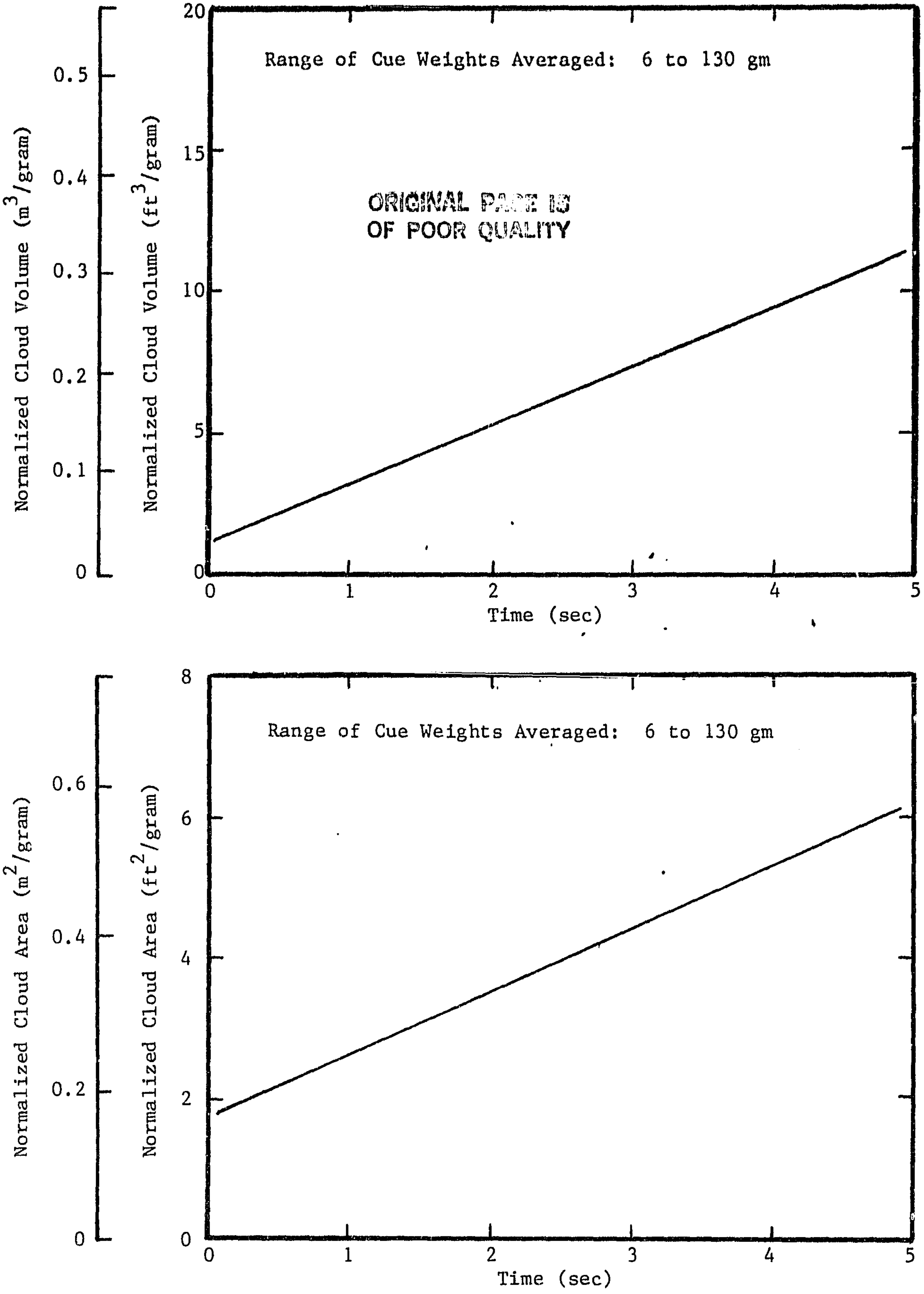


Figure 32. Normalized design curves for Purple-K inert powder (all data).

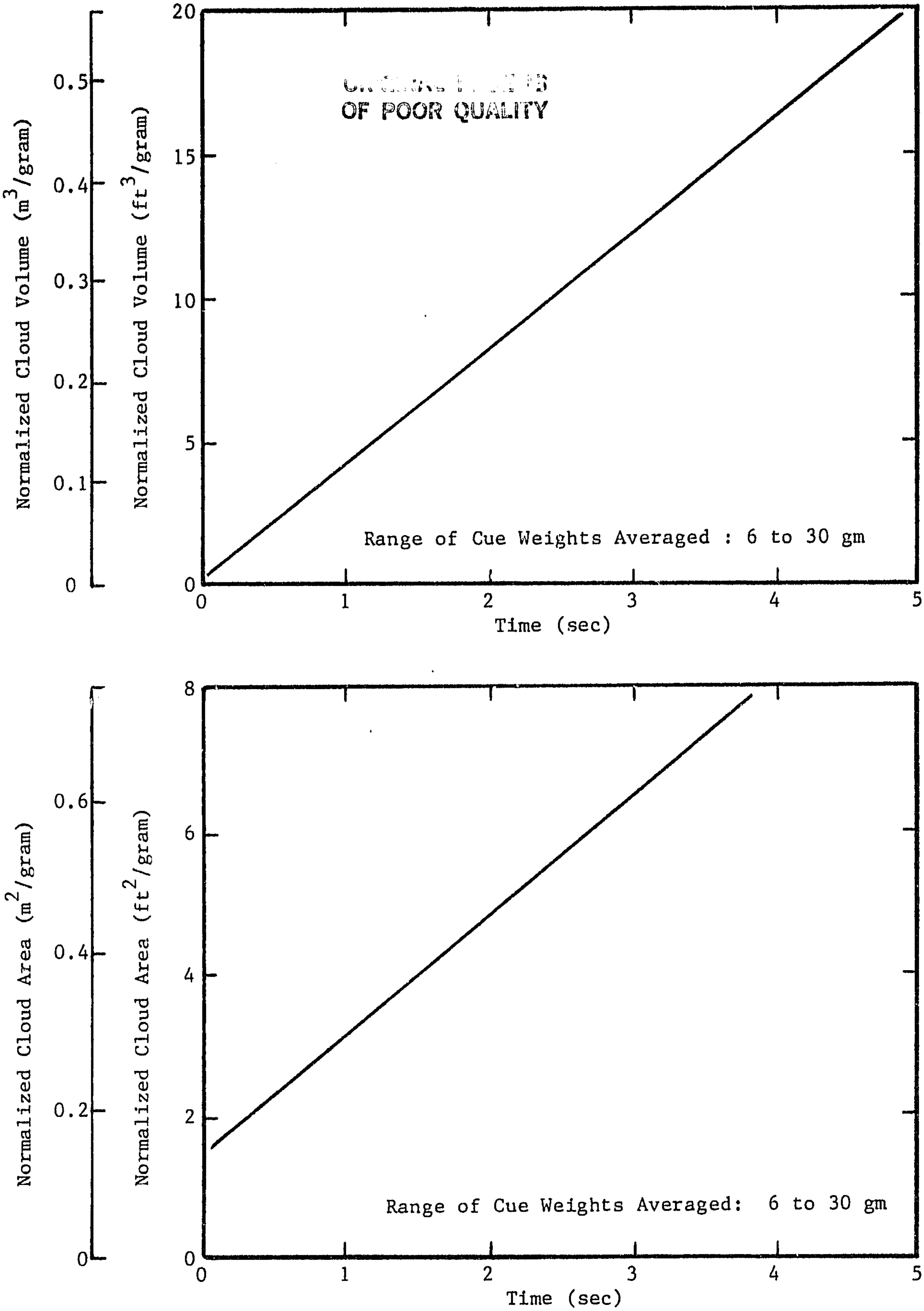


Figure 33. Normalized design curves for Purple-K inert powder (lower weight model).

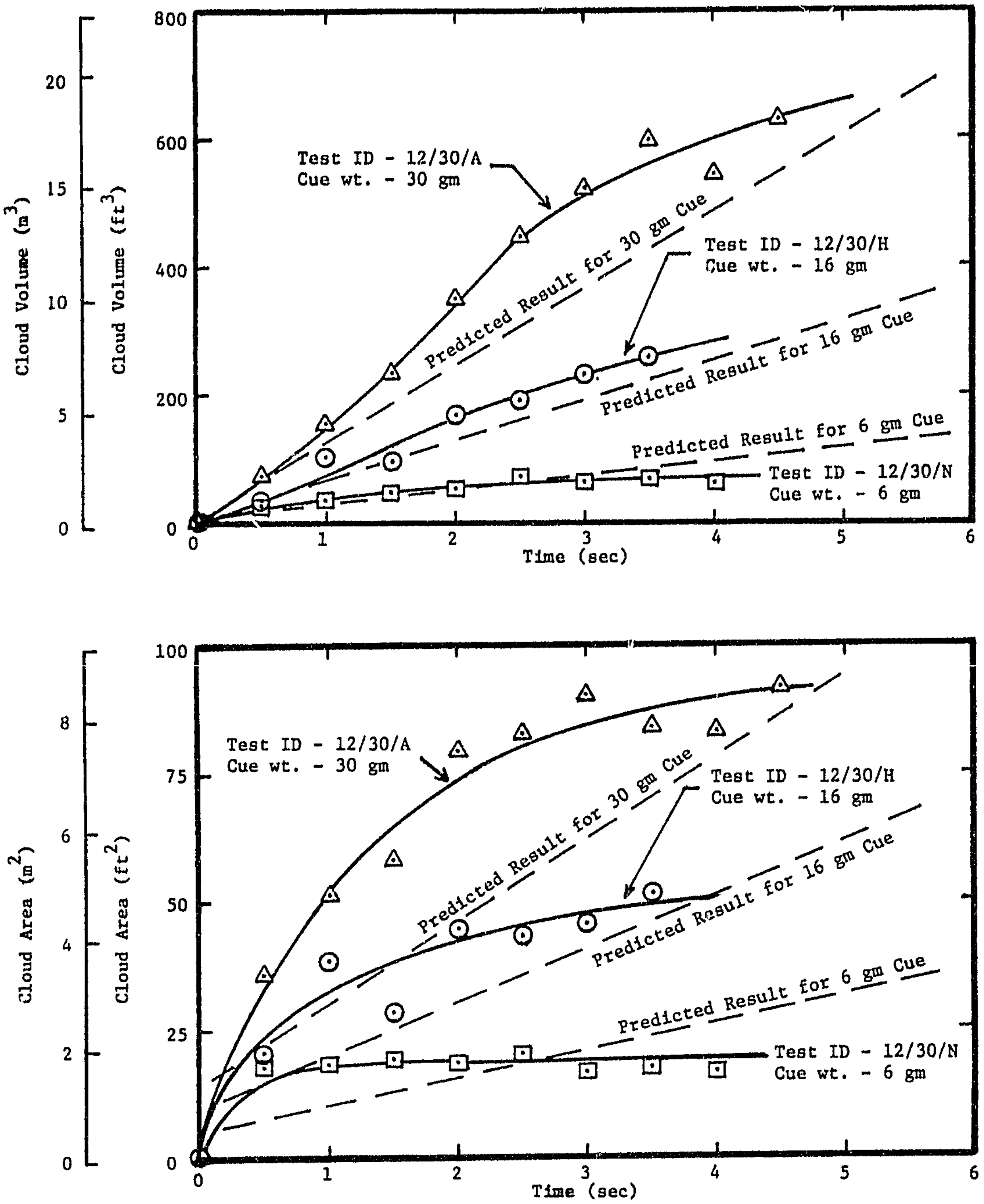


Figure 34. Measured and predicted smoke cloud signatures for different weights of Purple-K material.

represent the predicted performance from the normalized data curves presented in Figure 33 and described in Section 3. The measured data represented by these three curves are considered to be in reasonable agreement with the predicted results. Figure 35 compares the test results for a weight of 130 grams of Purple-K material with the two normalized data curves presented above. The cloud volume appears to follow the slope represented by the larger data base curve (see Figure 32, during the earlier portion of the smoke curve, then deviate to the predicted volume developed around the lower weight model (see Figure 33). The curve for cloud area appears to be in better agreement with the lower cue weight subset over the duration of the smoke cloud. The larger weight of cueing material may have contributed to slightly different results due to the change in aspect ratio of the launching tube (the same 25.4 millimeter (1 inch) diameter tube was used for the cue weights of 30 grams and above). The conclusion of the Purple-K analysis is to use the normalized data presented in Figure 33 for developing cue devices in the range of the devices delivered as demonstration units. This set of curves (area and volume) also appears to be the better choice for units with weights between 30 and 130 grams.

The data for all major smoke cueing concepts was averaged to produce the normalized curves similar to that presented previously for the Purple-K inert powder cue and for the flash powder cue. Normalized data sheets are presented in Appendix A for the smoke cue concepts shown in Table 14.

Three types of flash powder were tested using different combinations of materials. The standard flash powder produced the best cloud volume as shown in the nomalized curves in Figures A-1 through A-3 (see Appendix A). The aluminum material used in this powder was very fine flake aluminum paint pigment. This material was tested without an oxidizer and produced a good flash cue, but was ineffective in producing a smoke signature (see Figure A-4). The magnesium compound used in mixtures no. 1 and no. 3 was not as finely ground as the aluminum powder, which attributed to less efficient combustion. A more finely ground magnesium powder should give results similar to those experienced with the aluminum in the standard flash powder.

The standard flash powder appears to be a very efficient FBS cue material. However, the combustion process contains hazards in the fireball and burning particles emitted and in the acoustic impulse level generated.

ORIGINAL PAGE IS
OF POOR QUALITY

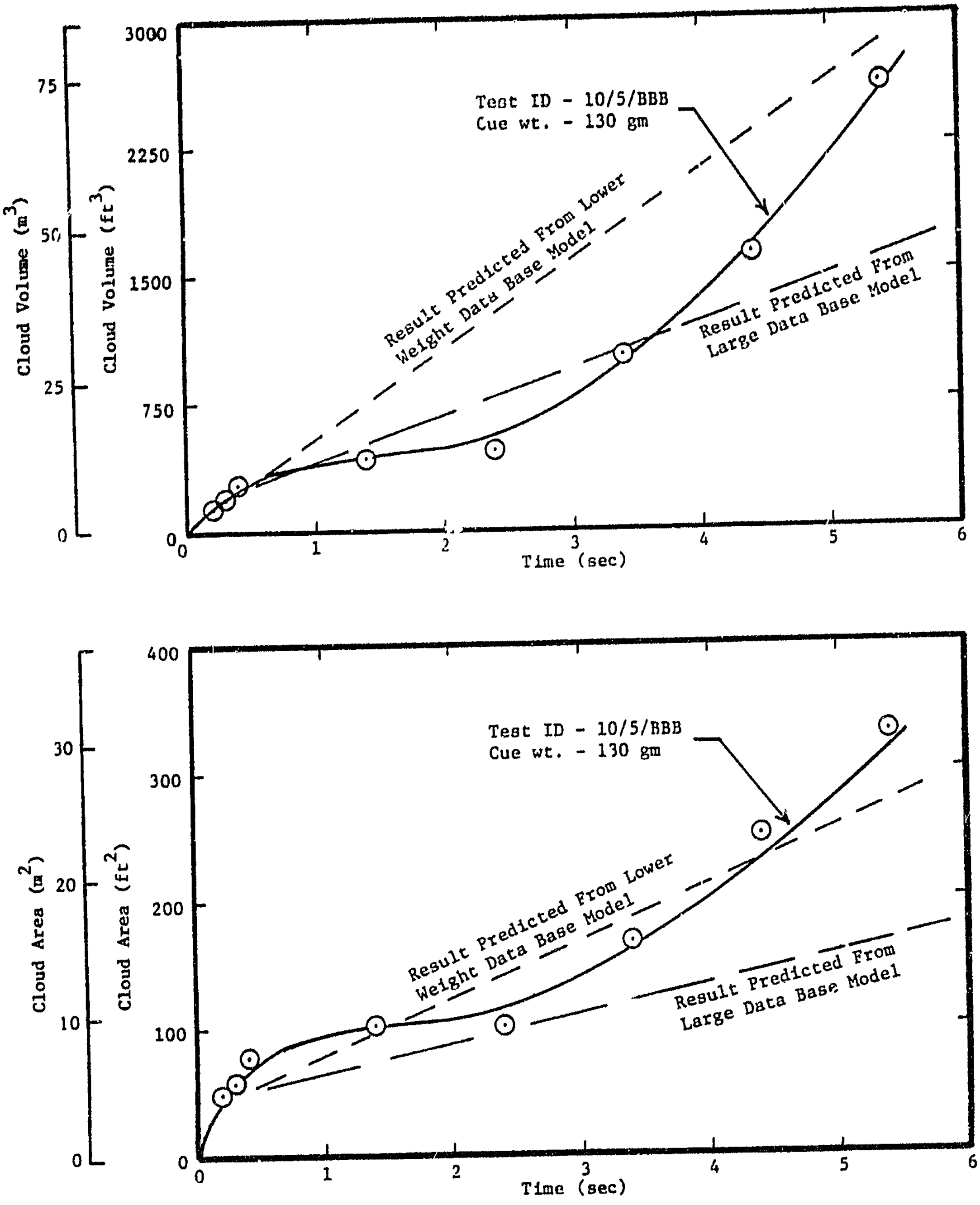


Figure 35. Measured and predicted smoke cloud signatures for large volume Purple-K cue.

TABLE 14. SMOKE CUE CONCEPTS EVALUATED

	Cue Material Tested	Number of Shots Averaged	Range of Cue Weights
Pyrotechnic Smoke Cues			
1.	Standard Flash Powder (34.2 % Al-65.8 % $KClO_4$)	8	3 to 16 gm
2.	Flash Powder Mixture No. 1 (21 % Mg - 9 % Al - 35 % $BaNO_3$ - 35 % $KClO_3$)	6	0.5 to 10 gm
3.	Flash Powder Mixture No. 3 (37 % Mg - 63 % $KClO_3$)	4	1 to 10 gm
4.	Aluminum Flake Powder	6	3 to 5.8 gm
5.	Black Powder (Cylindrical Burning Configuration)	6	4.2 to 12.8 gm
6.	4F Black Powder/Anthracene/$KClO_3$ (2-1-1 Mixture)	6	3.7 to 27 gm
7.	4F Black Powder/Anthracene/$KClO_3$ (1-1-1 Mixture)		63.6 to 10.1 gm
8.	4F Black Powder/Anthracene (2-1 Mixture)	8	4.8 to 11.3 gm
9.	Low Temperature Smoke compound	5	2.9 to 6.4 gm
Inert Smoke Compounds			
10.	Purple-K ($KHCO_3$) -Dry Chemical Fire Extinguisher Powder	29	6 to 130 gm
11.	Potassium Bicarbonate ($KHCO_3$) (Chemical Grade)	8	12 to 25 gm
12.	Calcium Carbonate ($CaCO_3$)	6	7.2 to 83 gm

The anthracene mixtures were explored as being fast burning materials that were readily ignitable. The different mix ratios were used to develop a carbon rich smoke cloud that would have a gray color. The black powder in the mixture increases the density of the smoke cloud and gives it some increased darkness. Open burning of these mixtures produced visible carbon particles in the atmosphere. The normalized results of these experiments are presented in Figures A-6 through A-8 of Appendix A. These materials were easily adaptable to the cylindrical burning configuration deployment concept. The burning process was slow enough that fire was spewed from the container and burning particles were not infrequently expelled. This material can produce a gray cloud, but the apparent darkness of the cloud is not as distinct as desired. The 2-1-1 and the 1-1-1 mixtures were nearly equal as smoke cloud generators and proved to be much better than the mixture without the oxidizer. The safety hazards of this material stem from the burning products that are not easily confined to the cue container.

A limited number of experiments were performed with a low-temperature burning proprietary compound for producing a smoke signature. The composition of the sample material was not known, but it is reported to be similar to a smoke generating material manufactured by Wallops Industries Limited. This compound was used in the cylindrical burning configuration by cutting thin slices from a block of the sample and affixing them to the inside surface of a shotgun shell. The material was ignited by a primer and a small booster charge of 4F black powder. This material was primarily designed for creating smoke screens but can be ground to obtain smaller grain sizes. As the grain size decreases, the burning rate of the material increases, but care must be taken not to reduce the total amount of material or a corresponding reduction in smoke cloud volume will result. A thick grain size of this material was used in this cue development effort, and consequently the material exhibited a relatively long burning time as compared to the other pyrotechnic materials tested. A slow burning rate typically causes the cloud to be strung out horizontally if there is any wind. This would preclude the use of a thick grain of this cueing material for an airburst since the slow deployment over a period of seconds would cause a smearing effect. This slow burning rate could be increased, possibly to acceptable levels, by using a finer grain of the material. This cue concept produced a good smoke cloud with minimal fire hazard to personnel and grass environments. Open burning of this cue material produces no flash or bang signature.

A major fire hazard was associated with the use of combustible wadding material. This was corrected by substituting plastic sheet material for the soft paper material previously used. Paper powder cups used with the inert smoke cue designs did not show a tendency to ignite.

A number of experiments were performed with inert powder material in an effort to define a smoke generating concept with a significantly greater man and range safety. Calcium carbonate, commonly used as a paint pigment (whiting), was used for the smoke cue in the feasibility demonstration under the previous USACDEC research effort. This material produces a good smoke cloud with minimum hazard by deploying the inert powder by means of a small charge of pistol powder. Calcium carbonate is only slightly soluble, but the small amounts of it that might be accidentally ingested by a nearby player are sufficiently soluble in body fluids so that they can be ejected from the body via normal bodily processes.

Potassium bicarbonate was also investigated as an alternate to the calcium carbonate since it is much more soluble. Two preparations of this material were included in the test firings. A commercially available chemical grade material was tested that had no special treatment. An alternate form sold under the trade name of Purple-K is commonly used as the powder in dry chemical fire extinguishers. This material is ground to be very fine and treated to improve its free flowing characteristics and to be less hydroscopic. The potassium bicarbonate proved to be a good smoke cue generator, but the Purple-K has slightly better cue producing properties. The deployment technique used (see Section 3) provided a low hazard level for good man safety. This cue concept was capable of generating a bang signature by confining the initial deployment with a rupture diaphragm. The normalized curves for the inert smoke cue materials are shown in Figures A-10 through A-12 of Appendix A.

Two long range visibility tests were conducted at Lake Lanier (see Section 3 for instrumentation description) to evaluate cueing concepts for the demonstration units to be delivered. Summaries of these experiments are given in Tables 15 and 16. The observer comments and a description of the cue device being tested are included in these tables.

ORIGINAL PAGE IS
OF POOR QUALITY

TABLE 15. 15 OCTOBER 1981 - LONG RANGE SMOKE VISIBILITY TESTS

Cue I.D.	Cue Description			Sound Level dBA @ 32'	Long Range Observations		
	Propellant	Smoke Material	Case		Sound	Smoke	Flash
10-15-C	0.61 gm Bullseye P.P.	11.46gm Purple K	12 G	110.4	Not detected	Visible	—
10-15-D	0.61 gm Bullseye P.P.	13.04gm Purple K	12 G	110.4	Weak	Visible	—
10-15-A	1.16 gm Bullseye P.P.	24.37gm Purple K	8 G	—	——— Dud ———		—
• 10-15-B	1.16 gm Bullseye P.P.	22.8 gm Purple K	8 G	112.1	Not detected	Visible	—
10-15-E	1.56 gm Bullseye P.P.	37.6gm Purple K	1"X6" Pipe	—	Not detected	Visible	—
• 10-15-F	1.56 gm Bullseye P.P.	37.65gm Purple K	1"X6" Pipe	—	Not detected	Visible	—
• 10-15-G	3.12gm Bullseye P.P.	92.2 gm Purple K	1"X6" Pipe	100.8	Not detected	Good	—
10-15-H	3.12gm Bullseye P.P.	81.8gm Purple K	1"x 6" Pipe	112.9	Not detected	Good	—
10-15-I	6 gm Bullseye P.P.	145.5gm Purple K	1"X12" Pipe	116.9	Moderate	Good	—
10-15-J	6 gm Bullseye P.P.	150gm Purple K	1"x12" Pipe	115.8	Moderate	Good	—
10-15-K	0.3cc 4F Black Powder	15gm Phos.Mix	12 G	117.3	Strong	Good	
• 10-15-M	0.3cc 4F Black Powder	24gm Phos. Mix	8 G	117.5	Strong	Good	
10-15-O	Flashbulb Squib	33gm Phos.Mix	1"X6" Pipe	119.5	Strong	Good	
• 10-15-Y	0.3cc 4F Black Powder	21.6gm Anth.Mix	8 G	104.2	Weak	Visible	
10-15-AA	Flash bulb Squib	37.5gm Anth. Mix	1"x6" Pipe	113.9	Strong	Good	
10-15-DD	Flashbulb Squib	75gm Anth. Mix	1"x6" Pipe	116.8	Very Strong	Excellent	Good
10-15-Q	.3cc 4F Blackpowder	10gm AL-KCLO$_3$	12 G	116.7	Very Strong	Good	
• 10-15-EE	Flashbulb Squib	13.15 gm AL-KCLO$_3$	No.5 F.B.	111.6	Weak	Moderate	Good
10-15-FF	Flashbulb Squib	33.46gm Anth.Mix	R/M-1"x12" pipe	76.5	Weak	Moderate Gray	
10-15-GG	Flashbulb Squib	18.56gm Anth. Mix	RM 1"x 6" Pipe	—	———	Good	Small
10-15-HH	Flashbulb Squib	13.15gm Al Flash Pd.	No.5 F.B.	—	Good	Good	Good
10-15-II	0.3cc 4F Black Powd.	12.7gm Anth. RM	8 G	—	None	Small	None
10-15-JJ	0.3cc 4F Black Pwd.	10.1gm Anth. RM	8 G	—	None	Moderate	None
10-15-P	Flashbulb Squib	33gm Phos.Mix	1"X6" Pipe	120.6	Good	Good	Weak
10-15-CC	Flash bulb Squib	75gm Anth. Mix	1"X6" Pipe	—	Good	Good	None
10-15-N	0.3cc 4F Black Powder	24gm Phos. Mix	8 G	—	Good	Good	Good

• Pictures of smoke clouds included in briefing

ORIGINAL PAGE IS
OF POOR QUALITY

TABLE 16. 6 NOVEMBER 1981 - LONG RANGE SMOKE VISIBILITY TESTS

Cue I.D.	Cue Description Propellant / Smoke Material / Case	Sound Level dBA	Long Range Observations		
			SOUND	SMOKE	FLASH
11-6-A	AG1B Flashbulb	—	—	—	Good
11-6-B	M-3B Flashbulb	—	—	—	Good
11-6-C	#5 Flashbulb	—	—	—	Good
11-6-D	2 AG1B Flashbulbs	—	—	—	Good
11-6-D-1	AG1B Flashbulb	—	—	—	Good
11-6-D-2	AG1B Flashbulb	—	—	—	Good
11-6-D-2	AG1B Flashbulb	—	—	—	Good
11-6-D-2	AG1B Flashbulb	—	—	—	Good
11-6-D-2	AG1B Flashbulb	—	—	—	Good
11-6-D-2	AG1B Flashbulb	—	—	—	Good
11-6-E	.5cc Bullseye P.P. / 9.3 gr. Purple K / 12G	85.9	Not detected	Weak	—
11-6-G	.7cc 4F Black Powder / 10.2 gr Purple K / SHORT 8G	86.1	Not detected	Weak	—
11-6-I	.7cc Bullseye P.P. / 18.6 gr. Purple K / 8G	84.[illegible]	Not detected	Visible	—
11-6-K	.5cc Black P., 1.6cc P.P. / 15 gr. Purple K / 1"×3¾" TUBE	85.1	Not detected	Visible	—
11-6-M	.5cc Black P., 1.6cc P.P. / 30 gr Purple K / 1"×3¾" TUBE	97.9	Not detected	Visible	—
11-6-O	.5cc Black P., .939 gr P.P. / 15 gr Purple K / 1"×3¾" TUBE	98.1	Not detected	Visible	—
11-6-Q	.5cc Black P., .939 gr P.P. / 30 gr Purple K / 1"×3¾" TUBE	77.8	Not detected	Moderate	—
11-6-S	.5cc Black P., 3.2cc P.P. / 45.96 gr Purple K / 1"×3¾" TUBE	—	Not detected	Very Weak	—
11-6-U	Flashbulb squib / 5 gr. Std. Flash Powder / SHORT 12G	115.6	Good	Good	Good
11-6-W	Flashbulb squib / 3 gr. $KClO_3$ Flash Powder / SHORT 12G	97.9	Not detected	Good	Good
11-6-Y	Flashbulb squib / 5 gr. $KClO_3$ Flash Powder / SHORT 12G	79.4	Not detected	Very Good	Good
11-6-AA	BRITISH SIMULATOR	117.5	Strong	Excellent	Very Good
11-6-R	.5cc Black P., .939 gr P.P. / 30 gr Purple K / 1"×3¾" TUBE	—	—	—	—
11-6-Z	Flashbulb squib / 10 gr $KClO_3$ Flash Powder / 12G	115.0	Good	Good	Very Good
11-6-X	Flashbulb squib / 3 gr. $KClO_3$ Flash Powder / SHORT 12G	79.8	Not detected	Moderate	Fair
11-6-V	Flashbulb squib / 10 gr Std. Flash Powder / 12G	116.3	Good	Very Good	Good
11-6-T	Flashbulb squib / 3 gr Std. Flash Powder / SHORT 12G	114.9	Moderate	Moderate	Fair
11-6-P	.5cc Black P., .939 gr. P.P. / 15 gr Purple K / 1"×3¾" TUBE	97.1	Not detected	Moderate	—
11-6-N	.5cc Black P., 1.6cc P.P. / 30 gr. Purple K / 1"×3¾" TUBE	77.8	Not detected	Moderate	—
11-6-L	.5cc Black P., 1.6cc P.P. / 15 gr Purple K / 1"×3¾" TUBE	75.4	Not detected	Fair	—
11-6-J	.7cc Bullseye P.P. / 19.2 gr. Purple K / 8G	94.5	Not detected	Fair	—
11-6-H	.7cc 4F Black Powder / 9.0 gr Purple K / SHORT 8G	—	Not detected	Small	—

The long range visibility tests allowed the observers to be looking at the expected cue firing and to receive a countdown of the event. This is not too dissimilar to the forward observer since he has requested that fire be directed to a given location and is looking for the event. As an example, good visibility was reported by the observers on cue test 11-6-U (5 grams of standard flash powder) at the viewing range of 2.5 kilometers. A check of the close range photographic recordings showed a cloud area of 5.1 square meters (55 square feet) at 2.5 seconds after cue activation. Figures 36 and 37 compare the average of the normalized volume and area data for the standard flash powder and the Purple-K cues fired during the 6 November test at Lake Lanier. The normalized area curves were derived from the measured normalized volume data using the spherical cloud model described in Section 3. The data for the flash powder shows reasonable agreement for both methods of observation. The data for the Purple-K inert material demonstrated a lower effective cloud area for the long range recordings than for the close range recordings. This was attributed to the high aspect ratio (height divided by width) of the Purple-K cloud. The relatively narrow width of the cloud developed by the inert powder was more subject to measurement errors than the larger more symmetric flash powder smoke clouds.

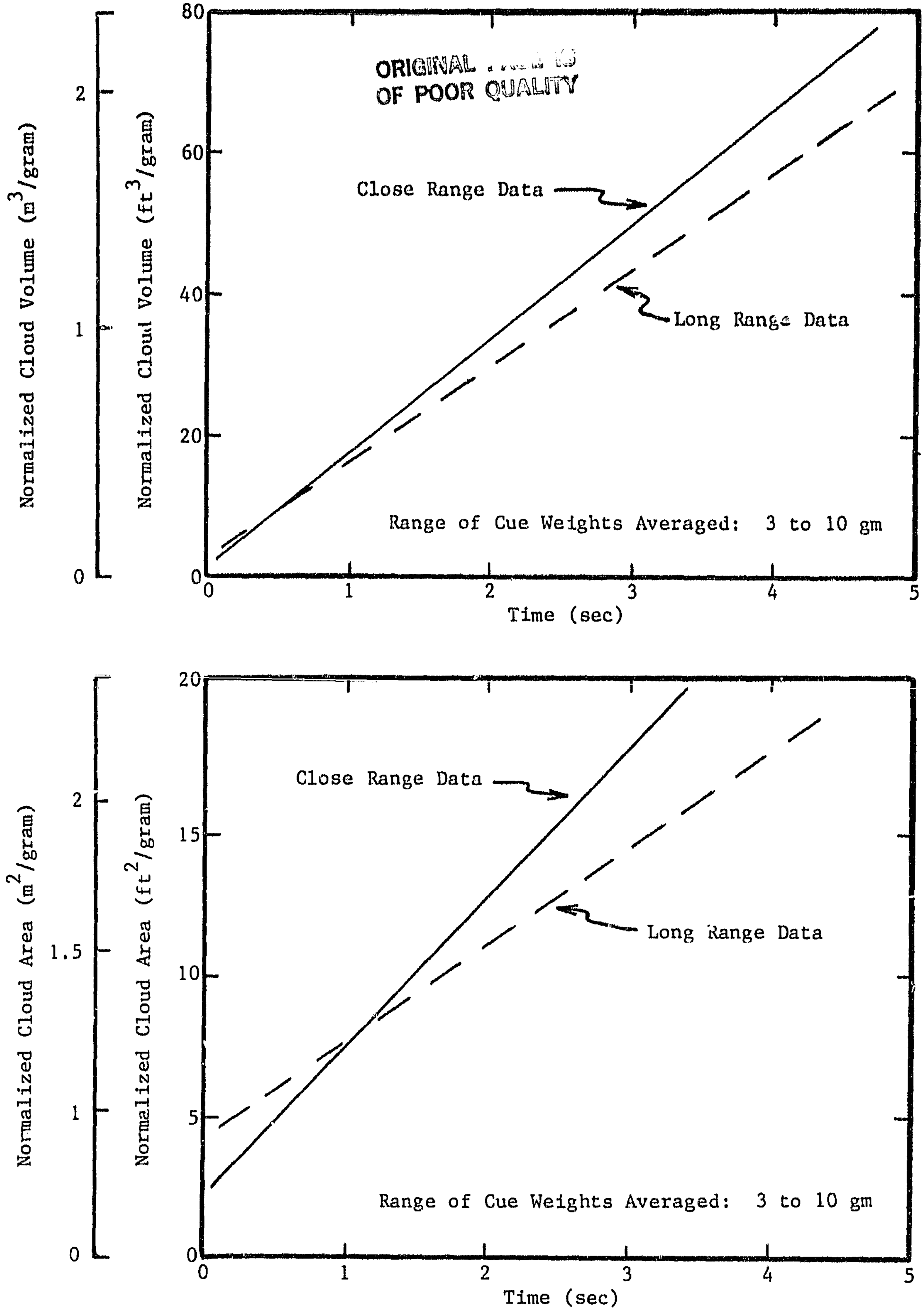


Figure 36. Comparison of short range test data and long range test data for standard flash powder cue.

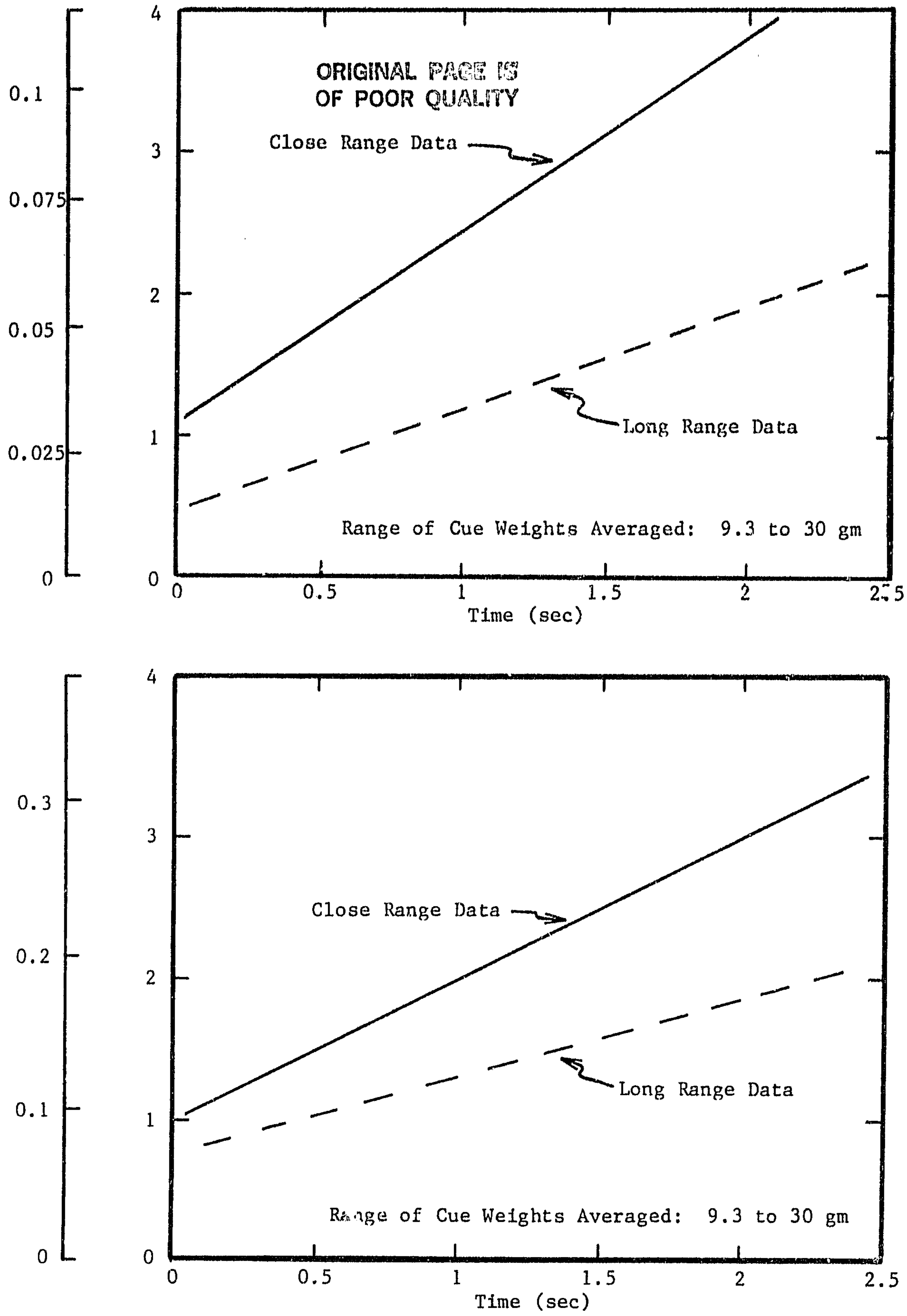


Figure 37. Comparison of short range test data and long range test data for Purple-K inert powder cue.

SECTION 5

DEMONSTRATION CUE UNIT EVALUATION

5.1 OVERVIEW

Several demonstration cueing devices were specified as deliverable items in the contract. A Technical Direction Memorandum from JPL dated 12 November 1981 directed Georgia Tech to deliver the demonstration rounds described below:

a. Eight each Flash/Bang/Smoke (FBS) cues using fine ground $KHCO_3$ that are small, medium and large using a flash bulb as an initiator, and a flash bulb as the flash cue.

b. Eight each FBS cues using the GIT $Al/KC10_4$ flash powder that are large and small.

c. The two small cues are to have the same size smoke cloud.

This memorandum directed that the inert components of the units described above be delivered to JPL by 30 November 1981. This was necessary since shipment of the completed demonstration rounds by commercial carrier would not allow the accelerated test schedule to be met. The memorandum also directed that the FBS cues be assembled at JPL by 2 December 1981 and that preliminary test firings be supported at the Edwards Test Station (ETS) during the week of 3 to 8 December. This phase was accomplished by Mr. Jack Kinney and the initial tests were satisfactory. Additional support was required for the final demonstration firings before the Army Study Advisory Group on 9 December. Mr. Frank Williamson attended this demonstration. All FBS units performed satisfactorily at this demonstration.

5.2 CUE ASSEMBLY DESCRIPTION

5.2.1 GENERAL DESCRIPTION

Demonstration units of two basic types of flash-bang-smoke (FBS) cue devices having characteristics that are desirable for indirect-fire cueing were constructed. The cueing concept proposed for operation near personnel is based upon the use of a fine inert powder as the smoke cue. The flash cue in this relatively man-safe cueing device is a simple flashbulb. The acoustic cue in this device is provided by a simple diaphragm rupture.

The second cueing concept used in these demonstration units is based upon a flash powder formula of aluminum powder and potassium perchlorate. This material is not considered as safe for operation near personnel due to the open burning of the flash material. However it represents an efficient FBS cueing material and can possibly be used in an airburst configuration.

All of the cueing demonstration units were ignited by a flashbulb squib. This device is considered to be reliable and to have less chance of accidental discharge due to static electricity than some conventional squib devices. The flashbulb squib was constructed around an AG-1 flashbulb. The AG-1 has convenient wire spring electrodes that can be easily connected to a wire lead. The heat flash from the flashbulb will ignite a coating of black powder on the surface of the bulb to provide a hot flash suitable for igniting other propellant material.

The flashbulb squib was prepared by soaking the bulb in acetone for approximately 15 seconds to soften the plastic coating on the glass bulb. This operation was performed after affixing the proper leads. Excess acetone was removed from the bulb by shaking the unit. Then the bulb was rolled in 4F black powder while the surface of the bulb was still soft. Excess powder was then removed from the bulb surface by gently tapping the bulb with a small tool or pencil. This unit was then allowed to dry completely before being assembled in the cueing device.

The specifications for the materials used in these cue devices are listed in Appendix C. The formula for the flash powder is also defined in Appendix C.

5.2.2 PURPLE-K SMOKE CUES

The demonstration cues use three size charges of purple-K (potassium bicarbonate) that are packaged in appropriately sized containers. These cues will be described in the order of descending cue loads. These cue packages are intended as demonstration units and do not necessarily represent suitable configurations for a cueing projectile. This type of cueing device uses an external flashbulb for a flash cue since there is no flash from the small powder charge from the material used to expell the inert smoke cue.

5.2.2.1 Large Inert Powder FBS Cue

This cueing unit was mounted in a rolled paper tube having a one inch inside diameter. A sketch of this device is given in Figure 38. One end of the tube was sealed with a wooden dowel that was glued to the paper tube. The flashbulb squib was positioned at the bottom of the cue device with the top of the flashbulb pointing downward. The leads of the flashbulb squib pass through this wooden plug and are sealed with hot-glue.

A propellant charge of approximately 1.3 cc of Bullseye pistol powder was used with this cue device. To insure good burning, an additional booster charge of 0.5 cc of 4F black powder was added to the charge of pistol powder. This was in addition to the black powder coating on the flashbulb squib.

The propellant charge was covered with a folded wad of 3 mil plastic under a paper powder cup. The powder cup forms a seal to keep the purple-k from mixing with the propellant charge. A charge of 30 grams of potassium bicarbonate was loaded in the tube with the tube being tapped or vibrated to settle the powder and remove excess air.

The end of the cue tube was sealed with either a single layer or a double layer paper seal to provide the rupture diaphragm for the bang generator. The cue device was coated with a clear spray to seal the porous tube against moisture.

The flash cue was added to the smoke-bang cue at the bottom of the wood plug as shown in Figure 38. The flash cue was provided by a simple flashbulb connected in parallel with the internal flashbulb squib. The flash cue was physically mounted inside of a plastic tube for mechanical protection.

5.2.2.2 Medium Size Inert Powder FBS Cue

The construction of this cue demonstration unit was similar to that described above with the exception of the container. The smoke-bang cueing portion of the unit was placed in an eight gauge shotgun shell as illustrated in Figure 39. The load of inert powder was approximately 16 grams and the propellant was proportionally smaller. A charge of approximately 0.7 cc of Bullseye pistol powder was placed around the flashbulb squib. A single wad of plastic was used between the propellant and the paper powder cup as before.

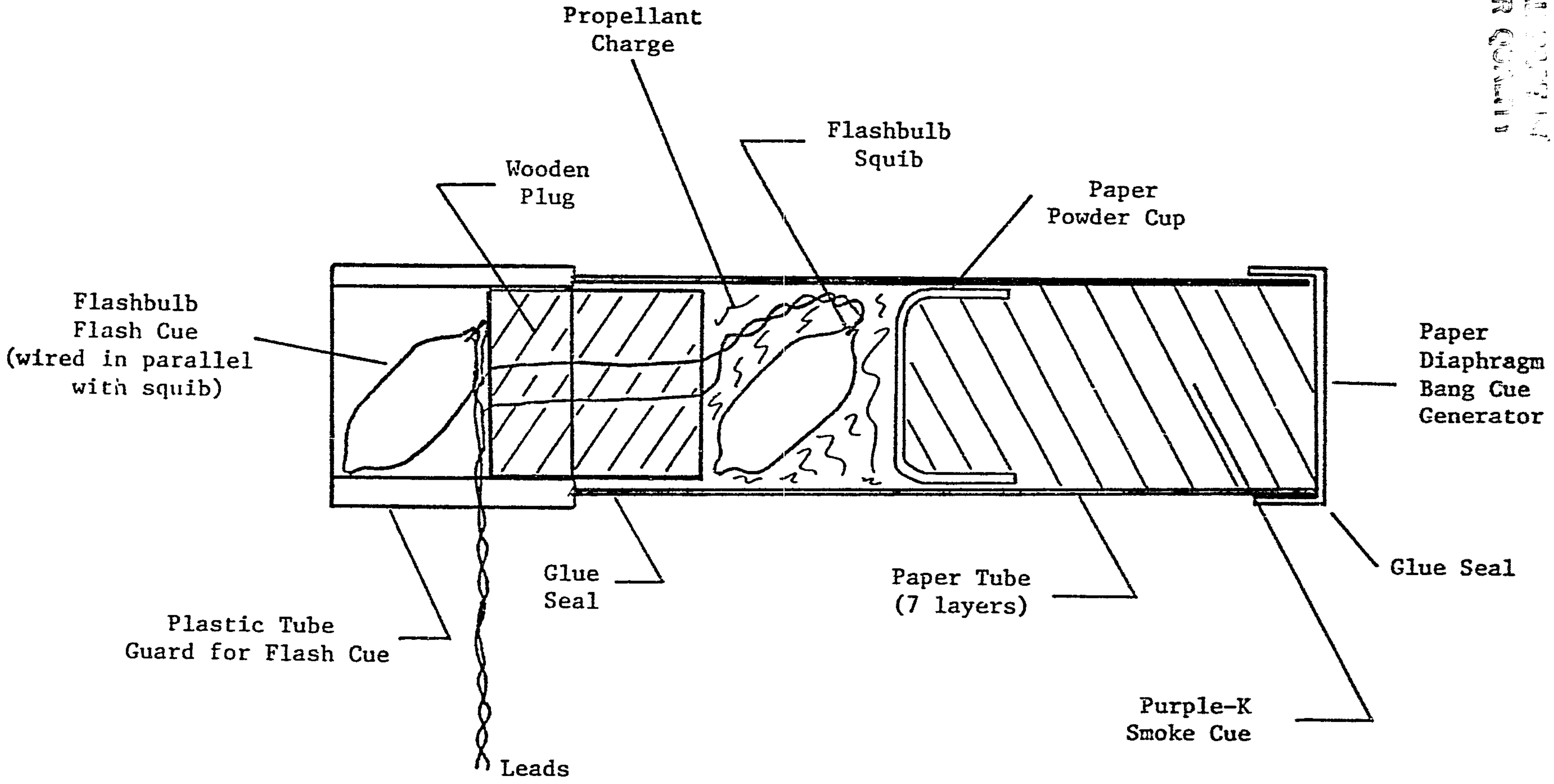


Figure 38. Schematic drawing of large inert powder FBS demonstration cue device.

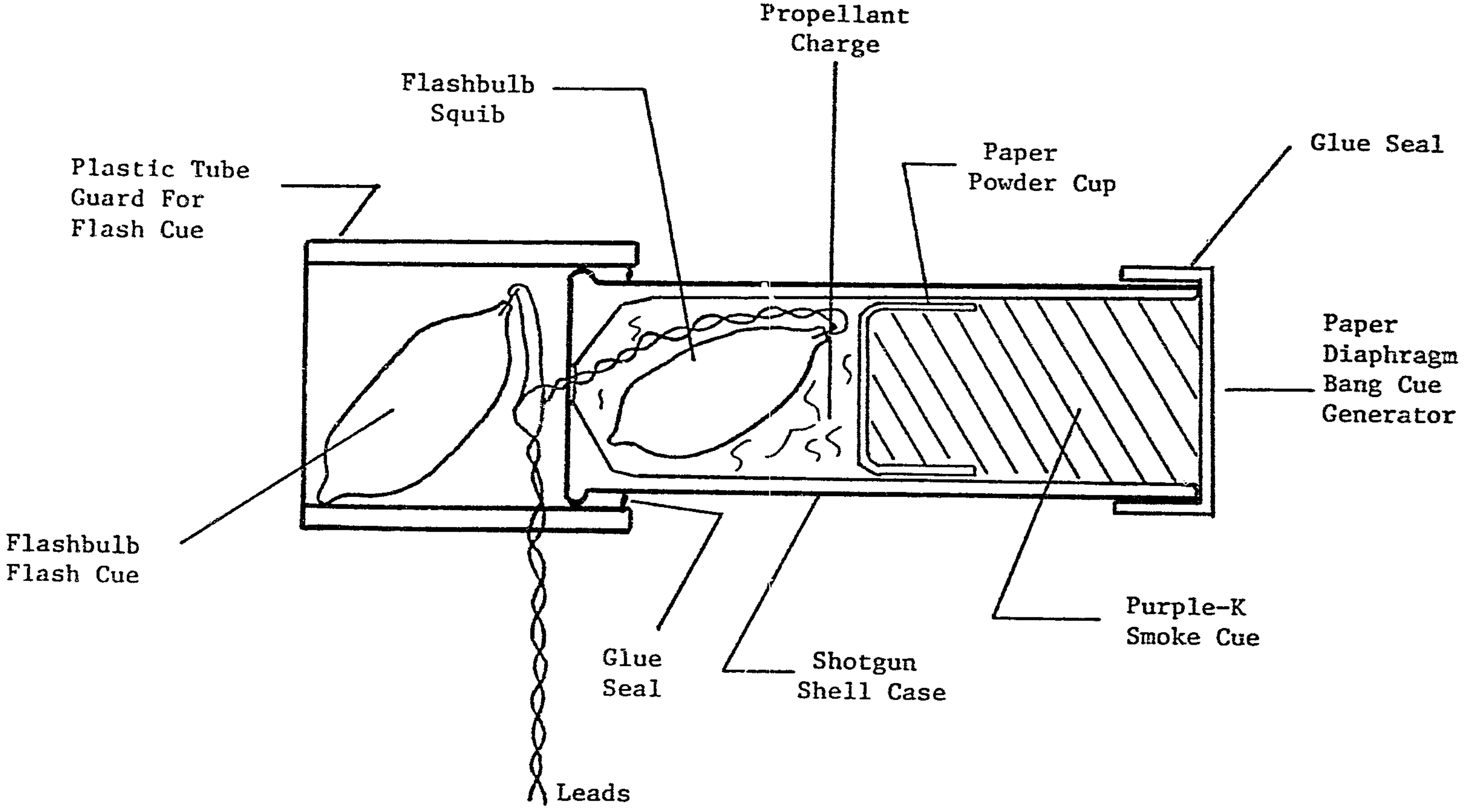


Figure 39. Schematic drawing of medium and small inert powder FBS demonstration cue device.

The bang cue was produced by the diaphram seal on the end of the shell as before. The seal was sprayed to protect against moisture.

5.2.2.3 Small Size Inert Powder FBS Cue

The small size demonstration cue was identical in construction to the medium size unit except a 12 gauge shotgun shell was used as the container. A weight of 6 grams of purple-k was used as the smoke cue. The propellant charge was composed of 0.5 cc of Bullseye pistol powder. The method of sealing the unit was identical to that used in the previously discussed units. The flash cue was provided by the flashbulb connected in parallel with the internal squib.

5.2.3 FLASH POWDER FBS CUES

The second type of cueing concept contained in the demonstration units makes use of a flash powder mixture of aluminum powder and potassium perchlorate. This cueing concept differs from the technology previously described. The smoke and flash cues are generated by open burning of the combustible material. This approach has a higher risk to nearby players and to the possibility of starting grass fires.

This FBS technology is an efficient cueing payload but care must be taken to insure that the cue is never ignited within some minimum distance to the ground or a player. This minimum distance is somewhat dependent upon the actual charge weight of the combustible material. Two charge weights of this type of FBS material have been included in these demonstration units. The packaging of the two units differs and is outlined in the descriptions given below.

5.2.3.1 Large Flash Powder FBS Cue

This demonstration cue was packaged in a 12 gauge shotgun shell and ignited by the flashbulb squib described above. The shotgun shell has been reduced in length to just accommodate the squib and the flash powder load. This cue contains 5 grams of the flash powder mixture. The black powder coating of the squib was sufficient to ignite the flash powder material directly. The flash powder in this unit was loaded directly in contact with the squib as shown in the diagram in Figure 40.

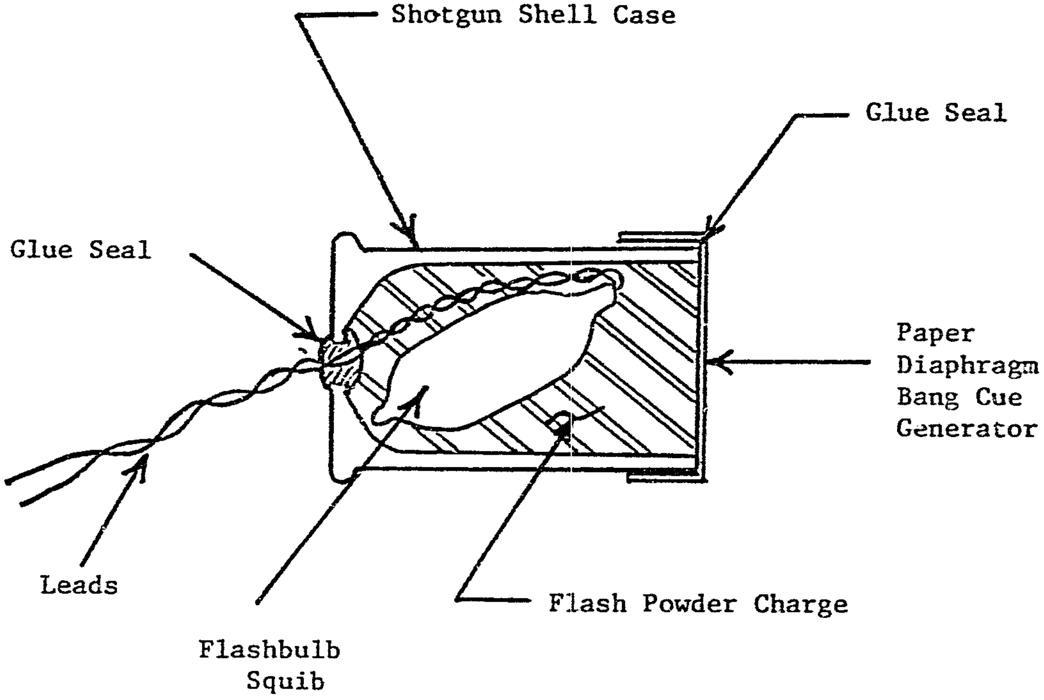


Figure 40. Schematic drawing of large flash powder FBS demonstration cue device.

This cue requires no external flash cue since a bright flash occurs with the discharge of the flash powder. A rupture seal covers the powder charge in the same manner as that used in the previous charges.

5.2.3.2 Small Flash Powder FBS Cue

This demonstration unit was developed to demonstrate a minimum cueing level for this flash powder cue technology. The small quantities involved in this demonstration unit required that the combustible material be in direct contact to the flashbulb squib. The black powder coating was attached to the flashbulb as before and allowed to dry. The prepared squib was then briefly dipped in acetone to wet the surface of the black powder coating and then rolled in the flash powder mix. The wet surface will cause the powder to coat the bulb but does not provide an adequate adhesive property. To overcome the fragile property of this coating, the unit was allowed to dry and was sprayed with a coating of a clear acrylic enamel (Trade name Utilac, manufactured by Benjamin Moore & Co.).

This demonstration cue was complete in the coated flashbulb. Since there was no confinement of the combustion in this form there was no bang cue. The roughness of the powder coating on the flashbulb may also prevent an effective moisture seal on the material with the spray coating. To overcome these limitations, these units have been housed in a large diameter plastic tube that was sealed at both ends with a simple diaphragm. This seal can provide an acoustic signature as well as providing protection against moisture. The clear plastic tube around this flash device provides some containment of the burning products of the cue.

This cue device contains approximately 0.3 grams of 4F black powder in the first coating on the flashbulb squib. The second coating of the flash powder mixture ranges from approximately 0.25 grams to 0.4 grams.

5.3 DEMONSTRATION UNIT TESTS

The inert powder cues were selected with cue weights of 6, 16, and 30 grams for the small, medium, and large demonstration units, respectively. The flash powder cues were selected with flash powder weights of 5 grams and approximately 0.3 grams (0.25 to 0.4 grams) for the large and small demonstration units. Figures 41 and 42 illustrate the cloud volume and cloud

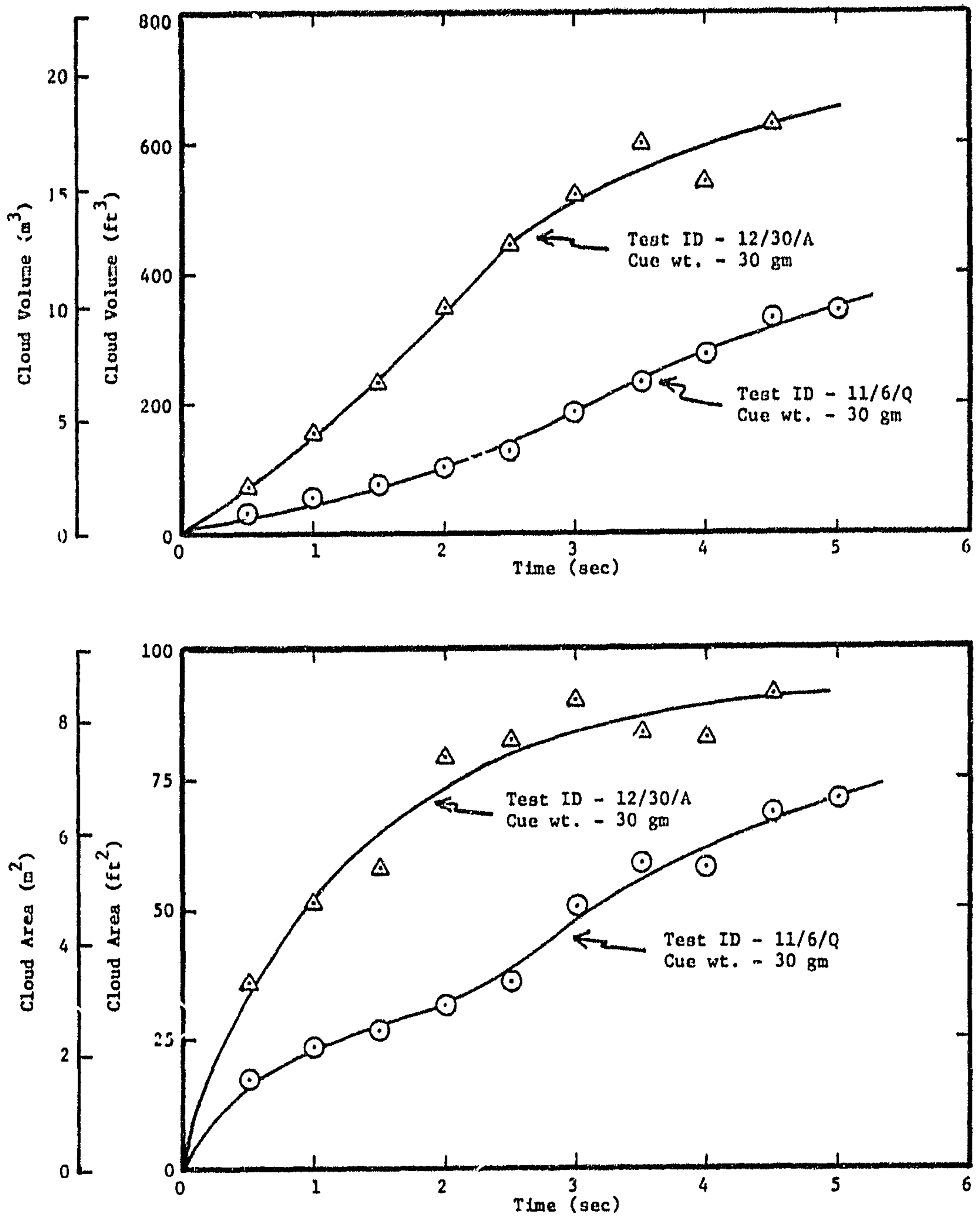


Figure 41. Smoke cloud measurement data of two sample cue units using 30 grams of Purple-K inert powder.

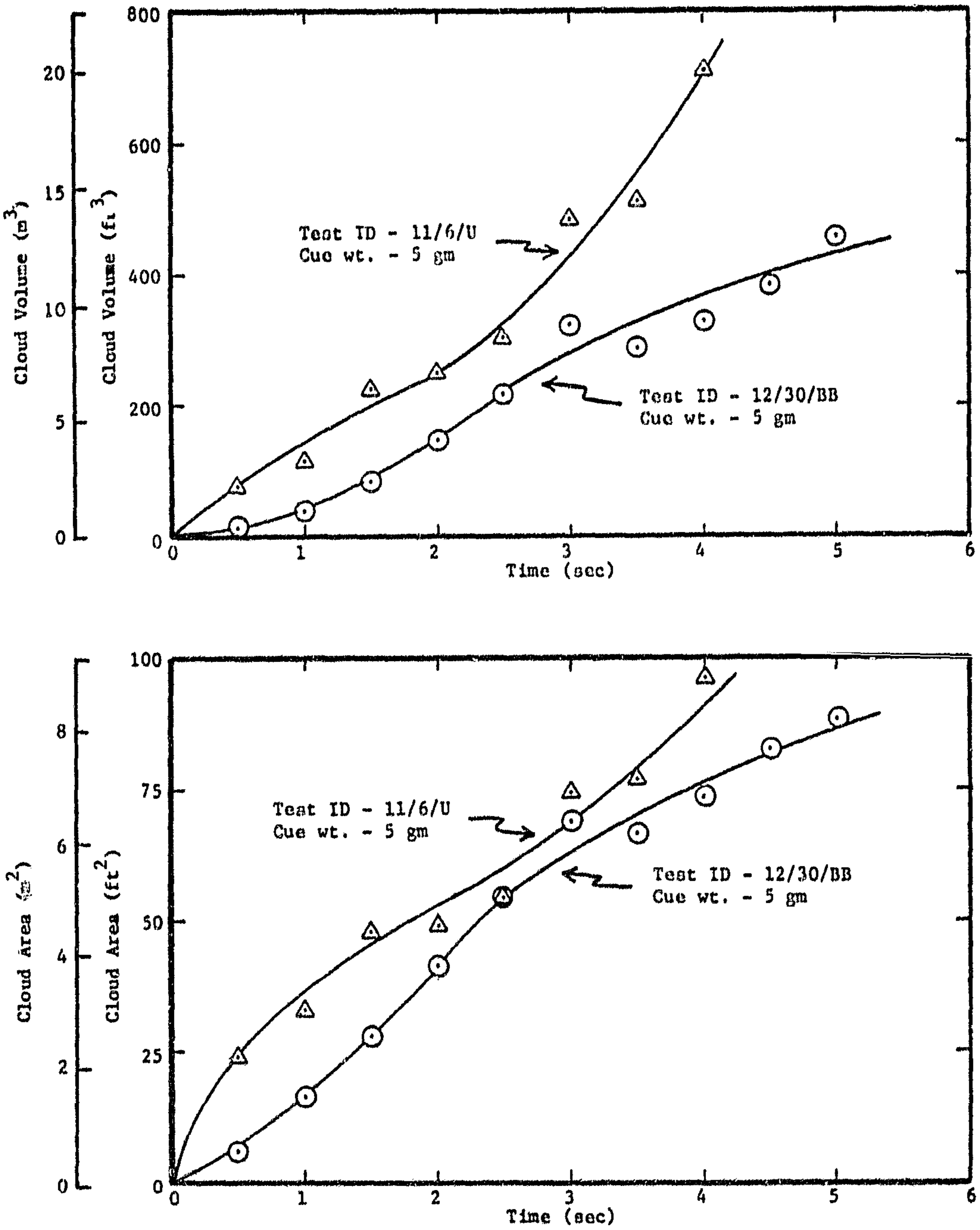


Figure 42. Smoke cloud measurement data of two sample cue units using 5 grams of standard flash powder.

area for two examples of the 30 gram inert powder demonstration cue and for two examples of the 5 gram flash powder demonstration cue. The differences between the smoke cloud signatures of similar cue devices in these two figures can be attributed to a number of random variables. The most influential of these variables is wind, which can vary considerably between cue test firings. Other random processes that contribute to differences between the curves within Figure 41 and Figure 42 are differences in the burning characteristics that will be found between different loads of the same cue and the operator's subjective definition of the cloud edge during data reduction. The peak sound level measurements for the demonstration cues are listed in Table 17. The 117.6 dB reading was in the saturation region of the sound level meter (see discussion in Section 4). These values have been plotted for comparison in Figure 43 in a format similar to the general measurements given in Figure 30.

TABLE 17. PEAK SOUND LEVELS

Cue Description	Test ID	Sound Level (dB) (at Test Distance of 9.75 Meters)
Purple-K Charge:		
30 gm	12/30/A	100.7
16 gm	12/30/H	102.0
6 gm	12/30/N	94.2
Std. Flash Powder Charge:		
5 gm	12/30/BB	117.6
Coated Squib	12/30/GG	79.7

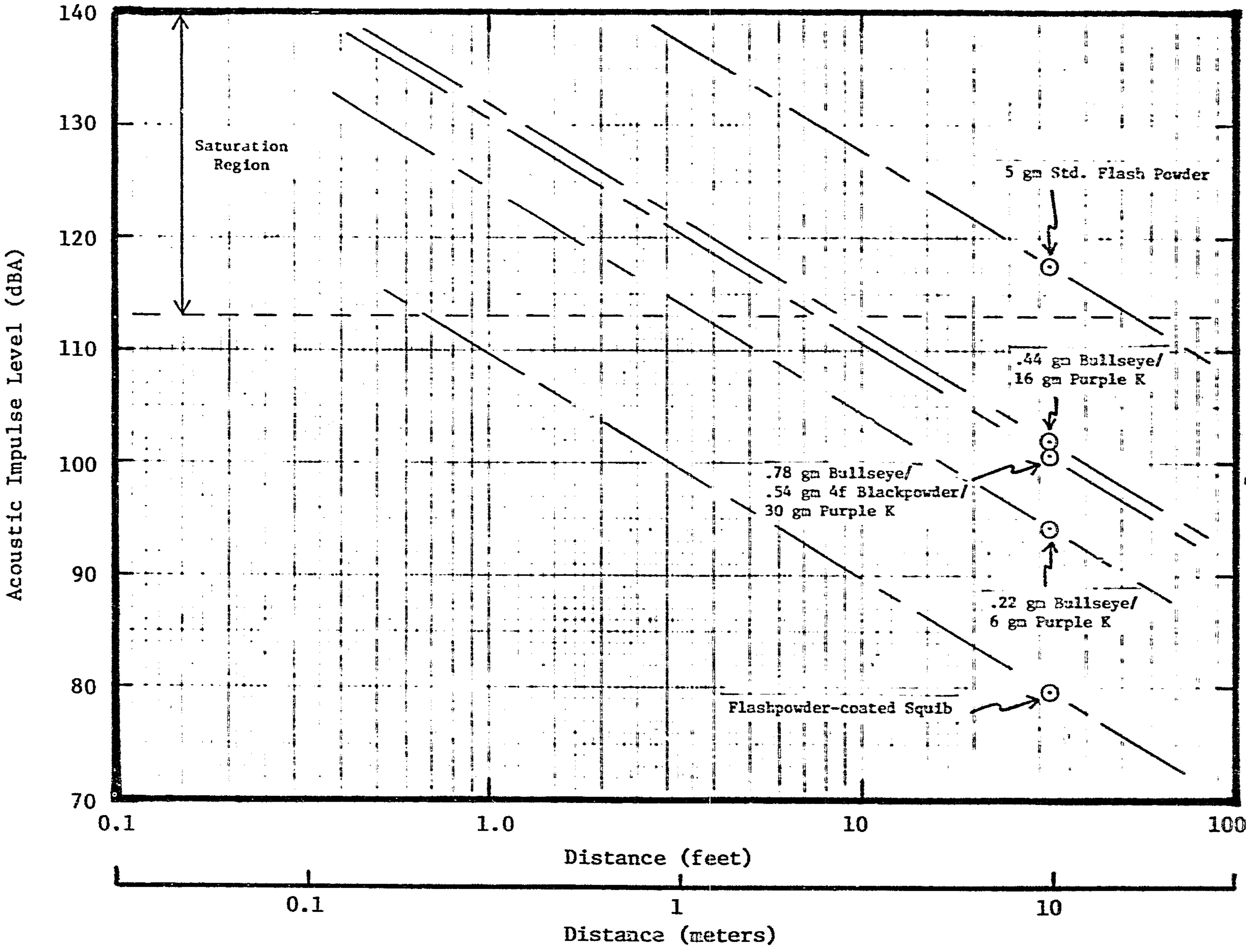


Figure 43. Acoustic measurements of representative samples of the delivered FBS demonstration cue units.

SECTION 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

A number of cueing concepts to produce flash/bang/smoke cue signatures to simulate a shell burst were systematically investigated. The concept definitions were formulated with the objective of developing cue technology that will be suitable for delivery through a remote-launched projectile to simulate an impact of indirect fire. The cue concepts are also considered applicable to other training devices such as mines.

The cue goals listed in Table 1 were used as guidelines for developing and evaluating the cueing techniques. These goals were primarily directed toward the smoke visibility, the flash visibility, and the safety of personnel and ranges. Specifications of the acoustic signature were limited only by the existing safety levels. These investigations were designed to quantify the cue signatures of the different cue concepts so that the maximum effect per unit volume of cue material could be defined. This approach allows the final cue design to be modified to meet changing cue requirements and to be extended to other training devices such as mines.

The cue tests and experiments indicated that the smoke cue and the flash cue requirements are fairly easy to meet in terms of the long range visibility goals if there is no limitation on personnel or range safety. These hazards restrict the cue design concepts to those that have a very high degree of safety in terms of fire danger and toxic products.

The primary cue evaluated during the long range and the short range tests was the smoke cue. Two basic approaches were used for generating the smoke cue signature. The first method involved the pyrotechnic compounds that produced smoke through a burning process. The second method produced a cloud signature by deploying an inert powder or dust. Some of the smoke cue concepts tested also produced a bang and flash cue as a by-product to the smoke signature.

Several cueing concepts were explored during the course of this investigation. Many properties (other than safety and the cue signatures) were considered, including those that would interact with other systems in the

C-2

simulated battlefield. Two basic applications were considered for the cue devices. The first application is in a ground burst where the close proximity of personnel and fire hazards such as grass are assumed. The second application is in an airburst where the distance from players and grass can be controlled by either a proximity or a time fuze. A matrix was constructed to allow comparisons to be made between the various cueing concepts. A separate matrix is presented for the case of the ground burst and the airburst applications in Tables 18 and 19. A numbering system (ranging from 0 to 5) is included in parentheses in each of these tables as a numerical estimation of the value of each property considered in the matrix (with 5 as the maximum value). Some of the categories in these tables include more than one powder mixture (for example, three basic flash powder formulas having similar properties were tested).

A basic goal during the evaluation of each cue concept was to establish design criteria that could be used for scaling the cue designs to different signature requirements. This scaling was primarily done for the smoke signature since this is the most visible quantity at the long ranges required for observation by a forward observer or other troop elements. Normalized curves for the smoke cloud area as a function of time were developed. A cloud area of approximately 5 square meters was derived from a model as being an appropriate cloud area for visibility at 3 kilometers. Table 20 compares the cue payload weights that are necessary to generate a 5 square meter smoke cloud area 3 seconds after cue ignition based on the normalized design curves presented in Appendix A of this report.

The flash signature is relatively simple to develop, and the long range tests verified that a simple photographic flashbulb could easily be seen at observing distances of 2.5 kilometers in normal daylight. Bulbs with greater intensity did not produce significantly brighter results to the observer. Flash powder fireballs were known to be larger in size, but also did not produce a subjective response in the observer that was significantly different from the simple flashbulb. The flashbulb is considered adequate for the flash cue, and the inherent safety of the contained combustion process presents no danger of flash burns to personnel and no danger of starting grass fires.

The acoustic signature generally presents a problem of reducing the level to a degree where accidental exposure of personnel at close ranges does not

TABLE 18. FLASH, BANG, SMOKE CUE EVALUATION SHEET (GROUND BURST)*

Cue	Inert Powder Potassium Bicarbonate	Inert Powder Calcium Carbonate	Anthracene Mix	Anthracene Mix (Thrust Motor)	Flash Powder	Phosphnorus Mix	Black Powder	Low Temp Smoke Material
Attributes	Good Safe Smoke Cue	Good Smoke Cue	Good FBS Cue Safe Byproducts	Good FBS Cue Safe Byproducts	Efficient FBS Cue	Efficient FBS Cue	Fair FBS Cue	Efficient Smoke Cue
Configuration	Smoke Cue Expelled by Powder Charge	Smoke Cue Expelled by Powder Charge	Contained Combustion	Thrust Motor	Contained Combustion	Contained Combustion	Thrust Motor	Thrust Motor
Payload Weight Requirements	Moderate	Moderate	Moderate	Moderate	Minimal	Minimal	Minimal	Minimal
Technical Feasibility	Currently Feasible	Currently Feasible	Currently Feasible	Currently Feasible	Currently Feasible	Currently Feasible	Currently Feasible	Currently Feasible
Cue Requirements:								
3 km Smoke Visibility	Yes (5)	Yes (5)	Yes (5)	Yes (5)	Yes (5)	Yes (5)	Yes (3)	Yes (5)
200 m Flash Visibility	No (0)*	No (0)*	No (0)*	No (0)*	Yes (5)	Yes (5)	Yes (3)	No (0)*
Bang Signature	Yes ( )	Yes ( )	Yes ( )	No (0)**	Yes (5)	Yes (5)	No (0)**	No (0)**
Hazards:								
Toxicity	Low (5)	Moderate (4)	Low (4)	Low (4)	Moderate (3)	P_2O_8 Product (0)	Moderate (2)	Low (?)
Flash (eye)	Nil (5)	Nil (5)	Nil (4)	Nil (4)	Moderate (1)	Moderate (1)	Moderate (3)	Nil (5)
Burn	Nil (5)	Nil (5)	Moderate (3)	Moderate (2)	Moderate (2)	Moderate (1)	Moderate (3)	Nil (5)
Sound	Nil (5)	Nil (5)	Nil (3)	Nil (3)	Moderate (2)	Moderate (1)	Moderate (4)	Nil (5)
Shrapnel	Nil (5)	Nil (5)	Nil (4)	Nil (4)	Nil (4)	Moderate (1)	Moderate (4)	Nil (5)
Fire (grass)	Nil (5)	Nil (5)	Nil (2)	Moderate (2)	Moderate (2)	Moderate (2)	Moderate (3)	Nil (5)
Cost (unit)	Low	Low	Low	Low	Low	Low	Low	Low
Reliability	Good	Good	Good	Good	Good	Food	Good	Good
Vehicle Interaction:								
Sound	Yes	Yes	Yes	Optional	Yes	Yes	Optional	Optional
Sight	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

*Flash cue developed by external flashbulb.
**Requires external bang generator.

TABLE 18. FLASH, BANG, SMOKE CUE EVALUATION SHEET (GROUND BURST)* cont.

Cue	Inert Powder Potassium Bicarbonate	Inert Powder Calcium Carbonate	Anthracene Mix	Anthracene Mix (Thrust Motor)	Flash Powder	Phosphorus Mix	Black Powder	Low Temp Smoke Material
Interference:								
Rain	Reduced Visibility	Reduced Visibility	Reduced Visibility	Reduced Visibility	Reduced Visibility	Reduced Visibility	Reduced Visibility	Reduced Visibility
Fog	Reduced Visibility	Reduced Visibility	Reduced Visibility	Reduced Visibility	Reduced Visibility	Reduced Visibility	Reduced Visibility	Reduced Visibility
Sun	None	None	None	None	None	None	None	None
Dust	Reduced Visibility	Reduced Visibility	Reduced Visibility	Reduced Visibility	Reduced Visibility	Reduced Visibility	Reduced Visibility	Reduced Visibility
Wind	Minimal	Minimal	Minimal	Minimal	Minimal	Minimal	Minimal	Moderate
Man-Made	Decreased Visibility In Obscuring Smoke	Decreased Visibility In Obscuring Smoke	Decreased Visibility In Obscuring Smoke	Decreased Visibility In Obscuring Smoke	Decreased Visibility In Obscuring Smoke	Decreased Visibility In Obscuring Smoke	Decreased Visibility In Obscuring Smoke	Decreased Visibility In Obscuring Smoke
Needed Information								
Needed Research and Field Data								
Comments	Good Ground Burst Simulation With Ext. Flash Cue							

*Flash cue developed by external flashbulb.
**Requires external bang generator.

TABLE 19. FLASH, BANG, SMOKE CUE EVALUATION SHEET (AIR BURST)**

Cue	Inert Powder Potassium Bicarbonate	Inert Powder Calcium Carbonate	Anthracene Mix	Anthracene Mix (Thrust Motor)	Flash Powder	Phosphorus Mix	Black Powder	Low Temp Smoke Material
Attributes	Good Safe Smoke Cue	Good Smoke Cue	Good FBS Cue Safe Byproducts	Good FBS Cue Safe Byproducts	Efficient FBS Cue Bright Flash	Efficient FBS Cue	Fair FBS Cue	Efficient Smoke Cue
Configuration	Smoke Cue Expelled by Pistol Powder Charge	Smoke Cue Expelled by Pistol Powder Charge	Contained Combustion	Thrust Motor	Contained Combustion	Contained Combustion	Thrust Motor	Thrust Motor
Payload Weight Requirements	Moderate	Moderate	Moderate	Moderate	Minimal	Minimal	Minimal	Minimal
Technical Feasibility	Currently Feasible	Currently Feasible	Currently Feasible	Currently Feasible	Currently Feasible	Currently Feasible	Currently Feasible	Currently Feasible
Cue Requirements:								
3 km Smoke Visibility	Yes (5)	Yes (5)	Yes (5)	Yes (5)	Yes (5)	Yes (5)	Yes (3)	Yes (5)
200 m Flash Visibility	Requires Auxiliary Flash Cue (0)	Requires Auxiliary Flash Cue (0)	Requires Auxiliary Flash Cue (0)	Requires Auxiliary Flash Cue (0)	Yes (5)	Yes (5)	Requires Auxiliary Flash Cue (3)	Requires Auxiliary Flash Cue (0)
Bang Signature	Yes ( )	Yes ( )	Yes ( )	Requires Auxiliary Bang Cue (0)	Yes (5)	Yes (5)	Requires Auxiliary Bang Cue (3)	Requires Auxiliary Bang Cue (0)
Hazards:								
Toxicity	Low (5)	Moderate (4)	Low (4)	Low (4)	Moderate (3)	P_2O_5 Product (0)	Moderate (2)	Low (?)
Flash (eye)	Nil (5)	Nil (5)	Nil (4)	Nil (4)	Moderate (1)*	Moderate (1)*	Nil (3)	Nil (5)
Burn	Nil (5)	Nil (5)	Moderate (3)	Moderate (2)	Nil (4)*	Nil (4)*	Nil (3)*	Nil (5)
Sound	Nil (5)*	Nil (5)*	Nil (4)*	Nil (5)	Moderate (2)*	Moderate (2)*	Nil (5)	Nil (5)
Shrapnel	Nil (5)	Nil (5)	Nil (4)	Nil (4)	Nil (4)	Nil (4)	Nil (4)	Nil (5)
Fire (grass)	Nil (5)	Nil (5)	Nil (3)	Nil (2)	Nil (3)*	Nil (3)*	Nil (2)*	Nil (5)
Cost (unit)	Low	Low	Low	Low	Low	Low	Low	Low
Reliability	Good	Good	Good	Good	Good	Good	Good	Good
Vehicle Interaction:								
Sound	Yes	Yes	Yes	Optional	Yes	Yes	Optional	Optional
Sight	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

*Based on ignition above player (minimum distance assumed to be 10 ft.).
**Ignition to be with flashbulb squib for greater resistance to accidental discharge from static electricity.

TABLE 19. FLASH/BANG/SMOKE CUE EVALUATION SHEET (AIR BURST)** cont.

Cue	Inert Powder Potassium Bicarbonate	Inert Powder Calcium Carbonate	Anthracene Mix	Anthracene Mix (Thrust Motor)	Flash Powder	Phosphorus Mix	Low Temp Black Powder	Smoke Material
Interference:								
Rain	Reduced Visibility	Reduced Visibility	Reduced Visibility	Reduced Visibility	Reduced Visibility	Reduced Visibility	Reduced Visibility	Reduced Visibility
Fog	Reduced Visibility	Reduced Visibility	Reduced Visibility	Reduced Visibility	Reduced Visibility	Reduced Visibility	Reduced Visibility	Reduced Visibility
Sun	None	None	None	None	None	None	None	None
Dust	Reduced Visibility	Reduced Visibility	Reduced Visibility	Reduced Visibility	Reduced Visibility	Reduced Visibility	Reduced Visibility	Reduced Visibility
Wind	Minimal	Minimal	Minimal	Minimal	Minimal	Minimal	Minimal	Moderate
Man-Made	Decreased Visibility In Obscuring Smoke	Decreased Visibility In Obscuring Smoke	Decreased Visibility In Obscuring Smoke	Decreased Visibility In Obscuring Smoke	Decreased Visibility In Obscuring Smoke	Decreased Visibility In Obscuring Smoke	Decreased Visibility In Obscuring Smoke	Decreased Visibility In Obscuring Smoke
Needed Information								Composition of Smoke Generating Material
Needed Research and Field Data	Study Package Configurations For Projectile							
Comments	Good Cloud Good Safety Requires Auxiliary Flash Cue			Slow Release	Efficient FBS Cue Some Burn and Fire Hazard		Slow Release	Long Time Required For Smoke Cue Generation Impractical for Air Burst

*Based on ignition above player (minimum distance assumed to be 10 ft.).
**Ignition to be with flashbulb squib for greater resistance to accidental discharge from static electricity.

TABLE 20. COMPARISON OF WEIGHT OF SMOKE CUE MATERIAL FOR 5 SQUARE METER CLOUD AREA

Cue Material	Weight of Material Needed to Satisfy Long-Range Visibility Requirements (5 square meter cloud) (at 3 seconds)
Standard Flash Powder	3.1 grams
Flash Powder Mix No. 1	4.1 grams
Flash Powder Mix No. 3	12.3 grams
Aluminum Flake Powder	10.0 grams
Black Powder (Cylindrical Burning Configuration)	9.0 grams
4F/Anthracene/$KClO_3$ (2-2-1 Mix)	7.8 grams
4F/Anthracene/$KClO_3$ (1-1-1 Mix)	8.3 grams
4F/Anthracene (2-1 Mix)	14.4 grams
Low Temperature Smoke Compound	7.2 grams
Purple-K	12.3 grams
Potassium Bicarbonate	33.8 grams
Calcium Carbonate	9.6 grams

require the use of hearing protection devices (earplugs). Cueing devices that do not develop a bang signature as a by-product of the combustion process must frequently be aided by the rupture of the container or a diaphragm. This was necessary in the design of many of the units that were tested. When a diaphragm rupture is used, the acoustic level can be modified by changing the burst strength of the diaphragm material.

Two types of demonstration units were constructed and delivered for testing and evaluation by JPL. These deliverables represented both airburst and ground burst cueing concepts. The unit sizes were based on long range tests that verified that the cue goals listed in Table 1 could be met. The deliverables also included cue sizes that provided signatures (primarily smoke) below the desired threshold of visibility.

A standard flash powder proved to be a very efficient cue concept and represents the first method or approach for smoke signature generation. This generic cue device has safety limitations due to the fireball that occurs at the time of ignition and is usually accompanied by a significant acoustic cue. The dangers to personnel and grass fires can be somewhat controlled by limiting the application of this cue type to a minimum distance from personnel (as in the case of an airburst).

Inert powder smoke cue studies centered around a commercially available preparation of potassium bicarbonate (sold under the trade name of Purple-K). This material is usually used as the powder in dry chemical fire extinguishers. Test firings with this material demonstrated that cloud signatures were adequate for the long range visibility requirements and that a higher degree of man and range safety could be obtained than with other cue concepts tested.

These two cueing concepts were represented in the cue designs delivered and tested before the user representatives from the U.S. Army at the December 1981 presentation. A detailed description of these cue designs is included in Section 5.

The different cueing signature levels that were demonstrated followed the predicted design information. Design data were developed for each cue concept on a normalized basis. Smoke cue payloads can be adjusted for different signature requirements (such as smoke cloud volume or area).

The degree of confidence in the man-safety of the inert powder cue design is shown in Figure 44 where the 30 gram cue design was hand-held while being activated. No ill effects were experienced from this event. The cue was held around the flash unit and no burns were produced. It has been demonstrated that the smoke and flash signatures of this cue model are sufficient to be seen in normal daylight to a distance of 2.5 kilometers. This cue concept is recommended by GIT/EES as meeting the stated cue goals and as having a very high degree of man-safety and range-safety.

This development effort has identified two basic cueing concepts for meeting the basic goals set forth in Table 1. The flash powder cue concept is a very efficient material, but has associated hazards in the fireball. The inert powder cue concept, when associated with the flashbulb flash signature generator, is a less efficient cue payload, but has demonstrated the ability to meet the cueing goals for long range smoke and flash visibility while providing a high degree of man and range safety.

6.2 RECOMMENDATIONS

The cue configurations used in the tests were similar to what might be used in an actual projectile configuration. Additional tests with the delivered cue concepts packaged in an actual projectile would enable refinement of the basic designs. Testing in a fired projectile, instead of a fixed test stand, will provide a dynamic test of the cue triggering and deployment mechanisms that have not been addressed in this study. A multiple exit nozzle for the inert powder, illustrated in Figure 45, shows promise for generating cloud signatures that have a greater width to height ratio.

Additional testing of actual cue configurations for projectiles (particularly in a dynamic mode) is the main recommendation made by GIT/EES.

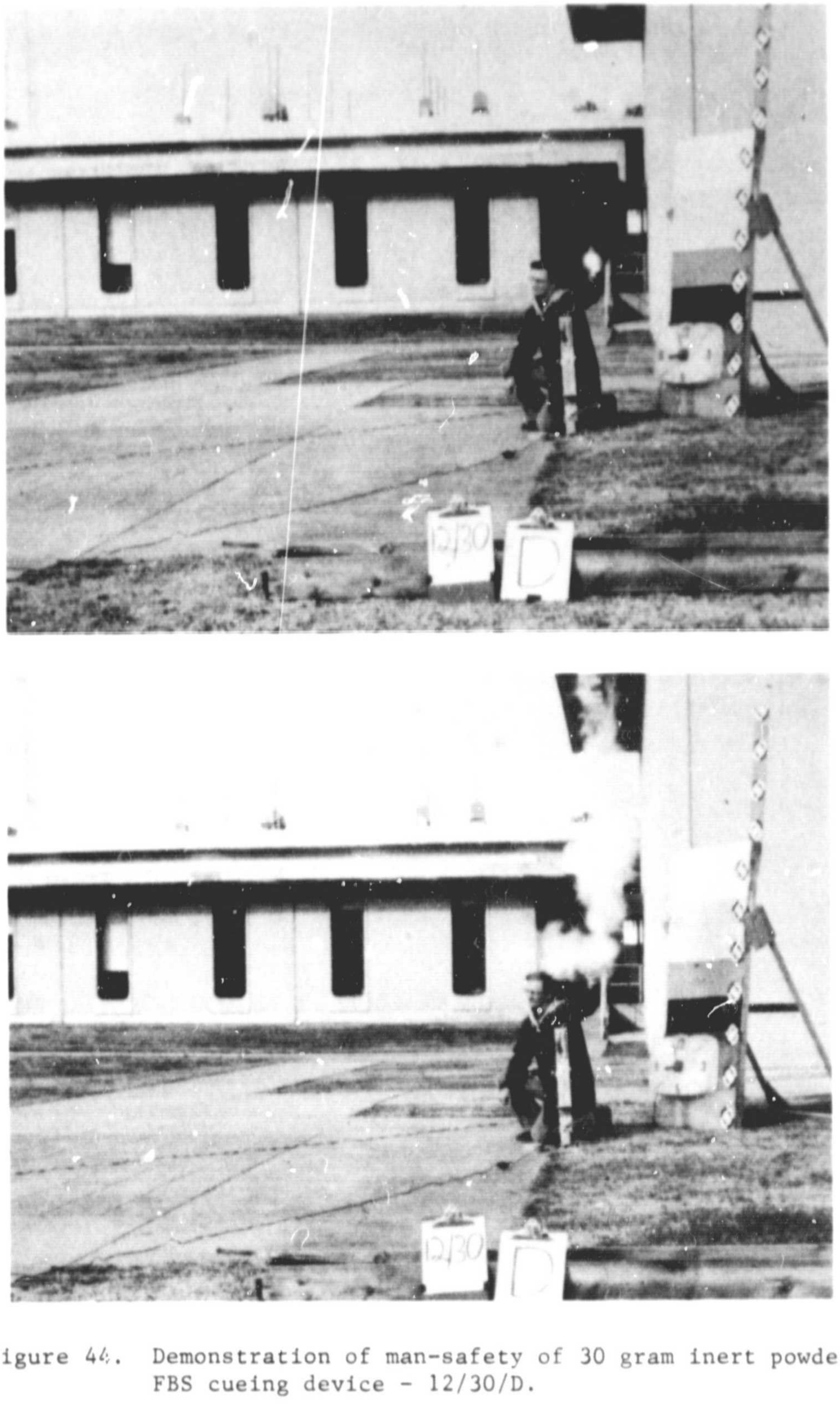
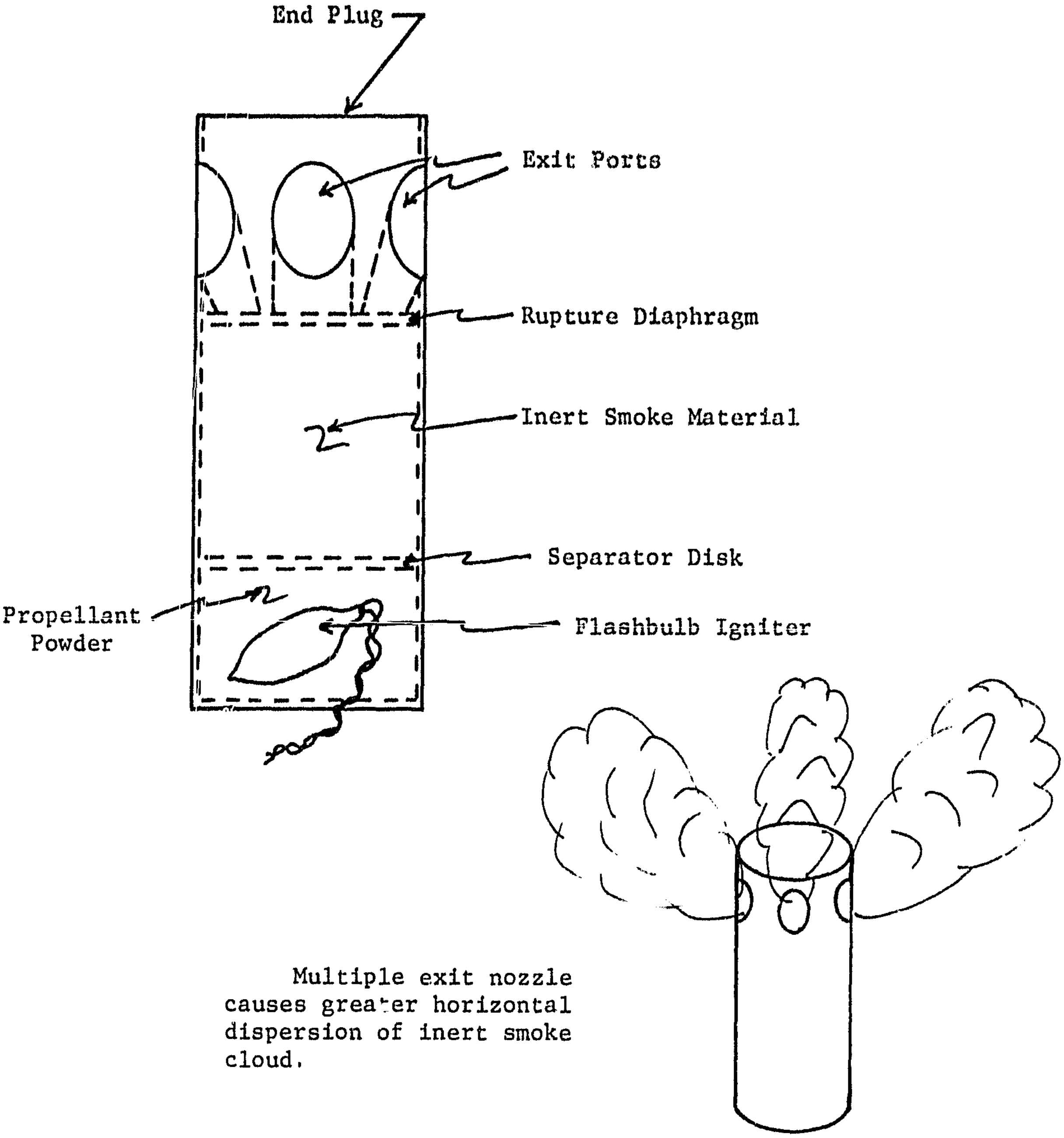


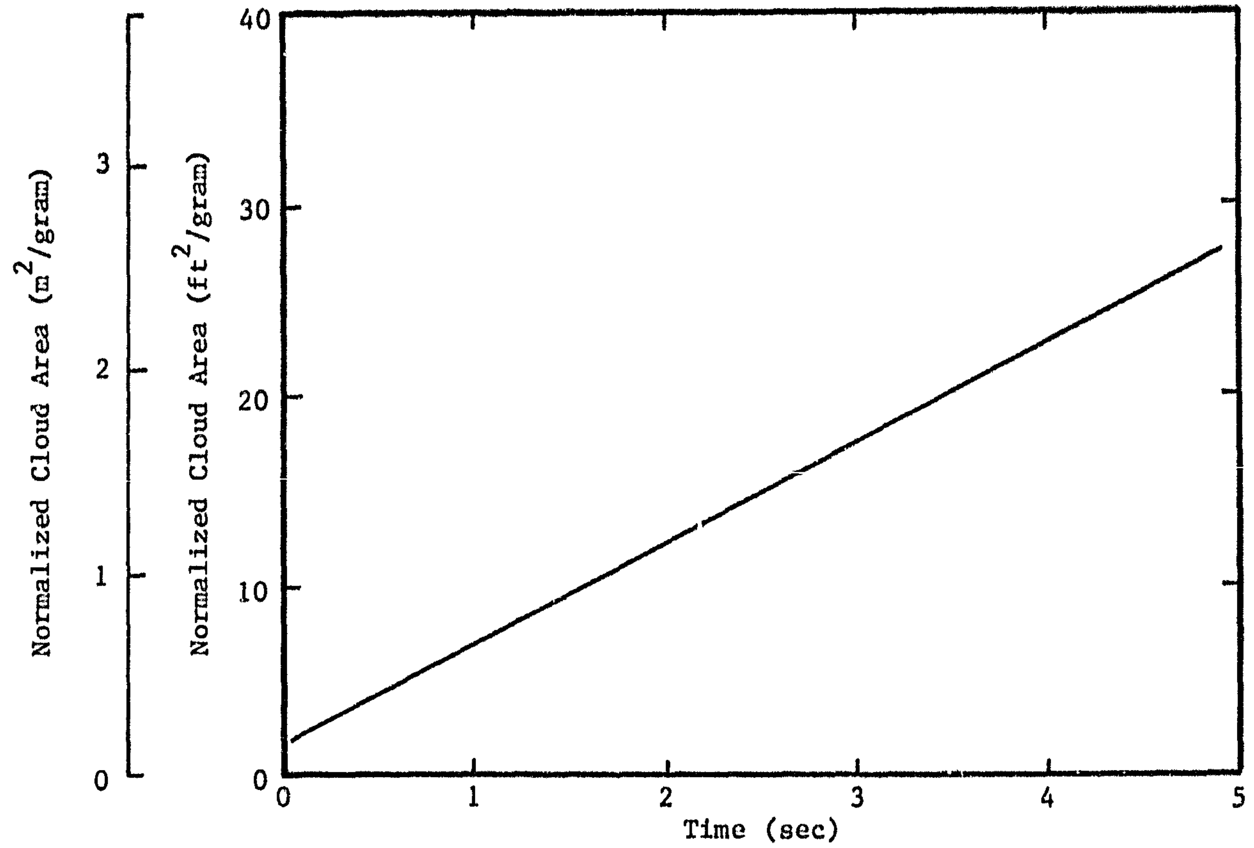
Figure 44. Demonstration of man-safety of 30 gram inert powder FBS cueing device - 12/30/D.



Multiple exit nozzle causes greater horizontal dispersion of inert smoke cloud.

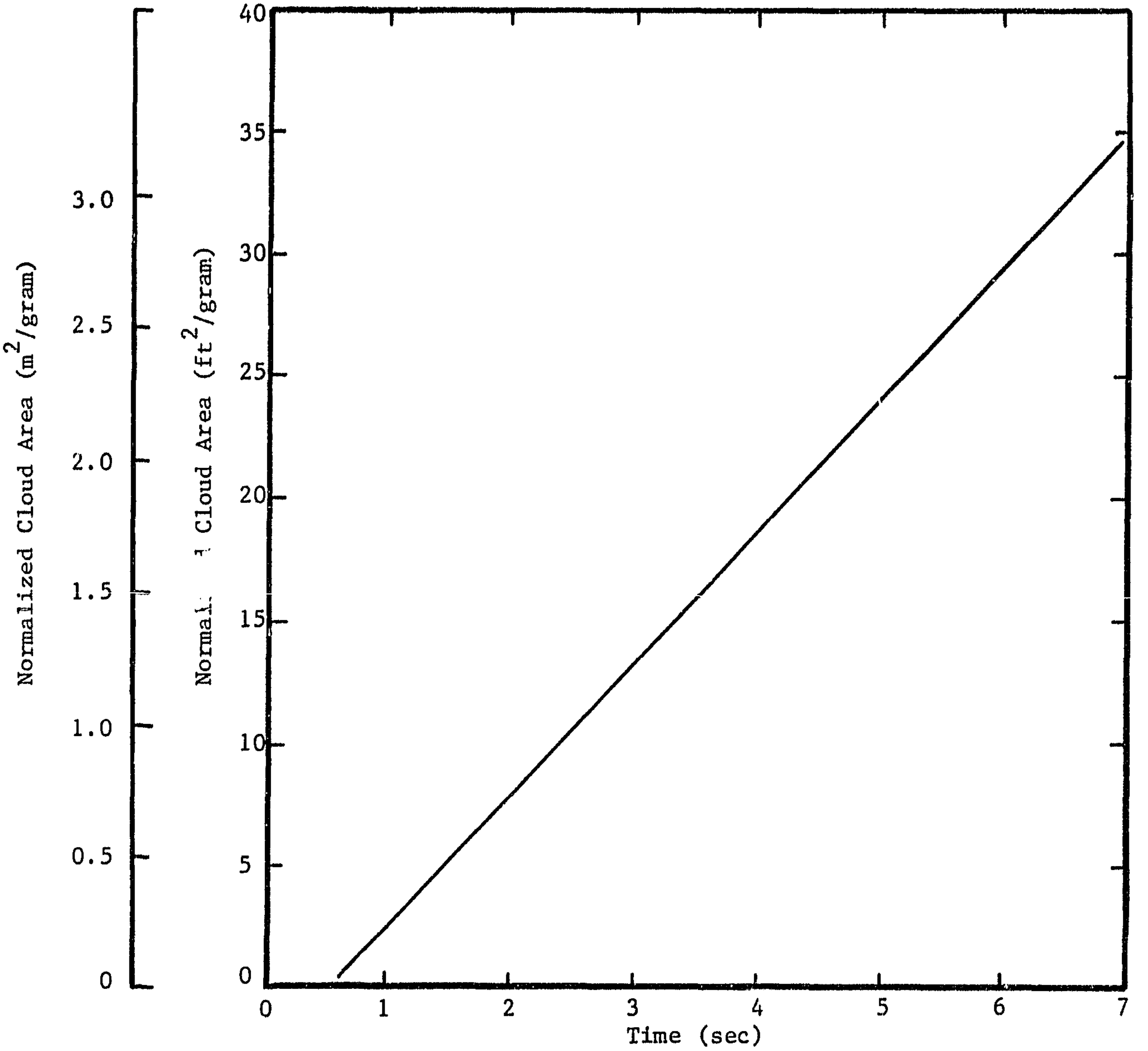
Figure 45. Multiple exit nozzle concept for greater dispersion of inert smoke cloud.

APPENDIX A
NORMALIZED SMOKE CLOUD DESIGN DATA



Cue Material	Standard Flash Powder
Mixture	34.2% Al, 65.8% $KClO_4$
No. of Shots Averaged	8
Range of Cue Weights Tested	3 to 16 grams

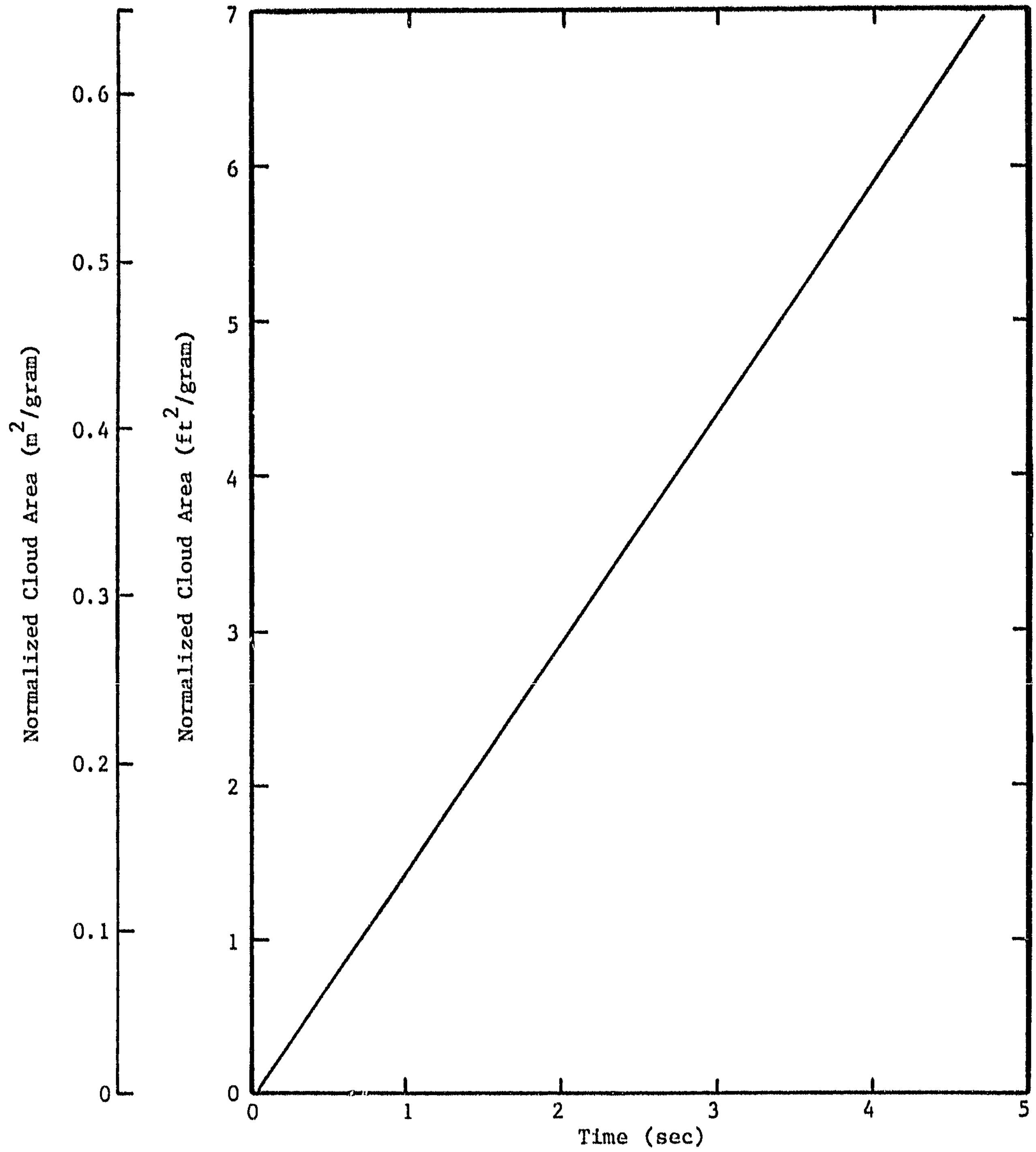
Figure A-1. Normalized smoke cloud test results for standard flash powder.



Cue Material	Flash Powder Mix No. 1
Mixture	21% Mg, 9% Al, 35% $BaNO_3$, 35% $KClO_3$
No. of Shots Averaged	6
Range of Cue Weights Tested	0.5 to 10 grams

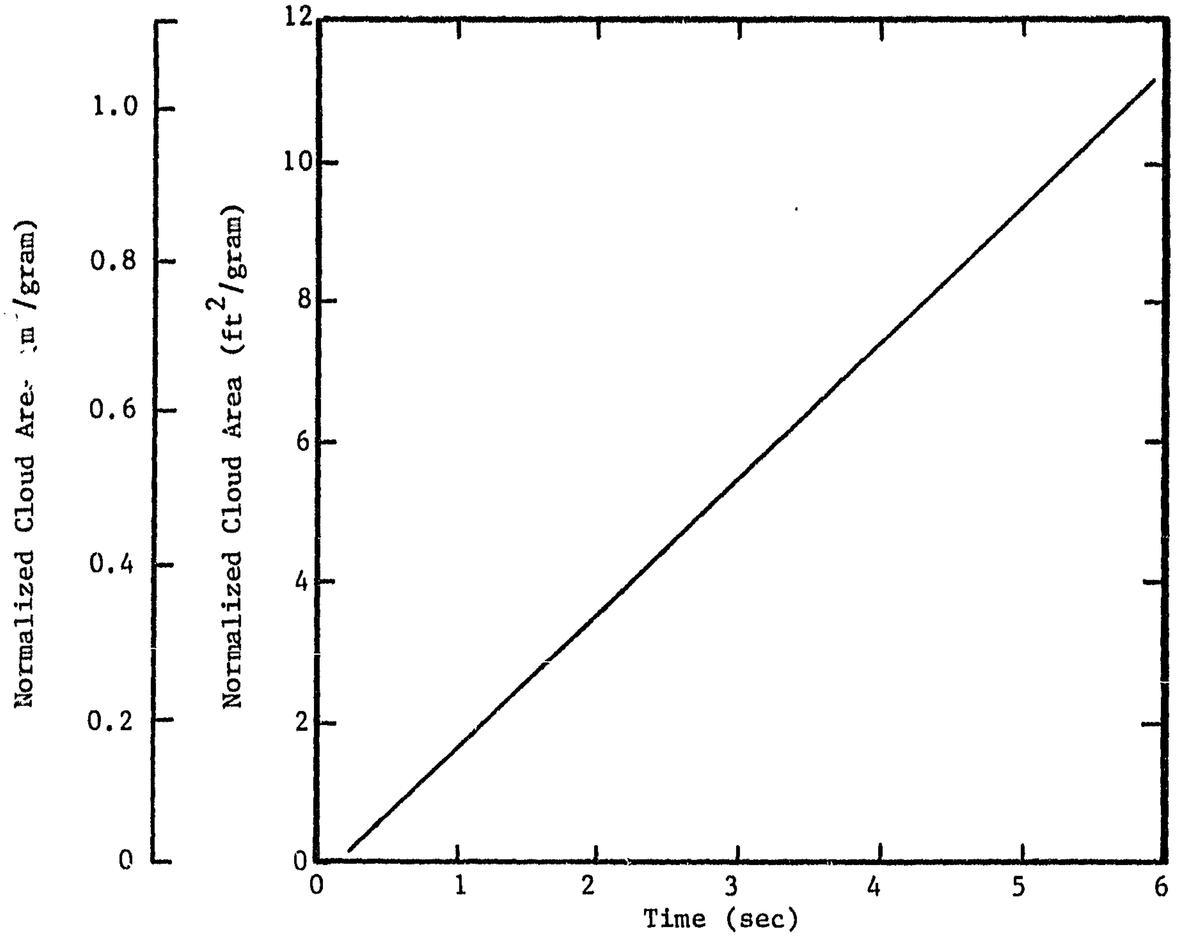
Figure A-2. Normalized smoke cloud test results for flash powder mixture no. 1.

ORIGINAL PAGE IS
OF POOR QUALITY



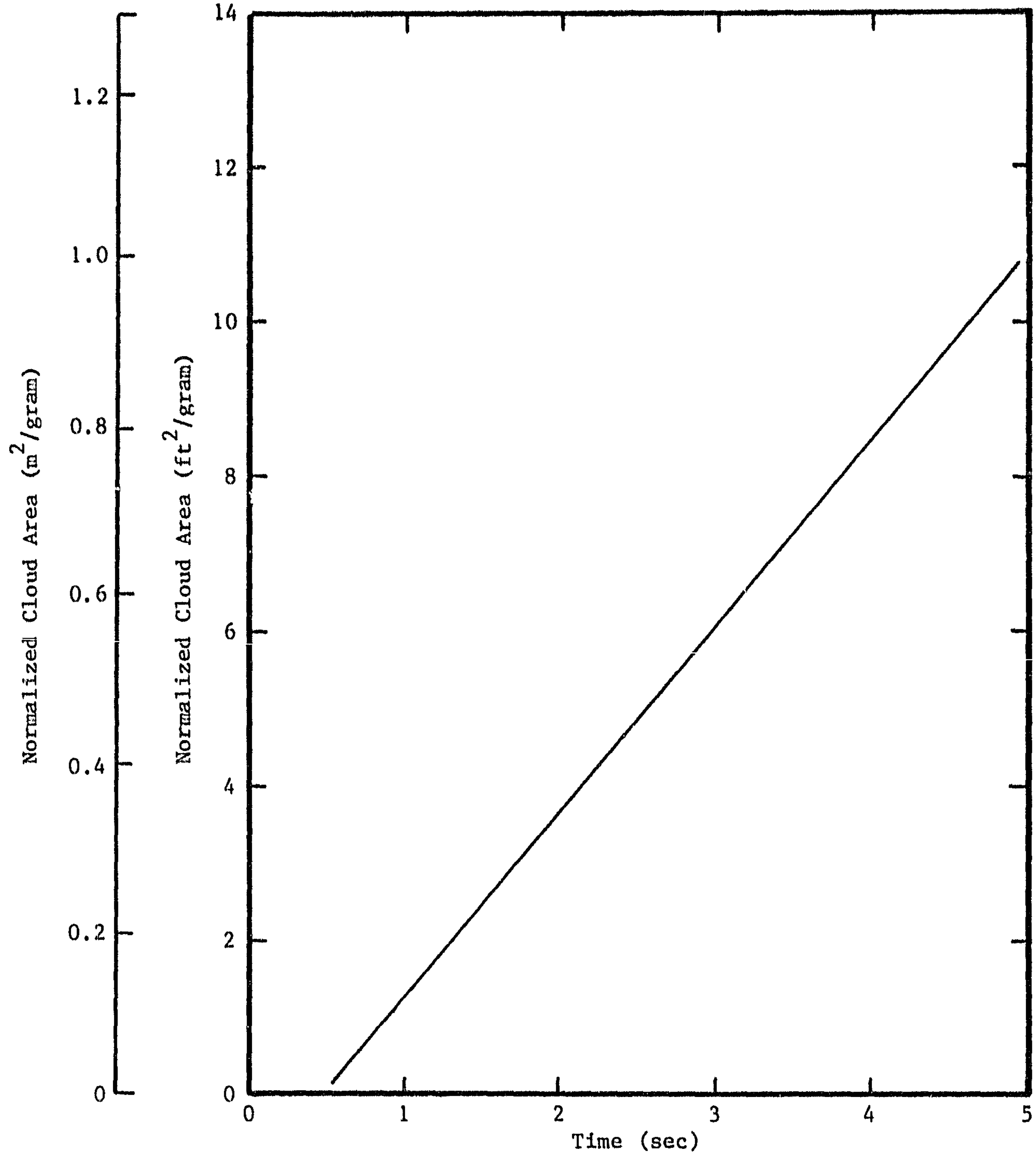
Cue Material	Flash Powder Mix No. 3
Mixture	37% Mg, 63% $KClO_3$
No. of Shots Averaged	4
Range of Cue Weights Tested	1 to 10 grams

Figure A-3. Normalized smoke cloud test results for flash powder mixture no. 3.



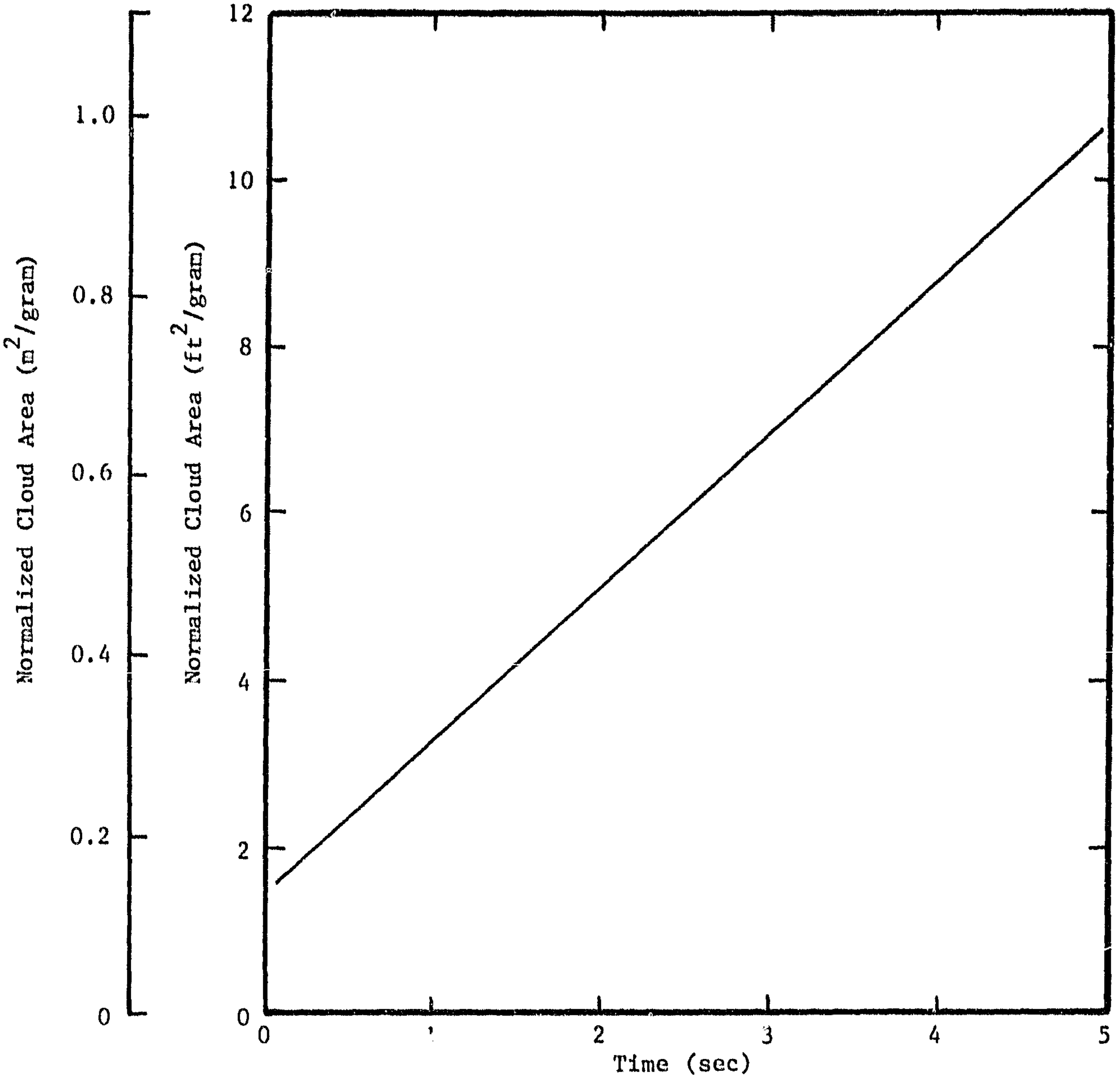
Cue Material	Aluminum Flake Powder
Mixture	Al flake
No. of Shots Averaged	6
Range of Cue Weights Tested	3 to 5.8 grams

Figure A-4. Normalized smoke cloud test results for aluminum flake powder.



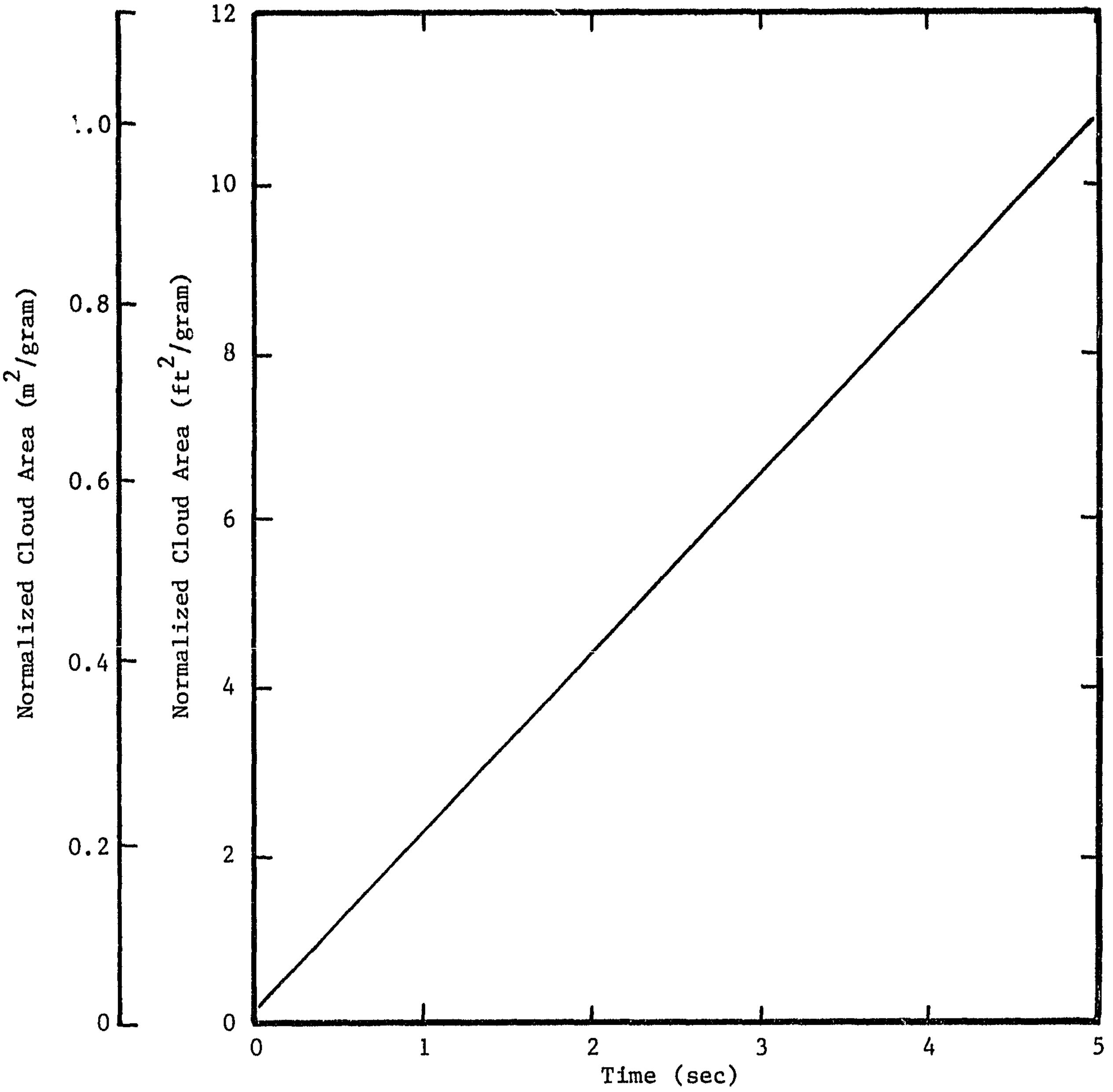
Cue Material	Black Powder (Cylindrical Burning Configuration)
Mixture	FFFFg Black Powder
No. of Shots Averaged	6
Range of Cue Weights Tested	4.2 to 12.8 grams

Figure A-5. Normalized smoke cloud test results for black powder cylindrical burning configuration cues.



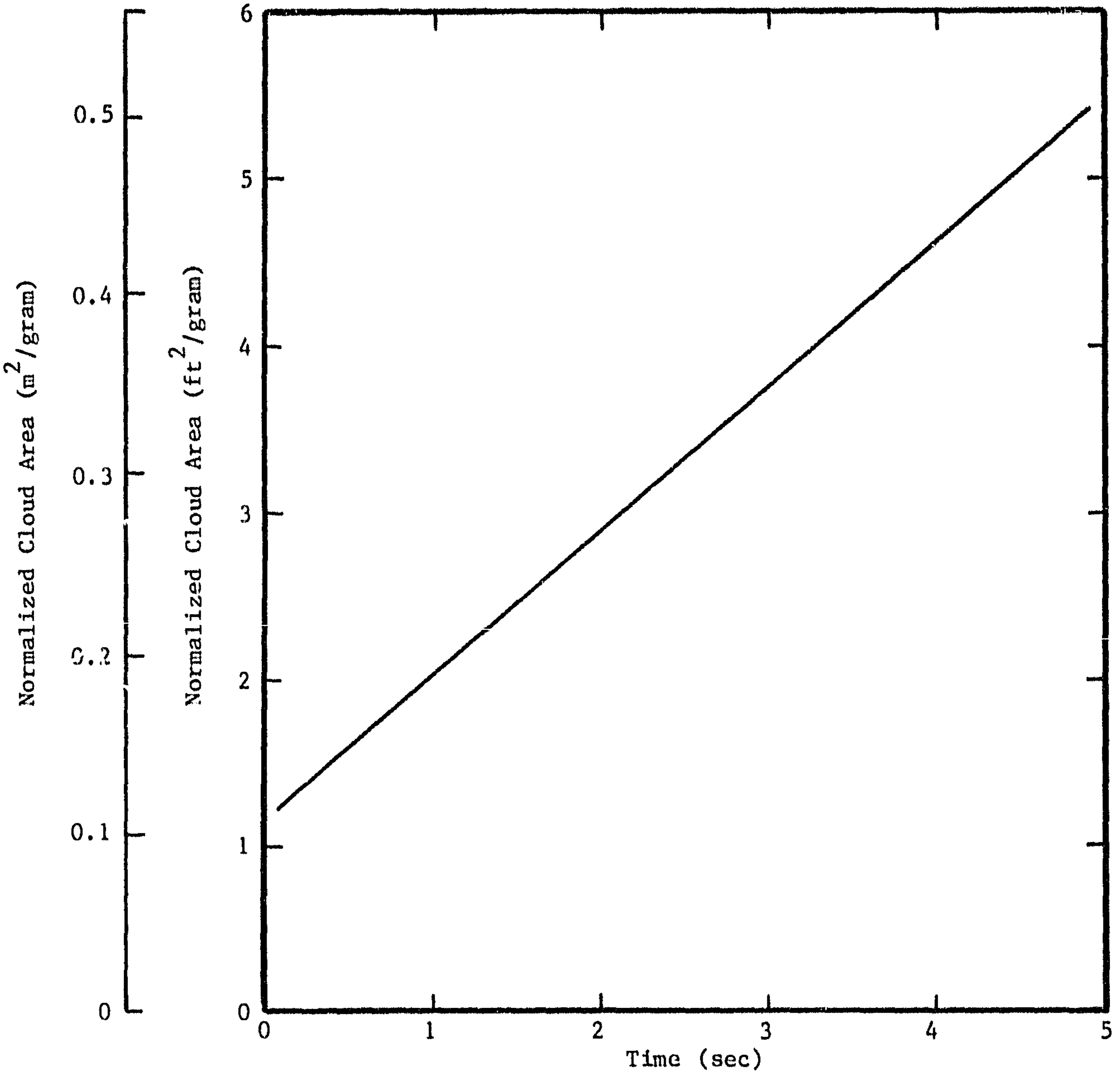
Cue Material	FFFFg Blackpowder/Anthracene/$KClO_3$
Mixture	2:1:1 parts by weight
No. of Shots Averaged	6
Range of Cue Weights Tested	3.7 to 27 grams

Figure A-6. Normalized smoke cloud test results for FFFFg blackpowder/anthracene/$KClO_3$ (2-1-1 mixture).



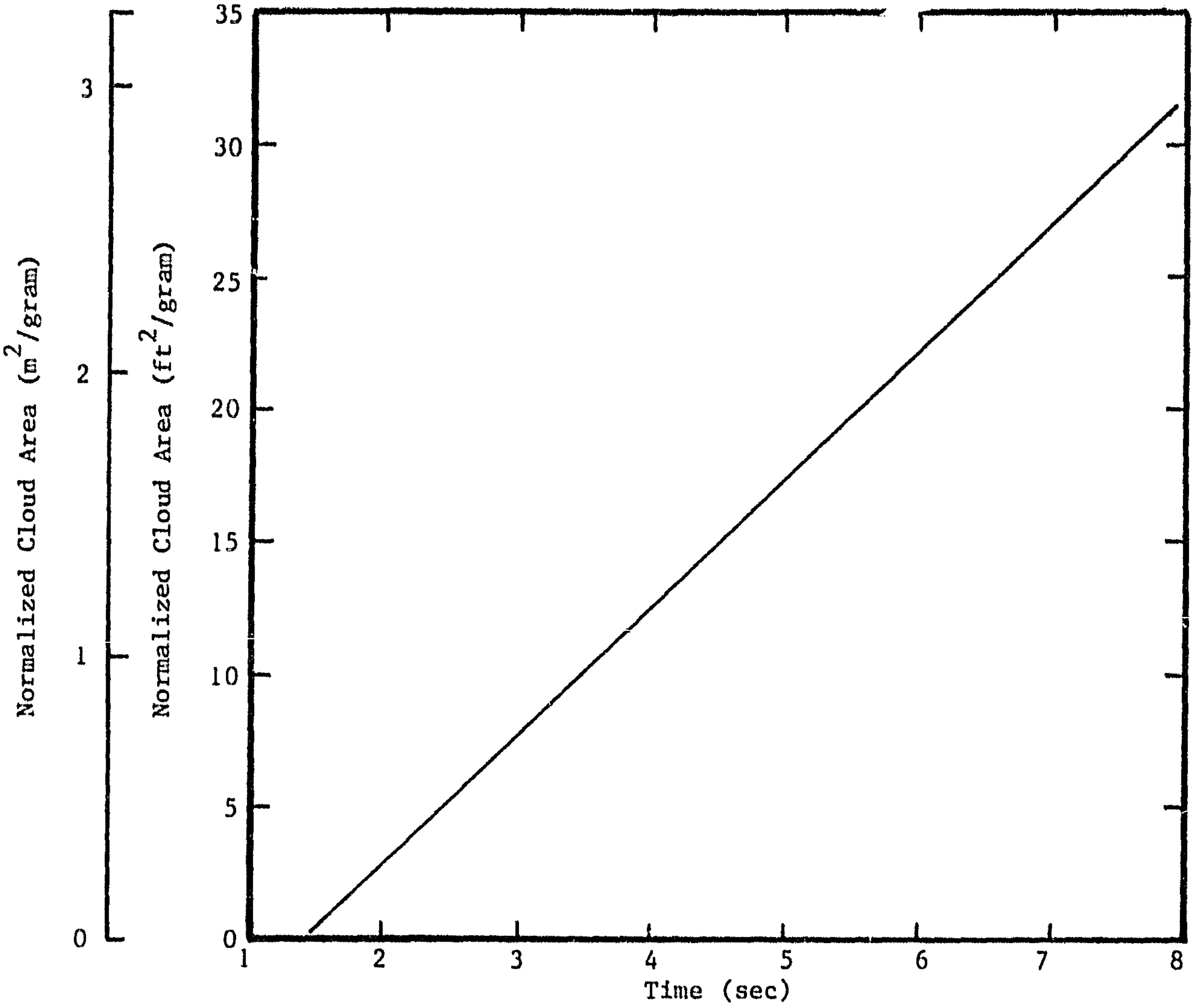
Cue Material	FFFFg Blackpowder/Anthracene/$KClO_3$
Mixture	1:1:1 parts by weight
No. of Shots Averaged	6
Range of Cue Weights Tested	3.6 to 10.1 grams

Figure A-7. Normalized smoke cloud test results for FFFFg blackpowder/anthracene/$KClO_3$ (1-1-1 mixture).



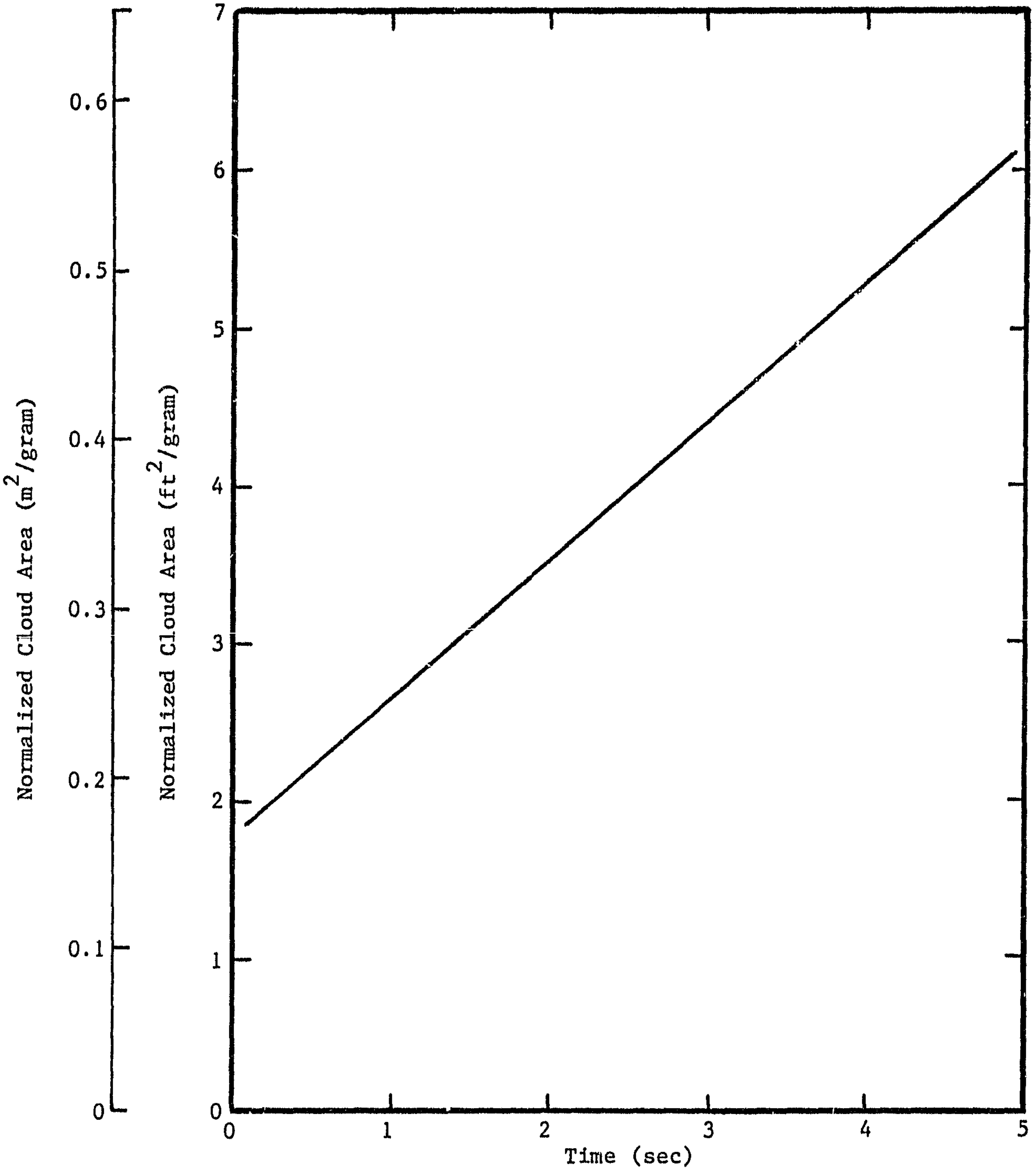
Cue Material	FFFFg Blackpowder/Anthracene
Mixture	2:1 parts by weight
No. of Shots Averaged	8
Range of Cue Weights Tested	4.8 to 11.3 grams

Figure A-8. Normalized smoke cloud test results for FFFFg blackpowder/anthracene (2-1 mixture).



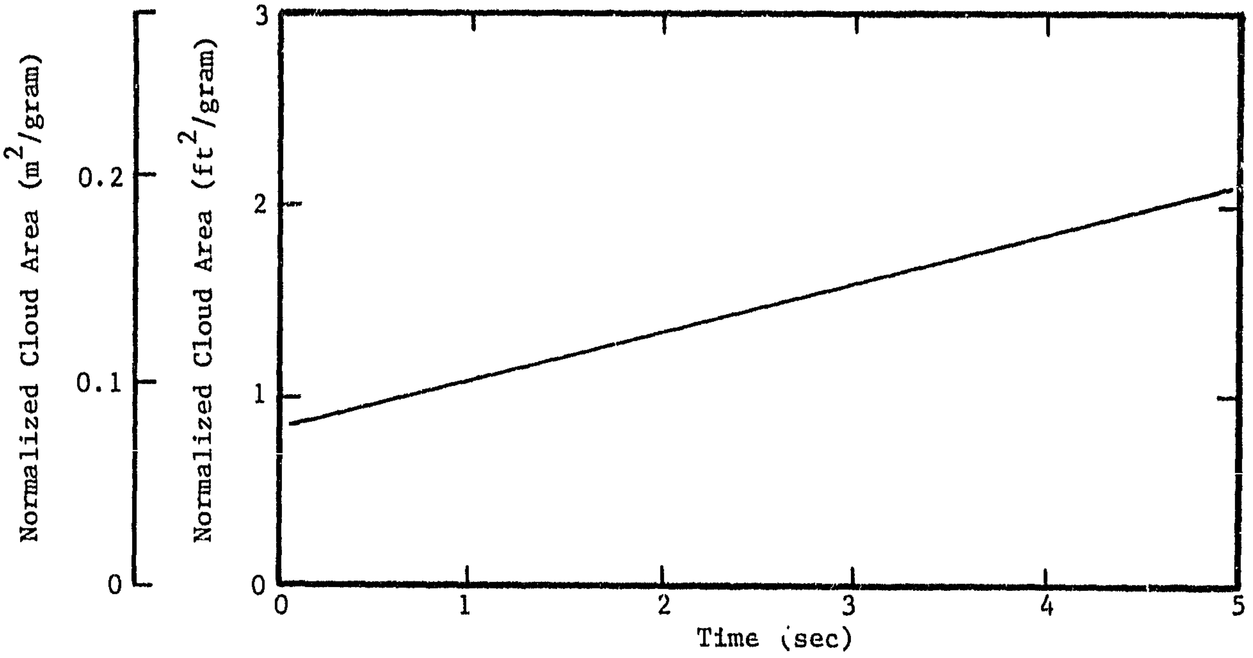
Cue Material	Low Temperature Smoke Compound
Mixture	Not Known
No. of Shots Averaged	5
Range of Cue Weights Tested	2.9 to 6.4 grams

Figure A-9. Normalized smoke cloud test results for low temperature smoke compound.



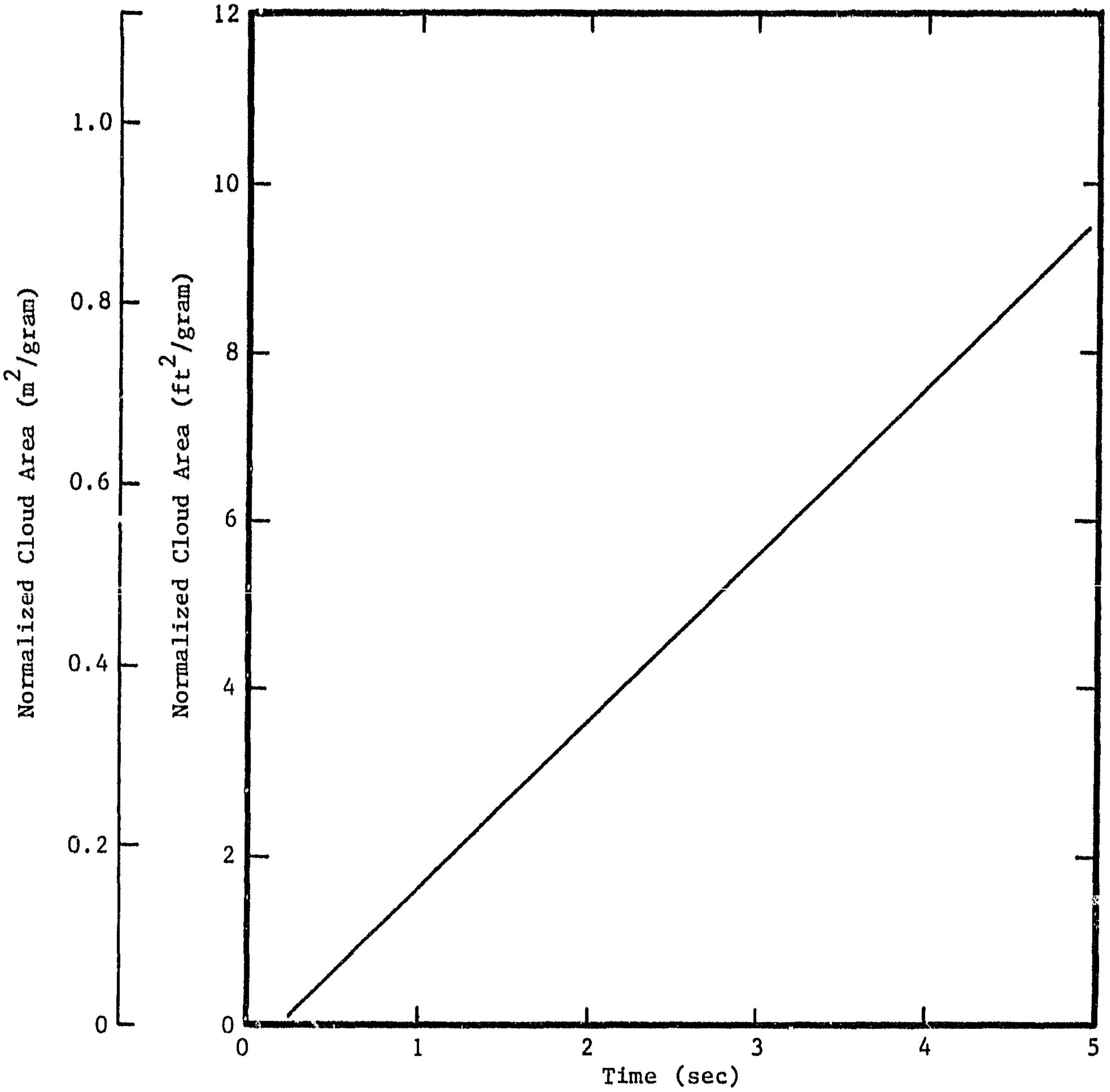
Cue Material	Purple-K
Mixture	Treated $KHCO_3$
No. of Shots Averaged	29
Range of Cue Weights Tested	6 to 130 grams

Figure A-10. Normalized smoke cloud test results for Purple-K.



Cue Material	Potassium Bicarbonate
Mixture	$KHCO_3$ (chemical grade)
No. of Shots Averaged	8
Range of Cue Weights Tested	12 to 25 grams

Figure A-11. Normalized smoke cloud test results for potassium bicarbonate.



Cue Material	Calcium Carbonate
Mixture	$CaCO_3$
No. of Shots Averaged	6
Range of Cue Weights Tested	7.2 to 83 grams

Figure A-12. Normalized smoke cloud test results for calcium carbonate.

APPENDIX B
DATA LOGS FOR FBS EXPERIMENTS

FBS TEST DATA RECORD

DATE 7/30/81

TEMPERATURE ≈ 80 °F HUMIDITY ____

TEST No.	LOCATION	SHELL GAUGE	PROPELLANT		WAD	SMOKE		SEAL			WIND		PEAK FEADINGS			COMMENTS
			TYPE	AMOUNT		TYPE	PACKING	WADS	CRIMP	OTHER	SPEED	DIRECTION	HEAT	LIGHT	SOUND	
B	Field bck: Trees	12	Pistol Smokeless	0.3 g	X	$CaCO_3$	Hand packed Medium pressure (30 lbs)	none	none	none	10 mph breezy	NNW			101.5	A-malfunction of firingmechanism
C	"	12	Pistol Smokeless	"	"	"	≈70 lbs Full SABOT	"	"	"	"	"			98.7	
D	"	"	"	"	"	"	SOFT PACKED	"	"	"	"	"			1006	
E	"	"	FFg	.93g	"	"	≈80 lbs	"	"	"	"	"			104.5	
F	"	"	FFFg	.93g	"	"	70 lbs	"	"	"	"	"			107.1	
G	"	"	Pistol Smokeless	.3g	"	"	Handpacked	"	"	"	"	"			104.4	
H	"	"	"	.3g	"	"	medium packed	"	"	"	"	"			100.5	

FBS TEST DATA RECORD

DATE 8/3/81

TEMPERATURE 90° HUMIDITY 45%

TEST No.	LOCATION	SHELL GAUGE	PROPELLANT		WAD	SMOKE		SEAL			WIND		PEAK READINGS			COMMENTS f5.6
			TYPE	AMOUNT		TYPE	PACKING	WADS	CRIMP	OTHER	SPEED	DIRECTION	HEAT	LIGHT	SOUND	
A	Field	12	Pistol Smokeless	.29g	X	Acacia Powder	Sabot Hard Packed	0		Pre Crimp	6	NNE			96.9	6.425g Acacia
B	"	"	"	"	X	"	Sabot	1	X		0-5	NW			100.6	6.045g Acacia
C	"	"	"	"	X	"	Sabot	2	X		0-5	N			99.3	55g Acacia (2 surfaces)
D	"	"	"	"	X	"	No Sabot	0		Pre Crimp	0-5	NW			97.1	7.05g Acacia seems to remain caked up after leaving shell.
E	"	"	"	"	X	"	"	1	X		0	W			101.4	7.395g
F	"	"	"	"	X	"	"	2	X		0-5	SW			99.8	7.715g So does Sod. Bicarb.
H	"	"	"	"	X	Sodium Bicarb	Sabot	0		Pre Crimp	0-5	SW			97.9	3.97g $Na(CO_3)_2$ Little Piece of caked Sod.
I	"	"	"	"	X	"	"	1	X		0-5	W			97.3	3.97g Bicarb may be found on
J	"	"	"	"	X	"	"	2	X		5	W			94.0	3.97g ground around test area
K	"	"	"	"	X	"	No Sabot	0		Pre Crimp	0	W			98.2	7.375g
L	"	"	"	"	X	"	No Sabot	1	X		0-5	N			100.4	7.375g
M	"	"	"	"	X	"	No Sabot	2	X		5-10	N			102.4	7.375g
N	"	"	"	"	X	$CaCO_3$	Sabot	0		Pre Crimp	0-5	N			97.9	6.76g [illegible]

Acacia Gum Not meant to b a sm powde

FBS TEST DATA RECORD

DATE 9/3/81 TEMPERATURE 90° HUMIDITY 45%

TEST No.	LOCATION	SHELL GAUGE	PROPELLANT		WAD	SMOKE		SEAL			WIND		PEAK READINGS			COMMENTS
			TYPE	AMOUNT		TYPE	PACKING	WADS	CRIMP	OTHER	SPEED	DIRECTION	HEAT	LIGHT	SOUND	
O	Field	12	Smokeless	.29g	X	$CaCO_3$	Sabot	1	X		5-10	NW			100.3	6.76g
P	Field	"	"	"	X	"	"	2	X		0-5	N			100.7	6.76g
Q	"	"	"	"	X	"	No Sabot	0		Pre Crimp	0-5	NE			104.5	10.5g
R	"	"	"	"	X	"	"	1	X		0	NW			103.4	10.5g
S	"	"	"	"	X	$CaCO_3$	"	2	X		0-5	W			105.6	10.5g
T	Field	16	Black Powder	.5g	X	NO	NE	—	—	Pre	0-5	E			98.4	FFg Powder
U	"	"	"	.7g	X	"	"	"	"	"	5-10	W			99.1	↓
V	"	"	"	1.0g	X	"	"	"	"	"	0	NNW			99.5	↓
W	"	"	"	1.54g	X	"	"	"	"	"	0-5	NNW			103.3	↓
X	"	"	"	1.27g	X	"	"	"	"	"	0-5	NE			103.6	↓
Y	"	12	"	2.98g	X	"	"	"	"	"	5-10	WNW			104.9	↓
Z	"	16	"	.535g	X	"	"	"	"	"	0-5	W			99.7	4F Powder (FFFFg)
AA	"	"	"	.7g	X	"	"	"	"	"	0-5	NNW			100.9	↓

FBS TEST DATA RECORD

DATE 8/3/81 TEMPERATURE 90° HUMIDITY 45%

TEST No.	LOCATION	SHELL GAUGE	PROPELLANT		WAD	SMOKE		SEAL			WIND		PEAK READINGS			f4.0 COMMENTS
			TYPE	AMOUNT		TYPE	PACKING	WADS	CRIMP	OTHER	SPEED	DIRECTION	HEAT	LIGHT	SOUND	
BB	Field	16	Black Powder	1.025g	X	NONE		—	—	Pre	0-5	W			102.2	↓
CC	"	16	"	1.375g	X	"	"	"	"	Pre	5	NW			104.9	
DD	"	16	"	1.725g	X	"	"	"	"	"	0-5	N			105.0	Not Recorded on Film

FBS TEST DATA RECORD

DATE Aug 6 1981 TEMPERATURE 90° HUMIDITY ______

TEST No.	LOCATION	SHELL GAUGE	PROPELLANT		WAD	SMOKE		SEAL			WIND		PEAK READINGS			COMMENTS
			TYPE	AMOUNT		TYPE	PACKING	WADS	CRIMP	OTHER	SPEED	DIRECTION	HEAT	LIGHT	SOUND	
A.	Field	—	4F	1g		—	—				6-8	SE				AG-1 Bulb. No significant sound produced.
B.	''	—	4F	2g		—	—				6	E				Sound Readings masked by Airplanes, Train
C.	''	—	4F	2g		—	—				0-5	E				Flash but no ignition
D	''	—	4F	1g		$CaCO_3$					0-5	E				
E	''	—	4F	2g		$CaCO_3$					0-5	NE				
F	''	—	4F	4g		—					5-6	N				
G	''	—	4F	2g		—					5	SE				#5 bulb
H	''	—	4F	5g		$CaCO_3$					0-5	E				#5 bulb
I	''	8	Pistol Powder	1g	X	$CaCO_3$	No Sabot	1		Pre Crimp	8	N			109.8	
J	''	8	''	1g	X	Purple K	''	1		''	6	NE			108.6	
K	''	12	$KClO_4$ $CaCO_4$ Red Pt	11.6g		—	Hard	1		''					1133	!!!! A very powerful explosion Test stand was damaged but still usable for a while
~~L~~			~~''~~	~~16.9g~~			~~''~~	~~2~~		~~''~~						Chickend Out - would have destroyed test stand
*M			''	4.15g	X	$CaCO_4$ 10.83g	No Sabot	1	4							SKIP to 1 on film Skip all other mixed powders until stand is rebuilt

FBS TEST DATA RECORD

DATE Aug 6 1981

TEMPERATURE 90° HUMIDITY ______

TEST No.	LOCATION	SHELL GAUGE	PROPELLANT		WAD	SMOKE		SEAL			WIND		PEAK READINGS			COMMENTS
			TYPE	AMOUNT		TYPE	PACKING	WADS	CRIMP	OTHER	SPEED	DIRECTION	HEAT	LIGHT	SOUND	
N	FIELD	12	KClO4 CaCO4 Red Ph	4.15g	X	CaCO4 11.9g	No. Sabot	1	"							Skipped
O	"	"	4F	.5g	X	Anth KClO3 4F	15g "	1	"							
P	"	"	4F	.29g		"	15g "	1	"							
Q	"	"	4F	.29g		"	15g "	1	"							
R	"	"	4F	.29g		"	15g "	1	"							
S	"	"	4F	.29g			15g "	1	"							
*T	"	"	FFg	.5cc	X	—	—				0-5	SE			96.8	Planes flying overhead Flash – Mg Holed Sabot
U	"	"	"	.5cc	X	—	—				5-6	E			99.6	Flash – Al Holed Sabot
V	"	"	Pistol	.25g	X	CaCO3	No Sabot	1	"		9	N			92.1	
W	"	"	"	.25g	X	"	Full Sabot	1	"		5	N			96.1	
X	"	"	4F	1g	X	—	" —			Pre Crimp	5-6	N			100.6	
Y	"	"	4F	2g	X	—	" —			"	0-5	NNE			103.1	
Z	"	"	4F	4g	X	—	" —			"	10	E			106.3	

FBS TEST DATA RECORD

DATE Aug 6 1981 TEMPERATURE 90° HUMIDITY ____

TEST No.	LOCATION	SHELL GAUGE	PROPELLANT TYPE	PROPELLANT AMOUNT	WAD	SMOKE TYPE	SMOKE PACKING	SEAL WADS	SEAL CRIMP	SEAL OTHER	WIND SPEED	WIND DIRECTION	PEAK READINGS HEAT	PEAK READINGS LIGHT	PEAK READINGS SOUND	COMMENTS
AA	Field	12	4F Carbon Black	2g & 1g		–	No Sabot	1		Pre Crimp	5-6	N			—	← NO BANG Diluted Propellant
BB	"	"	"	2g 1g		–	"	2		"	0-5	NE			—	↑
CC	"	"	"	2g 1g		–	"	3		"	0-5	NNW			—	Masked by
DD	"	"	"	2g 2g		–	"	1		"	0-5	E			—	Background Noise
EE	"	"	"	2g 2g		–	"	2		"	0-5	E			—	×1 Misfire
FF	"	"	"	2g 2g		–	"	3		"	8	SE			—	

FBS TEST DATA RECORD

DATE 8-12-81 TEMPERATURE 82°F HUMIDITY 69%

TEST No.	LOCATION	SHELL GAUGE	PROPELLANT		WAD	SMOKE		SEAL			WIND		PEAK READINGS			COMMENTS
			TYPE	AMOUNT		TYPE	PACKING	WADS	CRIMP	OTHER	SPEED	DIRECTION	HEAT	LIGHT	SOUND	
A	Field	12	4F (ROCKET LOADED)	Full Shell							5	NE			107.6	
B	"	"	4F + Carbon Black	" (ROCKET LOADED)							8	NE			—	Background Noise too high
C	"	—	4F	37g							6	NE			96.2	M2 bulb
D	"	—	4F c̄ Flash Powder								5	NE			94.3	AG2 bulb
E	"	12	$KClO_4$ $CaCO_4$ And Phen	4.15g	X	$CaCO_3$	11.9g NO Sabot	1		Pre Crimp	5	NE			112.8	
F	"	12	Anth $KClO_3$ 4F	15g + .5g 4F IGNITOR	X			1	X		0-5	E			104.5	
G	"	12	"	15g + .29g 4F IGNITOR	X			1	X		5	E			102.2	
H	"	12	Flash Powder	10g				1		Pre Crimp	5	E			114.2	
I	"	12	Mg-Al-BA Flash	10g				1		Pre Crimp	0-5	E			115.3	
J	"	12	Pistol Powder	1g	X	Purple K	11.8g No Sabot	2	X		6	E			111.0	
K	"	12	"	"	X	Plaster of Paris	9.45g No Sabot	2		Pre Crimp	9	E			111.7	
L	"	12	"	"	X	Calcium Carbonate	9.45g No Sabot	2	X		0-5	NNE			111.7	
M	"	12	"	"	X	Sod. Bicarb	5.607g No Sabot	2	X						111.3	

FBS TEST DATA RECORD

DATE 8-12-81

TEMPERATURE 82 °F HUMIDITY 69%

TEST No.	LOCATION	SHELL GAUGE	PROPELLANT		WAD	SMOKE		SEAL			WIND		PEAK READINGS			COMMENTS
			TYPE	AMOUNT		TYPE	PACKING	WADS	CRIMP	OTHER	SPEED	DIRECTION	HEAT	LIGHT	SOUND	
N	Field	16	Pistol Powder	½ g	X	Purple K	full Sabot 7.13g	1	X		0-5	E			103.3	
O	"	16	"	"	X	Plaster Paris	full Sabot 6.31g	1	X		5	NE			103.9	
P	"	"	"	"	X	Ca Carbonate	full Sabot 7.05g	1	X		6	ESE			104.9	
Q	"	"	"	"	X	Na Bicarb	3.78g full Sabot	1	X		5	NE			99.2	
R	"	12	"	"	X	Purple K	7.67g full Sabot	1	X		5	E			101.8	END OF FILM
S	"	12	"	"	X	Plaster Paris	7.05g full Sabot	1	X							These rounds to be done on 8-14-81 (A,B,C)
T	"	12	"	"	X	Ca Carbonate	7.8g full Sabot	1	X							
U	"	12	"	"	X	Na Bicarb	3.8g full Sabot	1	X							

ORIGINAL PAGE IS OF POOR QUALITY

FBS TEST DATA RECORD

DATE 8-14-81 TEMPERATURE 86° HUMIDITY 57%

TEST No.	LOCATION	SHELL GAUGE	PROPELLANT		WAD	SMOKE		SEAL			WIND		PEAK READINGS			COMMENTS
			TYPE	AMOUNT		TYPE	PACKING	WADS	CRIMP	OTHER	SPEED	DIRECTION	HEAT	LIGHT	SOUND	
A	Field	12	Pistol Powder	½g	X	Ca Carbonate	full Sabot 7.8g	1	X		0mph	—			101.9	Flash Camera 1/10th sec at f16.0 +4 stop filter A - flash picture lost
B	"	"	"	"	X	Plaster of Paris	full Sabot 7.05g	1	X		0	—			104.6	
C	"	"	"	"	X	Sodium Bicarb	full Sabot 3.8 g	1	X		0-5	ESE			100.0	Overcast day
D	"	"	4F rocket motor packed	8.2g	—	—	—	—	—	OPEN	0	—			No	Ignition
E	"	"	"	8.52g	—	—	—	—	—	OPEN	0	—			No	Ignition
F	"	"	"	15.15g	—	—	—	—	—	OPEN	0	—			No BANG	Beautiful!
G	"	8	"	14.69g	—	—	Layered gunpowder	—	—	OPEN	0	—			91.6	"
H	"	8	"	25.41g	—	—	—	—	—	OPEN	0	—			102.8	" Almost identical shells yet one made the bang and the other did not
I	"	8	"	27.68g	—	—	—	—	—	OPEN	0	—			No BANG	~83.3
J	"	12	Anth KClO3 4F	15g (+.2g 4F IGNITOR)	—	—	—	1	X		0	—			102.2	
K	"	"	"	"	—	—	—	1	X		0	—			100.4	
L	"	"	"	"	—	—	—	1	X		0-5	E			102.9	
M	"	"	KClO4 CaCO3 Red Phos	4.15g	X	Ca Carbonate	No Sabot 10.83g	1	X		0	—			111.3	

FBS TEST DATA RECORD

DATE 8-14-81

TEMPERATURE 86°

HUMIDITY 57%

TEST NO.	LOCATION	SHELL GAUGE	PROPELLANT		WAD	SMOKE		SEAL			WIND		PEAK READINGS			COMMENTS
			TYPE	AMOUNT		TYPE	PACKING	WADS	CRIMP	OTHER	SPEED	DIRECTION	HEAT	LIGHT	SOUND	
N	Field	12	$KClO_4$ $CaCO_3$ Red Phos	16.9g	—	—	—	2			0	—			113.5	
O	"	12	Std Flash Powder	10g	—	—	—	1		Pre Crimp	0	—			112.4	
P	"	12	Mg-Al -Ba Flash	11g	—	—	—	1		open	0	—			113.0	

FBS TEST DATA RECORD

DATE 8-19-81

TEMPERATURE 78°

HUMIDITY 67%

TEST No.	LOCATION	SHELL GAUGE	PROPELLANT		WAD	SMOKE		SEAL			WIND		PEAK READINGS			COMMENTS
			TYPE	AMOUNT		TYPE	PACKING	WADS	CRIMP	OTHER	SPEED	DIRECTION	HEAT	LIGHT	SOUND	
A	Field	12	4F Rocket-thrust design	1/4 full		—	—	—	—	—	0-5	S			94.7	
B	"	12	"	1/4 full 3.21g		—	—	—	—	—	0-5	S			93.4	
C	"	12	"	1/2 full 6.42g		—	—	—	—	—	↓	S			100.8	nice "Boom"
D	"	12	"	1/3 full		—	—	—	—	—	↓	S			92.7	
E	"	12	"	3/4 full 9.63g		—	—	—	—	—	↓	S			94.7	
F	"	12	"	3/4 full		—	—	—	—	—	↓	S			104	
G	"	12	"	full 12.83g		—	—	—	—	—	↓	S			too low- (FIZZLED)	PFFFT!
H	"	12	"	full		—	—	—	—	—	↓	S			91.6	Good flash!
I	"		.3cc 4F	.3cc Starter	-	4F blanket	2.19g	—	—	—	7 mph	SW			84.9	AG-2
J	"		4F	.15cc Starter	-	4F blanket	2.95g	—	—	—	3mph	SSW			X	AG-2
K	"		4F	.6cc Starter	-	4F blanket	3g	—	—	—	0-5	S			X	AG-2
L	"		4F Rocket thrust design	14.92g load		—	—	—	—	—	0-5	S			82.9	Ni-2

ORIGINAL ... OF POOR QUALITY

FBS TEST DATA RECORD

DATE 8/28/81

TEMPERATURE________ HUMIDITY______

TEST No.	LOCATION	SHELL GAUGE	PROPELLANT		WAD	SMOKE		SEAL			WIND		PEAK READINGS			COMMENTS
			TYPE	AMOUNT		TYPE	PACKING	WADS	CRIMP	OTHER	SPEED	DIRECTION	HEAT	LIGHT	SOUND	
A	Field	8	Pistol powder	.75g	✓	Carbon Black	loose 1.83g	✓	pre-		0-5	W			neg. (negligible)	USING FIRE-TEST MAT shell didn't empty
B	↓	8	P.powder 4F	1cc .25cc	✓	C	loose 1.76g	✓	pre		0-5	ESE			neg.	
C		8	P.powder	.75g	✓	C/CaCO3	layered w/CaCO3 7.73g	✓	pre		0-5	SSE			neg	
D		8	P.powder 4F	1cc .25cc	✓	C/CaCO3	Layered 5.58g	✓	pre		0-5	SSW			92.3	good flash
E		12	4F	1cc	✓	grey tinted CaCO3	loose (NOT DRIED) 7.63g	✓	pre		0-5	WSW			102.2	good bang
F		12	4F	1cc	✓	red CaCO3	Loose (NOT dried) 7.89g	✓	pre		0-5	W			102	NOT very brilliant colors ↓
G		12	4F	1cc	✓	Blue CaCO3	Loose (NOT dried) 6.53g	✓	pre	.	0-5	WSW			101.1	
H		12	4F	1cc	✓	Orange CaCO3	loose (not dried) 7.79	✓	pre		0-5	W			102.1	
I		12	4F	1cc	✓	Brown CaCO3	Loose (NOT dried) 8.98g	✓	pre		0-5	WSW			101.7	↓
J		12	4F	1cc	✓	CaCO3	loose 7.18g	✓	pre		0-5	WSW			100.6	
K		12	4F	1cc	✓	CaCO3	Loose 6.4g	✓	pre		0-5	SW			100.3	
L		12	4F	1cc	✓	AL	Loose 4.31g	✓	pre		0-5	W			104.4	skipped
M	↓	12	4F	1cc	✓	AL	Loose 3.42g	✓	pre		0-5	W			104.1	these due to wind direction ↓ go on to N-O, then L-M

FBS TEST DATA RECORD

DATE 8-28-81 TEMPERATURE______ HUMIDITY______

TEST No.	LOCATION	SHELL GAUGE	PROPELLANT		WAD	SMOKE		SEAL			WIND		PEAK READINGS			COMMENTS
			TYPE	AMOUNT		TYPE	PACKING	WADS	CRIMP	OTHER	SPEED	DIRECTION	HEAT	LIGHT	SOUND	
N	Field	12	4F	1cc	✓	red CaCO3	dried loose pack 8.5g		pre		0-5	W			102.3	Better when dried
O		12	4F	1cc	✓	brown CaCO3	dried loose-pak 9.04g		pre		0-5	SE			102.6	" " "
P	AG2 Bulb	FLASH	BLACK powder	.3cc		STARTER only	—				0-5	SSE			—	
Q	AG2 Bulb	FLASH	Black powder	.3cc		Starter only	—								—	MISFIRE
R	AG2 Bulb	FLASH	BLACK powder	.3cc		BLANKET powder	4.6g				5mph	SSE			—	} Thrust motor design
S	AG2 Bulb	FLASH	BLACK powder	.3cc		Blanket powder	4.15g				0-5	SSW			—	
T	AG2	Flash	Black powder	.3cc		Wallops SMOKE	≈ 2.9g				0-5	WSW			—	Slow burning, much smoke
U	AG2	Flash	Black powder	.3cc		Wallops smoke	≈ 2.5g				5	SW			—	not as good too much wind

FBS TEST DATA RECORD

DATE 9/9/81 TEMPERATURE 86°F HUMIDITY 40%

TEST No.	LOCATION	SHELL GAUGE	PROPELLANT		WAD	SMOKE		SEAL			WIND		PEAK READINGS			COMMENTS
			TYPE	AMOUNT		TYPE	PACKING	WADS	CRIMP	OTHER	SPEED	DIRECTION	HEAT	LIGHT	SOUND	
A	Field	8	Bullseye	1gm	X	Coal Dust	16.15g	1		Pre Crimp	—				107.3	
b		8	"	"	X	"	17g	1		"	0-5				96.3	
c		8	"	"	X	Coal Dust & (50/50) CaCO$_3$	16.58g	1		"	5				103.4	
D		8	"	"	X	"	16.24g	1		"	0-5				108.1	
*E		12	4F Bullseye Rocket Motor	11.87g												NOT USED
*F		12	"	12.03g												NOT USED
G		12	4F Rocket Motor	+Coal Dust (50/50 by weight) 11.7g							—				83.1	partial ignition
H		12	"	12.05g							0				82.4	4F no ignition
I		12	4F Rocket Motor	14.22g							—				81.7	"
J		12	"	14.87g							—				85.1	"
K		12	4F starter	.3g	X	(2 pts 4F 1 pt Anthracene)	11.13g	1		Pre Crimp	0-5				100	
L		12	"	"	X	"	8.03g	1	X		0				96.8	
M		12	"	"	X	"	4.75g	1	X		0				95.3	

FBS TEST DATA RECORD

DATE 9/9/81

TEMPERATURE 86°F HUMIDITY 40%

TEST No.	LOCATION	SHELL GAUGE	PROPELLANT		WAD	SMOKE		SEAL			WIND		PEAK READINGS			COMMENTS
			TYPE	AMOUNT		TYPE	PACKING	WADS	CRIMP	OTHER	SPEED	DIRECTION	HEAT	LIGHT	SOUND	
N	Field	12	4F starter	.3g	X	(1pt 4F 1pt anthracene 1pt KClO3)	8.32 g	1	X		0-5				99.9	
O		12	"	"	X	"	8.85g	1	X		5				99.5	
P		12	"	"	X	"	4.86g	1	X		0-5				94.5	
Q		12	"	"	X	(2pts 4F 1pt Anth 1pt KClO3)	10.78g	1	X		0				99.7	
R		12	"	"	X	"	9.43g	1	X		0-5				101.3	
S		12	"	"	X	"	3.66g	1	X		0-5				95.6	
T		12	4F starter	.3g	—	Wallops	3.05g (glued to sides)	—	—	—	5				90.8	
U		12	4F starter	.3g	—	—	—	—	—	—					—	

OF POOR QUALITY

FBS TEST DATA RECORD

DATE 9/17/81*/ 9/18/81 TEMPERATURE 66°F 9/18 HUMIDITY____

TEST No.	LOCATION	SHELL GAUGE	PROPELLANT		WAD	SMOKE		SEAL			WIND		PEAK READINGS			COMMENTS
			TYPE	AMOUNT		TYPE	PACKING	WADS	CRIMP	OTHER	SPEED	DIRECTION	HEAT	LIGHT	SOUND	
A*	Field	12	(1 pt $KClO_3$	4F, 1 pt), with		Anthracene, .3cc 4F	1 pt starter 11.12g	1		Pre. Crimp	12				102.8	
B	"		"	10.12g		—	—	1		"	8				107.8	
C			"	3.64g		—	—	1		"						
D*	"		(2 pts w/3cc	4F, 1 pt 4F starter		Anthracene, — 11.93g	pt $KClO_3$)	1		"	12				104.5	
E	"		"	11.99g		—	—	1		"	10				112.9	
F			"	6.84g		—	—	1		"						
G*	"		(2 pts	4F, 1 pt 11.32g		Anthracene)	w/. 3cc 4F starter	1		"	8				94.9	
H	"		"	11.24g		—	—	1		"	7				103.0	
I			"	6.87g		—	—	1		"						
J	"		Bullseye	.44g	1	2 pts 4F 1 pt Anth	~11.1g	1		"	9				105.3	→ 1 layer tape over hole in wad between bullseye & 4F/Anth mix
K			"	"	"	"	~11.1g	1		"						→ "
L			"	"	"	"	"	1		"						→ 2 layers tape over hole in wad between bullseye & mixture
M			"	"	"	"	"	1		"						→ "

FBS TEST DATA RECORD

DATE 9/17/81* / 9/18/81

TEMPERATURE 66°F 9/18 HUMIDITY ______

TEST No.	LOCATION	SHELL GAUGE	PROPELLANT TYPE	PROPELLANT AMOUNT	WAD	SMOKE TYPE	SMOKE PACKING	SEAL WADS	SEAL CRIMP	SEAL OTHER	WIND SPEED	WIND DIRECTION	PEAK READINGS HEAT	PEAK READINGS LIGHT	PEAK READINGS SOUND	COMMENTS
N	Field	12	Bullseye then coal dust	.44gm → 2.5cc on top	—	20% coal 80% whiting	~10gm	1		Pre Crimp						
O			"	"	—	"	"	1		"						
P*	"		4F BLANKET	5.4g		ROCKET (w/ .3cc	MOTOR 4F starter)	—		—	8				93.1	
Q	"		Bullseye	.44g	1	KHCO₃	13gm	1		Pre Crimp					—	
R			"	"	1	"	"	1		"						
S	"		Bullseye	.61 gm	1	KHCO₃	13gm	1		"	9				114.7	
T			"	"	1	"	"	1		"						
U	"		(.3cc) 4F starter (2@4F; 1pt Amis)	(1.2g)	1	KHCO₃	12gm	1		"						
V*	"		4F starter	.3cc	—	Blanket Rocket Motor 4F + Wallops	≈5.5g	—							—	First Run - Primer failed
W*	"		4F starter	.3cc	—	Blanket Rocket Motor 4F	≈5.7g	—			6				86.9	2nd Run - Wallops Material failed to ignite
X*	"		4F starter	.3cc	—	"	≈5.92g	—			6				93.4	
Y*	"	8	Bullseye	0.61g		CaCO₃	21.87g								—	← Powder did not fire
Z*	"	8	4F 1cc	Starter		12.75g	4F Blanket	—			6				89.0	

FBS TEST DATA RECORD

DATE 9/17/81* / 9/18/81 TEMPERATURE 66°F 9/18 HUMIDITY ____

TEST No.	LOCATION	SHELL GAUGE	PROPELLANT		WAD	SMOKE		SEAL			WIND		PEAK READINGS			COMMENTS
			TYPE	AMOUNT		TYPE	PACKING	WADS	CRIMP	OTHER	SPEED	DIRECTION	HEAT	LIGHT	SOUND	
AA*	Field	8	Bullseye	0.61g	1	$NaHCO_3$	13.92				8	—			93.0	
Bb*	"	"	4F BP.	2cc	1	Al	5.6g				11				103.1	
CC*	"	"	Bullseye	0,61g	1	Plaster of Paris	22.3g				8				104.7	
DD*	"	12	4F B.P.	.3cc	-	Wallops	3g				7				91.7	
EE	"	8	4F b.P	.6cc	—	2pts 4F 1pt Amt 1pt KClO	12.6g				11				104.3	← Blanket Materal Thrust Motor — did not all stay in Tube
FF	"	8	4F B.P.	.6cc	—	Wallops	6.4g				9				78.3	

FBS TEST DATA RECORD

DATE 9/22/81 TEMPERATURE 82°F HUMIDITY 48%

TEST No.	LOCATION	SHELL GAUGE	PROPELLANT		W A D	SMOKE		SEAL			WIND		PEAK READINGS			COMMENTS
			TYPE	AMOUNT		TYPE	PACKING	WADS	CRIMP	OTHER	SPEED	DIRECTION	HEAT	LIGHT	SOUND	
A	Field	1														
B																
C	Field	12	(1pt 4F, with	1pt Anthracene, .3cc 4F		starter	1pt $KClO_3$) - 3.64g	1		Pre Crimp	0-5				97.5	
D	"	12	.3 cc 15.6	B/E 7m PM/4	X	between		1 closure		"	–				118.6	
E	"	12	"	"	X	between		1 closure		"	6				119.8	
F	"	12	(2pts with	4F, 1pt Anthracene, .3cc 4F		starter	1pt $KClO_3$) 6.84g	1		Pre Crimp	0–5				101.7	
G	"	12	5g HC 15 Al 28 Anth		X	w/hole	between	1 closure		"	2				109.7	
H	"	12	"		X	"	"	"		"	2				108.9	
I	"	12	(2pts with	4F, 1pt Anthracene) .3cc 4F		starter	- 6.87g	1		Pre Crimp	5				94.0	
J																
K	"	12	Bullseye	.44g	1 with hole	2pts 4F 1pt Anth	11.1g	1		Pre Crimp	0				105.6	→1 layer tape over hole in wad
L	"	12	"	"	"	"	11.1g	1		"	1				105.9	→2 layers tape over hole in wad
M	"	12	"	"	"	"	11.1g	1		"	5				104.2	→ "

ORIGINAL PAGE IS
OF POOR QUALITY

FBS TEST DATA RECORD

DATE 9/22/81 TEMPERATURE 82°F HUMIDITY 48%

TEST No.	LOCATION	SHELL GAUGE	PROPELLANT		WAD	SMOKE		SEAL			WIND		PEAK READINGS			COMMENTS
			TYPE	AMOUNT		TYPE	PACKING	WADS	CRIMP	OTHER	SPEED	DIRECTION	HEAT	LIGHT	SOUND	
N	Field	12	Bullseye then cooldust	→ .44g →2.5cc [illegible]	–	20% coal 80% CaCO$_3$	10g	1		Pre Crimp	0-5				112.6	
O	"	12	"	"	–	"	"	1		"	0-5				91.3	
P	"	12	2/1/0 booster	w/ ⅓ Alum of ⅓ 4F/	X	between (10.8	whole gms)	1 closure		"	6				111.2	
Q	"	12	"	"	X	" (10.8	" gms)	1 closure		"	1				111.2	
R	"	12	Bullseye	.44g	1	KHCO$_3$	13g	1		Pre Crimp					112.9	
S																
T	"	12	Bullseye	.61g	1	KHCO$_3$	13g	1		Pre Crimp	5				115.1	
U	"	12	+4F (2pts 4F 1pt Anth)	.3cc → 1.2g	1	KHCO$_3$	12g	1		Pre Crimp	0-5				106.7	
V	"	8	4F	.3cc	–	2pts 4F 1pt Anth	9.8g				5				103.2	→(Blanket Rocket Motor)
W	"	8	"	"	–	"	8g				5				104.3	→(")
X		8	"	"	-	1pt 4F 1pt Anth 1pt KClO$_3$	10.1g									→(")
Y		8	"	"	–	"	12.7g									→(")
Z	"	8	4F starter	.6cc		Wallops (glued to walls)	5.1g				0				105.3	

FBS TEST DATA RECORD

DATE 9/22/81

TEMPERATURE 82°F HUMIDITY 48%

TEST NO.	LOCATION	SHELL GAUGE	PROPELLANT		WAD	SMOKE		SEAL			WIND		PEAK READINGS			COMMENTS
			TYPE	AMOUNT		TYPE	PACKING	WADS	CRIMP	OTHER	SPEED	DIRECTION	HEAT	LIGHT	SOUND	
AA	Field	8	Bullseye	(1.3cc) .77g	Paper	FLASH AL	5.85g				–				90.3	
BB	"	8	"	"	"	"	5.65g				0				85.7	
CC	"	12	"	"	"	FlASH AL	3.04g				5				90.5	fire on pod
DD	"	12	"	"	"	"	3.5g				–				101.2	

FBS TEST DATA RECORD

DATE 9/30/81

TEMPERATURE__________ HUMIDITY______

TEST No.	LOCATION	SHELL GAUGE	PROPELLANT		WAD	SMOKE		SEAL			WIND		PEAK READINGS			COMMENTS
			TYPE	AMOUNT		TYPE	PACKING	WADS	CRIMP	OTHER	SPEED	DIRECTION	HEAT	LIGHT	SOUND	
A	Field	12	4F - ANTH - $KClO_3$ -	5.25g 8.89 g 3.36g				1		Pre Crimp					102	
B	"	12	4F - ANTH - $KClO_3$ -	5.25g 7g 5.25g				1		"					106.3	
C	"	12	4F - Anth - $KClO_3$ -	4.25g 5.955g 6.275g				1		"					109.2	
D	"	12	4F - P/P -	.3cc .219g		Coal Dust	9.74g	1		"					107.9	
E	"	12	4F - P/P -	.3cc .44g		"	9.41g	1		"					105.4	
F	"	12	4F - P/P -	.3cc .61g		"	9.50g	1		"					112.6	
G	"	12	4F - P/P -	.3cc .219g		$KHCO_3$	16.35g	1		"					104.2	
H	"	12	4F - P/P -	.3cc .44g		"	15.47g	1		"					106.2	
I	"	12	4F - P/P -	.3cc .61g		"	15.68g	1		"					109.8	
J	"	12	4F - P/P -	.3cc .219g		Purple K	15.84g	1		"					106.1	
K	"	12	4F - P/P -	.3cc .44g		"	16.23g	1		"					1083	
L	"	12	4F - P/P -	.3cc .61g		"	15.48g	1		"					112.1	
M	"	8	4F - P/P -	.3cc .44g		Coal Dust	19.98g	1							109.1	
N	"	8	4F - P/P -	.3cc .7g		"	18.87g	1							112.5	

FBS TEST DATA RECORD

DATE 9/30/'81 TEMPERATURE______ HUMIDITY______

TEST No.	LOCATION	SHELL GAUGE	PROPELLANT		WAD	SMOKE		SEAL			WIND		PEAK READINGS			COMMENTS
			TYPE	AMOUNT		TYPE	PACKING	WADS	CRIMP	OTHER	SPEED	DIRECTION	HEAT	LIGHT	SOUND	
O	Field	8	4F - P/P -	.3cc 1g		Coal Dust	18.45g	1							114.0	
P	"	8	4F - P/P -	.3cc .44g		PurpleK	29.99g	1							109.7	
Q	"	8	4F - P/P -	.3cc .7g		"	29.36g	1							112.1	
R	"	8	4F - P/P -	.3cc 1g		"	28.05g	1							114.9	
S	"	8	4F - P/P -	.3cc .44g		$KHCO_3$	29.8g	1							105.5	
T	"	8	4F - P/P -	.3cc .7g		"	28.98g	1							111.4	
U	"	8	4F - P/P -	.3cc 1g		"	27.35g	1							114.8	
V	"	12	P/P -	.4g		$CaCO_3$	7.84g	1		Pre crimp					108.1	
W	"	8	P/P	.7g		"	16.58g	1							88.3	
X	"	3" Pipe	P/P	2g	1	"	27.95g	1							106.4	
Y	"	6" Pipe	P/P	4g	1	"	50g	1							117.5	
Z	"	12" Pipe	P/P	8g	1	"	83g	1							117.3	
AA	"	6" Pipe	1/1/1	20 gm		ROCKET 1/1/1 $KClO_3$, Anth, 4F	MOTOR 20gm								—	Fired straw
BB	"	6" Pipe	2/1/1	26.9		ROCKET 2/1/1 $KClO_3$, Anth, 4F	MOTOR 26.9g								—	

FBS TEST DATA RECORD

DATE 10/5/81

TEMPERATURE________ HUMIDITY_____

TEST No.	LOCATION	SHELL GAUGE	PROPELLANT		WAD	SMOKE		SEAL			WIND		PEAK READINGS			COMMENTS
			TYPE	AMOUNT		TYPE	PACKING	WADS	CRIMP	OTHER	SPEED	DIRECTION	HEAT	LIGHT	SOUND	
A	Field	8	P/P	2.11g	1	Purple K	19.2g	1		Pre Crimp					117.4	
B	"	8	P/P	2.11g		"	20.4g	1		"					116	
AAA	"	QUART JAR	FLASH AL/$KClO_3$	3.05g		FLASH Squib	BULB								—	Glass w/screw sealer disintegrated
BBB	"	12" Pipe	P/P	8g	1	Purple K	130g	1							118.7	
CCC	"	6" Pipe	P/P	4g	1	Purple K	60g	1							116.7	
DDD	"															

FBS TEST DATA RECORD

DATE 10/8/81 TEMPERATURE ______ HUMIDITY ______

TEST No.	LOCATION	SHELL GAUGE	PROPELLANT		WAD	SMOKE		SEAL			WIND		PEAK READINGS			COMMENTS
			TYPE	AMOUNT		TYPE	PACKING	WADS	CRIMP	OTHER	SPEED	DIRECTION	HEAT	LIGHT	SOUND	
A																
B																
C	Field	8	P/P	.93g	1	Purple K	21g	1		Pre Crimp	0-5	Variable			112.3	
D	"	8	P/P	.93g		"	23.75g	1		"	"				114.9	
E	"	12	4F	.3cc		2F - Coal Dust -	6g 6g (MIXED)	1		"	"				106.2	
F	"	12	"	"		2F - Coal Dust -	4g 8g (MIXED)	1		"	"				107.7	
G	"	12	"	"		2F - Coal Dust -	8g 4g (MIXED)	1		"	"				112.7	
H	"	12	4F P/P	.3cc 1g		Coal Dust	6.29g FULL SABOT	1		"	"				117.0	
I	"	12	4F P/P	.3cc .5g		Coal Dust	5.65g Full SaBoT	1		"	"				114.7	
J	"	12	"	"		Purple K	8g Full Sabot	1		"	"				114.6	
K	"	12	"	"		"	8g No Sabot	1		"					92.4	
L	"	12	4F P/P	.3cc 1g		"	8g Full Sabot	1		"					116.9	
M	"	12	"	"		"	8g No Sabot	1		"					114.1	
N	"	12	4F	.3cc		FLASH #1	.5g	1		"					112.4	← FLASH #1 = 21% Mg 9% Al 35% BaNO3 35% KNO3

ORIGINAL PAGE IS
OF POOR QUALITY

FBS TEST DATA RECORD

DATE 10/8/81

TEMPERATURE______ HUMIDITY______

TEST No.	LOCATION	SHELL GAUGE	PROPELLANT		WAD	SMOKE		SEAL			WIND		PEAK READINGS			COMMENTS
			TYPE	AMOUNT		TYPE	PACKING	WADS	CRIMP	OTHER	SPEED	DIRECTION	HEAT	LIGHT	SOUND	
O	Field	12	4F	.3cc		FLASH #1	1g	1		Pre Crimp					114.7	
P	"	12	"	"		"	2g	1		"					112.7	
R	"	12	"	"		"	5g	1		"					118	
Q	"	12	"	"		"	10g	1		"					117.6	
S	"	12	"	"		FLASH #3	1g	1		"					107.1	← {FLASH #3 = 37% Mg 63% KClO$_3$}
T	"	12	"	"		"	5g	1		"					100.7	
U	"	12	"	"		"	10g	1		"					108.0	
V	"	12	"	"		FLASH #4	1g	1		"					116.6	← {FLASH #4 = 34.2% Al 65.8% KClO$_4$}
W	"	12	"	"		"	5g	1		"					118.6	
X	"	12	"	"		"	10g	1		"					1183	
Y	"	12	P/P	(.22g)= .5cc		FLASH #1	10g	1		"					118.5	
Z	"	12	P/P	"		FLASH #3	10g	1		"					103.7	Ignition problem
AA	"	12	P/P	"		FLASH #4	10g	1		"					118.9	
BB	"	12	4F	.3cc	1	SMOKE #1	10g	1		"					108.6	{SMOKE #1 = 2.09g KClO$_3$ 5.39g Anth 3.18g 4F} 10g of This mix

FBS TEST DATA RECORD

DATE 10/8/81

TEMPERATURE________ HUMIDITY____

TEST No.	LOCATION	SHELL GAUGE	PROPELLANT		WAD	SMOKE		SEAL			WIND		PEAK READINGS			COMMENTS
			TYPE	AMOUNT		TYPE	PACKING	WADS	CRIMP	OTHER	SPEED	DIRECTION	HEAT	LIGHT	SOUND	
CC	Field	12	4F	.3cc	1	Smoke #2	10g	1		Pre Crimp					110.2	{SMOKE#2 = 10g of (3.18g $KClO_3$ 4.24g Anth 3.18g 4F)}
DD	"	12	4F	.3cc	1	Smoke #3	10g	1		"					108.2	{SMOKE#3 = 10g of (3.8g $KClO_3$ 3.61g Anth 3.18g 4F)}
EE	"	12	4F P/P	.3cc .22g	1	Coal Dust	8.57g	1		"					114.1	
FF	"	12	4F P/P	.3cc .44g	1	"	9.22g	1		"					114.1	
GG	"	12	4F P/P	.3cc .61g	1	"	8.67g	1		"					115.5	
HH		12	4F P/P	.3cc .22g	1	$KHCO_3$	~15g	1		"						
II		12	4F P/P	.3cc .44g	1	"	~15g	1		"						
JJ		12	4F P/P	.3cc .61g	1	"	~15g	1		"						
KK		12	4F P/P	.3cc .22g	1	Purple K	~15g	1		"						
LL		12	4F P/P	.3cc .44g	1	"	~15g	1		"						
MM		12	4F P/P	.3cc .61g	1	"	~15g	1		"						
NN		8	4F P/P	.3cc .44g	1	Coal Dust	24g	1								
OO		8	4F P/P	.3cc .78g	1	"	24g	1								
PP		8	4F P/P	.3cc 1.16g	1	"	24g	1								

ORIGINAL PAGE IS
OF POOR QUALITY

Page 1 of 2

FBS TEST DATA RECORD

DATE 10/13/81

Acoustic Meter – 32 ft. from test shot

TEMPERATURE 69° F HUMIDITY 47%

TEST No.	LOCATION	SHELL GAUGE	PROPELLANT		WAD	SMOKE		SEAL			WIND		PEAK READINGS			COMMENTS
			TYPE	AMOUNT		TYPE	PACKING	WADS	CRIMP	OTHER	SPEED	DIRECTION	HEAT	LIGHT	SOUND	
HH	Field	12	4F P/P	.3cc .22g	1	KHCO₃	15g	1		Pre Crimp	0-5	SW			105.4	
II	"	12	4F P/P	.3cc .44g	1	"	"	1		"	0-5	NW			108.0	
JJ	"	12	4F P/P	.3cc .61g	1	"	"	1		"	0-5	W			110.8	
KK	"	12	4F P/P	.3cc .22g	1	Purple K	15g	1		"	0-5	W			105.8	
LL	"	12	4F P/P	.3cc .44g	1	"	"	1		"	0-5	NW			109.3	
MM	"	12	4F P/P	.3cc .61g	1	"	"	1		"	0-5	W			111.8	
NN	"	8	4F P/P	.3cc .44g	1	Coal Dust	24g	1			0-5	WNW			101.3	
OO	"	8	4F P/P	.3cc .78g	1	"	"	1			6	WSW			105.2	> PP - bad
PP	"	8	4F P/P	.3cc 1.16g	1	"	"	1			0-5	NW			110.3	

page 2 of 2

FBS TEST DATA RECORD

DATE 10/13/81 * Acoustic Meter - 32 ft. from test shot TEMPERATURE 69°F HUMIDITY 47%

TEST No.	LOCATION	SHELL GAUGE	PROPELLANT		WAD	SMOKE		SEAL			WIND		PEAK READINGS			COMMENTS
			TYPE	AMOUNT		TYPE	PACKING	WADS	CRIMP	OTHER	SPEED	DIRECTION	HEAT	LIGHT	SOUND	
QQ	Field	8	4F P/P	.3cc .44g	1	KHCO3	25g	1			0-5	S			106.6	
RR	"	8	4F P/P	.3cc .78g	1		"	1			7	WNW			105.3	– "QQ" on flash camera
SS	"	8	4F P/P	.3cc 1.16g	1	"	"	1			0-5	W			96.6	
TT	"	8	4F P/P	.3cc .44g	1	Purplek	24g	1			0-5	SE			113.6	
UU	"	8	4F P/P	.3cc .78g	1	"	"	1			0-5	W			110.4	
VV	"	8	4F P/P	.3cc 1.16g	1	"	"	1			0-5	W			112.7	
1	"		Flash	Cube		6.15gm	Al/KClO3				0-5	W			—	
2	"		Flash	Cube		9.3gm	"								—	"1" good cloud on flash camera
3	"		Flash	Bulb		10 gm	"								—	

Page 2 of 3

FBS TEST DATA RECORD

DATE 10-15-81

TEMPERATURE ~72°F HUMIDITY

TEST No.	LOCATION	SHELL	PROPELLANT		WAD	SMOKE		SEAL			WIND		PEAK READINGS			F/8 COMMENTS
		GAUGE	TYPE	AMOUNT		TYPE	PACKING	WADS	CRIMP	OTHER	SPEED	DIRECTION	HEAT	LIGHT	SOUND	
C	Lake Lanier	12G	Bullseye Pistol Powder	0.61 cc	✓	11.46 gm Purple K		1	r/crimp		0-5	N			110.4	DeLAy in ignition
D	↓	"	"	0.61cc	✓	13.04 gm Purple K		1	"		0-5	N			110.4	"
A		8G	"	1.16 cc	✓	24.37 gm Purple K		1	"		↓	↓			—	bad primer
B		"	"	"	✓	22.8 gm Purple K		1	"						112.1	
E		6 inch of 1in dia. Pipe	"	1.56 cc	✓	37.6 gm Purple K		1	—	—					—	no bang - smoke
F		6" X 1" Pipe	"	"	✓	37.65 gm Purple K		1	—	—					—	no bang
G		6"X 1" Pipe	"	3.12 cc	✓	92.2 gm Purple K		1	—	—					100.8	good cloud
H		6"X 1" Pipe	"	"	✓	81.8 gm Purple K		1	—	—					112.9	"
I		12"X1" Pipe	"	6 cc	–	145.5 gm Purple K		1	—	—					116.9	blew pipe cap end off
J		12"X1" Pipe	"	6 cc	✓	150 gm Purple K		1	—	—					115.8	"
K		12G	4F B.P. Starter	0.3cc	—	15gm Phos. Mix		1	P/crimp						117.3	good bang & cloud
L		12G	"	0.3cc	—	15gm Phos. Mix		1	"						—	No fire (2) F/11
M		8G	"	0.3cc	—	24gm Phos Mix		1	"						117.5	
N		8G	"	0.3cc	—	24gm Phos Mix		1	"							

ORIGINAL PAGE IS OF POOR QUALITY

Pag. 2 of 3

FBS TEST DATA RECORD

DATE 10-15-81

TEMPERATURE ~72°F HUMIDITY

TEST No.	LOCATION	SHELL GAUGE	PROPELLANT		WAD	SMOKE		SEAL			WIND		PEAK READINGS			COMMENTS
			TYPE	AMOUNT		TYPE	PACKING	WADS	CRIMP	OTHER	SPEED	DIRECTION	HEAT	LIGHT	SOUND	
O	Lake Lanier	1X6" Pipe	Flashbulb squib			33gm Phos Mix									119.5	blew out cap
W		12G	4F B.P. Starter	0.3cc		13.7gm 1pt.Anth/	Anthracene Mix /1pt.KClO$_3$/1pt BP	1	P/Crimp						—	Dud. no fire (2 tries)
Y		8G	"	"		21.6gm 1pt Anth.	Anth. Mix /1pt KClO$_3$/1pt BP	1	"						104.2	
AA		1X6" Pipe	Flashbulb squib			37.5gm	Anth. Mix	1	—						113.9	excellent cloud
DD		1X6" Pipe	Flashbulb Squib			75.5gm	Anth Mix	1	—						116.8	
Q		12G	4F B.P. Starter	0.3cc		10gm Flash Powder Al/KClO$_3$		1	Pre Crimp						116.7	
T																
EE		#5 Flash Bulb	Al Flash Pwdr	13.15gm											111.6	
FF			R/M	33.46											76.5	
GG			R/M	18.56											—	
HH		#5 Flash Bulb	Al Flash Pwdr	13.15											—	
II		8G R/M	4FBP Starter	12.7											—	
JJ		R/M 8G	"	10.1											—	
P		1X6" Pipe	Phos Mix	33.9gm											120.6	

Page 3 of 3

FBS TEST DATA RECORD

DATE 10-15-81

TEMPERATURE ~72°F HUMIDITY

TEST No.	LOCATION	SHELL	PROPELLANT		WAD	SMOKE		STAL			WIND		PEAK READINGS			COMMENTS
		GAUGE	TYPE	AMOUNT		TYPE	PACKING	WADS	CRIMP	OTHER	SPEED	DIRECTION	HEAT	LIGHT	SOUND	
N	LAKE LANIER	8		24 gm Phos Mix												No Test — cannot get wand in holder —
T		8		Al-$KClO_3$ 15.8		Flash Mix									118.2	good
CC		1x6" Pipe	.	Anthra 75g												

FBS TEST DATA RECORD

DATE 11-6-81

TEMPERATURE 63°F HUMIDITY 54.5%

TEST No.	LOCATION	SHELL GAUGE	PROPELLANT		WAD	SMOKE		SEAL			WIND		PEAK READINGS			COMMENTS
			TYPE	AMOUNT		TYPE	PACKING	WADS	CRIMP	OTHER	SPEED	DIRECTION	HEAT	LIGHT	SOUND	
1-6 A	LAKE LANIER	AG1B FLASHBULB									0-5 with Gusts of 15mPH +	E-NE				
B		M3.B FBULB														
C		#5 B FBULB														
D		(2) AG1B c/L>1"														
01-07		SINGLE AG1B FBULB														
E		12	PISTOL POWDER	.5cc	H/W	PURPLE K	9.3 gr	2	HANDI-WRAP SEAL						859	
F		12	BLACK POWDER	.5cc	H/W	PURPLE K	11.8 gr	1	HANDI-WRAP SEAL						neg.	
G		SHORT 8	BLACK POWDER	.7cc	H/W	PURPLE K	10.2 gr	2	HANDI-WRAP						86.1	
H		SHORT 8	BLACK POWDER	.7cc	PAPER	PURPLE K	9.0 gr	1	HANDI-WRAP						neg.	f11
I		8	PISTOL POWDER	.7cc	PAPER	PURPLE K	18.6 gr	2	HANDI-WRAP						84.8	
J		8	PISTOL POWDER	.7cc	PAPER	PURPLE K	19.2 gr	1	HANDI-WRAP						94.5	good "bang" f11
K		1" TUBE	B/P P/P	.5cc 1.6cc	H/W	PURPLE K	15 gr	No CUP	SINGLE LAYER H/W						851	
L		1" TUBE	B/P P/P	.5cc 1.6cc	H/W	PURPLE K	15 gr	No CUP	DOUBLE LAYER H/W						75.4	3/4 sec flash f11

FBS TEST DATA RECORD

DATE 11-6-81

TEMPERATURE 63°F HUMIDITY 54.5%

TEST NO.	LOCATION	SHELL	PROPELLANT		WAD	SMOKE		SEAL			WIND		PEAK READINGS			COMMENTS
		GAUGE	TYPE	AMOUNT		TYPE	PACKING	WADS	CRIMP	OTHER	SPEED	DIRECTION	HEAT	LIGHT	SOUND	
M	LAKE LANIER	1" TUBE	B/P P/P	.5cc 1.6cc	H/W	PURPLE K	30 gr	NO CUP		SINGLE LAYER H/W	0-5 GUSTS OF	E-NE 15MPH +			97.9	
N		1" TUBE	B/P P/P	.5cc 1.6cc	PAPER	PURPLE K	30 gr	NO CUP		DOUBLE LAYER H/W					77.8	f11
O		1" TUBE	B/P P/P	.5cc .939 gr	PAPER	PURPLE K	15 gr	cup		DOUBLE LAYER H/W					98.1	TUBE RUPTURED
P		1" TUBE	B/P P/P	.5cc .939 gr	PAPER	PURPLE K	15 gr	cup		SINGLE LAYER H/W					97.1	f11 4/5 MIN.
Q		1" TUBE	B/P P/P	.5cc .939 gr	H/W	PURPLE K	30 gr	cup		DOUBLE LAYER H/W					77.8	
R		1" TUBE	B/P P/P	.5cc .939 gr	PAPER	PURPLE K	30 gr	cup		SINGLE LAYER H/W					neg.	f11
S		1" TUBE	B/P P/P	.5cc 3.2cc	PAPER	PURPLE K	45.96 gr	cup		SINGLE LAYER H/W						BLEW OUT
T		SHORT 12				STANDARD FLASH MIXTURE	3 gr								114.9	f11 good cloud - (curled back on itself) report heard across lake
U		SHORT 12					5 gr								115.6	long cloud
V		12					10 gr								116.3	excellent cloud - report heard across lake f11
W		SHORT 12				KClO$_3$ FLASH MIXTURE	3 gr								97.9	long cloud
X		SHORT 12					3 gr								79.8	f11
Y		SHORT 12					5 gr								79.4	

FBS TEST DATA RECORD

DATE 11-6-81

TEMPERATURE 63 °F HUMIDITY 54.5%

TEST No.	LOCATION	SHELL GAUGE	PROPELLANT		WAD	SMOKE		SEAL			WIND		PEAK READINGS			COMMENTS
			TYPE	AMOUNT		TYPE	PACKING	WADS	CRIMP	OTHER	SPEED	DIRECTION	HEAT	LIGHT	SOUND	
Z	LAKE LANIER	12				KCLO3 FLASH MIXTURE	10gr				0-5 GUSTS OF	E-NE 15MPH+			115	excellent cloud - report heard across lake f11
AA	"	BRITISH SIMULATOR									|	|			117.5	Shown as "Y" on film (letter designation not changed)

FBS TEST DATA RECORD

DATE 12/30/81 TEMPERATURE________ HUMIDITY_____

TEST No.	LOCATION	SHELL	PROPELLANT		W A D	SMOKE		SEAL			WIND		PEAK READINGS			COMMENTS
		GAUGE	TYPE	AMOUNT		TYPE	PACKING	WADS	CRIMP	OTHER	SPEED	DIRECTION	HEAT	LIGHT	SOUND	
A	Field	1" TUBE	P.P. B.P.	1.3cc .5cc	Cup	Purple K	30gr	2paper caps		Heat shrink					100.7	
B	Field	1" TUBE	PP BP	1.3cc .5cc	Cup	Purple K	30gr	2paper caps		Heat Shrink					—	
C	Field against yellow wall	1" TUBE	PP BP	1.3cc .5cc	Cup	Purple K	30gr	2paper caps		Heat Shrink					102.7	2 MISFIRES
D	Field against yellow wall	1" TUBE	PP BP	1.3cc .5cc	Cup	Purple K	30gr	2paper caps		Heat Shrink					111.4	
E		1" TUBE	PP BP	1.3cc .5cc	Cup	Purple K	30gr	2paper caps		Heat Shrink						
F		1" TUBE	PP BP	1.3cc .5cc	Cup	Purple K	30gr	2paper caps		Heat Shrink						
G		1" TUBE	PP BP	1.3cc .5cc	Cup	Purple K	30gr	2paper caps		Heat Shrink						
H	Field	8	P.P.	.7cc	Cup	Purple K	16gr	2paper caps		Heat Shrink					102.0	
I	Field against yellow wall	8	P.P.	.7cc	Cup	Purple K	16gr	2paper caps		Heat Shrink					97.5	
J		8	P.P.	.7cc	Cup	Purple K	16gr	2paper caps		Heat Shrink						
K		8	P.P.	.7cc	Cup	Purple K	16gr	2paper caps		Heat Shrink						
L		8	P.P.	.7cc	Cup	Purple K	16gr	2paper caps		Heat Shrink						
M		8	P.P.	.7cc	Cup	Purple K	16gr	2paper caps		Heat Shrink						

FBS TEST DATA RECORD

DATE 12/30/81

TEMPERATURE________ HUMIDITY_____

TEST No.	LOCATION	SHELL	PROPELLANT		WAD	SMOKE		SEAL			WIND		PEAK READINGS			COMMENTS
		GAUGE	TYPE	AMOUNT		TYPE	PACKING	WADS	CRIMP	OTHER	SPEED	DIRECTION	HEAT	LIGHT	SOUND	
N	Field	12	P.P.	.5cc	Cup	Purple K	6 gr	2 paper caps		Heat shrink					74.2	
O	Field against yellow wall	12	P.P.	.5cc	cup	Purple K	6 gr	2 paper caps		Heat Shrink					102.3	
P		12	P.P.	.5cc	Cup	Purple K	6 gr	2 paper caps		Heat Shrink						
Q		12	P.P.	.5cc	cup	purple K	6 gr	2 paper caps		Heat Shrink						
R		12	P.P.	.5cc	cup	purple K	6 gr	2 paper caps		Heat Shrink						
S		12	P.P	.5cc	cup	purple K	6 gr	2 paper caps		Heat Shrink						
T	Field	8			-	FLASH POWDER	16 gr	1 paper cap							117.5	
U	Field	12			-	FLASH POWDER	10 gr	1 paper cap							118.2	
V	Field	SHORT 12			-	FLASH POWDER	3 gr	2 paper caps		Heat shrink					—	
W	Field against yellow wall	SHORT 12			-	FLASH POWDER	3 gr	2 paper caps		Heat Shrink					121.8	
X		SHORT 12			-	FLASH POWDER	3 gr	2 paper caps		Heat Shrink						
Y		SHORT 12			-	FLASH POWDER	3 gr	2 paper caps		Heat Shrink						
Z		SHORT 12			-	FLASH POWDER	3 gr	2 paper caps		Heat Shrink						

FBS TEST DATA RECORD

DATE 12/30/81

TEMPERATURE________ HUMIDITY______

TEST No.	LOCATION	SHELL GAUGE	PROPELLANT		WAD	SMOKE		SEAL			WIND		PEAK READINGS			COMMENTS
			TYPE	AMOUNT		TYPE	PACKING	WADS	CRIMP	OTHER	SPEED	DIRECTION	HEAT	LIGHT	SOUND	
AA		SHORT 12			–	FLASH POWDER	4 gr	2 paper caps		Heat Shrink						
BB	Field	SHORT 12			–	FLASH POWDER	5 gr	2 paper caps		Heat Shrink					117.6	
CC		SHORT 12			–	FLASH POWDER	5 gr	2 paper caps		Heat Shrink						
DD		SHORT 12			–	FLASH POWDER	5 gr	2 paper caps		Heat Shrink						
EE		SHORT 12			–	FLASH POWDER	5 gr	2 paper caps		Heat Shrink						
FF		SHORT 12			–	FLASH POWDER	5 gr	2 paper caps		Heat Shrink						
GG	Field	1" CLEAR TUBE			–	FLASHBULB COATED	SQUIB W/ FLASH POWDER	2 layers paper on each end							79.7	
HH	Field against yellow wall	1" CLEAR TUBE			–	FLASHBULB COATED	SQUIB W/ FLASH POWDER	2 layers paper on each end							72.7	
II		1" CLEAR TUBE			–	FLASHBULB COATED W/	SQUIB FLASH POWDER	2 layers paper on each end								
JJ		1" CLEAR TUBE			–	FLASHBULB COATED W/	SQUIB FLASH POWDER	2 layers paper on each end								
KK		1" CLEAR TUBE			–	FLASHBULB COATED W/	SQUIB FLASH POWDER	2 layers paper on each end								
LL		1" CLEAR TUBE			–	FLASHBULB COATED W/	SQUIB FLASH POWDER	2 layers paper on each end								

FBS TEST DATA RECORD

DATE 12/30/81

TEMPERATURE______ HUMIDITY______

TEST No.	LOCATION	SHELL GAUGE	PROPELLANT		WAD	SMOKE		SEAL			WIND		PEAK READINGS			COMMENTS
			TYPE	AMOUNT		TYPE	PACKING	WADS	CRIMP	OTHER	SPEED	DIRECTION	HEAT	LIGHT	SOUND	
MM	Field	3 12g Together	P.P.	.5cc	Plastic	Purple K	3 @ 10gr ea 30gr total	1paper cap each							89.4	SEE NOTE AT BOTTOM *
NN	Field	3 12g Together	P.P.	.5cc	Plastic	Purple K	3 @ 10gr ea 30gr total	1paper cap each							81.9	*
OO	Field against yellow wall	3 12g Together	P.P.	.5cc	Plastic	Purple K	3 @ 10gr ea 30gr total	1paper cap each							—	*

* - The 3 12 gauge shells are glued at the base, forming a tripod like configuration with about 30° angle between the shells.

APPENDIX C
MATERIALS SPECIFICATIONS

MATERIAL SPECIFICATIONS

Aluminum	MIL-A-512A Type 1, Grade B, Class 1
Black Powder	MIL-P-223B Class 7
Anthracene	MIL-A-202B Class 2
Potassium Bicarbonate	MIL-P-3173 Mass Median Diameter 10 microns
Potassium Chlorate	MIL-P-150C Grade B, Class 6
Potassium Perchlorate	JAN-P-217 Class A
Calcium Carbonate	MIL-C-293A

FORMULAS

GRAY SMOKE

$KClO_3$	35.9%
Anthracene	34.1%
FFFFg Black Powder	30.0%

WHITE SMOKE, FLASH

Aluminum	34.2%
$KClO_4$	65.8%

WHITE SMOKE

Phosphorus	20.9%
$CaCO_3$	20.9%
$KClO_4$	58.2%