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## TEST & EVALUATION COMMAND



AD NO. AD841447 **509062**  
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Dugway Proving Ground Trial Record

DPGTR 384

30 March 1964

HAZARD CLASSIFICATION TEST FOR STORAGE, HANDLING,  
AND DISPOSAL OF M43 BOMB CLUSTER, BZ-FILLED, 750-  
1b, AND M44 GENERATOR CLUSTER, BZ-FILLED, 175-1b

USATECOM Project No. 5-3-0130-01

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14 DPG-Trial Record-384

Dugway Proving Ground Trial Record

DPGTR 384

11/30 Mar 1964

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6 HAZARD CLASSIFICATION TEST FOR STORAGE, HANDLING, AND DISPOSAL OF M43 BOMB CLUSTER, BZ-FILLED, 750-lb, AND M44 GENERATOR CLUSTER, BZ-FILLED, 175-lb.

USATECOM Project No. 5-3-0130-01

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Engineering Test Branch Test Design and Analysis Division Technical Plans and Evaluation Directorate Test and Evaluation Command Dugway Proving Ground Dugway, Utah

DA Project No. IR543603D01604

This document will be filed under Case File Number 3268

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HEADQUARTERS  
DUGWAY PROVING GROUND  
Dugway, Utah

STEDP-ET

SUBJECT: Dugway Proving Ground Trial Record (DPGTR) 384: Induced Ignition and Open-Fire Burning Trials: Hazard Classification Test for Storage, Handling, and Disposal of M43 Bomb Cluster, BZ-filled, 750-lb, and M44 Generator Cluster, BZ-filled, 175-lb

TO: Distribution List

I. TITLE: Hazard Classification Test for Storage, Handling, and Disposal of M43 Bomb Cluster, BZ-filled, 750-lb, and M44 Generator Cluster, BZ-filled, 175-lb, USATECOM Project No. 5-3-0130-01.

II. AUTHORITY: Letter, AMSTE-NBC, Headquarters, U. S. Army Test and Evaluation Command, Aberdeen Proving Ground, Maryland, 14 March 1963, subject: "Test Directive: Safety Hazard Classification for BZ Munitions."

III. REFERENCES.

A. Letter, SMUCR-TE(FE)3, U. S. Army Chemical Research and Development Laboratories (CRDL), Edgewood Arsenal, Maryland, 18 January 1963, subject: "Establishing Safety Criteria for the Storage, Handling, and Disposal of 750-lb, BZ-filled, M43 Bomb Clusters and 175-lb, BZ-filled, M44 Generator Clusters."

B. Trip report, SMUCR-TE(FE)3, CRDL, Edgewood Arsenal, Maryland, 8 May 1963, subject: "Report of Visit to Dugway Proving Ground (DPG) by I. S. Sherman Relative to the BZ Hazard Classification Test."

C. Dugway Proving Ground Test Plan (DPGTP) 645: Safety Hazard Classification of BZ Munitions, DPG, Dugway, Utah, 9 October 1963.

D. Message, Commanding Officer, CRDL, Edgewood Arsenal, Maryland, 10 October 1963, subject: "Request Suspension of Testing under DPGTP 645," to Commanding Officer, DPG, Dugway, Utah.

E. Message, Commanding Officer, CRDL, Edgewood Arsenal, Maryland, 4 November 1963, subject: "Resumption of Hazard Classification Trials," to Commanding Officer, DPG, Dugway, Utah.

F. Letter Report, STEDP-ET, Commanding Officer, DPG, Dugway, Utah, 5 November 1963, subject: "Preliminary Results of Trial 1, DPGTP 645, Phase B, Part 1, Induced Ignition, M44 Generator Cluster, BZ-filled, 175-lb, Lot No. 1021-34-12, USATECOM Project No. 5-3-0130-01," to Commanding Officer, CRDL, Edgewood Arsenal, Maryland.

G. Letter Report, STEDP-ET, Commanding Officer, DPG, Dugway, Utah, 15 November 1963, subject: "Preliminary Results of Trial 1, DPGTP 645, Phase A, and Trial 1, Phase B, Part 3, Open-Fire Burning; M43 Bomb Cluster, BZ-filled, 750-lb, Lot 1021-35-148, and M44 Generator Cluster, BZ-filled, 175-lb, Lot 1021-34-13, USATECOM Project No. 5-3-0130-01," to Commanding Officer, CRDL, Edgewood Arsenal, Maryland.

H. Addendum 1 to DPGTP 634: Hazard Classification Test for Storage, Handling and Disposal of M43 Bomb Cluster, BZ-filled, 750-lb, and M44 Generator Cluster, BZ-filled, 175-lb. USATECOM Project No. 5-3-0130-01, DPG, Dugway, Utah, 19 December 1963.

IV. OBJECTIVES: The objective of these tests is to provide data for evaluation of:

A. Hazards incidental to the handling and storage of BZ-filled M43 bomb clusters and M44 generator clusters.

B. Establishment of safe storage conditions.

C. The open-fire burning technique as a means of field disposal.

V. SCOPE: The tests reported are initial trials scheduled under DPGTP 645 (Ref C). As identified in the test plan, these are: Induced ignition, Trials 1, 1A, and 1B, Part 1, Phase B, each of which utilized two M44 munitions; open-fire burning, Trial 1, Part 3, Phase A, which utilized one M43 munition, and Trial 1, Part 3, Phase B, which utilized one M44 munition.

VI. BACKGROUND: The hazard classification test for storage, handling, and disposal of M43 bomb cluster, BZ-filled, 750-lb, and M44 generator cluster, BZ-filled, 175-lb, as prescribed in DPGTP 645, was based on a test plan prepared by CRDL (Ref A). Upon completion of the trials described in this report, testing was suspended pending a review of the initial test data and performance of test technology at DPG. Prior letter reports (Ref F and G) transmitted preliminary results of one induced ignition trial and the two burning trials. Before conducting induced-ignition Trials 1A and 1B, the storage igloo and test procedure were modified (Ref H).

VII. DESCRIPTION OF ITEMS: The M43 and M44 clusters are pyrotechnic munitions which are designed to generate aerosolized agent thermally. The M43 munition comprises 57 M138 bombs clustered (in three banks of 19 each) in the M30-type adapter casing. The M44 munition comprises three M16 generators clustered in an M39 cluster adapter. M43 munition from Lot 1021-35-48 and M44 munitions from Lot 1021-34-13 were used for these trials.

VIII. TEST LOCATION.

A. Part 1 trials, Induced Ignition, were conducted in a specially-constructed igloo located west of Camelback Mountain and south of Tower Grid at DPG.

B. Part 2 trials were deferred.

C. Part 3 trials, Phase A and B, were conducted at Tower Grid using the vertical sampling array.

IX. TEST METHODS.

A. Induced Ignition trials.

1. General. Induced ignition trials were conducted in a storage igloo constructed as described in Ref A, and modified as described in Ref B. All measurements were recorded continuously. Records of the trials give time references to specific events such as time of detonation and indexing of chemical samplers.

a. An anemometer and a pressure indicator were utilized to measure the volume of effluent smoke.

b. A continuous pressure indicator was installed adjacent to the door of the igloo and remote from the flue duct, to record variable pressure in the igloo.

c. Recording pyrometers recorded temperatures in the igloo smoke duct, and were placed 6 inches above the floor between Stack A and B, above the sprinkler heads, and in munitions cases as prescribed for specific trials.

d. During the trial, samples were taken of the flue effluent and inside the igloo. Sampling was accomplished with millipore filters aspirated at 1 liter per minute. Sampling schedule was as follows: 1/2-minute sampling for 2 minutes, 1-minute sampling for 2 minutes, and 2-minute sampling for 24 minutes. Finally, one sampler was aspirated until smoke was no longer emitted from the flue.

2. Special conditions for Trial 1A of induced ignition. As a result of Trial 1, as related in this record, design changes were made in the storage igloo and test technique as follows:

a. A self-closing, pressure-release door was installed. This door, hinged at the top and fitted with a counterweight, permits release of pressure and subsequent automatic closure after the internal pressure in the igloo has subsided.

b. For flow measurement in the vent, the flue was modified to include an S bend. An anemometer with steel cups and a pitot tube flow-measuring device were provided.

c. The glass window of the photographic tunnel was replaced with a steel plate. For BZ sampling in the igloo proper, a sequential sampler was positioned in the tunnel and sample tubes were inserted into the igloo through holes in the steel-plate barrier.

d. The test plan for Trials 1A and 1B was modified as follows: Two stacks of M44 cluster containers were utilized as in Trial 1, Phase B, Part 1, but the upper two tiers of sand-filled boxes were omitted and the stacks were only two containers in height. As shown in Figure 5 of the test plan, Container 2, and Container 6 on top of Container 2, contained M44 munitions. All other containers were sand-filled. The cluster was electrically ignited. During this test, a sprinkler system installed near the ceiling was used when the temperature rose above 140° F. Thermocouples were installed above the sprinkler pipe. There were two sprinkler heads on each of two sprinkler pipes (a total of four sprinkler heads). Other test procedures were as described in DPGTP 645, Paragraph XI, B, 1.

B. Disposal by Burning. The external heat (open-fire) burning trials, to evaluate burning as a method of disposal, were conducted basically as described in TB 700-2, Section I, Paragraph 7b, Explosive Hazard Classification Procedure. Other details were as described in DPGTP 645, Paragraph XI, B, 3. The trials with the M43 bomb cluster was conducted on the Tower Grid on 11 October 1963; fire time was 1119 hours. The trial with the M44 generator cluster was also conducted on the Tower Grid. Date of test was 9 October 1963 and fire time was 1610 hours. Agent cloud sampling, analysis of agent recovery, and meteorology data recording were conducted as prescribed in DPGTP 645. The method of cluster ignition was as follows: Three canisters in the center generator were wired with squibs and electrically fired.

## X. TEST RESULTS

### A. Induced Ignition.

1. Trial 1 (Phase B, Part 1).

a. General: Firing time was 1138:00 hour, 4 October 1963. At 1138:05, smoke started to issue from the exhaust stack, and the doors of the igloo were blown open by violent pressure developed inside the igloo. These doors had been wedged shut with a heavy 8- by 8-inch by 10-foot timber angled against the top of the door and restrained at the ground end. After this initial explosive blast, at 1138:25, smoke started to emit under pressure and continued for 8 seconds. The exhaust flue then smoked moderately until 1141:15 when the volume of black smoke increased. At 1143:20, the heavy volume of black smoke decreased, but at 1149:25, black smoke surged profusely from the stack, continued until 11:50:10, and then dwindled. At this time, one of the two door halves was almost shut, evidently pulled in by the air draft. Another surge of black smoke for 25 seconds duration occurred at 1153:30. Two more smoke surges occurred; one for a 20-second duration at 1154:10, and the other for a 25-second duration at 1154:35. Flaming was apparent in the igloo prior to each of these surges. Smoke issued both from the flue and the door of the igloo. At 1203:00, 25 minutes after firing time, smoke emission from the igloo was of slight volume. At 1208:00, rubble piles, resulting from the destruction of stacked munitions, were burning steadily. The heat from the fire in the igloo ignited wood frame structural parts in contact with metal exterior parts. Flammable parts of the photographic tunnel ignited at 1208:00, and film in the camera was destroyed. Intense heat in the exhaust duct destroyed the anemometer mounted therein. At the start of smoke emission from the igloo, light gray smoke was emitted. Thereafter, the smoke emitted was dark gray to black in color. Moving picture coverage (24 frames per second) was taken from an observation point away from the igloo and is available as a record of the trial.

b. Data:

(1) Pressure measurements: At  $Z + 4$  seconds, the pressure in the flue decreased to about 1 psi below atmospheric and recovered immediately. This may have been the instant that the door of the igloo was blown open. The door, however, was braced to require about 5-psi pressure rise to blow it open and there was no indication of pressure rise in the igloo. The chart record from the pressure-measuring transducers drifted considerably because the temperature to which they were exposed exceeded that for which they are designed. At  $Z + 25:40$ , an unmeasurable increase occurred in the flue pressure. At  $Z + 26:40$ , the pressure in the igloo increased for 1 psig but returned immediately to normal. At  $Z + 33:46$  the recorded pressure in the igloo rose to a value of 15 psig for 1.5 seconds. This could not be explained because there was no visible evidence of a pressure rise in the igloo. The pressure transducers were not burned out and were serviceable after completion of the trial.

(2) Temperature Measurements: In general, because temperatures prevailing were above the anticipated level, thermocouple readings are invalid at temperature levels above the initial rise to 500° F. The thermocouple attached to Container 9 gave pyrometer readings which were off of the scale most of the time. This chromel-alumel thermocouple had an insulation limit of 950° F.; upon examination after the trial, it was found to have exceeded this limit. Immediately after firing time, Z minute, temperatures exceeded the upper scale (500° F.) in less than 20 seconds. At Z + 5 seconds, temperatures in the igloo and in the flue began to increase sharply, and within 15 seconds had exceeded the measuring limit for copper-constantin thermocouples. The chromel-alumel thermocouple was off scale but still operative. At Z + 2:54 the chromel-alumel thermocouple (in Container 9) recording returned to the scale and recorded 740° F. for 11 seconds. The temperature recording then rose to and remained above the scale limit of approximately 1400° F. At this time, the thermocouple insulation probably burned out because the temperature in the igloo apparently was constant for about 12 minutes. At Z + 40:34, all instrumentation thermocouples were completely destroyed and the attempt to record temperatures was stopped.

(3) BZ Sampling and Analysis: Samplers stationed within the igloo were destroyed and no data were obtained. Sequential samplers in the flue position were operated and BZ was recovered in three of the 20 samplers, as follows:

(a) 30 gamma at 1144:05 to 1146:05

(b) 66 gamma at 1146:05 to 1148:05

(c) 26 gamma at 1202:05 to 1204:05

No BZ was detected in the other 17 flue samplers. No malfunctions occurred in the exhaust stack sequential samplers. The sampling flow rate was within the range of 1.00 + 0.05 liters per minute, continued for an over-all sampling period of 30 minutes.

c. Photographs: Full motion-picture coverage, through a glass panel, was anticipated. However, no motion pictures were obtained because of the intense heat which destroyed film in this camera. Still pictures of the igloo interior were hand carried to CRDL by Mr. Dean Kone. Representative pictures appear in Annex A. Figures 9 through 14 show views into the igloo after the trial. Figure 18 shows destruction in the photography tunnel after the trial.

d. Discussion.

(1) The destructive force of ignition and combustion of the M44 munition under the conditions of this trial was much greater than had been anticipated. Useful data such as temperature and pressure records were not obtained.

(2) Because of the results of this trial, it was decided in concurrence with Mr. Kone, the CRDI Project Engineer who witnessed the trial, to suspend further induced-ignition trials pending a review of the data.

(3) The test igloo was not seriously damaged and was made available for further munition-storage trials after repairs. Significant damage was: (a) heat warpage of the flue and the igloo doors, (b) destruction of the glass panel mounted between the igloo wall and the photographic tunnel, (c) destruction of thermocouples, anemometer and camera, (d) fire damage of wooden external igloo elements, and (e) combustion and charring of external wooden igloo structural components.

(4) Instrumentation was destroyed during this trial, therefore the trial did not adequately cover the sequence of events during the combustion of the packaged clusters in the igloo. Thermocouples rated at 1500° F., pressure amplifiers, and other improved instrumentation are now available to give better recording of events in subsequent igloo trials.

## 2. Trial 1A (Phase B, Part 1).

a. General. The munition (from Lot 1021-3-112) in Cluster 2 was electrically fired at 1339:00 hour, 12 December 1963. A light-colored smoke started to issue from the flue, 30 seconds after firing time, and the igloo doors blew open and closed immediately. At 48 seconds, a heavy yellow smoke issued from the flue but not from the door opening. There was no appreciable build-up of temperature and pressure in the igloo. At 3 minutes, smoke was still being emitted from the flue but in diminished volume. At 12 minutes, smoke emitted from the flue was only slightly visible. At 18 minutes, smoke emission continued very light and as intermittent puffs. Smoke emission was scarcely visible at 27 minutes and had ceased 32 minutes after firing of the munition. Temperatures recorded in the igloo showed only a few degrees of increase throughout the test and never sufficed to start the sprinkler system. Examination of the munitions stacks after the test showed:

(1) Only the center generator (that wired for ignition by electric squibs) functioned.

(2) The other two generators were not affected (there was no communication of firing to the adjacent generators).

(3) There was no appreciable damage to the M44 container (see Annex A).

(4) Other sand-filled M44 cluster shipping containers were not damaged.

(5) Sequential sampling functioned normally.

b. Data:

(1) Agent Sampling. Sampling time and agent recovery in the samplers are shown for the flue and the igloo interior. The results are shown in Table 2.

(2) Pressure, Temperature, and Flue Gas Velocity Data. No unrelieved pressure build-up nor significant temperature increase occurred in the igloo. Velocity of gases in the flue was not great enough to measure with the available flow measurement equipment.

3. Trial 1B (Phase B, Part 1).

A. General. The test was fired at 1116 hour, 18 December 1963. Smoke from under the door of the igloo was first detected at 19 seconds after firing time. Smoke emission from the flue started with the appearance of an initial puff of white smoke followed by a cloud of dense black smoke which lasted for about 8 seconds. During this interval, the doors of the igloo opened for about 2 seconds and then closed. Light-colored smoke then emitted from the flue. Within the first minute after firing time, a temperature in excess of 140° F. was recorded by the thermocouple positioned above the sprinkler heads, and the sprinkler system was turned on. Black smoke emitted continuously from the flue, but 6 minutes after firing time, the smoke became light in color, and the smoke abated and was barely visible 7 minutes after firing time. At 9 minutes after firing time, a second blast occurred, followed immediately by a third. Prior to these blasts, yellow-colored smoke was observed emerging from under the door of the igloo. The doors burst open during the blasts and flame emerged through the door opening. This condition persisted for 2 seconds when the door then returned to the closed position. The igloo was engulfed by a cloud of mixed black and yellow smoke, which indicated a flaming munition during functioning. At 10 minutes after fire time, smoke was emerging from the flue continuously and diminished in intensity for the following 6 minutes. At 20 minutes after fire time, the smoke cloud was light in color and appeared to be

Table 1. Agent Sampling

| SAMPLE POSITION | TIME     |           |               | AGENT RECOVERY   |                     |
|-----------------|----------|-----------|---------------|------------------|---------------------|
|                 | On (min) | Off (min) | Elapsed (min) | Flue (mg)        | Igloo Interior (mg) |
| 1               | 1334     | 1337      | 3             | 0.00             | 0.00                |
| 2               | 1337     | 1339:30   | 2             | 833.33           | 716.14              |
| 3               | 1339:30  | 1340      | 0.5           | 4,479.14         | 3,151.02            |
| 4               | 1340     | 1340:30   | 0.5           | 3,697.89         | 2,864.56            |
| 5               | 1340:30  | 1341      | 0.5           | 6,380.17         | 5,572.88            |
| 6               | 1341     | 1342      | 1             | 4,010.39         | 5,052.05            |
| 7               | 1342     | 1343      | 1             | 7,421.83         | 8,203.07            |
| 8               | 1343     | 1345      | 2             | 2,343.73         | 4,947.88            |
| 9               | 1345     | 1347      | 2             | 3,906.22         | 3,255.19            |
| 10              | 1347     | 1349      | 2             | 13,281.16        | 1,627.59            |
| 11              | 1349     | 1351      | 2             | 2,578.11         | 3,255.19            |
| 12              | 1351     | 1353      | 2             | 1,106.76         | 2,473.94            |
| 13              | 1353     | 1355      | 2             | 1,471.34         | 1,861.97            |
| 14              | 1355     | 1357      | 2             | 1,171.87         | 1,380.20            |
| 15              | 1357     | 1359      | 2             | NS <sup>a</sup>  | 1,041.66            |
| 16              | 1359     | 1401      | 2             | 859.37           | 1,002.60            |
| 17              | 1401     | 1403      | 2             | 403.64           | 546.87              |
| 18              | 1403     | 1405      | 2             | 520.83           | 403.64              |
| 19              | 1405     | 1407      | 2             | 768.22           | 859.37              |
| 20              | 1407     | 1415      | 8             | NS               | 39.06               |
|                 |          |           | <b>Total</b>  | <b>55,234.00</b> | <b>48,254.88</b>    |

<sup>a</sup>No smoke.

Table 2. Swab Samples of Igloo Interior after Trial 1.

| SAMPLE LOCATION                                      | DECONTAMINATION TREATMENT | AGENT PER SWAB (mg) |
|--|---------------------------|---------------------|
| North wall, first plate above ground                 | Before                    | 22                  |
|  | After                     | 0                   |
| North wall, second plate above ground                | Before                    | 40                  |
|  | After                     | 0                   |
| North wall, third plate above ground                 | Before                    | 22                  |
|  | After                     | 0                   |
| Floor under Stack A <sup>a</sup>                     | After                     | 0                   |
| Floor under Stack A <sup>a</sup>                     | After                     | 9                   |
| Yellow spot on north wall <sup>a</sup>               | After                     | 9                   |
| Bare spot on north wall <sup>a</sup>                 | After                     | 0                   |
| Yellow spot on south wall <sup>a</sup>               | After                     | 0                   |
| Liquid in drain barrel outside of igloo <sup>a</sup> | After                     | 36                  |
| Nut on south wall <sup>a</sup>                       | After                     | 0                   |

<sup>a</sup>Swab samples were not taken before decontamination.

mostly steam. At 25 minutes after firing time, water sprinkling was stopped and no visible smoke emission could be observed, although steam continued to issue from the flue. The igloo was opened the next day, 19 December 1963, and observations were made as follows:

(1) Only one M44 cluster had functioned.

(2) Apparently, two of the generators in the cluster had flamed and the other generator had functioned normally.

(3) Crate 6, on top of Crate 2, was not affected by the functioning of the Generator 2.

(4) A total of 800 gallons of water was sprayed over the stacks of munition crates at a rate of 32 gallons per minute. The temperature, as recorded by the thermocouple positioned above the sprinkler head was in excess of 140° F. during the entire interval of 25 minutes during which water was sprinkled into the igloo.

b. Data:

(1) Agent Sampling. Sampling time and agent recovery in the samplers are shown for the flue and the igloo interior (Table 3). Swab samples were taken after the test at several locations in the igloo with results as shown in Table 4.

(2) Temperature, Pressure, and Flue Gas Velocity Data. Data collected are presented chronologically from function time until no evidence remained of fire in the igloo (Tables 5 and 6):

(a) Only the cluster which was initiated functioned. The upper live cluster did not initiate, presumably because of the cooling effect of water from the sprinklers. The temperature recorded above the water spray head remained high throughout the burning period.

(b) Door opening events were recorded by strain gages which indicated each pressure change within the pneumatic closing cylinders. The north door was closed by pressure of 30 psi in the cylinders which is equal to approximately 0.14 psi in the building. The south door cylinders were set to resist approximately 0.19 psi in the building. The doors opened only on the shock generated by initiation of the munition.

(c) Calibration of the velocity pickups was done by physical comparison of instruments in the wind tunnel and the

Table 3. Agent Sampling

| SAMPLE POSITION | TIME     |           |               | AGENT RECOVERY |                     |
|-----------------|----------|-----------|---------------|----------------|---------------------|
|                 | On (min) | Off (min) | Elapsed (min) | Flue (mg)      | Igloo Interior (mg) |
| 1               | 1111     | 1114      | 3.0           | 13.2           | 13.4                |
| 2               | 1114     | 1116:30   | 2.5           | 0.0            | 26.8                |
| 3               | 1116:30  | 1117      | 0.5           | 0.0            | 67.2                |
| 4               | 1117     | 1117:30   | 0.5           | 13.2           | 26.8                |
| 5               | 1117:30  | 1118      | 0.5           | 66.1           | 94.1                |
| 6               | 1118     | 1119      | 1.0           | 132.3          | 67.2                |
| 7               | 1119     | 1120      | 1.0           | 211.6          | 349.5               |
| 8               | 1120     | 1122      | 2.0           | 185.2          | 161.3               |
| 9               | 1122     | 1124      | 2.0           | 873.0          | 2,903.0             |
| 10              | 1124     | 1126      | 2.0           | 3,527.0        | 3,575.0             |
| 11              | 1126     | 1128      | 2.0           | >3,527.0       | >3,575.0            |
| 12              | 1128     | 1130      | 2.0           | 158.7          | 53.8                |
| 13              | 1130     | 1132      | 2.0           | 52.9           | 67.2                |
| 14              | 1132     | 1134      | 2.0           | 13.2           | 0.0                 |
| 15              | 1134     | 1136      | 2.0           | 26.4           | 0.0                 |
| 16              | 1136     | 1138      | 2.0           | 0.0            | 0.0                 |
| 17              | 1138     | 1140      | 2.0           | 26.4           | 0.0                 |
| 18              | 1140     | 1142      | 2.0           | 13.2           | 0.0                 |
| 19              | 1142     | 1144      | 2.0           | 13.2           | 0.0                 |
| 20              | 1144     | 1155      | 11.0          | 13.2           | 26.8                |

Table 4. Swab Samples of Igloo Interior  
After Trial 1B.

| POSITION<br>SAMPLED      | AGENT PER<br>SWAB<br>(mg) |
|--------------------------|---------------------------|
| North wall 1             | 0.0                       |
| North wall 2             | 0.0                       |
| West wall 1              | 0.0                       |
| South wall 1             | 0.0                       |
| South wall 2             | 13.2                      |
| Ceiling thermocouple     | 13.2                      |
| South wall sampling part | 0.0                       |
| Munition Stack 1         | 198.0                     |
| Floor                    | 52.8                      |
| Munition Stack 2         | 3,575.0 <sup>a</sup>      |
| Door                     | 290.4                     |

<sup>a</sup>Cloudy sample

Table 5. Pressure Records (Trial 1B, Phase B, Part 1).

| TIME<br>(min:sec) | LOW-VELOCITY<br>PICKUP<br>(mph) | HIGH-VELOCITY<br>PICKUP<br>(mph) | BUILDING<br>PRESSURE<br>(psi) | FLUE<br>PRESSURE<br>(psi) |
|-------------------|---------------------------------|----------------------------------|-------------------------------|---------------------------|
| 0:00              | 0.0                             | 0.0                              | 0.0                           | 0.0                       |
| 0:02              | 2.7                             | 0.0                              | 0.0                           | 0.0                       |
| 0:0375            | 5.4                             | 0.0                              | 0.0                           | 0.0                       |
| 0:04              | 10.7                            | 0.0                              | 0.17                          | 0.82                      |
| 0:0425            | --                              | 25.7                             | --                            | -0.77                     |
| 0:05              | 0.0                             | 0.0                              | 0.0                           | 0.0                       |
| 0:0625            | 6.5                             | 0.0                              | 0.0                           | 0.0                       |
| 0:075             | 10.3                            | 0.0                              | 0.0                           | 0.0                       |
| 0:10              | 0.0                             | 0.0                              | 0.0                           | 0.0                       |
| 0:12              | 10.6                            | 0.0                              | 0.0                           | 0.0                       |
| 0:20              | 10.6                            | 0.0                              | 0.0                           | 0.0                       |
| 0:30              | 0.0                             | 0.0                              | 0.0                           | 0.0                       |
| 8:48              | 0.0                             | 0.0                              | 0.0                           | 0.0                       |
| 8:50              | 5.4                             | 0.0                              | 0.0                           | 0.0                       |
| 8:52              | 7.6                             | 0.0                              | 0.0                           | 0.0                       |
| 8:56              | 0.0                             | 0.0                              | 0.0                           | 0.0                       |
| 8:57              | 10.7                            | 0.0                              | -- <sup>a</sup>               | -- <sup>a</sup>           |
| 8:57.5            | 4.1                             | -- <sup>a</sup>                  | 0.0                           | 0.0                       |
| 8:5875            | 4.1                             | 0.0                              | 0.0                           | 0.0                       |
| 8:595             | 10.6                            | 0.0                              | 0.0                           | 0.0                       |
| 9:00              | -- <sup>b</sup>                 | 0.0                              | 0.0                           | 0.0                       |
| 9:01              | 10.6                            | 0.0                              | 0.0                           | 0.0                       |
| 9:03              | 10.7                            | 0.0                              | 0.0                           | 0.0                       |
| 9:10              | 6.9                             | 0.0                              | 0.0                           | 0.0                       |
| 9:15              | 5.4                             | 0.0                              | 0.0                           | 0.0                       |
| 9:20              | -- <sup>a</sup>                 | 0.0                              | 0.0                           | 0.0                       |
| 9:40              | 0.0                             | 0.0                              | 0.0                           | 0.0                       |

<sup>a</sup>Turbulence.

<sup>b</sup>Negative pulse

Table 6. Temperature (° F.) Records (Trial 1B, Phase B, Part 1).

| TIME<br>(min:sec) | FLOOR          |                |                 | CEILING        |                 |                 | END OF<br>FLUE<br>Tc 10<br>(° F.) | FLUE<br>NEAR<br>IGL00<br>Tc 11<br>(° F.) | CLUSTER<br>(° F.) |
|-------------------|----------------|----------------|-----------------|----------------|-----------------|-----------------|-----------------------------------|--|-------------------|
|                   | Tc 1<br>(° F.) | Tc 2<br>(° F.) | Tc 3<br>(° F.)  | Tc 6<br>(° F.) | Tc 7<br>(° F.)  | Tc 9<br>(° F.)  |                                   |  |                   |
| 0:05              | --             | 203            | --              | --             | -- <sup>a</sup> | -- <sup>a</sup> | -- <sup>a</sup>                   | -- <sup>a</sup>                          | --                |
| 0:0625            | --             | --             | --              | --             | --              | --              | --                                | 806                                      | --                |
| 0:10              | --             | --             | --              | --             | 1391            | 977             | 572                               | 374                                      | --                |
| 0:20              | --             | --             | --              | --             | --              | --              | --                                | --                                       | --                |
| 0:30              | --             | 131            | --              | --             | 662             | 428             | 266                               | --                                       | 572               |
| 1:00              | --             | 131            | --              | --             | 446             | 293             | 266                               | --                                       | --                |
| 2:00              | --             | --             | --              | --             | --              | --              | --                                | --                                       | 572               |
| 3:00              | --             | --             | --              | 239            | -- <sup>b</sup> | 122             | -- <sup>b</sup>                   | -- <sup>b</sup>                          | 608               |
| 3:50              | 77             | --             | --              | --             | --              | --              | --                                | --                                       | --                |
| 4:00              | 131            | --             | --              | --             | --              | --              | --                                | --                                       | --                |
| 5:00              | --             | --             | --              | 239            | --              | --              | --                                | --                                       | 754               |
| 8:50              | 131            | --             | 284             | 239            | 149             | 122             | 212                               | 140                                      | 541               |
| 8:59              | 239            | --             | --              | --             | 428             | --              | 1013                              | 1130                                     | --                |
| 9:00              | 239            | --             | --              | --             | --              | 158             | --                                | --                                       | 2462              |
| 9:05              | --             | --             | --              | 455            | --              | --              | --                                | --                                       | --                |
| 9:15              | 401            | 1508           | --              | --             | 212             | --              | 239                               | 374                                      | --                |
| 9:30              | --             | --             | -- <sup>b</sup> | 356            | --              | --              | --                                | --                                       | 1472              |
| 10:30             | 401            | --             | 248             | --             | 140             | 113             | 140                               | 266                                      | --                |
| 11:30             | 374            | --             | 248             | --             | --              | 70              | 140                               | 158                                      | --                |
| 12:00             | --             | --             | --              | 257            | --              | --              | --                                | --                                       | 1220              |
| 12:30             | 374            | --             | 248             | --             | --              | --              | --                                | --                                       | --                |
| 14:30             | 401            | --             | --              | --             | --              | --              | --                                | --                                       | 1040              |
| 15:00             | --             | --             | --              | 257            | --              | --              | --                                | --                                       | 1040              |
| 18:30             | 374            | --             | 248             | --             | --              | --              | --                                | --                                       | --                |
| 20:00             | --             | --             | 329             | --             | --              | --              | --                                | --                                       | 851               |

<sup>a</sup>Temperature increasing.  
<sup>b</sup>Temperature decreasing.

same sensitivity was reproduced in the field. These pickups were set electronically using the manufacturers' certified sensitivity. Certification was on the basis of standards of the U. S. Bureau of Standards.

(d) All previous pickups recorded shocks at the time of the two main initiations of blast in addition to a minor shock at firing time. Velocity of flue gas flow increased from firing time until 4 seconds later. At this time the burning mixture in the generator ignited with a shock which activated all of the pressure pickups.

(e) Total flow of gases could not be calculated from the pressure and temperature measurements because the flow velocity was less than the threshold value (0.75 mph) of the pitot tubes. This problem could be eliminated during subsequent trials of comparable smoke output by reducing the cross-sectional area of the flue and thus increasing the flow velocity at the flow-measurement stations. In addition to reduction in cross-sectional area, the present flue would require structural strengthening because it was slightly damaged by interior pressure.

(f) Temperature measurements were calculated from pyrometer recordings, and were based on a calibrated ohmmeter and new galvanometer with sensitivities certified by the manufacturer.

c. Discussion. The igloo and its doors were undamaged during this trial. Damage to the flue was slight. The door openers were undamaged. The quantity of air leaking into the igloo is assumed to be sufficient to permit the combustion of the wooden packing cases. It is believed, therefore, that the sprinklers are of great value in controlling damage to storage buildings, and their contents, when housing M44 munitions. The cooling effect of the water spray is significant.

## B. Disposal by Burning

1. M43 Bomb Cluster. The results of the test are reported in Table 7, where comparison is made with similar data for the M44 generator cluster. Wind direction during this trial averaged 180 degrees and ranged from 135 to 225 degrees. During the trial the only visible agent smoke was a white puff of smoke which occurred about 4.5 minutes after ignition of the fire. At all other times, the smoke resembled that from a normal wood-oil fire. After 7 minutes, visible smoke evolution had ceased but the pyre continued burning, with visible flame. Inspection of the debris after combustion had ceased and the rubble pile had cooled showed that the mixture in all of the bomblets had been either consumed by burning or dissipated.

Table 7. Vertical Grid Agent Recovery Data for C645, Trial A-3.

| MAST NUMBER   | HORIZONTAL FIELD OF INFLUENCE (meters) | DOSAGE AT INDICATED SAMPLING STATION           |  |  |  |  |   |                    |  | GRAND TOTAL |
|---|--|--|--|--|--|--|---|--------------------|--|-------------|
|   |  | 0.5 m <sup>a</sup><br>(mg/min/m <sup>3</sup> ) | 1.0 m <sup>b</sup><br>(mg/min/m <sup>3</sup> ) | 2.0 m <sup>c</sup><br>(mg/min/m <sup>3</sup> ) | 4.0 m <sup>d</sup><br>(mg/min/m <sup>3</sup> ) | 8.0 m <sup>e</sup><br>(mg/min/m <sup>3</sup> ) | 12.0 m <sup>f</sup><br>(mg/min/m <sup>3</sup> ) |                    |  |             |
| 50  | 2.0597                                 | 26.8   | 26.8   | 26.8   | 13.7   | 25.5   | 26.8  | 26.8               |  |             |
| 51  | 2.0940                                 | 25.5   | 64.0   | 25.5   | 25.5   | 13.0   | 36.6  | 36.6               |  |             |
| 52  | 2.1058                                 | 12.4   | 0.0  | 0.0  | 23.0   | 12.4   | 38.5  | 38.5               |  |             |
| 53  | 2.0940                                 | 98.5   | 28.1   | 54.1   | 14.3   | 40.4   | 0.0   | 0.0                |  |             |
| 54  | 2.0597                                 | 13.0   | 51.5   | 0.0  | 38.5   | 36.6   | 0.0   | 0.0                |  |             |
| 55  |  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0   | 0.0                |  |             |
| 56  |  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0   | 0.0                |  |             |
| 57  | 1.8761                                 | 37.5   | 23.8   | 0.0  | 12.5   | 23.8   | 0.0   | 0.0                |  |             |
| 58  | 1.9658                                 | 12.5   | 0.0  | 0.0  | 12.5   | 14.4   | 0.0   | 0.0                |  |             |
| 59  | 2.0340                                 | 0.0  | 12.5   | 0.0  | 0.0  | 0.0  | 0.0   | 0.0                |  |             |
| 60  | 2.0797                                 | 0.0  | 26.0   | 24.2   | 24.2   | 25.5   | 23.0  | 23.0               |  |             |
| 1   | 2.1028                                 | 0.0  | 13.0   | 38.5   | 25.5   | 12.4   | 0.0   | 0.0                |  |             |
| 2   | 2.1028                                 | 13.0   | 0.0  | 0.0  | 0.0  | 13.0   | 0.0   | 0.0                |  |             |
| 3   | 2.0797                                 | 25.5   | 38.5   | 38.5   | 13.0   | 0.0  | 0.0   | 0.0                |  |             |
| 4   | 2.0340                                 | 25.5   | 25.5   | 24.2   | 4.8  | 26.0   | 24.7  | 24.7               |  |             |
| 5   | 1.9658                                 | 37.1   | 49.4   | 7.6  | 13.0   | 39.0   | 24.7  | 24.7               |  |             |
| 6   | 1.8761                                 | 26.0   | 37.1   | 0.0  | 26.0   | 7.6  | 12.4  | 12.4               |  |             |
| 7   |  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0   | 0.0                |  |             |
| 8   | 2.0940                                 | 0.0  | 0.0  | 41.0   | 43.0   | 27.3   | 0.0   | 0.0                |  |             |
| 9   | 2.1058                                 | 13.0   | 13.0   | 13.0   | 26.0   | 0.0  | 13.0  | 13.0               |  |             |
| 10  | 2.0940                                 | 41.0   | 13.7   | 13.7   | 13.7   | 26.0   | 26.0  | 26.0               |  |             |
| TOTAL AGENT RECOVERED (grams)                           |  | 347.23   | 365.18   | 607.04   | 1457.55  | 2242.56  | 1590.20   | 6609.76            |  |             |
| TOTAL RECOVERY AS A PER CENT OF PURE AGENT DISSEMINATED |  | 1.01   | 1.06   | 1.76   | 4.22   | 6.50   | 4.61  | 19.15 <sup>h</sup> |  |             |

<sup>a</sup>Vertical field of influence, 0.75 m; average wind speed at South Tower, 20.8 mph.  
<sup>b</sup>Vertical field of influence, 0.75 m; average wind speed at South Tower, 21.1 mph.  
<sup>c</sup>Vertical field of influence, 1.50 m; average wind speed at South Tower, 23.6 mph.  
<sup>d</sup>Vertical field of influence, 3.00 m; average wind speed at South Tower, 26.8 mph.  
<sup>e</sup>Vertical field of influence, 4.00 m; average wind speed at South Tower, 30.0 mph.  
<sup>f</sup>Vertical field of influence, 4.00 m; average wind speed at South Tower, 31.9 mph.  
<sup>g</sup>See sample.  
<sup>h</sup>Based on 89.5% recovery of agent.

2. M44 Generator Cluster. The results of the test are shown in Table 8 where they are compared with results for the M43 bomb cluster. Six minutes after ignition of the fire, one generator ignited and a large torch-like flame was emitted from the generator cluster and endured for approximately 12 seconds. The billow of smoke was grayish in color. One minute after ignition of the first generator, the second ignited. The third generator ignited 30 seconds after the second generator. Within 20 minutes after fire time, burning was greatly reduced, with little smoke.

3. Photographic Coverage. Still pictures and motion pictures were obtained from the munition burning trials. Figures 42 and 43 show the M43 and M44 munitions on top of wood piles and surrounded by wood scraps, all saturated with oil and readied for ignition. Note the dike surrounding the placements to contain the excess oil which was poured over the piles. Figures 44 and 45 show the M43 and M44 munition after burning. Note that although the contents of the munitions were burned out, there were no explosions nor noticeable movement of the munitions away from the combustion sites. Figures 46 and 49 show additional details.

4. Discussion: The data show that under the condition of the test approximately 19 per cent of the BZ was airborne, not burned, in the trial with the M43 bomb cluster and approximately 13 per cent of the BZ was airborne, not burned, in the trial with the M44 generator cluster.

Table 8. Vertical Grid Agent Recovery Data for C645, Trial B-3.

| PAST NUMBER   | HORIZONTAL FIELD OF INFLUENCE (meters) | DOSAGE AT INDICATED SAMPLING STATION:          |  |  |  |  |   | GRAND TOTAL |
|---|--|--|--|--|--|--|---|-------------|
|   |  | 0.5 m <sup>a</sup><br>(mg/min/m <sup>3</sup> ) | 1.0 m <sup>b</sup><br>(mg/min/m <sup>3</sup> ) | 2.0 m <sup>c</sup><br>(mg/min/m <sup>3</sup> ) | 4.0 m <sup>d</sup><br>(mg/min/m <sup>3</sup> ) | 8.0 m <sup>e</sup><br>(mg/min/m <sup>3</sup> ) | 12.0 m <sup>f</sup><br>(mg/min/m <sup>3</sup> ) |             |
| 1   |  | 0.0  | 25.5   | 13.1   | 24.5   | 12.5   | 5.1   |             |
| 2   | 2.1058                                 | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0   |             |
| 3   | 2.0940                                 | 25.0   | 12.5   | 0.0  | 0.0  | 5.0  | 12.3  |             |
| 4   | 2.1058                                 | 5.0  | 4.9  | 24.5   | 25.5   | 26.0   | 0.0   |             |
| 5   | 2.0940                                 | 93.5   | 12.8   | 0.0  | 0.0  | 0.0  | 0.0   |             |
| 6   |  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0   |             |
| 7   |  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0   |             |
| 8   |  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0  | 0.0   |             |
| 9   | 2.0027                                 | 0.0  | 13.3   | 75.0   | 0.0  | 0.0  | 0.0   |             |
| 10  | 2.0597                                 | 0.0  | 0.0  | 0.0  | 0.0  | 5.0  | 13.3  |             |
| 11  | 2.0940                                 | 25.5   | 66.4   | 23.0   | 13.0   | 0.0  | 0.0   |             |
| 12  | 2.1058                                 | 37.7   | 13.0   | 37.7   | 11.7   | 11.7   | 0.0   |             |
| 13  | 2.0940                                 | 27.3   | 38.5   | 7.5  | 27.3   | 7.7  | 25.5  |             |
| 14  | 2.0597                                 | 0.0  | 0.0  | 13.7   | 0.0  | 33.5   | 25.0  |             |
| 15  | 2.0027                                 | 0.0  | 43.8   | 25.5   | 0.0  | 131.3  | 13.1  |             |
| TOTAL AGENT RECOVERED (grams)                           |  | 74.35  | 105.86   | 305.04   | 237.99   | 850.28   | 389.05  | 1962.57     |
| TOTAL RECOVERY AS A PER CENT OF PURE AGENT DISSEMINATED |  | 0.47   | 0.67   | 1.92   | 1.50   | 5.35   | 2.45  | 12.350      |

Vertical field of influence, 0.75 m; average wind speed at South Tower, 8.2 mph.  
 Vertical field of influence, 0.75 m; average wind speed at South Tower, 11.0 mph.  
 Vertical field of influence, 1.50 m; average wind speed at South Tower, 12.2 mph.  
 Vertical field of influence, 3.00 m; average wind speed at South Tower, 13.8 mph.  
 Vertical field of influence, 4.00 m; average wind speed at South Tower, 16.7 mph.  
 Vertical field of influence, 4.00 m; average wind speed at South Tower, 18.4 mph.  
 Based on 89.0% purity of agent.

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ANNEX A  
PHOTOGRAPHS

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INDUCED IGNITION TRIALS



Figure 1. Modified fuze with detonated squib that failed to ignite the M16 generator on first trial attempt, 3 October 1963 (Trial 1).

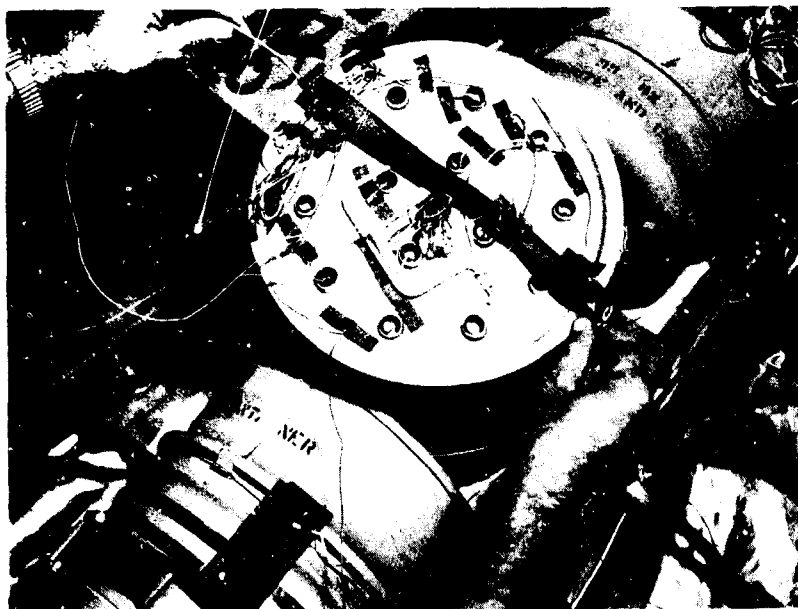


Figure 2. Method of wiring generator on successful trial of 4 October 1963. The squibs in the four center canisters were wired in series. The four outer canisters were wired in a standby circuit (Trial 1).



Figure 3. Typical loading operation viewed through the door of the igloo (Trial 1).

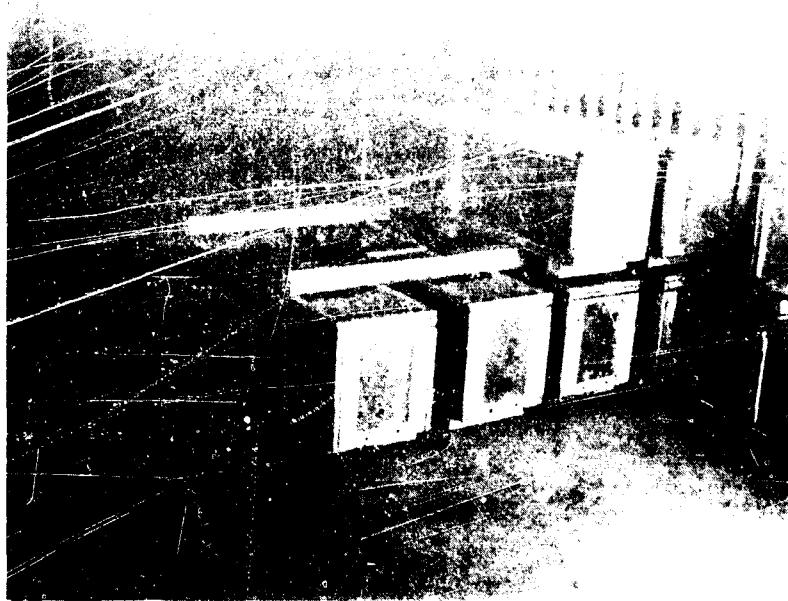


Figure 4. Start of Munition Stack B, nearest to exhaust flue (Trial 1).



Figure 5. Stack A on right and Stack B on left (Trial 1).



Figure 6. Stack A in center (Trial 1).

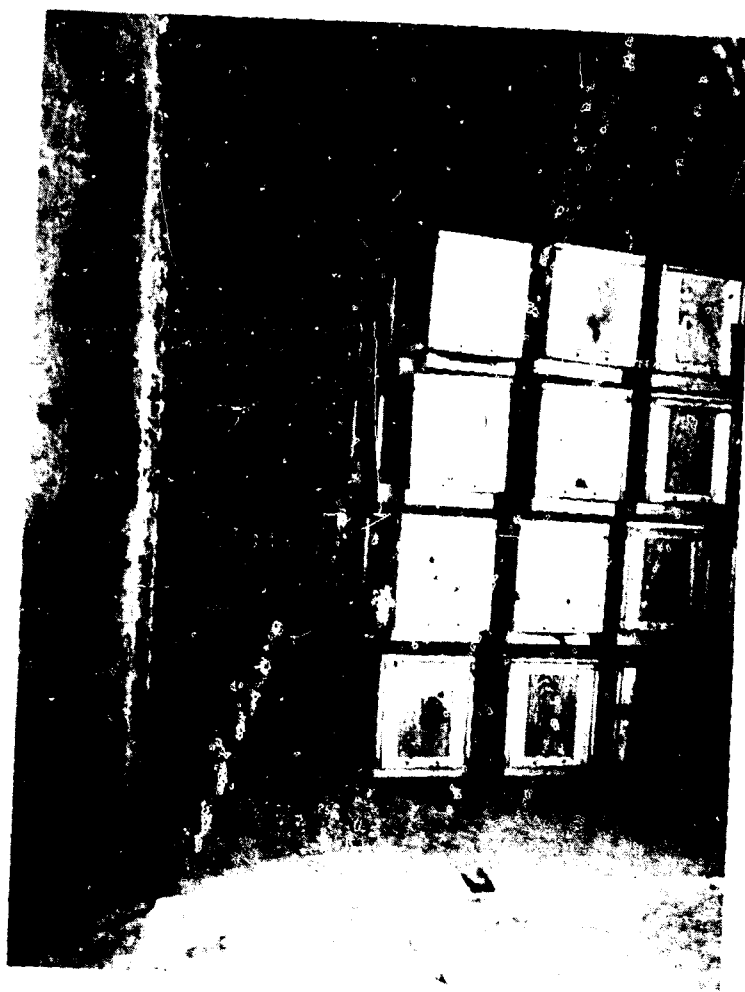


Figure 7. Stacks viewed through doorway.  
Stack A is in the foreground (Trial 1).



Figure 8. Sequential samplers positioned on floor of the igloo in preparation for the trial (Trail 1).



Figure 9. Closeup view of window to the photography tunnel after the fire (Trial 1).

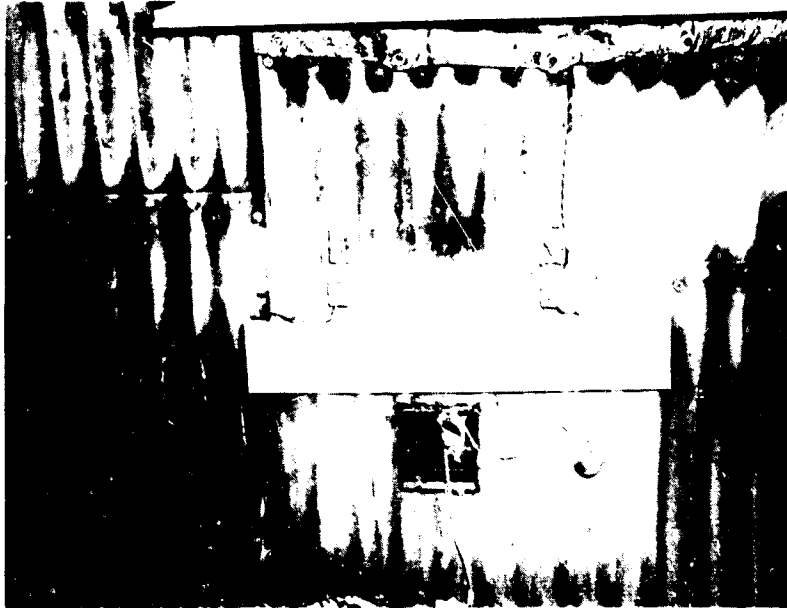


Figure 10. Igloo wall and damaged photographic lights (Trial 1).

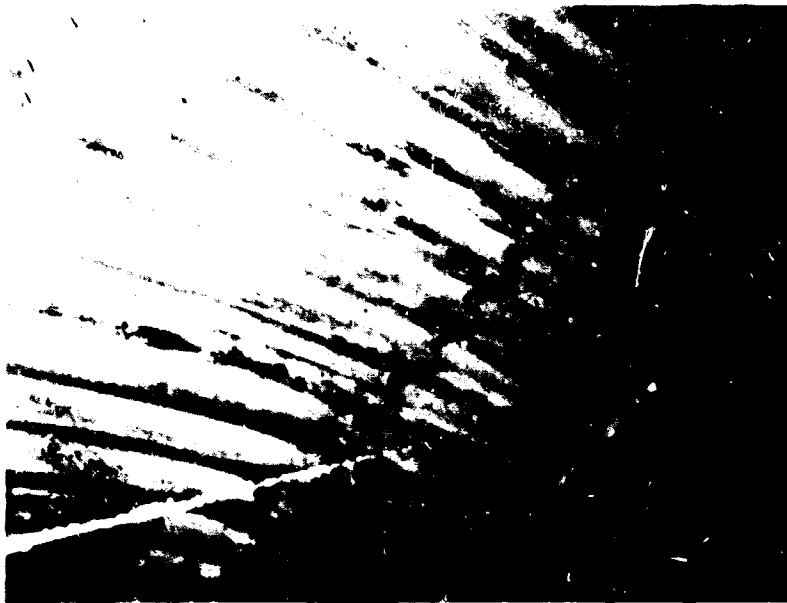


Figure 11. Igloo ceiling, sprinkler head, and burned thermocouple wires (Trial 1).

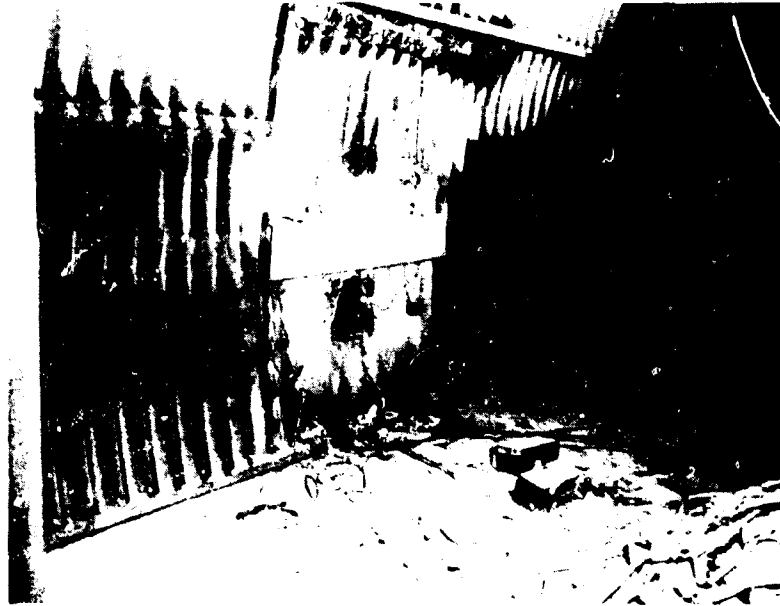


Figure 12. South wall of the igloo (Trial 1).

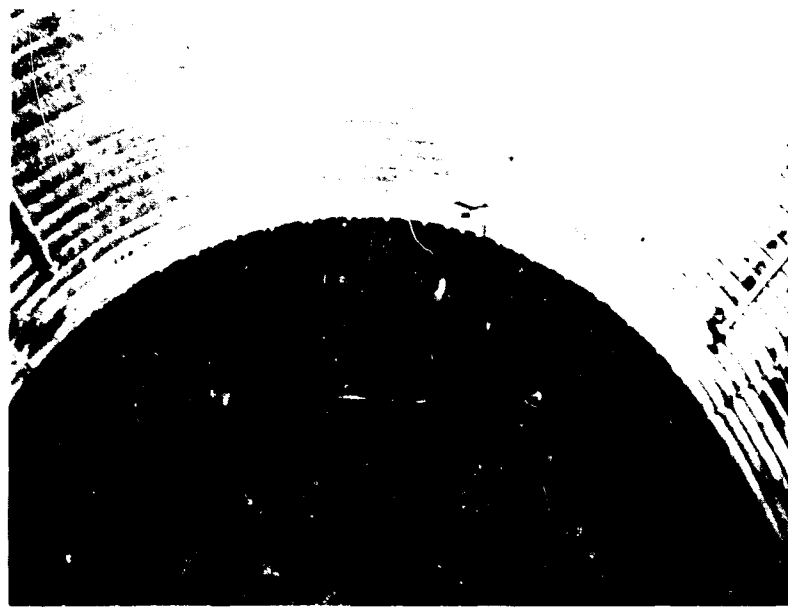


Figure 13. Exhaust flue showing the destroyed anemometer (Trial 1).

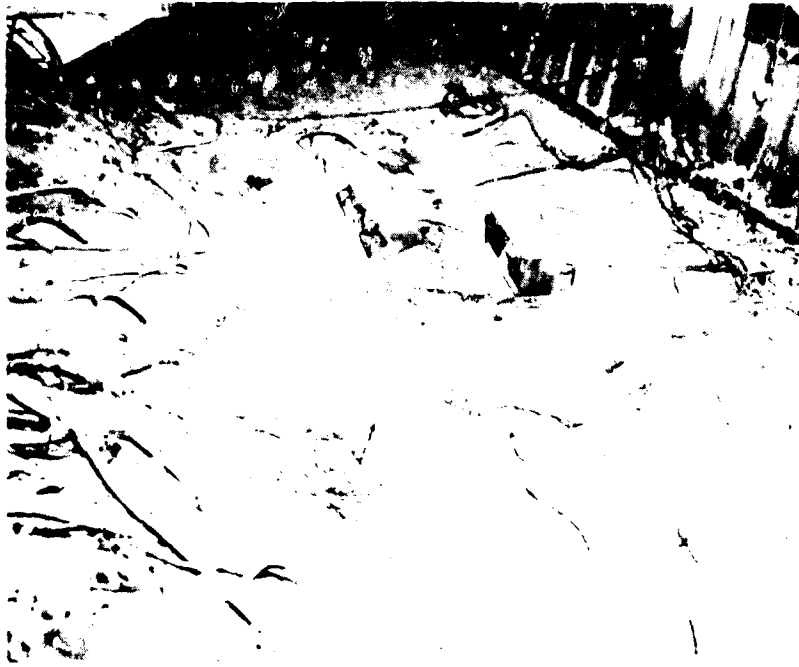


Figure 14. Destroyed sequential sampler and thermocouple wires (Trial 1).

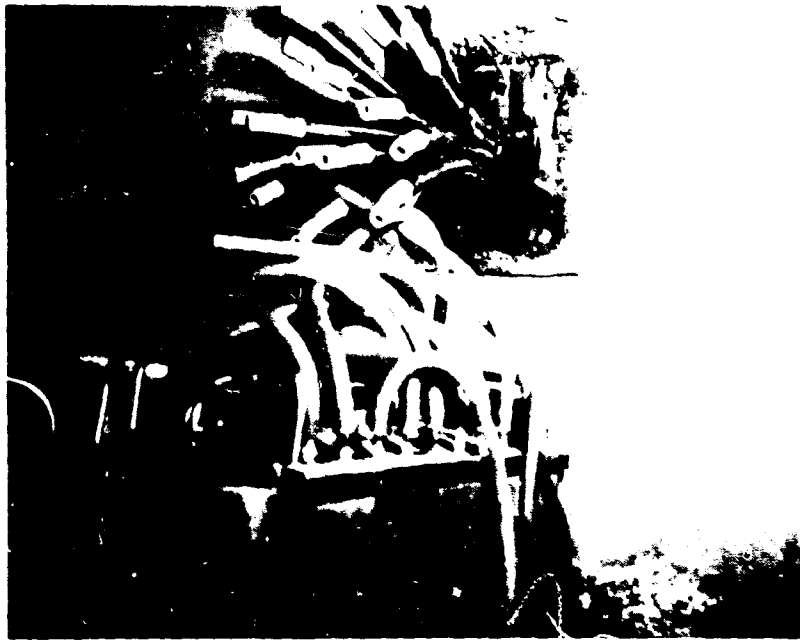


Figure 15. Remains of sequential sampling tubes positioned in the flue of the igloo (Trial 1).



Figure 16. Cold rubble pile viewed through the door of the igloo (Trial 1).



Figure 17. Charred photography tunnel (Trial 1).



Figure 18. Char. ed photography tunnel and  
destroyed thermocouple cold junction  
(Trial 1).

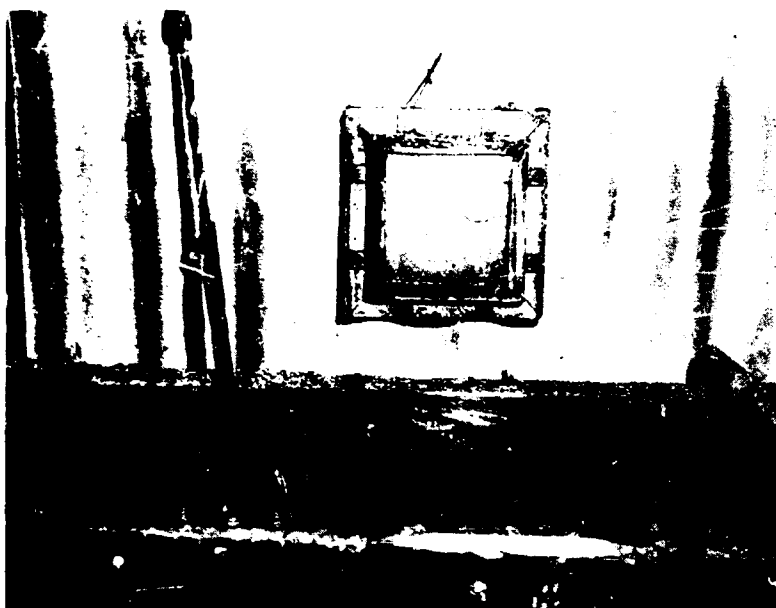


Figure 19. Closeup view of cracked Pyrex photography tunnel window (Trial 1).

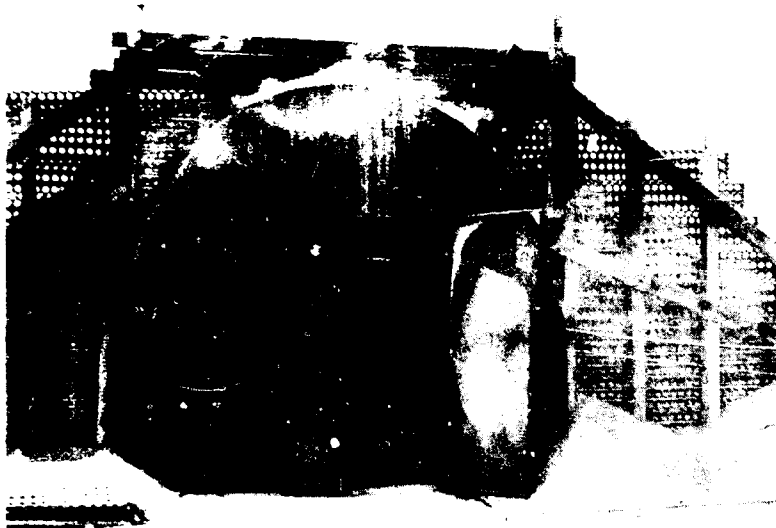


Figure 20. Igloo exterior with fire still burning (Trial 1).



Figure 21. Smoldering photography tunnel (Trial 1).

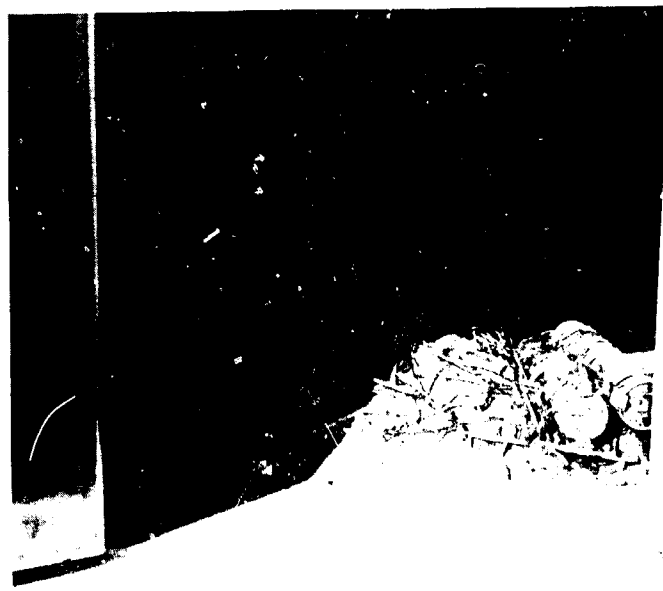


Figure 22. Cold rubble pile (Trial 1).



Figure 23. Stack A rubble pile (Trial 1).



Figure 24. Second view of Stack A rubble pile (Trial 1).



Figure 25. Stack B rubble pile (Trial 1).



Figure 26. Burning rubble pile about 45 minutes after "Z" time (Trial 1).

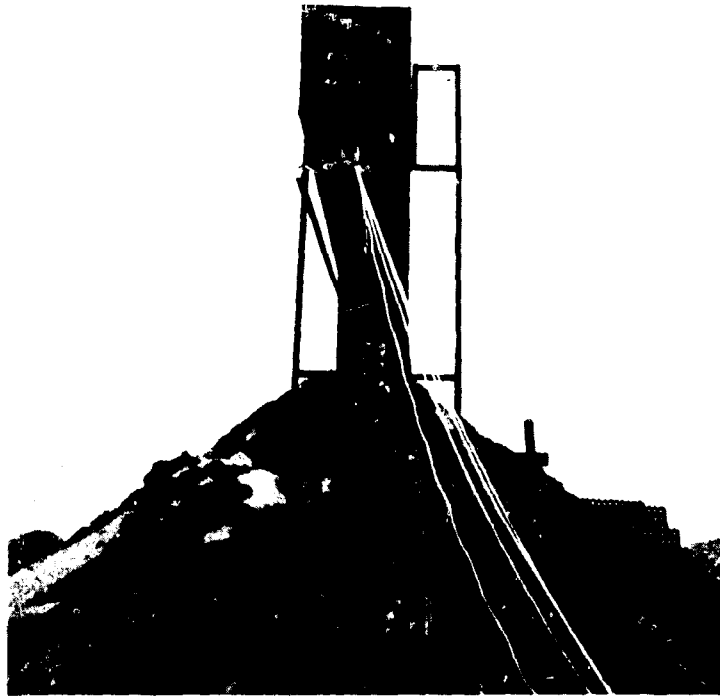


Figure 27. Rear view of igloo. Note that the anemometer has dropped to the bottom of the flue (Trial 1).

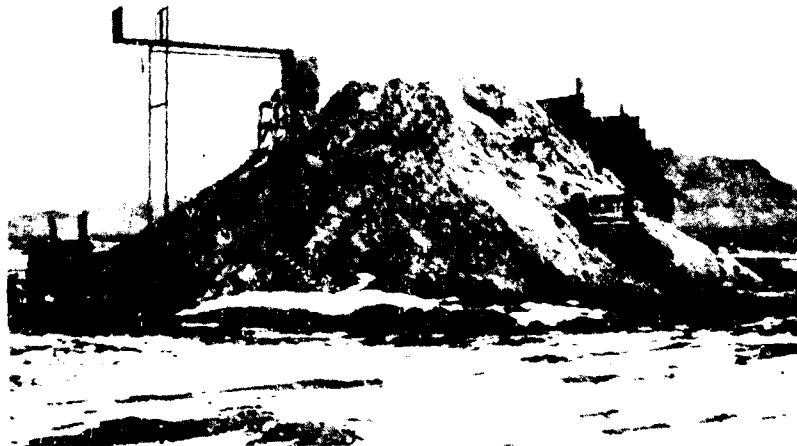


Figure 28. Over-all view of the igloo from the south.  
Note extension to the flue constructed for  
Trials 1A and 1B.



Figure 29. View of Stacks A and B after Trial 1A.  
The top of Stack B is slightly charred.

Figure 30.  
Closeup of Stack  
A showing Cluster  
2, Lot 1021-35-  
113. Note bulge  
at right side of  
cluster and black  
residue at bottom  
opposite cluster.

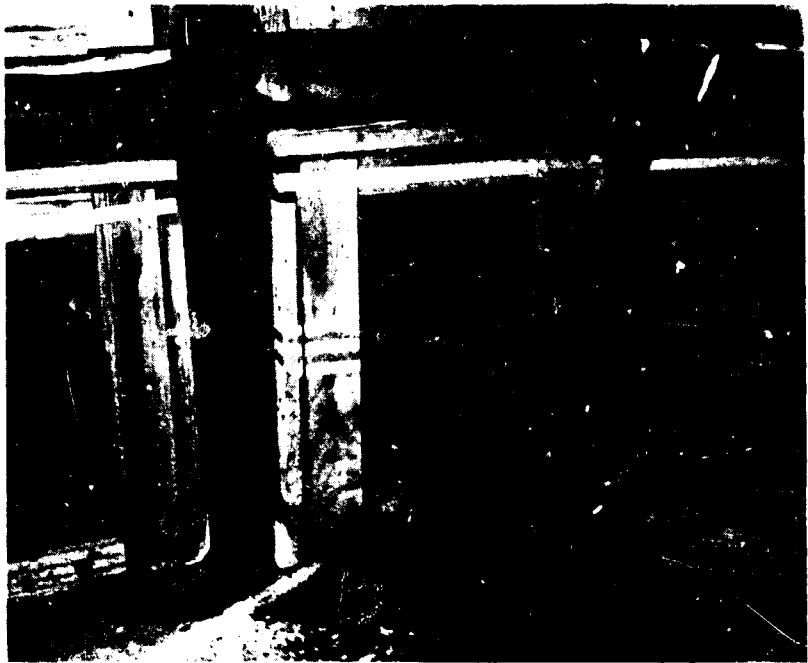


Figure 31.  
Between Stack A and  
B. Note charred  
end of Stack B and  
end of cluster  
container along  
with black residue  
at end of Stack A.

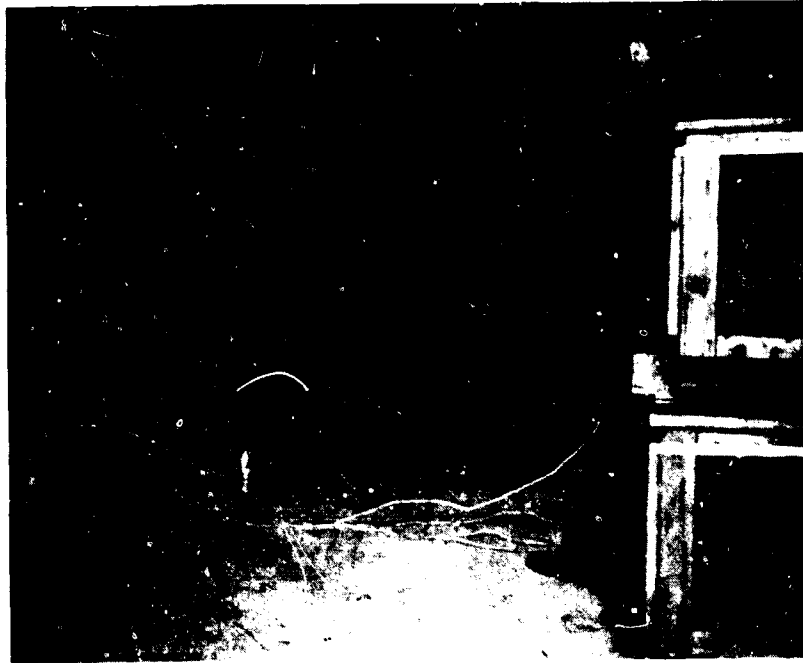


Figure 32. Instrumentation wiring and sampling port (Trial 1A).



Figure 33. View showing the partial functioning of the cluster. Note tarring from the end of the generator and the slightly bulged upper seam of the packing case (Trial 1B).



Figure 34. Over-all view of Stacks A and B after generator functioning (Trial 1B).



Figure 35. View between Stacks A and B. Note the tarring on the floor near the middle of the stacks (Trial 1B).

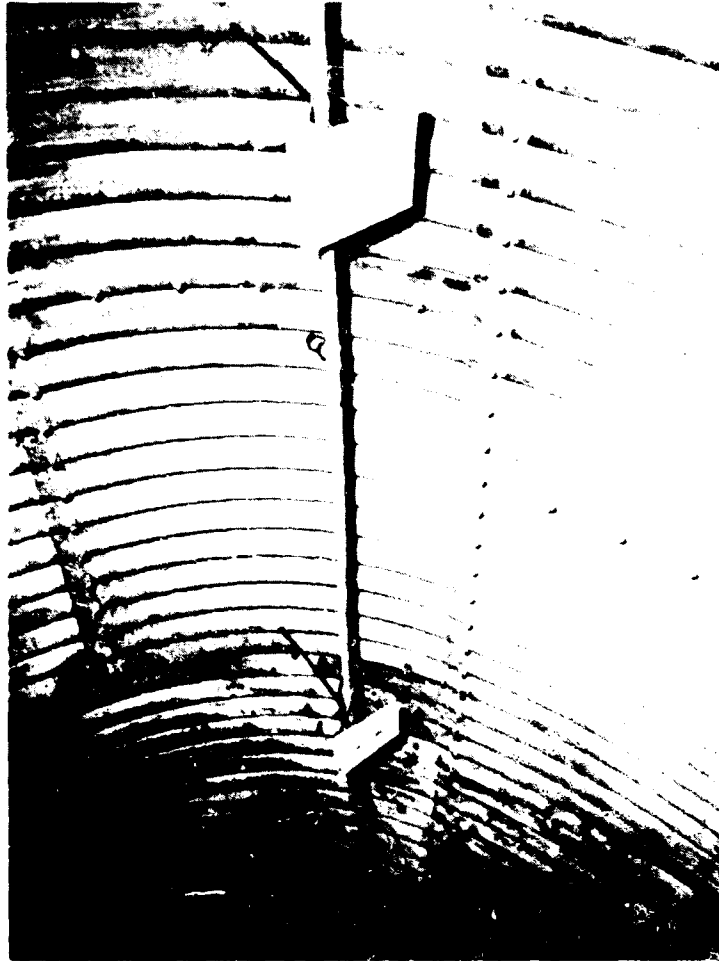


Figure 36. Position of thermocouples at the ceiling (Trial 1B).

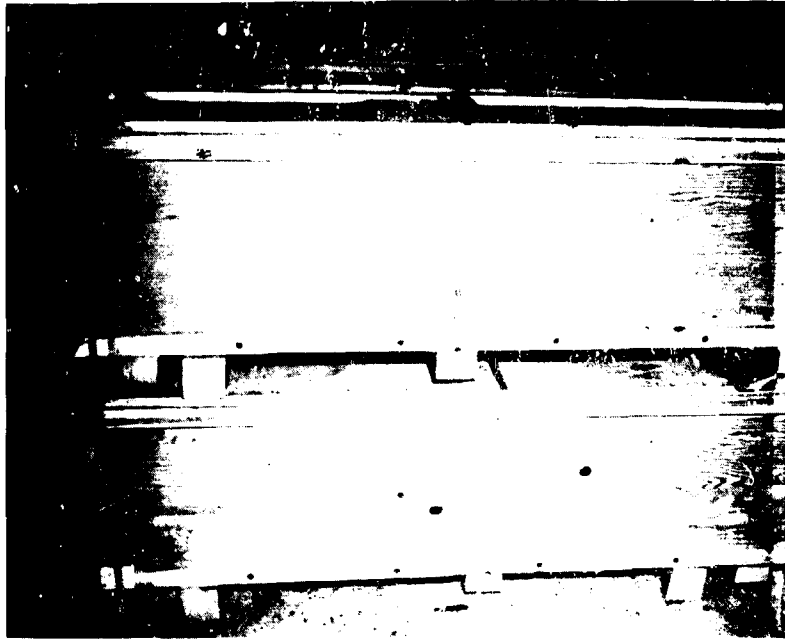


Figure 37. Stack B (Trial 1B). Note there is no damage to this stack.



Figure 38. M16 generator (Trial 1B). Note the discoloration of the can and the partially charred parachute and harness.



Figure 39. Charred interior of M44 cluster container.  
Note the crumbled cardboard and barrier  
material (Trial 1B).

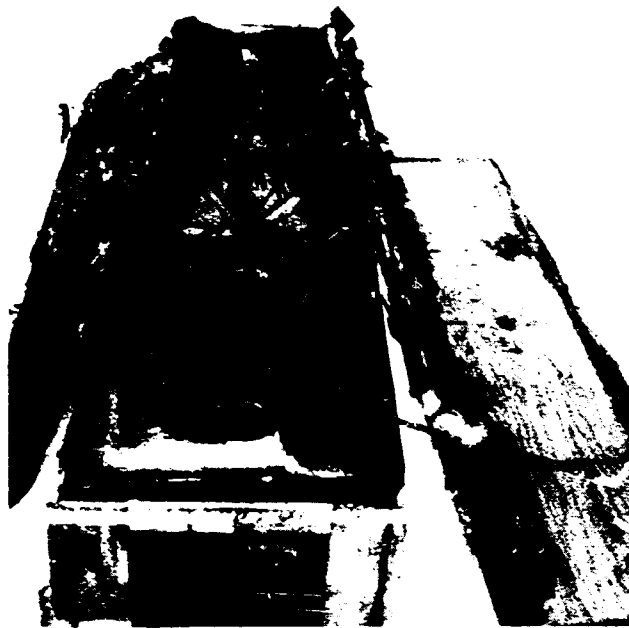


Figure 40. View of cluster in packing case.  
Note tarring and light damage to  
interior of the case (Trial 1B).



Figure 41. View of disassembled M16 generator (Trial 1B). Note the slagging of the emission holes.

OPEN FIRE BURNING TRIALS

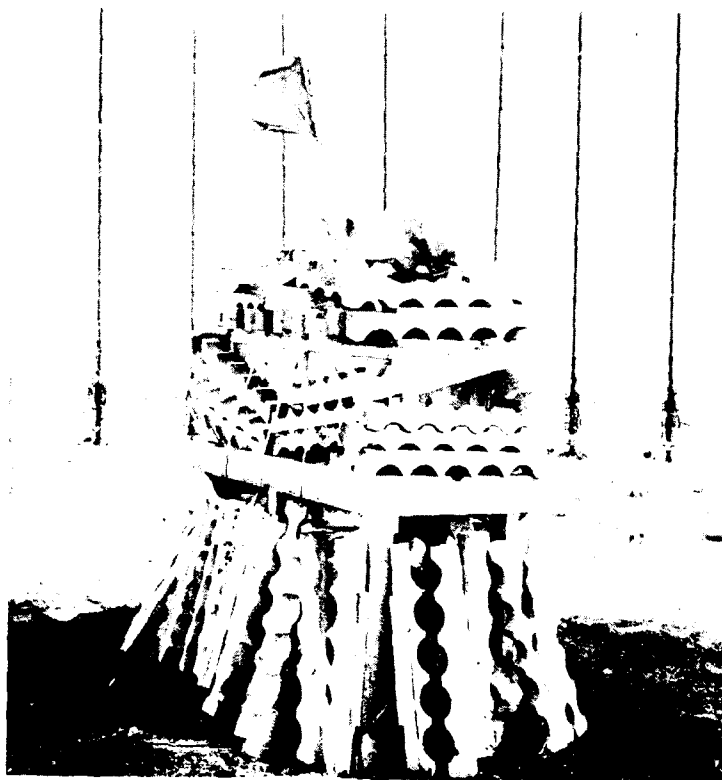


Figure 42. M43 cluster on top of wood pile prior to ignition (Trial 1).

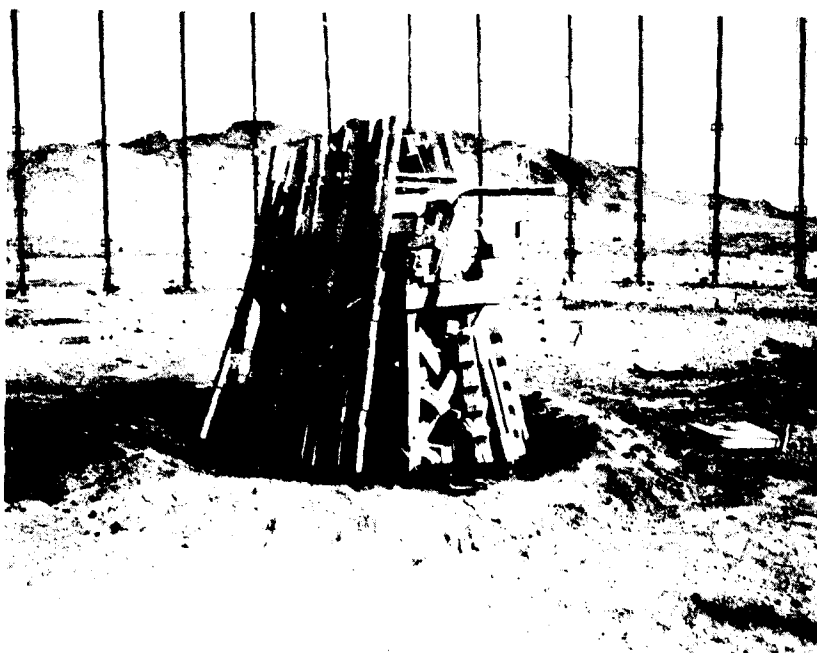


Figure 43. M44 cluster prior to ignition (Trial 2).



Figure 44. M43 cluster after burning. Note M44 cluster in background from previous trial (Trial 2).



Figure 45. View of M43 cluster burning, with typical cloud (Trial 2).



Figure 46. M43 cluster after fire had burned down (Trial 2).

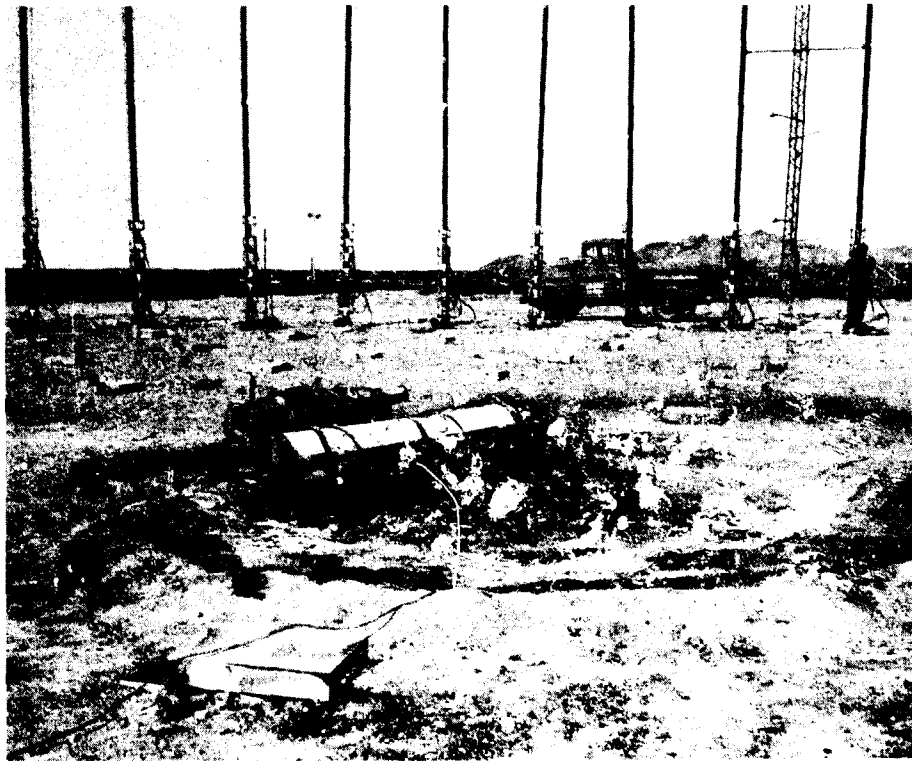


Figure 47. Another view of M43 cluster with M44 cluster from previous trials in the background (Trial 2).



Figure 48. Opened M43 cluster after destruction  
by fire (Trial 2).



Figure 49. Another view of M43 cluster after fire which shows that bomblets are thoroughly burned out.

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