



DEPARTMENT OF THE ARMY  
U.S. ARMY RESEARCH, DEVELOPMENT AND ENGINEERING COMMAND  
3071 ABERDEEN BOULEVARD  
ABERDEEN PROVING GROUND, MARYLAND 21005-5201

REPLY TO  
ATTENTION OF

RDCB-DPS-RS


04 DEC 2013

MEMORANDUM THRU Director, Edgewood Chemical Biological Center (ECBC) (Mr. RDCB-D/Mr. Joseph Wienand), 5183 Blackhawk Road, Aberdeen Proving Ground, MD 21010-5424

MEMORANDUM FOR Office of the Chief Counsel, US Army Research, Development and Engineering Command (RDECOM) (AMSRD-CCF/Ms. Kelly Knapp), 3071 Aberdeen Boulevard, Aberdeen Proving Ground, MD 21005-5424

SUBJECT: Freedom of Information Act (FOIA) FA-13-0097

1. The purpose of this memorandum is to recommend the release of information in regard to RDECOM FOIA FA-13-0097.
2. The ECBC received RDECOM FOIA Request FA-13-0097 from Ms. Kelly Knapp, RDECOM FOIA Officer. The original request was from Mr. Scott Macintire.
3. Subject Matter Experts from ECBC reviewed the requested document, AD-E472 718, which is a Technical Report authored by B.G. Macintire in July 1935. The document entitled, *155-MM Shell MK II (HOW), HS-FILLED: Serviceability of War Reserve Shell and Quantities of Ammunition Required to Produce 50% Casualties on Personnel*, is Unclassified and has been deemed suitable for release. The current distribution is "DoD Components Only," but a request has been forwarded through the Defense Technical Information Center, which requests the distribution to be changed to Distribution Statement A – Approved for public release, distribution unlimited.
4. The point of contact is Mr. Ronald L. Stafford, ECBC Security Specialist, at 410-436-6810 or [ronald.l.stafford.civ@mail.mil](mailto:ronald.l.stafford.civ@mail.mil).

  
MATTHEW A. SPAULDING  
Security Manager

**UNCLASSIFIED**

J. W.  
Lt.  
Comm

E.A.T.R. 172, COPY 1.

AD&

155-mm. SHELL MK. II (HOW.), HS-FILLED;  
SERVICEABILITY OF WAR RESERVE SHELL AND QUANTITY  
AMMUNITION REQUIRED TO PRODUCE 50% CASUALTIES ON PE

Project: A 1.1-1b.

By

B. G. Macintire.

**DECLASSIFIED  
DOD DIR 5200.9**

WAR DEPARTMENT  
CHEMICAL WARFARE SERVICE  
EDGEWOOD ARSENAL, MD.

LT. COLONEL J. W. LYON, COMMANDING

MAJOR E. MONTGOMERY, TECHNICAL DIRECTOR

CAPTAIN CHARLES E. LOUCKS, CHIEF, MUNITIONS DEVELOPMENT DIVISION

Forwarded to Chief, Chemical Warfare Service,

JUL 19 1935

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~~CONFIDENTIAL~~  
This is a secret document and should be handled in accordance with AR 330-5.  
No patentable features are involved in this report.

By authority of C. O., E. A.

OCT 1 1936

Major, C. W. S.

Cancelled  
OCT 1 1936

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155-mm. SHELL MK. II (HOW.), HS-FILLED;  
SERVICEABILITY OF WAR RESERVE SHELL AND QUANTITIES OF  
AMMUNITION REQUIRED TO PRODUCE 50% CASUALTIES ON PERSONNEL.

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155-mm. SHELL MK. II (HOW.), HS-FILLED;  
SERVICEABILITY OF WAR RESERVE SHELL AND QUANTITIES OF  
AMMUNITION REQUIRED TO PRODUCE 50% CASUALTIES ON PERSONNEL.

ABSTRACT

1. Object.

The object of the work described in this report was to determine if the HS-filled 155-mm. howitzer shell in War Reserve are serviceable and, if so, the number required to produce 50% casualties among personnel exposed on the target on which they burst.

2. Results.

The results of the ten tests conducted, in which 596 shell were fired (274 for effect), are shown in the following table:

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Test:	Date	Time	Terrain	Soil	Wind	Air	Exposure	Shell Required per 100-yd. sq.****	
:	:	of	:	:	ve-	temp.	period	Protected by:	Protected by gas mask
:	:	day	:	:	locity:	:	***	gas mask	and impregnated cloth.
:	1932	:	:	:	m.p.h.:	°F.:	:	:	:
A	May 23	9:53 a.m.	Open	Damp	3.2	59	Firing and following	25	71
:	:	:	country	:	:	:	10 min.	:	:
B	June 11	9:08 a.m.	Ditto	Dry	5.3	68	Ditto	14	138
C	Aug. 4	16:35 a.m.	Ditto	Dry	1.5	81	Ditto	9	84
D	Aug. 29	5:23 p.m.	Ditto	Dry	2.9	83	Ditto	8	180
:	1933	:	:	:	:	:	:	:	:
E	May 18	5:21 p.m.	Ditto	Wet	4.0	71	Firing and following	14	20
:	:	:	:	:	:	:	15 min.	:	:
F	June 15	6:00 p.m.	Ditto	Dry	2.0	69	Firing and following	10	72
:	:	:	:	:	:	:	20 min.	:	:
G	July 6	6:10 p.m.	Woods	Damp	0*	83	Firing and following	6	25
:	:	:	:	:	:	:	22 min.	:	:
H	Aug. 11	5:46 p.m.	Ditto	Damp	0**	72	Ditto	8	44
I	Sept. 19	5:10 p.m.	Ditto	Damp	0**	72	Ditto	12	51

\*In open country near target the wind velocity was 4.0 m.p.h.

\*\*Only slight drift in open country near target, same as on target in woods.

\*\*\*Total exposure period was about 25 min. including the firing period.

\*\*\*\*Shell required per 100-yd. sq. is the number required to produce 50% casualties among personnel exposed to the fire.

Of the 596 shell fired, 110, or approximately 18.5%, produced low-order bursts or were duds.

### 3. Conclusions.

It is concluded that:

a. When the HS-filled 155-mm. howitzer shell now in War Reserve are equipped with the Mk. III fuze and fired for impact burst at a range of about 5,200 yd., approximately 18% of the shell may be expected to be duds or produce low-order bursts.

b. The shell represented by those tested should be retained for future service use.

c. The following number of shell per 100-yd. sq. are required to produce 50% casualties when personnel is protected by gas mask only, the shell are fired when the temperature is above 59°F. and the wind is not appreciably above 5 m.p.h. on the impact area:

(1) When fired within the period between one hour after sunrise and one hour before sunset - about 20 shell.

(2) When fired within the period between one hour before sunset and one hour after sunrise - about 10 shell.

d. The following number of shell per 100-yd. sq. are required to produce 50% casualties when personnel is protected by gas mask and standard impregnated clothing and the temperature is above the freezing point of HS:

(1) Under normal soil conditions - about 38 shell.

(2) When the surface soil is dry and sandy - over 100 shell.

### 4. Recommendations.

It is recommended that:

a. The remaining HS-filled 155-mm. howitzer shell in War Reserve be retained for service.

b. A test be conducted using HS-filled 155-mm. howitzer shell meeting present standard specifications for the purpose of comparing the casualty-producing effects with those obtained in the tests covered by this report.

See Reviewer's Note, p. 19.

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155-mm. SHELL MK. II (HOW.), HS-FILLED;  
SERVICEABILITY OF WAR RESERVE SHELL AND QUANTITIES OF  
AMMUNITION REQUIRED TO PRODUCE 50% CASUALTIES ON PERSONNEL.

I.     INTRODUCTION.

The objects of the tests described in this report were as follows:

1.     To determine if the HS-filled 155-mm. howitzer shell in War Reserve at Edgewood Arsenal are serviceable.

- 2.    To determine the number of shell required to produce 50% casualties among personnel.

This work was authorized in the project program under project C5, item 2, for the fiscal year 1932 and project A 1.1-1b, "155-mm. Shell MII, (How.), HS-Filled", for the fiscal years 1933 and 1934. It was a joint Chemical Warfare Service-Ordnance Department project and is covered by Ordnance Committee Minutes, Item 9241.

The shell used in the tests were HS-filled, Mk. II, 155-mm. howitzer, taken from the stock in War Reserve at Edgewood Arsenal. The boosters in a large percentage of the shell were not fully assembled and it was questioned if they would function properly. The condition of this ammunition is given in a memorandum of May 4, 1931, from the office of the Chief of Ordnance to Chief, Chemical Warfare Service, subject: Gas Shell on Hand at Edgewood Arsenal, which is quoted in part below:

"1.    Following are the contents of a memorandum prepared by the Surveillance Section, Field Service, relative to chemical ammunition at Edgewood Arsenal.

'There are in stock at Edgewood Arsenal 7,223 shell, gas, HS, Mk. II, for 155-mm. howitzer, 27 shell, gas, FM, Mk. II, for 155-mm. howitzer, 43 shell, gas, CG, Mk. II, for 155-mm. howitzer. Many of the boosters in these shells are not fully assembled. There are too many threads exposed. The Ordnance Officer, Edgewood Arsenal, states that he considers these shells unserviceable . \* \* \* \* \* Should the above ammunition be retained in stock as War Reserve, or should it be disassembled and the serviceable components recovered?'

\* \* \* \* \*

"3. With reference to the 155-mm. shell in which the boosters have insufficient threads engaged, it may be practicable to simply disassemble these boosters and assemble new boosters without disturbing the filling. It is not known whether the difficulty is due to the booster being oversize or the shell being undersize. If due to the latter, it will be necessary to prepare special undersized boosters to fit the shell in question.

"4. Action through the Ordnance Committee will be taken upon receipt of information from the Chemical Warfare Service."

The 1st indorsement, dated June 8, 1931, from the Commanding Officer, Edgewood Arsenal, to the Chief, Chemical Warfare Service, to the letter (CWS 471/211, May 7, 1931) enclosing this memorandum is quoted below in part as follows:

"1. It is noted that there are in stock at Edgewood Arsenal the following:

a. 7,225 shell, gas, HS, Mk. II, for 155-mm. howitzer.

b. 27 shell, gas, FM, Mk. II, for 155-mm. howitzer.

c. 43 shell, gas, CG, Mk. II, for 155-mm. howitzer.

d. 78,634 shell, gas, NC, unfixed, CS, Mk. II, with A and B, Mk. IV, for 75-mm. gun.

"2. This office has no information that the fillings for any of the above shell are less serviceable than when they were placed in War Reserve or that any more serviceable fillings have been added for War Reserve for their replacement. It, therefore, knows of no technical reason why any substantial portion of them should be removed from War Reserve except for the necessary tests to obtain important technical information as to their performance.

\* \* \* \* \*

"6. Information is not available as to the efficiency of the shell, gas, HS, Mk. II, for 155-mm. howitzer, referred to, as these shell are probably assembled with both long and short type Mk. VIB boosters, and since there are no indication markings as to length of booster, the burster charge of each shell is unknown.

"7. Plans under Project C-5 during the calendar year 1932 contemplate field tests with HS-filled 155-mm. howitzer shell to determine the quantity of this standard ammunition required to set up an effective field concentration. It is possible that, despite the uncertainty as to the size and shape of burster charge, the 155-mm. howitzer shell referred to in the basic communication can be used for this purpose. It is, therefore, recommended that 200 of these shell and 50 additional boosters, Mk. VIB, present standard, of known capacity be made available for examination and firing test to determine whether this lot of shell is suitable for use in tests during the calendar year 1932. It is desired to conduct this preliminary test on August 11, 1932.

"8. The tests contemplated with approximately 500 of these shell during the calendar year 1932 would determine the efficiency of this lot.

The use of shell from the supply in War Reserve was authorized in the 3rd indorsement dated Oct. 22, 1931, from Ordnance Office, Washington, D.C., to Ordnance Officer, Edgewood Arsenal, file CWS 471/211, which is quoted in part as follows:

"1. You are authorized to turn over to the Chemical Warfare Service 50 Mk. VIB adapters and boosters and 200 shell, Gas, HS, Mk. II, for 155-mm. howitzer for firing tests. Shells used in the firing tests will be fused with serviceable Mk. III P.D. fuses. The functioning of the shell will be observed and reported to this office. . . . If these shell are found to be satisfactory for an effective field concentration test, you will be authorized to issue an additional 500 upon request.

\* \* \* \* \*

"3. It is requested that you submit a proposed program of test, giving ranges or zones at which these firings will be conducted in order that the proper powder charges can be furnished, and also what information is desired. Upon receipt of this program, it will be incorporated in an Ordnance Committee Item on War Reserve Tests.

"4. In view of the questionable serviceability of the 155-mm. shells, adequate safety precautions will be taken to prevent injury to personnel in case a malfunction occurs in the firing."

The lot numbers of the shell to be tested and other information is given in the 5th indorsement dated Jan. 4, 1932, from the Commanding Officer, Edgewood Arsenal to Ordnance Officer, Edgewood Arsenal, file EA 471/122, EO 471.1/698, as follows:

"1. An investigation reveals the following facts:

"a. Material for Test:

There are 4 main lots of the 155-mm. howitzer (HS) shell distributed as follows:

Lot MA 35-1-13	4979 shell
Lot 35-1-14	345 shell
Lot MA 35-1-16	988 shell
Lot 3050-1	911 shell

There is data available only on Lot MA 35-1-13, which shows they were loaded in 1921 and assembled with Mk. VIB boosters. These boosters in most instances are not fully assembled.

"b. Previous Tests:

One local test was conducted at Edgewood Arsenal, using a small quantity (number not determined) of shell from Lot MA 35-1-13 for the purpose of determining the quantity necessary to produce casualties from the HS content when fired statically.

"c. Historical:

These shell were taken from the Chemical Warfare Service with the establishment of the Ordnance Office at Edgewood Arsenal in March, 1923. When the HS content of the shells was tested for evidence of deterioration in 1924, no deterioration was noted.

"2. The object of this test is to determine if the stocks of these shell on hand are satisfactory for further tests involving the determination of effective field concentrations of HS.

"3. It is recommended that -

"a. Thirty-six shell picked at random from each of the four lots referred to be fired at a range of not less than 4800 yards.

"b. All personnel engaged in firing to be supplied with sufficient protective clothing, and all firing to be from barricades, firing with lanyard, and the gun-crews under cover.

"c. A record be kept of each round showing whether a dud or a burst and the order of burst, together with position of the booster with respect to the shell, i.e., whether the booster was not fully assembled, and the number of threads showing or whether the booster had been assembled too far in, with the depth below normal stated.

"d. Only in case the firing above recommended results in an excessive number of duds, 13 shell from each of the 2 largest lots to be re-boostered and fired under the same conditions as the first firings.

"e. Based upon the results obtained, a report of the test in detail be prepared together with a recommended program for the remainder of the shell to be tested.

"f. The Chemical Warfare Service to take the necessary steps to determine the distribution of HS due to burst of the shell.

"g. The test here proposed to be conducted before Mar. 1, 1932."

## II. HISTORICAL.

The physical, chemical and physiological properties of HS and its use in the World War are thoroughly discussed in E.A.C.D. 462, dated Apr. 26, 1928, by Walker. The use of HS in the World War is also discussed in the two following reports:

E.T.F. 550 G-90, Gas attacks upon the American Front in France, 1918.

E.T.F. 561-2, May 31, 1932, by Lt. Col. Avery, A Study of the Use of Chemicals by Artillery During the World War, and Possible Future Uses.

There are no records of previous tests in which HS-filled 155-mm. shell were fired from howitzers at Edgewood Arsenal, but some tests were conducted in which such shell were fired statically. In

the following reports, tests are outlined in which HS-filled 155-mm. howitzer shell equipped with the Mk. VIB booster were fired statically, and the effectiveness of the gas concentration set up was determined by means of animals and vapor-sampling machines:

E.T.F. 111.4-10, dated October, 1926.

Results of four tests are given. In three of these tests the HS was sprinkled by means of sprinkling cans and in the fourth test, the HS was put down by the static burst of 155-mm. shell.

A test was conducted on May 1, 1928, in which 11 shell were used. The results of this test are given in the two following reports:

E.A.M.R.D. 87, dated May 4, 1928, by Armstrong.

E.A.C.D. 467, dated April, 1929, by Smith.

Calculated figures of the number of HS-filled 6-in. howitzer shell required to deny an area to troops are given in G-2 report, E.T.F. 550 E-170, Artillery Gas Shell Fire Data from Great Britain.

The following tests conducted at Edgewood Arsenal are of interest in that HS was used:

Tests in which HS was laid down with the use of sprinkling cans:

E.A.M.R.D. 47, September 16, 1925, by Eldridge.

E.T.F. 111.4-10, August and October, 1926.

E.A.M.R.D. 66, December 31, 1926, by Eldridge.

E.A.C.D. 462, April 26, 1928, by Smith.

Tests in which HS was laid down by the static burst of 75-mm. shell or bottles containing HS:

E.A.M.R.D. 66, December 31, 1926, by Eldridge.

E.A.M.R.D. 84, November 30, 1927, by Armstrong.

E.A.M.R.D. 93, May 11, 1928, by Armstrong.

E.A.C.D. 462, April 26, 1928, by Walker.

E.A.M.R.D. 95, June 12, 1928, by Armstrong.

E.A.C.D. 467, April, 1929, by Smith.

Tests in which HS was laid down by burst of HS-filled 75-mm. shell fired from service weapons:

E.A.M.R.D. 100, July 20, 1928, by Armstrong.  
E.A.M.R.D. 104, Sept. 5, 1928, by Armstrong.  
E.A.T.R. 55, Nov. 5, 1931, by Macintire.  
E.A.T.R. 60, Jan. 7, 1932, by Linthicum.  
E.T.F. 11.4-19, Sept. 15, 1932. A compilation of  
results from some of the above reports by Captain Barker.

Miscellaneous tests in which HS was used:

E.A.M.R.D. 68, Jan. 5, 1927, by Eldridge,  
Determination of Effectiveness of Chlorine  
as an Agent to Destroy HS in the Field.

III. THEORETICAL.

In order for the shell to be satisfactory, there should not be any premature bursts and the number of duds on impact should not be abnormally large. The burst of the shell on impact should be of a sufficiently high order to distribute the major portion of the liquid HS in the shell on the surface of the ground.

Casualties are produced by effects of HS vapor and by effects of liquid HS. If a sufficiently high vapor concentration is set up, casualties may be produced by respiratory effects where personnel are not protected by gas mask, and by vesicant effects when personnel are protected by gas mask but not protected by impregnated clothing. If personnel are protected by gas mask and standard issue of impregnated clothing, casualties from HS can only be produced by HS liquid drops of sufficient size to penetrate the impregnated clothing.

IV. EXPERIMENTAL.

The details of the ten tests conducted and results obtained are given in the test reports attached to the present report. The ten tests consisted of a preliminary test in which 133 shell were fired to determine the percentage of normal bursts on impact, and nine additional tests in which a total of 463 shell were used (189 for adjustment, 274 for effect), to determine the number of shell required to produce 50% casualties among personnel, when fired under different terrain and meteorological conditions.

A. How the Tests were Conducted.

In all tests, the shell were fired by the Sixth Field Artillery. In the preliminary tests the shell were fired, one at a time, for impact in open area at a range of about 5,200 yd., and the numbers of normal bursts were noted by observation from a tower.

In each of the nine tests which followed, the shell were fired at a range of about 5,200 yd. for impact on a target 100 yd. wide by 200 yd. long. The target was prepared by marking its four corners, and placing on its area paper panels or silhouettes, vapor-sampling machines and animals. The paper panels or silhouettes, used to show distribution of liquid HS, were placed at 10-yd. intervals over the target. Vapor-sampling machines were placed at nine positions on the target and at nine positions 30 yd. outside of the target. Animals, consisting of goats and rats, were placed at 20-yd. intervals over the entire target. Chart 1 attached to each test report shows the positions of the panels, vapor-sampling machines and animals on the target as prepared for each test.

The shell were fired by a battery of four howitzers which were adjusted with the use of 20 to 40 shell directed at a position outside of the target. After adjustment, fire was directed on the target and the shell for effect were fired as rapidly as practicable. In tests in which the target was located in open area fire was directed for equal distribution of bursts over the target by the battery commander, who was located on an observation tower on one flank of the target. In tests in which the target was in woods, the shell were fired for impact on its short axis.

The animals were exposed on the target for a period of about 25 min., which included the firing period. Vapor samples were taken at sampling positions during the period animals were exposed, and in most tests for additional periods following the removal of the animals from the target. After firing the shell, the paper panels or silhouettes were collected and graded for size of HS drops and density of liquid pattern, and the positions of impacts were located and charted.

In some tests, to determine persistence of HS on the target, vapor samples were taken at sampling positions on the day following the firing of the shell, and in all tests animals were exposed in shell craters for one or more 24-hr. periods, which varied in the individual tests from a few days after firing the shell to 17 days after.

The number of duds was noted by observation from a tower on one flank during firing in tests in which impact was in open area. In tests in which the target was located in woods, duds were determined by examining the crater produced by each impact for HS odor.

B. How Data were Interpreted in Terms of Man Casualties.

1. Paper Panels and Silhouettes.

The effectiveness of the liquid HS, as registered on paper panels or silhouettes, is dependent on the size of the HS drops and the density of the pattern produced by the fine drops.

a. For Personnel Protected by Gas Mask and Impregnated Clothing.

The panels or silhouettes showing HS drops of 0.5 mg. or more were tabulated and man casualties were estimated as follows, for man protected by gas mask and standard issue of impregnated clothing:

HS drops 0.5 to 1.0 mg. in size - 40% casualties.  
HS drops over 1.0 mg. in size - 100% casualties.

These figures are based on the results of laboratory tests given in E.A.T.R. 100.

b. For Personnel Protected by Gas Mask and Non-impregnated Clothing.

All paper panels or silhouettes were tabulated for pattern, using the gradings heavy, medium, light and trace, as given on pattern scale accompanying this report. From the results of laboratory tests given in memorandum of Oct. 22, 1931, to the Chief, Engineering Division from the Chief, Protective Development Division, it was estimated that personnel protected by gas mask and standard issue of nonimpregnated clothing would experience casualties as follows:

Pattern on : Casualties of HS liquid through standard issue of non-	
panel :	impregnated clothing
	%
H - heavy :	100
M - medium :	100
L - light :	80
T - trace :	60

## 2. Casualties Based on HS Vapor.

In the present report, respiratory effects of HS vapor on man were not considered, as estimated casualties in all tests were based on man protected by gas mask. The vesicant effects of HS vapor were considered for man without protection of impregnated clothing. In estimating vapor casualties due to vesicant effects, the valuation curve on Graph 1, attached to this report, was used. The points on this curve are based on the c.t. value, which is the product of vapor concentration in milligrams per liter and the exposure period in minutes. Points on this curve are plotted from data given in Pharmacological Report No. 318.

## 3. Casualties Based on Effects on Animals.

After the animals were removed from the target, they were placed under observation for a period of three weeks. Man casualties were estimated from the effects on animals on the basis of (1) all deaths from gas or shell, and (2) all skin lesions. All other animal casualties were disregarded and are not given any weight in figuring the effectiveness of the gas concentration set up.

## 4. Shell Required for Effective Results.

The number of shell required to produce 50% casualties was figured from the results of each test for personnel protected by gas mask only and for personnel protected by gas mask and standard impregnated clothing.

In figuring the number of shell required for personnel protected by gas mask only, an average was taken of the number of shell required based on sample data and on animal data.

For personnel protected by gas mask and standard impregnated clothing, the number of shell required was figured from panel data only.

##### 5. Effective Gas Concentration.

In the present report, a gas concentration is considered effective when 50% casualties are produced among personnel on exposure to the gas for a period of about 25 min. A man is considered a casualty when the injury is sufficiently severe to normally require evacuation for hospitalization.

##### C. The Percentage of Normal Bursts.

The numbers of normal bursts in each of the tests conducted are summarized in Table 1, which follows. The total number of shell given for each test, represents shell used for adjustment as well as those used for effect.

Table 1.

Number of Normal Bursts in Each Test

Test	Total shell used	Normal bursts	Duds or low-order bursts
Preliminary	133	111	22
A	60	52	8
B	80	69	11
C	69	57	12
D	47	35	12
E	39	33	6
F	38	31	7
G	40	32	8
H	40	24	16
I	50	42	8
Total	596	486	110

The results given in Table 1 show that about 81.5% of the shell fired produced normal bursts.

None of the shell used in the tests burst prematurely.

##### D. The Number of Shell Required for Effective Results.

The number of shell required for effective results when personnel are protected by gas mask only is dependent on terrain and meteorological conditions. In the tests conducted, the meteorological conditions were changed by conducting tests at different time periods

between sunrise and sunset which included the periods about 1 hr. after sunrise, about 4 hr. after sunrise and about 1 hr. before sunset. These periods may be considered as being representative of day and night conditions in that there are generally very little or no effects from rising convection air currents about 1 hr. before sunset and 1 hr. after sunrise so that air motion is representative of night. The tests conducted about 4 hr. after sunrise are representative of day conditions in that the HS vapor is diluted due to effects of rising air currents. The terrain conditions were changed by locating the target in open country in some of the tests and in woods in the remaining tests.

A summary of the nine tests conducted is given in table 2 which follows. The results in this table show that the number of shell required per 100-yd. sq. to produce 50% casualties when personnel are protected by gas mask only varies from 6 to 25, depending on meteorological and terrain conditions. When personnel are protected by gas mask and standard impregnated clothing, the number of shell required per 100-yd. sq. to produce 50% casualties varied from 25 to 180. The great variation in the results was not due to meteorological or terrain conditions but to the degree of moisture in the surface soil on the target. When personnel are protected by gas mask and standard impregnated clothing, gas casualties are only produced by the penetration of liquid HS through the impregnated clothing. In tests in which the soil was very dry, very few HS liquid drops were shown on paper panels distributed over the target, due to the absorption of a large percentage of the HS spray by the heavy dust cloud produced by each burst.

In the tests conducted, there were 5 in which the soil was classified as damp and which show an average of 38 shell required to produce 50% casualties. An average of results in the remaining four tests, in which the soil was dry, show 119 shell required to produce 50% casualties. The results of the 9 tests conducted show that when personnel are protected by gas mask and standard issue of impregnated clothing, about 38 shell per 100-yd. sq. are normally required to produce 50% casualties, but when sandy conditions exist and the soil is very dry over 100 shell per 100-yd. sq. are required to produce 50% casualties.

Table 2.

Summary of Tests Conducted and Results.

Test:	Date	Time	Terrain:	Soil	Wind	Air	Exposure	Shell required per 100-yd. sq.****	
:	:	of	:	:	ve-	temp.:	period	Protected by:	Protected by gas mask
:	:	day	:	:	locity:	:	***	gas mask	and impregnated cloth.
:	1932	:	:	:	m.p.h.:	°F.:	:	:	:
A	May 23	9:53 a.m.	Open	Damp	3.2	59	Firing and following	25	71
:	:	:	country	:	:	:	10 min.	:	:
B	June 11	9:05 a.m.	Ditto	Dry	5.3	68	Ditto	14	138
C	Aug. 4	6:35 a.m.	Ditto	Dry	1.5	81	Ditto	9	84
D	Aug. 29	5:23 p.m.	Ditto	Dry	2.9	83	Ditto	8	130
:	1933	:	:	:	:	:	:	:	:
E	May 18	5:21 p.m.	Ditto	Wet	4.0	71	Firing and following	14	20
:	:	:	:	:	:	:	15 min.	:	:
F	June 15	6:00 p.m.	Ditto	Dry	2.0	69	Firing and following	10	72
:	:	:	:	:	:	:	20 min.	:	:
G	July 6	6:10 p.m.	Woods	Damp	0*	83	Firing and following	6	25
:	:	:	:	:	:	:	22 min.	:	:
H	Aug. 11	5:46 p.m.	Ditto	Damp	0**	72	Ditto	8	44
I	Sept. 19	5:10 p.m.	Ditto	Damp	0**	72	Ditto	12	31

\*In open country near target the wind velocity was 4.0 m.p.h.

\*\*Only slight drift in open country near target, same as on target in woods.

\*\*\*Total exposure period was about 25 min. including the firing period.

\*\*\*\*Shell required per 100-yd. sq. is the number required to produce 50% casualties among personnel exposed to the fire.

Of the 596 shell fired 110, or approximately 18.5%, produced low order bursts or duds.  
A summary of the duds and low order bursts is given in Table 1 included in this report.

Average results for each meteorological and terrain condition are given in table 3. The results in this table show that when personnel are protected by gas mask only and the target is located in open country, the following number of shell are required per 100-yd. sq. to produce 50% casualties:

<u>Period</u>	<u>Temp. gradient</u>	<u>Shell required</u>
Between 1 hr. after sunrise and 1 hr. before sunset	Zero	About 20 shell
Between 1 hr. before sunset and 1 hr. after sunrise	Inversion	About 10 shell

When the target is located in woods and the shell are fired between 1 hr. before sunset and 1 hr. after sunrise, about 9 shell per 100-yd. sq. are required.

Table 3.

Results under Various Terrain  
and Meteorological Conditions

Test:	Time	Terrain:	Wind : : ve- : locity:	Air : : temp.:	Exposure : period	:No. of shell per 100-yd. sq.	
:	:	:	:	:	:	: Protected:	: Protected by gas
:	:	:	:	:	:	: by	: mask and standard
:	:	:	:	:	:	: gas mask	: impregnated clothing
:	:	: M.p.h.:	: of.	:	:	:	:
A,B	:About 4	:Open	: 3.2	: 59	:About 25 min.:	20	: 20 to 180
	:hr.after:	:country:	: to	: to	:including	:	:
	:sunrise :	:	: 5.3	: 68	:firing	:	:
C,D	:1 hr. be-	:Open	: 1.5	: 69	:Ditto	: 10	: 20 to 180
E,F	:fore sun-	:country:	: to	: to	:	:	:
	:set to 1:	:	: 4.0	: 81	:	:	:
	:hr.after:	:	:	:	:	:	:
	:sunrise :	:	:	:	:	:	:
G,H	:1 hr. Be-	:Woods	: 0	: 72	:Ditto	: 9	: 20 to 180
I	:fore sun-	:	:	: to	:	:	:
	:set to 1:	:	:	: 83	:	:	:
	:hr.after:	:	:	:	:	:	:
	:sunrise :	:	:	:	:	:	:

The results in table 3 are based on tests fired during late spring and summer at a time when the air temperature was between 59° and 83°F. and the wind velocity between 0 and 5.3 m.p.h. Theoretically, if the air temperature had been lower or the wind velocity higher, additional shell would have been required for effective results so that the figures given in table 3 only apply when the temperature is in excess of 59°F. and the wind velocity less than 5.3 m.p.h. Under less favorable meteorological conditions, additional shell would be required for equally effective results.

The results in table 3 showed little difference in the effectiveness of HS-filled howitzer shell when fired for impact in woods and in open country, under the same meteorological conditions. This was due to the fact that in the tests conducted there were very few tree impacts which produced air bursts so that the only advantage in woods in these tests was to reduce air travel. Reduced air travel results in a higher vapor concentration that persists for a longer period.

To obtain most effective results when using HS-filled 155-mm. howitzer shell, whether fired for impact in woods or open country, the time selected should be between sunset and sunrise following a warm day, at a time when the wind velocity is less than 4 m.p.h.

#### E. Persistence of HS on Target.

In two of the tests conducted, vapor samples were taken on the target at sampling positions on the day following the shelling and in all the tests animals were exposed in shell craters for a period of 24 hr. after various time periods which varied in the various tests from one to 17 days after the target was shelled.

Results showed the presence of HS vapor on the target, on the day following shelling, in a sufficiently strong concentration to prevent the target area being occupied for a period of 3 or 4 hr. by personnel without complete gas protection. The gas concentration was not strong enough to require personnel to mask when exposed only for the short period required to cross the impact areas.

The persistence of liquid HS in shell craters is shown by animal data given in table 4, which follows. The results show that in some tests there were no animal casualties after the third day, and in other tests animal casualties were produced for a period in excess of 17 days after firing the shell. The variations in these results were probably due to the condition of the ground at the time the area was shelled and meteorological conditions which followed. The results indicate that unless the HS in shell craters is neutralized, casualties may be produced if the impact area is occupied in warm weather, within 17 days after being shelled, by personnel without

complete gas protection.

Table 4.

Persistence of HS in Shell Craters.

<u>Test : Results of animal tests on exposure for a period of 24 hr.</u>			
	<u>: Days after target was shelled</u>	<u>: Did animals show casualty</u>	<u>: effects - yes or no</u>
A	2	:	yes
	8	:	no
B	2	:	yes
	8	:	yes
	12	:	yes
	17	:	yes
C	2	:	yes
	6	:	yes
D	6	:	no
	8	:	no
E	4	:	yes
	10	:	no
F	1	:	yes
	4	:	yes
G	3	:	no
	6	:	no
H	4	:	yes
I	6	:	yes

V. DISCUSSION.

A. Suitability of Remaining Shell for Service.

In tests conducted, the shell showed about 18% duds and low-order bursts but there were no premature bursts in the firing. The number of duds and low-order bursts was abnormally large. It is understood that the total War Reserve of HS-filled 155-mm. howitzer shells in the continental limits of the United States totals about 6,623, of which those fired in these tests are representative. Since these are the only shells of this type available for immediate use and they are apparently not dangerous to use, they should be retained in the War Reserve.

B. Future Tests of HS-Filled 155-mm. Howitzer Shell.

It is believed that a test should be conducted using 155-mm. howitzer shell filled with HS to comply with present standard specifications to compare results with the present tests.

VI. CONCLUSIONS.

It is concluded that:

1. When the HS-filled 155-mm. howitzer shell now in War Reserve are equipped with the Mk. III fuze and fired for impact burst at a range of about 5,200 yd., approximately 18% of the shell may be expected to be duds or produce low-order bursts.

2. The shell represented by those tested should be retained for future service use.

3. The following number of shell per 100-yd.sq. are required to produce 50% casualties when personnel are protected by gas mask only, the shell are fired when the temperature is above 59°F. and the wind is not appreciably above 5 m.p.h. on the impact area:

a. When fired within the period between one hour after sunrise and one hour before sunset - about 20 shell.

b. When fired within the period between one hour before sunset and one hour after sunrise - about 10 shell.

4. The following number of shell per 100-yd. sq. are required to produce 50% casualties when personnel are protected by gas mask and standard impregnated clothing and the temperature is above the freezing point of HS:

a. Under normal soil conditions - about 38 shell.

b. When the surface soil is dry and sandy -  
over 100 shell.

VII. RECOMMENDATIONS.

It is recommended that:

1. The remaining HS-filled 155-mm. howitzer shell in War Reserve be retained for service.

2. A test be conducted using HS-filled 155-mm. howitzer shell meeting present standard specifications for the purpose of comparing the casualty-producing effects with those obtained in the tests covered by this report.

REVIEWER'S NOTE

It is believed that the fundamental data on which the interpretation of field test results are based are insufficient and unreliable for the purpose for which they have been used and that such data as exist have been improperly interpreted. This applies particularly to the interpretation of vapor concentration data and panel data. It is also believed that the assumption of direct proportionality between shell bursts and casualties for the entire range between 0 and 100% casualties is open to serious objection especially for the higher percentages. In extenuation it may be said that reliable and adequate basic data do not exist and their procurement presents almost insuperable difficulties, and that the correct relationship between shell bursts and casualties, for the entire range of casualties, involves a rigorous mathematical analysis which is not now available. In view of these facts it should be considered that the conclusions and recommendations of this report are not adequately substantiated.

C.A.R.

Submitted:

B. G. Macintire  
B. G. Macintire, \*  
Test Section,  
Munitions Development Division.

• Author.

Work started: Feb. 16, 1932.  
Work completed: Oct. 10, 1933.

155-mm. Shell Mk. II (How.), HS-  
Filled; Serviceability of War  
Reserve Shell and Quantities of  
Ammunition Required to Produce  
50% Casualties on Personnel.

E.A.T.R. 172.

Projects: C5, Item 2 (1932) obsolete  
A 1.1-lb.

8 copies made)  
Typed: dmb)

Supervised:

Charles E. Loucks  
Charles E. Loucks,  
Captain, C.W.S.,  
Munitions Dev. Division.

Reviewed:

Charles A. Rouiller  
Charles A. Rouiller, JUL 11 1935  
Information Division.

Approval recommended:

Charles E. Loucks  
Charles E. Loucks,  
Captain, C.W.S.,  
Chief, Munitions Dev. Division.

July 17, 1935

Approved. This approval includes approval of the reviewer's note which is concurred in and with the understanding that this report is considered incomplete and that, at a later date when sufficient data becomes available, the entire report will be revised in accordance therewith.

E. Montgomery  
E. MONTGOMERY,  
Major, C.W.S.,  
Technical Director.

Appendix A

Report of Test of HS-Filled 155-mm.  
Shell from War Reserve.

(February 16 and 17,  
1932.)

REPORT OF TEST  
OF  
HS-FILLED 155-mm. SHELL FROM WAR RESERVE

(February 16 and 17, 1932)

1. Thirty-six gas shell, Mk. II, loaded with HS for 155-mm. howitzer, were taken at random from each of four lots in War Reserve to determine if they functioned normally when fired from service weapons, for impact burst, when using a range of about 5,000 yd. These tests were authorized in the first paragraph of the 3rd indorsement dated October 22, 1931, from Ordnance Officer, Washington, D.C., to Ordnance Officer, Edgewood Arsenal, file C.W.S. 471/211, as follows: "You are authorized to turn over to the Chemical Warfare Service 50 MVI-B Adapters and Boosters, and 200 Shell, Gas, HS, MII, for 155-mm. Howitzer for firing tests. Shells used in the firing tests will be fused with serviceable MIII P.D. fuzes. The functioning of the shell will be observed and reported to this office. Money value of ammunition expended in this test will be reported (see O.D. Order No. 8, dated January 12, 1931). If these shells are found to be satisfactory for an effective field concentration test, you will be authorized to issue an additional 500 upon request." Before the shell were fired, the distance the booster extended from the nose of the shell was measured, and the number of threads exposed on the boosters was counted. A few shell in each of the three lots could not be used on account of having distorted adapters which interfered with the assembly of the fuzes. In the fourth lot, the adapters were retapped before the shell were taken to the field so that the total 36 shell were fired. After firing all the shell, an examination of three duds found on top of the ground showed that failure to function was due in each case to a defective fuse. The following results were obtained from each of the four lots:

a. Results of Lot 3050-1.

Duds - 2. With 4 and 6 threads exposed respectively.  
Low order of bursts - 3 with 3, 4, and 7 threads exposed.  
Normal bursts - 31 with 3 to 6 threads exposed.

b. Results from Lot 35-1-14.

Duds - 1. With 8 threads exposed.  
Low order of bursts - 2 with 5 threads exposed each.  
Normal bursts - 28 with 3 to 8 threads exposed each.

c. Results from Lot 35-1-13.

Duds - 5. With 3, 5, 6, 6, and 7 threads exposed respectively. Low order of bursts - 3 with 3, 4, and 5 threads exposed respectively. Normal bursts - 26 with 3 to 7 threads exposed.

d. Results from Lot 35-1-16.

Duds - 4. With 4, 4, 5, and 7 threads exposed respectively. Low order of bursts - 2 with 4 threads exposed each. Normal bursts - 26 with 3 to 8 threads exposed.

Tables covering the results of all of the shell fired accompany this report.

2. Conclusions.

- a. The distance the booster extends from the nose of the shell has little or no effect on the order of bursts when not exceeding the distance equivalent to eight threads.
- b. The shell in War Reserve are satisfactory for use in tests to obtain vapor concentration data for HS-filled 155-mm. howitzer shell.

3. Recommendations.

- a. That in accordance with request in the 3rd paragraph of the 3rd indorsement dated October 22, 1931, from Ordnance Office, Washington, D.C., to Ordnance Officer, E.A., a proposed program of tests of the remaining 500 shell be prepared to include object and ranges, so that information will be available for the Ordnance Department to furnish the proper powder charges and so that the program can be incorporated in an Ordnance Committee Item on War Reserve Tests.
- b. In using these shell, that the adapters be retapped before the shell are taken to the field.

B.G. MACINTIRE,  
Chief, Field Test Department,  
Engineering Division.

Recommending Approval:

CHARLES E. LOUCKS,  
Captain, C.W.S.,  
Chief, Engineering Division.

Approval:

E. MONTGOMERY,  
Major, C.W.S.,  
Technical Director.

March 24, 1932.

Appendix "A"

Table No. 1

Shell, Gas, Mk II, Loaded with HS for 155-mm. Howitzer  
(February 17, 1932)

Lot 3050-1

Number :	Shell :	Weight :	Range :	Average Elevation :	Booster Lot Number :	Height :	Threads Exposed :	Firing Action :	Charge :	Burst :	Remarks *
		yd.	mils								
1	L	5100	400		13257-5	17/32	4	OK	4	OK	
2	L	5100	400		-5	11/16	6	"	4	"	
3	L	5100	400		-6	21/32	6	"	4	"	200-yd. short
4	L	5100	400		-5	11/16	6	"	4	"	
5	L	5100	400		-5	5/8	5	"	4	"	
6	L	5100	400		-6	21/32	6	"	4	"	
7	L	5100	400		-6	17/32	4	"	4	"	200-yd. over
8	L	5100	400		-4	5/8	5	"	4	"	
9	L	5100	400		-4	5/8	5	"	4	"	200-yd. over
10	L	5100	400		-5	1/2	3	"	4	"	
11	L	5100	400		-6	3/4	6	"	4	"	
12	L	5100	400		-5	17/32	4	"	4	"	200-yd. short
13	L	5100	400		-5	5/8	5	"	4	"	
14	L	5100	400		-5	3/4	6	"	4	"	
15	L	5100	400		-5	5/8	4	"	4	"	200-yd. over
16	L	5100	400		-5	1/2	3	"	4	"	
17	L	5100	400		-5	1/2	3	"	4	"	
18	L	5100	400		-7	11/16	6	"	4	"	
19	L	5100	400		-4	1/2	3	"	4	"	
20	L	5100	400		-5	9/32	2	"	4	"	100-yd. short
21	L	5100	400		-6	5/8	5	"	4	"	100-yd. over
22	L	5100	400		-5	7/8	7	"	4	low order	100-yd. over
23	L	5100	400		-6	5/8	4	"	4	OK	
24	L	5100	400		-4	5/8	4	"	4	"	
25	L	5100	400		-4	5/8	4	"	4	"	200-yd. over
26	L	5100	400		-6	21/32	5	"	4	"	
27	L	5100	400		-6	5/8	4	"	4	"	100-yd. short
28	L	5100	400		-4	5/8	4	"	4	"	
29	L	5100	400		-5	5/8	4	"	4	"	
30	L	5100	400		-4	1/2	3	"	4	low order	dud
31	L	5100	400		-11	5/8	4	"	4	"	200-yd. over
32	L	5100	400		-5	11/16	5	"	4	OK	
33	L	5100	400		-6	11/16	6	"	4	"	
34	L	5100	400		-5	5/8	4	"	4	dud	
35	L	5100	400		-5	23/32	6	"	4	dud	100-yd. short
36	L	5100	400		-6	1/2	3	"	4	OK	200-yd. over

\* Estimates

SUMMARYShellNumber of Threads Exposed

2 Duds  
3 Low order  
31 Normal bursts

4 and 6  
7, 3, and 4  
3 to 6

Values given in column headed "Average Elevation", were obtained from the Battery Commander who did not record the individual elevation settings for each shot. The values do however, represent approximately the average elevation for the lot designated and at the time fired.

Shell, Gas, Mk II, Loaded with BS for 155-mm. Howitzer  
(February 17, 1932)

Number	Zone	Average	Booster	Height	Threads	Firing	Burst	Remarks	
of Shell	Weight	Range	Elevation	Lot Number	of Booster	Exposed	Action	Charge	
		yd.	mils						
1	3	5100	396	13257-	25/32	8	OK	4	Dud
2	3	5100	396	-5	7/8	8	"	4	OK
3	3	5100	396	-1	5/8	5	"	4	Low order
4	3	5100	396		21/32	5	"	4	OK
5	3	5100	396	-5	1/2	4	"	4	"
6	3	5100	396	-5	13/32	3	"	4	"
7	3	5100	396	-4	17/32	4	"	4	"
8	3	5100	396	-6	5/8	5	"	4	Low order
9	3	5100	396	-7	5/8	5	"	4	OK
10	3	5100	396	-5	5/8	5			Fuse would not assemble (adapter distorted)
11	3	5100	396	-6	19/32	5	OK	4	OK
12	3	5100	396	-1	19/32	5	"	4	"
13	3	5100	396	-6	5/8	5	"	4	"
14	3	5100	396	-6	11/16	6	"	4	"
15	3	5100	396	13257-	13/32	3	"	4	"
16	3	5100	396	-4	11/16	6	"	4	"
17	3	5100	396	-5	13/32	3	"	4	"
18	3	5100	396	-7	9/16	5	"	4	"
19	3	5100	396	-5	5/8	5	"	4	"
20	3	5100	396	-7	17/32	4	"	4	"
21	3	5100	396	-6	3/4	7	"	4	"
22	3	5100	396	13257-	11/16	5	"	4	"
23	3	5100	396	-4	25/32	7	"	4	"
24	3	5100	396	-6	23/32	6	"	4	"
25	3	5100	396	-6	3/4	6	"	4	"
26	3	5100	396	-5	17/32	4	"	4	"
27	3	5100	396	-7	1/2	4			Fuse would not assemble (adapter distorted)
28	3	5100	396	-4	3/4	6	OK	4	OK
29	3	5100	396	-1	17/32	5			Fuse would not assemble (adapter distorted)
30	3	5100	396	-7	17/32	5	OK	4	OK
31	3	5100	396	-6	17/32	5	"	4	"
32	3	5100	396	-6	17/32	6	"	4	"
33	3	5100	396	-4	13/32	3			Fuse would not assemble (adapter distorted)
34	3	5100	396	-4	3/4	7	OK	4	OK
35	3	5100	396	13257-	1/2	4			Fuse would not assemble (adapter distorted)
36	3	5100	396	-4	3/4	7	OK	4	OK

## SUMMARY

### Number of Threads

1	Dad	8
2	Low order	5
28	Normal bursts	3 to 6

Values given in column headed "Average Elevation", were obtained from the Battery Commander who did not record the individual elevation settings for each shot. The values do however, represent approximately the average elevation for the lot designated and at the time fired.

Table No. 3

Shell, Gas, Mk II, Loaded with HS for 155-mm. Howitzer  
(February 15, 1932)

Lot 35-1-13												
Number	Zone	Average	Booster	Height	Threads	Firing	Powder					
of Shell	Weight	Range	Elevation	Lot Number	of Booster	Exposed	Action	lot	Charge	Durst	Remarks *	
	yd.	mils										
1	2	5100	408	13257-11	5/8	5	OK	1798	4	OK		
2	3	5100	408	-6	5/16	4	"	"	4	"		
3	2	5100	408	-6	1/2	4	"	"	4	"		
4	2	5100	408	-11	9/16	4	"	"	4	"		
5	2	5100	408	-5	5/8	5	"	"	4	"		
6	2	5100	408	-7	1/2	4	"	"	4	Low order		
7	2	5100	408	-11	1/2	4	"	"	4	OK		
8	2	5100	408	-5	15/32	4	"	"	4	"		
9	2	5100	408	-7	19/32	5	"	"	4	"		
10	2	5100	408	-10	13/32	3	"	"	4	Dud		
11	2	5100	408	None	19/32	5	"	"	4	"	200-yd. short	
12	2	5100	408	13257-4	5/8	5	"	"	4	OK		
13	2	5100	408	-5	3/4	7	"	"	4	"		
14	2	5100	408	-6	1/2	4	"	"	4	"	300-yd. short	
15	2	5100	408	-10	7/16	3	"	"	4	Low order		
16	2	5100	408	-6	9/16	5	"	"	4	OK		
17	2	5100	408	-11	21/32	6	"	"	4	"	200-yd. short	
18	2	5100	408	-10	1/4	1	"	"	4	"		
19	2	5100	408	-6	5/8	5	"	"	4	"		
20	2	5100	408	-5	1/2	4	"	"	4	"		
21	2	5100	408	-5	3/4	7	"	"	4	"	150-yd. short	
22	2	5100	408	-4	5/8	5	"	"	4	"		
23	2	5100	408	13257-	7/16	3	"	"	4	"		
24	2	5100	408	-5	3/4	7	"	"		Fuse could not be assembled (adapter dis- torted)		
25	2	5100	408	-1	5/8	5	OK	"	4	Low order		
26	2	5100	408	-6	5/8	5	"	"	4	OK		
27	2	5100	408	-6	11/16	6	"	"	4	Dud		
28	2	5100	408	-6	5/8	5	"	"	4	OK		
29	2	5100	408	-4	5/8	5	"	"	4	"		
30	2	5100	408	-5	1/2	4	"	"	4	"		
31	2	5100	408	-5	5/8	5	"	"	4	Dud		
32	2	5100	408	-6	13/32	3	"	"	4	OK		
33	2	5100	408	-6	5/8	5	"	"	4	"		
34	2	5100	408	-11	1/2	4	"	"		Fuse could not be assembled (adapter dis- torted)		
35	2	5100	408	-5	5/8	5	OK	"	4	OK		
36	2	5100	408	-5	3/4	7	"	"	4	Dud		

\* Estimates

SUMMARY

<u>Shell</u>	<u>Number of Threads Exposed</u>
5 Duds	3, 5, 6, 5, and 7
3 Low order of bursts	4, 3, and 5
26 Normal bursts	3 to 7

Values given in column headed "Average Elevation", were obtained from the Battery Commander who did not record the individual elevation settings for each shot. The values do however, represent approximately the average elevation for the lot designated and at the time fired.

Table No. 4

Shell, Gas, Mk II, Loaded with HS for 155-mm. Howitzer  
(February 17, 1932)

Lot 35-1-16												
Number	Zone	Average	Booster	Height	Threads	Firing						
of Shell	Weight	Range	Elevation	Lot Number	of Booster	Exposed	Action	Charge		Burst		Remarks*
		yd.	mils									
1	:light	:5100	:410	:13257-5	:21/32	:5	:	:	:	:Fuse would not assem- :ble(adapter distorted)	:	:
2	: "	:5100	:410	: -6	:21/32	:5	:OK	:4	:	:OK	:	:
3	: "	:5100	:410	: -6	:17/32	:4	: "	:4	:	: "	:	:
4	: "	:5100	:410	: -4	:15/32	:3	: "	:4	:	: "	:	:
5	: "	:5100	:410	: -5	:19/32	:5	: "	:4	:	: "	:	:Short
6	: "	:5100	:410	: -6	:25/32	:7	: "	:4	:	:Dud	:	: "
7	: "	:5100	:410	: -5	:5/8	:5	:	:	:	:Fuse would not assem- :ble(adapter distorted)	:	:
8	: "	:5100	:410	: -4	:5/8	:5	:	:	:	:Fuse would not assem- :ble(adapter distorted)	:	:
9	: "	:5100	:410	: -5	:1/2	:4	:OK	:4	:	:Low order	:	:
10	: "	:5100	:410	: -4	:17/32	:4	: "	:4	:	:OK	:	:
11	: "	:5100	:410	: -4	:5/8	:5	: "	:4	:	: "	:	:
12	: "	:5100	:410	: -4	:5/8	:5	: "	:4	:	: "	:	:
13	: "	:5100	:410	: -6	:9/16	:4	: "	:4	:	: "	:	:
14	: "	:5100	:410	: -6	:15/32	:3	:	:	:	: "	:	:
15	: "	:5100	:410	: -5	:5/8	:5	:OK	:4	:	: "	:	:Over
16	: "	:5100	:410	: -6	:9/16	:4	: "	:4	:	: "	:	:
17	: "	:5100	:410	: -4	:19/32	:5	: "	:4	:	: "	:	:
18	: "	:5100	:410	: -5	:5/8	:5	: "	:4	:	: "	:	:
19	: "	:5100	:410	: -4	:5/8	:5	: "	:4	:	: "	:	:
20	: "	:5100	:410	: -6	:1/2	:4	: "	:4	:	: "	:	:
21	: "	:5100	:410	: -5	:1/2	:4	: "	:4	:	: "	:	:
22	: "	:5100	:410	: -4	:9/16	:4	: "	:4	:	:Dud	:	:Over
23	: "	:5100	:410	: -5	:1/2	:4	: "	:4	:	: "	:	:
24	: "	:5100	:410	: -5	:9/16	:4	: "	:	:	:OK	:	:
25	: "	:5100	:410	: -5	:17/32	:4	: "	:4	:	:Dud	:	:Short
26	:1 zone	:5100	:410	: -4	:17/32	:4	:	:	:	:Low order	:	:
27	: "	:5100	:410	: -5	:25/32	:7	:OK	:4	:	:OK	:	:
28	:light	:5100	:410	: -6	:7/8	:3	: "	:4	:	: "	:	:
29	: "	:5100	:410	: -6	:13/32	:3	: "	:4	:	: "	:	:
30	: "	:5100	:410	: -4	:5/8	:5	: "	:4	:	: "	:	:
31	:1 zone	:5100	:410	: -5	:3/4	:6	: "	:4	:	: "	:	:
32	:light	:5100	:410	: -6	:19/32	:5	: "	:4	:	:Dud	:	:Soft ground
33	: "	:5100	:410	: -5	:23/32	:6	: "	:4	:	:OK	:	:
34	:1 zone	:5100	:410	: -5	:23/32	:6	:	:	:	:Fuse would not assem- :ble(adapter distorted)	:	:
35	:light	:5100	:410	: -5	:19/32	:4	:OK	:4	:	:OK	:	:
36	: "	:5100	:410	: -5	:13/16	:7	: "	:4	:	: "	:	:

\* The shorts and overs recorded in this column represent estimates amounting to 100 to 200 yards.

## SUMMARY

## Shell

## Number of Threads Exposed

4 Duds	4, 4, 5, and 7
2 Low order of bursts	4 and 4
26 Normal bursts	3 to 8

values given in column headed "Average Elevation", were obtained from the Battery Commander who did not record the individual elevation settings for each shot. The values do however, represent approximately the average elevation for the lot designated and at the time fired.

Appendix B

Report of Test of HS-Filled 155-mm. Howitzer Shell.  
Test A - May 25, 1932.

### c. Meteorological Conditions.

The following meteorological conditions prevailed during the firing period and the periods following during which vapor samples were taken and animals were exposed on the target area:

Date	May 23, 1932			
Time	- 9:53 to 10:20 a.m. - 10:20 to 11:10 a.m. - 11:10 a.m. to 3:10			
Air temperature °F.	- 59	- 60	- 60 to 67	
Ground temperature °F.	- 74 to 77	- 77 to 83	- 83 to 96	
Ground condition	- damp	- damp	- damp	
Relative humidity %	- 64 to 60	- 60 to 58	- 58 to 50	
Wind velocity m.p.h.	- 3.2	- 5.0	- 5.2	
Wind direction	- NE to SE to S to SW	- SE to S	- S to SW	
Sky	- Hazy to clear	- Hazy to clear	- clear	

Date	- May 24, 1932	- May 25, 1932
Time	- 10:35 a.m. to 2:35 p.m.	- 10:30 a.m. to 2:30 p.m.
Air temperature °F.	- 67 to 74	- 72 to 79
Ground temperature °F.	- 83 to 96	- 85 to 99
Ground condition	- dry	- dry
Relative humidity %	- 90 to 76	- 90 to 64
Wind velocity m.p.h.	- 5.3	- 7.5
Sky	- clear	- clear

## 7. Results.

### a. Liquid HS.

(1) Size of HS Drops. The distribution of liquid HS by shell burst, was registered by means of paper panels eight inches square, placed flat on the ground over the target area, at intervals of ten yards, and also by tin plates of the same size, having a coating sensitive to HS liquid, which were placed beside the paper panels. The tin plates proved unsatisfactory due to difficulty in detecting the very fine drops of HS. The results on the paper panels were summarized for density of pattern and for size of drops in excess of 0.05 mg. The panels having drops in excess of 0.05 mg. are tabulated in the following table:

Table No. 1.

Size of HS Drops

No. of drops per panel	No. of panels with HS drops in excess of 0.05 mg.					
	.05 to .1 mg.	0.101 to 0.5 mg.	.501 to 1.0 mg.	1.01 to 3.0 mg.	Over 3.0 mg.	
1	1	3	7	3	7	
2 to 10	9	19	12	12	5	
11 to 20	3	2	1			
Over 20	4					

Total panels having drops of .05 mg. or greater - 33  
Total panels exposed on target area - 231

(2) Estimated Man Casualties from Liquid HS.

(a) Man Protected with Gas Mask Only. The paper panels were tabulated for density of pattern produced by the liquid HS, using the gradings heavy, medium, light, and trace, corresponding to the scale of gradings shown in the photostatic copy attached to this report. The panel gradings are tabulated in Table 2, which follows, together with estimated man casualties:

Table No. 2.

Estimated Man Casualties on Target Area from  
Liquid HS

Panel pattern	Panels contaminated		Estimated man casualties when man is protected with gas mask
	No.	Per cent of total	
			%
Heavy	14	6.1	6.1
Medium	18	7.8	7.8
Light	25	10.9	8.7
Trace	41	17.8	10.7
No. HS	132	57.4	-
Total	230	100.0	38.3

The position of shell craters and estimated man casualties from liquid HS are shown on Chart 2.

Note: The estimated man casualties, as given in Table 2, above, are based on estimates furnished by the Protective Development Division in memorandum of Oct. 22, 1931, to the Engineering Division, as follows:

Panel : Estimated man casualties through standard pattern: issue of unimpregnated clothing	
	%
Heavy :	100
Medium:	100
Light :	80
Trace :	60

(b) Man Protected with Gas Mask and Standard Impregnated Clothing.

The paper panels (8 in. by 8 in.) were tabulated for number and size of HS drops in excess of 0.5 mg. The results of the tabulation together with estimated man casualties are given in the following table:

Table No. 3.

Size of HS drops	No. of panels	Estimated man casualties when man is protected with gas mask and impregnated clothing	
mg.		% per panel	% on entire area
0.5 to 1.0	6	40	1.0
Over 1.0	19	100	8.2
Total	25		9.2

Note: The percent estimated man casualties given in the last column is based on laboratory tests by the Protective Development Division as given in memorandum of August 6, 1931, to the Technical Director. Laboratory tests showed that liquid HS penetrated two layers of standard protective clothing and produced casualties as follows:

HS drops 0.5 mg. in size - 40% man casualties  
 HS " 0.7 " " " - 80% " "  
 HS " 0.8 " " " -100% " "

b. Estimated Man Casualties from HS Vapor When Man is Protected with Gas Mask Only.

Sampling machines were placed to take vapor samples at positions indicated on Chart No. 1. In each of the tables which follow, representing different sampling periods, the sampling positions used are designated. The HS vapor concentration, c.t. value, and per cent estimated man casualties, as estimated from the vapor concentrations, are also included in each of the tables. The c.t. value is equal to the vapor concentration in milligrams per liter times the exposure period in minutes. Estimated man casualties are based on the c.t. value using the valuation curve given in Graph No. 1, attached to this report. The per cent estimated man casualties in the following tables represent man protected with gas mask but without the protection of impregnated clothing:

(1) On the Target Area.

(a) Firing Period Plus Ten Minutes.

Table No. 4.

Sampling position:	Elevation of sample	Vol. of air sampled	Sampling period	HS sampled	Vapor concn.	c.t. value	Estimated man casualties when man is protected with gas mask only
:	ft.	liters	min.	mg.	mg./l.	:	%
F	0	824	23	0.4	.0005	.012	17
K	1	954	27	0.4	.0004	.011	15
O	0	1126	31	1.2	.0011	.034	45
G	0	1054	29	0.0	.0	.0	0
L*	1	608	34	2.5	.0041	.14	100
P	0	1342	37	15.0	.0112	.41	100

46 Av.

\*The sample at position L, does not represent the whole sampling period as the sampling machine was put out of commission due to effects of shell fire.

(b) Fifty Minute Period, Beginning Ten  
Minutes after Cessation of Fire.

Table No. 5.

Sampling position:	Elevation of sample	Vol. of air sampled	Sampling period	HS sampled	Vapor concn.	c.t. value	Estimated casualties when man is protected with gas mask only
:	ft.	liters	min.	mg.	mg./l.	:	%
F	0	1932	54	0.0	.0	-	-
K	1	1940	55	0.6	.0003	.016	25
O	0	1966	55	0.8	.0004	.022	33
G	0	930	52	1.0	.0011	.057	64
P	0	1966	55	6.1	.0031	.170	100
							44 Av.

(c) Firing Period Plus One Hour.

Table No. 6.

Sampling position:	Elevation of sample	Vol. of air sampled	Sampling period	HS sampled	Vapor concn.	c.t. value	Estimated casualties when man is protected with gas mask only
:	ft.	liters	min.	mg.	mg./l.	:	%
F	0	2756	77	0.4	.0002	.012	15
K	1	2894	82	1.0	.0003	.027	39
O	0	3092	86	2.0	.0006	.052	60
G	0	1984	81	1.0	.0005	.041	51
L	1	1608	34	3.1	.0019	.064	69
P	0	3308	92	21.1	.0063	.58	100
B	1	2640	75	0	0	0	0
S	1	1670	46	1.9	.0011	.051	69
T	1	4436	122	59.2	.0133	1.68	100

(d) Four Hour Period Beginning One Hour  
After Cessation of Fire.

Table No. 7.

Sampling position:	Elevation of sample	Vol. of air sampled	Sampling period	HS sampled	Vapor concn.	c.t. value	Estimated casualties when man is protected with gas mask only
:	ft.	liters	min.	mg.	mg./l.	:	%
F	0	8540	235	0	0	0	0
K	1	8360	230	0	0	0	0
O	0	8120	227	:	:	:	Sample lost
G	0	8280	231	0	0	0	0
L	1	4000	220	1.7	.0004	.088	86
L	1	4000	220	1.0	.0003	.066	70
L	2	4000	220	1.7	.0004	.088	86
L	4	4000	220	lost	-	-	-
B	1	8480	240	0	0	0	0
T	1	6620	185	4.2	.00063	.11	100
P	0	7020	196	0.4	.00006	.012	16

(e) Four Hour Period on Day Following Test:  
(10:30 a.m. to 2:30 p.m., May 24, 1932).

Table No. 8.

Sampling position:	Elevation of sample	Vol. of air sampled	Sampling period	HS sampled	Vapor concn.	c.t. value	Estimated casualties when man is protected with gas mask only
Stake No.:	ft.	liters	min.	mg.	mg./l.	:	%
172	1	4290	240	0.0	.0000	.00	0
"	2	"	"	0.0	.0000	.00	0
"	4	"	"	0.0	.0000	.00	0
209	1	4270	239	1.2	.0003	.072	75
"	2	"	"	0.0	.0000	.00	0
"	4	"	"	0.0	.0000	.00	0
110	1	4260	235	0.0	.0000	.00	0
"	2	"	"	"	"	"	"
"	4	"	"	"	"	"	"

(f) Four Hour Period 2nd Day Following Test:  
(10:30 a.m. to 2:30 p.m., May 25, 1932).

Table No. 9.

Sampling position:	Elevation of sample	Vol. of air sampled	Sampling period	HS sampled	Vapor concn.	c.t. value	Estimated casualties when man is protected with gas mask only
Stake No.	ft.	liters	min.	mg.	mg./l.		%
110	1	4360	240	0.0	.0000	.00	0
"	2	"	"	"	"	"	0
"	4	"	"	"	"	"	0
172	1	4260	238	0.0	.0000	.00	0
"	2	"	"	"	"	"	0
"	4	"	"	"	"	"	0
216	1	4260	235	0.0	.0000	.00	0
"	2	"	"	"	"	"	0
"	4	"	"	"	"	"	0

(2) Outside of Target Area.

(a) Firing Period Plus One Hour.

Table No. 10.

Sampling position:	Elevation of sample	Volume of air sampled	Sampling period	HS sampled	Vapor concn.	c.t. value	Estimated casualties when man is protected with gas mask only
	ft.	liters	min.	mg.	mg./l.		%
E	1	1420	79	0.0	.0000	0	0
E	2	"	"	0.0	.0000	0	0
E	4	"	"	0.0	.0000	0	0
H	1	1490	82	lost	.0000	0	0
"	2	"	"	0.4	.0003	.024	35
"	4	"	"	0.8	.0006	.049	60
J	1	1480	84	0.0	.0000	.00	0
"	2	"	"	0.6	.0004	.034	45
"	4	"	"	0.0	.0000	.00	0
M	1	1590	89	1.7	.0011	.098	92
"	2	"	"	1.0	.0006	.053	62
"	4	"	"	1.0	.0006	.053	62

Table 10 (Cont'd.)

Sampling position:	Elevation of sample	Vol. of air sampled	Sampling period	HS Sampled	Vapor: concn.	c.t. value	Estimated man casualties when man is protected with gas mask only
:	ft.	liters	min.	mg.	mg./l.	:	%
N	1	1600	88	0.6	.0004	.035	47
"	2	"	"	0.0	.0000	.00	0
"	4	"	"	1.2	.0007	.061	66
Q	1	1670	92	1.0	.0006	.055	62
"	2	"	"	1.0	.0006	.055	62
"	4	"	"	0.8	.0005	.046	55
R	1	835	46	0.6	.0007	.032	44
"	2	"	"	0.8	.0010	.046	55
"	4	"	"	0.4	.0005	.023	33
U	1	2218	122	0.0	.0000	.00	0
"	2	"	"	0.0	.0000	.00	0
"	4	"	"	1.2	.0005	.061	66
A	1	1320	75	1.8	.0013	.10	73
"	2	"	"	1.9	.0014	.11	100
"	4	"	"	0.4	.0003	.02	30

(b) Four Hour Period Beginning One Hour After Cessation of Fire.

Table No. 11.

Sampling position:	Elevation of sample	Vol. of air sampled	Sampling period	HS Sampled	Vapor: concn.	c.t. value	Estimated man casualties when man is protected with gas mask only
:	ft.	liters	min.	mg.	mg./l.	:	%
H	1	4140	231	0.6	.00014	.032	46
"	2	"	"	0.0	.0000	.00	0
"	4	"	"	0.0	.0000	.00	0
M	1	3940	220	1.0	.00025	.055	63
"	2	"	"	1.0	.00025	.055	63
"	4	"	"	0.6	.00015	.033	47

c. Estimated Man Casualties Based on Effects on Animals.

Animals were placed on the target area and at positions downwind from the target area to determine effects of the gas concentration set up and how long the liquid HS persisted on the impact area. The position of the animals, as exposed during the various exposure periods, is shown on Charts 1, 7, 8, 9, and 10. The animal casualties and estimated man casualties, are given in the tables which follow. The man casualties are estimates made by the Medical Research Division which observed and studied the effects on all animals exposed. Estimated man casualties, based on effects on animals are shown on Charts 11, 12, 12A, and 13. In the tables, the following symbols are used to designate the nature of the animal casualty:

L - Gross pathology of lung.  
R - Respiratory symptoms.  
S - First degree skin burn.  
S<sub>2</sub> - Second " " "  
S<sub>3</sub> - Third " " "  
E - Simple conjunctivitis  
E<sub>2</sub> - Purulent "

In all tables, per cent estimated man casualties based on effects on animals are given as 0 or 100%, depending entirely on whether each animal represented a positive result or not.

(1) On Target Area.

(a) Firing Period and Following Ten Minutes.

During the firing period and following ten minutes, eighteen rats and sixteen goats were exposed on the target area. Animal casualties and estimated man casualties, when man is protected with gas mask only, are tabulated in Tables 12A and 12B, below. The position of the animals on the target area, is shown on Chart 7.

Table No. 12A.

RATS					
Position: of stake	Nature : of : casualty	Severity : of : casualty	Remarks	Estimated man casualties when man is protected with gas mask only	
55	: E <sub>2</sub> S	: Severe	: Burns on feet. Casualty in: : 24 hr.	: 100%	
91	: E	: Moderate	: Casualty in 24 hr.	: 0	
99	: ELS	: Death	: Burns on feet. Casualty in: : 6 hr. Death in 4 days..	: 100	
139	: ELS	: "	: Burns on feet. Casualty in: : 12 hr. Death in 4 days..	: 100	
179	: EL	: "	: Casualty in 12 hr. Death : in 7 days.	: 100	
183	: E <sub>2</sub> S	: Severe	: Burns on feet. Casualty in : 6 hr.	: 100	
227	: ES	: Moderate	: Burns on feet. Casualty in : 18 hr.	: 100	
Per cent Casualties			: Rats 39%	: Man 33%	

Table No. 12B.

GOATS					
Position: of stake	Nature : of : casualty	Severity : of : casualty	Remarks	Estimated man casualties when man is protected with gas mask only	
73	: E <sup>R</sup>	: Moderate	: Casualty in 12 hr.	: 0	
113	: R	: Light	: " " 6 hr.	: 0	
117	: ES	: Light	: Burns around abdomen. : Casualty in 8 hr.	: 100	
121	: ESL	: Death	: Burns around abdomen. : Casualty in 12 hr. Death : in 6 days.	: 100	
161	: S	: Light	: Casualty in 8 hr.	: 0	
206	: E <sub>2</sub> LS	: Death	: Burns around abdomen. : Casualty in 12 hr. Death : in 16 days.	: 100	
Per cent Casualties			: Goats - 37%	: Man 19%	

Per cent man casualties based on rats and goats - 26%

(b) Firing Period and Following Hour

During the firing period and following hour, fifteen rats and seventeen goats were exposed. Animal casualties and corresponding estimated man casualties are tabulated below. The position of the animals on the target area is shown on Chart 8 and the position of estimated man casualties is shown on Chart 12.

Table No. 13A.

RATS				
Position: of stake	Nature: of casualty	Severity: of casualty	Remarks	Estimated man casualties when man is protected with gas mask only
67	E	Moderate	Casualty in 6 to 12 hr.	0
71	ER	Light	" " " " " "	0
111	EL	Death	Casualty in 6 to 12 hr.	100
			Death in 6 days	
119	SE	Light	Burns on feet. Casualty in:	100
			12 hr.	
155	E	Light	Casualty in 12 hr.	0
163	S	Moderate	Burns on feet and ears.	100
			Casualty in 12 hr.	
203	ERS <sub>2</sub>	Severe	Burns on feet. Casualty 6	100
			to 12 hr.	
Per cent casualties			Rats - 46%	Man 26%

Table No. 13B.

GOATS					
Position: of stake	Nature : of casualty	Severity : of casualty	Remarks	Estimated man casualties when man is protected with gas mask only	
45	: R	: Light	: Casualty in 6 hr.	:	0
97	: ELS	: Death	: Burns on abdomen.	:	100
	:	:	: Casualty in 12 hr. Death	:	
	:	:	: in 4 days	:	
141	: RS	: Severe	: Burns on ears. Casualty	:	100
	:	:	: in 12 hr.	:	
181	: ER	: "	: Casualty in 12 hr.	:	100
185	: ERS	: "	: Burns on abdomen and ears.	:	100
	:	:	: Casualty in 12 hr.	:	
225	: E <sub>2</sub> RS	: "	: Burns on abdomen and ears.	:	100
	:	:	: Casualty in 12 hr.	:	
229	: EL	: Death	: Casualty in 6 to 12 hr.	:	100
	:	:	: Death in 7 days.	:	
Per cent Casualties			: Goats - 41%	: Man - 35%	

Per cent Man Casualties based on Rats and Goats - 31%

(c) Four Hours, from 2nd to 6th Hour After Firing.

During the four hour period following the first hour after firing, fifteen rats and nine goats were exposed. Animal casualties are tabulated below, also estimated man casualties. The position of the animals on the target area is shown on Chart 9, and the position of estimated man casualties is shown on Chart 12A.

Table No. 14A.

RATS					
Position :	Nature :	Severity :	Remarks	Estimated man	
of :	of :	of :		casualties when	
stake :	casualty :	casualty :		man is protected	
:	:	:		with gas mask only	
51	:	E	: Moderate : Casualty in 6 to 12 hr.	: 0	
71	:	E	: " " " " " " " " " " " "	: 0	
99	:	E	: Light : " " " " " " " " " " " "	: 0	
139	:	ES	: Severe : Burns on feet. Casualty	: 100	
	:	:	: in 6 to 12 hr.	:	
143	:	ER	: Moderate : Casualty in 6 to 12 hr.	: 0	
159	:	ES	: Light : Burns on feet. Casualty	: 100	
	:	:	: in 6 to 12 hr.	:	
163	:	L	: Death : Casualty 6 to 12 hr.	: 100	
	:	:	: Death in 24 hr.	:	
Per cent Casualties			: Rats - 46%	: Man - 20%	

Table No. 14B.

GOATS					
121	:	E <sub>2</sub> S <sub>2</sub>	:	Severe	:
	:		:	Burns on ears and	:
	:		:	abdomen. Casualty in	:
	:		:	6 to 12 hr.	:
161	:	R	:	Severe	:
	:		:	Casualty in 12 hr.	:
Per cent Casualties			:	Goats - 22%	:
			:	Man - 11%	:

Per cent Man Casualties based on Rats and Goats - 17%

(d) Twenty-four Hour Period from 6th to 30th  
Hour after Firing.

During the twenty-four hour period following the fourth hour after firing, eight rats and four goats were exposed. Animal casualties and estimated man casualties are tabulated in the following tables. The position of the animals on the target area is shown on Chart 10, and the position of estimated man casualties is shown on Chart 13.

Table No. 15A.

RATS					
Position of stake	Nature of casualty	Severity of casualty	Remarks	Estimated man casualties when man is protected with gas mask only	
91	ERS	Moderate	Burns on feet. Casualty when removed from area.	100	
95	ERS	"	Burns on feet. Casualty when removed from area.	100	
99	E	Light	Casualty when removed from area.	0	
115	ERS	"	Burns on feet. Casualty when removed from area.	100	
119	L	Death	Casualty when removed from area. Death in 20 days.	100	
135	ERS	Moderate	Burns on feet. Casualty when removed from area.	100	
139	ERS	"	Burns on feet. Casualty when removed from area.	100	
143	ERS	"	Ditto	100	
Per cent Casualties			Rats - 100%	Man - 88%	

Table No. 15B.

GOATS					
97	R	Moderate	Casualty when removed from area.	0	
141	S	Light	Burns on abdomen. Casual- ty when removed from area.	100	
Per cent Casualties			Goats - 50%	Man - 25%	

Per cent Man Casualties based on Rats and Goats - 67%

(e) Twenty-four Hour Period in Shell Craters  
on Third Day After Firing.

During the twenty-four hour period following the first forty-eight hours after firing, seven rats and one goat were exposed in separate shell craters on the target area. Animal casualties and estimated man casualties are tabulated in the following table:

Table No. 16.

RATS			
Nature of casualty :	Severity of casualty :	Remarks	Estimated man casualties when man is protected with gas mask only
LES	"	Burns on feet.	100
LES	-	" " "	100
S <sub>2</sub>	Severe	" " "	100
Per cent Casualties: Rats - 43%			Man - 43%

Per cent Man Casualties based on Rats and Goats - 37%

The goat exposed was not a casualty.

(f) Twenty-four Hour Period in Shell Craters on 9th Day After Firing.

During the twenty-four hour period following the first eight days after firing, seven rats and one goat were exposed in shell craters on the target area. Animal casualties and estimated man casualties are tabulated in the following table:

Table No. 17.

Nature of casualty :	Severity of casualty :	Estimated man casualties when man is protected with gas mask only
E	Light	0
E	"	0
Per cent Casualties : Rats - 28%, Man - 0%		

Per cent Man Casualties based on Rats and Goats - 0%

The goat exposed was not a casualty.

(2) Downwind from Target Area. Eight rats and four goats were exposed at positions downwind from the target area during the firing period and the following four hours at positions shown on Chart I. None of the animals were casualties.

## 8. Discussion.

a. Shell Distribution. Only 25 shell of the 40 fired for effect registered on the target area (200 yd. by 100 yd.). The craters produced by these 25 shell were all located within an area of 7850 sq. yd. which is only about 1/3 of the target area. Aside from the 25 impacts on the target, there were eleven additional impacts within a distance of 20 yd. upwind from the edge of the target area. All of these eleven shell probably contributed in some degree to the HS vapor and HS liquid concentration set up on the target area. The position of the shell craters is shown on Chart 2.

b. Impact Area. The number of animal positions included within the impact area was 25, and since each animal was located in the center of a 20 yd. sq., for purposes of discussion, the size of the impact area may be regarded as 10,000 sq. yd. The animal positions on the impact area and number of impacts on each 20 yd. sq. is given in the following table:

Table No. 18.

### Impact Area (10,000 sq. yd.)

<u>Stake at center 20 yd. square</u>	<u>Impacts within 20 yd. square</u>
97	2
99	2
117	2
119	2
121	5
137	1
139	1
141	0
143	5
159	0
161	1
163	0
166	1
181	1
183	1
185	1
187	0
203	0
205	3
207	0
209	1
225	0
227	2
229	1
231	0

Total -32

Seven of the impacts included in Table 18, were outside of the target area, but were included in the 20 yd. sq. occupied by an animal.

c. Estimated Man Casualties from Liquid HS:

(1) Protected with Gas Mask but Without Protection of Impregnated Clothing.

Results from paper panels given in Table 2, show that personnel exposed with equal distribution on the target area during the firing period, would suffer about 33% casualties from liquid HS, when protected with gas mask but without the protection of impregnated clothing. The percentages given in Table 2 are based on the entire target area which includes an area of about 10,000 sq.yd., on which there were no impacts. The figures given below, in Table 19, are based on results on the impact area (10,000 sq.yd.) as defined in paragraph 8 b, and on which 32 shell burst.

Table No. 19.

Estimated Man Casualties from Liquid HS  
on Impact Area (10,000 sq. yd.).

<u>Panel : Panels contaminated: Estimated man casualties when man</u>				
<u>pattern:</u>	<u>No. :</u>	<u>Per cent :</u>	<u>is protected with gas mask only</u>	
Heavy :	14 :	14.7 :		14.7%
Medium:	18 :	19.0 :		19.0
Light :	20 :	21.1 :		16.9
Trace :	19 :	20.0 :		12.0
No HS :	24 :	25.2 :		
Total :	95 :	100.0 :		62.6

If 32 shell distributed on an area of 10,000 sq.yd. will produce 62.5 per cent casualties from liquid HS when man is protected with gas mask, only, about 26 shell distributed per 100 yd. sq. are required to produce 50% casualties.

(2) Protected with Gas Mask and Standard Impregnated Clothing.

Results given in Table 3 show that personnel exposed with equal distribution on the target area during the firing period, would suffer about 9.2% casualties from liquid HS when protected with gas mask and standard impregnated clothing. The percentages given

in Table 3 are based on effects on the entire target area which includes an area of about 10,000 sq.yd. on which there were no impacts. The figures given below in Table 20, only include that part of the area (10,000 sq.yd.) on which the 82 shell, which registered on the impact area actually burst.

Table No. 20.

Estimated Man Casualties from Liquid HS  
on Impact Area.

Size of HS : No. :		Estimated man casualties when man is drops : of : protected with gas mask and standard panels:impregnated clothing		
mg.	:	:	Per panel %	Per cent
0.5 to 1.0	:	6	40	2.5
Over 1.0	:	19	100	20.0
Total	:	25	:	22.5

Total panels on impact area - 95.

If 32 shell distributed on an area of 10,000 sq.yd. will produce 22.5% casualties from liquid HS, when man is protected with gas mask and standard impregnated clothing, about 71 shell distributed per 100 yd. sq. are required to produce 50% man casualties.

d. Estimated Man Casualties from HS Vapor.

(1) Effects of Meteorological Conditions.

The vapor concentration set up from a given number of shell is dependent on wind velocity, air temperature and ground temperature. The higher the wind velocity, the more the HS vapor is diluted and the quicker it is carried away. For example, the effects from HS vapor on a contaminated area would theoretically be only 1/2 as great due to dilution, in the presence of a ten m.p.h. wind, as in the presence of a five m.p.h. wind, when other factors are equal.

The rate of evaporation of the liquid HS from the ground is dependent on surface exposed and ground temperature. The vapor pressure of HS at 20°C. is .0650 mm/Hg and at 30°C., .150 mm/Hg, so the evaporation rate and vapor concentration set up at 30°C. would be over two times as great as at 20°C. when other conditions are equal. It follows, that with other conditions equal, the vapor concentration set up is largely dependent on the ground temperature.

One of the most important factors which determines the effectiveness of HS vapor is the presence or absence of convection air currents. If the ground is warmer than the air, there is a tendency for HS vapor to rise with the convection currents set up so that the HS vapor becomes rapidly diluted and casualties are only produced on or near the area contaminated with liquid HS, where evaporation of the HS is taking place. On the other hand, if the ground is cooler than the air, convection air currents are set up and there is little tendency for the HS vapor to rise so that casualties from HS vapor may be produced 100 yd. or more downwind from the area contaminated with liquid HS.

On the day of the present test, the ground temperature was 88°F. to 92°F., and the wind velocity was 5.3 m.p.h. at an elevation of six feet. These conditions were favorable to set up a moderately high vapor concentration on the impact area. The ground temperature however, was about 20°F. higher than the air temperature so that convection air currents were undoubtedly set up. This theoretically resulted in the upwind travel of the HS vapor which prevented the building up of a high vapor concentration downwind from the area contaminated with liquid HS. Theoretically, the meteorological conditions during the test were not very favorable to produce casualties from HS vapor outside of the area contaminated with liquid HS.

## (2) Vapor Concentration Required to Produce Man Casualties.

A convenient method of expressing the severity of exposures to vapor is in terms of the c.t. value which is vapor concentration in milligrams per liter times the exposure period in minutes. From this expression, it is evident that a short exposure period to a high vapor concentration may be equivalent to a long exposure period to a low vapor concentration.

In considering man casualties in the present report, only the vesicant effects of the HS vapor is considered. Casualties from HS vapor, as given in the present report, are figured from the c.t. value using the valuation curve given on Graph 1, attached to this report. This curve was plotted from results of gas chamber tests given in Pharmacological Report No. 318. Aside from the points given on the graph to establish the curve, an additional point "B" is also given to represent exposure in the field of a man at Edgewood Arsenal who became a casualty for about 2 weeks due to vesicant effects of HS vapor. The vapor concentration and exposure period of this man was equivalent to a c.t. value of .043, which corresponds on the curve, to 53 per cent man casualties. All men are not equally resistant to HS vapor but the man exposed was shown by laboratory tests to represent an average subject. If a group of men, taken at random, were exposed to HS vapor corresponding to a c.t. value of .043, about 53% of the men exposed would be casualties according to the valuation curve.

(3) On the Target Area.

(a) Firing Period and the Following Ten Minutes.

From the results of vapor samples in Table 4, representing the firing period and the following ten minutes as taken at six sampling positions equally spaced on the target area, it is estimated that about 45% man casualties would result, when man is protected with gas mask. In the fifth column of Table 21, which follows, estimated man casualties from HS vapor are given for each 20 yd. sq. on the entire target area. The figures given for each square are estimates based on results obtained at the nearest sampling positions, the positions and number of nearest impacts and the wind direction. Estimated man casualties for the total target area, figured from estimates on each 20 yd. sq., amount to a total of about 48%, which very closely checks estimated casualties of 45% given in Table 4, representing average results at six sampling positions.

The per cent estimated casualties for each 20 yd. sq. as given in the fifth column of Table 21, is shown graphically on Chart 3. The shaded area on the chart indicates the percentage of the area on which 100% casualties would be produced from HS vapor when man is protected with gas mask only. The per cent casualties, as shown on Chart 3, are based on the effects of 32 shell. If 32 shell distributed on an area of 20,000 sq.yd., will produce 48% casualties, by the effects of HS vapor, it will require seventeen shell distributed per 100 yd. sq. to produce 50% man casualties by effects of HS vapor. Of course, when shell filled with HS are fired, casualties are produced by liquid HS, as well as by HS vapor, so that the shell required in actual operations to produce 50% casualties would be less than seventeen figured, when considering the effects of vapor only.

(b) Fifty Minute Period Beginning Ten Minutes After Firing Ceased.

Estimated man casualties from HS vapor, due to effect of exposure on the target area for a period of 50 min., beginning ten minutes after firing ceased, are given in Table 5. The results from vapor samples taken at five sampling positions equally distributed on the target area, as given in Table 5, show that personnel protected with gas mask only would suffer about 44% casualties due to the vesicant effect of HS vapor. The part of the target area on which it is estimated 100% casualties would be produced is shown on Chart 4.

(c) Four Hour Period Beginning One Hour After Cessation of Fire.

In Table 7, estimated man casualties are given representing exposures on the target area for a four hour period beginning one hour after firing ceased. Samples were taken at eight positions but the results were negative at five positions. The negative results were due to the position of shell craters, wind direction and also probably due to the fact that most of the liquid HS had evaporated except at positions in and around the shell craters where the amount of liquid HS originally present, was greater. At sampling position L, vapor samples were taken at elevations 1 and 2 feet. The results at the two elevations showed no difference in the vapor concentrations.

The positions at which vapor samples were taken are shown on Chart 6. The per cent shaded area, at each sampling position, represents the percentage of the 20 yd. sq. on which 100% casualties would be produced, or the per cent casualties on the 20 yd. sq.

(d) Four Hour Period on Day Following the Test.

The results of vapor samples taken for a period of four hours on the target area on the day following the test, are given in Table 8. Three samples taken at each of three positions, showed negative results in all cases but one. The results obtained at one position show that it would be unsafe for personnel to occupy the area for a period of three or four hours without the protection of gas mask and standard protective clothing.

(e) Four Hour Period on the Second Day Following Test.

The results of vapor samples taken for a period of four hours on the target area on the second day following the test, are given in Table 9. Three samples taken at each of three positions showed negative results. From these results it would probably be safe for personnel without protection of gas mask or protective clothing to occupy the area during the mid day period for a period of three or four hours provided they kept out of shell craters. The danger to unprotected personnel occupying the area would be greater directly after sunset, due to the absence of convection of air currents which is favorable for the building up of a dangerous HS vapor concentration.

(4) Outside of Target Area.

(a) Firing Period and Following Hour.

Estimated man casualties from HS vapor, resulting from exposure at the various sampling positions outside of the target area during the firing period and the following hour, are given in Table 10. Sampling

positions and percentage estimated man casualties at sampling positions are shown on Chart 5. Of the five sampling positions at which vapor samples were taken downwind from the target area, positions J, N, and R showed positive results. These results show that HS vapor was effective for a distance of about 45 yd. downwind from the area contaminated with liquid HS equivalent to a distance of about 65 yd. from the position of impact. Vapor samples were also taken at four positions upwind from the target area, three of which showed positive results. The presence of vapor upwind from the target area was due to upwind impacts and probably to a slight extent to upwind shell fired for adjustment of guns.

At many of the sampling positions, vapor samples were taken at elevations 1, 2, and 4 feet. The results at about half of the sampling positions showed a higher vapor concentration at elevations of 1 and 2 feet than at 4 feet, but at the remaining sampling positions, the reverse was true. The vapor concentration recorded at the lowest elevation in the case of each position sampled, was used in figuring percentages and in making up Chart 5.

(b) Four Hour Period Beginning One Hour After  
After Firing Ceased.

Estimated man casualties at four positions outside of the target area, for the four hour period beginning one hour after firing ceased, are given in Table 11. Sampling positions and percentage estimated man casualties at sampling positions are shown on Chart 6. Of the four sampling positions, H, M, Q, and U, positions H and M showed positive results. These results show that personnel, with gas mask protection of impregnated clothing would suffer casualties from HS vapor if stationed for a period of three or four hours, ten or twenty yards downwind from the impact position, one hour after firing ceased.

c. Estimated Casualties Based on Effects on Animals.

Animal casualties and estimated man casualties based on effects on animals are recorded in Tables 12A to 17 inclusive. Also animal positions, animal casualties and estimated man casualties, based on effects on animals, are shown on Charts, 1, 7, 8, 9, 10, 11, 12, and 13.

(1) On the Target Area.

(a) Firing Period and Following Ten Minutes.

Estimated man casualties, when man is protected with gas mask only, due to effects of exposure on the target area during the firing period and ten minutes are given in Tables 12A and 12B. From the animal casualties it is estimated that man casualties would be 33% based on rats and 19% based on goats, or 26% based on rats and goats.

(b) Firing Period and Following Hour.

Estimated man casualties, when man is protected with gas mask only, due to effects of exposure on the target area during the firing period and following hour, are given in Tables 13A and 13B. From the animal casualties it is estimated that man casualties would be 26% based on rats and 35% based on goats or 31% based on rats and goats.

(c) Four Hour Period from 2nd to 6th Hour After Firing.

Estimated man casualties when man is protected with gas mask only, due to effects of exposure on the target area during the four hour period following the first hour after firing ceased, are given in Tables 14A and 14B. From the animal results it is estimated that man casualties would be 20% based on rats and 11% based on goats, or 17% based on rats and goats. The positions of the animals exposed did not cover all parts of the target area, but taking into consideration the positions of the bursts as shown on Chart 9, the area on which the animals were included was probably representative of the entire target area.

(d) Twenty-four Hour Period Beginning Five Hours After Firing Ceased.

Estimated man casualties when man is protected with gas mask only, due to effects of exposure on the target area during the 24 hr. after firing ceased, are given in Tables 15A and 15B. From the animal casualties, it is estimated that man casualties would be 88% based on rats and 25% based on goats, or 67% based on rats and goats. The area on which the animals were exposed as shown on Chart 10, did not include the whole target area, but taking into consideration the position of the impacts, the effect on the area covered by the animals was probably representative of the average HS effect on the entire target area.

(2) Exposure in Shell Craters.

Estimated man casualties when man is protected with gas mask only, due to effects on animals exposed in shell craters for a period of 24 hr., are given in Tables 16 and 17. From the animal results, it is estimated that if the impact area is occupied by personnel protected with gas mask only for a period of 24 hr. beginning 48 hr. after firing ceased, casualties would result, but no casualties would probably result if occupied nine days after firing.

(3) Downwind from the Target Area.

(a) Firing Period and Following Four Hours.

Animals exposed downwind from the target area at positions shown on Chart 1, showed no casualties. This was partly due to a shift in the wind direction and also to the effects of convection air currents so that a high vapor concentration was not produced at the position of the downwind animals.

f. Comparison of Per Cent Estimated Man Casualties Based on Measurements of the Gas Concentration, and by Effects on Animals.

(1) Firing Period and Following Ten Minutes.

In Table No. 21, which follows, estimated man casualties are given for each 20 yd. square based on the following effects and method of figuring casualties, when man is protected with gas mask only, and is exposed in the target area during the firing period and following ten minutes:

- (a) HS liquid using panel data.
- (b) HS vapor from vapor samples.
- (c) Combined effect of HS liquid and HS vapor.
- (d) Effects on animals.

Figures in this table show that 100% casualties would be produced on 57% of the area, based on the combined effects of HS liquid and vapor, and 26% based on effects on animals, or about 42% based on the average of the two methods of figuring casualties.

Table No. 21.

Target Area 20,000 sq. yd.  
(Firing Period and Following Ten Minutes)

No. of stake at cone center square	Impacts within each square	HS liquid Estimated man casu- alties	HS vapor c.t. value alties	HS liquid and vapor Estimated man casu- alties	Effects on man and animals Animal Estimated man casu- alties when pro- tected with gas mask only
		%	%	%	%
1	0	0	.0	0	0
3	0	0	.0	0	0
5	0	20	.0	0	0
7	0	20	.0	0	0
9	0	40	.02	30	58
11	0	45	.02	30	61
23	0	0	.0	0	0
25	0	0	.0	0	0
27	0	0	.01	10	10
29	0	0	.01	10	10
31	0	13	.01	10	21
33	1	54	.02	30	63
45	0	0	.01	10	10
47	0	0	.01	10	10
49	0	0	.01	15	10
51	0	0	.02	30	30
53	0	20	.02	30	44
55	0	67	.02	30	74
67	0	0	.01	15	15
69	0	0	.01	15	15
71	0	7	.02	30	36
73	0	34	.02	30	54
75	0	40	.10	93	96
77	0	64	.10	93	97
89	0	0	.01	10	10
91	0	0	.01	15	15
93	0	13	.02	30	39
95	0	38	.10	10	44
97	2	54	.30	100	100
99	2	76	.30	100	100
111	0	0	.01	10	10
113	0	7	.01	15	21
115	0	38	.02	30	57
117	2	45	.15	100	100
119	2	55	.30	100	100

Table No. 21 (Cont'd.)

No. of impacts at center of square:	square	HS liquid Estimated casualties	HS vapor Estimated casualties	HS liquid Estimated casualties	Effects on man and animals Animal casualties when pro- tected with gas mask only
:	:	:	:	:	:
121	5	93	.60	100	ESL Death: 100
133	0	0	.01	10	0
135	0	13	.02	30	39
137	1	51	.04	50	75
139	1	67	.30	100	ESL Death: 100
141	0	51	.30	100	100
143	5	90	.60	100	100
155	0	0	.02	30	30
157	0	7	.02	30	35
159	0	29	.04	50	65
161	1	42	.30	100	100
163	0	62	.30	100	100
165	1	46	.30	100	100
177	0	0	.02	30	30
179	0	29	.02	30	51
181	1	47	.04	50	74
183	1	38	.20	100	100
185	1	65	.30	100	100
187	0	63	.10	93	97
199	0	0	.02	30	30
201	0	24	.03	43	67
203	0	75	.10	93	98
205	3	92	.50	100	100
207	0	96	.30	100	100
209	1	79	.20	100	100
221	0	15	.02	30	40
223	0	50	.03	43	81
225	0	80	.03	43	100
227	2	95	.35	100	100
229	1	90	.35	100	100
231	0	65	.10	93	97

33

Total and per-  
centages

34.2 : : 48.7 : 57.0 : 38 : 26

\*See page 11 for code of symbols, listed under this column.

The average percentages, as given in Table No. 21, are based on effects on the total target area which includes about 10,000 sq.yd. on which there was very little or no effect from the HS due to wind direction and distribution of the shell. In Table No. 22, which follows, results are given to include only the impact area as defined in paragraph 8 b.

Table No. 22.

Impact Area 10,000 sq.yd.  
(Firing Period and Following Ten Minutes)

No. of stakes at center of 20 yd. square	Estimated man casualties when man is protected with gas mask only		Based on HS liquid:Based on effects on and vapor samples : animals	
	:	%	:	%
97	:	100	:	100
99	:	100	:	100
117	:	100	:	100
119	:	100	:	
121	:	100	:	100
137	:	75	:	
139	:	100	:	100
141	:	100	:	
143	:	100	:	0
159	:	65	:	
161	:	100	:	0
163	:	100	:	
165	:	100	:	0
181	:	74	:	
183	:	100	:	100
185	:	100	:	
187	:	97	:	0
203	:	98	:	
205	:	100	:	100
207	:	100	:	
209	:	100	:	0
225	:	100	:	
227	:	100	:	100
229	:	100	:	
231	:	97	:	0
Average	:	96%	:	54%

Estimated casualties, given in Table No. 22, are based on an area of 10,000 sq.yd. on which 32 shell were effective. The figures in this table show an average of 96% man casualties, based on the effects of HS liquid and vapor samples and 54% based on the effects on animals, or an average of 75% based on the two methods of figuring casualties.

(2) Firing Period and Following Hour.

In Table No. 23, which follows, estimated man casualties are given for each 20 yd. sq. based on the following effects and method of figuring casualties, when man protected with gas mask only, is exposed on the target area during the firing period and the following hour.

- (a) HS liquid using panel data.
- (b) HS vapor from vapor samples.
- (c) Combined effect of HS liquid and HS vapor.

Figures in this table show 100% estimated casualties on 59% of the area, based on the combined effects of HS liquid and vapor, and 31% based on effects on animals, or about 45% based on the average of the two methods of figuring casualties.

Table No. 23.

Target Area 20,000 sq.yd.  
(Firing Period and Following Hour)

No. of at cen- ter of square	Impacts within each square	HS liquid: Estimated man casu- alties	HS vapor c.t.: Estimated man casu- alties	HS liquid: and vapor: Estimated man casu- alties	Effects on man and animals Animal casual- ties*	Estimated man cas- ualties when pro- tected with gas mask only
		%	%	%	%	%
1	0	0	.0	0	0	0
3	0	0	.0	0	0	0
5	0	20	.0	0	20	0
7	0	20	.0	0	20	0
9	0	40	.02	30	58	0
11	0	45	.02	30	61	0
23	0	0	.0	0	0	0
25	0	0	.0	0	0	0
27	0	0	.012	15	15	0
29	0	0	.012	15	15	0
31	0	13	.02	30	39	0
33	1	54	.02	30	67	0
45	0	0	.012	15	15	:R Light:
47	0	0	.012	15	15	: 0
49	0	0	.012	15	15	: 0
51	0	0	.057	62	62	: 0
53	0	20	.057	62	70	: 0
55	0	67	.08	80	93	: 0
67	0	0	.012	15	15	:E Mod. :
69	0	0	.012	15	15	: 0
71	0	7	.012	15	21	:ER Light:
73	0	34	.057	62	75	: 0
75	0	40	.057	62	77	: 0
77	0	64	.12	100	100	: 0
89	0	0	.016	20	20	: 0
91	0	0	.016	20	20	: 0
93	0	13	.026	40	48	: 0
95	0	38	.04	50	69	: 0
97	2	54	.40	100	100	:ELS Death: 100
99	2	76	.40	100	100	: 0
111	0	0	.016	20	20	:EL Death: 100
113	0	7	.027	33	38	: 0
115	0	38	.027	33	58	: 0
117	2	45	.173	100	100	: 0
119	2	55	.173	100	100	:SE Light: 100
121	5	93	.70	100	100	: 0
123	0	0	.012	15	15	: 0

Table No. 23 (Cont'd.)

No. of impacts at cen-ter of square	square	HS liquid Estimated man casu- alties	HS vapor e.t. value man casu- alties	HS liquid Estimated man casu- alties	Effects on man and animals and vapor Estimated casual- ties*	Estimated man cas- ualties when pro- tected with gas mask only
:	:	:	:	:	:	:
135	: 0	: 13	: .026	: 40	: 48	: 0 : 0
137	: 1	: 51	: .04	: 50	: 75	: 0 : 0
139	: 1	: 67	: .40	: 100	: 100	: 0 : 0
141	: 0	: 51	: .40	: 100	: 100	: E <sub>2</sub> RS Severe:100
143	: 4	: 90	: .80	: 100	: 100	: 0 : 0
155	: 0	: 0	: .026	: 40	: 40	: E Light: 0
157	: 0	: 7	: .045	: 53	: 58	: 0 : 0
159	: 0	: 29	: .045	: 53	: 66	: 0 : 0
161	: 1	: 42	: .40	: 100	: 100	: 0 : 0
163	: 0	: 62	: .58	: 100	: 100	: S Mod. : 100
165	: 1	: 46	: .58	: 100	: 100	: 0 : 0
177	: 0	: 0	: .026	: 40	: 40	: 0 : 0
179	: 0	: 29	: .045	: 53	: 66	: 0 : 0
181	: 1	: 47	: .045	: 53	: 75	: ER Severe: 100
183	: 1	: 38	: .58	: 100	: 100	: 0 : 0
185	: 1	: 65	: .58	: 100	: 100	: ERS Severe:100
187	: 0	: 63	: .58	: 100	: 100	: 0 : 0
199	: 0	: 0	: .026	: 40	: 40	: 0 : 0
201	: 0	: 24	: .04	: 50	: 62	: 0 : 0
203	: 0	: 75	: .60	: 100	: 100	: ERS <sub>2</sub> Severe:100
205	: 3	: 92	: .60	: 100	: 100	: 0 : 0
207	: 0	: 96	: .40	: 100	: 100	: 0 : 0
209	: 1	: 79	: .25	: 100	: 100	: 0 : 0
221	: 0	: 15	: .026	: 40	: 49	: 0 : 0
223	: 0	: 50	: .051	: 60	: 80	: 0 : 0
225	: 0	: 80	: .051	: 60	: 100	: E <sub>2</sub> RS Severe:100
227	: 2	: 93	: 1.60	: 100	: 100	: 0 : 0
229	: 1	: 90	: 1.60	: 100	: 100	: LE Death: 100
231	: 0	: 85	: .15	: 100	: 100	: 0 : 0
<hr/>						
Totals						
and						
Avg.	: 32	: 34.2	:	: 55.1	: 59.6	: 44 : 31

\*See page 11 for code of symbols listed under this column.

Per cent estimated casualties, based on the HS concentration, as obtained from HS liquid and vapor samples, given in Tables 21, 22, and 23, are about double the per cent casualties, based on effects on animals. Estimates based on effects on animals, were very conservatively made and are probably low.

g. Number of Shell Required to Produce 50% Man Casualties.

In the present test, the impacts are segregated to too great an extent to determine the minimum number of shell required, under the prevailing meteorological conditions, to produce 50% casualties. This is indicated by the fact that on some twenty yard squares, as many as four or five shell burst whereas one may have been sufficient to produce 100% casualties. If the excess shell had been distributed to other parts of the area, additional casualties would probably have been produced. It would probably be impracticable to distribute the shell over the target to produce maximum effects and the present test is probably representative of average distribution in practice.

It was stated in paragraph 8 c (1), that about 26 shell distributed per 100 yd. sq. will produce 50% casualties from liquid HS when man is protected with gas mask only.

From figures given in Table 22, it was estimated that the impact of 32 shell on a 100 yd. sq. would produce 96% casualties based on effects of HS liquid and vapor and 54% based on effects on animals, when exposed during the firing period and following ten minutes. On this basis, the following number of shell per 100 yd. sq., will be required to produce 50% casualties when man is protected with gas mask only:

Based on HS liquid and vapor samples	= 17 shell
Based on effects on animals	= 30 "
Av.	= $\frac{47}{2}$ "

Based on the two methods of figuring casualties, about 25 shell distributed are required per 100 yard square to produce 50% casualties, when man is protected with gas mask only.

9. Conclusions.

From the results of the present test, the following conclusions are drawn with respect to the use of 155-mm. howitzer shell, filled with HS, when fired under the meteorological conditions which existed at the time of the present test:

a. When man is exposed on the impact area during the firing period and following ten minutes, the number of shell required per 100 yd. sq. to produce 80% casualties when distributed as equally as practicable, are as follows:

(1) When man is protected with gas mask and standard impregnated clothing - 71 shell (see page 20).

(2) When man is protected with gas mask only - 24 shell (see page 33).

b. If the impact area is occupied by personnel, protected with gas mask only, within 48 hr. after being shelled, casualties will result (see page 25).

c. Personnel protected with gas mask only, stationed downwind within 65 yd. from the position of impact during the firing period and directly after, will suffer casualties from the vesicant effects of HS vapor (see page 24).

10. Recommendations. It is recommended that this test be repeated and an attempt be made to obtain better distribution of the impacts on the target area.

Submitted:

/s/ B.G. Macintire,  
B. G. MACINTIRE,  
Weapons Department,  
Munitions Development Division.

Recommending approval:

Report of Test of HS-Filled  
155-mm. Howitzer Shell.  
Test A - May 23, 1932.

/s/ Charles E. Loucks,  
CHARLES E. LOUCKS,  
Captain, C.W.S.,  
Chief, Munitions Development Division.

Project: A 1.1-1b.

Typed by hh     )  
Sept. 26, 1932)

Approved:

/s/ E. Montgomery,  
E. MONTGOMERY,  
Major, C.W.S.,  
Technical Director.

BATTERY "C" 6TH FIELD ARTILLERY  
Fort Hoyle Maryland;  
May 24, 1932.

MEMORANDUM :- TO- The Technical Director, Edgewood Arsenal  
Md.

In compliance with instructions contained in letter to  
Commanding General, Ft. Hoyle, concerning Mustard Gas Shoot  
of 155mm Howitzers manned by this battery the following report  
is submitted:

B.C.'s Commands	Elev..	Sensings	Remarks.
Compass 3208, On #1			
4, Shell Mustard Gas,			
Charge 5, Fuse Long,			
#1, 1 Rd.	272	300 Left Short	
	290	70 " "	DUD (#1 out to repair Breechblock
#2 , 1 Rd	290	300 Left, Short	
	310	80 " "	
	330	250 Right, Over	
	320	180 " "	
	315	90 " "	
	313	80 " "	
	311	10 " "	
3 Rds	311	40 " "	
1 Rd	311	Line (Rotating Band came off)	
#2 mark Base Def. #3 Adjust,		80 Right, Over	
#3, 1 Rd,	311	80 " "	
	310	80 " "	
#3 mark Base Def, #4 Adjust			
#4 , 1 Rd	310	? Short, Def Short	
Left 10,	310	Line " " "	DUD
Left 5	310	25 Right, Over, Def. Over	DUD
Left 5	310	115 Left, Short, #4 mark B.D.	
#1, 1 Rd.	310	80 Right, Over	
	310	8 " " Def. OK.	
		END OF ADJUSTMENT.	
FIRE FOR EFFECT.			
Base Def. Right 45 on #1 Open 5,			
Battery 6 Rds	310	3 Overs, 1 Short	1 DUD

	310	2	Overs, 1 Line, 1 Short.		
	310	1	"	3	"
	<del>310</del>	<del>5</del>	<del>"</del>	<del>1</del>	<del>"</del> <i>kur</i>
	310	1	"	3	"
	310	<del>5</del>	"	1	" 1 DUD
8 Rds	307	0	" 1 T	3	" (This elev. 50 yds short of center of impact.)
	307	2	"	2	"
	307	0	" 1 T,	3	"
Right 5, 2 Rds					
	313	3	"	1	" (This elev. 50 yds over center of impact)
	313	3	"	1	"

NOTE- All settings in Fire for Effect made on center panel of area.

*Leo T. McMahon*  
 Leo T. McMahon  
 Capt. 6th F.A.  
 Commanding.

# Graph No. 1

## Casualty Producing Effect of Mustard Vapor on Masked Men

Percent casualties

100  
90  
80  
70  
60  
50  
40  
30  
20  
10  
0

⊙ B

✕ 3

✕ A

✕ 2

✕ 1

C-t value

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18

Note:

The c-t value is the product of the vapor concentration in mps. per liter and the time of exposure in minutes.

Points 1 & 2 from chamber tests given in PR 318.

Point 3 is the estimate of the author of PR 318 after conducting the tests.

Point A represents the chamber exposure of the author of PR 318

Point B represents the exposure of a man in the field at Edgewood Arsenal.

CHART I  
TARGET AREA  
AS PREPARED FOR  
TEST A

May 23, 1932.

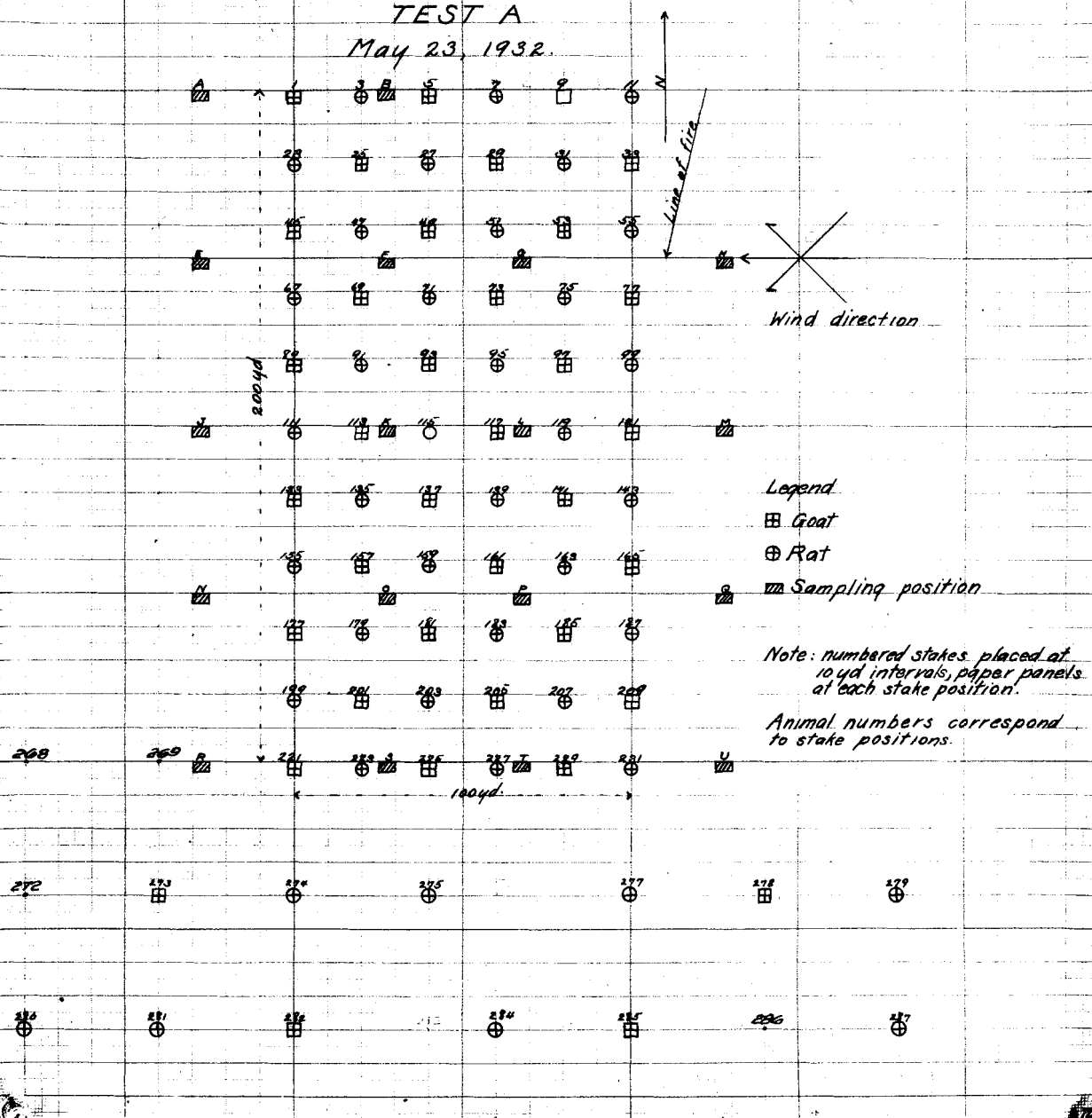
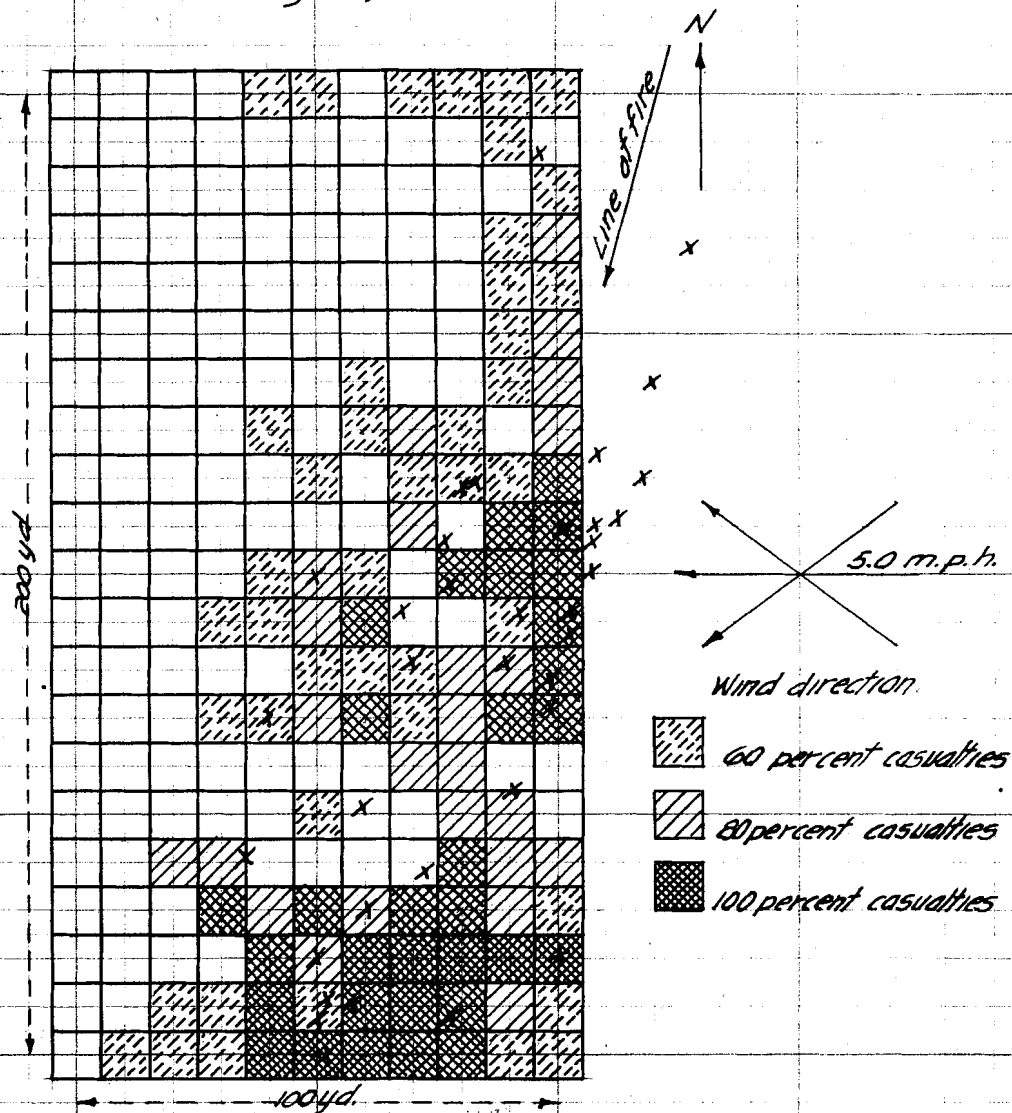


CHART 2  
ESTIMATED MAN CASUALTIES  
FROM H.S. LIQUID  
TEST A May 23, 1932



Note-

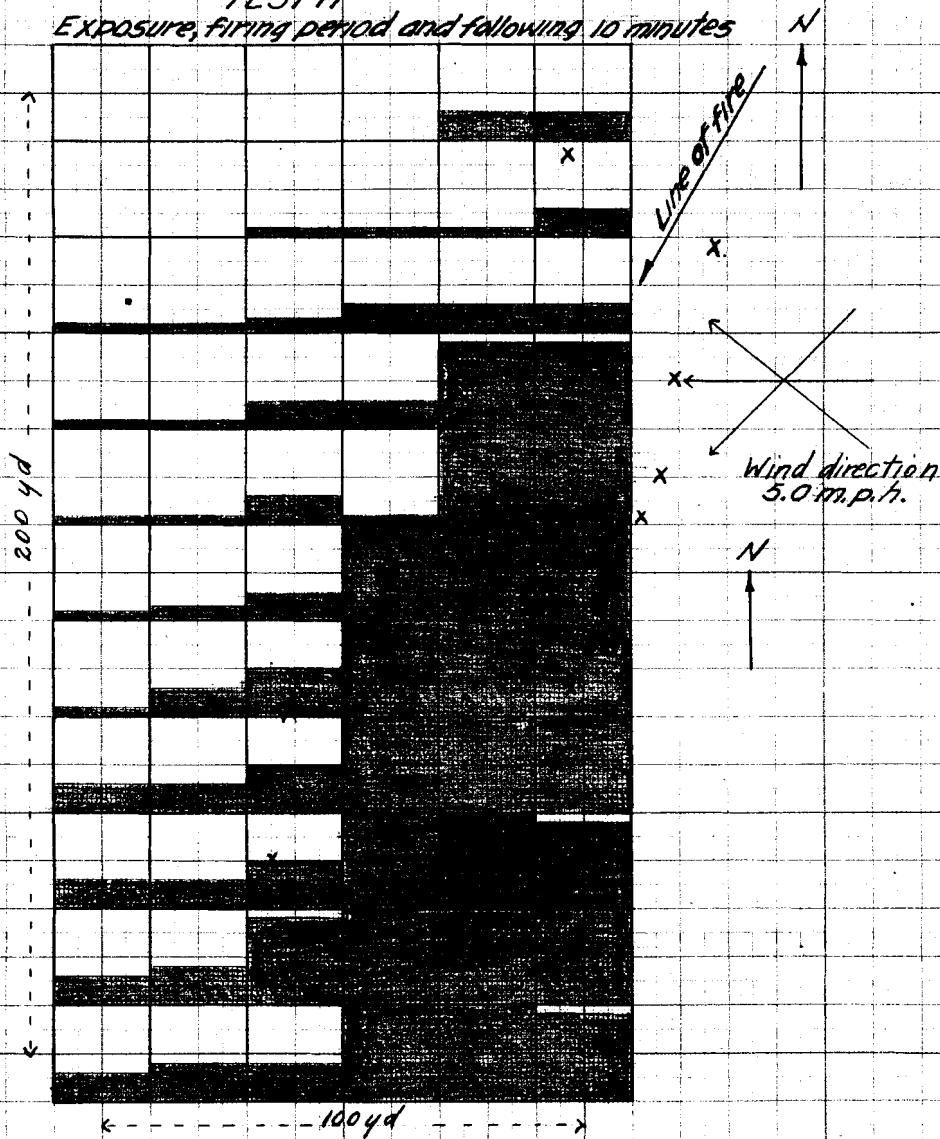
Results derived from patterns on  
paper panels and casualties estimated  
on men protected with gas mask only.

# CHART 3

## ESTIMATED MAN CASUALTIES DUE TO H5 VAPOR

TEST A

Exposure, firing period and following 10 minutes



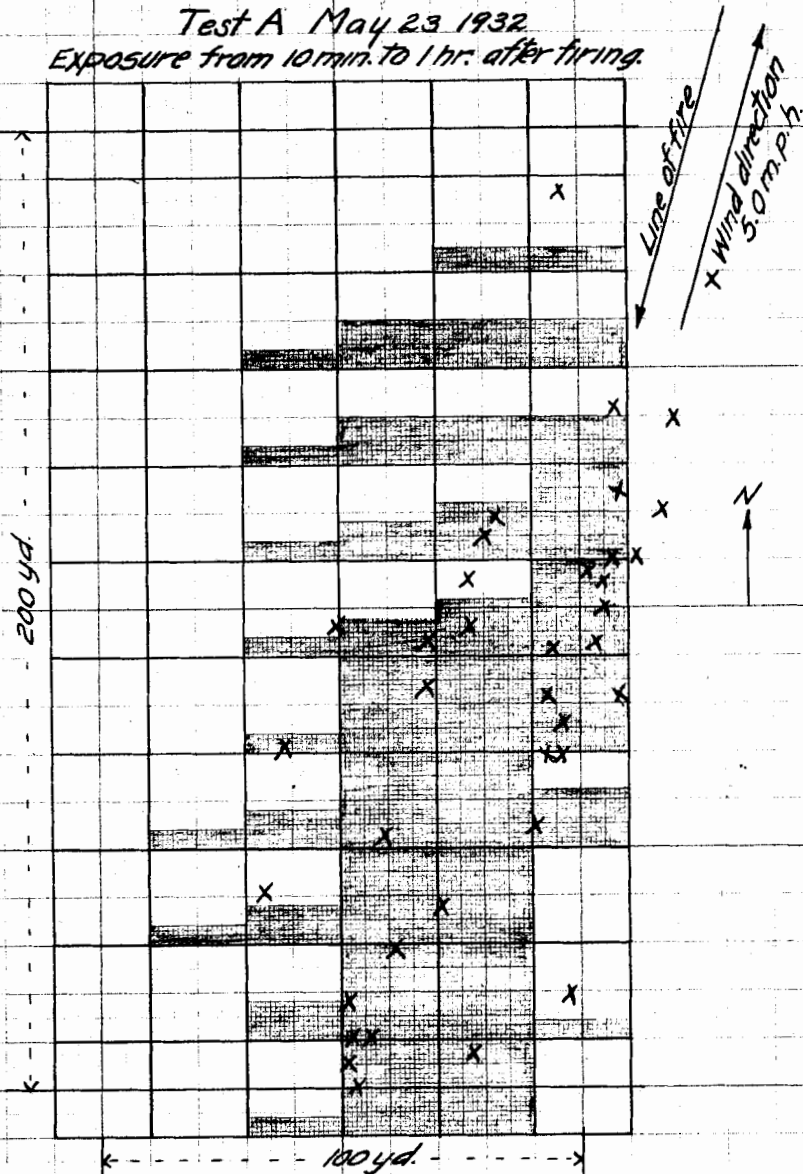
Legend

Shaded area 100 percent man casualties  
with gas mask protection only.

X Impacts

# CHART 4 ESTIMATED MAN CASUALTIES DUE TO HS VAPOR

Test A May 23 1932  
Exposure from 10 min. to 1 hr. after firing.



## Legend

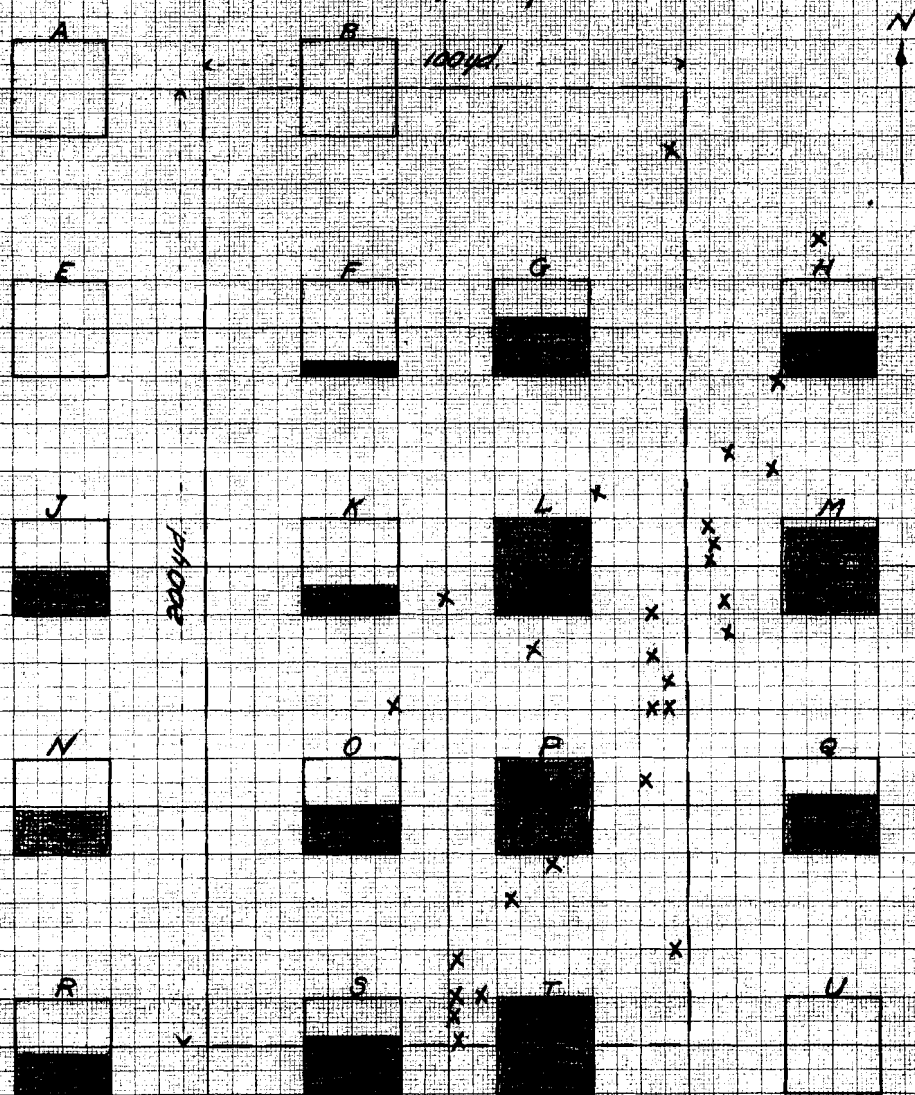
Shaded area 100 percent man casualties  
with gas mask protection only.

x Impacts.

# CHART 5 ESTIMATED MAN CASUALTIES DUE TO HS VAPOR\*

Exposure, firing period plus one hour.

Test A, May 23, 1932.



## Legend

x Impacts.

Shaded area represents 100% casualties upon personnel provided with gas masks.

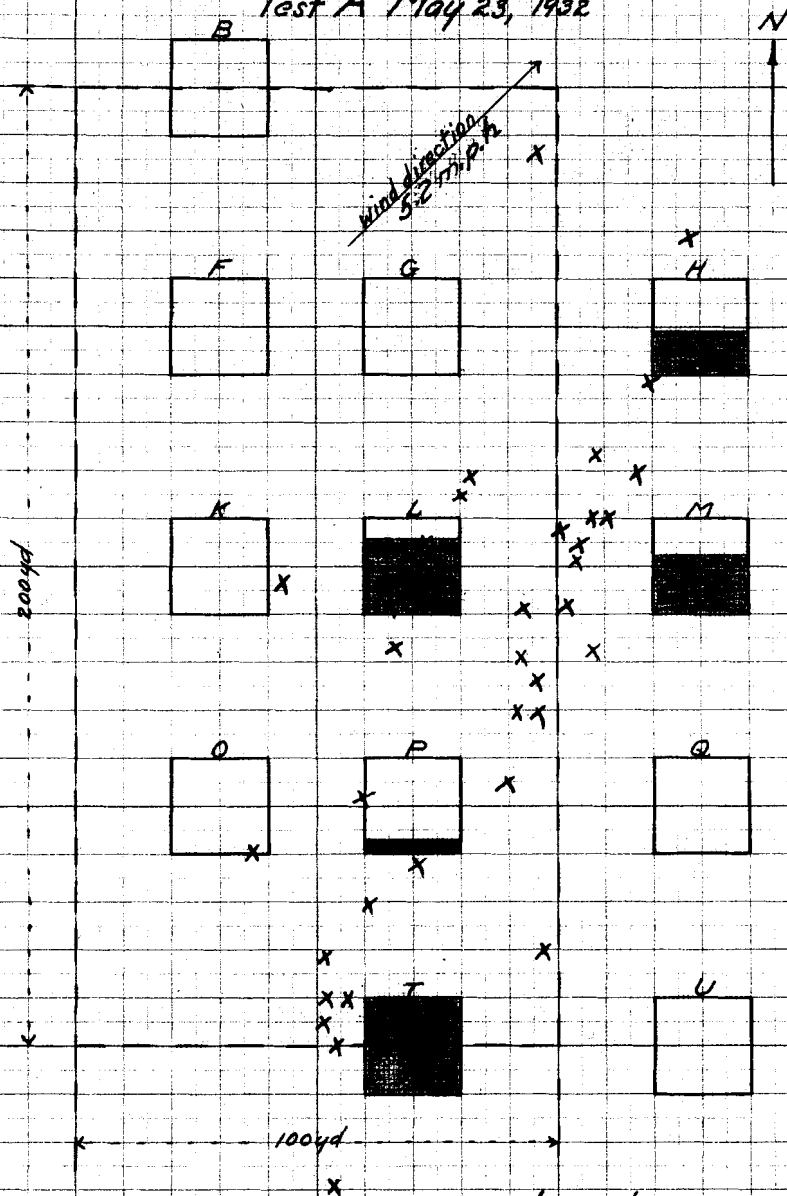
Letters designate sampling positions.

\* Estimated casualties are only shown at sampling positions.

# CHART 6 ESTIMATED MAN CASUALTIES DUE TO HS VAPOR\*

Exposure period 4 hrs. from 2nd to 5th hrs.  
after firing.

Test A May 23, 1932



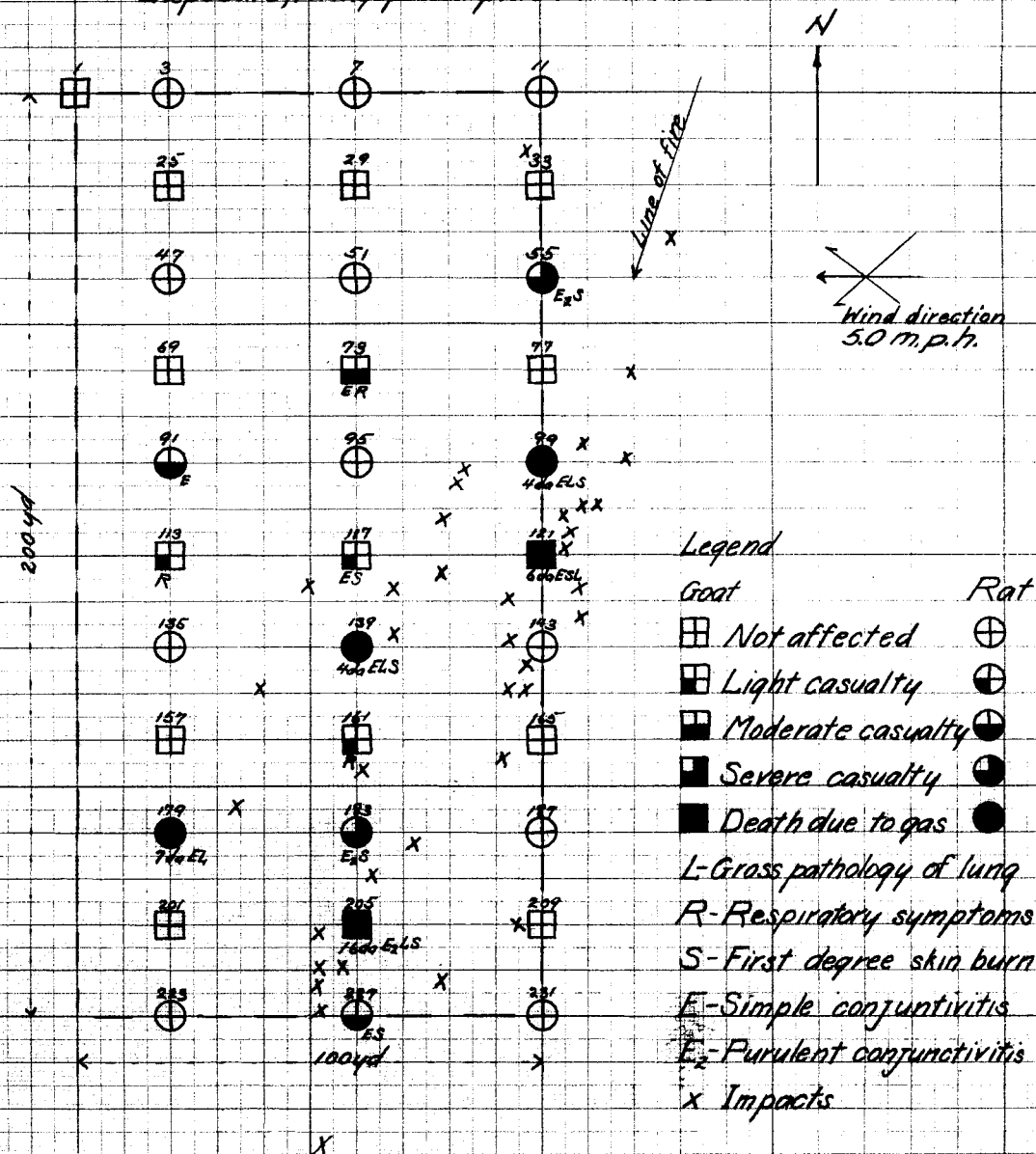
Legend  
x Impacts

Shaded area represents  
100% casualties upon  
personnel provided with  
gas masks.

Letters designate sampling  
positions.

\* Estimated casualties are  
only shown at sampling  
positions.

**CHART 7**  
**ANIMAL CASUALTIES**  
 Test A, May 23, 1932.  
 Exposure, firing period plus ten minutes



**CHART B**  
**ANIMAL CASUALTIES**  
 Test A May 23, 1932  
 Exposure, firing period plus one hour

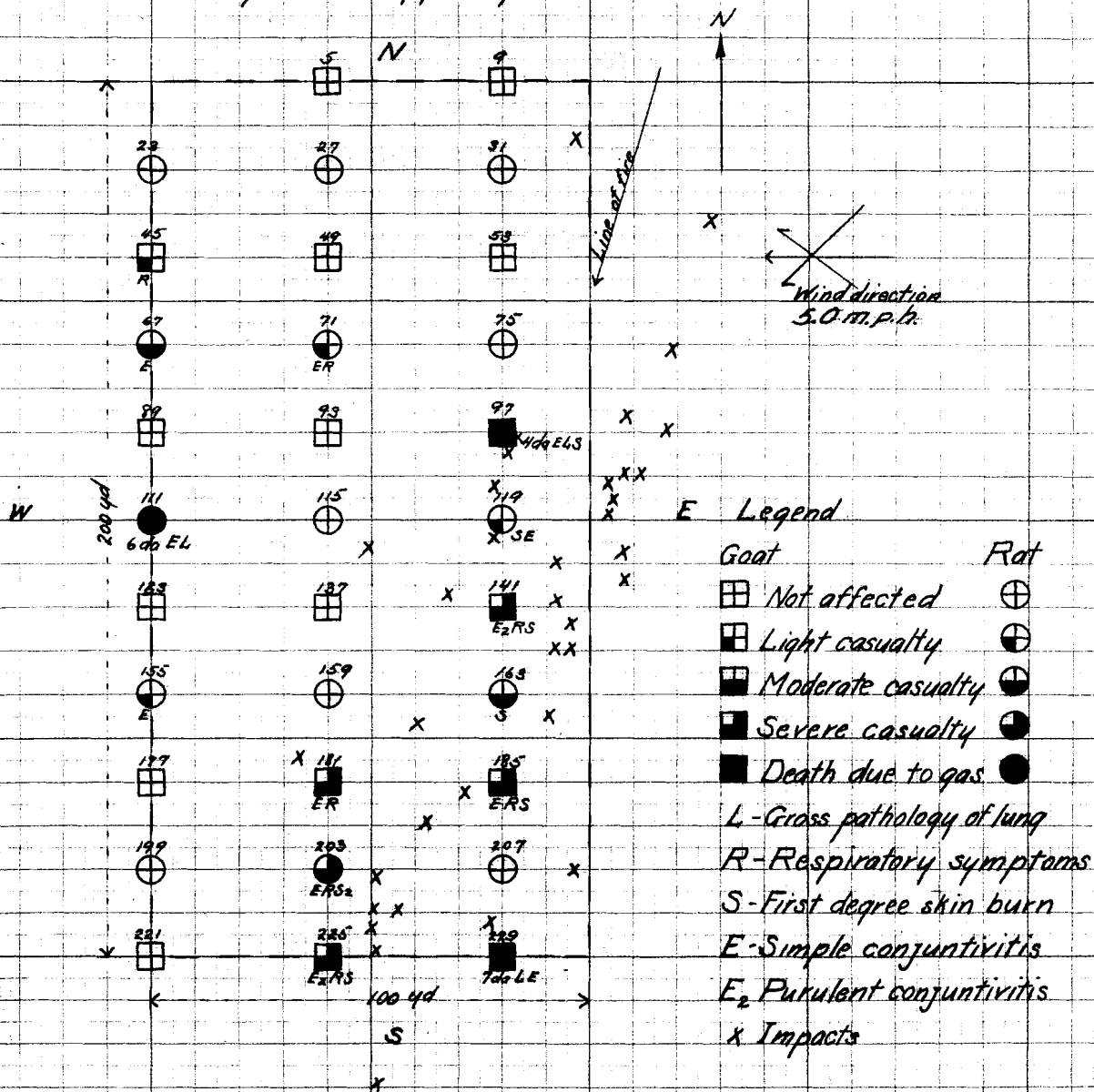


CHART 10  
ANIMAL CASUALTIES  
Test A, May 23, 1932  
Exposure 24 hrs. From 6th to  
30th hours after firing.

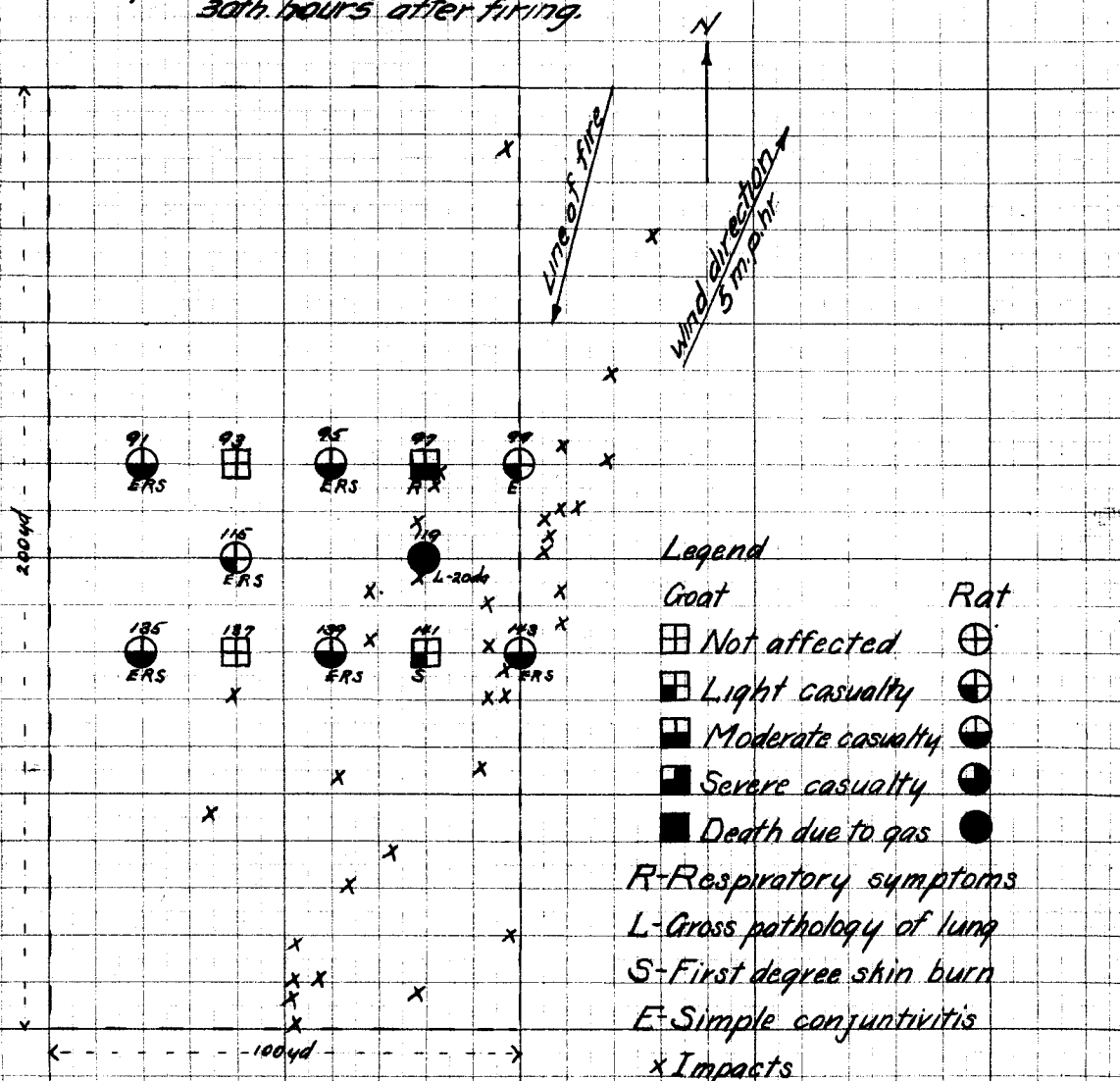
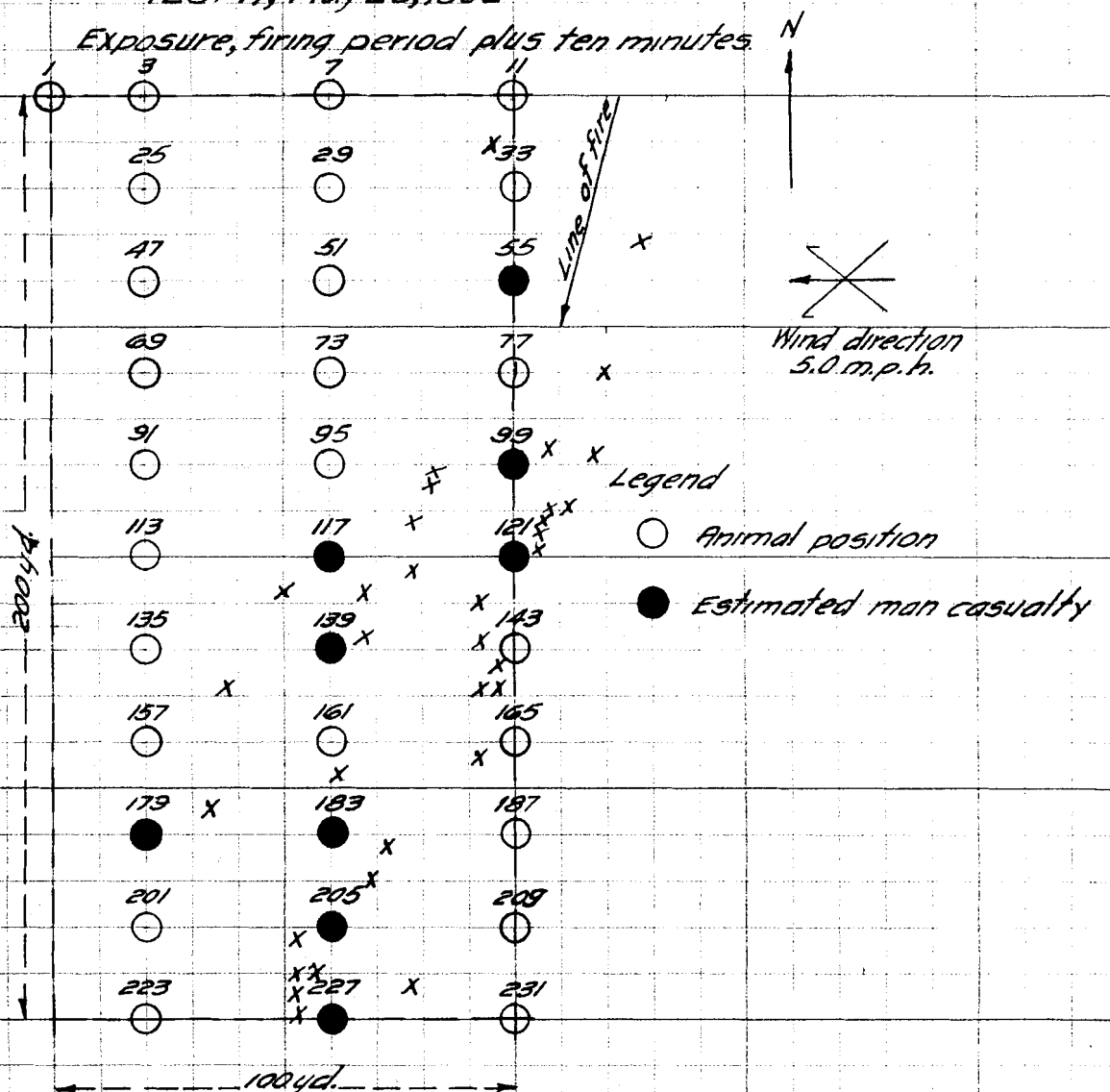


CHART II  
ESTIMATED MAN CASUALTIES BASED  
ON EFFECTS ON ANIMALS.

TEST A, May 23, 1932

Exposure, firing period plus ten minutes.



# CHART 12 ESTIMATED MAN CASUALTIES BASED ON EFFECTS ON ANIMALS

TEST A, May 23, 1932

Exposure, firing period plus one hour

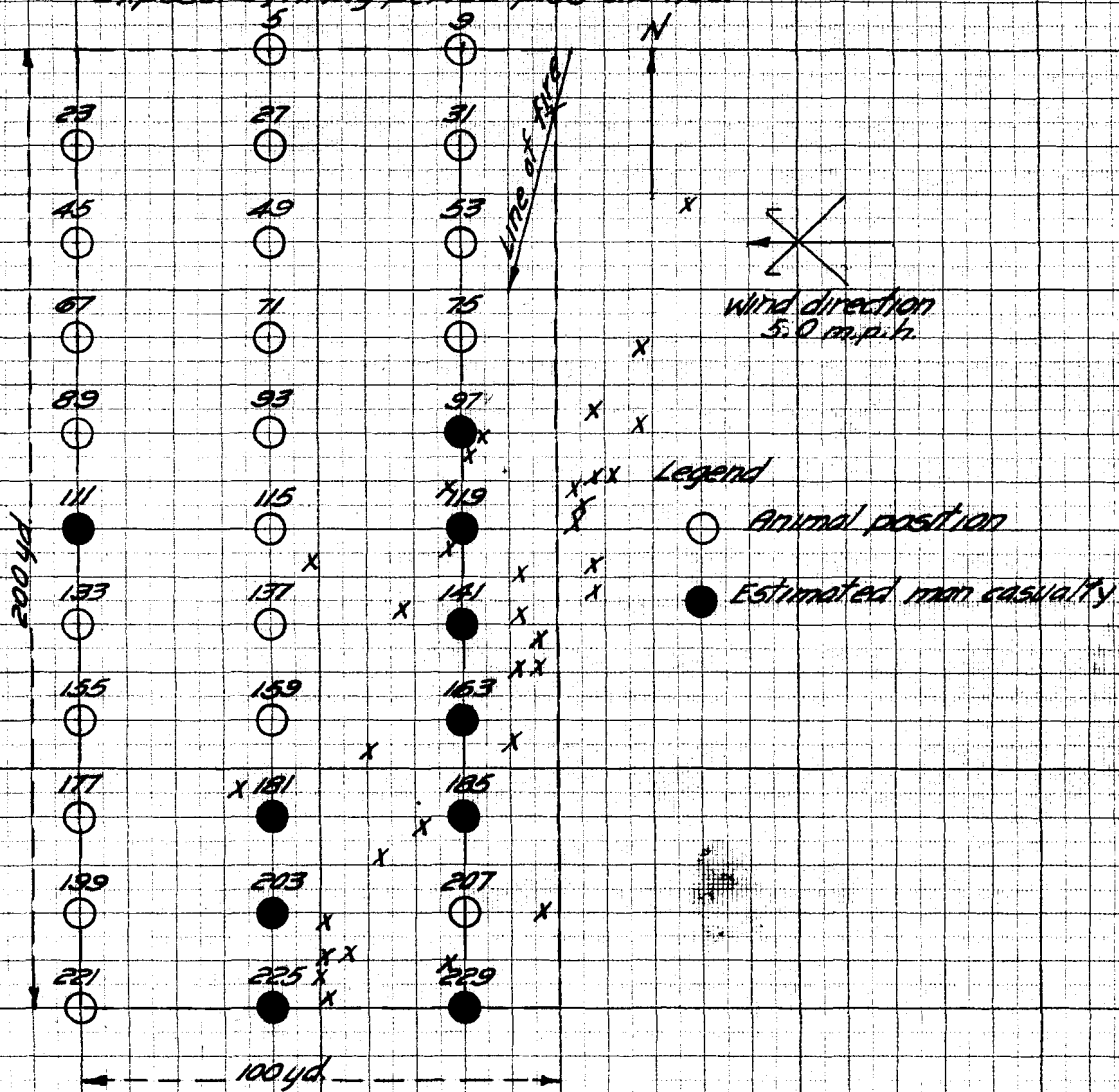
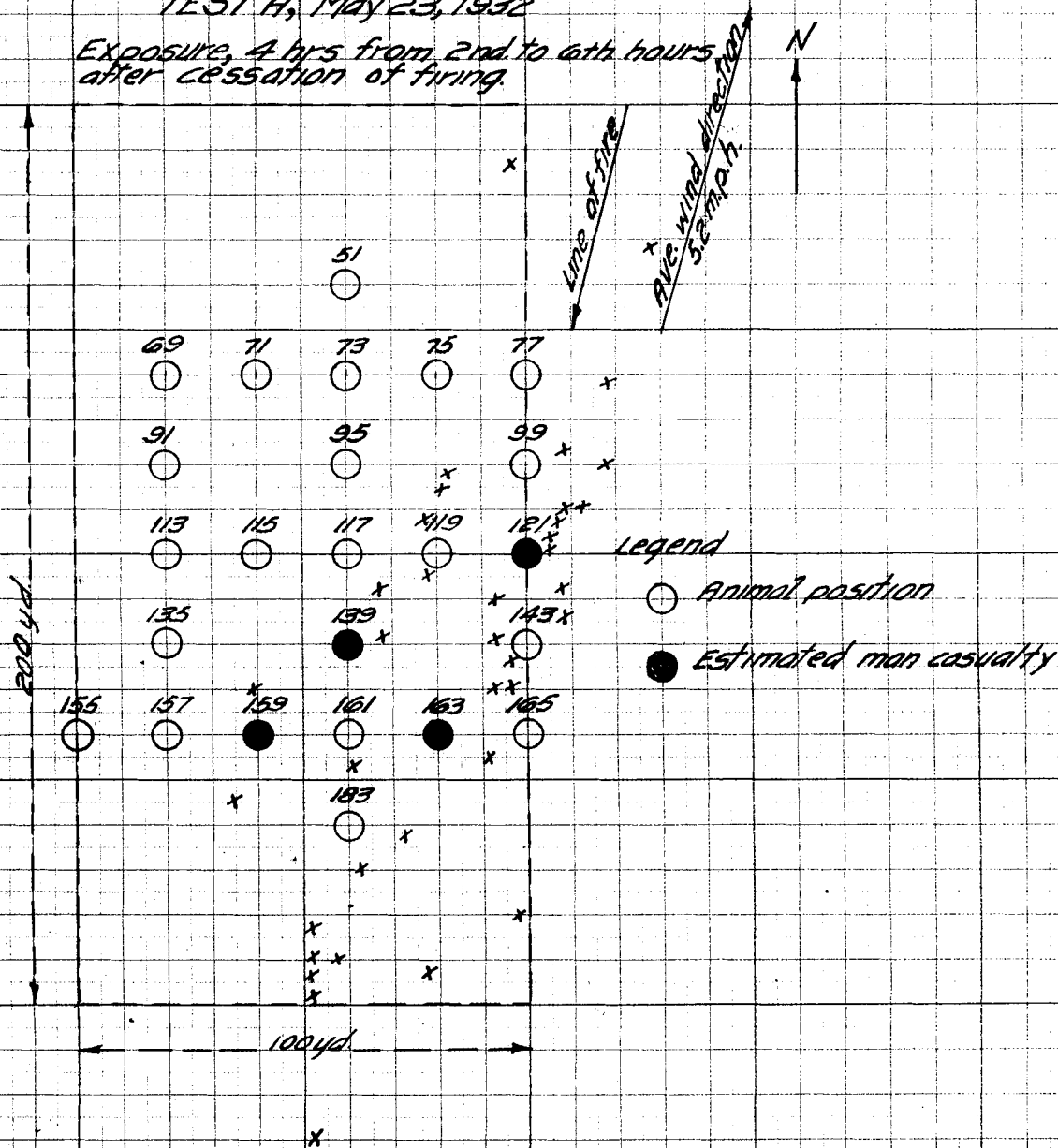


CHART 12'A  
ESTIMATED MAN CASUALTIES BASED  
ON EFFECTS ON ANIMALS

TEST A, May 23, 1932

Exposure, 4 hrs from 2nd to 6th hours  
after cessation of firing.

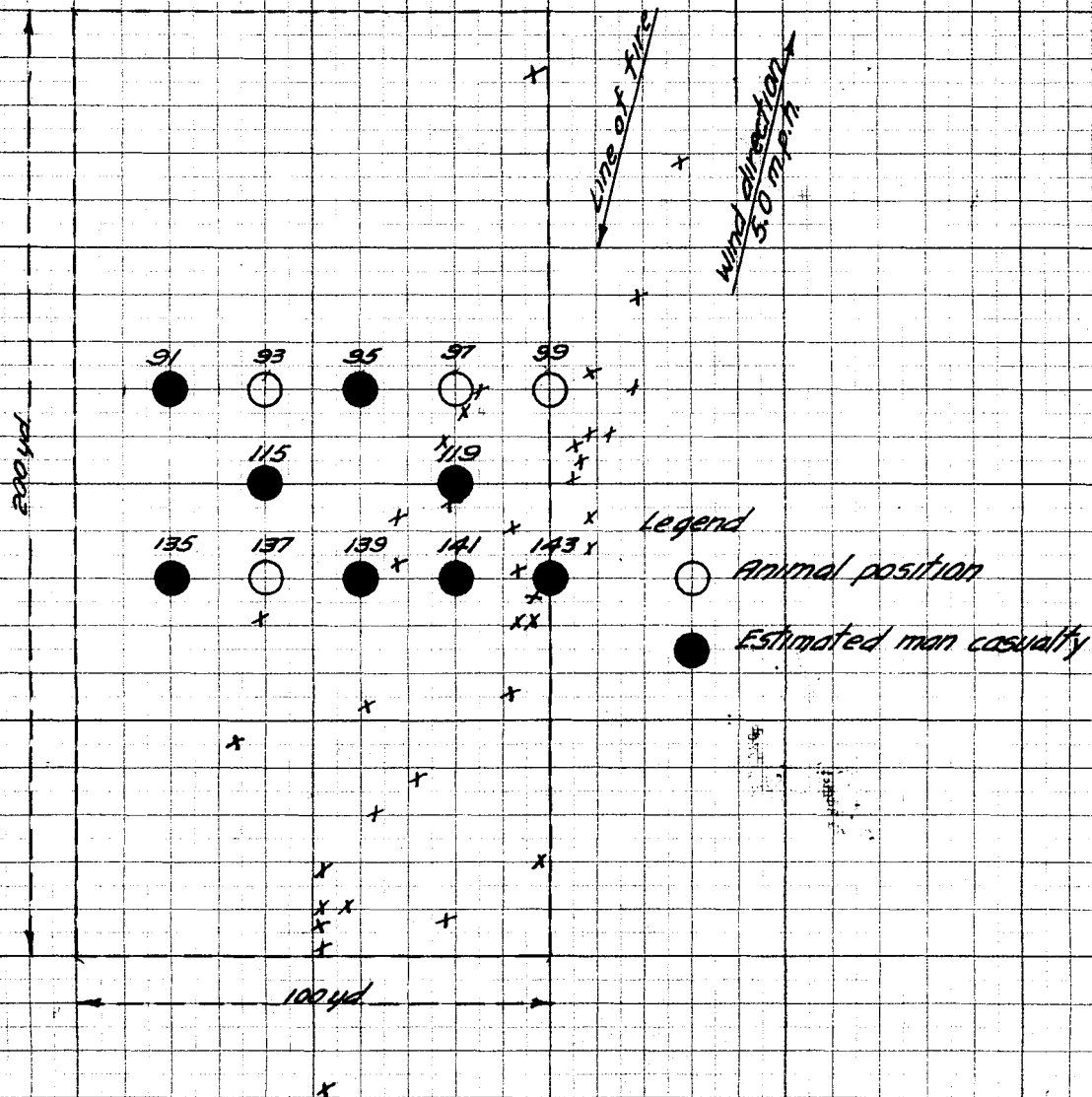


# CHART 13

ESTIMATED MAN CASUALTIES BASED  
ON EFFECTS ON ANIMALS.

TEST A, May 23, 1932

Exposure 24 hrs, from 6th to 30th hours  
after cessation of firing.



Appendix C.

Report of Test of HS-Filled 155-mm. Howitzer Shell.  
Test B - June 11, 1932.

REPORT  
OF  
TEST OF HS-FILLED 155-mm. HOWITZER SHELL  
TEST B - JUNE 11, 1932

1. Object. The object of this test was to determine the number of 155-mm. howitzer shell filled with HS, which is required in open country under the meteorological conditions which existed at the time of the test to produce 50% casualties, requiring evacuation for hospitalization.

2. Authority. This test was conducted under authority contained in 3rd Indorsement from the office of the Chief of Ordnance, Washington, D.C., Oct. 22, 1931, to Ordnance Officer, Edgewood Arsenal, Maryland (O.O 471/7466; CWS 471/211; EO 471.1/698.

3. Previous Tests. A test was conducted on February 16 and 17, 1932, in which 36 shell from each of four lots of shell, representing the shell used in the present test, were fired from service weapons to determine if the shell functioned normally, but no attempt was made in the test to determine the gas concentration set up. A second test was conducted on May 23, 1932, in which 40 shell were fired for impact on a target 100 yd. wide by 200 yd. deep. The effectiveness of the gas concentration set up in this test was determined by (1) effect on animals, (2) by use of paper panels to determine pattern produced by liquid HS, and (3) by the use of vapor sampling machines to determine vapor concentration. From a preliminary study of the results of this test, it was estimated that it would require about 25 shell per 100 yd. sq., to produce 50% casualties, when man is protected with gas mask only.

4. Materials Used.

a. Shell. The shell used in the present test, were the Mk. II, 155-mm. howitzer filled with HS. They were taken from War Reserve at Edgewood Arsenal and represent a lot which were filled at Edgewood Arsenal in the years 1921-22, for shipment to the Hawaiian Islands. The HS used in filling the shell was from War Reserve and was probably made by the Leivinstein process. The void used in filling the HS into the shell is not known, but was probably about 10%, based on the maximum volume of the shell.

b. Booster. The booster used was the Mk. VIB, which contained a bursting charge of 29 g. of tetryl and 253 g. of TNT. A visual examination of the boosters, as assembled in the shell, showed that a large percentage of them were improperly seated. In the case of some shell, as many as seven or eight booster threads were exposed.

c. Fuse. The fuse used was the Mk. III, super quick point detonating fuse.

d. Number of Shell Used. Forty of these shell, as taken from stock in War Reserve, were used for adjustment and forty for effect.

e. Howitzers Used. A battery of four 155-mm. howitzers was used under command of Captain MacMahon of the 6th Field Artillery. The position of the howitzers was on "C" field in the vicinity of coordinates 690.4, 1869.1, as shown on the special military map of Gun Powder Neck, prepared under the direction of the Chief of Engineers, U.S. Army, 1923.

5. Target Area. The target area was rectangular, 100 yd. wide by 200 yd. deep. The area was located in open country covered with weeds and grass 1-1/2 to 2 ft. high. The vegetation on two-thirds of the area was light but heavy on the remaining third. The area located on "H" field was in the vicinity of coordinates 690.5, 1864.0. In preparing the area it was divided into ten yard squares by placing numbered stakes at ten yard intervals. Paper panels, sampling machines, and animals were placed on the area to determine the effectiveness of the gas concentration set up. Chart 1 accompanying this report, shows the target area as it was prepared for the test with positions of animals, panels and sampling machines.

## 6. Experimental.

a. Method of Conducting the Test. After adjustment of howitzers, the shell for effect were fired as rapidly as possible with change in elevation for equal distribution of impacts over the target area. After completing the firing of the shell, the paper panels were collected for tabulation of results and the animals on the target area and at positions downwind from the target area, were removed at definite periods and replaced by other animals. Also during the firing period and the animal exposure periods, vapor samples were taken with the use of field sampling machines. The meteorological data was recorded during the period of the test.

### b. Firing of Shell.

(1) Adjustment of Howitzers. The howitzers were adjusted in parallel on a target about 100 yd. east of the target area, using 40 shell filled with HS. Adjustment firing was from 7:22 a.m. to 8:29 a.m.

During adjustment firing, five duds and three low order bursts were noted.

(2) Firing for Effect. When firing for effect, the howitzers were ranged in parallel on the target area using two elevations. One half of the shell were fired for impact on a line 50 yd. beyond the center of the area and the balance for impact on a line 50 yd. short of the center. The range was about 5,100 yd. Firing for effect started at 9:05 a.m. and ended at 9:16 a.m., a period of eleven minutes. Of the 40 shell fired, one dud and two low order bursts were noted. A photo-static copy of a memorandum dated August 4, 1932, to the Technical Director from the Battery Commander, giving the firing data by round is attached to this report.

(3) Impacts. The positions of the impacts are shown on Chart 2. Of the 40 shell fired for effect, 31 registered on the target area and the remaining nine within 50 yd. of the edge of the target area.

c. Meteorological Conditions. The following meteorological conditions prevailed during the firing period and the periods following during which vapor samples were taken and animals were exposed on the target area:

Date	-	6/11/32	-	6/11/32	-	6/11/32
Time	-	9:05 to 9:26 a.m.	-	9:26 to 10:16 a.m.	-	10:16 a.m. to 2:16 p.m.
Air temperature, °F.	-	68	-	68 to 72	-	72 to 77
Ground temperature, °F.	-	88 to 92	-	92 to 100	-	100 to 110
Ground condition	-	dry	-	dry	-	dry
Relative humidity, %	-	66	-	66 to 52	-	50
Wind velocity, m.p.h	-	5.3	-	4.8	-	3.0
Wind direction	-	NE	-	E to N	-	E to S to W
Sky	-	clear	-	clear	-	hazy

## 7. Results.

### a. Liquid HS.

(1) Size of Liquid HS Drops. The distribution of liquid HS was registered by means of paper panels eight inches by eight inches, placed flat on the ground at each stake position over the entire target area. The panels having drops in excess of 0.05 mg. are tabulated in the following table:

Table No. 1.

Size of HS Drops.

No. of drops per panel	No. of panels classified					
	.05 to	.1 to	.5 to	1.01 to	Over	
	.1 mg.	.5 mg.	1.0 mg.	3.0 mg.	3.0 mg.	
1	0	10	5	0	0	
2 to 10	23	13	4	4	2	
11 to 20	6	0	2	0	0	
Over 20	12	1		0	0	

Total panels having drops of .05 mg. or greater - 49  
 " " exposed on target area -228

(2) Estimated Man Casualties from Liquid HS.

(a) Man Protected with Gas Mask but Without the  
Protection of Impregnated Clothing.

The paper panels were tabulated for density of pattern using the gradings heavy, medium, light and trace. A photostat of the scale used in grading the panels is attached to this report. The panel gradings are tabulated in the following table, together with estimated man casualties:

Table No. 2.

Estimated Man Casualties on Target Area from Liquid HS.

Panel pattern:	Panels classified		Estimated masked man cas- ualties
	No.	% of total	
		on target area	
Heavy	8	3.3	3.5
Medium	19	8.3	8.3
Light	44	19.3	15.4
Trace	62	27.2	16.3
No HS	95		
Total & Avs.	228	58.3	43.5

From panel data given in Table No. 2, it is estimated that personnel exposed on the target area during the firing period, protected with gas mask only, would suffer about 45% casualties, if they are distributed. The position of shell craters and estimated man casualties from liquid HS are shown graphically on Chart 2.

Note: The estimated man casualties as given in Table 2, above, are based on estimates furnished by the Protected Development Division in memorandum of October 22, 1931, to the Engineering Division, as follows:

Panel	:	Estimated man casualties through
pattern	:	standard issue of unimpregnated
	:	clothing
	:	%
Heavy	:	100
Medium	:	100
Light	:	80
Trace	:	60

(b) Man Protected with Gas Mask and Standard Impregnated Clothing.

The paper panels were tabulated for number of HS drops on panels in which the drop size was in excess of 0.5 mg. The results of the tabulation, together with estimated man casualties, are given in the following table:

Table No.3.

Estimated Man Casualties on Target Area from Liquid HS.

Size of HS drops	:	No. of panels	:	Estimated man casualties when protected with gas mask and standard impregnated clothing
mg.	:		:	per panel : entire target area
.5 to 1.0	:	11	:	40% : 1.9%
Over 1.0	:	6	:	100% : 2.6%
Total	:	17	:	4.5%

Total number of panels on area - 228.

From panel data given in Table No. 3, it is estimated that personnel protected with gas mask and standard impregnated clothing, would suffer 4.6% casualties by effects of liquid HS, if exposed with distribution on the target area, during the firing period.

Note: The per cent estimated man casualties given in the last column of Table No. 3, is based on laboratory tests by the Protective Development Division, the results of which are given in memorandum of August 6, 1931 to the Technical Director. These tests showed that liquid HS penetrated two layers of standard protective clothing and produced casualties as follows:

HS drops	0.6 mg.	in size	-	40%	man casualties
"	"	0.7	"	80%	"
"	"	0.8	"	100%	"

b. Estimated Man Casualties from HS Vapor. Sampling machines were placed to take vapor samples at positions indicated on Chart 1. In each of the tables which follow, representing different sampling periods, the sampling positions used are designated. The HS vapor concentration, c.t. value, and per cent estimated man casualties, as estimated from the vapor concentration, are also included in each of the tables.

The c.t. value is equal to the vapor concentration in milligrams per liter times the exposure period in minutes. Estimated man casualties are based on the c.t. value using the valuation curve given on Graph 1, attached to this report. The per cent estimated man casualties in the following tables represent man protected with gas mask, but without the protection of impregnated clothing.

(1) On the Target Area.

(a) Firing Period Plus Ten Minutes.

Table No. 4.

Sampling position:	Elevation of sample:	Vol. of air sampled:	Sampling period:	HS sampled:	Vapor concn.:	c.t. value:	Estimated man casualties when man is protected with gas mask only
:	ft.	liters	min.	mg.	mg./l.	:	%
G	0	590	17	17.1	.0290	.49	100
K	1	730	21	6.5	.0089	.19	100
L	1	630	20	0	0	0	0
O	0	822	24	4.0	.0049	.12	100
P	0	775	23	0	0	0	0

Av. 60

(b) Fifty Minute Period Starting Ten Minutes After Firing Ceased.

Table No. 5.

Sampling position:	Elevation of sample	Vol. of air sampled	Sampling period	HS sampled	Vapor concn.	c.t. value	Estimated man casualties when man is protected with gas mask only
:	ft.	liters	min.	mg.	mg./l.	:	%
G	0	1860	52	15.7	.0084	.44	100
K	1	1770	51	2.5	.0014	.072	74
L	1	1860	52	0.8	.0004	.02	30
O	0	872	51	2.9	.0033	.16	100
P	0	1884	56	0	0	0	0
F	0	1762	50	6.7	.0038	.19	100
Av.							67.3

(c) Firing Period Plus One Hour.

Table No. 6.

Sampling position:	Elevation of sample	Vol. of air sampled	Sampling period	HS sampled	Vapor concn.	c.t. value	Estimated man casualties when man is protected with gas mask only
:	ft.	liters	min.	mg.	mg./l.	:	%
B	1	1564	45	15.7	.0180	.45	100
F	0	1762	50	6.7	.0038	.19	100
G	0	2450	69	32.8	.0134	.93	100
K	1	2500	72	9.0	.0036	.26	100
L	1	2490	72	0.8	.0003	.02	30
O	0	1699	75	6.9	.0041	.31	100
P	0	2659	79	0	0	0	0
S	1	2890	82	0	0	0	0
T	1	2950	85	0	0	:	0
Av.							59

(d) Four Hour Period Beginning One Hour  
After Firing Ceased.

Table No. 7.

Sampling position:	Elevation of sample	Vol. of air sampled	Sampling period	HS sampled	Vapor concn.	c.t. value	Estimated man casualties when man is protected with gas mask only
:	ft.	liters	min.	mg.	mg./l.	:	%
F	0	8460	240	3.4	.0004	.09	87
G	0	4260	238	8.2	.0019	.46	100
K	1	8240	237	1.9	.0002	.05	58
L	1	4220	232	0	0	0	0
O	0	8060	233	4.4	.0005	.13	100
S	1	8340	229	0	0	0	0
P	0	7660	227	0	0	0	0
T	1	8140	224	0	0	0	0
Stake 50:	1	4450	256	4.6	.0010	.25	100
" "	2	4450	256	2.7	.0006	.15	100
" "	4	4450	256	0.4	.0001	.02	33

(e) Four Hour Period a Day Following Firing.

No samples were taken on account of rain.

(f) Four Hour Period on Second Day Following Firing.

No samples were taken on account of rain.

(2) Downwind from Impact Area.

(a) Firing Period Plus One Hour.

Table No. 8.

Sampling position:	Elevation of sample	Vol. of air sampled	Sampling period	ES sampled	Vapor concn.	c.t. value	Estimated man casualties when man is protected with gas mask only
	ft.	liters	min.	mg.	mg./l.		%
A	1	782	45	9.0	.0115	.52	100
"	2	"	"	1.2	.0015	.07	73
"	4	"	"	0	0	0	0
H	1	1198	69	0	0	0	0
"	2	"	"	0	0	0	0
"	4	"	"	0	0	0	0
J	1	1250	72	2.3	.0018	.15	100
"	2	"	"	1.0	.0008	.057	64
"	4	"	"	1.2	.0010	.072	75
M	1	1137	92	0	0	0	0
"	2	"	"	0	0	0	0
"	4	"	"	0	0	0	0
N	1	1282	75	8.8	.0039	.51	100
"	2	"	"	9.5	.0074	.55	100
Q	1	1330	79	0	0	0	0
"	2	"	"	0.4	.0003	.024	35
"	4	"	"	0.4	.0003	.024	35
R	1	1445	82	1.0	.0007	.057	64
"	2	"	"	1.0	.0007	.057	64
"	4	"	"	0.8	.0006	.049	58
U	1	1475	85	1.0	.0007	.06	66
"	2	"	"	.8	.0006	.04	50
"	4	"	"	1.0	.0007	.06	66

Note: The positions of sampling machines are shown on Chart 1.

(b) Four Hour Period Beginning One Hour  
After Firing Ceased.

Table No. 9.

Sampling position:	Elevation of sample	Vol. of air sampled	Sampling period	HS sampled	Vapor concn.	c.t. value	Estimated man casualties when man is protected with gas mask only
	ft.	liters	min.	mg.	mg./l.		%
E	1	4230	240	0	0	0	0
"	2	"	"	0	0	0	0
"	4	"	"	0.4	.0001	.02	30
H	1	4260	238	0	0	0	0
"	2	"	"	0	0	0	0
"	4	"	"	0	0	0	0
J	1	4120	237	0.4	.0001	.02	30
"	2	"	"	0.4	.0001	.02	30
"	4	"	"	0.4	.0001	.02	30
M	1	4220	232	0	0	0	0
"	2	"	"	0	0	0	0
"	4	"	"	0	0	0	0
N	1	4030	233	1.0	.00025	.06	66
"	2	"	"	1.7	.00043	.10	93
Q	1	3830	227	0	0	0	0
"	2	"	"	0	0	0	0
"	4	"	"	0	0	0	0
R	1	4170	229	0.6	.0001	.02	30
"	2	"	"	0	0	0	0
"	4	"	"	0.4	.0001	.02	30
U	1	4070	224	0	0	0	0
"	2	"	"	0	0	0	0
"	4	"	"	0	0	0	0

Note: The positions at which vapor samples were taken are shown on Chart 1.

c. Estimated Man Casualties Based on Effects on Animals.

Animals were placed on and downwind from the target area to determine effect of the gas concentration set up and how long the HS persisted on the impact area. The position of the animals as exposed during the various exposure periods is shown on Charts 1, 7, 8, 9, 10, and 11. The animal casualties and estimated man casualties, are given in the tables which follow. The man casualties are estimates made by the Medical Research Division who observed and studied the effects of the HS on all animals exposed. Estimated man casualties from the effects on animals are shown on Charts 12, 13, 14, 15, and 16. On the Charts as well as in the tables which follow, the following symbols are used to designate the nature of the animal casualty:

L - Gross pathology of lung.  
R - Respiratory symptoms.  
S - First degree skin burn.  
S<sub>2</sub> - Second " " "  
S<sub>3</sub> - Third " " "  
E - Simple conjunctivitis.  
E<sub>2</sub> - Purulent. "  
F - Injury by shell fragment.

(1) On Target Area.

(a) Firing Period and the Following Ten Minutes.

During the firing period and following ten minutes, 18 rats and 16 goats were exposed on the target area. Animal casualties and estimated man casualties, when man is protected with gas mask only, are tabulated below. The position of the animals is shown on Chart 7, and estimated man casualties are shown on Chart 12.

Table No. 10A.

Estimated Man Casualties Based on Effects  
on Rats.

Position: of stake	Nature of casualty	Severity of casualty	Remarks	Estimated casualties when man is pro- tected with gas mask only
7	ELS	Death	Burns on feet. Casualty in: 3 hrs.	100%
47	ERS <sub>2</sub>	Severe	Burns on feet. Casualty in: 12 hrs.	100%
95	ELS	Death	Burns on feet. Casualty in: 24 hrs.	100%
135	ELS <sub>2</sub>	Death	Burns on feet. Casualty in: 4 hrs.	100%
139	EL	Death	Casualty in 4 hrs.	100%
223	ELS	Death	Burns on feet. Casualty in: 12 hrs.	100%
Av.				33%

Table No. 10B.

Estimated Man Casualties Based on Effects  
on Goats.

25	EL	Death	Casualty in 12 hrs. Death in 9 days.	100%
69	ER	Moderate	Casualty in 12 hrs.	100
73	ES	"	Burns on body. Casualty in in 4 hrs.	100
77	ES	Light	Burns on body. Casualty in 12 hrs.	100
113	ERS <sub>2</sub>	Severe	Burns on body and nose. Casualty in 6 hrs.	100
167	ER	Death	Death on area.	100
185	LS	Light	Burns on body. Casualty in: 24 hrs.	100
201	E	Moderate	Casualty in 4 hrs.	0
205	SR	"	Burns on body. Casualty in: 12 hrs.	100
209	ELS	Death	Casualty in 6 hrs. Burns on body. Death in 3 days.	100
Av.				56%

(b) Firing Period and the Following Hour.

During the firing period and following hour, 15 rats and 17 goats were exposed on the target area. Animal casualties and estimated man casualties where man is protected with gas mask only, are tabulated in Tables 11A and 11B, given below. The position of the animals is shown on Chart 8, and the position of estimated man casualties is shown on Chart 13.

Table No. 11A.

Estimated Man Casualties Based on Effects  
on Rats.

Position: of stake	Nature of casualty	Severity of casualty	Remarks	Estimated casualties when man is protected with gas mask only
71	ELS	Death	Burns on feet. Casualty : : in 12 hrs.	100%
75	ELS	"	Burns on feet. Casualty : : in 4 hrs. Death in 4 da.:	100
111	ERS	Medium	Burns on feet. Casualty : : in 4 hrs.	100
115	EL	Death	Death in 4 hrs.	100
155	SE	Medium	Burning on feet. Casualty: : in 12 hrs.	100
159	ELS	Death	Burns on feet. Casualty : : in 12 hrs. Death in 4 : days.	100
				Av. 40%

Table No. 11B.

Estimated Man Casualties Based on Effects  
on Goats.

Position: of stake	Nature of casualty	Severity of casualty	Remarks	Estimated casualties when man is protected with gas mask only
46	ERS <sub>2</sub>	Severe	Burns on body and nose. Casualty in 12 hrs.	100%
49	ELS	Death	Burns on body. Casualty in 6 hrs. Death in 9 days	100
89	ERS	Severe	Burns on ears. Casualty in 4 hrs.	100
93	ERS	Moderate	Burns on body. Casualty in 12 hrs.	100
133	ES	Moderate	Burns on body. Casualty in 12 hrs.	100
137	ELS	Death	Burns on feet and body. Casualty in 6 hrs. in 15 days	100
177	ERS	Severe	Burns on body. Casualty in 12 hrs.	100
181	E <sub>2</sub>	Severe	Casualty in 4 hrs.	0
221	ELS	Death	Burns on ears and body. Casualty in 4 hrs.	100
225	S	Light	Burns on body. Casualty in 12 hrs.	100
229	E	Moderate	Casualty in 12 hrs.	0
Av.				53%

(c) Four Hour Period Beginning One Hour After  
Firing Ceased.

During the four hour period beginning one hour after firing ceased, 15 rats and 9 goats were exposed on the target area. Animal casualties and estimated man casualties, where man is protected with gas mask only, are tabulated in tables 12A and 12B below. The positions of the animals are shown on Chart 9, and position of estimated man casualties is shown on Chart 14.

Table No. 12A.

Estimated Man Casualties Based on Effects on  
Rats.

Position: of stake	Nature of casualty	Severity of casualty	Remarks	Estimated casualties when man is protected with gas mask only
51	E	Moderate	Casualty in 6 hrs.	0
71	S	"	Burns on feet. Casualty in 15 hrs.	100
75	E	Light	Casualty in 4 hrs.	0
115	ER	"	" " " "	100
119	ES	Moderate	Burns on feet. Casualty in 4 hrs.	100
135	ES	"	Burns on feet. Casualty in 12 hrs.	100
Av.				27%

Table No. 12B.

Estimated Man Casualties Based on Effects on  
Goats.

73	ES	Light	Burns on body. Casualty in 6 hrs.	100%
77	R	Moderate	Casualty in 12 hrs.	0
113	S	Light	" " " "	100
121	E	"	Casualty in 4 hrs.	0
157	E <sub>2</sub> LS	Death	Burns on body. Casualty in 12 hrs.	100
Av.				33%

(d) Twenty-four Hour Period Beginning Five Hours  
After Firing Ceased.

During the 24 hour period beginning five hours after firing ceased, eight rats and four goats were exposed on the target area. Animal casualties and estimated man casualties, where man is protected with gas mask only, are tabulated in Tables 13A and 13B, given below. Animal positions are shown on Chart 10 and estimated man casualties on Chart 15.

Table No. 13A.

Estimated Man Casualties Based on Effects on Goats.

Position: of stake	Nature of casualty	Severity of casualty	Remarks	Estimated casualties when man is protected with gas mask only
97	S	Light	Burns on body	100%
141	R	"	:	0
				Av. 25%

Table No. 13B.

Estimated Man Casualties Based on Effects on Rats.

139	ES	Light	:	100%
				Av. 12%

(e) Twenty-four Hour Exposure in Shell Craters  
on Third Day After Firing.

During the 24 hr. period beginning the third day after firing, seven rats and one goat were exposed on the target area in shell craters. Animal casualties resulting and estimated man casualties, where man is protected with gas mask only, are tabulated in tables 14A and 14B, which follows:

Table No. 14A.

Estimated Man Casualties Based on Effects on Rats.

Position: of stake	Nature of casualty	Severity of casualty	Remarks	Estimated casualties when man is protected with gas mask only
:	ELS	Death	Burns on feet. Death in 6 da.	100%
:	E <sub>2</sub> RS <sub>2</sub>	Severe	Burns on feet.	100
:	ELS	Death	Burns on feet. Death in 3 da.	100
:	ELS <sub>2</sub>	"	Burns on feet. Death in 6 da.	100
:	ERS	Moderate	Burns on feet.	100
:	E	Light	:	0

Table No. 14B.

Estimated Man Casualties Based on Effects on Goats.

Position:	Nature	Severity:	Remarks	Estimated cas-
of	of	of		ualties when man
stake	casualty	Casualty:		is protected with
:	:	:		gas mask only
:	S <sub>2</sub>	Moderate:	Burns on body.	100%

(f) Twenty-four Hours Exposure in Shell Craters on Ninth Day After Firing.

During the 24-hr. period beginning the ninth day after firing, seven rats and one goat were exposed on the target area in shell craters. Animal casualties resulting and estimated man casualties, where man is protected with gas mask only, are tabulated in Table No. 15, which follows:

Table No. 15.

Estimated Man Casualties Based on Effects on Rats.

Nature of:	Severity :	Remarks	Estimated casualties
casual-	of :		when man is protected
ty :	casualty :		with gas mask only
LS	Death	Burns on feet. Death in 24 hr.:	100%
ES	Light	:	100
ES	"	:	100
ES	"	:	100
ES	"	:	100
ES	"	:	100
ES	"	:	100

The goat exposed was not a casualty.

(g) Twenty-four Hour Exposure in Shell Craters  
on Thirteenth Day After Firing.

During the 24-hr. period beginning the thirteenth day after firing, seven rats were exposed on the target area in shell craters. Animal casualties resulting and estimated man casualties, where man is protected with gas mask only, are tabulated in Table No. 16, which follows:

Table No. 16.

Estimated Man Casualties Based on Effects on Rats.

Nature of: casualty	Severity of: casualty	Remarks	Estimated casualties when man is protected with gas mask only
RE	: Light	:	: 0%
RE	: "	:	: 0
L	: Death	: Death in 24 hr.	: 100
E	: Light	:	: 0
ES	: "	:	: 100

(h) Twenty-four Hour Exposure in Shell Craters  
on Seventeenth Day After Firing.

During the 24-hr. period beginning the seventeenth day after firing, seven rats were exposed on the target area in shell craters. Animal casualties resulting and estimated man casualties, where man is protected with gas mask only, are tabulated in Table No. 17, which follows:

Table No. 17.

Estimated Man Casualties Based on Effects on Rats.

Nature of: casualty	Severity of: casualty	Remarks	Estimated casualties when man is protected with gas mask only
S	: Light	: Casualty when removed : from area.	: 100%
S	: "	: Ditto.	: 100
S	: "	: Ditto.	: 100

(2) Downwind from Target Area.

(a) Firing Period and Following Four Hours.

Eight rats and four goats were exposed at positions downwind from the target area during the firing period and the following four hours at positions shown on Chart 1. Animal casualties resulting and estimated man casualties, where man is protected with gas mask only, are tabulated in Tables 18A and 18B, which follow. The positions of the animals, and casualties are shown on Chart 11 and the positions of the estimated man casualties are shown on Chart 16.

Table No. 18A.

Estimated Man Casualties Based on Effects on Rats.

Position of stake	Nature of casualty	Severity of casualty	Remarks	Estimated casualties when man is protected with gas mask only
249	ES	Light	Burns on feet. Casualty in 6 hr.	100%
261	RE	"	Casualty in 12 hr.	0
280	ES	"	Burns on feet. Casualty in 6 hr.	100
252	ERS	Moderate	Burns on feet. Casualty in 6 hr.	100
269	ER	Light	Casualty in 6 hr.	0
288	ES	"	Burns on feet. Casualty in 8 hr.	100
253	ES	Moderate	Casualty in 12 hr.	100

Table No. 18B.

Estimated Man Casualties Based on Effects on Goats.

264	ERS	Severe	Burns on body.	100%
266	ES	Moderate	" " "	100
257	ES	Moderate	" " "	100

## 8. Discussion.

a. Shell Distribution. The shell were fired for equal distribution of impacts over the entire target area. Of the 40 shell fired for effect on the target, 31 registered on the target area, one of which was a dud. The craters produced by these 31 shell were all within the area of 16,800 sq.yd. which is about 84% of the target area. Aside from the impacts on the target area, there were seven additional impacts within a distance of 40 yd. from the edge of the target area. Only two of these shell were at all effective on the target on account of wind direction and direction of fire. The positions of the shell craters are shown on Chart 2.

b. Impact Area. The number of animal positions included within the impact area was 42, and since each animal was located on the center of a 20 yd. sq., for purposes of discussion the size of the impact area may be regarded as 16,800 sq. yd. The animal positions on the impact area and number of impacts on each 20 yd. sq., are given in Table No. 19, which follows:

Table No. 19.

Impact Area (16,800 sq.yd.)

Stake at center of: 20 yd. sq.	:	Impacts within 20 yd. sq.	:	Stake at center: of 20 yd. sq.	:	Impacts within 20 yd. sq.
1	:	0	:	95	:	0
3	:	0	:	97	:	0
5	:	0	:	111	:	1
7	:	0	:	113	:	0
23	:	0	:	115	:	2
25	:	2	:	117	:	1
27	:	0	:	133	:	1
29	:	3	:	135	:	2
45	:	0	:	137	:	2
47	:	0	:	139	:	1
49	:	0	:	155	:	0
51	:	1	:	157	:	2
53	:	3	:	159	:	0
67	:	1	:	161	:	1
69	:	0	:	177	:	1
71	:	0	:	179	:	0
73	:	0	:	181	:	1
75	:	3	:	199	:	0
89	:	0	:	201	:	1
91	:	0	:	221	:	1
93	:	1	:	223	:	0
				Total	:	31

e. Estimated Man Casualties from Liquid HS.

(1) Effects of Meteorological Conditions.

The only meteorological factor having any effect on the size of the area covered with liquid HS, by the burst of a single shell, is wind velocity. An increase in the wind velocity will result in an increase in the size of the area sprinkled due to the liquid drops being carried in the direction of wind travel to a greater distance. On the other hand, a decrease in the wind velocity will result in a smaller area being contaminated by the liquid HS due to the liquid drops not being carried so far by the wind.

(2) Protected with Gas Mask but without Protection of Impregnated Clothing.

Results from paper panels given in Table No. 2, show that personnel exposed with equal distribution on the target area during the firing period, would suffer about 45% casualties from liquid HS when protected with gas mask only. The percentages given in Table No. 2, are based on the entire target area which includes about 3,200 sq.yd. on which there was little or no effect from liquid HS. The figures given below, in Table No. 20, are based on results on the impact area only (16,800 sq.yd.), as defined in paragraph 8 b. Thirty-one shell bursts are included within the impact area.

Table No. 20.

Estimated Man Casualties from Liquid HS on Impact Area (16,800 sq.yd.).

Panel pattern:	Panels contaminated: No.	Estimated masked man casualties: Per cent
Heavy	8	5.3
Medium	19	12.6
Light	44	29.1
Trace	61	40.4
No HS	19	12.6
Total	151	100

If 31 shell distributed will produce 65.4% casualties from the effects of liquid HS on an area of 16,800 sq.yd., about fourteen shell distributed per 100 yd.sq., are required to produce 50% casualties when man is protected with gas mask only.

In Table No. 19, the number of shell bursts are given for each 20 yd. sq. included within the impact area. The figures in the table show as many as three shell bursts on some of the 20 yd. sq., whereas one in the upwind part of the square would have probably produced 100% casualties. If the two additional shell had been distributed to other parts of the area, it is probable that estimated casualties would have been greater and shell requirements to produce 50% casualties would have figured slightly less.

(3) Protected with Gas Mask and Standard Impregnated Clothing.

From results given in Table No. 3, it is estimated that personnel protected with gas mask and standard impregnated clothing, exposed with distribution on the target area during the firing period would suffer about 4.5% casualties from liquid HS. There were some parts of the target area, however, on which there was little or no effect from liquid HS, due to wind direction and position of impacts. In Table No. 20, which follows, percentages are based on effects on the impact area (16,800 sq.yd.), as defined in paragraph 8b, on which there were 31 impacts.

Table No. 21.

Estimated Man Casualties from Liquid HS on Impact Area (16,800 sq.yd.)

Panels showing HS drops: Estimated man casualties when in excess of 0.5 mg. man is protected with gas mask and standard impregnated clothing				
Size of HS: drops	No. of panels			
mg.		per panel		impact area
.5 to 1.0:	11	40%		2.9%
Over 1.0 :	6	100%		3.8
Total				6.6%

Total panels on impact area (16,800 sq.yd.) - 156.

If 31 shell distributed on an area of 16,800 sq.yd. will produce 6.6% casualties, when man is protected with gas mask and standard impregnated clothing, it will require about 140 shell distributed per 100 yd.sq., to produce 50% casualties.

d. Estimated Man Casualties from HS Vapor.

(1) Effects of Meteorological Conditions. A theoretical discussion of the effect of meteorological conditions on the vapor concentration set up, is given in report of Test A, conducted on May 23, 1932.

During the present test, the ground temperature was 88°F. to 92°F., the air temperature was 68°F., and the wind velocity was 5.3 m.p.h. These conditions were favorable to set up a moderately high vapor concentration on the target area. The ground temperature was about 20°F. higher than the air temperature however, so that convection air currents were set up. This theoretically resulted in the upward travel of the HS vapor so that meteorological conditions were unfavorable for the building of a high vapor concentration outside of the area contaminated with liquid HS. Theoretically, the vapor concentration set up downwind from the target area was not as great as it would have been with the same wind conditions, if the test had been held after sunset, when there are no effects from convection air currents.

(2) Vapor Concentration Required to Produce Man Casualties.

A discussion of the exposure period required to produce man casualties from HS vapor is given in Test "A", "Report of Test of HS Filled 155-mm. Howitzer Shell", conducted May 23, 1932.

(3) On the Target Area. Estimated man casualties on the target area from the effects of HS vapor for the different exposure periods, are tabulated in Tables No. 4 to 7, inclusive, and results are shown on Charts 3 to 6A, inclusive.

(a) Firing Period and Following Ten Minutes.

From the results of vapor samples given in Table No. 4, representing the firing period and following ten minutes, it is estimated that man with the protection of gas mask only would suffer about 60% casualties from effects of HS vapor. This estimated is based on the results of vapor samples taken at five different positions on the target area.

In the fifth column of Table No. 22, which follows, estimated vapor casualties are given for each 20 yd. sq. on the entire target area. The figures as given in this column are estimates based on results obtained at sampling position, the position of nearest impact, and the wind direction. Estimated vapor casualties for the total target area, figured from estimates on each 20 yd.sq., are 64%, which very closely checks 60%, the estimate given in Table No. 4, representing results at five sampling positions.

The per cent estimated casualties for each 20 yd.sq. as given in the fifth column of Table No. 22, is shown graphically on Chart 3. The shaded area on the chart represents the percentage of the area on which 100% casualties would be produced from HS vapor when man is protected with gas mask only. The per cent casualties, as shown on Chart 3, are based on the effects of 31 shell. If 31 shell distributed on an area of 16,800 sq.yd. will produce 64% casualties by effects of HS vapor, it will require about 15 shell, distributed to produce 50% casualties from HS vapor, when man is protected with gas mask. The above figures do not take into consideration the effect of liquid HS, which is also present and will cause additional casualties.

(b) Firing Period and Following Hours.

From the results of vapor samples given in Table No. 6, representing the firing period and following hour, it is estimated that man with the protection of gas mask only, would suffer about 59% casualties from HS vapor. This estimate is based on the result of vapor samples taken at nine positions on and at the edge of the target area. In the fifth column of Table No. 24, estimated vapor casualties are given for each 20 yd.sq. on the entire target area. The figures as given in this column are estimates based on results obtained at sampling positions, the position of impacts in and around each square, and the wind direction. Estimated vapor casualties for the total target area, figured from estimates on each 20 yd.sq., is 63.6% which very closely checks 59%, the per cent given in Table No. 6, representing results at nine sampling positions. Chart 4 shows that part of the target area on which it is estimated 100% man casualties would result from HS vapor, on exposure for a period of 50 min., beginning ten minutes after the cessation of fire.

(c) Four Hour Period Beginning One Hour After Cessation of Fire.

From the results of vapor samples given in Table No. 7, representing the four hour period beginning one hour after cessation of fire, it is estimated that man with the protection of gas mask only,

would suffer about 53% casualties from HS vapor. The east side of the area was free from impacts and could have been occupied without danger from HS vapor, as long as the wind continued to blow from the east. That part of the target area on which it is estimated 100% man casualties would result from HS vapor is shown on Chart 5.

(4) Outside the Target Area. Estimated man casualties downwind from the impact position are given in Tables 8 and 9. Table No. 8 represents the firing period and following hour, and Table No. 9 represents the four hour period beginning one hour after firing ceased. The per cent estimated casualties at sampling positions is shown graphically on Charts 6 and 6A. The per cent estimated casualties at these positions is represented by the shaded position of the 20 yd.sq.

e. Estimated Man Casualties Based on Effects on Animals.

Animals casualties and estimated man casualties based on effects on animals are recorded in Tables No. 10A to 18B inclusive. Also animal positions, animal casualties, and estimated man casualties, based on effects on animals, are shown on Charts 7 to 16 inclusive.

(1) Estimated Man Casualties on the Target Area when Man is Protected with Gas Mask Only.

(a) Firing Period and Following Ten Minutes.

Estimated man casualties due to exposure on the target area during the firing period and following ten minutes, are given in Tables No. 10A and 10B. From the animal casualties it is estimated that man casualties would be 33% based on rats and 56% based on goats, or 44% based on rats and goats.

(b) Firing Period and Following Hour.

Estimated man casualties due to exposure on the target area during the firing period and following ten minutes, are given in Tables 11A and 11B. From the animal casualties it is estimated that man casualties would be 40% based on rats, and 53% based on goats, or 47% based on rats and goats.

(c) Four Hours from Second to Sixth Hours after Firing Ceased.

Estimated man casualties due to exposure on the target area during the four hour period following the first hour after firing ceased, are given in Tables 12A and 12b. From the animal casualties

it is estimated that man casualties would be 27% based on rats and 33% based on goats, or 30% based on rats and goats. The animals used did not cover the target area but taking into consideration the position of the impacts, the area covered by the animals was representative of the entire target area.

(d) Twenty-Four Hour Period Beginning Five Hours After Firing Ceased.

Estimated man casualties due to exposure on the target area during the 24-hr. period beginning five hours after firing ceased are given in Tables No. 13A and 13B. From the animal casualties it is estimated that man casualties would be about 12% based on rats and 25% based on goats, or 18% based on rats and goats. The animals used did not cover the target area but taking into consideration the position of impacts, the area covered by the animals was representative of the entire target area.

(e) Exposure in Shell Craters.

Estimated man casualties due to exposure in shell craters for a period of 24 hr. are given in Tables No. 14 to 17, inclusive. From the animal results, it is probable that casualties would result, if the impact area was occupied by personnel within seventeen days after the date it was shelled, unless they were protected with gas mask and standard impregnated clothing.

(2) Downwind from the Target Area.

(a) Firing Period and Following Four Hours.

Estimated man casualties where man is protected with gas mask only, due to exposure directly downwind from the target area during the firing period and following four hours, are given on Tables No. 18A and 18B. From the animal results, it is estimated that personnel occupying the downwind area within 100 yd. from the impact position, for the period stated above, would probably become casualties.

f. Comparison of Per Cent Estimated Man Casualties Based on Measurements of the Gas Concentration and by Effects on Animals, when Man is Protected with Gas Mask Only.

(1) Firing Period and Following Ten Minutes.

In Table No. 22, estimated man casualties are given for each 20 yd. sq., based on the following effects and methods of figuring casualties, when man protected with gas mask only, is exposed on the target area during the firing period and following ten minutes:

- (a) HS Liquid using panel data.
- (b) HS vapor from vapor samples.
- (c) Combined effect of HS liquid and HS vapor.
- (d) Effect on animals.

Figures in this table show that 100% casualties would be produced on 67% of the area, based on the combined effect of HS liquid and vapor and 41% based on the effects on animals or 54% based on the two methods of figuring casualties.

Table No. 22.

Estimated Casualties on the Target Area Representing  
Exposure during Firing and Following  
10 Min. (Area 20,000 sq.yd.)

No. of stakes at: center of square	Impacts: within each square	From HS Liquid: Estimated Man casualties	From HS Vapor: c.t.: Estimated Man casualties	From HS Liquid and vapor: Estimated Man casualties	From Effects on animals Estimated Animal casualties
		%	%	%	%
1	0	0	.10 : 93	93	0
3	0	30	.15 : 100	100	0
5	0	67	.25 : 100	100	
7	0	67	.30 : 100	100	ELS : 100
					death :
9	2	10	.00 : 0	10	
11	0	0	.00 : 0	0	
23	0	30	.20 : 100	100	
25	2	54	.15 : 100	100	EL : 100
					death :
27	0	55	.20 : 100	100	
29	3	55	.20 : 100	100	
31	0	15	.00 : 0	15	
33	0	0	.00 : 0	0	
45	0	56	.20 : 100	100	
47	0	75	.20 : 100	100	ERS <sub>2</sub> : 100
					severe :
49	0	80	.30 : 100	100	
51	1	64	.20 : 100	100	
53	3	27	.20 : 100	100	
55	0	0	.00 : 0	0	
67	1	77	.20 : 100	100	
69	0	80	.20 : 100	100	ER Mod- : 100
					erate :
71	0	82	.30 : 100	100	

Table No. 22 (Cont'd.)

No. of stakes at center of square	Impacts: within each square	From HS Liquid: Estimated Man casualties	From HS Vapor: o.t.: Estimated man: casualties	From HS Liquid: Estimated man casualties	From Effects on animals: Animal: Estimated casual-: man ties casualties
		%		%	%
73	0	82	.60	100	100
75	3	87	.10	93	97
77	0	0	.00	0	0
89	0	77	.20	100	100
91	0	61	.20	100	100
93	1	67	.30	100	100
95	0	80	.40	100	100
97	0	47	.20	100	100
99	0	0	.00	0	0
111	1	63	.20	100	100
113	0	65	.20	100	100
115	2	69	.20	100	100
117	1	59	.10	93	97
119	0	18	.00	0	18
121	0	0	.00	0	0
133	1	50	.20	100	100
135	2	71	.30	100	100
137	2	50	.20	100	100
139	1	49	.20	100	100
141	0	7	.00	0	7
143	0	0	.00	0	0
155	0	60	.20	100	100
157	2	90	.30	100	100
159	0	73	.20	100	100
161	1	38	.10	93	95
163	0	0	.00	0	0
165	0	0	.00	0	0
177	1	51	.20	100	100
179	0	67	.10	93	97
181	1	56	.10	93	97
183	0	20	.00	0	20
185	0	0	.00	0	0
187	0	0	.00	0	0
199	0	76	.15	100	100
201	1	78	.15	100	100
203	1	49	.10	93	97
205	0	7	.00	0	7
207	0	0	.00	0	0

Table No. 22 (Cont'd).

No. of stakes at center of square	Impacts within each square	From HS liquid: Estimated man casualties	From HS vapor: c.t. value	Estimated man casualties	From HS liquid and vapor: Estimated man casualties	From effects on animals: Animal casualties	Estimated man casualties
:	:	:	:	ties	:	ties *	:
:	:	%	:	%	:	%	%
209	0	0	.00	0	0	ELS death	100
221	1	85	.20	100	100	:	:
223	0	90	.10	93	99	ELS death	100
225	0	17	.00	0	17	:	:
227	0	0	.00	0	0	:	0
229	0	10	.00	0	10	:	:
231	0	10	.00	0	10	:	0
Av.		42.0		64	66	:	41

\*See page 11 for symbols.

The average percentages as given in Table No. 22, are based on the total target area which includes about 3,200 sq.yd. on which there was little or no effect from the HS due to wind direction and shell distribution. In Table No. 23, which follows, results are given to include only the impact area as defined in paragraph 8b.

Estimated casualties given in Table No. 23, are based on an area 16,800 sq.yd., on which 31 shell burst. Results in this table show an average of 95% man casualties based on the effects of HS liquid and vapor, and 50% based on effects on animals, or an average of 73% based on the two methods of figuring casualties.

Table No. 23.

Estimated Casualties on the Impact Area (16,800 sq.yd.)  
Firing Period and Following Ten Minutes.

No. of stake at center of 20 yd.sq.	Estimated man casualties	Effects on animals
:	HS liquid and vapor: samples	:
1	93	0
3	100	0
5	100	:
7	100	100
23	100	:
25	100	100
27	100	:
29	100	0

Table No. 23 (Cont'd.)

No. of stake at center of 20 yd. sq.	Estimated man casualties	
	HS liquid and vapor samples	Effects on animals
45	100	
47	100	100
49	100	
51	100	0
53	100	
67	100	
69	100	100
71	100	
73	100	100
75	97	
89	100	
91	100	0
93	100	
95	100	100
97	100	
111	100	
113	100	100
115	100	
117	97	0
133	100	
135	100	100
137	100	
139	100	100
155	100	
157	100	100
159	100	
161	95	0
177	100	
179	97	0
181	97	
199	100	
201	100	
221	100	
223	<u>99</u>	<u>100</u>
Av.	95	50

(2) Firing Period and Following Hour.

In Table No. 24, which follows, estimated man casualties are given for each 20 yd. sq. based on the following effects and method of figuring casualties, when man protected with gas mask only, is exposed on the target area during the firing period and the following hour:

- (a) HS liquid using panel data.
- (b) HS vapor from vapor samples.
- (c) Combined effect of HS liquid and HS vapor.
- (d) Effect on animals.

Figures in Table No. 24, show 100% estimated casualties on 66% of the area, based on the combined effects of HS liquid and vapor and 44% based on effects on animals, or 55% based on the average of the two methods of figuring casualties.

Table No. 24.

Estimated Casualties on the Target Area, Representing Exposure  
During the Firing and Following Hour (Area 20,000 sq.yd.)

No. of stakes at center of square	Impacts within each square	From HS liquid Estimated man casualties	From HS vapor c.t.: Estima- value: ted man casual-	From HS liquid and vapor Estimated man casualties	From effects on animals Animal: Est. man casual- Casualties
:	:	%	ties	%	%
1	0	0	.20 : 100	100	:
3	0	30	.30 : 100	100	:
5	0	67	.45 : 100	100	:
7	0	67	.50 : 100	100	:
9	2	10	.00 : 0	10	:
11	0	0	.00 : 0	0	:
23	0	30	.30 : 100	100	:
25	2	54	.20 : 100	100	:
27	0	55	.30 : 100	100	:
29	3	55	.30 : 100	100	:
31	0	7	.00 : 0	7	:
33	0	0	.00 : 0	0	:
45	0	58	.30 : 100	100	:ERS <sub>2</sub> : 100
					:severe :
49	0	80	.40 : 100	100	:ELS death 100
47	0	75	.30 : 100	100	:
51	1	64	.30 : 100	100	:
53	3	27	.30 : 100	100	:
55	0	0	.00 : 100	100	:
67	1	77	.30 : 100	100	:
69	0	80	.30 : 100	100	:
71	0	82	.40 : 100	100	:ELS death 100
73	3	57	.15 : 100	100	:
75	3	57	.15 : 100	100	:ELS death 100

Table No. 24 (Cont'd.)

No. of stakes at center of square	Impacts within each square	From HS liquid: Estimated man casualties	From HS vapor: o.t. Estimated man casualties	From HS liquid and vapor: Estimated man casualties	From effects on animals: Animal: Est. man casualties
:	:	:	:	:	:
:	:	:	:	:	:
:	:	:	:	:	:
77	: 0	: 0	: .00 : 0	: 0	: : :
89	: 0	: 77	: .25 : 100	: 100	: ERS : 100
	:	:	:	:	: severe:
91	: 0	: 61	: .25 : 100	: 100	: : :
93	: 1	: 67	: .40 : 100	: 100	: ERS Mod.: 100
95	: 0	: 80	: .50 : 100	: 100	: : :
97	: 0	: 47	: .25 : 100	: 100	: : 0
99	: 0	: 0	: .00 : 0	: 0	: : :
111	: 1	: 63	: .25 : 100	: 100	: ERS Mod.: 100
113	: 0	: 65	: .26 : 100	: 100	: : :
115	: 2	: 69	: .25 : 100	: 100	: EL death 100
117	: 1	: 59	: .15 : 100	: 100	: : :
119	: 0	: 18	: .00 : 0	: 18	: : 0
121	: 0	: 0	: .00 : 0	: 0	: : :
133	: 1	: 50	: .25 : 100	: 100	: ES Mod.: 100
135	: 2	: 71	: .40 : 100	: 100	: : :
137	: 2	: 50	: .25 : 100	: 100	: ELS death 100
139	: 1	: 49	: .25 : 100	: 100	: : :
141	: 0	: 7	: .00 : 0	: 7	: : 0
143	: 0	: 0	: .00 : 0	: 0	: : :
155	: 0	: 60	: .25 : 100	: 100	: : 0
157	: 2	: 90	: .40 : 100	: 100	: : :
159	: 0	: 73	: .25 : 100	: 100	: ELS death 100
161	: 1	: 38	: .00 : 0	: 38	: : :
163	: 0	: 0	: .00 : 0	: 0	: : 0
165	: 0	: 0	: .00 : 0	: 0	: : :
177	: 1	: 51	: .25 : 100	: 100	: ERS : 100
	:	:	:	:	: severe:
179	: 0	: 67	: .15 : 100	: 100	: : :
181	: 1	: 56	: .15 : 100	: 100	: E <sub>2</sub> severe 0
183	: 0	: 20	: .00 : 0	: 20	: : :
185	: 0	: 0	: .00 : 0	: 0	: : :
187	: 0	: 0	: .00 : 0	: 0	: : :
199	: 0	: 26	: .20 : 100	: 100	: : 0
201	: 1	: 78	: .20 : 100	: 100	: : :
203	: 1	: 49	: .15 : 100	: 100	: : 0
205	: 0	: 7	: .00 : 0	: 7	: : :
207	: 0	: 0	: .00 : 0	: 0	: : :
209	: 0	: 0	: .00 : 0	: 0	: : 0

Table No. 24 (Cont'd.)

No. of stakes at center of square	Impacts within each square	From HS liquid Estimated man casualties	From HS vapor c.t. Estima- value: ted man casual- ties	From HS liquid and vapor Estimated man casualties	From effects on animals Animal: Est. Man casual- ties*	casual- ties
:	:	%	:	%	:	%
221	1	85	.25	100	100	ELS death 100
223	0	90	.15	100	100	:
225	0	17	.00	0	17	S light: 100
227	0	0	.00	0	0	:
229	0	10	.00	0	10	E Mod. : 0
231	0	10	.00	0	10	:
	Av.	42	:	64	66	:
			:			44

\*See page 11 for symbols.

Per cent estimated casualties based on the combined effects of HS liquid and vapor are considerably higher than corresponding figures based on effects on animals. There would have been a still greater spread between these figures if a smaller number of shell had been used, because on many of the 20 yd. sq. the HS liquid and vapor present was in excess of estimated requirements to produce 100% casualties.

Estimates based on effects on animals were very conservatively made and are probably low. It is also probable that estimates based on effects of HS vapor alone, are high for average temperature conditions so that an average, based on effects on animals and from measurements of the HS liquid and vapor present, is probably more nearly correct than by either method alone.

g. Number of Shell Required to Produce 50% Man Casualties.

It was stated in paragraph 8 c (2) that about fourteen shell distributed per 100 yd.sq. will produce 50% casualties from liquid HS, when man is protected with gas mask only.

From figures given in Table No. 23, it was estimated that the impact of 30 shell, excluding one dud, on an area of 16,800 sq.yd. would produce 95% casualties based on effects of HS liquid and vapor, and 50% based on effects on animals, when exposed during the firing period and following ten minutes. On this basis, the following number of shell per 100 yd.sq. will be required to produce 50% casualties when man is protected with gas mask only:

Based on HS liquid and vapor samples	- 9 shell
Based on effects on animals	- 18 "
Av.	- $\frac{14}{2}$ "

Based on the two methods of figuring casualties, about fourteen shell distributed, are required per 100 yd.sq. to produce 50% casualties, when man is protected with gas mask only.

9. Conclusions. From the results of the present test, the following conclusions are drawn with respect to the use of 155-mm. shell filled with HS, when fired under the meteorological conditions existing at the time of the test:

a. The number of shell required per 100 yd. sq. to produce 50% casualties when distributed as equally as practicable, are as follows:

(1) When man, protected with gas mask and standard impregnated clothing, is exposed during the firing period - 140 shell (see p. 23).

(2) When man, protected with gas mask only, is exposed during the firing period and following ten minutes - 14 shell (see subparagraph g, above).

b. Personnel who occupy the downwind area, within 100 yd. of the impact area during the firing period and the following hour, will suffer casualties unless they are protected with gas mask and standard impregnated clothing (see pp. 9 and 26).

c. If the impact area is occupied by personnel within seventeen days, after the date it was shelled, they will probably suffer casualties unless they are protected with gas mask and standard impregnated clothing (see p. 26).

10. Recommendations. It is recommended that the present test be repeated with a change in the firing period from 9 a.m. to one hour before sunset to determine the effects of meteorological conditions on the number of shell required for effective results.

Submitted:

/s/ B. G. Macintire,  
B.G. MACINTIRE,  
Weapons Department,  
Munitions Development Division.

Recommending approval:

Report of Test of HS-Filled  
155-mm. Howitzer Shell.  
Test "B" - June 11, 1932.

/s/ Charles E. Loucks,  
CHARLES E. LOUCKS,  
Captain, C.W.S.,  
Chief, Munitions Development Division.

Project A 1.1-1b.

Approval:

Typed by hh  
10/4/32

/s/ E. Montgomery,  
E. MONTGOMERY,  
Major, C.W.S.,  
Technical Director.

*Munitions*  
*Log*

BATTERY "C" SIXTH FIELD ARTILLERY.  
FORT HOYLE MARYLAND

August 4, 1932.

MEMO: TO- The Technical Director, Edgewood Arsenal Md.

1. The following data was used in the 155MM Mustard Gas Shoot of June 11, 1932.

Commands	Elev.	Sensings	Remarks.
Compass 3210, On No.1 Close 3, Shell M.Gas, Charge 5, Fuse Long, No.1 1 Rd. Quad			
	300	60 L Short	
Left 8	308	80 Right Over	
	304	60 " "	DUD
	302	100 " "	DUD
	302	20 Left Short	
Left 4, 2 Rds	302	80 Left Short	
		80 Right Over	DUD
Left 4	302	Line Over	
		30 Left Short	
Right 4 1Rd	302	Target.	
No.1 Mark Base Def.			
No.2 Adj. 1 Rd	302	60 Left Short	
	310	50 " "	DUD
Left 4	310	30 Left "	
Right 2	310	130 Right Over	
2 Rds	310	Over	
		140 R ight Over	
1 Rd	306	80 Right Over.	
	304	80 Right Over	
	302	80 Right Over	
2 Rd	302	60 Right Over	
		25 Right Over.	
No.2 Mark Base Def.			
No.3 Adjust 1 Rd	302	10 Right Over	
	302	30 Right Over	
	298	Line Over	
Right 4	298	50 Right Over	
	290	160 Left Short	
	294	180 Left Short	
	296	60 Left Short Def. Over	
Right 4	298	40 Left Short Def. Short	
Left 4	298	50 Left Short Def. Short.	
Left 2, 2 Rds	298	80 Left Short, 100 Left Short	
No.3 Mark Base Def.			

No.4 Adjust 1 Rd.	302	150 Left Short	
	310	25 Right Over	DUD
	306	100 Right Over	DUD
	304	30 Right Over	
	302	120 Left Short	DUD
	303	50 Left Short	Def.Over
Right 4	304	100 Right Over	
	303	40 Left Short.	

No. 4 Mark Base Def.

COMMANDS? FIRE ON AREA.

Base Def. Right 45, On.No.1 Open 5, Battery 3 Rds.

Quad, At my Command Elevs. No.1-302, No.2-301, No.3-299, No.4-303

1st.Volley-	2 Shorts, 2 Overs	1 DUD
2nd. "	2 Shorts, 2 Overs	
3d Volley	2 Shorts, 2 Overs	

Btry 2 Rds, Same Elevations

1st.Volley	4 Shorts,
2d.Volley	2 Shorts, 2 Overs.

Btry 3 Rds. Elevs. No.1-306, No.2-305, No.3-303, No.4-303

1st.Volley	3 Overs, 1 Line
2nd.Volley	1 Short, 2 Overs # 3 Out.
3d.Volley	1 Line, 2 Shorts.

Btry 2 Rds, Same Elevations

<del>XXXXX</del> 1st.Volley	1 Short, 2 Overs. # 3 In.
2nd. Volley	1 Short, 3 Overs.
3d.Volley	1 Line, 20vers.

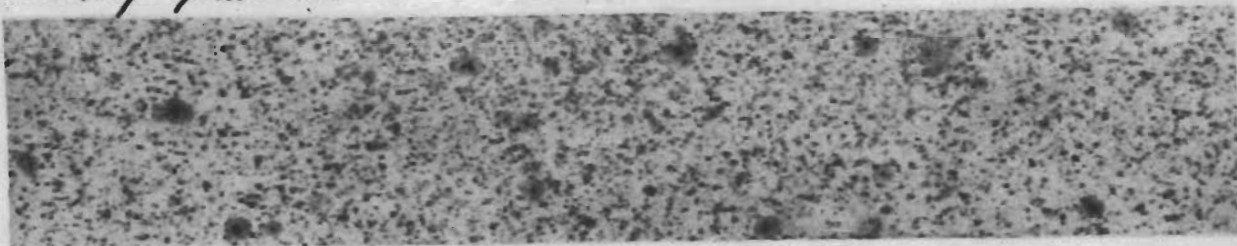
NOTE\* The above sensings made on panel in center of area.

The last volley above was the 3 rds left over because of # 3 being out of action for 3 volleys.

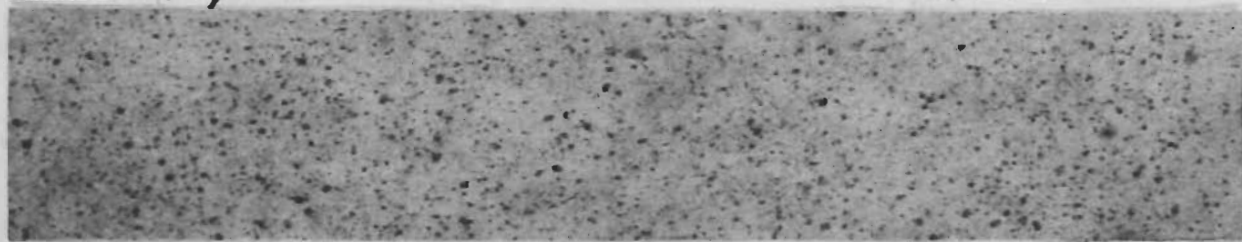
*Leo T. McMahon*  
 Leo T. McMahon  
 Capt. 6th.F.A.

# *PATTERNS OF LIQUID HS ON PAPER PANELS*

*Heavy pattern*



*Medium pattern*



*Light pattern*



*Trace pattern*



# Graph No. 1

## Casualty Producing Effect of Mustard Vapor on Masked Men

Percent casualties

100

90

80

70

60

50

40

30

20

10

0

⊙ B

\* A

\* 2

\* 1

C:t value

0

1

2

3

4

5

6

7

8

9

10

11

12

13

14

15

16

17

18

Note:

The c:t value is the product of the vapor concentration in mps. per liter and the time of exposure in minutes.

Points 1 & 2 from chamber tests given in PR 318.

Point 3 is the estimate of the author of PR 318 after conducting the tests.

Point A represents the chamber exposure of the author of PR 318

Point B represents the exposure of a man in the field at Edgewood Arsenal.

CHART I  
TARGET AREA  
AS PREPARED FOR  
TEST B

June 11, 1932

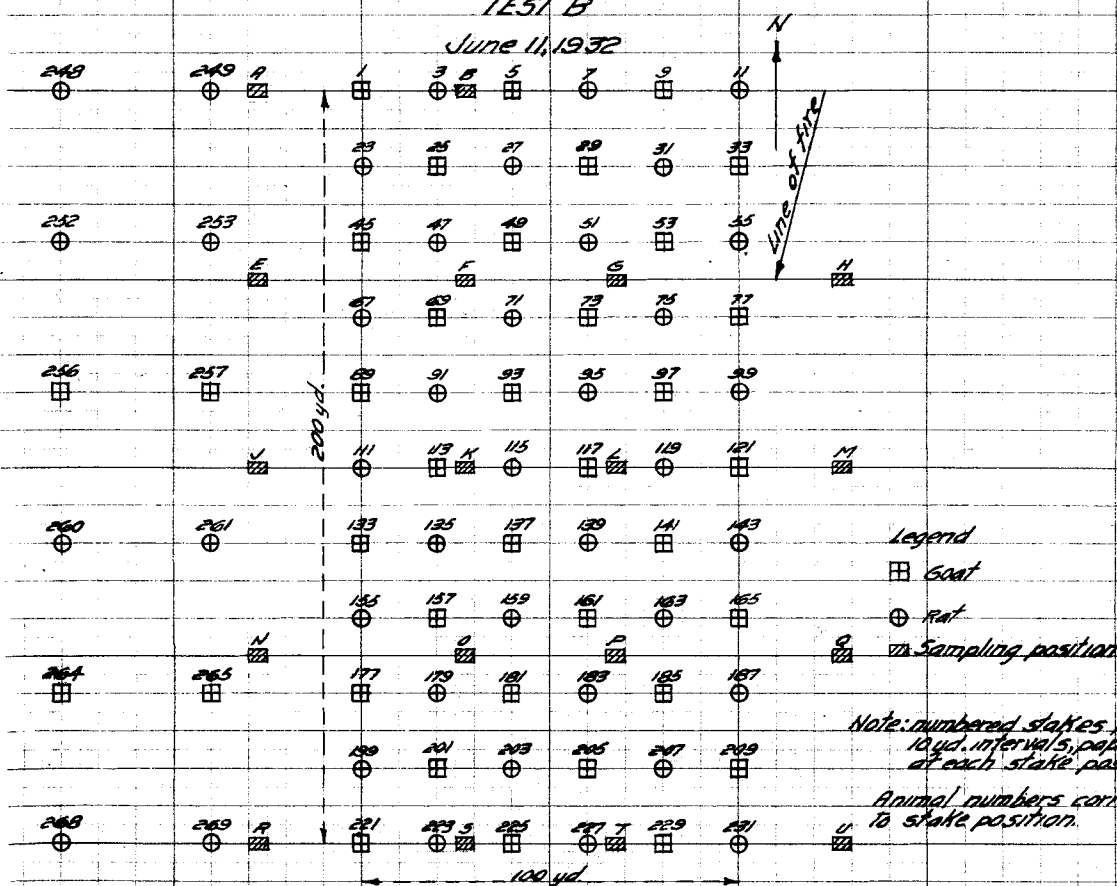


CHART 3  
ESTIMATED MASKED MAN  
CASUALTIES  
DUE TO H5 VAPOR  
Test B, June 11, 1932

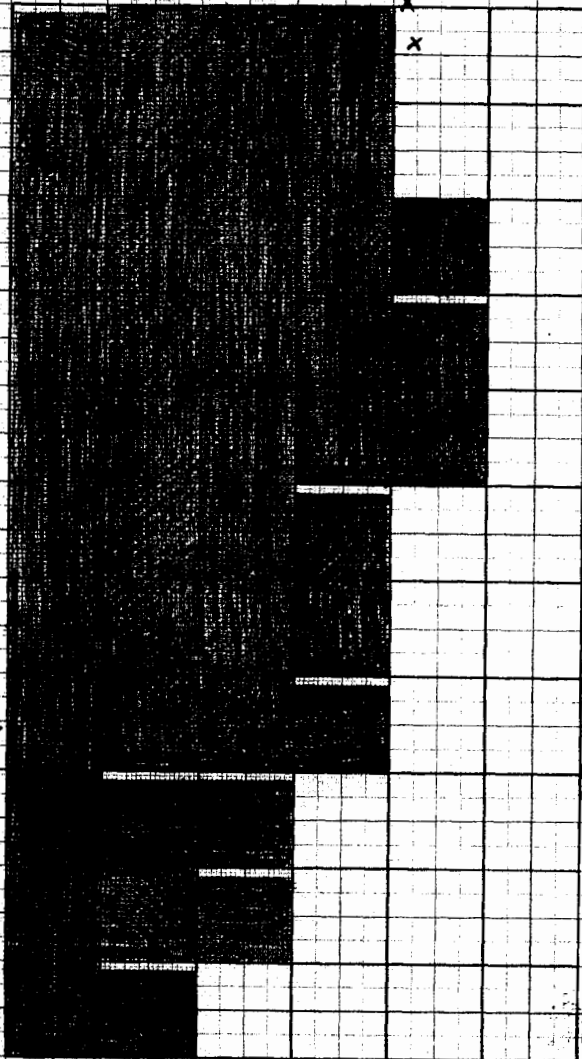
Wind direction  
5.3 m.p.h.

Legend

shaded area  
represents 100%  
casualties exposed  
during firing plus  
10 minutes  
X - Impacts

Photo

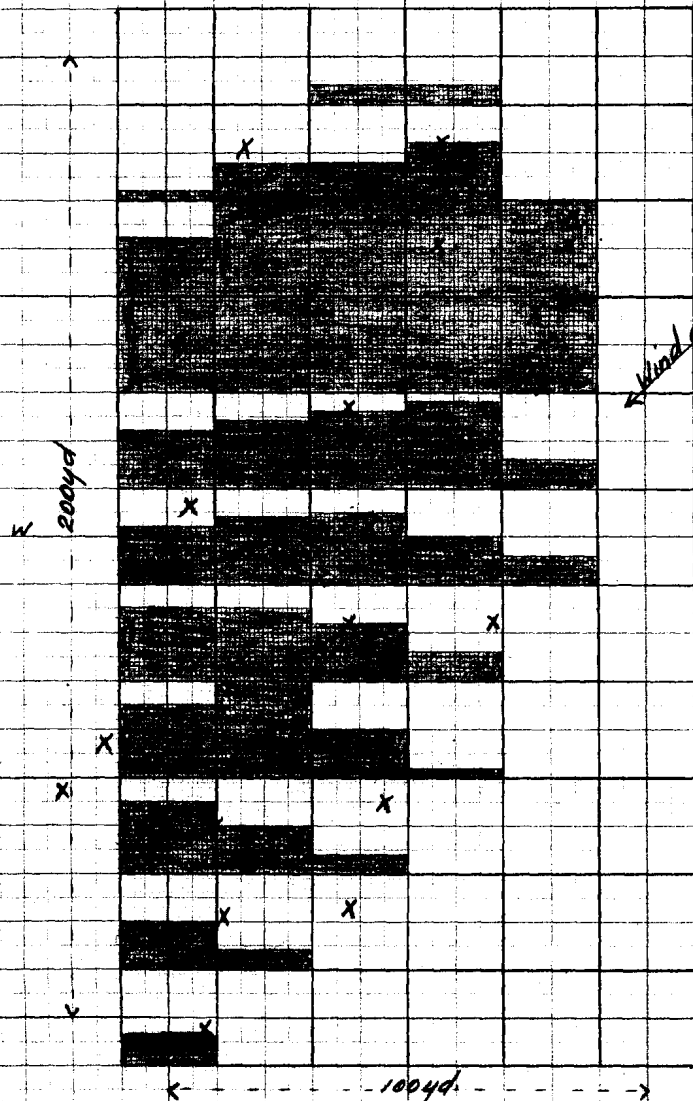
100 yd



# CHART 4 ESTIMATED MAN CASUALTIES DUE TO HS VAPOR

Test B June 11, 1932

Exposure 50 minutes, from  
10 min to 1 hour after firing  
ceased.



## Legend

Shaded area 100 per  
cent man casualties with  
gas mask protection only.

# CHART 5 ESTIMATED MAN CASUALTIES DUE TO HS VAPOR

Test B June 11, 1932.

Exposure 4 hours, from  
2nd to 5th hours after firing  
ceased.

Wind direction  
3.0 m.p.h.

## Legend

Shaded area 100 percent man  
casualties with gas mask pro-  
tection only.

x Impacts

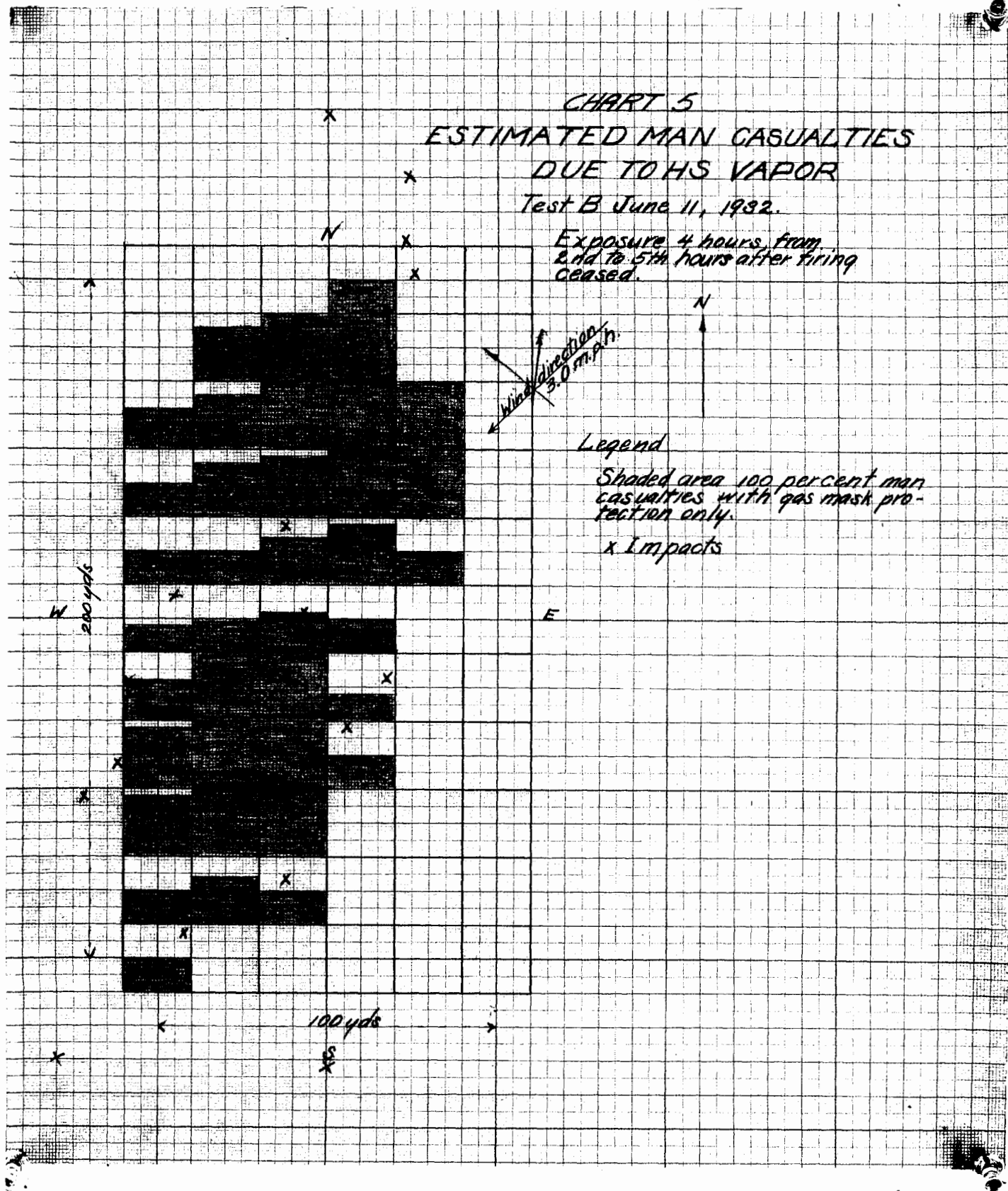
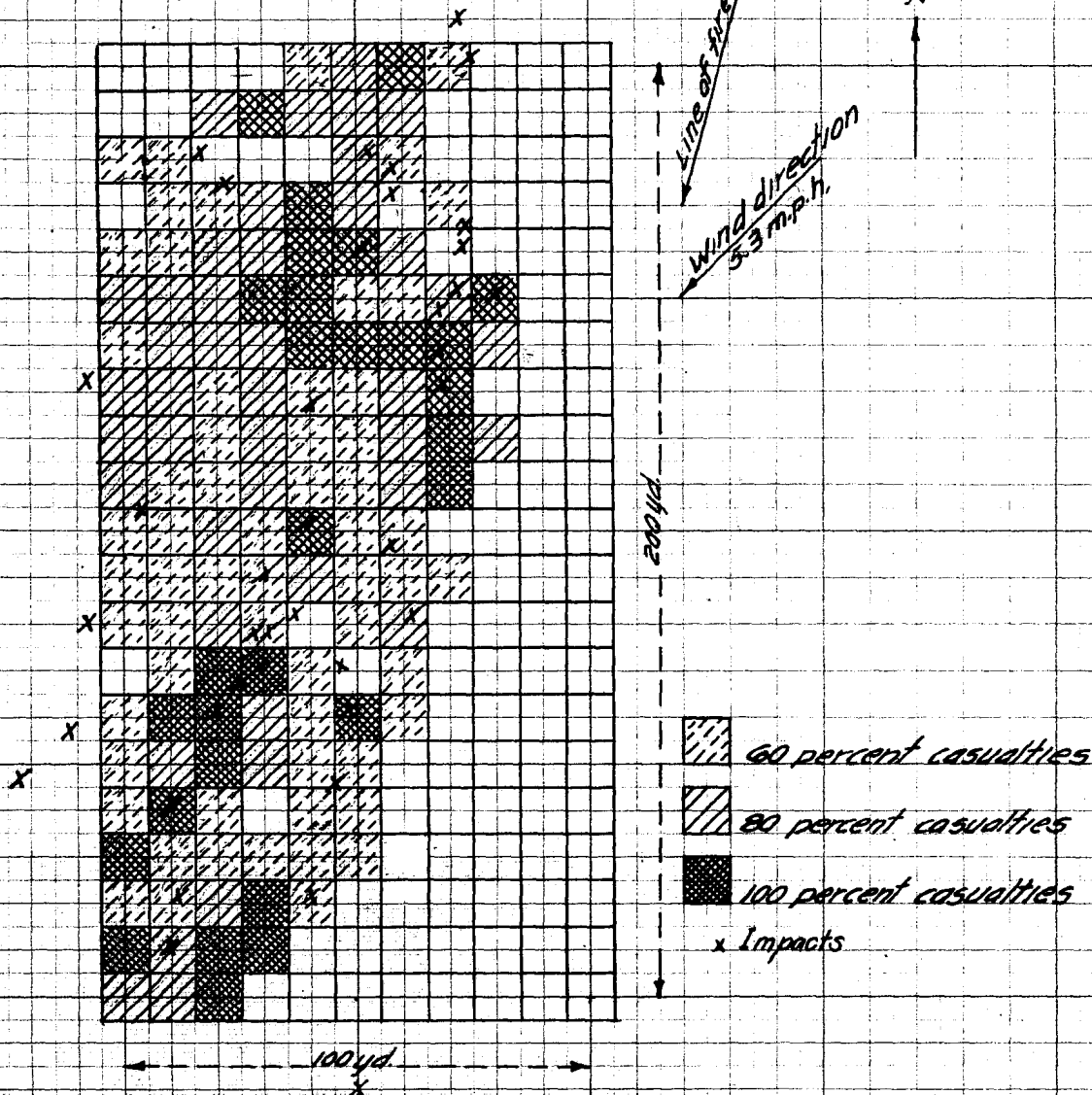
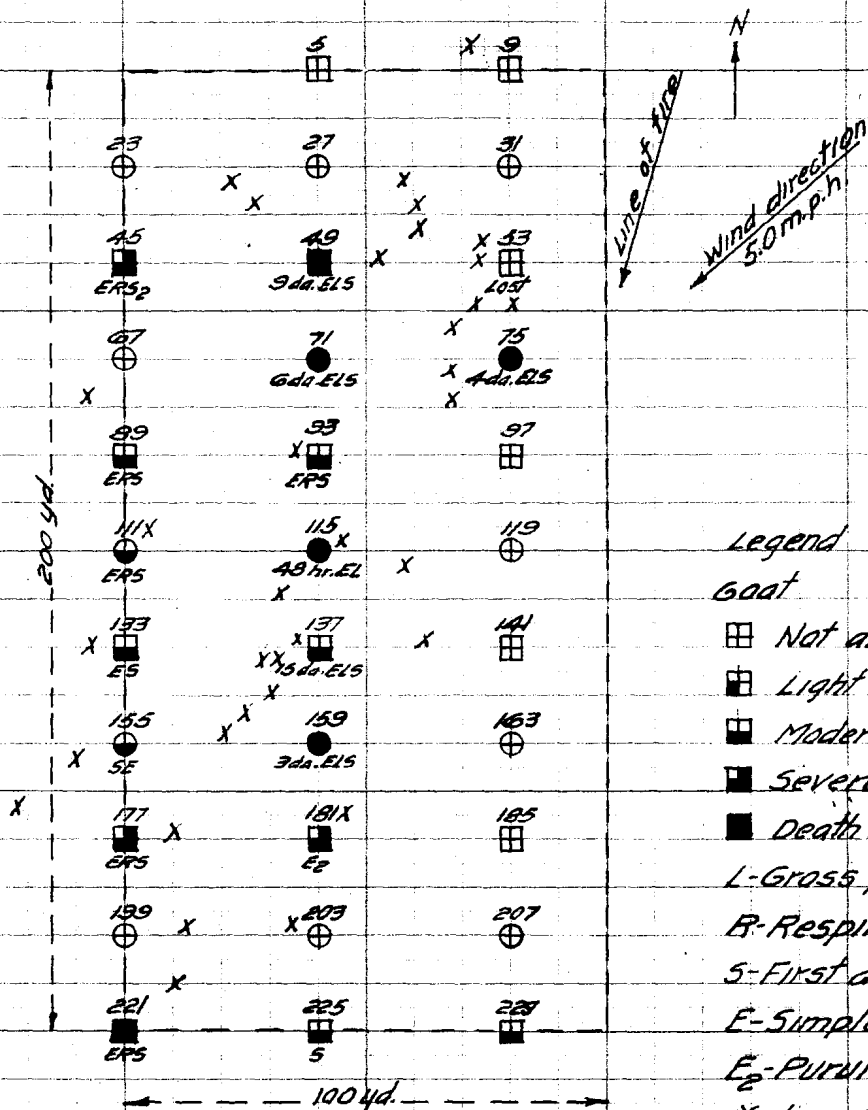


CHART 2  
ESTIMATED MAN CASUALTIES  
FROM LIQUID H<sub>5</sub>  
TEST B, June 11, 1932



Note—  
Results derived from patterns on paper panels  
and casualties on men.

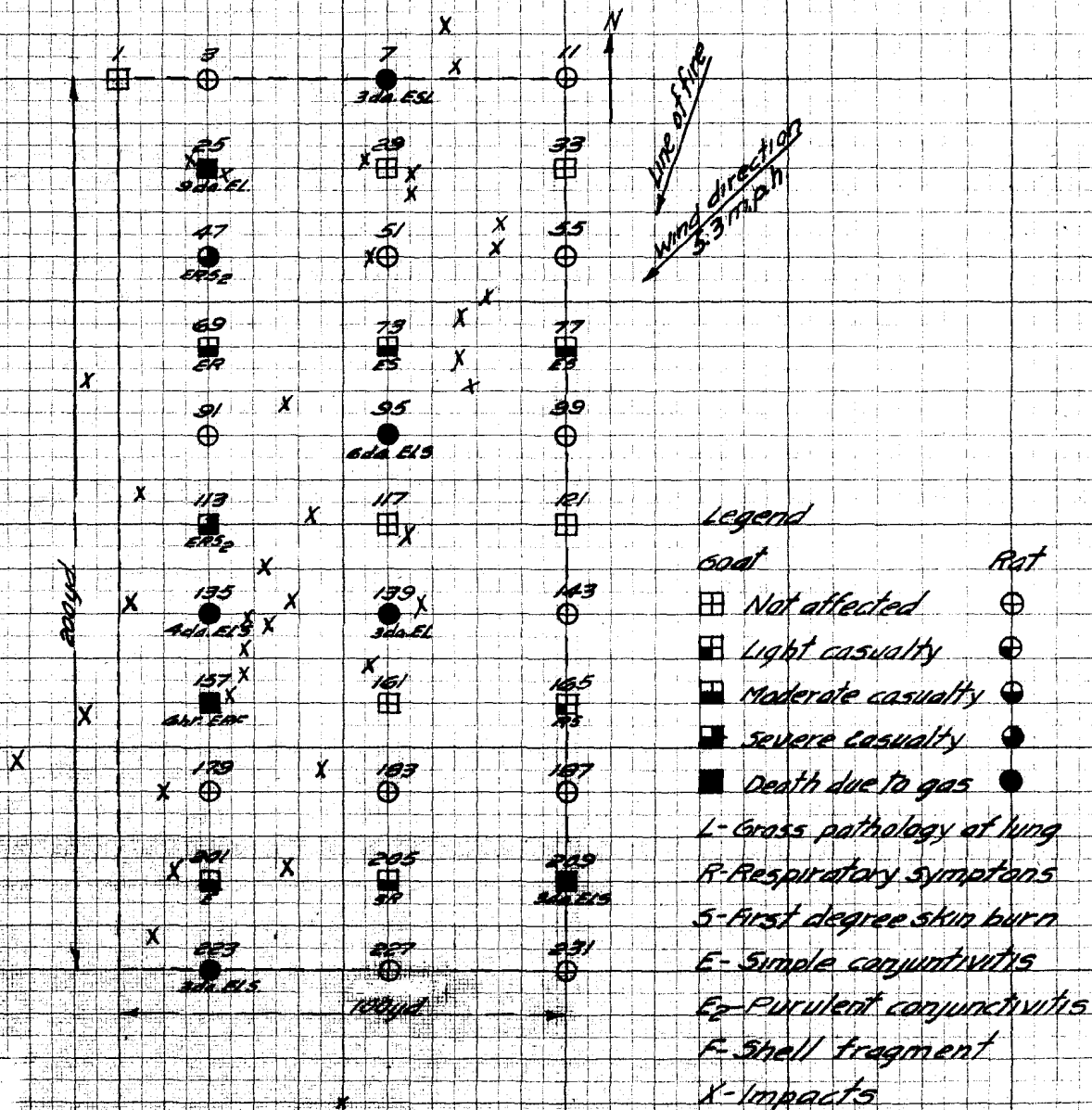
CHART 8  
ANIMAL CASUALTIES  
TEST B, June 11, 1932  
Exposure, firing period plus one hour



# CHART 7 ANIMAL CASUALTIES

Test B, June 11, 1932

Exposure, firing period plus ten minutes



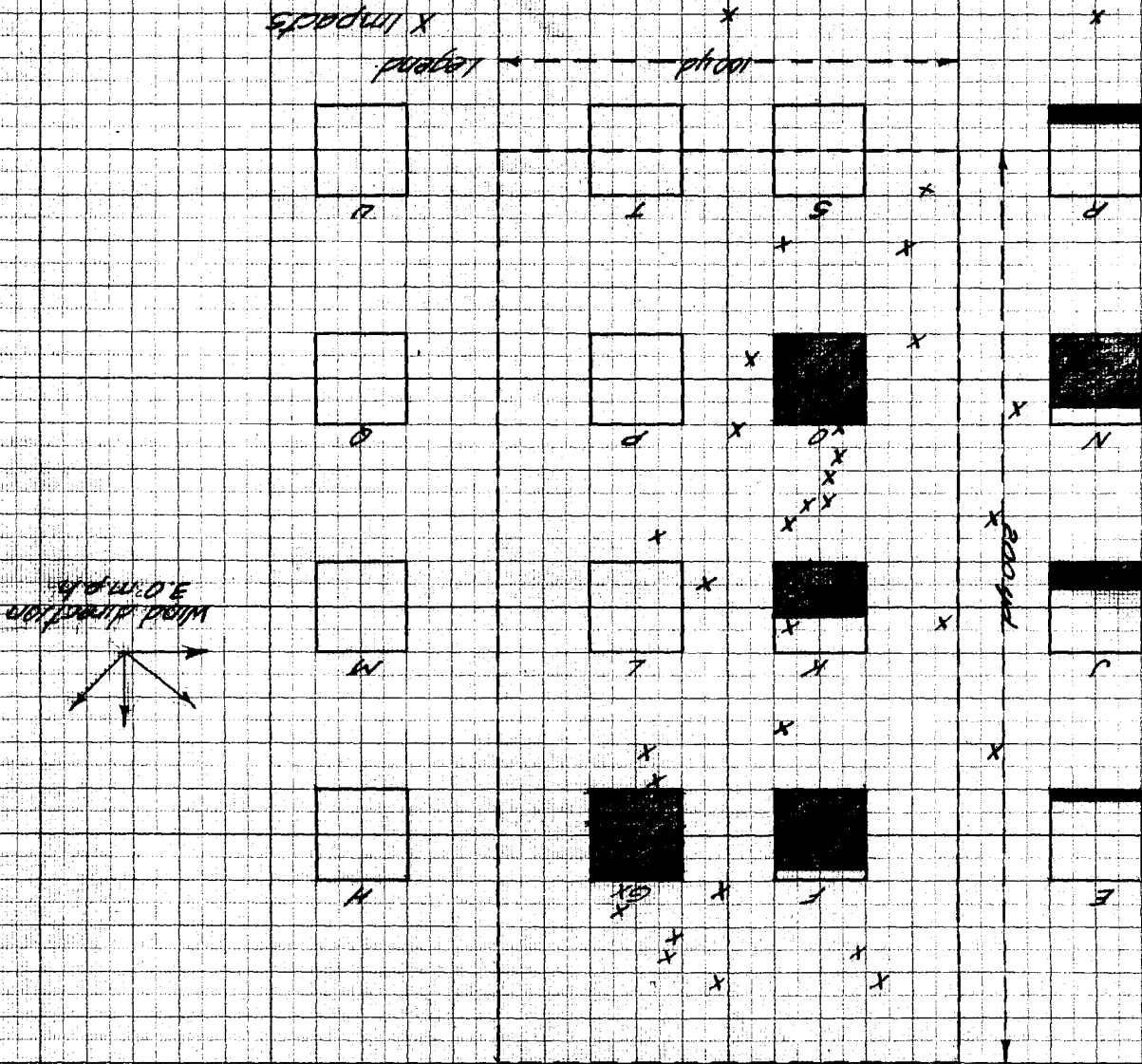
# CHART 10A

ESTIMATED MAN CASUALTIES

DUE TO H5 WEAPONS \*

TEST B, June 11, 1952

EXPOSURE PERIOD 4 hrs. from 2nd to 5th hrs. after firing



Shaded area represents personnel provided with gas masks. Letters designate sampling positions. \* Estimated casualties are only shown at sampling positions.

CHART 9  
ANIMAL CASUALTIES  
Test B, June 11, 1932  
Exposure 4 hrs. from 2nd to  
6th hours after firing ceased

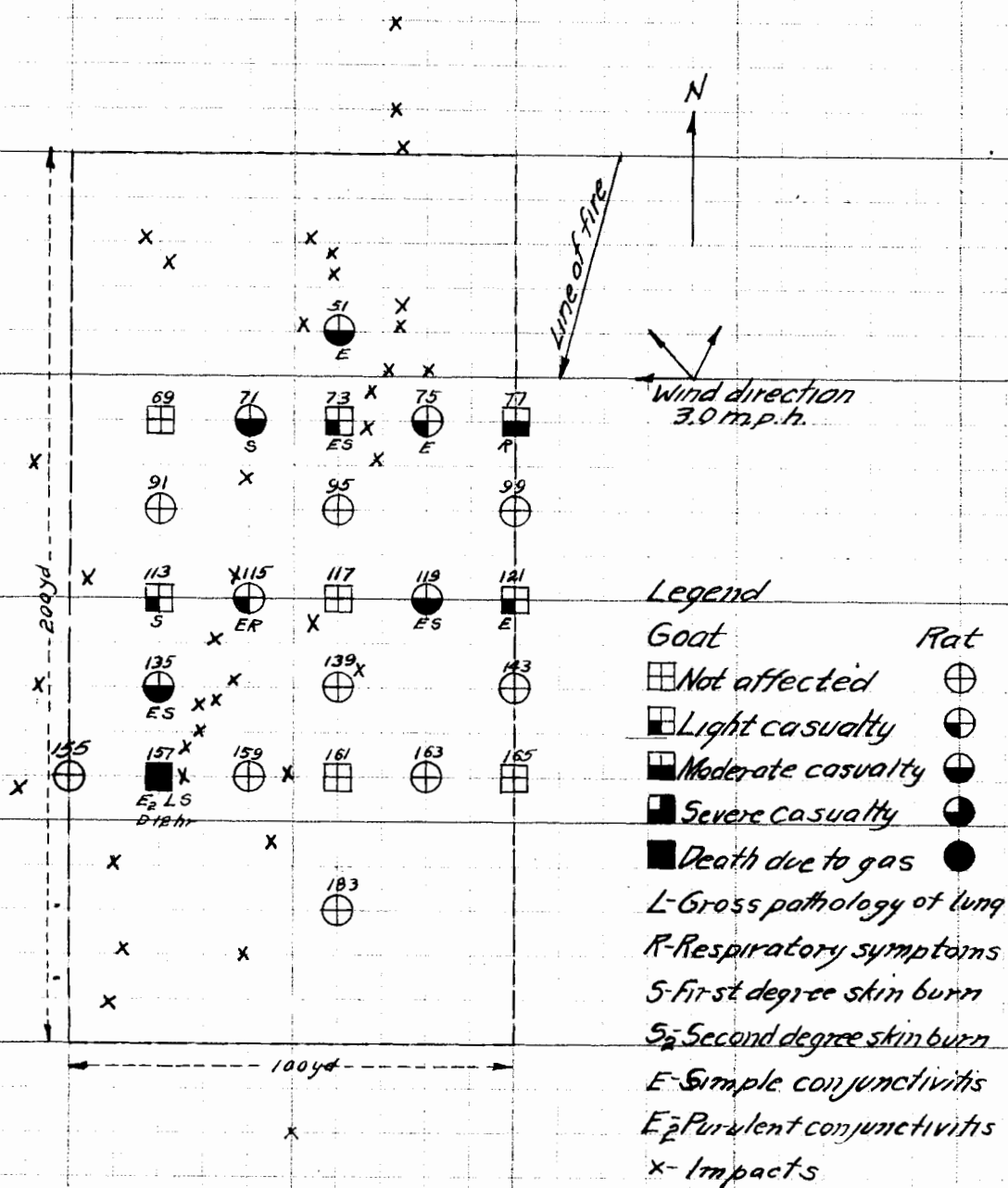


CHART 10  
ANIMAL CASUALTIES  
Test B, June 11 1932  
Exposure 24 hrs. from 6th to  
30th hours after firing

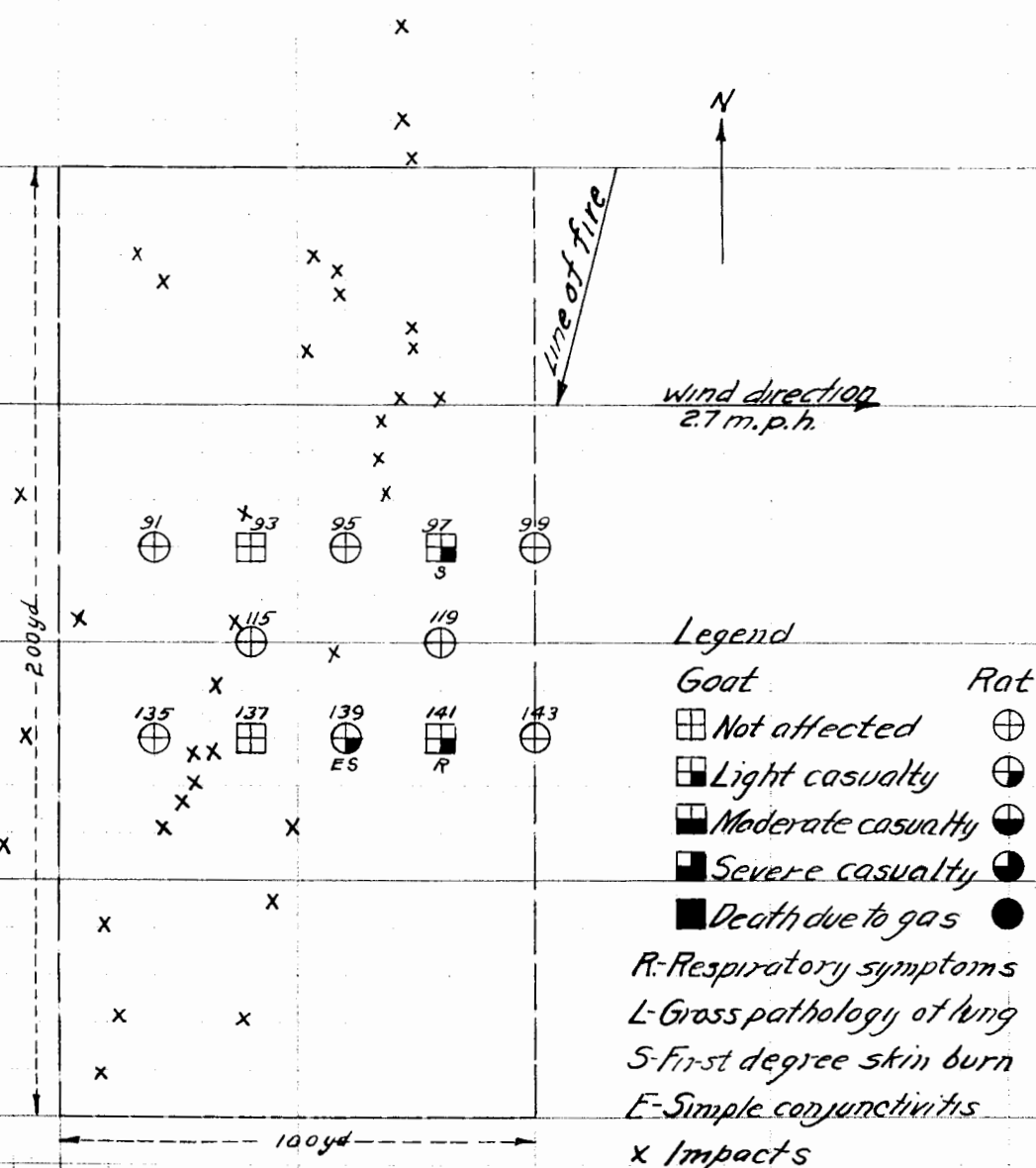


CHART II  
ANIMAL CASUALTIES, DOWN WIND  
FROM THE TARGET AREA

TEST B, June 11, 1932

Firing period and following 4 hours.

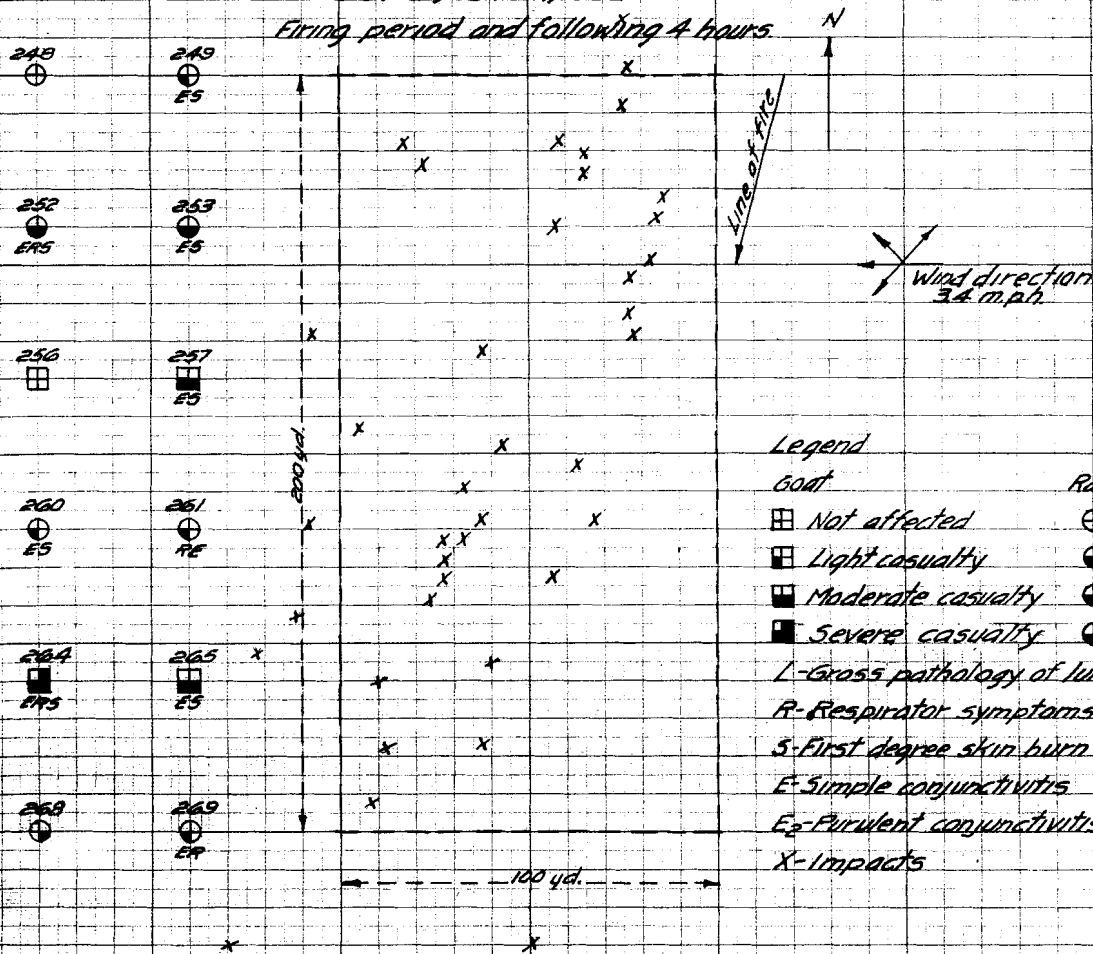
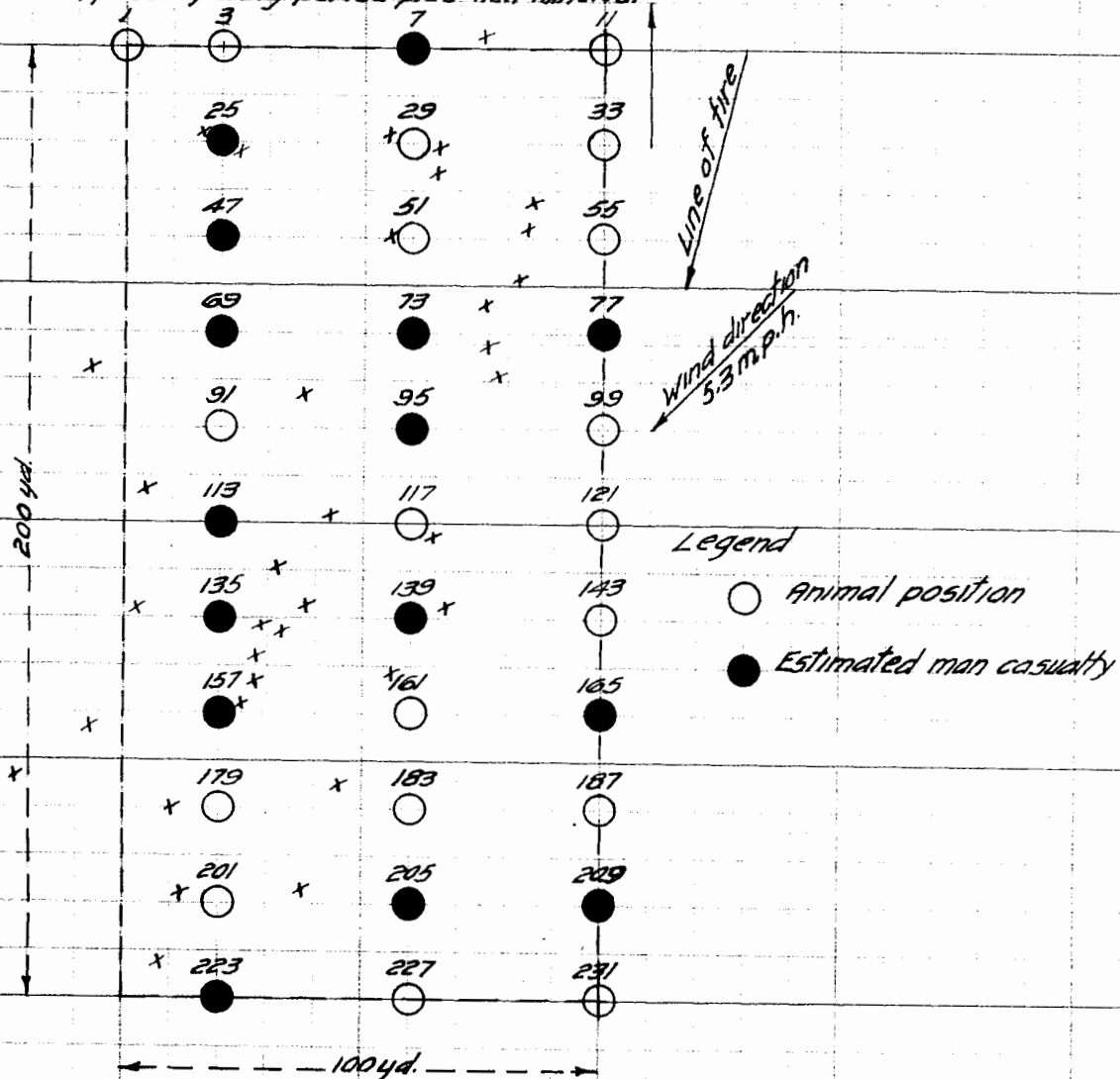


CHART 12  
ESTIMATED MAN CASUALTIES BASED  
ON EFFECTS ON ANIMALS.

TEST B, June 11, 1932

Exposure, firing period plus ten minutes. N

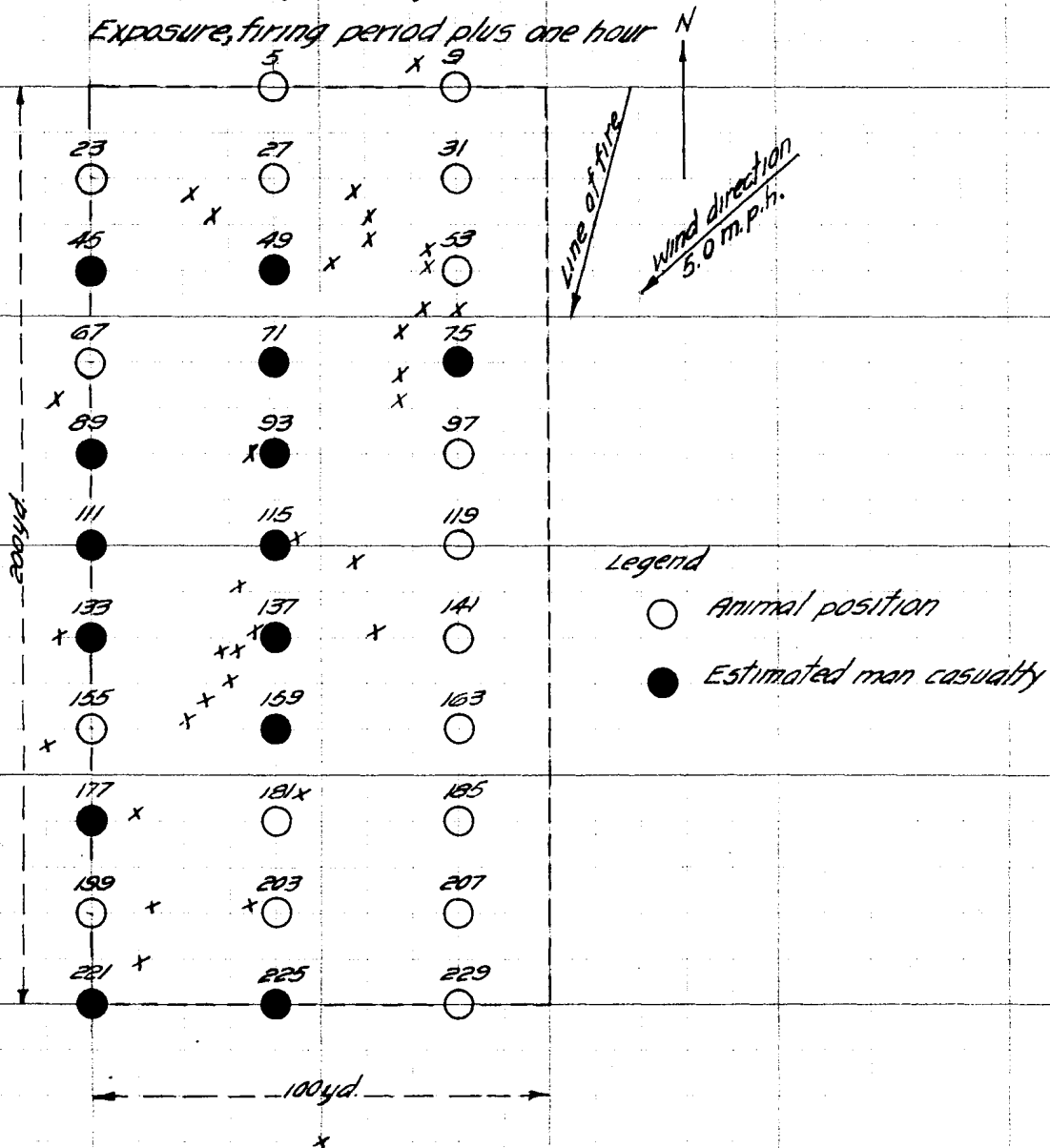


# CHART 13

ESTIMATED MAN CASUALTIES BASED  
ON EFFECTS ON ANIMALS.

TEST B, June 11, 1932

Exposure, firing period plus one hour



# CHART \*14

## ESTIMATED MAN CASUALTIES BASED ON EFFECTS ON ANIMALS.

TEST B, June 11, 1932

Exposure 4 hrs. from 2nd to 6th  
hours after firing ceased.

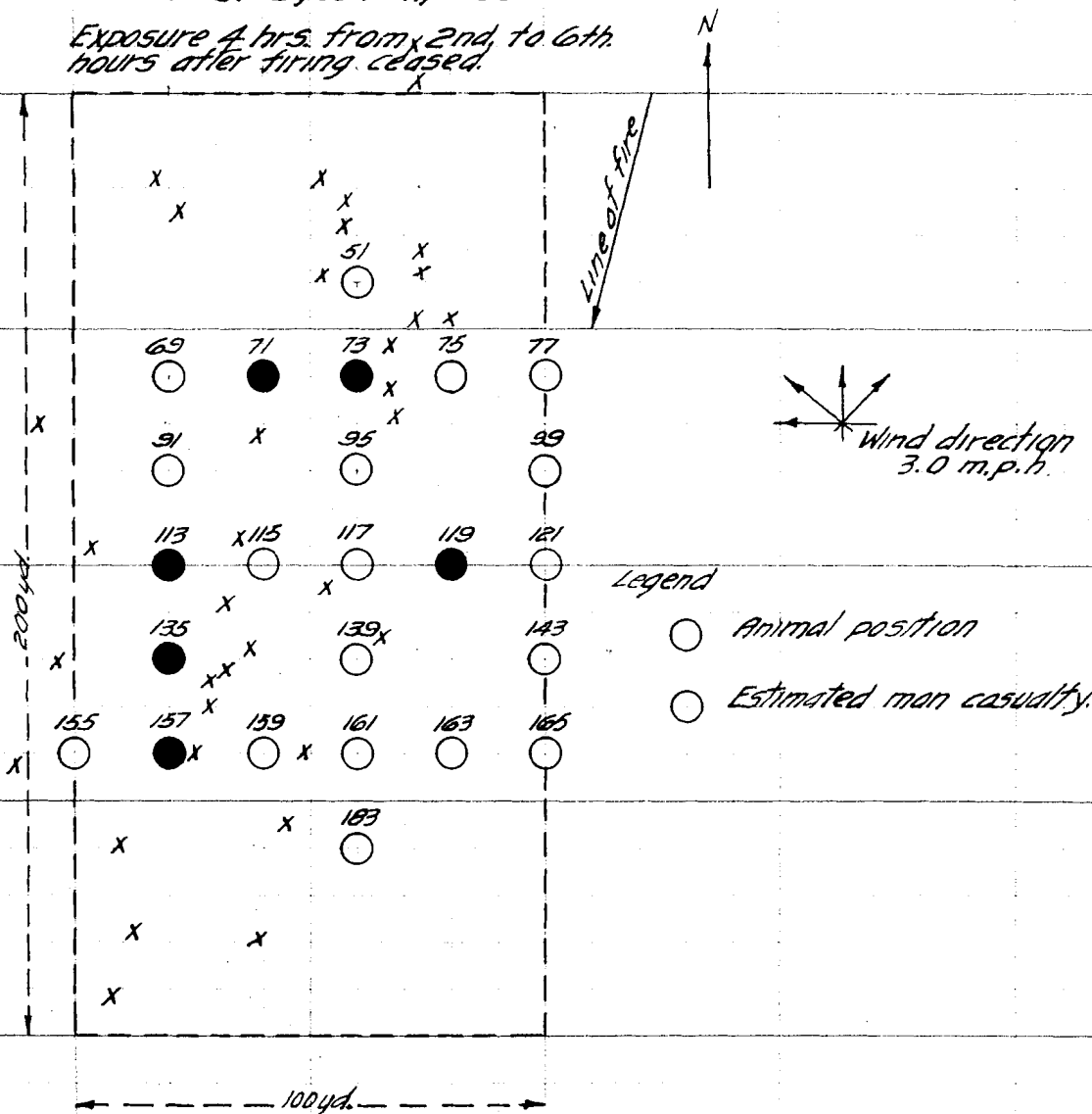


CHART \*15  
ESTIMATED MAN CASUALTIES BASED  
ON EFFECTS ON \*ANIMALS.

TEST B, June 11, 1932

EXPOSURE 24 hrs. from 6th to  
30th hours after firing

N

Line of fire

Wind direction  
29 m.p.h.

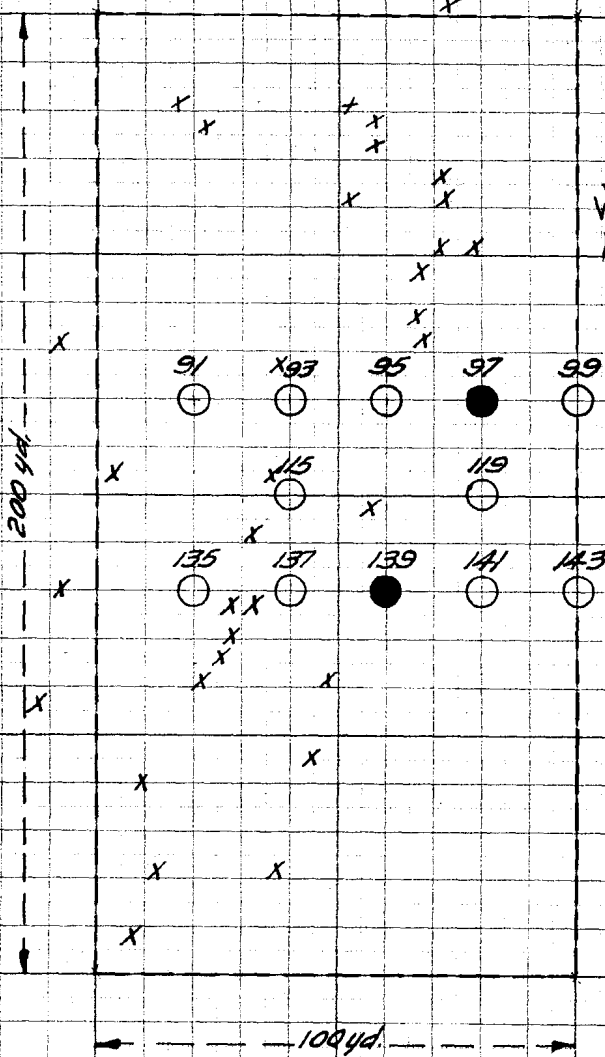
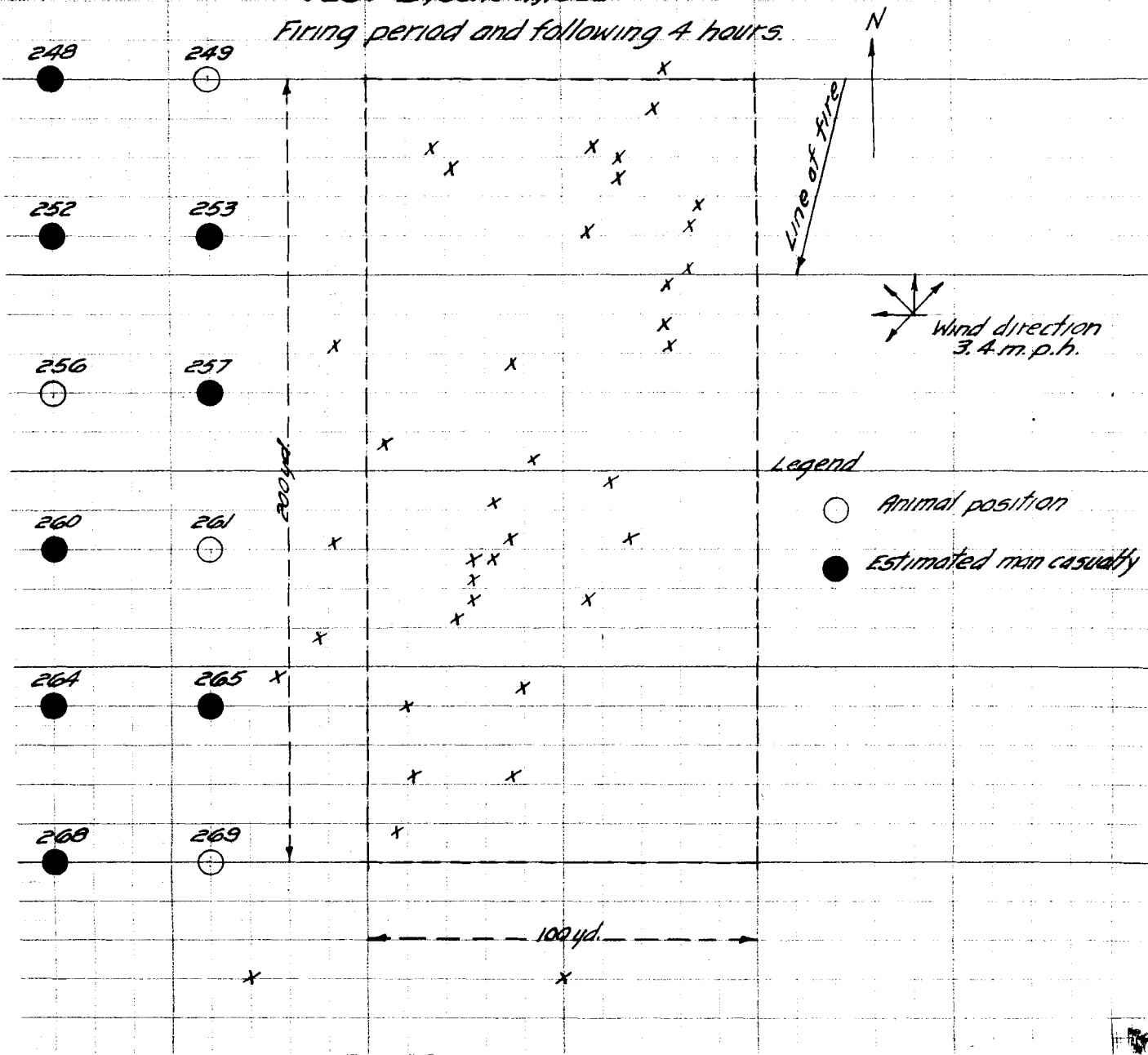


CHART 16  
ESTIMATED MAN CASUALTIES BASED  
ON EFFECTS ON ANIMALS.

TEST B, June 11, 1932  
Firing period and following 4 hours.



Appendix D

Report of Test of HS-Filled 155-mm. Howitzer Shell  
Test C - August 4, 1932.

REPORT  
OF  
TEST OF HS FILLED 155-mm. HOWITZER SHELL  
TEST C - AUGUST 4, 1932

1. Object: The object of this test was to determine the number of 155 mm. howitzer shell filled with HS, which is required in open country under the meteorological conditions which existed at the time of the test to produce 50% casualties, requiring evacuation for hospitalization.

2. Authority: This test was authorized in the Project Program for Edgewood Arsenal for the Year 1933, under Project A 1.1-1b, 155 mm. Shell, MII (Howitzer), HS Filled.

3. Previous Tests: A test was conducted on February 16th and 17th, 1932, in which 36 shell from each of four lots of shell, representing the shell used in the present test, were fired from service weapons to determine if the shell functioned normally, but no attempt was made to determine the gas concentration set up.

A second test was conducted on May 23, 1932, in which 40 shell were fired for impact on a target 100 yards wide by 200 yards deep. From a preliminary study of the results it was estimated that it would require about 28 shell per 100 yard square, to produce 50% casualties, when man is protected with gas mask only.

A third test was conducted on June 11, 1932, in which 40 shell were fired for impact burst on the same target used in the previous test. It was estimated, from a preliminary study of the results of the test, that about 14 shell per 100 yard square are required to produce 50% casualties, when man is protected with gas mask only.

4. Materials Used:

a. Shell. The shell used in the present test was the MII, 155-mm. Howitzer, filled with HS. They were taken from war reserve at Edgewood Arsenal and represent a lot which were filled in the years 1921-1922, for shipment to the Hawaiian Islands. The HS used in filling the shell was from war reserve and was probably made by the Levinstein process. The void used in filling the HS into the shell is not known, but was probably about 10%, based on the maximum volume shell.

b. Booster. The booster used was the MVI-B, which contains a bursting charge of 29 grams of tetryl and 253 grams of TNT. Many of the boosters in these shell were improperly seated.

c. Fuze. The fuze was the MIII, super quick point detonating fuze.

d. Number of Shell Used. Sixty-nine, 29 for ranging and 40 for effect.

e. Howitzers Used. A battery of four 155-mm. Howitzers was used under command of Captain L. T. McMahon. The Howitzers were set up on "C" field in the vicinity of coordinates 690.4, 1869.1 as shown on the special military map of Gun Powder Neck, prepared under the direction of the Chief of Engineers, U.S. Army, 1923.

5. Target Area: The target area was a rectangular field of open country 100 yards wide by 200 yards deep; located on "H" field in the vicinity of coordinates 690.5, 1864.0 with the long axis oriented to line of fire. The area was covered with grass and weeds having an average height of 1 to 2 feet. The area was divided into 10-yard squares by placing numbered stakes at 10-yard intervals. Paper panels, sampling machines and animals were placed on the area to determine the effectiveness of the gas concentration set up. Chart 1, accompanying this report shows the target area as it was prepared for the test with positions of animals, panels and sampling machines.

6. Experimental:

a. Method of Conducting Test. After adjustment, the Howitzers were ranged on the target and fired as rapidly as possible with change in elevation for distribution of impacts over the target area. On completing the firing of the shell, the paper panels were collected for tabulation of results and the animals on the target area and at positions downwind from the target area, were removed at definite periods and replaced by other animals. Also during the firing period and the animal exposure periods, vapor samples were taken with the use of field sampling machines. The meteorological data were recorded during the period of the test.

b. Firing of Shell.

(1) Adjustment of Howitzers. The Howitzers were adjusted in parallel on a target about 100 yards east of the target area, using 29 shell filled with HS. Firing for adjustment began at 4.38 p.m. and ended at 5.40 p.m. The impacts were recorded as follows:

22 Bursts  
 3 Low order bursts  
 2 Duds  
 2 Ricochets

(2) Firing for Effect. Firing for effect started about 6.35 p.m. and ended at 8.55 p.m., a period of 20 minutes. To obtain distribution of the impact over the target area the Howitzers were ranged in parallel using three changes in elevation. Sixteen rounds were fired for impact on a line 50 yards short of the center and 20 rounds for impact on a line 50 yards beyond the center. In an attempt to fill in the gaps resulting from the first 36 rounds, the last four rounds were fired for impact on a line through the center of the target. A photostatic copy of a memorandum dated August 4, 1932, to the Technical Director, from the Battery Commander, giving the firing data by round, is attached to this report. From observation at the O.P. during firing, the following bursts were recorded.

36 - High order  
 4 - Low order  
 1 - Dud (outside target area)

(3) Impacts. The positions of the impacts are shown on Chart 2. Of the 40 shell fired for effect, 26 registered on the target area and an additional 12 within 70 yards of the target area.

c. Meteorological Conditions. The following meteorological conditions prevailed.

	<u>August 4, 1932</u>	
Time	6.35 p.m. to 7.05 p.m.	7.05 to 7.55 p.m.
Air temperature	83 to 80°F.	80 to 78°F.
Ground temperature	85 to 82°F.	83 to 79°F.
Ground condition	Dry	Dry
Relative humidity	61%	70%
Wind velocity	1.5 m.p.h.	1.7 m.p.h.
Wind direction	SW	SW
Sky	Clear	Clear

	Aug. 4 - 7:55 p.m. to Aug. 5 - 9:00 a.m.	Aug. 5 - 10:25 a.m. to 2:30 p.m.
Air temperature	75 to 65 to 80°F.	80 to 88°F.
Ground temperature	81 to 66 to 78°F.	78 to 115°F.
Ground condition	damp (dew)	dry
Relative humidity	61% to 90% to 70%	70 to 50%
Wind velocity	1.0 m.p.h.	3.0 m.p.h.
Wind direction	S.W.	S.W.

## 7. Results:

### a. Liquid HS.

(1) Size of Liquid HS Drops. The distribution of liquid HS was registered by means of paper panels 8 inches square, placed flat on the ground at each stake position over the entire target area. The panels having drops in excess of 0.1 mg. are tabulated in the following table.

Table No. 1.

#### Size of HS Drops

No. of drops:		Number of panels classified						
per panel		0.1 to	0.5 to	1.0 to	Over			
		0.5 mg.	1.0 mg.	3.0 mg.	3.0 mg.			
1	:	2	:	3	:	1	:	0
2 to 10	:	37	:	17	:	4	:	0
11 to 20	:	10	:	7	:	0	:	0
Over 20	:	11	:	1	:	0	:	0

Total panels having drops of 0.1 mg. or greater - 60  
Total panels exposed on target area - 230

### (2) Estimated Man Casualties from Liquid HS.

(a) Man Protected with Gas Mask but Without the Protection of Impregnated Clothing. The paper panels were tabulated for density of pattern using the gradings, heavy, medium, light and trace. A photostat of the scale used in grading the panels is attached to this report. The panel gradings are tabulated in the following table, together with estimated man casualties.

Table No. 2.

Estimated Man Casualties on Target Area from Liquid HS

Pattern	Panel gradings:		Estimated casualties	
	number:	percent:	when man is protected	
	:	:	with gas mask only	
	:	:	:	%
Heavy	: 22	: 9.6	:	9.6
Medium	: 39	: 17.0	:	17.0
Light	: 81	: 36.2	:	28.2
Trace	: 38	: 16.5	:	9.9
No mustard	: 50	: 21.7	:	-
Total and	:	:	:	
average	: 230	: 100.0	:	64.7

From results given in table 2, it is estimated that personnel exposed on the target area during the firing period, protected with gas mask only, would suffer about 65% casualties, if they were equally distributed over the area. The position of shell craters and estimated man casualties from liquid HS are shown graphically on Chart 2.

NOTE: The basis for estimated casualties in Table 2, is given in report of Test "B", 155-mm. howitzer shell, conducted on June 11, 1932.

(b) Man Protected with Gas Mask and Standard Impregnated Clothing. The paper panels were tabulated for number of HS drops on panels in which the drop size was in excess of 0.5 mg. The results of the tabulation, together with estimated man casualties, are given in the following table.

Table No. 3.

Estimated Man Casualties on Target Area from Liquid HS

Size of : Number of : Estimated man casualties when pro-				
HS drops: panels :		ected with gas mask and standard		
:		impregnated clothing.		
mg. :	:	per panel :	%	
0.5 to :	:	:		
1.0 :	20 :	40% :	3.5	
Over 1.0:	8 :	100% :	3.5	
Total :	28 :	:	7.0	

Total panels on area ~ 230.

Note: The basis for estimated casualties in Table 3, is given in report of test "B", 155-mm. howitzer shell, conducted on June 11, 1932.

b. Estimated Man Casualties from Effects of HS Vapor.

Sampling machines were placed to take vapor samples at positions indicated on Chart 1. In each of the tables which follow, representing different sampling periods, the sampling positions used are designated. The HS vapor concentration, c.t. value, and % estimated man casualties, as estimated from the vapor concentration, are also included in each of the tables.

The c.t. value is equal to the vapor concentration in milligrams per liter times the exposure period in minutes. Estimated man casualties are based on the c.t. value using the valuation curve given on Graph 1, attached to this report. The per cent estimated man casualties in the following tables represent man protected with gas mask, but without the protection of impregnated clothing. The sampling periods as given in each of the sub-headings which follow are only approximate due to time required to change samples in sampling machines.

(1) On the Target Area.

(a) Firing Period Plus 10 Minutes.

Table No. 4.

Posi-: Ele- : <u>Sampling period</u> : Air : HS : Vapor : c.t. : Estimated	tion : vation: time : min.: sampled: in : concen-: value: masked man	: : : : : : : casualties					
: : : : : : : : %	: : : : : : : : %	: : : : : : : : %					
O : 0 : 6.35 to 7.08 p.m.	33 : 1146 : 1.2 : .0010 : .03 : 42						
K : 1 : 6.35 to 7.05 p.m.	30 : 1044 : 76.0 : .0753 : 2.28 : 100						
F : 0 : 6.35 to 6.55 p.m.	20 : 684 : 8.9 : .0129 : .26 : 100						
G : 0 : 6.35 to 7.02 p.m.	27 : 966 : 65.3 : .0676 : 1.82 : 100						
P : 1 : 6.35 to 7.07 p.m.	32 : 1144 : 78.8 : .0692 : 2.20 : 100						
Average							88.4

(b) Fifty Minute Period Starting Ten Minutes After Firing Ceased.

**Table No. 5.**

Position	Elevation	Sampling Period Time	Air min. sampled	HS in	Vapor concen-	c.t. value	Estimated masked man
	ft.		liters	mg.	mg./l.		%
O	0	7.10 to 7.55 p.m.	45	1564	1.8	.0012	.05
K	1	7.06 to 7.55 p.m.	49	1700	67.9	.0400	1.96
G	0	7.03 to 7.55 p.m.	52	1860	51.5	.0277	1.43
P	0	7.08 to 7.55 p.m.	47	1680	50.3	.0300	1.41
Average							89.2

(c) Firing Period Plus One Hour.

**Table No. 6.**

Position :	Elevation :	Sampling period Time	: Min. : sampled:	Air : in	HS : concentration:	Vapor : value:	c.t. : masked man	Estimated casualties
:	ft. :	:	:	liters :	mg.	mg./l. :	:	%
S :	1 :	6.35 to 7.55 p.m.	80 :	2860 :	8.7 :	.0031 :	.25 :	100
C :	1 :	6.35 to 7.55 p.m.	80 :	2820 :	55.8 :	.0198 :	1.59 :	100
T :	1 :	6.35 to 7.55 p.m.	80 :	2820 :	10.9 :	.0038 :	.30 :	100
O :	0 :	6.35 to 7.55 p.m.	80 :	2710 :	3.0 :	.0011 :	.09 :	88
K :	1 :	6.35 to 7.55 p.m.	80 :	2744 :	146.3 :	.0533 :	4.21 :	100
G :	0 :	6.35 to 7.55 p.m.	80 :	2826 :	106.8 :	.0378 :	2.99 :	100
P :	0 :	6.35 to 7.55 p.m.	80 :	2824 :	129.1 :	.0457 :	3.38 :	100
						<b>Average</b>		<b>98.8</b>

(d) Four Hour Period on Day Following Firing.

Table No. 7

Posi-:Ele- tion :vation:	Sampling period Time	Air :Min.:	HS :sampled:	Vapor :c.t. :concen-:value:	Estimated :masked man :casualties
: stake:	: ft. :	: a.m. p.m. :	: liters:	: mg. :mg./l. :	: %
75 :	1 :	10.25 to 2.30 :	245: 4520 :	1.4 : .0003 :	.07 : 73
75 :	2 :	10.25 to 2.30 :	245: 4520 :	0.8 : .0002 :	.05 : 58
75 :	4 :	10.25 to 2.30 :	245: 4520 :	0.4 : .0001 :	.02 : 30
120 :	1 :	10.30 to 2.30 :	240: 4300 :	0.6 : .0001 :	.02 : 30
120 :	2 :	10.30 to 2.30 :	240: 4300 :	0.0 : .0000 :	.00 : 0
185 :	1 :	10.35 to 2.30 :	235: 4270 :	0.8 : .0002 :	.04 : 50
185 :	2 :	10.35 to 2.30 :	235: 4270 :	0.0 : .0000 :	.00 : 0
185 :	4 :	10.35 to 2.30 :	235: 4270 :	0.8 : .0002 :	.04 : 50
Average					38.1

(2) Outside of Target Area.

(a) Firing Period Plus One Hour.

Table No. 8.

Posi- tion	Ele- vation	Sampling Period		Air	HS	Vapor	c.t.	Estimated
		Time	Min.	sampled	in	concen- tration	value	masked man casualties
	ft.			liters	mg.	mg./l.		%
R	1	:6.35 to 7.55 p.m.	80	1430	5.9	.0041	.35	100
R	2	:6.35 to 7.55 p.m.	80	1430	1.2	.0008	.06	66
R	4	:6.35 to 7.55 p.m.	80	1430	1.2	.0008	.06	66
N	1	:6.35 to 7.55 p.m.	80	1390	7.3	.0052	.42	100
N	2	:6.35 to 7.55 p.m.	80	1390	5.3	.0038	.30	100
N	4	:6.35 to 7.55 p.m.	80	1390	3.7	.0027	.21	100
J	1	:6.35 to 7.55 p.m.	80	1390	7.5	.0054	.43	100
J	2	:6.35 to 7.55 p.m.	80	1390	5.5	.0040	.32	100
J	4	:6.35 to 7.55 p.m.	80	1390	3.3	.0024	.19	100
D	1	:6.35 to 7.55 p.m.	80	1410	3.5	.0025	.20	100
D	2	:6.35 to 7.55 p.m.	80	1410	4.7	.0033	.27	100
D	4	:6.35 to 7.55 p.m.	80	1410	9.5	.0067	.54	100
H	1	:6.35 to 7.55 p.m.	80	1432	9.9	.0069	.55	100
H	2	:6.35 to 7.55 p.m.	80	1432	7.1	.0050	.40	100
H	4	:6.35 to 7.55 p.m.	80	1432	11.1	.0078	.62	100
M	1	:6.35 to 7.55 p.m.	80	1390	11.7	.0084	.67	100
M	2	:6.35 to 7.55 p.m.	80	1390	11.7	.0084	.67	100
M	4	:6.35 to 7.55 p.m.	80	1390	7.1	.0051	.41	100
Q	1	:6.35 to 7.55 p.m.	80	1430	7.1	.0050	.40	100
Q	2	:6.35 to 7.55 p.m.	80	1430	7.1	.0050	.40	100
Q	4	:6.35 to 7.55 p.m.	80	1430	5.7	.0040	.32	100
U	1	:6.35 to 7.55 p.m.	80	1410	5.5	.0039	.31	100
U	2	:6.35 to 7.55 p.m.	80	1410	2.9	.0021	.17	100
U	4	:6.35 to 7.55 p.m.	80	1410	4.3	.0030	.24	100

c. Estimated Man Casualties Based on Effects on Animals.

Animals were placed on the target area and at positions downwind from the target area to determine effects of the gas concentration set up and how long the liquid HS persisted on the impact area. The position of the animals which were exposed during the various exposure periods is shown on Charts 6 to 10 inclusive. The animal casualties and estimated man casualties, when man is protected with gas mask only, are given in the tables which follow. The man casualties are esti-

mates by the Medical Research Division, which observed and studied the effects on all animals exposed. Estimated man casualties, based on effects on animals are shown on Charts 11 to 15 inclusive. In the tables and on the charts, the following symbols are used to designate the nature of the animal casualties:

L - Gross pathology of lung  
 R - Respiratory symptoms  
 S - First degree skin burn  
 S<sub>2</sub> - Second degree skin burn  
 S<sub>3</sub> - Third degree skin burn  
 E - Simple conjunctivitis  
 E<sub>2</sub> - Purulent conjunctivitis  
 F - Injury by shell fragment  
 X - Stomatitis

(1) On Target Area.

(a) Firing Period and Following 10 Minutes. During the firing period and following 10 minutes, 18 rats and 16 goats were exposed on the target area. Results are tabulated in the following tables. The positions of the animals are shown on Chart 6, and estimated man casualties on Chart 11.

Table No. 8a

Estimated Man Casualties Based on Effects on Rats

Position of stake	Nature of casualty	Severity of casualty	Position of burn	Est. casualties when man is protected with gas mask only
7	S <sub>3</sub>	severe	feet	100%
11	E <sub>1</sub> S <sub>2</sub>	death	feet	100%
47	E <sub>1</sub> S <sub>2</sub>	death	feet	100%
51	S <sub>3</sub>	severe	feet	100%
55	ESL	death	feet	100%
99	ES <sub>2</sub> L	death	feet	100%
139	ES	moderate	feet	100%
179	S	light	feet	100%
183	E	light		0
187	S <sub>3</sub>	severe	feet	100%
227	ELS	death	feet	100%
231	S <sub>2</sub> L	death	feet	100%

Average casualties based on 18 rats positions = 61%.

Table No. 8b

Estimated Man Casualties Based on Effects on Goats

Position of stake :	Nature of casualty :	Severity of casualty :	Position of burn :	Est. casualties when man is protected with gas mask only
1	E	light	-	0
29	E <sub>2</sub> LS	death	body	100%
33	E <sub>2</sub> R	severe	-	0
73	E <sub>2</sub> LS <sub>2</sub> X	death	body and nose	100%
77	E <sub>2</sub> RS	severe	body and nose	100%
113	E <sub>2</sub> RS	severe	body	100%
117	E <sub>2</sub> RS	severe	ears	100%
121	E <sub>2</sub> LS <sub>2</sub> X	death	body	100%
161	E <sub>2</sub> RS <sub>2</sub>	severe	body	100%
165	E <sub>2</sub> RS <sub>2</sub>	severe	body	100%
209	E <sub>2</sub> R	severe	body	0

Average casualties based on 16 goats positions = 50%.

(b) Firing Period and Following Hour. During the firing period and following hour, 15 rats and 17 goats were exposed on the target area. Results are tabulated in the following tables. The position of the animals are shown on Chart 7, and estimated man casualties on Chart 12.

Table No. 9a

Estimated Man Casualties Based on Effects on Rats

Position of stake :	Nature of casualty :	Severity of casualty :	Position of burn :	Est. casualties when man is protected with gas mask only.
23	RS	severe	feet	100%
27	S	moderate	feet	100%
31	ESL	death	feet	100%
67	S	light	feet	100%
75	ESL	death	feet	100%
111	S <sub>2</sub>	moderate	feet	100%
115	ELS	death	feet	100%
119	ESL	death	feet	100%
163	ERS	light	feet	100%
203	ES	light	feet	100%
207	ELS <sub>2</sub>	death	feet	100%

Average casualties based on 15 rats positions = 73%.

Table No. 9b

Estimated Man Casualties Based on Effects on Goats

Position of stake :	Nature of casualty :	Severity of casualty :	Position of burn :	Est. casualties when man is protected with gas mask only
53	: E <sub>3</sub> RS <sub>2</sub>	: severe	: nose and body:	100%
89	: E <sub>3</sub> S <sub>2</sub>	: severe	: ears :	100%
93	: E <sub>2</sub> RS <sub>2</sub>	: severe	: body :	100%
97	: E <sub>2</sub> L <sub>3</sub>	: death	: body :	100%
133	: S	: light	: body :	100%
137	: E <sub>2</sub> RS	: severe	: ears and body:	100%
141	: E <sub>2</sub> LS	: death	: body :	100%
181	: E <sub>3</sub> RS	: severe	: body :	100%
185	: EL	: death	:	100%
229	: ELS <sub>2</sub>	: death	: body :	100%

Average casualties based on 17 goats positions = 59%.

(c) Period from Second to Fourteenth Hour After Firing. During the period from the second and fourteenth hour after firing, 15 rats and 9 goats were exposed on the target area. Results are tabulated in the following tables. The positions of the animals are shown on Chart 8, and estimated man casualties on Chart 13.

Table No. 10a

Estimated Man Casualties Based on Effects on Rats

Position of stake :	Nature of casualty :	Severity of casualty :	Position of burn :	Est. casualties when man is protected with gas mask only
23	: ELS <sub>2</sub>	: death	: feet :	100%
31	: LS	: death	: feet :	100%
67	: ELS	: death	: feet :	100%
71	: ELS	: death	: feet :	100%
75	: ERS	: severe	: feet :	100%
116	: SR	: severe	: feet :	100%
119	: S <sub>2</sub>	: severe	: feet :	100%
155	: S <sub>2</sub>	: severe	: feet :	100%
159	: ELS <sub>2</sub>	: death	: feet :	100%
163	: S <sub>3</sub> R	: severe	: feet :	100%
203	: S <sub>2</sub>	: severe	: feet :	100%
207	: S <sub>2</sub> RE	: severe	: feet :	100%

Average casualties based on 15 rats positions = 80%.

Table No. 10b

Estimated Man Casualties Based on Effects on Goats

Position of stake :	Nature of casualty :	Severity of casualty :	Position of burn :	Est. casualties when man is protected with gas mask only
89	: E <sub>2</sub> R <sub>5</sub>	: severe	: body	: 100%
97	: E <sub>3</sub> R	: severe	: body	: 100%
137	: E <sub>2</sub> RS	: severe	: ears and body:	: 100%
141	: E <sub>2</sub> LS	: death	: ears and body:	: 100%
181	: E	: moderate	:	: 0
185	: E <sub>2</sub> RS	: severe	: ears and body:	: 100%

Average casualties based on 9 goats positions - 56%.

(d) Day Following Firing (15th to 18th Hour). On the day following firing, from the 15th to the 18th hour inclusive, eight rats and four goats were exposed on the target area. Results are given in the following tables. The positions of the animals are shown on Chart 9, and estimated man casualties on Chart 14.

Table No. 11a

Estimated Man Casualties Based on Effects on Rats

Position of stake :	Nature of casualty :	Severity of casualty :	Position of burn :	Est. casualties when man is protected with gas mask only
95	: ES	: light	: feet	: 100%
139	: ERS	: severe	: feet	: 100%
143	: E <sub>2</sub> LS	: death	: feet	: 100%

Average casualties based on 8 rats positions - 37.5%.

Table No. 11b

Estimated Man Casualties Based on Effects on Goats

Position of stake :	Nature of casualty :	Severity of casualty :	Position of burn :	Est. casualties when man is protected with gas mask only
97	: S <sub>2</sub>	: moderate	: body	: 100%

Average casualties based on 4 goats positions - 25%.

(e) Exposed in Shell Craters on Third Day After Firing. On the third day after firing seven rats and one goat were exposed on the target area in shell craters. Results are given in the following table.

Table No. 12

Estimated Man Casualties Based on Effects on Rats

Nature of casualty	Severity of casualty	Position of burn	Est. casualties when man is protected with gas mask only.
L	death	:	100%
E <sub>2</sub> RS <sub>2</sub>	severe	:	100%
L	death	:	100%
E	light	feet	0

The goat exposed was not a casualty.

(f) Exposed in Shell Craters on Seventh Day After Firing. On the seventh day of the firing, seven rats and one goat were exposed on the target area in shell craters. Results are given in the following table.

Table No. 13

Estimated Man Casualties Based on Effects on Rats

Nature of casualty	Severity of casualty	Position of burn	Est. casualties when man is protected with gas mask only
ES	light	feet	100%
E <sub>3</sub> S	severe	feet	100%
E	light	:	0
ERS	light	feet	100%

The goat exposed was not a casualty.

(2) Downwind from Target Area.

(a) Firing Period and Following Hour. During the firing period and following hour, eight rats and four goats were exposed at positions downwind from the target area. Results are given in the following tables. The positions of the animals are shown on Chart 10 and estimated man casualties on Chart 15.

Table No. 14a

Estimated Man Casualties Based on Effects on Rats

Position of stake :	Nature of casualty :	Severity of casualty :	Position of burn :	Est. casualties when man is protected with gas mask only :
250 :	ES :	moderate :	feet :	100%
251 :	ES <sub>2</sub> L :	death :	feet :	100%
258 :	S :	moderate :	feet :	100%
259 :	ES :	moderate :	feet :	100%
263 :	S <sub>2</sub> :	severe :	nose :	100%
271 :	S <sub>2</sub> :	severe :	nose :	100%

Table No. 14b

Estimated Man Casualties Based on Effects on Goats

Position of stake :	Nature of casualty :	Severity of casualty :	Position of burn :	Est. casualties when man is protected with gas mask only :
254 :	E <sub>2</sub> RS :	severe :	feet :	100%
255 :	ER :	moderate :	:	0
266 :	E <sub>2</sub> R* :	moderate :	:	0 *
267 :	E <sub>2</sub> R* :	severe :	:	0 *

\* The author does not agree with man casualty estimates, made by the Medical Research Division, representing goats nos. 266 and 267. It is thought that these animal casualties should be interpreted as 100% man casualties instead of 0% man casualties.

8. Discussion.

a. Shell Distribution. The shell were fired for equal distribution of impacts on the target area. Of the 40 shell fired for effect, 26 registered on the target. The craters produced by these 26 shell were all within an area of 16,000 square yards which is about 80% of the target area. Aside from the impacts on the target area, there were 12 additional impacts within a distance of 70 yards from the edge of the target area. Eight of these were partly effective on the target area due to wind direction. This is shown on Chart 2, by the presence of liquid HS on the extreme west side of the area.

b. Impact Area. The number of animal positions included within the impact area, as distinguished from the target area, was 55, and since each animal was located on the center of a 20-yard square, for purposes of discussion, the size of the impact area may be regarded as 22,000 sq. yd. The animal positions on the impact area and number of impacts on each 20-yard square are given in table 16.

c. Estimated Man Casualties from Liquid HS.

(1) Effects of Meteorological Conditions. The only meteorological factor having any effect on the size of the area covered with liquid HS, by the burst of a single shell, is wind velocity. The wind velocity during the firing period in the present test was 1.5 m.p.h. which was too low to carry the large HS drops very far, since the distance they are carried is dependent on the interval of time they are in the air and wind travel during that period. Theoretically, the wind velocity was too low to produce the maximum number of casualties from liquid HS per shell due to the restricted size of the area which would theoretically be covered with liquid HS by each burst, in the presence of such a low wind.

(2) Protected with Gas Mask but Without Protection of Impregnated Clothing. Results from paper panels in table 2, show that personnel exposed with equal distribution on the target area during the firing period would suffer 64.7% casualties from liquid HS when protected with gas masks only. These estimated casualties were partly due to the impact of 7 shell west of the target area, all of which were only slightly effective. Liquid HS effects on the target area, from shell which burst outside of the target area, was probably much more than counter balanced by effects downwind from the target area, by shell which burst on the target area. The effectiveness of the HS liquid downwind is indicated by a heavy pattern on about 50% of the panels on the downwind edge of the target area, so that in calculations no serious error will be involved to disregard effects of impacts upwind from the target.

If 27 shell will produce 64.7% casualties by effects of liquid HS, on an area of 23,100 sq. yd., about 9 shell distributed per 100-yard square are required to produce 50% casualties, when man is protected with gas mask only.

(3) Protected with Gas Mask and Standard Impregnated Clothing. From results given in table 3, it is estimated that personnel protected with gas masks and standard impregnated clothing, exposed with equal distribution on the target area during the firing period would suffer about 7% casualties from liquid HS.

If 27 shell will produce 7% casualties from the effects of liquid HS on an area of 23,100 sq. yd., about 84 shell distributed per 100-yard square are required to produce 50% casualties when man is protected with gas mask and standard impregnated clothing.

d. Vapor Concentration Required to Produce Man Casualties.  
A discussion of the exposure period required to produce man casualties from HS vapor is given in Test "A", "Report of Test of HS Filled 155-mm. Howitzer Shell", conducted May 23, 1932.

In the present test, the air temperature was 83° to 80°F. and wind velocity 1.5 m.p.h. during the firing period and following hour. These meteorological conditions were very favorable to build up a high vapor concentration.

(1) On the Target Area. Estimated man casualties on the target area, from the effects of HS vapor for the different exposure periods, are tabulated in tables 4 to 7 inclusive, and results are shown graphically on Charts 3 to 5 inclusive.

(a) Firing Period and Following Ten Minutes.  
From the results of vapor samples in table 4, representing the firing period and following ten minutes, it is estimated that man with the protection of gas mask only, would suffer about 88.4% casualties from effects of HS vapor. This estimate is based on the average results of vapor samples taken at 5 different positions on the target area.

Some figures are given in the fifth column of table 15, which represent a more complete study of the vapor concentration on the target area. The figures in this column for each 20-yard square, are estimates based on results obtained at the five sampling positions, the position of nearest impacts and the wind direction. Based on the figures in this column, personnel exposed on the target area during the firing period and following 10 minutes, would suffer about 95% casualties, when protected with gas mask only.

The percent estimated casualties for each 20-yard square as given in table 15, is shown graphically on Chart 3. The shaded area on the chart represents that part of the area on which 100% casualties would be produced by the effects of HS vapor when man is protected with gas mask only. The percent casualties shown on Chart 3, are based on the effects of 28 shell. If 28 shell, distributed over an area of 26,400 sq. yd. will produce 95% casualties by effects of HS vapor, it will require theoretically, about 5.6 shell distributed per 100-yard square to produce 50% casualties. When the area to be gassed consists of a number of 100-yard squares, then the number of shell

required per square will be reduced, since the HS vapor from shell bursts on the upwind square will travel downwind and be effective on the downwind squares. The above discussion does not take into consideration the effects from liquid HS, which will result in additional casualties. For casualties by effects of liquid HS, see sub-paragraph 8 c (2).

(b) Firing Period and Following Hour. From the results of vapor samples given in table 6, representing the firing period and following hour, it is estimated that man with the protection of gas mask only, would suffer about 98.3% casualties from HS vapor if exposed on the target area during the firing period and following hour. This estimate is based on the average results of vapor samples taken at 7 different positions on the target area.

Some figures are given in the fifth column of table 17, which represent a more complete study of the vapor concentration on the target area. The figures in this column, for each 20-yard square, are estimates based on results obtained at the seven sampling positions, the position of nearest impacts and the wind direction. Based on the figures in this column, personnel exposed on the target area during the firing period and following hour, would suffer about 99.0% casualties which checks 98.3%, the percent given in table 6, representing average results at seven sampling positions. The shaded area on Chart 4, shows that part of the target area on which it is estimated 100% casualties would result from HS vapor on exposure during the firing period and following hour, when man is protected with gas mask only.

If 27 shell distributed on an area of 26,400 sq. yd. will produce 99.0% casualties by effects of HS vapor, it will require about 5.4 shell distributed, per 100-yard square to produce 50% casualties from HS vapor, when man is protected with gas mask only.

In figuring the above shell requirements, as well as shell requirements in the previous paragraph, for firing period plus 10 min., the fact was not taken into consideration that the c.t. values for each of the periods show that the vapor concentration on many of the 20-yard squares, was very much in excess of requirements to produce 100% casualties.

In the fourth column of table 17, the average c.t. value is 0.96, which is about nine times 0.11, the c.t. value required to produce 100% casualties. On this basis, less than one shell per 100-yard square would be required to produce 50% casualties from the effects of HS vapor. This figure is only of theoretical interest

however, as probably only a small part of the 100-yd. square would be covered with HS vapor from the impact burst of a single shell. The figures however are of interest as they show that the vapor from one shell, if sufficiently and evenly distributed over the area, would produce 50% man casualties, when man is protected with gas mask, under the meteorological conditions of the test.

(c) Four Hour Period on Day Following Firing.

From the results of vapor samples in table 7, representing the four hour period on day following firing, it is estimated that man, with the protection of gas mask only, would suffer casualties if they occupied the area for a period of three or four hours.

(2) Outside of the Target Area. Estimated man casualties at sampling positions outside of the target area, are given in table 8 for the firing period and following hour. Vapor samples were obtained upwind as well as downwind from the impact area. The fact that vapor samples were obtained upwind was due to the impact of shell outside of the target area. A high vapor concentration was obtained at all downwind sampling positions. It is estimated, from the vapor concentration at each of the five sampling positions, that personnel protected with gas mask only, exposed during the firing period and following hour, at positions 30 yd. downwind from the target area, would suffer 100% casualties from HS vapor.

e. Estimated Man Casualties Based on Effects on Animals.

Animal casualties and estimated man casualties based on effects on animals are recorded in tables 8a to 14b inclusive. Animal positions, animal casualties, and estimated man casualties, based on effects on animals, are shown on Charts 6 to 15 inclusive.

(1) Estimated Man Casualties on the Target Area, when Man is Protected with Gas Mask Only.

(a) Firing Period and Following Ten Minutes. From the animal casualties given in tables 8a to 8b, it is estimated that man, protected with gas mask, exposed on the target area during the firing period and following 10 min. would suffer 61% casualties, based on rats and 50% based on goats or 55.5% based on rats and goats.

(b) Firing Period and Following Hour. Estimated man casualties on the target area for the firing period and following hour are given in tables 9a and 9b. It is estimated that man protected with gas mask, would suffer about 73% casualties based on effects on rats and 59% based on goats or about 66% based on rats and goats.

(c) Period from 2nd to 15th Hour After Firing. Estimated man casualties due to exposure on the target area during the

12 hr. period from the 2nd to the 13th hour after firing, are given in tables 10a and 10b. From the animal casualties it is estimated that man casualties would be 80% based on rats and 56% based on goats or about 71% based on rats and goats.

(d) Day Following Test (13th to 18th hour).

Estimated man casualties due to exposure on the target area on the day following firing, from the 13th to the 18th hour, are given in tables 11a and 11b. The results show that if the target area is occupied by personnel with protection of gas masks only, on the day following firing for a period of three or four hours, casualties will result.

(e) Exposure in Shell Craters. Estimated man casualties due to exposure in shell craters for a period of 24 hr. are given in tables 12 and 13. From the animal casualties, it is estimated that casualties will result, if the impact area is occupied by personnel protected with gas masks only, within seven days after date of shelling.

(2) Downwind from Target Area.

(a) Firing Period and Following Hour. Estimated man casualties downwind from the target area are given in tables 14a and 14b. From the animal results, it is estimated that personnel protected with gas masks only who occupy the downwind area, within 80 yd. from the position of impact, during the firing period and following hour, will probably become casualties.

f. Comparison of Percent Estimated Man Casualties Based on Measurements of the Gas Concentration and by Effects on Animals, When Man is Protected with Gas Mask Only.

(1) Firing Period and Following Ten Minutes. In table 15, estimated man casualties are given for each 20-yard square, based on the following effects and methods of figuring casualties, when man protected with gas mask only, is exposed on the target area during the firing period and following ten minutes.

- (a) HS liquid using panel data.
- (b) HS vapor from vapor samples.
- (c) Combined effect of HS liquid and HS vapor.
- (d) Effect on animals.

Figures in this table show that 100% casualties would be produced on 96.6% of the target area, based on the combined effect of HS liquid and vapor and 57.6%, based on effects on animals or 77.0% based on an average of the two methods of figuring casualties.

Table No. 15

Estimated Casualties on the Target Area Representing Exposure  
During Firing and Following 10 Minutes  
 (Area 28,400 sq.yd.)

Stake no.:	Impacts:	From HS liquid:	From HS vapor:	From HS liquid:	From effects on
at center:	within	Estimated man	Est. Man:	and vapor	animals
of 20-yd.:	20-yd.:	casualties	values:	casualties	Animal
square	square	:	ties	casualties	casualties:
		%	%	%	%
1	0	0	.07: 73	73	E light 0
3	0	0	.20: 100	100	0
5	0	23	.60: 100	100	
7	2	73	.90: 100	100	S <sub>2</sub> severe 100
9	1	66	.90: 100	100	
11	0	65	.60: 100	100	E <sub>1</sub> S <sub>2</sub> death 100
23	0	10	.05: 58	62	
25	0	36	.15: 100	100	0
27	1	50	.10: 93	97	
29	2	79	.80: 100	100	E <sub>2</sub> LS death 100
31	0	86	.80: 100	100	
33	0	86	.60: 100	100	E <sub>2</sub> R severe 0
45	0	30	.05: 58	71	
47	0	79	.15: 100	100	E <sub>1</sub> S <sub>2</sub> death 100
49	1	92	1.0: 100	100	
51	0	87	1.5: 100	100	S <sub>3</sub> severe 100
53	1	100	1.5: 100	100	
55	0	96	.80: 100	100	ESL death 100
67	1	62	.30: 100	100	
69	0	79	.30: 100	100	0
71	1	87	.30: 100	100	
73	1	91	1.50: 100	100	E <sub>2</sub> LS <sub>2</sub> X death 100
75	3	96	1.5: 100	100	
77	0	93	1.0: 100	100	E <sub>3</sub> RS severe 100
89	0	83	.30: 100	100	
91	1	73	1.00: 100	100	0
93	0	80	.40: 100	100	
95	0	85	.40: 100	100	0
97	0	96	1.00: 100	100	
99	1	90	1.00: 100	100	ES <sub>2</sub> L death 100
111	0	46	.30: 100	100	
113	1	81	1.00: 100	100	E <sub>3</sub> RS severe 100
115	0	82	1.00: 100	100	
117	0	89	.40: 100	100	E <sub>3</sub> RS severe 100
119	2	100	1.00: 100	100	
121	1	100	1.00: 100	100	E <sub>2</sub> LS <sub>2</sub> X death 100
133	0	73	.30: 100	100	
135	0	81	.20: 100	100	0
137	1	87	.40: 100	100	

Table No. 15 (Cont'd.)

Stake no.	Impacts	From HS liquids	From HS vapor	From HS Liquid	From effects on
at center	within	Estimated man	o.t. : Est. man	and vapor	animals
of 20-yd.	20-yd.	casualties	values: casual-	Estimated man	Animal
square	square	:	ties	casualties	casualties: casualties
		%	%	%	%
139	0	85	.40: 100	100	ES moderate 100
141	0	88	1.0: 100	100	:
143	0	100	.80: 100	100	:
155	0	80	.30: 100	100	:
157	0	52	.03: 42	72	:
159	1	67	.10: 93	98	:
161	0	78	1.00: 100	100	E <sub>2</sub> RS <sub>2</sub> severe 100
163	2	75	2.00: 100	100	:
165	0	53	.6: 100	100	E <sub>2</sub> RS <sub>2</sub> severe 100
177	0	53	.30: 100	100	:
179	0	9	.03: 42	47	S light 100
181	0	32	.03: 42	60	:
183	0	54	.10: 93	97	E light 0
185	3	63	2.00: 100	100	:
187	0	48	.60: 100	100	S <sub>3</sub> severe 100
199	0	50	.20: 100	100	:
201	0	0	.10: 93	93	:
203	0	14	.10: 93	94	:
205	0	40	.20: 100	100	:
207	0	87	.20: 100	100	:
209	0	63	.20: 100	100	E <sub>2</sub> R severe: 0
221	0	15	.15: 100	100	:
223	0	0	.15: 100	100	:
225	0	10	.15: 100	100	:
227	0	33	.15: 100	100	ELS death 100
229	1	86	.15: 100	100	:
231	0	85	.15: 100	100	S <sub>2</sub> L death 100
Total and:	:	:	:	:	:
averages	28	64	:	95	96.6
	:	:	:	:	57.5

NOTE: See page 10 for meaning of symbols used in column 7.

The average percentages given in table 15, are based on the total target area. In table 16, which follows, results are given to include only the impact area as defined in paragraph 8 b.

Estimated casualties given in table 16, are based on an area of 22,000 sq. yd. on which there were 28 impacts. Results in this table show an average of 98.6% man casualties based on the effects of HS liquid and vapor, and 62.1% based on effects on animals, or an average of 80.3% based on the two methods of figuring casualties.

Table No. 16

Estimated Casualties on the Impact Area (22,000 sq.yd.)  
Firing Period and Following Ten Minutes.

Stake number : Impacts			Estimated man casualties		
at center of : within			: From HS liquid : From effects		
20-yd. square: 20 yd. sq.			: and vapor : on animals		
5	:	0	:	100	:
7	:	2	:	100	:
9	:	1	:	100	:
11	:	0	:	100	:
25	:	0	:	100	:
27	:	1	:	97	:
29	:	2	:	100	:
31	:	0	:	100	:
33	:	0	:	100	:
47	:	0	:	100	:
49	:	1	:	100	:
51	:	0	:	100	:
53	:	1	:	100	:
55	:	0	:	100	:
67	:	1	:	100	:
69	:	0	:	100	:
71	:	1	:	100	:
73	:	1	:	100	:
75	:	3	:	100	:
77	:	0	:	100	:
89	:	0	:	100	:
91	:	1	:	100	:
93	:	0	:	100	:
95	:	0	:	100	:
97	:	0	:	100	:
99	:	1	:	100	:
111	:	0	:	100	:
113	:	1	:	100	:
116	:	0	:	100	:
117	:	0	:	100	:
119	:	2	:	100	:
121	:	1	:	100	:
133	:	0	:	100	:
135	:	0	:	100	:
137	:	1	:	100	:
139	:	0	:	100	:
141	:	0	:	100	:
143	:	0	:	100	:
155	:	0	:	100	:
157	:	0	:	72	:
159	:	1	:	98	:

Table No. 16 (Cont'd.)

Stake number :		Impacts :		Estimated man casualties		
at center of :		within :		From HS liquid	From effects	
20-yd. square:		20-yd.sq. :		and vapor	on animals	
161	:	0	:	100	:	100
163	:	2	:	100	:	
165	:	0	:	100	:	100
177	:	0	:	100	:	
181	:	0	:	80	:	
183	:	0	:	97	:	0
185	:	3	:	100	:	
187	:	0	:	100	:	100
205	:	0	:	100	:	0
207	:	0	:	100	:	
209	:	0	:	100	:	0
227	:	0	:	100	:	100
229	:	1	:	100	:	
231	:	0	:	100	:	100
Total and Average		28	:	98.6	:	62.1

(2) Firing Period and Following Hour.

In table 17, which follows, estimated man casualties are given for each 20-yard square, when man protected with gas masks only, is exposed on the target area during the firing period and the following hour.

Table No. 17

Estimated Casualties on the Target Area Representing Exposure  
During Firing and Following Hour  
(Area 26,400 sq.yd.)

Stake no.:	Impacts:	From HS Liquid:	From HS vapor:	From HS liquid:	From effects on
at center:	within	Estimated man	c.t. : Est. man:	and vapor	animals
of 20-yd.:	20-yd. :	casualties	value:casual-	Estimated man	Animal
square	square :	:	ties :	casualties	casualties:
		%		%	%
1	0	0	.12: 100	100	
3	0	0	.34: 100	100	
5	0	23	1.02: 100	100	0
7	2	73	1.59: 100	100	
9	1	66	1.59: 100	100	0
11	0	65	1.02: 100	100	
23	0	10	.08: 80	82	:RS severe: 100
25	0	36	.25: 100	100	
27	1	50	.17: 100	100	:S moderate: 100
29	2	79	1.36: 100	100	
31	0	86	1.36: 100	100	:ESL death: 100
33	0	86	1.02: 100	100	
45	0	30	.08: 80	86	0
47	0	79	.25: 100	100	
49	1	92	1.70: 100	100	0
51	0	87	2.50: 100	100	
53	1	100	2.50: 100	100	:E <sub>3</sub> RS <sub>2</sub> severe 100
55	0	96	1.36: 100	100	
67	1	62	.51: 100	100	:S light: 100
69	0	79	.51: 100	100	
71	1	87	.51: 100	100	0
73	1	91	2.99: 100	100	
75	3	96	2.99: 100	100	:ESL death: 100
77	0	93	1.70: 100	100	
89	0	83	.51: 100	100	:E <sub>3</sub> S <sub>2</sub> severe 100
91	1	73	1.70: 100	100	
93	0	80	.68: 100	100	:E <sub>2</sub> RS <sub>2</sub> severe 100
95	0	85	.68: 100	100	
97	0	96	1.70: 100	100	:E <sub>2</sub> LS death 100
99	1	90	1.70: 100	100	
111	0	45	.51: 100	100	:S <sub>2</sub> moderate 100
113	1	81	1.70: 100	100	
115	0	82	1.70: 100	100	:ELS death: 100
117	0	89	.68: 100	100	
119	2	100	1.70: 100	100	:ELS death: 100
121	1	100	1.70: 100	100	
133	0	73	.51: 100	100	:S light: 100
135	0	81	.31: 100	100	
137	1	87	.68: 100	100	:E <sub>2</sub> RS severe 100

Table No. 17 (Cont'd.)

Stake no.:	Impacts:	From HS liquid:	From HS vapor:	From HS liquid:	From effects on		
at center:	within :	Estimated man :	e.t. :	Est. man :	and vapor :	animals	
of 20-yd.:	20-yd. :	casualties :	value:	casual-:	Estimated man :	Animal :	Est. man
square :	square :	:	ties :	casualties :	casualties :	casualties:	casualties
:	:	% :	:	% :	% :	:	% :
139	: 0 :	85	: .68:	100	: 100	:	:
141	: 0 :	88	: 1.70:	100	: 100	:E <sub>2</sub> LS death:	100
143	: 0 :	100	: 1.36:	100	: 100	:	:
155	: 0 :	80	: .51:	100	: 100	:	: 0
157	: 0 :	52	: .05:	58	: 80	:	:
159	: 1 :	67	: .17:	100	: 100	:	: 0
161	: 0 :	78	: 1.70:	100	: 100	:	:
163	: 2 :	75	: 3.40:	100	: 100	:ERS light :	100
165	: 0 :	53	: 1.02:	100	: 100	:	:
177	: 0 :	53	: .51:	100	: 100	:	: 0
179	: 0 :	9	: .09:	88	: 90	:	:
181	: 0 :	32	: .09:	88	: 92	:E <sub>3</sub> RS severe	100
183	: 0 :	54	: .17:	100	: 100	:	:
185	: 3 :	63	: 3.38:	100	: 100	:EL death :	100
187	: 0 :	46	: 1.02:	100	: 100	:	:
199	: 0 :	50	: .34:	100	: 100	:	: 0
201	: 0 :	0	: .17:	100	: 100	:	:
203	: 0 :	14	: .17:	100	: 100	:E <sub>5</sub> light :	100
205	: 0 :	40	: .34:	100	: 100	:	:
207	: 0 :	87	: .34:	100	: 100	:ELS <sub>2</sub> death:	100
209	: 0 :	63	: .34:	100	: 100	:	:
221	: 0 :	15	: .25:	100	: 100	:	: 0
223	: 0 :	0	: .25:	100	: 100	:	:
225	: 0 :	10	: .25:	100	: 100	:	: 0
227	: 0 :	33	: .30:	100	: 100	:	:
229	: 1 :	86	: .30:	100	: 100	:ELS <sub>2</sub> death:	100
231	: 0 :	85	: .25:	100	: 100	:	:
<hr/>							
Total and:	:	:	:	:	:	:	:
average :	28	: 64	: .96:	98.4:	99.0	:	: 62.5

NOTE: See page 10 for meaning of symbols used in column 7.

Figures in table 17, show 100% casualties on 99.0% of the area, based on the combined effects of HS vapor and liquid and 62.8% based on effects on animals, or 80.7% based on the two methods of figuring casualties.

Per cent estimated casualties in tables 15, 16 and 17, based on the combined effects of HS liquid and vapor, are considerably higher than corresponding figures, based on effects on animals. There would have been a still greater spread between these two sets of figures if a smaller number of shell had been used, because on many of the 20-yard squares the HS vapor concentration was much in excess of estimated requirements to produce 100% casualties.

Estimates based on effects on animals were very conservatively made and are probably low. It is also probable that estimates based on effects of HS vapor alone, are high for average temperature conditions, so that an average based on effects on animals and from measurements of the HS liquid and vapor present, is probably more nearly correct than either method alone.

g. Number of Shell Required to Produce 50% Man Casualties.

It was estimated in paragraph 8 c (2) that about 9 shell distributed per 100 yd. square will produce 50% casualties from liquid HS, when man is protected with gas mask only.

From figures given in table no. 16, it was estimated that the impact of 28 shell, on an area of 22,000 sq. yd. would produce 98.6% casualties, based on a measure of the HS liquid and vapor present, and 62.1% based on effects on animals, when exposed during the firing period and following 10 minutes. On this basis, the following number of shell per 100-yard square will be required to produce 50% casualties when man is protected with gas mask only:

Based on HS liquid and vapor samples	-	6.5 shell
Based on effects on animals	-	10.2 shell
Average	-	8.3 shell

Based on the two methods of figuring casualties, about 8.3 shell distributed, are required per 100-yard square to produce 50% casualties, when man is protected with gas mask only.

9. Conclusions. From the results of the present test, the following conclusions are drawn with respect to the use of 155-mm. shell filled with HS, when fired under the meteorological conditions existing at the time of the test.

a. The number of shell required per 100-yard square to produce 50% casualties when distributed as equally as practicable, are as follows:

(1) When man, protected with gas mask and standard impregnated clothing, is exposed during the firing period - 84 shell (see page 17).

(2) When man, protected with gas mask only, is exposed during the firing period and following ten minutes - 9 shell. (See sub-paragraph g, page 28).

b. Personnel who occupy the downwind area within 80 yd. of the impact area during the firing period and the following hour will suffer casualties if protected with gas mask only, (see page 20).

c. If the impact area is occupied by personnel with gas mask protection only, for a period of 25 hr. or possibly less, within 7 da. after the date it was shelled, they will suffer casualties. (See page 20).

#### 10. Recommendations.

No recommendations are made in view of the fact that the next test, Test "D", was conducted before the study of the present test was completed.

Submitted:

/s/ B. G. Macintire  
B. G. MACINTIRE,  
Weapons Department,  
Munitions Dev. Division.

Report of Test of HS Filled  
155-mm. Howitzer Shell, Test "C"  
August 4, 1932.

Recommending Approval:

Project A 1.1-1b

/s/ Charles E. Loucks  
CHARLES E. LOUCKS,  
Captain, C.W.S.,  
Chief, Munitions Dev. Division.

Typed nsm 11-25-32

Approved:

/s/ E. Montgomery  
E. MONTGOMERY,  
Major, C.W.S.,  
Technical Director.

Appendix D

A 1-1-1  
155-5-17-2/1

BATTERY "C" SIXTH FIELD ARTILLERY  
Fort Hoyle, Maryland.

9-7-32

MEMORANDUM: To Commanding Officer,  
Bigwood Arsenal, Maryland.

1. Upon the request of Captain Loucks, the undersigned submits a copy of the record kept by Captain McMahon, for the firing done by him of the 155 MM Howitzer shoot of August 4, 1932.

Initial Commands-

Compass 3210 - On fl Close 4 - Shell

Mustard Gas - Charge 5 - fuse long - No.1 1 Round

Quadrant

B.C. Commands	Round No.	Elev	Observers sensings	Deviation	Range	Deflection	Remarks
	1	300	25 R	+	+		
Right 8	2	300	150 R	+	+		
Right 8	3	290	20 R	+	+		Dad
Right 4	4	292	150 R	+	+		
	5	290	10 K	+	+		
Right 8	6	290	Line	+	+		
Right 4	7	290	200 R	+	+		
	8	280	150 R	+	+		Low Order
	9	280	30 L	—	?		
Right 4	10	280	150 L	—	?		
	11	285	150 R	+	?		
	12	285	125 L	—	—		Dad
	13	285	Target	OK	OK		
No.1-3 Rounds	14	285	30 L	—	—		
	15		70 L	—	—		
	16		60 L	—	—		
Adjusted Elevation	287	No 1	Record Base	Deflection			
No 2 Adjust	17	287	150 L	—	—		
	18		10 R		+		
No.2 Left 20	19	287			—		
No.2 Left 10	20	287	20 L	—	+		
No.2 Adjust	21	287	70 R	+	—		Missile on No.3
	22		60 L	—	—		
No.3 Left 30	23	287	80 L	—	—		
No.3 record	24	287	10 R	+	—		
Base Deflect:							

43/4/34

No.4 adjust.left 30:	25	287	130 L	—	?
No.4-1 Rd.	26	287	150 L	—	—
No.4 Record					
Base Deflection.	27	290	30 L	—	—
No.1 Adjust.No.1					
1 Rd.	28	287	20 L	—	—
No.1 Right 4	29	287	Target	OK	OK
No. 1 Record: Base Deflection					
Base Deflection	30	No.1,2,		—	
Right 45.On #1 open		3, 288		—	
6.Battery Right at:	31	No.4,	Fire		
my command.No.1,2,	Miss	291			
3, 288 No.4, 291	32			—	
Battery 2 Rds	33	No.1,2,3		—	No.3
	34	288	Lost		
	35	No.4	—		in
Same Elevation	36	291	+		
	37		—		
	38		+		
	39		+		
	40		—		
Left 3	41	No.1,2,3	Lost		
	42	288	Lost		
Btry 2 Rds	43	No.4	—		
	44	291	—		
	45		—		
	46		—		
	47		—		
	48		+		
Battery 2 Rds	49	No.1,2,3	—		Dud
	50	292	—		
	51	No.4	+		
	52	295	+		
	53		—		
	54		—		
	55		+		
	56		+		
Left 2 Btry 3 Rds:	57	No.1,2,3			
		292			
		No.4,	+		
		295			
Same			out		Mistake
Elevation	58		+		
	59		out		Mistake
Cease firing					
Battery right	60	No.1,2,	+		
at 5 seconds	61	290	+		
	62	No.4	+		
	63	292	+		
No.1 Left 10	64	No.1,2,3			
		290	Lost		

: Same Elev. :	65 :	No. 4-293 :	+	:	:
:	66 :	:	=	:	:
:	67 :	:	=	:	:
No. 1. Left 10 :	68 :	290 :	+	:	#1.4 :
:	69 :	1 :	+	:	Out :

TOTAL ROUNDS IN BATTERY 80

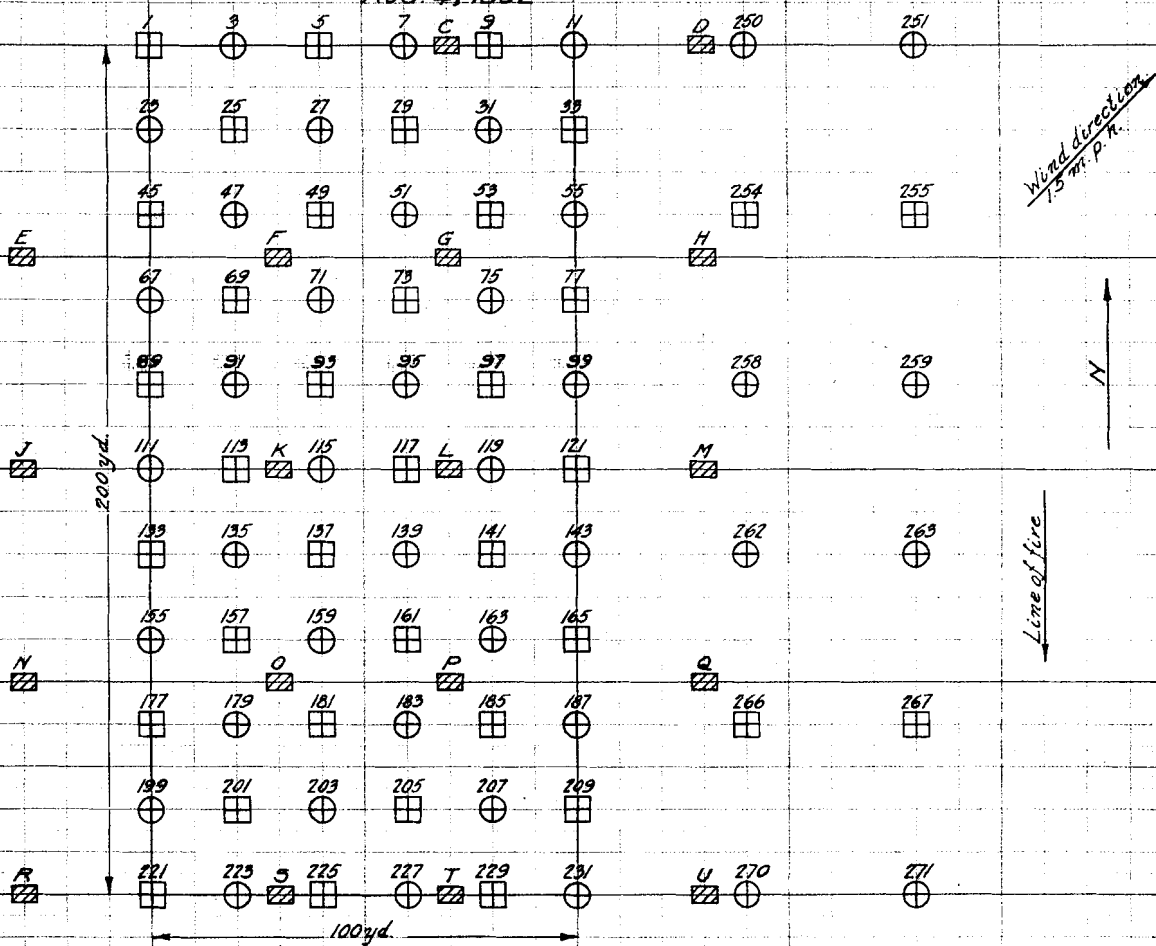
ROUNDS EXPENDED 69

ROUNDS TURNED BACK 11

*Chas. C. Brown*

CHAS. C. BROWN,  
Captain, 6th Field Artillery,  
Commanding

CHART I  
TARGET AREA  
AS PREPARED FOR  
TEST C  
AUG. 4, 1932



Legend

Goat

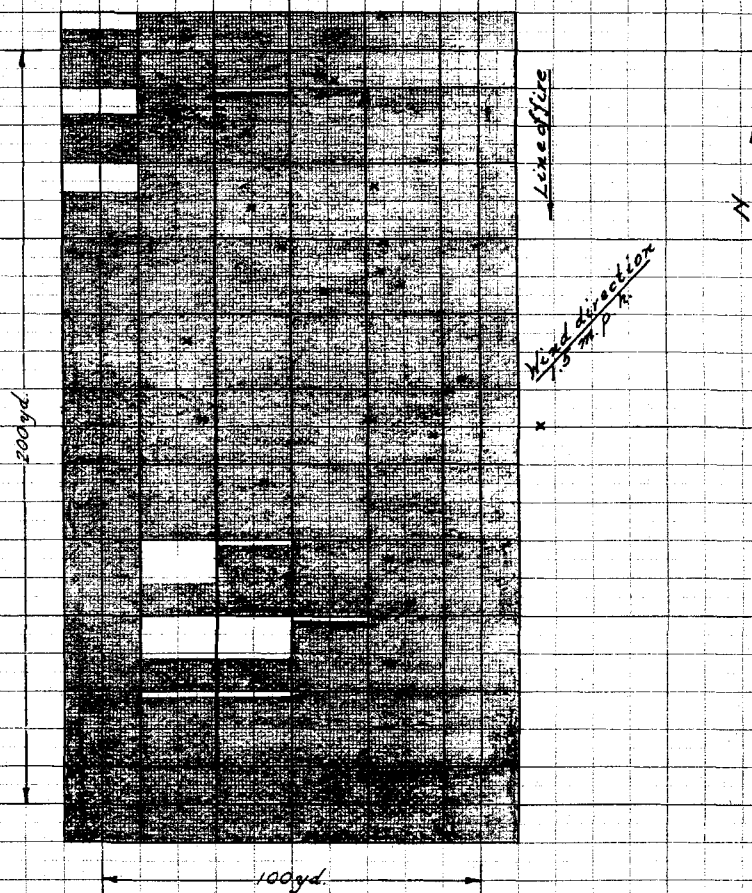
Rat

Sampling Position.

NOTE:- Numbered stakes placed at 10yd intervals, paper panels at each stake position.

Animal numbers correspond to stake positions.

CHART 3  
ESTIMATED MAN CASUALTIES DUE TO  
EFFECTS OF H5 VAPOR  
TEST C  
AUG. 4, 1932  
FIRING PERIOD AND FOLLOWING 10 MINUTES



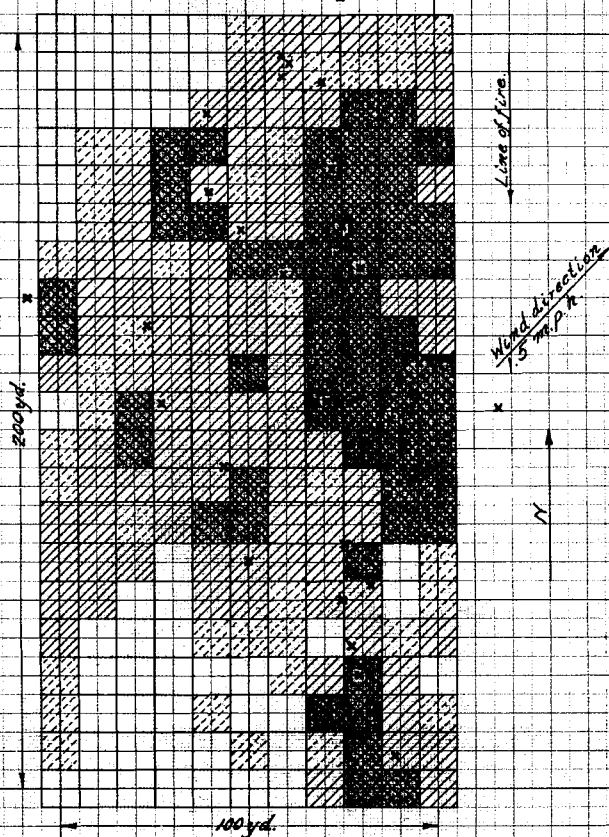
Legend.  
Shaded area 100 percent max. casualties  
with gas mask protection only.  
x Impact.

CHART 2  
ESTIMATED MAN CASUALTIES  
DUE TO EFFECTS OF H5 LIQUID

TEST C

AUG. 4, 1932

155 mm. H.C.



60% Casualties. Total Casualties 64.7%

80%

100%

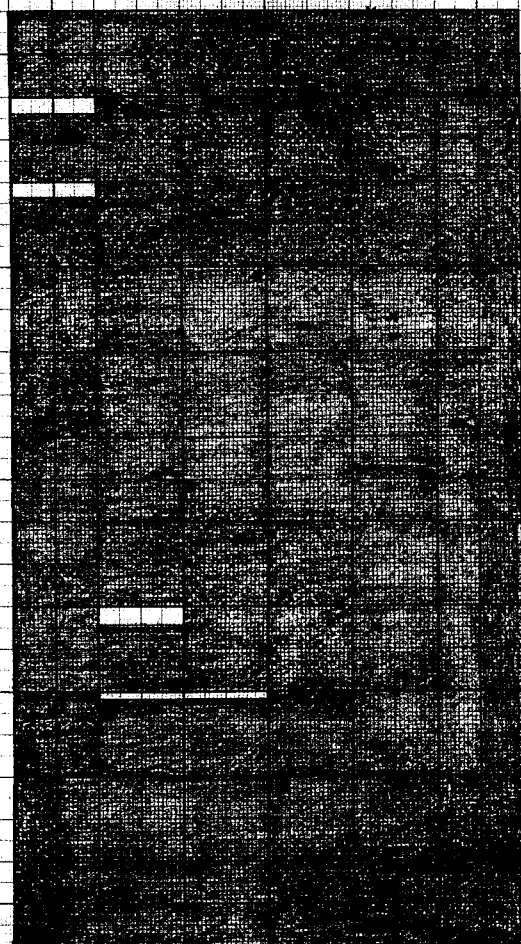
\* Impact, 26 on area 100x200 yd.

CHART 4  
ESTIMATED MAN CASUALTIES DUE TO  
EFFECTS OF HS VAPOR.

TEST C

AUG 4, 1932

FIRING PERIOD AND FOLLOWING HOUR.



Legend

Shaded area 100 percent man casualties  
with gas mask protection only.

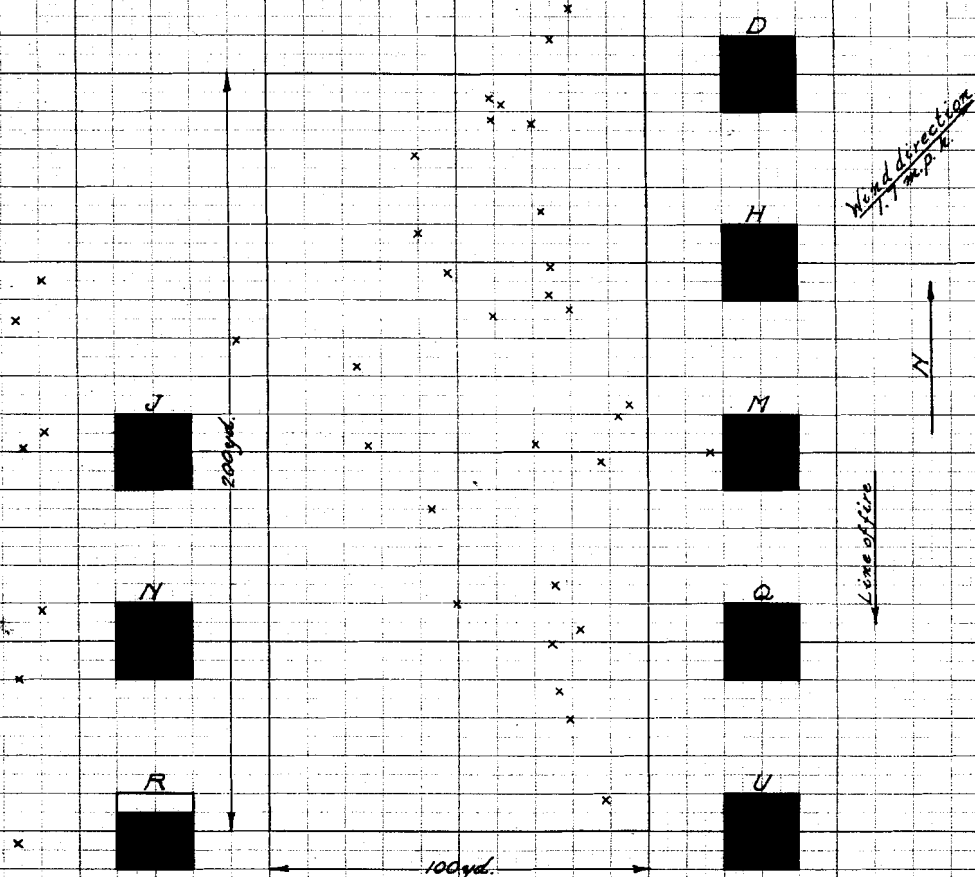
x Impact.

CHART 5  
EFFECTIVENESS OF H5 VAPOR  
OUTSIDE OF TARGET AREA \*

TEST C

AUG. 4, 1932

FIRING PERIOD AND FOLLOWING HOUR



Legend.

x Impact

Shaded area represents 100% casualties upon personnel provided with gas masks

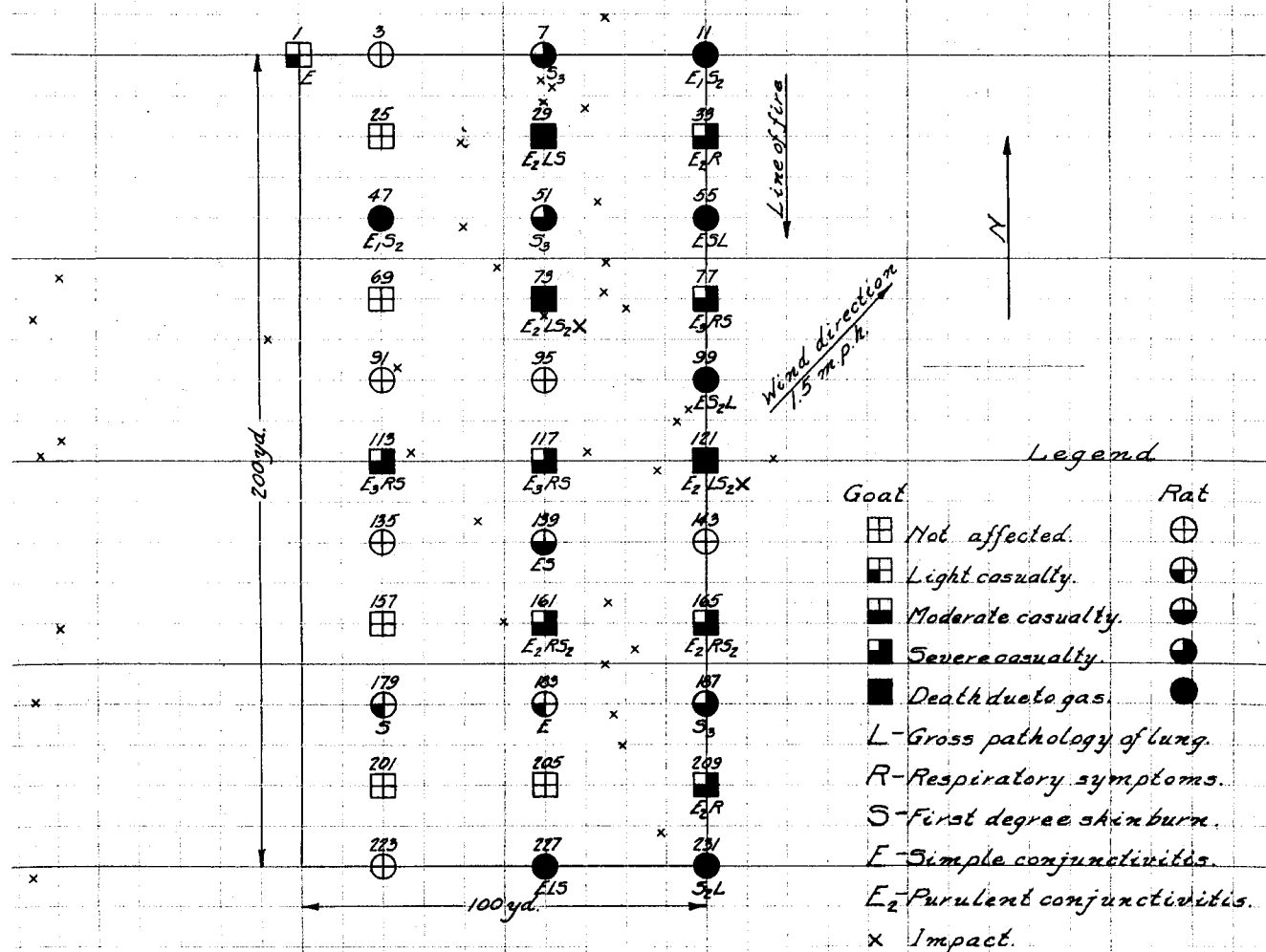
Letters designate sampling positions

\* Estimated casualties are only shown at sampling positions

# CHART 6 ANIMAL CASUALTIES TEST "C"

AUG. 4, 1932

FIRING PERIOD AND FOLLOWING 10 MINUTES.



# CHART 7 ANIMAL CASUALTIES TEST C

AUG 4, 1932

FIRING PERIOD AND FOLLOWING HOUR

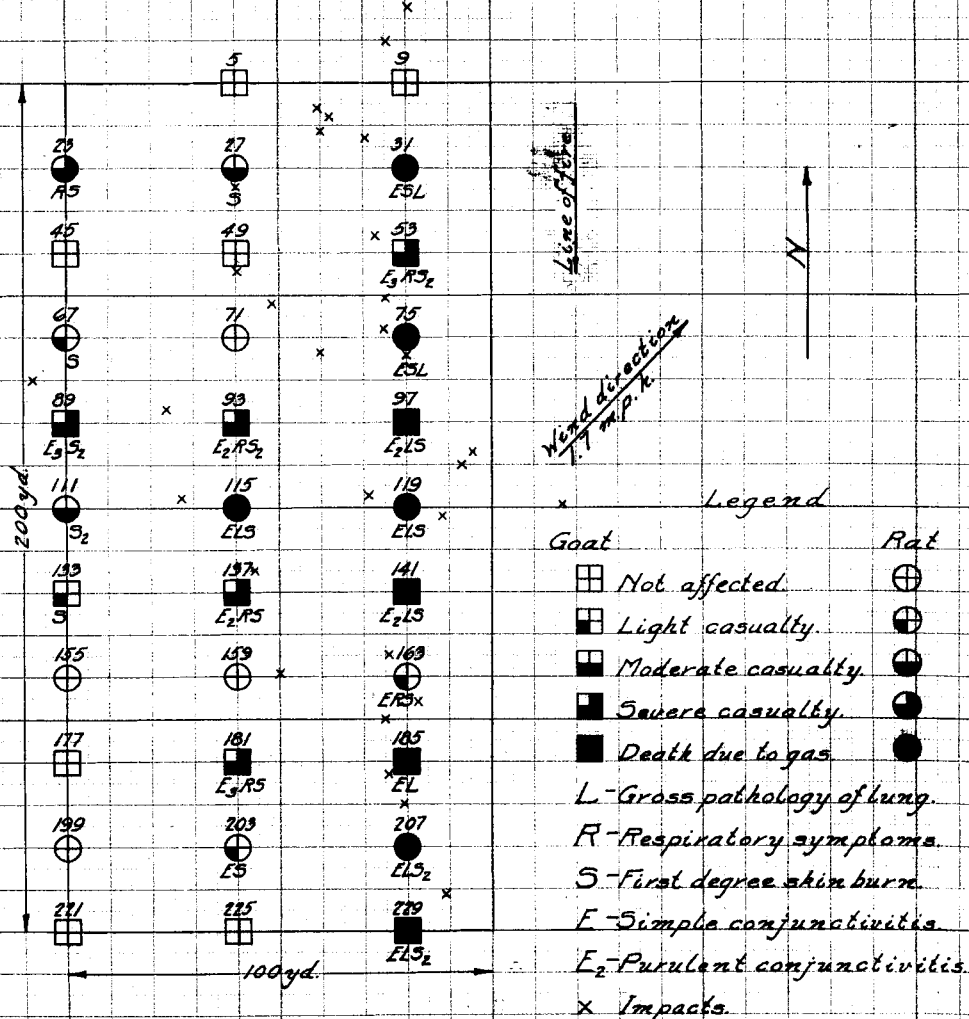


CHART 8  
ANIMAL CASUALTIES  
2<sup>ND</sup> TO 14<sup>TH</sup> HOUR AFTER FIRING.

TEST C

AUG. 4, 1932

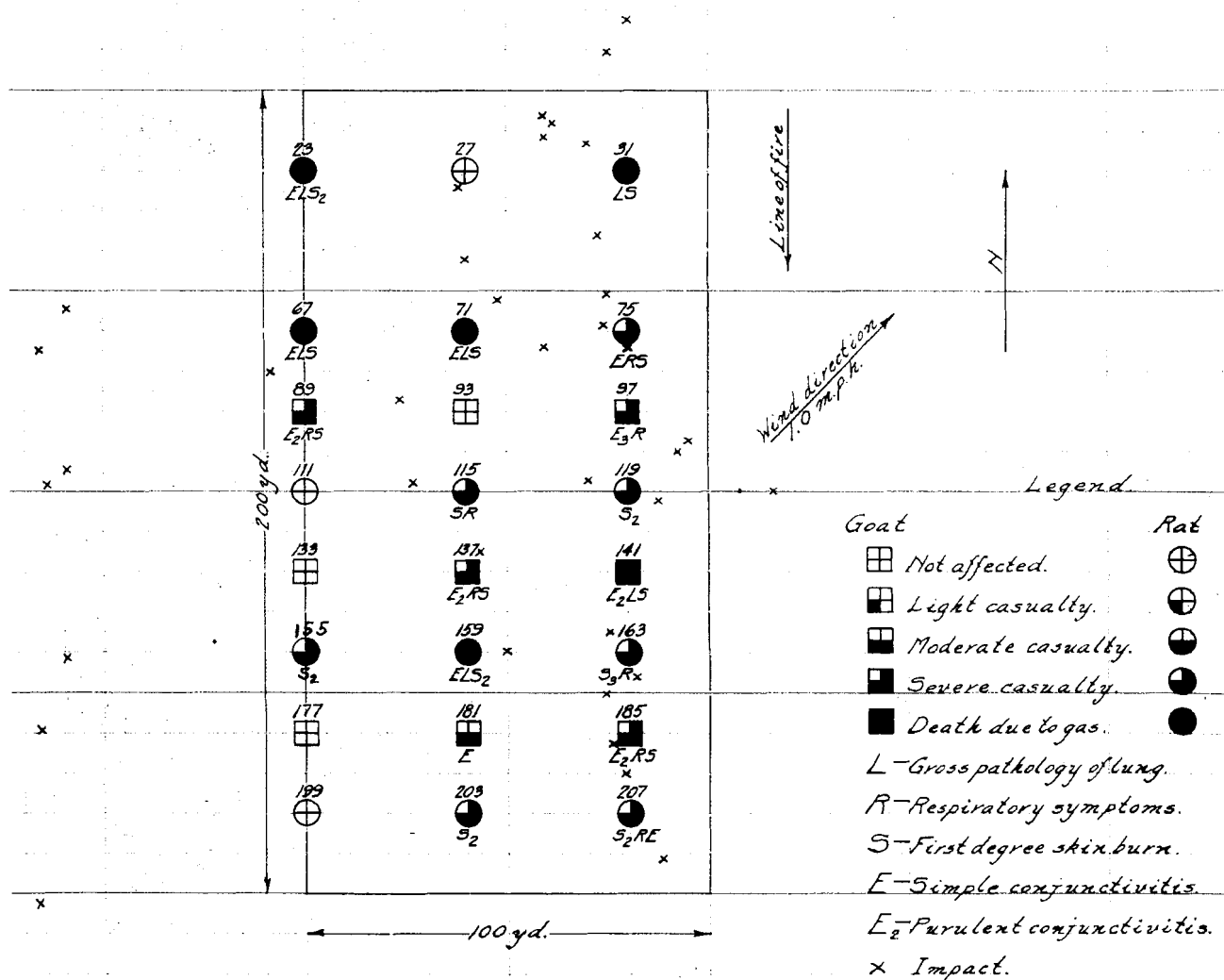


CHART 9  
ANIMAL CASUALTIES  
13<sup>TH</sup> TO 18<sup>TH</sup> HOUR AFTER FIRING (DAY FOLLOWING)  
TEST C  
AUG. 4, 1932

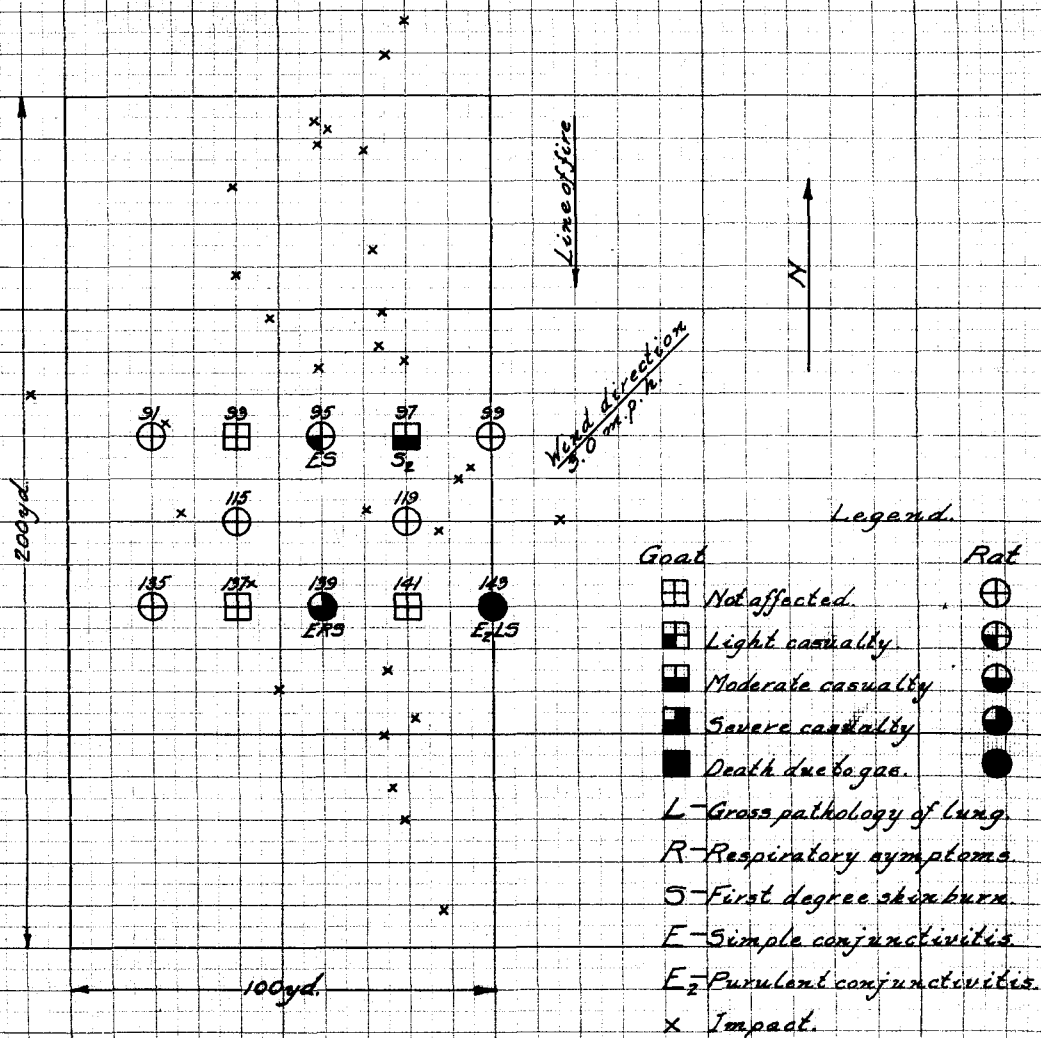


CHART 10  
ANIMAL CASUALTIES DOWN WIND  
FROM TARGET AREA  
TEST C  
AUG. 4, 1932  
FIRING PERIOD AND FOLLOWING HOUR

Wind direction  
1.7.2.4

N

Line of fire

200 yd

100 yd

Legend

Goat		Rat	
⊕	Not affected	⊕	
⊕	Light casualty	⊕	
⊕	Moderate casualty	⊕	
⊕	Severe casualty	⊕	
⊕	Death due to gas	⊕	
L	Gross pathology of lung		
R	Respiratory symptoms		
S	First degree skin burn		
F	Simple conjunctivitis		
F <sub>2</sub>	Purulent conjunctivitis		
x	Impact		

250  
L<sub>5</sub>

251  
L<sub>5</sub>L

254  
L<sub>5</sub>R<sub>5</sub>

255  
L<sub>5</sub>R

256  
S

259  
L<sub>5</sub>

262  
⊕

263  
S<sub>2</sub>

266  
L<sub>5</sub>R

267  
L<sub>5</sub>R

270  
⊕

271  
S<sub>2</sub>

CHART II  
ESTIMATED MAN CASUALTIES BASED ON  
EFFECTS ON ANIMALS.  
TEST C  
AUG. 4, 1932  
FIRING PERIOD AND FOLLOWING 10 MINUTES.

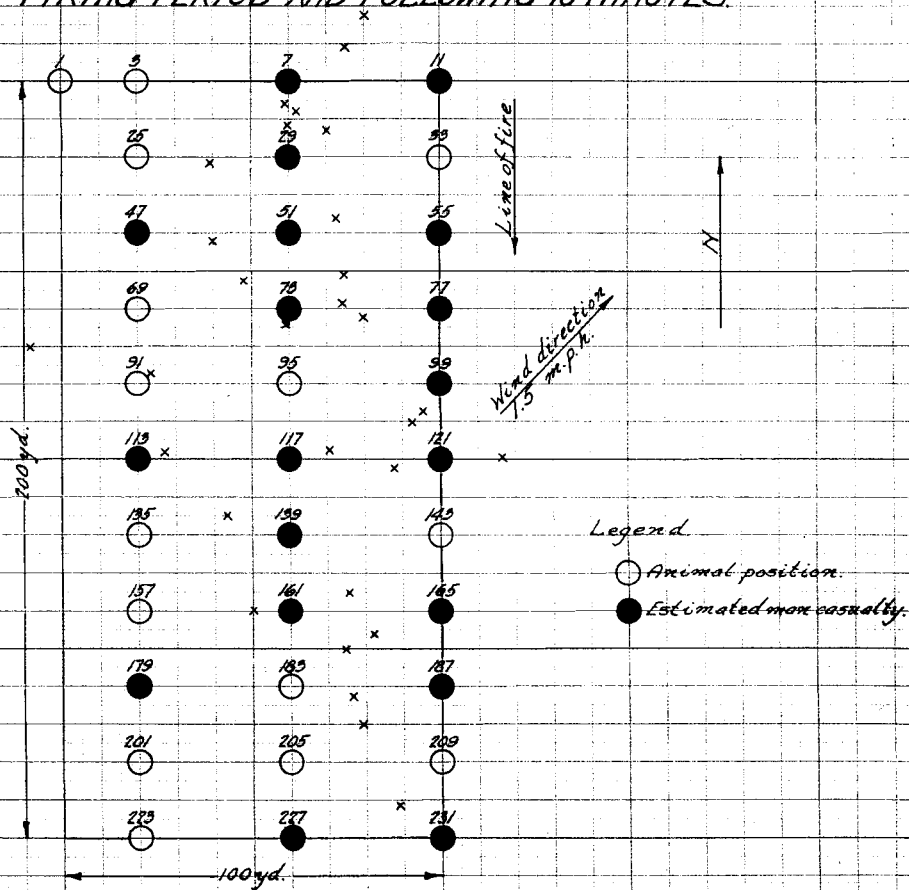


CHART 15  
 ESTIMATED MAN CASUALTIES  
 DOWN WIND FROM TARGET AREA  
 TEST C  
 AUG. 4, 1932  
 FIRING PERIOD AND FOLLOWING HOUR.

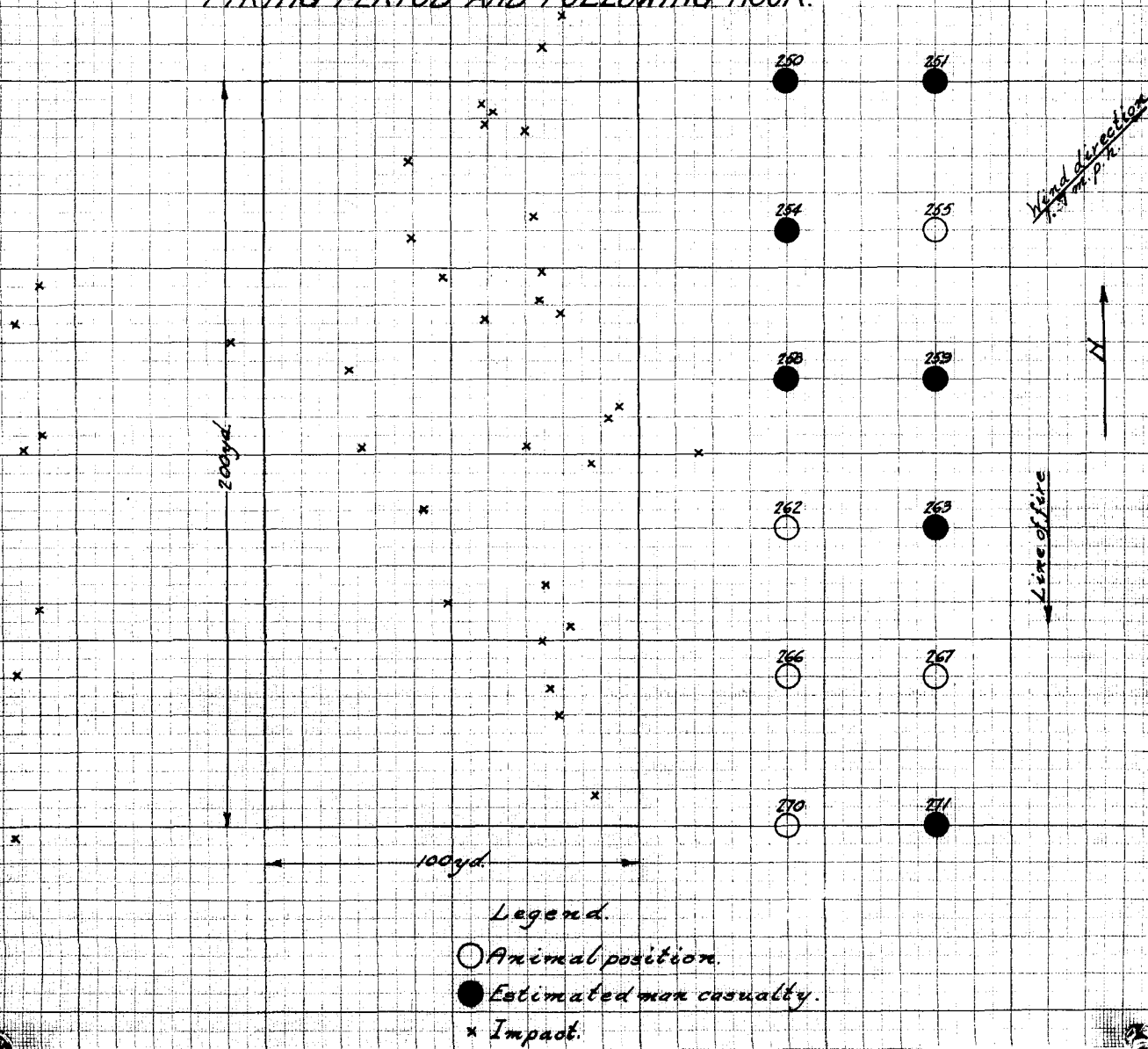


CHART 14  
ESTIMATED MAN CASUALTIES  
13<sup>TH</sup> TO 18<sup>TH</sup> HOUR AFTER FIRING (DAY FOLLOWING)  
TEST "C"

AUG. 4, 1932

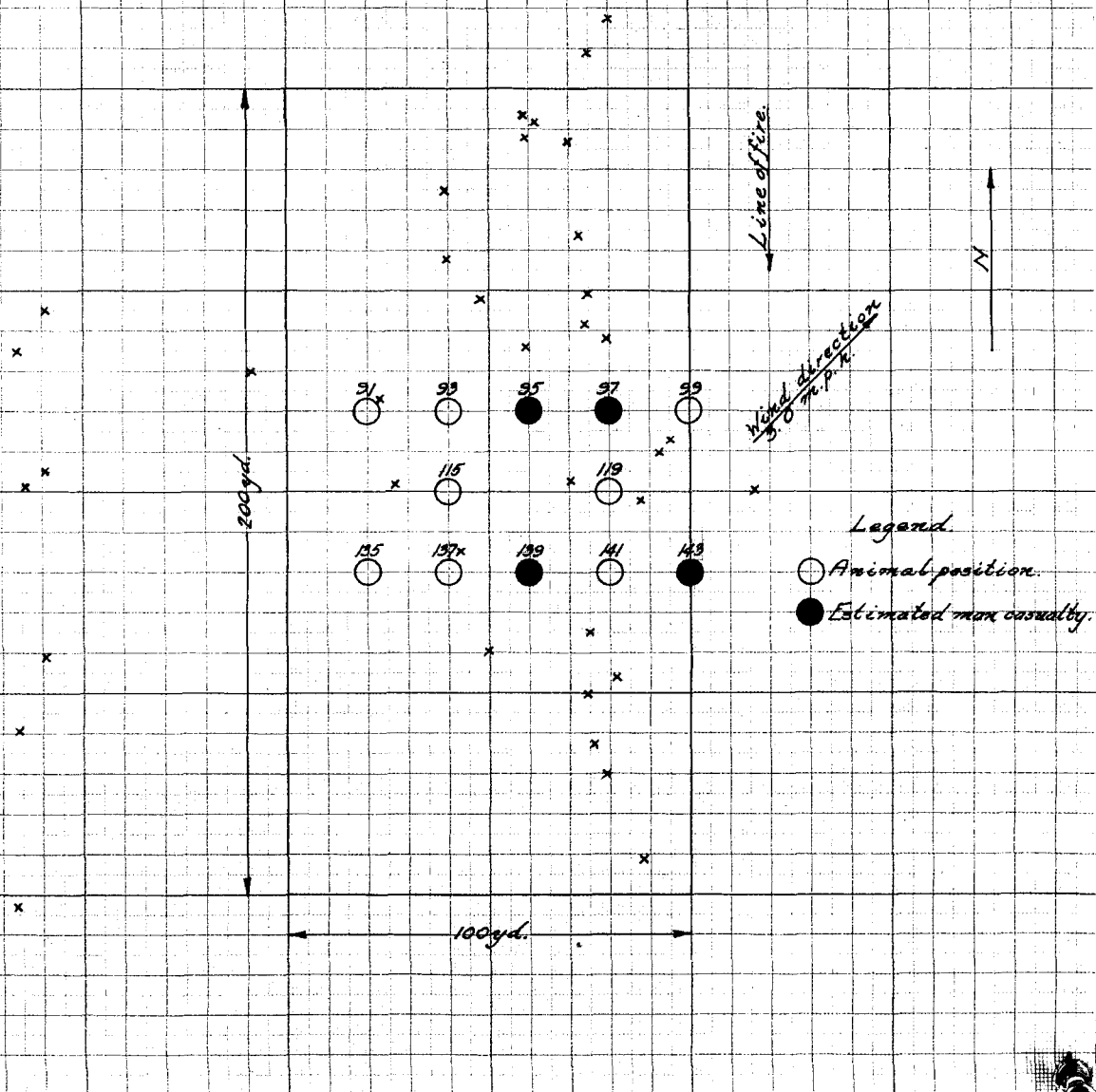
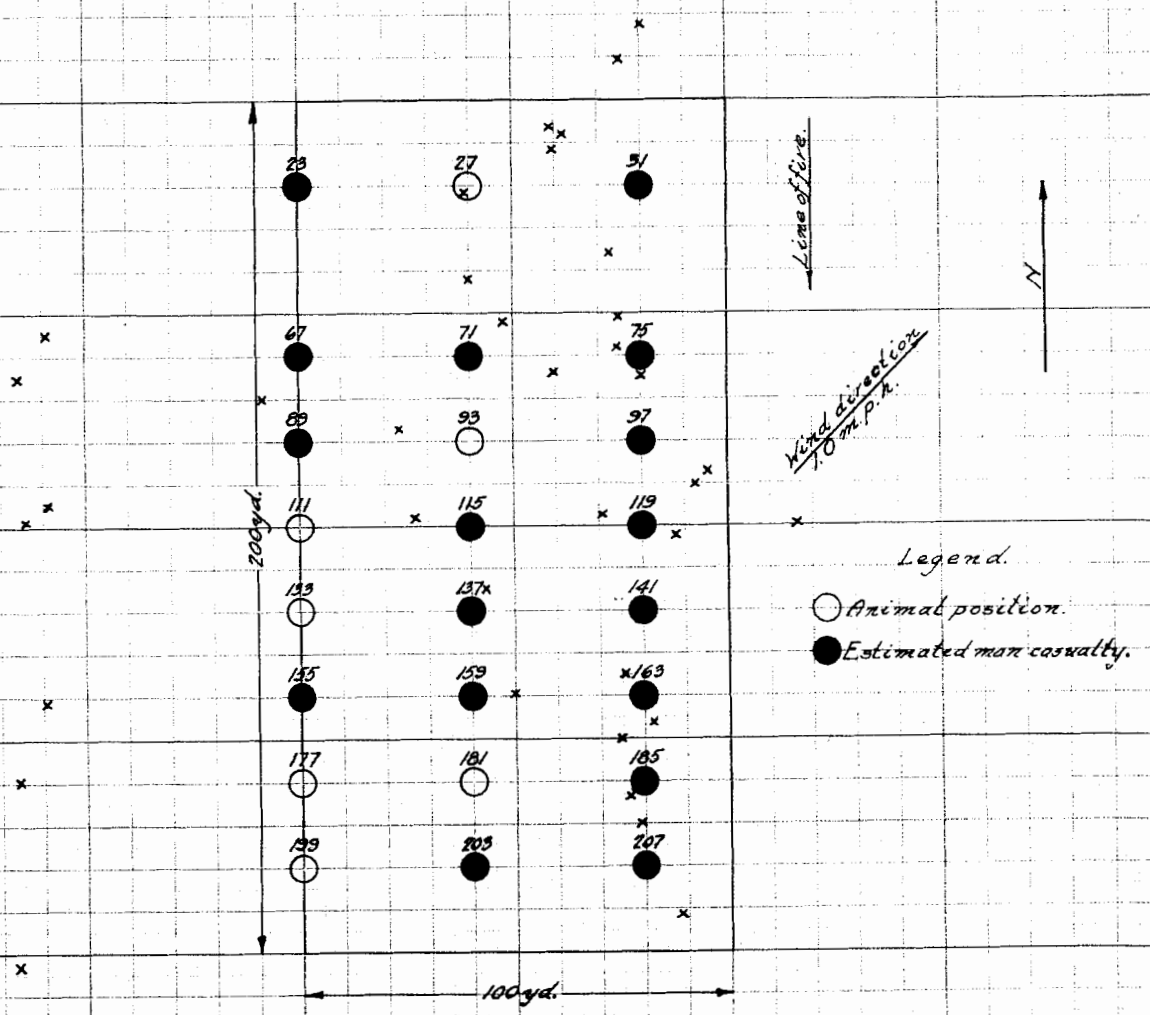
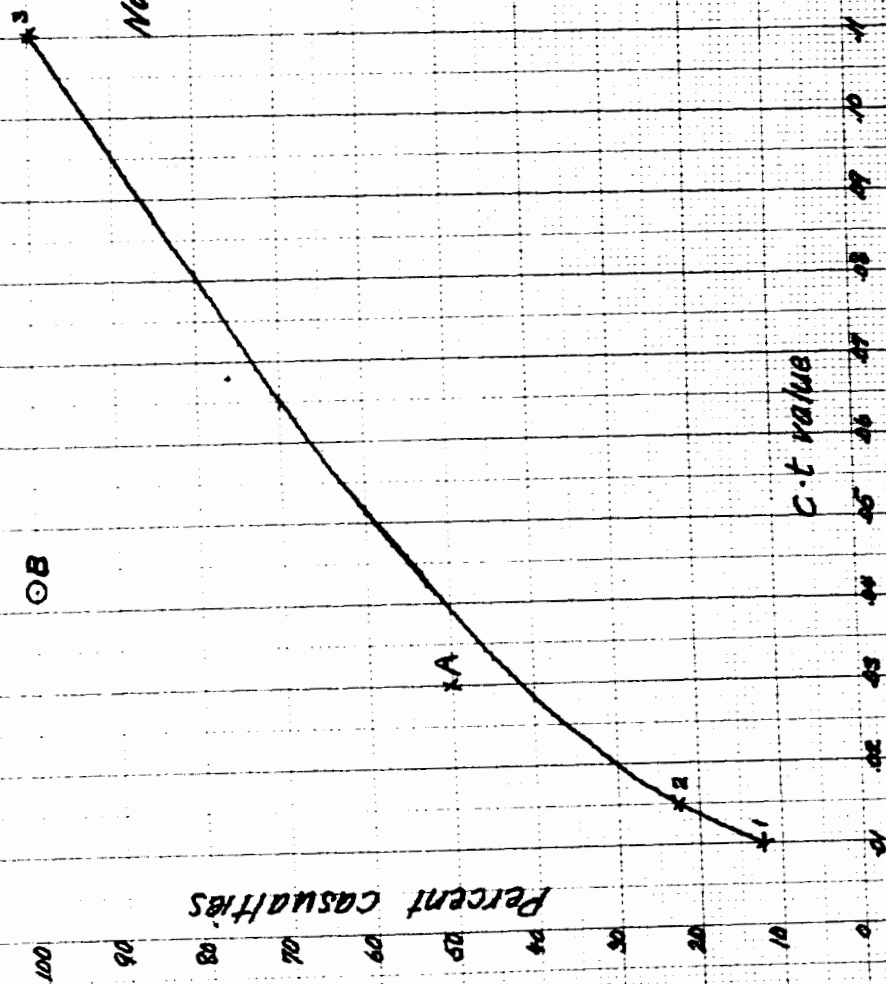


CHART 13  
ESTIMATED MAN CASUALTIES  
2<sup>ND</sup> TO 14<sup>TH</sup> HOUR AFTER FIRING  
TEST C  
AUG. 4, 1932 \*



# Graph No. 1

## Casualty Producing Effect of Mustard Vapor on Masked Men



Note:

The c.t. value is the product of the vapor concentration in mps. per liter and the time of exposure in minutes.

Points 1 & 2 from chamber tests given in PR 318.

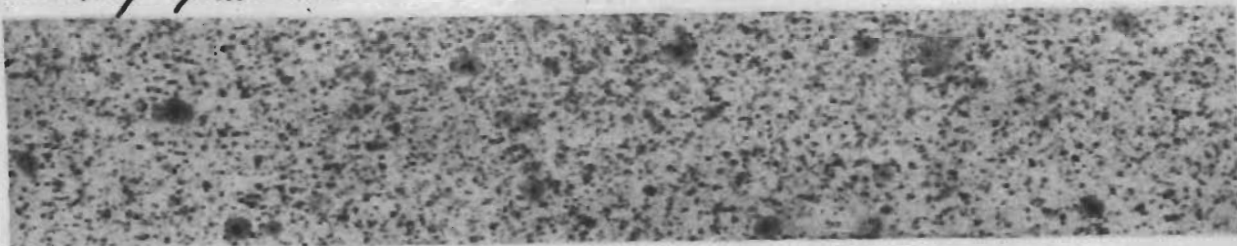
Point 3 is the estimate of the author of PR 318 after conducting the tests.

Point A represents the chamber exposure of the author of PR 318.

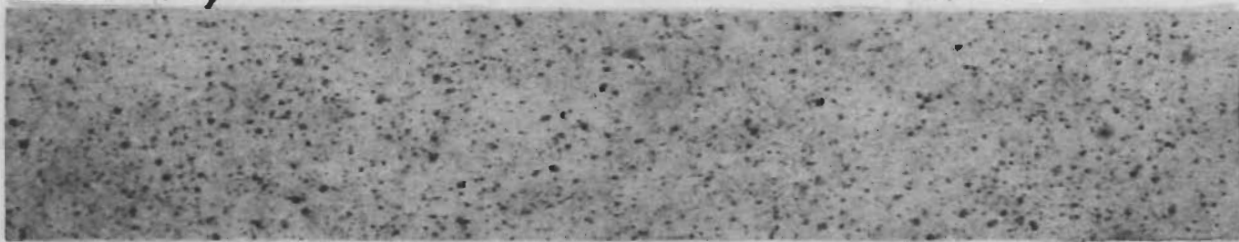
Point B represents the exposure of a man in the field at Edgewood Arsenal.

# *PATTERNS OF LIQUID HS ON PAPER PANELS*

*Heavy pattern*



*Medium pattern*



*Light pattern*



*Trace pattern*



Appendix E

Report of Test of HS-Filled 155-mm. Howitzer Shell  
Test "D" - August 29, 1932.

REPORT  
OF  
TEST OF HS FILLED 155-mm. HOWITZER SHELL  
TEST "D" - AUGUST 29, 1932

1. Object. The object of this test was to determine the number of 155 mm. howitzer shell filled with HS, which is required in open country under the meteorological conditions which existed at the time of the test, to produce 50% casualties, requiring evacuation for hospitalization.

2. Authority. This test was conducted under authority contained in the Project Program for Edgewood Arsenal, for the year 1933, under Project A 1.1-1b - "155-mm. Shell, MII (how.), HS Filled."

3. Previous Tests. A test was conducted on February 16th and 17th, 1932, in which 36 shell from each of four lots of shell, representing the shell used in the present test, were fired from service weapons to determine if the shell functioned normally, but no attempt was made to determine the gas concentrations set up.

A second test was conducted on May 23, 1932, in which 40 shell were fired for impact on a target 100 yards wide by 200 yards deep. From a preliminary study of the results it was estimated that it would require about 25 shell per 100 yard square to produce 50% casualties, when man is protected with gas mask only.

A third test was conducted on June 11, 1932, in which 40 shell were fired for impact burst on the same target used in the previous test. It was estimated, from a preliminary study of the results of the test, that about 14 shell per 100 yard square are required to produce 50% casualties, when man is protected with gas mask only.

A fourth test was conducted on August 4, 1932, in which 40 shell were fired for effect. The fourth test was fired about one hour before sundown whereas, the two previous tests were fired at 9 a.m. It was estimated from the results of the fourth test, that about 8 shell per 100 yard square are required to produce 50% casualties, when man is protected with gas mask only.

4. Materials Used in Present Test.

a. Shell. The shell used was the MII, 155 mm. howitzer,

filled with HS, from War Reserve. The history of the shell is given in report of tests A, B, and C, referred to in paragraph 3.

b. The booster used was the M VI-B.

c. The fuse used was the MIII long, P.D.

d. Number of Shell Used. Forty-seven, 19 for adjustment and 28 for effect.

e. Howitzers. A battery of four 155-mm. howitzers was used under command of Captain W. J. Egan of the Sixth Field Artillery. The howitzers were set up on "C" field in the vicinity of coordinates 690.4, 1869.1 as shown on the special military map of Gun Powder Neck, prepared under the direction of the Chief of Engineers, U.S. Army, 1923.

5. Target Area. The target area was a rectangular field of open country 100 yd. wide by 200 yd. deep, located on "H" field in the vicinity of coordinates 690.5, 1864.0 with the long axis oriented to line of fire. The area was covered with grass and weeds having an average height of 1 to 2 feet. It was divided into 10-yard squares by placing numbered stakes at 10-yd. intervals. Paper panels, sampling machines and animals were placed on the area to determine the effectiveness of the gas concentration set up. Chart 1, accompanying this report, shows the target area as it was prepared for the test with positions of animals, panels and sampling machines.

## 6. Experimental.

a. Method of Conducting Test. After adjustment, the howitzers were ranged on the target and fired as rapidly as possible with change in elevation for distribution of impacts over the target area. On completing the firing of the shell, the paper panels were collected for tabulation of results and the animals on the target area and at positions downwind from the target area, were removed at definite periods and replaced by other animals. Also during the firing period and the animal exposure periods, vapor samples were taken with the use of field sampling machines. The meteorological data were recorded during the period of test.

### b. Firing of Shell.

(1) Adjustment of Howitzers. The howitzers were adjusted in parallel on a target about 100 yd. east of the target area using 19 shell filled with HS. Firing for adjustment began at 3.59 p.m. and ended at 4.39 p.m. The impacts were recorded as follows:

18 high order bursts  
1 ricochet

(2) Firing for Effect. When firing for effect, the howitzers were ranged in parallel, using two elevations for distribution of impacts. The range was about 5100 yd. Firing started at 5.23 p.m. and ended at 5.36 p.m., a period of 13 min. From observation at the Q.P., the impacts were recorded as follows:

17 high order bursts  
3 low order bursts  
7 duds  
1 ricochet

A photostatic copy of a memorandum dated September 1, 1932, to the Technical Director from the Battery Commander, giving the firing data by round, is attached to this report.

(3) Impacts. The positions of the impacts, including duds and bursts, are shown on Chart 16. Of the 28 shell fired for effect, 22 registered on the target area of which 15 were bursts and 7 were duds. In addition, there were two bursts within 30 yd. of the target area.

c. Meteorological Conditions. The following meteorological conditions prevailed during the firing period and the periods following during which vapor samples were taken and animals were exposed on the target area.

Date	- 8-29-32	8-29-32	8-29 to 8-30-32	8-30-32
	5.23 to	5.46 to	6.36 p.m. to	11.00 a.m.
Time	- 5.46 p.m.	6.36 p.m.	9.00 a.m.	to 3.00 p.m.
Air temperature °F.	- 84 to 82	83 to 80	80 to 68	79 to 84
Ground temperature °F.	- 92 to 89	89 to 81	81 to 71	93 to 100
Ground condition	- very dry	very dry	wet - rain	wet
Relative humidity %	- 60	60 to 78	78 to 92	68
Wind velocity m.p.h.	- 2.9	3.0	1.7	5.1
Wind direction	- SW	SW	SW	SW
Sky	- partly cloudy	partly cloudy	cloudy - rain	partly cloudy

## 7. Results.

### a. Liquid HS.

(1) Size of Liquid HS Drops. The distribution of the liquid HS was registered by means of paper panels 8 inches square, placed flat on the ground at each stake position over the entire target area. The panels having HS drops of a size in excess of 0.1 mg. are tabulated in the following table:

Table No. 1

Size of HS Drops

Number of : drops on panel	Panels having drops of size			
	: 0.1 to : 0.5 mg.	: 0.5 to : 1.0 mg.	: 1.0 to : 3.0 mg.	: over : 3.0 mg.
1	: 0	: 5	:	:
2 to 10	: 9	: 2	: 2	: 1
11 to 20	: 2	:	:	:
Over 20	:	:	:	:

Panels on which drops of above size were registered - 11.  
Total panels exposed on the target area - 229.

(2) Estimated Man Casualties from Liquid HS.

(a) Man Protected with Gas Mask but Without  
Protection of Impregnated Clothing.

The paper panels were tabulated for density of pattern using the gradings heavy, medium, light and trace. A photostat of the scale used in grading the panels is attached to this report. The panel gradings are tabulated in the following table, together with estimated man casualties.

Table No. 2

Estimated Man Casualties on Target Area from Liquid HS

Panel pattern	Panels classified		Estimated man casualties when man is protected with gas mask only
	Number	Percent of total on target area	
Heavy	: 7	: 3.0	: 3.0%
Medium	: 8	: 3.5	: 3.5%
Light	: 13	: 5.7	: 4.6%
Trace	: 43	: 18.8	: 11.3%
No HS	: 158	: 69.0	:
Total	: 229	: 100.0	: 22.4

From the results in table 2, it is estimated that personnel exposed on the target area during the firing period protected with gas mask only, would suffer about 22.4% casualties. The position of shell craters and estimated man casualties from liquid HS is shown graphically on Chart 2.

NOTE. The basis for the man casualty estimates given in table 2, is explained in report of Test "A", conducted May 23, 1932, referred to in paragraph 3 of the present report.

(b) Man Protected with Gas Mask and Standard Impregnated Clothing.

The paper panels were tabulated for number and size of HS drops on panels in which the drop size was in excess of 0.5 mg. The results of the tabulation, together with estimated man casualties, are given in the following table:

Table No. 3

Estimated Man Casualties on Target Area from Liquid HS

Size of HS drops	Number of panels	Estimated man casualties when protected with gas mask and standard impregnated clothing	
mg.		per panel %	entire target area %
0.5 to 1.0	5	40	0.9
Over 1.0	2	100	0.9
Total			1.8

Total panels on area - 229

NOTE. Man casualties in table 3, were estimated from data furnished by the Protective Development Division. The basis for the estimate is explained in report of Test "A", conducted May 23, 1932, which is referred to in paragraph 3 of the present report.

b. Estimated Man Casualties from HS Vapor. Vapor sampling machines were placed to take samples at positions indicated on Chart 1. In each of the tables which follow, representing the different sampling periods, the sampling positions are designated by letters. The HS vapor concentration, c.t. value, and per cent estimated man casualties from HS vapor, are included in each of the tables.

The c.t. value is equal to the vapor concentration in milligrams per liter, times the exposure period in minutes. Estimated man casualties are based on the c.t. value using the evaluation curve represented by Graph 1. The per cent estimated man casualties given in the following tables, represent man protected with gas mask but without the protection of impregnated clothing. The sampling-time periods given in the sub-paragraph headings are only approximate.

(1) On the Target Area.

(a) Firing Period and Following 10 Minutes.

Table No. 4

Sampling position:	Elevation of sample:	Sampling Period Time	Vol. of air sampled:	HS sampled:	Vapor concentration:	c.o.t. value:	Estimated casualties when man is protected with gas mask only
:	ft.	:	Min.:	liters:	mg.	mg./l.	%
F	0	5.23 to 5.46 p.m.	23	824	3.1	.0038	.09: 87
K	1	5.23 to 5.48 p.m.	25	882	43.3	.0491	1.30: 100
O	0	5.23 to 5.51 p.m.	28	1004	4.1	.0041	.11: 100
G	0	5.23 to 5.47 p.m.	24	808	9.1	.0113	.27: 100
L	1	5.23 to 5.49 p.m.	26	904	10.9	.0121	.31: 100
P	0	5.23 to 5.52 p.m.	29	1008	44.7	.0443	1.29: 100
Average							99.5

(b) Fifty Minute Period, 10 to 60 Min. After Firing.

Table No. 5

Sampling position:	Elevation of sample:	Sampling Period Time	Vol. of air sampled:	HS sampled:	Vapor concentration:	c.o.t. value:	Estimated casualties when man is protected with gas mask only
:	ft.	p.m.	Min.:	liters:	mg.	mg./l.	%
F	0	5.47 to 6.36	49	1754	8.7	.0050	.24: 100
K	1	5.49 to 6.36	47	1678	48.2	.0291	1.37: 100
O	0	5.52 to 6.36	44	1574	0.0	.0000	.00: 0
G	0	5.48 to 6.36	48	1616	14.4	.0089	.42: 100
L	1	5.51 to 6.36	45	1562	17.4	.0111	.50: 100
P	0	5.53 to 6.36	43	1494	79.4	.0532	2.39: 100

(c) Firing Period and Following Hour.

Table No. 6

Sampling position:	Elevation of sample :	Sampling period Time :	Vol. of air sampled :	HS sampled :	Vapor concn-: :	c.t. value: :	Estimated man casualties when man is protected with gas mask only
	ft.	P.M.	Min.	liters	mg.	mg./l.	%
C	1	5.23 to 6.36	73	2500	5.9	.0024	.17: 100
T	1	5.23 to 6.36	73	2616	12.3	.0047	.34: 100
S	1	5.23 to 6.36	73	2580	4.5	.0017	.13: 100
F	0	5.23 to 6.36	73	2578	11.8	.0045	.34: 100
K	1	5.23 to 6.36	73	2569	91.5	.0356	2.60: 100
O	0	5.23 to 6.36	73	2578	4.1	.0015	.11: 100
G	0	5.23 to 6.36	73	2424	23.5	.0097	.71: 100
L	1	5.23 to 6.36	73	2466	23.3	.0116	.84: 100
P	0	5.23 to 6.36	73	2502	124.1	.0495	3.60: 100

(d) Four Hour Period on Day Following Test.

Table No. 7

Sampling position:	Elevation of sample:	Sampling period		Time	Min.	Vol. of air sampled:	HS sampled:	Vapor concentration:	c.t. value:	Estimated man casualties when man is protected with gas mask only
stake	ft.	a.m.	p.m.			liters	mg.	mg./l.		%
182	4	11.00	to 3.00	240		4170	0.0	.0000	.00	0
182	2	11.00	to 3.00	240		4170	0.0	.0000	.00	0
182	1	11.00	to 3.00	240		4170	0.0	.0000	.00	0
104	4	11.00	to 3.00	240		4300	0.0	.0000	.00	0
104	2	11.00	to 3.00	240		4300	0.0	.0000	.00	0
104	1	11.00	to 3.00	240		4300	0.0	.0000	.00	0
52	4	10.00	to 3.00	240		4360	0.0	.0000	.00	0
52	2	10.00	to 3.00	240		4360	0.0	.0000	.00	0
52	1	10.00	to 3.00	240		4360	0.0	.0000	.00	0
Average										0

(2) Outside of Target Area.

(a) Firing Period and Following Hour.

Table No. 8

Sampling position:	Elevation of sample:	Sampling Period Time:	Vol. of air sampled:	HS sampled:	Vapor concentration:	Estimated man casualties when man is protected with gas mask only
:	ft.:	p.m.:	liters:	mg.:	mg./l.:	%
J	1	5.23 to 6.36	73	1287	1.6	.0012 : .09 : 87
J	2	5.23 to 6.36	73	1287	3.5	.0027 : .20 : 100
J	4	5.23 to 6.36	73	1287	3.1	.0024 : .18 : 100
E	1	5.23 to 6.36	73	1308	0.0	.0000 : .00 : 0
E	2	5.23 to 6.36	73	1308	0.0	.0000 : .00 : 0
E	4	5.23 to 6.36	73	1308	0.0	.0000 : .00 : 0
N	1	5.23 to 6.36	73	1308	0.0	.0000 : .00 : 0
N	2	5.23 to 6.36	73	1308	0.0	.0000 : .00 : 0
N	4	5.23 to 6.36	73	1308	0.0	.0000 : .00 : 0
R	1	5.23 to 6.36	73	1287	0.0	.0000 : .00 : 0
R	2	5.23 to 6.36	73	1287	0.0	.0000 : .00 : 0
R	4	5.23 to 6.36	73	1287	0.0	.0000 : .00 : 0
D	1	5.23 to 6.36	73	1250	0.0	.0000 : .00 : 0
D	2	5.23 to 6.36	73	1250	0.4	.0003 : .02 : 30
D	4	5.23 to 6.36	73	1250	0.4	.0003 : .02 : 30
H	1	5.23 to 6.36	73	1230	0.0	.0000 : .00 : 0
H	2	5.23 to 6.36	73	1230	0.4	.0003 : .02 : 30
H	4	5.23 to 6.36	73	1230	0.4	.0003 : .02 : 30
M	1	5.23 to 6.36	73	1270	0.4	.0003 : .02 : 30
M	2	5.23 to 6.36	73	1270	0.6	.0005 : .04 : 50
M	4	5.23 to 6.36	73	1270	0.6	.0005 : .04 : 50
Q	1	5.23 to 6.36	73	1270	0.0	.0000 : .00 : 0
Q	2	5.23 to 6.36	73	1270	0.0	.0000 : .00 : 0
Q	4	5.23 to 6.36	73	1270	0.0	.0000 : .00 : 0
U	1	5.23 to 6.36	73	1308	0.0	.0000 : .00 : 0
U	2	5.23 to 6.36	73	1308	0.0	.0000 : .00 : 0
U	4	5.23 to 6.36	73	1308	0.0	.0000 : .00 : 0

c. Estimated Man Casualties Based on Effects on Animals.

Animals were placed on and downwind from the target area to determine effect of the vapor concentration set up and how long the HS persisted on the impact area. The position of the animals during the various exposure periods is shown on Charts 6 to 10 inclusive. The animal casualties and the estimated man casualties, when man is protected with gas mask only, are given in the tables which follow. The man casualties are estimates made by the Medical Research Division who observed and studied the effects of the HS on all animals exposed.

Man casualties estimated from effects on animals are shown on Charts 11 to 15 inclusive. On the charts as well as in the tables which follow, the following symbols are used to designate the nature of the animal casualty:

L - Gross pathology of lung  
 R - Respiratory symptoms  
 S - First degree skin burn  
 S<sub>2</sub> - Second degree skin burns  
 S<sub>3</sub> - Third degree skin burns  
 E - Simple conjunctivitis  
 E<sub>2</sub> - Purulent conjunctivitis  
 E<sub>3</sub> - Ruptured cornea  
 F - Injury by shell fragment  
 X - Stomatitis

(1) On the Target Area.

(a) Firing Period and the Following Ten Minutes.

During the firing period and following ten minutes, 13 rats and 16 goats were exposed on the target area. Results are tabulated in the following tables.

The positions of the animals are shown on Chart 6 and estimated man casualties on Chart 11.

Table No. 9a

Estimated Man Casualties Based on Effects on Rats

Stake position:	Nature of casualty:	Severity of casualty:	Position of burn:	Estimated man casualties when man is protected with gas mask only
135	S	light	feet	100%
139	ELS	death	feet	100%
179	E	light		0
227	ELS	death	feet	100%
Average casualties based on 13 rat positions				16.7%

Table No. 9b

Estimated Man Casualties Based on Effects on Goats

Stake position:	Nature of casualty :	Severity of casualty :	Position of burn :	Estimated man casualties when man is protected with gas mask only
29	: E	: moderate	:	: 0
69	: ER	: severe	:	: 100%
73	: ERS	: severe	: body	: 100%
113	: ER	: moderate	:	: 0
117	: S <sub>2</sub> R	: severe	: body	: 100%
121	: E	: light	:	: 0
161	: ERS	: death	: ears	: 100%
205	: E <sub>2</sub> RS	: severe	: body	: 100%
209	: S	: light	: body	: 100%
Average casualties based on 16 goat positions				37.5%

(b) Firing Period and Following Hour.

During the firing period and following hour, 15 rats and 17 goats were exposed on the target area. Results are tabulated in the following tables. The positions of the animals are shown on Chart 7, and estimated man casualties on Chart 12.

Table No. 10a

Estimated Man Casualties Based on Effects on Rats

Stake position:	Nature of casualty :	Severity of casualty :	Position of burn :	Estimated man casualties when man is protected with gas mask only
27	: ELS	: death	: feet	: 100%
67	: ELS	: death	: feet	: 100%
71	: ELS	: death	: feet	: 100%
115	: ELS	: death	: feet	: 100%
119	: EL	: death	:	: 100%
163	: E	: light	:	: 0
203	: ELS	: death	: feet	: 100%
Average casualties based on 16 rat positions				40%

Table No. 10b

Estimated Man Casualties Based on Effects on Goats

Stake position:	Nature of: casualty :	Severity of: casualty :	Position of: burn :	Estimated man casualties when man is protected with gas mask only
5	: ER	: moderate	:	0
9	: ER	: moderate	:	0
45	: ER	: moderate	:	0
49	: E <sub>3</sub> S	: severe	: body	100%
53	: E <sub>3</sub> RS	: severe	: body	100%
89	: E	: moderate	:	0
93	: E <sub>2</sub> LS	: death	: body	100%
97	: E <sub>3</sub> R	: severe	:	0
133	: ERS	: moderate	: body	100%
137	: ES	: light	:	100%
141	: ERS	: moderate	: body	100%
181	: E <sub>3</sub> RS	: severe	: body	100%
185	: E <sub>2</sub>	: severe	:	0
225	: ELS	: death	: body	100%
Average casualties based on 17 goat positions =				47.1%

(c) Period from Second to 14th Hr. After Firing.

During the 2nd to 14th hr. after firing, 15 rats and 9 goats were exposed on the target area. Results are tabulated in the following tables. The positions of the animals are shown on Chart 8 and estimated man casualties on Chart 13.

Table No. 11a

Estimated Man Casualties Based on Effects on Rats

Stake position:	Nature of: casualty :	Severity of: casualty :	Position of: burn :	Estimated man casualties when man is protected with gas mask only
27	: S	: light	: feet	100%
71	: ELS	: death	: feet	100%
75	: ELS	: death	: feet	100%
111	: ELS	: death	: feet	100%
115	: ELS <sub>2</sub>	: death	: feet	100%
119	: ELS <sub>2</sub>	: death	: feet	100%
155	: ELS	: death	: feet	100%
159	: ERS <sub>2</sub>	: severe	: feet	100%
163	: ELS <sub>2</sub>	: death	: feet	100%
203	: ES <sub>2</sub>	: death	: feet	100%
207	: ELS	: severe	: feet	100%
Average casualties based on 15 rat positions				73.3%

Table No. 11b

Estimated Man Casualties Based on Effects on Goats

Stake position:	Nature of: casualty :	Severity of: casualty :	Position of: burn :	Estimated man casualties when man is protected with gas mask only
89	: E <sub>2</sub>	: severe	:	: 0
93	: E <sub>2</sub>	: severe	:	: 0
97	: E <sub>2</sub>	: severe	:	: 0
133	: ELS	: death	: body	: 100%
137	: E	: moderate	:	: 0
141	: E <sub>2</sub>	: severe	:	: 0
181	: E <sub>3</sub>	: severe	:	: 0
186	: E <sub>3</sub>	: severe	:	: 0
Average casualties based on 9 goat positions				11.1%

(d) Day Following Firing (13th to 17th Hour).

On the day following firing, from the 13th to the 17th hr. inclusive, 8 rats and 4 goats were exposed on the target area. Results are given in the following table. The positions of the animals are shown on Chart 9, and estimated man casualties on Chart 14.

Table No. 12a

Estimated Man Casualties Based on Effects on Rats

Stake position:	Nature of: casualty :	Severity of: casualty :	Position of: burn :	Estimated man casualties when man is protected with gas mask only
115	: E	: light	: no skin	: 0
139	: E	: light	: burns	: 0
Average casualties based on 8 rat positions				0

The 4 goats exposed were not casualties.

(e) Exposed in Shell Crater. Seven rats and 1 goat were exposed in shell craters for a period of 24 hr. on the 7th and 9th da. of the firing. None of the animals were casualties.

(2) Downwind from Target Area.

(1) Firing Period and Following Hour. During the firing period and following hour, 8 rats and 4 goats were exposed at positions downwind from the target area. Results are given in the following table. The positions of the animals are shown on Chart 10 and estimated man casualties on Chart 15.

Table No. 13

Estimated Man Casualties Based on Effects on Goats

Stake position:	Nature of: casualty :	Severity of: casualty :	Position of: burn :	Estimated man casualties when man is protected : with gas mask only
254 :	E :	slight :	no skin :	0%
:	:	:	burn :	:

None of the 8 rats exposed were casualties.

8. Discussion.

a. Shell Distribution. The shell were fired for equal distribution of impacts over the target area. Of the 20 bursts resulting from the fire of 28 shell, fifteen registered on the target area and two within a distance of 30 yd. from the target area. The three remaining bursts were not located. The two shell which burst within 30 yd. from the target were partly effective on the target area.

b. Impact Area. The number of animal positions included within the impact area, as distinguished from the target area, was 44, and since each animal was located on the center of a 20 yard square, for purposes of discussion, the size of the impact area may be regarded as 17,600 sq. yd. The animal positions on the impact area and the number of impacts on each 20 yard square, are given in table 15.

c. Estimated Man Casualties from Liquid HS.

(1) Effects of Meteorological Conditions. The only meteorological factor having any effect on the size of the area covered with liquid HS, by the burst of a single shell, is wind velocity. The wind velocity during the firing period in the present test, was 2.9 m.p.h. which was too low to carry the large HS drops very far. Previous field tests have demonstrated, however, that under the prevailing wind conditions, a fine HS mist which will produce a liquid HS pattern corresponding to trace, may be carried 50 yd. or more from the position of shell burst.

(2) Protected with Gas Mask but without Protection of Impregnated Clothing. Results from paper panels given in table 2, show that personnel exposed with equal distribution on the target area during the firing period, would suffer 22.4% casualties from liquid HS when

protected with gas mask only. The liquid HS on the area, which was the basis of the 22.4% estimated casualties, was partly due to the impact of one shell outside of the area, which was only slightly effective, and to the impact of 15 shell on the target area. Effects from the one shell outside of the target area, were more than counterbalanced by effects outside of the target area by shell which burst on the area, so that no serious error will be involved in calculations if the effects of the one upwind shell is disregarded.

If 15 shell will produce 22.4% casualties by effects of liquid HS on an area of 23,100 sq. yd., about 14.5 shell distributed per 100 yard square are required to produce 50% casualties, when man is protected with gas mask only.

(3) Protection with Gas Mask and Standard Impregnated Clothing. From results in table 3, it is estimated that personnel protected with gas mask and standard impregnated clothing, exposed with equal distribution on the target area during the firing period would suffer about 1.8% casualties from liquid HS.

If 15 shell will produce 1.8% casualties from the effects of liquid HS on an area of 23,100 sq. yd., about 180.5 shell distributed per 100 yard square are required to produce 50% casualties when man is protected with gas mask and standard impregnated clothing.

It is probable that the effectiveness of the liquid HS was very much reduced by the excessive dust cloud produced by shell burst. At the time of the test, the ground was extremely dry to a distance of a foot or more below the surface, and the dust cloud produced probably absorbed a large percentage of the HS liquid drops before they reached the ground.

#### d. Effects of HS Vapor.

(1) Vapor Concentration Required to Produce Man Casualties. A discussion of the exposure period required to produce man casualties from HS vapor is given in Test "A", "Report of Test of HS Filled 155-mm. Howitzer Shell", conducted May 23, 1932. Per cent casualties are based on the c.t. value, using the valuation curve on Graph 1.

(2) Effect of Meteorological Conditions on Effectiveness of HS Vapor. A theoretical discussion of the effect of meteorological conditions on effectiveness of HS vapor is given in report of Test "A", "HS filled 155-mm. Howitzer Shell", conducted on May 23, 1932.

In the present test, the air temperature was 84° to 82°F. and wind velocity 2.9 m.p.h. during the firing period and following hour. These meteorological conditions were very favorable to build up a high vapor concentration, although the conditions were not as good as in the case of test "C", conducted on August 4, 1932, on account of a higher wind velocity.

(3) On the Target Area.

(a) Firing Period and Following Ten Minutes. From the results of vapor samples in table 4, representing the firing period and following ten minutes, it is estimated that man protected with gas mask only, would suffer about 99.5% casualties from the effects of HS vapor. This estimate is based on the average results of vapor samples taken at 6 different positions. These positions were not representative of the entire target area, however, as some parts of the area were not gassed.

Vapor concentration figures for each 20-yard square on the target area are given in the fifth column of table 14. The figures in this column are estimates, based on the results obtained at the six sampling positions on the area, the position of nearest impacts and the wind direction. From an average of the figures in this column, it is estimated that personnel exposed in the target area during firing and the following ten minutes would suffer about 77.5% casualties from the effects of HS vapor, when protected with gas mask only.

The per cent estimated casualties for each 20-yard square, as given in table 14, is shown graphically on Chart 3. The shaded area on the chart represents that part of the area on which 100% casualties would be produced by the effects of HS vapor when man is protected with gas mask only. The per cent casualties shown on Chart 3 are based on the effects of 15 shell. If 15 shell distributed over an area of 26,400 square yards will produce 77.5% casualties by effects of HS vapor, it will require theoretically about 4 shell distributed per 100 yard square to produce 50% casualties.

A brief study of data representing some of the previous tests of HS filled 155-mm. shell, show that the average spread of the liquid HS at right angles to the wind, from a single shell, is about

20 yd. On this basis, 5 shell correctly placed will cover a front of 100 yd. Results of test "C", conducted August 4, 1932, show that HS vapor will drift downwind to a distance of 100 yd. or more, from the position of burst and produce casualties. Considering these facts, 4 shell per 100-yard square, as figured in the preceding paragraph, is theoretically ample to cover the area sufficiently to produce 50% man casualties under the favorable meteorological conditions which existed at the time of the present test.

(b) Firing Period and Following Hour. The results of vapor samples, representing the firing period and following hour, are given in table 6. The figures in this table were used in estimating the average vapor concentration for each 20-yard square on the target area, as given in the fifth column of table 16. The figures in this column for each 20-yard square, are estimates based on results obtained at the nine sampling positions on the area, the position of the impacts and the wind direction. Based on the figures in this column, personnel exposed on the target area during the firing period and following hour, would suffer about 83.4% casualties.

Casualties from the effects of HS vapor are shown graphically on Chart 4. The shaded area represents that part of the target area, on which it is estimated 100% casualties would result from HS vapor, on exposure during the firing period and following hour, when man is protected with gas mask only.

If 15 shell distributed on an area of 26,400 sq. yd. will produce 83.4% casualties by effects of HS vapor, it will require about 3.4 shell distributed, per 100-yard square to produce 50% casualties from HS vapor, when man is protected with gas mask only.

The number of shell figured per 100-yard square to produce 50% casualties is about the same for the firing period plus the following 10 min. and firing period plus the following hour. This is due to the fact that the c.t. vapor value, for the firing period plus 10 min. was sufficiently high to produce 100% estimated casualties over a large percentage of the target area, consequently, the 50 min. additional exposure period, represented by firing period plus one hour, would result in only a few additional casualties.

(c) Four Hour Period on Day Following Firing. The results of vapor samples, on the day following firing, are given in table 7. The sampling period was 4 hr. and the results were negative. The fact that negative results were obtained is not conclusive evidence that the area could be occupied by personnel without casualties resulting as it is very difficult to sample low concentrations of HS vapor.

(2) Outside of the Target Area.

Estimated man casualties at sampling positions outside of the target area are given in table 8 for the firing period and following hour. Vapor samples were obtained upwind from the target area as well as downwind. The upwind samples were due to a shell impact west of the target area. It is estimated from the results of samples taken at positions downwind that personnel stationed 70 yd. downwind from the impact position would suffer casualties if exposed during the firing period and following hour with only gas mask protection.

e. Estimated Man Casualties Based on Effects on Animals.

Animal casualties and estimated man casualties based on effects on animals are included in tables 9a to 13 inclusive. Animal positions, animal casualties, and estimated man casualties, based on effects on animals, are shown on Charts 6 to 15 inclusive.

(1) Estimated Man Casualties on the Target Area, When Man is Protected with Gas Mask Only.

(a) Firing Period and Following Ten Minutes.

From the animal casualties given in tables 9a and 9b, it is estimated that man protected with gas mask, exposed on the target area during the firing period and following 10 min., would suffer 16.7% casualties based on rats and 37.5% based on goats or 27.1% based on rats and goats.

(b) Firing Period and Following Hour.

Estimated man casualties on the target area for the firing period and following hour are given in tables 10a and 10b. It is estimated that man protected with gas mask, would suffer about 40% casualties based on effects on rats and 47.1% based on goats or about 43.5% based on rats and goats.

(c) Period from 2nd to 14th Hour After Firing.

Estimated man casualties due to exposure on the target area during the 12-hr. period from the beginning of the 2nd hr. after firing, are given in tables 11a and 11b. From the animal casualties it is estimated that man casualties would be 73.3% based on rats and 11.1% based on goats or about 50% based on rats and goats.

(d) Day Following Test (13th to 18th Hour).

Estimated man casualties due to exposure on the target area on the day following firing, from the 13th to the 18th hour, are given in table 12a. The results were negative but that does not positively indicate that the area could be occupied by personnel protected with gas mask only, as the skin of man is much more susceptible to HS vapor than that of a goat or rat.

(e) Exposure in Shell Craters.

None of the animals exposed in shell craters for a period of 24 hr. on the 7th and 9th days respectively after firing were casualties. This was probably due to the very dry condition of the ground and high temperature condition after the test which resulted in rapid evaporation of the HS.

(2) Downwind from Target Area.

The results of animals, stationed downwind from the target during the firing period and following hour, are given in table 13. Of the 12 animals exposed, only one was a slight casualty. Chart 10 showing animal positions, shell craters and wind direction, indicates that only about 3 of the 12 animals exposed were actually downwind from the position of the shell craters. The animal which was a casualty was located about 100 yd. downwind, in the direction of wind travel, from the nearest shell crater, and its nature of casualty was not interpreted, by the Medical Research Division, as representing a man casualty. From the data available, it is impossible to state definitely whether personnel stationed 100 yards downwind from the position of impact, would be casualties or not, when protected with gas mask.

f. Comparison of Per Cent Estimated Man Casualties Based on Measurements of the Gas Concentration and by Effects on Animals, When Man is Protected with Gas Mask Only.

(1) Firing Period and Following Ten Minutes.

In Table 14, estimated man casualties are given for each 20-yard square, based on the following effects and methods of figuring casualties, when man protected with gas mask only is exposed on the target area during the firing period and following ten minutes.

- (a) HS liquid using panel data
- (b) HS vapor from vapor samples
- (c) Combined effect of HS liquid and HS vapor
- (d) Effect on animals.

Figures in this table show that 100% casualties would be produced on 80.0% of the target area, based on the combined effect of HS liquid and vapor and 23.5% based on effect on animals or 51.7% based on an average of the two methods of figuring casualties.

Table No. 14

Estimated Casualties on the Target Area Representing Exposure  
During Firing and Following 10 Minutes  
(Area 26,400 sq. yd.)

Stake No.:	Impacts:	From HS liquid:	From HS vapor:	From HS liquid:	From effects on
at center:	within :	Estimated man :	c.t. :	Est. man:	and vapor :
of 20-yd.:	20-yd. :	casualties :	value:casual-	Estimated man :	Animal :
square :	square :	:	ties :	casualties :	casualties :
		%		%	
1	0	15	.00:	0	13
3	0	20	.00:	0	20
5	2	63	.15:	100	100
7	0	70	.10:	93	98
9	0	40	.04:	50	70
11	0	15	.04:	50	58
23	0	0	.00:	0	0
25	0	13	.05:	57	64
27	0	44	.15:	100	100
29	1	53	.20:	100	100
31	0	24	.15:	100	100
33	0	0	.10:	93	93
45	0	0	.00:	0	0
47	0	0	.10:	93	93
49	0	7	.15:	100	100
51	1	38	.30:	100	100
53	0	53	.30:	100	100
55	0	10	.20:	100	100
67	1	23	.00:	0	0
69	0	0	.08:	80	80
71	1	18	.15:	100	100
73	0	20	.20:	100	100
75	0	22	.20:	100	100
77	0	10	.10:	93	94
89	0	27	.10:	93	95
91	0	7	.10:	93	94
93	2	21	1.00:	100	100
95	0	13	.60:	100	100
97	0	0	.25:	100	100
99	0	0	.15:	100	100
111	0	0	.10:	93	93
113	0	13	.10:	93	94
115	0	42	1.00:	100	100
117	2	46	1.30:	100	100
119	0	18	.30:	100	100
121	0	20	.20:	100	100
133	1	23	.10:	93	95
135	0	7	.10:	93	94

Table No. 14 (Cont'd.)

Stake no.:Impacts:From HS liquid:From HS vapor:From HS liquid:From effects on									
at center:within		:Estimated man		:c.t. :Est.Man:		and vapor		: animals	
of 20-yd.:20-yd.		: casualties		:value:casual-		:Estimated man		:Animal	
square	:square	:	:	:	ties	: casualties	:casualties	:	:casualties
:	:	:	%	:	%	:	%	:	%
137	: 0	:	11	:	.10:	93	:	94	:
139	: 1	:	40	:	.10:	93	:	96	:ELS death
141	: 0	:	24	:	.50:	100	:	100	:
143	: 0	:	0	:	.10:	93	:	93	:
155	: 0	:	23	:	.00:	0	:	23	:
157	: 0	:	7	:	.08:	80	:	81	:
159	: 0	:	0	:	.15:	100	:	100	:
161	: 0	:	44	:	1.00:	100	:	100	:ERS death
163	: 0	:	31	:	1.00:	100	:	100	:
165	: 0	:	0	:	.10:	93	:	93	:
177	: 0	:	0	:	.00:	0	:	0	:
179	: 0	:	7	:	.05:	57	:	61	:E light
181	: 2	:	44	:	.20:	100	:	100	:
183	: 0	:	58	:	.50:	100	:	100	:
185	: 0	:	32	:	.03:	42	:	60	:
187	: 0	:	20	:	.10:	93	:	95	:
199	: 0	:	0	:	.00:	0	:	0	:
201	: 0	:	7	:	.03:	42	:	46	:
203	: 1	:	71	:	.15:	100	:	100	:
205	: 0	:	55	:	.10:	93	:	96	:E <sub>2</sub> RS severe
207	: 0	:	13	:	.10:	93	:	94	:
209	: 0	:	20	:	.10:	93	:	95	:S light
221	: 0	:	0	:	.00:	0	:	0	:
223	: 0	:	0	:	.03:	42	:	42	:
225	: 0	:	43	:	.05:	57	:	82	:
227	: 0	:	39	:	.10:	93	:	96	:ELS death
229	: 0	:	10	:	.10:	93	:	94	:
231	: 0	:	20	:	.10:	93	:	95	:
Total and:									
average	: 15	:	21.4	:	:	77.5	:	80.0	:
									23.5

The average percentages given in table 14, are based on the total target area. In table 15, which follows, results are given to include only the impact area, as defined in paragraph 8b.

Estimated casualties given in table 15, are based on an area of 17,400 sq. yd. on which there were 15 impacts. Results in this table show an average of 91.4% man casualties based on the effects of HS liquid and vapor, and 41.2% based on effects on animals, or an average of 66.3% based on the two methods of figuring casualties.

Table No. 15

Estimated Casualties on the Impact Area (17,400 sq.yd.)  
Firing Period and Following Ten Minutes

Stake no.:	Impacts	Estimated man casualties		
		at center:	within	
of 20-yd.:	20-yd.sq.	square	square	
square	:	:	:	:
5	:	2	:	100
7	:	0	:	95
9	:	0	:	70
27	:	0	:	100
29	:	1	:	100
31	:	0	:	100
49	:	0	:	100
51	:	1	:	100
53	:	0	:	100
67	:	1	:	0
69	:	0	:	80
71	:	1	:	100
73	:	0	:	100
75	:	0	:	100
89	:	0	:	95
91	:	0	:	94
93	:	2	:	100
96	:	0	:	100
97	:	0	:	100
111	:	0	:	95
113	:	0	:	94
115	:	0	:	100
117	:	2	:	100
119	:	0	:	100
133	:	1	:	95
135	:	0	:	94

Table No. 15 (Cont'd.)

Stake no.:	Impacts at center:	within of 20-yd. square	20-yd.sq. :	Estimated man casualties	
				From HS liquid and vapor	From effects on animals
137	:	0	:	94	:
139	:	1	:	96	: 100
141	:	0	:	100	:
143	:	0	:	93	: 0
155	:	0	:	23	:
157	:	0	:	81	: 0
159	:	0	:	100	:
161	:	0	:	100	: 0
163	:	0	:	100	:
181	:	2	:	100	:
183	:	0	:	100	: 0
185	:	0	:	60	:
203	:	1	:	100	:
205	:	0	:	96	: 100
207	:	0	:	94	:
225	:	0	:	82	:
227	:	0	:	96	: 100
229	:	0	:	94	:
Total and	:	:	:	:	:
average	:	15	:	91.4	: 41.2

(2) Firing Period and Following Hour.

In table 16, which follows, estimated man casualties are given for each 20-yard square, when man protected with gas mask only, is exposed on the target area during the firing period and the following hour.

Table No. 16

Estimated Casualties on the Target Area Representing Exposure  
During Firing and Following Hour  
(Area 26,400 sq. yd.)

Number of: Impacts: From HS liquid: From HS vapor: From HS liquid: From effects on										
stake at: within		Estimated man		c.o.t. : Est. man		and vapor		animals		
center of: each		casualties		value: casual-		Estimated man		Animal		Est. man
square	: square	:	:	:	ties	:	casualties	:	casualties	: casualties
	:	:	%	:	:	%	:	:	:	%
1	: 0	:	15	:	0:	0	:	15	:	:
3	: 0	:	20	:	0:	0	:	20	:	:
5	: 2	:	63	:	.27:	100	:	100	:	ER moderate
7	: 0	:	70	:	.18:	100	:	100	:	:
9	: 0	:	40	:	.17:	100	:	100	:	ER moderate
11	: 0	:	15	:	.07:	73	:	77	:	:
23	: 0	:	0	:	0 :	0	:	0	:	0
25	: 0	:	13	:	.09:	86	:	88	:	:
27	: 0	:	44	:	.27:	100	:	100	:	ELS death
29	: 1	:	53	:	.36:	100	:	100	:	:
31	: 0	:	24	:	.27:	100	:	100	:	0
33	: 0	:	0	:	.18:	100	:	100	:	:
45	: 0	:	0	:	0:	0	:	0	:	ER moderate
47	: 0	:	0	:	.18:	100	:	100	:	:
49	: 0	:	7	:	.34:	100	:	100	:	E <sub>3</sub> S severe
51	: 1	:	38	:	.54:	100	:	100	:	:
53	: 0	:	53	:	.71:	100	:	100	:	E <sub>3</sub> RS severe
55	: 0	:	10	:	.36:	100	:	100	:	:
67	: 1	:	23	:	0 :	0	:	23	:	ELS death
69	: 0	:	0	:	.15:	100	:	100	:	:
71	: 1	:	18	:	.27:	100	:	100	:	ELS death
73	: 0	:	20	:	.36:	100	:	100	:	:
75	: 0	:	22	:	.36:	100	:	100	:	0
77	: 0	:	10	:	.18:	100	:	100	:	:
89	: 0	:	27	:	.18:	100	:	100	:	E moderate
91	: 0	:	7	:	.18:	100	:	100	:	:
93	: 2	:	21	:	1.80:	100	:	100	:	E <sub>2</sub> LS death
95	: 0	:	13	:	1.08:	100	:	100	:	:
97	: 0	:	0	:	.45:	100	:	100	:	E <sub>3</sub> R severe
99	: 0	:	0	:	.27:	100	:	100	:	:
111	: 0	:	0	:	.18:	100	:	100	:	0
113	: 0	:	13	:	.18:	100	:	100	:	:
115	: 0	:	42	:	2.60:	100	:	100	:	ELS death
117	: 2	:	45	:	1.72:	100	:	100	:	:
119	: 0	:	18	:	.84:	100	:	100	:	EL death
121	: 0	:	20	:	.36:	100	:	100	:	:

Table No. 16 (Cont'd.)

Number of:Impacts:From HS liquid:From HS vapor:From HS liquid: From effects on									
stake at		:within		:Estimated man		:o.t. :Est.man:		and vapor : animals	
center of:		each		: casualties		:value:casual-		:Estimated man :Animal	
square		:square :		: : ties		: casualties		:casualties :casualties	
		:		:		:		:	
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Figures in table 16, show 100% casualties on 85.1% of the area, based on the combined effects of HS vapor and liquid and 43.8% based on effects on animals, or 64.4% based on the two methods of figuring casualties.

Per cent estimated casualties in tables 14, 15 and 16, based on the combined effects of HS liquid and vapor, are considerably higher than corresponding figures, based on effects on animals. Estimates based on effects on animals were very conservatively made and are probably low. It is also probable that estimates based on effects of HS vapor alone, are high for average temperature conditions, so that an average based on effects on animals and from measurements of the combined HS liquid and vapor present, is probably more nearly correct than either method alone.

g. Number of Shell Required to Produce 50% Man Casualties.

It was estimated in paragraph 8 c (2) that about 14.5 shell distributed per 100-yard square will produce 50% casualties from liquid HS, when man is protected with gas mask only.

From figures given in table 15, it was estimated that the burst of 15 shell, on an area of 17,400 sq. yd. would produce 91.4% casualties, based on a measure of the HS liquid and vapor present, and 41.2% based on effects on animals, when man is exposed during the firing period and following 10 min. On this basis, the following number of shell per 100-yard square will be required to produce 50% casualties when man is protected with gas mask only:

Based on HS liquid and vapor samples -	4.7 shell
Based on effects on animals -	10.4 shell
Average -	7.5 shell

Based on the two methods of figuring casualties, about 8 shell distributed, are required per 100-yard square to produce 50% casualties, when man is protected with gas mask only.

9. Conclusions.

From the results of the present test, the following conclusions are drawn with respect to the use of 155-mm. shell filled with HS, when fired under the meteorological conditions existing at the time of the test.

a. The number of shell required per 100-yard square to produce 50% casualties when distributed as equally as practicable, are

as follows:

(1) When man, protected with gas mask and standard impregnated clothing, is exposed during the firing period - 180 shell (see page 14).

(2) When man, protected with gas mask only, is exposed during the firing period and following ten minutes - 8 shell (see sub-paragraph 8, page 26).

10. Recommendations.

It is recommended that additional tests be conducted as follows:

a. Conduct a test in the late spring to determine effect of season on the gas concentration set up.

b. Use the minimum propellant charge and determine the effect of angle of impact on the efficiency of the shell.

c. Determine the effect of terrain by firing for impact in woods.

d. Conduct one test under favorable meteorological conditions on a larger scale than all previous tests and determine the vapor concentration set up downwind from the impact area.

Submitted:

/s/ B. G. Macintire  
B. G. MACINTIRE,  
Weapons Department,  
Munitions Development Division.

Recommending Approval:

Report of Test of HS Filled  
155-mm. Howitzer Shell, Test "D"  
August 29, 1932.

/s/ Charles E. Loucks  
CHARLES E. LOUCKS,  
Captain, C.W.S.,  
Chief, Munitions Dev. Division.

Project A 1.1-1b

Approved:

Typed nsm 12-6-32

/s/ E. Montgomery  
E. MONTGOMERY,  
Major, C.W.S., Technical Director.

Appendix E

**BATTERY "A" SIXTH FIELD ARTILLERY  
Fort Hoyle, Maryland.**

**September 1, 1932.**

**MEMORANDUM: For the Technical Director, Edgewood Arsenal.**

1. The following report is submitted on firing of 155 mm HS filled shell on August 29, 1932.

a. A map transfer of fire was used for this shoot.

b. The check point used was 167 yards east of the center of the target area and fifty yards short of this area. A precision adjustment was made on this point for which an adjusted elevation of 290 was obtained.

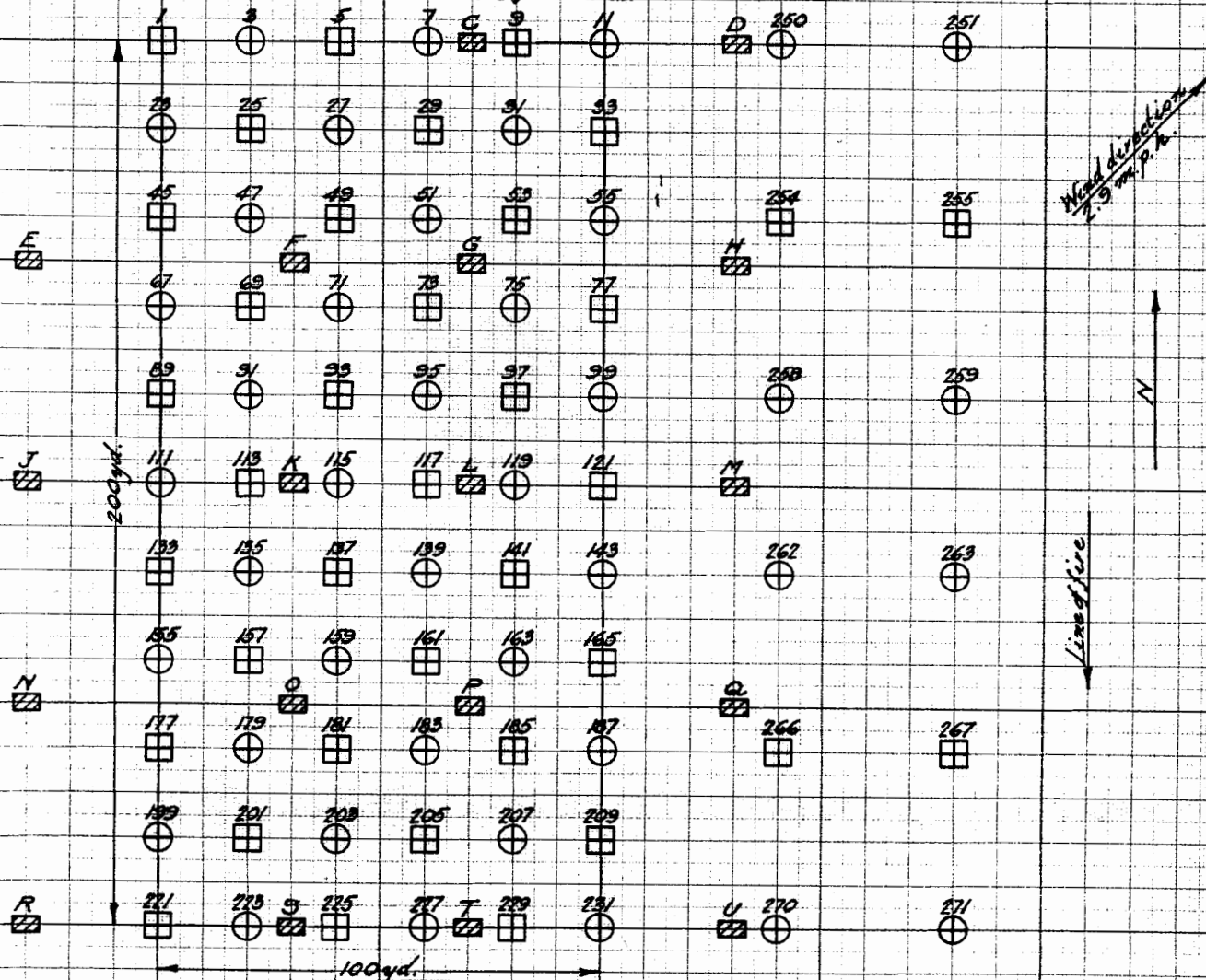
c. The following is a round to round statement of the firing giving elevation and deflections used.

<u>Round</u>	<u>Gun Number</u>	<u>Deflection</u>	<u>Elevation</u>
1	4	3247	290
2	3	3248	290
3	2	3249	290
4	1	3250	290
5	4	3247	290
6	3	3248	290
7	2	3249	290
8	1	3250	290
9	4	3247	295
10	3	3248	295
11	2	3249	295
12	1	3246	295
13	4	3247	295
14	3	3248	295
15	2	3249	295
16	4	3247	290
17	3	3248	290
18	2	3249	290
19	3	3248	290
20	2	3249	290
21	4	3247	290
22	3	3248	290
23	2	3249	290
24	1	3246	290
25	1	3246	295
26	3	3248	295
27	2	3249	295
28	4	3247	295

**WILLIAM J. BOAN,  
Captain, 6th Field Artillery,  
Commanding.**

CHART I  
TARGET AREA  
AS PREPARED FOR  
TEST D

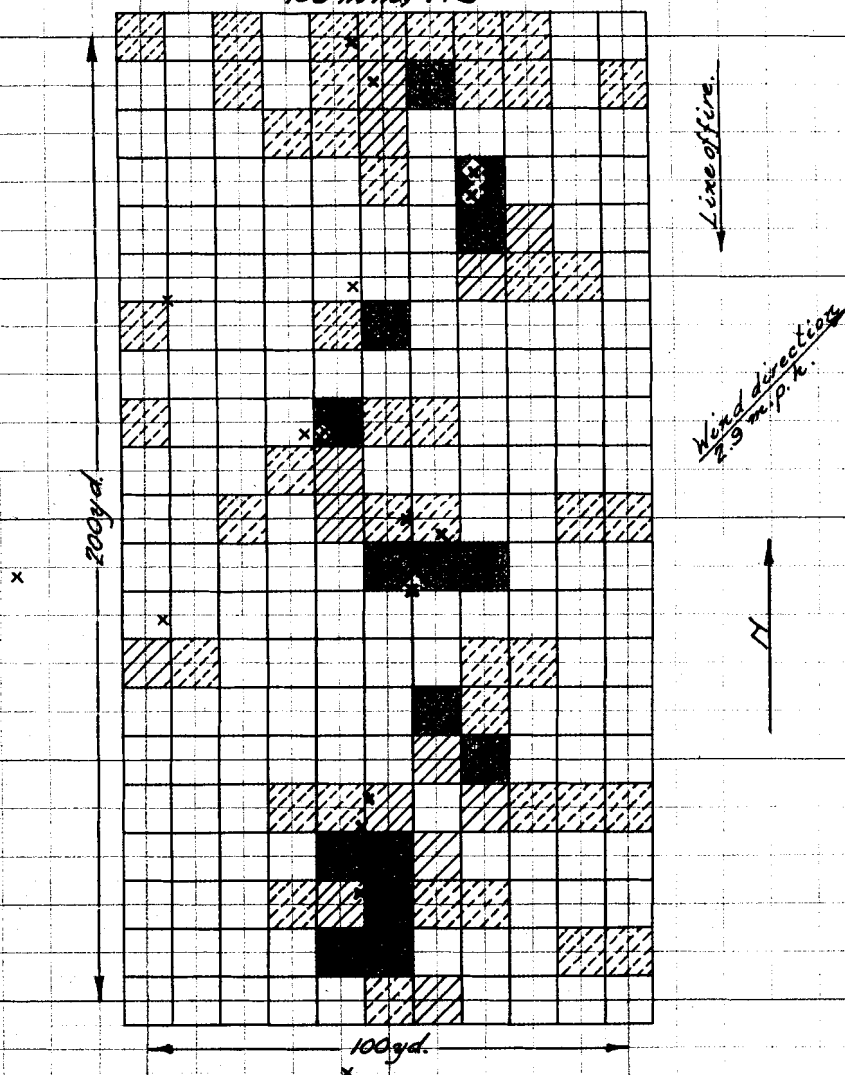
AUG. 29, 1932.



# CHART 2 ESTIMATED MAN CASUALTIES DUE TO EFFECTS OF H5 LIQUID TEST D

AUG. 29, 1932

155 mm. H5



## Legend.





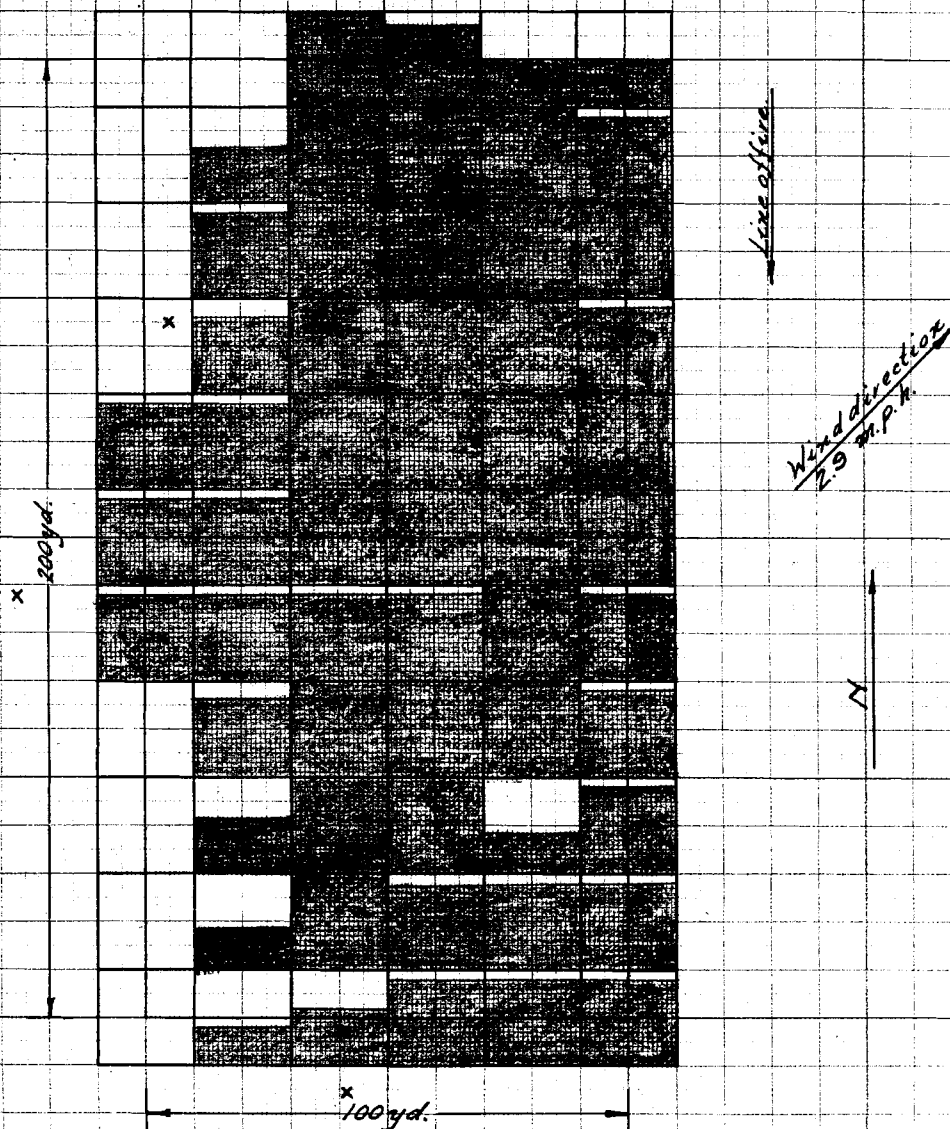
-  60 percent casualty.
-  80 " " " "
-  100 " " " "
-  Impact.

CHART 3  
ESTIMATED MAN CASUALTIES DUE TO  
EFFECTS OF HS VAPOR  
FIRING PERIOD AND FOLLOWING 10 MINUTES  
TEST D  
AUG. 29, 1932



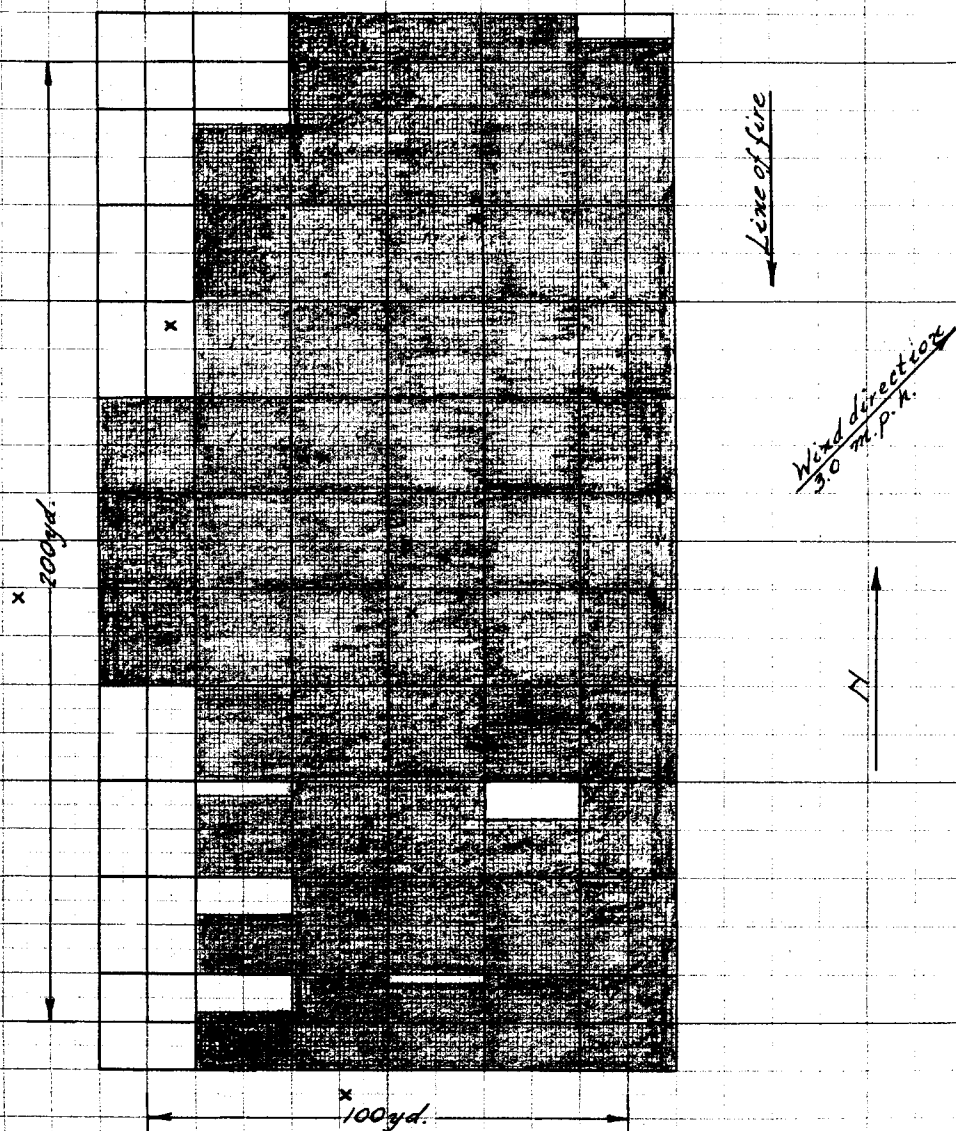
Legend.

Shaded area 100 percent max casualties  
with gas mask protection only.

x Impact.

CHART 4  
ESTIMATED MAN CASUALTIES DUE TO  
EFFECTS OF HS VAPOR  
FIRING PERIOD AND FOLLOWING HOUR.  
TEST D

AUG. 29, 1932



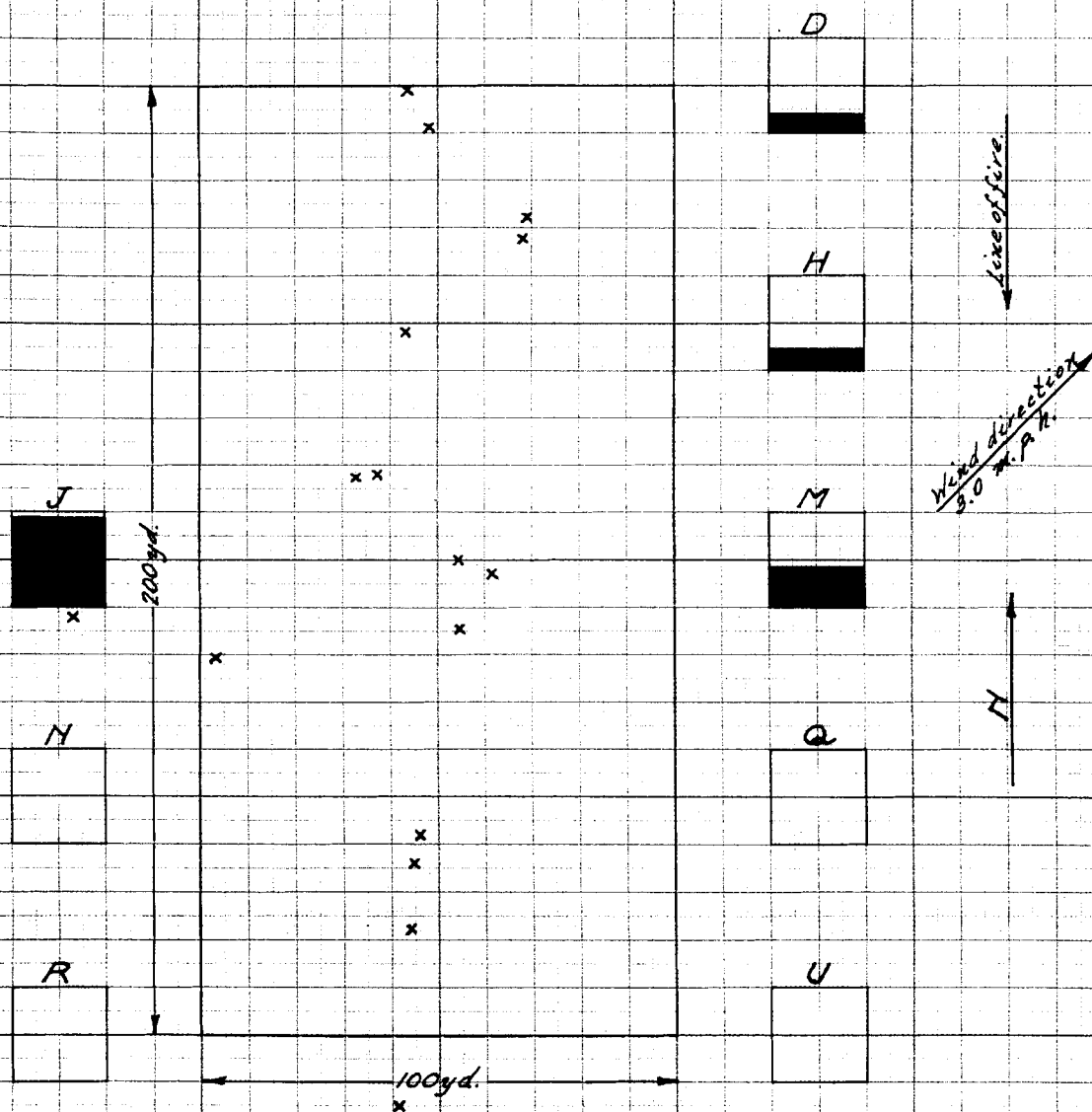
Legend.

Shaded area 100 percent max casualties  
with gas mask protection only.

x Impact.

CHART 5  
EFFECTIVENESS OF H5 VAPOR  
OUTSIDE OF TARGET AREA\*  
FIRING PERIOD AND FOLLOWING HOUR.  
TEST D

AUG. 29, 1932



Legend

x Impact

Shaded area represents 100% casualties upon personnel provided with gas masks.

Letters designate sampling positions.

\* Estimated casualties are only shown at sampling positions.

CHART 6  
ANIMAL CASUALTIES  
FIRING PERIOD AND FOLLOWING 10 MINUTES  
TEST D  
AUG. 29, 1932

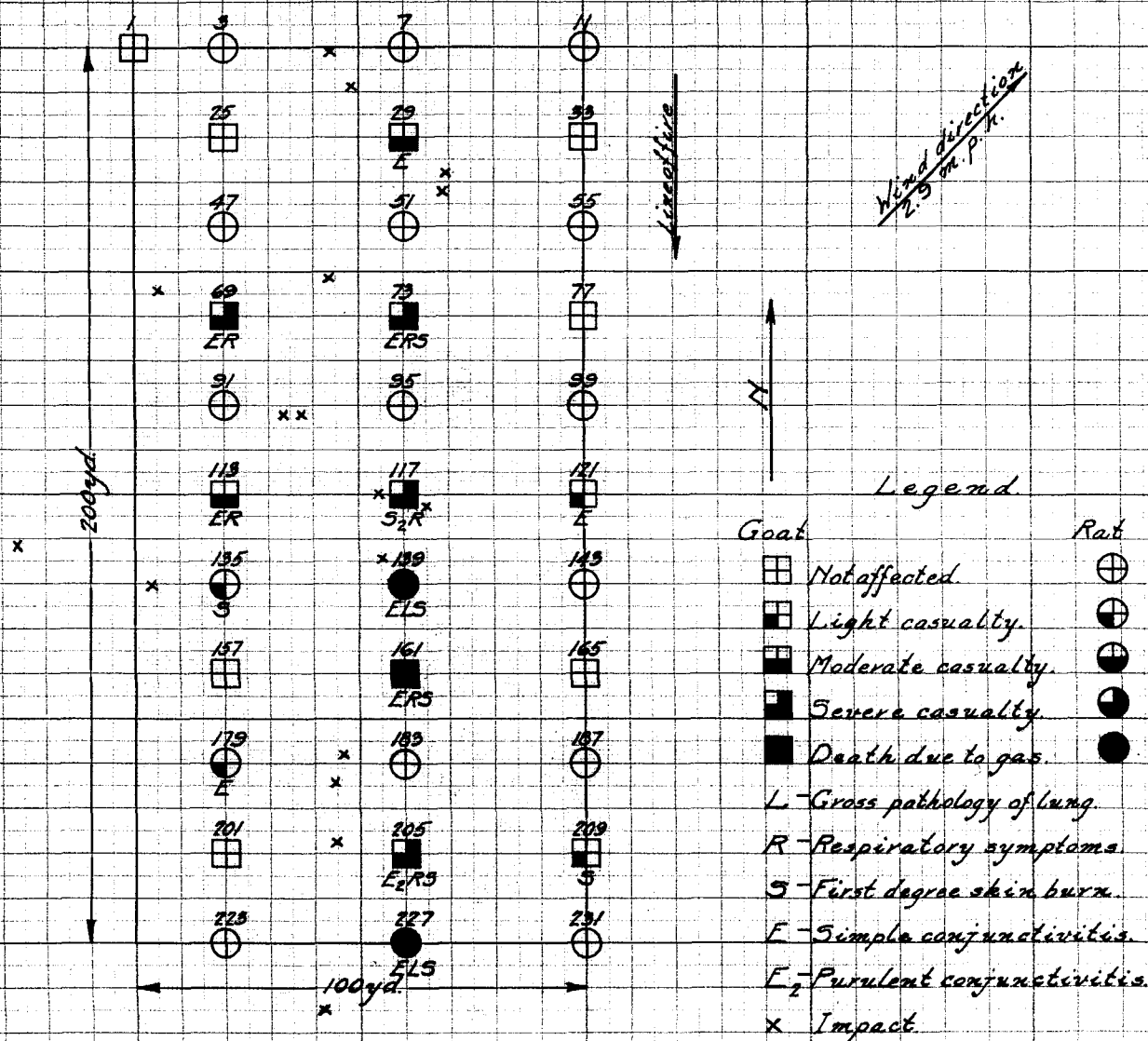


CHART 7  
ANIMAL CASUALTIES  
FIRING PERIOD AND FOLLOWING HOUR.  
TEST D

AUG. 29, 1932

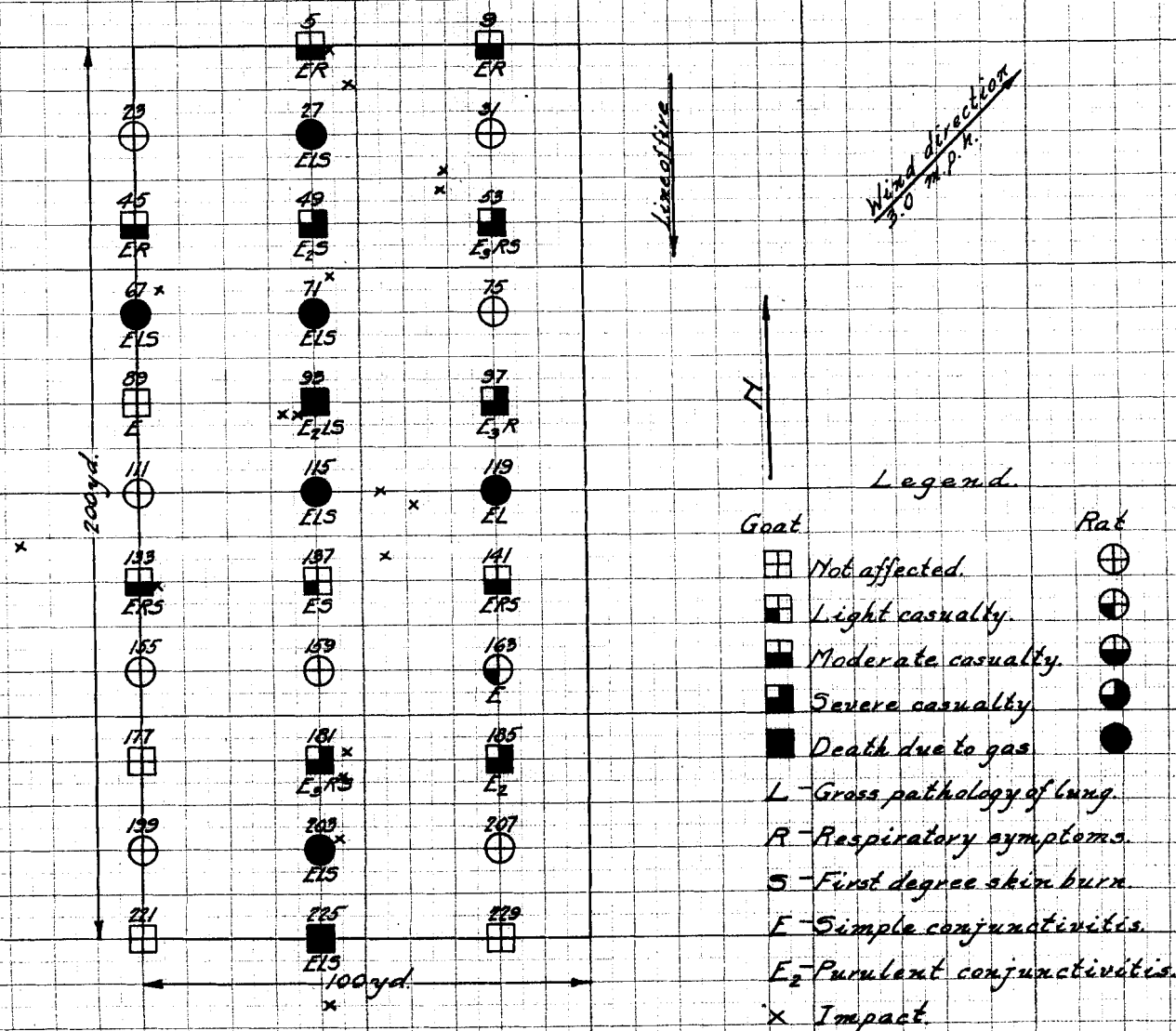


CHART 8  
ANIMAL CASUALTIES  
2<sup>ND</sup> TO 14<sup>TH</sup> HOUR AFTER FIRING  
TEST D  
AUG 29, 1932.

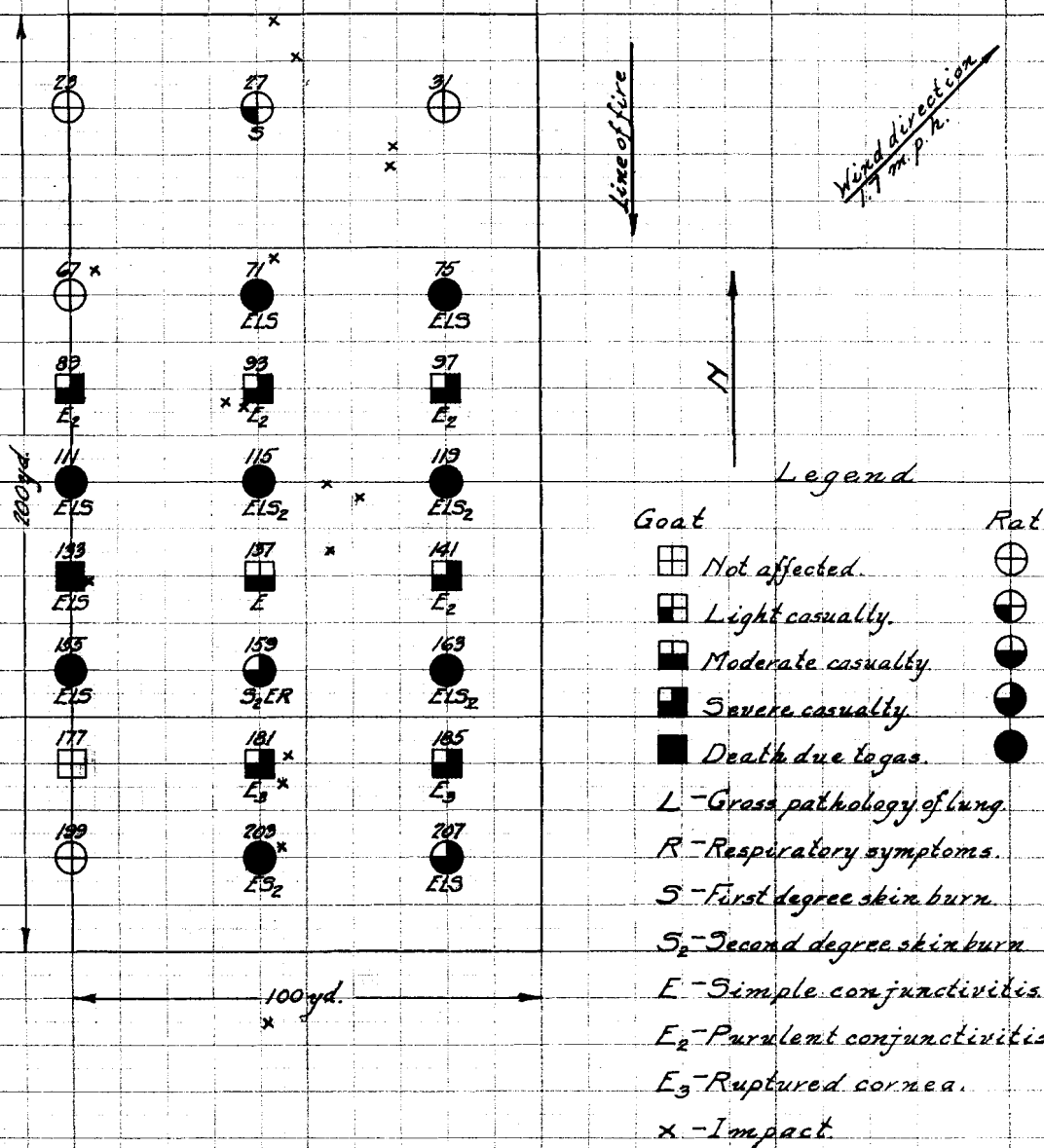


CHART 9  
ANIMAL CASUALTIES  
13<sup>TH</sup> TO 18<sup>TH</sup> HOUR AFTER FIRING (DAY FOLLOWING)  
TEST D  
AUG 29, 1932

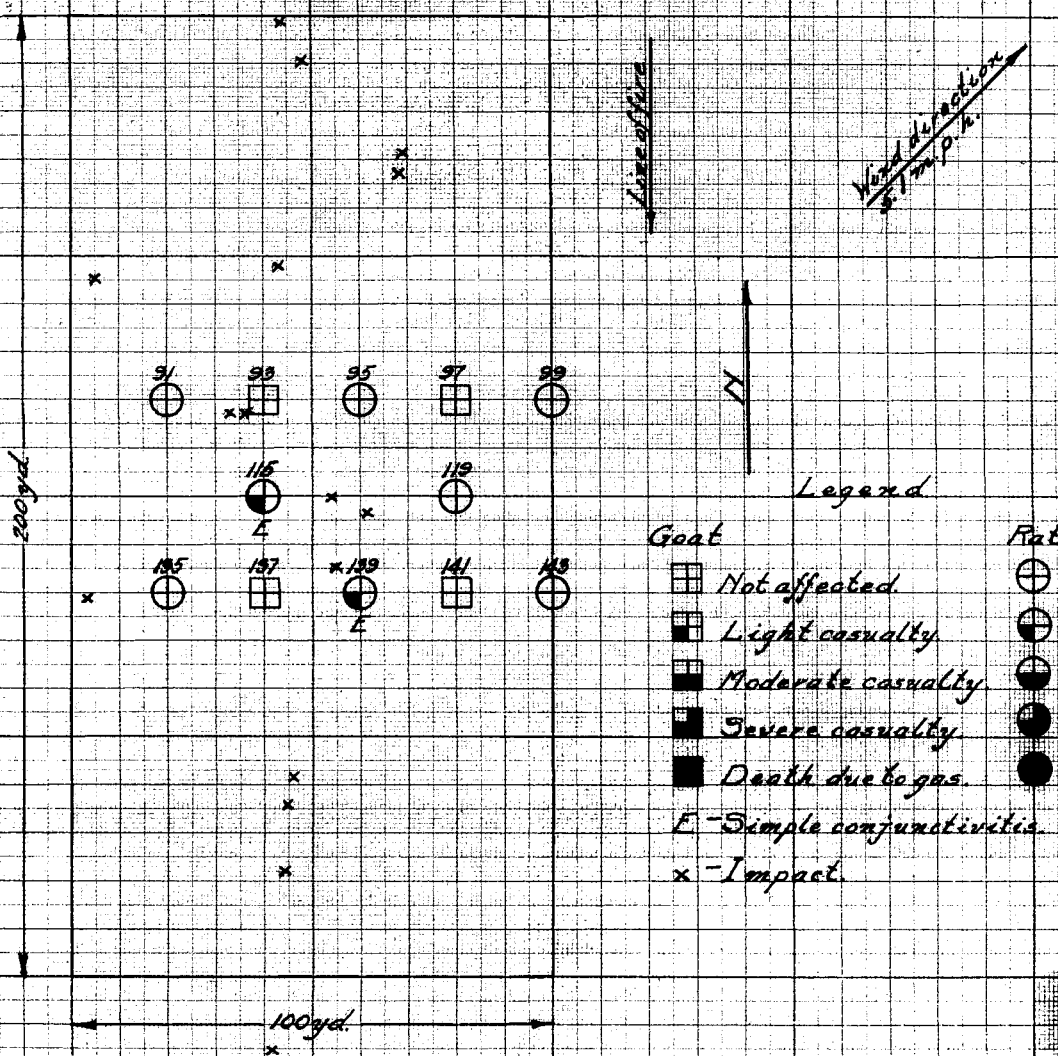


CHART 10  
ANIMAL CASUALTIES DOWN WIND  
FROM TARGET AREA.  
FIRING PERIOD AND FOLLOWING HOUR.  
TEST D  
AUG. 29, 1932

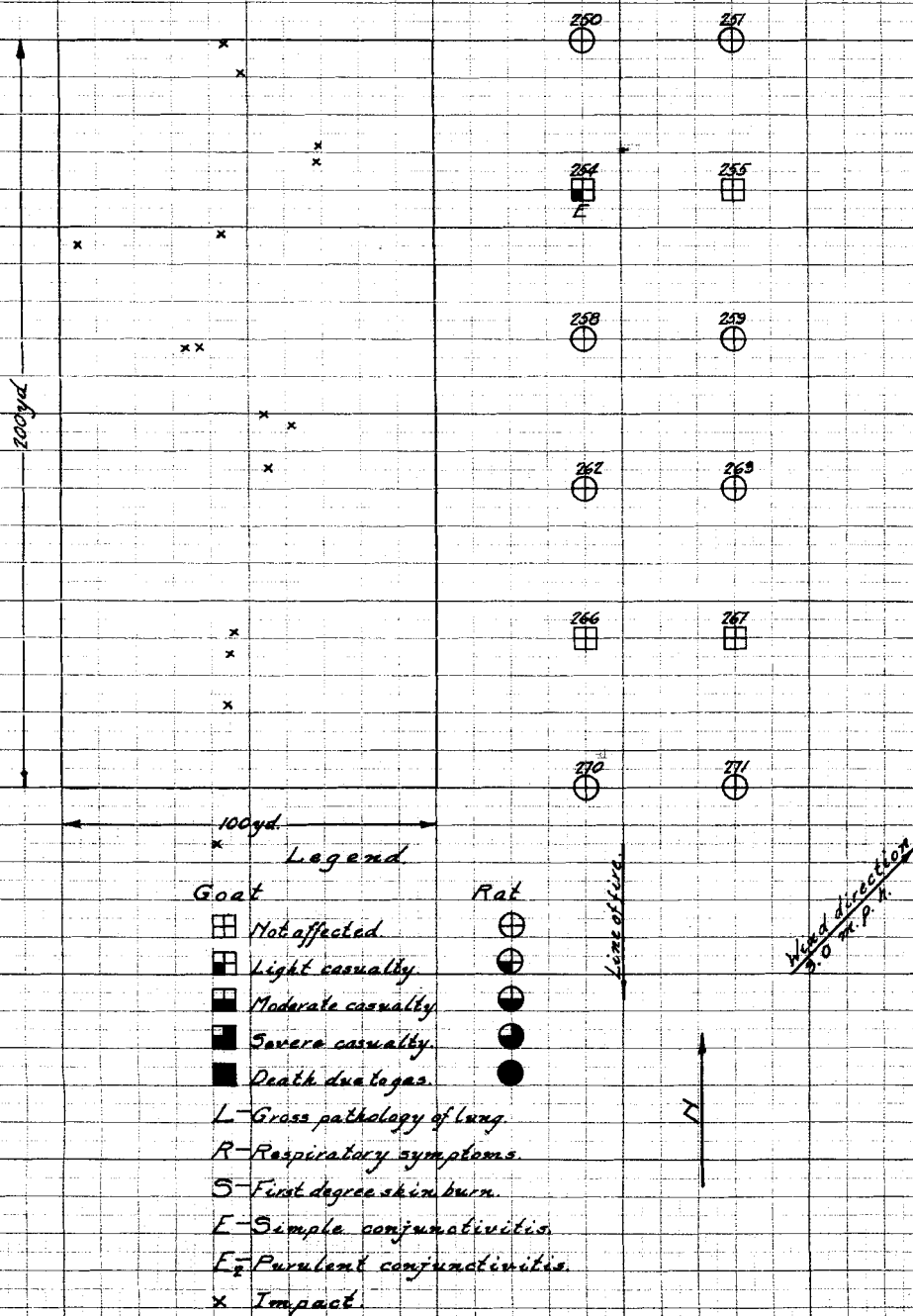


CHART II  
ESTIMATED MAN CASUALTIES BASED ON  
EFFECTS ON ANIMALS.  
FIRING PERIOD AND FOLLOWING 10 MINUTES.  
TEST D

AUG. 29, 1932

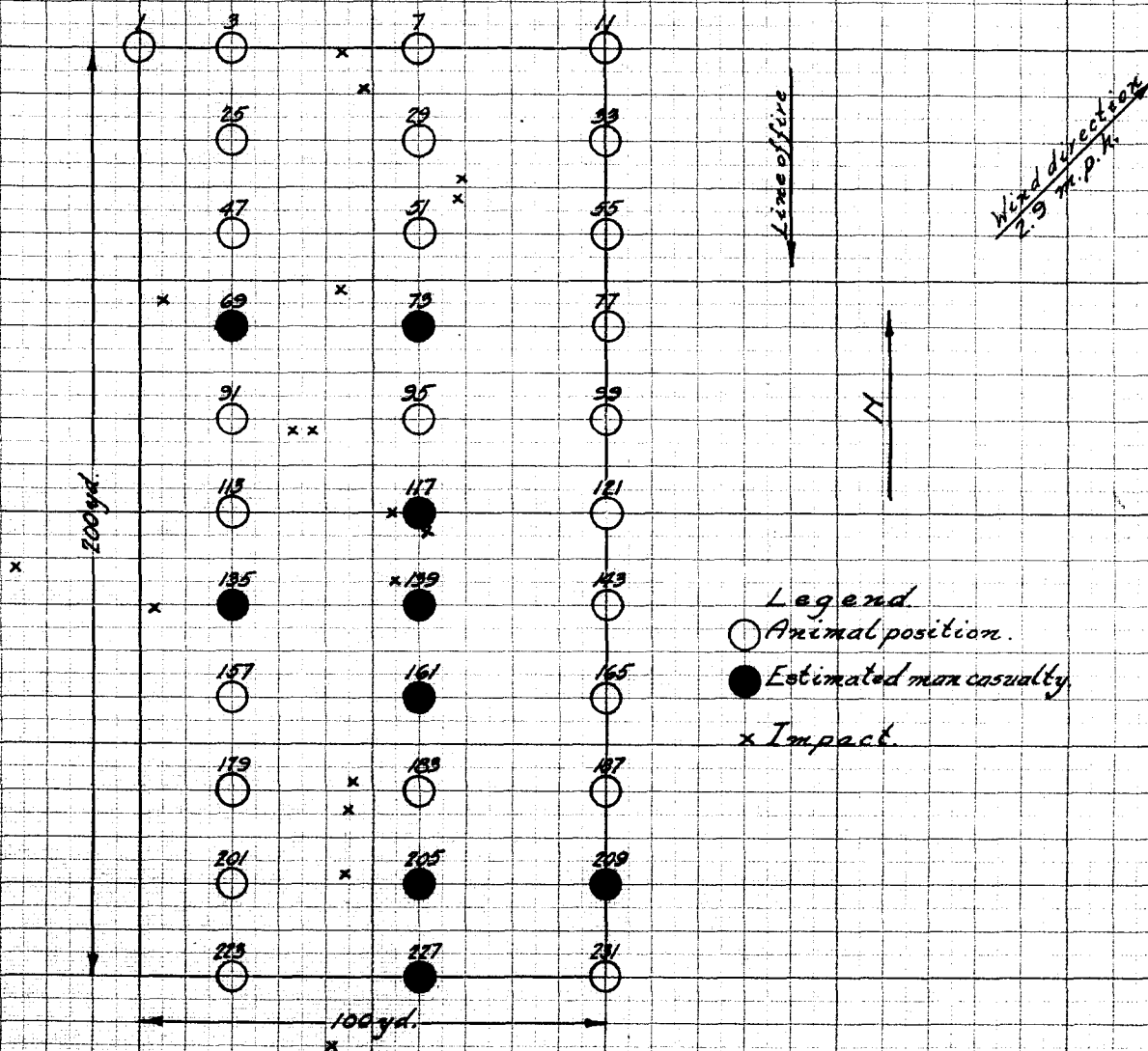


CHART 12  
ESTIMATED MAN CASUALTIES BASED ON  
EFFECTS ON ANIMALS.  
FIRING PERIOD AND FOLLOWING HOUR.  
TEST D

AUG. 29, 1932.

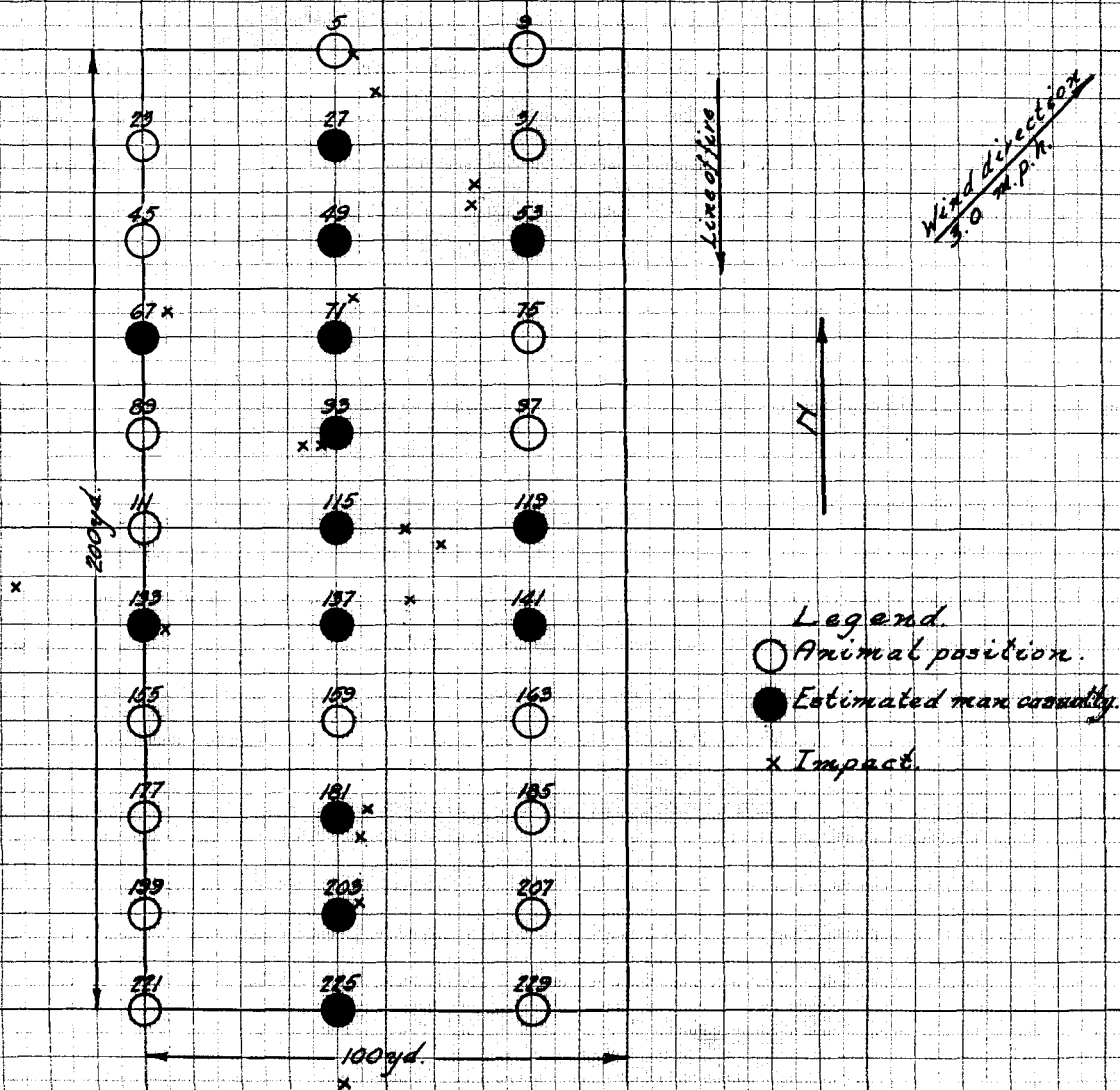


CHART 13  
ESTIMATED MAN CASUALTIES  
2<sup>ND</sup> TO 14<sup>TH</sup> HOUR AFTER FIRING  
TEST D

AUG. 29, 1932

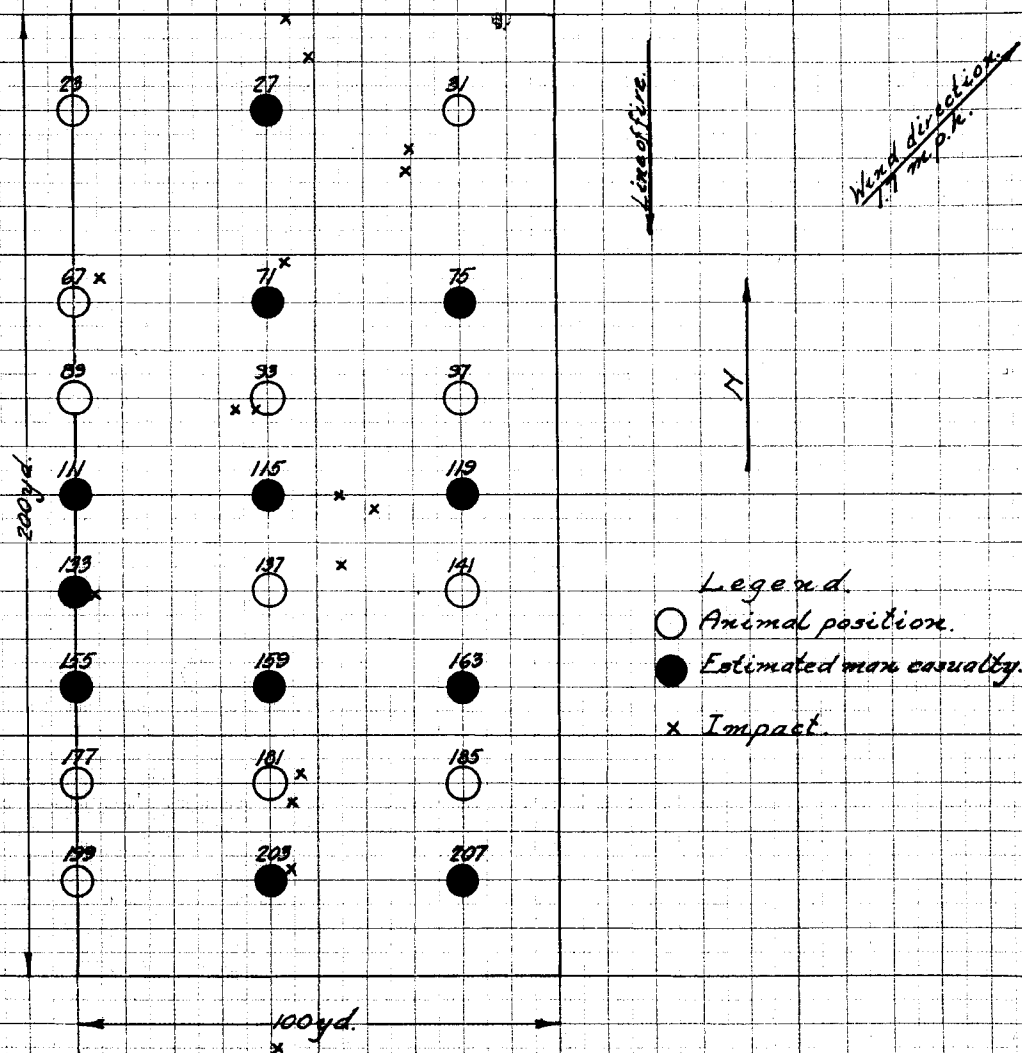


CHART 14  
ESTIMATED MAN CASUALTIES  
15<sup>TH</sup> TO 16<sup>TH</sup> HOUR AFTER FIRING (DAY FOLLOWING)  
TEST D  
AUG. 29, 1932

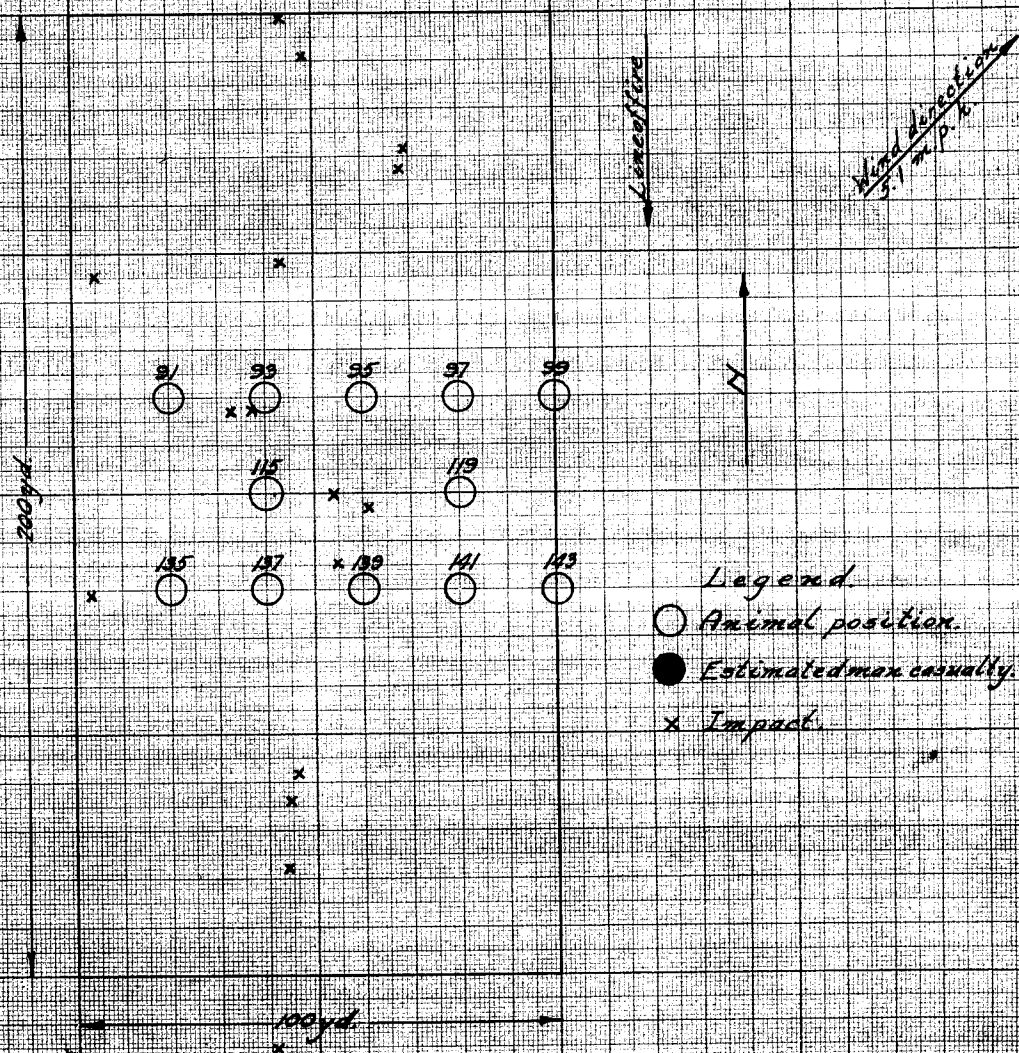
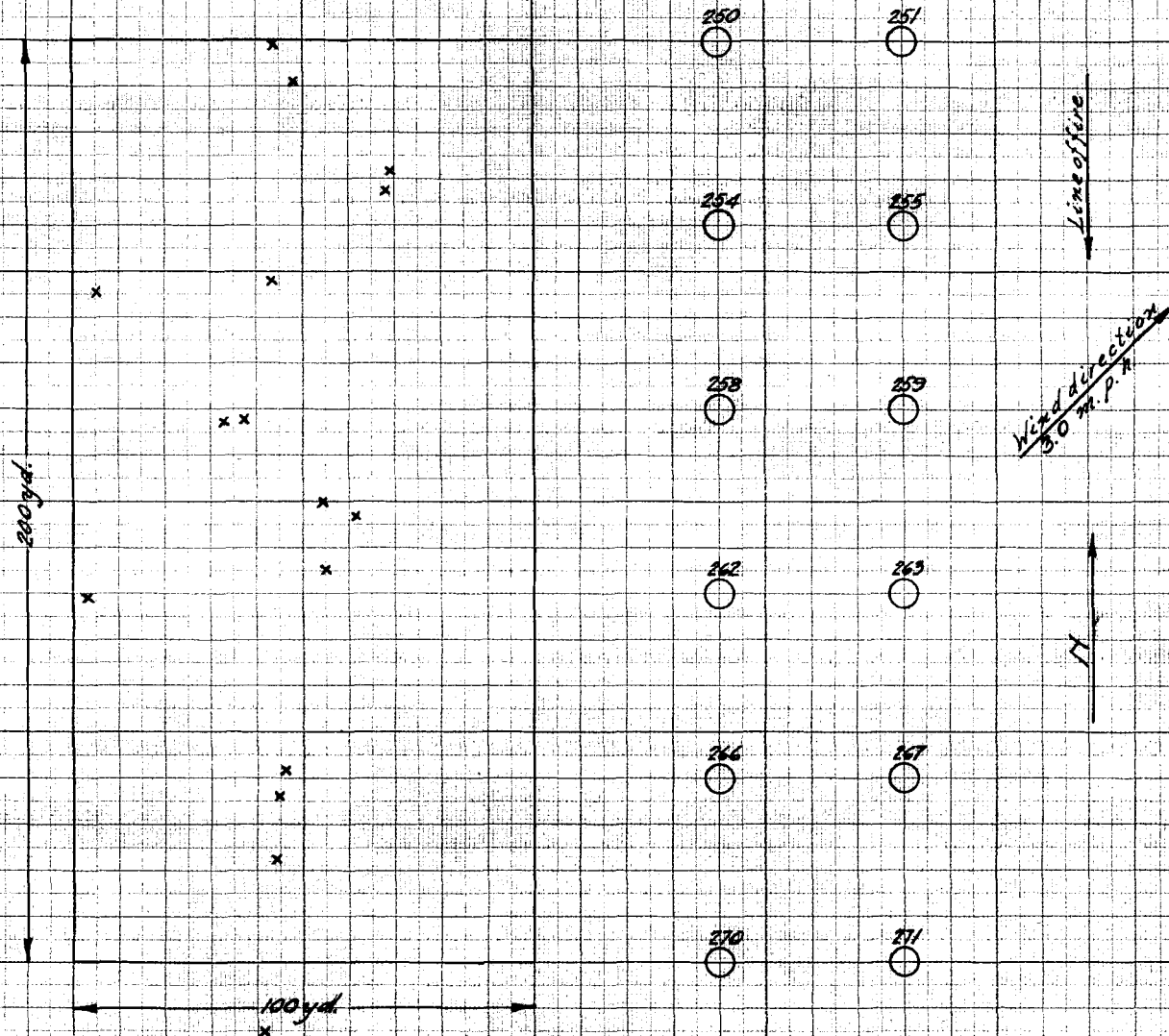


CHART 15  
ESTIMATED MAN CASUALTIES  
DOWN WIND FROM TARGET AREA  
FIRING PERIOD AND FOLLOWING HOUR.  
TEST D

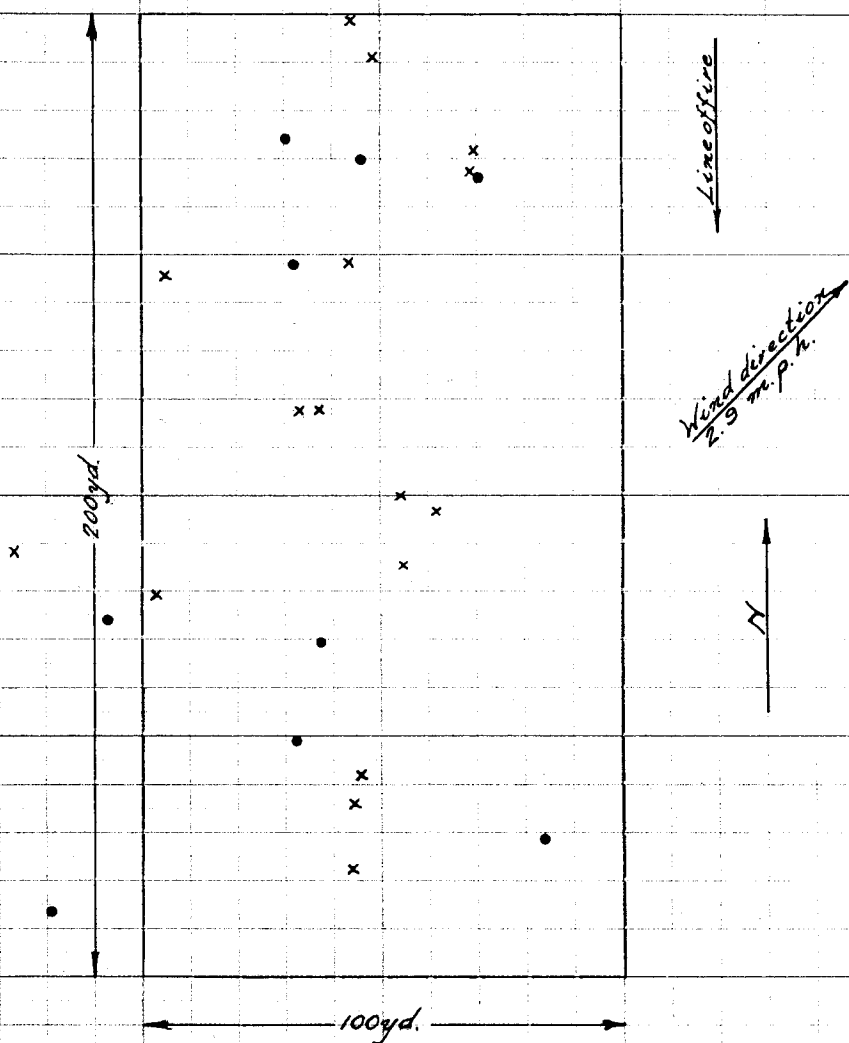
AUG 29, 1932



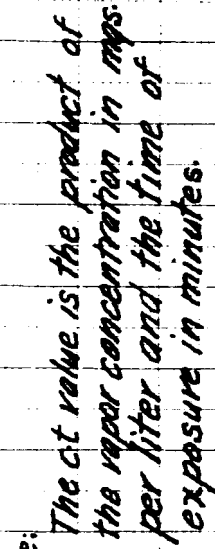
Legend.

- Animal position.
- Estimated man casualty.
- x Impact.

CHART 16  
 IMPACTS  
 ON  
 TARGET AREA  
 TEST D  
 AUG. 29, 1932.



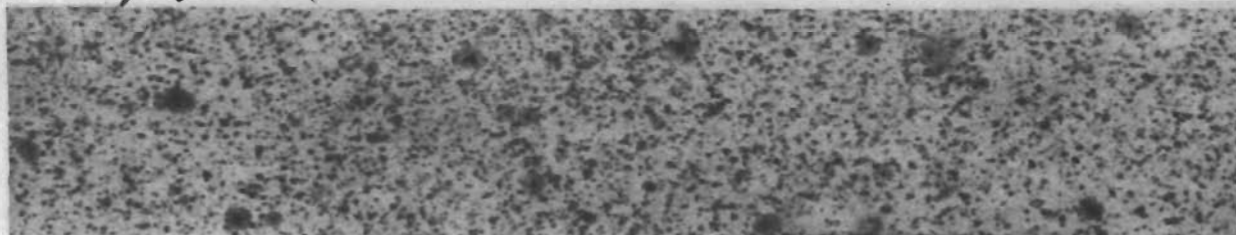
# Casualty Producing Effect of Mustard Vapor on Masked Men



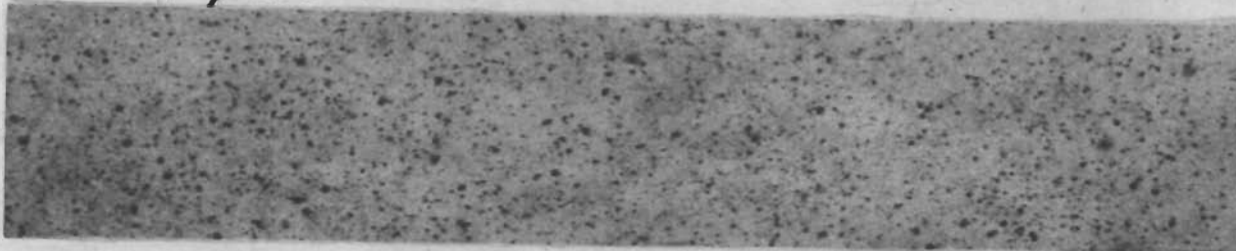
Points 1 & 2 from chamber tests given in PR 318.  
Point 3 is the estimate of the author of PR 318 after conducting the tests.  
Point A represents the chamber exposure of the author of PR 318.  
Point B represents the exposure of a man in the field at Edgewood Arsenal.

# *PATTERNS OF LIQUID HS ON PAPER PANELS*

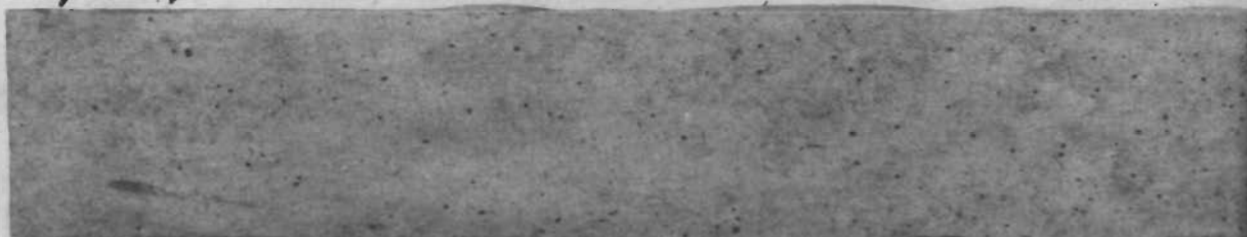
*Heavy pattern*



*Medium pattern*



*Light pattern*



*Trace pattern*



Appendix F

Report of Test of HS-Filled 155-mm. Howitzer Shell  
Tests "E" to "I" Inclusive.  
Year 1933.

REPORT  
OF  
TEST OF HS-FILLED, 155-mm. HOWITZER SHELL  
TESTS "E" TO "I" INCLUSIVE.  
YEAR 1933

Project A 1.1-1b

1. Object. The object of the tests described in this report was to determine the number of HS-filled 155-mm. howitzer shell required under various field conditions to produce 50% casualties, requiring evacuation for hospitalisation.

2. Authority. This work was authorized in the Project Program for Edgewood Arsenal for the fiscal years 1932 to 1934 inclusive under Project A 1.1-1b "155-mm. Shell, MII (How.), HS-Filled". It was a joint C.W.S.-Ordnance project and tests were conducted in accordance with program outlined by Ordnance Committee Minutes, Item 9241.

3. Previous Work. Five tests were conducted prior to the present tests, using HS-filled 155-mm. shell from the same lot of ammunition used in the present tests. A list of the previous tests is given below.

February 16 and 17, 1932: Thirty-six shell from each of four lots of ammunition representing shell used in the present tests, were fired for impact burst to determine if the shell functioned normally, but no attempt was made to measure the gas concentration set up.

May 23, 1932: Forty shell were fired for impact on a target 100 by 200 yd. It was estimated from the results that it would require about 25 shell per 100 yd. sq. to produce 50% casualties, when personnel are protected by gas mask only.

June 11, 1932: Forty shell were fired for impact on the target used in the test of May 23. It was estimated from the results that about 14 shell per 100 yd.sq. are required to produce 50% casualties, when man is protected by gas mask only.

August 4, 1932: Forty shell were fired for effect on a target 100 by 200 yd. It was estimated from the results of the test that about 8 shell per 100 yd. sq. are required to produce 50% casualties when personnel are protected by gas mask only. The test of August 4th was fired about 1 hr. before sunset whereas the two previous tests were fired at 9 a.m.

August 29, 1932: Twenty-eight shell were fired about 1 hr. before sunset for impact on a target 100 by 200 yd. From results of the test it was estimated that about 8 shell per 100 yd.sq. are required to produce 50% casualties when personnel are protected by gas mask only.

#### 4. Materials Used in the Present Test.

a. Shell. The shell used was the MII, 155-mm. filled with HS. They were obtained from War Reserve at Edgewood Arsenal and represent shell filled in the years 1921-1922, for shipment to the Hawaiian Islands. The HS used in filling the shell was from War Reserve and was probably made by the Leivinstein process. The void used in filling the HS into the shell is not known, but was probably about 10%, based on the maximum volume shell.

b. Booster. The booster used was the MVI-B, which contains a bursting charge of 29 g. of tetryl and 253 g. of TNT. Many of the boosters in these shell were improperly seated.

c. Fuze. The fuze used was the MIII super quick point detonating.

d. Howitzer Used. In all tests a battery of four howitzers was used in firing the shell, under command of an officer of the 6th Field Artillery. The implacment of the howitzers was on "C" field in the vicinity of coordinates 690.9, 1869.1, as shown on the special military map of Gunpowder Neck, prepared under the direction of the Chief of Engineers, U.S. Army.

5. Target. In all tests the target consisted of an area 100 yd. wide by 200 yd. deep, located on "H" field. The effectiveness of the gas concentration set up was determined with the use of paper panels or silhouettes, vapor sampling machines and animals which were placed on the target at definite positions.

#### 6. Method of Interpreting Results.

a. Paper Panels or Silhouettes. The paper panels or silhouettes placed on the target to register liquid HS, were collected after the firing and tabulated for size of HS drops and pattern produced, using the pattern scale attached to this report. Panel or silhouette data were interpreted as follows:

(1) Casualties Based on Penetration of Unimpregnated Clothing.

All paper panels were tabulated for pattern using the gradings heavy, medium, light and trace, as given on pattern scale accompanying this report. Casualties estimated from the gradings were based on the results of laboratory tests given in Memorandum of Oct. 22, 1931 to the Chief, Engineering Division from the Chief, Protective Development Division. From the results of these tests, it was estimated that personnel protected by gas mask and standard issue of unimpregnated clothing would experience casualties as follows:

Pattern on panel	Size of HS drops	Estimated man casualties thru standard issue of unimpregnated clothing
	mg.	%
H Heavy	.002 to 0.10	100
M Medium	.002 to .05	100
L Light	.002 to .05	80
T Trace	.001 to .03	60

(2) Casualties Based on Penetration of Impregnated Clothing.

The minimum size HS drops, as registered by paper panels, which will produce casualties when personnel are protected by gas mask and standard issue of impregnated clothing, were determined by laboratory tests reported in Memorandum of Aug. 6, 1931 to the Technical Director from the Chief, Protective Development Division. From these tests, it was concluded that HS drops of the following sizes would penetrate two layers of standard impregnated clothing and produce casualties as follows:

HS drops 0.5 mg. in size - 40% casualties  
HS drops 0.7 mg. in size - 80% casualties  
HS drops 0.8 mg. in size - 100% casualties

In the tests conducted, no attempt was made to classify drop sizes between 0.5 and 1.0 mg. due to difficulty in identifying the intermediate drop sizes.

b. HS Vapor Samples. A description of the vapor sampling machines and method of analysis of the HS is given in E.A.T.R. 55.

In the present report the respiratory effects of HS vapor were not considered but only vesicant effects, which in the case of HS vapor was based on its c.t. value. The c.t. value is the product of vapor concentration in milligrams per liter and the exposure period in minutes. Man casualties were figured from the c.t. value, using the valuation curve given on Graph 1. This curve was plotted from results of gas chamber tests given in Pharmacological Report No. 318. Aside from the points given on the graph to establish the curve, an additional point "B" is also given to represent exposure in the field of a man at Edgewood Arsenal who became a casualty for about 2 wks. due to vesicant effects of HS vapor. The vapor concentration and exposure period of this man was equivalent to a c.t. value of about .043, which corresponds on the curve, to 53% man casualties. All men are not equally resistant to HS vapor but the man exposed was shown by laboratory tests to represent an average subject. If a group of men, taken at random, were exposed to a c.t. value of .043 the valuation curve shows that about 53% would be casualties.

c. Based on Effects on Animals. In all tests, the animals were handled by the Medical Research Division and after each test, were subjected to observation by that division for a period of about 3 wks. The following symbols were used to designate the nature of the animal casualties.

N - not affected  
D - death  
E - simple conjunctivitis  
E<sub>2</sub> - cloudy cornea  
R - respiratory effects  
S - erythema of skin  
S<sub>2</sub> - second degree skin burns  
KF - killed by shell

The severity of the casualty was classified as light, medium, severe and death designated by LC, MC, SC, and D respectively.

All animal casualties were interpreted by the Medical Research Division in terms of man casualties. From the effects on the animal, it was estimated by the Medical Research Division, whether in their opinion, a man subjected to the same exposure as the animal, when protected by gas mask and standard issue of unimpregnated clothing, would have been a casualty. In the case of each animal, the answer was yes or no, so that no intermediate interpretations are given.

A man casualty is defined as one having an injury sufficiently severe to normally require evacuation for hospitalization.

In recording data in this report, at positions where two rats were exposed, if either rat was rated an estimated man casualty, estimated man casualties at that position are given a rating of 100 %.

7. Effective Concentration. In this report, an effective concentration is considered to be one which will produce 50% casualties when personnel are exposed to the effects of the vapor for a period of about 25 min.

8. Tests Conducted. The five tests were conducted and results obtained as follows:

a. Test of May 18, 1933.

(1) Object. The object of this test was to determine the effect of spring conditions on the number of HS-filled 155-mm. howitzer shell required to produce 50% casualties when fired at sundown at personnel protected by gas mask only, who are exposed in open country for a period of about 25 min. including firing.

(2) Materials Used. Thirty-nine MII, 155-mm. howitzer shell, filled with HS, were used in the test. The history of these shell and the type of fuze and booster used are given in paragraph 4.

(3) Target. The target was a rectangular area 100 yd. wide by 200 yd. deep, located in open country on "H" field in the vicinity of coordinates 690.5, 1863.8, and oriented so that the long axis was in line with the direction of fire. It was covered with grass and weeds having a height of about 6 in. of varying density and the soil was extremely wet. The target was divided into 10-yd. squares, by placing numbered stakes at 10-yd. intervals, and paper panels, 8 in. sq. were distributed over the area by placing one at each stake position. A silhouette 20 in. by 40 in., was placed at the center of each 10-yd. square and at the center of alternate 20 yd. squares, a goat was placed in a fox-hole, having a depth of about 18 in. On intervening 20 yd. squares, a rat in a cage was suspended from a stake at an elevation of 18 in. At alternate rat positions, a rat was placed in a cage on the ground under the rat suspended at an elevation of 18 in. The target was at a range of about 5,300 yd. from the position of the howitzers as given in paragraph 4.

Chart 1E accompanying this report, shows the target as it was prepared for the test with position of animals, panels and sampling machines.

(4) Firing of Shell.

(a) Adjustment of Howitzers. Sixteen shell were used. Registration fire was directed at a position about 100 yd. east of the target. Firing started at 4:09 p.m. and ended at 4:46 p.m.

(b) Fire for Effect. The four howitzers were ranged in parallel using three elevations for distribution of impacts. Firing for effect started at 5:21 p.m. and ended at 5:39 p.m., a period of 18 min. A photostatic copy of a Memorandum dated May 22, 1933 to Capt. C.E. Loucks, from the Battery Commander giving the firing data by round, is attached to this report.

(5) Meteorological Conditions.

(a) During the Firing Period and Following Hour.

Time: 5:21 p.m. to 5:39 p.m.  
 Air temperature, °F. 71  
 Ground temperature, °F. 81  
 Relative humidity, % 58  
 Barometric pressure 30.45  
 Wind velocity \* 4.0  
 Wind direction SSW  
 Sky clear

\*Taken at an elevation of 6 ft.

(b) During the First 14 Days Following Firing.

Date		Temp. °F.	Rainfall:	Cloudiness				
From:	To	Max. Min.	8 a.m. : in.	8 a.m. : 10 a.m.	10 a.m. : 12 noon	12 noon : 2 p.m.	2 p.m. : 4 p.m.	
5/18	5/19	75.9 : 48.0	60.8 : 0			clear	clear	clear
5/19	5/20	74.6 : 63.3	63.9 : trace	clear	clear	4/10	4/10	6/10
5/20	5/21	87.3 : 61.6	68.2 : 0.32	5/10	6/10	cloudy	cloudy	cloudy
5/21	5/22	81.5 : 60.3	71.1 : 0	4/10	5/10	2/10	clear	clear
5/22	5/23	79.0 : 55.6	66.0 : 0	cloudy	cloudy	cloudy	cloudy	6/10
5/23	5/24	76.9 : 65.0	61.9 : 0	cloudy	cloudy	cloudy	7/10	5/10
5/24	5/25	90.2 : 63.4	72.0 : .06	4/10	5/10	5/10	5/10	3/10
5/25	5/26	87.0 : 64.4	70.5 : 0	cloudy	6/10	8/10	cloudy	cloudy
5/26	5/27	86.3 : 69.0	78.3 : trace	clear	4/10	5/10	8/10	cloudy
5/27	5/28	89.2 : 65.4	78.0 : 0.49	6/10	3/10	clear	4/10	8/10
5/28	5/29	79.0 : 69.0	70.2 : 0	cloudy	cloudy	cloudy	cloudy	6/10
5/29	5/30	81.3 : 67.9	70.5 : trace	5/10	2/10	4/10	8/10	6/10
5/30	5/31	78.2 : 62.0	69.0 : 0.16	9/10	cloudy	cloudy	rain	rain
5/31	6/1	76.8 : 57.0	68.0 : 0	cloudy	cloudy	cloudy	cloudy	cloudy

(6) Results.

(a) Impacts. The position of impacts are shown on Chart 2E. Of the 23 shell fired for effect 15 registered on the target and 8 within a distance of 40 yd. of the target.

Of the 39 shell fired including the 16 used for adjustment, there were 5 duds, 1 low order burst, and 33 normal bursts.

(b) Liquid HS.

1. Size of HS Drops. The paper panels and silhouettes on the target area were tabulated for size of HS drops. Results are given in the following tables:

Table No. 1.

Number of Panels Showing HS Drops of 0.1 mg. or Over.

Panel:	No. of HS drops			
no.:	0.1 to	Over 0.5	Over 1.0	Over 3.0
	0.5 mg.:	to 1.0 mg.:	to 3.0 mg.:	mg.
6	:	:	1	:
7	:	2	:	:
17	:	1	:	:
20	:	75	:	25
26	:	:	:	3
27	:	:	:	1
28	:	3	:	1
29	:	3	:	:
30	:	:	:	1
31	:	25	:	50
38	:	:	:	2
39	:	100	:	2
41	:	10	:	20
42	:	5	:	10
43	:	:	:	3
52	:	10	:	20
54	:	1	:	:
55	:	3	:	:
73	:	3	:	:
83	:	1	:	1
86	:	15	:	1
87	:	3	:	5
89	:	12	:	2

Table No. 1 (Cont'd.)

Panel:		No. of HS drops			
no.:	0.1 to	Over 0.5	Over 1.0	Over 3.0	
	0.5 mg.:	1.0 mg.:	3.0 mg.:	mg.:	
90 :	5 :		1 :		
98 :		5 :			
99 :	75 :	25 :			
101 :	5 :				
112 :		2 :			
114 :	1 :				
116 :	3 :				
128 :	4 :				
133 :			3 :		
134 :	4 :	3 :	1 :		
136 :	2 :	1 :			
138 :	5 :	2 :			
141 :			1 :		
145 :	20 :	3 :			
146 :		10 :			
148 :		5 :	2 :		
155 :	5 :				1
157 :	3 :		2 :		1
191 :		3 :			
192 :	15 :	5 :			
194 :		3 :	5 :		1
198 :	100 :	100 :			
201 :			1 :		
202 :	5 :				
203 :	5 :	3 :			
205 :	25 :				
206 :		2 :			
212 :	2 :				
213 :	25 :	10 :			
214 :		5 :	5 :		
225 :		5 :			

Table No. 1A.

Number of Silhouettes Showing HS Drops of 0.1 mg. or Over.

Silhou- ette no.	No. of HS drops			
	0.1 to :0.5 mg.	:Over 0.5 :to 1.0 mg.	:Over 1.0 :to 3.0 mg.	:Over 3.0 : mg.
1	1			
6	20	5	5	
7	40	30	10	
8	5	3	1	1
9	500			
16	5	3	4	
17	5		3	5
18			1	1
19	10	3		
24		2	1	
25	25	25	10	5
26	10	10	1	
27	40	20	15	1
28	200	100		
29	50	40	10	5
30			2	
34	1			1
35	3	2	1	
36		2		
37	2			
38	10	3	1	
39	30	10	5	3
40	40	2		
44	5	2	1	
46	5			
47	10	2	1	
50	5	4		
57	5			2
58	20	10		
59	4			2
60		4		
61		2		
65		1		
66	2			
67	2			
68		3		
69	10	5		
71	10		2	
72	5			
74		2		
76	5			

Table No. 1A (Cont'd.)

Silhou- ette no.	No. of HS Drops			
	0.1 to 0.5 mg.	Over 0.5 to 1.0 mg.	Over 1.0 to 3.0 mg.	Over 3.0 mg.
79	:	:	2	:
82	:	10	:	20
83	:	10	:	10
101	:	5	:	3
102	:	5	:	2
106	:	20	:	3
107	:	4	:	:
112	:	5	:	3
114	:	10	:	5
115	:	5	:	:
116	:	10	:	:
117	:	20	:	:
121	:	10	:	5
122	:	10	:	2
123	:	10	:	2
124	:	5	:	1
125	:	5	:	2
131	:	20	:	2
132	:	20	:	10
133	:	5	:	3
141	:	3	:	3
142	:	3	:	1
176	:	50	:	2
177	:	50	:	5
178	:	5	:	:
182	:	5	:	5
183	:	10	:	1
184	:	20	:	:
185	:	5	:	2
186	:	5	:	1
192	:	2	:	:
193	:	10	:	5
194	:	20	:	5
195	:	2	:	5

(c) Estimated Man Casualties from Liquid HS.

1. Man Protected by Gas Mask but Without Protection of Impregnated Clothing.

A tabulation of the density of pattern on paper panels and silhouettes together with estimated man casualties are given in the following tables. The pattern scale is attached to this report. The basis of estimated casualties is explained in paragraph 7.

Table No. 2.

Estimated Man Casualties on Target Based on Liquid HS on Panels.

<u>Pattern; Panels classified; Estimated man</u>			
	<u>: No. :</u>	<u>Per cent of:</u>	<u>casualties for</u>
		<u>: total on target</u>	<u>: man protected</u>
		<u>: get</u>	<u>: by gas mask</u>
			<u>: only</u>
			<u>: %</u>
Heavy	: 8 :	3.5	: 3.5
Medium	: 23 :	10.0	: 10.0
Light	: 33 :	14.3	: 11.4
Trace	: 102 :	44.1	: 26.4
No HS	: 65 :	28.1	:
Total	: 231 :	100.0	: 51.3

Table No. 2A.

Estimated Man Casualties on Target Based on Liquid HS on Silhouettes.

Heavy	: 16 :	8.0	: 8.0
Medium	: 36 :	18.0	: 18.0
Light	: 34 :	17.0	: 13.6
Trace	: 52 :	26.0	: 15.6
No HS	: 62 :	31.0	:
Total	: 200 :	100.0	: 55.2

2. Man Protected by Gas Mask and Standard Impregnated Clothing.

From results in Tables No. 1 and 1A, tabulations are given in the following tables of the number of panels and silhouettes showing HS drops of 0.5 mg. or larger together with estimated man casualties. The basis of the estimated casualties is explained in paragraph 6,a,(2).

Table No. 3.

Estimated Man Casualties from Liquid HS Based on Panel Data.

Size of HS drops:		No. of:	Estimated casualties for	
		panels:	man protected by gas mask	
		:	and standard impregnated	
		:	clothing	
mg.	:	per panel	%:	target area %
One drop or more:	25	40	:	4.3
between 0.5 and	:	:	:	:
1.0 but with no	:	:	:	:
drop exceeding	:	:	:	:
1.0	:	:	:	:
One drop or more:	16	100	:	6.9
exceeding 1.0	:	:	:	:
Total	:	:	:	11.2

Total panels on target - 231

Table No. 3A.

Estimated Man Casualties from Liquid HS Based on Silhouette Data.

Size of HS drops:		No. of:	Estimated casualties for	
		silhouettes:	man protected by gas mask	
		:	and standard impregnated	
		:	clothing	
mg.	:	per panel	%:	target area %
One drop or more:	22	40	:	4.4
between 0.5 and	:	:	:	:
1.0 but with no	:	:	:	:
drops exceeding	:	:	:	:
1.0	:	:	:	:
One drop or more:	37	100	:	18.5
exceeding 1.0	:	:	:	:
Total	:	:	:	22.9

Total silhouettes on target - 200.

(d) Estimated Man Casualties from HS Vapor.

Vapor sampling machines were placed to take samples at positions shown on Chart 1. In Tables No. 4 and 4A which follow, the vapor concentration, c.t. value and per cent estimated man casualties from HS vapor, are given for each sampling position, representing man protected by gas mask but without protection of impregnated clothing. The basis of estimated casualties is explained in paragraph 6 b.

1. Firing Period and Following 15 Minutes.

Table No. 4.

Estimated HS Vapor Casualties on Target.

Sampling position:	Elevation of samples:	Vol. of air sampled:	HS sampled:	Vapor concn.:	c.t. value:	Estimated man casualties for man protected by gas mask only
:	ft.	liters	mg.	mg./l.	*	%
C	1	888	8.8	.0099	.25	100
F	1	880	1.8	.0020	.05	58
G	0	914	5.2	.0057	.14	100
J	0	862	5.6	.0065	.16	100
K	1	844	10.1	.0119	.30	100
N	1	884	0	0	0	0
O	0	830	1.8	.0022	.05	58
R	0	884	0	0	0	0
S	1	884	1.2	.0014	.03	41

\*The time period used in figuring the c.t. value was 25 min. (1/2 firing period plus 15 min).

Table No. 4A.

Estimated HS Vapor Casualties at Positions Outside of  
Target.

Sampling position:	Elevation of	Vol. of air sampled	HS sampled	Vapor concn.	c.t. value	Estimated man casualties for man protected by gas mask only
	ft.	liters	mg.	mg./l.		%
D	0	444	1.2	.0027	.07	78
	1	444	0			0
	2	444	0			0
	4	444	0			0
H	0	457	0			
	1	457	1.6	.0035	.09	87
	2	457	0			0
	4	457	0.4	.0009	.02	30
L	0	422	0			0
	1	422	0			0
	2	422	0			0
	4	422	0			0
P	0	415	0			0
	1	415	0			0
	2	415	0			0
	4	415	0			0
T	0	442	0			0
	1	442	0			0
	2	442	0			0
	4	442	0			0

(e) Estimated Man Casualties Based on Effects  
on Animals.

Animals consisting of goats and rats were placed on the target at positions shown on Chart 1E. Animal casualties and estimated man casualties, when man is protected by gas mask only, are given in Tables No. 5A, 5B, and 5C. Animal casualties and estimated man casualties, based on effects on animals, are shown on Charts 4E and 5E. The basis of estimated casualties and the symbols used to designate the nature of the animal casualties on the charts and in the tables, is explained in paragraph 7 c.

1. Firing Period and Following 15 Minutes.

Table No. 5A.

Estimated Man Casualties Based on Effects on Rats Suspended  
at an Elevation of 18 Inches.

Stake position:	Nature of: casualty :	Severity of casualty :	Estimated man casualties
	:	:	%
13	: ERS	: Death in	: 100
	:	: 5 days	:
85	: ERS	: Death in	: 100
	:	: 3 days	:
101	: S	: LC	: 100
193	: KF	: D	: 100

Total estimated man casualties - 4

Total rats suspended in cages - 25

Per cent estimated man casualties - 16%

Table No. 5B.

Estimated Man Casualties Based on Effects on Rats in  
Cages on Ground.

85	: ERS	: Death in	: 100
	:	: 3 days	:
129	: ERS	: Death in	: 100
	:	: 8 days	:
173	: S <sub>2</sub>	: Death in	: 100
	:	: 8 days	:
193	: ERS <sub>2</sub>	: Death in	: 100
	:	: 8 days	:

Total estimated man casualties - 4

Total rats exposed on ground - 13

Per cent estimated man casualties - 30.8%

Table No. 5C.

Estimated Man Casualties Based on Effects on Goats.

Stake position	Nature of casualty	Severity of casualty	Estimated man casualties
			%
19	ES	MC	100
39	ERS	Death in 3 days	100
43	E	LC	0
63	S	LC	100
79	ER	MC	0
107	E	LC	0
171	S	LC	0
195	ER	MC	0

Total estimated man casualties - 2

Total goats exposed - 25

Per cent estimated man casualties - 8%

2. Fifth and 14th Day After Firing.

Two goats were exposed in shell craters near stakes 74 and 116 for a period of 24 hr. on the fifth day after firing and two additional goats were exposed in craters near stakes 59 and 151 on the 14th day after firing.

Of the two goats exposed on the fifth day after firing, one was a medium casualty showing a second degree skin burn. The other goat exposed on the fifth day after firing and the two goats exposed on the 14th day after firing showed no casualty effects.

(7) Discussion.

(a) Shell Distribution. The positions of impacts on and around the target are shown on Chart 2E. There were 13 normal bursts on the target and 8 outside of the target. None of the bursts outside of the target were appreciably effective on the target.

(b) Impact Area. For purposes of study, the impact area may be regarded as that part of the target represented by the 20-yd. squares listed in Table No. 6A. The impact area is shown on Chart 1aE.

(c) Estimated Man Casualties from Liquid HS.

1. Effects of Meteorological Conditions.

The only meteorological factor having any effect on the size of the area covered with liquid HS, by burst of a single shell, is wind velocity. The wind velocity during the firing was 4.0 m.p.h. which was too low to have much effect on the pattern produced by the large HS drops. Previous field tests have demonstrated however, that under the prevailing wind conditions, a fine HS mist which will produce an HS pattern corresponding to trace in the pattern scale used, may be carried about 50 yd. from the position of burst.

2. Man Protected by Gas Mask but Without Protection of Impregnated Clothing.

It is estimated from results in Tables No. 2 and 2A that personnel protected by gas mask only if exposed with equal distribution on the target during firing, would experience about 51.3% casualties from liquid HS based on panel data and 55.2% based on silhouette data or an average of about 53.2% casualties based on silhouette and panel data. The liquid HS on the area, which was the basis of 53.2% estimated casualties, was due to the burst of 13 shell. On the basis of 13 shell on an area of 20,000 sq.yd. to produce 53.2% casualties from effects of liquid HS, when man is protected by gas mask only, it will require about 6.1 shell per 100 yd. sq. to produce 50% casualties.

3. Man Protected by Gas Mask and Standard Impregnated Clothing.

From results in Tables 3 and 3A, it is estimated that personnel protected by gas mask and standard impregnated clothing who are exposed on the target during the firing period, would experience from effects of 13 shell, about 11.2% casualties, based on panel data and 22.9% casualties based on silhouette data or an average of 16.5% casualties based on silhouette and panel data.

On the basis of 13 shell on an area of 20,000 sq.yd. to produce 16.5% casualties, when man is protected by gas mask and standard impregnated clothing, it will require about 20 shell per 100 yd. sq. to produce 50% casualties.

(d) Effects of HS Vapor.

1. Discussion of Meteorological Conditions.

In the present test the air temperature was 71°F. and wind velocity 4 m.p.h. These conditions were not extremely favorable for the use of HS as the temperature was a little low for rapid evaporation of the HS and the wind velocity slightly high as it carried the HS vapor away too fast for most effective results.

2. Firing Period and Following 15 Minutes.

(a). On Target.

Results of vapor samples taken at 9 sampling positions on the target are given in Table No. 4 for the firing period and following 15 min. The vapor concentration for each 20-yd. sq. of the target was figured from results in this table taking into account the positions of nearest impacts and wind direction. These results are given in the 5th column of Table No. 6. From the average of the figures in the 5th column, it is estimated that personnel with gas mask protection only, would experience about 56.6% casualties from HS vapor if exposed on the target during firing and the following 15 min.

The per cent estimated casualties for each 20-yd. sq. as given in Table No. 6, is shown graphically on Chart 3E. The shaded area on the chart represents that part of the area on which 100% casualties would be produced by the effects of HS vapor when man is protected by gas mask only. The per cent casualties shown on Chart E3 are based on the effects of 13 shell. If 13 shell distributed over an area of 20,000 sq.yd. will produce 56.6% casualties by effects of HS vapor, it will require about 6 shell correctly placed per 100 yd.sq. to produce 50% casualties when man is protected by gas mask only.

(b). Outside of Target.

Estimated man casualties at sampling positions 30 yd. downwind from the target are given in Table No. 4a for the firing period and following 15 min. Only two positions, D and H, showed the presence of HS. These sampling positions were located opposite the northeast corner of the target and are the positions where the highest vapor concentration would be expected. Personnel exposed at positions from D to H, during the firing period and following 15 min. would experience some casualties from effects of HS vapor if they were provided with gas mask protection only.

(e) Estimated Man Casualties Based on Effects on Animals.

1. Firing Period and Following 15 Minutes.

Animal casualties and estimated man casualties, based on effects on animals, are given in Tables No. 5A, 5B, and 5C for exposure on the target during firing and the following 15 min. The results in these three tables are consolidated in the last two columns of Table No. 6. From the consolidated results, it is estimated from animal casualties, that personnel protected by gas mask only, would experience 18% casualties if exposed on the target during the firing period and following 15 min.

2. Persistence of HS on Impact Area.

Results given in paragraph 9,a,(6),(e),2 show one animal casualty out of two exposed in shell craters for a period of 24 hr. on the 5th day after firing and no casualties out of two exposed on the 11th day after firing.

These results indicate that if the impact area is occupied for a period of about 24 hr. by personnel provided with only gas mask protection within the fifth day after firing, some casualties will be produced. It is probable that the area could be occupied following the 10th day after firing by personnel without gas mask protection, without experiencing serious casualties, provided shell craters are avoided.

(f) Comparison of Per Cent Estimated Masked Man Casualties Based on Measurements of the Gas Concentration and by Effects on Animals.

1. On Target (100 yd. by 200 yd.).

In Table No. 6, estimated man casualties are given for each 20 yd.sq., representing an animal position based on:

HS liquid as determined by panel data  
HS vapor as determined by vapor samples  
Combined effect of HS liquid and vapor from  
sample data  
From effects on animals

Results in Table No. 6, show 74.78% casualties based on effects of HS liquid and vapor present as determined by samples and 18% based on effects on animals.

Table No.6.

Estimated Masked Man Casualties on Target on Exposure  
During Firing and the Following 15 Minutes -  
(Area 20,000 sq.yd.) May 18, 1933

Stake no. at center of 20-yd. square	Impacts within 20-yd. square	From HS liquid Estimated man casualties	From HS vapor c.t.: Estima- valued man: casual- ties	From HS liquid and vapor Estimated man casualties	From effects on animals Animal casual- ties	Estimated man casualties
		%	%	%		%
13	0	0	.00	0	ERS death	100
					(2)	
15	0	29	.01	15	0	0
17	0	62	.10	93	0	0
19	1	75	.25	100	ES Med.	100
21	0	64	.12	100	0	0
35	0	0	.01	15	0	0
37	0	31	.03	42	0	0
39	2	67	.12	100	ERS death	100
41	0	86	.10	93	0	0
43	0	80	.14	100	E light	0
57	0	27	.05	58	0	0
59	0	40	.05	58	0	0
61	0	55	.10	93	0	0
63	1	71	.14	100	S light	100
65	1	69	.08	80	0	0
79	0	62	.15	100	ER Med.	0
81	1	53	.12	100	0	0
83	0	58	.06	66	0	0
85	1	69	.12	100	ERS death	100
					(1 & 2)	
87	0	78	.06	66	0	0
101	0	78	.12	100	S light	100
					(2)	
103	0	71	.16	100	0	0
105	0	62	.12	100	0	0
107	0	60	.30	100	E light	0
109	0	56	.06	66	0	0
123	1	73	.10	93	0	0
125	1	71	.16	100	0	0
127	1	73	.10	93	0	0
129	0	67	.10	93	ERS death	100
					(1)	
131	0	73	.02	30	0	0

Table No. 6. (Cont'd.)

Stake no. at center of 20-yd. square	Impacts: within 20-yd. square	From HS liquid: Estimated man casualties	From HS vapor: c.t. value Estimated man casualties	From HS liquid: Estimated man casualties	From effects on animals	Animal casualties	Estimated man casualties
		%	%	%			%
145	0	93	.00	0	93	0	0
147	1	71	.02	30	80	0	0
149	0	49	.02	30	64	0	0
151	0	42	.02	30	59	0	0
153	0	33	.01	15	43	0	0
167	0	62	.00	0	62	0	0
169	0	11	.0	0	11	0	0
171	0	13	.03	42	50	S light	0
173	0	24	.05	58	68	S <sub>2</sub> death	100
						(1)	
175	0	7	.02	30	35	0	0
189	0	40	.00	0	40	0	0
191	1	48	.02	30	64	0	0
193	1	71	.05	58	88	KF (2)	100
						ERS <sub>2</sub> (1)	
195	0	62	.03	42	78	ER Med.	0
197	0	20	.02	30	44	0	0
211	0	38	.00	0	38	0	0
213	0	75	.0	0	75	0	0
215	0	69	.00	0	69	0	0
217	0	27	.03	42	57	0	0
219	0	27	.03	42	57	0	0
Totals and	18	52.64		56.6	74.78		18%
Averages							

NOTE: Symbols used in column 7 to designate the nature of the animal casualties are explained in paragraph 6 c.  
 (1) designates rat in cage on ground.  
 (2) designates rat in cage suspended at an elevation of 18 in.

## 2. On Impact Area (15,200 sq.yd.).

The impact area as defined in paragraph 9,a,(7),(b) is shown on Chart 1aE and the 20-yd squares included within its area are tabulated in Table No. 6A. On its area of 15,200 sq.yd., there were 13 bursts. Results show 77.7% estimated casualties based on sample data and 18.5% based on animal data.

Table No. 6A.

Estimated Masked Man Casualties on Impact Area on Exposure  
During Firing and the Following 15 Minutes, -  
(Area 15,200 sq.yd.) May 18, 1933.

Stake no. at center of 20-yd. square	Impacts: within 20-yd. square	From HS liquid: Estimated casualties	From HS vapor: c.t.: Estima- value: ted man: casual- ties	From HS liquid: Estimated man casualties	From effects on and vapor animals Animal casual- ties	Estimated man casualties
		%	%	%		%
13	0	0	0	0	ERS death (2)	100
15	0	29	.01	15	0	0
17	0	62	.10	93	0	0
19	1	75	.25	100	ES Med.	100
21	0	64	.12	100	0	0
35	0	0	.01	15	0	0
37	0	31	.03	42	0	0
39	2	67	.12	100	ERS death	100
41	0	86	.10	93	0	0
43	0	80	.14	100	E light	0
57	0	27	.05	58	0	0
59	0	40	.05	58	0	0
61	0	55	.10	93	0	0
63	1	71	.14	100	S light	100
65	1	69	.08	80	0	0
79	0	62	.15	100	ER Med.	0
81	1	53	.12	100	0	0
83	0	58	.06	66	0	0
85	1	69	.12	100	ERS death (1 & 2)	100
87	0	78	.06	66	0	0
101	0	78	.12	100	S light (2)	100
103	0	71	.16	100	0	0
105	0	62	.12	100	0	0
123	1	73	.10	93	0	0
125	1	71	.16	100	0	0

Table No. 6A (Cont'd.)

Stake no. at center of 20-yd. square	Impacts within 20-yd. square	From HS liquid Estimated man casualties	From HS vapor c.t. Estima- valued man casualties	From HS liquid and vapor Estimated man casualties	From effects on animals Animal casualties	Estimated man casualties
		%	%	%		%
127	1	73	.10	93	98	0
145	0	93	.0	0	93	0
147	1	71	.02	30	80	0
149	0	49	.02	30	64	0
167	0	62	.0	0	62	0
169	0	11	.0	0	11	0
171	0	13	.03	42	50	S light
189	0	40	.0	0	40	0
191	1	48	.02	30	64	0
193	1	71	.06	58	68	KF (2)
						ERS <sub>2</sub> (1)
211	0	38	.0	0	38	0
213	0	75	.0	0	75	0
215	0	69	.0	0	69	0
Total and	13	56.3		89.3	77.7	13.5%
Averages						

NOTE: Symbols used in column 7 to designate the nature of the animal casualties are explained in paragraph 6 c.  
 (1) designates rat in cage on ground.  
 (2) designates rat in cage suspended at an elevation of 18 in.

Per cent estimated casualties based on the combined effects of HS liquid and vapor given in Table No. 6A, are considerably higher than corresponding percentages based on effects on animals. The discrepancy of these two sets of figures is partly accounted for by the fact that estimates based on effects on animals were very conservatively made and are probably low whereas, estimates based on HS vapor alone are probably high for average summer conditions. Also in arriving at per cent estimated man casualties based on effects on animals, no weight is given to certain animal casualties which individually are not considered the equivalent of a man casualty. On considering these facts, it is probable that an average of the animal and sample data is more nearly correct than percentage based on either method alone of obtaining data.

(g) Number of Shell Required to Produce 50% Man Casualties.

From figures given in Table No. 6A, it was estimated that the burst of 13 shell on an area of 15,200 sq.yd. would produce 77.7% casualties based on a measurement of the HS liquid and vapor present, and 18.5% based on effects on animals, when man is exposed during the firing period and following 15 min. On this basis the following number of shell per 100 yd.sq. will be required to produce 50% casualties when man is protected by gas mask only.

Based on HS liquid and vapor samples -	5.5	shell
Based on effects on animals -	22.9	"
Average -	14.2	"

(h) Rate of Fire.

The 23 shell used for effect were fired in a period of 18 min. This rate of fire was too slow for most effective results.

(8) Conclusions. From the results of the present test, the following conclusions are drawn with respect to the use of 155-mm. howitzer shell filled with HS, when fired under the meteorological conditions existing at the time of the test.

(a) The number of shell required per 100 yd.sq. to produce 50% casualties when distributed as equally as practicable, are as follows:

1. When man protected by gas mask and standard impregnated clothing is exposed during the firing period - 20 shell (see p. 17).

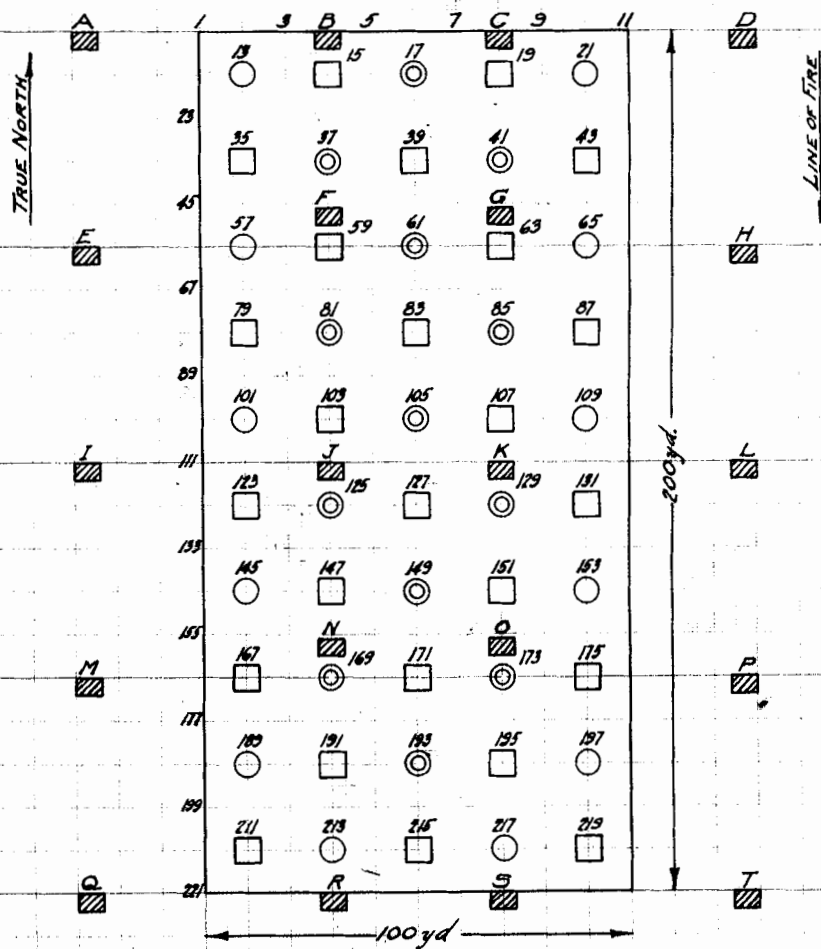
2. When man protected by gas mask only, is exposed during the firing period and following 15 min. - about 14 shell (see (7), (g), above).

(b) That this test be repeated because of the slow rate at which the shell were fired for effect.

CHART 1  
TEST OF HS FILLED 155-mm HOWITZER SHELL.  
(PROJECT A.I.I-16)

MAY 18, 1933

TARGET AREA



+ LEGEND +

- Goat
- ▨ Sampling Machine
- Rat in Cage Suspended at Elevation of 18 inches.
- ⊙ Rat in Cage on Ground in Addition to Rat in Cage Suspended at Elevation of 18 inches.

+ NOTE +

PAPER PANELS 8" SQUARE WERE PLACED AT STAKE POSITIONS. SILHOUETTES 20"x40" WERE PLACED AT THE CENTER OF EACH 10 YD. SQUARE.

50 YDS  
SCALE

### POSITION OF IMPACTS

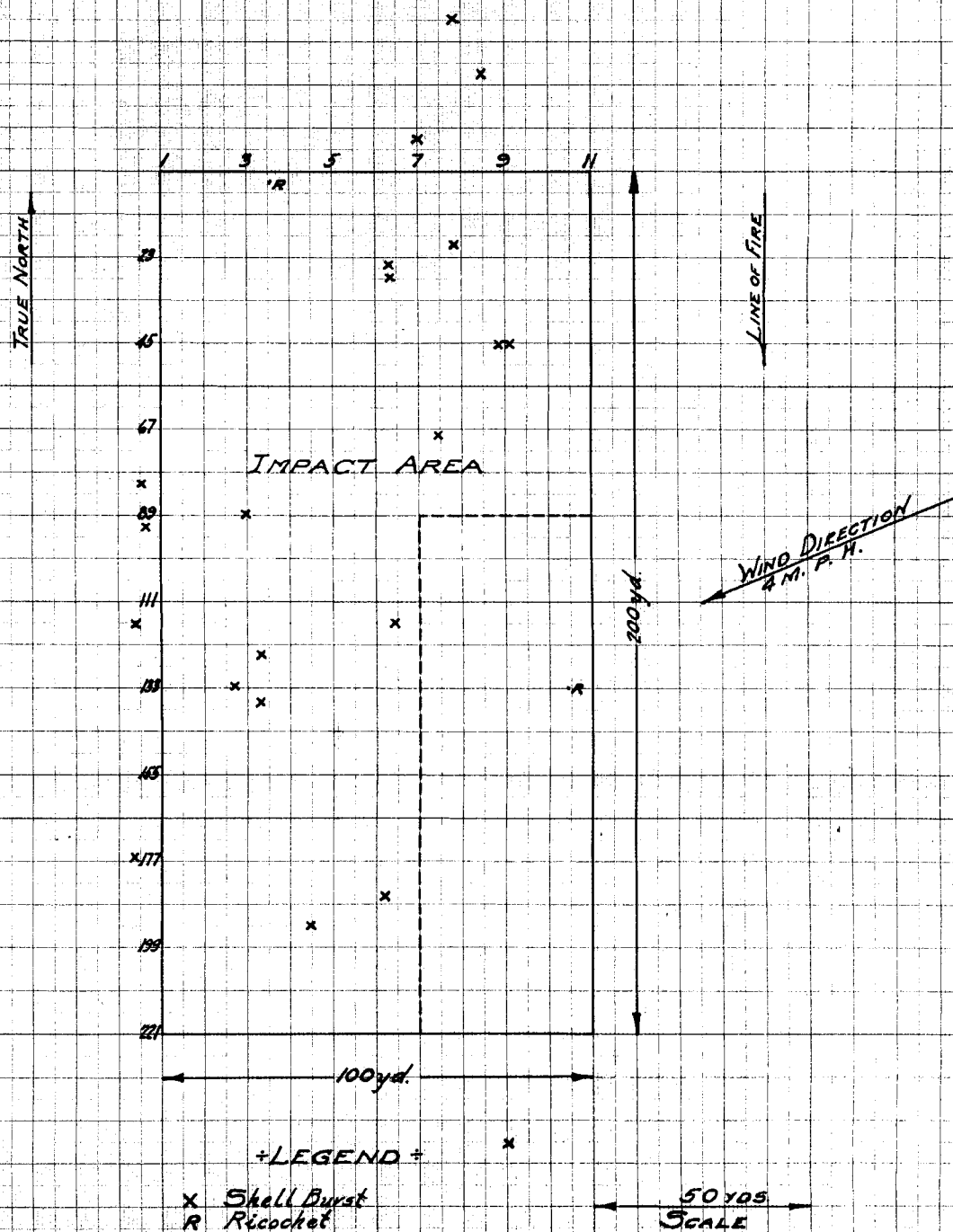
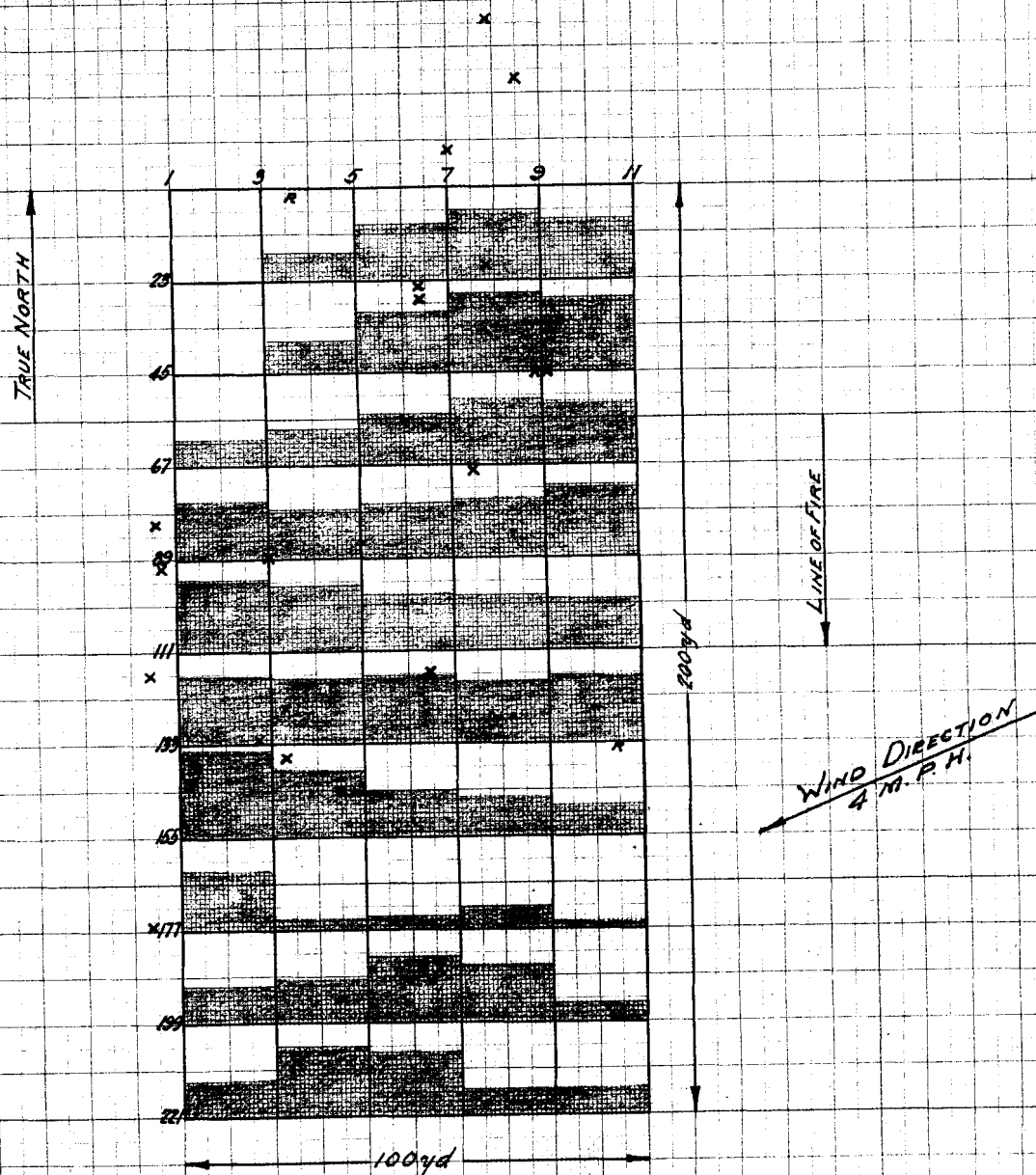


CHART 2 E  
 TEST OF HS FILLED 155-mm HOWITZER SHELL  
 (PROJECT A1.1-16)  
 MAY 18, 1933  
 ESTIMATED MAN CASUALTIES DUE TO EFFECTS  
 OF HS LIQUID.



\*LEGEND\*

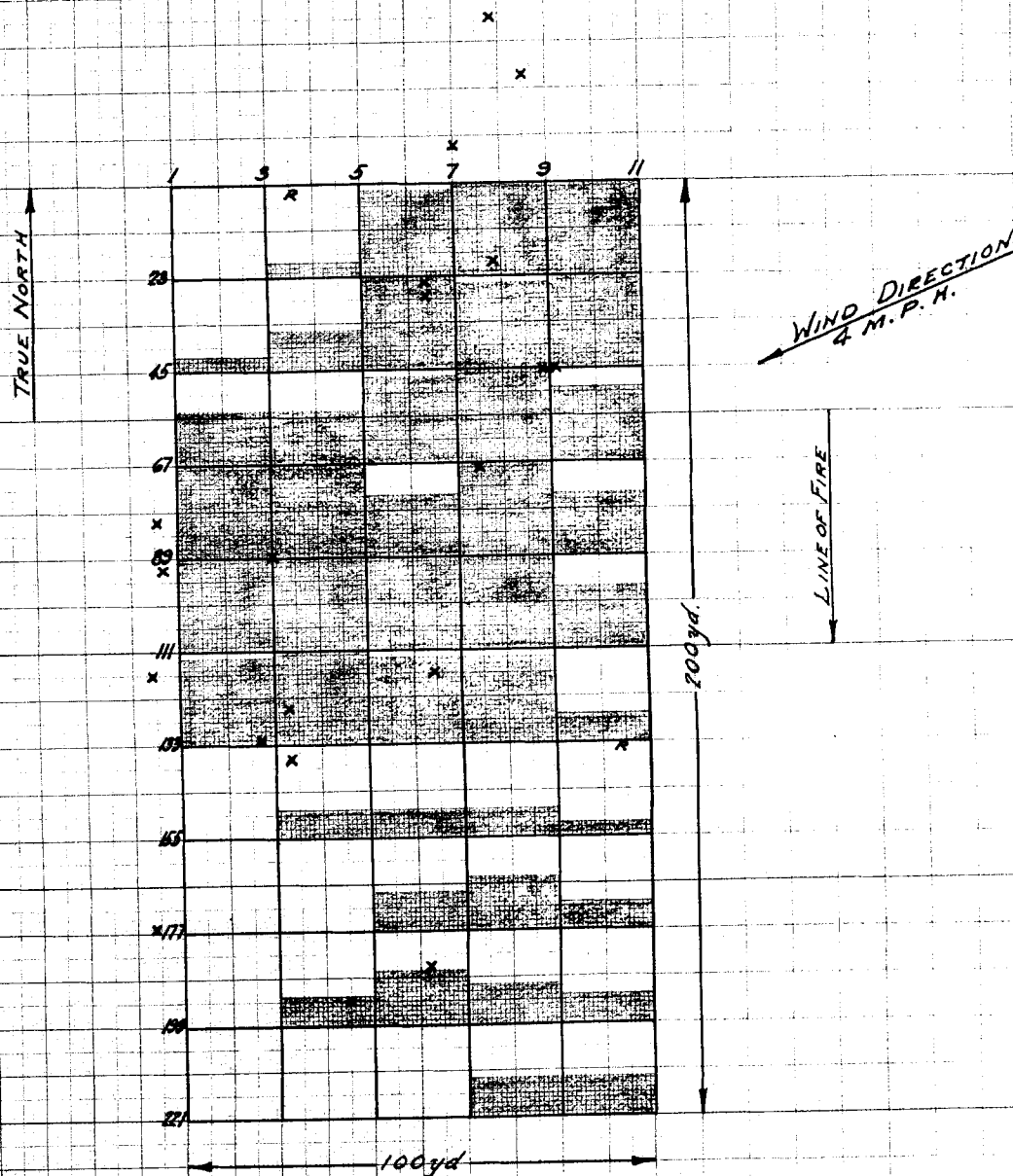
X Position of Burst  
 R Ricochet  
 Shaded Area Represents  
 100% Max Casualties.

\*NOTE\*

MAN PROTECTED BY GAS MASK AND  
 STANDARD ISSUE OF UNIMPREGNATED  
 CLOTHING.  
 CASUALTIES BASED ON EXPOSURE DURING  
 THE FIRING PERIOD.

50 YDS.  
 SCALE

CHART 3E  
 TEST OF H5 FILLED 155-mm HOWITZER SHELL  
 (PROJECT A.I.1-18)  
 MAY 18, 1933  
 ESTIMATED MAN CASUALTIES DUE TO EFFECTS  
 OF H5 VAPOR \*



\* LEGEND \*  
 X Position of Burst  
 R Rocket  
 Shaded Area Represents  
 100% Max Casualties.

\* NOTE \*

MAN PROTECTED BY GAS MASK AND  
 STANDARD ISSUE OF UNIMPREGNATED  
 CLOTHING.

\* CASUALTIES BASED ON EXPOSURE DURING  
 FIRING PERIOD AND FOLLOWING 15 MINUTES.

CHART 4E

(PROJECT A11-18)

MAY 18. 1933

ANIMAL CASUALTIES DUE TO EXPOSURE DURING  
FIRING AND FOLLOWING 15 MINUTES.



LINE OF FIRE









WIND DIRECTION  
M. P. H.

-200yd-

100yd.

RAT + LEGEND +

GOAT

- |   |   |   |
|---|---|---|
|  | LC - Light Casualty.                      |  |
|  | MC - Moderate Casualty.                   |  |
|  | D - Death.                                |  |
|   | E - Contaminations.                       |  |
|   | R - Respiratory Effects.                  |   |
|   | S - Erythema of Skin.                     |   |
|   | S <sub>2</sub> - Second Degree Skin Burn. |   |
|   | KF - Killed By Shell.                     |   |
|   | (1) - Rat on Ground.                      |   |
|   | (2) - Rat Suspended.                      |   |
|   | No Casualty.                              |  |

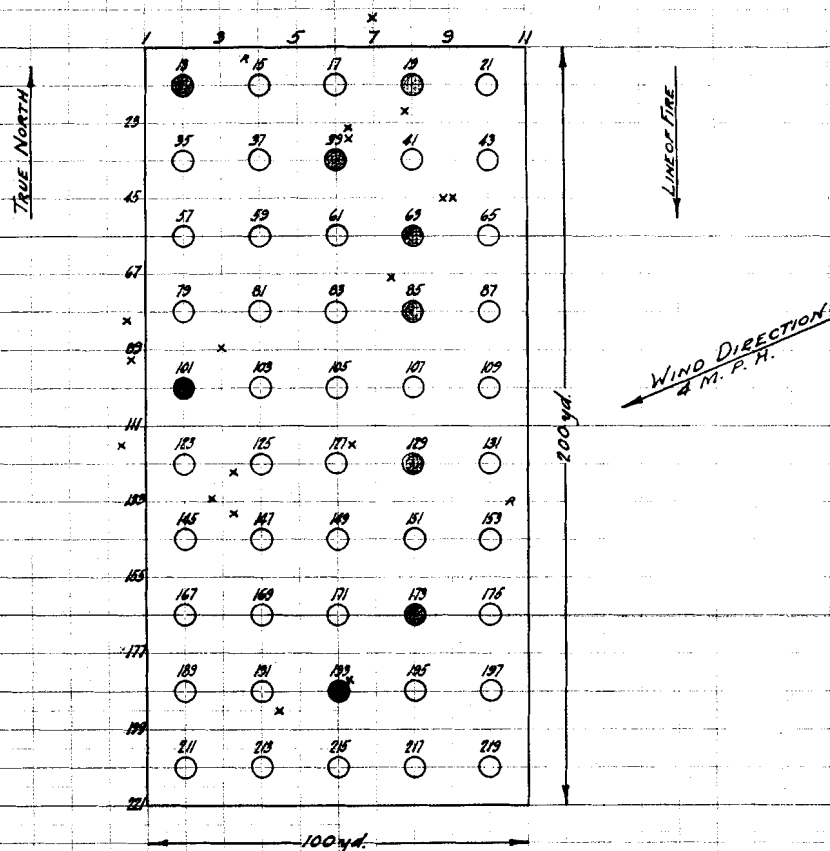
- |   |   |
|---|---|
| ○ | Rat Suspended at Elevation of 18" only.                     |
| ○ | Rat in Cage on Ground and Rat Suspended at Elevation of 18" |
| x | Shell Burst.  |
| R | Ricochet  |

50 yds  
9 cal

CHART 5 E  
TEST OF HS FILLED 155-mm HOWITZER SHELL.  
(PROJECT A1-10)

MAY 18, 1933

ESTIMATED MAN CASUALTIES BASED ON EFFECTS  
ON ANIMALS EXPOSED DURING FIRING AND  
FOLLOWING 15 MINUTES.



+ LEGEND +

- Estimated no Casualties.
- Estimated man Casualties.
- x Shell Burst.
- R Ricochet.

50 YDS  
SCALE

b. Test of June 15, 1933.

(1) Object. To determine the effect of meteorological conditions typical of spring on the number of HS-filled 155-mm. howitzer shell required to produce 50% casualties when fired about 1 hr. before sundown at personnel protected by gas mask only, who are exposed in open country, for a period of about 25 min. including the firing period.

(2) Materials Used. Thirty-eight MII, 155-mm. howitzer shell filled with HS, were used in the test.

(3) Target. The target was a rectangular area 100 yd. wide by 200 yd. deep, located in open country on "H" field in the vicinity of coordinates 690.5, 1863.8, and oriented so that the long axis was in line with the direction of fire. It was covered with grass and weeds having a height of about 1 ft. and the soil was dry. The target was divided into 10-yd. squares, by placing numbered stakes at 10 yd. intervals. Paper panels 8 in. square, were distributed over the area by placing one at each stake position. On alternate 20-yd. squares, a goat was placed in a fox-hole about 18 in. deep, located at the center of each square. On intervening 20-yd. squares, a rat in a cage was suspended from a stake at an elevation of 18 in. At alternate rat positions, a cage containing a rat was placed under the suspended rat. The target was located at a range of about 5300 yd. from the position of the howitzers on "C" field, (see par. 4). Chart 1F, accompanying this report shows the target as it was prepared for the test with position of animals, panels and vapor sampling machines.

(4) Firing of Shell.

(a) Adjustment. Twelve shell were used. Registration fire was directed at a position about 100 yd. east of the target. Firing started at 4:51 p.m. and ended at 5:15 p.m.

(b) Fire for Effect. The howitzers were ranged in parallel for impact on a line through the short axis of the target. Firing for effect started at 6:00 p.m. and ended at 6:11 p.m., a period of 11 min. Twenty-six shell were used.

A photostatic copy of a memorandum dated June 30, 1933 to Capt. C.E. Loucks from the Battery Commander giving firing data by round, is attached to this report.

(5) Meteorological Data.

(a) Firing Period and Following Hour.

Time	6:00 to 6:31 p.m.	6:01 to 7:16 p.m.
Air temperature, °F.	69	67
Ground temperature, °F.	72	66
Relative Humidity, %	41	56
Wind velocity, m.p.h.*	2.0	less than 1.0
Wind direction	NE	NE
Sky	clear	clear

\*Taken at an elevation of 6 ft.

(b) First Six Days Following Test.

Date :		Temp. °F.	Rainfall:		Cloudiness					
From:	To :	Max.:Min.:	8 a.m.:	inches :	8 a.m.:	10 a.m.:	12 noon:	2 p.m.:	4 p.m.:	
6/15:	6/16:	69.7:52.9:	56.0 :	0.30 :	5/10 :	6/10 :	9/10 :	3/10 :	1/10 :	
6/16:	6/17:	69.1:59.2:	61.9 :	0 :	cloudy:	cloudy :	cloudy :	cloudy :	rain :	
6/17:	6/18:	81.5:55.0:	61.7 :	0 :	cloudy:	7/10 :	cloudy :	cloudy :	6/10 :	
6/18:	6/19:	78.0:59.0:	63.6 :	0 :	cloudy:	cloudy :	8/10 :	2/10 :	clear :	
6/19:	6/20:	82.6:63.4:	65.1 :	0 :	cloudy:	7/10 :	2/10 :	4/10 :	5/10 :	
6/20:	6/21:	84.0:59.0:	74.6 :	0 :	6/10 :	5/10 :	8/10 :	cloudy :	cloudy :	
6/21:	:	:	74.6 :	:	8/10 :	2/10 :	clear :	:	:	

(6) Results.

(a) Impacts.

The positions of bursts are shown on Chart 2F. Of the 26 shell fired for effect, there were 14 bursts on the target and 6 additional within 40 yd. of the target.

Of the 38 shell fired, including the 12 used for adjustment, there were a total of 7 duds.

(b) Liquid HS.

The paper panels on the target were tabulated for size of drops. Results are given in the following table:

Table No. 7.

Number of Panels Showing HS Drops of 0.1 mg. or Larger.

Panel: no.	No. of HS drops			
	:0.1 to	:Over 0.5	:Over 1.0	:Over 3.0
	:0.5 mg.:	:to 1.0 mg.:	:to 3.0 mg.:	mg.
4	5	3	2	:
25	20	6	2	:
38	10	6	4	:
40	10	4	:	:
47	100	10	4	:
68	:	1	:	:
78	:	4	1	:
79	50	4	:	:
89	3	:	:	:
90	20	:	:	:
102	:	1	:	:
119	3	1	1	:
124	3	1	1	:
126	6	:	:	:
134	10	2	2	:
139	3	:	2	:
150	:	:	1	:
155	:	3	:	:
156	2	:	:	:
187	2	:	:	:

Total panels on target - 231.

(c) Estimated Man Casualties from Liquid HS.

1. Man Protected by Gas Mask but without Protection of Impregnated Clothing.

The paper panels on the target were tabulated for density of pattern using the gradings heavy, medium, light, and trace. A photostat of the scale used in grading the panels is attached to this report. The panel gradings are tabulated in the following table, together with estimated man casualties. The basis of estimated casualties is explained in paragraph 6,a.

Table No. 8.

Estimated Man Casualties from HS Liquid Based on Panel Data.

Pattern:	Panel	classified:	Estimated man
:	No. :	Per cent of:	casualties
:	:	total on :	when man is
:	:	target :	protected by
:	:	:	gas mask only
:	:	:	%
Heavy :	34 :	14.6 :	14.6
Medium:	46 :	20.0 :	20.0
Light :	49 :	21.2 :	17.1
Trace :	85 :	36.8 :	22.1
No HS :	17 :	7.4 :	
Total :	231 :	100.0 :	73.8

2. Man Protected by Gas Mask and Standard Impregnated Clothing.

From results in Table No. 7, a tabulation is given in Table No. 9 of panels showing HS drops of 0.5 mg. or larger together with estimated casualties for man protected by gas mask and standard impregnated clothing. The basis of estimated casualties is explained in paragraph 6,a,(2).

Table No. 9.

Estimated Man Casualties from HS Liquid Based on Panel Data.

Size of HS:	No. of:	Estimated casualties for
drops :	panels:	man protected by gas mask
:	:	and standard impregnated
:	:	clothing
mg. :	:	Per panel %:
:	:	target area %
One drop :	5 :	40 :
or more be-	:	:
tween 0.5 :	:	:
and 1.0 but	:	:
with no :	:	:
drop ex-	:	:
ceeding 1.0:	:	:
One drop :	10 :	100 :
or more :	:	:
exceeding :	:	:
1.0 :	:	:
Total :	:	- 28 - :

Total panels on area - 231.

(d) Estimated Man Casualties from HS Vapor.

Vapor samples were taken at positions shown on Chart 1F. In Tables 10, 10A, 11 and 11A, which follow, the vapor concentration, c.t. value, and per cent estimated casualties from HS vapor, for man protected by gas mask only, are given for each sampling position. The basis of estimated casualties is explained in paragraph 6 b.

1. Firing and Following 20 Minutes.

Table No. 10.

Estimated Masked Man Casualties on the Target from HS Vapor.

Sampling position:	Elevation of sample	Vol. of air sampled	HS : mg.	Vapor : concn. : mg./l.	c.t. value : *	Estimated man casualties for man protected by gas mask only
	ft.	liters				%
C	1	842	11.4	.0135	.54	100
F	1	802	35.3	.0440	1.10	100
G	0	842	5.4	.0064	.16	100
J	0	884	63.8	.0720	1.81	100
K	1	434	11.6	.0268	.67	100
N	1	884	4.0	.0045	.11	100
O	0	884	10.7	.0124	.31	100
R	0	884	0.6	.0007	.02	30
S	1	884	0.4	.0005	.01	11
Av.						82.3

\*Based on a time period of 25 min. (1/2 firing period plus 20 min.).

Table No. 10A.

Estimated Masked Man Casualties from HS Vapor Outside of the Target.

Sampling position:	Elevation of sample	Vol. of air sampled	HS sampled	Vapor concn.	c.t. value	Estimated man casualties for man protected by gas mask only
	ft.	liters	mg.	mg./l.		%
D	0	421	0			0
D	1	421	0			0
D	2	421	0			0
D	4	421	0			0
E	0	401	0.2	.0005	.01	11
	1	401	1.0	.0025	.06	66
	2	401	0.4	.0010	.03	42
	4	401	2.2	.0056	.14	100
H	0	422	1.2	.0029	.07	73
	1	422	0.4	.0010	.02	30
	2	422	0.4	.0010	.02	30
	4	422	0.4	.0010	.02	30
I	0	442	0.3	.0008	.02	30
	1	442	1.1	.0025	.06	66
	2	442	0.2	.0004	.01	11
	4	442	0.4	.0010	.03	41
L	0	434	0		0	0
	1	434	0		0	0
	2	434	0		0	0
	4	434	0		0	0
M	0	442	0		0	0
	1	442	0		0	0
	2	442	0		0	0
	4	442	lost		lost	0
P	0	434	0		0	0
	1	434	0		0	0
	2	434	0		0	0
	4	434	0		0	0
Q	0	442	lost		lost	-
	1	442	0		0	0
	2	442	0		0	0
	4	442	.2	.0004	.02	30
T	0	442	0		0	0
	1	442	0		0	0
	2	442	0		0	0
	4	442	0		0	0

2. From the 30th to 65th Minute after Firing.

Table No. 11.

Estimated Masked Man HS Vapor Casualties on the Target.

Sampling position:	Elevation of	Vol. of air sampled	HS sampled	Vapor concn.	c.t. value	Estimated man casualties for man protected by gas mask only
: sample	: ft.	: liters	: mg.	: mg./l.	: :	: %
C	: 1	: 1180	: 15.7	: .0153	: .47	: 100
F	: 1	: 570	: 10.0	: .0175	: .61	: 100
G	: 0	: 1180	: 2.2	: .0019	: .06	: 66
J	: 0	: 1234	: 12.9	: .0105	: .37	: 100
K	: 1	: 1216	: 12.5	: .0103	: .36	: 100
N	: 1	: 1234	: 1.6	: .0013	: .05	: 59
O	: 0	: 1216	: 5.2	: .0043	: .15	: 100
R	: 0	: 1234	: 0.0	: 0	: 0	: 0
S	: 1	: 1234	: 0.0	: 0	: 0	: 0
Av.						69.4

Table No. 11A.

Estimated Masked Man HS Vapor Casualties Outside the Target.

D	: 0	: 590	: 0	: 0	: 0	: 0
	: 1	: 590	: 0.4	: .0007	: .02	: 30
	: 2	: 590	: 1.0	: .0017	: .06	: 66
	: 4	: 590	: 0	: 0	: 0	: 0
H	: 0	: 590	: 0	: 0	: 0	: 0
	: 1	: 590	: 0	: 0	: 0	: 0
	: 2	: 590	: 0	: 0	: 0	: 0
	: 4	: 590	: 0	: 0	: 0	: 0
L	: 0	: 608	: 0	: 0	: 0	: 0
	: 1	: 608	: 0	: 0	: 0	: 0
	: 2	: 608	: 0	: 0	: 0	: 0
	: 4	: 608	: 0	: 0	: 0	: 0
P	: 0	: 608	: 0	: 0	: 0	: 0
	: 1	: 608	: 0	: 0	: 0	: 0
	: 2	: 608	: 0	: 0	: 0	: 0
	: 4	: 608	: 0	: 0	: 0	: 0

Table No. 11A (Cont'd.)

Sampling position:	Elevation of sample	Vol. of air sampled	HS sampled	Vapor concn.	c.t. value	Estimated man casualties for man protected by gas mask only
	ft.	liters	mg.	mg./l.		%
T	0	617	0	0	0	0
	1	617	0	0	0	0
	2	617	0	0	0	0
	4	617	0	0	0	0
E	0	562	0.2	.0004	.01	11
	1	562	1.4	.0025	.09	87
	2	562	0.6	.0010	.03	42
	4	562	3.2	.0056	.20	100
I	0	618	0.5	.0008	.03	42
	1	618	1.5	.0025	.09	87
	2	618	0.2	.0004	.01	11
	4	618	0.6	.0010	.04	51
M	0	618	0	0	0	0
	1	618	0	0	0	0
	2	618	0	0	0	0
	4	618	lost	0	0	0
Q	0	618	lost	0	0	-
	1	618	0	0	0	0
	2	618	0	0	0	0
	4	618	0.2	.0004	.01	11

(e) Estimated Man Casualties Based on Effects on Animals.

Animals consisting of goats and rats were placed on the target at positions shown on Chart 1F. Animal casualties and estimated man casualties, for man protected by gas mask only, are given in Tables No. 12A, 12B, and 12C. Animal casualties and estimated man casualties, based on effects on animals, are shown on Charts 5F and 6F. The basis of estimated casualties and the symbols used to designate the nature of the animal casualties on the charts and in the tables are explained in paragraph 6 c.

1. Firing Period and Following 20 Minutes.

Table No. 12A.

Estimated Masked Man Casualties Based on Effects on  
Rats Suspended at an Elevation of 18 in.

Position: of stake	Nature of casualty	Severity of casualty	Estimated man casualties
			%
17	S <sub>2</sub>	MC	100
101	S	Death in: 4 days	100
145	S	Death in: 5 days	100
149	KF		100

Total estimated man casualty positions - 4  
Total rats suspended in cages - 25  
Estimated man casualties on the target  
based on rats suspended in cages - 16%

Table No. 12B.

Estimated Masked Man Casualties Based on Effects on  
Rats in Cages on Ground.

17	R	LC	0
37	S	LC	100
61	S <sub>2</sub>	MC	100
125	S <sub>2</sub>	MC	100

Total estimated man casualty positions - 3  
Total rats in cages on ground - 13  
Estimated man casualties on the target  
based on rats in cages on ground - 23%

Table No. 12C.

Estimated Masked Man Casualties Based on Effects on Goats.

Position: of stake	Nature : of : casualty:	Severity : of : casualty:	Estimated man cas- : ualties
			%
15	: ERS	: SC	: 100
19	: ER	: LC	: 0
35	: ERS	: Death in:	100
		: 3 days :	
39	: R	: LC	: 0
43	: R	: LC	: 0
59	: ERS	: SC	: 100
79	: ERS	: SC	: 100
87	: S	: LC	: 0
103	: ERS	: Death in:	100
		: 6 days :	
107	: E	: LC	: 0
123	: ER	: SC	: 0
127	: ER	: SC	: 0
131	: ERS	: SC	: 100
147	: R	: LC	: 0
151	: ER	: MC	: 0
167	: ER	: MC	: 0
175	: ER	: MC	: 0

Total estimated man casualty positions - 6

Total goats exposed - 25

Estimated man casualties based on goats  
exposed - 24%.

2. Second and Fifth Day After Firing.

Two goats were exposed in shell craters near stake numbers 78 and 79 for a period of 24 hr. on the 2nd day after firing and two additional on the 5th day after firing. The following results were obtained:

2nd Day After Firing

<u>Stake No.</u>	<u>Nature of Casualty</u>
78	N
79	severe (S <sub>2</sub> R)

5th Day After Firing

<u>Stake No.</u>	<u>Nature of Casualty</u>
78	N
79	medium (S <sub>2</sub> )

(7) Discussion.

(a) Shell Distribution. The positions of impacts on and around the target are shown on Chart 2F. There were 14 normal bursts on the target and four within the first 30 yd. north of the target which were partly effective in the target. It is estimated that the effects of these four shell north of the target were equivalent to the burst of one shell directly on the target so that total shell effects on the target were equivalent to the burst of 15 shell.

(b) Impact Area. For purposes of study, the impact area will be considered as having a size 160 yd. by 100 yd. and to consist of that part of the target north of a line parallel with the short axis of the area passing through the position of stake 177. The impact area is shown on Chart 2F.

(c) Estimated Man Casualties from Liquid HS.

1. Effects of Meteorological Conditions.

The wind velocity during firing was 2.0 m.p.h. This velocity was too low to influence appreciably the drift of HS drops of a size in excess of 0.5 mg. but fine HS mist, which produces a pattern corresponding to trace in the pattern scale used, may be carried 25 yd. or more from the position of burst.

2. Man Protected by Gas Mask but Without Protection of Impregnated Clothing.

It is estimated from results given in the third column of Table No. 13, which are based on panel data, that personnel provided with gas mask protection only, who are exposed with equal distribution on the target during firing will experience about 75.7% casualties from liquid HS. Effects on the target were due to the burst of 15 shell as discussed in paragraph 2,b,(7),(a), above.

3. Man Protected by Gas Mask and Standard Impregnated Clothing.

From results in Table No. 9, it is estimated that personnel protected by gas mask and standard impregnated clothing, would experience about 5.2% casualties from effects of liquid HS if exposed with equal distribution on the target during the firing period.

Results on the target, which represented an area of 20,000 sq.yd., was due to the burst of 15 shell. On this basis it will require 72 shell per 100 yd. sq. to produce 50% casualties, when man is protected by gas mask and standard impregnated clothing.

(d) Effects of HS Vapor.

1. Effect of Meteorological Conditions on the Effectiveness of HS Vapor.

In the present test, the air temperature was 69°F. and wind velocity 2 m.p.h. The wind velocity was favorable to build up a high vapor concentration as the wind travel was only about 60 yd. per minute. The air temperature was unfavorable however, as the vapor pressure of HS at 69°F. is only 0.65 mm./Hg which is less than one half the vapor pressure at a temperature of 86°F. which is a temperature representative of summer conditions at Edgewood Arsenal.

2. Firing Period and Following 20 Minutes.

(a) On Target.

Results of vapor samples taken at 9 sampling positions on the target are given in Table No. 10 for the firing period and following 20 min. The vapor concentration for each 20-yd. sq. of the target was figured from results in this table taking into consideration the positions of nearest impacts and wind direction. The results of these calculations are given in the fifth column of Table No. 13. From the average of the figures in the fifth column, it is estimated that personnel with gas mask protection only, would experience about 88.1% casualties if exposed on the target during firing and the following 20 min.

Per cent estimated casualties from effects of HS vapor is shown graphically on Chart 3F. The shaded area on the chart represents that part of the target on which it is estimated 100% casualties would be produced by effects of HS vapor when man is protected by gas mask only.

(b) Outside of Target.

Estimated casualties at sampling positions 30 yd. downwind from the target are given in Table No. 10A for the firing period and following 20 min. Only two position, E and I showed the presence of HS and at these positions estimated casualties varied from 11 to 100 per cent. These positions are located directly downwind from the impacts on the target. The results given in Table No. 10A show that personnel protected by gas mask only, exposed about 30 yd. downwind from the impact position during the firing period and following 20 min., would experience some casualties.

3. From the 30th to 65th Minute After Firing.

(a) On the Target.

From results of vapor samples given in Table No. 11, it is estimated that man protected by gas mask only would experience about 69.4% casualties from effects of HS vapor if exposed on the impact area from the 30th to 65th min. after firing. This estimate is based on average results of vapor samples taken at 9 positions distributed over the target.

Estimated casualties from the effects of HS vapor on exposure with protection of gas mask only on the target, for the period between the 30th and 65th min. after firing, is shown graphically on Chart 3aF.

(b) Outside of Target.

Estimated vapor casualties are given in Table No. 11A, based on results at sampling positions 30 yd. downwind. From the results obtained, it is estimated that personnel protected by gas mask only, would experience from 11 to 100 per cent casualties if exposed 30 yd. downwind from the impact position during the period from the 30th to the 65th minute after firing.

(c) Estimated Masked Man Casualties Based on Effects on Animals.

1. Firing Period and Following 20 Minutes.

Animal casualties and estimated man casualties, based on effects on animals, are given in Tables No. 12A, 12B, and 12C representing exposure on the target during firing and the following 20 min. Results in these three tables are consolidated in the last two columns of Table No. 13. From the consolidated results, it is estimated from animal casualties, that personnel protected by gas mask only, would experience

26% casualties if exposed on the target during firing and the following 20 min. In arriving at per cent estimated man casualties on the target from animal casualties, no weight was given to animal casualties which individually was not considered the equivalent of a man casualty.

## 2. Persistence of HS on Impact Area.

Results given in Paragraph 9,b,(6),(e),2 show one animal casualty out of two animals exposed in shell craters for a period of 24 hr. on the 2nd day after firing and one out of two exposed on the 5th day after firing. These results show that casualties would probably result if the impact area was occupied by personnel within 5 days after firing, for a period of 24 hr. or less, unless they were protected by gas mask and impregnated clothing.

### (f) Comparison of Per Cent Estimated Man Casualties Based on Measurements of the Gas Concentration and by Effects on Animals for Man Protected by Gas Mask Only.

#### 1. On Target (100 yd. by 200 yd.).

In Table No. 13 estimated man casualties are given for each 20 yd.sq., representing an animal position based on:

HS liquid as determined by panel data  
HS vapor as determined by vapor samples  
Combined effect of HS liquid and vapor from sample data  
From effects on animals

Table No. 13.

Estimated Masked Man Casualties on Target on Exposure  
During Firing and the Following 20 Min.  
(Area 20,000 sq.yd.) June 15, 1933.

Stake no. at center of 20-yd. square	Impacts within 20-yd. square	From HS liquid Estimated man casualties	From HS vapor c.t.: Estima- value: ted man casual- ties	From HS liquid and vapor Estimated man casualties	From effects on animals Animal casual- ties	Estima- ted man casual- ties
		%	%	%		%
13	2	44	.40	100	0	0
15	0	89	.40	100	ERS	100
					severe	
17	0	66	.40	100	S <sub>2</sub> med.	100
					(1 & 2)	
19	0	40	.34	100	ER light	0
21	0	13	.10	93	0	0
35	0	84	.60	100	ERS death	100
37	1	95	1.00	100	S light	100
					(1)	
39	1	82	.60	100	R light	0
41	0	67	.20	100	0	0
43	0	40	.12	100	0	0
57	0	73	.60	100	0	0
59	0	98	1.10	100	ERS	100
					severe	
61	0	75	.50	100	S <sub>2</sub> med.	100
					(1)	
63	0	55	.16	100	0	0
65	0	40	.10	93	0	0
79	1	93	1.00	100	ERS	100
					severe	
81	0	98	1.50	100	0	0
83	0	82	.80	100	0	0
85	0	67	.30	100	0	0
87	0	60	.20	100	S light	0
101	0	95	1.00	100	S death	100
103	1	89	1.80	100	ERS	100
					death	
105	0	73	1.00	100	0	0
107	0	75	.60	100	E light	0
109	1	69	.20	100	0	0
123	2	93	1.00	100	ER	0
					severe	

Table No. 13 (Cont'd.)

Stake no. at center of 20-yd. square	Impacts: within 20-yd. square	From HS liquid: Estimated man casualties	From HS vapor: c.t.: value:Estima- casual- ties	From HS liquid and vapor Estimated man casualties	From effects on animals Animal casual- ties	Estima- ted man casual- ties
:	:	%	%	%	:	%
125	0	91	1.00	100	S2 med.	100
					(1)	
127	1	80	.60	100	ER	0
					severe	
129	2	78	.60	100	0	0
131	0	78	.80	100	ERS	100
					severe	
145	0	84	.30	100	S death	100
147	0	91	.30	100	R light	0
149	1	80	.30	100	KF death	100
					(2)	
151	00	78	.30	100	ER med.	0
153	0	64	.30	100	0	0
167	0	89	.11	100	ER med.	0
169	0	93	.11	100	0	0
171	0	80	.11	100	0	0
173	0	75	.31	100	0	0
175	1	73	.30	100	ER med.	0
189	0	93	.06	66	0	0
191	0	89	.06	66	0	0
193	0	87	.06	66	0	0
195	0	71	.06	66	0	0
197	0	87	.03	42	0	0
211	0	82	.02	30	0	0
213	0	71	.02	30	0	0
215	0	73	.02	30	0	0
217	0	73	.01	12	0	0
219	0	73	.01	12	0	0
Total and average	14	75.7		88.1	97.2	26

NOTE: Symbols used in column 7 to designate the nature of the animal casualties are explained in paragraph 6 c.

(1) designates rat in cage on ground.

(2) designates rat in cage suspended at an elevation of 18 in.

Results in Table No. 13 show 97.2% estimated casualties based on HS liquid and vapor samples and 26% based on effects on animals.

2. On Impact Area (100 yd. by 160 yd.)

The impact area as defined in paragraph 9,b,(7),(b) is 100 yd. wide by 160 yd. long. It includes that part of the target north of a line parallel with its short axis passing through a point 40 yd. north of the south side of the target. It includes the data in Table No. 13 exclusive of results on 20 yd. squares represented by stake numbers 189 to 219 inclusive. A summary of data on the impact area is given below:

Total number of effective bursts - 15  
Estimated casualties based on HS liquid - 74.7%  
Estimated casualties based on HS vapor - 99.6%  
Estimated casualties based on HS vapor and HS liquid - 99.7%  
Estimated casualties based on animals - 32.5%

(g) Number of Shell Required to Produce 50% Man Casualties.

From data given in the preceding paragraph it was estimated that the burst of 15 shell on an area of 16,000 sq.yd. would produce 99.7% casualties based on measurement of HS liquid and vapor present and 32.5% based on effects on animals, when personnel protected by gas mask only, are exposed on the impact area during firing and the following 20 min. On this basis the following number of shell per 100 yd.sq. are required to produce 50% casualties when man is protected by gas mask only.

Based on HS liquid and vapor samples -	4.8 shell
Based on effects on animals -	14.5 shell
Average	9.7 shell

(8) Conclusions. From the results of the present test, the following conclusions are drawn with respect to the use of 155-mm. howitzer shell filled with HS, when fired under the meteorological conditions existing at the time of the test.

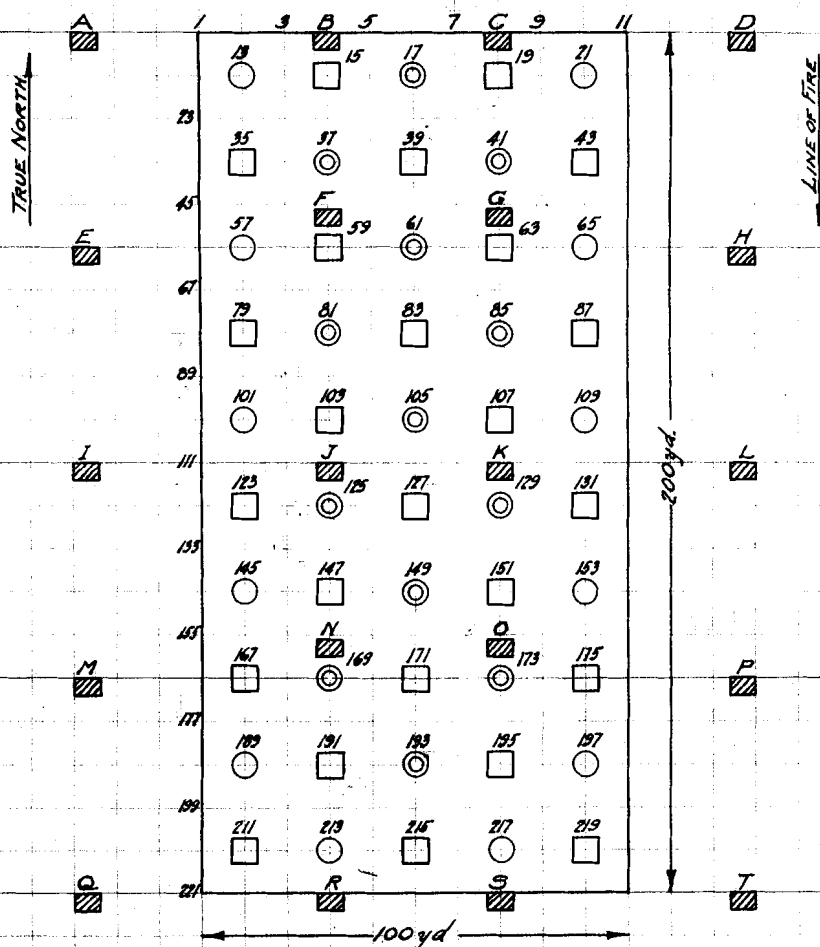
(a) The number of shell required per 100 yd.sq. to produce 50% casualties when distributed as equally as practicable, are as follows:

1. When man protected by gas mask and standard impregnated clothing is exposed during the firing period - 72 shell (see p. 36).

CHART 1  
TEST OF HS FILLED 155-mm HOWITZER SHELL.  
(PROJECT A1.1-18)

JUNE 15, 1933

TARGET AREA



+LEGEND+

- Goat
- ▨ Sampling Machine
- Rat in Cage Suspended at Elevation of Birches.
- ⊙ Rat in Cage on Ground in Addition to Rat in Cage Suspended at Elevation of Birches.

+NOTE+

PAPER PANELS 8" SQUARE WERE PLACED AT STAKE POSITIONS.

50 YDS  
SCALE

CHART 2 F  
 TEST OF HS FILLED 155-mm HOWITZER SHELL  
 (PROJECT A11-18)  
 JUNE 15, 1933.  
 POSITION OF IMPACTS

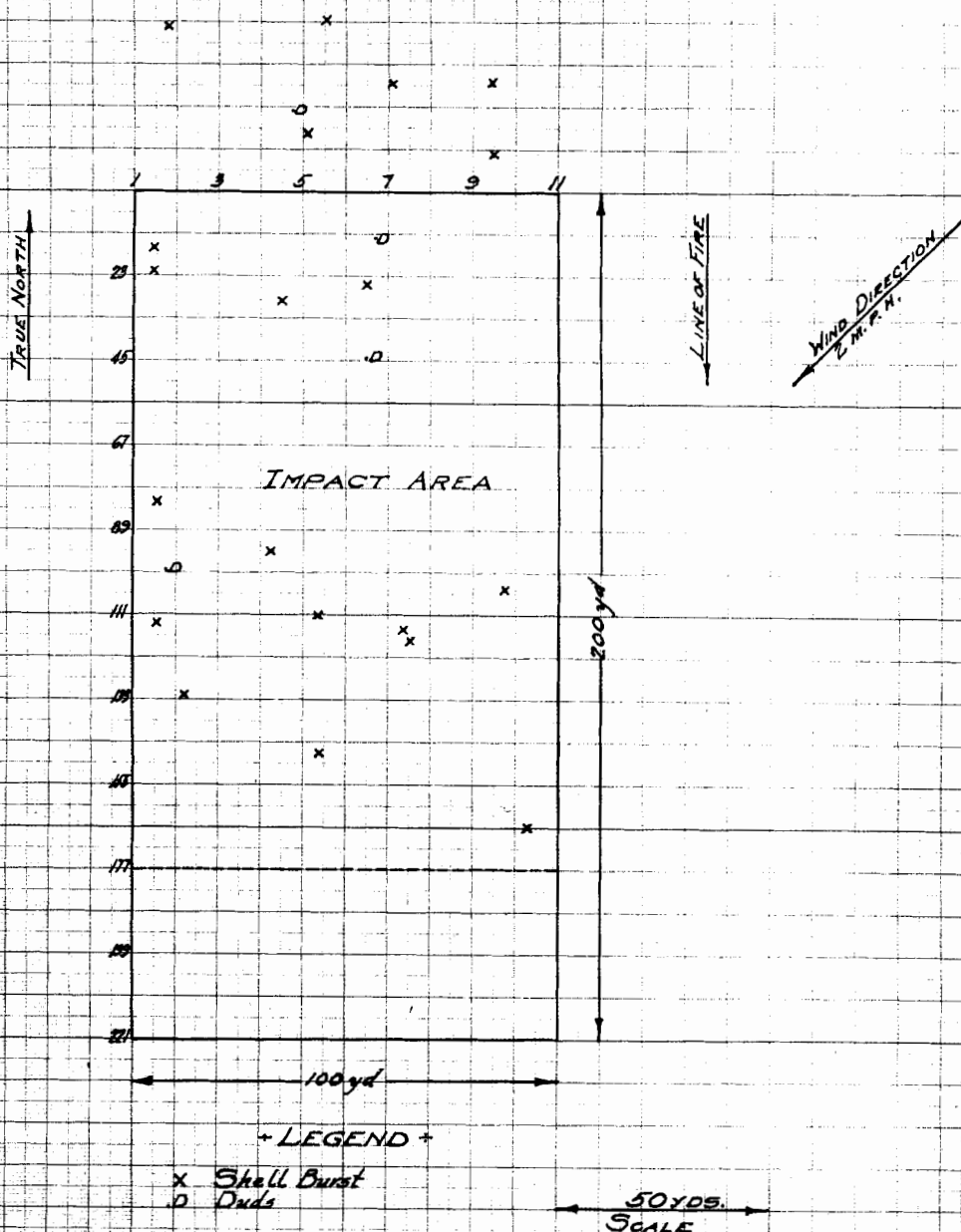
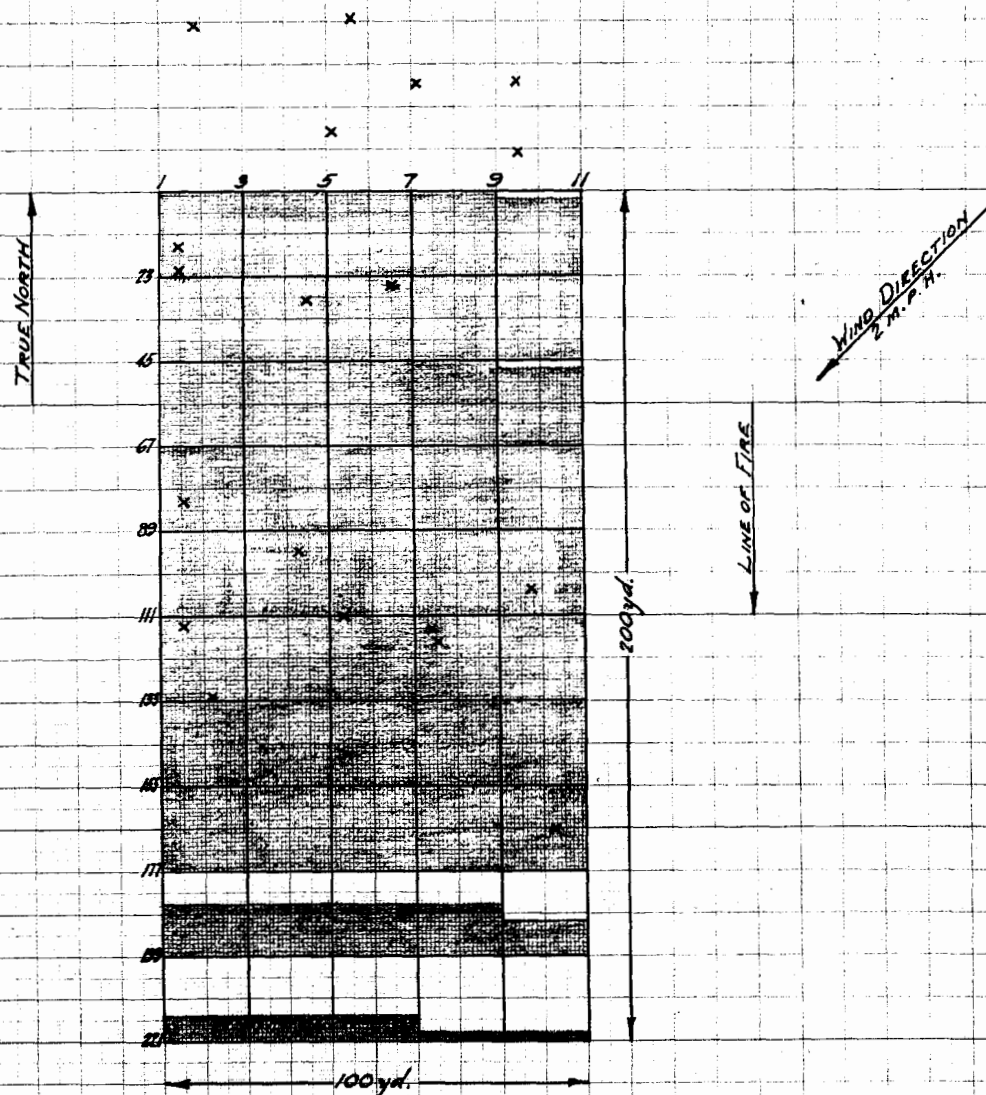


CHART 3 F  
 TEST OF HS FILLED 155-mm HOWITZER SHELL  
 (PROJECT A11-18)  
 JUNE 15, 1933  
 ESTIMATED MAN CASUALTIES DUE TO EFFECTS  
 OF HS VAPOR\*

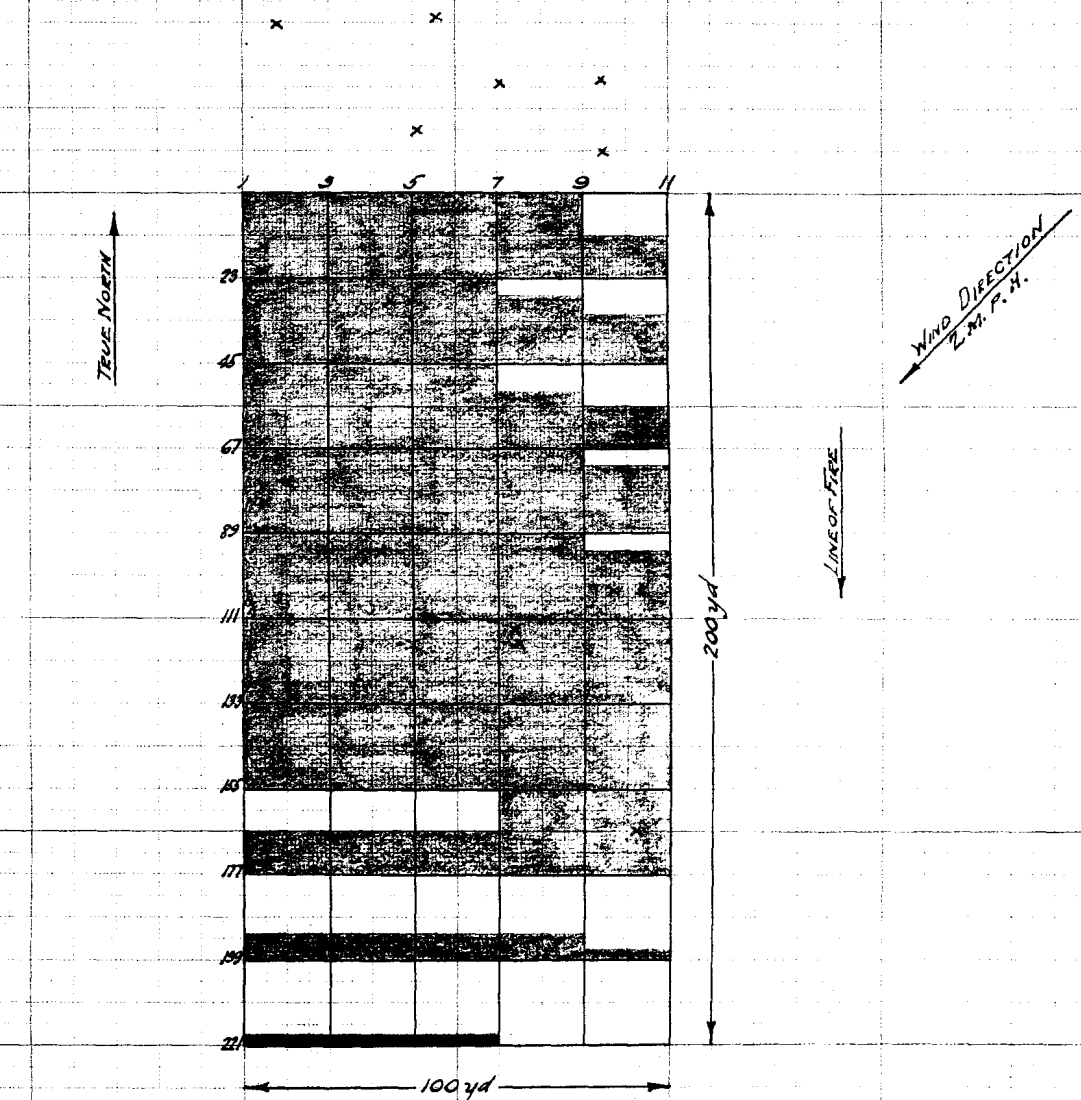


+LEGEND+  
 x - Position of Burst  
 Shaded Area Represents  
 100% Max Casualties.

+NOTE+  
 MAN PROTECTED BY GAS MASK AND  
 STANDARD ISSUE OF UNIMPREGNATED  
 CLOTHING.  
 \* CASUALTIES BASED ON EXPOSURE DURING FIRING  
 PERIOD AND FOLLOWING 20 MINUTES.

50 yds.  
 SCALE

CHART 3aF  
 TEST OF HS FILLED 155<sup>mm</sup> HOWITZER SHELL  
 (PROJECT A.I.I-16)  
 JUNE 15, 1933  
 ESTIMATED MAN CASUALTIES DUE TO EFFECTS  
 OF HS VAPOR\*



LEGEND:-

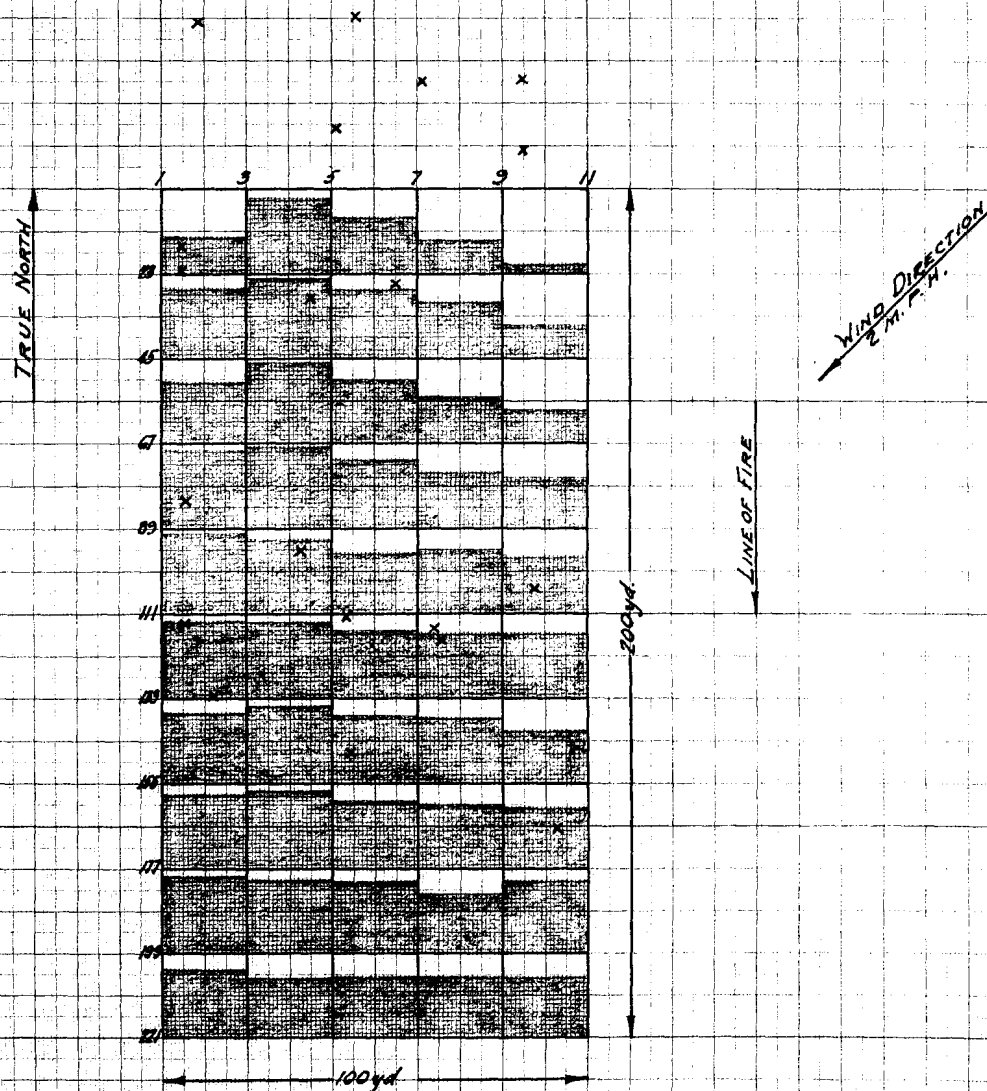
- x - Position of Burst
- Shaded Area Represents 100% Man Casualties

NOTE:-

- MAN PROTECTED BY GAS MASK AND STANDARD ISSUE OF UNIMPREGNATED CLOTHING
- \* CASUALTIES BASED ON EXPOSURE FROM THE 30TH TO THE 65TH MINUTE AFTER FIRING.

50 YDS  
 SCALE

CHART 4F  
 TEST OF HS FILLED 155-mm HOWITZER SHELL  
 (PROJECT A11-16)  
 JUNE 15, 1933  
 ESTIMATED MAN CASUALTIES DUE TO EFFECTS  
 OF HS LIQUID.\*



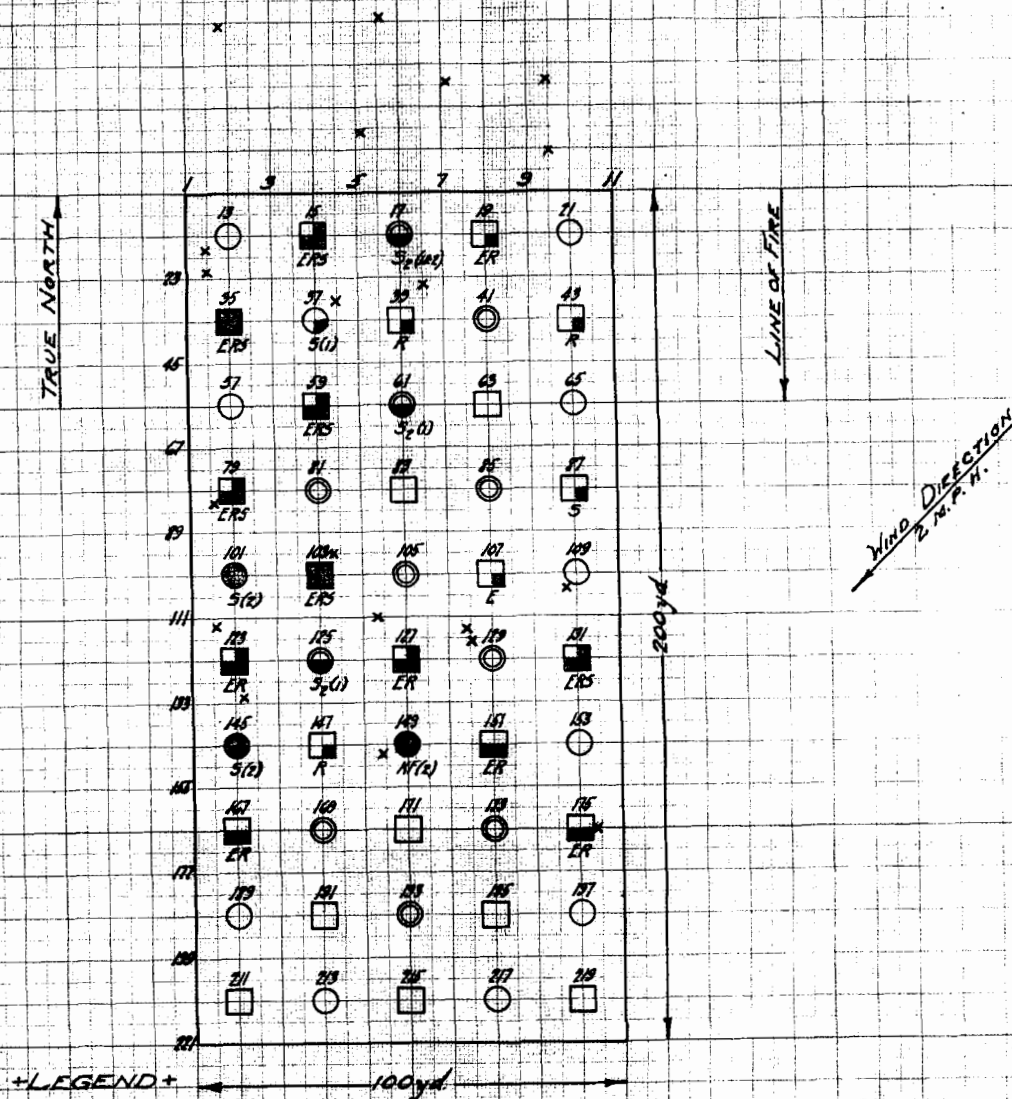
+LEGEND+  
 x - Position of Burst  
 Shaded Area Represents  
 100% Man Casualties.

+NOTE+  
 MAN PROTECTED BY GAS MASK AND  
 STANDARD ISSUE OF UNIMPREGNATED  
 CLOTHING.  
 \* CASUALTIES BASED ON EXPOSURE DURING  
 THE FIRING PERIOD.

50 YDS.  
 SCALE

**CHART 5F**  
**TEST OF H5 FILLED 155-mm HOWITZER SHELL**  
**(PROJECT A11-16)**

JUNE 15, 1933  
**ANIMAL CASUALTIES DUE TO EXPOSURE DURING  
 FIRING AND FOLLOWING 20 MINUTES.**



**RAT**

**GOAT**

- No Casualty.
- ◐ LC - Light Casualty.
- ◑ MC - Moderate Casualty.
- ◒ SC - Severe Casualty.
- D - Death.
- E - Conjunctivitis.
- R - Respiratory Effects.
- S - Erythema of Skin.
- S<sub>2</sub> - Second Degree Skin Burn.

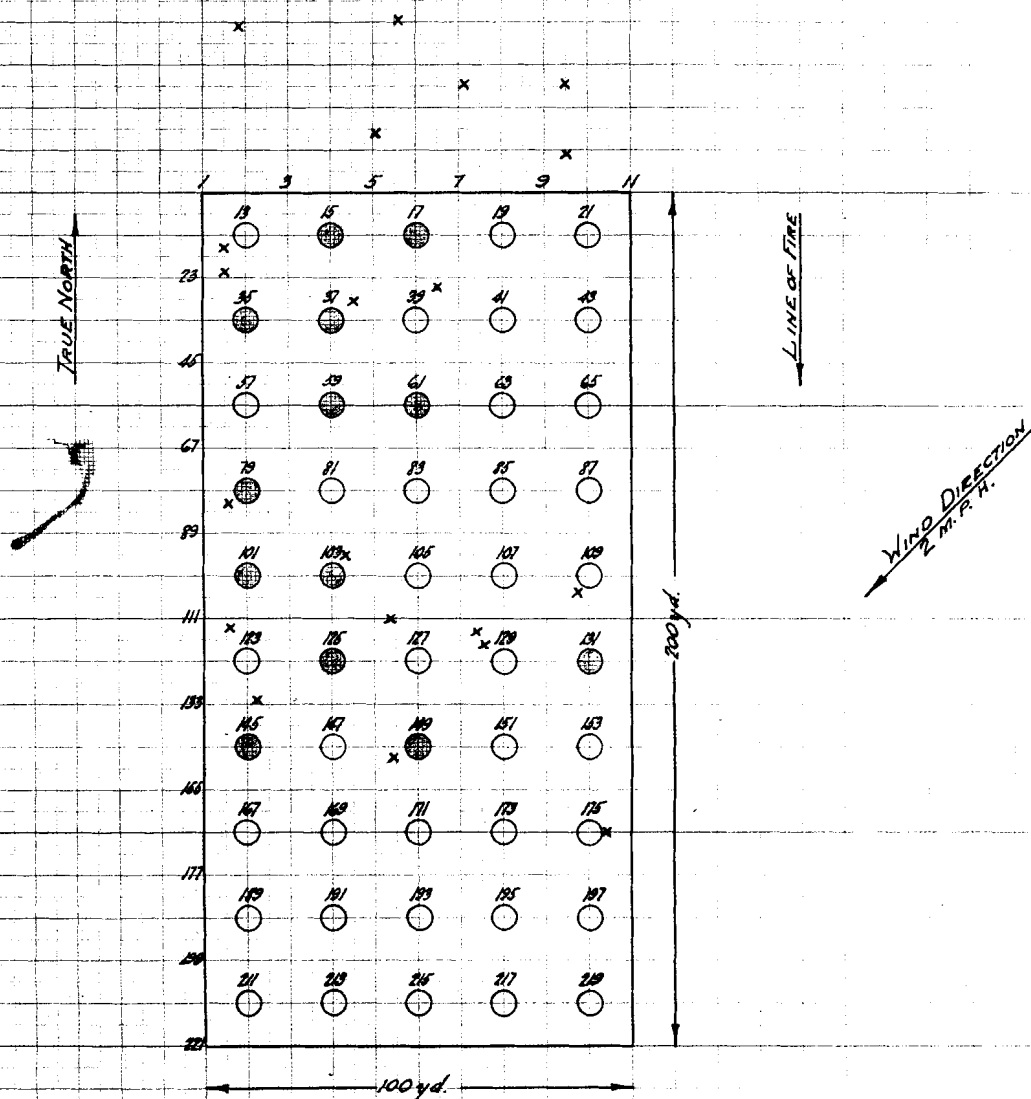
- KF - Killed By Shell.
- (1) - Rat on Ground.
- (2) - Rat Suspended.
- Rat Suspended at Elevation of 18° only.
- ◐ Rat in Cage on Ground and Rat Suspended at Elevation of 18°.
- x Shell Burst.

CHART 6F  
TEST OF HS FILLED 155mm HOWITZER SHELL.

(PROJECT A11-14)

JUNE 15, 1933

ESTIMATED MAN CASUALTIES BASED ON EFFECTS  
ON ANIMALS EXPOSED DURING FIRING AND  
FOLLOWING 70 MINUTES.



+LEGEND+

- Estimated no Casualties.
- Estimated man Casualties.
- x Shell Burst.

50 YDS  
SCALE

2. When man protected by gas mask only is exposed during the firing period and following 20 min. - about 10 shell (see p. 41).

(b) That a test be conducted with the target located in woods, instead of open country, to determine the effects of terrain on the number of shell required for effective results.

c. Test of July 6, 1933.

(1) Object. To determine the number of HS filled 155-mm. howitzer shell required to produce 50% casualties when fired about 1 hr. before sunset at personnel protected by gas mask only, who are located in wooded country and are exposed on the impact area for a period of 25 min. including the firing period.

(2) Materials Used. Forty MII, 155-mm. howitzer shell filled with HS, were used in the test. The history of these shell and the type of fuze and booster used are given in paragraph 4.

(3) Target. The target was a rectangular area 100 yd. by 200 yd. deep, located in wooded country on "H" field in the vicinity of coordinates 690.8, 1863.7, with its long axis oriented in line with the direction of fire. The target was covered with large trees about 100 ft. tall, with very little undergrowth and the soil was moist due to a heavy rain four days previous. The target was divided into 10 yd. squares by placing numbered stakes at 10 yd. intervals. Paper panels 8 in. square were distributed over the area by placing one at each stake position. On alternate 20-yd. squares, a goat was placed in a fox-hole about 18 in. deep, located at its center. On intervening 20-yd. squares, a rat in a cage was suspended from a stake at an elevation of 18 in. At alternate rat positions, a cage containing a rat was placed under the suspended rat. The target was located at a range of about 5,400 yd. from the position of the howitzers on "C" field (see paragraph 4).

Chart 1G, accompanying this report shows the target as it was prepared for the test with position of animals, panels and sampling machines.

(4) Firing of Shell.

(a) Adjustment. Seventeen shell were used. Registration fire was directed at a position about 200 yd. east of the target. Firing started at 4:59 p.m. and ended at 5:27 p.m.

(b) Firing for Effect. The howitzers were ranged in parallel for impact on a line through the short axis of the target. Firing started at 6:10 p.m. and ended at 6:17 p.m., a period of 7 min. Twenty-three shell were used.

A photostatic copy of a Memorandum dated July 12, 1933 to Capt. C.E. Loucks, from the Battery Commander giving firing data by round, is attached to this report.

(5) Meteorological Conditions.

The following is a record of meteorological conditions:

(a) Firing and the Hour Following.

Time	6:10 p.m.	7:00 p.m.
Air temperature, °F.	83	80
Ground temperature, °F.	79	77
Relative humidity, %	45	47
Wind velocity m.p.h.		
(on open area near target)*	4.0	3.0
Wind velocity m.p.h. (on target)*	too low to turn vane anemometer	
Wind direction	SW	SW
Sky	clear	clear

\*Taken at an elevation of 6 ft.

(b) During First Eight Days Following Test.

Date		Temp. °F.		Rainfall	Wind	Weather				
From:	To	Max.	Min.	8 a.m. inches	8 a.m. miles	8 a.m.	10 a.m.	12 noon	2 p.m.	4 p.m.
7/6	7/7	87.0	61.9	74.0	0	113	clear	clear	clear	clear
7/7	7/8	88.2	67.0	73.8	0	124	clear	clear	clear	clear
7/8	7/9	89.5	75.0	74.3	0	163	cloudy	2/10	clear	4/10
7/9	7/10	90.0	62.8	76.6	trace	97	cloudy	cloudy	8/10	6/10
7/10	7/11	83.4	66.8	73.0	0.01	128	clear	4/10	8/10	cloudy
7/11	7/12	77.9	63.8	71.1	0	160	cloudy	cloudy	cloudy	cloudy
7/12	7/13	77.9	57.8	66.0	0	130	cloudy	cloudy	cloudy	8/10
7/13	7/14	78.9	60.0	66.9	0	154	cloudy	cloudy	4/10	6/10
7/14			62.2				cloudy	cloudy	cloudy	

(6) Results.

(a) Impacts.

The positions of impacts are shown on Chart G2. There were 20 impacts accounted for in and around the target of which 8 were bursts on the target.

Of the 40 shell fired including the 17 used for adjustment, there were 8 duds.

(b) Size of HS Drops.

The distribution and size of HS drops were registered by paper panels 8 in. square placed at 10 yd. intervals over the target (see paragraph 6,a). Panels showing HS drops of 0.1 mg. or larger are tabulated in the following table:

Table No. 14.

Number of Panels Showing HS Drops of 0.1 mg. or Larger.

Panel:		No. of HS drops			
no.		:0.1 to	:Over 0.5	:Over 1.0	:Over 3.0
		:0.5 mg.	:to 1.0 mg.	:to 3.0 mg.	: mg.
33 :	1 :	:	:	:	:
51 :	50 :	:	10 :	:	:
62 :	100 :	:	20 :	:	:
74 :	1 :	:	:	:	:
84 :	:	:	3 :	:	:
85 :	15 :	:	5 :	:	1
95 :	5 :	:	3 :	3 :	3
96 :	10 :	:	:	2 :	:
97 :	15 :	:	2 :	1 :	:
107 :	5 :	:	:	:	:
108 :	3 :	:	1 :	:	:
109 :	5 :	:	3 :	:	:
120 :	3 :	:	:	:	:
121 :	:	:	1 :	:	:
132 :	15 :	:	5 :	3 :	:
141 :	25 :	:	25 :	10 :	:
143 :	15 :	:	:	:	:
151 :	50 :	:	5 :	:	:
152 :	25 :	:	3 :	:	:
153 :	5 :	:	2 :	:	:
154 :	20 :	:	:	:	:
163 :	10 :	:	5 :	:	:
164 :	2 :	:	1 :	:	:
175 :	11 :	:	2 :	1 :	:
186 :	20 :	:	:	:	:
194 :	5 :	:	:	:	:
195 :	100 :	:	20 :	:	:
196 :	:	:	1 :	:	:
205 :	50 :	:	5 :	:	:
206 :	25 :	:	25 :	25 :	:
207 :	10 :	:	3 :	:	:
217 :	35 :	:	25 :	10 :	:
218 :	2 :	:	1 :	:	:
220 :	2 :	:	4 :	:	1
226 :	5 :	:	2 :	1 :	3
227 :	11 :	:	7 :	3 :	3
229 :	5 :	:	:	:	:

(c) Estimated Man Casualties from Liquid HS.

1. Man Protected by Gas Mask but without Protection of Impregnated Clothing.

The paper panels on the target were tabulated for density of pattern using the pattern scale attached to this report. Results are tabulated in the following tables together with estimated man casualties. The basis of estimated casualties is explained in paragraph 6,a.

Table No. 15.

Estimated Man Casualties from HS Liquid Based on Panel Data.

Pattern:	Panels classified:		Estimated casualties	
	: No. :	Per cent of:	for man protected by	
	:	: total on	: gas mask only	
	:	: target	:	
	:	:	%	
Heavy	: 17 :	7.4	:	7.4
Medium	: 12 :	5.2	:	5.2
Light	: 18 :	7.8	:	6.2
Trace	: 19 :	8.2	:	4.9
No HS	: 165 :	71.4	:	
Total	: 231 :	100.0	:	23.7

2. Man Protected by Gas Mask and Standard Impregnated Clothing.

From results in Table No. 14, a tabulation is given in Table No. 16 of panels showing HS drops of 0.5 mg. or larger, together with estimated casualties for man protected by gas mask and standard impregnated clothing. The basis of estimated casualties is explained in paragraph 6,a,(2).

Table No. 16.

Estimated Man Casualties from HS Liquid Based on Panel Data.

Size of HS drops:	No. of:	Estimated casualties for	
		panels:	man protected by gas mask and standard impregnated clothing
mg.	:	per panel %:	target area %
One drop or more:	17	40	3.0
between 0.5 to	:	:	:
1.0 but with no	:	:	:
drop exceeding	:	:	:
1.0	:	:	:
One drop or more:	12	100	5.2
exceeding 1.0	:	:	:
Total	29	:	8.2

Total panels on target - 231.

(d) Estimated Man Casualties from HS Vapor.

Vapor samples were taken at positions shown on Chart 1G. In Tables 17, 17A, 18 and 18A which follow, the vapor concentration, c.t. value and per cent estimated casualties from HS vapor for man protected by gas mask only, are given for each sampling position. The basis of estimated casualties is explained in paragraph 6,b.

1. Firing Period and Following 22 Minutes.

Table No. 17.

Estimated HS Vapor Casualties on Target.

Sampling position:	Elevation of sample	Vol. of air sampled	HS sampled	Vapor concn.	c.t. value *	Estimated casualties for man protected by gas mask only
	ft.	liters	mg.	mg./l.		%
F	0	828	2.4	.0029	.07	73
G	1	884	12.5	.0142	.35	100
J	0	894	2.0	.0022	.05	58
K	1	922	11.2	.0121	.30	100
N	0	884	0.8	.0009	.02	30
O	1	894	12.9	.0144	.26	100
R	0	868	0.4	.0005	.01	11
S	0	842	18.9	.0224	.56	100
Av.						71.5

\*Based on a time period of 25 min. (1/2 firing period plus 22 min.).

Table No. 17A.

Estimated HS Vapor Casualties at Sampling Positions Outside of Target.

D	0	469	33.5	.0714	1.79	100
	1	469	28.1	.0600	1.50	100
	2	469	14.3	.0305	.76	100
	4	469	8.6	.0183	.46	100
L	0	635	2.6	.0041	.10	93
	1	635	2.6	.0041	.10	93
	2	635	2.4	.0038	.10	93
	4	635	1.0	.0016	.04	50
H	0	607	2.6	.0043	.11	100
	1	607	2.6	.0043	.11	100
	2	607	2.6	.0043	.11	100
	4	607	2.4	.0040	.10	93
P	0	627	5.4	.0086	.22	100
	1	627	8.2	.0131	.33	100
	2	627	5.8	.0093	.23	100
	4	627	2.6	.0042	.11	100
T	0	598	2.8	.0047	.12	100
	1	598	4.6	.0078	.19	100
	2	598	2.2	.0037	.09	86
	4	598	0.4	.0007	.02	30

2. From the 32nd to 67th Minute after Firing.

Table No. 18.

Estimated HS Vapor Casualties on Target.

Sampling position:	Elevation of sample	Vol. of air sampled	HS sampled	Vapor concn.	c.t. value	Estimated casualties for man protected by gas mask only
	ft.	liters	mg.	mg./l.		%
C	0	938	1.2	.0013	.03	42
F	0	1140	2.4	.0021	.07	73
G	1	1214	12.7	.0104	.37	100
J	1	1254	0	0	0	0
K	0	1270	8.0	.0063	.22	100
N	0	1214	0	0	0	0
R	1	1214	0	0	0	0
S	0	598	16.1	.0269	.94	100
Av.						51.9

Table No. 18 A.

Estimated HS Vapor Casualties at Sampling Position Outside of Target.

H	0	442	17.5	.0397	1.39	100
	1	442	17.5	.0397	1.39	100
	2	442	17.5	.0397	1.39	100
	4	442	11.6	.0254	1.89	100
L	0	462	3.8	.0082	.29	100
	1	462	4.0	.0087	.31	100
	2	462	3.0	.0065	.23	100
	4	462	3.0	.0065	.23	100
P	0	447	15.5	.0346	1.21	100
	1	447	17.1	.0382	1.34	100
	2	447	13.1	.0293	1.03	100
	4	447	5.8	.0130	.46	100
T	0	421	6.0	.0143	.50	100
	1	421	5.4	.0128	.45	100
	2	421	4.6	.0109	.38	100
	4	421	2.6	.0062	.22	100

(e) Estimated Man Casualties Based on Effects on Animals.

Animals consisting of goats and rats were placed on the target at the positions shown on Chart 1G. Animal casualties and estimated man casualties for man protected by gas mask only, are given in Tables No. 19A, 19B, and 19C. Animal casualties and estimated man casualties, based on effects on animals, are shown on Charts 5G and 6G. The basis of estimated casualties and the symbols used in this table and on the charts to designate the nature of the animal casualties, are explained in paragraph 6,c.

1. Firing Period and Following 22 Minutes.

Table No. 19A.

Estimated Masked Man Casualties Based on Effects on Rats  
Suspended at an Elevation of 18 in.

Position: of stake	Nature : of casualty	Severity : of casualty	Estimated man cas- ualties
			%
109	S	Medium	100
149	ER	Death in: : 4 days :	100
153	S	Medium	100
193	S	Medium	100
197	S	Medium	100
217	S, R 2	Death in: : 4 days :	100

Total suspended rat positions - 25  
Estimated man casualty positions - 6  
Per cent estimated man casualties - 24

Table No. 19B.

Estimated Masked Man Casualties Based on Effects on Rats  
in Cages on Ground.

Position: of stake	Nature : of casualty	Severity : of casualty	Estimated man cas- ualties
			%
85	S	Death in: : 4 days :	100
129	ES	Medium :	100

Total ground rat positions - 13  
Estimated man casualty positions - 2  
Per cent estimated man casualties - 15.4

Table No. 19C.

Estimated Masked Man Casualties Based on Effects on Goats

19	ER	Medium	0
39	ER	Medium	0
43	E	Medium	0
83	E	light	0
87	ERS	Medium	100
107	ER	Medium	0
127	E	Light	0
131	ERS	Medium	100
147	ER	Medium	0
151	KF	Death	100
167	S	Light	100
171	S	Medium	100
175	E <sub>2</sub> R	Severe	0
191	RS <sub>2</sub>	Medium	100
195	ERS	Death	100
219	ERS	Medium	100

Total goats exposed - 25  
Estimated man casualty positions - 8  
Per cent estimated man casualties - 32

## 2. Fourth and Seventh Day After Firing.

Two goats were exposed in shell craters located between stakes 194 and 195 for a period of 24 hr. on the fourth day after firing and two additional goats were exposed at the same position for a period of 24 hr. on the seventh day after firing. None of these goats showed casualties.

### (7) Discussion.

(a) Shell Distribution. The positions of impacts on and around the target are shown on Chart 2G. There were six normal bursts on the target and two tree bursts. None of the bursts outside of the target were appreciably effective on the target so that total effects on the target were due to the burst of 8 shell.

(b) Impact Area. For purposes of discussion the impact area may be regarded as that part of the target east of a line through stake 5 and 225 and south of line through stakes 23 and 28. It is shown on Chart 2G and the animal squares (20-yd. squares) of which it is composed are given in Table No. 21.

### (c) Estimated Casualties from Liquid HS.

#### 1. Effect of Meteorological Conditions.

The wind velocity over the target during firing was zero so that distribution and casualty effect of liquid HS were not affected at all by meteorological conditions.

2. Effects of Terrain. Of the eight shell bursts on the target, two were due to tree impacts. Theoretically, the burst of shell filled with HS above the ground, as in the case of bursts on impact against trees, will result in greater distribution of the liquid HS with a corresponding greater percentage of casualty effects than in the case of bursts on impact with the ground.

#### 3. Man Protected by Gas Mask but without Protection of Impregnated Clothing.

It is estimated from results in Table No. 15, that personnel protected by gas mask only, would experience about 23.7% casualties from liquid HS if they remain equally distributed over the target during the firing period. The liquid HS on the target was due to the burst of eight shell. On the basis of 8 shell on an area of 20,000 sq.yd. to produce 23.7% casualties from liquid HS when personnel are protected by gas mask only, it will require 8.4 shell per 100 yd.sq. to produce 50% casualties.

4. Man Protected by Gas Mask and Standard Impregnated Clothing.

From results in Table No. 16 it is estimated that personnel protected by gas mask and standard impregnated clothing who are exposed on the target during the firing period will experience about 8.2% casualties, if they are equally distributed. On this basis it will require about 24.4 shell per 100 yd. sq. to produce 50% casualties.

(d) Effect of HS Vapor.

1. Discussion of Meteorological Conditions.

During the present test, the air temperature was 83°F. and air travel over the target was too low to be registered by a vane anemometer. These conditions were extremely favorable for the use of HS.

2. Firing Period and Following 22 Minutes.

(a) On Target.

Results of vapor samples taken at 9 sampling positions on the target are given in Table No. 17 for the firing period and following 22 min. The vapor concentration for each 20-yd. square of the target was figured from results in this table, taking into consideration the positions of nearest impacts and wind direction. These results are given in the fifth column of Table No. 20. From the average of the figures in the fifth column, it is estimated that personnel with gas mask protection only, would experience about 64.3% casualties if exposed during firing and the following 22 min.

Per cent estimated casualties from effects of HS vapor is shown graphically on Chart 3G. The shaded area on the chart represents that part of the area on which it is estimated 100% casualties would be produced by effect of HS vapor when man is protected by gas mask only.

(b) Outside of Target.

Estimated casualties at sampling positions downwind from the target are given in Table No. 17A for the firing period and following 22 min. All positions downwind from the target showed a strong concentration of HS vapor. The presence of HS vapor at the five sampling positions was partly due to the drift of HS vapor downwind from the target and partly to the burst of shell outside of the target near the sampling positions.

3. From the 32nd to 67th Minute After Firing.

(a) On Target.

From results of vapor samples in Table No. 18, it is estimated that personnel protected by gas mask only would experience about 51.9% casualties from effects of HS vapor if they are exposed on the target from the 32nd to 67th minute after firing. Estimated casualties are shown graphically on Chart 3aG, for the period.

(b) Outside of Target.

Estimated vapor casualties are given in Table No. 18A based on results at sampling positions downwind from the target. The results show 100% estimated casualties from effect of HS vapor, if personnel protected by gas mask only are exposed about 30 yd. downwind from the target from the 32nd to the 67th min. after firing. The vapor concentration set up downwind from the target was partly due to the drift of HS vapor from the target and partly to the burst of shell outside of the target near the sampling positions.

(c) Estimated Man Casualties Based on Effects on Animals.

1. Firing Period and Following 22 Minutes.

Animal casualties and estimated man casualties, based on effects on animals, are given in Tables No. 19A, 19B, and 19C representing exposure on the target during firing and the following 22 min. The results in these 3 tables are consolidated in the last two columns of Table No. 20 where consolidated results, based on animal casualties, show 32% estimated man casualties. The results in these two columns are also shown graphically on Charts 5G and 6G.

2. Persistence of HS on Impact Area.

Results given in paragraph 9,c,(6),(e),2 showed no casualties on exposure of two animals in shell craters for a period of 24 hr. on the 4th and on the 7th day after firing. These results indicate that the area could probably be occupied by unprotected personnel following the 3rd day after firing without experiencing serious casualties provided shell craters were avoided.

(f) Comparison of Per Cent Estimated Man Casualties Based on Measurements of the Gas Concentration and by Effects on Animals, for Man Protected by Gas Mask Only.

1. On Target (100 yd. by 200 yd.).

In Table No. 20, estimated man casualties are given for each 20 yd. sq., representing an animal position based on:

HS liquid determined by panel data  
 HS vapor determined by vapor samples  
 Combined effect of HS liquid and vapor from sample data  
 From effects on animals

Table No. 20.

Estimated Masked Man Casualties on Target on Exposure During Firing and the Following 22 Min. (Area - 20,000 sq.yd.) July 6, 1933.

Stake no. at center of 20-yd. square	Impacts within 20-yd. square	From HS liquid: Estimated man casualties	From HS vapor: c.t. value: Estimated man casualties	From HS liquid and vapor: Estimated man casualties	From effects on animals: Animal casualties	Estimated man casualties
		%	%	%	%	%
13	:	0	0	0	0	0
15	:	0	.01	11	11	0
17	:	0	.03	42	42	0
19	:	0	.03	42	42	ER med.
21	:	13	.03	42	50	0
35	:	0	0	0	0	0
37	:	0	.05	58	58	0
39	1	36	.20	100	100	ER Med.
41	:	29	.20	100	100	0
43	:	16	.15	100	100	ER med.
57	:	0	0	0	0	0
59	:	0	.07	73	73	0
61	:	53	.20	100	100	0
63	:	55	.35	100	100	0
65	:	0	.15	100	100	0
79	:	0	0	0	0	0
81	:	0	.05	58	58	0

Table No. 20 (Cont'd.)

Stake no. at center of 20-yd. square	Impact within 20-yd. square	From HS liquid Estimated man casualties	From HS vapor c.t.: value:	Estimated man casualties	From HS liquid and vapor Estimated man casualties	From effects on animals Animal casualties	Estimated man casualties
:	:	%	:	%	%	:	%
83	:	42	: .20	100	100	:E Light	0
85	: 1	69	: .30	100	100	:S death	100
	:	:	:	:	:	: (1)	:
87	:	18	: .15	100	100	:ERS med.	100
101	:	0	: 0	0	0	: 0	0
103	:	0	: .05	58	58	: 0	0
105	:	18	: .20	100	100	: 0	0
107	:	58	: .30	100	100	:ER med.	0
109	:	58	: .20	100	100	:S med.	100
123	:	0	: 0	0	0	: 0	0
125	:	0	: .04	51	51	: 0	0
127	:	9	: .15	100	100	:E light	0
129	:	29	: .35	100	100	:ES death	100
	:	:	:	:	:	: (1)	:
131	:	35	: .35	100	100	:ERS med.	100
145	:	0	: 0	0	0	: 0	0
147	:	0	: .03	42	42	:ER med.	0
	:	:	:	:	:	: (1)	:
149	:	15	: .12	100	100	:ER death	100
151	: 2	80	: .60	100	100	: KF	100
153	:	85	: .35	100	100	:S med.	100
167	:	0	: .0	0	0	:S light	100
169	:	0	: .02	30	30	: 0	0
171	:	15	: .15	100	100	:S med.	100
173	:	44	: .29	100	100	: 0	0
175	:	74	: .15	100	100	:E <sub>2</sub> R	0
	:	:	:	:	:	: severe	:
189	:	0	: 0	0	0	: 0	0
191	:	0	: .01	11	11	:RS med.	100
193	:	20	: .15	100	100	:S med.	100
195	: 3	69	: .40	100	100	:ERS death	100
197	:	67	: .15	100	100	:S med.	100
211	:	0	: 0	0	0	: 0	0
213	:	0	: .01	11	11	: 0	0
215	:	33	: .10	93	95	: 0	0
217	: 1	90	: .30	100	100	:S <sub>2</sub> R	100
	:	:	:	:	:	: death	:
219	:	60	: .15	100	100	:ERS med.	100
Total and:	8	23.8	:	64.3	64.8	:	32
average	:	:	:	:	:	:	:

NOTE: Symbols used in column 7 to designate the nature of the animal casualties are explained in paragraph 6,c.  
 (1) designates rat in cage on ground.  
 (2) designates rat in cage suspended at an elevation of 18 in.

Results in Table No. 20 show 64.8% casualties based on sample data and 32% based on effects on animals.

## 2. On Impact Area (10,800 sq.yd.).

The impact area as defined in paragraph 9,c,(7)(b) is shown on Chart 2G and the 20-yd. squares, included within its area, are tabulated in Table No. 21. On its area of 10,800 sq.yd. there were 8 bursts. Results in Table No. 21 show 97.6% estimated casualties based on sample data and 51.8% based on animal data.

Table No. 21.

Estimated Masked Man Casualties on Impact Area on Exposure  
During Firing and the Following 22 Min.  
(Area - 10,800 sq.yd.) July 6, 1933.

Stake no. at center of 20-yd. square	:Impact: :within: :20-yd.: :square:	:From HS liquid: :Estimated man : casualties	:From HS vapor: : c.t.: :value:	:Estima- : ted man : casual- : ties	:From HS liquid: : and vapor : Estimated man : casualties	:From effects : on animals : Animal : casual- : ties	:Estima- : ted man : casual- : ties
	:	:	:	:	:	:	:
	:	%	:	%	%	:	%
39	: 1 :	36	: .20 :	100	: 100	:ER med.	: 0
41	: :	29	: .15 :	100	: 100	:E med.	: 0
43	: :	16	: .15 :	100	: 100	:E med.	: 0
61	: :	43	: .20 :	100	: 100	: 0	: 0
63	: :	55	: .35 :	100	: 100	: 0	: 0
65	: :	0	: .35 :	100	: 100	: 0	: 0
83	: :	42	: .20 :	100	: 100	:E light	: 0
85	: 1 :	69	: .30 :	100	: 100	:S death	: 100
	: :		: :	:	:	: (1)	:
87	: :	18	: .15 :	100	: 100	:ERS med.	: 100
105	: :	18	: .20 :	100	: 100	: 0	: 0
107	: :	58	: .30 :	100	: 100	:ER med.	: 0
109	: :	58	: .20 :	100	: 100	:S med.	: 100

Table No. 21 (Cont'd.)

Stake no.:	Impact:	From HS liquid:	From HS vapor:	From HS liquid:	From effects
at center:	within:	Estimated man	c.t.:	Estimated man	and vapor
of 20-yd.:	20-yd.:	casualties	valued:	Estimated man	on animals
square	square:	:	casual-	casualties	Animal
:	:	:	ties :	:	ties
:	:	:	:	:	ties
:	:	%	:	%	:
127	:	9	: .15	100	: 100
129	:	29	: .35	100	: 100
:	:	:	:	:	:
131	:	35	: .35	100	: 100
149	:	15	: .03	42	: 51
151	: 2	80	: .12	100	: 100
163	:	85	: .35	100	: 100
171	:	15	: .15	100	: 100
173	:	44	: .29	100	: 100
175	:	74	: .15	100	: 100
:	:	:	:	:	:
193	:	20	: .15	100	: 100
195	: 3	69	: .40	100	: 100
197	:	67	: .15	100	: 100
215	:	33	: .10	93	: 95
217	: 1	90	: .30	100	: 100
:	:	:	:	:	:
219	:	60	: .15	100	: 100
Total and:	8	43.6	:	97.6	: 97.6
average :	:	:	:	:	:

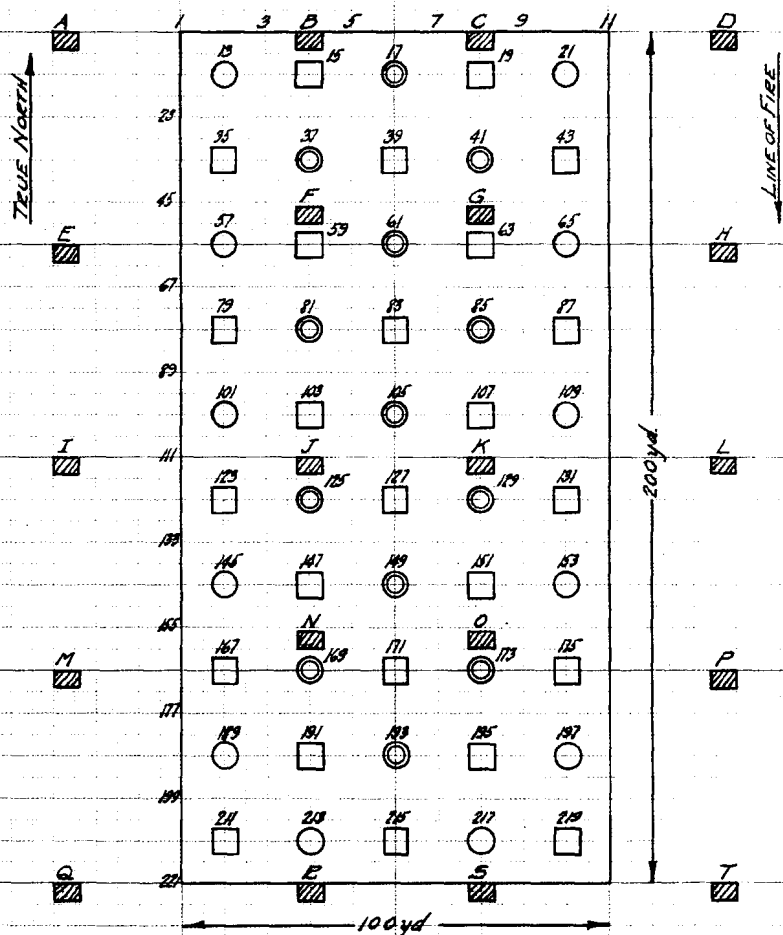
NOTE: Symbols used in column 7 to designate the nature of the animal casualties are explained in paragraph 6,c.  
 (1) designates rat in cage on ground.  
 (2) designates rat in cage suspended at an elevation of 18 in.

(g) Number of Shell Required to Produce 50% Man Casualties.

From data given in paragraph 9,b,(7),(f),2 it was estimated that the burst of 8 shell on an area of 10,800 sq.yd. would produce 97.6% casualties based on sample data and 51.8% based on effects on animals, when personnel who have only gas mask protection are exposed on the impact area during firing and the following 22 min. On this basis the following number of shell are required to produce 50% casualties per 100 yd.square:

CHART 1G  
TEST OF H5 FILLED 155mm HOWITZER SHELL  
PROJECT A.I.1-16  
JULY 6, 1933

TARGET AREA



LEGEND:

- Goat
- Sampling Machine
- Rat in Cage Suspended at Elevation of Biches
- Rat in Cage on Ground in Addition to Rat in Cage Suspended at Elevation of Biches.

NOTE:

PAPER PANELS 8" SQUARE WERE PLACED AT STAKE POSITIONS

50 YDS  
SCALE

CHART 2G  
 TEST OF HS FILLED 155mm HOWITZER SHELL  
 PROJECT A11-14  
 JULY 6, 1933

POSITION OF IMPACTS

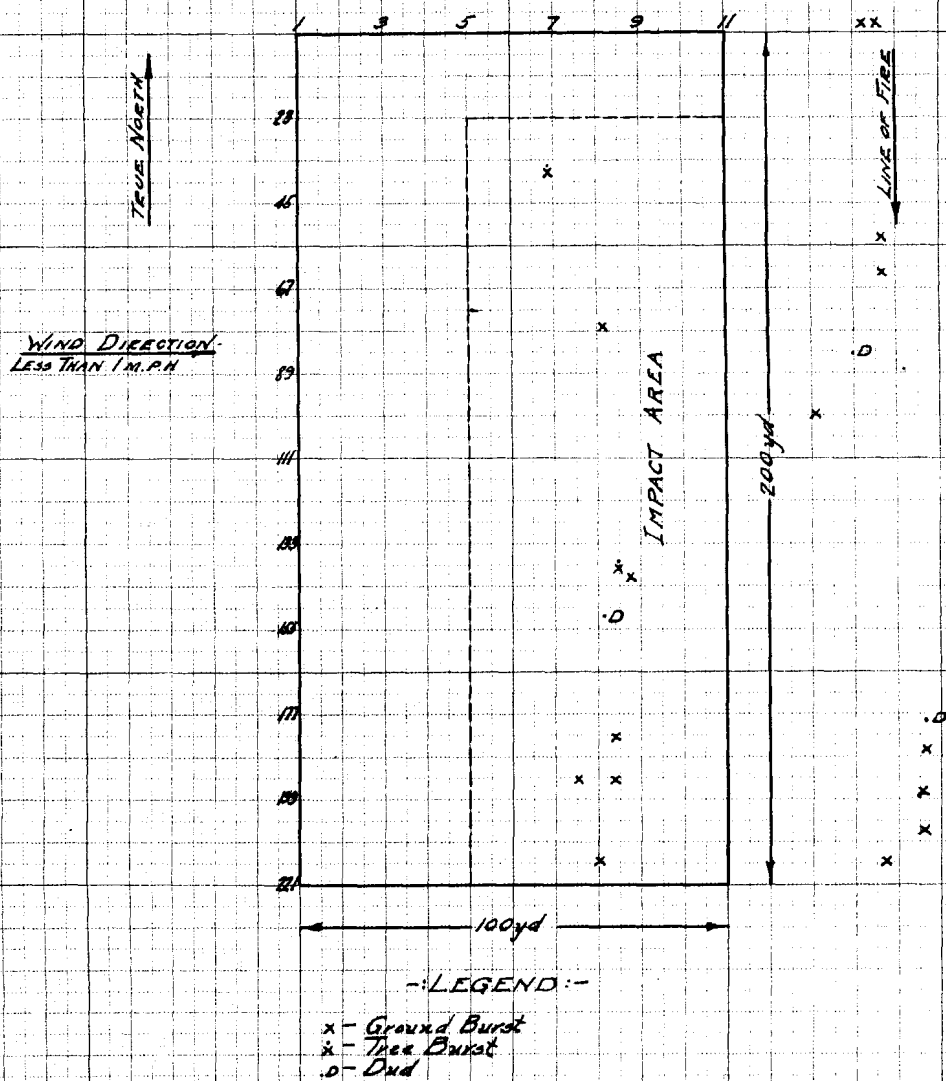
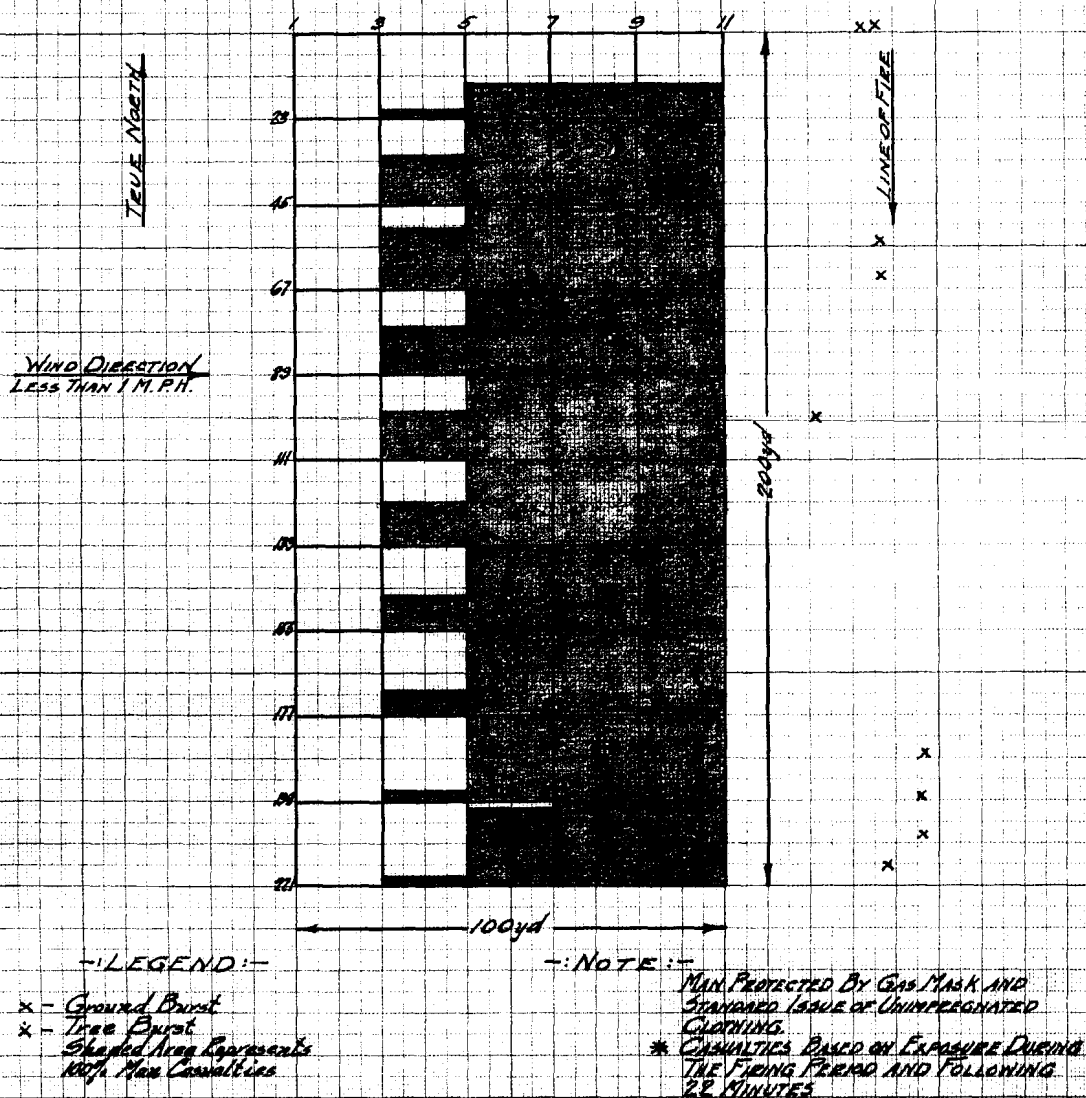


CHART 3G  
 TEST OF H5 FILLED 155<sup>mm</sup> HOWITZER SHELL  
 PROJECT A.I.1-16  
 JULY 6, 1933  
 ESTIMATED MAN CASUALTIES DUE TO EFFECTS  
 OF H5 VAPOR\*



TRUE NORTH

WIND DIRECTION  
LESS THAN 1 M.P.H.

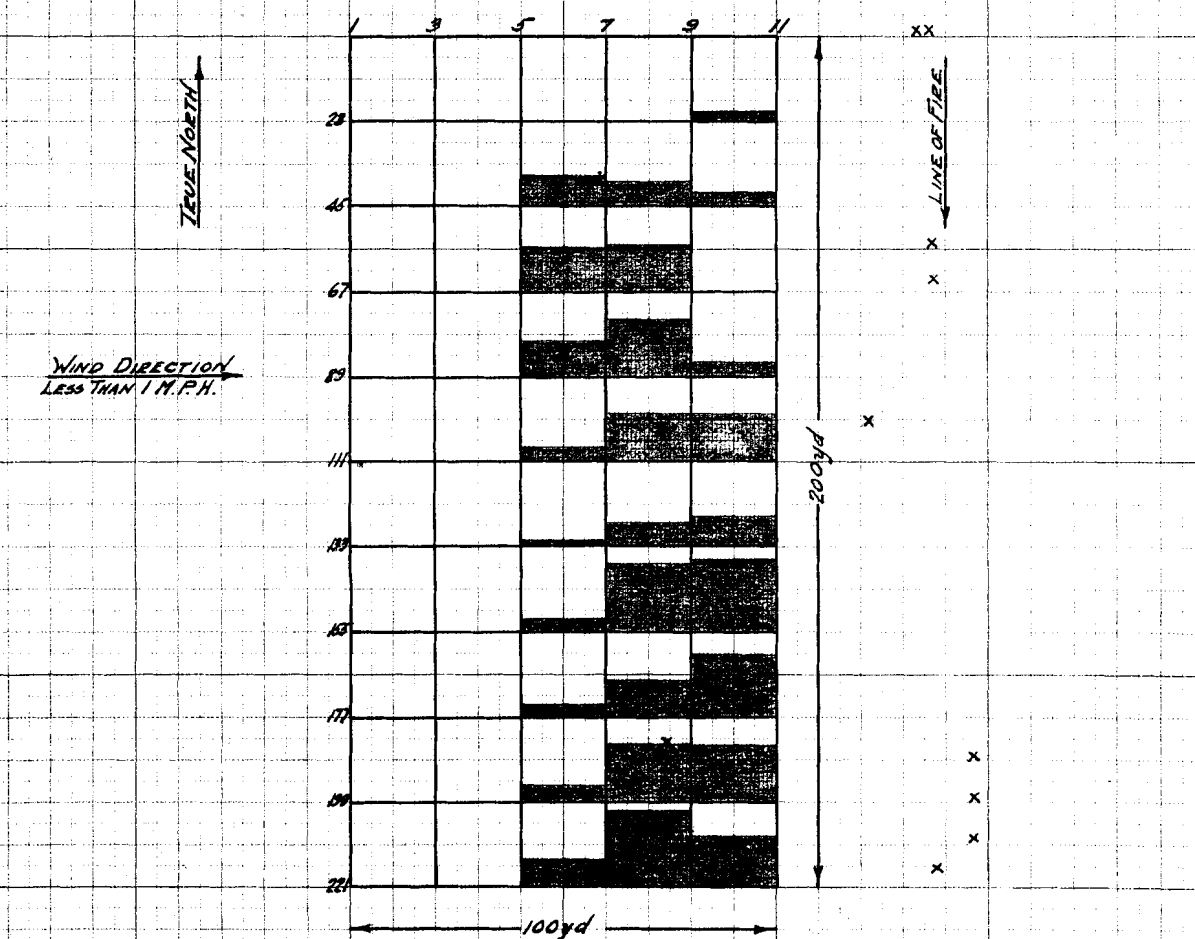
200 yd

100 yd

LINE OF FIRE

50 YDS  
SCALE

CHART 4G  
 TEST OF H5 FILLED 155<sup>mm</sup> HOWITZER SHELL  
 PROJECT A1.1-16  
 JULY 6, 1933  
 ESTIMATED MAN CASUALTIES DUE TO EFFECTS  
 OF H5 LIQUID \*



LEGEND:-

- x - Ground Burst
- x - Tree Burst
- Shaded Area Represents  
 100% Max. Casualties.

NOTE:-

MAN PROTECTED BY GAS MASK AND  
 STANDARD ISSUE OF UNIMPERMEATED  
 CLOTHING.  
 \* CASUALTIES BASED ON EXPOSURE DURING  
 THE FIRING PERIOD.

CHART 5G  
TEST OF HS FILLED 155mm HOWITZER SHELL  
PROJECT A11-16  
JULY 6, 1933  
ANIMAL CASUALTIES DUE TO EXPOSURE DURING  
FIRING AND FOLLOWING 22 MINUTES

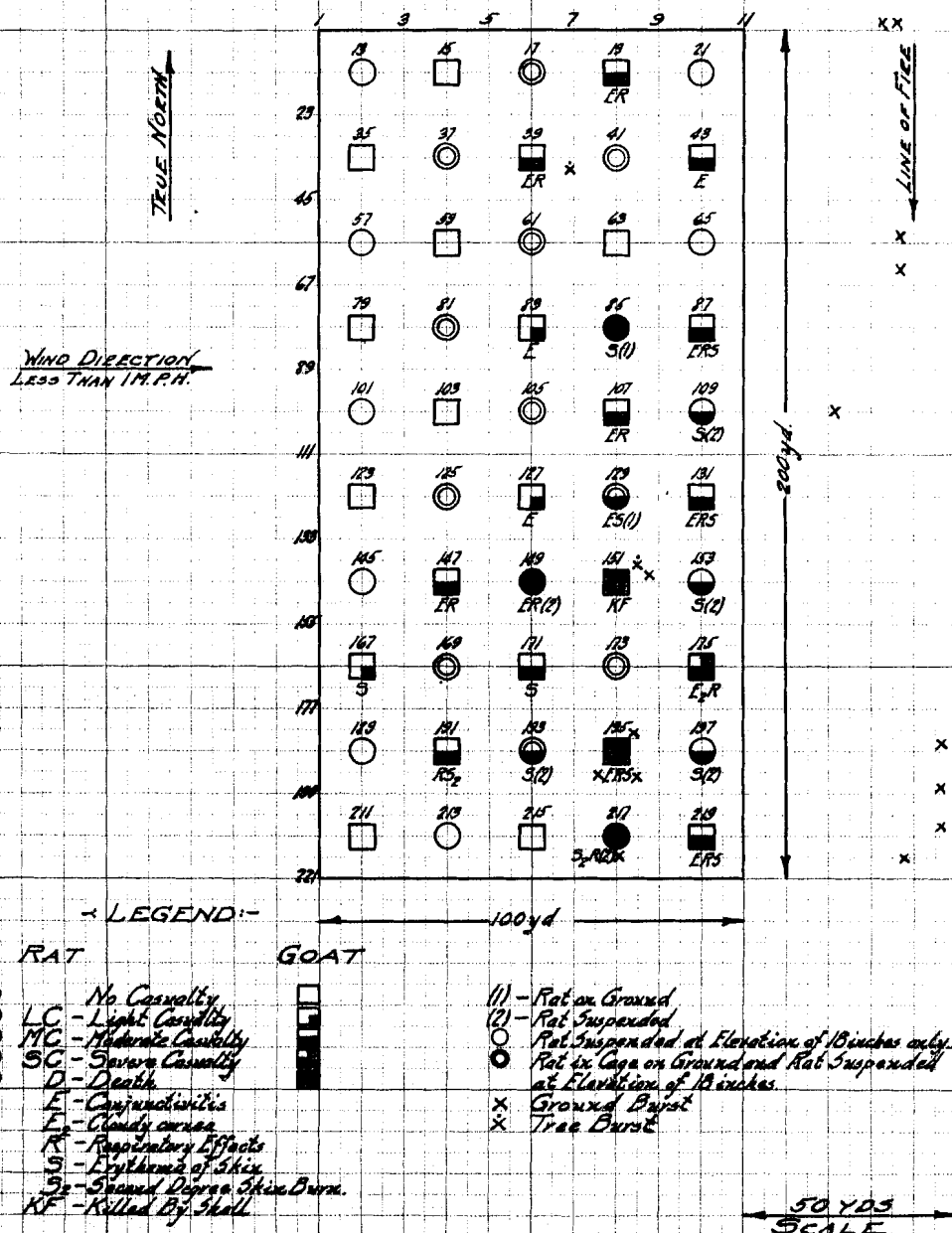
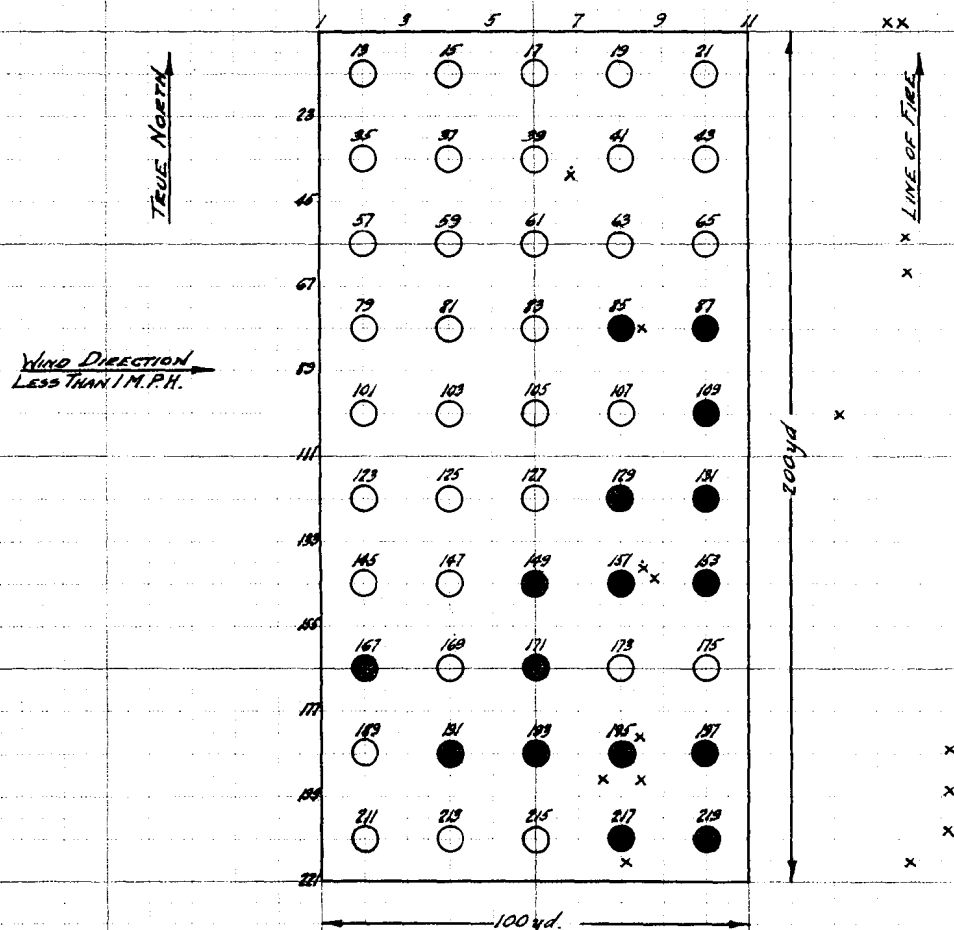


CHART 6G  
TEST OF H5 FILLED 155mm HOWITZER SHELL

PROJECT A1.1-16

JULY 6, 1933

ESTIMATED MAN CASUALTIES BASED ON EFFECTS  
ON ANIMALS EXPOSED DURING FIRING AND  
FOLLOWING 22 MINUTES



-: LEGEND :-

- - Estimated no Casualties
- - Estimated Max Casualties
- x - Ground Burst
- \* - Tree Burst

50 YDS  
SCALE

Based on HS liquid and vapor samples -	3.8 shell
Based on effects on animals -	7.1 shell
Average	<u>5.5 shell</u>

(8) Conclusions. From the results of the present test, the following conclusions are drawn with respect to the use of 155-mm. howitzer shell filled with HS under the meteorological and terrain conditions of the test.

(a) The number of shell required per 100 yd. square to produce 50% casualties when distributed as equally as practicable, are as follows:

1. When man protected by gas mask and standard impregnated clothing is exposed during the firing period - about 25 shell (see paragraph 9,c,(7),(c),4).

2. When man protected by gas mask only, is exposed on the target for a period of 25 min. including firing - about 6 shell (see paragraph 9,c,(7),(g) above).

(b) This test should be repeated due to the small number of bursts on the target and the fact that all these bursts were on the downwind side of the target.

d. Test of August 11, 1933.

(1) Object. To determine the number of HS-filled 155-mm. howitzer shell required to produce 50% casualties when fired about 1 hr. before sunset at personnel protected by gas mask only, who are located in wooded country and remain on the impact area for a period of 25 min. including the firing period.

(2) Materials Used. Forty MII, 155-mm. howitzer shell filled with HS were used in the test. The history of these shell and the type of fuze and booster used are given in paragraph 4.

(3) Target. The location of the target and positions of vapor sampling machines, panels and animals were the same as in previous test conducted on July 6, 1933. At the time of the test, the soil was wet from effects of a rain on the previous night.

Chart LH, shows the target as it was prepared for the test with positions of animals, panels and vapor sampling machines.

(4) Firing of Shell.

(a) Adjustment. Fourteen shell were used. Registration fire was directed at a position about 200 yd. west of the target. Firing started at 4:45 p.m. and ended at 5:10 p.m., a period of 25 min.

(b) Firing for Effect. The howitzers were ranged in parallel for impact on a line through the short axis of the target. Firing started at 5:46 p.m. and ended at 5:52 p.m., a period of 6 min. Twenty-six shell were used.

A photostatic copy of a Memorandum dated August 11, 1933 to Capt. C.E. Loucks, from the Battery Commander giving firing data by round, is attached to this report.

(5) Meteorological Conditions.

(a) During Firing and Following Hour.

Time	5:50 p.m.	6:15 p.m.	7:00 p.m.
Air temperature, °F.	72	72	69
Ground temperature, °F.	74	74	71
Relative humidity, %	80	80	86
Wind velocity (on open area near target)*	slight drift	slight drift	slight drift
Wind velocity (on target)*	slight drift	slight drift	slight drift
Wind travel	NE	NE	NE
Sky	cloudy	cloudy	cloudy

\*At an elevation of 6 ft.

(b) During the First Nine Days Following Test.

Date :		Temp. °F.		Rainfall:		Cloudiness				
From:	To :	Max.:	Min.:	8 a.m.:	inches :	8 a.m.:	10 a.m.:	12 noon:	2 p.m.:	4 p.m.:
8/12:	8/13:	85 :	62 :	70 :	.06 :	1. :	1. :	1. :	1. :	1. :
8/13:	8/14:	90 :	70 :	78 :	0 :	.8 :	.8 :	.3 :	.3 :	.2 :
8/14:	8/15:	77 :	61 :	69 :	.31 :	1. :	1. :	1. :	1. :	1. :
8/15:	8/16:	84 :	60 :	71 :	0 :	0 :	.2 :	.6 :	.6 :	.6 :
8/16:	8/17:	80 :	61 :	71 :	.07 :	.8 :	.9 :	.9 :	.9 :	1. :
8/17:	8/18:	81 :	68 :	70 :	.19 :	.9 :	.9 :	.8 :	.9 :	.9 :
8/18:	8/19:	82 :	70 :	73 :	0 :	1. :	1. :	.9 :	.7 :	.4 :
8/19:	8/20:	86 :	73 :	74 :	0 :	1. :	1. :	.9 :	1. :	1. :
8/20:	8/21:	81 :	70 :	71 :	0 :	1. :	1. :	1. :	1. :	1. :

(6) Results.

(a) Impacts. The positions of impacts are shown on Chart 2H. There were 26 impacts accounted for on and around the target of which 7 were bursts on the target.

Of the 40 shell fired including the 14 used for adjustment, there were 11 duds, 5 low order bursts and 24 normal bursts.

(b) Liquid HS.

1. Size of HS Drops. The paper panels on the target were tabulated for size of HS drops. Results are given in the following table:

Table No. 22.

Number of Panels Showing HS Drops of 1.0 mg. or Larger.

Panel: no.	No. of HS drops			
	:0.1 to :0.5 mg.:	:Over 0.5 :to 1.0 mg.:	:Over 1.0 :to 3.0 mg.:	:Over 3.0 mg.:
1	25	1		
7	5	2	1	
8	15	2		
9	15	2		
10	3		2	1
12	25			
18	100	100	50	
20	5	2		
23	100			
31	3	1		
33	1			
34	9			
46	15	3		
48	3			
49	5			
52	15			
57	15	3	1	
59	15	5	3	2
61	15	2		
63	15			
64	100	9		
65	2			
69	5	3		
72	3			
74	2	1	1	
75	6	2		
82	1			
102	1	5		
103	2			
135	11			

(c) Estimated Man Casualties from Liquid HS.

1. Man Protected by Gas Mask but without Protection of Impregnated Clothing.

The paper panels on the target were tabulated for density of pattern using the pattern scale attached to this report. Results are tabulated in the following tables together with estimated man casualties. The basis of estimated casualties is explained in paragraph 6,a.

Table No. 23.

Estimated Masked Man Casualties from HS Liquid Based on Panel Data.

<u>Pattern: Panels classified: Estimated casual-</u>			
	<u>: No. :</u>	<u>Per cent of:</u>	<u>ties for man pro-</u>
		<u>total on</u>	<u>ected by gas mask</u>
		<u>target</u>	<u>only</u>
			<u>%</u>
Heavy	: 6 :	2.6	: 2.6
Medium	: 24 :	10.4	: 10.4
Light	: 32 :	13.9	: 11.1
Trace	: 50 :	21.6	: 13.0
No HS	: 119 :	51.5	:
Total	: 231 :	100.0	: 37.1

2. Man Protected by Gas Mask and Standard Impregnated Clothing.

From results in Table No. 22, a tabulation is given in Table No. 24, of panels showing HS drops of 0.5 mg. or larger, together with estimated casualties for man protected by gas mask and standard impregnated clothing. The basis of estimated casualties is explained in paragraph 6,a,(2).

Table No. 24.

Estimated Masked Man Casualties from HS Liquid Based  
on Panel Data.

Size of HS drops:	No. of panels:	Estimated casualties for man protected by gas mask and standard impregnated clothing:	per panel %:	per target %:
One drop or more:	11		40	1.9
between 0.5 to 1.0 but with no drop exceeding 1.0 mg.				
One drop or more exceeding 1.0 mg.	6		100	2.6
Total	17			4.5

Total panels on target - 231

(d) Estimated Man Casualties from HS Vapor.

Vapor samples were taken at positions shown on Chart 1H. In Tables No. 25, 25A, 26 and 26A which follow, the vapor concentrations, c.t. value, and per cent estimated casualties from effects of HS vapor for man protected by gas mask only, are given for each sampling position. The basis of estimated casualties is explained in paragraph 6.b.

1. Firing Period and Following 22 Minutes.

Table No. 25.

Estimated Masked Man Casualties from HS Vapor on Target.

Sampling position:	Elevation of sample	Vol. of air sampled	HS sampled	HS Vapor concn.	c.t. value	Estimated man casualties for man protected by gas mask only
	ft.	liters	mg.	mg./l.		%
C	1	850	37.3	.0438	1.10	100
F	1	836	4.0	.0048	.12	100
G	0	824	15.7	.0190	.47	100
J	0	850	11.0	.0129	.32	100
K	1	836	5.0	.0060	.15	100
N	1	824	3.2	.0039	.10	93
O	0	824	2.2	.0027	.07	73
R	0	816	1.0	.0012	.03	42
S	1	824	0	0	0	0

\*Based on a 25 min. period (1/2 firing period plus 22 min.).

Table No. 25A.

Estimated Masked Man Casualties from HS Vapor at Position Outside of Target.

D	0	425	0.8	.0019	.05	58
	1	425	2.4	.0056	.14	100
	2	425	0.4	.0009	.02	30
	4	425	1.0	.0023	.06	66
E	0	418	0.6	.0014	.04	50
	1	418	0.6	.0014	.04	50
	2	418	0.6	.0014	.04	50
	4	418	0.6	.0014	.04	50
H	0	412	1.8	.0044	.11	100
	1	412	2.8	.0068	.17	100
	2	412	1.6	.0039	.10	93
	4	412	2.6	.0063	.16	100
I	0	425	2.2	.0052	.13	100
	1	425	0.8	.0019	.05	58
	2	425	0.4	.0009	.02	30
	4	425	0.4	.0009	.02	30
L	0	418	1.6	.0038	.10	93
	1	418	0.4	.0010	.02	30
	2	418	4.0	.0095	.24	100
	4	418	1.4	.0033	.08	80

Table No. 25A. (Cont'd.)

Sampling position:	Elevation of sample	Vol. of air sampled	HS sampled	Vapor concn.	c.t. value	Estimated casualties for man protected by gas mask only
	ft.	liters	mg.	mg./l.	*	%
P	0	412	0.8	.0019	.05	58
	1	412	1.6	.0039	.10	93
	2	412	1.4	.0034	.08	80
	4	412	1.0	.0024	.06	66
T	0	412	0.4	.0010	.02	30
	1	412	0	0	0	0
	2	412	0.4	.0010	.02	30
	4	412	0	0	0	0

Samples taken at positions M and Q showed negative results.

2. From the 32nd to 67th Minute After Firing.

Table No. 26.

Estimated Masked Man Casualties from HS Vapor on Target.

C	1	1234	26.1	.0211	.74	100
G	0	1216	19.3	.0159	.56	100
J	0	1144	1.4	.0012	.04	50
K	1	1234	0.8	.0004	.01	11
R	0	1216	0	0	0	0
O	0	1216	0	0	0	0
N	1	1234	0	0	0	0
S	1	1216	0	0	0	0
Av.						32.6

Table No. 26A.

Estimated Masked Man Casualties from HS Vapor at Positions  
Outside of Target.

Sampling position:	Elevation of sample	Vol. of air sampled	HS sampled	HS Vapor concn.	c.t. value	Estimated casualties for man protected by gas mask only
	ft.	liters	mg.	mg./l.		%
D	0	617	0.4	.0006	.02	30
	1	617	1.2	.0019	.07	73
	2	617	1.2	.0019	.07	73
	4	617	1.2	.0019	.07	73
E	0	635	1.2	.0019	.07	73
	1	635	1.6	.0025	.09	87
	2	635	1.2	.0019	.07	73
	4	635	1.2	.0019	.07	73
H	0	608	1.2	.0020	.07	73
	1	608	1.0	.0018	.06	66
	2	608	1.0	.0018	.06	66
	4	608	0.8	.0013	.05	58
I	0	572	0.4	.0007	.02	30
	1	572	0	0	0	0
	2	572	0.4	.0007	.02	30
	4	572	0	0	0	0
L	0	617	0.6	.0010	.03	42
	1	617	0	0	0	0
	2	617	0.6	.0010	.03	42
	4	617	0.6	.0010	.03	42
T	0	608	0.4	.0006	.02	30
	1	608	0.4	.0006	.02	30
	2	608	0	0	0	0
	4	608	0.4	.0006	.02	30

Samples taken at positions M, Q, and P showed negative results.

(e) Estimated Man Casualties Based on Effects on Animals.

Animals consisting of goats and rats were placed on the target at positions shown on Chart 1H. Animal casualties and estimated man casualties for man protected by gas mask only, are given in Tables No. 27A, 27B, and 27C. Animal casualties and estimated man casualties, based on effects on animals, are shown on Charts 5H and 6H. The basis of estimated casualties and the symbols used in the tables and on the charts, to designate the nature of the animal casualties are explained in paragraph 6,c.

1. Firing Period and Following 22 Minutes.

Table No. 27A.

Estimated Masked Man Casualties Based on Effects on Rats  
Suspended at an Elevation of 18 ih.

Position: of stake	Nature : of : casualty	Severity : of : casualty	Estimated man cas- ualties
			%
17	: S	:Light	100
41	: ERS	:Death in: : 4 days :	100
57	: S	:Medium	100
61	: ERS	:Death in: : 2 days :	100
105	: S	:Light	100
145	: S	:Light	100
149	: S	:Light	100

Total suspended rat positions - 25

Estimated man casualty positions - 7

Per cent estimated man casualties - 28

Table No. 27B.

Estimated Masked Man Casualties Based on Effects on Rats  
In Cages on Ground.

Position of stake	Nature of casualty	Severity of casualty	Estimated man casualties %
41	ERS	Death in: 3 days	100
61	ERS	Death in: 3 days	100
129	S	Light	100

Total rats in cages on ground - 13  
Estimated man casualty positions - 3  
Per cent estimated man casualties - 23.1

Table No. 27C.

Estimated Masked Man Casualties Based on Effects on Goats.

15	ER	Medium	0
19	ERS	Medium	100
35	ERS	Death in: 2 days	100
39	ER	Medium	0
43	R	Medium	0
59	ERS	Medium	100
63	E	Medium	0
83	ER	Medium	0
87	E	Medium	0
103	E	Medium	0
127	ER	Light	0
147	ER	Medium	0
191	R	Light	0
211	R	Medium	0

Total goats exposed - 25  
Estimated man casualty positions - 3  
Per cent estimated man casualties - 12

2. Fifth Day After Firing. Two goats were exposed in shell craters located near stake 47 for a period of 24 hr. on the fifth day after firing. One of these goats was unaffected but the other was a light skin casualty.

(7) Discussion.

(a) Shell Distribution. The positions of impacts on and around the target are shown on Chart 2H. There were two low order bursts, 1 tree burst and four normal bursts on the target. Three bursts north of the target were probably slightly effective on the target. If it is assumed that these three bursts outside of the target are equivalent to 1 burst on the target, the total effects on the target were equivalent to 8 shell.

(b) Impact Area. For purposes of discussion the impact area may be regarded as that part of the target represented by the 20-yd. squares listed in Table No. 29. The impact area is shown on Chart 2H.

(c) Estimated Casualties from Liquid HS.

1. Effects of Meteorological Conditions.

The wind velocity over the target during firing was zero so that distribution and casualty effect of liquid HS were not affected at all by meteorological conditions.

2. Effects of Terrain. Of the seven shell bursts on the target, one was due to a tree impact. Theoretically, this shell should be more effective than a ground burst, due to distribution of liquid HS over a larger area.

3. Man Protected by Gas Mask but without Protection of Impregnated Clothing.

From results given in Table No. 23, it is estimated that personnel protected by gas mask only would experience about 37.1% casualties from liquid HS if they are equally distributed over the target and remain there during the firing period. The liquid HS on the target was due to the burst of 8 shell. On the basis of 8 shell on an area of 20,000 sq.yd. to produce 37.1% casualties from liquid HS when personnel are protected by gas mask only, it will require 5.4 shell per 100 yd. square to produce 50% casualties.

4. Man Protected by Gas Mask and Standard Impregnated Clothing.

From results in Table No. 24, it is estimated that personnel protected by gas mask and standard impregnated clothing, who are exposed on the target during the firing period will experience about 4.5% casualties if they are equally distributed over its area. On this basis it will require about 44.4 shell per 100 yd. square to produce 50% casualties.

(d) Effects of HS Vapor.

1. Discussion of Meteorological Conditions.

During the test, the air temperature was 72°F. and there was almost no air motion. The temperature was low for most effective results. The absence of air motion theoretically resulted in the vapor being very effective directly over the area sprinkled with HS but resulted in a very slow spread of the vapor beyond the contaminated area. Under such stagnant conditions, if personnel moved off the impact area within the first 25 min. after firing, a large percentage would not be so thoroughly gassed as they would if there was slightly more air motion, due to the long period required for the vapors to spread downwind from the contaminated area.

2. Firing Period and Following 22 Minutes.

(a) On Target.

Results of vapor samples taken at the 9 sampling positions on the target area are given in Table No. 25 for the firing period and following 22 min. The vapor concentration for each 20-yd. sq. of the target was figured from results in this table taking into consideration the positions of nearest impacts and wind direction. These results are given in the fifth column of Table No. 28. From the average of the figures in the fifth column, it is estimated that personnel with gas mask protection only, would experience about 84.6% casualties if exposed on the target during firing and the following 22 min.

Per cent estimated casualties from effects of HS vapor is shown graphically on Chart 3H. The shaded area on the chart represents that part of the area on which it is estimated 100% casualties would be produced by effects of HS vapor when man is protected by gas mask only.

(b). Outside of Target.

Estimated casualties at sampling positions downwind from the target are given in Table No. 25A. Results show estimated casualties varying at the different positions from about 30 to 100% from effects of HS vapor for personnel protected by gas mask only, who are exposed 30 yd. downwind from the impact area during firing and the following 22 min.

3. From the 32nd to 67th Minute After Firing.

(a) On Target.

From results of vapor samples in Table No. 26, it is estimated that personnel protected by gas mask only would experience about 32.6% casualties from effects of HS vapor if they are equally distributed over the target and exposed from the 32nd to 67th min. after firing. Estimated casualties for this period are shown graphically on Chart 3aH.

(b) Outside of the Target.

Estimated vapor casualties are given in Table No. 26A based on results at sampling positions 30 yd. downwind from the target for the period between the 32nd and 67th min. after firing. Estimates from these results vary from about 30% to 87% casualties, for man protected by gas mask only.

(c) Estimated Masked Man Casualties Based on Effects on Animals.

1. Firing Period and Following 22 Minutes.

Animal casualties and estimated man casualties, based on effects on animals, are given in Tables No. 27A, 27B, and 27C, representing exposure on the target during firing and the following 22 min. Results in the three tables are consolidated in the last two columns of Table No. 28 where consolidated results, based on animal casualties, show 22% estimated man casualties. The results in these two columns are also shown graphically on Charts 5H and 6H.

2. Persistence of HS on Impact Area.

Results given in paragraph 9,d,(6),(e),2 show one animal casualty out of two animals exposed in shell craters for a period of 24 hr. on the fifth day after firing. These results indicate that the impact area could not be occupied on the 5th day after firing by personnel with only gas mask protection for a period of about 24 hr. without experiencing casualties.

(f) Comparison of Per Cent Estimated Masked Man Casualties Based on Measurements of the Gas Concentration and by its Effects on Animals.

1. On Target (100 yd. by 200 yd.).

In Table No. 28, estimated man casualties are given for each 20-yd. square representing an animal position based on:

HS liquid determined by panel data  
 HS vapor determined by vapor samples  
 Combined effects of HS liquid and vapor from sample data  
 From effects on animals

Table No. 28.

Estimated Masked Man Casualties on Target on Exposure During Firing and the Following 22 Min. (Area - 20,000 sq.yd.) August 11, 1933.

Stake no.:		Impact:	From HS liquid:	From HS vapor:	From HS liquid:	From effects								
at center:		within:	Estimated man.:	c.t.:	Estima-:	and vapor	:	on animals						
of 20-yd.:		20-yd.:	casualties	:	estimated man:	Estimated man:	Animal	Estima-						
square	:	square	:	:	casual-	casualties	casual-	ted man						
:	:	:	:	:	ties	:	ties	casual-						
:	:	:	:	:	:	:	:	ties						
<hr/>														
:	:	:	%	:	%	:	:	%						
13	:	0	:	49	:	.50	:	100	:	100	:	N	:	0
15	:	0	:	9	:	.40	:	100	:	100	:	Med. ER	:	0
17	:	0	:	64	:	.50	:	100	:	100	:	Light S	:	100
	:		:		:		:		:		:	(2)	:	
19	:	0	:	82	:	1.10	:	100	:	100	:	Med. ERS	:	100
21	:	0	:	60	:	.50	:	100	:	100	:	N	:	0
35	:	1	:	73	:	.30	:	100	:	100	:	Death	:	100
	:		:		:		:		:		:	ERS	:	
37	:	1	:	47	:	.40	:	100	:	100	:	N	:	0
39	:	1	:	60	:	.50	:	100	:	100	:	Med. ER	:	0
41	:	0	:	78	:	.50	:	100	:	100	:	Death	:	100
	:		:		:		:		:		:	ERS	:	
	:		:		:		:		:		:	(1 & 2)	:	
43	:	0	:	35	:	.40	:	100	:	100	:	Med. R	:	0
57	:	0	:	82	:	.12	:	100	:	100	:	Med. S	:	100
	:		:		:		:		:		:	(2)	:	
59	:	0	:	87	:	.12	:	100	:	100	:	Med. ERS	:	100
61	:	0	:	78	:	.30	:	100	:	100	:	Death	:	100
	:		:		:		:		:		:	ERS (1)	:	
	:		:		:		:		:		:	ERS (2)	:	

Table No. 28 (Cont'd.)

Stake no.:	Impact:	From HS liquid:	From HS vapor:	From HS liquid:	From Effects
at center:	within:	Estimated man	c.t.:	Estimated man	and vapor
of 20-yd.:	20-yd.:	casualties	value:	Estimated man	Estimated man
square	square:	:	:	casual-	casualties
:	:	:	:	ties :	:
:	:	:	:	:	:
:	:	%	:	%	:
:	:	:	:	:	:
63	: 1 :	82	: .47 :	100	: 100
66	: 0 :	58	: .30 :	100	: 100
79	: 0 :	55	: .30 :	100	: 100
81	: 0 :	67	: .30 :	100	: 100
83	: 0 :	58	: .30 :	100	: 100
85	: 0 :	44	: .30 :	100	: 100
87	: 0 :	33	: .20 :	100	: 100
101	: 1 :	51	: .30 :	100	: 100
103	: 0 :	87	: .32 :	100	: 100
105	: 0 :	38	: .25 :	100	: 100
	:	:	:	:	:
107	: 0 :	0	: .15 :	100	: 100
109	: 0 :	0	: .13 :	100	: 100
123	: 1 :	73	: .20 :	100	: 100
125	: 0 :	89	: .32 :	100	: 100
127	: 0 :	60	: .20 :	100	: 100
129	: 0 :	13	: .15 :	100	: 100
	:	:	:	:	:
131	: 0 :	0	: .11 :	100	: 100
145	: 1 :	47	: .15 :	100	: 100
	:	:	:	:	:
147	: 0 :	71	: .15 :	100	: 100
149	: 0 :	27	: .10 :	93	: 95
	:	:	:	:	:
151	: 0 :	7	: .10 :	93	: 93
153	: 0 :	0	: .09 :	87	: 87
167	: 0 :	42	: .09 :	87	: 92
169	: 0 :	44	: .10 :	93	: 96
171	: 0 :	0	: .09 :	87	: 87
173	: 0 :	0	: .07 :	73	: 73
175	: 0 :	0	: .07 :	73	: 73
189	: 0 :	24	: .03 :	42	: 55
191	: 0 :	22	: .06 :	66	: 73
193	: 0 :	0	: .03 :	42	: 42
195	: 0 :	0	: .02 :	30	: 30
197	: 0 :	0	: .03 :	42	: 42
211	: 0 :	0	: .03 :	42	: 42

:Med. E : 0  
: N : 0  
: N : 0  
: N : 0  
:Med. ER : 0  
: N : 0  
:Med. E : 0  
: N : 0  
:Med. E : 0  
:Light S : 100  
: (2) :  
: N : 0  
: N : 0  
: N : 0  
: N : 0  
:Light ER: 0  
:Light S : 100  
: (1) :  
: N : 0  
:Light S : 100  
: (2) :  
:Med. ER : 0  
:Light S : 100  
: (2) :  
: N : 0  
: N : 0  
: N : 0  
: N : 0  
: N : 0  
: N : 0  
: N : 0  
: N : 0  
:Light R : 0  
: N : 0  
: N : 0  
: N : 0  
:Med. R : 0

Table No. 28 (Cont'd.)

Stake no.:	Impact:	From HS liquid:	From HS vapor:	From HS liquid:	From effects
of center:	within:	Estimated man	c.t.:	Estimated man	on animals
of 20-yd.:	20-yd.:	casualties	valued	Estimated man	Animal
square	square:	:	casual-	casualties	casual-
:	:	:	ties :	:	ties :
:	:	:	:	:	:
:	:	%	:	%	:
213	: 0 :	13	: .03 :	42	: 50
215	: 0 :	0	: .02 :	30	: 30
217	: 0 :	0	: .0 :	0	: 0
219	: 0 :	0	: .01 :	11	: 11
Total and:	7 :	38.2	:	84.6:	85.4
average :	:	:	:	:	:

NOTE: Symbols used in column 7 to designate the nature of the animal casualties are explained in paragraph 6, c.

(1) designates rat in cage on ground.

(2) designates rat in cage suspended at an elevation of 18 in.

Results in Table No. 28 show 85.4% casualties based on sample data and 22% based on effects on animals.

## 2. On Impact Area (10,000 sq.yd.).

The impact area as defined in paragraph 9,d,(7),(b) is shown on Chart 2H and the 20 yd. sq. included within its area are tabulated in Table No. 29. On its area of 10,000 sq.yd. there were 7 bursts and effects from other bursts outside of the target, estimated as equivalent to one additional burst, making the total effects equivalent to 8 bursts. Results show 99.5% estimated casualties based on sample data and 32.0% based on animal data.

Table No. 29.

Estimated Casualties on Impact Area on Exposure During  
Firing Period and the Following 22 Minutes  
(Area - 10,000 sq.yd.) August 11, 1933.

Stake no.	Impact at center of 20-yd. square	Within 20-yd. square	Estimated casualties	From HS liquid : c.t. value	From HS vapor : Estimated casualties	From HS liquid and vapor : Estimated casualties	From effects on animals : Animal casualties	Estimated man : Estimated casualties
			%		%	%		%
13	0		49	.50	100	100	N	0
15	0		9	.40	100	100	Med. ER	0
17	0		64	.50	100	100	Light S	100
							(2)	
19	0		82	1.10	100	100	Med. ERS	100
21	0		60	.50	100	100	N	0
35	1		73	.30	100	100	Death	100
							ERS	
37	1		47	.40	100	100	N	0
39	1		60	.50	100	100	Med. ER	0
41	0		78	.50	100	100	Death	100
							ERS (1)	
							ERS (2)	
43	0		35	.40	100	100	Med. R	0
57	0		82	.12	100	100	Med. S	100
							(2)	
59	0		87	.12	100	100	Med. ERS	100
61	0		78	.30	100	100	Death	100
							ERS (1)	
							ERS (2)	
63	1		82	.47	100	100	Med. E	0
65	0		58	.30	100	100	N	0
79	0		55	.30	100	100	N	0
81	0		67	.30	100	100	N	0
101	1		51	.30	100	100	N	0
103	0		87	.32	100	100	Medium	0
123	1		73	.20	100	100	N	0
125	0		87	.32	100	100	N	0
145	1		47	.15	100	100	Light S	100
							(2)	
147	0		71	.15	100	100	Med. ER	0

Table No. 29 (Cont'd.)

Stake No.	Impact at center of 20-yd. square	Within 20-yd. square	From HS liquid: Estimated man casualties	From HS vapor: c.t. value	From HS liquid and vapor: Estimated man casualties	From effects on animals: Animal casualties	Estimated man casualties
167	0		42	.09	87	N	0
169	0		44	.10	93	N	0
Total and average	7		62.7		99.2		32

NOTE: Symbols used in column 7 to designate the nature of the animal casualties are explained in paragraph 6,c.  
 (1) designates rat in cage on ground.  
 (2) designates rat in cage suspended at an elevation of 18 in.

(g) Number of Shell Required to Produce 50% Masked Man Casualties per 100 Yard Square.

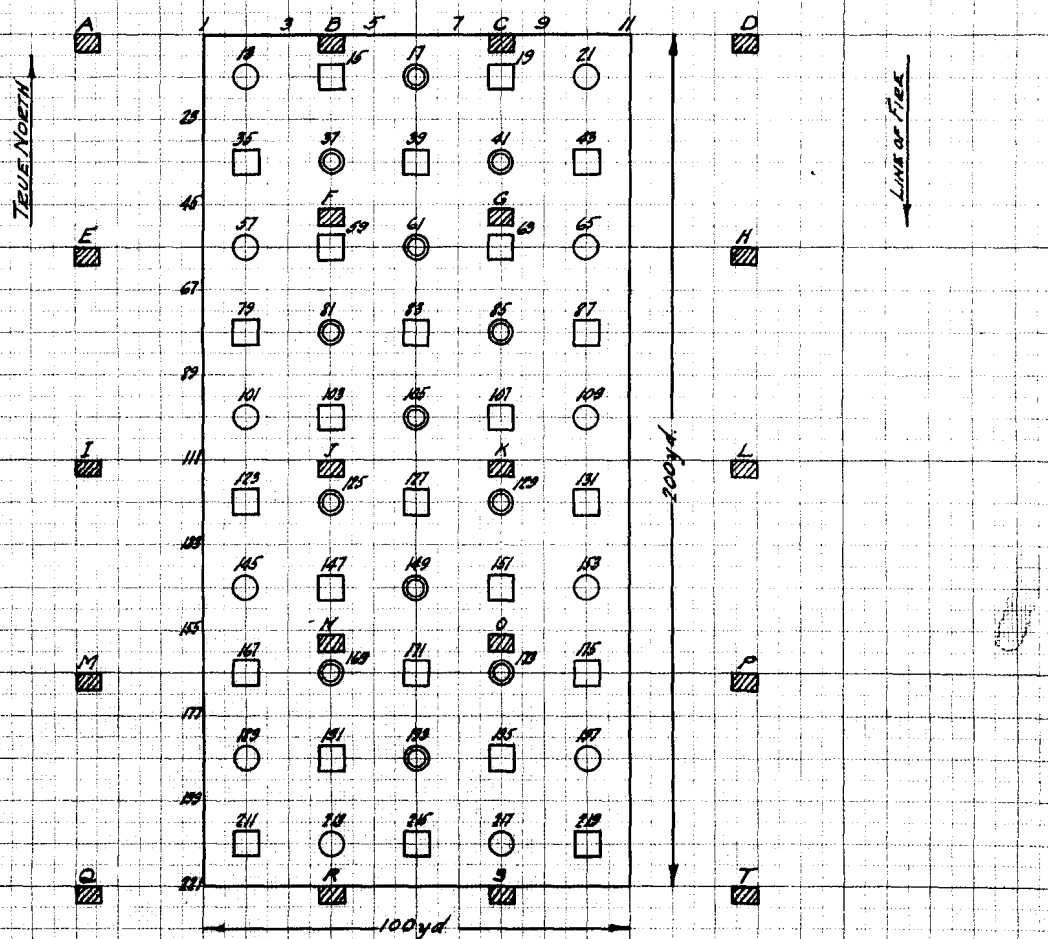
From data given in paragraph 9,d,(7),(f),2 above, it was estimated that the burst of 8 shell on an area of 10,000 sq. yd. would produce 99.5% casualties, based on sample data and 32.0% based on effects on animals, when personnel who have only gas mask protection are exposed on the impact area during firing and the following 22 min. On this basis the following number of shell are required to produce 50% casualties when man is protected by gas mask only.

Based on HS liquid and vapor samples -	4 shell
Based on effects on animals -	12.5 shell
Average -	8.3 shell

(8) Conclusions. From the results of the present test, the following conclusions are drawn with respect to the use of 155-mm. howitzer shell filled with HS under the meteorological and terrain conditions of the test.

CHART 1H  
TEST OF HS FILLED 155mm HOWITZER SHELL  
PROJECT A1.1-16  
AUGUST 11, 1933

TARGET AREA



LEGEND:-

- Goat
- Sampling Machine
- Rat in Cage Suspended at Elevation of 15 inches
- Rat in Cage on Ground in Addition to Rat in Cage Suspended at Elevation of 15 inches.

NOTE:-

PAPER PANELS & SCALES WERE PLACED AT SPARK POSITIONS.

50 YDS  
SCALE

CHART 2H  
 TEST OF HS FILLED 155mm HOWITZER SHELL  
 PROJECT A.I.1-16  
 AUGUST 11, 1933  
 POSITION OF IMPACTS

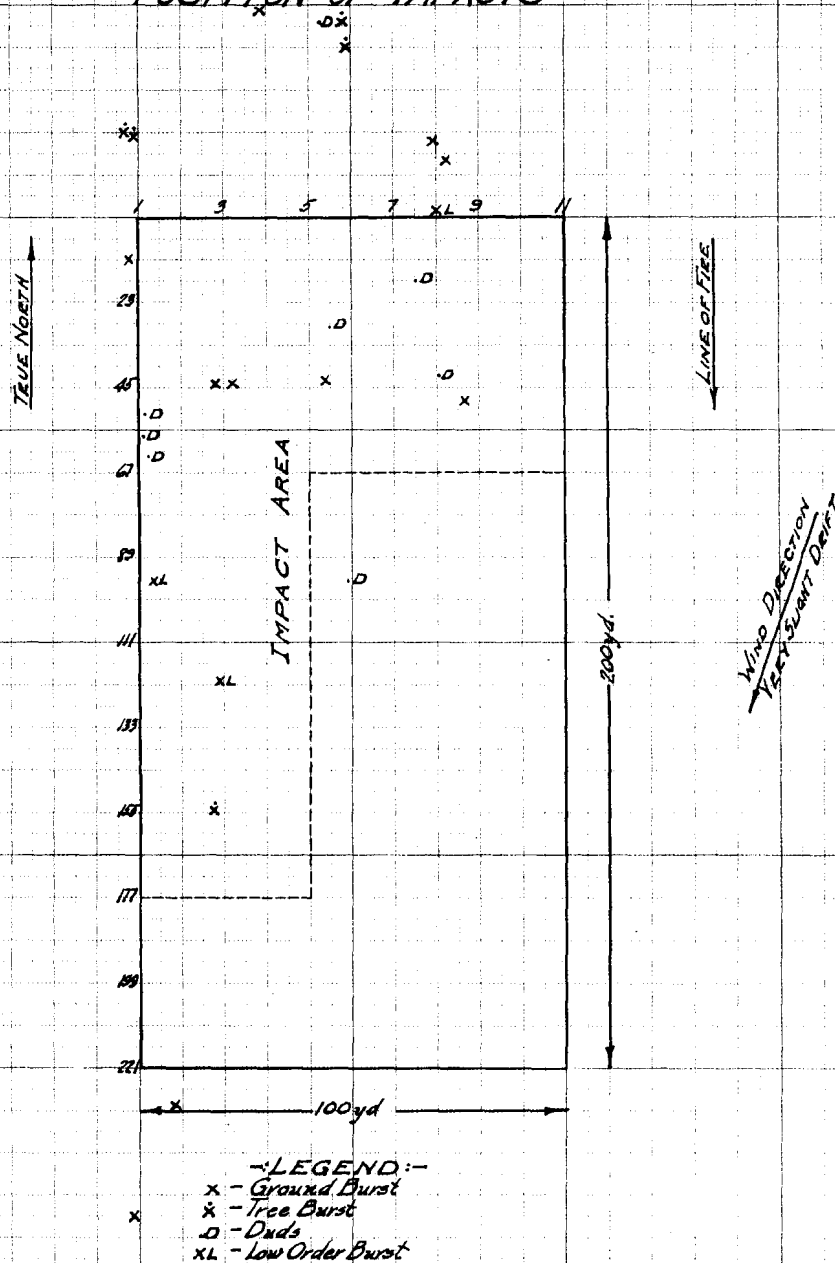
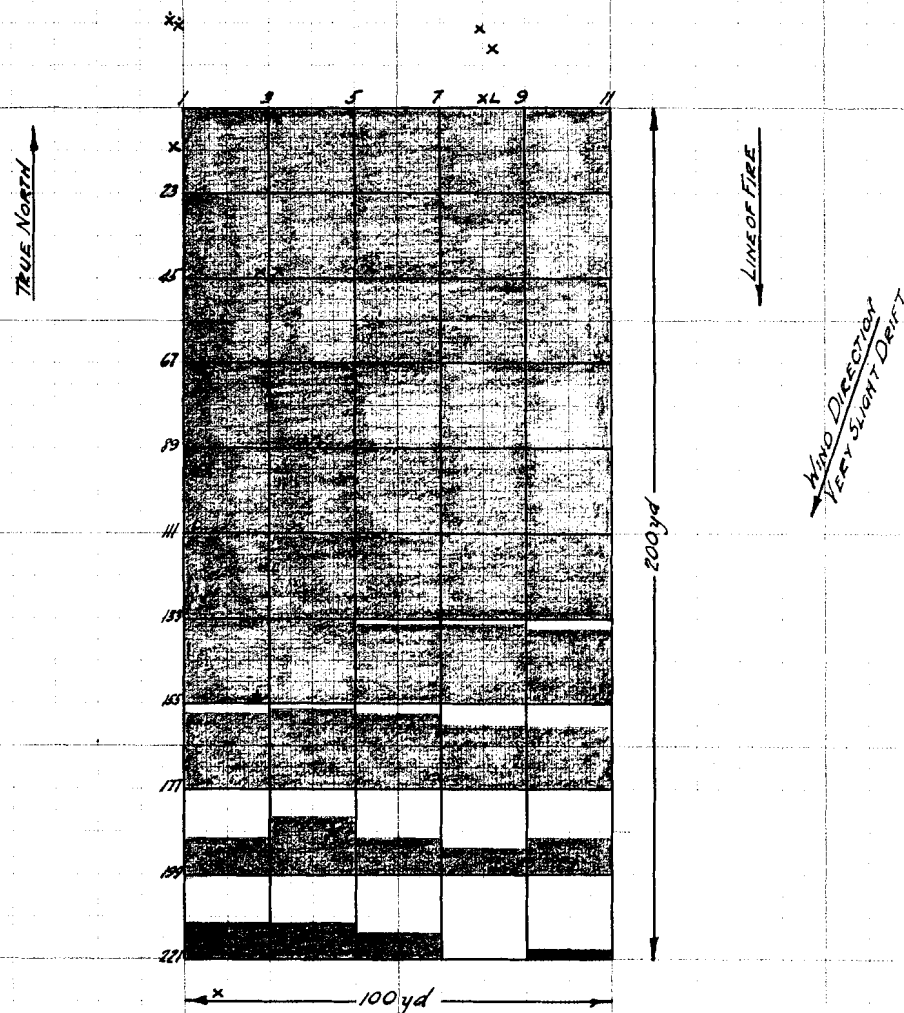


CHART 3H  
 TEST OF HS FILLED 155mm HOWITZER SHELL  
 PROJECT A1.1-16  
 AUGUST 11, 1933  
 ESTIMATED MAN CASUALTIES DUE TO EFFECTS  
 OF HS VAPOR \*



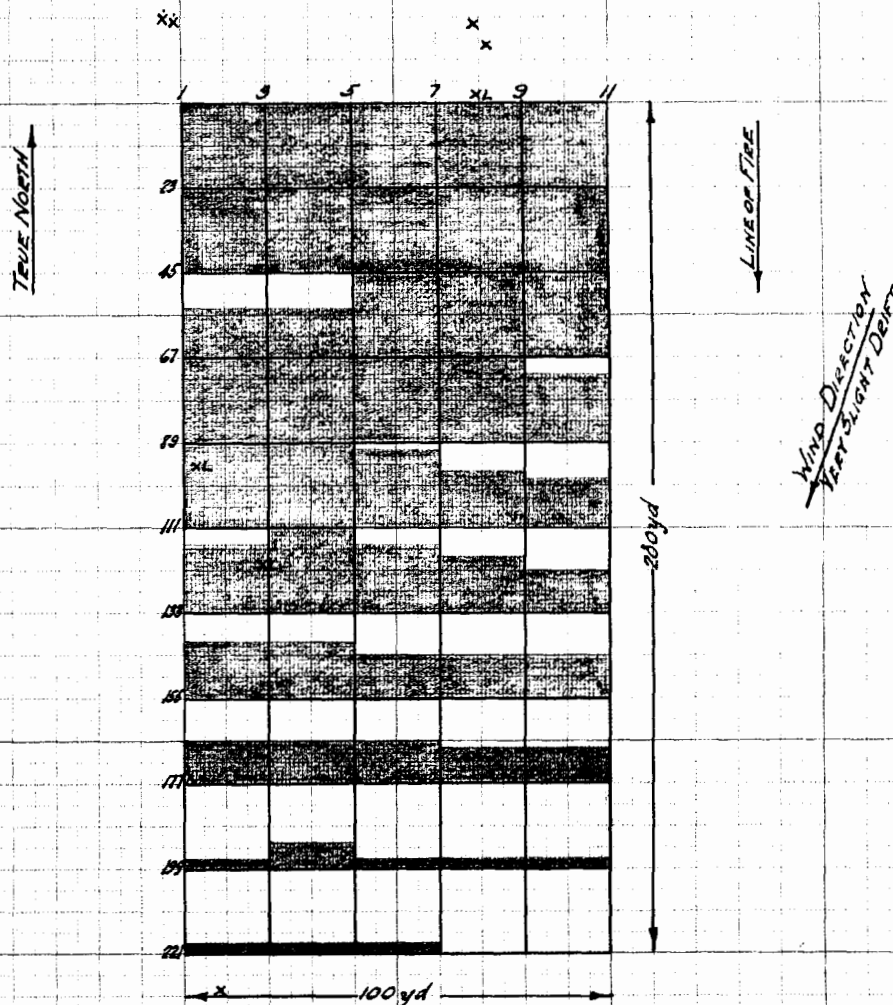
LEGEND:-

- \* - Ground Burst
- \* - Tree Burst
- XL - Low order Burst
- Shaded Area Represents 100% Man Casualties

NOTE:-

- MAN PROTECTED BY GAS MASK AND STANDARD ISSUE OF UNIMPREGNATED CLOTHING.
- \* CASUALTIES BASED ON EXPOSURE DURING THE FIRING PERIOD AND FOLLOWING 22 MINUTES

CHART 3aH  
 TEST OF HS FILLED 155mm HOWITZER SHELL  
 PROJECT A1.1-16  
 AUGUST 11, 1933  
 ESTIMATED MAN CASUALTIES DUE TO EFFECTS  
 OF HS VAPOR\*



-LEGEND:-

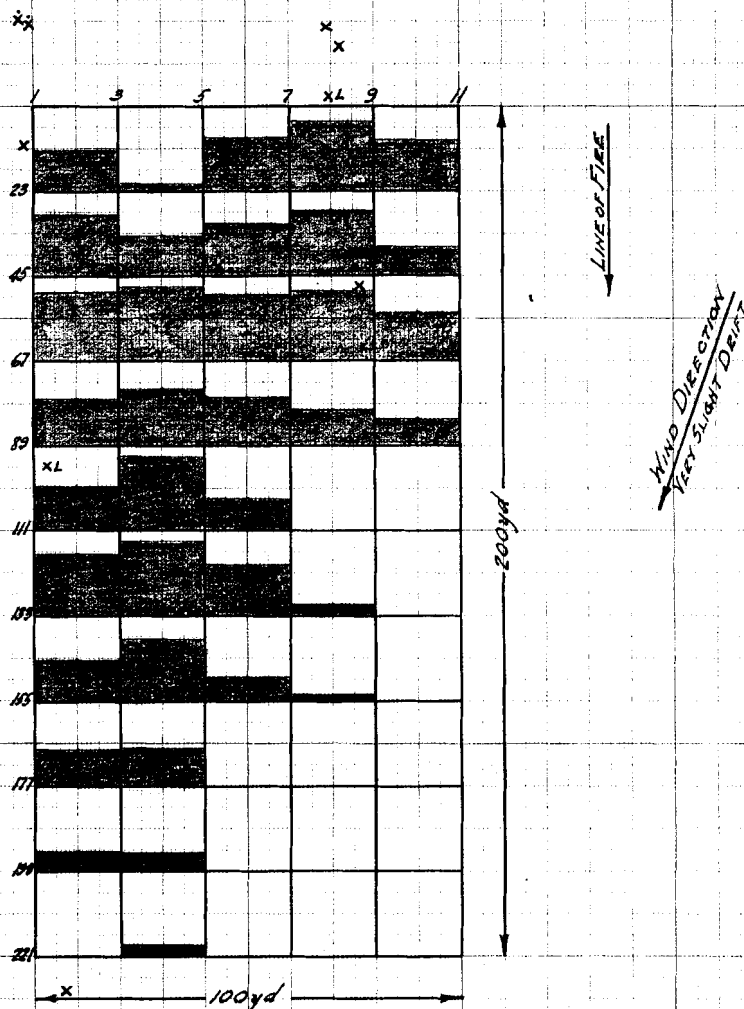
- x - Ground Burst
- x - Tree Burst
- xl - Low Order Burst
- Shaded Area Represents 100% Max Casualties

-NOTE:-

MAN PROTECTED BY GAS MASK AND STANDARD ISSUE OF UNIMPREGNATED CLOTHING.  
 CASUALTIES BASED ON EXPOSURE FROM THE 32<sup>ND</sup> TO THE 67<sup>TH</sup> MINUTE AFTER FIRING.

50YDS  
 SCALE

CHART 4H  
 TEST OF HS FILLED 155<sup>mm</sup> HOWITZER SHELL  
 PROJECT A11-16  
 AUGUST 11, 1933  
 ESTIMATED MAN CASUALTIES DUE TO EFFECTS  
 OF HS LIQUID\*



LEGEND

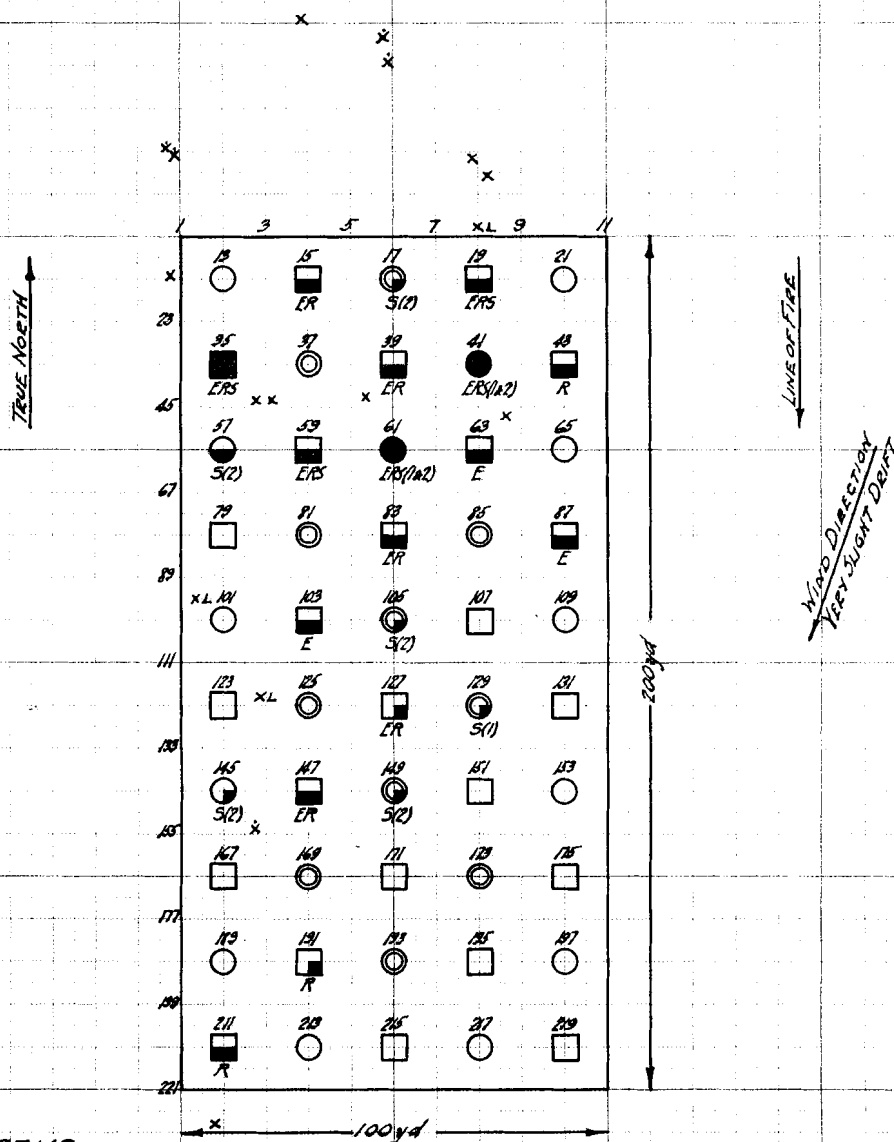
- x - Ground Burst
- x - Tree Burst
- xl - Low order Burst
- Shaded Area Represents 100% Man Casualties

NOTE

MAN PROTECTED BY GAS MASK AND STANDARD ISSUE OF UNIMPREGNATED CLOTHING  
 \* CASUALTIES BASED ON EXPOSURE DURING THE FIRING PERIOD

50 YDS  
 SCALE

CHART 5H  
TEST OF H5 FILLED 155<sup>mm</sup> HOWITZER SHELL  
PROJECT A1.1-16  
AUGUST 11, 1933  
ANIMAL CASUALTIES DUE TO EXPOSURE DURING  
FIRING AND FOLLOWING 22 MINUTES



LEGEND:-

RAT GOAT

○ - No Casualty  
○ - Light Casualty  
○ - Moderate Casualty  
○ - Severe Casualty  
○ - Death  
○ - Conspicuous  
○ - Respiratory Effects  
○ - Erythema of Skin  
○ - Second Degree Skin Burn  
○ - Killed By Shell

(1) - Rat on Ground  
(2) - Rat Suspended  
○ - Rat Suspended at Elevation of 18° only  
○ - Rat in Cage on Ground and Rat Suspended at Elevation of 18°  
x - Ground Burst  
x - Tree Burst  
xL - Low Order Burst

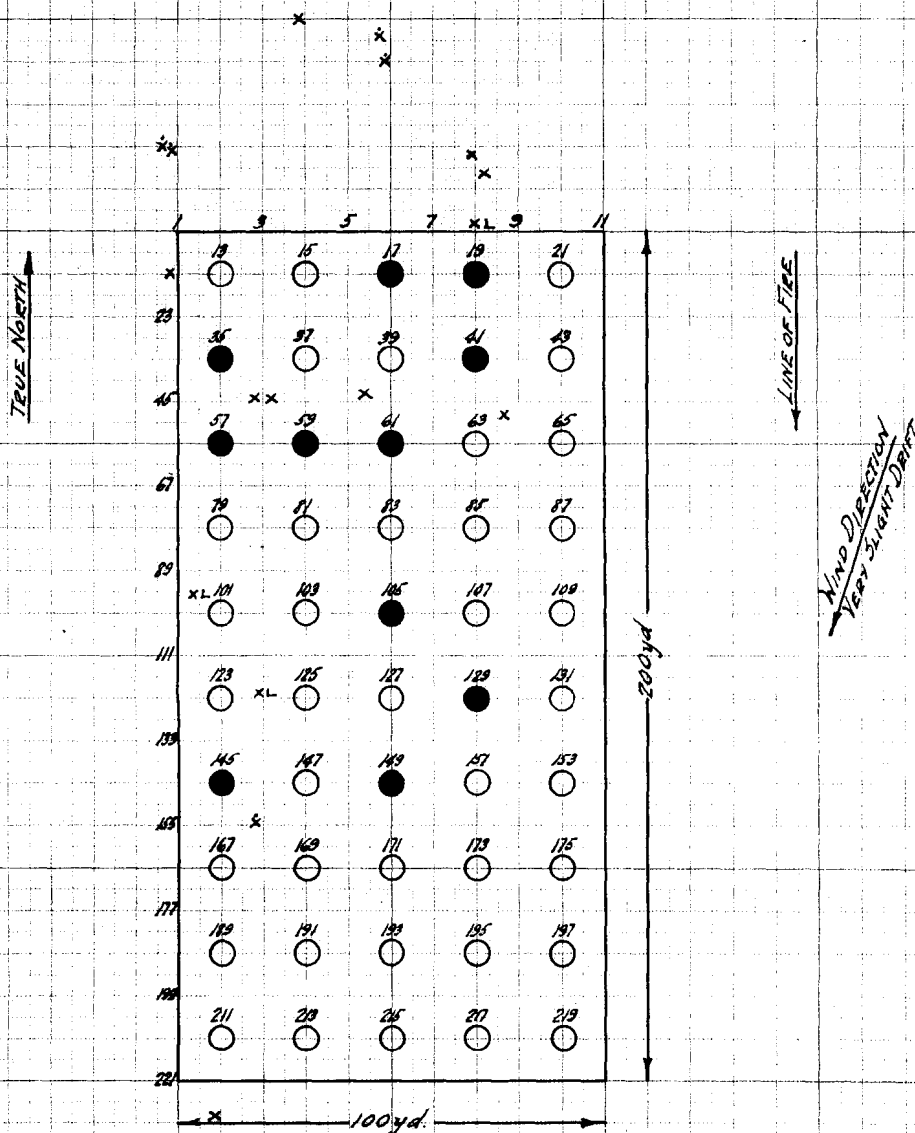
# CHART 6H

TEST OF H5 FILLED 155mm HOWITZER SHELL

PROJECT ALI-14

AUGUST 11, 1933

ESTIMATED MAN CASUALTIES BASED ON EFFECTS  
ON ANIMALS EXPOSED DURING FIRING AND  
FOLLOWING 22 MINUTES



## LEGEND

- - Estimated no Casualties
- - Estimated max Casualties
- x - Ground Burst
- \* - Tree Burst
- xL - Low order Burst

(a) The number of shell required per 100 yd. sq. to produce 50% casualties when distributed as equally as practicable, are as follows:

1. When man protected by gas mask and standard impregnated clothing is exposed during the firing period - about 44 shell (see page 71).

2. When man protected by gas mask only, is exposed on the target for a period of 25 min. including firing - about 8 shell (see paragraph 9,d,(7),(g), above).

(b) In view of the small number of bursts on the target, this test should be repeated.

e. Test of September 19, 1933.

(1) Object. To determine the number of HS-filled 155-mm. howitzer shell required to produce 50% casualties when fired about 1 hr. before sunset at personnel protected by gas mask only, who are located in wooded country and remain on the impact area for a period of 25 min. including the firing period.

(2) Materials Used. Fifty MII, 155-mm. howitzer shell filled with HS were used in the test. The history of these shell and the type of fuze and booster used are given in paragraph 4.

(3) Target. The location of the target and position of vapor sampling machines, panels and animals were the same as in previous test conducted on August 11, 1933.

Chart 11, shows the target as it was prepared for the test with position of animals, panels and sampling machines.

(4) Firing of Shell.

(a) Adjustment. Twenty-two shell were used. Registration fire was directed at a position about 200 yd. west of the target. Firing started at 4:01 p.m. and ended at 4:35 p.m.

(f) Firing for Effect. The howitzers were ranged in parallel for impact on a line through the short axis of the target. Firing started at 5:10 p.m. and ended at 5:16 p.m., a period of 6 min. Twenty-eight shell were used.

A photostatic copy of a Memorandum dated September 19, 1933 from the Battery Commander to the Commanding Officer, Edgewood Arsenal giving firing data by round, is attached to this report.

(5) Meteorological Conditions.

(a) During Firing and One Hour Following.

Time	5:20 p.m.	5:40 p.m.	6:00 p.m.	6:25 p.m.
Air temperature, °F.	72	70	67	66
Ground temperature, °F.	74	72	69	68
Relative humidity, %	73	77	87	87
Wind velocity, m.p.h.*	slight drift only			
Wind direction	W	NW	N	NW
Sky	Partly cloudy			

\*Recorded at an elevation of 6 ft.

(b) During the First Ten Days Following Firing.

From :		Temp. °F.		Rainfall:		Cloudiness				
From:	To :	Max.	Min.	8 a.m.:	inches	8 a.m.:	10 a.m.:	12 noon:	2 p.m.:	4 p.m.
9/20:	9/21:	86	62	68	.07	.9	.1	.8	.7	.2
9/21:	9/22:	88	56	62	trace	1.	1.	1.	1.	.9
9/22:	9/23:	69	53	61	0	.3	.5	.8	1.	1.
9/23:	9/24:	77	44	55	trace	.9	1.	.9	.4	1.
9/24:	9/25:	84	61	65	0	0	0	0	0	0
9/25:	9/26:	88	63	68	0	.2	.2	.2	.3	.1
9/26:	9/27:	82	64	68	.12	1.	1.	1.	1.	1.
9/27:	9/28:	85	65	71	trace	.3	.3	.2	.7	1.
9/28:	9/29:	74	66	79	0	.9	.9	.1	.5	1.
9/29:	9/30:	74	53	60	.49	.3	0	0	0	0
9/30:		78	56	61	0	0	0	.0	.1	.1

(6) Results.

(a) Impacts. The positions of impacts are shown on Chart 2I. There were 28 impacts accounted for on and around the target of which 14 were normal bursts on the target.

Of the 50 shell fired including the 22 used for adjustment, there were 7 duds and 1 low order burst noted.

(b) Liquid HS.

1. Size of HS Drops. The paper panels on the target were tabulated for size of HS drops. Results are given in the following table:

Table No. 30.

Number of Panels Showing Drops of 0.1 mg. or Larger.

Panel: no.	No. of HS drops			
	:0.1 to :0.5 mg.:	:Over 0.5 :to 1.0 mg.:	:Over 1.0 :to 3.0 mg.:	:Over 3.0 mg.:
30 :	7 :	2 :	:	:
31 :	:	1 :	:	:
35 :	98 :	33 :	11 :	:
41 :	26 :	6 :	:	:
45 :	7 :	7 :	7 :	5
52 :	5 :	1 :	:	:
69 :	4 :	2 :	3 :	1
70 :	5 :	3 :	1 :	1
71 :	:	2 :	:	:
73 :	:	1 :	:	:
80 :	7 :	7 :	1 :	:
81 :	21 :	11 :	:	:
82 :	9 :	5 :	:	:
83 :	:	:	1 :	:
84 :	3 :	:	:	:
86 :	7 :	4 :	2 :	1
87 :	17 :	7 :	:	:
88 :	99 :	:	:	:
89 :	15 :	4 :	:	:
91 :	:	1 :	2 :	:
93 :	:	1 :	1 :	:
95 :	21 :	3 :	:	:
98 :	5 :	2 :	:	:
99 :	25 :	12 :	:	:
106 :	80 :	15 :	:	:
110 :	3 :	2 :	:	:
117 :	59 :	11 :	:	:
129 :	1 :	:	:	:
130 :	15 :	3 :	2 :	:
131 :	3 :	:	:	:
132 :	12 :	3 :	:	:
141 :	2 :	:	:	:

Table No. 30 (Cont'd.)

Panel:	No. of HS drops				
no.:	0.1 to	:Over 0.5	:Over 1.0	:Over 3.0	
	:0.5 mg.:	to 1.0 mg.:	to 3.0 mg.:	mg.	
142:	7	:	3	:	:
143:	15	:	5	:	:
153:	2	:	:	:	:
156:	4	:	:	:	:
157:	5	:	:	:	:
198:	:	:	:	:	1
206:	:	:	:	:	1
207:	:	:	1	:	1
208:	6	:	:	:	2
209:	25	:	25	:	25
210:	2	:	:	:	:
211:	25	:	15	:	:
212:	15	:	5	:	:
218:	3	:	:	:	:
219:	15	:	:	:	:
220:	25	:	:	2	:
226:	:	:	:	1	:
227:	:	:	:	1	:
228:	12	:	7	:	1
229:	2	:	:	:	:
230:	:	:	3	:	:
231:	:	:	4	:	:

(c) Estimated Man Casualties from Liquid HS.

1. Man Protected by Gas Mask but without Protection of Impregnated Clothing.

The paper panels on the target were tabulated for density of pattern using the pattern scale attached to this report. Results are tabulated in the following table together with estimated man casualties. The basis of estimated casualties is explained in paragraph 6,a.

Table No.31.

Estimated Man Casualties from HS Liquid Based on Panel Data.

Pattern:	Panel	classified	Estimated casualties
:	No.	Per cent of:	for man protected by
:	:	total on	gas mask only
:	:	target	:
:	:	:	%
Heavy	: 32	: 13.9	: 13.9
Medium	: 24	: 10.4	: 10.4
Light	: 33	: 14.3	: 11.4
Trace	: 53	: 22.9	: 13.7
No HS	: 89	: 38.5	:
Total	: 231	: 100.00	: 49.4

2. Man Protected by Gas Mask and Standard Impregnated Clothing.

From results in Table No. 30, a tabulation is given in Table No. 32 of panels showing HS drops of 0.5 mg. or larger together with estimated casualties for man protected by gas mask and standard impregnated clothing. The basis of estimated casualties is explained in paragraph 6,a,(2).

Table No. 32.

Estimated Man Casualties from HS Liquid Based on Panel Data.

Size of HS drops:	No. of:	Estimated casualties for man
:	panels:	protected by gas mask and
:	:	standard impregnated clothing
mg.	:	per panel %:target area %
One drop or more:	23	: 40 : 4.0
between 0.5 to	:	:
1.0 but with no	:	:
drop exceeding	:	:
1.0	:	:
One drop or more:	19	: 100 : 8.2
exceeding 1.0	:	:
Total	: 42	: : 12.2

Total panels on target - 231

(d) Estimated Masked Man Casualties from HS Vapor.

Vapor samples were taken at positions shown on Chart II. In Tables No. 33, 33A, 34 and 34A, which follow, the vapor concentration, c.t. value and per cent estimated casualties from effects of HS vapor for man protected by gas mask only, are given for each sampling position. The basis of estimated casualties is explained in paragraph 6, b.

1. Firing Period and Following 22 Minutes.

Table No. 33.

Estimated HS Vapor Casualties on Target.

Sampling position:	Elevation: of	Vol. of: air sam-	HS sampled:	Vapor: concn.:	c.t. value:	Estimated casualties for man protected by gas mask only
: sample	: ft.	: liters:	: mg.	: mg./l.:	: :	: %
C	: 1	: 850	: 16.5	: .0194	: .49	: 100
F	: 1	: 826	: 12.3	: .0154	: .38	: 100
G	: 0	: 836	: 10.8	: .0129	: .32	: 100
J	: 0	: 216*	: 1.2	: .0111	: .28	: 100
K	: 1	: 800	: 4.2	: .0052	: .13	: 100
N	: 1	: 826	: 14.1	: .0171	: .43	: 100
O	: 0	: 836	: 4.4	: .0052	: .13	: 100
R	: 0	: 814	: 2.4	: .0030	: .07	: 73
S	: 1	: 212*	: 0.6	: .0057	: .14	: 100
Av.						97.0

NOTE: \*Sampling machine stopped 6 min. after firing began due to effects of a shell burst.

Table No. 33A.

Estimated HS Vapor Casualties at Positions Outside  
of Target.

Sampling position:	Elevation of sample	Vol. of air sampled	HS sampled	Vapor concn.	c.t. value	Estimated casualties for man protected by gas mask only
	ft.	liters	mg.	mg./l.		%
D	0	425	0.6	.0014	.04	50
	1	425	1.0	.0023	.06	66
	2	425	1.4	.0033	.08	80
	4	425	1.6	.0038	.09	87
E	0	413	1.0	.0024	.06	66
	1	413	1.6	.0039	.10	93
	2	413	2.0	.0048	.12	100
	4	413	2.0	.0048	.12	100
H	0	418	2.0	.0048	.12	100
	1	418	2.4	.0057	.14	100
	2	418	2.8	.0068	.17	100
	4	418	2.6	.0062	.15	100
I	0	425	1.0	.0024	.06	66
	1	425	0.8	.0019	.05	58
	2	425	0.8	.0019	.05	58
	4	425	0.8	.0019	.05	58
L	0	400	4.6	.0115	.29	100
	1	400	5.2	.0130	.32	100
	2	400	6.4	.0160	.40	100
	4	400	4.2	.0105	.26	100
M	0	413	1.0	.0024	.06	66
	1	413	0.6	.0014	.04	50
	2	413	0.6	.0014	.04	50
	4	413	0.4	.0010	.02	30
P	0	418	4.2	.0100	.25	100
	1	418	5.2	.0124	.31	100
	2	418	5.2	.0124	.31	100
	4	418	6.2	.0148	.37	100
Q	0	407	0.4	.0010	.02	30
	1	407	0.4	.0010	.02	30
	2	407	0	0	0	0
	4	407	0	0	0	0
T	0	418	2.8	.0068	.17	100
	1	418	1.8	.0043	.11	100
	2	418	2.0	.0048	.12	100
	4	418	3.2	.0076	.19	100

2. From the 32nd to 67th Minute After Firing.

Table No. 34.

Estimated HS Vapor Casualties on Target.

Sampling position:	Elevation of	Vol. of air sampled	HS sampled	Vapor concn.	c.t. value	Estimated casualties for man protected by gas mask only
: sample	: ft.	: liters	: mg.	: mg./l.	: :	: %
C	1	1252	5.4	.0043	.15	100
F	1	1216	4.0	.0033	.11	100
G	0	1236	3.8	.0031	.11	100
K	1	1180	3.6	.0030	.11	100
N	1	1216	16.5	.0135	.47	100
O	0	1272	2.8	.0022	.08	78
R	0	1196	0.4	.0003	.01	11
Av.						84.1

Table No. 34A.

Estimated HS Vapor Casualties at Positions Outside of Target.

Sampling position:	Elevation of	Vol. of air sampled	HS sampled	Vapor concn.	c.t. value	Estimated casualties for man protected by gas mask only
: sample	: ft.	: liters	: mg.	: mg./l.	: :	: %
D	0	626	1.2	.0019	.07	73
	1	626	1.4	.0022	.08	80
	2	626	1.4	.0022	.08	80
	4	626	1.4	.0022	.08	80
E	0	608	0.4	.0007	.02	30
	1	608	0.8	.0013	.05	58
	2	608	0.8	.0013	.05	58
	4	608	0.8	.0013	.05	58
H	0	618	1.6	.0026	.09	87
	1	618	2.2	.0035	.12	100
	2	618	2.2	.0035	.12	100
	4	618	lost			
I	0	608	0	0	0	0
	1	608	0	0	0	0
	2	608	0	0	0	0
	4	608	0.4	.0006	.02	30

Table No. 34A. (Cont'd.)

Sampling position:	Elevation of sample	Vol. of air sampled	HS : mg.	Vapor : concn. : mg./l.	c.t. value	Estimated casualties for man protected by gas mask only
:	ft.	liters	:	:	:	%
L	0	590	2.0	.0034	.12	100
	1	590	1.8	.0030	.11	100
	2	590	2.4	.0040	.14	100
	4	590	1.8	.0030	.11	100
P	0	636	4.2	.0066	.23	100
	1	636	4.2	.0066	.23	100
	2	636	4.2	.0066	.23	100
	4	636	3.0	.0047	.17	100
T	0	618	1.2	.0019	.07	73
	1	618	0.6	.0010	.03	42
	2	618	1.2	.0019	.07	73
	4	618	0.4	.0006	.02	30

Samples taken at stations M and Q showed negative results.

(e) Estimated Man Casualties Based on Effects on Animals.

Animals consisting of goats and rats were placed on the target at positions shown on Chart 1I. Animal casualties and estimated man casualties for man protected by gas mask only, are given in Tables No. 35A, 35B and 35C. Animal casualties and estimated man casualties, based on effects on animals, are shown on Charts 5I and 6I. The basis of estimated casualties and the symbols used in the tables and on the charts, to designate the nature of the animal casualties are explained in paragraph 6,c.

1. Firing Period and Following 22 Minutes.

Table No. 35A.

Estimated Masked Man Casualties Based on Effects on Rats  
Suspended at an Elevation of 18 in.

Position of stake	Nature of casualty	Severity of casualty	Estimated man cas- ualties
			%
17	R	Death in: : 2 days :	100
41	ERS	Death in: : 4 days :	100
81	S	Medium :	100
105	No rec- : ord	Death in: : 1 day :	100
213	ERS	Death in: : 3 days :	100

Total suspended rat positions - 25  
Estimated man casualty positions - 5  
Per cent estimated man casualties - 20

Table No. 35B.

Estimated Masked Man Casualties Based on Effects on Rats  
in Cages on Ground.

41	ERS	Death in: : 2 days :	100
81	ERS	Death in: : 4 days :	100
105	ERS	Death in: : 2 days :	100
149	ERS	Medium :	100

Total rats in cages on ground - 13  
Estimated man casualty positions - 4  
Per cent estimated man casualties - 30.8

Table No. 35C.

Estimated Masked Man Casualties Based on Effects on Goats.

Position of stake	Nature of casualty	Severity of casualty	Estimated man casualties
			%
15	ER	Death in 5 days	100
19	ER	Death in 3 days	100
35	R	Medium	100
43	ER	Medium	0
59	E	Medium	0
63	ER	Medium	0
79	ER	Death in 5 da.	100
87	ER	Medium	0
127	E	Light	0
131	ERS	Medium	100
147	E	Light	0
151	ER	Medium	0
167	E	Light	0
211	E	Light	0
219	ER	Medium	0

Total goats exposed - 25

Estimated man casualty positions - 5

Per cent estimated man casualties - 20

2. Seventh and Tenth Days After Firing.

(a) Seventh Day After Firing.

Two goats were exposed in shell craters located between stakes 145 and 147 for a period of 24 hr. on the seventh day after firing. Goat casualties and estimated casualties for man protected by gas mask only are as follows:

Goat No. 103 - ER light - no man casualty

Goat No. 127 - E light - no man casualty

(b) Tenth Day After Firing.

Two goats were exposed in shell craters located between stakes 145 and 147 for a period of 24 hr. on the tenth day after firing. Both of these goats showed negative results.

(7) Discussion.

(a) Shell Distribution.

The positions of impacts on and around the target are shown on Chart 2I. There were 14 normal ground bursts on the target and two bursts east of the target which were partly effective on the target. It is estimated that the effects of these two shell east of the target were equivalent to one burst directly on the target so that on this basis total effects on the target were equivalent to the burst of 15 shell.

(b) Impact Area.

For purposes of discussion the impact area may be regarded as that part of the target represented by the 20-yd. squares listed in Table No. 36. The impact area is shown on Chart 2I.

(c) Estimated Casualties from Liquid HS.

1. Effects of Meteorological Conditions.

The wind velocity over the target during firing was zero so that distribution and casualty effect of liquid HS were not affected at all by meteorological conditions.

2. Effects of Terrain.

All shell bursts on the target were ground bursts so that each burst represented a normal burst in open country. The location of the target in woods in the present test, had little or no effect on the total area covered by the liquid HS, other than effects due to a retarded wind velocity.

3. Man Protected by Gas Mask but without Protection of Impregnated Clothing.

From results in Table No. 31 it is estimated that personnel protected by gas mask only would experience about 49.4% casualties from liquid HS, if they are equally distributed over the target and remain there during the firing period. The liquid HS on the target was due to the burst of 15 shell. On the basis of 15 shell on an area of 20,000 sq.yd. to

produce 49.4% casualties from liquid HS when personnel are protected by gas mask only, it will require 7.6 shell per 100 yd. sq. to produce 50% casualties.

4. Man Protected by Gas Mask and Standard Impregnated Clothing.

From results in Table No. 32 it is estimated that personnel protected by gas mask and standard impregnated clothing who are exposed on the target during the firing period will experience about 12.2% casualties, if equally distributed over its area. On this basis it will require about 30.7 shell per 100 yd. sq. to produce 50% casualties.

(d) Effects of HS Vapor.

1. Discussion of Meteorological Conditions.

During the test, the air temperature was 71°F. and there was almost no air travel. These conditions were almost identically the same as in the previous test (Test of August 11, 1933) which is discussed in paragraph 9,d,(7),(d),1.

2. Firing Period and Following 22 Minutes.

(a) On Target.

Results of vapor samples taken at 9 sampling positions on the target are given in Table No. 33 for the firing period and following 22 minutes. The vapor concentration for each 20-yd. square of the target was figured from results in this table taking into consideration the positions of nearest impacts and wind direction. These results are given in the fifth column of Table No. 36. From the average of the figures in the fifth column, it is estimated that personnel with gas mask protection only, would experience about 97.9% casualties if exposed on the target during firing and the following 22 min.

Per cent estimated casualties from effects of HS vapor is shown graphically on Chart 3I. The shaded area on the chart represents that part of the target on which it is estimated 100% casualties would be produced by effects of HS vapor when man is protected by gas mask only.

(b) Outside of Target.

Estimated casualties at sampling positions downwind from the target are given in Table No. 33A. Results show estimated casualties varying at the different positions from about 30 to 100% from effects of HS vapor for personnel protected by gas mask only, who are exposed 30 yd.

downwind from the impact position during firing and the following 22 min.

3. From the 32nd to 67th Minute After Firing.

(a) On Target.

From results of vapor samples in Table No. 34, it is estimated that personnel protected by gas mask only would experience about 84.1% casualties from effects of HS vapor if they are equally distributed over the target and exposed from the 32nd to 67th min. after firing. Estimated casualties for this period are shown graphically on Chart 3aI.

(b) Outside of Target.

Estimated vapor casualties are given in Table No. 33A based on results at sampling positions 30 yd. downwind from the target for the period between the 32nd and 67th min. after firing. Estimates from these results vary from about 30 to 100% casualties for man protected by gas mask only who are exposed from the 32nd to 67th min. after firing.

(c) Estimated Man Casualties Based on Effects on Animals.

1. Firing Period and Following 22 Minutes.

Animal casualties and estimated man casualties on the target resulting from exposure during firing and the following 22 min. are given in Tables No. 35A, 35B, and 35C. The results in these three tables are consolidated in the last two columns of Table No. 36. From the consolidated results it is estimated from animal casualties, that personnel protected by gas mask only would experience 22% casualties if exposed on the target during firing the following 22 min. In arriving at per cent estimated man casualties, no weight was given to the large number of animal casualties which individually, were not considered the equivalent of a man casualty.

2. Persistence of HS on Impact Area.

Results given in paragraph 9,c,(6),(e),2 show two slight animal casualties out of two animals exposed in shell craters for a period of 24 hr. on the seventh day after firing but no animal casualties out of two animals exposed on the 10th day after firing.

(a) On Seventh Day After Firing.

The animal casualties on the seventh day after firing indicate that the impact area could not be occupied by personnel for a period of 24 hr. without experiencing casualties unless they are protected by gas mask and impregnated clothing.

(b) On the 10th Day After Firing.

From the animal results it is probable that the impact area could be occupied by personnel without gas protection on the 10th day after firing, provided shell craters were avoided.

(f) Comparison of Per Cent Estimated Masked Man Casualties Based on Measurements of the Gas Concentration and by its Effects on Animals.

1. On Target (100 yd. by 200 yd.)

In Table No. 36, estimated man casualties are given for each 20 yd. sq. representing an animal position, based on:

HS liquid determined by panel data.  
HS vapor determined by vapor samples  
Combined effects of HS liquid and vapor from sample data  
From effects on animals

Table No. 36.

Estimated Casualties on Target on Exposure During Firing  
and the Following 22 Min. (Area - 20,000 sq.yd.),  
Sept. 19, 1938.

Stake no.	Impacts at center of 20-yd. square	within 20-yd. square	From HS liquid: Estimated casualties	From HS vapor: c.t. value	From HS liquid: Estimated casualties	From effects and vapor: Estimated casualties	on animals: Animal casualties	Estimated casualties
			%		%	%		%
13	1		64	.80	100	100	N	0
15	0		42	.50	100	100	Death ER	100
17	0		7	.30	100	100	Death R	100
							(2)	
19	1		55	.49	100	100	Death ER	100
21	0		53	.30	100	100	N	0
35	0		64	.40	100	100	Death ERS	100
37	0		18	.30	100	100	N	0
39	0		13	.30	100	100	R Mod.	0
41	0		73	.30	100	100	Death ERS	100
							(1)	
							Death ERS	
							(2)	
43	0		62	.30	100	100	Mod. ER	0
57	0		58	.40	100	100	N	0
59	0		31	.38	100	100	Mod. E	0
61	0		14	.30	100	100	N	0
63	1		60	.32	100	100	Mod. ER	0
65	0		35	.30	100	100	N	0
79	1		89	.30	100	100	Death ER	100
81	1		89	.30	100	100	Death ER	100
							(1)	
							Mod.S (2)	
83	0		75	.20	100	100	N	0
85	1		73	.30	100	100	N	0
87	1		69	.30	100	100	Mod. ER	0
101	0		51	.20	100	100	N	0
103	0		38	.28	100	100	N	0
105	0		64	.20	100	100	Death ERS	100
							(1)	
							Death (2)	
107	0		69	.13	100	100	N	0
109	0		60	.13	100	100	N	0

Table No. 36 ( Cont'd.)

Stake no.:	Impacts:	From HS liquid:	From HS vapor:	From HS liquid:	From effects		
at center:	within :	Estimated man :	c.t.:	Estima-:	and vapor	on animals	
of 20-yd.:	20-yd. :	casualties	value:	ted man:	Estimated man :	Animal :	Estima-
square	square:			casuale:	casualties	casual-	ted man
:	:			ties :		ties :	casual-
:	:						ties
:	:	%	:	%	:	:	%
123	: 0 :	35	:	.20 : 100 :	100	: N :	0
125	: 0 :	22	:	.30 : 100 :	100	: N :	0
127	: 0 :	31	:	.15 : 100 :	100	:Light E :	0
129	: 0 :	82	:	.15 : 100 :	100	: N :	0
131	: 2 :	73	:	.30 : 100 :	100	:Mod. ERS:	100
145	: 1 :	35	:	.20 : 100 :	100	: N :	0
147	: 0 :	20	:	.30 : 100 :	100	:Light E :	0
149	: 0 :	20	:	.13 : 100 :	100	:Mod. ERS:	100
	:		:	:		: (1) :	
151	: 1 :	73	:	.15 : 100 :	100	:Mod. ER :	0
153	: 0 :	86	:	.20 : 100 :	100	: N :	0
167	: 0 :	46	:	.20 : 100 :	100	:Light E :	0
169	: 0 :	60	:	.43 : 100 :	100	: N :	0
171	: 0 :	13	:	.30 : 100 :	100	: N :	0
173	: 0 :	33	:	.13 : 100 :	100	: N :	0
175	: 0 :	80	:	.10 : 100 :	98	: N :	0
189	: 0 :	7	:	.10 : 93 :	93	: N :	0
191	: 0 :	20	:	.20 : 100 :	100	: N :	0
193	: 0 :	7	:	.15 : 100 :	100	: N :	0
195	: 0 :	33	:	.13 : 100 :	100	: N :	0
197	: 0 :	75	:	.10 : 93 :	98	: N :	0
211	: 0 :	31	:	.04 : 60 :	65	:Light E :	0
213	: 0 :	11	:	.07 : 73 :	76	:Death ERS	100
215	: 0 :	35	:	.10 : 93 :	95	: N :	0
217	: 0 :	64	:	.14 : 100 :	100	: N :	0
219	: 3 :	95	:	.20 : 100 :	100	:Mod. ER :	0
Total and:	14 :	48.3	:	:	97.9:	98.5	:
average :	:		:	:			:

NOTE: Symbols used in column 7 to designate the nature of the animal casualties are explained in paragraph 6,c.  
 (1) designates rat in cage on ground.  
 (2) designates rat in cage suspended at an elevation of 18 in.

Results in Table No. 36 show 98.5% casualties based on sample data and 22% based on animal data. It will be noted in the table, that no weight was given in the final average to a large number of animal casualties which were not severe enough individually to be classed as the equivalent of a man casualty requiring evacuation for hospitalization.

## 2. On Impact Area (15,200 sq.yd.).

The impact area as defined in paragraph 9,e,(7),(b) is shown on Chart 2I and the 20-yd. squares included within its area are tabulated in Table No. 37. On its area of 15,200 sq.yd., there were 14 bursts and effects from two other bursts outside of the target, estimated as equivalent to one additional burst, making a total of 15 bursts. Results show 99.9% estimated casualties based on sample data and 26.3% based on animal data.

Table No. 37.

### Impact Area - (15,200 sq.yd.).

Stake no.	Impacts	From HS liquid	From HS vapor	From HS liquid	From effects
at center	within	Estimated man	c.t.:	Estimated man	on animals
of 20-yd.	20-yd.	casualties	value:	Estimated man	Animal
square	square:	:	casual-	casualties	casual-
:	:	:	ties :	:	ties :
:	:	:	:	:	ties :
:	:	%	:	%	%
13	1	64	.80	100	100
15	0	42	.50	100	100
17	0	7	.30	100	100
					(2)
19	1	55	.49	100	100
21	0	53	.30	100	100
35	0	64	.40	100	100
37	0	18	.30	100	100
39	0	13	.30	100	100
41	0	73	.30	100	100
					(1)
					Death ERS:
					(2)
43	0	62	.30	100	100
57	0	58	.40	100	100
					Mod. ER :
					N :
					0

Table No. 37 (Cont'd.)

Stake no. at center of 20-yd. square	Impacts within 20-yd. square	From HS liquid Estimated man casualties	From HS vapor c.t. value	Estimated man casualties	From HS liquid Estimated man casualties	From effects on animals Animal casualties	Estimated man casualties
:	:	%	:	%	%	:	%
59	0	31	.38	100	100	Mod. E	0
61	0	14	.30	100	100	N	0
63	1	60	.32	100	100	Mod. ER	0
65	0	35	.30	100	100	N	0
79	1	89	.30	100	100	Death ER	100
81	1	89	.30	100	100	Death ERS	100
						(1)	
						Mod.S (2)	
83	0	75	.20	100	100	N	0
85	1	73	.30	100	100	N	0
87	1	69	.30	100	100	Mod. ER	0
101	0	51	.20	100	100	N	0
103	0	38	.28	100	100	N	0
105	0	64	.20	100	100	Death ERS	100
						(1)	
						Death (2)	
107	0	69	.13	100	100	N	0
109	0	60	.13	100	100	N	0
123	0	35	.20	100	100	N	0
125	0	22	.20	100	100	N	0
127	0	31	.15	100	100	Light E	0
129	0	82	.15	100	100	N	0
131	2	73	.30	100	100	Mod. ERS	100
145	1	35	.20	100	100	N	0
147	0	20	.30	100	100	Light E	0
149	0	20	.13	100	100	Mod.ERS	100
						(1)	
151	1	73	.15	100	100	Mod. ER	0
153	0	86	.20	100	100	N	0
175	0	80	.10	93	98	N	0
197	0	75	.10	93	98	N	0
219	3	95	.20	100	100	Mod. ER	0
Total and average	14			99.8	99.9		25.3

NOTE: Symbols used in column 7 to designate the nature of the animal casualties are explained in paragraph 6,c.  
(1) designates rat in cage on ground.  
(2) designates rat in cage suspended at an elevation of 18 in.

(g) Number of Shell Required to Produce 50% Masked Man Casualties.

From data given in paragraph 9,e, (7), (f), 2 it was estimated that the burst of 15 shell on an area of 15,200 sq.yd. would produce 99.9% casualties, based on sample data and 26.3% based on effects on animals when personnel who have only gas mask protection are exposed on the impact area during firing and the following 22 min. On this basis the following number of shell are required per 100 yd. square to produce 50% casualties when man is protected by gas mask only:

Based on HS liquid and vapor samples -	4.9
Based on effects on animals -	18.6
Average -	<u>11.7</u>

(8) Conclusions. From the results of the present test, the following conclusions are drawn with respect to the use of 155-mm. howitzer shell filled with HS under the meteorological and terrain conditions of the test.

(a) The number of shell required per 100 yd. square to produce 50% casualties when distributed as equally as practicable, are as follows:

1. When man protected by gas mask and standard impregnated clothing is exposed during the firing period - about 31 shell (see paragraph 9,e, (7), (c), 4).

2. When man protected by gas mask only, is exposed on the target for a period of 25 min. including firing, about 12 shell (see paragraph 9,e, (7), (g), above).

9. General Discussion.

a. Duds. Of the 207 shell used in the five tests discussed in this report, there were 38 duds or an average of 18.3%.

CHART II  
TEST OF HS FILLED 155mm HOWITZER SHELL  
PROJECT A.I.-16  
SEPTEMBER 19, 1933  
TARGET AREA

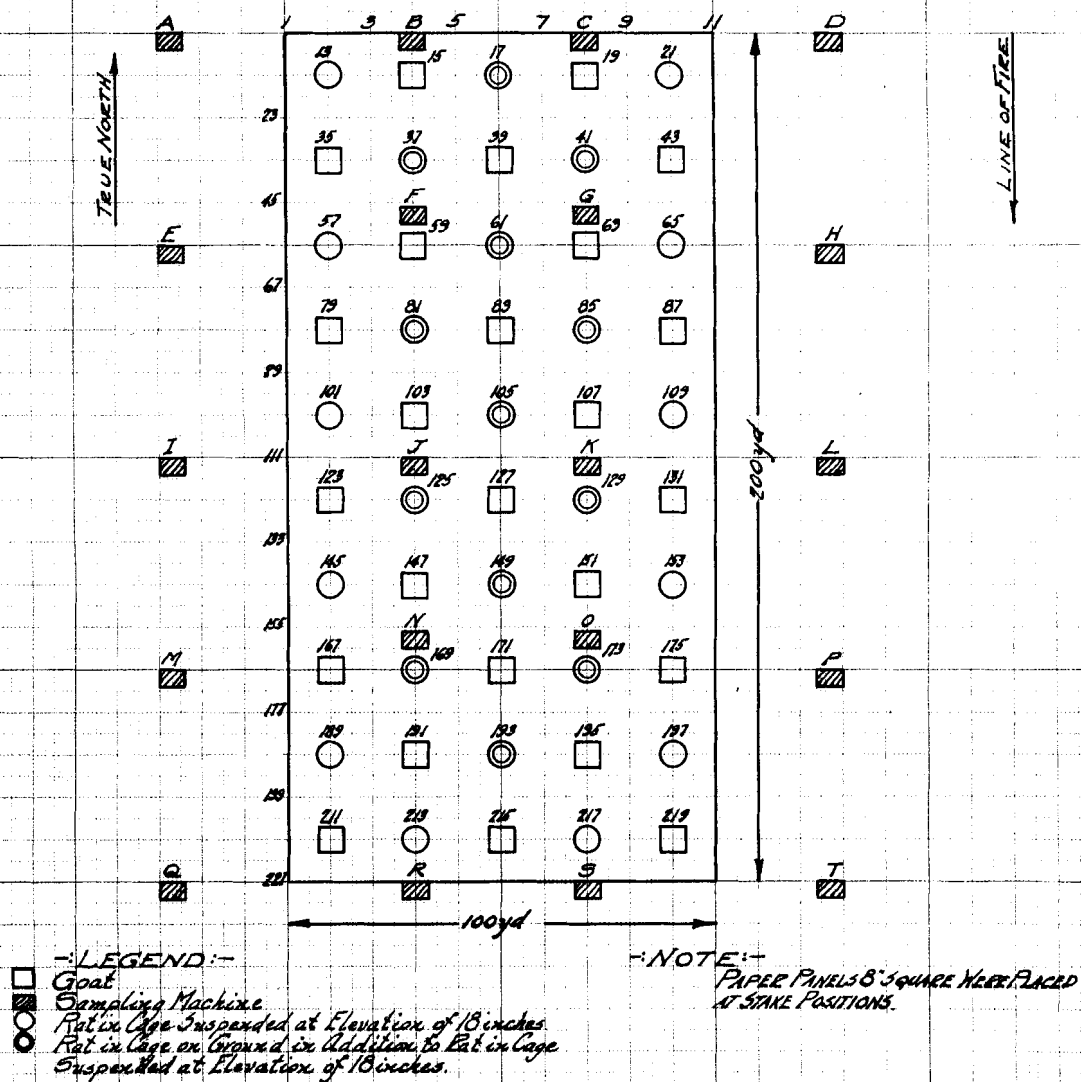
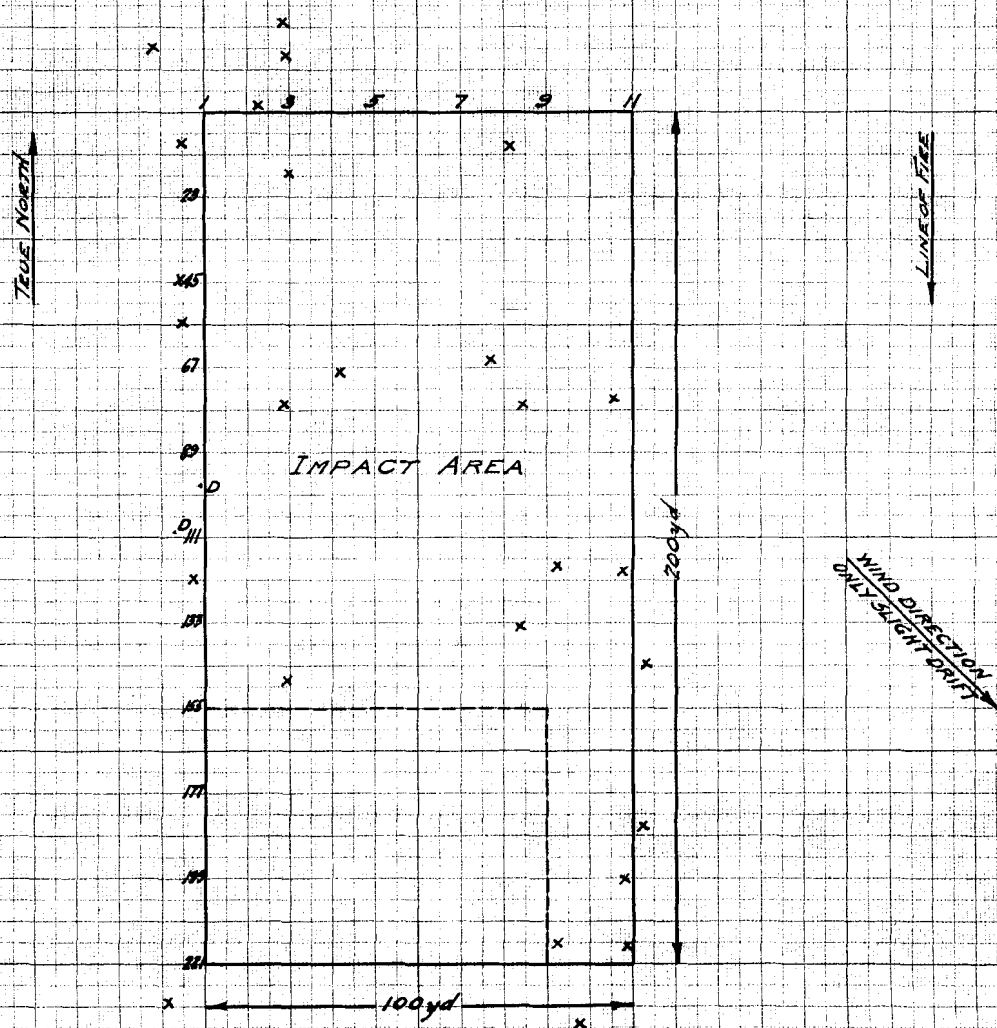


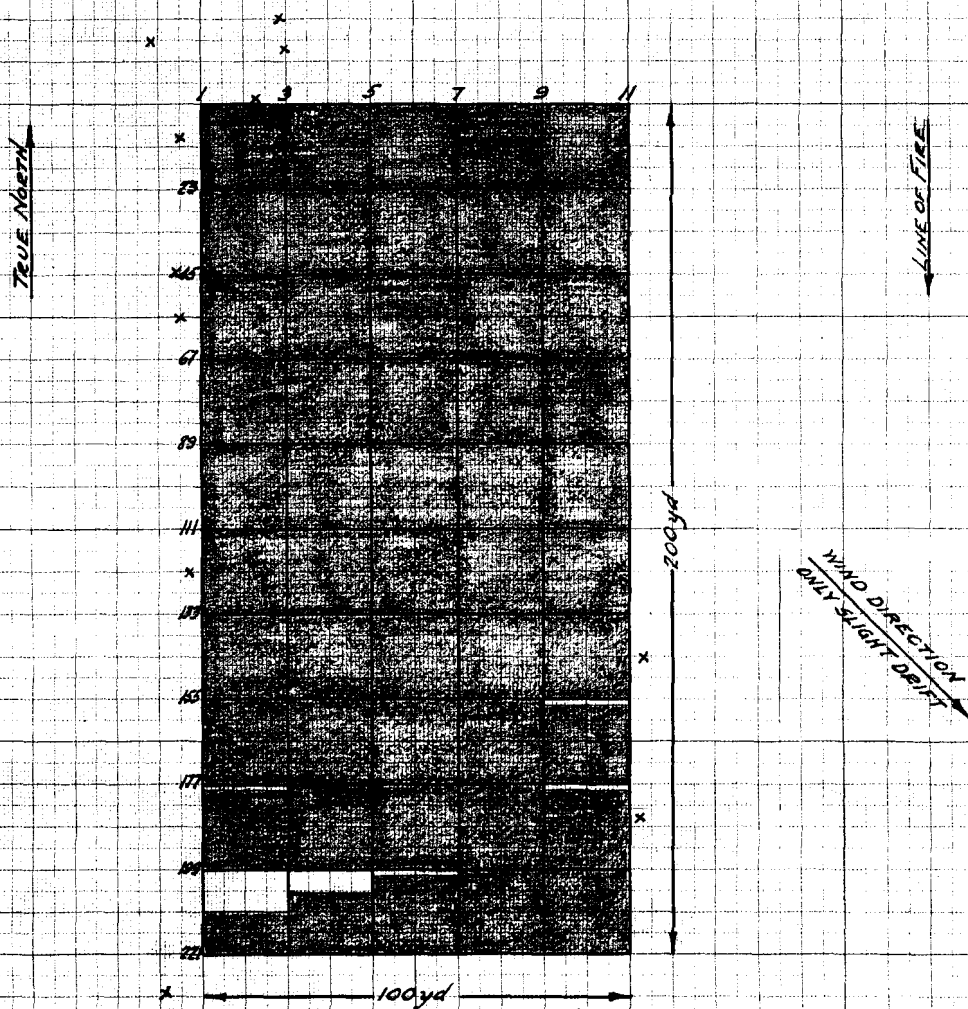
CHART 21  
 TEST OF HS FILLED 155<sup>mm</sup> HOWITZER SHELL  
 PROJECT A1.1-16  
 SEPTEMBER 19, 1933  
 POSITION OF IMPACTS



LEGEND:-  
 x - Ground Burst  
 D - Dud

50 YDS  
 SCALE

CHART 3I  
 TEST OF HS FILLED 155<sup>mm</sup> HOWITZER SHELL  
 PROJECT A1.1-16  
 SEPTEMBER 19, 1933  
 ESTIMATED MAN CASUALTIES DUE TO EFFECTS  
 OF HS VAPOR \*



LEGEND:-

x - Ground Burst  
 Shaded Area Represents  
 100% Man Casualties

NOTE:-

MAN PROTECTED BY GAS MASK AND  
 STANDARD ISSUE OF UNIMPREGNATED  
 CLOTHING.  
 \* CASUALTIES BASED ON EXPOSURE DURING  
 THE FIRING PERIOD AND FOLLOWING  
 22 MINUTES.

50 YDS  
 SCALE

CHART 3aI  
 TEST OF HS FILLED 155mm HOWITZER SHELL  
 PROJECT A.I.1-16  
 SEPTEMBER 19, 1933  
 ESTIMATED MAN CASUALTIES DUE TO EFFECTS  
 OF HS VAPOR\*

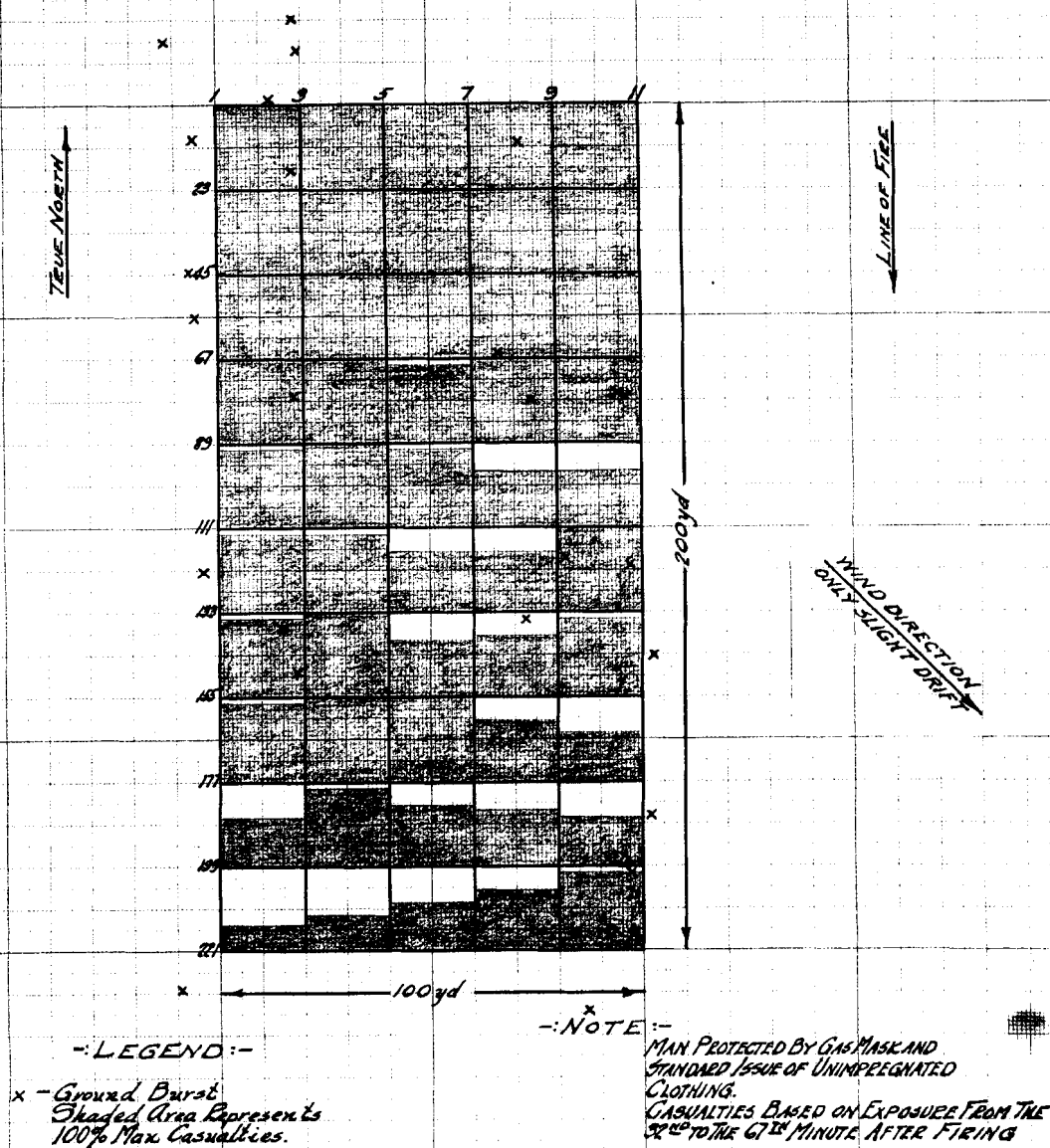


CHART 41  
 TEST OF H5 FILLED 155<sup>mm</sup> HOWITZER SHELL  
 PROJECT A11-16  
 SEPTEMBER 19, 1933  
 ESTIMATED MAN CASUALTIES DUE TO EFFECTS  
 OF H5 LIQUID\*

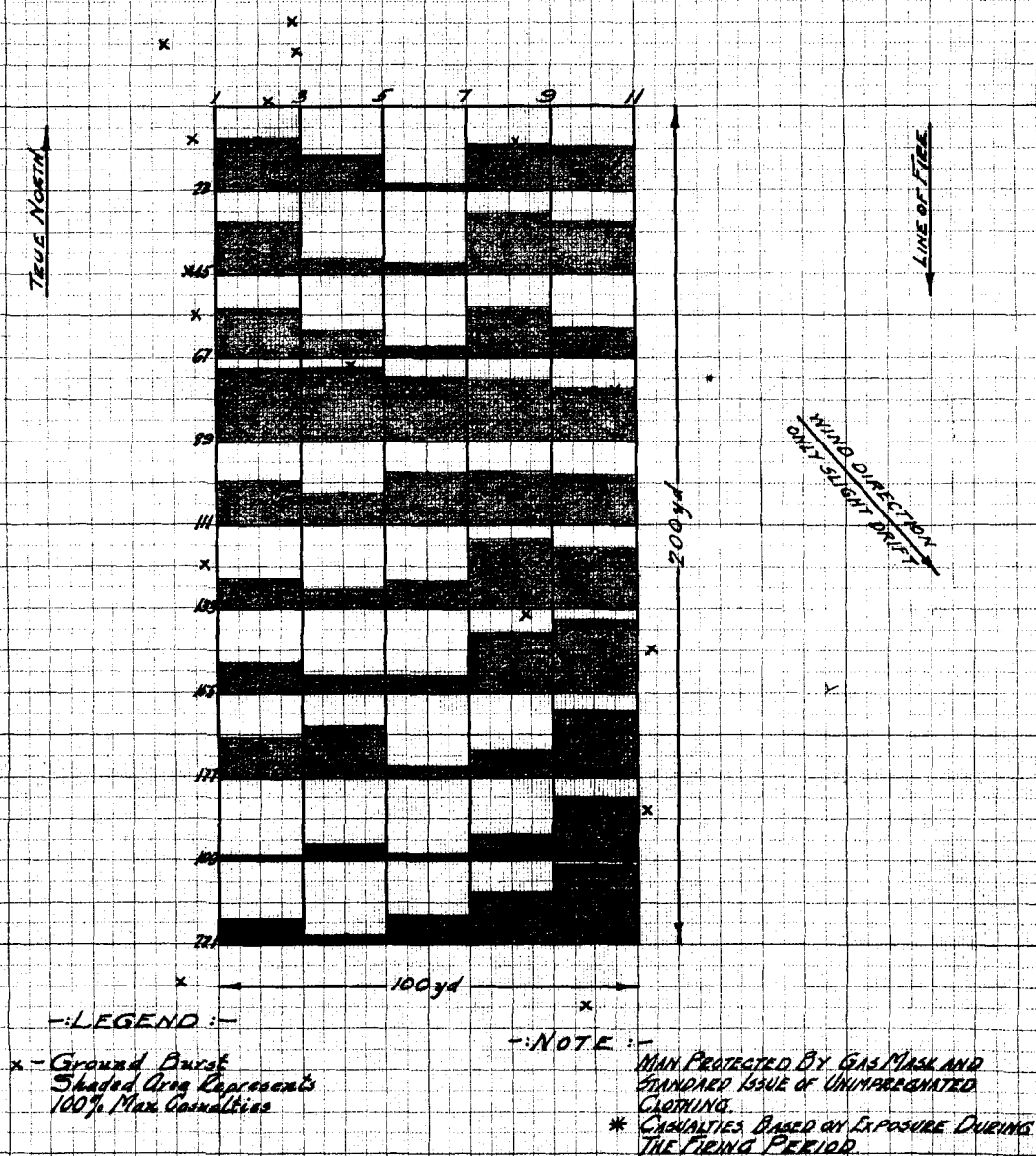
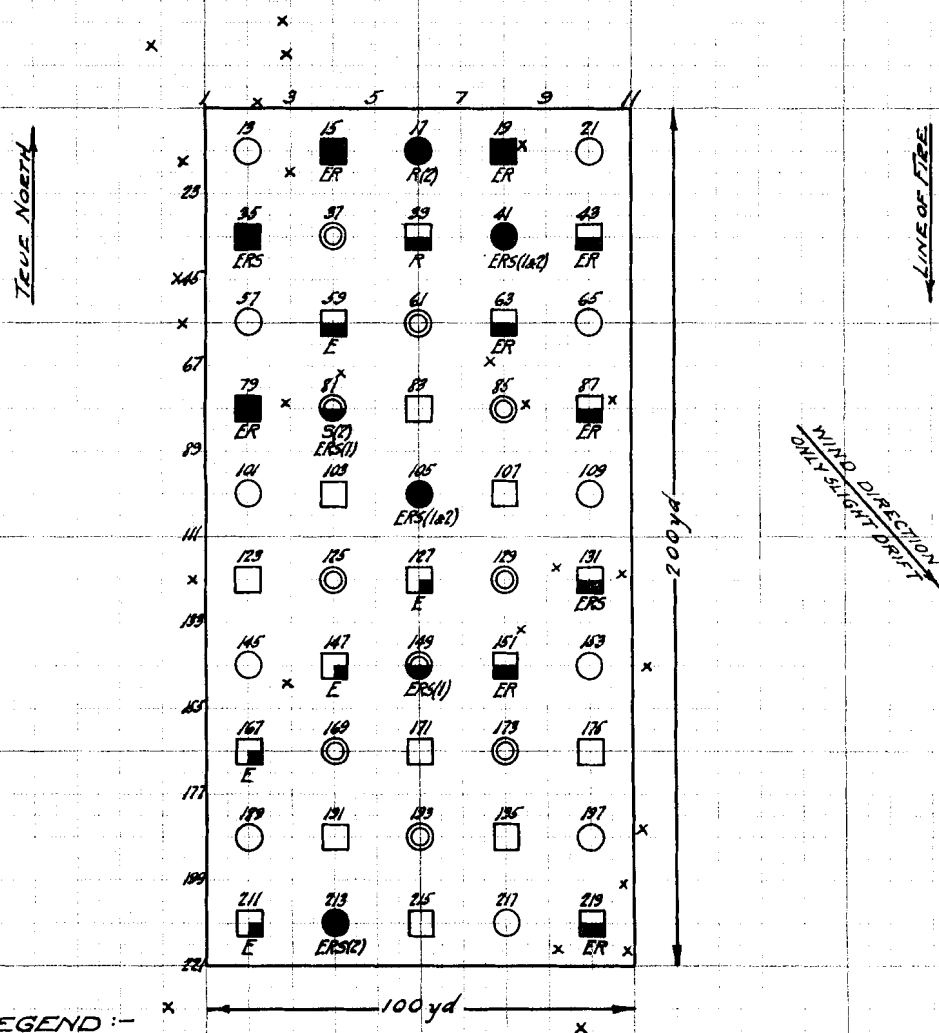


CHART 51  
TEST OF HS FILLED 155mm HOWITZER SHELL  
PROJECT A1.1-16  
SEPTEMBER 19, 1933  
ANIMAL CASUALTIES DUE TO EXPOSURE DURING  
FIRING AND FOLLOWING 22 MINUTES



LEGEND :-

RAT

GOAT

- (1) - Rat on Ground
- (2) - Rat Suspended
- Rat Suspended at Elevation of 18° only
- Rat in Cage on Ground and Rat Suspended at Elevation of 18°
- x - Ground Buried

- No Casualty
- LC - Light Casualty
- MC - Moderate Casualty
- SC - Severe Casualty
- D - Death
- E - Conjunctivitis
- R - Respiratory Effects
- S - Erythema of Skin
- S<sub>2</sub> - Second Degree Skin Burn
- KF - Killed By Shell

50 YDS  
SCALE

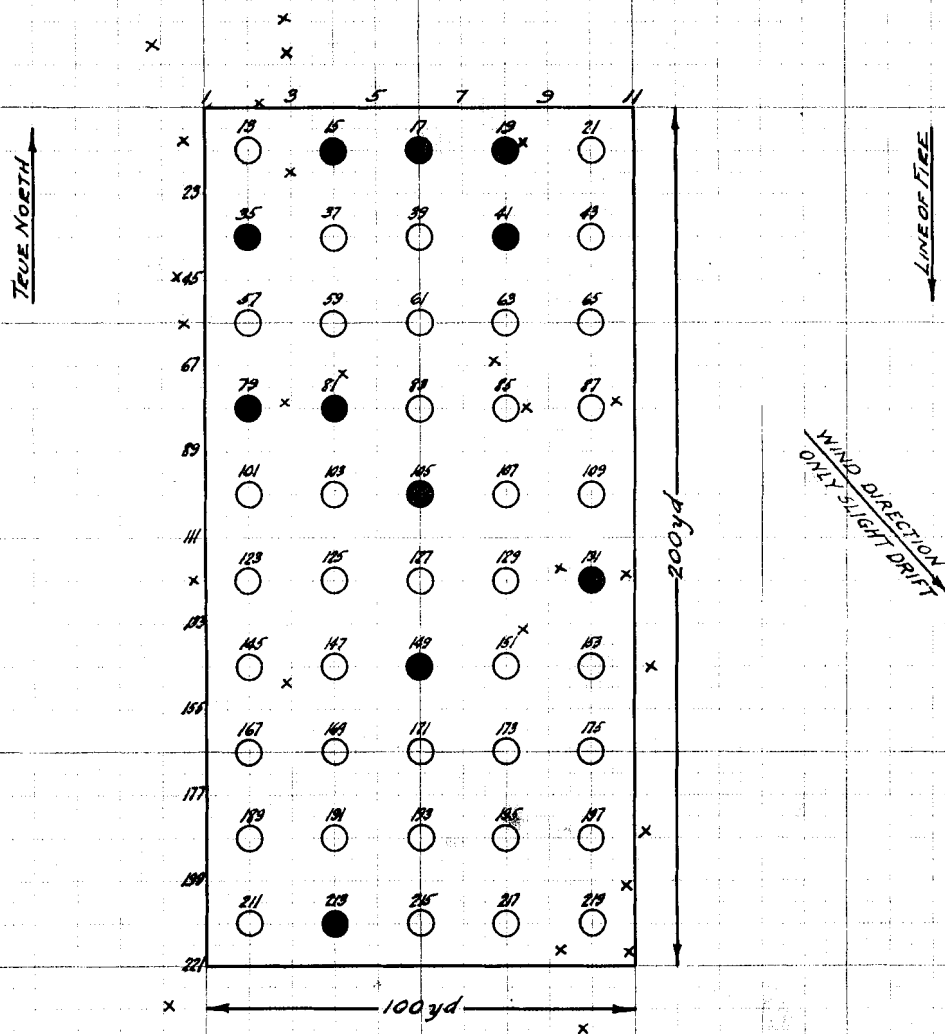
# CHART 61

TEST OF H5 FILLED 155mm HOWITZER SHELL

PROJECT A.I.1-16

SEPTEMBER 19, 1933

ESTIMATED MAN CASUALTIES BASED ON EFFECTS  
ON ANIMALS EXPOSED DURING FIRING AND  
FOLLOWING 22 MINUTES



## LEGEND

- O - Estimated no Casualties
- O - Estimated Max Casualties
- x - Ground Burst

50 YDS  
SCALE

b. Results. From the results of the tests, the following number of shell are required per 100 yd. square to produce 50% casualties, depending on terrain and meteorological conditions.

For man protected by gas mask only, from 6 to 14 shell.

For man protected by gas mask and standard impregnated clothing, from 20 to 72 shell.

c. Future Tests. It is believed that sufficient tests of HS-filled 155-mm. howitzer shell have been conducted to determine the number of shell required for effective results under different terrain and meteorological conditions. It is believed that a study should be made of the results of the 9 tests conducted and that an E.A.T. report be prepared thereon.

10. Recommendations.

That an E.A.T. report be prepared covering the 9 tests of HS-filled 155-mm. howitzer shell which have been conducted.

Submitted by

/s/ B.G. Macintire,  
B.G. MACINTIRE,  
Test Section,  
Munitions Development Division.

Report of test of HS-Filled  
155-mm. Howitzer Shell  
Tests "E" to "I" inclusive  
Year 1933

Approval recommended

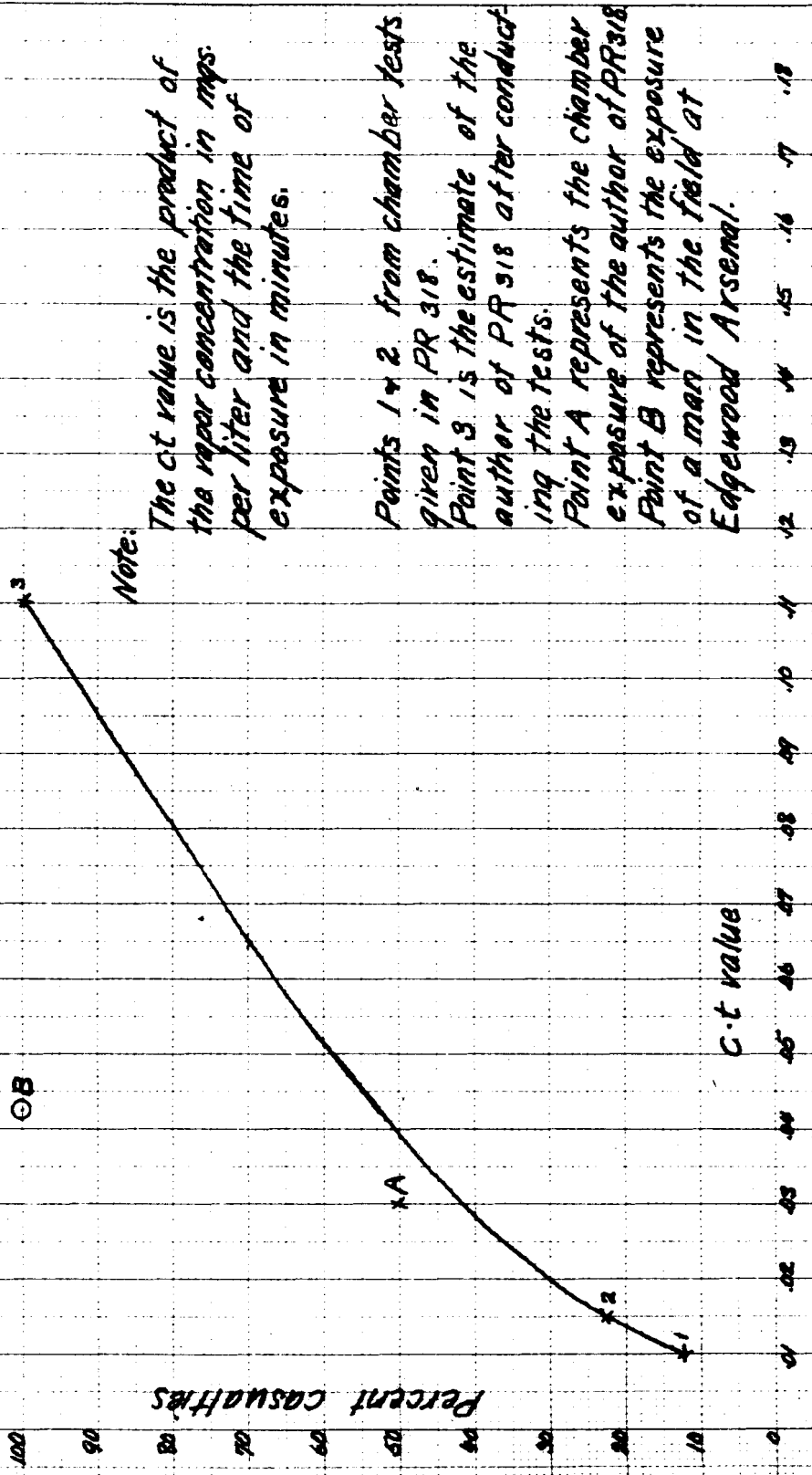
/s/ Charles E. Loucks,  
CHARLES E. LOUCKS,  
Captain, C.W.S.,  
Chief, Munitions Development Division.

Typed nsm  
December 12, 1933

Approved

/s/ Charles E. Loucks,  
CHARLES E. LOUCKS,  
Captain, C.W.S.,  
Acting Technical Director.

# Graph No. 1 Casualty Producing Effect of Mustard Vapor on Masked Men



Note: The ct value is the product of the vapor concentration in mps. per liter and the time of exposure in minutes.

Points 1 & 2 from chamber tests given in PR 318.

Point 3 is the estimate of the author of PR 318 after conducting the tests.

Point A represents the chamber exposure of the author of PR 318

Point B represents the exposure of a man in the field at Edgewood Arsenal.

BATTERY "C" SIXTH FIELD ARTILLERY      OCB/fob  
Fort Hoyle, Maryland.  
June 20, 1933.

MEMO : To Captain C.E. Loucks. C.W.S.

The following record of the Mustard Gas Shoot performed by this battery on June 15, 1933 is submitted.

REGISTRATION

Weather Clear, gentle wind from N.W. Initial data corrected for drift only. Registration point 140 yards East of East side of impact area at center range. First round fired at 4:50 P.M.

Data	Elev.	Range	Deflection	Remarks	Rounds.
Compass 3211 on No.1	:	:	:	:	:
close 4. Shell Mustard	:	:	:	:	:
Gas, fuse long charge	:	:	:	:	:
5 No.1. 1 round	:303:	+	+	:	1
R 5	:303:	+	-	:	2
L 3	:300:	+	-	: DUD	3
L 2	:296:	+	?	:	4
	:290:	-	+	:	5
R 1	:294:	+	+	:	6
R L No.1 record B.D.	:	:	:	:Adj.Elev:	:
	:	:	:	:293:	:
No.2 Adj.No.2. 1 rd.	:293:	-	+	:	7
R 2	:295:	+	+	:	8
R 1 No.2 record B.D.	:	:	:	:Adj.Elev:	:
	:	:	:	:294:	:
No.3 adj.No.3. 1 rd.	:293:	-	+	: DUD	9
R 2	:294:	-	+	:	10
R 2 No.3 record B.D.	:	:	:	:Adj.Elev:	:
	:	:	:	:295:	:
No.4 adj. No. 4. 1 rd.	:294:	-	+	: DUD	11
R 2	:295:	+	C	:	12
No.4. record B.D. C.F.:	:	:	:	:Adj.Elev:	:
	:	:	:	:294:	:

FIRE FOR EFFECT 6:00 P.M. NO WIND.

Btry adj B.D. Right	:	:	:	:	:
28 on No.4 open, 5,	:	:	:	:	:
Shell M.G. fuse long	:	:	:	:	:
ch.5 Right Platoon	:293:	:	:	:	:
1 round	:294:	C -	C C	:	14
Battery 5 rounds	:295:	:	:	:	:
	:294:	:	:	:	:
	:295:	:	:	:1st. Rd.:	:
	:294:	- - - -	C	:1 DUD	18
	:	+	C	:2nd. Rd.:	22
Minimum Elev. 2 mils	:	+	C	:3rd. Rd.:	26
	:	+	C	:4th. Rd.:	30
	:	- - C C	C	:5th. Rd.:	34
Btry. 1 Rd. Same Elev.:	:	- - - C	C	:	38

All sensings in fire for effect are made on panel in center of area.

+ OVER  
- SHORT  
C CORRECT

*Chas. C. Brown*  
Chas. C. Brown,  
Captain 6th Field Artillery.

# BATTERY "C" SIXTH FIELD ARTILLERY

Fort Hoyle, Maryland.

CCB/fob

May 22, 1933.

MEMO : To Captain C.E. Loucks, C.W.S.

The following report is submitted as a record of the Mustard Gas Shoot performed for the C.W.S. School by Battery "C" 6th Field Artillery on May 18, 1933.

## REGISTRATION

Weather clear wind from S.W. Initial data corrected for drift only. Registration point 140 yds East of East side of impact area and at winter range. First round 4:10 P.M.

DATA	ELEVATION	RANGE	DEFLECTION	REMARKS	NO. RDS
Compass 3310 on #401.4					
Sh. Mustard Gas Ch.5 Fuse					
Long No.1 one rd.	290	-	?		1
	293	?	+		2
Right 10	293	-	?		3
	295	-	?		4
	300	-	-		5
Left 5	303	-	-		6
Left 2	305	-	-		7
Left 1	307	+	-		8
Left 1 No.1 Record B.D.					
No.2 Adj. No.3 1 rd	306	CR	+		9
Right 2	306	+	-		10
Left 1 No.2 Record B.D.					
No.3 Adj. No.3 1 rd	306	+	-		11
Left 5	303	-	CR		12
	304	CR	+		13
Right 2 No.3 Record B.D.					
No.4 Adj. No.4 1 rd.	306	CR	+		14
Left 4	306	-	CR		15
	307	+	-		16
Left 1 No.4 Record B.D.					

## FIRE FOR EFFECT 5:30 P.M.

Base Def. Right 26 On #4	No.2, 310				
open 5. No.2&3 1 rd.	No.3, 308	+	-	CR	18
Battery 1 Round	309	+++	-	+	22
Right 4	309	+++		CR	26
		EUD			
Nos. 2 & 3 1 Round	No.2, 302				
	No.3, 300	CR	CR	CR	28
Battery 1 Round	No.1, 302				
	No.2, 302				
	No.3, 300			ONE	
	No.4, 302	-CR	CR	EUD	32
Battery 1 Round	No.1, 303				
	No.2, 303	CR	CR		
	No.3, 302	CR	+		
	No.4, 303			CR	36
Battery 1 Round	306	CR	CR		
		CR		CR	
				No.5 SHOT	
				FIRE	
				DEFECTIVE	
				SHELL	39

*Chas. C. Brown*

Chas. C. Brown,

Captain 6th Field Artillery

BATTERY "C" SIXTH FIELD ARTILLERY  
Fort Hoyle, Maryland,

CCBfob

July 12, 1933.

MEMO : To Captain C.E. Loucks, C.W.S.

The following record of the Mustard Gas Shoot performed  
by this battery on July 6, 1933.

REGISTRATION

Weather clear, gentle wind from the West. Initial data  
corrected for drift only.

First round fired 5:00 P.M.

DATA	ELEV.	RANGE	DEFLECTION	REMARKS	ROUNDS
Compass 3211 on	:	:	:	:	:
No.1 Close 4, Shell:	:	:	:	:	:
Mustard Gas, Fuse	:	:	:	:	:
long, Charge 5, No.:	:	:	:	:	:
1. 1 rd.	:300	-	+	:	1
Right 5	:310	+	?	:	2
	:305	+	?	:	3
	:302	+	?	:	4
	:300	+	+	:	5
Right 5	:295	-	-	:	6
Left 3	:297	+	-	:	7
Left 2	:297	+	?	:	8
	:297	+	-	:	9
Left 1	:295	-	0	:	10
	:295	+	0	:	11
No.1 Record B.D.	:	:	:	:	:
No.2 Adj. No.2.1 rd.	:295.5	+	?	:	12
	:294.5	+	+	Low Order	13
Right 2. No.2 Rec-	:	:	:	:	:
ord B.D. No.3 Adj.	:	:	:	:	:
No.3. 1 rd.	:294.5	-	-	:	14
Left 2	:294.5	0	0	:	15
No.3. Record B.D.	:	:	:	:	:
No.4 Adj. No.4,	:	:	:	:	:
1. rd.	:294.5	+	+	:	16
Right 2	:294.5	-	+	:	17
Right 2. No.4 Rec-	:	:	:	:	:
ord B.D. Cease Fir-	:	:	:	:	:
ing.	:	:	:	:	:
	: FIRE FOR EFFECT : 6:05 P.M.				
Battery Adj. Base	:	:	:	:	:
Def. Left 50 on No.:	:	:	:	:	:
1 open 5 Shell Mus-	:	:	:	:	:
tard Gas fuse long:	:	:	:	Observation: of effect not possible.	:
charge 5 Battery	:	:	:	: 23 rounds fired for effect.	:
6 rounds	:308.2	:	:	:	40

BATTERY "D" SIXTH FIELD ARTILLERY,  
Fort Hoyle, Maryland,

CCB-FOB

August 14, 1933.

Memo : To Captain C.E. Loucks, C.W.S.

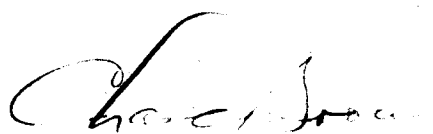
The following record of the Mustard Gas shoot performed by  
this battery on August 11, 1933.

REGISTRATION

Weather overcast, no wind. Initial corrected for drift only.

First Round fired 4:46 P.M.

DATA	ELEV	RANGE	DEFLECTION	REMARKS	ROUND
Compass 3211.Cn No.1 :	:	:	:	:	:
close 4 Shell M.G.fuse:	:	:	:	:	:
longCharge 5. No.1,1rd:	:	:	:	:	:
Quad.	:300	: +	: +	:	: 1 :
Right 5	:300	: -	: -	:	: 2 :
Left 3	:300	: +	: +	:	: 3 :
Right 1	:300	: +	: CR	:	: 4 :
3 rounds	:297	:+ - -	:+ + +	:	:5,6,7 :
Right 1. No.1 record	:	:	:	:	:
base deflection	:	:	:	:	:
No.2 Adjust.No.2,1 rd.	:298.5:	: +	: -	:	: 8 :
Left 5	:298.5:	: -	: +	:	: 9 :
Right 3. No.2 Record	:	:	:	:	:
Base Deflection	:	:	:	:	:
No.3 Adjust. No.3,1.rd:	:298.5:	: +	: -	:	: 10 :
Left 5	:298.5:	: +	: +	:	: 11 :
Right 2. No.3 Record	:	:	:	:	:
Base Deflection	:	:	:	:	:
No.4 adjust. No.4.1 rd:	:298.5:	: +	: -	:	: 12 :
Left 5	:298.5:	: -	: -	:	: 13 :
Left 2	:298.5:	: -	: +	:	: 14 :
Right 1. No.4 Record	:	:	:	:	:
Base Deflection	:	:	:	:	:
FIRE FOR EFFECT FIRST ROUND 5:47 P.M.					
Battery Adjust. Base :	:	:	:	:	:
Def. Left 40. On No.1 :	:	:	:	:	:
open 5. Shell M.G.	:312.2:	:	FIRE FOR EFFECT	:	: 15 :
fuse long.Charge 5.	:	:	NOT OBSERVED.	:	: to :
Battery 7 rounds	:	:	:	:	: 40 :

  
Chas. C. Brown,  
Captain 6th Field Artillery

BATTERY "A" SIXTH FIELD ARTILLERY  
Fort Hoyle, Maryland.

411-12  
230-1-111

September 25, 1933.

SUBJECT: Report on 155 mm Shoot, September 19, 1933.

To : Lieut. Colonel J.W. Lyon, Edgewood Arsenal, Maryland.

herewith is report of 155 mm Howitzer, Mustard Gas Shoot,  
fired by this Battery at 4:00 P.M. September 19, 1933.

Clear to partly cloudy.  
Wind, moderate westerly.  
Temperature 65 degrees - 70 degrees.  
Time of adjustment: 4:00 P.M.  
Time of fire for effect: 4:50 P.M.  
Number of rounds for adjustment - 22.  
Number of rounds for effect - 28.

ADJUSTMENT

COMMANDS	ELEV.	# OF RD	RANGE	DEFL.	REMARK
Compass, 3211	:	:	:	:	:
Cn #1 close 4	:	:	:	:	:
Shell M.G. Ch.5.FL	:	:	:	:	:
#1, 1 Rd Quad.	300	1	plus	?	dud
	295	2	minus	minus	:
Left 5	298	3	?	?	dud
	298	4	minus	plus	:
Right 3	300	5	minus	minus	:
Left 2	302	6	minus	?	:
	303	7	plus	minus	:
Left 1 3 Rds.	302.5	8	Minus	Minus	:
	:	9	minus	plus	Def. Correct
	:	10	plus	minus	:
# 1 record Base Deflection.	:	:	:	:	:
# 2 adjust.	:	:	:	:	:
# 2, 1 Rd	302.6	11	plus	plus	:
Right 5	300	12	minus	?	Piccochet
	301	13	minus	?	:
	302	14	minus	?	:
	302.6	15	plus	minus	:
Left 2, # 2 record Base Deflection.	:	:	:	:	:
#3, adjust.	:	:	:	:	:
#3, 1 Rd	302.6	16	minus	plus	:
Right 2	302.6	17	plus	plus	:
Right 2	302	18	correct	correct	:
#3 record Base Deflection.	:	:	:	:	:

26  
411/127

#4, adjust	:	:	:	:	:	:
#4, 1 Rd	:	302.8	:	19	:	plus : plus :
Right 5	:	302	:	20	:	plus : Plus :
Right 3	:	300	:	21	:	Minus : plus :
Right 2	:	301	:	22	:	Minus : minus :

#4 record Base Deflection.

Adjusted elevation - 302.3

Check adjusted range =  $\frac{5781}{5280} = 1.101 (K)$   
 Check map range

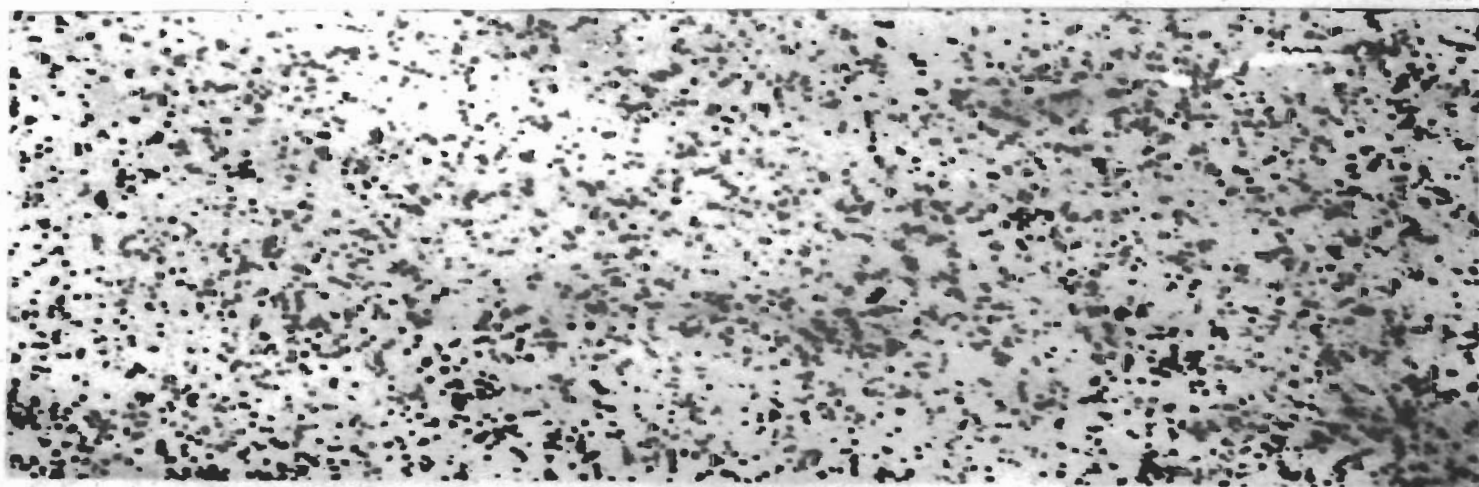
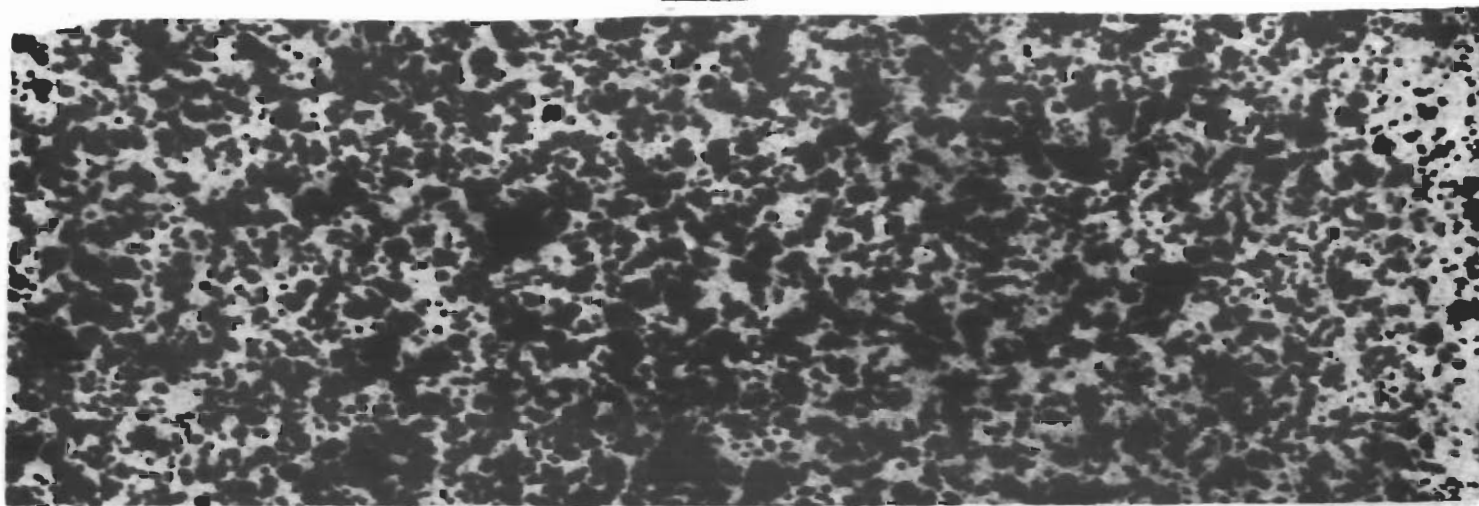
EFFECT

Initial range - 5430 (target map range) x 1.101 (K) - 5978 yds.  
 Initial elevation - Quadrant 316.4.

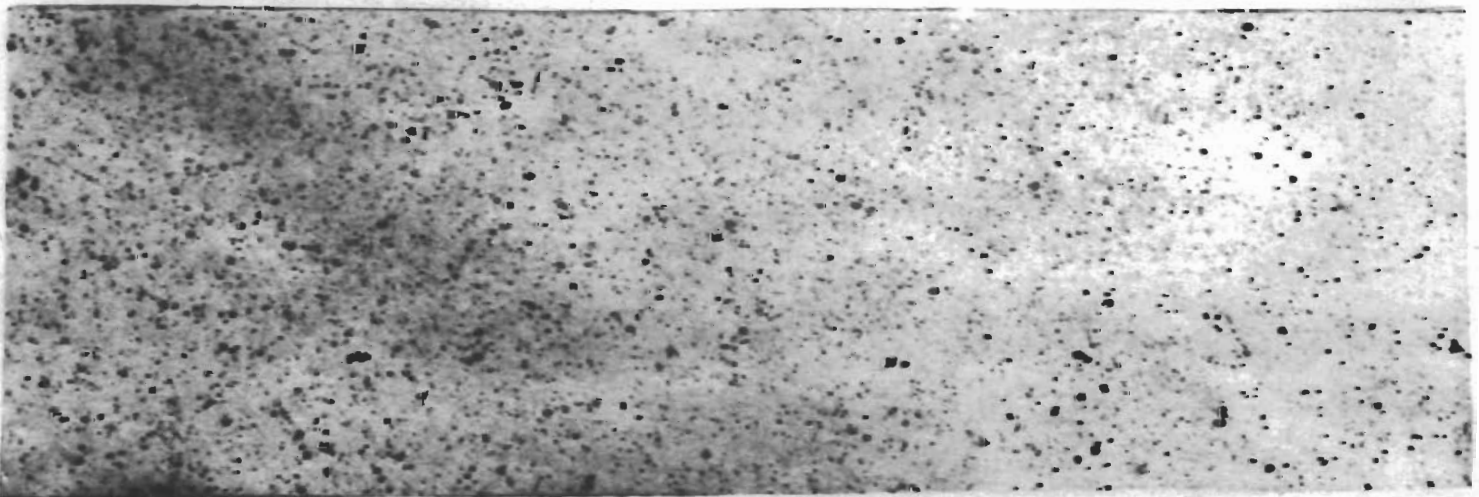
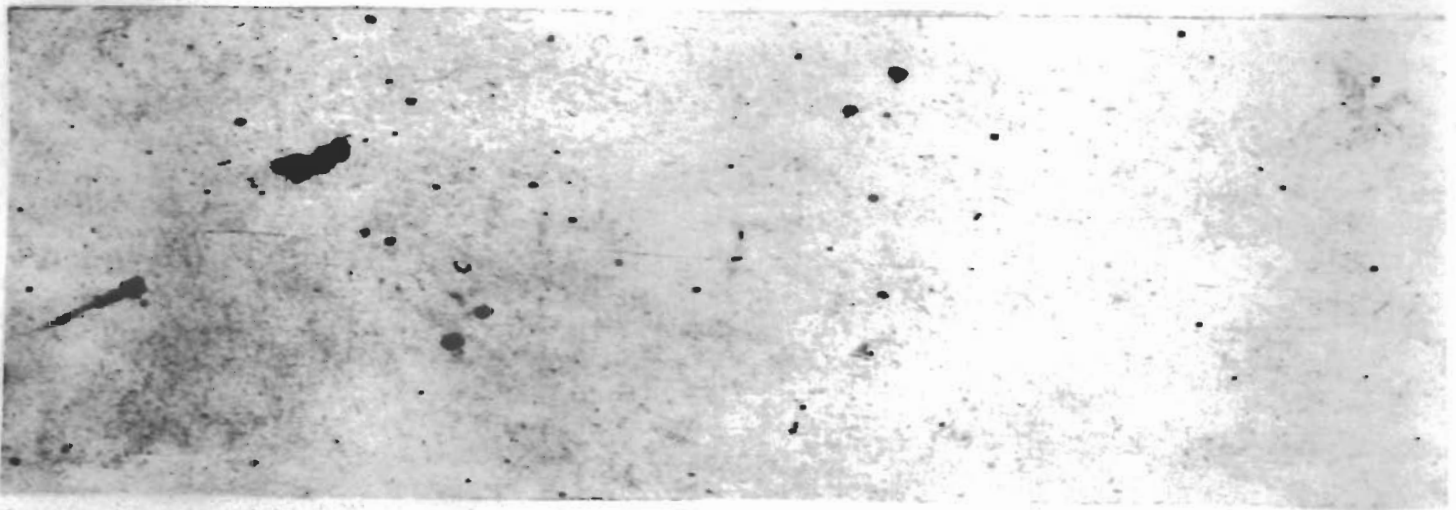
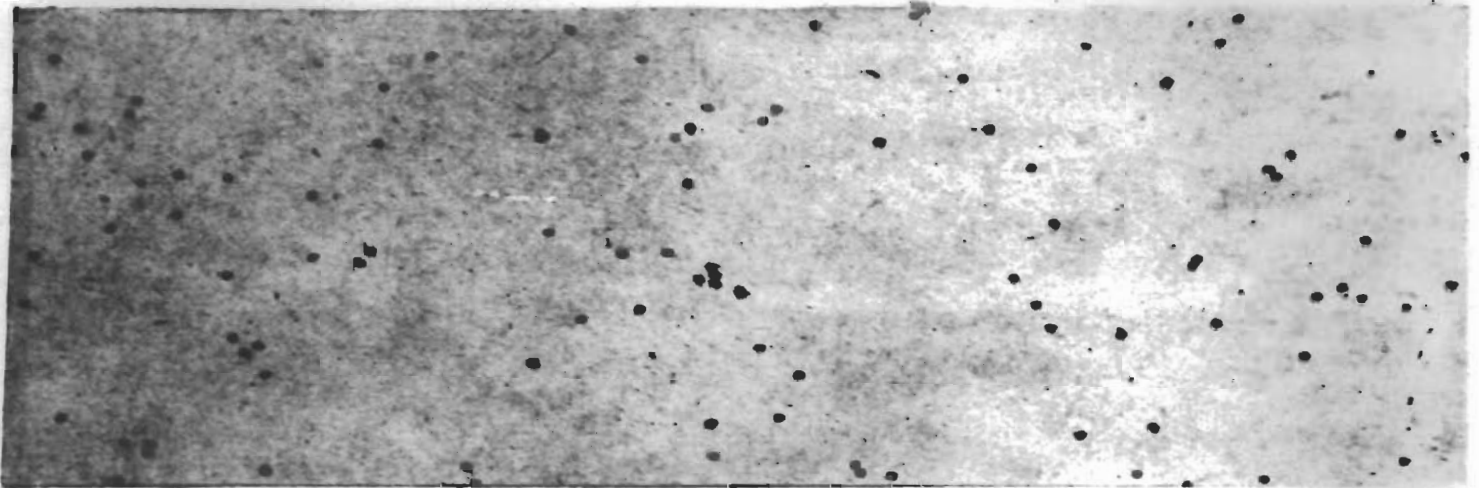
Battery adjust  
 Base deflection, Left 40  
 On #1 open 5  
 Shell, Mustard Gas, Charge 5, Fuze Long  
 Battery 7 rounds (28 rounds)  
 Quadrant 316.4

*F.C. Holebrook*  
 F.C. HOLEBROOK,  
 1st Lieut., 6th F. A.,  
 Commanding.

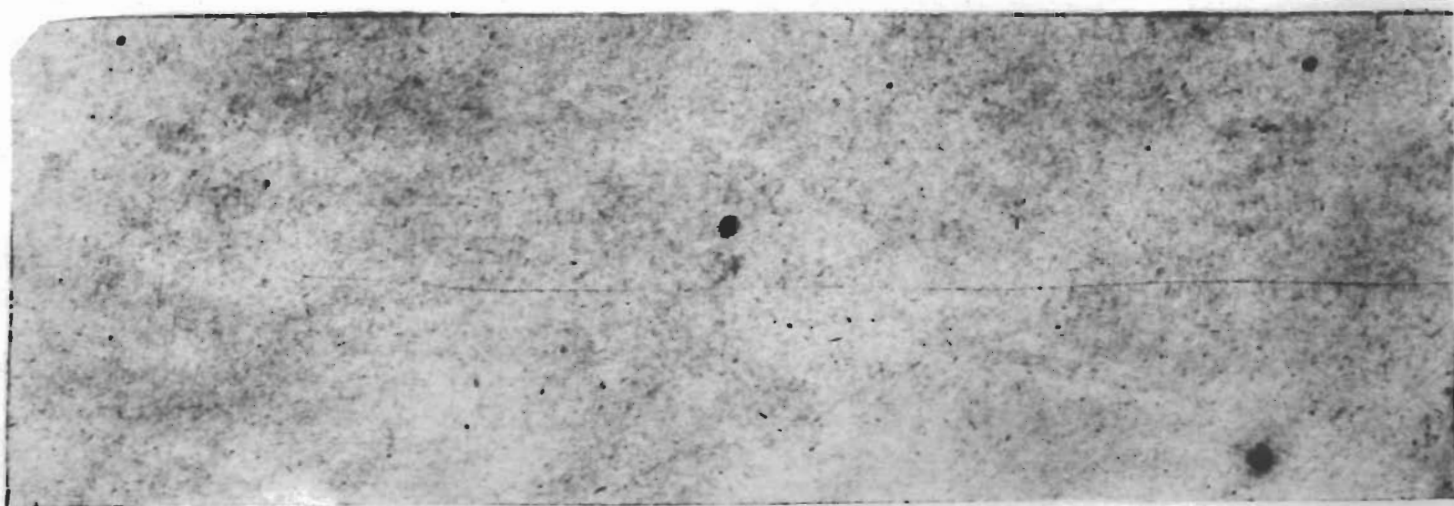
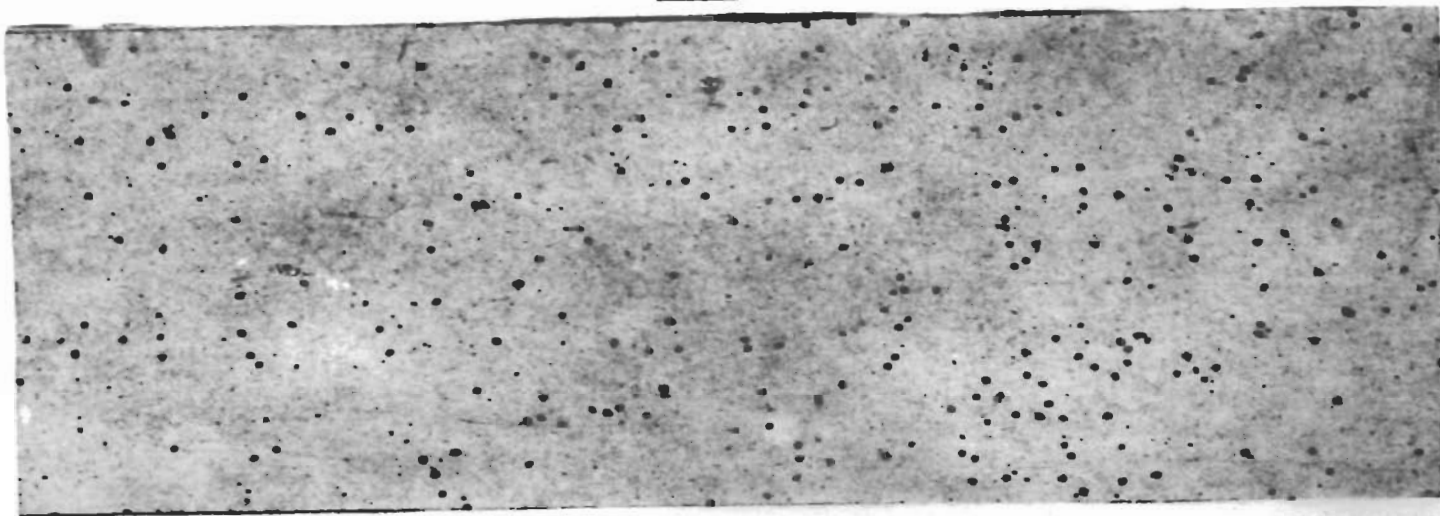
PATTERN SCALE (155-mm. Shell, HS)  
HEAVY



PATTERN SCALE (155-~~mm~~. Shell, HS)  
MEDIUM



PATTERN SCALE (155-mm. Shell, HS)  
LIGHT



PATTERN SCALE (155-mm. Shell, HS)

TRACE

UNCLASSIFIED

2. A test be conducted using HS-filled 155-mm. howitzer shell meeting present standard specifications for the purpose of comparing the casualty-producing effects with those obtained in the tests covered by this report.