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CHEMISTRY DIVISION - PROTECTIVE CHEMISTRY SECTION

9 January 1946

CHAMBER TESTS WITH HUMAN SUBJECTS

XVIII. TESTS WITH HN VAPORS

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Report No. P-2734

CONFIDENTIAL

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ABSTRACT

The calibration and operation of the NRL chamber for the exposure of human subjects to nitrogen mustard vapors is described in detail in the first part of this report.

Concentrations of HN vapors are established by means of special design saturators and by a "flash distillation" system. Analysis of the HN vapor is carried out by a colorimetric method based on the reaction with DB-3.

Operation of the chamber has been standardized for HN-1 vapor exposures ranging from 200 to 2000 CT (60 min.) and for HN-3 vapor exposures ranging from 100 to 900 CT (60 min.). The precision of the operation is such that a CT within 5% of the desired value is obtained with T factors of 50 to 70 minutes.

In the second part of this report, a series of tests is described in which human volunteers were exposed to HN-1 or HN-3 at various CTS at 90°F, 65% R.H., wearing masks and either ordinary or protective clothing. The most vulnerable body regions were the neck and the scrotum. Severe reactions on unprotected necks under summer conditions were observed following exposure to HN-1 at CT 300 and HN-3 at CT 150. The scrotal lesions resulting from exposure to the vapors of these agents were similar in time of onset, duration, and appearance to those from H vapor. CC-2 impregnated clothing offered poor protection against HN-1. Scrotal lesions were produced in men wearing both protective suits and shorts at CT 400 under summer conditions. On the other hand, good protection was afforded by this clothing against HN-3 up to the highest CT at which tests were conducted. No changes in the leucocyte counts were observed in any of the test subjects.

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INTRODUCTION

A. Authorization.

1. This work was authorized under Project 547/41, "Maintenance, Bureau of Ships", dated 16 December 1940. The problems which were proposed for study were given in Bureau of Ships letter S-S77 (Dz), Serial 811 of 17 December 1940.

2. Participation of volunteer Navy personnel in tests for the study of vesicant gases was approved by the Secretary of the Navy (Acting Sec. Nav. ltr. to OSRD dated 8 May 1942). Performance of such tests at the Naval Research Laboratory was approved by the Chief of the Bureau of Medicine and Surgery (Bu Med ltr. Serial No. 446 X:0A A11/EN10 (430320) (SC) dated 20 March 1943).

B. Statement of Problem.

3. This investigation was undertaken (a) to calibrate and study the operation of the NRL chamber for exposure of human subjects to HN vapors, (b) to determine the effects of these vapors at various CTs on human volunteers wearing masks and ordinary clothing; and (c) to evaluate against these vapors the protective clothing currently available.

C. Known Facts Bearing on Problem and Theoretical Considerations

4. The calibration and operation of the NRL chamber for HN vapor exposures presented several problems which were not encountered in the comparable study involving H vapor exposures. These problems were primarily concerned with (a) the instability of HN compounds, especially at high temperatures, (b) the low volatility of HN-3, and (c) the tendency toward formation of aerosols.

5. In the development of methods and techniques for establishment and maintenance of HN vapor concentrations in the NRL chamber, it was considered desirable to use as far as possible those methods which had been developed and found satisfactory in connection with H vapor exposures. However, it was considered necessary to modify these methods to whatever extent required to prohibit any decomposition of the liquid agents or the production of aerosols. The methods described in this report are believed to meet these requirements satisfactorily.

6. At the time this series of tests was begun, no man-chamber data on the nitrogen mustards were available. Preliminary arm-chamber studies had been performed at this Laboratory.

7. An extensive series of tests was carried out by Dr. Simon Black, et al., by means of exposures of human forearms on the vapor train at U CTL and was reported in OSRD Report No. 3944, dated 30 August 1944. This work has been discussed in relation to the NRL arm-chamber tests in NRL Report No. P-2464.

8. Recent man-chamber tests with HN-1, conducted at Edgewood Arsenal, Md., and to be published soon, showed that men, unprotected except for masks, carbon-cloth shorts, and ordinary clothing, sustained intense general erythema at CT 350 with subsequent superficial desquamation. Two layer CC-2 impregnated clothing offered inadequate protection to men exposed to CT 1600. AT CT 2400, delayed crusted scrotal lesions developed whereas at CT 3100, scrotal bleb formation and intense general erythema were evident within twenty-four hours after exposure. All these chamber exposures took place for 48 to 60 minutes at 90°F, 85% RH during the summer of 1945. It was concluded that CC-2 impregnated clothing offered inadequate protection against HN-1 vapor.

9. In an analogous series of tests with HN-3 at Edgewood Arsenal, Md., it was shown that men, protected with masks and protective shorts and "stripped to the waist", showed intense general erythema at CT 350 with vesication of the neck. In tests in which the men wore CC-2 impregnated clothing, it was found that the break point (intense erythema) for one and one-half layer protection occurred at at about CT 1600 and, for two-layer protection, at about CT 5000. It was concluded that CC-2 impregnated clothing gave moderately good protection against HN-3.

10. In none of the subjects exposed to HN vapor at Edgewood Arsenal were any changes observed in the blood counts.

D. Previous Work Done at This Laboratory.

11. This report is the eighteenth of a series on "Chamber Tests With Human Subjects" in which the results obtained in the evaluation of various protective devices against the effects of persistent chemical agents are reported.

12. NRL letter, C-S77-2 (459-HWC), C-459-604, to Bu Ships, dated 20 October 1944 on "Basic Chamber Tests with H and HN-1" contains a status report on work which is included in the present report. NRL letter C-S77-2 (459-HWC), C-459-646, to Bu Ships, dated 11 November 1944, is a comparable report on "Basic Chamber Tests with HN-3". NRL Report No. P-2464, dated March 1945, gives a detailed account of "Arm Chamber Exposures to HN Vapors".

EXPERIMENTAL

Part I. Operation and Calibration of the Large Chamber for HN Exposures.

13. A complete description of the NRL gas chamber is given in NRL Report No. P-2208, "Chamber Tests with Human Subjects. I. Design and Operation of Chamber," dated 22 December 1943. Included in that report is (a) a discussion of the methods of establishing and controlling chamber conditions, i.e., temperature, relative humidity, and air velocity, (b) a discussion of the methods of establishing, analysing, and maintaining H. vapor concentrations in the chamber, and (c) description of the operation of the chamber for H vapor exposures.

14. In using the chamber for HN vapor exposures, the chamber conditions are established and controlled exactly as for H vapor exposures. (Temperature = 90 ± 0.5°F; relative humidity = 65 ± 3%;, air velocity = 2.5 m.p.h.).

A. Methods of Establishing HN Vapor Concentrations.

(1) HN-1. Operation of the chamber has been standardized for HN-1 vapor concentrations ranging from 3 to 35 micrograms HN-1 per liter (0.003 to 0.035 mg./l.) Two methods are used for establishing these concentrations.

(a) Bead Saturator: For concentrations ranging from 3 to 10 micrograms/l., the bead saturator described in NRL Report No. P-2208 for establishing H vapor concentrations is used. Plate 1 shows a schematic diagram of the saturator. Air is passed through the saturator containing liquid HN-1, freshly prepared from pure HN-1 hydrochloride, at rates varying from 10 to 20 liters/min. The saturator is operated at room temperature.

(b) Flash Distillation: The flash distilliation apparatus, described in NRL Report No. P-2208 for establishing H vapor concentrations, is used for setting-up HN-1 concentrations ranging from 10 to 35 micrograms HN-1/l. Plate 2 shows a schematic diagram of this assembly. For HN-1 concentrations the oil bath is maintained at 70°C, at which temperature there have been no indications of decomposition of HN-1. Measured volumes of freshly prepared HN-1 are run into the flask from the burette and as the HN-1 is vaporized it is carried into the chamber through the heated glass tube by an air stream, at rates ranging from 10 to 50 liters/min., depending upon the concentration desired.

(2) HN-3. Operation of the chamber has been standarized for HN-3 vapor concentrations ranging from 1 to 15 micrograms HN-3/l. (0.001 to 0.015 mg/l.).

(a) In the early tests involving HN-3 vapor, concentrations from 1 to 8 micrograms/l. were established by means of two bead saturators of the type used for H and HN-1 and shown in Plate 1. The saturators are wound with nichrome resistance wire so they may be operated at any desired temperature. For establishing the HN-3 vapor concentrations, they were controlled at approximately 55°C. At this temperature no decomposition of H N-3 has been observed. Air was passed through each saturator at from 10 to 20 liters/min. and then into the chamber through glass tubes, heated to prevent condensation.

(b) In the later tests involving HN-3 vapor, concentrations from 1 to 15 micrograms/l. were established by means of three specially designed and constructed "large" saturators. The saturator assembly is shown in Plates 3 and 4. The saturators each contain 500-700 ml. of liquid HN-3. Air at about 5 lbs. pressure is bubbled through the HN-3 into the chamber. A dry-ice acetone trap is used to remove water vapor from the air line and the saturators are equipped with heating coils to maintain the temperature of the liquid HN-3 at 30°C.

B. Method of Analysis for HN Vapor Concentration.

15. Analysis of HN vapor concentration in the chamber is is carried out continuously during the period of exposure. The method of analysis, a modification of the DB-3 method described by W. N. Aldridge in Porton Report No. 2412, January 9 1942, has been discussed in detail in NRL Report No. P-2464 "Chamber Tests with Human Subjects, V. Arm Chamber Exposures to HN Vapors", dated March 1945. The theoretical principles upon which the method is based, the reagents, procedure, and standardization of the method have been included in that report.

C. Standardization of Chamber for HN Vapor Exposures.

16. A number of test runs were conducted to determine the optimum conditions for operation of the chamber for HN vapor exposures and to familiarize the laboratory personnel with the technique of operation. These test runs are described individually.

(1) Simulated HN-1 Vapor Chamber Exposures at Low Concentration.

17. To evaluate the method for establishment of low concentrations of HN-1 vapor (bead saturator method) and to determine the most efficient method of operating the saturator for maintaining low concentrations, a simulated HN-1 vapor exposure was conducted. The conditions set-up

for this test and the results obtained are shown in the following table:

Table I

Simulated HN-1 Vapor Exposure at Low CT

Conditions: Desired concentration = 8.3 γHN-1/l.-CT=250 (30 min)
Bead saturator at room temperature.
Chamber empty.

Time (Min.)	Conc. HN-1 γHN-1/l	Saturator Operating Time (Min.)	Flow Rate Thru Saturator (liters/min.)
5	0.6	Continuous	10
10	0.6	"	"
15	0.4	"	"
20	0.4	"	"
25	0.2	"	"
30	0.2	"	"
35	0.2	"	"
40	0.4	"	"
45	0.6	"	20
50	1.4	"	"
55	2.0	"	"
60	2.8	"	"
65	4.6	"	"
70	5.4	"	"
75	5.8	"	"
80	7.4	Off	
85	8.6	"	
90	8.4	"	
95	8.6	"	
100	9.4	"	
105	9.6	"	
110	8.2	"	
115	9.2	"	

18. The data given in the above table are also shown graphically in Plate 5. It may be seen that considerable HN-1 vapor was introduced into the chamber before the concentration began to increase. This indicates a relatively large "pick-up" by the walls and other surfaces. When the concentration began to build up, a good linear vapor input rate was observed. From the slope of the curve in Plate 3, an input rate of 0.19 γHN-1/l./min. is indicated. When a concentration approaching the desired value of 8.3 γ HN-1/l. was obtained the saturator was turned off. It was found that within a 30 min. period there was no loss of vapor in the chamber. The average concentration during this "control" period was 8.9 γHN-1/l., giving at CT of 267. The desired CT of 250 would have been obtained with a 28 minute exposure.

(2) Simulated HN-1 Vapor Chamber Exposure at High Concentration

19. Another simulated HN-1 vapor exposure was conducted to investigate the operation of the "flash saturator" method for establishing HN-1 concentrations. The conditions and results of this test are given in Table II and Plate 6.

Table II

Simulated HN-1 Vapor Exposure at High CT

Conditions: Desired concentration = 33.3 γHN-1/l - CT = 2000 (60 min.) Flash saturator at 70°C.

Time (Min.)	Conc. HN-1 (γHN-1/l.)	Ml. HN-1 Added	Remarks
0	-	10	
5	3.2		
10	6.5		
15	11.4		
20	15.7		
25	18.8		
30	24.8		
35	27.9		
40	32.0		
45	36.5		5 Carbon Suits Placed in chamber
50	40.7		
55	38.8	5	
60	45.0		
65	40.4		
70	40.9		
75	30.7		
80	36.0		
85	33.0		
90	30.7		
95	28.9		
100	28.9		
105	26.0		

20. The data in Table II and Plate 6 show a good linear input rate of HN-1 using the "flash saturator" system. As measured from the slope of the curve in Plate 6 this rate is 0.83 γ HN-1/l./min. The average concentration of HN-1 vapor during the "control period" with 5 carbon suits in the chamber was 35.5 γHN-1/l. This corresponds to a CT of 2130 for 60 min. A CT of 2000 was obtained in 56 minutes.

21. It was concluded as a result of the data obtained in simulated HN-1 exposures, that satisfactory chamber

operation could be obtained by using the described systems and technique for establishing and maintaining HN-1 concentrations.. As in the case of HN arm chamber exposures (NRL Report No. P-2464), it was decided to conduct the chamber operation by adjusting the time (T) of exposure within the range of 50-70 minutes so as to obtain CTs within 5% of the desired value. This time adjustment is necessary because of the 12-13 minute lag in obtaining the analytical results and the consequent difficulty in accurately estimating saturator operating time and HN-1 additions.

(3) Establishment of HN-3 Vapor Concentrations

22. The described procedure for the establishment of HN-3 vapor concentrations in the large chamber in early tests was evaluated by conducting a test run in which the bead saturators were operated continuously and the HN-3 vapor input rate measured by analysis of the chamber atmosphere. The data obtained in this test are presented in Table III and Plate 7.

Table III

Establishment of HN-3 Vapor Concentration-Bead Saturators

Conditions: Bead Saturators at 55°C - Continuous Operation
Chamber Empty

Time (Min.)	Conc. HN-3 (γ/l.)	Input Rate (γ HN-3/l./min.)
5	1.5	
10	2.3	
15	1.9	
20	2.9	
25	2.4	
30	3.2	
35	2.8	
40	3.8	
45	3.1	
50	3.7	
55	3.7	
60	3.7	
65	3.7	
70	4.3	
75	3.7	
80	4.7	
85	4.7	
90	5.7	
95	5.0	
100	5.6	
105	5.3	
110	6.3	
115	6.0	0.037

23. The above data indicate a slow but uniform HN-3

input rate. It was concluded on the basis of this test that using the described procedure, HN-3 vapor concentration of 2 to 7 γHN-3/l. could be established and maintained satisfactorily. Exposures at these concentrations for 60 minutes give CT values from 100 to 400.

24. A test run using the "large" saturator system employed in the later HN-3 tests was conducted in the fo following manner: The 3 saturators were operated continuously at 33-34°C for 90 minutes with the chamber empty. Eight standard aqueous process CC-2 impregnated suits were then placed in the chamber, and the operation was continued for 70 minutes. The HNN3 vapor input rate was measured and the effect of the CC-2 clothing on the HN-3 vapor concentration were determined by the standard method of analysis. The results of this test are shown in Table IV and Plate 8.

Table IV

Establishment of HN-3 Vapor Concentration "Large Saturators"

Time (Min.)	Conc. HN-3 (γ/l.)	Input Rate γHN-3/l./min.	Remarks
20	5.9		Chamber Empty
30	9.9		
40	11.2		
50	12.2		
60	16.3		
70	17.1		
80	23.7		
90	25.6	.28	8 CC-2 Suits Placed in Chamber
100	22.0		
110	18.2		
120	18.6		
130	14.6		
140	16.9		
150	13.2		
160	17.6		

25. As may be seen from the data in the above table and from Plate 8, a concentration of 25.6 γHN-3/l. had been obtained in the chamber at the time at which the suits were introduced. The concentration then dropped to a level of about 15γHN-3/l. where it became relatively constant. Thus, it was indicated that using this method of establishing and maintaining concentrations of HN-3 vapor, a maximum concentration of 15γHN-3/l. (CT= 900 for 60 min.) could be maintained in the presence of 8 CC-2 impregnated suits.

D. Operation of Chamber for Physiological Tests

26. A detailed description of the exact procedure used in operating the large chamber for an H vapor exposure is given in NRL Report No. P-2208. The same procedure is followed for HN-1 and HN-3 vapor exposures. The exposure time is varied within 50-70 minutes to give a CT within 5% of the desired value. The complete log and data for typical HN-1 and HN-3 tests are presented in the following tables.

Table V.

Data for Typical HN-1 Chamber Test (Test #4).

Conditions: (a) 10 men in the chamber, each dressed in standard dungaree clothing with watch caps and gas masks.
(b) Desired concentration =5.0 γ HN -1/l. for 1 hr. (CT = 300).
(c) Air passed through bead saturator at 10 liters/min.
(d) Saturator operated at room temperature.

Preparation of Calibration Curve.

Solution No.	γ HN-1	% Transmission
1	5.1	66.8
2	10.2	42.0
3	15.2	26.4
4	20.3	16.5
5	25.4	10.5

The calibration curve prepared from the above data is shown in Plate 9 (Upper Curve).

Analysis of HN-1 Vapor from Chamber

Time (Min.)	Saturator Operating Time (Min.)	%Transmission	γHN-1/l.	Remarks
5	0	97.0	0.6	
10	0	96.6	0.8	
15	5	97.2	0.5	
20	5	94.8	1.2	
25	5	91.5	2.0	
30	5	87.0	3.2	
35	5	82.4	4.4	
40	5	78.3	5.6	
45	0	77.6	5.8	Men in Chamber
50	2.5	79.9	5.2	at 45 min.
55	1.8	81.0	4.8	
60	4.0	82.0	4.6	
65	3.5	83.2	4.2	
70	4.0	83.3	4.2	
75	4.0	82.7	4.4	

Table V (Cont'd

Analysis of HN-1 Vapor from Chamber (Cont'd)

Time (Min.)	Saturator Operating Time (Min.)	%Transmission	γHN-1/l.	Remarks
80	3.2	82.5	4.5	
85	5.0	83.0	4.3	
90	5.0	81.0	4.8	
95	4.5	79.9	5.2	Men out of
100	4.7	79.9	5.2	Chamber at
105	4.5	79.9	5.2	106 min.

Summary

Concentration of HN-1 Vapor (γHN-1/l.)
Average = 4.8, Maximum = 5.8, Minimum = 4.2
Average Deviation from Mean = ± 0.4

Temperature (°F) = 90
Relative Humidity (%) = 65
CT - Actual CT = 293 (61 Min.)

Table VI

Data For Typical HN-3 Chamber Test (Test #1).

Conditions: (a) 8 men in the chamber, each dressed in standard dungaree clothing with watch caps and gas masks.
(b) Desired concentration = 1.7 γ HN-3/l. for 1 hour (CT = 100).
(c) Air passed through bead saturators at 10 liters/min
(d) Saturators operated at 55°C.

Preparation of Calibration Curve

Solution No.	γ HN-3	%Transmission
1	0.86	94.4
2	1.73	91.4
3	2.59	86.0
4	3.46	82.0
5	4.32	77.6

The calibration curve prepared from the above data is shown in Plate 9 (Lower Curve).

Table VI (Cont'd)

Analysis of HN-3 Vapor from Chamber.

Time (Min.)	Saturator Operating Time (Min.)	%Transmission	γHN-3/l.	Remarks
5	5	96.9	1.0	
10	5	98.7	0.4	
15	5	97.3	0.8	
20	5	98.7	0.4	
25	5	98.0	0.6	
30	5	99.2	0.2	
35	5	96.1	1.3	
440	5	97.0	1.0	
45	5	95.8	1.4	
50	5	96.5	1.2	
55	5	95.2	1.6	
60	5	96.0	1.3	
65	5	94.1	2.0	Men in
70	5	95.2	1.6	Chamber at
75	5	92.0	2.8	75 min.
80	5	93.5	2.3	
85	5	94.0	2.1	
90	4	95.0	1.7	
95	2	94.2	2.0	
100	0	95.6	1.5	
105	3,5	95.1	1.7	
110	3	96.3	1.2	
115	00	93.8	2.2	
120	1,5	94.5	1.9	Men out of
125	3,1	94.6	1.9	Chamber at
130	0	95.9	1.4	130 min.

Summary

Concentration of HN-3 Vapor (γHN-3/l.)
Average = 1.9, Maximum = 2.8, Minimum = 1.2
Average Deviation from Mean = ± 0.3
Temperature (°F) = 90
Relative Humidity (%) = 65
CT - Actual CT = 105 (55 Min.)

Part II. Chamber Tests with Human Subjects.

A. Procedure

(1) General routine.

27. The procedure employed in these tests was essentially the same as that for the tests with H vapor and has

been described in detail in NRL Report No. P-2579, "Chamber Tests with Human Subjects IX. Basic Tests with H.Vapor", dated 14 August 1945.

(2) Test Subjects.

28. The men used in these tests were volunteer Naval personnel from US Naval Training Center, Bainbridge, Maryland, and were usually seamen, second class, from eighteen to twenty years of age, who had just completed their "boot" training. Their homes were mostly in the Atlantic Seaboard States, both north and south of Washington, D. C. All men received a routine physical and laboratory examination (blood and urine) and only those approved by a medical officer participated in the experiments. At the end of the tests, the men were granted special leave and an entry was made in their service records attesting their attendance at this activity. Recently, authorization has been granted for the commanding officer to give commendation to especially deserving individuals.

(3) Clothing.

29. The clothing worn during chamber exposure in the basic tests was the same as that for the tests with H vapor, i.e., standard issue skivvy shirts and Nainsook shorts, watch caps, blue denim shirts, dungaree pants, standard socks and shoes. Shirt collars were buttoned and shirt sleeves were buttoned at the wrist. All men wore ND Mark III or IV masks. In some of the tests, the Nainsook shorts were replaced by CC-2 impregnated shorts (so-called one-half layer protection). These latter were of the rib-knit type, impregnated by the aqueous process, and contained about 0.5 mg.Cl+/cm.^{2}. In all tests since 1 January 1945, the men have worn suspenders made of carbon-coated cloth (August model). The protection afforded by these suspenders causes a subjacent area of relatively normal skin which contrasts with the erythematous area and facilitates observations. (This effect is faintly visible in Fig. 4, Plate 11).

30. In addition to the basic tests, a few tests were carried out in which the men wore the standard CC-2 impregnated Arhzen cloth protective suits (so-called one-layer protection). These suits were impregnated by the aqueous method, using 100 parts C -2, 25 parts ZnO, 75 parts chlorinated paraffin, 3.75 parts polyvinol alcohol, and 9 parts dye; the usual Cl+ content of the cloth was 0.5 mg./cm.^{2}. In some of the tests the men also wore CC-2 impregnated protective shorts (so-called one and one-half layer protection).

(4) Conditions related to chamber exposure.

31. All chamber exposures for this series of tests were conducted at 90°F and 65% R.H. Single exposures were employed in all tests except No. 22(a double exposure).

The men were in the chamber 50-70 minutes, the time being varied to obtain the desired CT (within 5%). During exposure, the men stood at ease but were required to change positions about every five minutes. In general, before and after chamber exposure, the men led a relatively sedentary existence except for occasional participation in mild athletics.

(5) Daily Readings and the Recording and Evaluation of Data

32. The men were inspected by a medical officer daily for 4 to 8 days or longer after exposure. The usual arbitrary intensity scale was used to record the maximum reading for a given body region:

0 = no reaction
1 = mild erythema
2 = moderate erythema
3 = intense erythema
4 = a. erythema with edema
b. maceration of axillary skin
c. dry scaling of scrotum
5 = a. vesicle
b. numerous pinpoint vesicles
c. crusting or ulceration of scrotum or axilla.

33. The same body regions were described as are listed in the report on the tests with H Vapor (NRL Report No. P-2579), but have been somewhat condensed as listed in Tables X and XI in the appendix.

34. For the evaluation of data from the tests with H vapor, it was found advantageous to employ a total damage index which represented a combination of the intensity of reaction and the surface area involved. This index did not prove practical for evaluation of the data from the HN vapor tests because the reactions were generally quite localized in this limited series of tests. Hence, this data has been treated in a more qualitative or descriptive fashion with special emphasis on those regions primarily affected, namely, the neck and the scrotum.

(6) Leucocyte Counts

35. Total and differential leucocyte counts were taken on many of these subjects before and after chamber exposure. These counts are recorded in Table XIII of the Appendix.

B. Results

(1) Tests with HN1

36. The maximum readings for seventeen body areas for

each man are tabulated in Table X in the Appendix. In Table VII, these data have been summarized to present the average intensities of reaction for the group of men employed in a given test. The reactions for the neck and scrotum, which were especially affected, are listed separately; whereas the reactions of the other body areas have been averaged and expressed as the "rest of body" (i.e., excluding readings for neck, scrotum, and penis).

(a) Neck Reactions

37. In the summer basic tests at CT 100, neck reactions were relatively mild; but at CTs 200 and 300, intense erythema and, in many cases, erythema with edema, were observed with subsequent intense pigmentation. In the basic tests run in the winter (Tests 7-9), the neck reactions were more severe than those for any other region but were much milder than those of the summer series even though the CTs of exposure were considerably higher.

Table VII

Tests With HN-1

Test No.	Date	CT	No. Men	Prot.	Neck	Scrotum Av.	No. C.	%C	Rest of Body Av.
1	8/10/44	100	10	B	1.3	1.2	0 C.	0	0.3
2	8/15/44	200	10	B	3.4	1.4	0 C.	0	1.2
3	8/22/44	300	10	B	3.3	4.6	(7 C. 70 (2Sc.)		1.7
4	8/22/44	300	10	IL*	2.2	3.3	(3C 1Sc)	30	0.7
5	8/29/44	400	10*	IL*	2.6	4.6	9 C.	90	1.1
6	9/ 2/44	400	9	1-1/2L*	2.9	4.3	7 C.	78	1.4
7	1/16/45	300	8	B	1.9	0.6	0 C.	0	0.3
8	1/18/45	450	4	B	1.8	1.5	1 Sc.	0	0.6
9	1/20/45	700	6	B	2.2	4.0	(4 C.) (1Sc.)	67	0.6

B = basic test, i.e., men wore dungarees
B-1/2L = dungarees, plus CC-2 impregnated shorts
IL = one layer, i.e., CC-2 impregnated suits
1-1/2L = one and one-half layer, i.e., CC-2 impregnated suits and shorts
* = S-330 protective ointment worn on neck.
C = crusted or ulcerated scrotal lesions.
Sc = dry, scaling scrotal lesion.

38. In the basic tests (1-3, 7-9), most of the skin of the neck was exposed bare in the chamber but part of it was covered by the buttoned collar of the blue denim shirt. It is evident from Fig. 1, Plate 10, that some degree of protection was afforded by plain clothing. In tests 4,5, and 6, S-330 protective ointment was worn on the neck which was further protected by the hood of the

suit. These measures offered some protection, but nevertheless, severe neck reactions occurred; and the protection given was certainly not in the same category with that which these same measures would have afforded against H vapor.

(b) Scrotal Reactions.

39. The vulnerability of the scrotum to HN-1 is outstanding. From Table XII, Appendix, it can be seen that, at CT 300 and above, a large number of the men in the tests performed during the summer sustained crusted lesions of the scrotum. This occurred even in the men wearing both protective shorts and suits, and exposed to CT 400. Of special interest is the test of the winter series at CT 700. Neck reactions were moderate, the rest of the body was very mildly affected and yet, of 6 men 4 developed crusted lesions and one showed dry scaling. In no case was actual bleb formation observed.

40. The time of occurrence of these lesions, the severity and duration as presented in Table XII, Appendix, was approximately like those for the H vapor tests. Since the appearance of these HN-1 lesions was in no way specific and was similar to those presented for H vapor, no color prints of scrotal lesions have been included in this report (see NRL Report No. P-2579 for pictures of H vapor scrotal lesions).

(c) Reactions of the Rest of the Body

41. While considerably milder than the reactions of the scrotum and neck, these also showed an increase in severity parallel with an increase in CT of exposure. Even at higher CTs, reactions in tests of the winter series were much milder than those of the summer. One layer of ordinary clothing (denim shirt) offered some protection as can be seen in Fig. 1, Plate 10, if the arms and lower neck are compared with the upper neck which was exposed bare. Two layers of ordinary clothing offered even more protection since the outline of the skivvy shirt is evident in the aforementioned picture. The hands and wrists of the same individual are illustrated in Figure 2 and show an unusually severe reaction.

42. There is an indication that CC-2 impregnated clothing offered some protection to the general body surface (compare tests 3 and 4); and, in spite of a higher CT (400), tests 5 and 6 showed slightly milder reactions than test 3 at CT 300.

Effect of Wearing Clothing After Leaving Chamber as Compared With Bathing Immediately.

43. In the first four tests with HN-1 (Tests 1-4, Table VII), half of the men took a shower bath immediately upon leaving the chamber and donned fresh (unexposed) clothing. The other half wore the same clothing which they had worn in the chamber for four hours afterwards. The average intensities of reaction per man per area are listed in Table VIII. There is no appreciable difference between the two groups.

Table VIII

Effect of Wearing of Clothing

Test	Shower Men No.	Av./Man/Area*	4 Hr. Wear. Men No.	Av/Man/Area*
1	1-5 (incl.)	0.4	6-10(incl.)	0.4
2	1-5 (incl.)	1.2	6-10(incl.)	1.6
3	1-5 (incl.)	1.8	6-10(incl.)	2.1
4	1-4 (incl.)	1.1	5-10(incl.)	0.9
AVERAGE		1.1		1.3

* All 17 areas listed are included.

(d) Leucocyte Counts

44. From Table XIII, Appendix, it is evident that no significant changes occurred.

(2) Tests with HN-3

45. The results for these tests have been tabulated in a manner analogous to those for the HN-1 tests and are presented in Table XI of the Appendix and are summarized in Table IX.

Table IX

Tests with HN-3

Test No.	Date	CT	No. Men	Prot.	Neck	Scrotum Av.	Scrotum No.C.	Scrotum %C	Rest of Body Average
10	9/7/44	50	8	B	1.8	0.5	0C.	0	0.2
11	9/7/44	100	8	B	3.0	1.9	1C.	13	0.8
12	9/16/44	150	8	B	4.0	4.0	6C.	75	1.8
13	9/16/44	150	7	II	1.1	1.6	1SC	0	0.3
14	9/16/44	200	7	1-1 2L*	1.1	0.3	0C	0	0.2
15	2/9/45	150	6	B	1.5	0.3	0C	0	0.7
16	2/19/45	250	6	B	2.5	1.5	2SC	0	0.8
17	2/27/45	350	8	B	4.9	3.6	(6C) 1SC	75	1.7

Table IX (con't)

Tests With HN-3

Test No.	Date	CT	No. Men	Prot.	Neck	Scrotum Av.	No.C.	%C	Rest of Body Average *
18	8/10/45	150	8	B-1/2L	2.0	0	0C	0	0.2
19	8/10/45	200	8	1-1/2L*	2.0	0	0C	0	0.2
20	8/20/45	500	6	1-1/2L*	1.7	0.3	0C	0	0.3
21	8/27/45	850	6	1-1/2L*	2.0	0.3	0C	0	0.7
22	9/4/45	2000**	6	1-1/2L*	1.3	0	0C	0	0.3

B = basic test, i.e., men wore dungarees.
B-1/2L = dungarees plus CC-2 impregnated shorts.
IL = one layer, i.e., CC-2 impregnated suits.
1-1/2L = one and one-half layer, i.e., CC-2 impregnated suits and shorts.
* = S-330 protective ointment worn on neck.
C = crusted or ulcerated scrotal lesion.
SC = dry, scaling scrotal lesion
** = 2 exposures of 1000 CT each.

(a) Neck Reactions

46. The basic tests at CTs 50, 100, and 150 (Tests 10, 11, and 12, respectively) showed a progressive increase in the severity of neck reactions, three out of ten men at CT 150 showing vesication of the neck. Tests 13 and 14, run concurrently with test 12, showed that the hood of CC-2 protective clothing offered good protection to the neck. It is not possible to evaluate the added protection afforded by the ointment worn on the neck in Test 14.

47. The reactions of the basic tests of the winter series (Tests 15, 16 and 17) showed a progressive increase in severity of reaction with increase in CT. At CT 150, the reactions were much milder in the winter series. In the winter series, at CT 350 (Test 17), 7 out of 8 men suffered vesication of the neck and subsequently developed intense pigmentation (Figures 3 and 4, Plate 11). From these figures it is also evident that the plain denim shirt collar offered some protection to the area of the neck it covered.

48. Some of the tests were repeated in the summer of 1945. At CT 150 (Test 18), the reactions of the neck were only mild to moderate. Many of the men's necks showed moderate actinic erythema or pigment prior to the test, making evaluation of the reactions difficult. The reduction in severity as compared with the previous summer test at CT 150 cannot be explained. In the other tests of this series, at higher CTs, the neck was protected by S-330 ointment; and

by the hood of the CC-2 impregnated suits. At the highest CT tested (2 exposures of 1000 CT each), the neck was well protected and showed only a mild reaction.

(b) Reactions of the Scrotum

49. These reactions are listed in Table XII of the Appendix. In the summer series, one man out of eight developed a crusted lesion at CT 100; but at CT 150 (Test 12) such lesions were evident in six out of eight men. Standard CC-2 impregnated suits protected completely at CT 150; at CT 200+ protective suits plus protective shorts gave complete protection.

50. In the winter basic tests, no crusted lesions were observed at CT 250 but two men did show dry scaling lesions which indicated damage slightly below the crusting level. Out of eight men exposed at CT 350, six suffered crusted lesions and one, a scaling lesion.

51. In all the tests which were repeated in the summer of 1945, CC-2 impregnated protective shorts were worn and, in all tests except No. 18, also CC-2 impregnated suits. In none of these tests, were any crusted scrotal lesions observed.

52. Time of occurrence and healing of these crusted scrotal lesions was similar to those from H vapor. No specificity in appearance or location was evident for HN-3.

(c) Reactions of the rest of the body.

53. As for HN-1, increase in CT resulted in increased severity of reaction, and at CT 150 the first summer series (1944) showed more intense reactions than the winter series. However, as for the neck reactions, the repeated summer tests (1945) resulted in extremely mild reactions on the general body surface.

54. Plain clothing offered some protection against HN-3 and CC-2 clothing offered good protection up to the highest CT tested (2 exposures of 1000 CT each).

55. It should be mentioned that the axillae proper were not affected in the HN-1 or HN-3 tests in contrast to those with H vapor. Where axillary reactions occurred, they involved the folds or upper medial arms (e.f. Figure 3, Plate 11). Since central axillary reactions from H vapor occurred primarily at temperatures below 80°F, and usually not at 90°F., it may be that a similar phenomenon applies to the HN reactions. All tests in this series with HN, however, were run at 90°F.

(d) Leucocyte Counts on Test Subjects

56. Upon inspection of the limited data in Table XIII, in the Appendix, no significant alteration is observed.

SUMMARY AND CONCLUSIONS

1. The calibration and operation of the NRL large chamber for the exposure of human subjects to nitrogen mustard vapors are described in detail.

2. Concentrations of HN-1 vapor are established and maintained by means of a bead saturator (for low concentrations) and a "flash distillation" system (for high concentrations). The bead saturator is operated at room temperature and the "flash distillation" system at 70°C.

3. Concentrations of HN-3 vapor have been established by two methods: (a) Bead saturators operated at 55°C., and (b) "large" saturators operated at 30°C.

4. For the operating conditions and methods as described there has been no evidence of decomposition of the agents or of aerosol production.

5. Analysis of the HN vapor in the chamber is carried out by means of the DB-3 method described by W. N. Aldridge in Porton Report No. 2412, January 9, 1942, and modified at this Laboratory as described in NRL Report No. P-2464.

6. Operation of the chamber has been standardized for HN-1 exposures ranging from 200 to 2000 CT (60 min.) and for HN-3 vapor exposures ranging from 100 to 900 CT (60 min.). The precision of this operation is such that a CT within 5% of the desired value is obtained with T factors ranging from 50 to 70 minutes (optimum = 60 min.).

7. Reactions to HN-1 and HN-3 vapor, are much more severe on the neck and the scrotum than on the rest of the body surface.

8. In basic tests, under summer conditions, severe neck reactions occurred at CT 300 with HN-1 and at CT 150 in one series of tests with HN-3.

9. Scrotal reactions due to HN-1 and HN-3 were similar to those from H vapor as regards appearance, time of onset and duration.

10. As for H vapor, severity of reaction increased with CT; and summer reactions were more severe than those in winter.

11. For the HN-1 basic tests, no difference was noted whether a shower was taken at once after exposure or if the clothing worn in the chamber was worn for four hours after exposure.

12. Some protection by ordinary clothing is evident for the nitrogen mustards.

13. CC-2 impregnated clothing offers very poor protection against HN-1 (CT 400 under summer conditions). Up to the highest CT tested (2 exposures of 1000 CT each), it offered good protection against HN-3.

14. A limited amount of data indicated no effect of chamber exposure to HN-1 or HN-3 on the leucocyte counts.

RECOMMENDATIONS

1. It is recommended that standard CC-2 impregnated clothing be considered as offering inadequate protection against exposure to HN-1 vapor.

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Table X

Tests with HN1

Maximum Regional Readings for Individual Subjects and Average Maximum Regional Readings for Each Test Group

Test No. 1 B
8/10/44
HN1
CT = 100

Man No.	1	2	3	4	5	6	7	8	9	10	Av.
hook	2	1			2		3	1	1	2	1.5
ax										2	0.2
sh	2		1				1	1			0.5
se	1										0.1
wth					1					1	0.2
lth											
dth										1	0.1
shd											
pen		1	1	2	1	1		2	1		0.9
ser	1	1	1	2	1	1	1	2	1	1	1.2
bt									1		0.1
arm	1	1									0.
af	1	1		2	1		1		1	1	0.6
ar		1				1					0.2
thi			1	2	1			1	1		0.6
pop		1		1	1	1			1	1	0.6
leg							1				0.1

Test No. 2 B
8/15/44
HN1
CT = 200

Man No.	1	2	3	4	5	6	7	8	9	10	Av.
hook	3	3	4	3	3	4	4	2	4	4	3.4
ax		1						1		3	0.5
sh		1		3	1	1	2	2	1	1	1.2
se	1		1	1		1	5		1	1	1.1
wth	1	1	2	2	1	2	2	1	2	3	1.7
lth	1	1	2	2	1	2	2	1	1		1.3
dth	1	1	2	2	1	2	2	2	2	2	1.7
shd	1	1	2			1	1	1			0.7
pen	1		1		1	1	2	3			0.9
ser	1		1		1	2	2	3	3	1	1.4
bt										2	0.2
arm	1	2	4	2	1	3	3	1	1	2	2.0
af	2	2	4	3	2	2	3	1	3	3	2.5
ar	1	2	5	1	1	3	3	1	3	2	2.2
thi		1	1		1	1	2	1	1		0.8
pop	1	1	2	1	1		1	1	1	1	1.0
leg			1			1	2	1	1		0.6

Test No. 3 B
8/22/44
HN1
CT = 300

Man No.	1	2	3	4	5	6	7	8	9	10	Av.
hook	3	3	3	4	3	4	4	3	3	3	3.3
ax	2	1				4					0.7
sh	1	1	2	3	2	2	2	1	2	2	1.8
se		1	2	3	2		2	2		2	1.4
wth	3	3	1	3	2	2	3	2	2	2	2.3
lth	3	3	1	3	2	2	3	2	1	2	2.2
dth	3	3	1	3	2	2	3	2	1	2	2.2
shd		3				3					0.6
pen		2		2	2	3	3	3	1	2	1.8
ser	4	5	3	5	4	5	5	5	5	5	4.6
bt	1			1		1	2	2	2	1	1.0
arm	3	3	2	3	2	5	2	2	1	2	2.5
af	2	3		3	1	4	3	2	3	3	2.4
ar	3	2	2	2	2	2	3	2	1	2	2.1
thi	1		2	1		2	3		1	1	1.1
pop	2	2	2	1		5	5	2	2	1	2.2
leg	1		1	1		2	3		1	1	1.0

Test No. 4 1L•
8/22/44
HN1
CT = 300

Man No.	1	2	3	4	5	6	7	8	9	10	Av.
hook	2	3	1	3	2	2	3	2	3	1	2.2
ax											
sh	2	2	2	3	2	2	2		2	2	1.9
se	2	2		3	1	2			2	2	1.4
wth							1			2	0.3
lth											
dth			2	1					2		0.5
shd											
pen		2	2	3	1	2	3		2	2	1.7
ser		3	2	5	4	3	5	3	5	3	3.5
bt				4		2					0.6
arm			1	5			5		2		1.1
af	1		1	3		1			1		0.7
ar	2			3			2		3	2	1.2
thi		1		3	1	1			1		0.7
pop	4	1	1	3	1	1	3		1	1	1.6
leg											

Test No. 5 1L•
8/29/44
HN1
CT = 400

Man No.	1	2	3	4	5	6	7	8	9	10	Av.
hook	2	2	3	3	4	2	3	3	3	2	2.6
ax		2		3							0.5
sh	1	2		2	3		2	3	2	2	1.7
se		2	1	2	4	2	2	2	2	2	1.9
wth			1			2		1			0.4
lth			1								0.1
dth						2	2		2		0.6
shd				1							0.1
pen		3	3	5	4	4	3	3	3	3	3.1
ser	1	5	5	5	5	5	5	5	5	5	4.6
bt				3	4	3	2	3	1	3	1.9
arm		2	1	1			2	2	1		0.9
af		2	2			4	2	2		2	1	1.5
ar				1			2	2	1	2	2	1.0
thi			2	1	2	5	1	2	1	1	1	1.6
pop	2	2	1	2	2	1	1	1	1	3	1.5
leg	2			1	1	1		1	1	1	0.8

Test No. 6 1½L•
9/2/44
HN1
CT = 400

Man No.	1	2	3	4	5	6	7	8	9	Av.
hook	2	3	3	2	2	3	2	4	3	2.9
ax							3		3	0.6
sh		3	2	1	2	2	4	4	3	2.3
se	1	5	3	2	3	3	4	4	4	3.2
wth	2	2	1			3	2	4	3	1.9
lth		1	1							0.2
dth	1	3			1			4	4	1.4
shd										
pen			3		3	1	3	3	3	1.8
ser	5	5	5	5	5	1	5	5	3	4.3
bt	2	2					4	4	2	1.6
arm	2	3	3	1	2		5	4	3	2.6
af	2	1	3	1			1	4	3	1.7
ar								2	2	0.4
thi	1	2	2			1	2	4	1	1.4
pop		2	3			3	4	3	3	2.0
leg		2	1				2	4	1	1.1

Test No. 7 B
1/14/45
HN1
CT = 300

Man No.	1	2	3	4	5	6	7	8	Av.
hook	1	3	1	1	1	3	2	3	1.9
ax									
sh	1	1			1			2	0.6
se		1		1				2	0.5
wth									
lth									
dth				1	1			2	0.5
shd									
pen								1	0.1
ser	1	1	1			1		1	0.6
bt	1		1	1	1	1		1	0.8
arm							3		0.4
af	1						3		0.5
ar	1	1	1		1	1			0.6
thi			1	1		1			0.4
pop									
leg									

Test No. 8 B
1/18/45
HN1
CT = 450

Man No.	1	2	3	4	Av.
hook	2	2	2	1	1.8
ax					
sh	1	1	1	1	1.0
se	1	1	1	1	1.0
wth			1		0.3
lth					
dth	1	1	1	1	1.0
shd			1		0.3
pen					
ser		2	4		1.5
bt	1			1	0.5
arm		1	1	1	0.8
af		1		1	0.5
ar		1			0.3
thi		2	1	1	1.3
pop		1	1	1	1.0
leg		1	1		0.5

Test No. 9 B
1/20/45
HN1
CT = 700

Man No.	1	2	3	4	5	6	Av.
hook	3	2	2	3	1	2	2.2
ax							
sh	1	1	1	1	1	1	1.0
se	1	2	1	1	1	1	1.2
wth				2	1		0.5
lth				1	1		0.3
dth	1	1	1	1	1	1	1.0
shd							
pen	5		5	4	5	5	4.0
ser		1	1	1	1	1	0.8
bt							
arm		1		2			0.5
af		1		1	2	1	0.8
ar			1	1	2	1	0.8
thi		1		1	1	1	0.7
pop		1		2			0.5
leg		1					0.2

B = basic test, i.e., man wore dungarees.
1L = one layer, i.e., CC-2 impregnated suits.
1½L = one and one-half layer, i.e., CC-2 impregnated suits and shorts.

• = G330 protective ointment worn on neck.

Table XI

Tests with HN3

Maximum Regional Readings for Individual Subjects and Average Maximum Regional Readings for Each Test Group

Test No. 10 B
9/7/44
HN3
CT = 50

Man No.	1	2	3	4	5	6	7	8	Av.
neck	2	1	1	2	2	1	1	4	1.6
ax			1					1	0.3
sh					1			1	0.3
sc						1			0.1
vth	I								0.1
lth									
dth				1			1		0.3
abd									
pen			1		1		1		0.4
scr		1	1		1			1	0.5
bt									
arm					1			1	0.3
ef		1			1	1		2	0.6
wr									
thi	1					1	1	1	0.5
pop				1					0.1
leg							1		0.1

Test No. 11 B
9/7/44
HN3
CT = 100

Man No.	1	2	3	4	5	6	7	8	Av.
neck	4	2	4	2	3	2	3	4	3.0
ax	2				1				0.4
sh	2	1		1	2			1	0.9
sc	2	1	2	1	1	1	1	1	1.3
vth	1				1			1	0.4
lth									
dth	2	1			1			1	0.6
abd	1								0.1
pen				2			2	1	0.6
scr	1	2	2	2		1	2	5	1.9
bt	1			1	1		1	1	0.6
arm	2	2	1		1	1		1	1.0
ef	3	2	1	1	1	1	1	4	1.8
wr				1	1	1			0.4
thi	2	1	1	2	1	1	1	1	1.3
pop	2	2	2		1	1	1	1	1.3
leg	2			2			1	1	0.8

Test No. 12 B
9/16/44
HN3
CT = 150

Man No.	1	2	3	4	5	6	7	8	Av.
neck	5	4	3	3	3	4	5	5	4.0
ax	3					3			0.8
sh		1		2		1	3	2	1.1
sc	3	2	3	1	1	2	5	3	2.5
vth	2	3	2		1	2	4	1	1.9
lth	1						4		0.6
dth	3	2	3	1	2	2	4	2	2.4
abd	3					1			0.5
pen	2		2			2		2	1.0
scr	5	5	5	5	5	2	5		4.0
bt	2		2		1		2	2	1.1
arm	5	3	3	2	2	3	5	3	3.3
ef	5	3	3	2	2	4	5	3	3.4
wr	3	3	3			3	4		2.0
thi	2	1	2	1	1	1	4	4	2.3
pop	2	1	3	1	1	2	4	3	2.1
leg			2			2	4	2	1.3

Test No. 13 1L
9/16/44
HN3
CT = 150

Man No.	1	2	3	4	5	6	7	Av.
neck	3	2	1	1		1		1.1
ax								
sh	1	1	1			1	1	0.7
sc	1	1	1	1	1	1	1	1.0
vth	1							0.1
lth								
dth	1	1		1				0.4
abd								
pen			1	1		1		0.4
scr	4	2	1	3			1	1.6
bt								
arm	1				1			0.3
ef	1		1					0.3
wr	1							0.1
thi	1	1	1	1			1	0.7
pop		1						0.1
leg	1							0.1

Test No. 14 1½L
9/16/44
HN3
CT = 200

Man No.	1	2	3	4	5	6	7	Av.
neck	1		2	1	3	1		1.1
ax								
sh	1				1	1	1	0.6
sc					2	1		0.4
vth								
lth								
dth					1			0.1
abd								
pen								
scr	1				1			0.3
bt						1		0.1
arm	1							0.1
ef						1	1	0.3
wr								
thi	1		1	1		2		0.7
pop						1		0.1
leg						2		0.3

Test No. 15 B
2/9/45
HN3
CT = 150

Man No.	1	2	3	4	5	6	Av.
neck	1	1	1	3	2	1	1.5
ax			1				0.2
sh	1	1		1	1	1	0.8
sc	1	1		1	1	1	0.8
vth	1			1			0.3
lth	1			1			0.3
dth	1	1		1	1	1	0.8
abd							
pen							
scr		1			1		0.3
bt	1	1	1		1	1	0.8
arm	1	1		2	1	1	1.0
ef	1	1			1	1	0.7
wr	1	1		2	1	1	1.0
thi	1	1	1	1	1	1	1.0
pop	1	1		1	1	1	0.8
leg	1	1		1	1	1	0.8

Test No. 16 B
2/19/45
HN3
CT = 250

Man No.	1	2	3	4	5	6	Av.
neck	3	4	2	1	3	2	2.5
ax	1	3					0.7
sh		2	1		2		0.8
sc		2			2		0.7
vth		2					0.3
lth		2					0.3
dth		2			2		0.7
abd		2					0.3
pen							
scr	4		4			1	1.5
bt	1	2	2		2	1	1.3
arm		2	1		2		0.8
ef	2	2	2	1	2		1.5
wr	1	1	2		1	1	1.0
thi		2	1	1	2	1	1.2
pop	1	2	1		1	1	1.0
leg		2	1		1	1	0.8

Test No. 17 B
2/27/45
HN3
CT = 350

Man No.	1	2	3	4	5	6	7	8	Av.
neck	5	5	5	5	5	5	4	5	4.9
ax	3	3	3	3		2	3	3	2.5
sh	3	3	3	2	2	3	2	1	2.4
sc	3	3	3	2	2	3	2	1	2.4
vth	1	2	2			3	1		1.1
lth	1	3	1			2	3		1.3
dth	3	3	3	2	2	1	2	1	2.1
abd	1	2	2			1	1	1	1.0
pen	2	2		4					1.0
scr	5	5	2	5	4	5	5	5	4.5
bt	2	3	1	1	1	2	3	2	1.9
arm	2	2	3	3		1	1		1.5
ef	3	3	3	3	3	3	3	4	3.1
wr	1	1	1	2			1		0.8
thi	1	3	2	1	1	1	1		1.3
pop	1		2	1	1	1	1	3	1.3
leg			1			1	1		0.4

Test No. 18 B½L
8/10/45
HN3
CT = 150

Man No.	1	2	3	4	5	6	7	8	Av.
neck	2	2	2	2	2	2	2	2	2.0
ax									
sh					1	1			0.3
sc					1	1			0.3
vth						1			0.1
lth									
dth					1	1			0.3
abd									
pen									
scr	1				1	1		1	0.5
bt	1	1	1	1	1	1			0.8
arm	1	1	1			1			0.5
ef	1								0.1
wr									
thi									
pop									
leg									

B = basic test, i.e., men wore dungarees
B½L = dungarees plus CC-2 impregnated shorts
1L = one layer, i.e., CC-2 impregnated suits
1½L = one and one-half layer, i.e., CC-2 impregnated suits and shorts.

* = 3350 protective ointment worn on neck.

Table XI (Cont'd.)

Tests with HN3

Maximum Regional Readings for Individual Subjects and Average Maximum Regional Readings for Each Test Group

Man No.	Test No. 19 8/10/45 HN3 CT = 200 1½L*									Test No. 20 8/20/45 HN3 CT = 500 1½L*							Test No. 21 8/27/45 HN3 CT = 850 1½L*							
	1	2	3	4	5	6	7	8	Av.	1	2	3	4	5	6	Av.	1	2	3	4	5	6	Av.
neck	2	2	2	3	1	2	2	2	2.0	2	2	1	2	1	2	1.7	2	2	2	2	2	2	2.0
ax																							
sh		1							0.1								1	1	2	1	1	1	1.2
sc		1		1					0.3								2	1	2	1	2		1.3
vth																							
lth																							
dth		1		1	2				0.5						1	0.2	1		1		3		0.8
abd																							
pen																							
scr														2		0.3			2				0.3
bt																							
arm	1	1		2					0.5	1			2	2	1	1.0	1				1	2	0.7
cf	1	1				2	1		0.6	1	2		1	1		0.8	2	1	2	2	2	3	2.0
wr	1		1	1					0.4														
thi	1			2		1			0.5	2	2		2	1	2	1.5	2	2	2	1	2	2	1.8
pop				1					0.1	1					2	0.5	1	2	1		2	2	1.3
leg				1					0.1	1	1				2	0.7	1	2	1		2	2	1.3

Man No.	Test No. 22 9/4/45 CT = 930 9/5/45 CT = 882 Total CT = 1812 1½L*						
	1	2	3	4	5	6	Av.
neck	1	1	2	2	2		1.3
ax						1	0.2
sh		1	1				0.3
sc			1				0.2
vth							
lth							
dth			1				0.2
abd							
pen							
scr							
bt							
arm		1					0.2
cf	1	1	1	1		1	0.8
wr							
thi		1	1	1	1	1	0.8
pop			1	1			0.3
leg			1	1		1	0.5

B = basic test, i.e., men wore dungarees
B½L = dungarees, plus CC-2 impregnated shorts
1L = one layer, i.e., CC-2 impregnated suits
1½L = one and one-half layer, i.e., CC-2 impregnated suits and shorts.

* = S330 protective ointment worn on neck.

C O N F I D E N T I A L

Test No.	Man No.	Max. Intensity	Days Begin	Days Healed	Days Duration
3	1	SC	-	-	-
(HN1)	2	C	3	18*	15
(CT	4	C	3	22*	19
300)	5	SC	-	-	-
	6	C	3	22*	19
	7	C	3	27*	24
	8	C	3	15*	
	9	C	3	22*	19
	10	C	(6-15*)		
4	4	C	8	9+	
(HN1)	5	SC	-	-	-
(CT	7	C	(6-15*)	20	
300)	9	C	7	20*	13
5	2	C	5	11	6
(HN1)	3	C	3	20*	17
(CT	4	C	3	20*	17
400)	5	C	2	23*	21
	6	C	3	(13-23*)	
	7	C	3	20*	17
	8	C	3	23*	20
	9	C	3	20*	17
	10	C	3	20*	17
6	1	C	5	19	14
(HN1)	2	C	4	19	15
(CT	3	C	3	9*	6
400)	4	C	4	16*	12
	5	C	4	16*	12
	7	C	4	19*	15
	8	C	3	25*	22

Test No	Man No.	Max. Intensity	Days Begin	Days Healed	Days Duration
8	3	SC	18-*	21	
(HN1)					
(CT					
700)					
9	1	C	5	19	14
((HN1)	3	C	5	7+*	
(CT	4	SC	(7-13*)	14+*	
700)	5	C	(7-14*)	27	
	6	C	(7-14*)	21	
11(HN3)	8	C	7	9*	2
(CT 100					
12 (HN3)	1	C	3	16	
(CT 150)	2	C	4	16	
	3	C	(6-16*)	16+	
	4	C	(6-16*)	16+	
	5	C		16+	
	7	C	(6-16)	16+	
(13 (HN3)	1	SC	-	-	-
(CT 150)					
(16(HN3)	1	SC	4	7	3
(CT 250)	3	SC	(7-18)	18+	
17 (HN3)	1	C	4	24	20
(CT 350)	2	C	4	30	
	4	C	(8-16)	20	
	5	SC	(8-16)	20	
	6	C	11	20-30	
	7	C	5	20-30	
	8	C	5	20-30	

** Days after chamber exposure
SC Scaling lesion, dry
C Ulcerated, crusted lesion
* Approximated

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Table XIII
Leucocyte Counts

Agent	CT	Man No.	Before WBC	4 Days WBC	Day No.	WBC
HN1	300	1	7,800	8,350		
		2	7,550	7,950	13	7,000
		3	8,100	7,600		
		4	8,550	9,250	13	7,950
		5	9,200	9,050		
		6	5,800	5,400	13	6,000
		7	11,450	9,250	13	9,450
		8	8,500	7,600		
		9	9,950	9,300	13	8,350
		10	9,850	10,400		
HN1	300	1	9,300	9,150	15	9,200
		2	12,050	9,900	15	9,750
		3	7,000	7,600	15	7,450
		4	6,600	6,100	22	6,300
		5	9,150	8,800	15	9,200
		6	9,450	9,050	20	8,550
		7	5,850	6,100	15	6,350
		8	6,500	6,850	15	6,600
		9	8,700	8,450	20	8,900
		10	10,600	9,650	13	9,550
HN1	400	1	5,150	5,550	10	5,400
		2	8,100	9,650	10	9,150
		3	6,850	8,200	10	8,550
		4	7,300	9,850	10	9,200
		5	9,900	9,000	10	8,550
		6	9,750	5,500	10	9,200
		7	6,850	6,100	10	6,650
		8	8,450	7,650	10	8,100
		9	7,350	8,850	10	9,100
		10	6,100	5,250	10	5,650
HN1	400	1	6,850	7,250		
		2	9,150	9,400		
		3	8,850	8,350		
		4	5,300	6,150		
		5	7,700	7,200		
		6	10,100	9,750		
		7	10,150			
		8	9,850			
		9	6,100			

Table XIII (Cont'd)

Test No. 17
HN3
CT 350

Man No.	Before Exp.	Days	Days	6 Days	7 Days	8 Days	9 Days
1	12,400	10,800	11,200	10,000	12,100	10,000	11,400
Diff.	79-28- 0- 2	60-38- 0- 2	64-36	66-32- 1- 1	68-32	68-31- 0- 1	74-23- 0- 3
2	10,300	13,200	12,800	10,800	10,800	11,700	10,100
Diff.	67-33	72-38	68-32	66-33- 0- 1	66-34	62-38	66-34
3	9,700	12,000	9,000	11, 400	10,400		
Diff.	61-38- 0- 1	55-45	62-36- 0- 2	61-38- 1	54-44- 0- 2		
4	11,400	13,400	9,500	12,100	10,600		
Diff.	68-32- 0- 1	58-42	62-37- 0- 1	60-40	56-42- 0- 2		
5	9,500	10,000	11,200	8,000	8,800		
Diff.	61-38- 0- 1	53-45- 0- 2	60-38-0- 2	68-31- 0- 1	56-43- 0- 1		
6	10,600	6,400	7,000	8,200	7,200	10,500	9,600
Diff.	60-38- 1- 1	64-36	58-41- - 1	64-36	58-40- 0- 2	60-39- 0- 1	60-37- 0- 3
	7,200	7,400	7,700	7,800	8,200	9,700	9,400
Diff.	59-31- 1- 1	62-38	54-46	58-32	69-30- 0- 1	64-34- 0- 2	-26- 0- 2
3	11,900	11,200	10,000	8,900	7,600	10,200	13,100
Diff.	55-41- 0- 4	56-44	50-47- 0- 3	51-44- 0- 5	50-46- 0- 4	62-36- 0- 2	58-38- 0- 4

Diffs Polys - Lymphs - Mono - Eos - Ba

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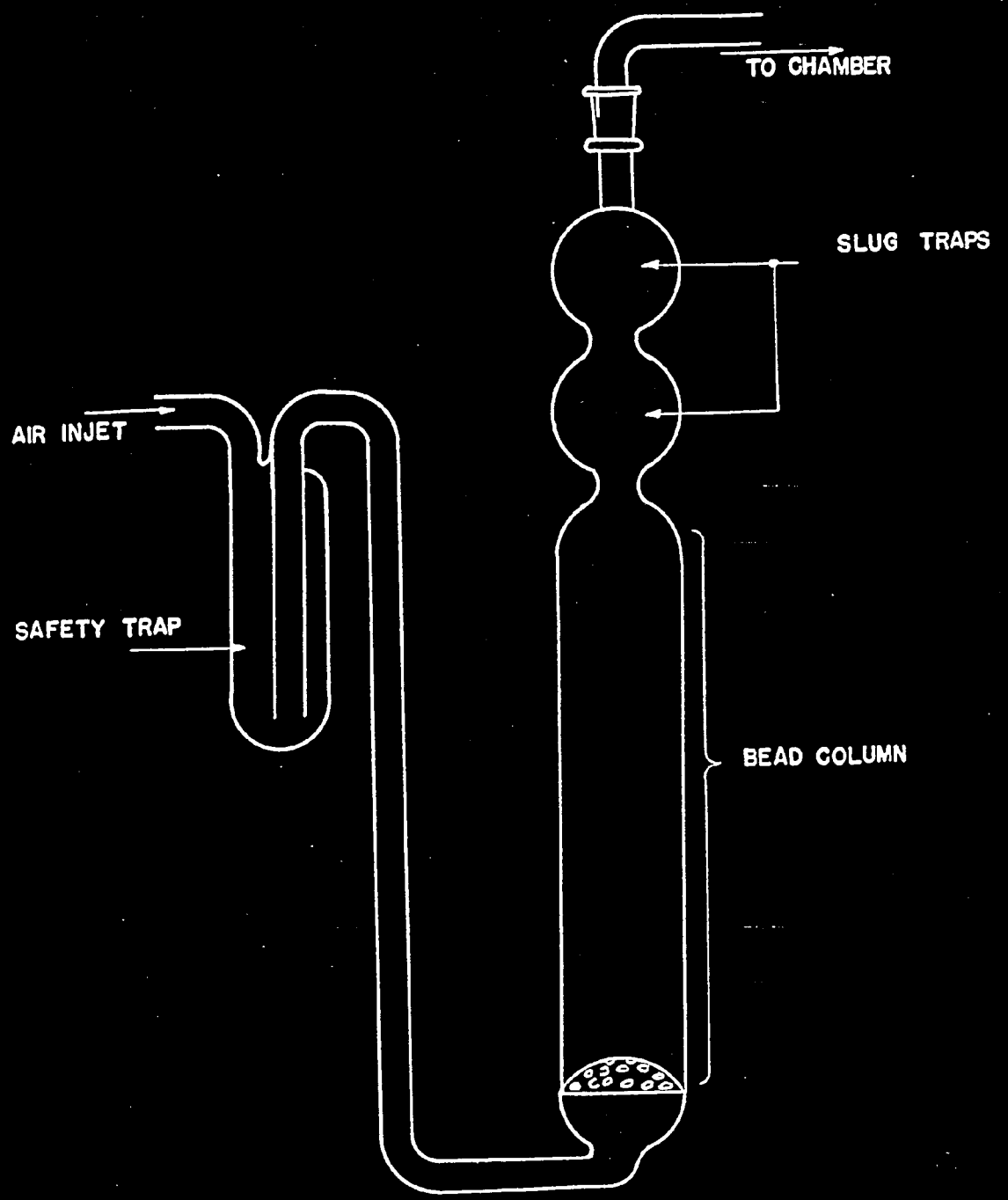
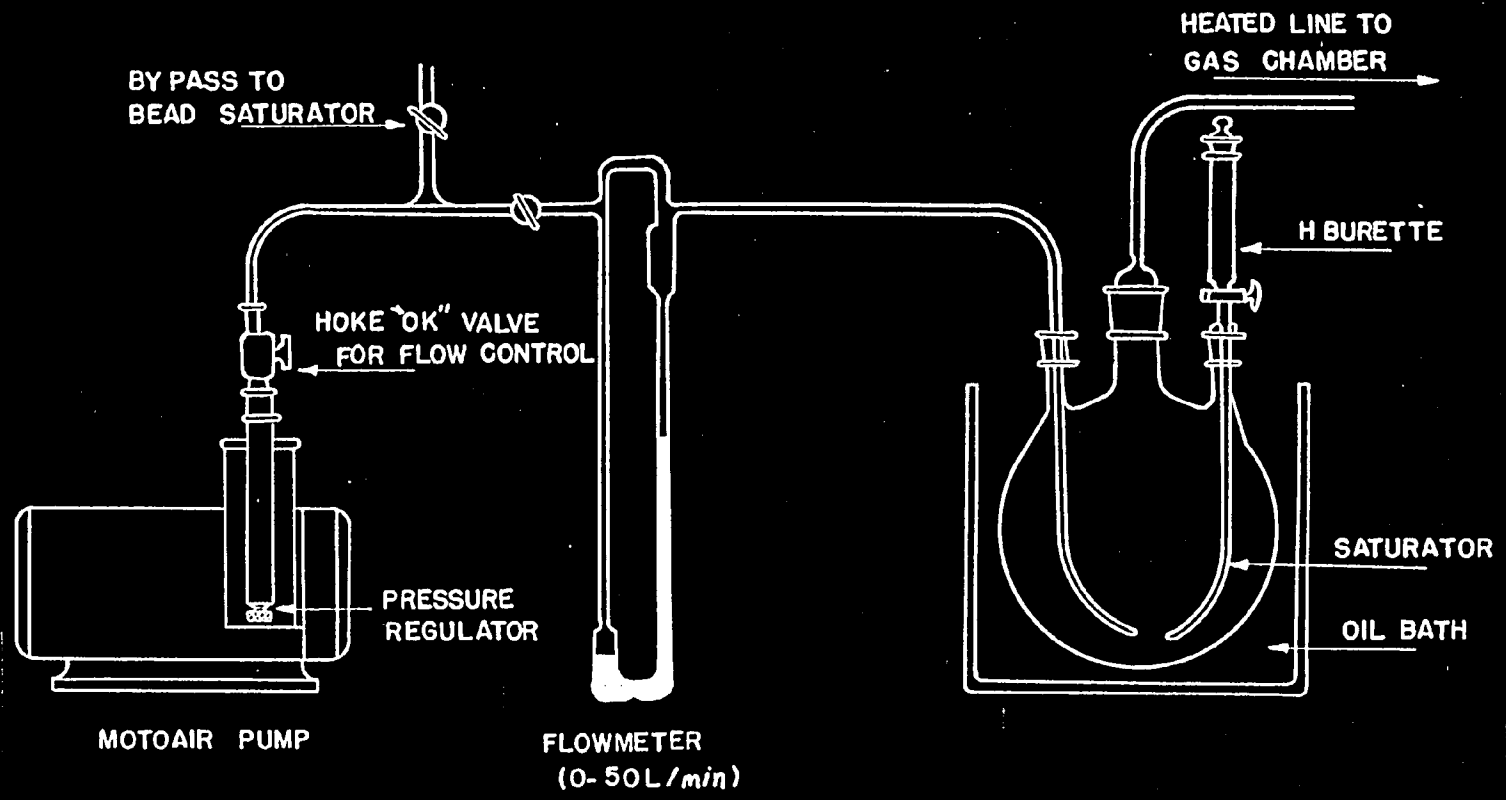
Table XIII (Con'd)

Test No.	Agent	CT	Man No.	Before Exp. WBC	Before Exp. Diff.*	4 Days WBC	7 Days WBC	7 Days Diff.*
10	HN3	50	1	6,500	70-24- 4- 2		7,400	75-20- 4- 1
			2	5,350	72-19- 7- 1- 1		5,750	68-26- 5- 1
			3	6,100	66-29- 5		5,250	61-32- 4- 3
			4	7,450	56-38- 5- 1		8,400	68-24- 4- 8
			5	8,100	62-28- 6- 4		7,700	60-30- 6- 4
			6	8,500	78-18- 4		8,950	71-22- 5- 2
			7	6,950	76-20- 3- 1		5,950	68-27- 3- 1
			8	7,600	70-28- 2		9,950	51-43- 6
						4 Days	7 Days	
11	HN3	100	1	7,550	59-30- 9- 2	8,250	5,300	49-45- 4- 2
			2	6,700	76-21- 2- 1	6,300	6,950	52-43-2-3
			3	7,050	57-29- 3- 1	6,500	8,300	78-18- 3- 1
			4	5,900	61-34- 3- 2	6,450	5,100	49-48- 3
			5	5,300	70-23- 5- 2	6,050	6,150	65-28- 4- 3
			6	7,750		7,100	6,900	54-43- 3
			7	6,800	55-37- 6- 2	6,200	5,500	70-21- 7- 2
			8	8,600	60-32- 6- 2	9,350	6,200	57-41- 2
						5 Days		
12	HN3	150	1	7,050		7,950		
			2	6,600		5,500		
			3	6,300		6,800		
			4	8,350		8,800		
			5	8,000		7,600		
			6	8,250		7,400		
			7	8,600		9,100		
			8	6,900		7,250		
						5 Days		
13	HN3	150	1	9,050		8,700		
			2	7,400		7,950		
			3	6,200		5,600		
			4	8,600		8,300		
			5	8,100		8,700		
			6	6,400		6,950		
			7	5,350		5,800		
						6 Days		
14	HN3	200	1	7,050		8,100		
			2	7,500		8,000		
			3	7,800		6,700		
			4	7,300		7,550		
			5	9,700		9,050		
			6	8,400		7,800		
			7	5,100		6,250		

* Differential Counts listed in order: polymorphonuclear leucocytes, lymphocytes, eosinophiles, monocytes, basophiles (P-L-E-M-B)

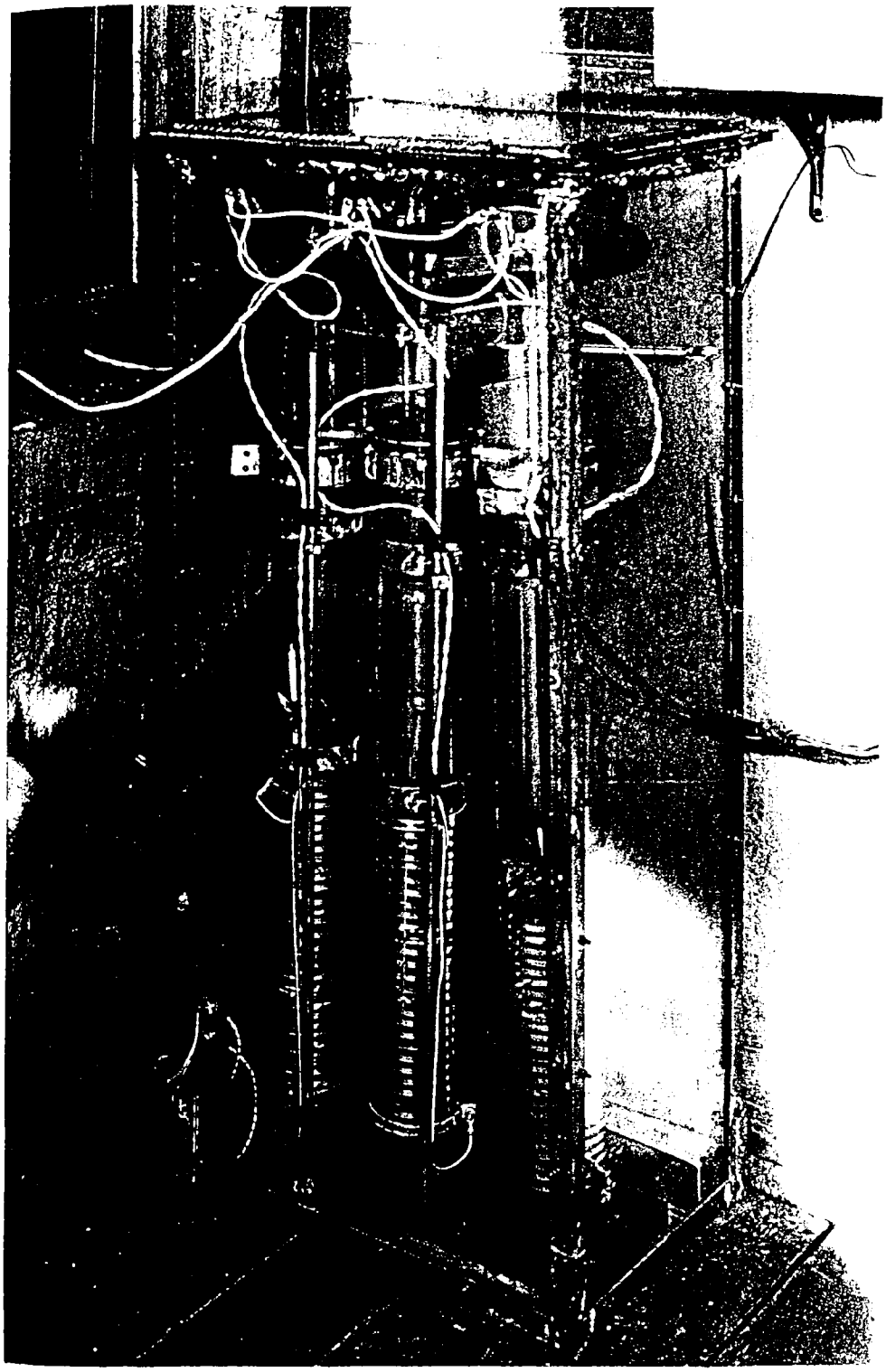


BEAD SATURATOR

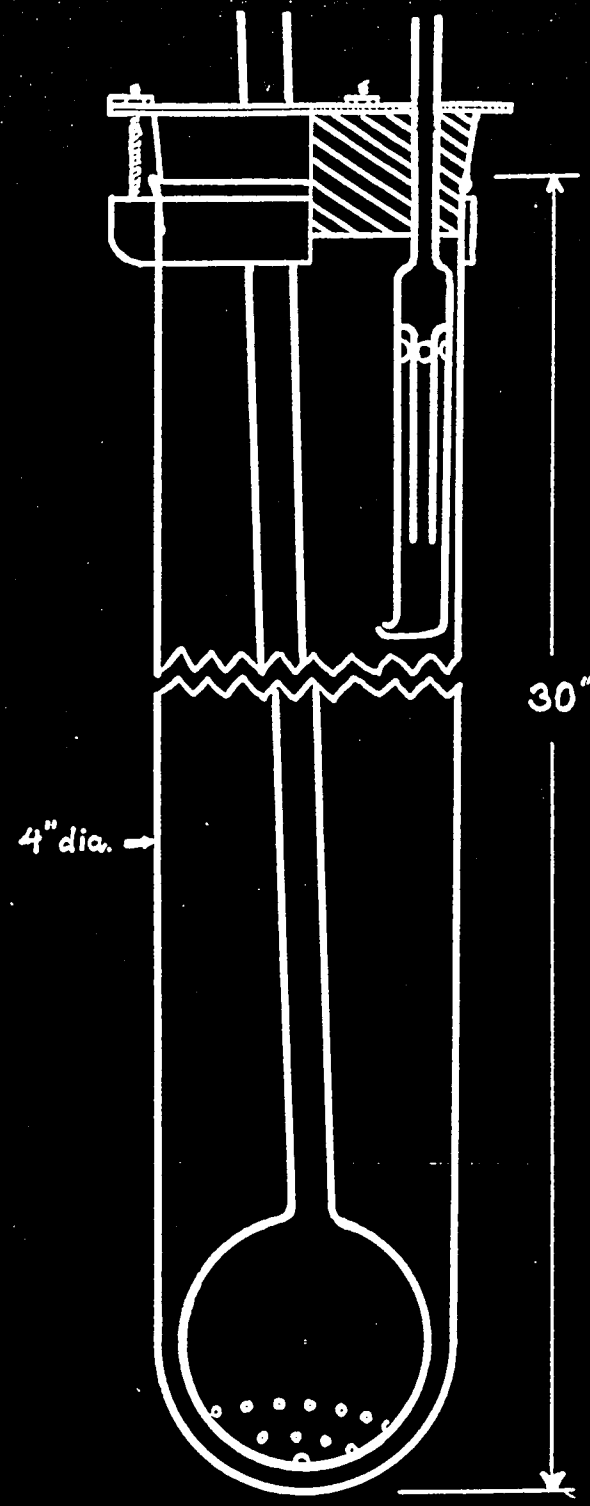


FLASH DISTILLATION
SYSTEM

PLATE 2



HN-3 SATURATOR



HN Saturator

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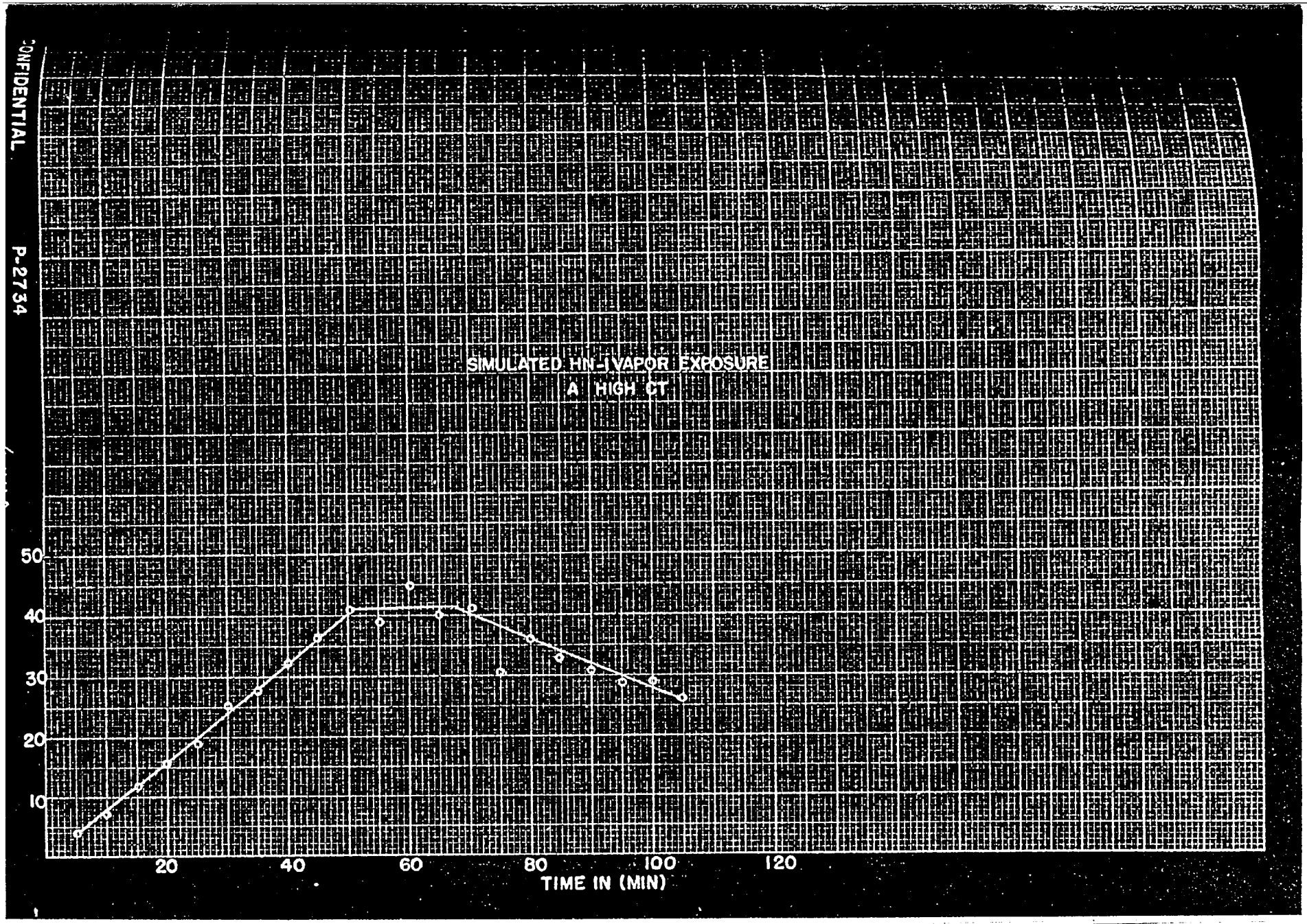

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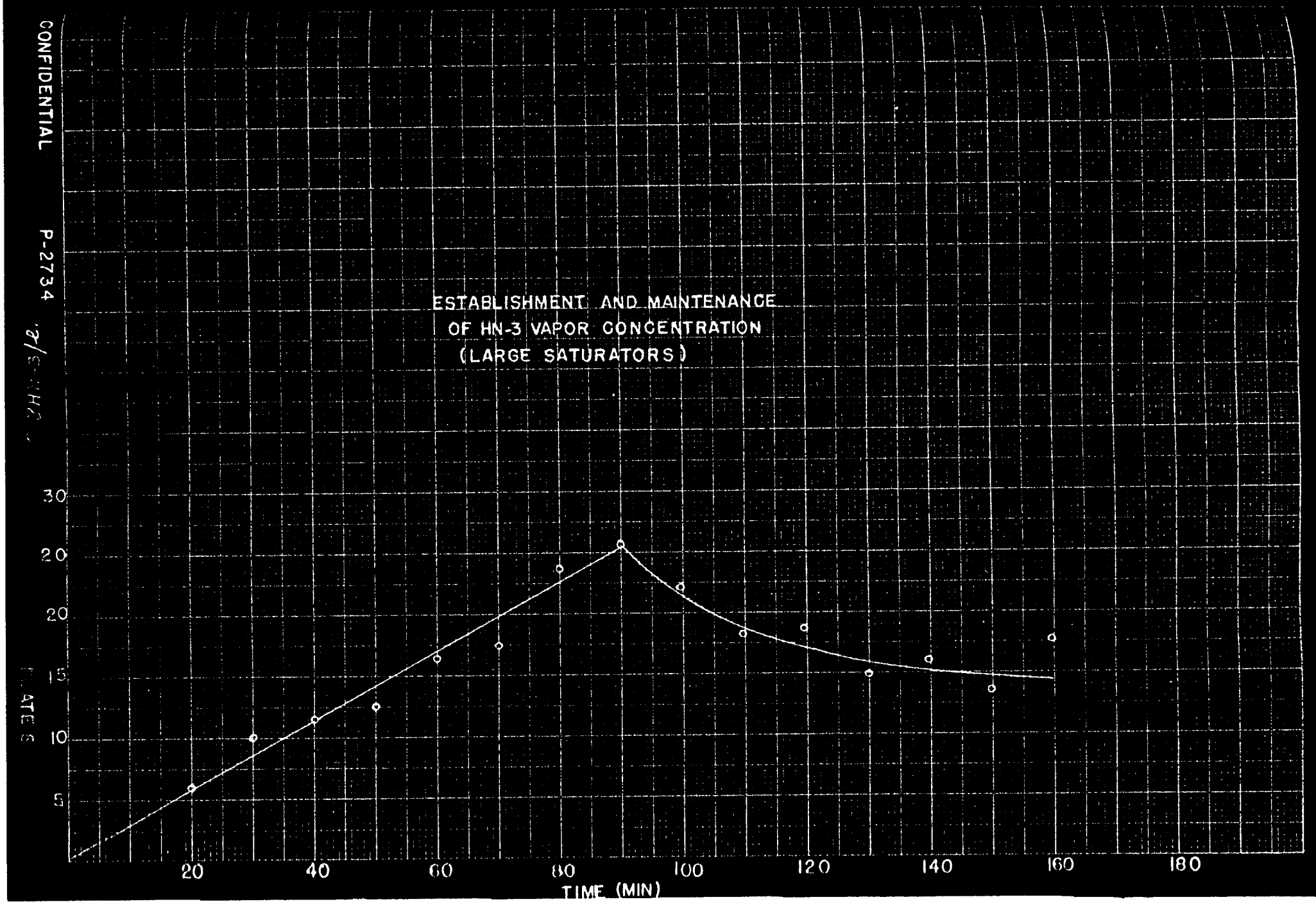

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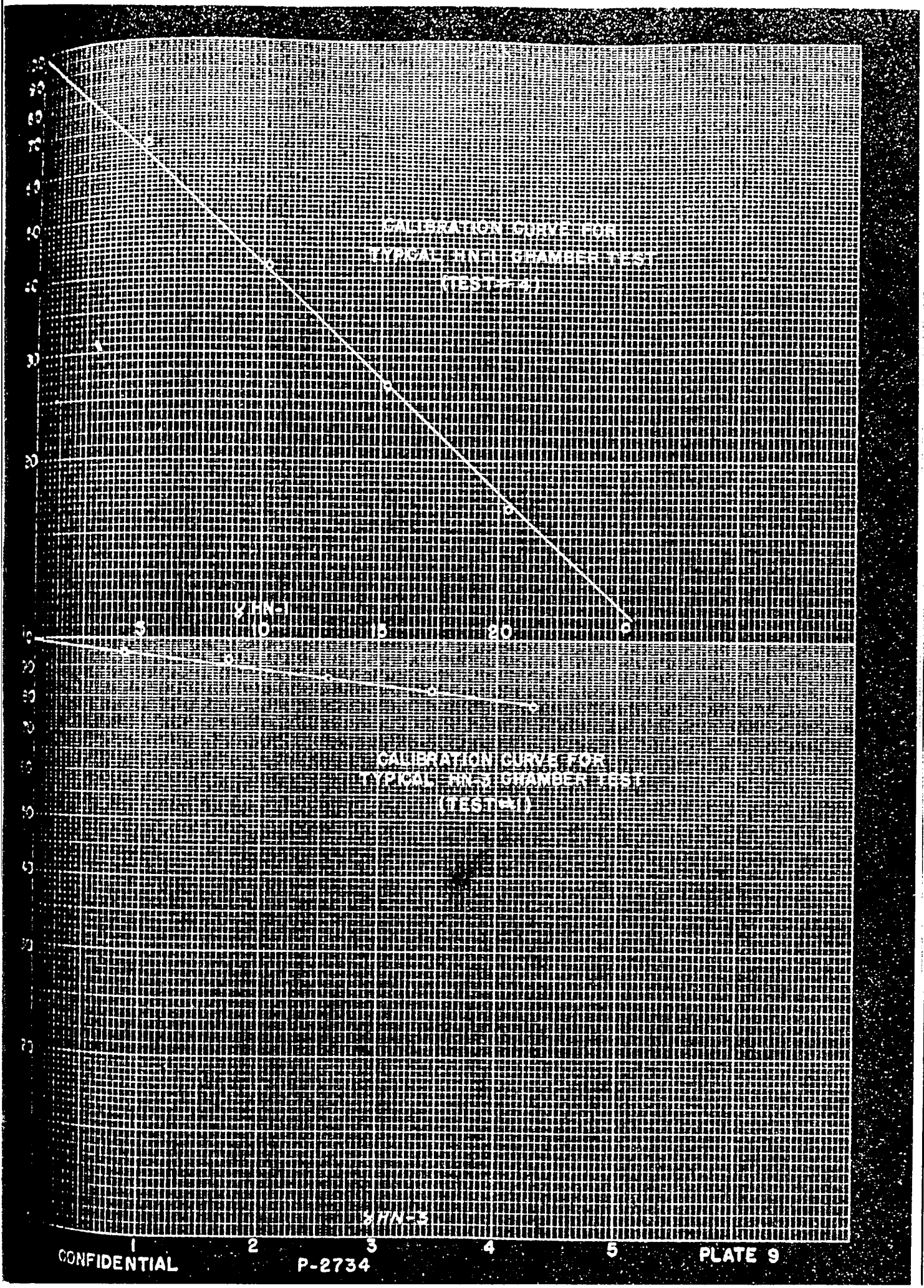
RHN-3/8-NHR

PLATE 7



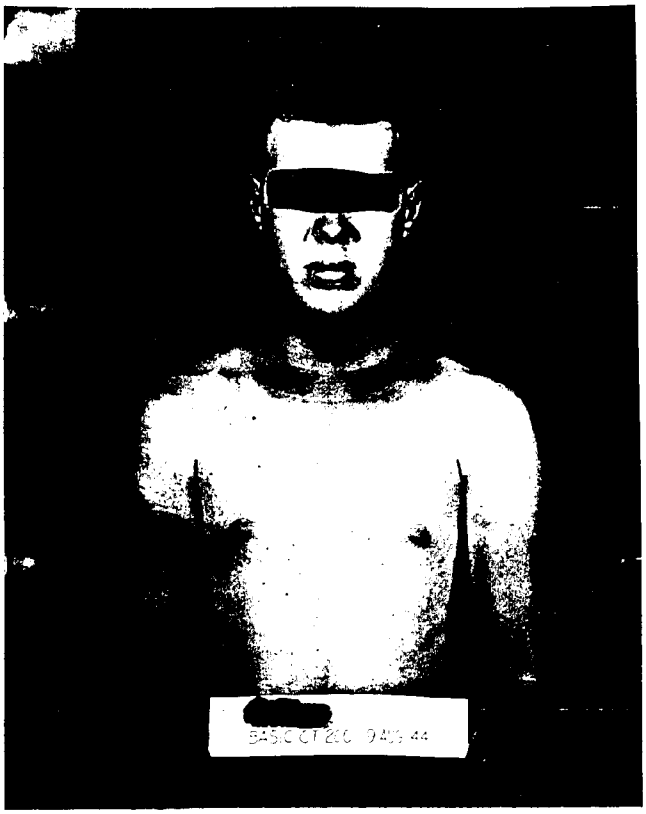


FIG. 1 4 DAYS

FIG. 2 8 DAYS

HN1 CT 200
90°F. 65% RH
TEST No. 2
SUBJECT 3

FIG. 3

FIG. 4

HN3 CT 350
90°F. 65% RH
TEST NO. 17
SUBJECTS 1-4
6 DAYS