

dp
22 January 1944

CONFIDENTIAL

SERIAL No. 43

NRL Report No. P-2219

NAVY DEPARTMENT

Report on

Chamber Tests with Human Subjects
III. Design, Operation, and Calibration of
A Chamber for Exposing Forearms to H Vapor

NAVAL RESEARCH LABORATORY
ANACOSTIA STATION
WASHINGTON, D. C.

DECLASSIFIED: By authority of
100-1115200-8
Date
Site Authority
Entered by
NRL Code

Number of Pages: Text - 17 Tables - 9 Plates - 13
Authorization: Project #547-41 "Maintenance, Bureau of Ships", dated
16 December 1940; Bureau of Ships letter S-S77-2(Dz)
Serial 811 of 17 December 1940.

Date of Tests: October 1943 - December 1943.

Submitted by:

William H. Taylor Jr., Chemist

Homer W. Carhart, Chemist

L. Eugene Daily, Lt., Comdr., (Mc), USN

Reviewed by:

W. C. Lanning, Senior Chemist

P. Borgstrom, Head Chemist, Superintendent,
Chemistry Division

Approved by:

A. H. Van Keuren, R. Admiral, USN, Director

Distribution:

BuShips (5)
BuM&S (4)
BCSO (6)
CNO (5) (3 copies for future transmittal to
ALUSNA, London)
CWS (4)
NRC, Canada (2)
NRC, Wash. (2)
CoorRAD (2)
NDRC (4)

APPROVED FOR PUBLIC
RELEASE - DISTRIBUTION
UNLIMITED

UNCLASSIFIED
CONFIDENTIAL

Report Documentation Page				Form Approved OMB No. 0704-0188	
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.					
1. REPORT DATE 22 JAN 1944		2. REPORT TYPE		3. DATES COVERED 00-00-1944 to 00-00-1944	
4. TITLE AND SUBTITLE Report on Chamber Tests with Human Subjects III. Design, Operation, and Calibration of a Chamber for Exposing Forearms to H Vaport				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Research Laboratory, 4555 Overlook Avenue SW, Washington, DC, 20375-5320				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES 70	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

TABLE OF CONTENTS

<u>SUBJECT</u>	<u>PAGE</u>
ABSTRACT	
AUTHORIZATION	1
STATEMENT OF PROBLEM	1
KNOWN FACTS BEARING ON PROBLEM	1
THEORETICAL CONSIDERATIONS	1
PREVIOUS WORK DONE AT THIS LABORATORY	1
EXPERIMENTAL WORK	2
General Description	2
Services	2
Control of Chamber Conditions	3
Method of Establishing H Vapor Concentrations	4
Method of Analysis for H Vapor Concentration	4
Standardization of Chamber for H Vapor Exposures	5
Operation of Gas Chamber for Physiological Tests	10
Correlation with Large Chamber	13
SUMMARY AND CONCLUSIONS	17
RECOMMENDATIONS	17

CONFIDENTIAL

ABSTRACT

This report describes the design, calibration, and operation of a chamber for the exposure of the forearms of human subjects to the vapors of chemical warfare agents. The construction of the chamber is such that the temperature, relative humidity, air velocity, and concentration of vesicant agent can be controlled closely over a wide range of conditions.

Tests have been made to correlate this "arm chamber" with the large chamber now being used at this Laboratory in evaluating Navy Issue Protective Clothing, Ointments, and Masks. It has been found in these tests that in exposing forearms to H vapor at $90^{\circ}\pm 1^{\circ}\text{F}$ and $65 \pm 3\%$ R.H., with the rest of the body at $70 - 80^{\circ}\text{F}$ and $20 - 30\%$ R.H., twice as great a CT value (mg. min./m^3) is required to produce the same degree of burn as when the entire body is equilibrated at 90°F and 65% R.H.

CONFIDENTIAL

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-S77-2(Dz), Serial 811 of 17 December 1940.

STATEMENT OF PROBLEM

2. This investigation was undertaken to design, calibrate, and study the operation of a gas chamber for the exposure of the forearms of human volunteers to the vapors of chemical warfare agents.

KNOWN FACTS BEARING ON PROBLEM

3. At the present time a 50 m³ gas chamber for the exposure of human subjects is in operation at this Laboratory, in which Navy Issue Protective Clothing, Ointments, and Masks are being evaluated. In order to accelerate this program it was considered desirable to construct a small chamber in which only the forearms of human subjects are exposed to vesicant vapors. Tests in this chamber are designed to serve as "screening" tests in the evaluation of new developments in Protective Clothing and Ointments and to indicate proper and safe conditions for operation of the large chamber in testing these developments.

THEORETICAL CONSIDERATIONS

4. Since the "arm chamber" is designed to serve primarily as a "screen" for the large chamber, it was considered important that it be constructed to operate in the same manner and under the same conditions as the latter. Accordingly it is constructed as a static chamber in which the temperature, relative humidity, air velocity, concentration of vesicant vapor, and time of exposure may be varied at will to match any condition of operation in the large chamber.

5. The forearm was chosen as the part of the body most suitable for chamber screening tests for several reasons: (a) it represents an area which may be readily and easily prepared for, and subjected to, an exposure of vesicant vapor; (b) the sensitivity of the forearm is about average with respect to the sensitivity of other parts of the body, e.g. it is more sensitive than areas such as the hands, feet, and head, but less sensitive than the scrotal area; (c) vesication of this area would not result in disability of the subject, and (d) correlation with data from previous arm "patch" tests conducted at this and other Laboratories is facilitated.

PREVIOUS WORK DONE AT THIS LABORATORY

6. Gas chamber tests conducted at this Laboratory have been reported in N.R.L. Reports No. P-2208, "Chamber Tests With Human Subjects; I. Design and Operation of Chamber; II. Initial Tests of Navy Issue Protective Clothing against H vapor.

EXPERIMENTAL WORK

GENERAL DESCRIPTION

7. The NRL "arm chamber" consists of a ply-wood, sheet metal-lined box, constructed to fit in a well ventilated hood in one of the laboratories. It is designed as a static chamber; i.e. no large volume of air is passed through the chamber during a test, but air in the chamber is continually circulated, and volatilized agent is added as required to maintain a desired concentration. The volume of the chamber is such as to conveniently accommodate three arms, and construction is according to the following specifications;

8. Size: Inside dimensions are 40" X 25-1/2" and 25-1/2" high, giving a volume of 15 ft.³ or 0.4m.³.

9. Construction: The chamber is of 3/4" plywood construction with 1" X 3" reinforcements around the front and back edges. The interior is completely lined with 22 gauge sheet metal, soldered at all joints. The entire front of the chamber is removable, being clamped to the rest of the chamber with window latches. A gas tight seal is obtained by means of a sponge rubber gasket.

10. Entrance: Forearms of the subjects are introduced into the chamber through holes 6" in diameter in the front of the chamber. These holes are 11" from the bottom and thus 4' from the room floor. A gas tight seal around the arm is obtained by means of a sponge rubber gasket with a hole in the center slightly smaller than the arm. This gasket is clamped over the entrance hole by means of a removable plywood ring, 8" outside diameter and 6" inside diameter. Four bolts and wing nuts are used to clamp each ring and gasket in place. The lower sector of each ring is filled in with a plywood block to furnish a support for the arm.

11. Hand Rest: An iron bar, 1" in diameter, extends the width of the chamber, 15" from the front and 12" from the bottom. This serves as a support and rest for that part of the arm within the chamber.

12. Observation Window: A window, 12" X 5", is located in the front of the chamber, above the arm holes. It is supported in a plywood frame and a gas tight seal is obtained by means of a synthetic rubber gasket.

SERVICES

13. Light: Two 60 watt light bulbs are mounted on the ceiling, one at each side of the chamber.

14. Air Circulation: Two squirrel cage fans, 4-1/2" in diameter are located near the ceiling in the center of the chamber. These fans are operated by two American Instrument Company Motors (Flange Mounted, 115 volts AC, 1/30 H.P., 1700 R.P.M.) mounted on the roof.

15. Heat: A 250 watt oven heater (Aminco LoLag) is mounted on each of the side walls of the chamber.

16. Humidification: An electrically heated glass tube is run through the side wall of the chamber. Air saturated with water vapor at 65°C is passed into the chamber through this tube at 5 l./min.

17. Cooling and Dehumidification: A copper coil is mounted on the back wall of the chamber. Cold water (at 10°C) is run through this coil. A drain pan is provided beneath the coil to catch and drain off condensed water vapor.

18. Exhaust System: A 2" hole in the ceiling of the chamber is provided with a removable cover on the inside, and a small exhaust blower (Aminco #4-690) is mounted over it on the roof.

19. Plates 1 - 3 show views of the "arm chamber" and serve to illustrate the design and construction as well as the various facilities as described in this section.

CONTROL OF CHAMBER CONDITIONS

20. Since the primary purpose of the "arm chamber" is to serve as a means of making "screening" tests on new developments, prior to complete evaluation in the large chamber, temperature, humidity, and air circulation conditions were selected to be comparable to those set as a standard for the latter; i.e. 90°F, 65% relative humidity, and 2.5 miles per hour. However, these conditions may be varied and controlled at other desired values.

21. Temperature: The temperature is controlled at $90 \pm 0.5^\circ\text{F}$ by means of an American Instrument Company, Bimetallic Regulator System. The Regulator (Plate - 2D) is mounted from the top center of the chamber and the temperature is measured by means of a thermometer (Plate - 2K) placed at the rear.

22. Heat is supplied in two ways: (a) by one 250 watt oven heater (Plate - 2E) controlled by the regulator system and (b) by one 250 watt heater (Plate - 2F) regulated manually by a 5 amp. variac. Cooling is accomplished by regulating the flow of cold water through the cooling coil. (Plate - 2B).

23. Humidity: Relative humidity in the chamber is maintained at $65 \pm 3\%$ and is controlled by a mercury regulator equipped with a wick and water reservoir (Plate - 2A). This regulator functions as a wet-bulb temperature regulator. A wet-bulb thermometer (Plate - 2J) is also placed at the rear of the chamber and the humidity calculated from the dry and wet bulb temperature readings.

24. Humidification is accomplished by passing air saturated with water vapor at 65°C into the chamber through an electrically heated glass tube.

The air pump supplying this air stream is operated through the wet bulb mercury regulator. Thus water vapor is introduced only as required to maintain the wet bulb temperature at the desired value. The air is saturated by passing through a bead bubbler in a 65°C water bath. (A sketch of this saturator is shown in Plate - 4)

25. Dehumidification is accomplished by regulating the flow of cold water through the cooling coil (Plate - 2B).

26. Air Velocity: Circulation of air in the chamber is obtained by means of two squirrel cage fans as shown in Plate - 2C. The motors driving these fans are operated through a 5 amp. variac so that the rate of circulation may be varied. Measurements of wind velocity with an anemometer at various heights and locations with the empty chamber showed that the highest average rate of circulation obtainable is 2 miles per hour.

METHOD OF ESTABLISHING H VAPOR CONCENTRATION

27. Concentrations of H vapor in the "arm chamber" cover the same range of values as employed in the large chamber; i.e. from 1 to 100 micrograms per liter (0.001 to 0.1 mg./l.). These concentrations are established by means of a bead saturator (Plate - 5). The saturator is set up in a small battery jar and operated at any desired temperature. The saturator is wound with nichrome resistance wire and the heat input is controlled by a 5 amp. variac. Air is passed through the saturator from two Haddaway air pumps, connected in parallel, at rates varying from 500 to 1500 ml./min. The saturated air is run into the chamber through a heated glass tube to prevent condensation.

METHOD OF ANALYSIS FOR H VAPOR CONCENTRATION

28. Analysis of H vapor concentration in the chamber is carried out continuously during the period of exposure. A Northrop Titrimeter similar to that used in connection with the large chamber and described in NRL Report No. P-2208 has been constructed and is used to measure all concentrations. The original design of this instrument has been modified by replacing the drum recording unit with an automatic timer. This timer automatically measures the sampling time and titration time with two electric clocks, and, while not supplying a permanent record, gives a more accurate measurement than the drum recorder. The analyzer and timer are shown in Plates 1 and 2 and in addition Plate - 6 shows a circuit diagram of the timer.

29. To check the operation of the new Northrop Titrimeter, a definite concentration of H vapor in an air stream was established and analyzed by both the new and old Analyzers. The H vapor concentration was established by passing a pure, dry air stream at 200 ml./min. through a Vigreux type bubbler thermostated at 30°C and containing 5 ml. of 1.7% solution of liquid H in dibutyl phthalate. A summary of the results obtained is shown in Table I.

Table I

COMPARISON OF NORTHROP TITRIMETERS -

ANALYSIS OF AIR STREAM CONTAINING H VAPOR

Conc. of H. Vapor ($\gamma/l.$)		Conc. of H Vapor ($\gamma/l.$)	
<u>"Old" Analyzer</u>	<u>Average ($\gamma/l.$)</u>	<u>"New" Analyzer</u>	<u>Average ($\gamma/l.$)</u>
26.0		26.0	
26.4		28.5	
27.2		25.4	
27.2		26.6	
26.8		26.4	
29.5 (?)		27.2	
26.8	27.1	26.6	26.5

30. The above table shows that results obtained with the two instruments agree very well and consequently the new analyzer was considered satisfactory for use.

STANDARDIZATION OF CHAMBER FOR H VAPOR EXPOSURES

31. To determine the best methods of operation of the chamber, to study the effect of variations in operating conditions, and to secure practice in the technique of operation, a number of preliminary test runs were made. These runs are described individually.

#1 - 2 - 3 - Flow Rate Through H Saturator.

32. To obtain a "working" curve for establishing various concentrations of H vapor in the chamber, tests were first made in which air was passed through the saturator at various flow rates and the rate of H input determined. Results of these runs are given in Table II, and are shown graphically in Plate - 7.

Table II

EFFECT OF FLOW RATE ON ESTABLISHMENT OF H VAPOR CONCENTRATION

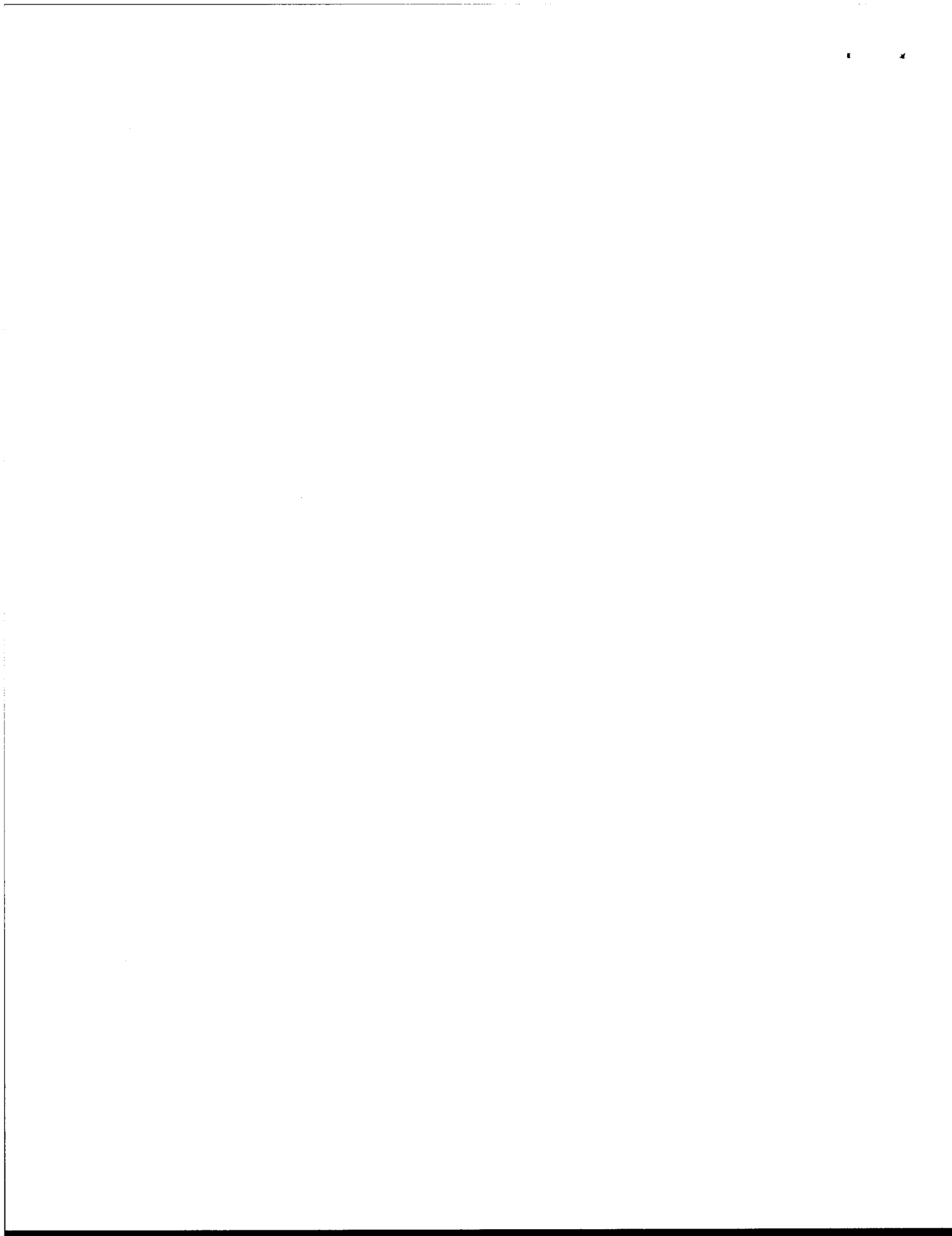
CONDITIONS: Saturator at Room Temperature (27°C) - Run Continuously

<u>Flow Rate of Air Through Saturator (Liters/min)</u>	<u>Time (Min.)</u>	<u>Conc. H (g/l.) Found</u>	<u>Rate of H Vapor Input (gH/l./min.)</u>	<u>Av.</u>
0.5	0.0	--	--	0.53
	4.2	12.3	--	
	9.2	15.5	0.64	
	14.4	16.8	0.25	
	19.4	20.6	0.76	
	29.5	26.6	0.59	
	34.5	27.2	0.12	
	39.5	31.2	0.80	
1.0	0.0	13.0	--	0.97
	5.0	17.8	0.96	
	9.8	21.8	0.83	
	14.6	27.2	1.13	
1.5	0.0	11.7	--	1.51
	4.3	13.4	--	
	9.2	21.8	1.71	
	14.5	27.8	1.11	
	19.4	36.8	1.84	
	26.1	43.1	0.98	
	31.3	53.3	1.89	

33. As shown above a fairly uniform rate of H vapor input is obtained, and an input flow rate curve is shown in Plate - 8. From this curve it is possible to determine the time necessary to establish a definite vapor concentration in the chamber, using any desired flow rate through the saturator at room temperature.

#4 - 5 Effect of Impregnated Sleeves on Establishment and Stability of
H Vapor Concentration

34. To determine the influence of standard impregnated clothing on the H vapor concentration in the chamber, two tests were made in which three Arnzen sleeves impregnated with S-145 were hung in the chamber. These tests were designed to determine the maximum concentration which could be maintained at various flow rates through the H saturator, and also to determine the technique required for maintaining a definite concentration



in the presence of impregnated clothing. The data obtained in these tests are given in Table III.

Table III

EFFECT OF IMPREGNATED SLEEVES ON ESTABLISHMENT AND STABILITY OF
H VAPOR CONCENTRATION

CONDITIONS: Saturator at Room Temperature (27°C)

Flow Rate of Air Through Saturator (l./min.)	Time (Min.)	Conc. H (H/l.) Found	Notes
0.5	0.0	--	
	4.1	4.2	
	9.5	5.1	
	14.9	4.2	
	20.3	5.6	
	25.6	6.9	
	30.9	6.9	
	36.0	7.8	
	41.3	7.8	
	47.6	7.8	
	53.2	8.3	
	67.2	9.2	
	72.3	9.6	
	77.5	9.6	
	82.6	9.6	Maximum Concentration Ob- tainable
	87.5	7.6	
	92.8	7.6	Control Period in which Desired Concentration was 8.3 H/l.
	97.9	9.2	
	103.0	8.7	
	108.1	8.7	
	113.1	9.2	
1.0	0.0	--	
	4.3	6.2	
	9.2	8.3	
	14.2	11.0	
	19.1	11.6	
	23.9	14.3	
	28.7	13.6	
	33.6	13.0	
	38.4	13.0	
			Av. during Control Period = 8.7 H/l.

Table III continued --

Flow Rate of Air Through Saturator (l./Min.)	Time (Min.)	Conc. H (μ /l.) Found	Notes
1.0	43.2	13.0	Maximum Concentration Obtainable
	48.0	11.0	
	53.0	9.7	
	57.9	9.0	Control Period in which Desired Concentration was 8.3 H/l.
	62.9	9.0	
	66.7	9.7	
	72.7	8.3	
	77.2	9.7	
	82.7	10.5	
	87.8	9.7	
	92.8	9.0	
	97.9	8.3	
	102.7	10.5	
			Average during Control Period = 9.5 μ H/l.

35. It may be seen, as previously shown in NRL Report No. P-2208, impregnated clothing is very efficient in removing H vapor from the chamber. At room temperature, 9.6 and 13.0 μ H/l. are the maximum concentrations which may be maintained at flow rates of 0.5 and 1.0 liters/min. respectively. Concentrations within this range may be satisfactorily maintained as shown in the above Table by regulating the time during which air is passed through the H saturator. This time is estimated from the concentration value obtained in the analysis of the preceding sample. The data in Table III are shown graphically in Plate - 9.

#6 - Effect of Temperature of H Saturator on Establishment and Maintenance of H Vapor Concentration

36. Since it was found that concentrations of H vapor above 13 micrograms/l. could not be maintained with the saturator operating at room temperature, a test run was made in which the temperature of the saturator was varied and the flow rate kept constant at 1.0 liters/min. The temperature was varied by means of the 5 amp. variac in the heating circuit. The maximum concentrations which could be maintained at different variac settings are determined and a "working" curve obtained by plotting maximum concentration versus variac setting. This curve is shown in Plate 11 and the data obtained in this test are given in Table IV and Plate - 10.

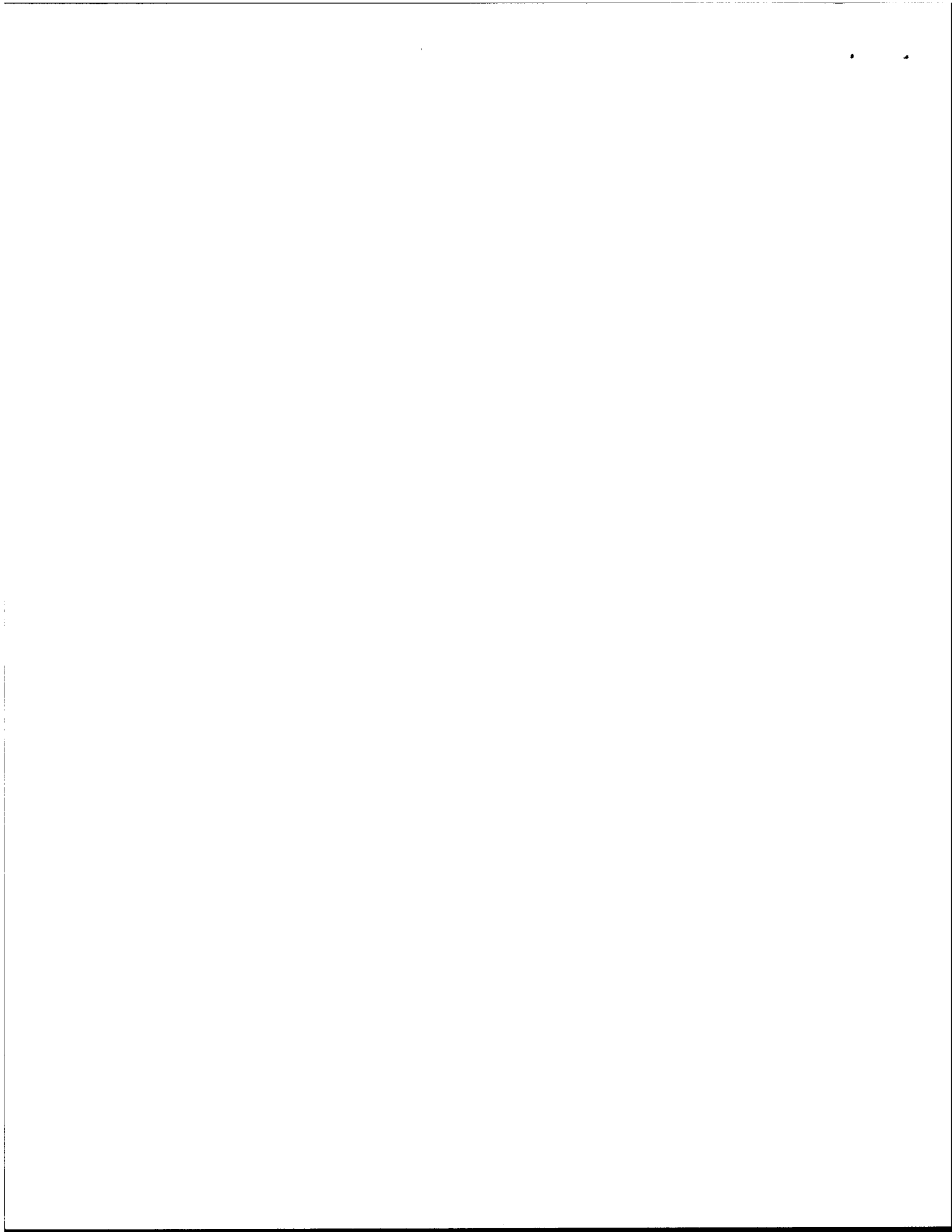
Table IV

EFFECT OF TEMPERATURE OF H SATURATOR ON ESTABLISHMENT
AND MAINTENANCE OF H VAPOR CONCENTRATION

CONDITIONS: Flow Rate = 1.0 Liters/Min. - 3 Sleeves in Chamber

Variac Setting	Time (Min.)	Conc. H (g/L)	
		Found	Maximum
0	0.0	--	
	4.3	6.2	
	9.2	8.3	
	14.2	11.0	
	19.1	11.6	
	23.9	14.3	
	28.7	13.6	
	33.6	13.0	
	38.4	13.0	
	43.2	13.0	13.0
10	53.2	14.4	
	58.2	15.1	
	63.2	15.1	
	68.2	15.1	
	73.1	14.4	15.1
20	78.1	17.9	
	83.4	17.9	17.9
25	87.9	17.9	
	93.6	18.4	
	98.5	21.8	
	103.4	23.2	
	108.3	23.2	
	113.4	22.4	23.2
30	118.2	28.3	
	123.2	36.0	
	128.2	39.2	
	133.2	39.2	
	138.2	40.5	
	143.3	41.1	41.1

37. The results of this test show that any desired concentration may be established and maintained by adjusting the variac setting to the proper value as determined from the "working" curve (Plate - 11) and regulating the time of operation as indicated by analysis of the chamber



atmosphere. This method has been used in all subsequent tests and has proven satisfactory.

OPERATION OF CHAMBER FOR PHYSIOLOGICAL TESTS

38. This section of the report gives a detailed description of the exact procedure used in operating the "arm chamber" for an exposure to H vapor. A complete log and data for a typical test are presented.

Preliminary Operations:

39. Lights and fans in the chamber are turned on, and the cover placed over the exhaust blower opening. The wet bulb thermometer and regulator reservoirs are filled with water. The rubber gaskets for the arm holes are put in place and a sheet of cellophane is clamped over each gasket by means of the plywood rings.

The Northrop Titrimeter is checked for performance and a solution of Br₂ is prepared and standardized against standard solutions of thiodiglycol.

Temperature and Humidity Adjustment

40. The temperature control circuit is turned on and the heat input from the continuous heater adjusted to give optimum control conditions by means of the variac. The hot plate supplying heat for the humidification system is turned on and air is passed through the water saturator at 5 liters/min. After the humidity has been brought to the desired value (65% RH), the flow of cold water through the cooling coil is started and adjusted to give optimum control conditions.

Establishment of H Vapor Concentration

41. The variac controlling the H saturator temperature is set at zero and the time and optimum flow rate for operation of the saturator to establish the desired H vapor concentration is determined from the "working" curve (Plate - 8). Air is then passed through the saturator into the chamber at the determined rate and for the determined period of time.

Analysis of H Vapor Concentration

42. Analyses of air from the chamber, using the Northrop Titrimeter are started at the same time as the H is introduced into the chamber and are continued throughout the period of the test. As soon as these analyses indicate that the desired concentration of H vapor has been established, the subjects insert their arms in the chamber.

Introduction of Subject's Forearms into Chamber.

43. The forearms of the subjects, prepared according to the nature of the test, are introduced into the chamber in the following manner:

The cellophane membrane covering the arm hole is pierced with a sharp knife and the arm immediately forced through the hole in the rubber gasket. The subject is instructed to push his arm in far enough to enable him to secure a comfortable support from the iron bar running across the interior of the chamber. For most subjects the gasket will then be around the arm half-way between the elbow and shoulder.

44. During the course of the test the subjects sit on stools as shown in Plate - 3. The center man is instructed to report wet and dry bulb temperature readings from the thermometers at the rear of the chamber. These readings are made through the observation window at prescribed intervals and are reported to the nearest 0.5°F.

Maintenance of H Vapor Concentration

45. Maintenance of the desired H vapor concentration during the test is accomplished by the method previously described.

Exhausting of the Chamber

46. At the conclusion of the chamber test, the lid covering the exhaust blower duct is removed by the subject on the left. This is accomplished by pulling the string attached to the cover. The exhaust blower is turned on and the subjects then withdraw their arms from the chamber. The blower is run for approximately 30 minutes to exhaust the chamber.

Final Operations

47. The lights, circulating fans, heaters, Northrop Analyzer, and humidification system are all turned off until the next scheduled test.

Log of Typical Chamber Test

48. Table V shows a complete record of the data obtained in a typical "arm chamber" test.

Table V

DATA FOR TYPICAL CHAMBER TEST (TEST #28)

- CONDITIONS:
- (a) 3 forearms in the chamber, each clothed in an Arnzen sleeve impregnated with S-330 from a water suspension.
 - (b) Desired concentration = 40.0 $\mu\text{H/l.}$ for one hour (CT = 2400)
 - (c) Air passed through H saturator at 1.0 liters/min. (Variac setting = 12.5) for 8 minutes to establish concentration.
 - (d) Variac set at 15 for maintenance of concentration.

PREPARATION OF BR₂ SOLUTION

0.4 ml. of saturated Br₂ water were diluted to 500 ml. with 3% H₂SO₄.

STANDARDIZATION OF BR₂ SOLUTION WITH THIODIGLYCOL SOLUTIONS

<u>Solution #</u>	<u>Volume (ml.)</u>	<u>pH</u>	<u>End-Point (Min.)</u>		<u>Av.</u>
1	1.00	49.0	0.56	0.57	0.57
			0.58	0.57	
2.	1.00	39.2	0.47	0.47	0.47
			0.47	0.47	
3	1.00	29.4	0.36	0.37	0.36
			0.36	0.36	

pH/min. (Soln. #1) = 49.0/0.57 = 86.0
" (Soln. #2) = 39.2/0.47 = 83.4
" (Soln. #3) = 29.4/0.36 = 81.6

A curve of pH/min. vs. min. was plotted so that the correct value of pH/min. could be determined for any titration obtained in the analysis of the chamber atmosphere. This curve is shown in Plate - 12. At 200 ml./min. sampling rate;

$$\text{pH/Liter} = \frac{\text{Titration Time (min.)} \times \text{pH/min. (from curve)}}{\text{Collection Time (min.)} \times 0.200}$$

ANALYSIS OF H VAPOR FROM CHAMBER

<u>Time</u>	<u>Titration Time (Min.)</u>	<u>Collection Time (Min.)</u>	<u>γ H/Min. (from curve)</u>	<u>γ H/l.</u>	<u>Saturator Operation (Min.)</u>
1507	--	--	--	--	--
1512	0.15	4.15	--	--	4.0
1517	0.26	4.51	79.9	23.0	5.0
1522	0.36	4.36	81.6	33.7	4.0
1526	0.46	4.46	83.4	43.0	4.5
1528	Arms in chamber				
1531	0.46	4.46	83.4	43.0	4.2
1536	0.38	4.38	82.0	35.5	4.4
1541	0.37	4.37	81.9	34.6	5.0
1546	0.38	4.38	82.0	35.5	5.0
1551	0.39	4.39	82.1	36.4	5.0
1556	0.40	4.40	82.2	37.4	5.0
1601	0.43	4.43	82.9	40.2	4.8
1606	0.44	4.44	83.0	41.1	4.8
1611	0.42	4.42	82.8	39.4	5.0
1616	0.45	4.45	83.1	42.0	4.8
1621	0.45	4.45	83.1	42.0	4.9
1626	0.47	4.47	83.6	44.0	
1628	Arms out of chamber				

SUMMARY

Concentration H Vapor (γ H/l.)

Average = 39.3 Maximum = 44.0 Minimum = 34.6
Average Deviation from Mean = $\pm$ 2.8

Temperature ($^{\circ}$ F)

Twelve readings - all = 90 $^{\circ}$ F

Relative Humidity

Twelve wet bulb readings - all = 80 $^{\circ}$ F RH = 65%

CT

Actual CT = 2358

Room Temperature

79.5 - 82 $^{\circ}$ F

Room Humidity (Sling Psychrometer)

17 - 25%

CORRELATION WITH LARGE CHAMBER

49. To compare the results which might be obtained from exposures in

the "arm chamber" with those obtained in the large chamber a screening test was made in which small areas of the ventral surface of the forearm of several subjects were exposed to various CT values in the "arm chamber".

50. In this test a hole about 3/4 to 1 inch in diameter was cut through the glove and sleeve of a standard protective assembly in the center of the ventral side of the forearm. A short glass tube, 1/2 inch high and 3/4 inch inside diameter, having a 1/2 inch flat flange on the bottom, was placed through the hole, the flange being next to the skin to prevent trauma and leakage. The sleeve and glove were then taped tightly around the arm. The arms thus prepared were exposed in the chamber in the standard manner.

51. The results of these exposures were observed after 24 and 48 hours and the 24 hr. reaction is shown in the following table.

Table VI

EXPOSURE OF UNPROTECTED ARMS AT VARIOUS CT VALUES

<u>No. of Arms</u>	<u>CT</u>	<u>Wt./1 .</u>	<u>Exposure Time (Min.)</u>	<u>Room T (°F)</u>	<u>Conditions R.H. (%)</u>	<u>Reaction (24 hr.)</u>
3	500	8.3	60	70-80	20-30	E-(?) E-(?) O
3	894	14.9	60	70-80	20-30	E- E- E
3	1200	20.0	60	70-80	20-30	E+ E E
3	1488	24.8	60	70-80	20-30	E E E E
3	2018	33.6	60	70-80	20-30	E+ E+ E+
3	2452	40.9	60	70-80	20-30	E+ E+ E+

Legend: O = No effect
E-(?) = Trace
E- = Mild Erythema

E = Moderate Erythema
E+ = Papular Erythema
V = Vesicle

52. The results of this test show a trend which is more clearly represented in the following table.

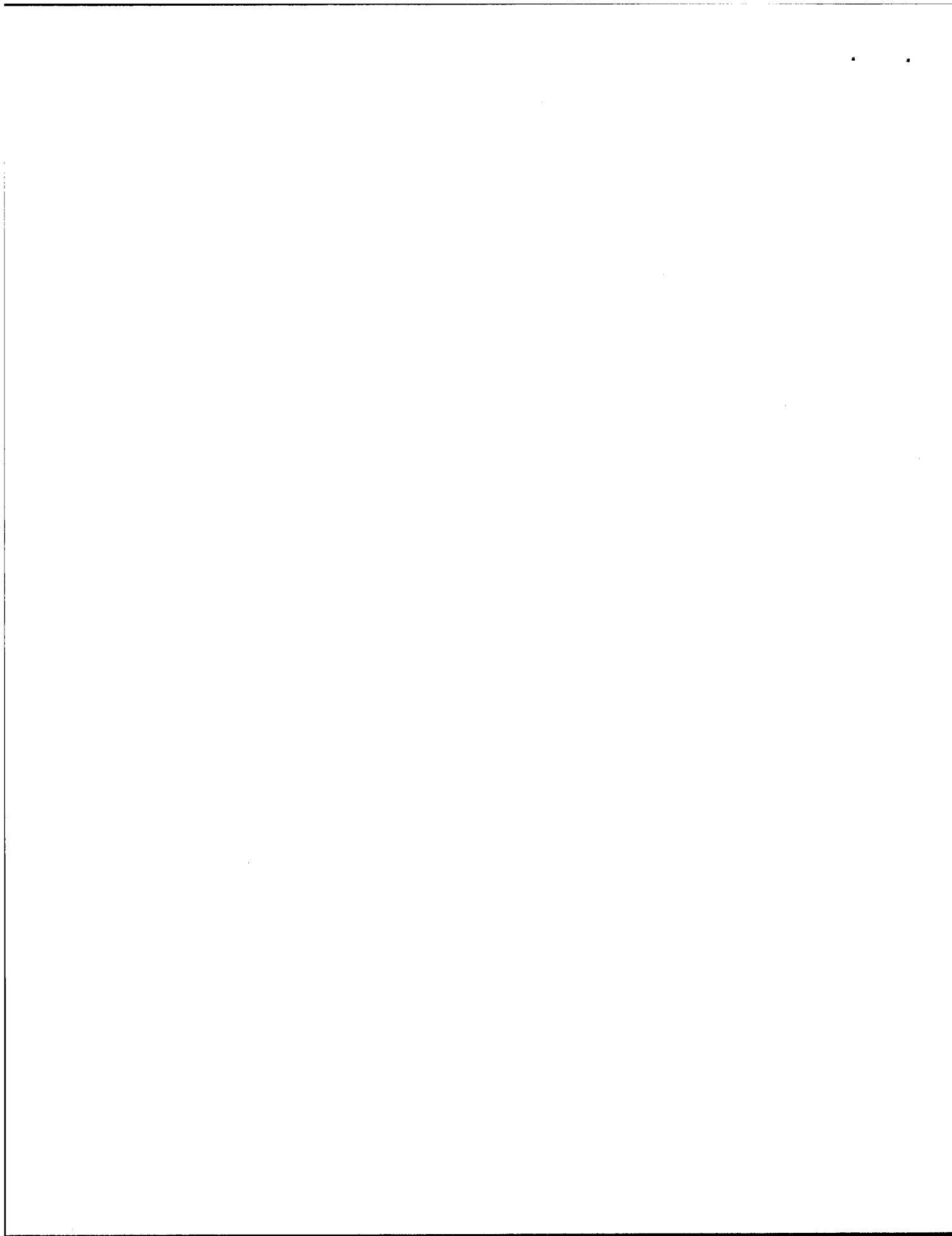


Table VII

EXPOSURE OF UNPROTECTED ARMS AT VARIOUS CT VALUES - SUMMARIZED

CT	Total No. of Arms	Reactions (24 hrs.)					V
		<u>0</u>	<u>E-(?)</u>	<u>E-</u>	<u>E</u>	<u>E+</u>	
500	3	1	2				
894	3			2	1		
1200	3				2	1	
1488	3				3		
2018	3					3	
2452	3					3	

53. A further representation of these data is shown in Plate - 13. in which the reaction is plotted versus CT. In this plate, the following arbitrary values were assigned to the various reactions: 0 = 0, E-(?) = 0.5, E- = 1, E = 2, E+ = 3, and V = 4.

54. Whereas the number of exposures at any CT in this series is too small to give an absolute picture of the effect of these exposures, a reasonably accurate indication of the reaction to be expected at any given CT may be obtained from the curve in Plate - 13.

55. A series of tests similar to this has previously been conducted in the large chamber, and has been reported in NRL Report No. P-2208. For purposes of comparison and correlation the following summarized data are taken from that report.

Table VIII

EXPOSURE OF UNPROTECTED ARMS AT VARIOUS CT VALUES INTHE LARGE CHAMBER

CT	Total No. of Arms	Reactions (24 hrs.)					V
		<u>0</u>	<u>E-(?)</u>	<u>E-</u>	<u>E</u>	<u>E+</u>	
114	5	2	1	2			
210	5	3		1		1	
300	5		1	2	2		
414	5		1	2	1	1	
594	5			4		1	
786	5			1	1	3	
804	4				2	2	
996	4				2	2	
1015	1					1	
2030	7						7

56. These data also are plotted in Plate - 13. It may readily be seen that exposures in the large chamber at any given CT produce a significantly more severe reaction than similar exposures in the "arm chamber". In general, exposures in the large chamber produce reactions which are approximately twice as severe as those produced in the "arm chamber" at the same CT.

57. The only difference between these exposures is the fact that, in the "arm chamber" exposures, though the forearms of the subjects are maintained at 90°F and 65% RH, the remainder of the body is at a lower temperature and humidity (70-80°F and 20-30% RH). Two tests were made in which the room conditions were adjusted and controlled at 90°F and 65% RH. In these tests the subjects were completely dressed in protective clothing, including gloves, socks, arctics and gas masks. An area of the ventral surface of the forearm was exposed in the "arm chamber" at CT values of 900 and 1200 as in the previous tests. The data obtained in these tests are shown in Table IX.

Table IX

EXPOSURE OF UNPROTECTED ARMS AT VARIOUS CT VALUES WITH ROOM CONDITIONS

OF 90°F AND 65% RH

<u>No. of Arms</u>	<u>CT</u>	<u>gH/l.</u>	<u>Exposure Time (Min.)</u>	<u>Room T (°F)</u>	<u>Room R.H. (%)</u>	<u>Reaction (24 hrs.)</u>
3	900	15.0	60	92	60	E E E
3	1194	19.9	60	90	63	E+ E+ E+

58. The above data show that exposures under the conditions of this test produce reactions which approach those from similar exposures in the large chamber (cf. Plate - 13). Thus it is indicated that even though the arms of subjects are maintained at high temperatures and humidities, the rest of the body, if at moderate conditions, is capable of functioning as a "radiator" and thus succeeds in altering the reactivity of the exposed surface and reduces the severity of the reaction. This is considered a good illustration of the importance of temperature and/or humidity on the effects of exposure to H vapor.

59. It should be mentioned that the large chamber exposures were made during severe summer weather, and therefore the reactions obtained in these exposures may be more severe than reactions obtained in similar tests during winter weather. Studies are in progress to complete the correlation of test conditions.

SUMMARY AND CONCLUSIONS

1. A chamber for the exposure of the forearms of human subjects to the vapors of chemical warfare agents has been constructed and is in operation. The design, calibration and operation of this chamber have been described. The construction of the chamber is such that the temperature, relative humidity, air velocity, and concentration of vesicant agent can be closely controlled over a wide range of conditions.

2. Preliminary tests have been conducted to compare and correlate the results of exposures in the described "arm chamber" with the results of exposures under the same conditions in the large chamber now being used at this Laboratory.

3. It has been found that the effects obtained in each chamber are close to the same for a given CT value when the entire body of the subject is maintained at the same conditions of temperature and humidity (90°F and 65% RH in these tests). However, if only the forearms of the subjects are maintained at this high temperature and humidity, with the rest of the body at moderate conditions (70-80°F and 20-30% RH), twice as great a CT value is necessary to produce the same degree of burn. This is considered a good illustration of the importance of temperature and/or humidity on the effects of exposure to H vapor.

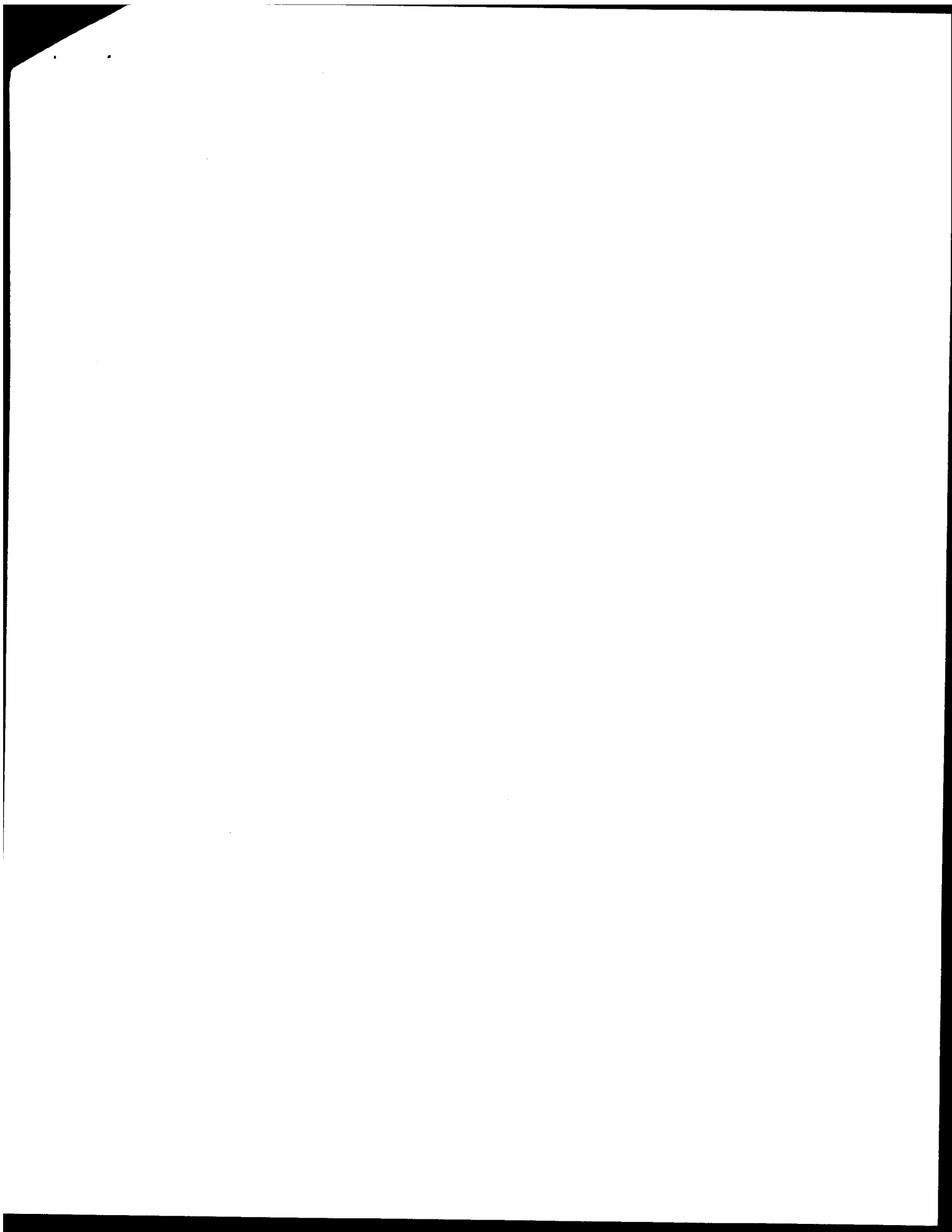
RECOMMENDATIONS

1. None, tests are continuing in which the "arm chamber" is being used to screen new developments in Protective Clothing and Ointments prior to their final evaluation in the large chamber.

PLATE I

ARM CHAMBER AND CONTROLS

- A. Arm Holes
- B. Observation Window
- C. Control Panels
- D. Northrop Analyzer
- E. Recorder



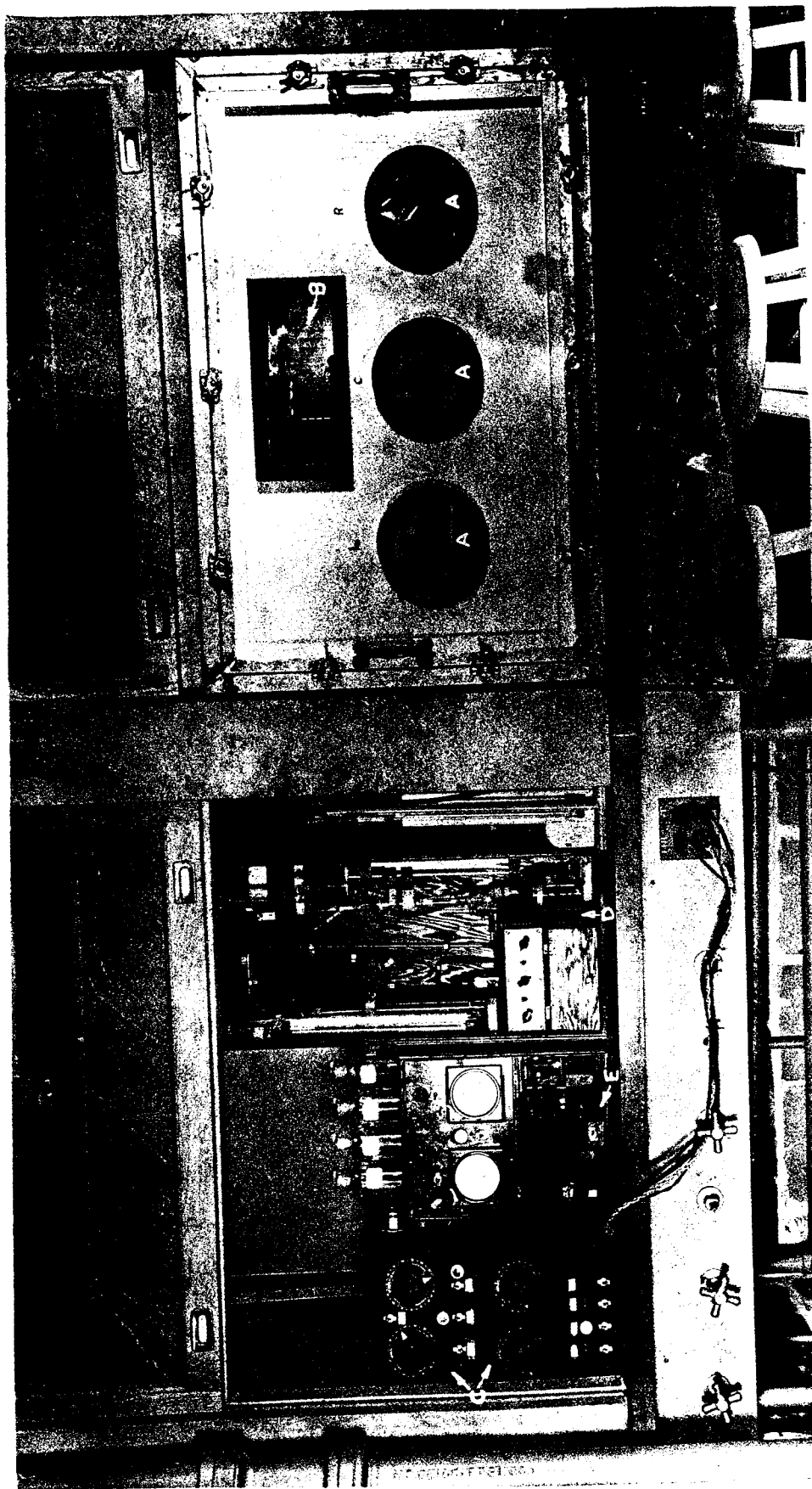


PLATE I

PLATE II

ARM CHAMBER INTERIOR AND CONTROLS

- A. Wet-bulb Regulator and Reservoir
- B. Cooling Coil
- C. Circulating Fans
- D. Bimetallic Thermoregulator
- E. Intermittent Heater
- F. Continuous Heater
- G. Exhaust Duct and Cover
- H. Lights
- J. Wet-bulb Thermometer
- K. Dry-bulb Thermometer
- L. Arm Support





PLATE III

EXPOSURE OF SUBJECTS

IN

ARM CHAMBER

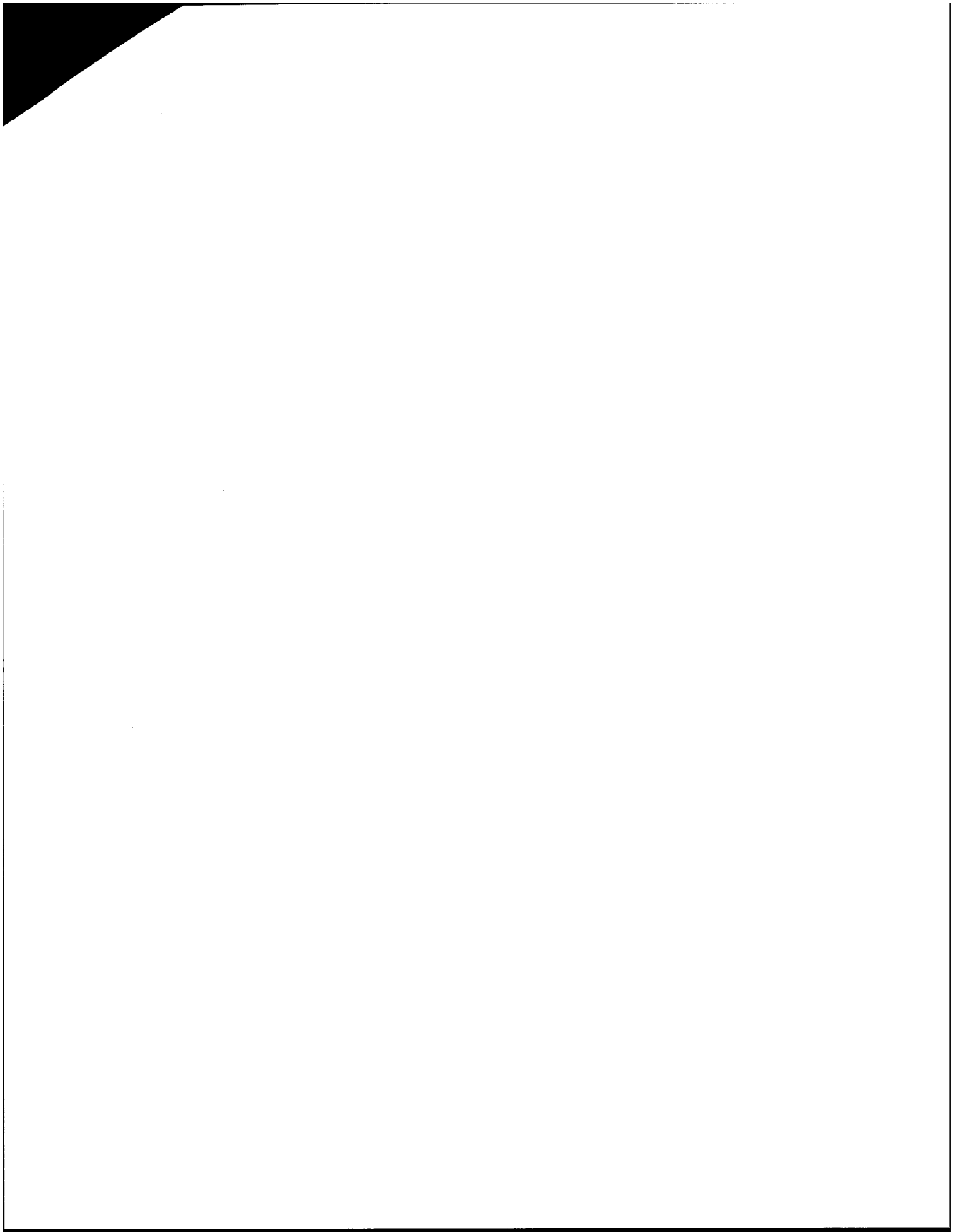
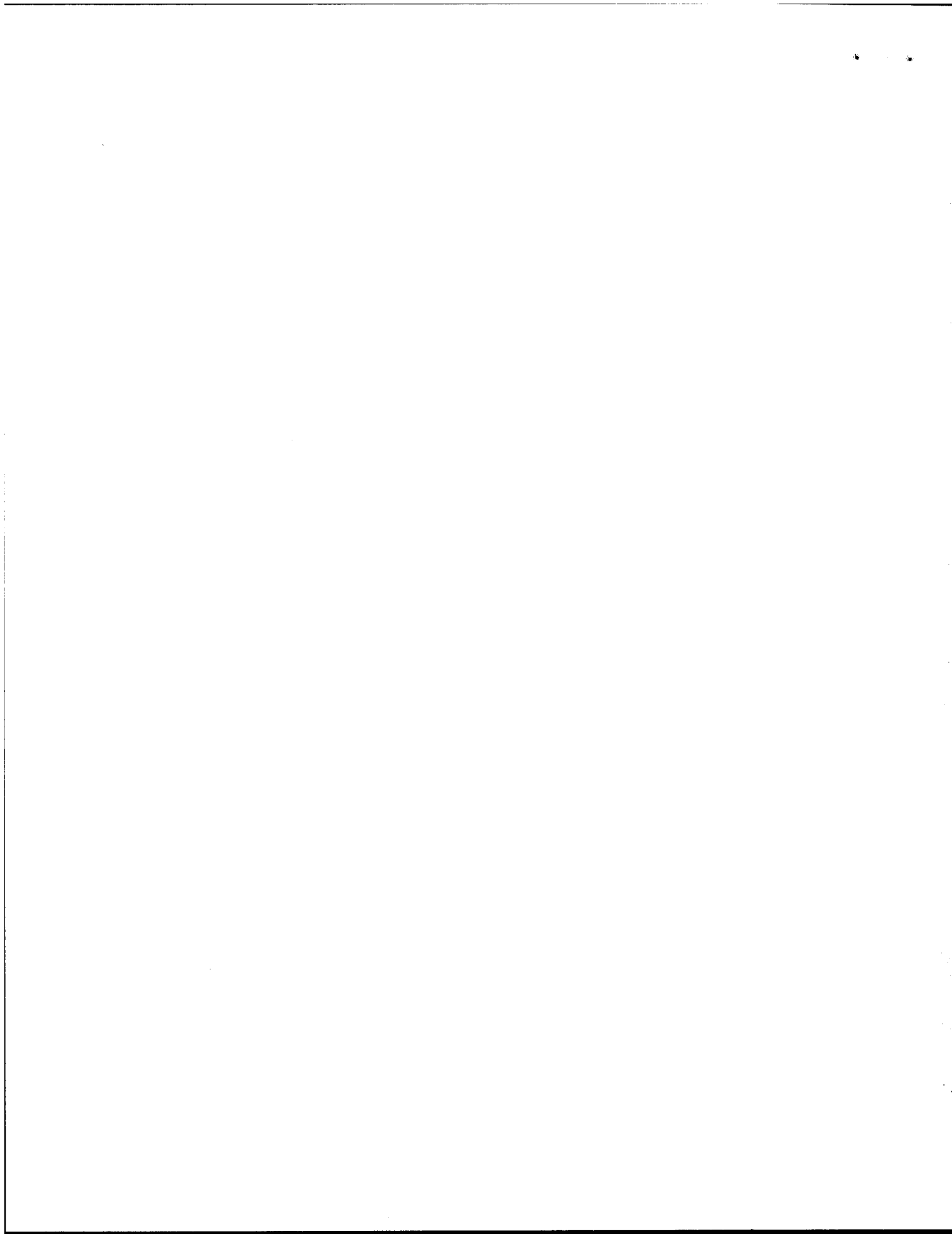
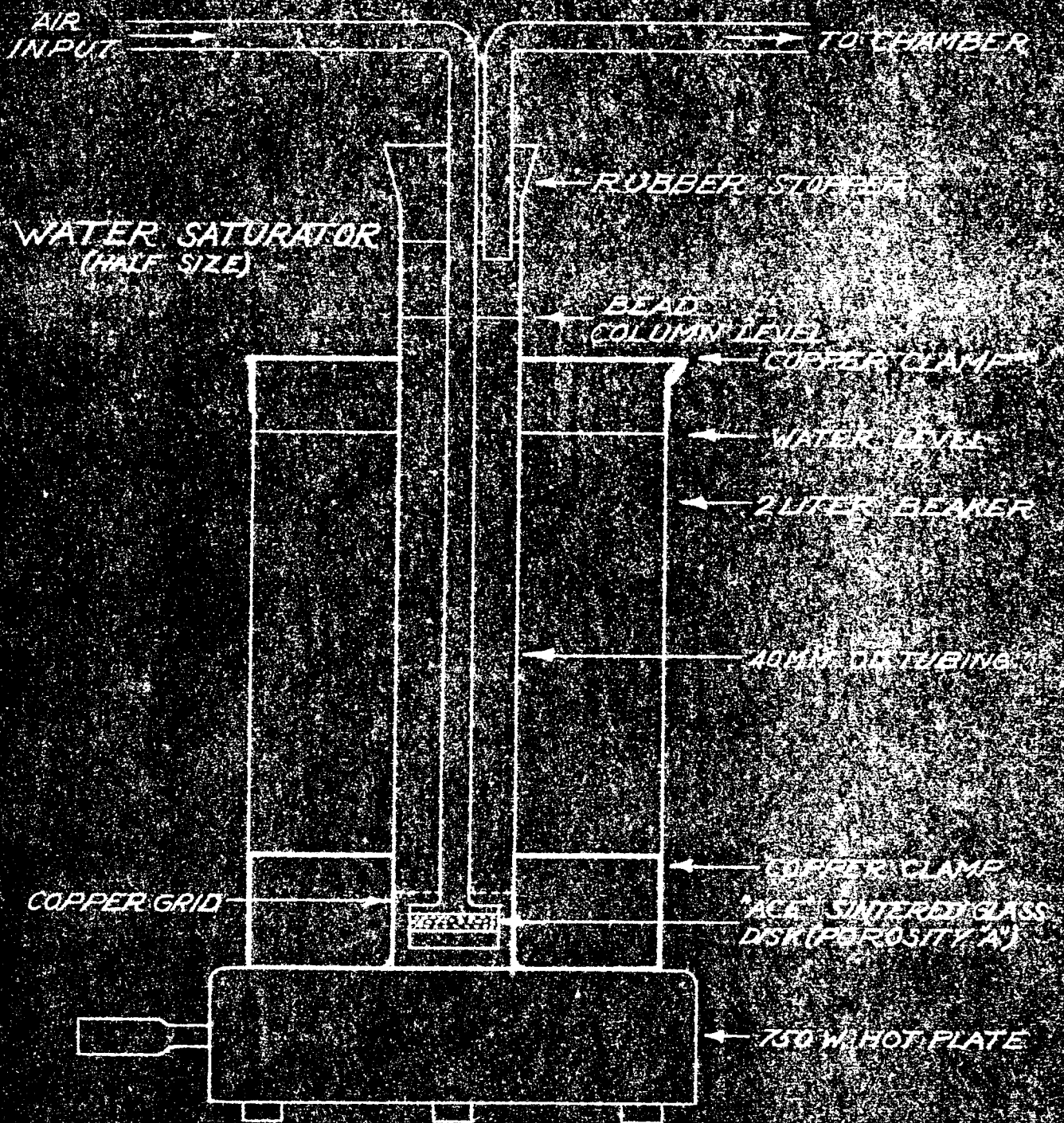
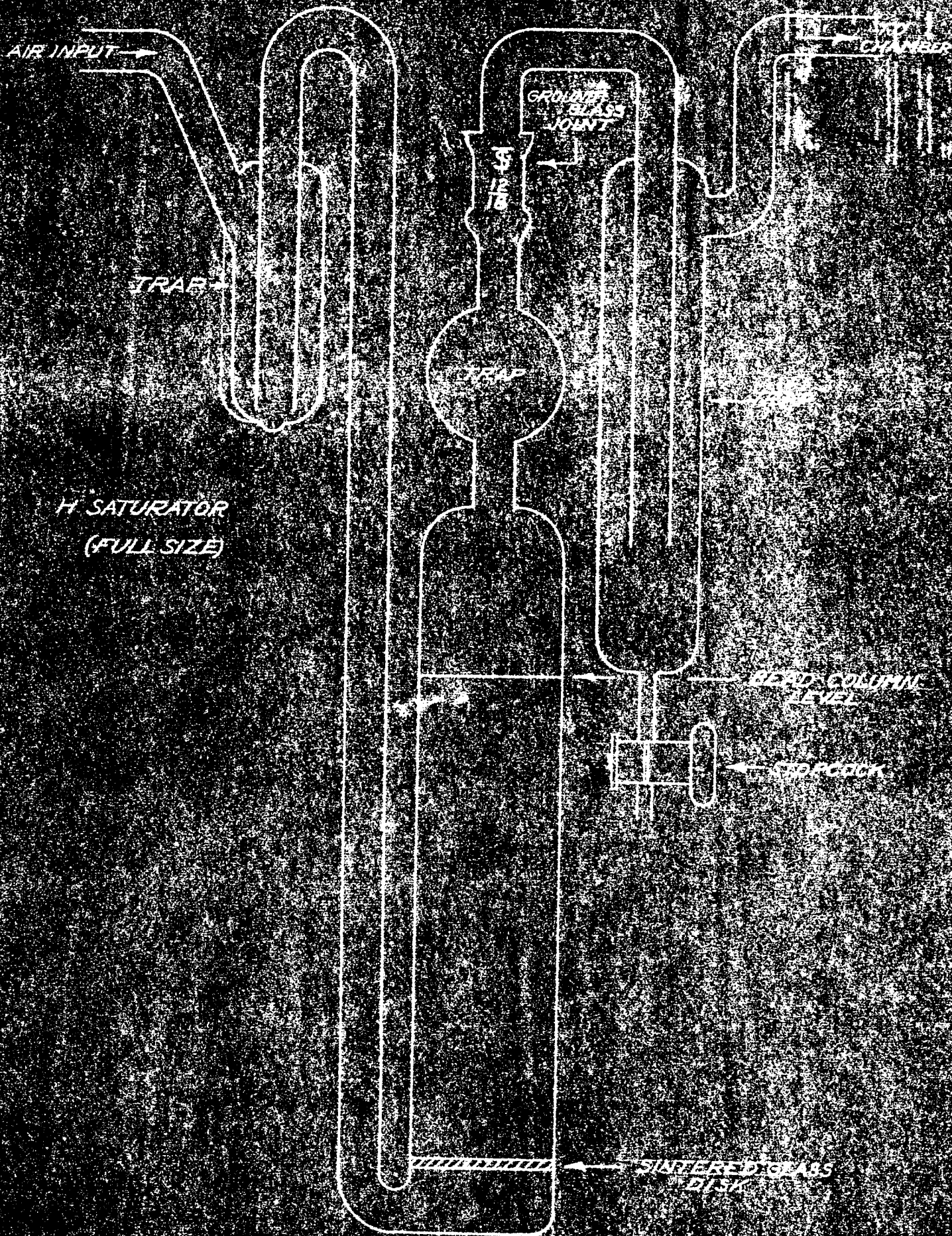


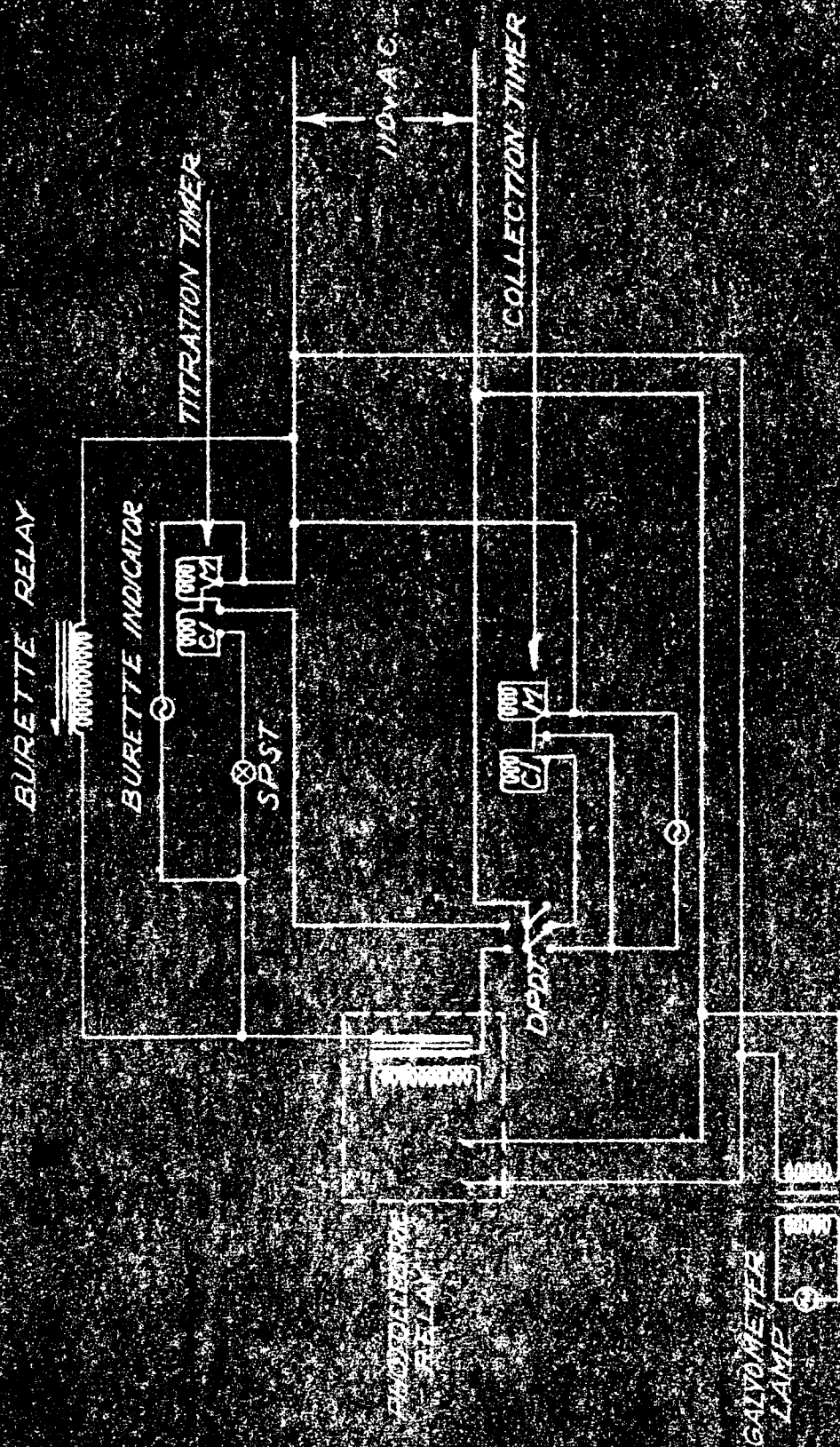


PLATE 3

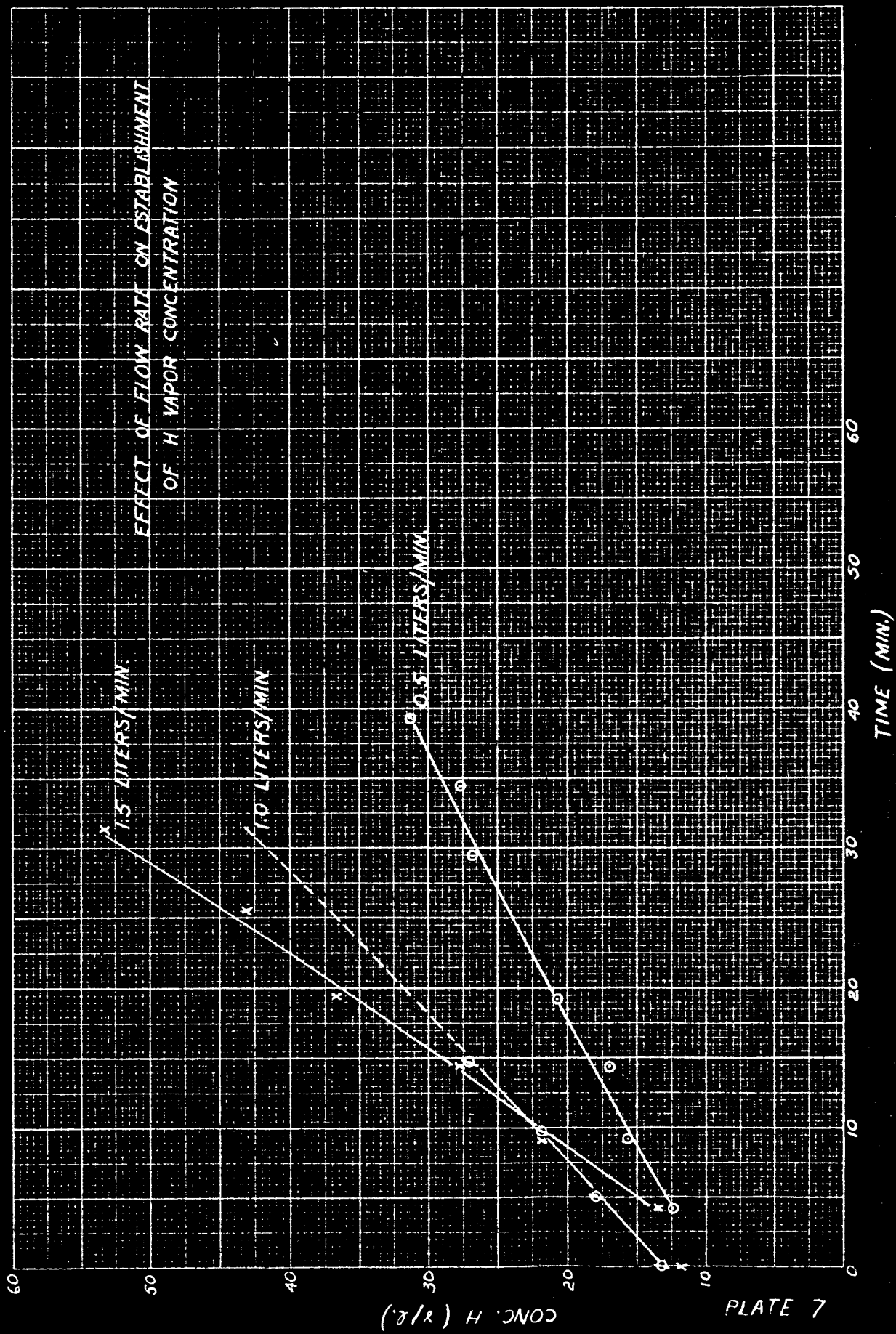


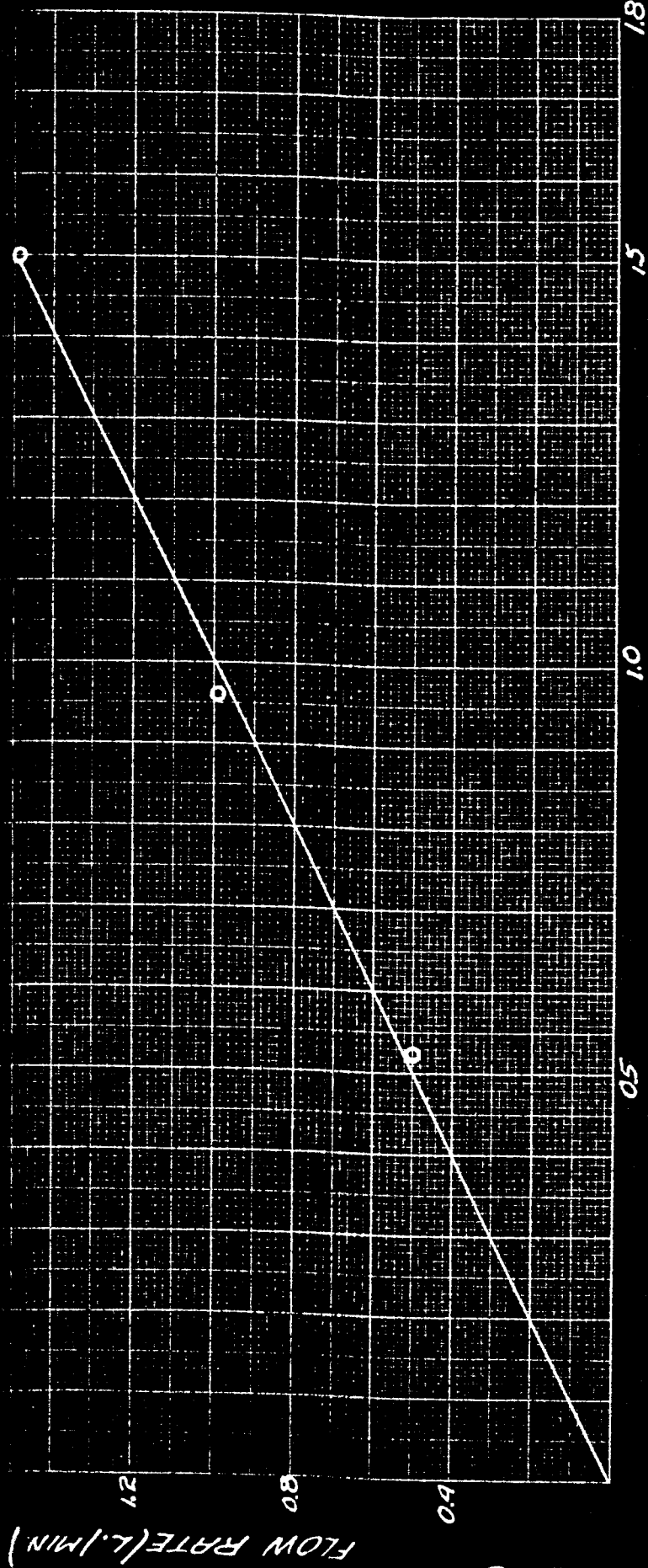
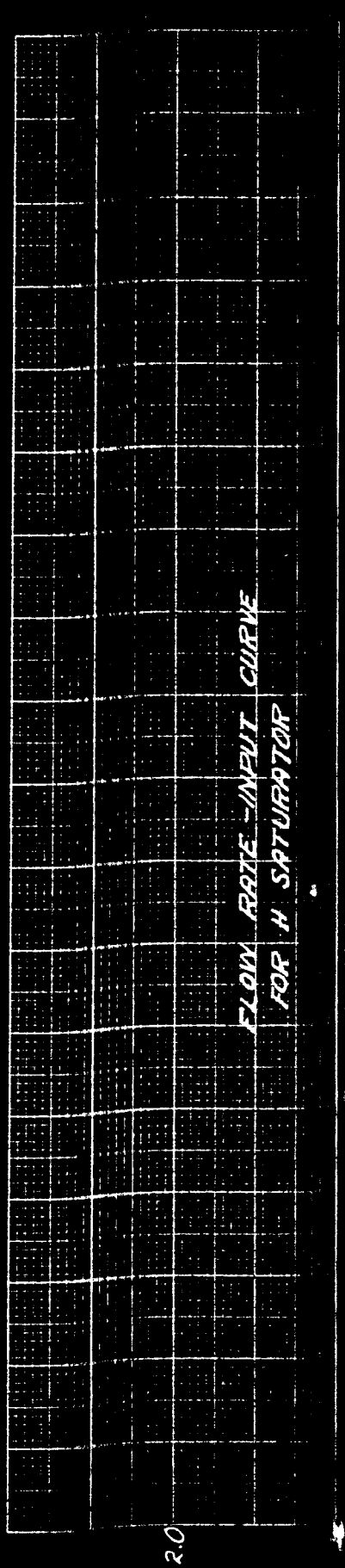






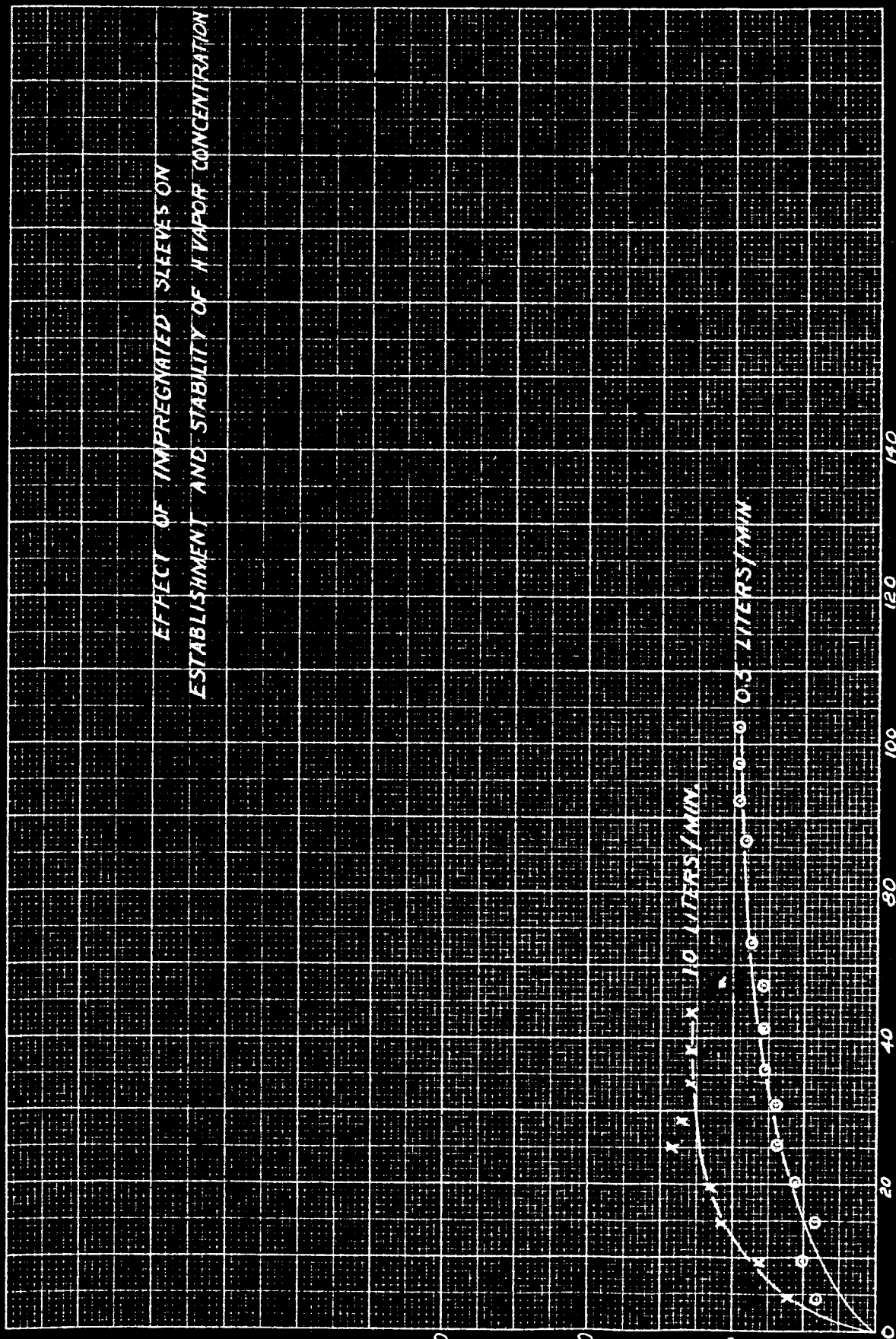
AUTOMATIC TIMER
 FOR NORTHROP TITRIMETER



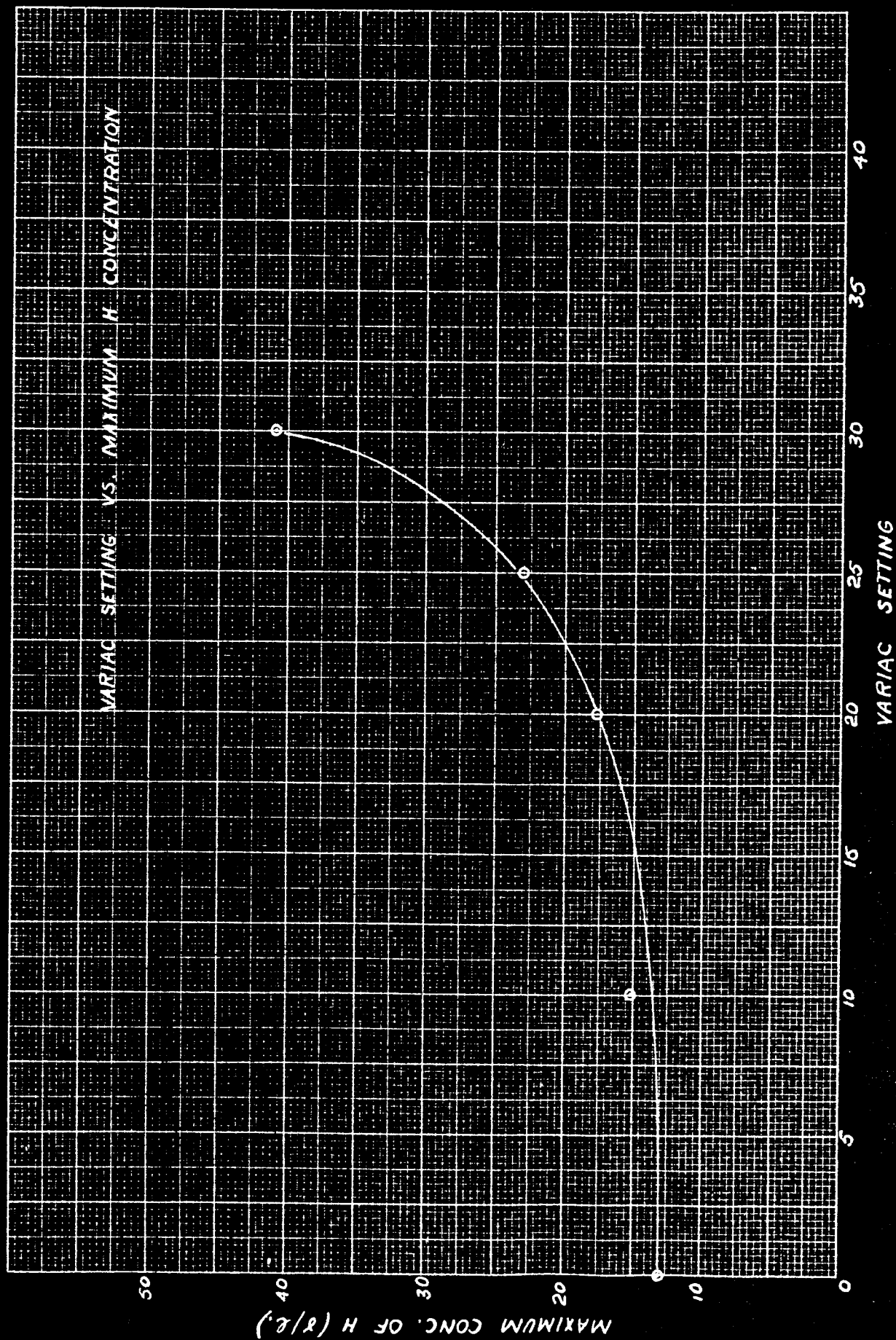


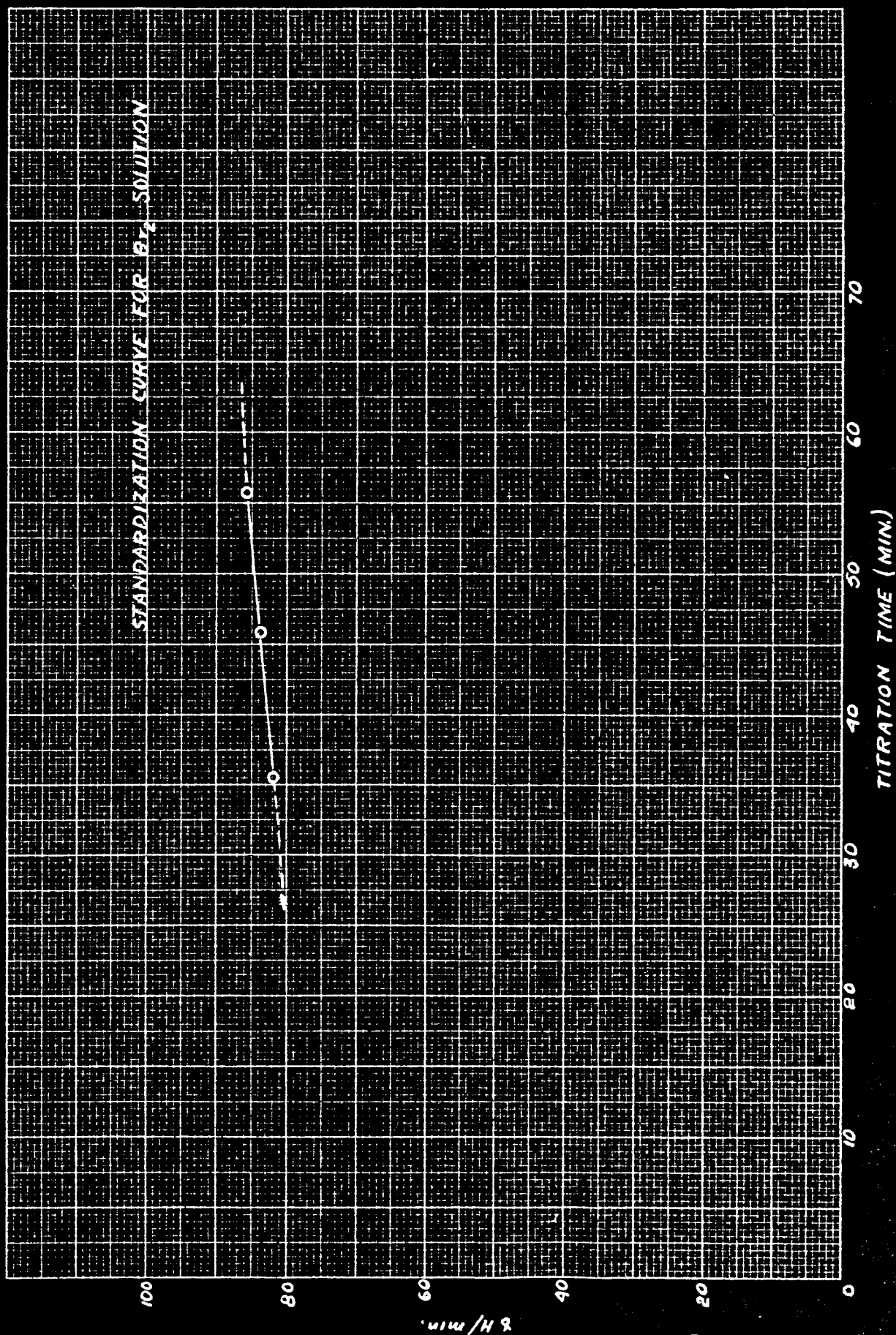
CONC. OF H VAPOR (g/l.)

TIME (MIN.)



EFFECT OF IMPREGNATED SLEEVES ON
ESTABLISHMENT AND STABILITY OF H VAPOR CONCENTRATION





AUTHOR INDEX

Blake, L. V. R-2217
Carhart, Homer W. P-2219
Connor, John A. R-2215
Daily, L. Eugene, Lt.Comdr.(MC)USN.. P-2219
der Matoesian, EdwardH-2214, H-2218
Friedman, Herbert H-2214, H-2218
Herring, R. A. R-2213
Hulburt, E. O. H-2210
Johnson, J. E. P-2211
Main, W. F. R-2217
Nemecek, Joseph J. H-2218
Richardson, R. A., Ensign,USNR R-2212
Ruark, Arthur E. O-2216
Squires, Rodney M. O-2216
Taylor, William H., Jr. P-2219

