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Erbguth, P.
Aston, J. C.

Instruments (9)
Instrument Testing and Calibration (8)
Thermometers (93800)

20597

OSRD R-4780

Methods of production and calibration of combination vapor pressure and gas dial thermometers

O.S.R.D., N.D.R.C., Div. 11, Washington, D. C.

U.S. Eng.

Conf'd 1 Mar '45 22

photos, tables, graphs, drawings

The methods of production and calibration of combination vapor pressure and gas dial thermometers are described. The methods of construction and testing of the Bourdon springs as well as the bulbs are given. These procedures yield a thermometer which gives accurate readings with a single standard dial. The routine checking of the final thermometer at certain fixed points is outlined as well as the checking method for the occasional complete calibration of the instrument.



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Division 11
NATIONAL DEFENSE RESEARCH COMMITTEE
of the
OFFICE OF SCIENTIFIC RESEARCH AND DEVELOPMENT

METHODS OF PRODUCTION AND CALIBRATION OF COMBINATION VAPOR
PRESSURE AND GAS DIAL THERMOMETERS

to
January 26, 1945
by
P. Erbguth and J. G. Aston

Report OSRD No. 4780

Copy No. 29

Date: March 7, 1945

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Section 11.1

METHODS OF PRODUCTION AND CALIBRATION OF COMBINATION VAPOR
PRESSURE AND GAS DIAL THERMOMETERS

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Endorsement (1) from H. M. Chadwell, Chief, Division 11 to
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Defense Research Committee.

Forwarding report and noting:

"A thermometer was developed and put on a production
basis having the full temperature range of interest
in the operation of liquid air plants."

This is a progress report under Contract 11-439, OEMsr-934
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**METHODS OF PRODUCTION AND CALIBRATION
OF
COMBINATION VAPOR PRESSURE AND GAS DIAL THERMOMETERS**

BY

**Paul Erbguth - Mechanical Laboratory Manager
Tagliabue Manufacturing Company
New York, New York**

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Central Engineering Laboratory
University of Pennsylvania
Philadelphia, Pennsylvania**

January 26, 1945

NDRC, Section 11.1

Contract OEMsr-934

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SUMMARY

The combined vapor pressure and gas thermometer described in Report O.S.R.D. No. 3483 developed in collaboration with the Tagliabue Manufacturing Company has been put on a production basis.

In this report the methods of construction and testing of the Bourdon Springs as well as the bulbs are described. These methods yield a thermometer which gives accurate readings with a single standard deal.

The routine method of checking the final thermometers at certain fixed points are described as well as that for occasional complete calibrations of the instruments.

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Final Report on Methods for Production and Calibration of Combination
Vapor Pressure and Gas Dial Thermometer.

Introduction

The development and final details of the "Combination Vapor Pressure and Gas Dial Thermometer" have already been given in a final report to the National Research Committee (Report O.S.R.D. No. 3483)

It turned out that the preparations for the production of these instruments was a more arduous task than was first supposed.

The difficulties which have been overcome are:

- A- Rolling of a Bourdon spring of a volume of about 1 cc without possibility of collapsing of the walls to the point of touching.
- B- Control of the volume of the Bourdon springs to within .1 cc or better in order that all instruments be fitted by a single scale in the gas range to within 3°F.
- C- Control of the bulb volume to within .5 cc to correspond to the control of the spring volume.

Construction of Bourdon Springs.

Plate A is a photograph of one of the beryllium-copper alloy springs made by the improved methods which consisted of coiling the spring under an internal gas pressure of approximately 2,000 psig. Before this procedure was adopted many springs had to be discarded because of internal friction due to touching of the walls.

Calibration and Control of Volume of Springs.

From the start each spring was pressure calibrated and therefore all of the thermometers fitted a single dial in the vapor pressure range. Table I is a typical pressure calibration of a spring. Column I gives the

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pressure in psig while column 2 gives the reading in angular degrees and column 3 gives the reading based on linearity.

TABLE I

Pressure calibration of a Typical Thermometer.

1	2	3
Pressure psig	Scale Reading Angular Degrees	
0	0.0	0.0
10	5.5	5.4
20	11.0	10.8
30	16.5	16.2
40	22.0	21.6
50	26.5	27.0
100	54.0	54.0
200	107.5	108.0
250	134.5	135.0
300	161.0	162.0
400	215.5	216.0
500	270.0	270.0

At first no system of control of the spring volume was available except a uniform procedure in manufacture. It was found that thermometers made up from these springs showed sufficient variation in calibration that individual temperature calibration over the entire gas range was necessary.

The final method of controlling the spring volume was to heat the spring (initially at 80°F) in a molten salt bath to 620°F (1080°R) with the filling tube of the thermometer connected to the gas burette

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shown in Fig. I. When gas ceases to pass over into the burette the volume in the burette is read. Since the final Rankin temperature of the spring is just twice the initial temperature of the spring, the volume of the gas in the burette is half the volume of the spring if the burette is at 80°F (neglecting the partial pressure of water in the burette.) By this means the spring could be calibrated to .05 cc. For the thermometers filled with 500 psig nitrogen the spring volume adopted was 1.4 cc and all springs had to have this volume to within $\pm .1$ cc.

For the 600 psig oxygen filled thermometers the volume was 1.2 cc $\pm .1$ cc.

Filling of the Thermometers

The procedure was essentially that described in the report on the development of the thermometer (O.S.R.D. No. 3483).

Plate "B" shows the line for evacuating the thermometers and plate "C" shows the oil bath for heating the thermometer bulbs during evacuation and the line for introducing the filling gas into the instruments shown on the rack. Tank oxygen and nitrogen are used and dried by passing through a coil in dry ice.

The thermometers were filled with the bulb held at 100°F in a constant temperature water bath to the equivalent scale points 237.7° for the 600 psig oxygen and 252.7° for 500 psig Nitrogen thermometers. (0° equals 0 psig gage or .1 atm)

The filling tube is closed by means of a special screw clamp and sealed by welding.

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Construction of the scales.

In the case of both the oxygen and nitrogen filled thermometers the scale in the vapor pressure ranges was constructed from the appropriate vapor pressure equation. In both oxygen and nitrogen the data of Dodge and Dunbar (J. Am. Chem. Soc. 49, 591 (1927)) were used.

The scale in the gas ranges was constructed from the experimental data. Fig. 3 shows the experimental points and the final calibration curve for the 600 psig filled oxygen instruments while Fig. 4 shows the experimental points and final calibration curve for the 500 psig filled nitrogen instruments.

Calibration Apparatus.

The apparatus used in taking the experimental data for the thermometers in the vapor pressure and the gas range for temperatures below -100°F and for the exhaustive spot check calibration on the instruments from the production line is similar to that used at the Pennsylvania State College for the instruments used in the development and described in the final report on the instruments (Report O.S.R.D. No. 3483). The temperatures were checked by copper-constantan thermocouples connected to a super sensitive Tagliabue Indicating Potentiometer calibrated 0-5500 Microvolts. Fig. 5 is a schematic drawing of this apparatus while plate "D" is a photograph of it. Six stainless steel tubes serve as wells for the thermometers whose bulbs are pushed to the bottom thus placing them in the middle of the copper block. The uniform temperature of the block is measured by a standard thermocouple.

The production thermometers were checked in a bath of liquid air in a one liter dewar, a bath of dry ice and alcohol in a twelve liter dewar, a bath of finely shaved ice as well as a water bath for the temperatures up to 200°F .

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The production thermometers were checked in a bath of liquid air in a one liter dewar, a bath of dry ice and alcohol in a twelve liter dewar, a bath of finely shaved ice as well as a water bath for the temperatures up to 200°F .

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For routine checking of the instruments readings are taken in a bath of liquid air contained in a one liter dewar, a bath of dry ice and alcohol in a twelve liter dewar, a bath of finely shaved ice as well as water bath at 100°F, 150°F and 200°F.

Table II represents the check points taken from a number of thermometers with calibration scales. The standard scale divisions for the various temperatures are given for comparison.

Table II

<u>500# Nitrogen Thermometers</u>							
Temp. °F	-303.6	-103	+32	+80	+100	+145	
Std. Scale	15.4	166.6	226.9	246.8	254.4	270.6	
N - 500-34	14	168	228	246	254.5	271	
-36	15.5	169.5	226	248.5	254.5	271	
-37	15	169	228	247	254.5	270.5	
-38	15.5	166.5	226.5	245.5	254.5	271	
-39	14.5	168	227	246.5	254.5	271	
-40	14.5	166.5	226.5	245.5	254.5	270	
<u>600# Oxygen Thermometers</u>							
Temp. °F	-303.6	-103	+32	+80	+100	+150	+170
Std. Scale	3	155.9	215.2	234.5	242.3	260.8	268
O - 600-26	3	156	213.5	233	241.5	259	266
-31	3	156.5	215	233	242	260	267.5
-33	1.5	158.5	215.5	234.5	241.5	259	266.5
-37	3	157.5	217	234.5	241.5	257.5	267
-39	4	157	214	233.5	241.5	260.5	267.5
-40	2.5	155	215.5	235	242.5	261	268

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Table III represents the check points taken from a number of thermometers with final scales.

Table III

500# Nitrogen Thermometers

<u>N - 500 - 25</u>		<u>N - 500 - 26</u>		<u>N - 500 - 29</u>	
of	Dial Reading	of	Dial Reading	of	Dial Reading
-308	-308	-308	-305	-308	-308
-104.2	-100	-104.2	-104	-104.2	-105
†150	†147	†150	†151	†150	†149
<u>N - 500 - 30</u>		<u>N - 500 - 32</u>		<u>N - 500 - 31</u>	
-308	-309	-308	-308	-308	-306
-104.2	-107	-104.2	-108	-104.2	-104
†150	†153	†150	†155	†150	†155

600# Oxygen Thermometers.

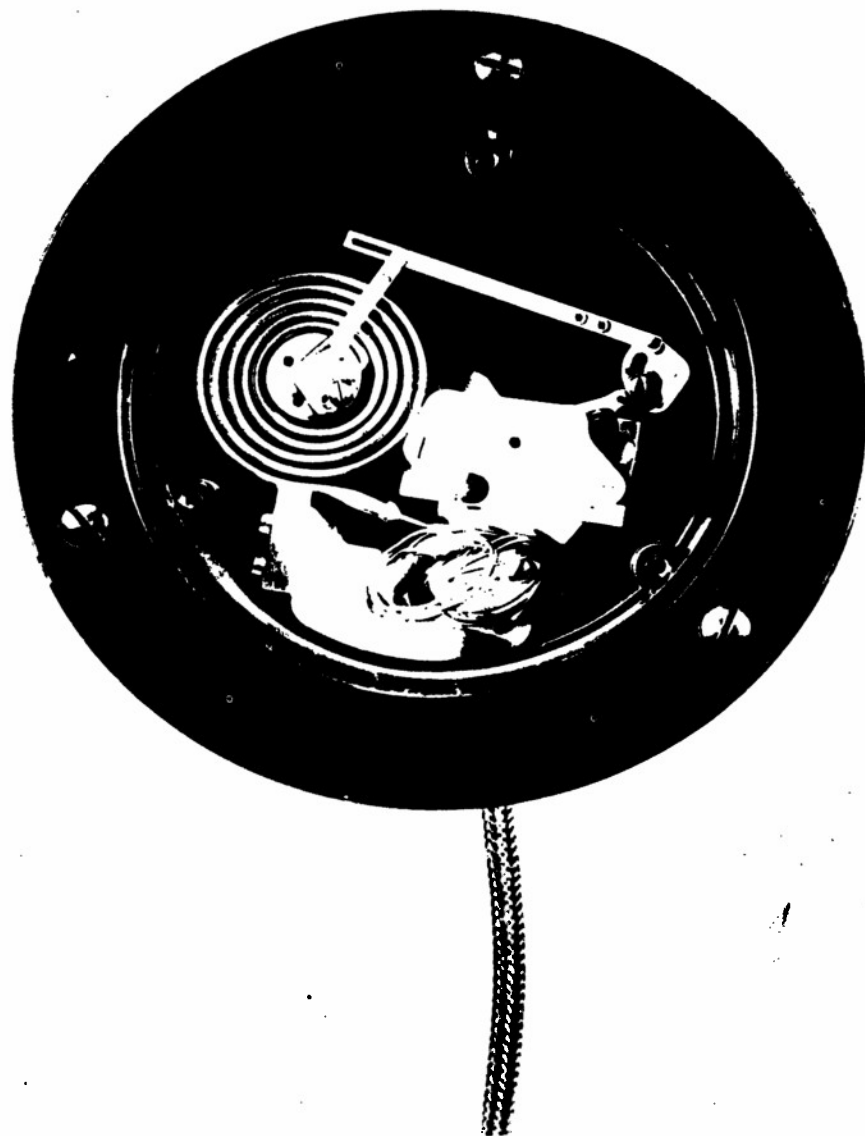
<u>O - 600 - 26</u>		<u>O - 600 - 22</u>		<u>O - 600 - 20</u>	
-312	-312	-310	-308	-310	-310
-101.2	-100	-98.1	-94	-98.1	-94
†152	†155	†150	†148	†150	†147
<u>O - 600 - 30</u>		<u>O - 600 - 25</u>		<u>O - 600 - 27</u>	
-310	-310	-310	-310	-310	-312
-98.1	-98	-98.1	-96	-98.1	-95
†150	†145	†150	†148	†150	†154

Completed Thermometers

Plate E shows a completed oxygen thermometer and Plate F a completed nitrogen thermometer.

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PLATE A
OPEN THERMOMETER
WITH BOURDON SPRING



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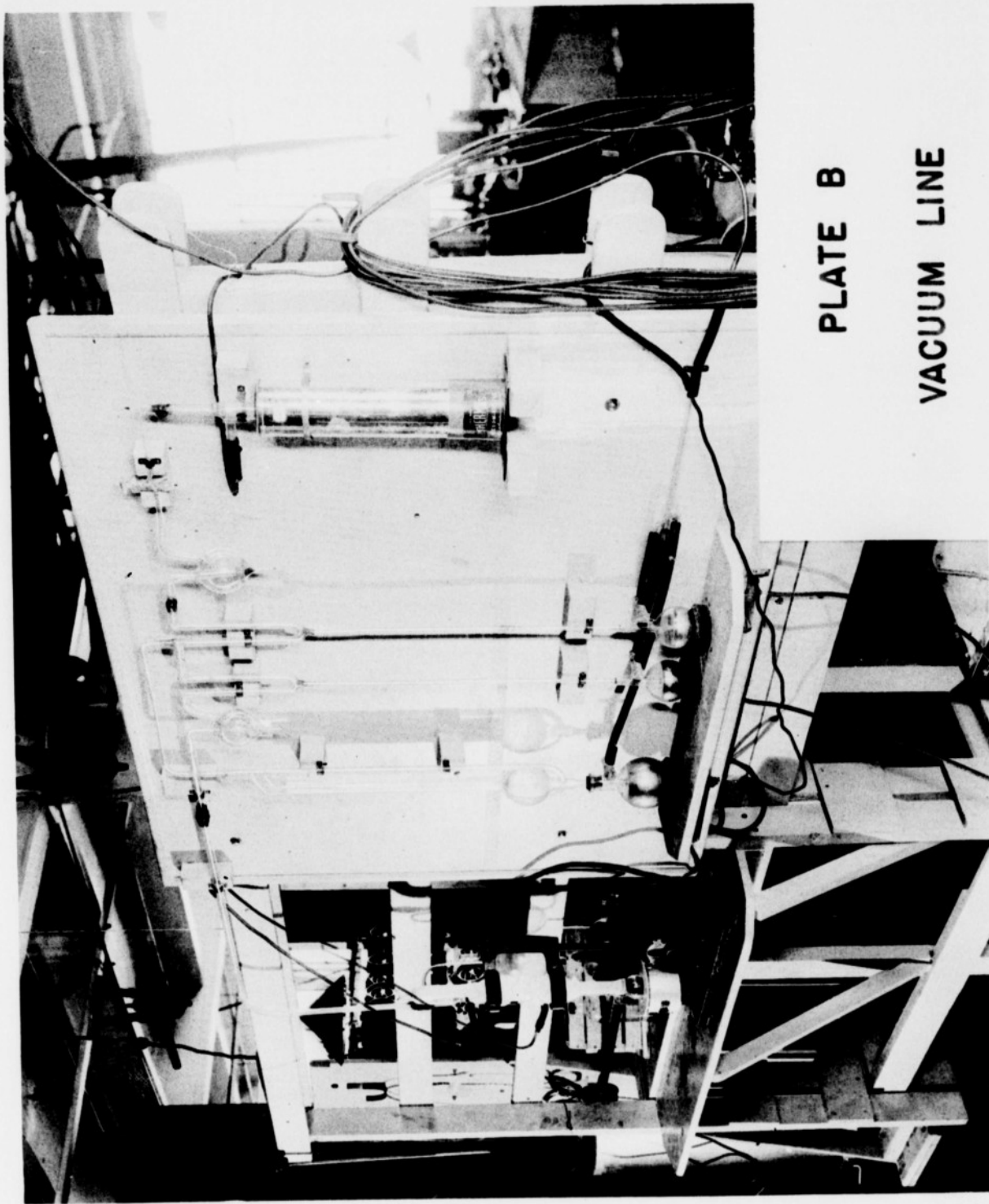


PLATE B
VACUUM LINE

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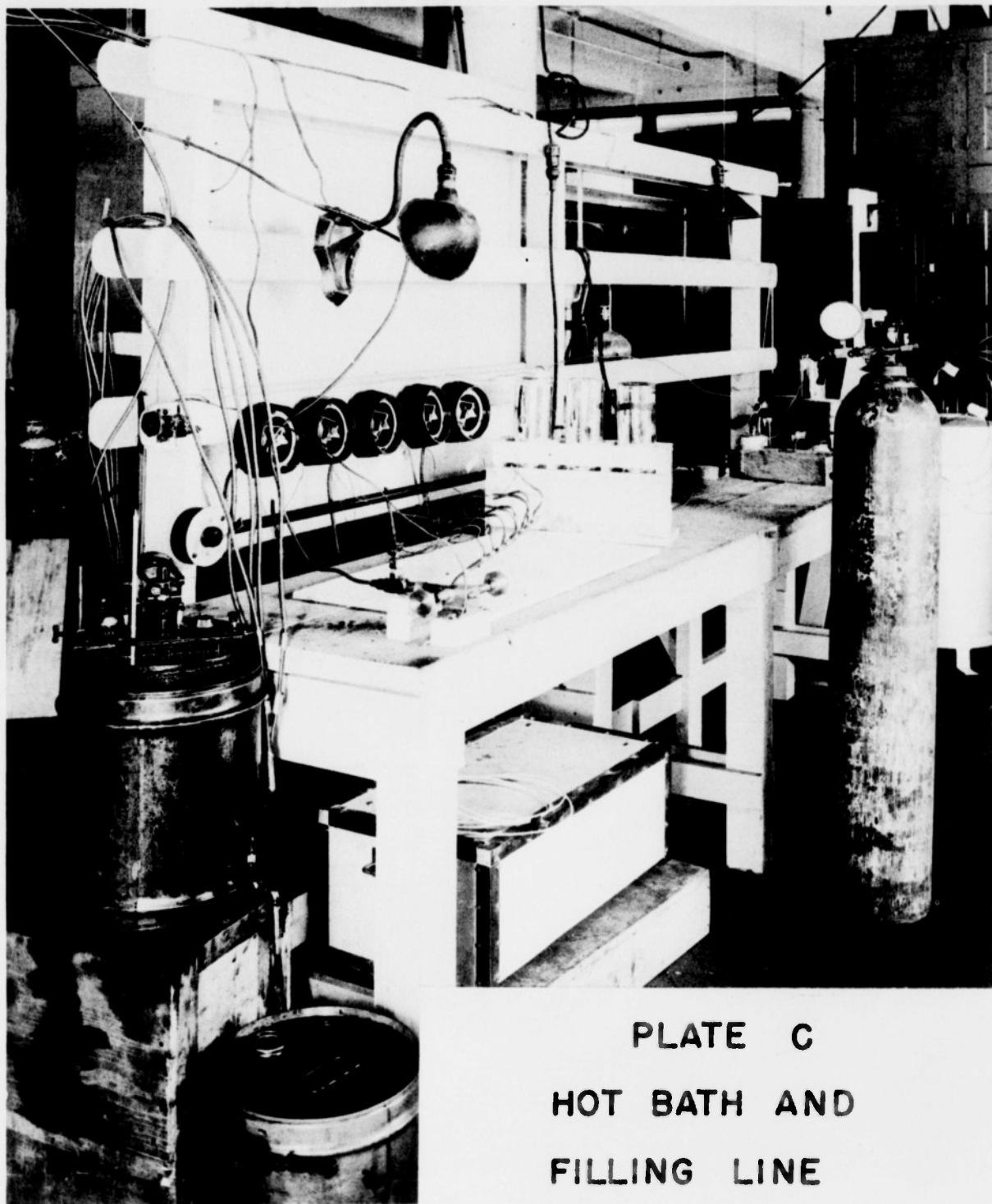
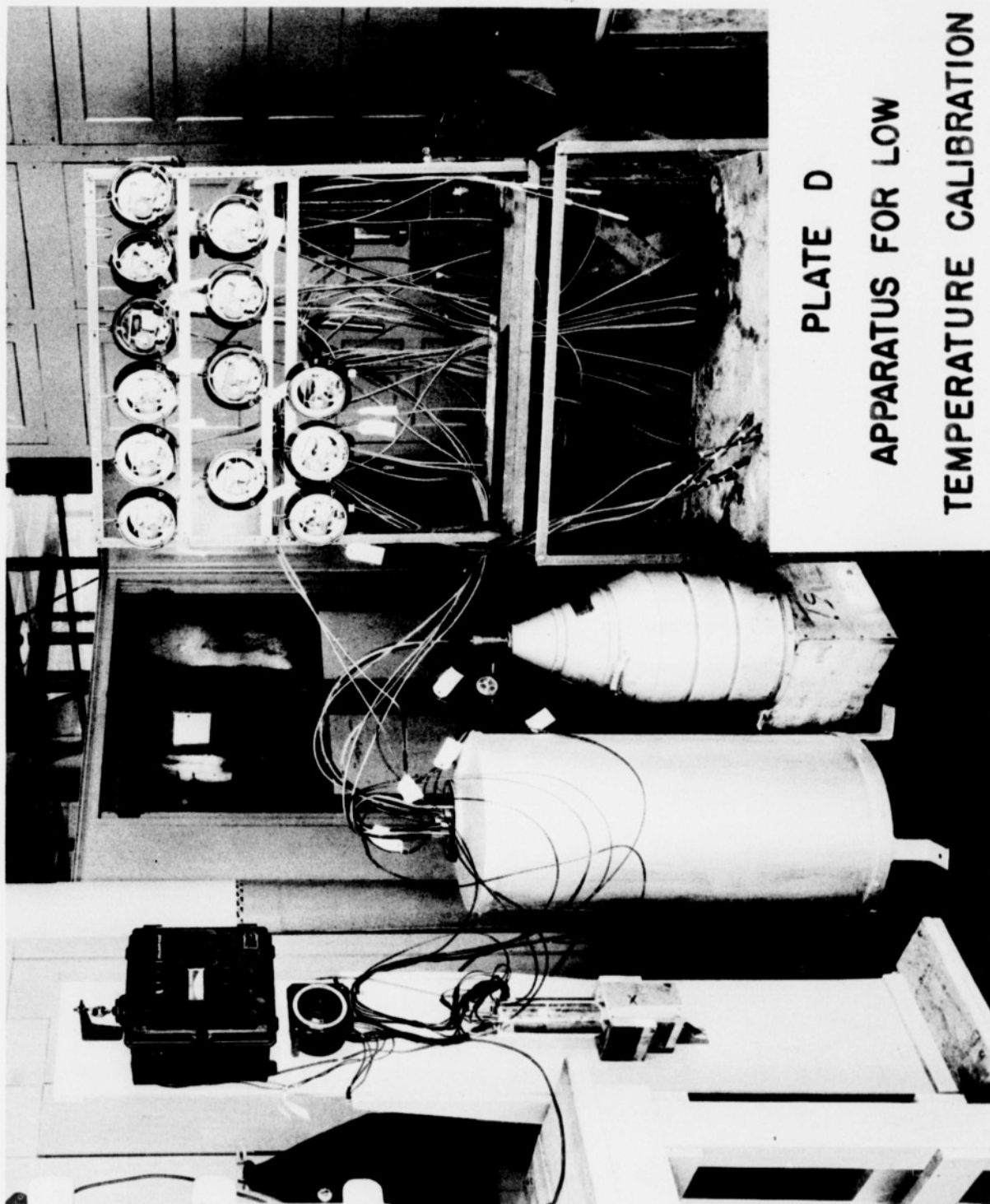


PLATE C
HOT BATH AND
FILLING LINE

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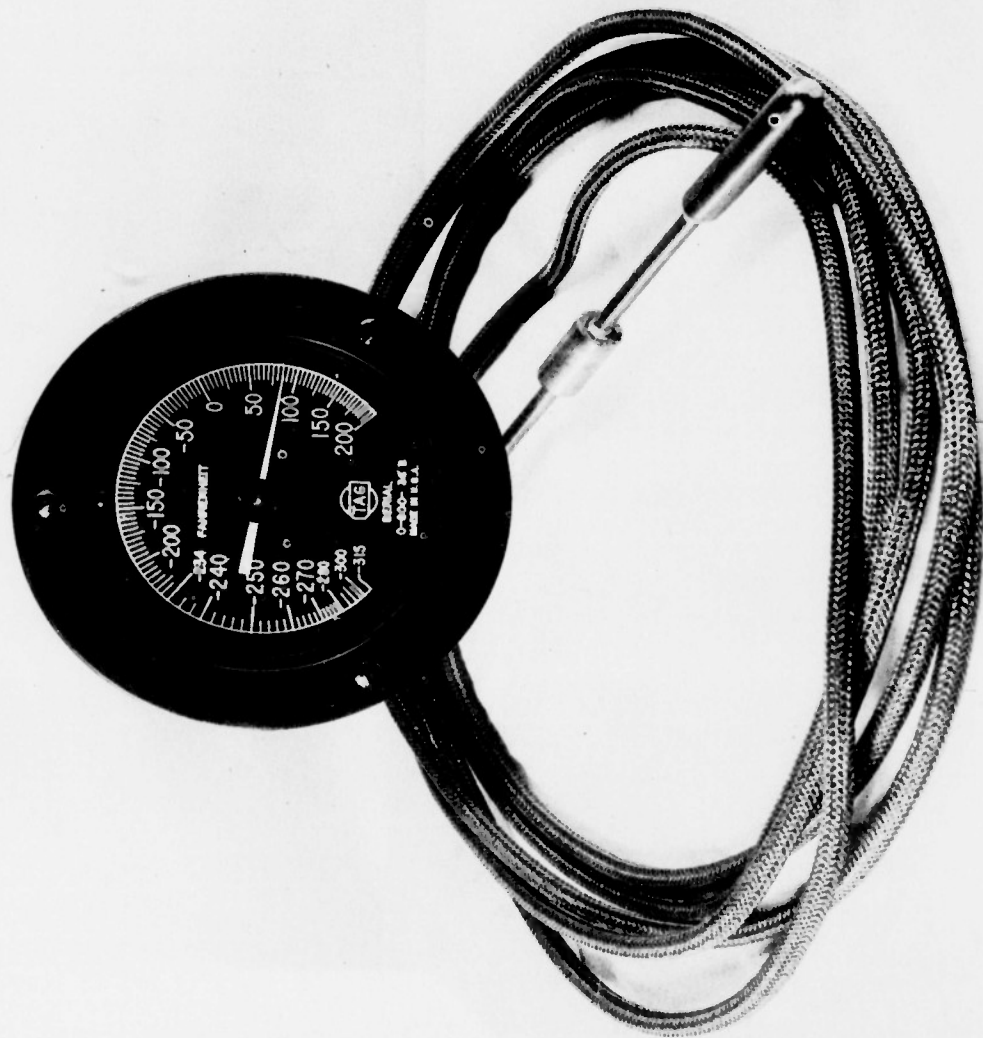
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PLATE D
APPARATUS FOR LOW
TEMPERATURE CALIBRATION



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PLATE E
OXYGEN THERMOMETER

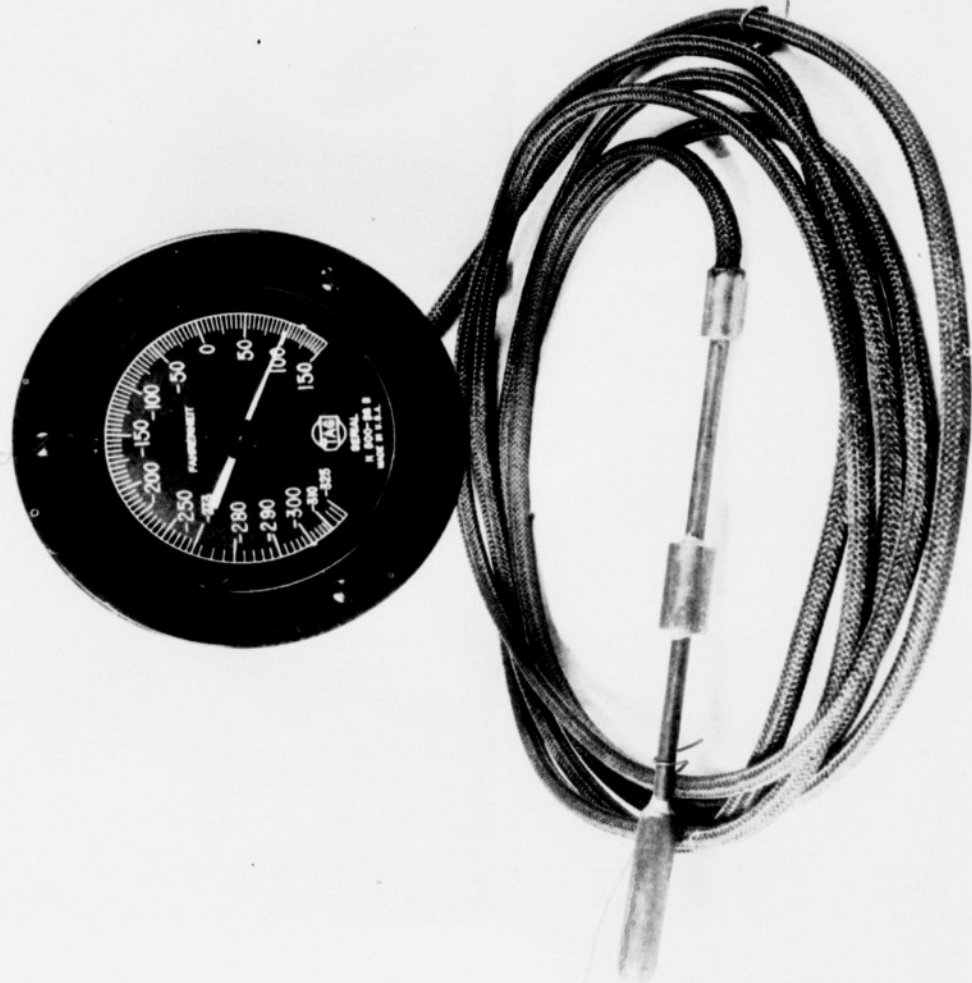


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PLATE F
NITROGEN THERMOMETER



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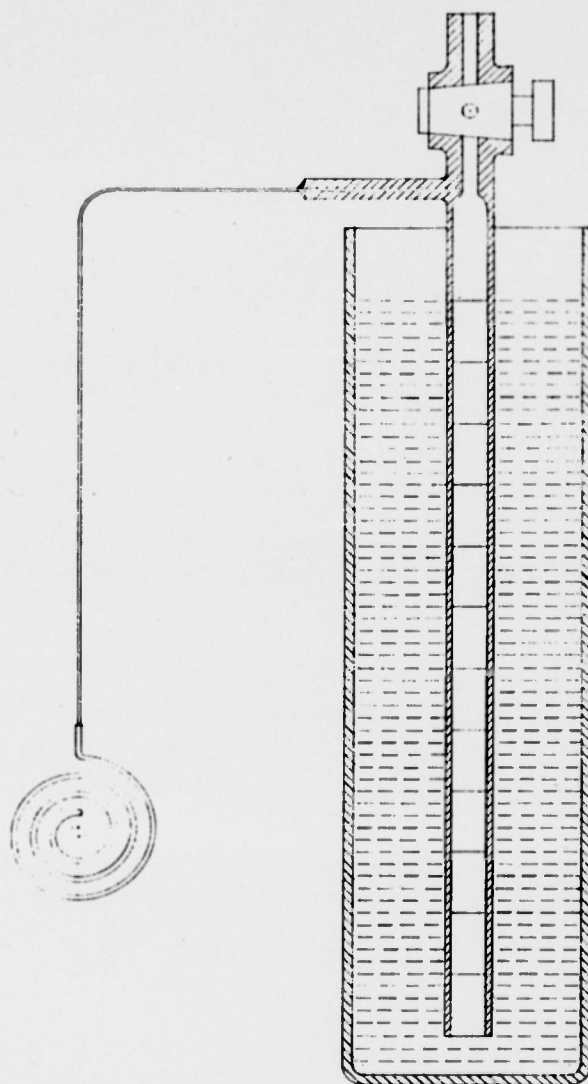


FIG. I
GAS BURETTE

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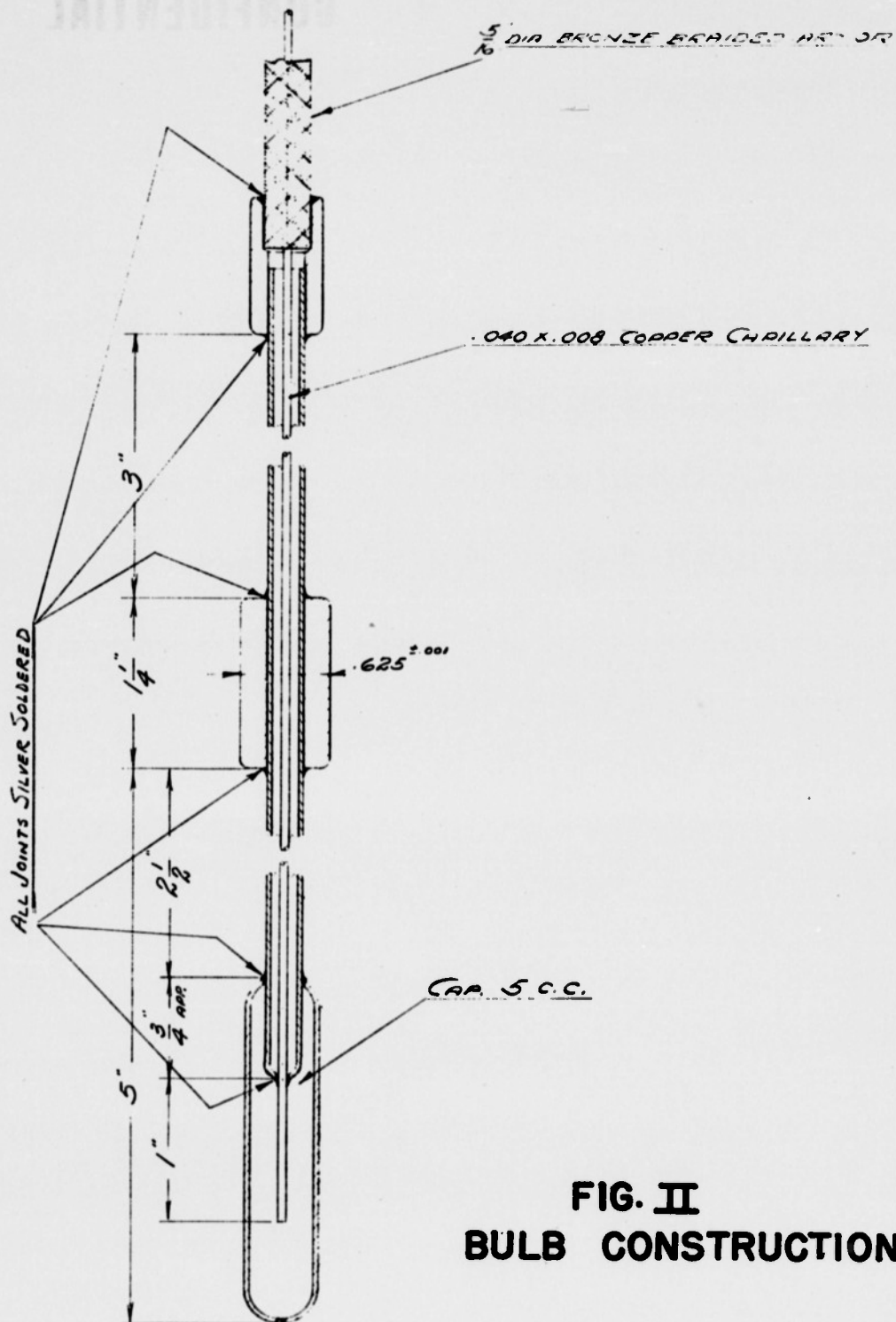
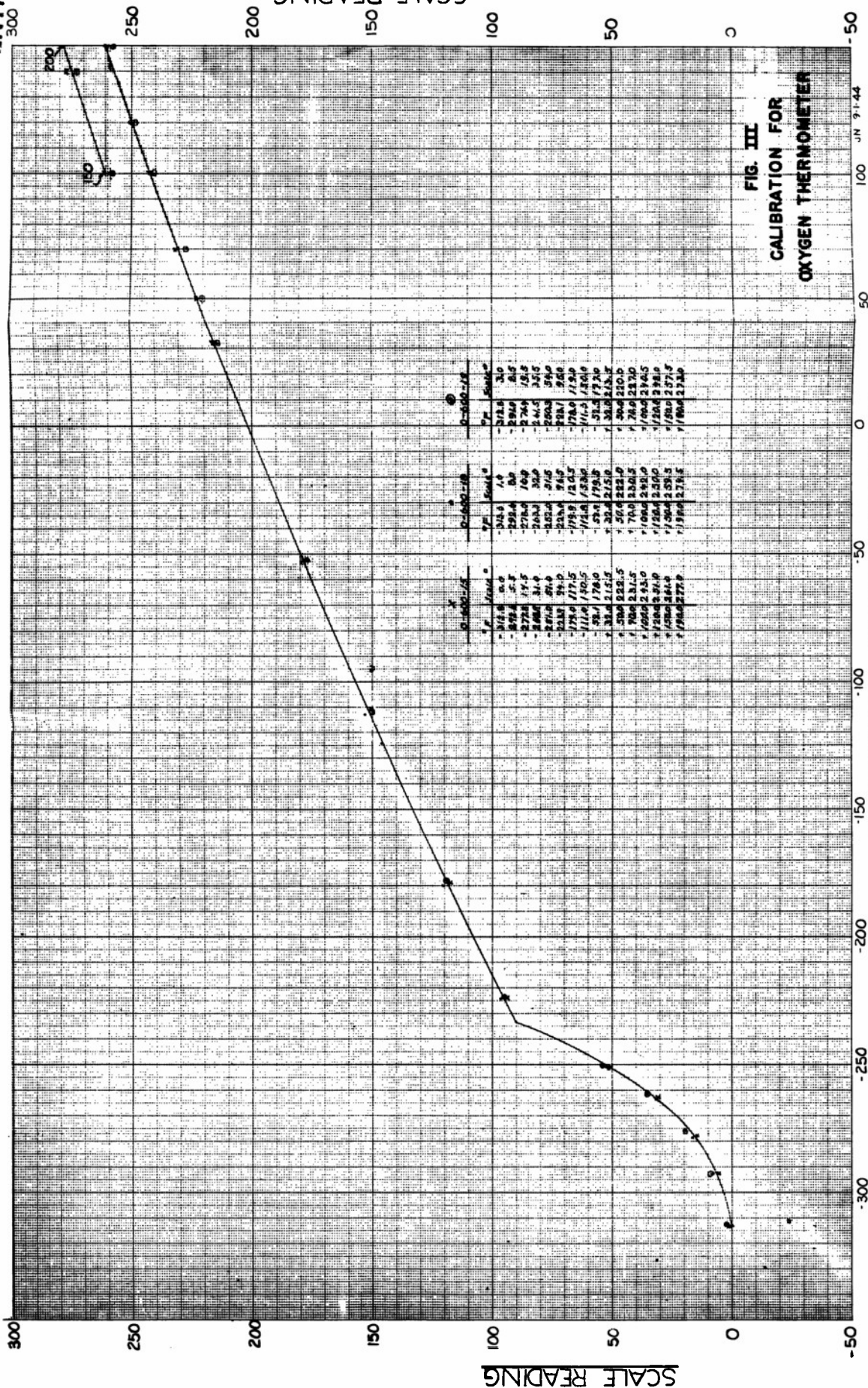


FIG. II
BULB CONSTRUCTION

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TEMPERATURE, DEGREES FAHRENHEIT

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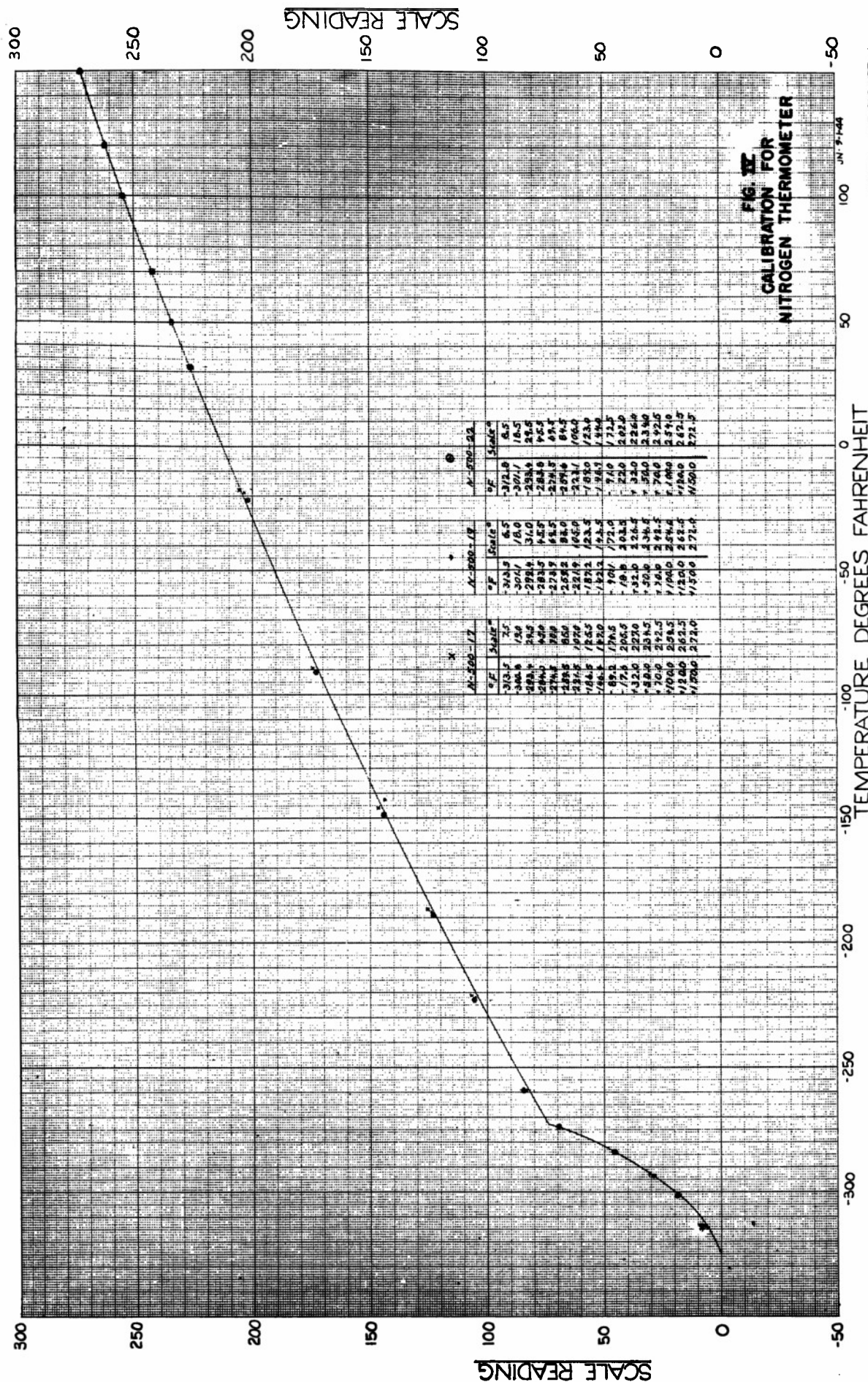
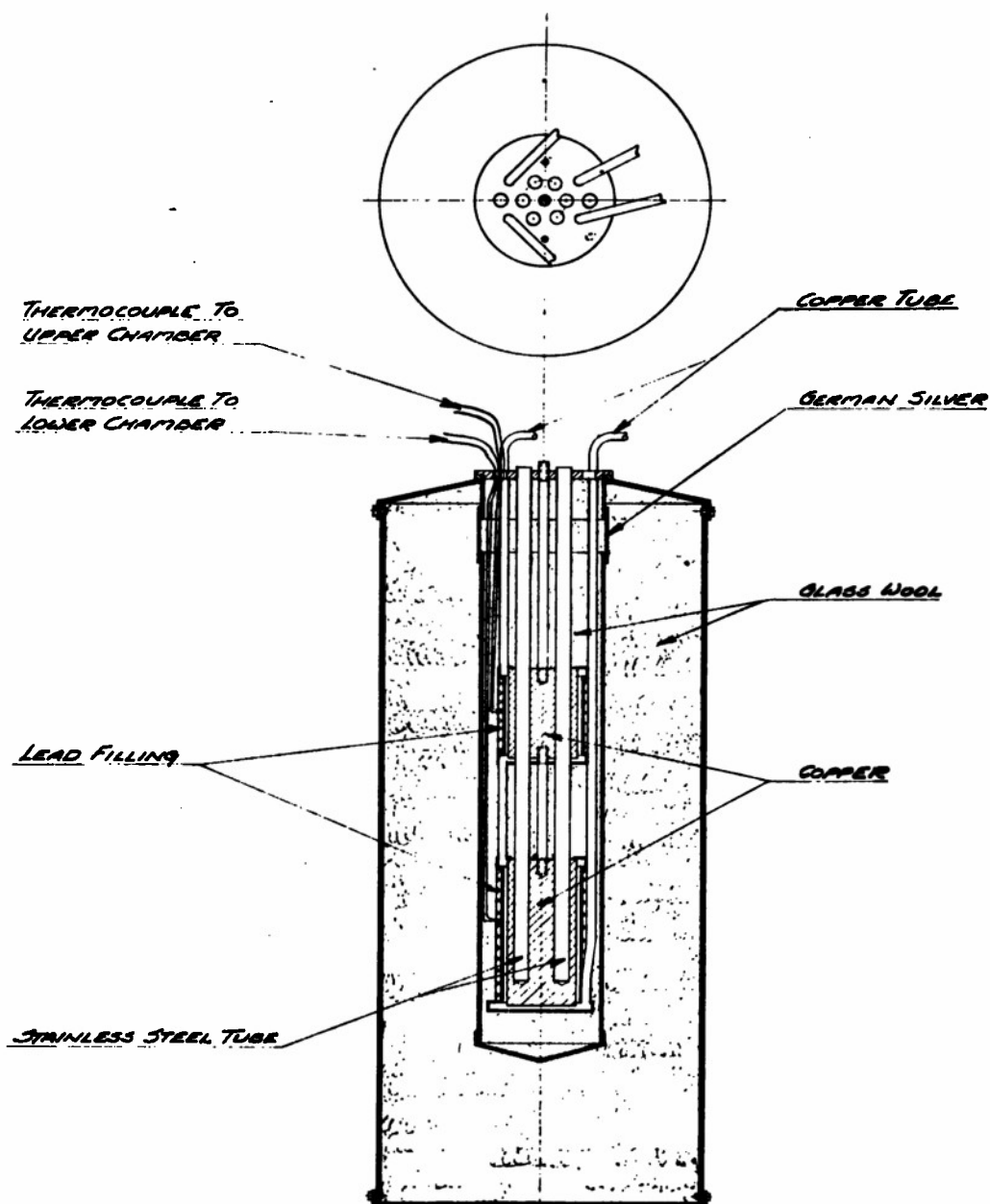


FIG. V

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APPARATUS FOR LOW TEMPERATURE CALIBRATION



SCALE 1/8

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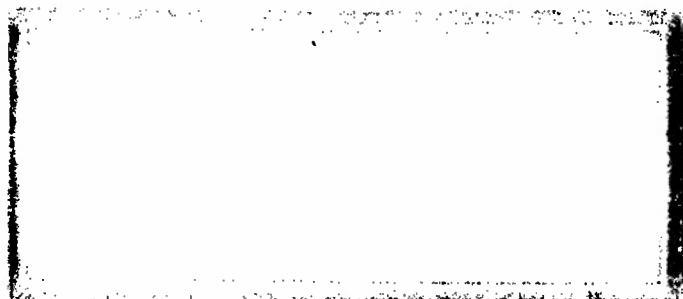
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ABSTRACT:

The methods of production and calibration of combination vapor pressure and gas dial thermometers are described. The methods of construction and testing of the Bourdon springs as well as the bulbs are given. These procedures yield a thermometer which gives accurate readings with a single standard dial. The routine checking of the final thermometer at certain fixed points is outlined as well as the checking method for the occasional complete calibration of the instrument.

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