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The Prevention of Fogging of Optics in Submarine Periscopes

NAVAL RESEARCH LABORATORY
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NAVY DEPARTMENT

Report on

The Prevention of Fogging of Optics in Submarine Periscopes

NAVAL RESEARCH LABORATORY
ANACOSTIA STATION
WASHINGTON, D. C.

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Work done by: Willian H. Schechter, Assistant Chemist

Prepared by: R. R. Miller, Senior Chemist

Reviewed by: P. Borgstrom, Superintendent, Chemistry Division

Approved by: A.H. Van Keuren, Rear Admiral, USN, Director

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ABSTRACT

This report covers the experimental work done on the evacuation of periscopes by this laboratory for the purpose of reducing the condensable vapor concentration to values below the dew points for any service temperatures. The equipment necessary and part of the operations have been reviewed.

[redacted]

AUTHORIZATION

1. BuShips ltr. to Director of NRL, C-S24-9(350 dated November 28, 1942.

STATEMENT OF PROBLEM

2. Fogging of the optics in submarine periscopes is due to condensation of vapor on the optical surface when the temperature of the optics is below the dew point of the periscope atmosphere. The problem is therefore one of removing the vapors from a periscope to such a level that condensation cannot take place from the gas within the periscope at service temperatures.

KNOWN FACTS ON THE PROBLEM

3. Fogging of optics by condensed vapors can be caused by any compound present in quantities above its dew point at the temperature of operation. The amount of vapors which can be present from the drying of cements, sealing compounds and any nonmetallic parts is assumed to be less than could cause fogging at temperatures encountered. Water vapor is considered to be the cause of fogging taking place in submarine periscopes. Any water vapor present above partial pressures shown on plate 2 at the various temperatures can cause fogging. In an enclosure where circulation of the gas is limited, fogging can be visualized with less water than enough to saturate the entire volume of gas. When one part of the periscope is below the dew point of the gas for long periods of time water vapor can slowly condense in this part. Water vapor will slowly diffuse from the entire periscope until the vapor pressure of the entire tube is in equilibrium with the low temperature. On warming, the water will only return to the remainder of the periscope by diffusion and for a time may saturate the gas in one part to a value much higher than the average throughout the tube. In this one spot it will then, for a period of time, be possible to get fogging at a temperature much higher than would be expected. For this reason the water vapor should be reduced to the lowest practicable value.

THEORETICAL CONSIDERATIONS

4. Two acceptable methods of drying are available. (1) Circulating dry gas through the periscope. (2) Reducing the pressure to a suitable low value and filling the periscope with dry gas. Both methods have advantages and disadvantages with respect to each other; the advantages being greater in the vacuum method. Flow drying may leave some parts, where poorly ventilated, retaining considerable water vapor. It is not easy to know when the periscope is dry by

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this method. For the vacuum method to be entirely satisfactory it must be assumed that all water present is in the vapor phase, and when evacuated to 4 mm. [as directed in Restricted ltr. BuShips SS/S24-9(815), Jan. 2, 1943 to the Comdr. Submarine Atlantic Fleet, Comdr. Submarine Southwest Pacific Fleet and Comdr. Submarine Force Pacific Fleet] from atmospheric pressure or above that, at least no more than 4/760 of the original water is present in the periscope. 4/760 of saturated gas at 25°C. will give a dew point of -38°C. This method has the advantage of determining inward leaking by securing at low pressure, and also can show if condensed water is present in quantity by the pumping down curve. When the method is applied as described in BuShips ltr. (identified above) liquid water would show a constant pressure on the gauge equal to the vapor pressure of water at the temperature of the periscope until the liquid had evaporated. If such were the case most of the gas in the periscope when 4 mm. is reached would probably be water vapor, and the dew point would be near 30°F. (plate 2). This can be remedied by increasing the pressure in the periscope from 4 mm. to 1/4 to 1/2 an atmosphere with dry nitrogen and again reducing the pressure to 4 mm. of Hg.

5. 4 mm. of Hg. has no particular significance as a pressure to be attained except that it is well below the vapor pressure of water at the temperature recommended (50°F. BuShips ltr.) for the low temperature of evacuation. This pressure is also approximately the vapor pressure of ice at the freezing point. While water and ice can be evaporated by reducing the pressure below the vapor pressure of the liquid or solid, the process is very slow for the lower temperatures. The rate at which gas moves through an orifice is proportional to the difference in pressure across the orifice. Thus when water (fog) is to be removed from a periscope it should be done well above the freezing temperature to the 4 mm. Where fogging temperature is above 32°F. it will take less time for evacuation when it is done above the fogging temperature than would be required to evacuate it below that temperature.

EXPERIMENTAL WORK

6. A periscope which had shown fogging on the USS Runner was evacuated under the direction of Comdr. Frank Dettman by personnel of the optical school at the Washington Navy Yard and observed by NRL personnel. A copy of a memorandum to the Director of NRL on this work is included as Appendix I. The only requirement other than stock items appeared to be a vacuum pump suitable for handling on shipboard and a vacuum gauge suitable for accurate reading at low pressures (1-10 mm.). The gauge besides being sensitive should also be sufficiently durable for shipboard use.

[redacted]

7. Two methods of making a satisfactory gauge were investigated, one being a protected glass manometer with mercury as the pressure indicating liquid. This was the type selected and is shown in a sketch drawing in plate 3 and a photograph on plate 4.

8. The second method of gauging low pressure was making use of mechanical amplification of the extension and contraction of a pressure sensitive bellows. This method gives satisfactory results but is more susceptible to leaks. Small leaks in the gauge would give faulty readings and if they could be repaired the calibration would more than likely be incorrect. Glass parts were also required and in a more delicate position. The gauge used can be used as any sensitive metal gauge is used. It has a 1/4 in. standard male pipe thread on a standard size brass shank. This can be tightened and loosened in the vacuum line with a wrench. The manometer is connected to the brass block through a Kovar metal to glass seal with the Kovar fitted and soldered into the brass. The enlarged leg on the glass tube contains a bulb of silver turnings to prohibit mercury vapor from reaching the solder, brass or periscope. Just above the silver is a trap large enough to hold all of the mercury in case the tube ever developed a crack in the liquid arm and allowed the mercury to flow out of the U-tube proper. The glass tube is held to the back in a number of spots with rubber to limit the motion of the tube and prohibit strong forces on the glass-metal seal in case of shock. The rubber is a self setting elastic cement. The gauge is enclosed in a heavy metal case fitted with a sight glass and cover. Twenty-six of these gauges were made up and shipped as directed by the Bureau of Ships.

9. The vacuum pump recommended is the Cenco Megavac type housed in a vertical position with the pump mounted above the motor. In this position the unit is about 14" x 14" by 30" high. It has two handles for carrying or raising and lowering through hatchways. The total weight is about 160 lbs. The housing covers the moving parts and is of sufficient strength to protect the pump and motor in case the unit is accidently upset. These pumps are capable of pumping to a few mm. of Hg. after several hundred hours of pumping with reasonable care. Instructions are stamped onto the cover plate of the pump proper.

10. After completion of a gauge and remounting a pump, laboratory personnel took the apparatus to the submarine base at New London and proceeded to evacuate a periscope in the shop. Considerable difficulty was experienced with leaks in the vacuum line. However, by careful manipulation and satisfactory sealing of the joints, a periscope was evacuated and the dew point reduced to -30°F., a satisfactory value. The memorandum of this work is included as Appendix II.

[redacted]

11. Six pumps were housed and made ready for shipment, and each used to evacuate a cylinder of approximately the same volume as the 40 foot periscopes. The pumps gave values of pressure in the cylinder against time as shown on plate 1. The gas was removed through a hole 1/32" diameter and 1/4" in length. This is a very close approximation to the size of the outlet hole in the periscope. The gas in the cylinder was not hampered in freedom of motion as is the case in a periscope. Nevertheless, the "outlet" opening of the periscope is without doubt the cause of the limited flow from the periscope. This was further shown by evacuating the cylinder with a Hyvac pump. This pump has only about 1/3 the displacement but was only 20 to 30 minutes slower at any point in reducing the pressure to the same value. The effect of the small hole is paramount to the other connections since the pumping of the cylinder and the periscope are of approximately the same duration. It was stated in appendix I that shorter vacuum lines would probably have increased the speed of pumping. Both of the pumps described above were able to keep the pressure sufficiently low in the vacuum line so that the difference of time was only a fraction of the total pumping time. Thus the size of the vacuum line is not too important but it should not be longer, however, than required. There are some advantages of the Megavac pumps over the Hyvac such as length of satisfactory running life, more moisture and sludge can be tolerated in the Megavac, and the ultimate pressure obtainable is somewhat less with the Megavac.

12. In attaching this apparatus to the periscope, contact is made through threaded holes (1/4" diameter) which connect with the 1/32" hole to the seating chamber of a needle valve which seals the periscope. A screw attached to the valve must be backed out to open the valve. Leaking can take place between the seating chamber and the exterior of the periscope since this hole is closed only with the loosened screw. When on evacuation the screws required sealing of some type. A soft sealing wax has been used which in all cases gave satisfactory results. Wax made at this laboratory contained the following: Beeswax (4 parts), Venice turpentine (1 part) and Rosin (2 parts). A small jar was supplied with each gauge.

DISCUSSION

13. The most serious trouble in all probability will be the making of vacuum tight joints in the vacuum lines to the periscope. For that reason carefully tightened and sealed joints will save considerable time. The connection between the pump and "outlet" on the periscope should be short (3'-6') and with as few joints as possible. Any good grade heavy wall rubber tubing would be satisfactory. The rubber should be one piece between the pump and the thread fitting which screws

[redacted]

into the periscope "outlet." The vacuum gauge will connect directly with a 1/4" pipe elbow to the threaded fitting which screws into the periscope "inlet." At least a part of the pieces for making contact with the periscope have a threaded section which is too long to tighten into the periscope on a single gasket (leather washer) without obstructing the air flow in the 1/32" hole. The use of two of the gaskets on each connector has been sufficient to eliminate the trouble on periscopes evacuated.

14. Evacuation, once started, should be completed without interruption and while evacuating the pumps should always be attended. In case of power failure the stopped pump with its valves is required to hold atmospheric pressure against whatever is present in the periscope. A small amount of dirt may cause the valve to seat improperly and allow the oil to flow back into the periscope. In case the power fails the periscope should be secured and the pump-to-periscope vacuum line disconnected. Wax or some other method of sealing will always be required over the screws lifting the periscope valves and occasionally on some joints.

15. Attention should be called to the method of determining dew point used at New London, Appendix II. Where solid CO_2 or other suitable cooling means are available the dew point of the periscope atmosphere can be determined on the staunching window or eyepiece of the periscope. When the periscope is horizontal, a sleeve or collar can be sealed to the staunching window or eyepiece with wax so as to have the optical piece make the bottom of an open container or cup. The sleeve can be any material that will hold alcohol and CO_2 snow - metal, glass, waxed paper, etc. The cooling is done by pouring alcohol or acetone into the cup and dropping in the CO_2 snow slowly, following the temperature with a thermometer in the solution. The formation of water on the underside of the optical piece is observed through the solution. On a vertical periscope, a clear glass bottle or large glass tube, cut on an angle, can be fitted with a wax seal in a similar manner. The observation of the moisture formed inside the optical piece can be observed through the glass and solution, normal to the optical piece. Observations made on cooling 1/4" plate glass show that each temperature should be held 15 minutes for temperature equilibrium before further cooling is started. On cooling, 5° to 10° intervals may be used to locate the approximate dew point, then the dew point temperature should be approached more slowly to determine it more accurately.

16. The enclosures of the BuShips' letter, identified on page 2, should be consulted for changes in the present silica gel dryer to make it suitable for this work.

[redacted]

CONCLUSIONS

17. Periscopes should be evacuated when their coldest part is not below 40°F. (6.5 mm.) and at higher temperature if possible. Nothing would be accomplished below 32°F. Dew points at -30° to -40°F. can be readily obtained on gas tight periscopes by evacuating and refilling with dry nitrogen. The nitrogen should be dried with a good desiccant such as silica gel or activated alumina.

[redacted]

APPENDIX I.

C-S24-9(452)hdr December 15, 1942

MEMORANDUM to the Director.

Subject: Drying of Fogging Periscopes.

On December 8th, I reported to the Navy Yard at 5 p.m. to observe the drying of a periscope by the method suggested by Comdr. Frank Dettman. The method consists essentailly of pumping air from a periscope to a vacuum of approximately 4 or 5 mm. of mercury and allowing dry nitrogen to flow into the periscope, thereafter the pressure being raised approximately 7 lbs. per sq.in. with dry nitrogen. The operations carried out on the USS Runner periscope #2 were in general as described above. The work was being done by Ensigns Debenham and Clearman of the Optical School with the aid of enlisted personnel from the optical shop at New London, Connecticut (Mr. C. A. Stanish and Mr. Pete Martinelli). The pumping was done with a Kenny high vacuum pump which had a large capacity for this work, and the limit of pumping was determined by the opening in the periscope itself and the connections between this opening and the pump. The hole in the periscope for removing air is approximately 1/32th of an inch in diameter and about 1/2 inch long. This feature, to a great extent, controls the pumping rate on the periscope, however, considerable larger tubing from this connection to the pump is important in the pumping speed. Since the flow of gas through an opening is proportional to the area and inversely proportional to the length of the opening, a considerable increase in the rate of pumping could be made by increasing the size of this hole to 1/16 inch diameter. Doubling the diameter increases the area four times. The pumping speed is also a function of the difference in pressure across the opening. Since most water, when in a condensed form, would be removed at relative low pressures (0-25 mm. of mercury) the size of the opening becomes even more important.

In the method used on the USS Runner some delay in acquiring a vacuum was no doubt due to the small copper tubing used in connecting the periscope to the pump, however, enlarging this tubing would not have shortened the pumping time by any large amount. It required approximately one hour to reduce the pressure from atmospheric to 100 mm. of mercury. Several hours were then required to bring the pressure in the neighborhood of 5 mm. (approximately 5 hours). A U-tube in the line when dipped in dry ice - alcohol mixture - showed that considerable water was being removed from the periscope. A part of the time required to bring the pressure down may have been required to evaporate the exhaust water from the interior of the periscope. The nitrogen used to fill the

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periscope was passed through a copper coil in a mixture of dry ice and acetone. The rate of flow was slow to insure that all water was removed to a dew point of this temperature.

This method of drying periscopes appears to be satisfactory and with the use of the proper technique the drying should be completed in the order of 3 to 4 hours depending on the amount of water vapor present in the periscope and its physical state at the time the drying is started.

Apparatus required to make this method plausible for shipboard use is listed below with comments.

1. Pressure gauges which are sensitive, from 40 mm. to 0 mm. of mercury, are necessary to determine accurately the pressure to which the periscope has been evacuated. This requires a gauge which is stable in use and shipboard stowage. Three types of apparatus would be satisfactory; a short mercury manometer, a sensitive bellows type gauge and the Stokes Portable Mcleod gauge. All three require some section of clear material for reading the pressure. In each case glass would probably be most suitable and could be so constructed as to be satisfactory. A model of each of these types will be available at the Laboratory in the near future.

2. Some method of further drying the nitrogen is required. Suitable containers of a desiccant similar to silica gel would be satisfactory for this purpose. Two shipments of silica gel are being reactivated to send to the optical shop at New London for experimental tests. At the same time tests will be conducted at this Laboratory to determine the dryness of the nitrogen and the limits on this type dryer.

3. Some method of removing water vapor from the gas entering the oil pump should be used. The same type container as used for drying nitrogen could be used on this line. This container should be used only after reactivation in drying the nitrogen, however, a unit which had been used to dry nitrogen could then be used on the pump before reactivation.

4. To give consistent and satisfactory results a good oil pump of the Kenny or "Cenco Megavac" type should be used. With care these pumps will pump to a few millimeters after hundreds of hours

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of operation. Inquiry has been made into the availability and price of the "Cenco" pumps. The "Cenco Megavac" pump with 1/2 h.p. for 110 A.C. are available at $155 each. At least six are on hand at the Central Scientific Co., Chicago, Ill.

Investigation of this problem has been going forward as authorized by BuShips' letter to NRL dated 28 November 1942, file #C-S24-9(350).

R. R. Miller
Chemistry Division

cc: BuShips (350)

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APPENDIX II.

C-S24-9(452:WHS)hdr January 1, 1943.

MEMORANDUM to the Director.

Subject: Periscope Drying - Tests at New London
Submarine Base, December 22 & 23, 1942.

The tests at New London were conducted in the optical shop of the Engineering and Repair Division of the Submarine Base. The Submarine Base was represented by Comdr. Howard Clark, Engineering and Repair Officer; Lt. Comdr. Zabilsky, Ass't. Officer; Machinist F. A. Payne, in charge of optical shop; Machinist D. W. Drury; C.M.M. Martinelli; and C.M.M. Hawk. Comdr. Beltz and Mr. Cartin were from the Bureau of Ships, Lt. Kerridge from the Bureau of Ordnance, and Mr. Kollmorgen from the Kollmorgen Optical Corporation. The Naval Research Laboratory was represented by Lt. Ferguson and W. H. Schechter.

Comdr. Beltz outlined the procedure to be followed in the tests. The periscope on which the tests were run had been overhauled about two months previously in the optical shop and charged with dry nitrogen. The dew point of this periscope was found to be between 10 and 20°F. and it had lost only a small amount of gas in the two month period. The periscope was evacuated but due to leaks the 4 mm. limit was not reached, so air from the room was allowed to run in over night in order that plenty of moisture would be present in the periscope. The next morning, using a Cenco Hyvac pump connected to the "air-out" opening, the periscope was evacuated to 4 mm. Due to a leak which was finally eliminated, it took 3 1/2 hours to reach this pressure but with no leaks this time would be shortened considerably. As soon as 4 mm. was reached the "air-out" opening was closed and the pump removed. After standing three hours the periscope still maintained the same reading so it was assumed to have no appreciable leak.

While evacuated, the dew point of the periscope was tested by Lt. Ferguson. A glass bottle was cut and fitted to the staunching window so that it could be cooled and observed. The dew point was found to be about -40°F. and after filling with dry nitrogen had raised only 5° or 10°. The nitrogen was dried by passing it through about 12 inches of freshly reactivated silica gel, then filtered through cotton to keep any fine silica particles from getting on the optics of the periscope. Diopter readings were taken during the filling process and gave -1/2 diopter at 5# N_2, -1 diopter at 10#, and -1 1/2 to 2 diopters at 15#. Because of the difference of refractive index of the nitrogen at

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different pressures the periscopes must be adjusted when assembled for a certain pressure then this pressure maintained as long as the periscope is in use.

As a check on factory assembled periscopes the dew point on two that had been installed only a couple of months was determined on the U.S.S. Scamp. One was found to have a dew point of around -25°F. and the other about -5°F. One periscope was in the danger zone as the submarine had been operating in sub-zero weather.

From these tests it would seem that the evacuation of the periscope to 4 mm. and then filling with dry nitrogen to a specified pressure and this pressure maintained would be a satisfactory and rather simple method of lowering the dew point sufficiently to prevent fogging.

W. H. Schechter
Chemistry Division

[redacted]

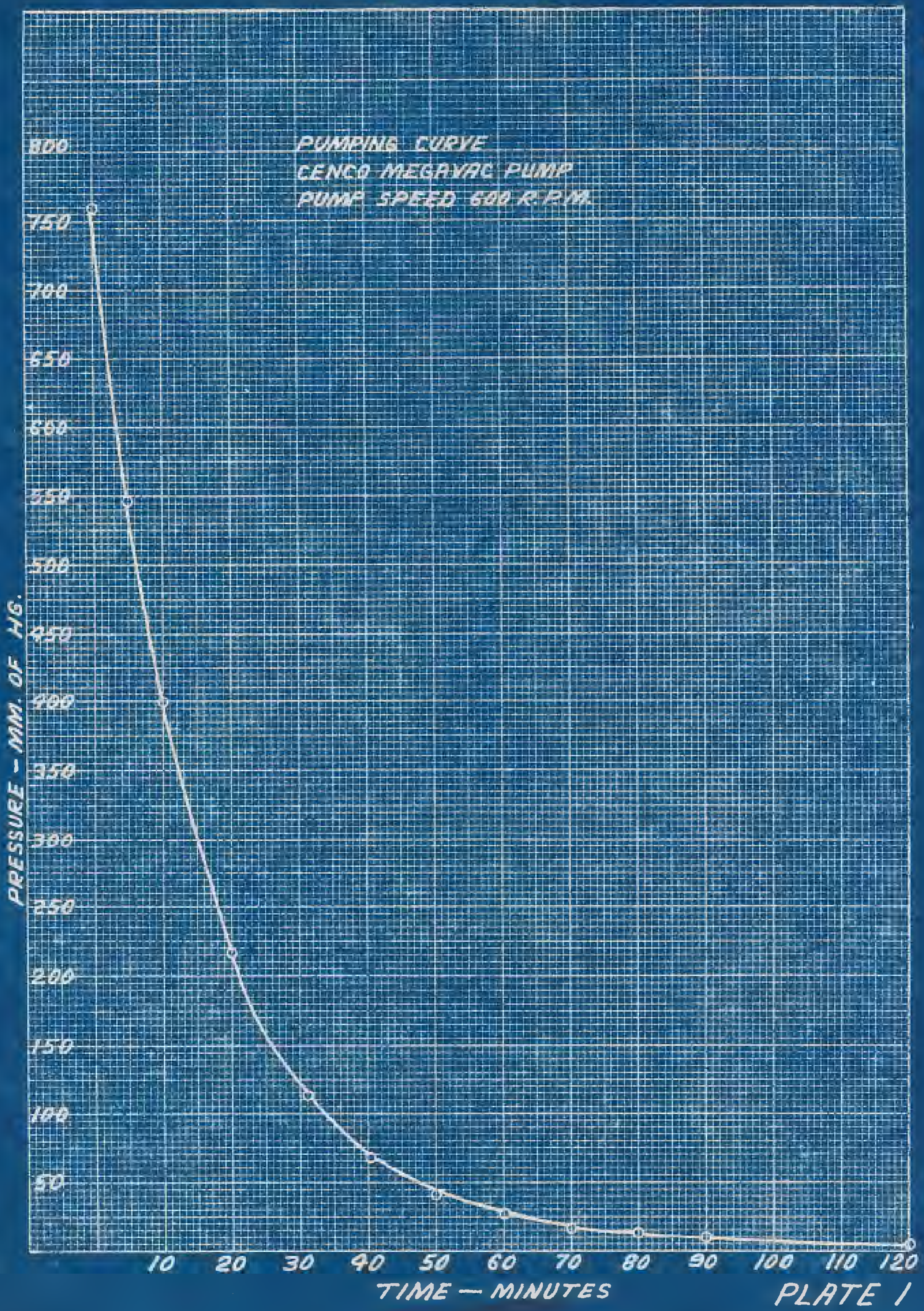
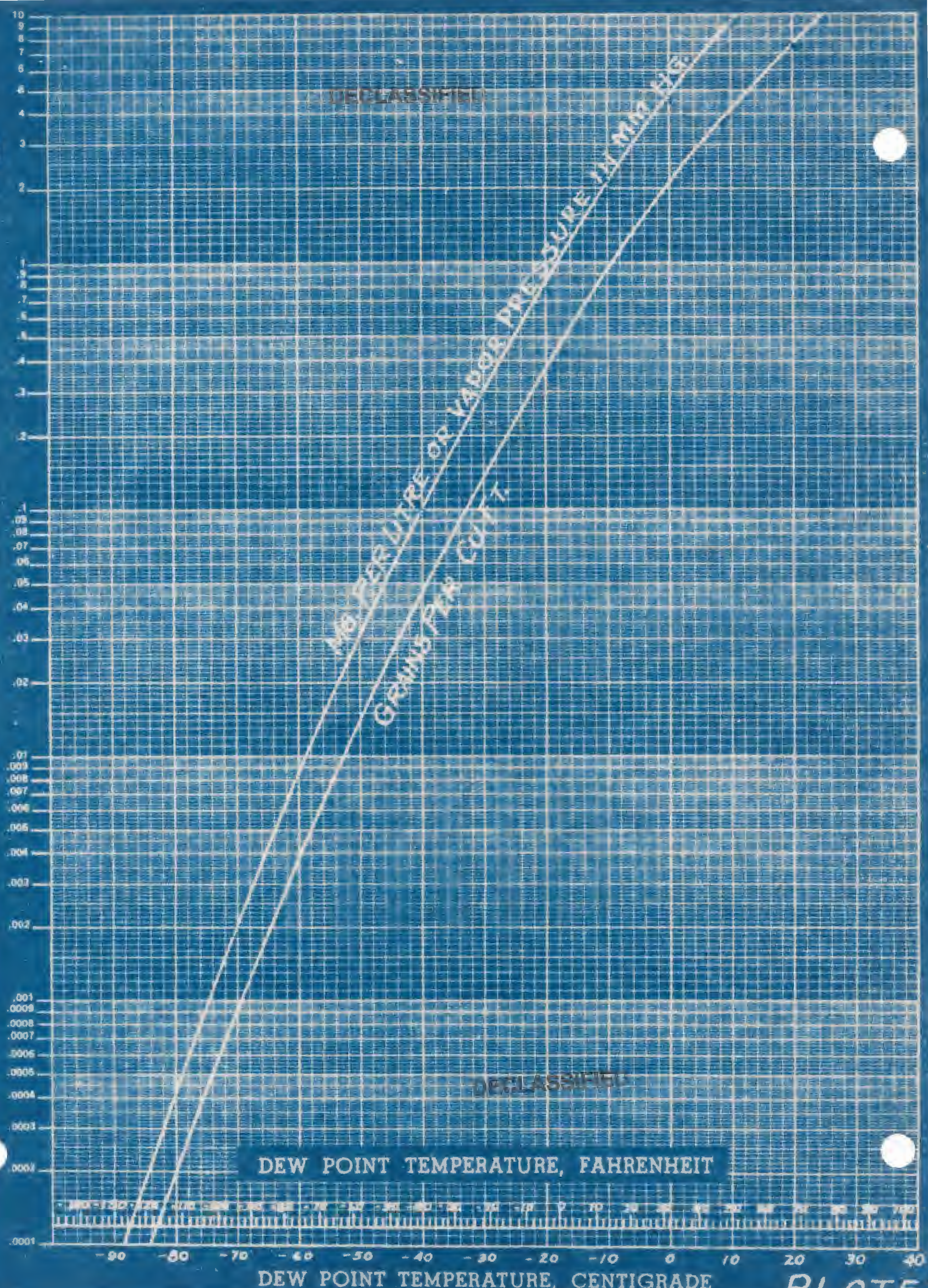

PUMPING CURVE
CENCO MEGAVAC PUMP
PUMP SPEED 600 R.P.M.
800
750
700
650
600
550
500
450
400
350
300
250
200
150
100
50
PRESSURE - MM. OF HG.
10
20
30
40
50
60
70
80
90
100
110
120
TIME — MINUTES

PLATE I


DECLASSIFIED
MG. PER LITRE OR VAPOR PRESSURE IN MM. HG.
GRAINS PER CU. FT.
DECLASSIFIED
DEW POINT TEMPERATURE, FAHRENHEIT
DEW POINT TEMPERATURE, CENTIGRADE

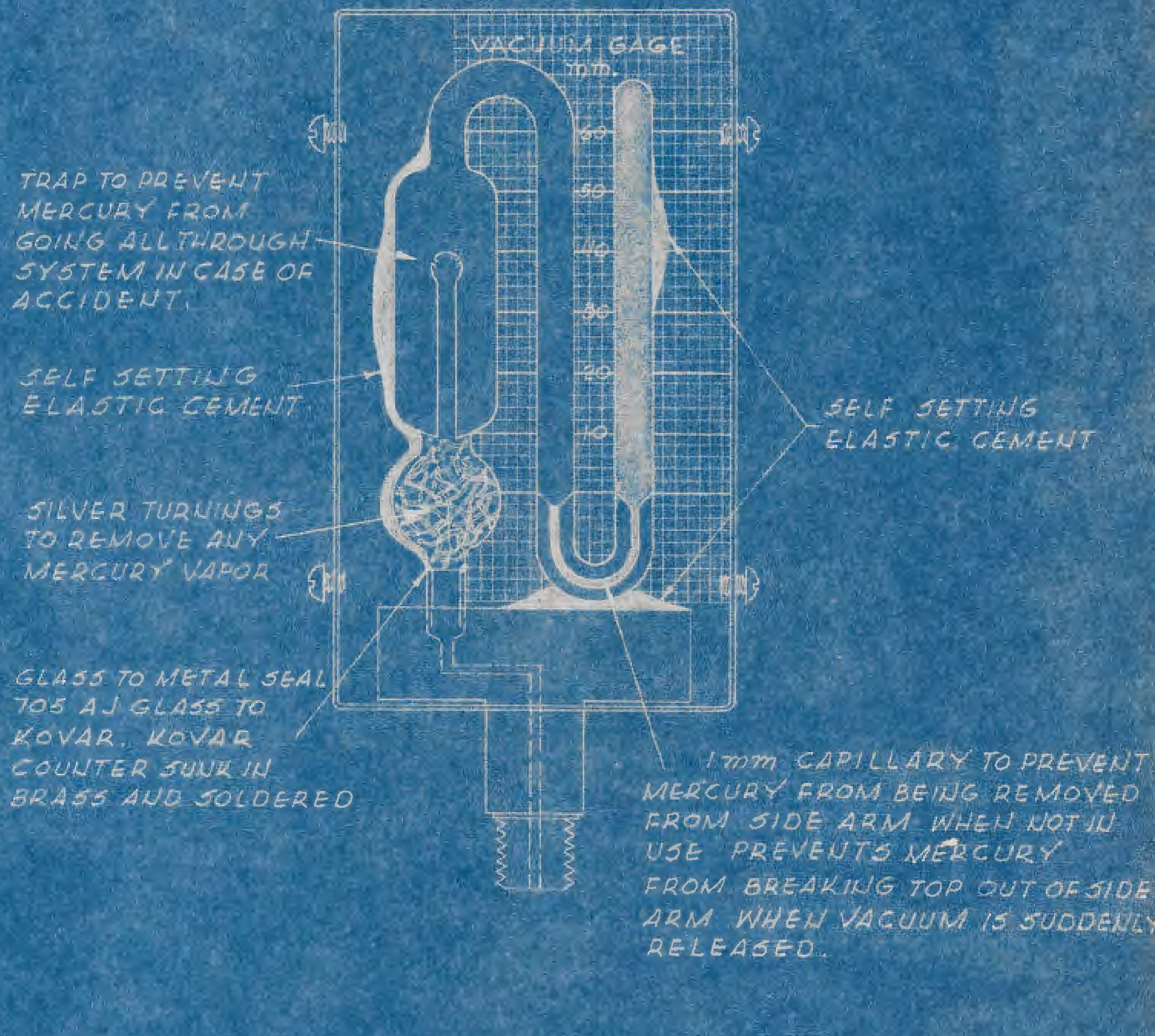

VACUUM GAGE
mm.
60
50
40
30
20
10
TRAP TO PREVENT MERCURY FROM GOING ALL THROUGH SYSTEM IN CASE OF ACCIDENT.
SELF SETTING ELASTIC CEMENT
SILVER TURNINGS TO REMOVE ANY MERCURY VAPOR
GLASS TO METAL SEAL 705 AJ GLASS TO KOVAR. KOVAR COUNTER SUNK IN BRASS AND SOLDERED
SELF SETTING ELASTIC CEMENT
1 mm CAPILLARY TO PREVENT MERCURY FROM BEING REMOVED FROM SIDE ARM WHEN NOT IN USE PREVENTS MERCURY FROM BREAKING TOP OUT OF SIDE ARM WHEN VACUUM IS SUDDENLY RELEASED.

PLATE 3

PLATE 4