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PR-2127

REPORT NO. O-2127

DATE 30 July 1943

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SUBJECT

Fourth Partial Report on Liquid Thermal Diffusion Research

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Reference Authority
6/8/59
J Bliss
Signature of Custodian

NAVAL RESEARCH LABORATORY

BELLEVUE, D. C.

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SERIAL No. 11

July 30, 1943 N.R.L. Report No. O-2127

NAVY DEPARTMENT

Fourth Partial Report

on

Liquid Thermal Diffusion Research

[redacted]

NAVAL RESEARCH LABORATORY
ANACOSTIA STATION
WASHINGTON, D. C.

Number of Pages: Test - 4 Plates - 8

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TABLE OF CONTENTS

Introduction

1. Considerable work has been performed in the investigation of the liquid thermal diffusion isotope separation method during the period between February 1, 1943 and July 15, 1943. In that time, 18 columns have been built or completely renovated, apparatus has been operated 1000 column days, and a total of 400 samples have been sent for analysis. This work has led to the design and testing of columns suitable for operation at high temperatures and pressures and possessing no bellows and little dead space. A pyramid consisting of four layers and employing eight columns has been successfully operated for 42 days. A series of experiments employing high pressure steam has demonstrated the value of employing high hot wall temperatures. Experiments have shown that columns built alike perform alike. Other tests show that columns may be run for long periods without change in performance.

Column Construction

2. About February 1, 1943 it became clear that the construction of a column capable of withstanding high temperatures and pressures was necessary if the advantages of high hot wall temperatures were to be exploited. Ultimately, a design was perfected leading to columns capable of being run at a hot wall temperature of 286° C and a UF_6 pressure of 4000 lbs per square inch. A typical UF_6 operating pressure is 1000 p.s.i. The column possesses no bellows and is simpler to construct than earlier models.

3. The new type column has been tested under various operating conditions over a total of 600 column days. No failures of any kind have occurred. Blueprints (Plates 1-3) of the new design are attached.

Reproducibility

4. One question of interest in connection with the performance of columns is that of reproducibility. Some generalizations can be made; any column one can construct will give isotope separation. If the O.D. of the nickel and the I.D. of the copper are properly chosen, this separation will be fairly large even if the nickel is not spaced concentric with the copper, or even if other gross imperfections are present. Thus, an imperfectly constructed column might have a spacing of .20 mm. on one side and .30 mm. on the other. Yet this column would give an equilibrium separation of 60% to 90% that of a much more carefully constructed unit whose spacing was always close to .25 mm. At the same time, it is observed that an imperfect column has a longer equilibrium time.

5. An experiment has been conducted using five columns to check reproducibility. These columns were made as nearly alike as possible. Hot wall temperature of 185° C and a cold wall temperature of 60° C were employed. The results are shown in the following table:

Time	Col. #33	Col. #34	Col. #37	Col. #38	Col. #41	Average
1-1/4 days	11.0	11.4	10.3	11.4	8.8	10.6
3-1/4 days	17.7	14.9	17.0	19.3	15.7	16.9
8-1/4 days	28.5	29.7	22.0	28.6	25.7	26.9
12-1/4 days	31.8	34.0	35.7	35.5	31.7	33.7
17-1/4 days	37.4	41.8	43.6	41.5	39.1	40.7

6. It is of interest to note that the initial part of the curve deviates strongly from the equation:

$$\log S = B(1-e^{-kt})$$

7. A number of our columns have been run practically continuously for six months at a hot wall temperature of 185° C and a cold wall of 60-65° C. Performance curves were obtained at the beginning of operation of the pilot plant. Recently new performance curves were obtained. The two sets of data are in good agreement as shown in Plate 4.

The Pyramid

8. Several combinations of columns in series and parallel have been run successfully. Most noteworthy is a group of eight arranged in a pyramid consisting of 1-2-4-1 and connected together in the manner shown in Plate 5. Circulation in the loops is obtained through the action of thermal convection. To prevent convection between columns, valves are placed as indicated in Plate 5. The valve action is obtained by freezing UF_6 in a section of the 1/16" I.D. tubing.

9. The pyramid was placed in operation as follows: The eight columns (no bellows type) were produced by renovating eight old bellows type units. After being hung in place the columns were cleaned, dried, and fluorinated. Connecting loops were installed and a storage chamber placed in position and heated. Steam and circulating water were turned on. At this point the unit should have been in operation. However, due to incomplete drying of the columns a plug occurred in one of the loops. This was quickly corrected. The pyramid was operated for 42 days with no further difficulty or interruption. Operation ceased only when a shutdown occurred for a customary boiler cleaning and it was felt that other experiments should be performed. During the period the duties of operating personnel consisted in changing circulation every two hours, occasionally checking circulating water temperature, and removing samples.

10. At the withdrawal rate of 205. gms. per day of enriched material, the pyramid settled down to the following average conditions:

Bottom of pyramid = Bottom of 4 columns in parallel	Bottom of Two Columns in parallel	Bottom of Top Column	Top of Pyramid
- 5.7	+ 9.2	+ 23.2	+ 30.2

11. It is clear that the pyramid was not operated under optimum withdrawal conditions. The proper rate was about 100 gms. per day which would have resulted in a separation factor between top and bottom of close to S = 1.7 instead of S = 1.376.

Column Performance at High Temperatures

12. A study has been made of the possible use of high hot wall temperatures. Unfortunately, our present steam facilities do not permit the simultaneous operation of more than one 48 foot column at steam pressures over 170 lbs. We have operated in the pressure range from 600# to 1000# three 12 foot, four 24 foot, three 36 foot, and four 48 foot columns. The data collected from runs on these columns is presented in the following table:

Col.#	d mm.	L	T_1 °C	T_2 °C	Power Cals/sec	Col. gms.	Bellows gms.	Max. Meas. Sepn.	Calc Equil Sepn.	Calc. Half Time No Bellows	Effec. L
27	.25	36'	65	254	29,000	1260	400	1.367	1.40	.51 days	18'
28	.30	36'	65	254		1500	400	1.20			
29	.25	24'	65	254		1100	100	1.185	1.19	1.2 days	24'
30	.25	24'	65	254		1100	100	1.19	1.195	1.2 days	24'
31	.20	36'	65	254	35,000	150	400	1.28	1.496		
32	.20	24'	65	254		700	100	1.24	1.31	1.8 days	24'
35	.23	24'	65	254		820	100	1.16	1.20	1.4 days	24'
42	.25	12'	61	254		380		1.106	1.107	5 hrs.	12'
43	.25	12'	61	254		380		1.071	1.073		
45	.23	12'	61	286		340		1.12	1.123	7.5 hrs	12'
34	.25	48'	65	254		1720		1.45	1.62	2.5 days	40'
34	.25	48'	65	270				1.52	1.66	2.25 days	40'
34	.25	48'	60	286	48,000	1600		1.62	1.785	1.7 days	38'
36	.23	48'	61	286		1540		1.51	1.62	2 days	40'
44	.23	48'	61	267	51,500	1540		1.71	1.90	5 days	46'
46	.20	48'	61	259	50,750	1340		1.793	2.23	8 days	41.5'

13. In the above table we have presented all the data that has been collected in the course of high temperature runs. Some of this data was obtained from columns which post mortem examination showed to be not perfect. The last column, labeled effective length, refers to the fact that the neutral point of some columns is not at the end. This is important when considering the true equilibrium time of the whole column. Figures for the separation are given for the full length as listed in the third column.

[redacted]

Rate of Material Withdrawal

14. The relation between hold-up, equilibrium time, and permissible rate of withdrawal has not been well established. The problem is complicated by the fact that an equation of the type $\log S = B(1-e^{-kt})$ does not hold over the entire range of the s vs. t curve. Under these circumstances the concept of a half equilibrium time is of limited significance. Fortunately, deviation from the exponential type of curve occurs mainly at the start with observed separation increasing much more rapidly than $\log S = B(1-e^{-kt})$. In plates 6 and 7 are shown two typical curves of time vs. separation. Over the portion of the curve from half of equilibrium on, it is possible to fit an exponential curve with reasonable accuracy.

15. A plot of amounts which can be withdrawn at various fractions of equilibrium separation is given in Plate 8.

16. Work is progressing in an effort to obtain more points on this curve. In our calculations of permissible withdrawal rate, we assume that at half equilibrium one can withdraw .36 columns per half time period. On this basis one can withdraw from a .25 mm. 48 foot column operating at 1000# of steam, 208 gms. UF_6 per day with a separation factor of 1.336. For purposes of plant design it would probably be safer to take a production rate of 150 gms. per day with a separation of 1.30.

Separated Materials on Hand

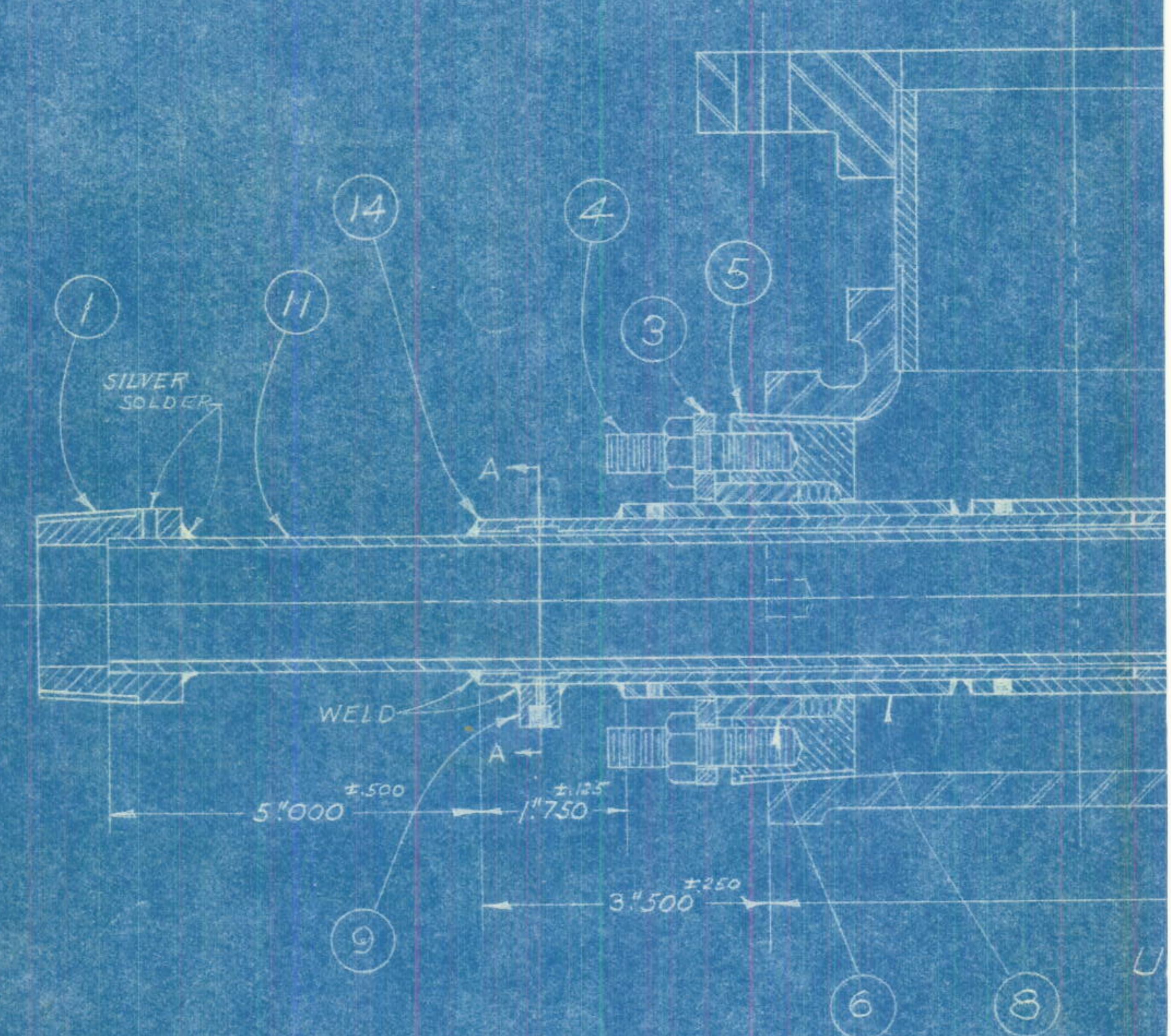
17. Incidental to our various experiments we have collected certain quantities of UF_6. This material represents less than half of that actually separated. A list of the principal items on hand follows:

1 lb.	+ 38.9
8.5 lbs.	+ 30.4
15 lbs.	+ 21.7
16.5 lbs.	+ 14.1
29 lbs.	+ 13.8
15 lbs.	- 17%
46 lbs.	- 8%

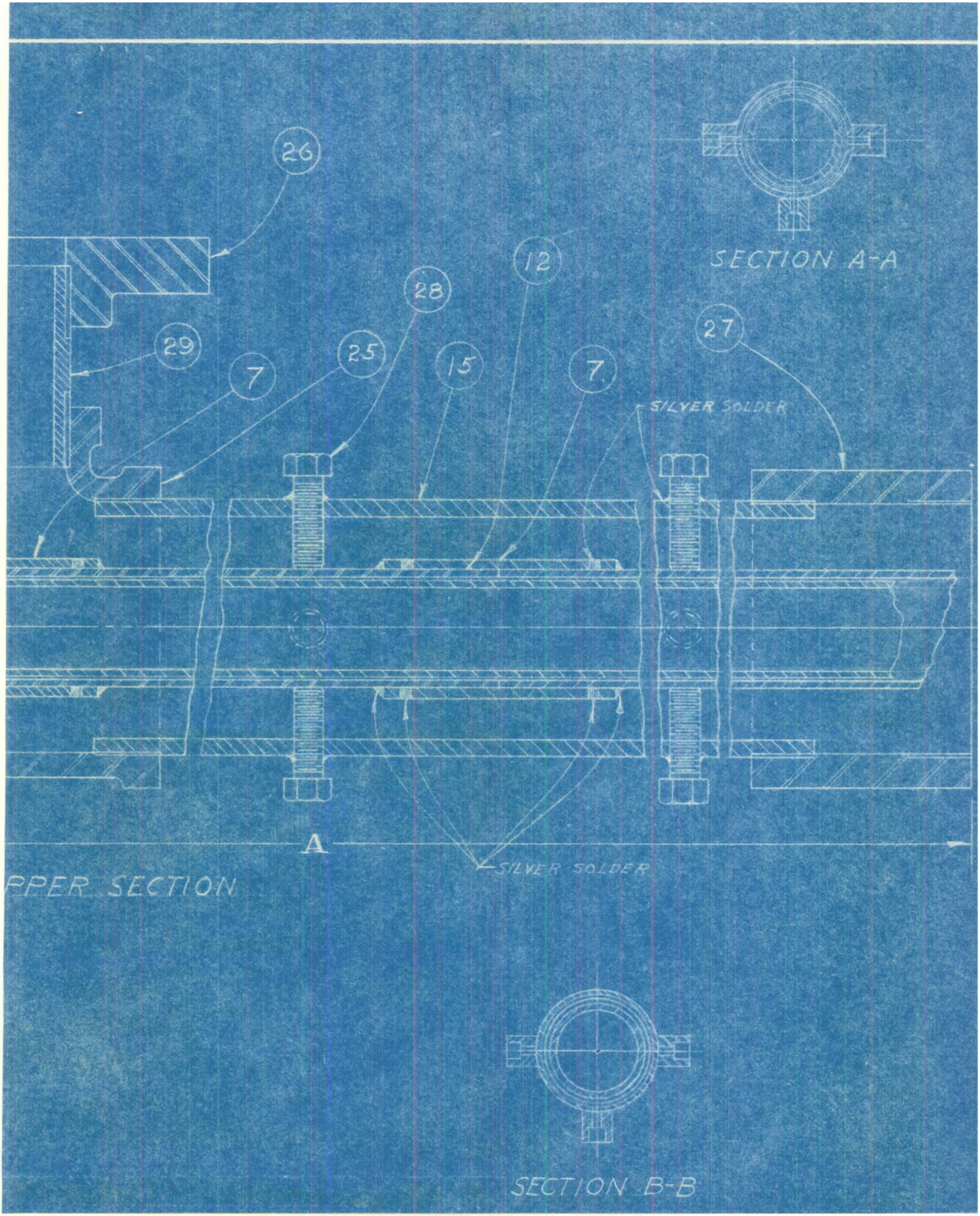
The enriched material could be mixed together to give 70 lbs. of+17.8% UF_6.

[redacted]

N. R. L. 66



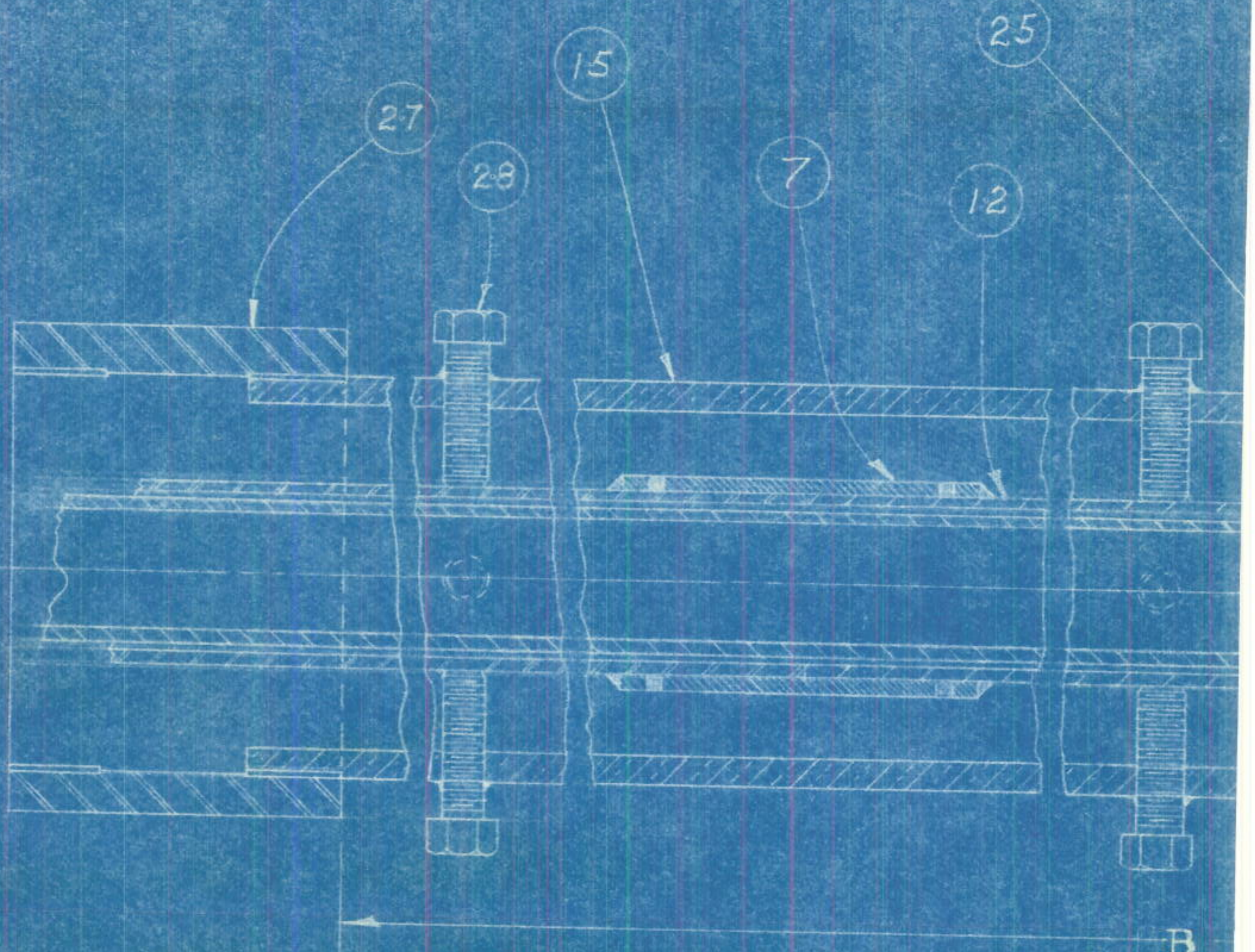
SILVER SOLDER
14
4
5
1
11
3
A
WELD
A
5."000 ±.500
1."750 ±.125
3."500 ±.250
9
6
8

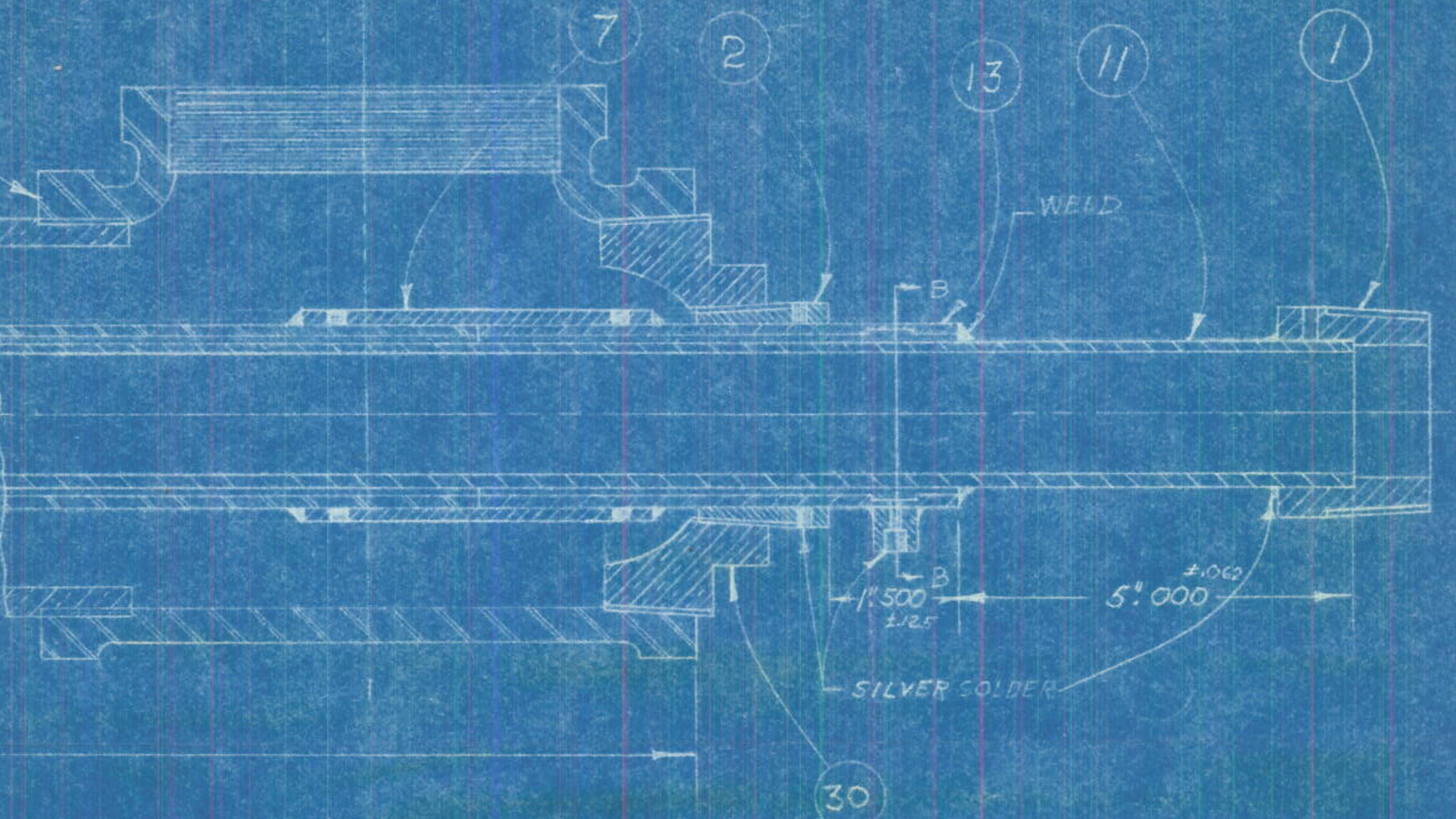


SECTION A-A
26
12
28
27
29
25
7
15
7
SILVER SOLDER
A
SILVER SOLDER
PPER SECTION
SECTION B-B

PART NO.	NO. REQ'D.	MATERIAL	DESCRIPTION	REMARKS
			PARTS NOT DETAILED	
25a	2	STEEL	STANDARD 4" TEE	COMMERCIAL
26a	1	"	" 4" FLANGE	"
27a	AS REQ'D.	"	" 4" COUPLING	"
28a	16	"	$\frac{1}{2}$"-20 X 2" AM. ST'D. HEX. HEAD BOLT	"
29a	1	"	STANDARD 4" NIPPLE $3\frac{1}{2}$" LONG.	"
30a	1	"	" 4" X 2" REDUCING COUPLING	"

NOTE:
A PLUS B = 46'8"





LOWER SECTION

ASSEMBLY

ALTERATION TABLE

DELINEATOR	W.L.CISSEL	IN CHARGE OF M&E DRAFTING	CHIEF DRAFTSMAN
TRACER		CRS	
CHECKER	F.L.B.		

APPROVAL

PHYSICIST	SUPT. OF M&E DIVISION
Philip H Abelson	Ross Gunn

FOR DIRECTOR

COMDR. U. S. N.

BUREAU OF SHIPS	REFERENCE

SYMBOLS AND THEIR EQUIV. TOLERANCES (UNLESS OTHERWISE NOTED)

SYMBOL 1	±.0005
SYMBOL 2	±.0010
SYMBOL 2½	±.0030
SYMBOL 3	±.0050
SYMBOL 3½	±.0100
SYMBOL 4	±.0250
SYMBOL 5	

U. S. NAVAL RESEARCH LABORATORY
"BELLEVUE," ANACOSTIA, D. C.

HEAT EXCHANGER NO. 2

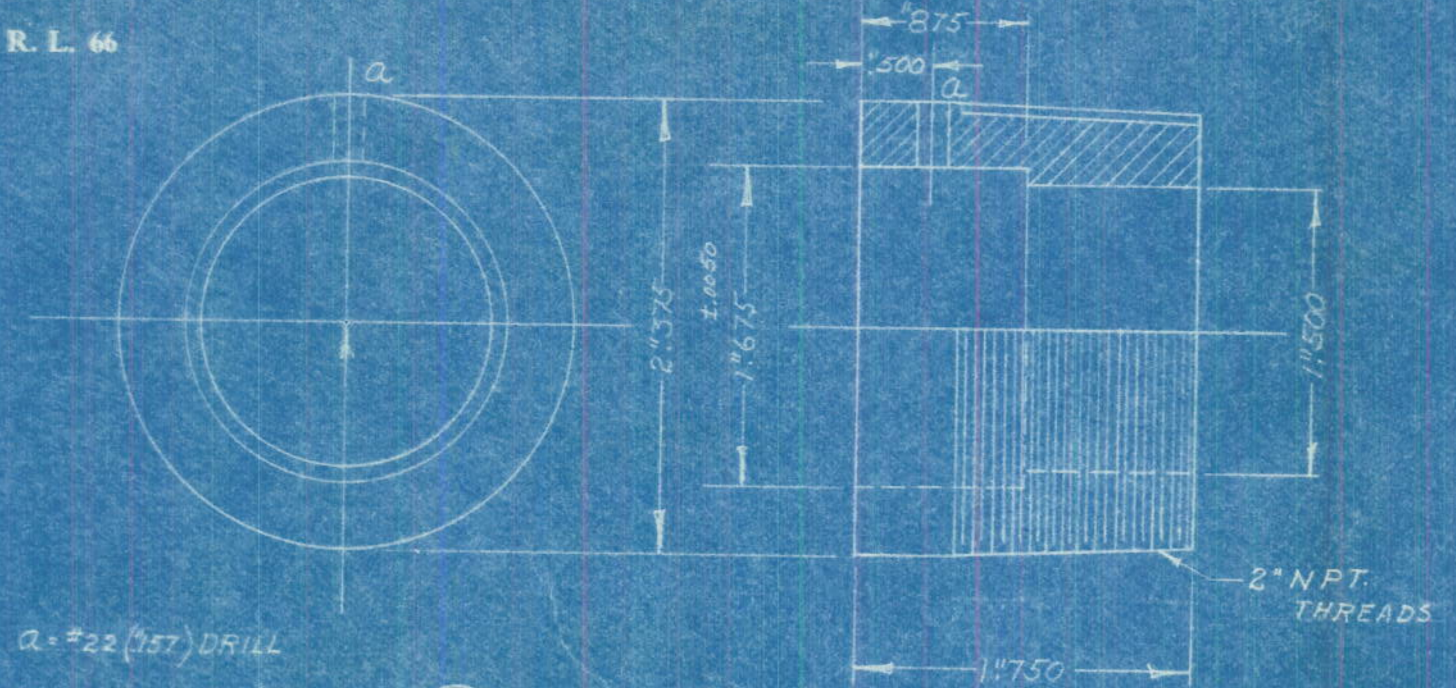
ASSEMBLY

SCALE 6 IN = 1 FT **DATE** JUNE 5 1943

F601 A

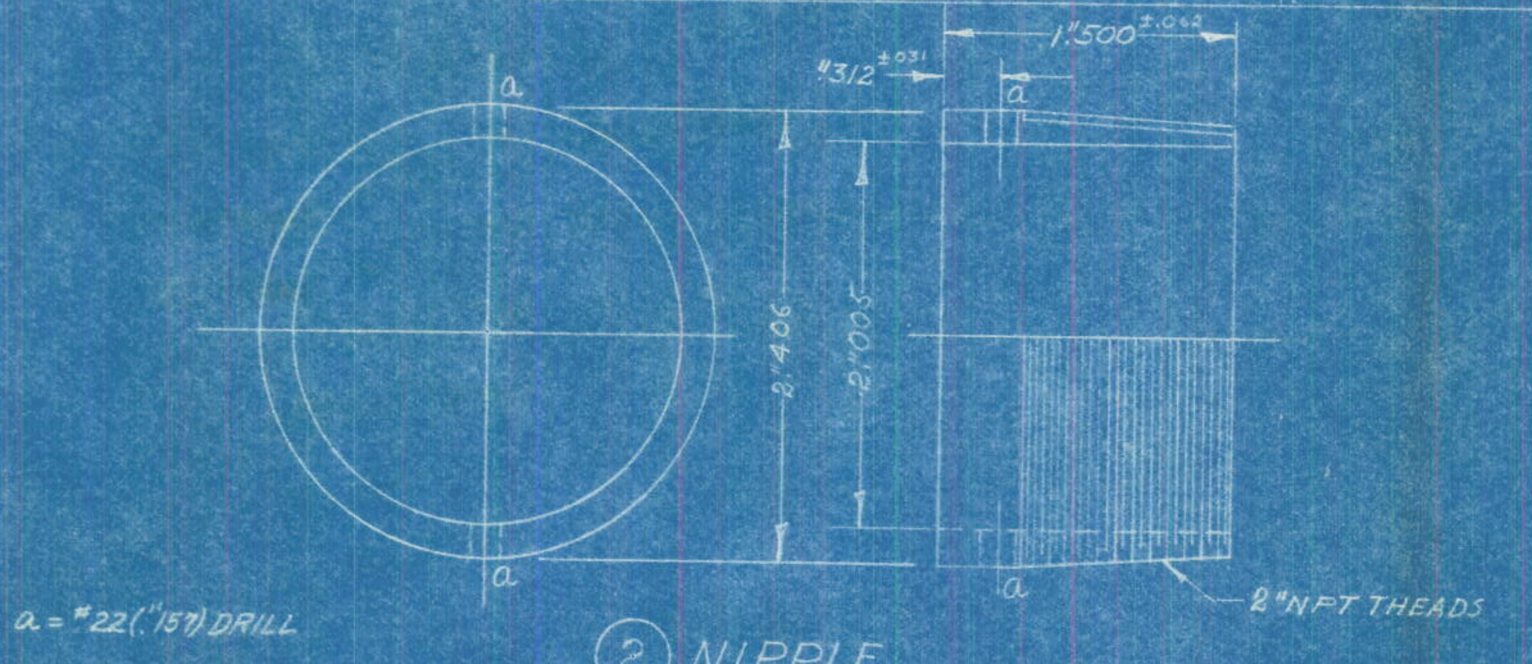
3 SHEETS SHEET 1 PLATE 1

N. R. L. 66



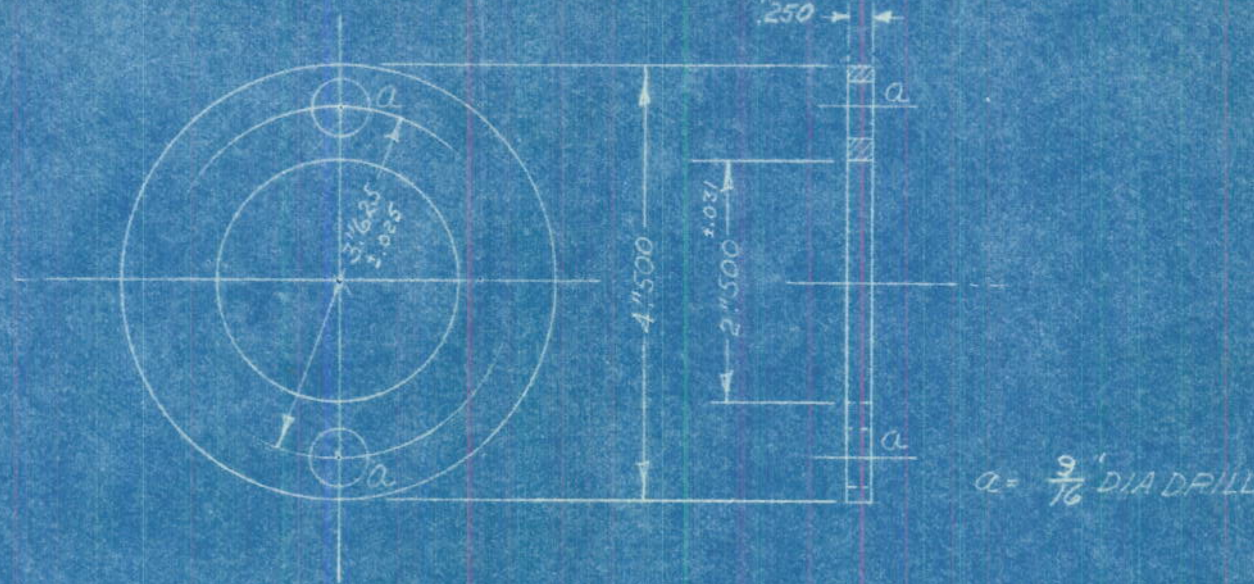
a (1) BUSHING
COLD ROLLED STEEL
SYMBOL 3
2 REQ'D

SCALE FULL SIZE
F 601



a (2) NIPPLE
COPPER (COMPO. Cu-r)
SYMBOL 2½
1 REQ'D

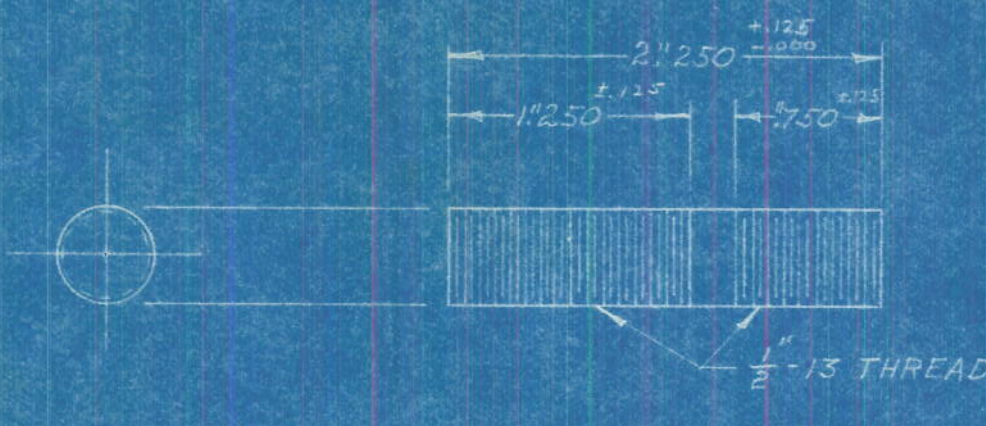
SCALE FULL SIZE
F 601



a (3) PACK RING
COLD ROLLED STEEL
SYMBOL 5
1 REQ'D

SCALE 6" IN = 1 FT.

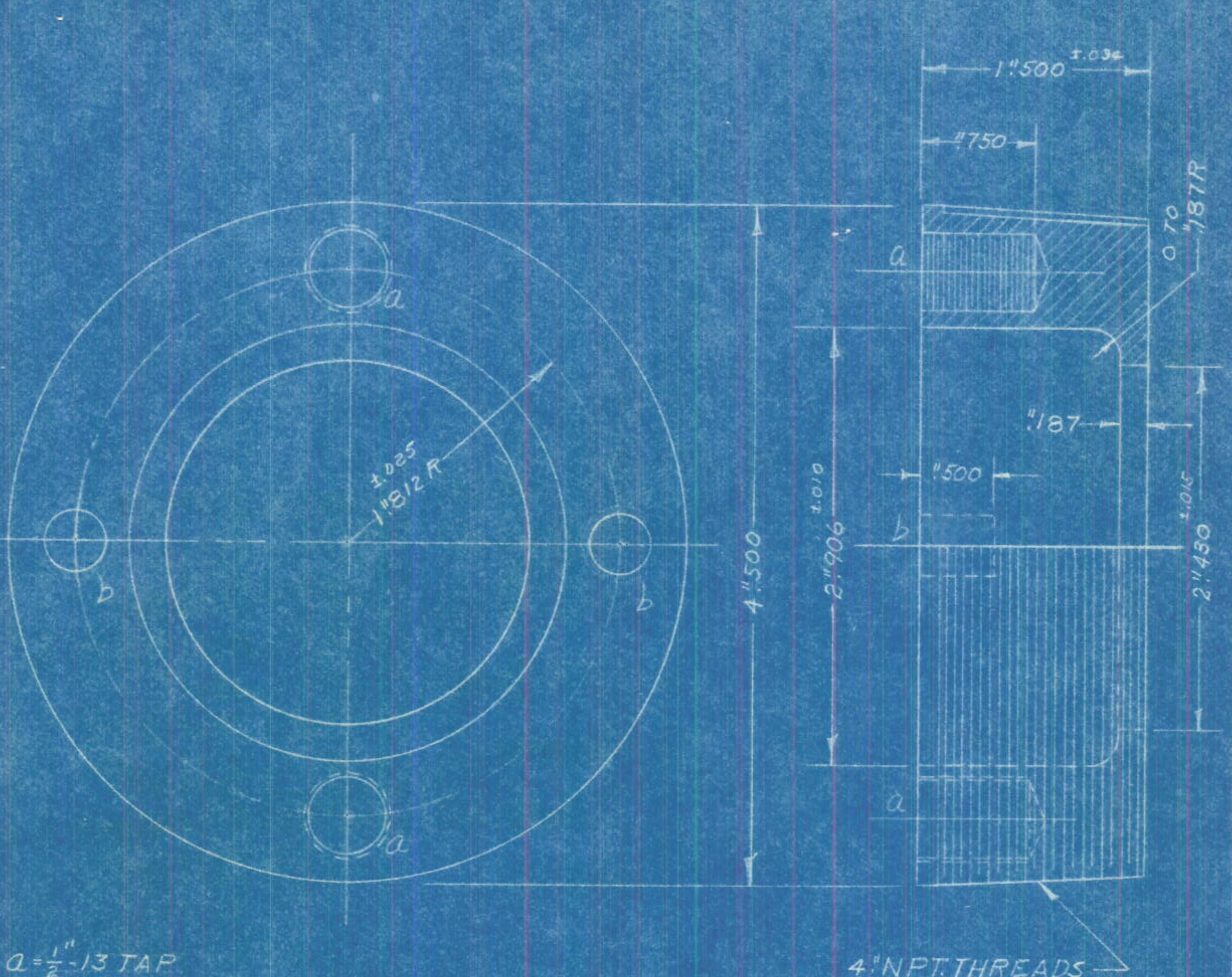
F 601



a (4) STUD
COLD ROLLED STEEL
SYMBOL 3
2 REQ'D.

SCALE FULL SIZE

F 601

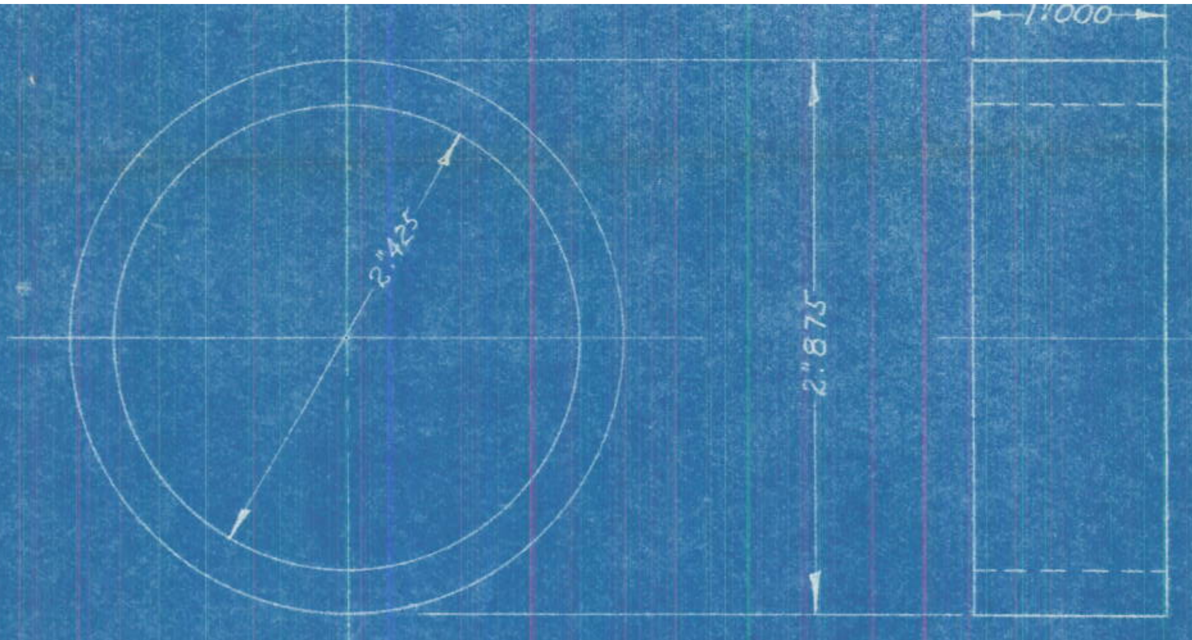


a = 1/2"-13 TAP
b = 13/32" DIA DRILL FOR
SPANNER WRENCH

a (5) PACK NUT
BRASS (COMPO B-r.)
SYMBOL 5
1 REQ'D

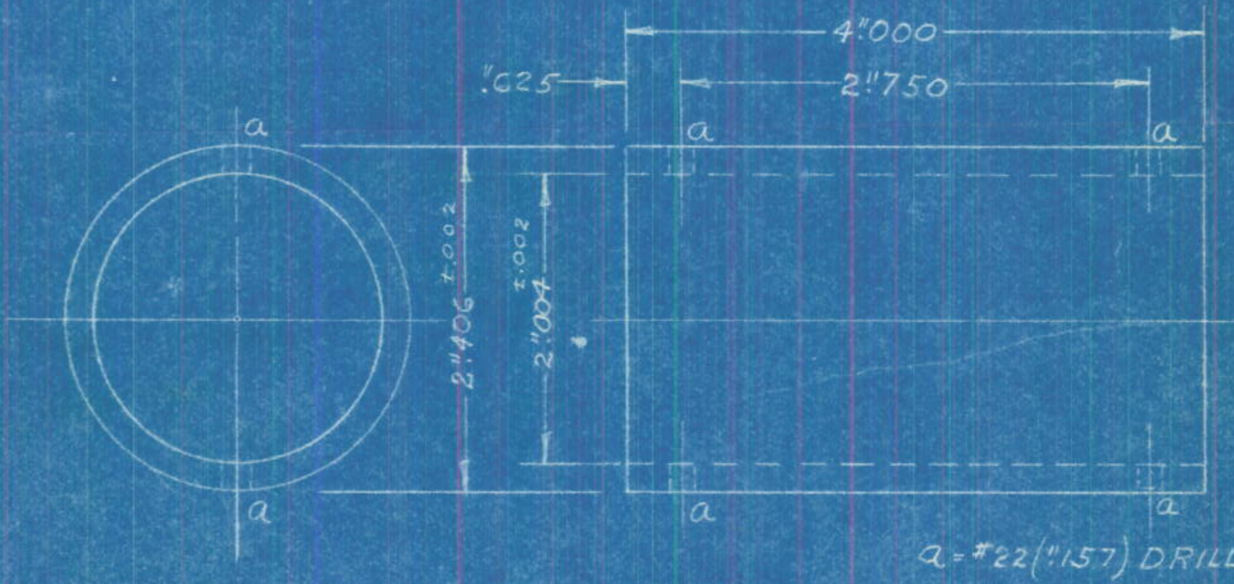
SCALE FULL SIZE

F 601



a (6) SLEEVE
BRASS (COMPO B-Y.)
SYMBOL $3\frac{1}{2}$
1 REQ'D.

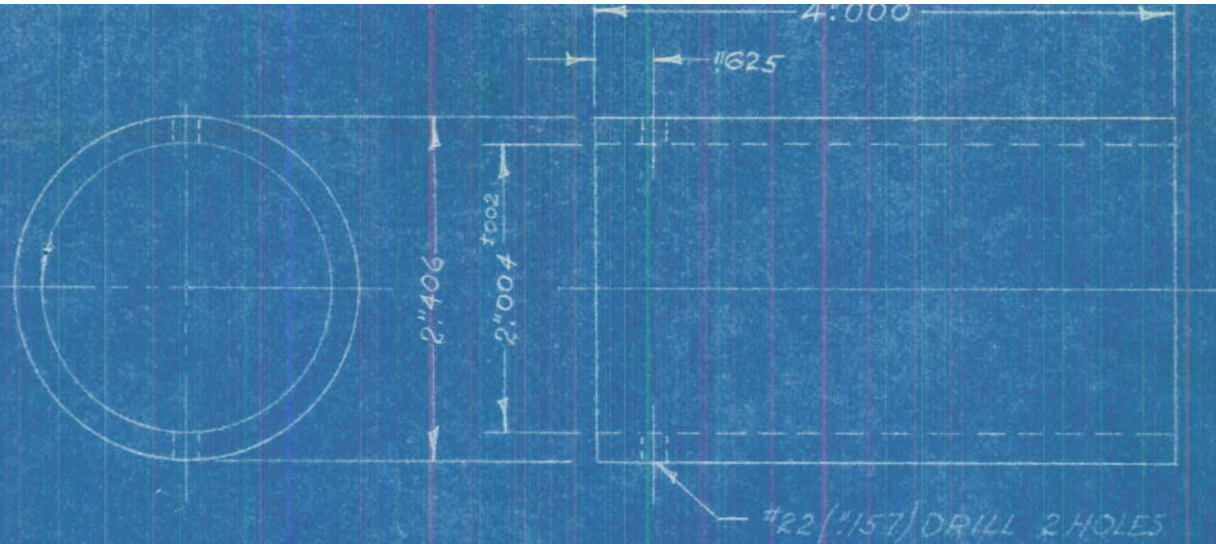
SCALE FULL SIZE
F 601



a = #22(".157) DRILL

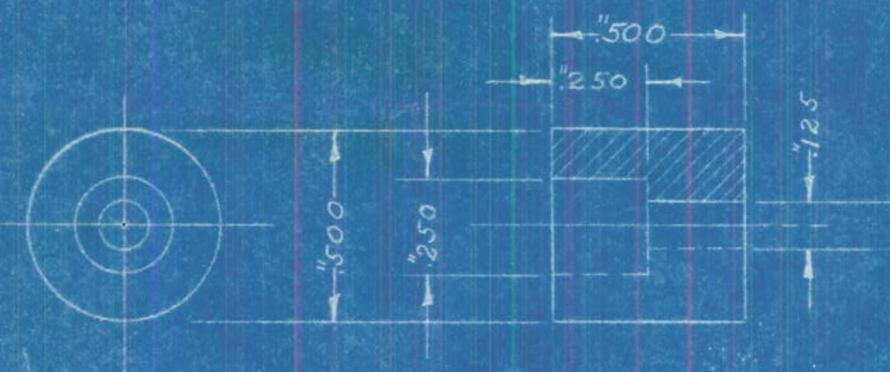
a (7) CONNECTING SLEEVE
COPPER (COMPO. Cu-Y)
SYMBOL 5
5 REQ'D.

SCALE 9 IN = 1 FT.
F 601



a (8) SLEEVE
COPPER (COMPO Cu-r)
SYMBOL 3
1 REQ'D.

SCALE 9 IN = 1 FT.
F 601



a (9) PLUG
NICKEL
SYMBOL 3
6 REQ'D.

SCALE 24 IN = 1 FT.
F 601

ALTERATION TABLE

DELINEATOR	W.L. GISSEL	IN CHARGE OF M & E DRAFTING	CHIEF DRAFTSMAN
TRACER		CRS.	
CHECKER	F.L.B.		

APPROVAL

PHYSICIST	SUPT. OF M & E DIVISION

FOR DIRECTOR

COMDR. U. S. N.

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SYMBOL 5	±.0500

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"BELLEVUE," ANACOSTIA, D. C.

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NO. 2

DETAILS

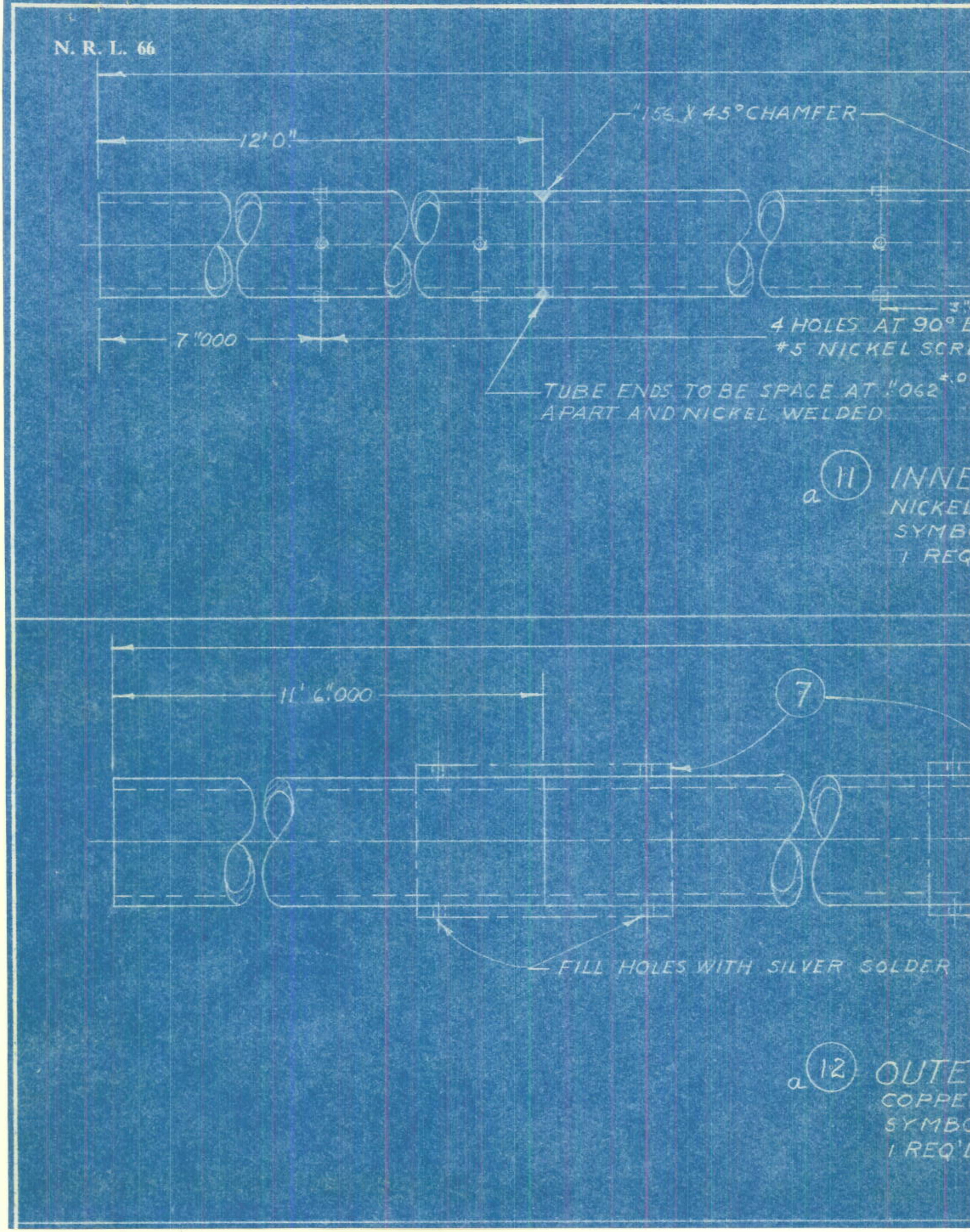
SCALE

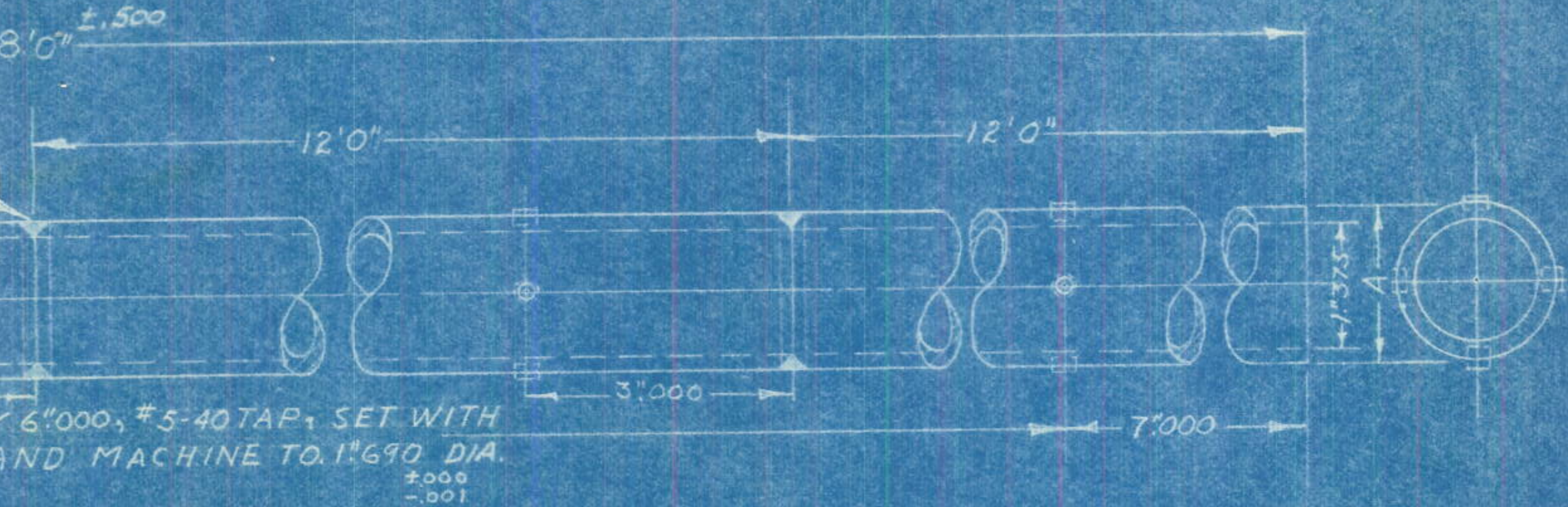
DATE JUNE 5 1943

F601

SHEET 2A

PLATE 2

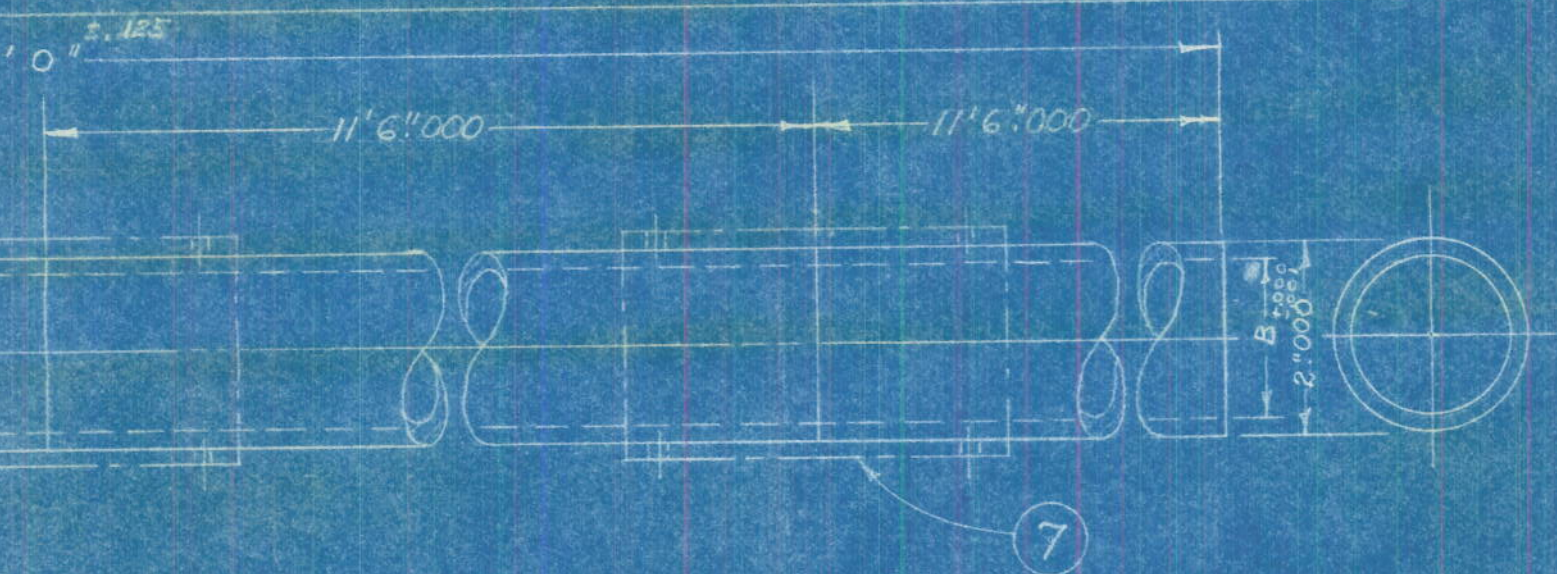

N. R. L. 66
12' 0"
".156 X 45° CHAMFER
7".000
4 HOLES AT 90°
#5 NICKEL SCR
TUBE ENDS TO BE SPACE AT ".062
APART AND NICKEL WELDED
a 11 INNE
NICKEL
SYMBO
1 REQ
11' 6".000
7
FILL HOLES WITH SILVER SOLDER
a 12 OUTE
COPPE
SYMBO
1 REQ'D



TUBE
BING

SCALE 6 IN.=1 FT.

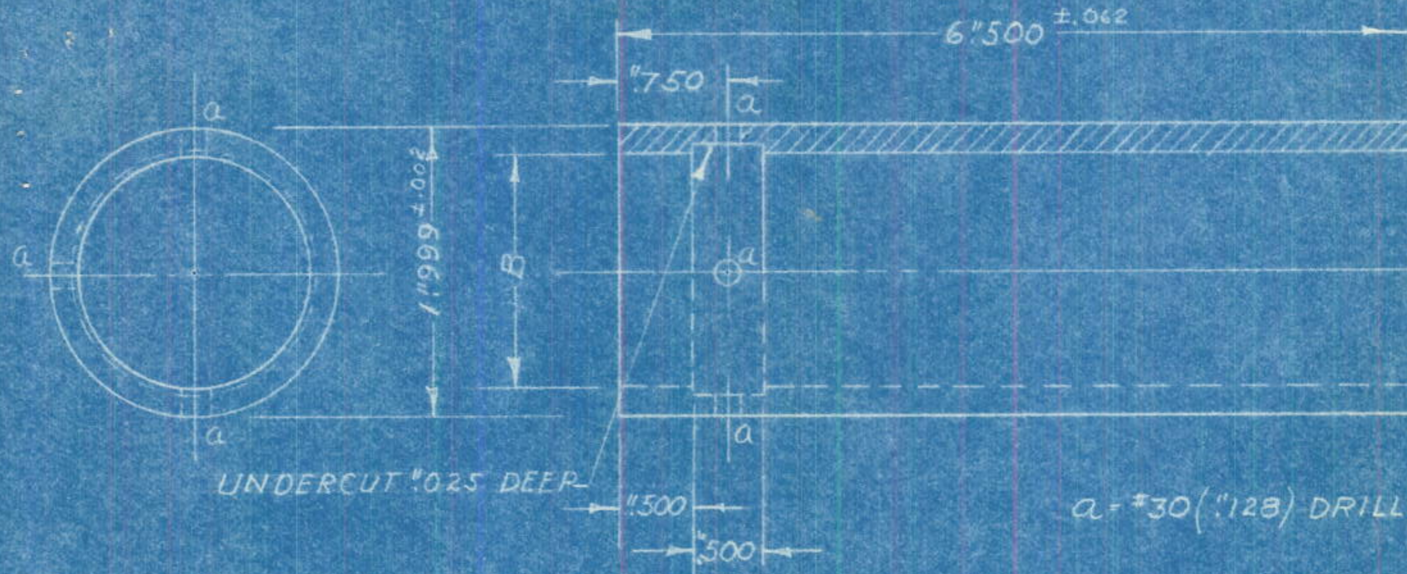
F 601



TUBE
UBING HARD DRAWN (COMPO. Cu-r)

SCALE 6 IN.=1 FT.

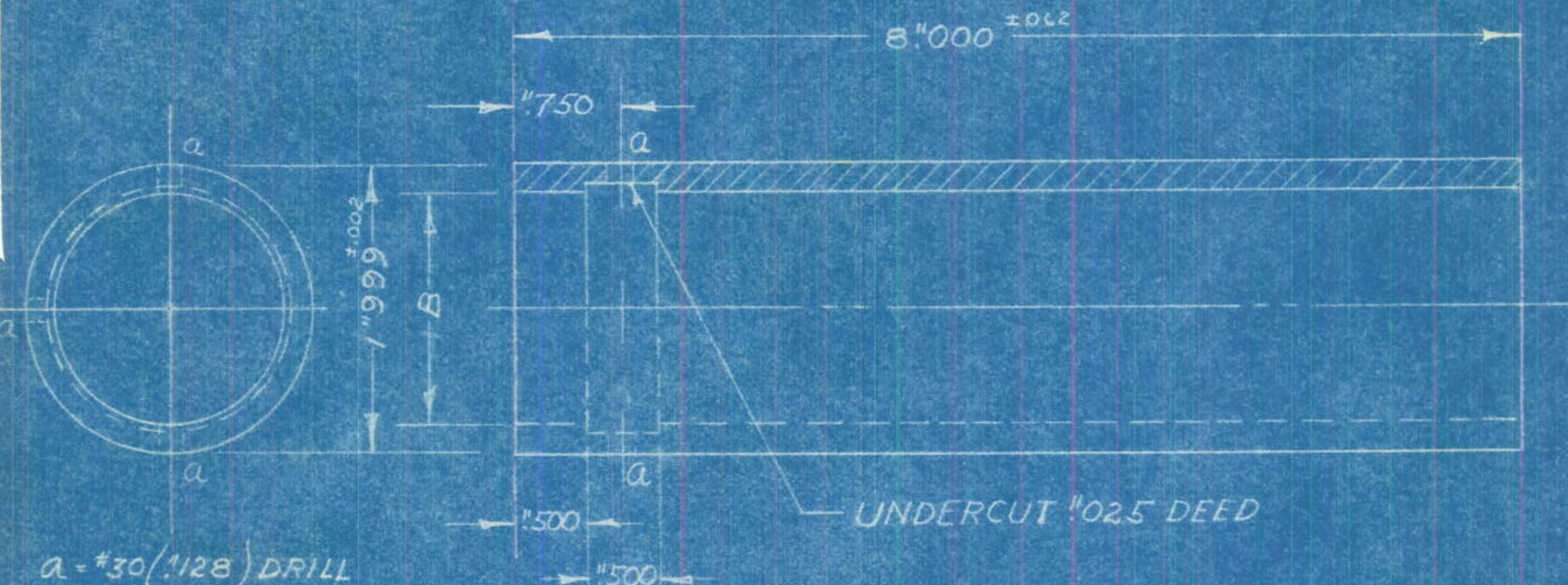
F 601



a (13) SLEEVE
NICKEL
SYMBOL 5
1 REQ'D.

SCALE 9 IN = 1 FT.

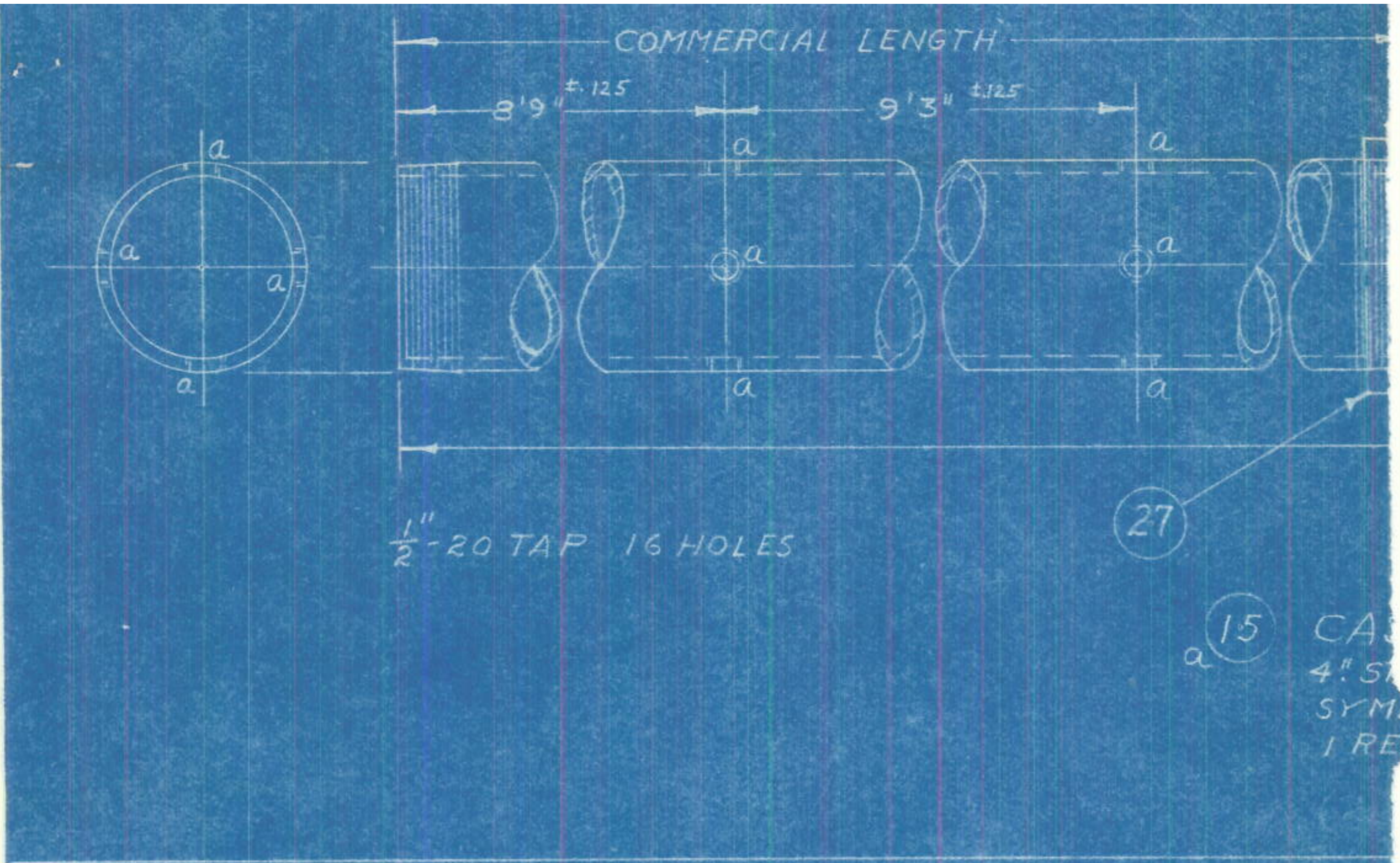
F 601



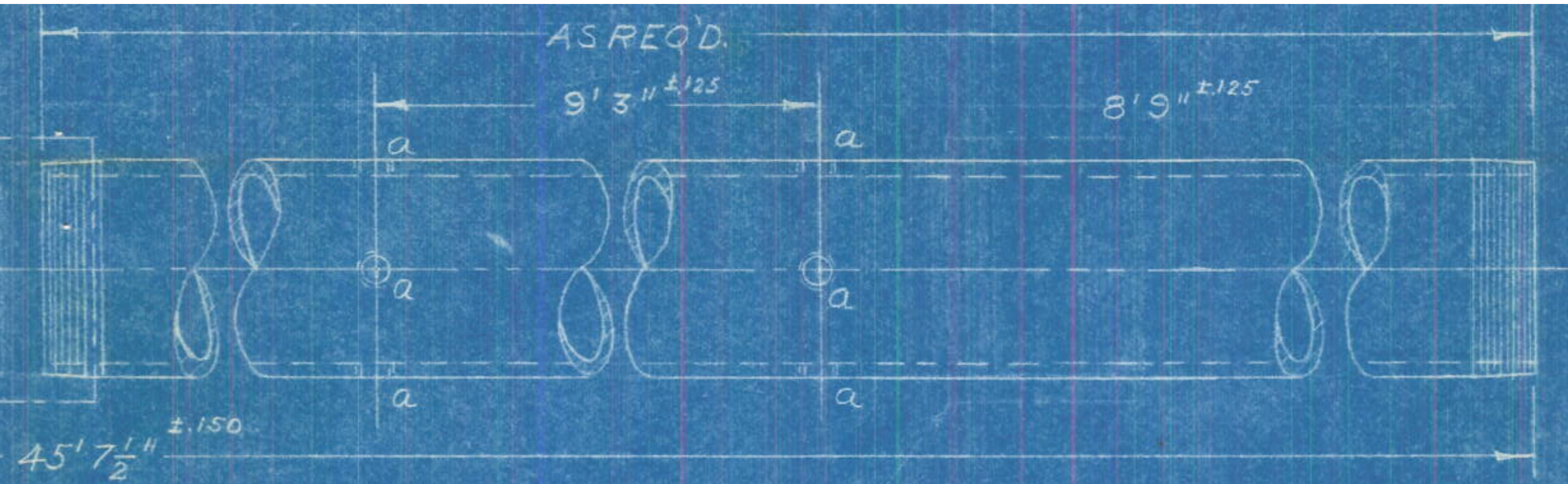
a (14) SLEEVE
NICKEL
SYMBOL 5
1 REQ'D

SCALE 9 IN = 1 FT.

F 601



COMMERCIAL LENGTH
8'9" ±.125
9'3" ±.125
a
27
1/2"-20 TAP 16 HOLES
a 15
CAS
4" ST
SYM
1 RE



NG
DARD STEEL PIPE
L 5
D.

SCALE 3 IN = 1 FT.

F 601

ALTERATION TABLE

DELINEATOR	W.L. GISSEL	IN CHARGE OF M&E DRAFTING	CHIEF DRAFTSMAN
TRACER		CRS.	[illegible]
CHECKER	F.L.B.		

APPROVAL

PHYSICIST	SUPT. OF M&E DIVISION

FOR DIRECTOR

COMDR. U. S. N.

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SYMBOL 5	±.0500

U. S. NAVAL RESEARCH LABORATORY
"BELLEVUE," ANACOSTIA, D. C.

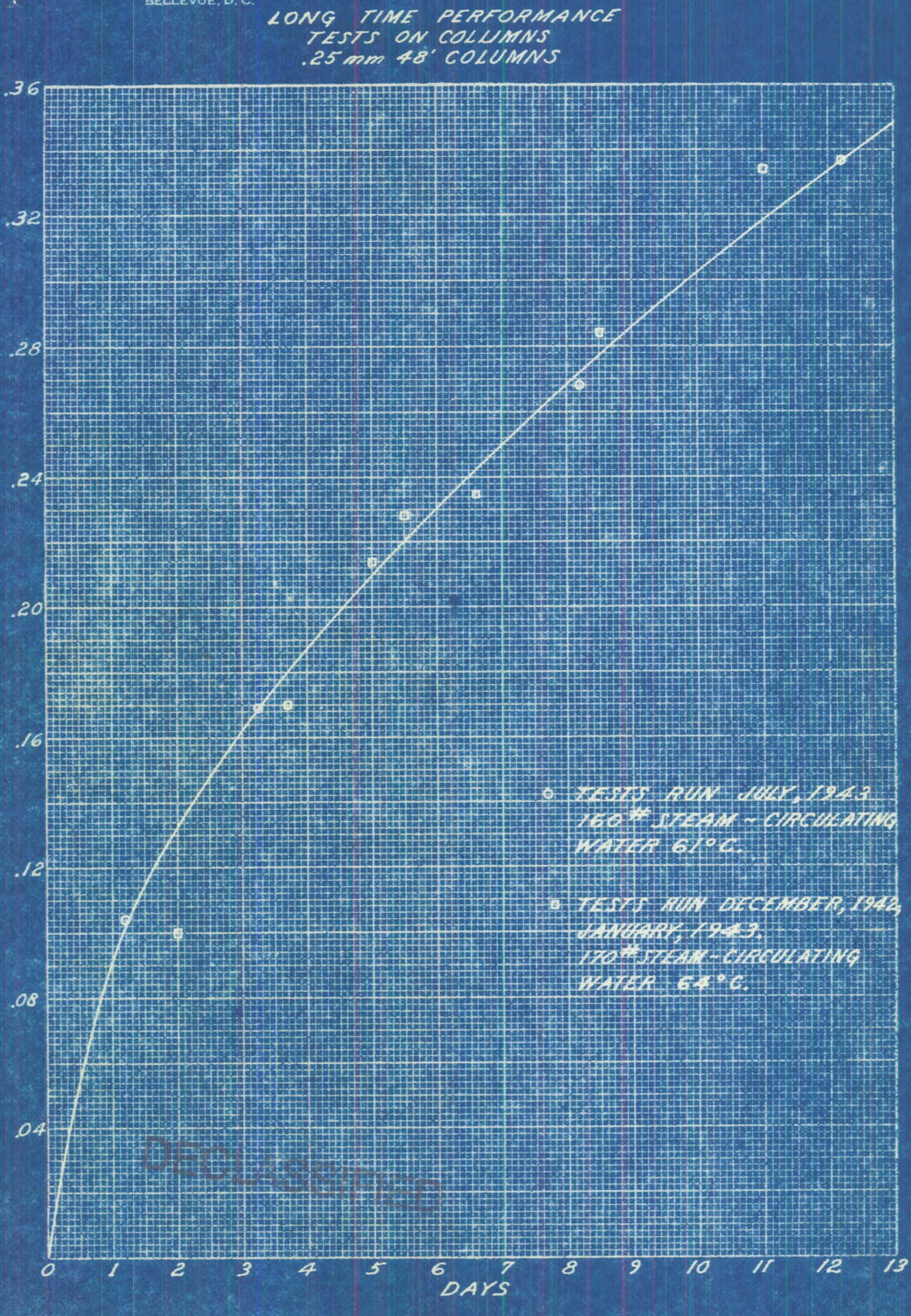
HEAT EXCHANGER
NO. 2
DETAILS

SCALE

DATE JUNE 5 1943

F601

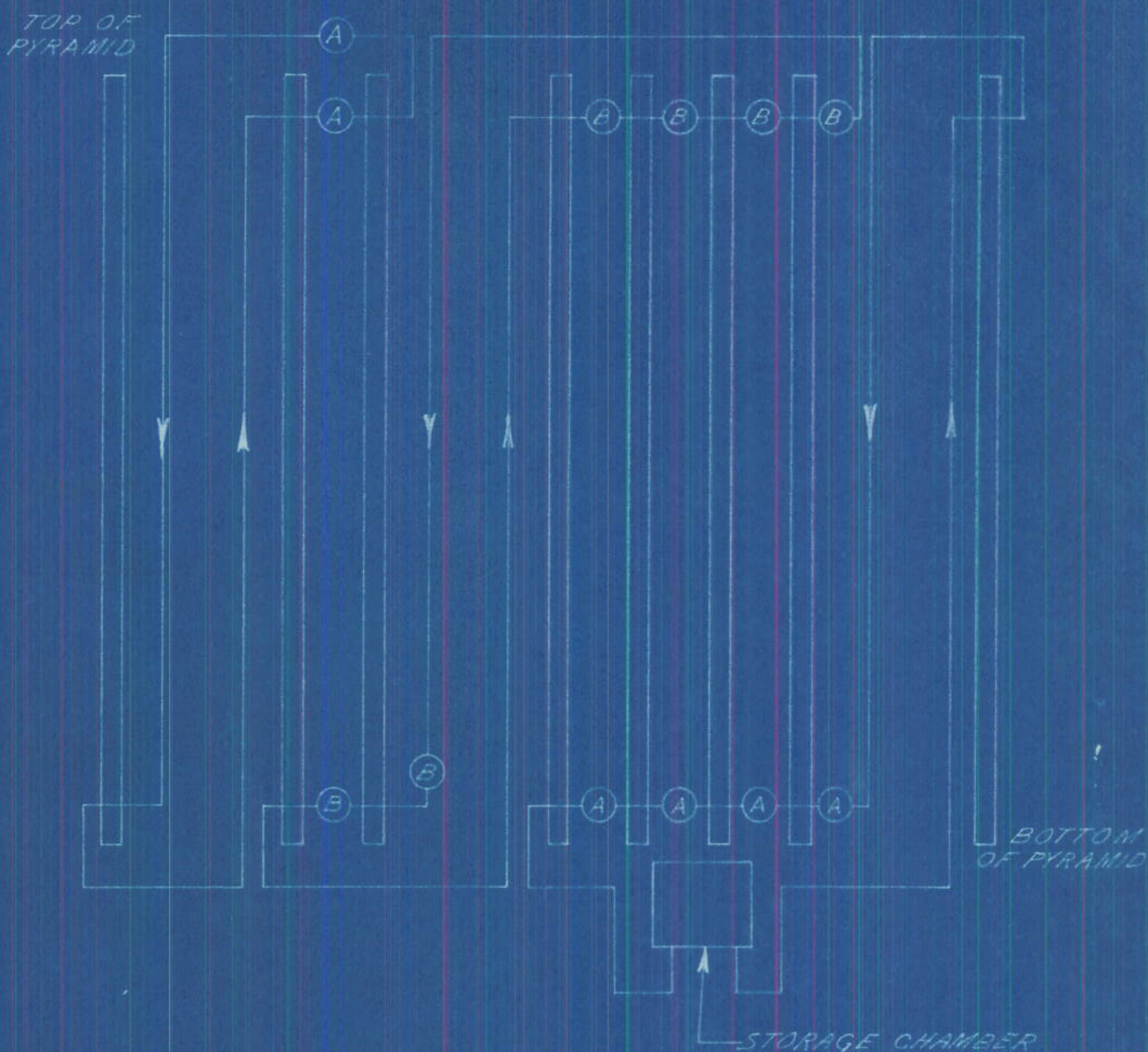
SHEET 3A PLATE 3


LONG TIME PERFORMANCE
TESTS ON COLUMNS
.25 mm 48' COLUMNS
.36
.32
.28
.24
.20
.16
.12
.08
.04
0
1
2
3
4
5
6
7
8
9
10
11
12
13
DAYS
TESTS RUN JULY, 1943
160# STEAM - CIRCULATING
WATER 61°C.
TESTS RUN DECEMBER, 1942,
JANUARY, 1943.
170# STEAM - CIRCULATING
WATER 64°C.

S-1

PLATE 4

THE PYRAMID



ALL VALVES DESIGNATED BY LETTER "A" ARE CLOSED WHILE ALL "B" VALVES ARE OPEN, AND VICE VERSA. CIRCULATION CHANGED EVERY TWO HOURS

IF SHEET IS READ THIS WAY (HORIZONTALLY) THIS MUST BE TOP. IF SHEET IS READ THE OTHER WAY (VERTICALLY) THIS MUST BE LEFT-HAND SIDE.

N. R. L. 31A

U. S. NAVAL RESEARCH LABORATORY
BELLEVUE, D. C.

DATE

APPROACH TO EQUILIBRIUM
48' COLUMN ~ .20 mm SPACING
700 # STEAM ~ 65°C CIRCULATING WATER

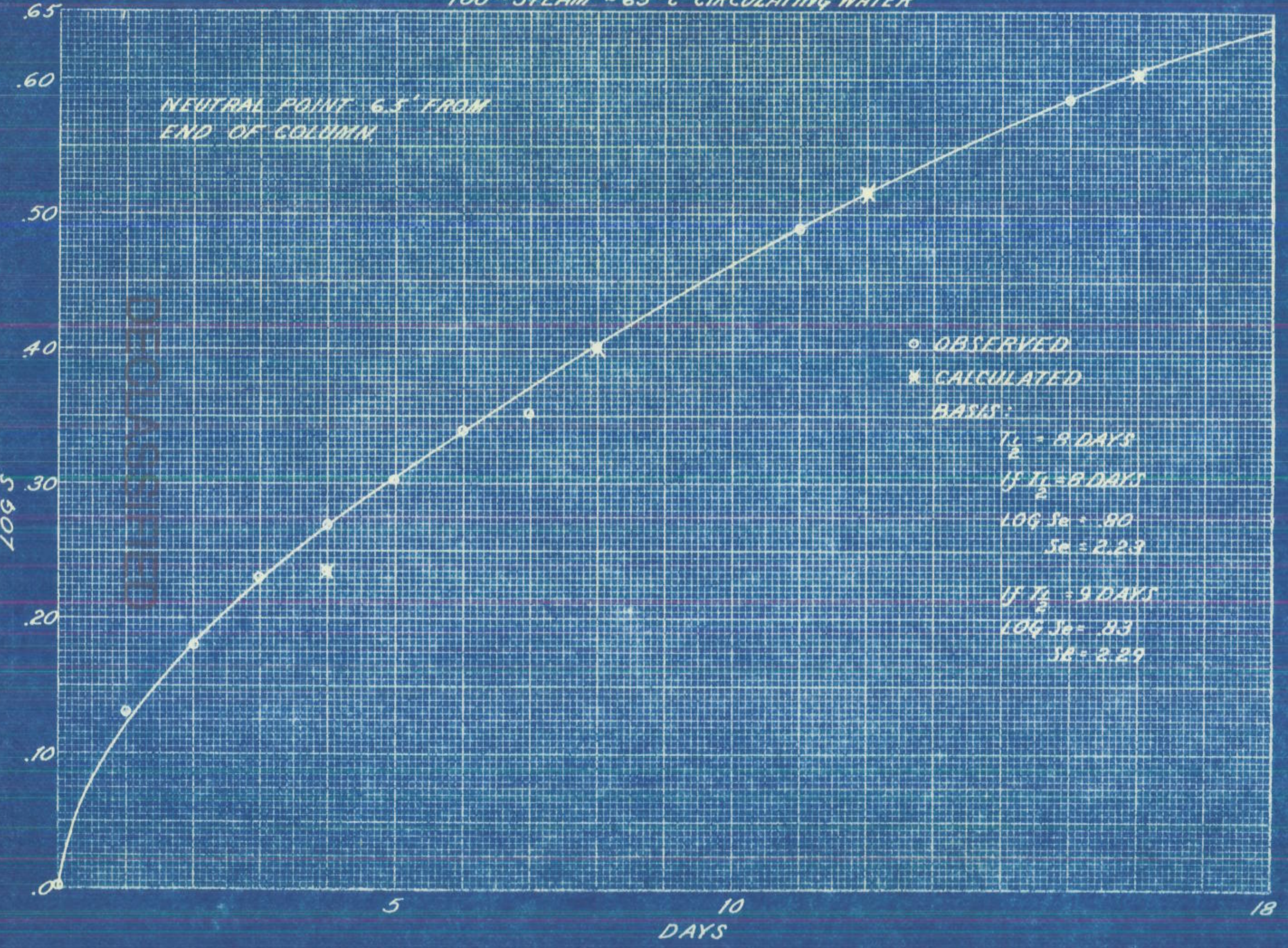
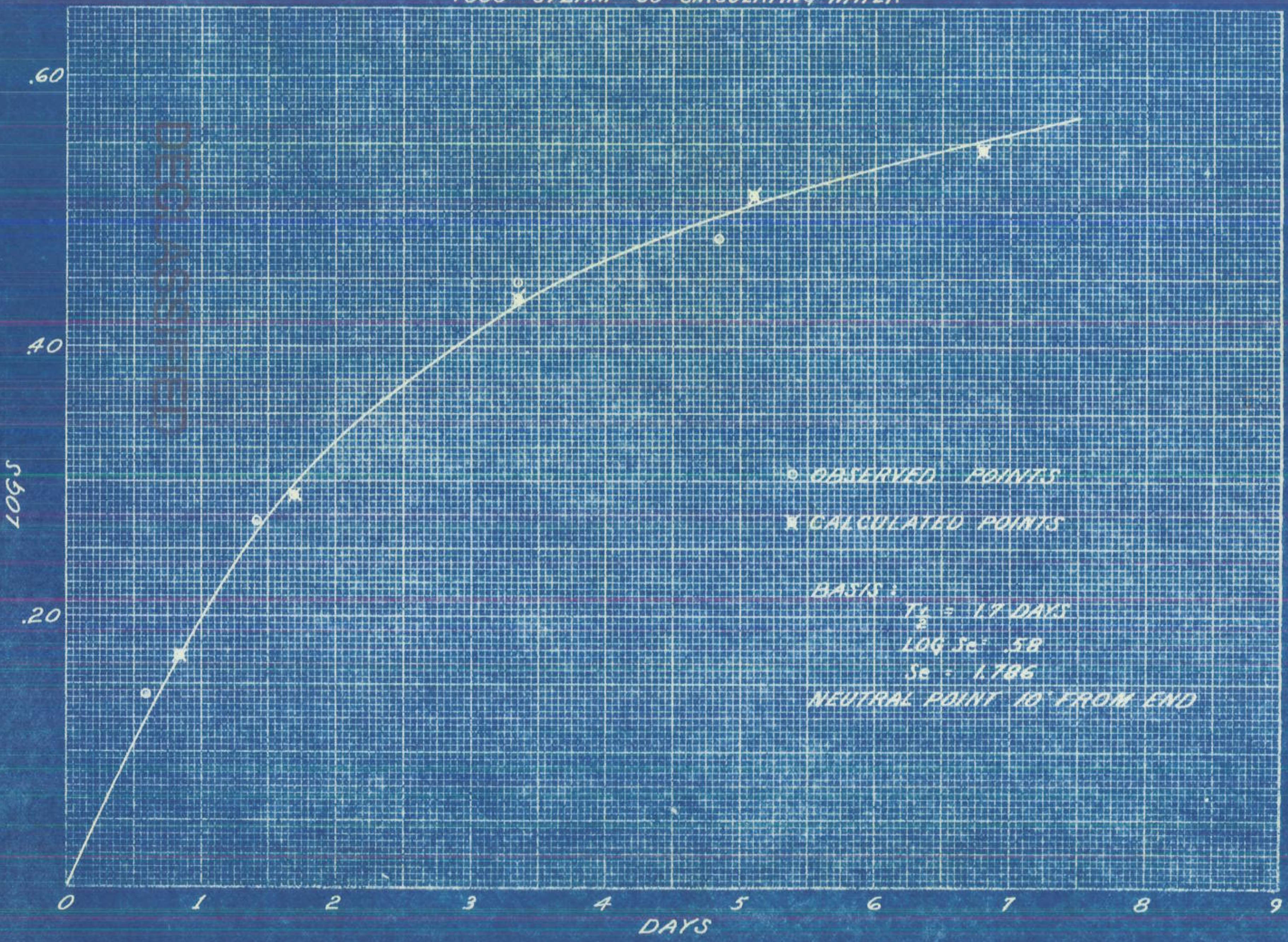


PLATE 6

APPROACH TO EQUILIBRIUM
.25 mm 48' COLUMN
1000 # STEAM ~ 60° CIRCULATING WATER



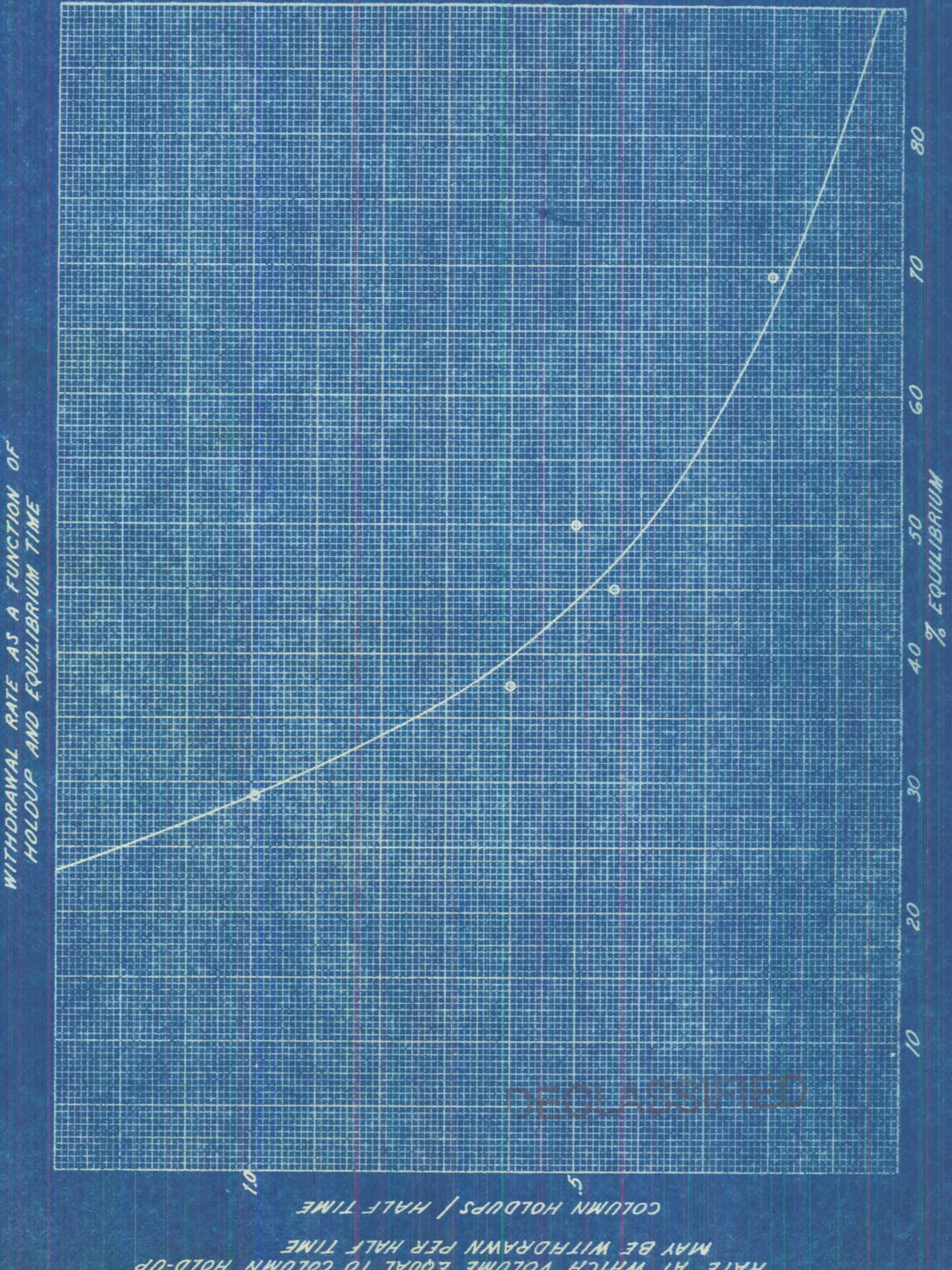

WITHDRAWAL RATE AS A FUNCTION OF
HOLDUP AND EQUILIBRIUM TIME
% EQUILIBRIUM
10
20
30
40
50
60
70
80
1.0
.5
COLUMN HOLDUPS / HALF TIME
RATE AT WHICH VOLUME EQUAL TO COLUMN HOLD-UP
MAY BE WITHDRAWN PER HALF TIME

PLATE 8