NAVY DEPARTMENT
BUREAU OF ORDNANCE
WASHINGTON 25, D. C.

To all holders of ORDNANCE DATA 6697
insert change; write on cover 'Change 2 inserted'
Approved by The Chief of the Bureau of Ordnance

NAVORD OD 6697 **CHANGE 2**

10 August 1954

N P Okunkewur
Assistant Director, Research & Development Division

Page _____ Page 1
(Sheets 15 & 16 attached)

ORDNANCE DATA 6697
  is changed as follows:

TACTICAL DATA FOR TORPEDO MARK 18

1. NAVORD OD 6697 has been downgraded. Delete. "RESTRICTED" from all pages.

2. **Revision A, dated 21 June 1950, revising page 10, should have been issued as CHANGE 1.**

3. Sheet 8, paragraph 9. Change this paragraph to read:

The speed of the Torpedo Mark 18 decreases as the electrolyte temperature of the batteries decreases. As stated in paragraph 5, the speed also decreases toward the end of the run. The combination of these effects places limitations on the run of the torpedo. It has also been determined by means of torpedo-borne instrumentation that depth control is lost during 40° and 30°F. electrolyte temperature runs prior to the end of the run. To insure accuracy and reliability, torpedo runs should be restricted as follows:

Electrolyte Temperature	Torpedo Run
60°F. and over	4000 yards
50°F.	3600 yards
40°F.	2200 yards
30°F	2000 yards

Subject to the range restrictions, the following corrections for variation from standard running speed caused by differences in electrolyte temperature should be made:

Electrolyte Temperature	Correction for S_z (Knots)
80	0.35
70	0.15
60	-0.05
50	-0.60
40	(See Figure C)
30	(See Figure D)

Figures C and D are graphs of correction for S_z (Knots) vs. distance of torpedo run for electrolyte temperatures of 40° and 30°F. These graphs are the result of a series of special low electrolyte temperature range runs made at Newport during the winters of 1951 and 1952. As noted on Figures C and D, these corrections for S_z are negative.

4. Paragraph 15 of Revision A (Sheet 10). Change this paragraph to read:

Originally paragraph 9 contained restrictions based on special tests compiled at the Naval Torpedo Station, Newport, R. I., during March-May 1949. However, the accuracy of this original data at the lower electrolyte temperatures regarding range (Torpedo Run) and speed correction was questioned by the Commander, Submarine Force, U. S. Atlantic Fleet, in letter FF4-12/X25 ser 041 dated 12 Jan 1951, to the Chief, Bureau of Ordnance (Re6a). As a result Newport was authorized to commence tests on the cold weather performance of the Torpedo Mark 18. During the winters of 1951 and 1952 cold weather tests of Mark 18 Mod 2 Torpedoes, under controlled conditions, were undertaken to evaluate speed, range and depth characteristics. The tests and results of this evaluation program were published by the U. S. Naval Underwater Ordnance Station, Newport, R. I., in Technical Memorandum No. 16, entitled "Cold Weather Performance of Torpedoes Mark 18 Mod 2". As a result, the restrictions originally set forth in paragraph 9 have been modified in accordance with the recommendations contained in USNUOS T.M. No. 16.

5. Insert attached pages. Attach this CHANGE sheet following the cover, to become a permanent part thereof.
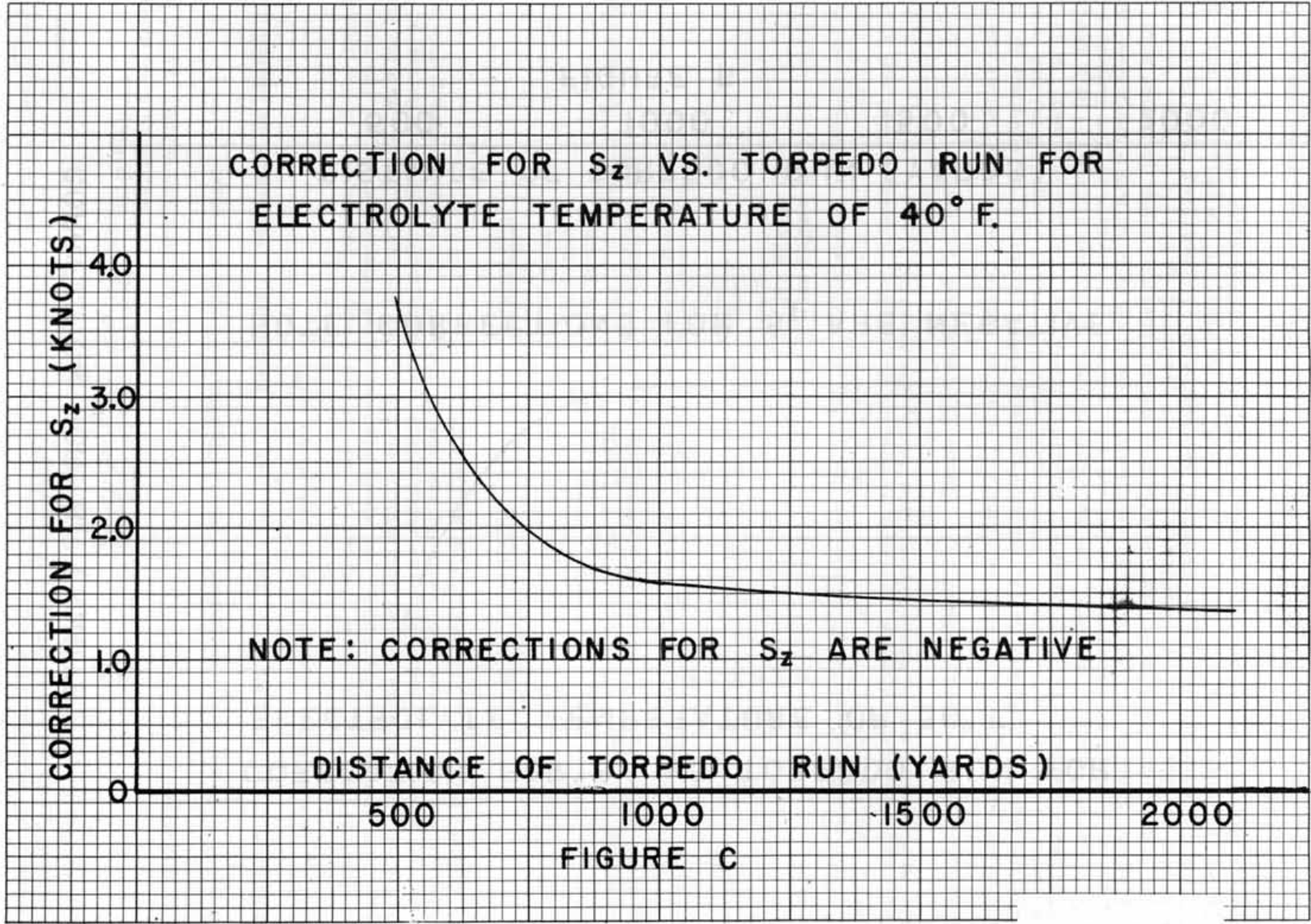
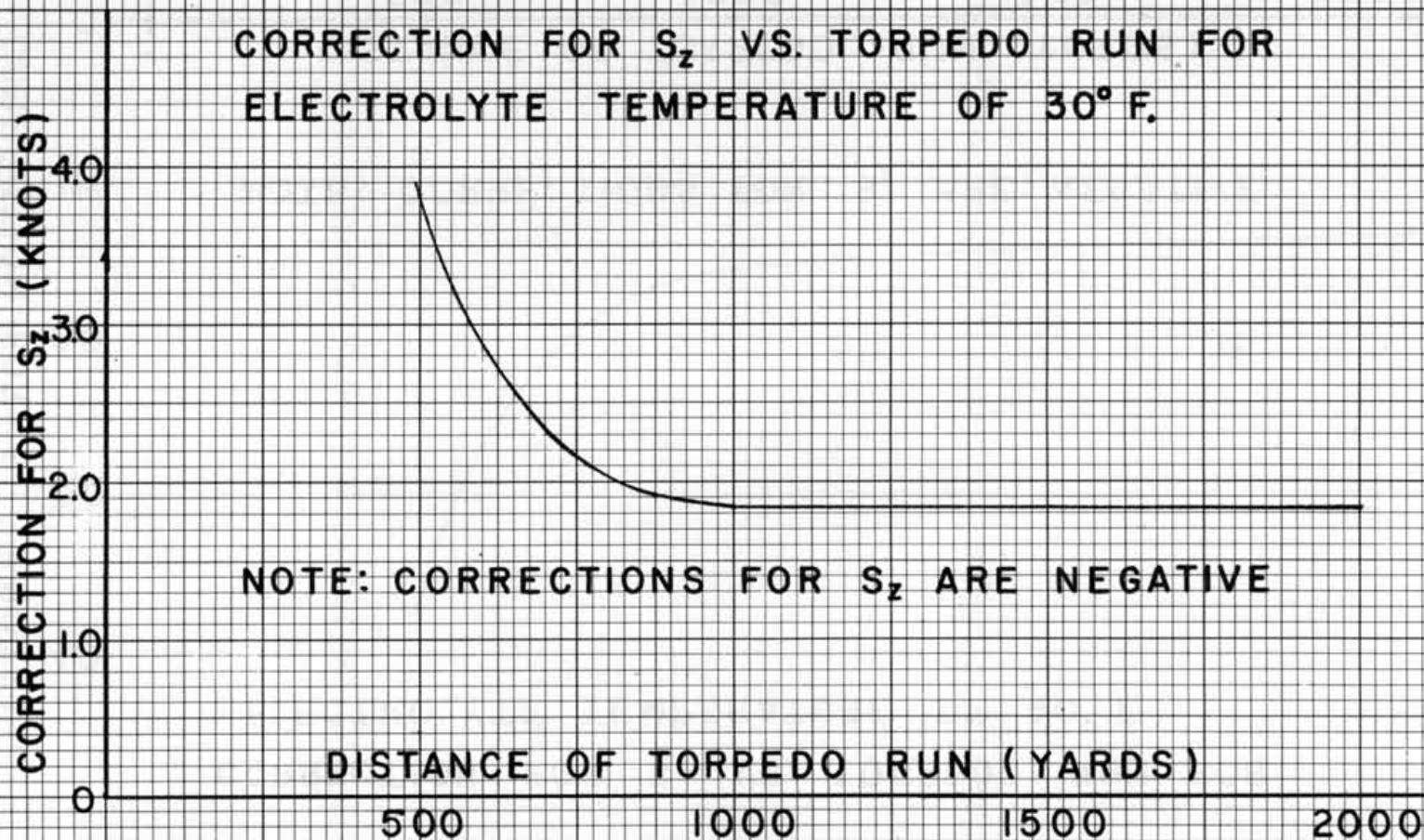CORRECTION FOR S_z VS. TORPEDO RUN FOR ELECTROLYTE TEMPERATURE OF 40° F.

NOTE: CORRECTIONS FOR S_z ARE NEGATIVE

FIGURE C

CORRECTION FOR S_z VS. TORPEDO RUN FOR ELECTROLYTE TEMPERATURE OF 30° F.

NOTE: CORRECTIONS FOR S_z ARE NEGATIVE

FIGURE D

RESTRICTED

WARNING: THE DISCLOSURE OF NATIONAL DEFENSE SECRETS IS A PENAL OFFENSE, PUNISH-ABLE BY FINE, IMPRISONMENT OR BOTH.

ORDNANCE DATA

TACTICAL DATA FOR TORPEDO MARK 18

SUBMITTED   AUGUST 31 , 1949

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REVISIONS			
LOC.	NO.	DATE	CHANGES APPEAR ON SHEETS:

ORDNANCE DATA

TORPEDO MARK 18 TACTICAL DATA

1.   Ordnance Data 6697 contains tactical data required for fire control of Torpedo Mark 18 Mods 1 and 2 from a submarine. These data were computed by statistical methods and are for use with Torpedo Data Computer Mark 4 and Fire Control System Mark 101.

2.   This publication does not supersede any existing publication.

3.   Extracts may be made from this publication when necessary for use with training or combat equipment.

TACTICAL DATA FOR TORPEDO MARK 18

INTRODUCTION

1.   The data supplied in this publication were compiled from records of proof firings of the Torpedo Mark 18.

2.   These tactical data are for setting in the Torpedo Data Computer Mark 4 and the Fire Control System Mark 101. In their computation, the method of least squares, and other statistical methods were used.

3.   The data given below apply to a set of standard conditions for firing. "Standard" denotes a depth setting of 15 feet, electrolyte and sea water temperatures of 62 degrees F, and a torpedo tube depth of 10 feet. When firing under conditions other than standard, see paragraphs 7, 9, and 10 for corrections and settings.

DEFINITIONS

4.   The symbols and terms used in this publication are defined below. Figure A on sheet 6 illustrates some of these symbols and terms.

Df - Torpedo Drift - After the torpedo has turned through its Gyro angle, the distance in yards between any particular point along the observed path and the line on which it would have run had it continued on a straight path after completing its gyro angle, measured right or left. Torpedo drift, when measured in mils, is called torpedo deflection.

G - Gyro Angle - The angle between the torpedo tube axis and the final torpedo track, measured clockwise from 0 to 360 degrees.

J - Torpedo Advance - The distance in yards between the tangent at the end of the curved path and a line through the torpedo tube muzzle parallel to this tangent.

M - Reach - The initial straight path of the torpedo in yards.

Ml - Left Reach - The reach for a left shot.

Mr - Right Reach - The reach for a right shot.

TACTICAL DATA FOR TORPEDO MARK 18

Sa - Average Torpedo Speed - The average speed in knots of the torpedo computed using the travelled distance from the torpedo tube muzzle to the point of intercept and the time between the instant of pressing the firing key and the instant the torpedo nose reaches the point of intercept.

Ss - Semi-pseudo Torpedo Speed - The average speed in knots computed from Us and Ta.

Sz - Torpedo Running Speed - The uniform running speed of the torpedo at proof depth after the initial acceleration is complete.

Ta - Time of Torpedo Run - The time in seconds between the instant of pressing the firing key and the instant the torpedo nose reaches the point of intercept when running at proof depth.

U - Torpedo Run - The distance in yards which the torpedo actually travels along its path from the torpedo tube muzzle to the point of intercept.

Ug - The difference in yards between the actual torpedo run and the semi-pseudo torpedo run (U-Us).

Us - Semi-Pseudo Torpedo Run - The projection, on a line parallel to the final torpedo course, of the actual torpedo run, measured in yards.

Uy - Torpedo Run Difference - The actual torpedo run (U) for a given time from the instant of pressing the firing key minus the distance the torpedo would have run in the same time if the torpedo had been running at Torpedo running speed (Sz).

Y - Torpedo Transfer - The distance in yards from the torpedo tube muzzle, measured parallel to the theoretical final course of the torpedo, to a point abreast of the end of the curved path.

Z - Torpedo Turning Radius - The radius of the circle, an arc of which is assumed to be part of the torpedo's course in angle firings.

Zl - Torpedo Turning Radius (Left) - The torpedo turning radius for a left gyro angle shot.

Zr - Torpedo Turning Radius (Right) - The torpedo turning radius for a right gyro angle shot.

TORPEDO RUN EQUATION

5.   The Torpedo Mark 18 tends to lose speed toward the end
of its run. However for ranges not exceeding 4000 yards, the
torpedo run may be expressed by the equation

$$U = .563 \, Sz \, Ta + Uy \tag{1}$$

The values for Sz and Uy which best fit the range performance of
the Torpedo Mark 18 are

$$Sz = 28.34 \text{ knots} \quad \text{and} \quad Uy = +51.86 \text{ yards}$$

ANGLE FIRE PERFORMANCE

6.   The subject torpedo, when angle fired, is assumed to
start on a straight path, the Reach (M), and then to describe a
circular path of radius Z until the final course is reached. (See
Figure "A"). Gyro angles are treated in this pamphlet in terms of
right and left, measured from the torpedo tube axis. Data for
reaches and radii for the Torpedo Mark 18 are

M RIGHT	(yards)	19.5
M LEFT	(yards)	27.0
Mr-Ml	(yards)	-7.5
Z RIGHT	(yards)	82.1
Z LEFT	(yards)	86.6
Zr-Zl	(yards)	-4.5

The advance, J, and torpedo run time, Ta, may be calculated
from the following equations:

$$J = M \sin G + Z(1 - \cos G) \tag{2}$$

$$Ta = \frac{1}{.563Sz} \left[M(1 - \cos G) + Z \left(\frac{\pi G}{180} - \sin G \right) + Us - Uy \right] \tag{3}$$

which may be set up directly from Figure (A). Left and right
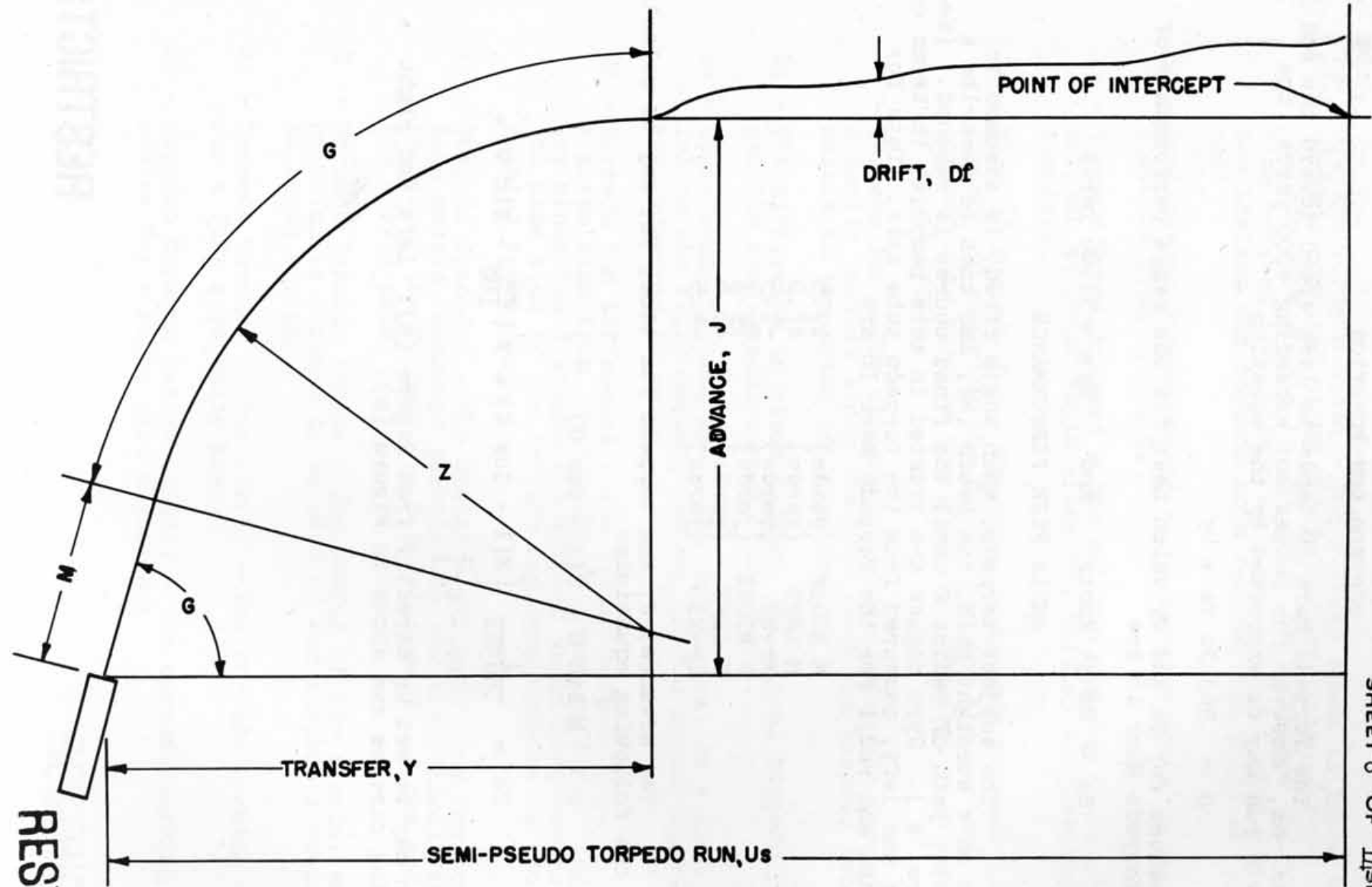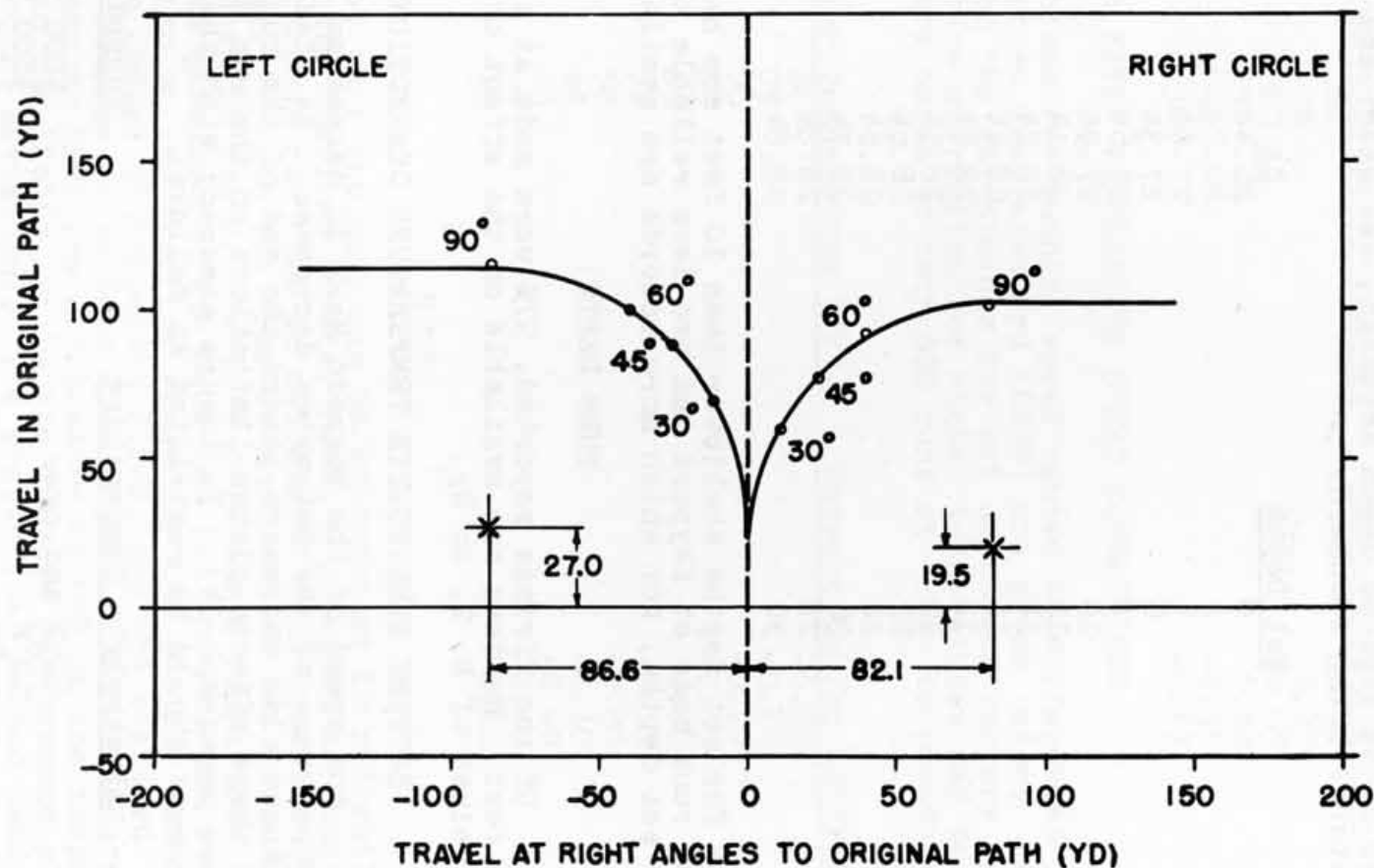turning circles are shown in Figure (B).

FIGURE A

FIGURE B
TORPEDO MARK 18 MOD 2
LEFT AND RIGHT TURNING CIRCLES

DATA: 418 ANGLE RUNS AT N.T.S. KEYPORT, DECEMBER 1944-APRIL 1945

DEPTH RUNNING SPEED CORRECTION

7.   The range data analyzed show a consistent increase in speed with set depth. The following table shows the values to be used for Sz at various depth settings, sea water and electrolyte temperatures being standard.

Set Depth	Sz
0	26.44
2	26.74
4	27.04
6	27.34
8	27.64
10	27.94
12	28.14
14	28.24
16	28.44
18	28.44
20	28.54
22	28.64
24	28.64
26	28.74
28	28.84
30	28.84

The data for set depths shallower than 10 feet are based on 100 straight runs made at Keyport and are less reliable than those at greater set depths, for which more records are available.

TUBE DEPTH

8.   Of the firings reported, 97% were made at tube depths of 5 or 10 feet. No data are available on the effect of deep firing on the values of M, Z, or Uy.

BATTERY ELECTROLYTE TEMPERATURE CORRECTIONS

9.   The speed of the Torpedo Mark 18 decreases as the electrolyte temperature of the batteries decreases. As stated in paragraph 5, the speed also decreases toward the end of the run. The combination of these effects places limitations on the run of the torpedo (see note paragraph 14). To insure accuracy with the stated settings torpedo runs should be restricted as follows:

Electrolyte Temperature	Torpedo Run
$60^{\circ}F$ and over	4000 yards
$50^{\circ}F$	3600 yards
$40^{\circ}F$	3200 yards
$30^{\circ}F$	2800 yards

Subject to the range restrictions, the following corrections for variation from standard running speed caused by differences in electrolyte temperature should be made:

Electrolyte Temperature (°F)	Correction for Sz (knots)
80	0.35
70	0.15
60	-0.05
50	-0.20
40	-0.35
30	-0.45

SEA WATER TEMPERATURE SPEED CORRECTIONS

10.　　Corrections for running speed caused by differences in sea water temperature from standard (62°F) are given below. These are in addition to the adjustments for set depth and battery temperatures. The negative correction for higher temperatures may be unexpected, but the figures are based on over 600 runs at these temperatures at Newport.

Sea Water Temperature (°F)	Correction for Sz (knots)
80	-0.30
75	-0.20
70	-0.10
65	-0.05
60	0.00
55	-0.10
50	-0.20
45	-0.30
40	-0.40
35	-0.50
30	-0.60

NOTES

11.　　In order that the user may be informed as to reliability of the tactical data compiled herein, Table 1 provides a comparison between Ta, the torpedo run time as calculated from Equation (3) and Tm, the average torpedo run time as measured on the proof range, for the Torpedo Mark 18 Mod 2. Table 2 provides a comparison between Ja, the advance as calculated from Equation (2) and Jm, the average advance as measured on the proofing range for the subject torpedo, together with the number of torpedoes fired, and the standard deviation of the advance at various gyro angles. (The standard deviation is chosen so that the performance of 68% of the torpedoes fired falls within the limits set by the average performance plus or minus the standard deviation). The statistical method used in analyzing the proof data produces values of the tactical constants which give the best possible agreement between the observed and the computed values of advance and torpedo run time.

12.　　　　The average drift of the torpedo may be computed from the equation

$$Drift(yards) = Deflection(mils) \times Us(in\ thousands\ of\ yards)$$

Table 3 shows average deflection for straight runs, for right and left gyro angles, and for various values of semi-pseudo torpedo run. The standard deviations for deflection are also shown. These quantities are of value in determining spread doctrine. Table 4 shows expected deflection in mils as a function of set depth and range. It will be noted that deflection decreases with set depth down to thirty feet.

13.　　　　The exercise head used in these firings was Mark 34 Mod 1, weighing approximately 745 pounds.

14.　　　　Information as to decrease of speed with torpedo run accompanied BuOrd letter SS/S75 of 5 June 1945. It should be noted that because of the decreasing speed, the average speed necessary for accuracy must exceed the value of Sz used in fire control.

　　　　　　Special tests for overrun were made at Newport, March - May 1949. Battery temperatures ranged from $42°F$ to $64°F$, water temperatures from $41°F$ to $47°F$. All torpedoes travelled over 4000 yards; average speeds were satisfactory up to the limits indicated in paragraph 9. Beyond those limits the fire control solution is inaccurate due to the rapid reduction in speed. Speeds for these special runs were used to check the temperature corrections stated in paragraphs 9 and 10; the agreement was very good.

TABLE 1
TORPEDO 18 MOD 2
TABLE OF CALCULATED TIME OF TORPEDO RUN Ta (sec.)
AND OBSERVED TIME OF TORPEDO RUN Tm FOR VARIOUS RANGES AND GYRO ANGLES

Sec.	to 1000 Yds.			to 2000 Yds.			to 3000 Yds.			to 4000 Yds.		
	Ta	Tm	Ta-Tm	Ta	Tm	Ta-Tm	Ta	Tm	Ta-Tm	Ta	Tm	Ta-Tm
90L	64.21	65.11	- .90	126.88	125.92	.96	189.55	188.33	1.22	252.22	253.44	-1.22
60L	61.25	63.15	-1.90	123.92	122.77	1.15	186.59	185.20	1.39	249.26	249.53	- .27
45L	60.34	61.18	- .84	123.01	121.69	1.32	185.68	183.85	1.83	248.35	248.91	- .56
30L	59.77	60.74	- .97	122.44	121.48	.96	185.11	183.60	1.51	247.78	248.84	-1.15
0	59.42	60.52	-1.10	122.09	121.08	1.01	184.76	183.06	1.73	247.43	248.58	-1.15
30R	59.71	60.60	- .89	122.38	121.51	.87	185.05	183.92	1.13	247.72	249.35	-1.63
45R	60.18	61.56	-1.38	122.85	121.76	1.09	185.52	184.22	1.30	248.19	249.53	-1.34
60R	60.96	62.76	-1.80	123.63	122.40	1.23	186.30	184.54	1.76	248.97	250.06	-1.09
90R	63.58	64.49	- .91	126.25	125.39	.86	188.92	188.20	.72	251.59	253.72	-2.13

Ta is calculated from the equation

$$Ta = \frac{1}{.563Sz}\left[M(1 - \cos G) + Z\left(\frac{\pi G}{180} - \sin G\right) + Us - Uy\right]$$

Tm is the average running time to the designated range station as measured on the proof range.

TABLE 2
TORPEDO MARK 18 MOD 2
COMPARISON OF OBSERVED
AND CALCULATED YARDS OF ADVANCE

G	Ja	Jm	Ja-Jm	No.	S.D.(Yds)
90L	113.60	111.82	1.78	38	9.70
60L	66.68	63.83	2.85	58	8.71
45L	44.46	40.46	4.00	90	8.12
30L	25.10	21.27	3.83	186	8.49
30R	-20.75	-23.43	2.68	228	6.32
45R	-37.84	-43.02	5.18	122	9.78
60R	-57.94	-63.60	5.66	58	7.50
90R	-101.60	-104.61	3.01	33	16.73

Ja is calculated from equation

$$Ja = M \sin G + Z(1 - \cos G)$$

Jm is the average advance as measured on the proof range, in yards.

No. is number of Torpedoes fired.

S.D. is Standard Deviation of the advance in yards.

Negative numbers indicate distances to left of the range centerline.

Positive numbers indicate distances to the right of the range centerline.

TABLE 3
TORPEDO DEFLECTION (MILS)
MARK 18 MOD 2 - KEYPORT
(JUNE 1944 - JUNE 1946)

Distance from Launching	1000 Yds.			2000 Yds.			3000 Yds.			4000 Yds.		
Type of Run	Ave.	S.D.	No.	Ave.	S.D.	No.	Ave.	S.D.	No.	Ave.	S.D.	No.
Left Gyro	1.78	3.35	374	3.64	4.55	373	3.56	5.12	373	4.10	6.01	355
Straight Run	1.30	3.50	229	4.64	3.00	229	4.64	3.50	229	5.40	3.80	229
Right Gyro	4.08	3.84	443	6.47	5.83	442	8.58	6.63	438	9.98	7.80	401

Ave. is the average deflection in mils.
S.D. is the standard deviation of deflection in mils.
No. is the number of torpedoes.

All deflections are right.

Drift (yards) = Deflection (mils) x Distance (thousands of yards)

TABLE 4
TORPEDO MARK 18 MOD 2
VARIATION IN AVERAGE DEFLECTION WITH SET DEPTH AND RANGE
DATA: 1190 STRAIGHT RUNS AT NTS KEYPORT, DEC. 1944 - JUNE 1945

Set Depth (ft)	Expected Deflection - Mils			Set Depth (ft)	Expected Deflection - Mils		
	1000 Yd	2000 Yd 3000	4000 Yd		1000 Yd	2000 Yd 3000	4000 Yd
0	7.4	10.3	13.1	15	1.3	4.6	5.4
1	5.6	9.2	10.8	16	1.2	4.5	5.4
2	4.8	8.5	9.9	17	1.1	4.4	5.3
3	4.2	8.0	9.2	18	1.0	4.3	5.2
4	3.6	7.4	8.6	19	0.9	4.2	5.1
5	3.3	7.0	8.1	20	0.9	4.1	5.0
6	2.9	6.6	7.6	21	0.8	4.0	5.0
7	2.6	6.4	7.3	22	0.8	4.0	5.0
8	2.4	6.0	7.0	23	0.7	3.9	4.9
9	2.2	5.8	6.6	24	0.7	3.9	4.9
10	2.0	5.6	6.4	25	0.7	3.8	4.9
11	1.8	5.4	6.2	26	0.6	3.8	4.9
12	1.6	5.2	6.0	27	0.6	3.8	4.8
13	1.5	5.0	5.8	28	0.6	3.7	4.8
14	1.4	4.8	5.6	29	0.6	3.7	4.8
				30	0.5	3.7	4.8

All deflections are right.

Drift (yards) = Deflection (mils) x Distance (thousands of yards)