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From: Chief, Naval Technical Mission to Japan.
To : Chief of Naval Operations.

Subject: Target Report - Japanese Torpedo Fire Control.

Reference: (a)"Intelligence Targets Japan" (DNI) of 4 Sept. 1945.

1. Subject report, covering Target 0-32 of Fascicle 0-1 of reference (a), is submitted herewith.

2. The investigation of the target and the target report were accomplished by Lt. (jg) D. G. Jackson, USNR.

C. G. Grimes

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Captain, USN

RESTRICTED

O-32

JAPANESE TORPEDO FIRE CONTROL

"INTELLIGENCE TARGETS JAPAN" (DNI) OF 4 SEPT. 1945

FASCICLE O-1, TARGET O-32

FEBRUARY 1946

U.S. NAVAL TECHNICAL MISSION TO JAPAN

SUMMARY

ORDNANCE TARGETS

JAPANESE TORPEDO FIRE CONTROL

The Japanese spent considerable effort on the design and manufacture of torpedo fire control equipment. The various units are well constructed and function with good accuracy. Their submarine torpedo data computers and auxiliary equipment are more simplified and less accurate than U.S. equipment, while above water torpedo control gear (especially for cruisers) is more complicated and is equal in merit to that of U.S. design.

The Japanese approach to the torpedo problem for above water launching is surprisingly complete and comprehensive, provision having been made for introducing into the computing unit almost every conceivable constant and variable pertaining to the problem. Torpedo fire control equipment contains the only examples of automatic inputs using electrical follow-up gear which have been found in Japanese fire control of any kind. Use has been made of slip ring follow-ups controlling a reversible motor through a magnetic-type hunter switch.

Target designation systems as well as torpedo indicating and firing panels were not well developed in submarine installations and only slightly better in destroyer and cruiser applications.

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REFERENCES

Location of Target:

Nippon Optical Company, MIZUNOKUCHI, Tokyo.

Japanese Navy Technical Department, TOKYO.

Japanese Personnel Interviewed:

Mr. K. FUKAEDA, designing engineer for Nippon Optical Company, TOKYO.

Mr. S. TSUKAMOTO, civilian engineer at Japanese Navy Technical Department, TOKYO.

INTRODUCTION

The bulk of the information is this report was obtained from notes prepared by Mr. FUKAEDA, designing engineer for the Nippon Optical Company, which was the manufacturing agent for most of this equipment.

The report is divided into three parts: (I) below water or submarine torpedo control, (II) above water torpedo control and (III) communications and firing panels. Only the more recent designs are described.

Installations for above water torpedo fire control were made with combinations of various units. For destroyers, one of the following combinations was used:

1. Type 97 (or other similar design) director only.
2. Type 97 director with Type 3 target course and speed instrument.
3. Type 97 director with Type 3 target course and speed instrument and Type 93 computer.

The torpedo fire control systems for cruisers consisted of one of the following combinations:

1. Type 97 (or Type 92, Mod 2) director with Type 93 computer (or Type 0) and the Type 3 or Type 93 target course and speed instrument.
2. Type 97 director and Type 1 computer.

No attempt has been made to describe separately the destroyer and cruiser systems. The various sections of the report on above water torpedo control are devoted to individual units.

For information on anti-submarine fire control see NavTechJap Report "Japanese Anti-Submarine Warfare", Index No. S-24.

THE REPORT

Part I
SUBMARINE TORPEDO FIRE CONTROL EQUIPMENT

A. TYPE 5, MOD 3 TORPEDO FIRING DIRECTOR

1. General. The torpedo fire control director Type 5, Mod 3 is a central computing instrument for use in smaller submarines and is designed so that one operator may obtain the necessary firing data. The instrument is a small, compact device, inexpensive and easily manufactured. The performance is limited and the instrument serves merely to calculate the gyro angle which is then transmitted to the torpedo room by means of a selsyn motor.

2. Data Chart.

Notation	Item	Range of Values	Remarks
V	Torpedo speed	Two constant speeds	Inherent for torpedoes
S	Target speed	0 to 40, 0 to 32	Two scales used
B	Target course	360°	Set by hand
D	Range	500 to 3000 meters	Set by hand
β	Bearing angle	$\pm 90^{\circ}$	Follow the pointer
θ	Output gyro angle	$\pm 90^{\circ}$	Calculated

3. Auxiliary Equipment.

a. Bearing angle transmitter - Type 3, Mod 2. This transmitter consists of a selsyn motor which transmits the periscope bearing at the rate of 20° of bearing angle for one revolution of the selsyn.

b. Gyro angle transmitter. This selsyn is adjusted by the operator in solving the problem of calculated gyro angle and transmits this angle to the torpedo chamber at the rate of 10° per revolution.

4. Principle of Calculation. The diagram, Figure 1, indicates the problem to be solved where:

B - Target position

A - Own ship

C - Point of hit

P - Equivalent point of fire

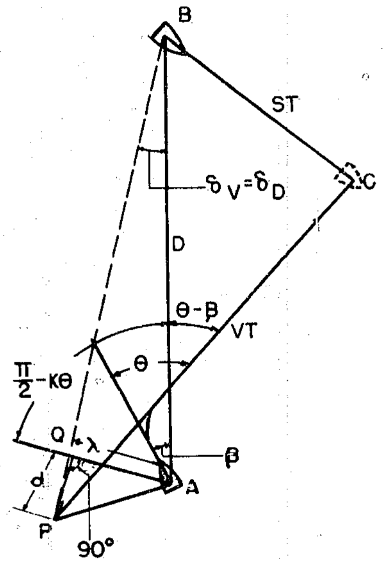


Figure 1
TYPE 5 VECTOR DIAGRAM

It can be seen that:

$$\tan \delta_V = \frac{\sin(\theta - \beta) - \frac{S}{V}\sin B}{\cos(\theta - \beta) + \frac{S}{V}\cos B}$$

$$\tan \delta_D = \frac{\lambda \sin(\beta + \frac{\pi}{2} - k\theta) - d\sin(\beta - k\theta)}{D - \lambda\cos(\beta + \frac{\pi}{2} - k\theta) + d\cos(\beta - k\theta)}$$

Where δ_V = Parallax angle of P solved from velocity triangle.

δ_D = Parallax angle of P solved from range polygon ABPCQ

$\delta_V = \delta_D$

λ = Experimental function of gyro angle,

δ_d and δ_k = Experimental constants of torpedo.

δ_d and δ_V are calculated by two parallax mechanisms and are indicated on a single dial by two arrow marks. Therefore, by turning the handle of gyro angle and putting $\delta_V = \delta_D$ or matching the two arrows, the required gyro angle, θ, can be obtained. This may be read from the dial; or, in equipment having manufacturers serial number above 31, it is transmitted by the gyro angle transmitter shown in the schematic diagram (Figure 2).

A plan view of the equipment is shown in Figure 3. The bearing angle clutch is engaged when the target course (B) remains constant; any deviation from the range vector diagram is controlled by alteration of bearing angle β only.

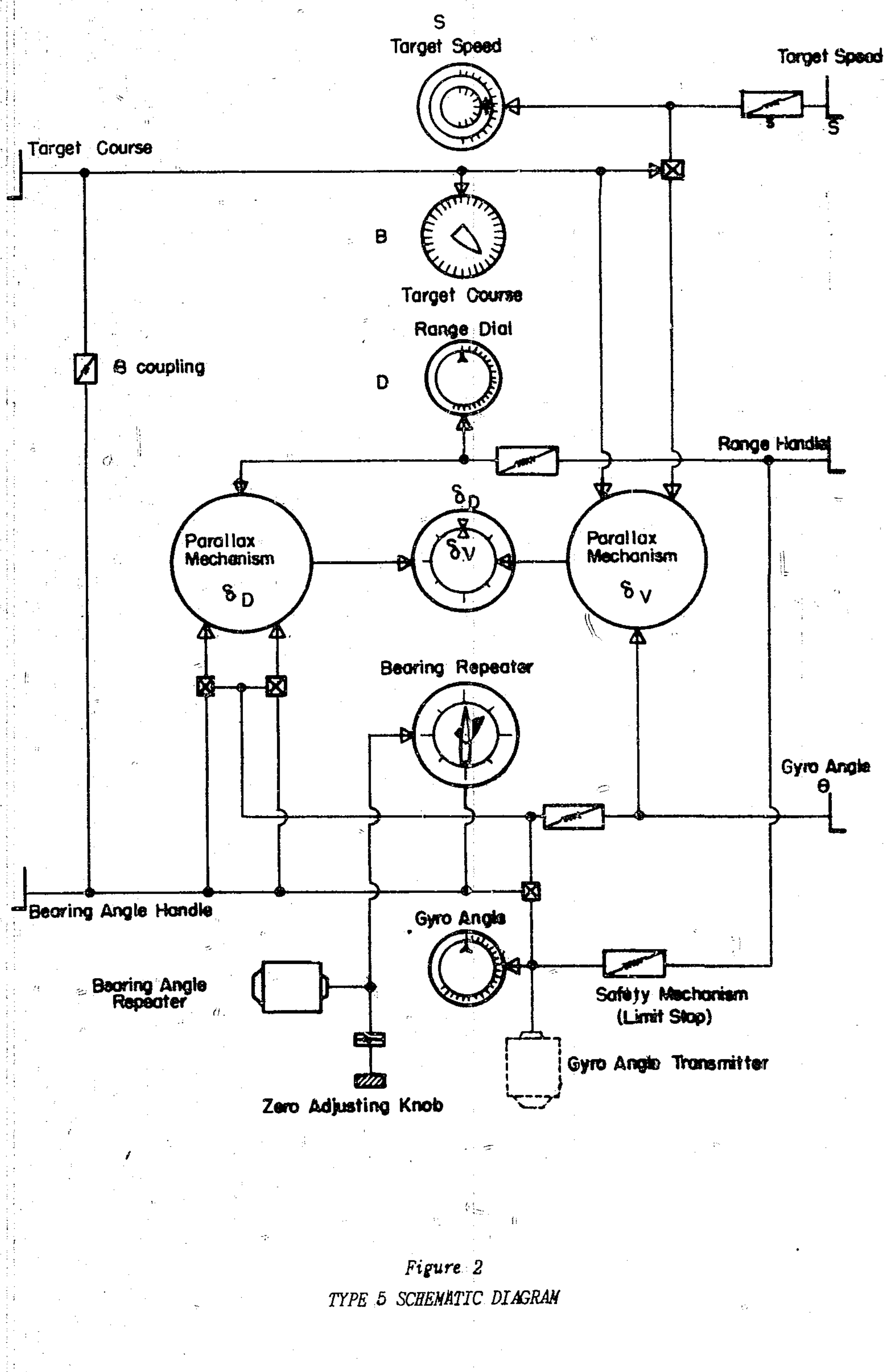


Figure 2
TYPE 5 SCHEMATIC DIAGRAM

Two of these units manufactured by the Nippon Optical Company have been shipped to Ordnance Investigation Laboratory, Indian Head, Md. See Enclosure (B).

5. Weights and Sizes.

Length	0.8 meters
Width	0.5 meters
Height	0.1 meters
Weight	220 kg
Cost	¥ 22,000

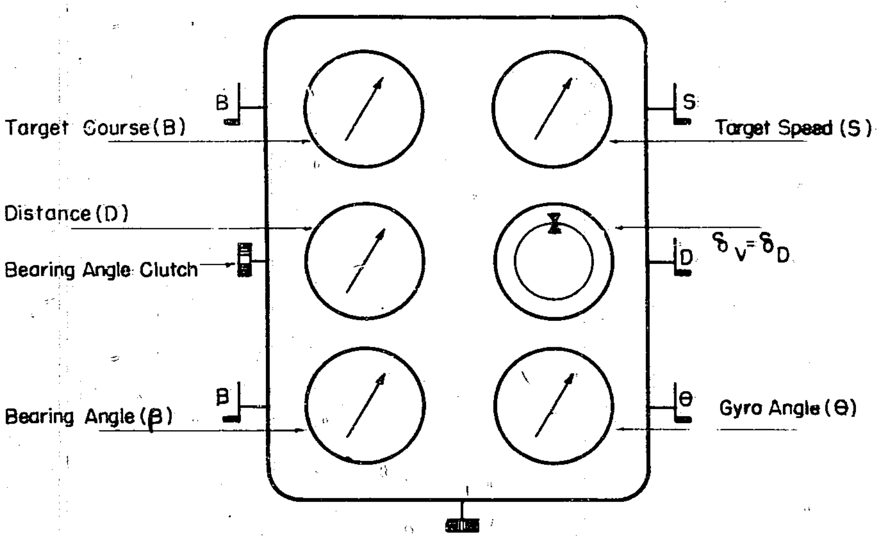


Figure 3
TYPE 5 PLAN VIEW

F. TYPE 92, MOD 2 TORPEDO FIRING DIRECTOR

1. General. The torpedo firing director Type 92, Mod 2 is a central computing instrument used in larger submarines. It is designed so that the necessary firing data with no dead time may be obtained by one operator. To accomplish this, the gyro angle is calculated for a future time (chosen arbitrarily from 0 to 40 seconds) and five seconds before the time to fire a bell begins to ring. The torpedo is launched when the bell stops ringing.

2. Data Chart.

Notation	Item	Range of Values	Notes
V	Torpedo speed	26 to 56 knots	Set on dial by hand
T	Time interval	0 to 40 seconds	Set on dial by hand
v	Own speed	3 to 20 knots	Set on dial by hand
β	Bearing angle	360°	Automatic input
C	Turning angle	± 20°	Automatic input
S	Target speed	5 to 40 knots	Set on dial by hand
B	Target course	360°	Set on dial by hand
D	Range	500-4000 meters	Set on dial by hand
θ	Gyro angle	± 120°	Calculated
$\Delta\theta$	Gyro angle correction	± 10°	Spotted
β'	Shooting bearing	360°	Calculated

3. Description of Data.

a. Input data before engagement of target.

Torpedo speed: Inherent speed of torpedo; i.e., speed of torpedo some minutes after firing.

Own speed: Speed of own submarine.

Time interval: Time interval between observation and firing; chosen arbitrarily.

b. Input data after engaging target.

Target speed: Observed or estimated speed of target.

Target course: Observed or estimated course of target.

Range: Observed distance between own ship and target; from periscope, sonar or radar.

c. Automatic input data.

Bearing angle: The bearing angle of the periscope is continuously transmitted by selsyn to the director while the periscope is up.

Turn angle: Deviations of own ship course after periscope is lowered; transmitted automatically by selsyn from master compass.

d. Required output data.

Gyro angle: The angle between shooting direction and the terminal running direction of the torpedo. The angle is calculated by the instrument and transmitted by selsyn to the torpedo rooms.

Shooting bearings: Bearing angle at shooting position; this angle is used for checking in drill.

A plan view of the equipment in Figure 4 shows the layout of the dials and location of handwheels.

4. Principle of Calculation. Referring to Figure 5 the following notes apply:

A_1 -- Observing point of own ship

A_2 - Firing point of own ship

A_3 - Equivalent point of firing

B_1 - Target position observed

B_2 - Target position at firing

B_3 - Hitting point

$$\tan \delta_0 = \frac{ST \sin B + vT \sin (\beta - C)}{D - [ST \cos B + vT \cos (\beta - C)]} \qquad (1)$$

$$\tan \delta_D = \frac{ST \sin B + vT \sin (\beta - C) + \lambda \sin (\beta - C + \frac{\pi}{2} k\theta)}{D - [ST \cos B + vT \cos (\beta - C) + \lambda \cos (\beta - C + \frac{\pi}{2} k\theta)]} \qquad (2)$$

$$\tan \delta_V = \frac{V \sin (\beta - C - \theta) + S \sin B}{V \cos (\beta - C - \theta) + S \cos B} \qquad (3)$$

$\tan \delta_0$ = Difference of bearing angle

$\tan \delta_D$ = Parallax angle of equivalent point of firing calculated from the range vector $B_1 B_3 A_3 A_2 A_1$

$\tan \delta_V$ = Parallax angle of equivalent point of firing calculated from the speed triangle

λ = Experimental or empirical function of gyro angle θ

k = Experimental or empirical constant of torpedo.

5. Description of Operation and Schematic Diagrams. Figure 7 shows a simplified schematic diagram of the mechanical principles of the instrument and Figure 8 shows the electrical circuits in simplified form. Both may be referred to in the following description.

Before sighting, the handwheels 1a, 1b and 1c are rotated to set the torpedo constants and the chosen time T. After sighting a target, handwheels 2, 3, and 4 are adjusted according to observations or estimations. The two markers for δ_D and δ_0 will not coincide, so handwheel 5 (gyro angle θ) is rotated until the two pointers are matched. This is the required gyro angle and is read on the appropriate dial (also automatically transmitted to the torpedo rooms). While sighting through the periscope, bearing angle β is automatically received and introduced into the device by means of a slip ring type electrical follow-up device. This follow-up was found only in the torpedo fire control of the Japanese Navy. Its operation is easily understood by referring to the electrical wiring diagram. The contact points consist of a tungsten silver brush and the slip rings are made of platinum alloy 6mm wide.

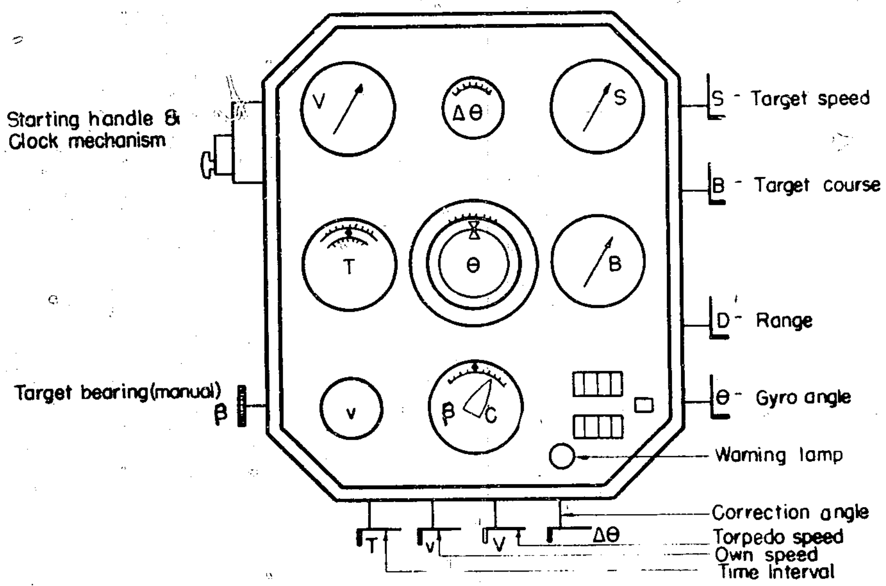


Figure 4
TYPE 92 PLAN VIEW

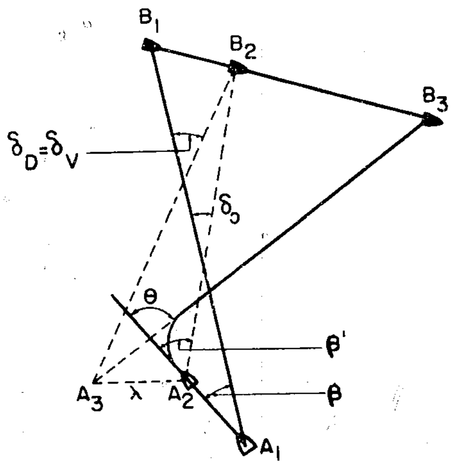


Figure 5
TYPE 92 VECTOR DIAGRAM

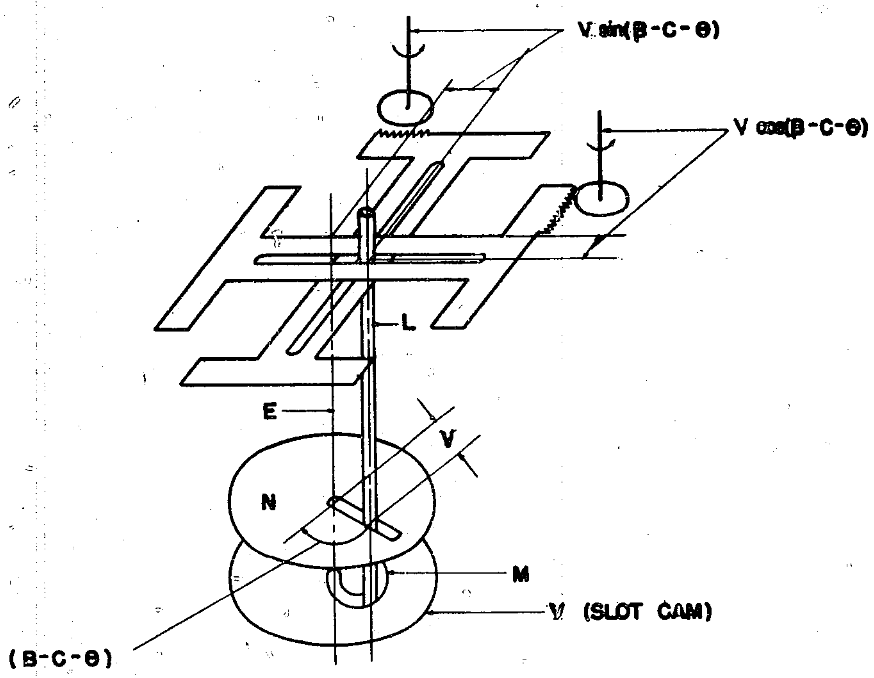


Figure 6

TYPE 92 "V" CALCULATING MECHANISM

Referring to Figure 7, when the periscope is lowered, the starting handle, 6, is moved; this starts the clock mechanism and also actuates the magnetic clutches 7 and 8 which put the turn angle electrical follow-up into the circuit. While the periscope is transmitting bearing angle, turn angle has no effect on the inputs. After lowering the periscope, any changes in the submarine's course are automatically introduced by the turn angle follow-up.

At five seconds before firing time, the firing alarm switch, 9, is closed by the clock mechanism and a bell rings until the end of the five seconds; the torpedo is then fired.

The "warning lamp contacts" provide a warning that the input data cannot be satisfactorily solved. Contacts 10, 11 and 12 are actuated by the denominators of formulae (1), (2), and (3) when these values are below a certain minimum. Contacts 13 and 14 are actuated by the denominators of formulae (2) and (3) when these are above a given maximum value.

The mechanisms shown by V, S, λ, vT and ST in Figure 7 are similar to the diagram, Figure 6, showing the calculating mechanism for V. The bottom disc contains a slotted cam and is turned by the torpedo speed handwheel. The rod L is displaced from the center by the cam and the distance from the center represents V. The other disc is rotated in terms of $(\beta - C - \theta)$. This displaces the two sliding arms and the pinions moved by racks on these arms are rotated the appropriate amounts to give the values indicated.

The mechanisms δ_0, δ_D and δ_V are similar to the one shown for V in construction and operation, the only difference being that the inputs are applied to the moving arms and the output is obtained at a single lower disc.

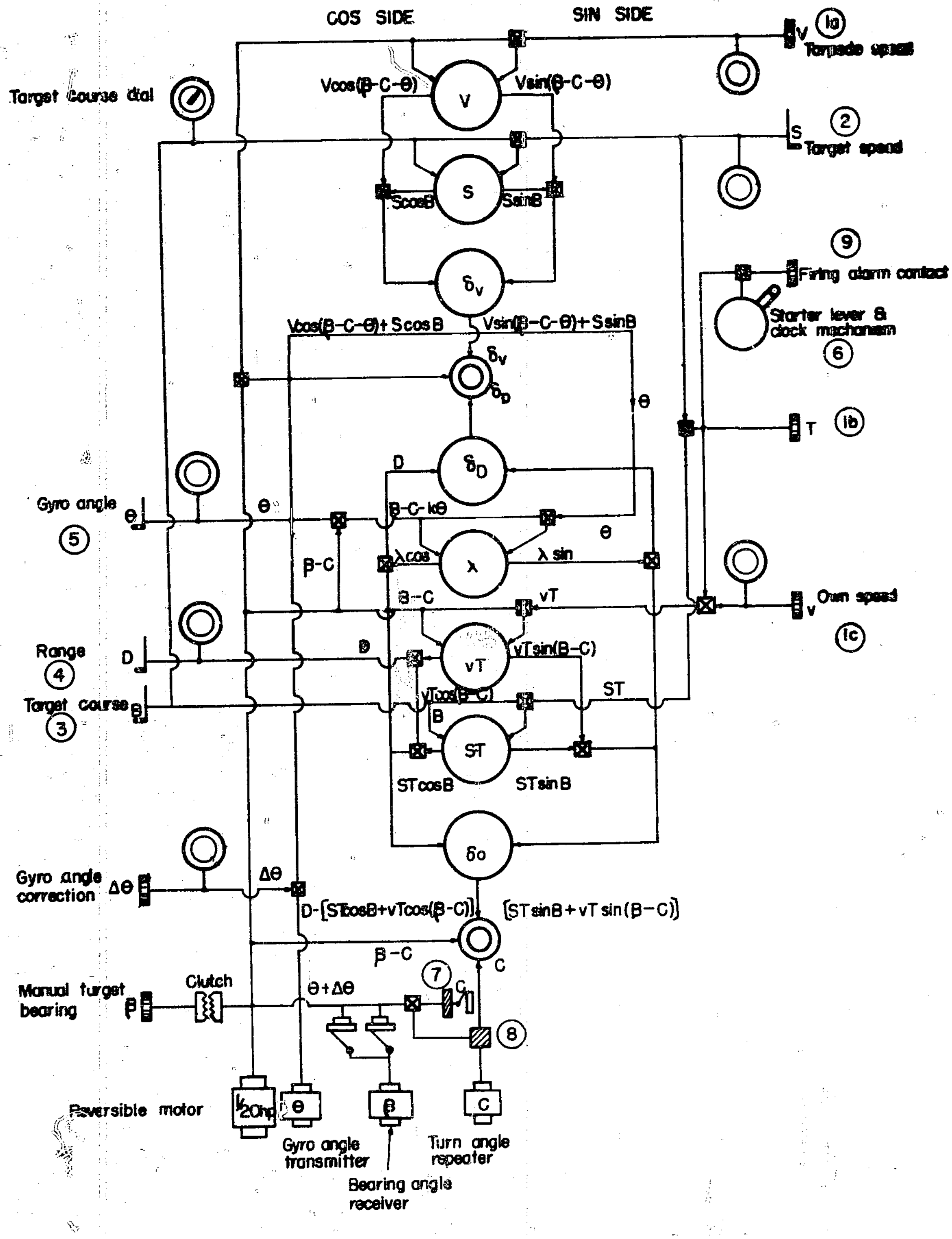


Figure 7

TYPE 92 MECHANICAL SCHEMATIC DIAGRAM

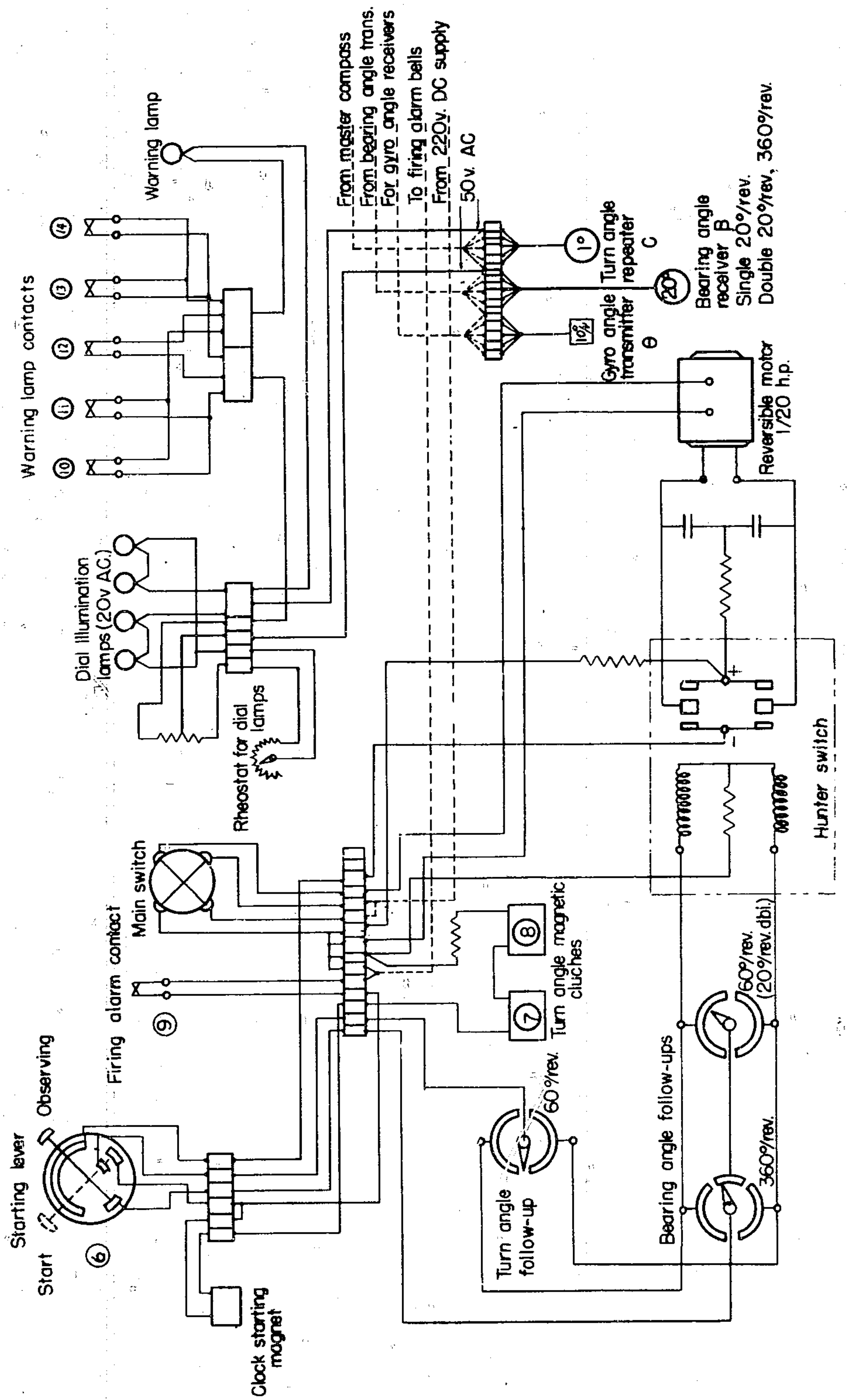


Figure 8
TYPE 92, MOD 2 ELECTRICAL SCHEMATIC DIAGRAM.

When operating this equipment for drill purposes, is used as a check. Observation of target is made and calculations commence. When the bell stops ringing, the bearing angle (which is constantly observed during drill) should be equal to β or shooting bearing angle as calculated and shown as $\beta' + \delta_0$.

6. Weights and Sizes.

Length	0.8 m
Width	0.8 m
Height	1.0 m
Weight	300 kg (approx.)
Cost	¥ 33,000

Production was begun in April 1943 by the Nippon Optical Company and terminated March 1945 after 60 units were produced. Two of these units have been shipped to the United States. See Enclosure (B).

Part II
ABOVE WATER TORPEDO FIRE CONTROL EQUIPMENT

A. TYPE 97, MOD 2 DIRECTOR (HOIBAN)

1. General. This director is a simple sight mechanism. It mounts a binocular type sight, the supporting column of which is nested inside several annular rings. Both the sight column and the rings are free to be adjusted in rotation.

2. Description of Use. There are two methods for use. In the first method the target is observed and various inputs made to the different rings; i.e., gyro angle, training angle of tubes, correction angle (dead time, parallax, etc.), gyro correction angle to standard firing line (lead angle for spread), and range. The marker which indicates firing bearing (the bearing of target ship when torpedo should be fired) can be matched with the marker for line of sight. Thus, when the target once again comes into view in the sights, the signal is given for the launching of the torpedo. It is possible to wait until the relative movements of own and target ship cause the target to appear in the sights, or own ship may be conned into the proper position for earlier firing.

The second method for using the Type 97 director is to track the target continuously with the pin (shown in the upper left hand part of the diagram in Figure 9) engaged in the hole provided. Under this condition, the director acts merely as a target transmitter. Installed aboard cruisers, the operation of the director is usually in this manner. Target bearing is transmitted to the computer and to the target course and speed instruments. However, should damage occur to the other equipment, the director may be used alone by disengaging the pin and operating as in the first method.

3. Remarks. The Japanese had other directors which were substantially the same as this Type 97 in construction and principle, among them were Type 1 (known as HASSHASHIKIBAN); Type 90, Mod 3; Type 0 and Type 92, Mod 2. Two samples of the Type 92, Mod 2 were obtained and have been shipped to the United States. See Enclosure (B).

B. TYPE 3 TARGET COURSE AND SPEED INSTRUMENT (SOKUTEKIBAN)

1. General. This instrument is used to obtain target course and speed after setting own speed, present bearing and range. With this device it is possible to conduct blind firing should the target enter a smoke screen or otherwise be lost from view.

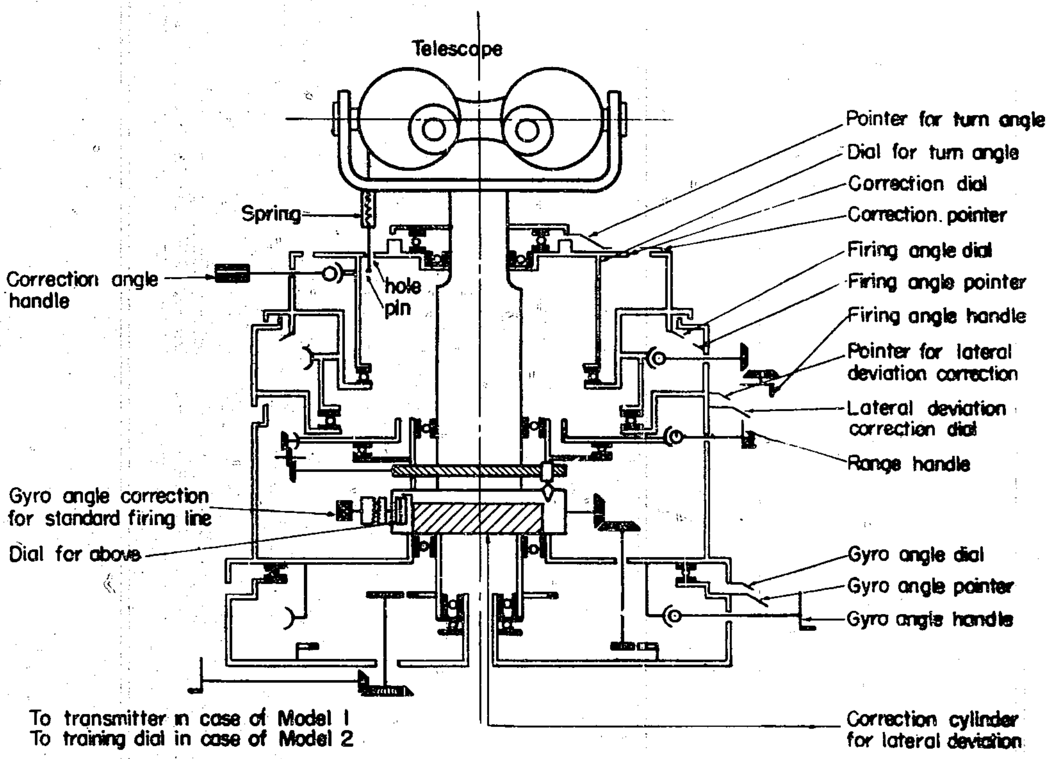


Figure 9

TYPE 97, MOD 1 AND 2 DIRECTOR

2. <u>Data Chart</u>.

Symbol	Item	Range of Values	Notes
β	Target bearing	360°	From radar or director, automatic input
D	Range	2000-20,000 m	From radar or rangefinder, automatic input
v	Own speed	0 to 40 knots	Hand input
B	Target course	360°	Calculated
S	Target speed	6 to 40 knots	Calculated
C	Own course	360°	Automatic from gyro compass
S_1	Lateral speed component	Maximum, 40 knots	Adjusted to coincide with light slit on tracer
S_2	Longitudinal speed component	Maximum, 40 knots	Adjusted to coincide with light slit on tracer

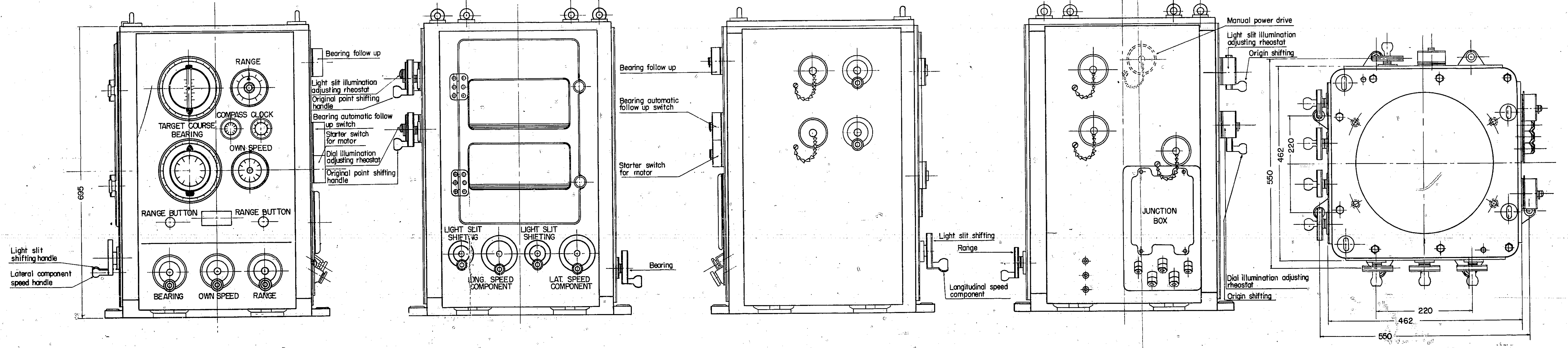


Figure 10

COURSE AND SPEED INSTRUMENT, GENERAL

3. General Construction. Figure 10 indicates the size and appearance of the instrument. Its weight is 290 kg. There are five levels in the unit which are as follows:

First level: Bearing and range receivers, own speed component resolver, rate mechanism for longitudinal own speed component.

Second level: Rate mechanism for own lateral speed component, target lateral speed component and target longitudinal speed component.

Third level: Longitudinal projector and rate mechanism for apparent lateral speed component.

Fourth level: Lateral projector and compass repeater.

Fifth level: Constant speed motor, automatic follow-ups and plot marking electromagnet.

Extending through the third, fourth and fifth levels - Plot.

4. Principle of Calculation.

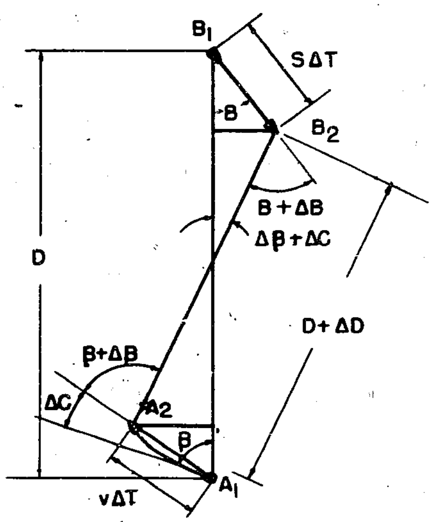


Figure 11

TYPE 3 TARGET COURSE AND SPEED INSTRUMENT, VECTOR DIAGRAM

A_1 - Initial own ship position

A_2 - Own ship position after ΔT sec

B_1 - Initial target ship position

B_2 - Target position after ΔT sec

β, D, B --------- represent initial bearing, range and target course, and $\beta + \Delta\beta$, $D + \Delta D$, $B + \Delta B$ are these values after ΔT sec.

From the diagram, Figure 11, we get the following relationships:

$$(D + \Delta D) \sin (\Delta\beta + \Delta C) = S \Delta T \sin B + v \Delta T \sin (\beta - \tfrac{1}{2} \Delta C)$$

$$D - (D + \Delta D) \cos (\Delta\beta + \Delta C) = S \Delta T \cos B + v \Delta T \cos (\beta - \tfrac{1}{2} \Delta C)$$

Dividing both equations by ΔT and putting $\Delta T \to 0$

$$D \frac{d(\beta + C)}{dt} = S \sin B + v \sin \beta$$

$$-\frac{dD}{dt} = S \cos B + v \cos \beta$$

Therefore,

$$S_1 = S \sin B = D \frac{d(\beta + C)}{dt} - v \sin \beta$$

$$S_2 = S \cos B = -\frac{dD}{dt} - v \cos \beta$$

or

$$S_1 = \frac{d}{dt} [\int D d(\beta + C) - \int v \sin \beta \, dt] \text{ ------------------------------ } (1)$$

$$S_2 = -\frac{d}{dt} (D + \int v \cos \beta \, dt) \text{ ------------------------------------- } (2)$$

According to these equations, S_1 and S_2 can be calculated with the result that target speed and course will be obtained continuously. A schematic diagram of the system is shown in Figure 12.

C. <u>TYPE 93 TARGET COURSE AND SPEED INSTRUMENT (SOKUTEKIBAN)</u>

1. <u>General</u>. The principle of this Type 93 target course and speed instrument is similar to that of the Type 3 described in the preceding section. However, the mechanical equations used are different.

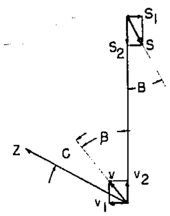
Rate mechanisms play the most important part in the Type 3. By obtaining the lateral and longitudinal speed components (S_1 and S_2), target course and speed are available continuously. With the Type 93 it will be seen that range change (ΔD) and bearing angle difference (ϕ) play the important roles and, because of this, target course and speed are not available continuously.

	NAME	RANGE	QUANTITY set/rev. hand	NOTES
B	Bearing	all round	3° 10°	power selsyn
D	Range	2000 20000	500 M	power selsyn
v	Own speed	0 – 40R.	2 K	
B	target course	all round	10°	
S	target speed	10 - 400	—	
S_1	lateral component speed	0 - ±40 K	5 K	
S_2	longitudinal comp. speed	0 - ±40 K	5 K	
L_1	light slit shift (long.)	(8000 M)	(500 M)	
L_2	light slit shift (lat.)	(8000 M)	(500 M)	
C	compass	all round	—	
P_1	plotting pen shifting (lat.)	(8000 M)	500 M	
P_2	plotting pen shifting (long)	(8000 M)	500 M	

FUNDAMENTAL EQUATION – Target speed

$S_1 = \frac{\Delta}{\Delta t}\left[\int D\Delta(C+\beta) - \int v \sin\beta \Delta t\right]$

$S_2 = \frac{\Delta}{\Delta t}\left[D + \int v \cos\beta \Delta t\right]$



AUXILIARY EQUATIONS

$v_1 = v \sin\beta$

$v_2 = v \cos\beta$

$E = \int D\Delta(C+\beta)$

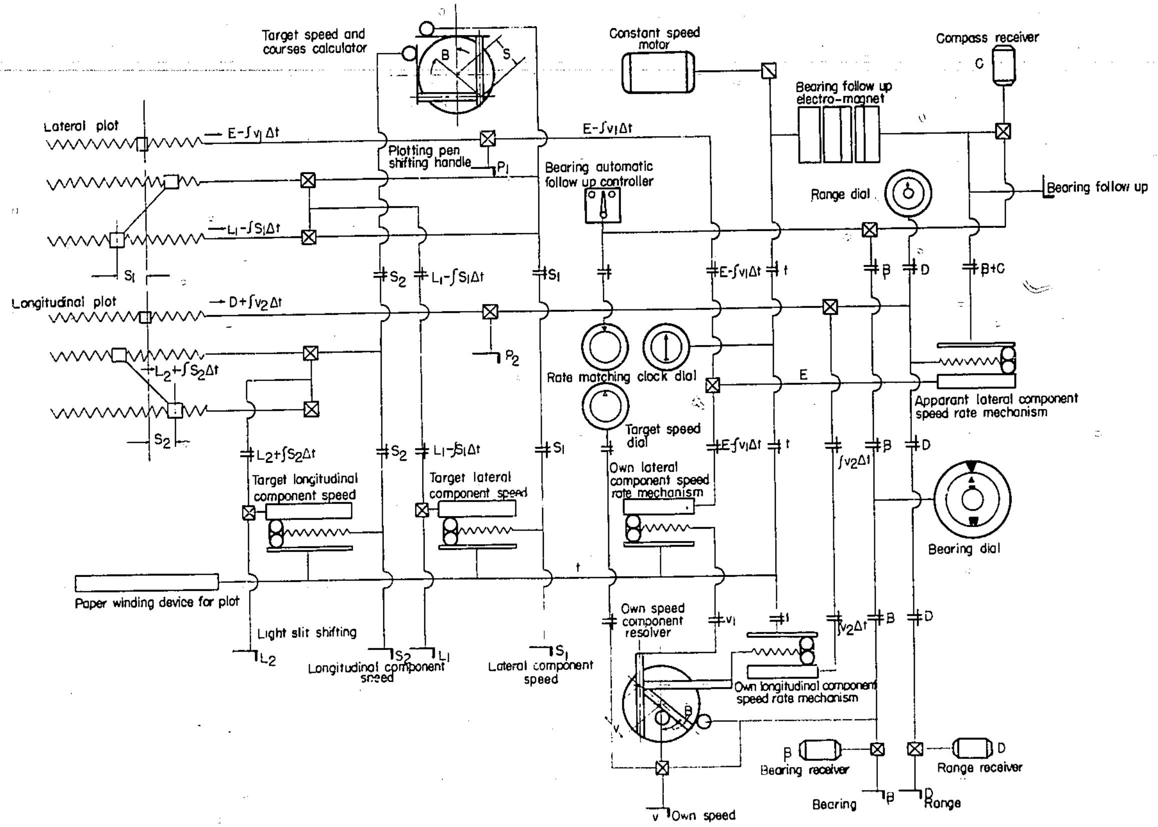


Figure 12

TYPE 3 TARGET COURSE AND SPEED INSTRUMENT, SCHEMATIC

2. Data Chart.

Symbol	Item	Range of Values
S	Target speed	6 to 40 knots
B	Target course	360°
D	Range	5000 to 40,000 m
v	Own speed	0 to 40 knots
α	Inclinometer angle	0 to 60/1000
β	Target bearing	360°
L	Target length	30 to 330 m for a ship 90 to 1000 m for a line of ships
C	Own ship course	360°
D	Range at start of observation	5000 to 40,000 m
T	Time interval	0 to 90 seconds
ϕ	Bearing angle difference	0 to 33°
ΔD	Range difference	0 to 3600 m
$S \sin B \pm v \sin \beta$	Lateral speed component	0 to 80 knots
$S \cos B \pm v \cos \beta$	Longitudinal speed component	0 to 80 knots

3. Data to be set.

D, β, α, L, D' Come from rangefinder and director

v From pit log

C From master gyro compass

$T, \phi, \Delta D$ Buzzer indicated - from control station

4. Principle.

Method A

$$S = \frac{(D \pm \Delta D) \sin \phi \pm v \sin \beta}{\sin B} \quad \text{------} \quad (1)$$

$$\sin B = \frac{\alpha D}{L} \quad \text{------} \quad (2)$$

Method B

$$S \cos B \pm v \cos \beta = \Delta D + D' (1 - \cos \phi) \quad \text{------} \quad (3)$$

When α cannot be obtained, (1) and (3) are used and when α can be obtained, (2) and (3) are used.

5. Crew Required. It requires five men to operate the Type 93 target course and speed instrument (SOKUTEKIBAN).

6. Size and Weight.

1.18 by 0.58 by 0.8 meters

840 kg.

D. TYPE 93 COMPUTER (SHAHOBAN)

1. General. This unit was designed originally for use aboard cruisers. However, it was also installed on some of the old battleships having torpedo tubes and on the newest and largest destroyers.

The computer calculates theoretical gyro angle and also future range, which latter may be used to check the accuracy of calculated data.

2. Data Chart.

Symbol	Item	Range of Values
D	Range	10,000 to 40,000 m
β	Target bearing	360°
S	Target speed	0 to 50 knots
B	Target course	360°
S'	Target turning speed	10 to 50 knots
ω	Target turning angle	0 to $\pm 90^{\circ}$
r	Target turning raduis	250 to 1000 m
T	Time straight run (before turning)	0 to 20 min
T'	Time straight run (after turning)	0 to 20 min
γ	Training angle of tubes	$\pm (75^{\circ}$ to $105^{\circ})$
Δ	Launching correction	0 to $\pm 25^{\circ}$
V	Torpedo speed	38 to 60 knots
R	Torpedo range	8,000 to 40,000 m
δ	Correction angle	0 to $\pm 10^{\circ}$
θ	Gyro angle	0 to $\pm 90^{\circ}$
K	Dispersion degree	0 to 6° to 16°

Notes on data chart: For destroyer installation, the dials for D, T, T' and R are altered so that their ranges are: 4,000 to 16,000 meters for D, 0 to 8 minutes for T, 0 to 12 minutes for T' and 3000 to 16,000 meters for R.

The launching correction (Δ) is a correction applied for the "tail flip" of the torpedo when launched and the resultant alteration of launching angle. This "tail flip" is due to the fact that the nose of the torpedo strikes the water first and inertia (imparted to torpedo by own ship's

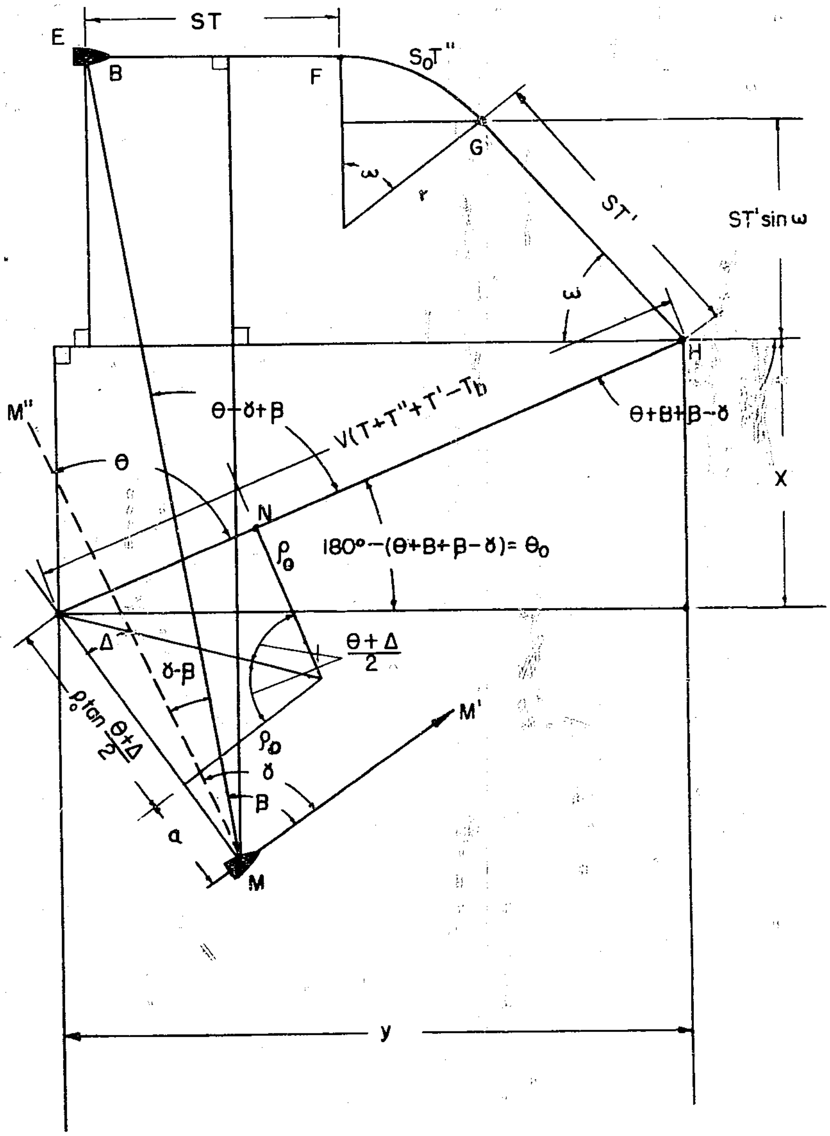


Figure 13
TYPE 93 COMPUTER VECTOR DIAGRAM

speed) causes the weapon to be disturbed from the relative firing angle. This correction is obtained from charts devised for each particular ship since it is dependent not only on the variables of own ship's speed (v) and training angle of tubes (γ), but also on the height of the tubes above the water.

3. Principle. Nomenclature given in the data chart and the following notes apply to Figure 13.

M Own ship at time of firing torpedo

E Target ship at time of firing torpedo

F Target ship begins to turn

G End of target ship turn

MM' Own ship running direction

MM'' Direction of firing tubes

V_0 Torpedo speed between M and N

a Torpedo reach (distance before torpedo begins to change course)

ρ_0 Torpedo turning radius

T Time between E and F

T'' Time between F and G

T' Time between G and H

T_b Time between M and N

R Torpedo range

Solving for x and y indicated in the diagram we get:

$$x = D \sin B - y + r \cos \omega - ST' \sin \omega - (a + \rho_0 \tan \frac{\theta + \Delta}{2}) \sin (B + \beta - \gamma - \Delta)$$

$$y = D \cos B - VT - r \sin \omega - ST' \cos \omega - (a + \rho_0 \tan \frac{\theta + \Delta}{2}) \cos (B + \beta - \gamma - \Delta)$$

These equations may be solved mechanically with x and y being indicated on dials. Matching pointers manually, these values are applied to an arc tangent mechanism the output of which is indicated on another dial and is θ_0 since:

$$\theta_0 = \tan^{-1} \frac{x}{y} = \theta + B + \beta - \gamma$$

This value of θ_0 as indicated on the dial is matched with a pointer, the movement of which is controlled through a differential by the quantity ($B + \beta - \gamma$) (from another section of the computer) plus a hand input of gyro angle, θ.

This θ is transmitted automatically to the tubes after first being corrected for dispersion. The dispersion factor is dependent upon the number of torpedos to be fired and is represented as:

$K = \frac{\theta_2 - \theta_1}{n - 1}$ where n is the number of torpedos to be fired, and θ_1 and θ_2 represent the maximum and minimum values of gyro angle indicated on a dial. Adjusting a pointer to the mid value of the indicated θ_1 and θ_2

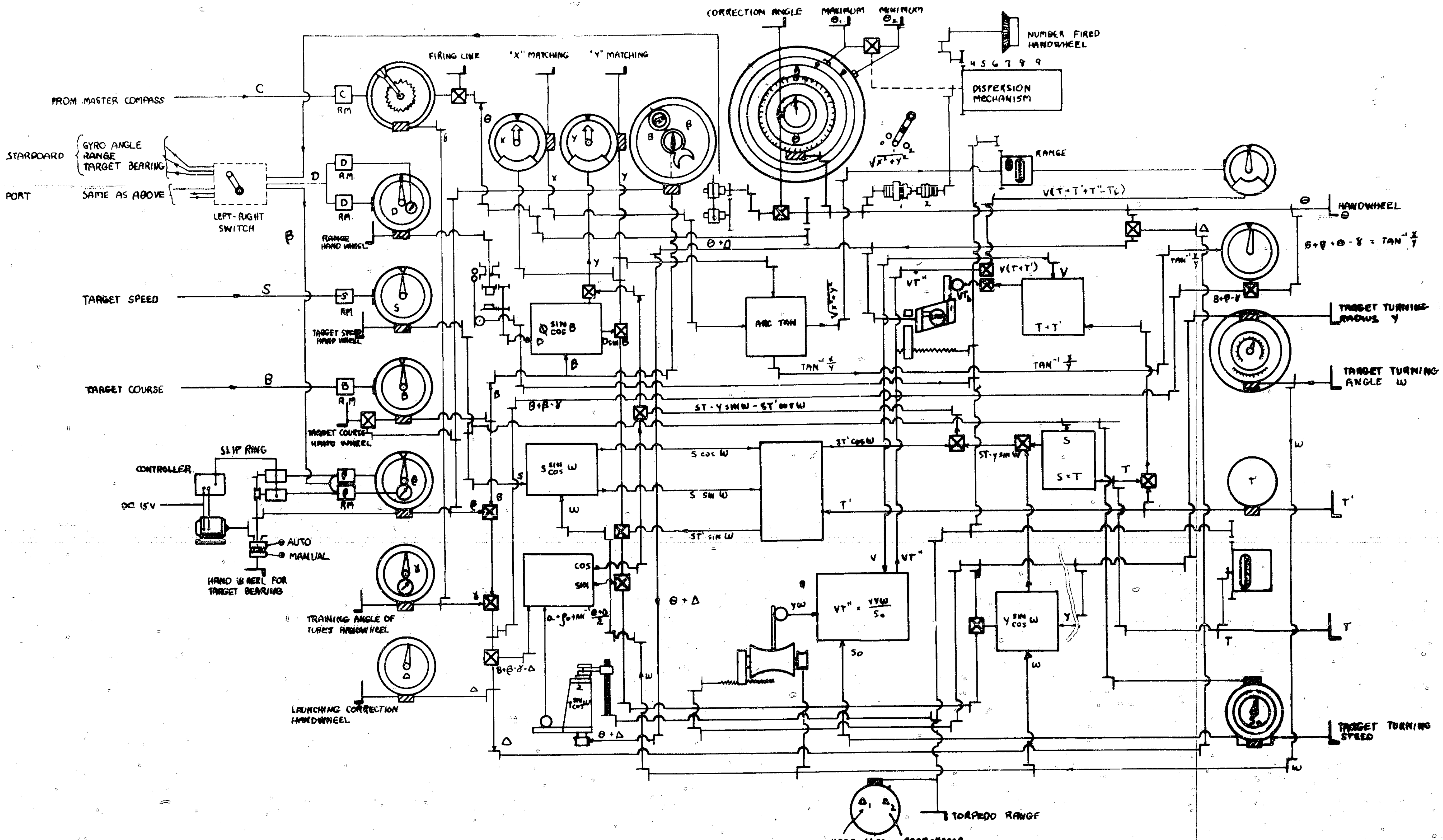


Figure 14
TYPE 93 COMPUTER SCHEMATIC DIAGRAM

the correction for dispersion is added to the calculated θ.

In addition to the foregoing, the following information is obtained from this computer:

$$R = \sqrt{x^2 + y^2} = V(T + T') + VT'' - VT_b$$

$$VT_b = k[a + \rho_0 (\theta + \Delta)] - \rho_0 \tan \frac{\theta + \Delta}{2}$$

where $VT'' = V\frac{r\omega}{S_0}$ and $k = \frac{V}{V_0}$ = assumed constant

This data is used for checking the accuracy of the calculations and to assist in determining the amount of correction angle (δ). A schematic diagram of the computer is shown in Figure 14.

4. Size and Weight.

Length .... 1.18 m
Width .... 0.58 m
Height .... 0.79 m
Weight .... 880 kg

Personnel required: five men.

E. TYPE 1 COMPUTER (SHAHOBAN)

1. General. This computer represents the most advanced torpedo fire control equipment of the Japanese Navy and is based on a combination of modified older types (such as the Type 0 computer).

The Type 1 computer is composed of three parts which are as follows:

a. Target course and speed unit (SOKUTEKI). By setting range, target bearing, own speed, inclinometer angle, and target length; target course and speed are obtained.

b. Computer section. Inputs of tube training angle, torpedo speed, launching correction, time interval, and own ships course are combined with outputs of part (a) above to give gyro angle, torpedo range and dispersion angle.

c. Position indicator part. A continuous plot of target position as well as own ship position permits indirect firing.

2. Data Chart.

Symbol	Item	Range of Values	Notes
D	Range	5000 to 40,000 m	Automatic
ΔD	Range difference	0 to 15,000 m	Automatic
β	Target bearing	360°	Automatic
$\Delta\beta$	Target bearing difference	0 to ± 25°	Automatic
E	Inclinometer angle	0 to 60/1000	Automatic
ΔC	Own course change	0 to ± 90°	Automatic
t_0	Time interval	0 to 5 min	Automatic

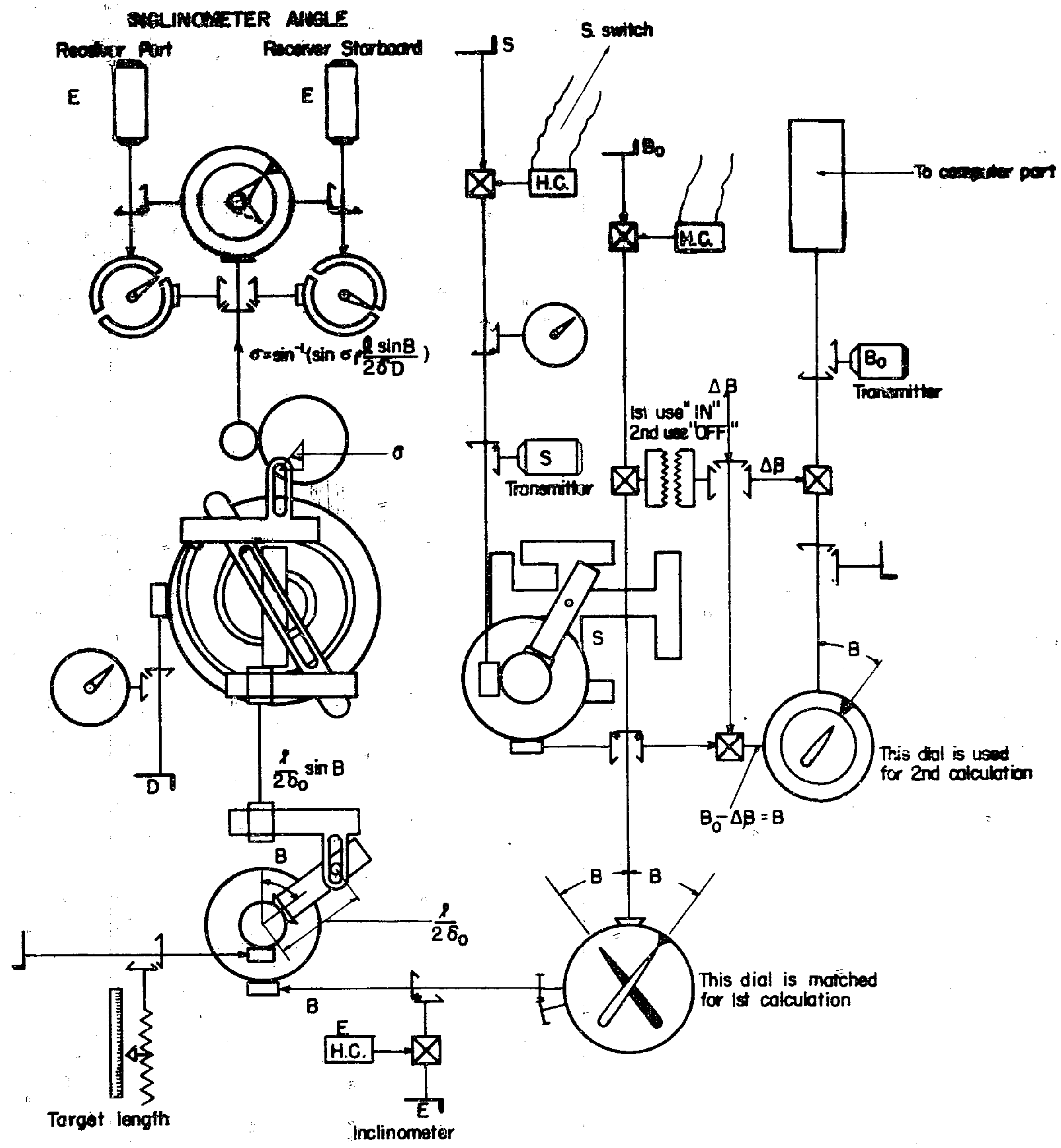


Figure 15

TYPE 1 COMPUTER TARGET COURSE AND SPEED SECTION

Data Chart Continued.

Symbol	Item	Range of Values	Notes
l	Target length	30 to 1000 m	Manual
B	Target course (setting)	360°	Manual
B_0	Target course (following)	360°	Automatic
S	Target speed	0 to 40 knots	Automatic
γ	Training angle of tubes	$\pm(75^{\circ}$ to $105^{\circ})$	Manual
Δ	Launching correction	0 to $\pm 25^{\circ}$	Manual
ω	Target turning angle	0 to $\pm 90^{\circ}$	Manual
r	Target turning radius	250 to 1000 m	Manual
S'	Target turning speed	10 to 50 knots	Manual
T	Time straight run (before turn)	0 to 20 min	Manual
T'	Time straight run (after turn)	0 to 30 min	Automatic
V	Torpedo speed	30 to 60 knots	Manual
δ	Correction angle	0 to $\pm 15^{\circ}$	Manual
θ_0	Gyro angle follow-up	0 to $\pm 90^{\circ}$	Automatic
θ_m	Gyro angle limiting	0 to $\pm 90^{\circ}$	Manual
θ_i	Gyro angle transmitted	0 to $\pm 90^{\circ}$	Calculated
ρ	Dispersion angle	0 to 6° to 16°	Calculated
R	Torpedo range	3000 to 46,500 m	Calculated
N	Number tubes fired	4 to 9	Manual
v	Own speed	0 to 40 knots	Manual

3. Target Course and Speed (SOKUTEKI) Part. This section was designed along the same principles as the Type 93 target course and speed instrument described in Part II section C. There are two applications. The first bases its calculations on the angle of rotation (σ) of the deflecting prism of the inclinometer so that we can obtain the relationship:

$$E = \frac{l \sin B_0}{D}$$

$$E = 2\delta_0 (\sin \sigma_1 + \sin \sigma)$$

$$\sigma = \sin^{-1}\left(\sin \sigma_1 + \frac{\frac{l}{2\delta_0} \sin B}{D}\right)$$

which are solved for target course (B).

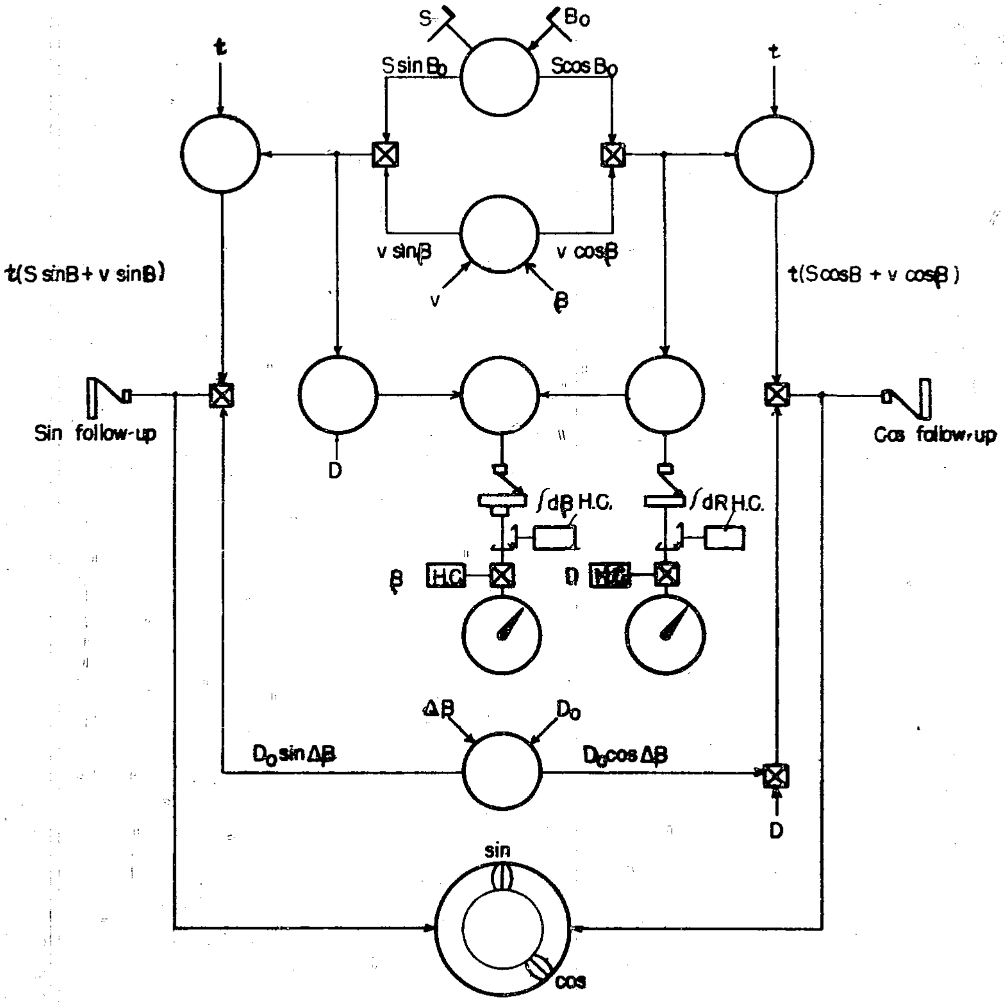


Figure 16
TYPE 1 COMPUTER TARGET COURSE AND SPEED SECTION

The second calculation is based on the following:

$$D_0 \sin \Delta\beta = (S \sin B + v \sin \beta)t$$

$$D_0 \cos \Delta\beta - D = (S \cos B + v \cos \beta)t$$

These two equations are solved automatically for S and B.

Figure 15 shows part of the target speed and course section illustrating the first method of use and Figure 16 schematically indicates the mechanisms for the second calculation.

An additional feature of this desigh is the ability to obtain the values of $\int \frac{dR}{dt}\,dt$ and $\int \frac{d\beta}{dt}\,dt$ by the relationship:

$$\frac{dR}{dt} = S \cos B + v \cos \beta$$

$$\frac{d\beta}{dt} = \frac{1}{D}(S \sin \beta - S \sin B)$$

In case the target should disappear in a smoke screen or otherwise be lost from view, the position just before disappearance is taken as standard and the above values added appropriately to range and bearing from time to time. Assuming that the target course remains constant, it will be possible to calculate continuously range and bearing.

4. Computer Section. Referring to the data chart and also Figure 17, the following equations are derived:

$$x = V(T' + T + T'' + T_b) \sin(\beta + B + \theta - \gamma) = D \sin B -$$

$$2r \sin\frac{\omega}{2} \sin\frac{\omega}{2} ST' \sin\omega - (a + \rho_0 \tan\frac{\theta + \Delta}{2}) \sin(B_0 + \beta - \gamma - \Delta)$$

$$y = V(T' + T - T'' - T_b) \cos(\beta + B + \theta - \gamma) = D \cos B - ST -$$

$$2r \sin\frac{\omega}{2} \cos\frac{\omega}{2} - ST' \cos\omega - (a + \rho_0 \tan\frac{\theta + \Delta}{2}) \cos(B_0 + \beta - \gamma - \Delta)$$

Where

$$V(T + T' + T'') = R$$

$$T'' = \frac{r\omega}{S'}$$

$$T_b = \frac{a + \rho_c(\theta + \Delta)}{V_0} - \frac{\rho_0 \tan\frac{\theta + \Delta}{2}}{V}$$

(V_0 = initial torpedo speed and a = torpedo reach).

These equations are solved automatically. The main control section of the computer is identical to the Sperry type control (automatic quadrant switch). The diagram in Figure 18 shows a schematic outline of the essential mechanical computing mechanisms.

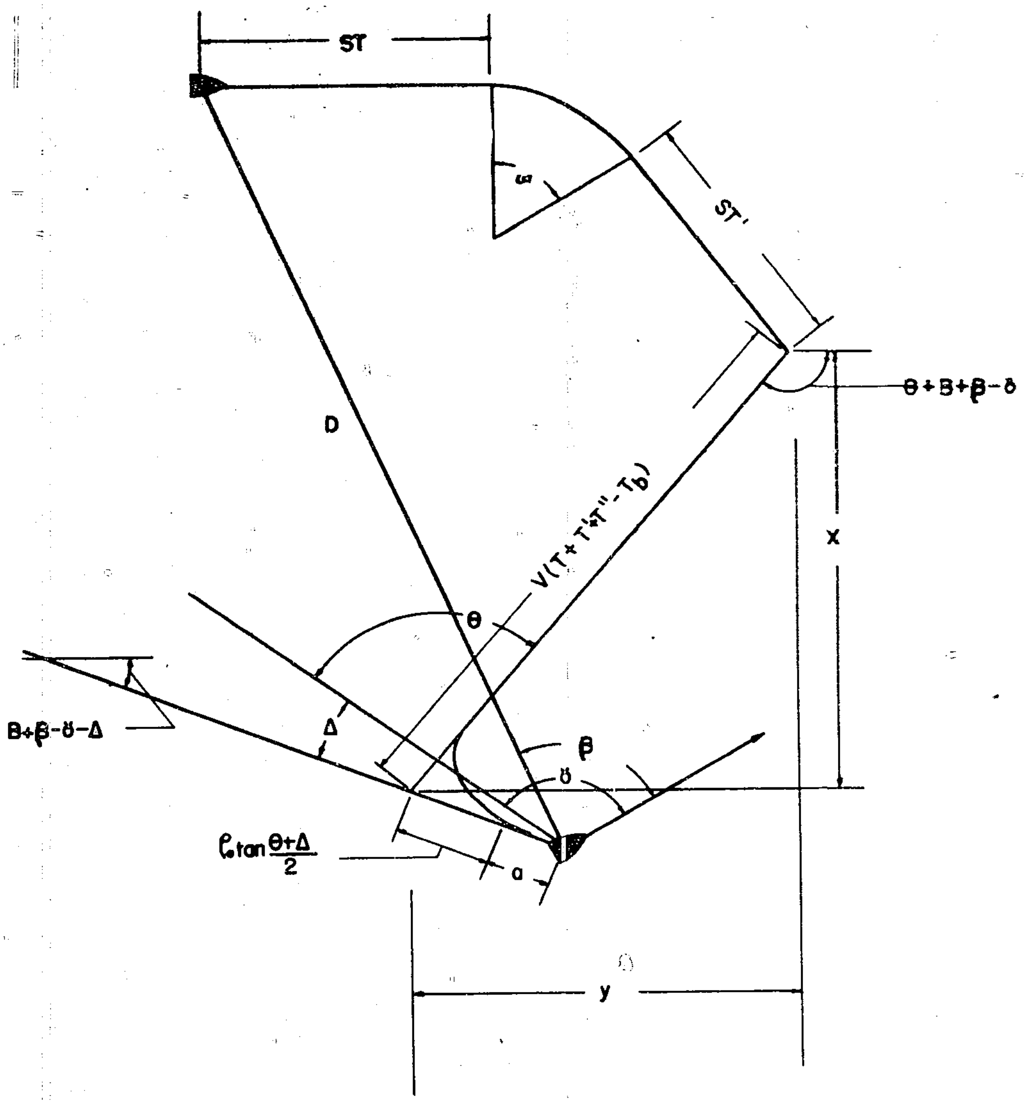


Figure 17
TYPE 1 COMPUTER, VECTOR DIAGRAM

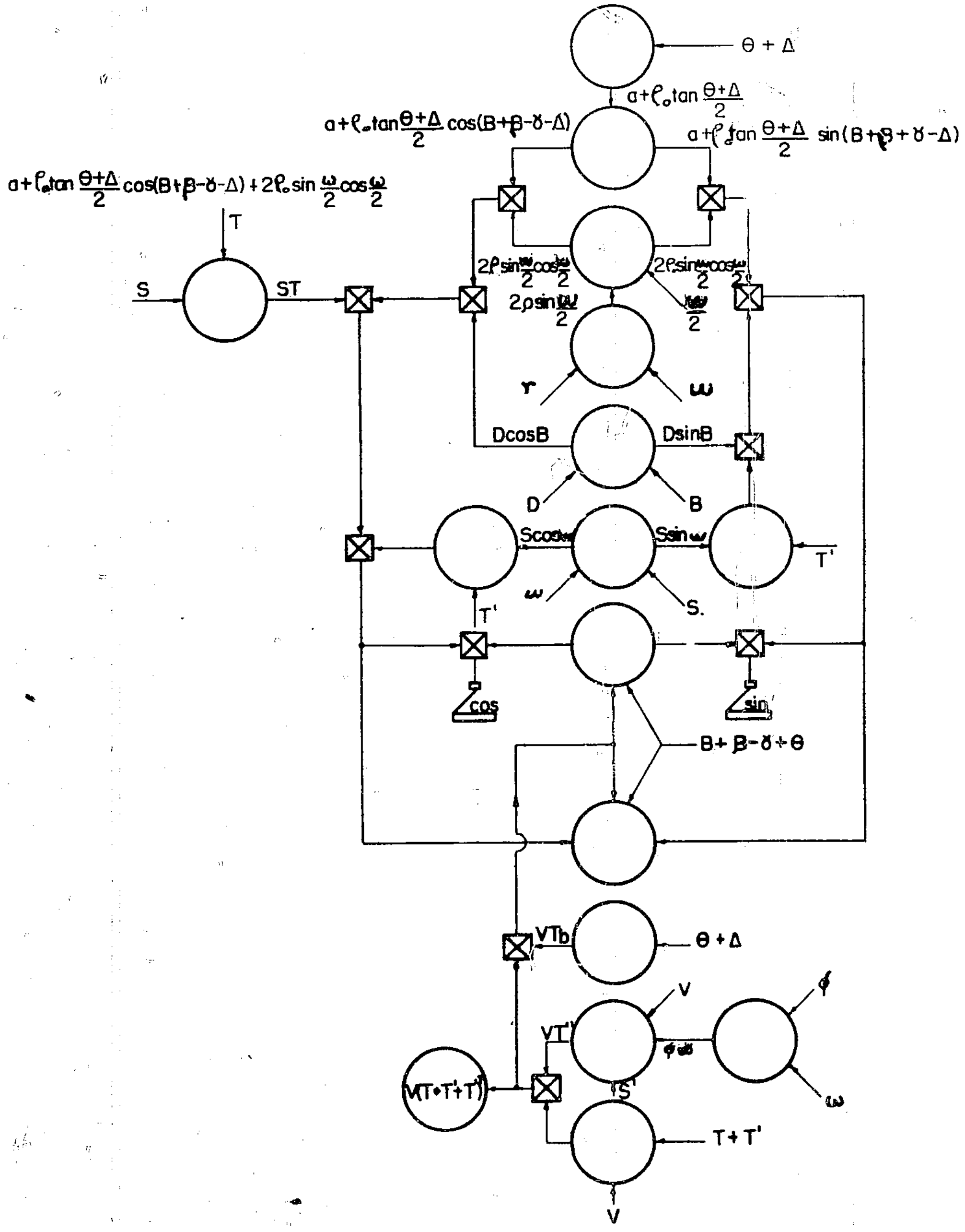


Figure 18

TYPE 1 COMPUTER, SCHEMATIC OF ESSENTIAL PARTS

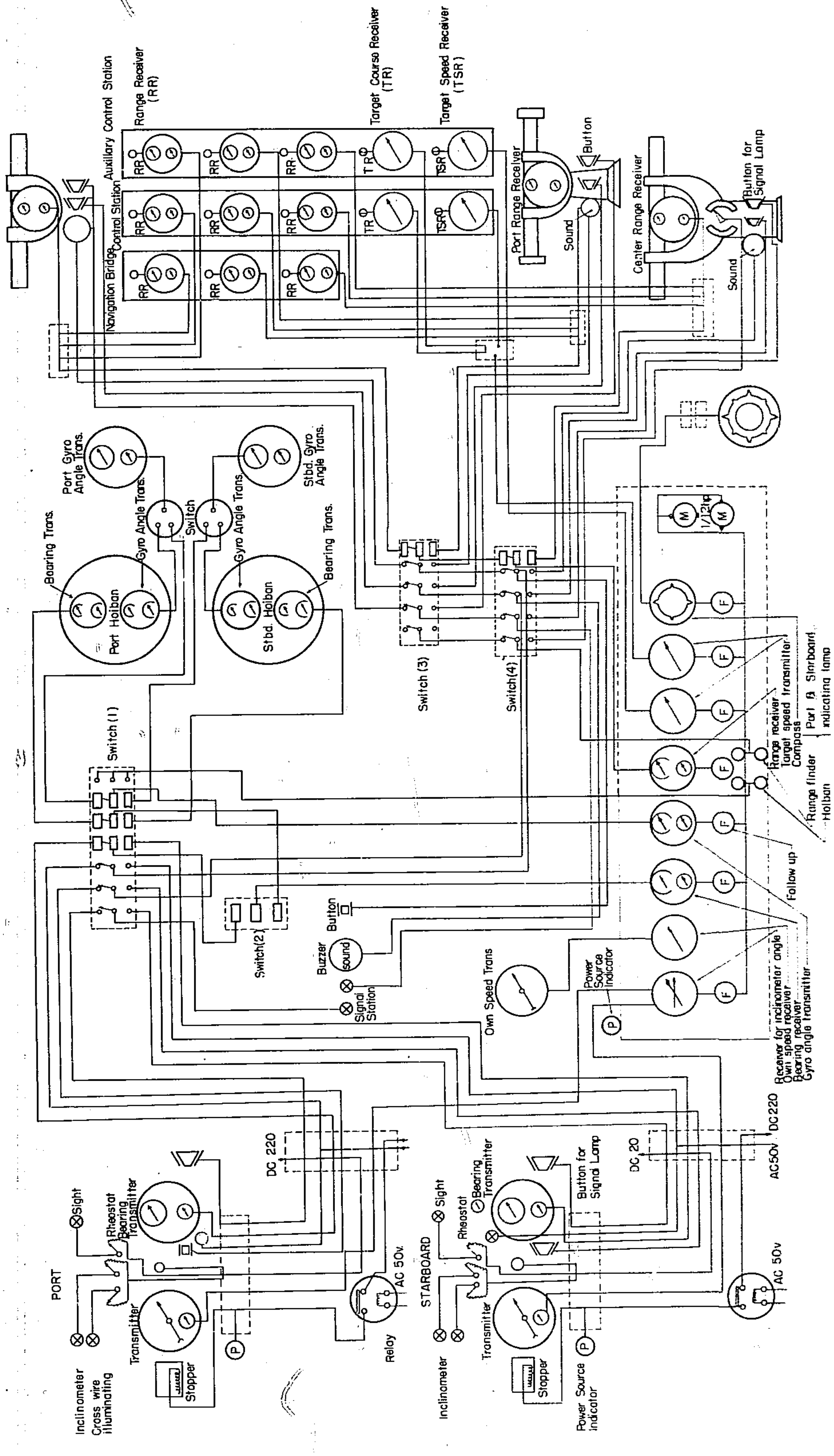


Figure 19

CRUISER TORPEDO FIRE CONTROL SYSTEM

F. TYPE 14 DIRECTOR (HOIBAN)

Small torpedo boats made use of this very simply constructed Type 14 director. In substance it is nothing more than an alidade. The line of sight (determined by two upright wires) is adjusted for correction angle and firing angle so that aiming line is obtained. The boat is maneuvered until the target is in the line of sight and the torpedo is then launched.

Part III
COMMUNICATIONS AND TORPEDO FIRING PANELS

The only available information on this subject is shown in the following diagrams.

Figure 19 shows a typical torpedo fire control installation with Type 1 computer (SHAHOBAN) aboard a cruiser and is self-explanatory.

Figure 20 is a sketch of the connection between a Type 97 director (HOIBAN) and the torpedo tubes on board a destroyer. The time separator has four settings giving a range of from 3 to 6 seconds and is a clock escapement controlled switch.

Figure 21 is a diagram of an installation using a Type 93 target course and speed instrument (SOKUTEKIBAN), Type 93 computer (SHAHOBAN), Type 97 director (HOIBAN) and an inclinometer station.

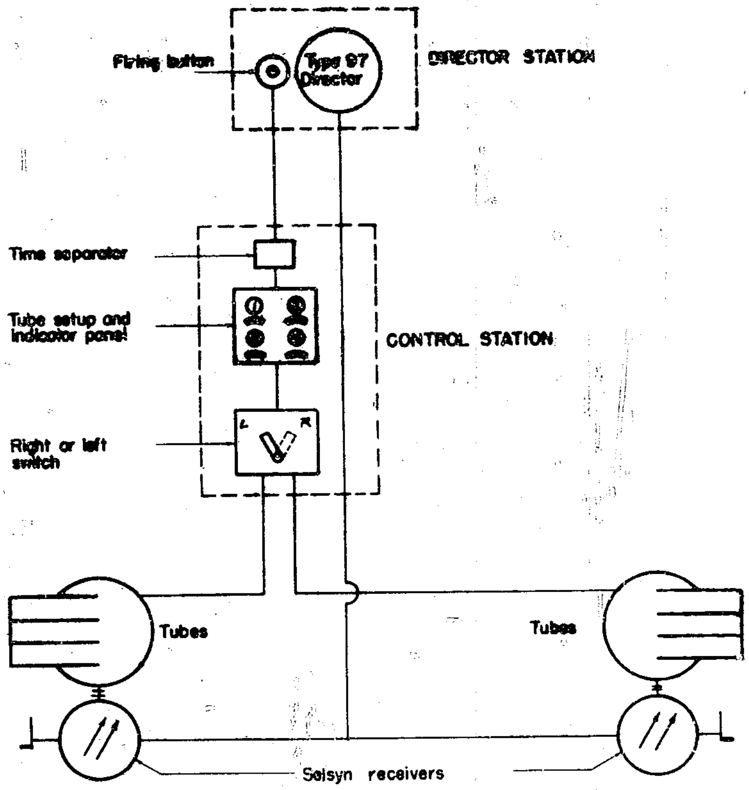


Figure 20

DESTROYER TORPEDO FIRE CONTROL SYSTEM

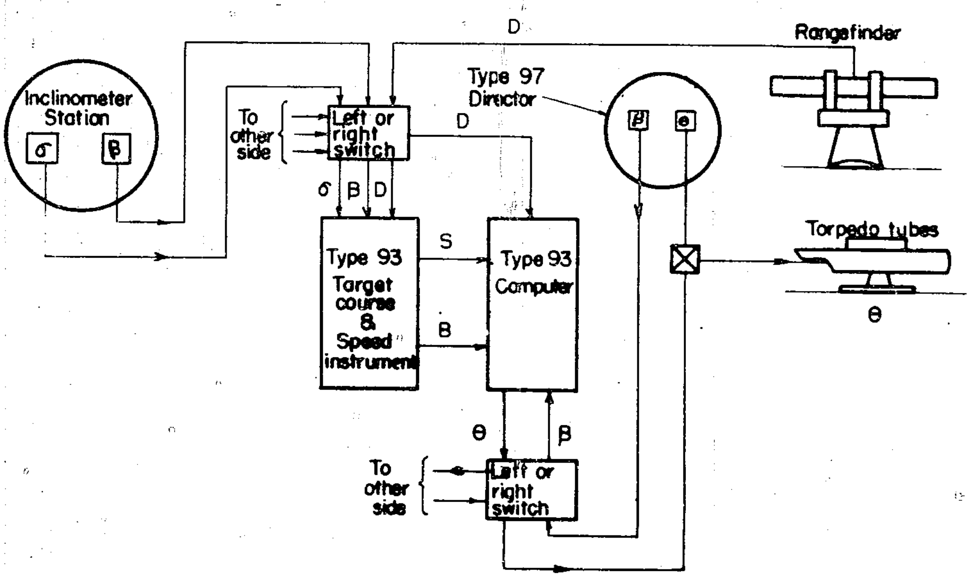


Figure 21
TYPICAL TORPEDO FIRE CONTROL SYSTEM

ENCLOSURE (A)

LIST OF DOCUMENTS FORWARDED TO THE WASHINGTON DOCUMENT CENTER

NavTechJap No.	ATIS No.	Description
ND50-3029	4603	Report of Conference on Torpedo Fire Control Systems on Submarines.

ENCLOSURE (B)

LIST OF JAPANESE EQUIPMENT SHIPPED TO THE
ORDNANCE INVESTIGATION LABORATORY, INDIAN HEAD, MD.

NavTechJap No.	Item
JE-50-3001-1	Type 92, Mod 2 Submarine Torpedo Director
JE-50-3001-2	Type 92, Mod 2 Submarine Torpedo Director
JE-50-3002	Type 5, Mod 3 Submarine Torpedo Director
JE-50-3003	Type 5, Mod 3 Submarine Torpedo Director
JE-21-3400	Type 92, Mod 2 Director, Right
JE-21-3401	Type 92, Mod 2 Director, Left
JE-23-0001	Model 92 Modification 1, Locating Panel for Torpedo Fire Control